PEARSON science

NEW SOUTH WALES

S.B.

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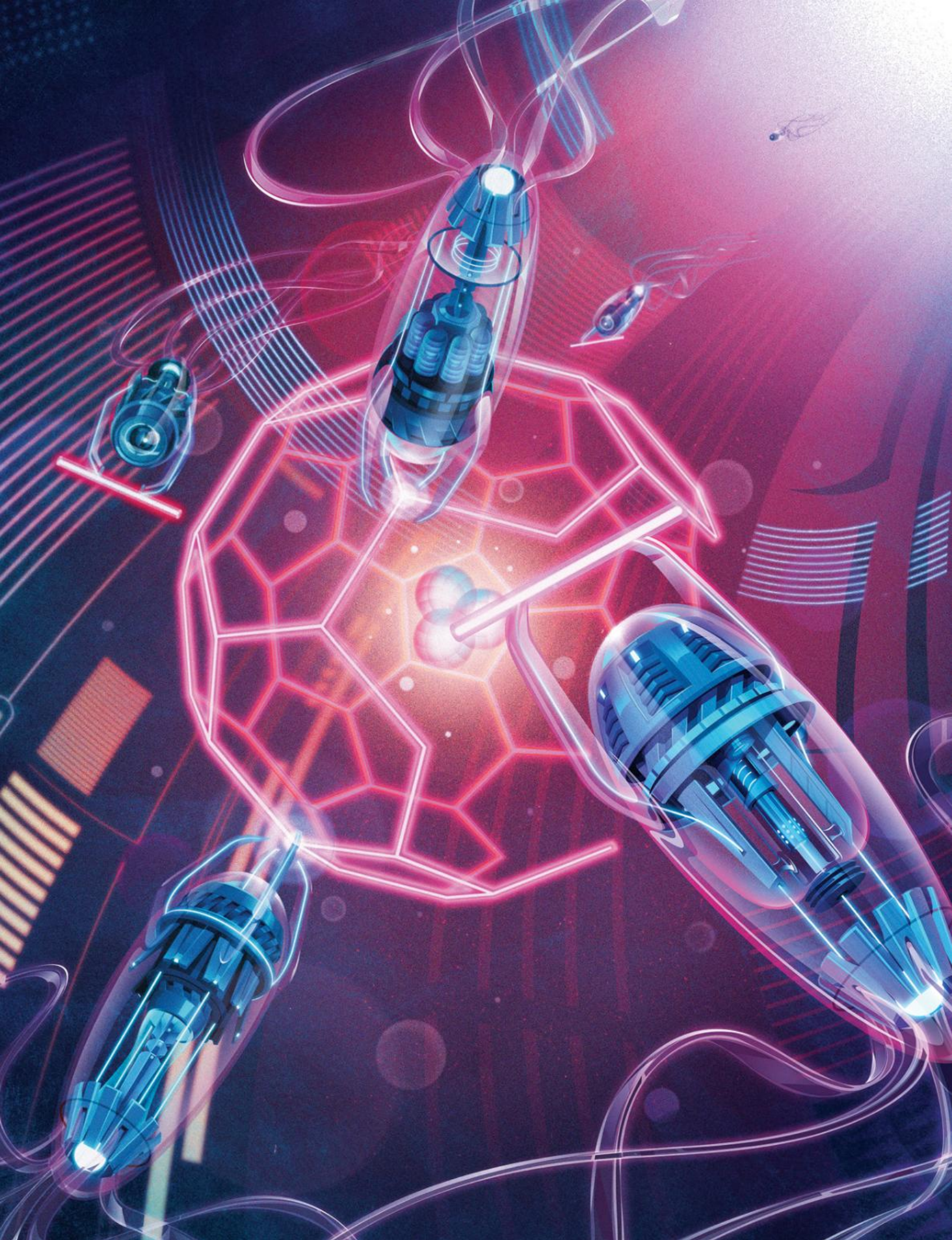
We would like to thank our authors for their extraordinary dedication and their contribution to the development of this project.

As technology and our understanding of matter increases, it is possible to build smaller and smaller machines. This is the world of nanotechnology. This original illustration by Jason Solowczuk imagines nanobots of the future.



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Warrick, Clarke, author.
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PEARSON science NEW SOUTH WALES

Writing and Development Team

Greg Rickard
Teacher, Former Head of Department
Coordinating Author

Misal Belvedere
Publisher
Pearson Australia

Alicia Brown
Publisher
Pearson Australia

Dr Warrick Clarke
Education Research Solutions
Author, New South Wales

Jacinta Devlin
Teacher
Author, Victoria

Merrilyn Lean
Teacher, Head of Department
Reviewer, New South Wales

Greg Linstead
Teacher, Former Head of Department
Author, Western Australia

Catherine Litchfield
Teacher
Reviewer, New South Wales

Professor Kristina Love
Head, Victoria
Faculty of Education
Australian Catholic University
Literacy Consultant

Rochelle Manners
Teacher
Reviewer, Queensland

Robert Paynter
Teacher, Head of Department
Reviewer, New South Wales

Maggie Spenceley
Teacher
Author, Queensland

Brett Stone
Teacher, Head of Department
Reviewer, New South Wales

Jim Sturgiss
Teacher, Former Head of Department
Reviewer, New South Wales

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PEARSON science

NEW SOUTH WALES

Student Book

Written from the ground up for the Australian Curriculum and developed specifically for the NSW Science Syllabus for the Australian Curriculum, the student book acts as a guide for both student and teacher.

- Developed specifically for the NSW Science Syllabus
- Utilises an inquiry approach throughout
- The content is presented in a range of contexts within the interrelated strands of Knowledge and Understanding and Working Scientifically.

Activity Book

The activity book is a write-in resource designed to enrich students' skills by providing a variety of activities and questions to reinforce learning outcomes.

- Supports and extends the student book
- Caters for a range of learning styles.

Teacher Companion

The teacher companion makes lesson preparation easy by combining full-colour textbook pages with teaching strategies, ideas for class activities and fully worked solutions.

- Ties the entire **Pearson Science New South Wales** package together
- Includes all answers to the student and activity book.

EAL/D Activity Book

The EAL/D activity book incorporates tailored language and vocabulary support for English as an Additional Language or Dialect (EAL/D) learners. With activities matching page-for-page, the EAL/D activity book can be used alongside the standard activity book.

AUSTRALIAN CURRICULUM

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How to use this book

PEARSON science NEW SOUTH WALES 9 Student Book

PEARSON science NEW SOUTH WALES 9 has been designed for Stage 5 of the NSW Science Syllabus for the Australian Curriculum. It includes content and activities that cover all learning outcomes within the interrelated strands of Knowledge and Understanding, and Working Scientifically. The content is presented through a range of contexts to engage students and assist them to make connections between science and their lives.

Additional syllabus content is clearly identified and carefully placed in the flow of core content. Learning Across the Curriculum content is addressed throughout the series and indicated using icons.

PEARSON science NEW SOUTH WALES 9 is designed for an inquiry approach to science learning. Its engaging design, unambiguous features and clear easy-to-understand language make this a valuable resource for students of all interests and abilities.

Chapter opening page

The chapter opener engages students through questions that get them thinking about the content and concepts to come.

The key ideas reflect the syllabus content relevant to the chapter.

science4fun

Inquiry-based activities using everyday materials assist students to understand key concepts under development.

These can be used as a focus or context for the unit.

Icons indicate whether an activity is suitable to be done at home or requires teacher supervision.

Look who is using science

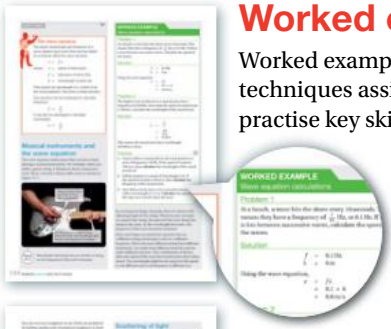
Careers pages spread throughout the book look at careers that involve and use science.

Skill builder

Key skills are outlined in clear steps to support science learning.

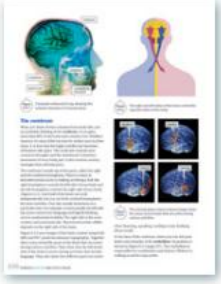
Unit opening

Each chapter is divided into self-contained units. The unit opener includes an introduction that places the material to come in a meaningful context.



Worked example

Worked examples of problems and techniques assist students to master and practise key skills.



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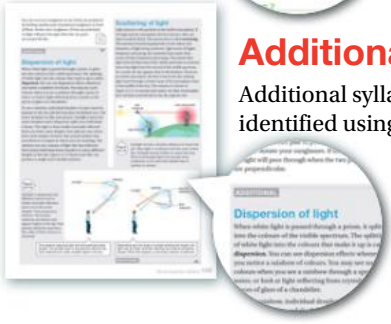

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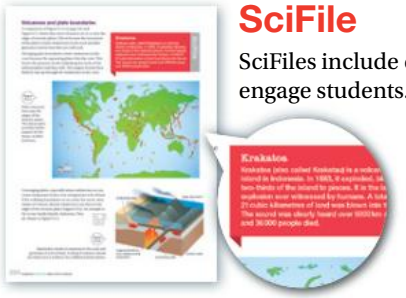
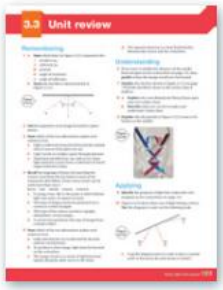


SciFile

SciFiles include quirky information to engage students.



Unit review

Each unit finishes with a set of questions and activities organised under the headings of Bloom's Taxonomy of Cognitive Processes. To further students' understanding of the intent of a question and level of explanation expected, bolded verbs are used throughout. A list of all verbs and their meanings can be found on page xii.

The final heading is 'Inquiring'. These questions challenge students to use their inquiry skills to research additional syllabus content and to go beyond the unit content.

Practical investigations

Practical investigations are placed at the end of each unit. Practical investigation icons appear throughout the units to indicate suggested times for practical work.

A Student-design icon indicates that an activity includes student input and design.

Safety boxes highlight significant hazards.

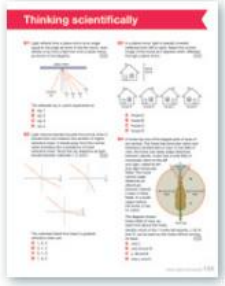
A safety glasses icon reminds students when appropriate to wear safety glasses.

Learning Across the Curriculum

Learning Across the Curriculum content is addressed throughout the Student Book using icons and in Learning Across the Curriculum spreads. A full list of Learning Across the Curriculum icons can be found on page xiii.

Chapter review

Each chapter finishes with a set of questions and activities organised under the headings of Bloom's Taxonomy of Cognitive Processes.

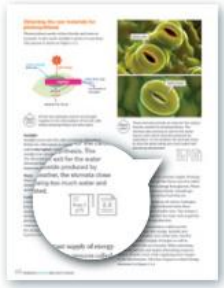


Thinking scientifically

Following the Chapter review are Thinking scientifically style questions relevant to that chapter. These test students' science and interpretive skills.

Glossary

Every chapter concludes with an illustrated glossary that engages students and provides a ready reference for the key terms of the chapter.



Activity Book icon

This icon indicates a related Activity Book worksheet that enhances or extends this area.

Go to icon

Go to icons are used to make important links to relevant content within the student book and to the next student book in a stage.

The PEARSON science NSW 9 package

Don't forget the other PEARSON science NEW SOUTH WALES 9 package components that will help engage and excite students in science:

- Activity Book
- EAL/D Activity Book
- eBook 3.0
- Teacher Companion
- Pearson Assess New South Wales

Verbs

The verbs below, based on Bloom's Taxonomy, appear in **bold** text throughout this book. The verbs help students know the level of response required for a question. The verbs in black are consistent with the key verbs used in NSW syllabuses and examinations. The verbs shown in blue in this list may also feature throughout the book and are provided for additional support to teachers and students.

Remembering	
enter	Place data into a computer program by key strokes or copying from a digital source, e.g. CD, DVD, USB storage device
label	Add annotations to a diagram or drawing
list	Write down phrases or items only without further explanation
name	Present remembered ideas, facts or experiences
present	Provide information for consideration
recall	Present remembered ideas, facts or experiences
record	Store information and observations for later
specify	State in detail
state	Provide information without further explanation
Understanding	
account	Account for—state reasons for, report on. Give an account of—narrate a series of events or transactions
calculate	Ascertain/determine from given facts, figures or information (simply repeating calculations that are set out in the text)
clarify	Make clear or plain
construct	Prepare or devise something, such as a key or diagram
define	State meaning and identify essential qualities
describe	Provide characteristics and features
determine	Find out the size or extent, either by using an equation, counting, estimating, or similar method
discuss	Identify issues and provide points for and/or against
draw	Use a pencil to produce a likeness onto a page, or sketch to provide a representation or view
explain	Provide a sequence to make the relationships between things evident; provide why and/or how
extract	Choose relevant and/or appropriate details
gather	Collect items from different sources
modify	Change in form or amount in some way
outline	Sketch in general terms; indicate the main features
predict	Suggest what may happen based on available information
produce	Provide
propose	Put forward for consideration or action
rank	Place in order of size, age, or as instructed
recount	Retell a series of events
summarise	Express, concisely, the relevant details
write	Compose or construct a sentence that explains a feature
Applying	
apply	Use, utilise, employ in a particular situation
calculate	Ascertain/determine from given facts, figures or information
demonstrate	Show by example
examine	Inquire into
identify	Recognise and name
use	Employ for some purpose
Analysing	
analyse	Identify components and the relationship between them; draw out and relate implications
calculate	Ascertain/determine from given facts, figures or information (requiring more manipulation than simply applying the maths)
classify	Arrange or include in classes/categories
compare	Show how things are similar or different
contrast	Show how things are different or opposite
critically (analyse/ evaluate)	Add a degree or level of accuracy, depth, knowledge and understanding, logic, questioning, reflection and quality to (analyse/ evaluate)
discuss	Identify issues and provide points for and/or against

distinguish	Recognise or note/indicate as being distinct or different from; to note differences between
infer	Recognise and explain patterns and meaning and relationships
interpret	Draw meaning from
research	Investigate through literature or practical investigation
Evaluating	
appreciate	Make a judgement about the value of
assess	Make a judgement of value, quality, outcomes, results or size
conclude	Come to a judgement or result based on the reasoning or arguments that you present
critically (analyse/ evaluate)	Add a degree or level of accuracy, depth, knowledge and understanding, logic, questioning, reflection and quality to (analyse/ evaluate)
deduce	Draw conclusions
evaluate	Make a judgement based on criteria; determine the value of
extrapolate	Infer from what is known
justify	Support using an argument or conclusion
propose	Put forward (for example a point of view, idea, argument, suggestion) for consideration or action
recommend	Provide reasons in favour
select	Choose one or more items, features, objects
Creating	
construct	Make; build; put together items or arguments
design	Provide steps for an experiment or procedure
investigate	Plan, inquire into and draw conclusions about
synthesise	Put together various elements to make a whole

Learning Across the Curriculum

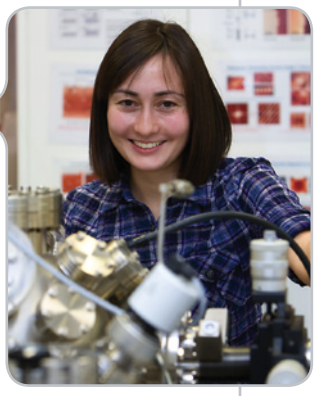
NSW Syllabus Learning Across the Curriculum content is addressed throughout the series and is identified using the following icons.

Learning Across the Curriculum icons	
AHC	Aboriginal and Torres Strait Islander histories and cultures
A	Asia and Australia's engagement with Asia
CC	Civics and citizenship
CCT	Critical and creative thinking
DD	Difference and diversity
EU	Ethical understanding
ICT	Information and communication technology capability
IU	Intercultural understanding
L	Literacy
N	Numeracy
PSC	Personal and social capability
S	Sustainability
WE	Work and enterprise

SCIENCE TAKES YOU PLACES

Look who is using science

NANOSCIENTIST

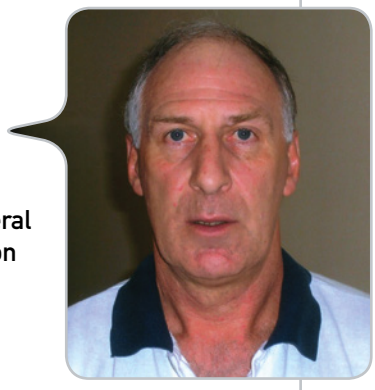


My name is Jill Miwa. I work in the new and exciting field of nanoscience. I use a special microscope that can 'see' and 'touch' individual atoms and molecules in materials such as silicon that are used in everyday electronic devices such as laptops, televisions and mobile phones.

I use the microscope to study how atoms and molecules interact with each other. By understanding what happens at such a small scale, scientists like me can design and build faster, smaller electronics. At the University of New South Wales, we are using our microscope to position atoms into the world's smallest silicon computer chip!

I really enjoy working in a research laboratory. It's a fantastic place to work because all the newest technology is at my fingertips, and each day I get to go to work and try to solve the mysteries of how the world around us works.

ORTHOPAEDIC TECHNICIAN



My name is Terry James and I am an orthopaedic technician working at a general hospital. To get to this position I completed a Certificate IV in Orthopaedic Technology. I studied the anatomy of the skeleton and muscles, all aspects of applying casts to broken arms and legs, and the application of traction as a way of getting the bones and muscles of the skeleton back into their correct position.

In my position as an orthopaedic technician it is very important to have a professional attitude when working with the medical staff to make sure that the best possible outcome is achieved for all patients.

A career within the health sector can be extremely rewarding. It is an achievable goal for anyone interested in the health industry. Once you have employment, funded courses are available and these may lead to opportunities for advancement in the field of orthopaedic technology.

BEAUTY THERAPIST

I am Bianca Chamberlin and I run my own business as a beauty therapist.

The main goal for clients who come to see me is to improve the texture and general health of their skin.

As a beauty therapist I need to understand the structure of cells in order to diagnose and treat the different skin types and conditions I see on a daily basis. I also need to understand the products I use and how they interact with skin cells.

While many of my peers thought it strange for me to study science at school, it gave me a great grounding and understanding for when I started study for my Diploma of Applied Science for my career in beauty therapy.

1 Materials

Have you ever wondered...

- how we know the structure of an atom without being able to look inside?
- why jewellery body piercings are usually made of stainless steel?
- what the difference is between an acid and a base?
- why new materials are developed?

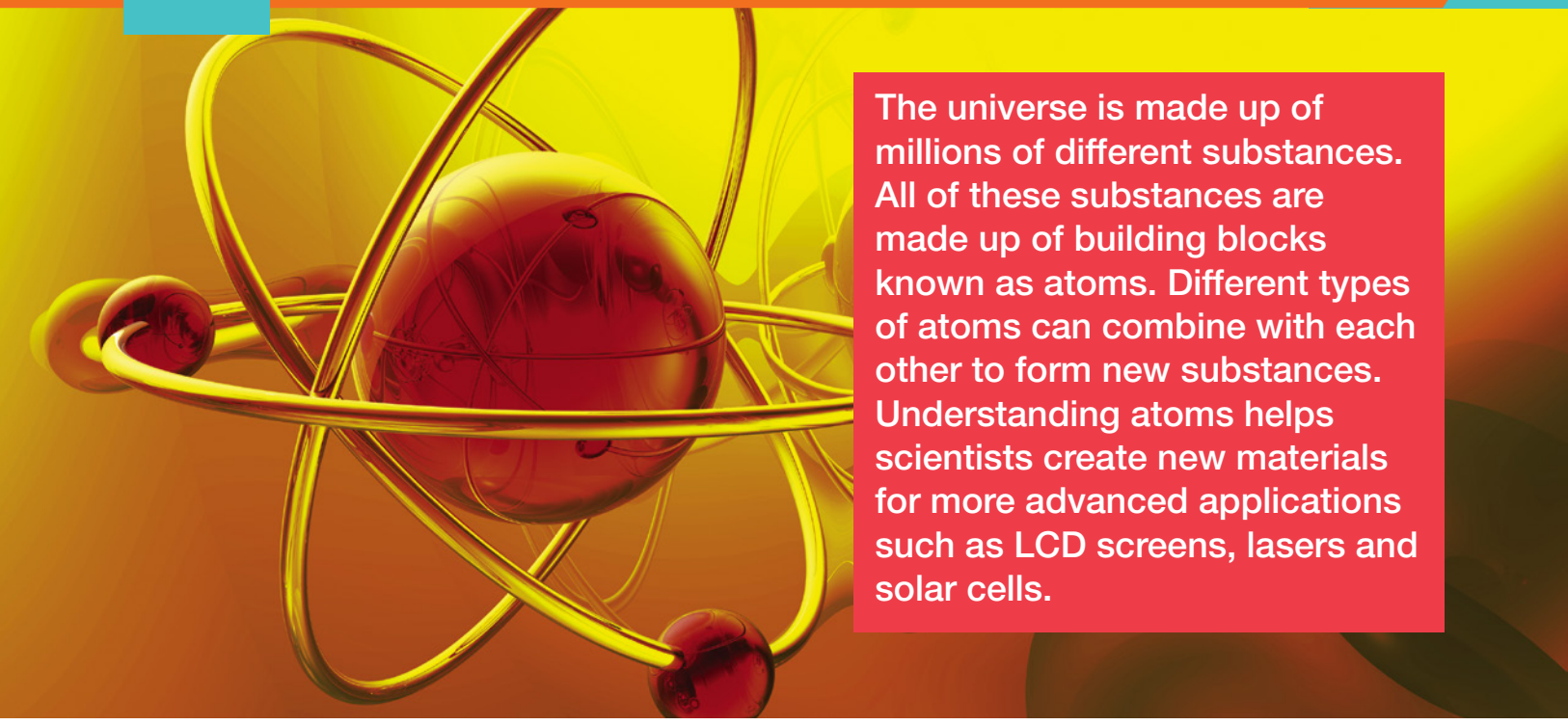
After completing this chapter students should be able to:

- identify that all matter is made up of atoms, which are composed of protons, neutrons and electrons
- describe the structure of atoms
- demonstrate how atomic models have been contested and refined over time L
- identify a range of compounds using their common names and chemical formulae
- classify compounds on the basis of common chemical characteristics
- analyse how social, ethical and environmental considerations can influence decisions about scientific research related to the development of new materials CCT EU L S
- describe examples of where advances in science affect people's lives, including generating new careers in areas of chemical science CCT L WE

ADDITIONAL

- describe the arrangement of electrons in energy levels
- investigate the production of new materials from synthetic fibres L
- use scientific evidence to evaluate claims made in relation to a product.

1.1 Atoms



The universe is made up of millions of different substances. All of these substances are made up of building blocks known as atoms. Different types of atoms can combine with each other to form new substances. Understanding atoms helps scientists create new materials for more advanced applications such as LCD screens, lasers and solar cells.

Atomic building blocks

Look around you and you will see thousands of different materials—paper, plastic, wood, glass, skin and many more. All these different materials are made up of tiny building blocks known as **atoms**.

Atoms are so small that they cannot be seen with even the most powerful optical microscope. To see atoms, scientists must use a special type of microscope known as a scanning tunnelling microscope or STM. Figure 1.1.1 shows an image of silicon atoms taken with an STM.

There are 118 known types of atoms and only 98 of these are found naturally on Earth. The remaining 20 types of atoms must be made in a laboratory.

Each type of atom is given its own chemical symbol that is usually made up of one or two letters. In some special cases the symbol may have three letters. Often, the chemical symbol is related to the name of the atom. For example, the symbol for hydrogen is H and the symbol for carbon is C; the symbol for magnesium is Mg, while chlorine is Cl. However, sometimes the symbol does not appear to be related to the name of the atom. This is because the symbol has come from the atom's name in another language, usually Latin. For example, the chemical symbol for sodium is Na, which comes from its Latin name *natrium*. Similarly, the chemical symbol for potassium is K, which comes from its Latin name *kalium*.

SciFile

Natural or synthetic?

Some of the heavier natural elements such as plutonium and californium are very rare, and are often made in the laboratory. This leads to confusion about whether these elements are classified as natural or synthetic. For this reason, the numbers of natural and synthetic elements in the periodic table given in different sources vary greatly. In this text, an element is called natural if it is found in nature, even in incredibly small amounts.

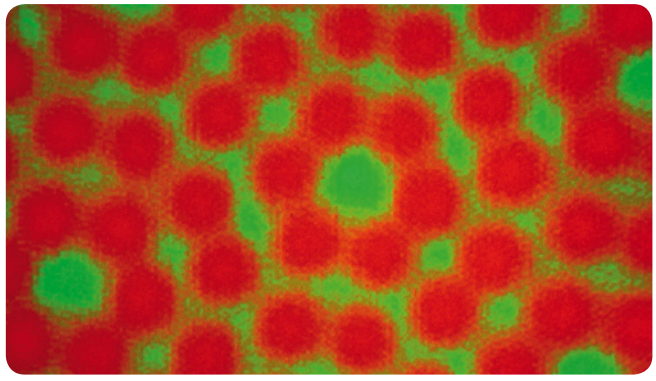


Figure 1.1.1 Billions of silicon atoms like these stick together to form a crystal of silicon. Silicon is used in the computer industry to make microchips.

Atoms in elements and compounds

Atoms stick together to form all of the different substances that you see around you. When atoms stick together they can form either clusters of atoms known as **molecules** or large grid-like structures known as **crystal lattices**. Examples of both are shown in Figure 1.1.2.

For example, water (H_2O) is made up of molecules. Every water molecule is identical and contains two hydrogen atoms (H) and one oxygen atom (O). On the other hand, a grain of beach sand is a crystal lattice of silicon (Si) and oxygen (O) atoms. The number of atoms in the lattice depends on the size of the grain of sand.

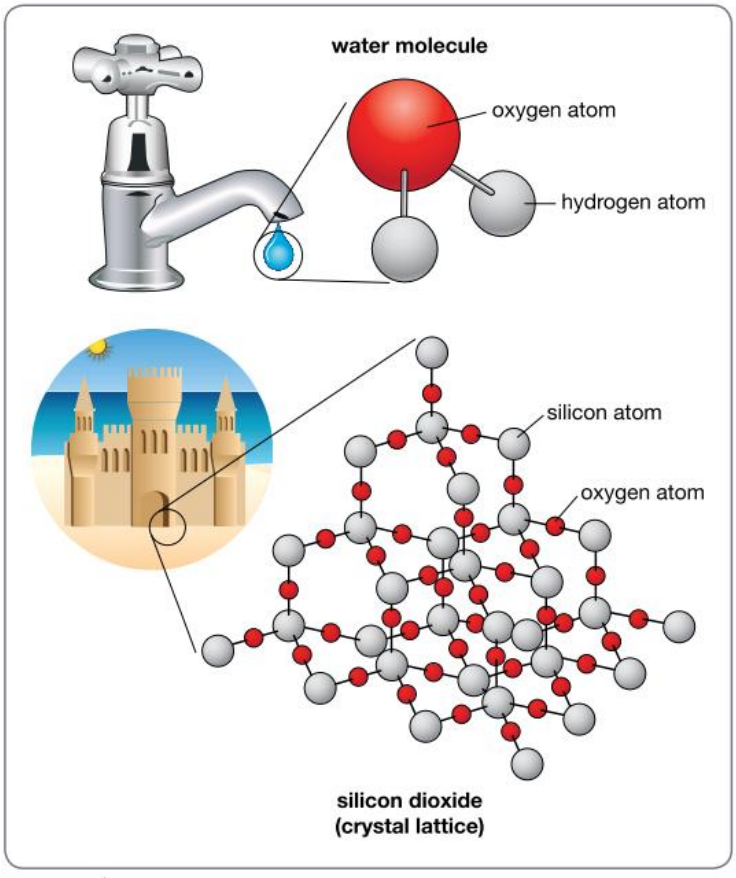


Figure 1.1.2 Atoms can form molecules like the water molecule, or large crystal lattices like that of silicon dioxide in beach sand.

Elements

If a substance is made up of just one type of atom, then it is referred to as an **element**. Molecular elements are made up of small molecules like the oxygen, phosphorus and sulfur molecules shown in Figure 1.1.3. Carbon is a unique element because carbon atoms can form extremely large molecules. A buckyball is made up of 60 carbon atoms (C_{60}) in the shape of a soccer ball, while a carbon nanotube can have thousands of carbon atoms forming a long cylinder.

Carbon is also the only non-metallic element that can form crystal lattices. The diamonds found in jewellery and the graphite in pencil 'leads' are two forms of carbon crystal lattices. Metallic elements such as copper and gold always form crystal lattices. Figure 1.1.4 compares these two types of lattices.

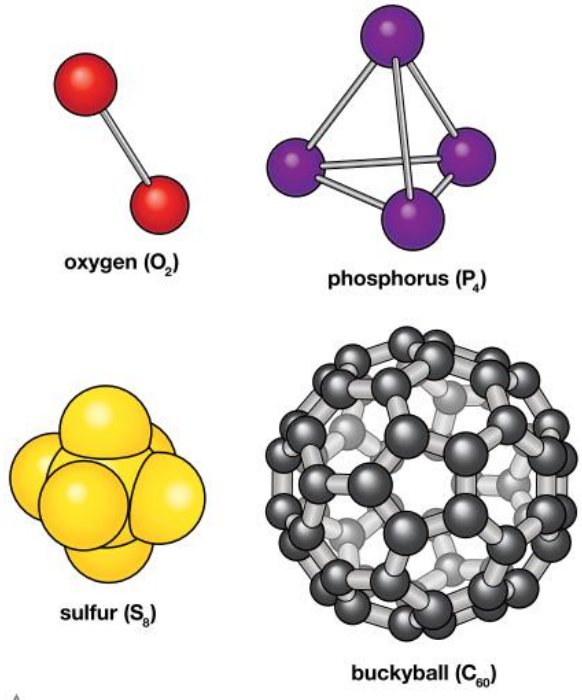


Figure 1.1.3 In molecular elements, each molecule is made up of just one type of atom.

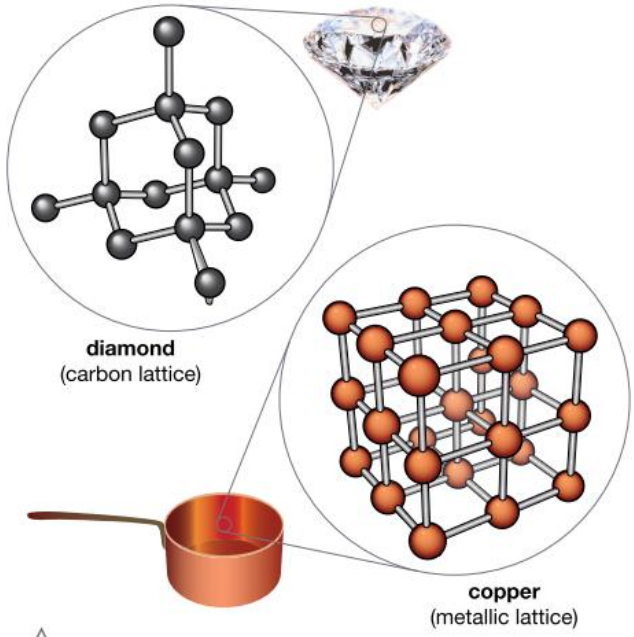


Figure 1.1.4 Elements that exist as crystal lattices contain many atoms of the same type.

Compounds

If a substance is made up of different types of atoms, then it is known as a **compound**. The molecules that make up compounds range from small to very large. For example, a glucose sugar molecule is made up of just 24 atoms. In contrast, a single molecule of DNA inside one of your cells is made up of billions of atoms and can be stretched to over a metre in length.

Many compounds are crystal lattices. Common table salt is a lattice of sodium (Na) and chlorine (Cl) arranged into a three-dimensional grid. Figure 1.1.5 compares the molecular structure of sugar with the lattice structure of salt.

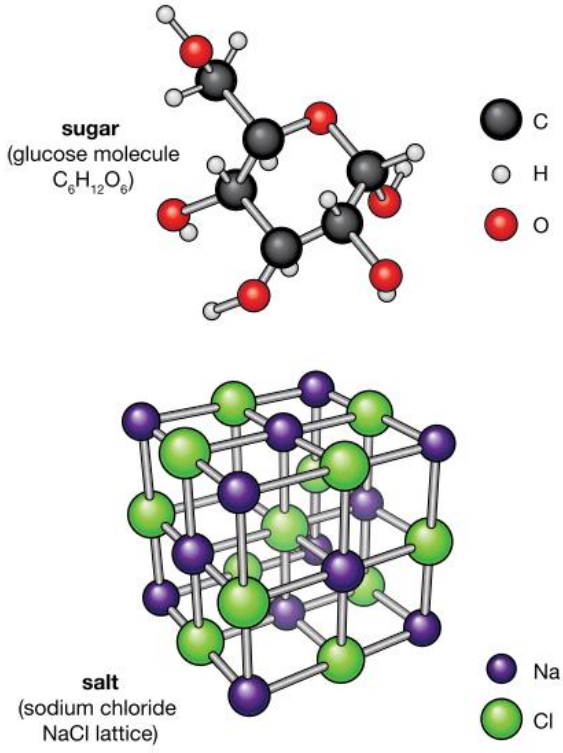


Figure 1.1.5 A sugar molecule and a sodium chloride lattice are both compounds because they both contain more than one type of atom.

Inside atoms

Atoms were once thought to be hard and unbreakable. Today, scientists know that atoms are made up of even smaller particles known as **subatomic particles**. Each atom is made up of three types of subatomic particles: **protons**, **neutrons** and **electrons**.

The protons and neutrons form a cluster that sits at the centre of the atom, as shown in Figure 1.1.6. This cluster is known as the **nucleus**. The electrons are much smaller and lighter and move very fast around the nucleus to form an **electron cloud** that surrounds the nucleus.

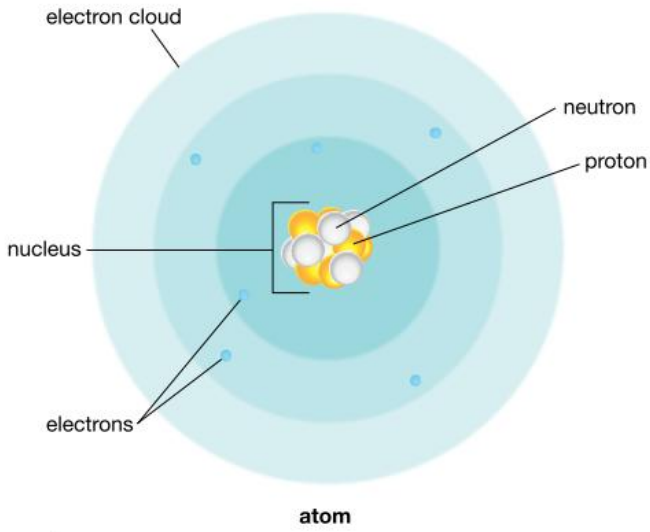


Figure 1.1.6 Atoms are made up of subatomic particles known as protons, neutrons and electrons.

Table 1.1.1 summarises some of the important properties (characteristics) of protons, neutrons and electrons. Protons and neutrons are similar in mass. However, protons have a positive electric charge while neutrons have no electric charge. Electrons are approximately 1800 times lighter than protons and neutrons, and have a negative electric charge.

Table 1.1.1 Properties of subatomic particles

Subatomic particle	Location	Mass compared with the mass of an electron	Electric charge
Proton	Nucleus	× 1800	+1
Neutron	Nucleus	× 1800	0
Electron	Electron cloud around the nucleus	× 1	–1

The negative charge of electrons causes them to be attracted to the positively charged protons in the nucleus. This is because opposite electric charges attract each other, a bit like the way opposite poles of a magnet attract each other. This attractive force is known as electrostatic attraction.

The atomic universe

Approximately 98% of the atoms in the universe are either hydrogen (H) or helium (He) atoms. These atoms make up the Sun and the stars. The other types of atoms make up only 2% of all the atoms in the universe.

SciFile

INQUIRY

science 4 fun

Electrostatic attraction

Can you use electrostatic force to stick a balloon to the wall?

Collect this ...

- balloon
- head of clean, dry hair

Do this ...

1. Inflate the balloon and tie a knot in it.
2. Rub the balloon vigorously on the hair.
3. Gently place the balloon in contact with a wall and see if it will stay.

Record this ...

Describe what you saw.

Explain why you think this happened.

Atomic number and mass number

The number of protons in the nucleus determines the type of atom it is and what element it belongs to. For example, all gold atoms contain 79 protons while all oxygen atoms contain eight protons. The number of protons in an atom is called the **atomic number**.

The number of protons plus neutrons in an atom is called the **mass number**. These numbers are often written alongside the chemical symbol. For example, an atom of sodium, Na, can be shown as:

Mass number → 23
Atomic number → 11
Na

From this one symbol, you can calculate the number of protons, neutrons and electrons in the sodium atom:

- The number of protons is the atomic number, 11. So there are 11 protons in the nucleus.
- The number of electrons is equal to the number of protons. So there are 11 electrons spinning in a cloud around the nucleus.
- The number of neutrons is the mass number minus the atomic number: 23 – 11 = 12. So there are 12 neutrons in the nucleus.

1.1 1.2

BUILDER SKILL

Writing atomic symbols

To show the mass number and atomic number of an atom, scientists write an **atomic symbol**. The atomic symbol for helium is:

Mass number → 4
Atomic number → 2
He

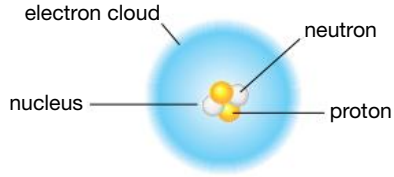
This shows the chemical symbol for helium (He), with the mass number above and the atomic number below. From this symbol it is possible to work out the number of neutrons in the nucleus by subtracting the atomic number from the mass number.

Number of neutrons = 4 – 2 = 2

It is also possible to work out the number of electrons, which is equal to the atomic number:

Number of electrons = atomic number = 2

In this way, the atomic symbol can be used to obtain a complete description of the subatomic particles of the helium atom, shown in Figure 1.1.7.



atom of helium

Figure 1.1.7 This helium atom has two protons and two neutrons. So its atomic number is 2 and its mass number is 4. Helium also has two electrons that form the electron cloud.

WORKED EXAMPLE
Writing atomic symbols

Problem

Determine the number of protons, electrons and neutrons in:

39
19 K

Solution

1 Number of protons = atomic number = 19
2 Number of electrons = atomic number = 19
3 Number of neutrons = mass number – atomic number
= 39 – 19
= 20

Practice

N

Calculate the number of protons, neutrons and electrons in:

56
26 Fe

Electrons and the nucleus

The number of electrons surrounding the nucleus of an atom is exactly equal to the number of protons in the nucleus. As a result, atoms are **neutral**. This means that they have no charge—the positive charge of the protons is exactly balanced by the negative charge of the electrons.

Although each electron is 1800 times lighter than a proton, the electron clouds can be 100 or even 1000 times wider than the nucleus. This means that if the nucleus were the size of a golf ball, the electrons would form clouds the size of a football stadium and the electrons would be the size of a single grain of sand. It also means that most of an atom is empty space.

In 1909, the New Zealand scientist Ernest Rutherford (1871–1937) discovered that the nucleus only takes up a small fraction of the space inside an atom. In a famous experiment, Rutherford fired a beam of helium nuclei (alpha particles) at a thin sheet of gold foil. This is shown in Figure 1.1.8. To his surprise, most of the nuclei passed straight through the foil and only a small fraction were deflected or bounced back. Up until that point, most scientists had believed that atoms were completely solid. If atoms were solid, then almost all of the alpha particles should have bounced back. From this experiment, Rutherford realised that atoms are mostly empty space, but they have a small, positively charged nucleus surrounded by a cloud of electrons. These nuclei caused the occasional change in direction of the alpha particles.

Prac 1 p12

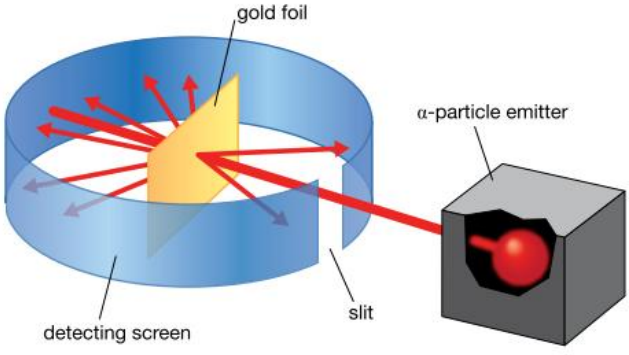


Figure 1.1.8 In Rutherford's famous experiment, a beam of helium nuclei (alpha particles) was fired at gold foil. Most of the alpha particles went straight through and only a small number were deflected. Rutherford concluded that atoms are mostly empty space with a small, positively charged nucleus and a large negatively charged electron cloud.

ADDITIONAL

Electron shells

Even the electron cloud that surrounds the nucleus has structure. The electron cloud can be broken down into **electron shells** that surround the nucleus like the layers of an onion, as shown in Figure 1.1.9.

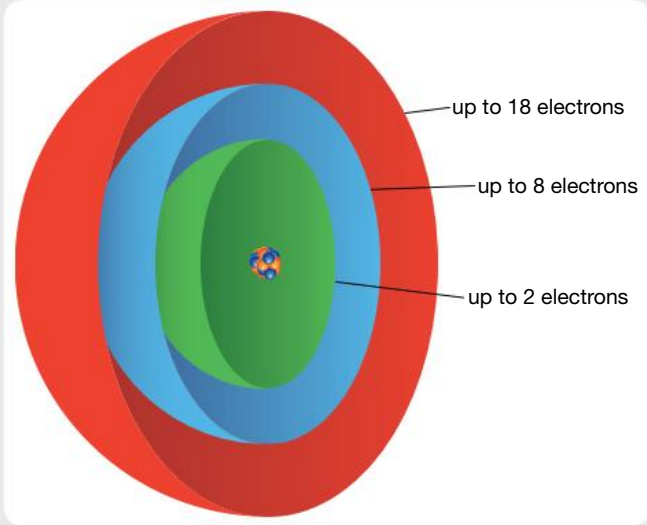


Figure 1.1.9 The electron clouds form shells around the nucleus.

Each shell can only hold a certain number of electrons. The innermost shell is small and can only hold two electrons, the second shell holds up to eight electrons, the third shell holds up to 18 electrons while the fourth electron shell can hold a maximum of 32 electrons. The nucleus is tiny in comparison, being around 100–1000 times smaller than the electron shells. This means that the electron shells take up most of the space in an atom.

The way the electrons are organised in the shells of an atom is known as the atom's electron configuration. For example, there are 17 electrons in a chlorine atom. Two electrons are in the first shell, eight are in the second and the remaining seven are in the third shell. This is written as an electron configuration of 2,8,7.

An aluminium atom has an electron configuration of 2,8,3. This indicates that an aluminium atom has 13 electrons—two electrons in the first shell, eight in the second and three in the outermost third shell.

GO TO Pearson science NSW 10 Unit 4.4

ADDITIONAL

Ions

Atoms can lose or gain electrons to become electrically charged particles called **ions**. If an atom loses electrons, then it has more protons than electrons. This gives the atom a positive charge. The ion formed is known as a **cation**. If an atom gains electrons, then it has more electrons than protons. It is now negatively charged and is known as an **anion**.

The symbol for an ion is the same as the chemical symbol for the atom it was formed from, but with the charge of the ion added to it. For example, when a sodium atom (Na) forms a sodium cation, it loses one electron. This gives it a charge of +1 and so the symbol of the sodium ion is Na^+. Similarly, the symbol Mg^{2+} indicates that a magnesium ion is formed when a magnesium atom loses two electrons.

The same is true for anions. When a chlorine atom gains one electron, it forms an ion with a charge of –1. Its symbol is Cl^-. If an oxygen atom gains two electrons, then it becomes an anion with a charge of –2 and its symbol is written as O^{2-}. Unlike with cations, the name of the anion changes slightly by adding -ide to the end of the atom name. So the chlorine atom becomes the chloride ion and the oxygen atom becomes the oxide ion.

Ions can be formed in many situations but they are most commonly formed when some substances are dissolved in water. Not all substances will form ions when dissolved and you can determine which substances form ions by passing an electric current through the solution. Substances that form ions when dissolved will conduct electricity because the charged ions are free to move through the liquid, carrying the electric current with them. For example, salt (sod ium chloride, NaCl) dissolves because water molecules break up the lattice. This releases sodium ions (Na^+) and chloride ions (Cl^-) into the solution. The presence of these ions in the solution means that salt water is a conductor of electricity.

In contrast, sugar does not release ions when it dissolves in water—there is nothing in the solution that can conduct electricity.

Prac 2 p13

SciFile

Lightning

During a thunderstorm, the clouds build up huge amounts of static electric charge. This charge causes the gas particles in the air to form ions. When enough of the atoms in the air become ions, the electric charge stored in the clouds can travel down to the Earth's surface, producing a spectacular flash of light that we see as lightning.

LEARNING ACROSS THE CURRICULUM

CRITICAL AND CREATIVE THINKING

HISTORY OF THE ATOMIC MODEL

The internal structure of an atom cannot be seen with any microscope. Therefore, scientists must rely on indirect observations to build a model of what is inside an atom. As technology has advanced, scientists' understanding of atoms has increased and the atomic model has evolved.

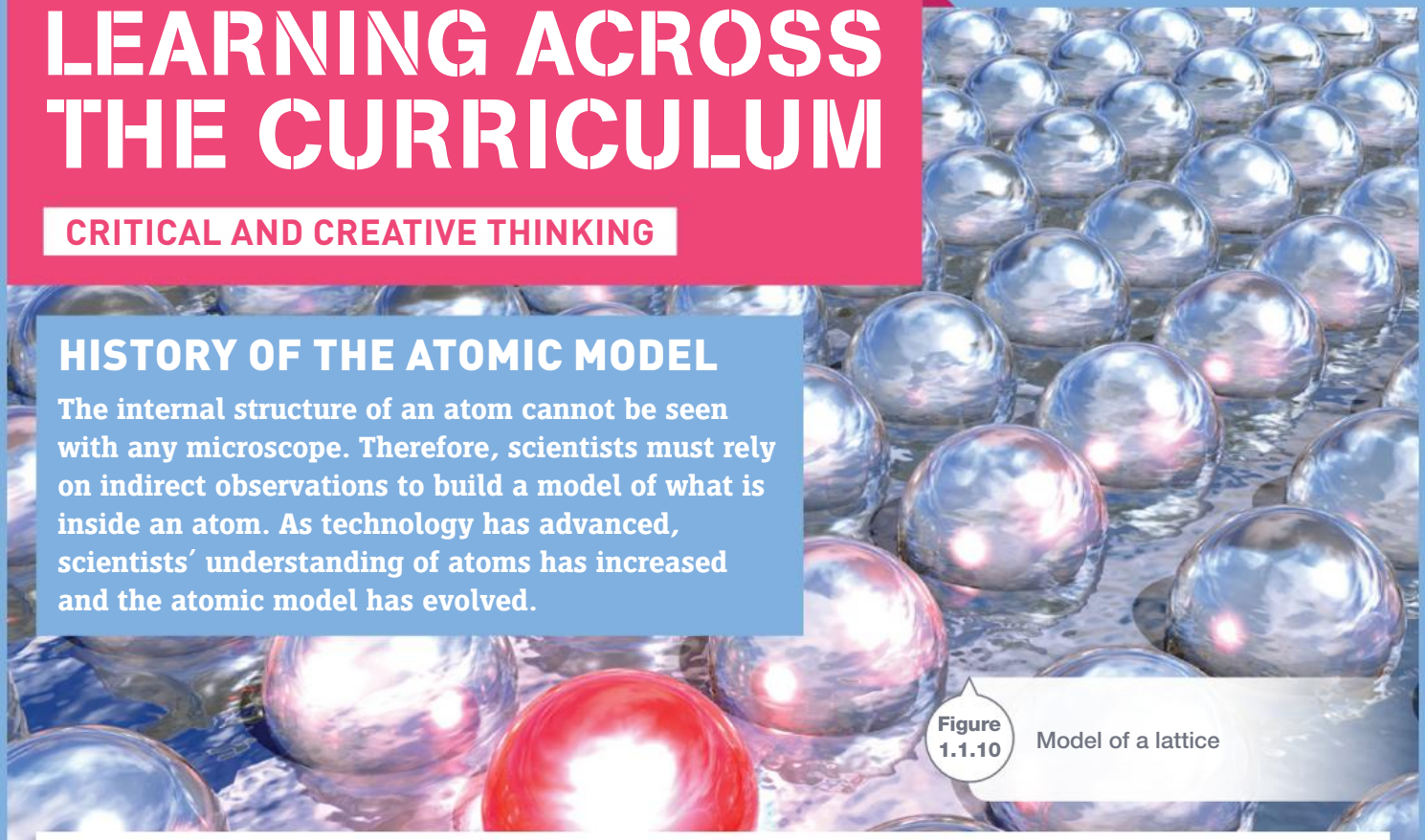
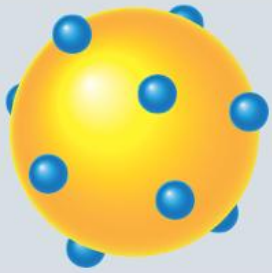
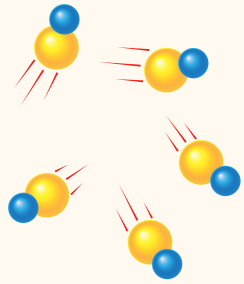
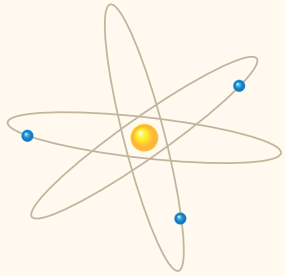
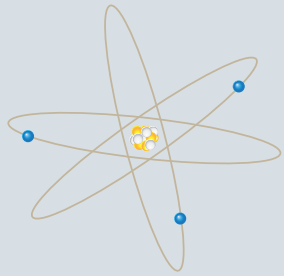
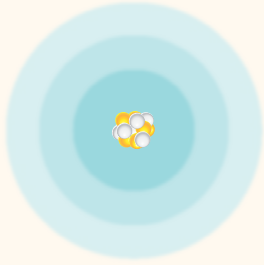


Figure 1.1.10 Model of a lattice

Year	Observation and theory	Model
Early BCE	The ancient Greeks believed that all matter was made up of only four fundamental elements: earth, fire, air and water. This was the basis of the continuum model, which predicted that regardless of the number of times you halve a piece of matter, it can always be broken down into even smaller pieces.	Continuum model
460–370 BCE	Greek philosopher Democritus suggested that matter was not continuous but was made up of tiny, solid and unbreakable particles. He was the first to use the term *atomos* meaning 'indivisible', from which the word *atom* comes.	Solid-ball model
1904	British scientist Joseph John Thomson (J.J. Thomson) discovered the electron and its negative charge in 1897. However, Thomson knew that there must also be a source of positive charge in the atom to make the atom charge neutral. Therefore, in 1904 he proposed the plum pudding model. In this model, an atom is thought of as a round ball of positive charge with negatively charged electrons embedded in it (like plums or sultanas in a plum pudding).	 Plum pudding model

Year	Observation and theory	Model
1904	Hungarian scientist Philipp Lenard described atoms as mostly empty spaces filled with fast-moving 'dynamides'. These were neutrally charged particles made up of a heavy positive particle stuck to a light negative particle.	 Dynamide model
1909–1911	In 1909, New Zealand scientist Ernest Rutherford performed an experiment where he fired a beam of positively charged alpha particles at gold foil. He found that while most of the alpha particles went through the foil, a small number bounced back. This led to the development of a nuclear model of the atom in 1911. In this model most of the mass is contained in a small positive nucleus surrounded by a large space occupied by negative electrons.	Nuclear model
1913	Danish scientist Niels Bohr modified Rutherford's model and proposed that electrons can only travel along certain pathways around the nucleus, called orbits. As a result, this model is sometimes called the planetary model.	 Planetary model
1932	English scientist James Chadwick discovered the neutron, showing that the nucleus was not just a mass of positive charge but a cluster of positively charged protons and charge-neutral neutrons.	 Planetary model with neutrons
1932–today	Today, scientists have concluded that the position of an electron in an atom can never be known exactly. This means that it is impossible for electrons to revolve around the nucleus in specific orbits as suggested by Niels Bohr. Instead, the electrons form clouds around the nucleus. Scientists can predict the shape of these clouds but never the exact location of electrons within them.	 Electron cloud model

REVIEW

1.3

1 **Name** the scientist who discovered the existence of the atomic nucleus.

2 **Compare** the model proposed by Niels Bohr with the motion of the planets around the Sun.

3 **Explain** where the term *atom* came from. L

4 **Calculate** how long it took to discover the neutron after the discovery of the electron. N

5 **Propose** a reason why the neutron was the last of the subatomic particles to be discovered.

1.1 Unit review

Remembering

1 For each of the subatomic particles electrons, protons and neutrons: N
   a **state** its charge
   b **state** its relative mass
   c **specify** where it is located in the atom.

2 **State** whether the following are elements or compounds.
   a carbon (C)
   b water (H_2O)
   c silicon dioxide (SiO_2)
   d sulfur (S_8)
   e sodium chloride (NaCl)

3 **State** whether the following elements are made of molecules or are crystal lattices.
   a oxygen (O_2)
   b copper (Cu)
   c diamond (C)
   d phosphorus (P_4)

Understanding

4 **Define** the terms *atomic number* and *mass number*. L

5 **Explain** why an atom is electrically neutral.

6 a **Outline** Rutherford's experiment with gold foil and alpha particles.
   b **Explain** how he deduced that the atom was largely empty space.

7 **Outline** how a:
   a magnesium atom Mg becomes a magnesium ion Mg^{2+}
   b chlorine atom Cl becomes a chloride ion Cl^-.

Applying

8 **Use** the chemical formulas to **identify** whether the following are elements or compounds.
   a $C_6H_{12}O_6$
   b C_{60}
   c Fe
   d $MgCl_2$
   e H_2SO_4

9 **Determine** the atomic symbol that completely describes the following atoms. N
   a An oxygen atom with 8 protons, 8 neutrons and 8 electrons
   b A calcium atom with 20 protons, 20 neutrons and 20 electrons
   c A gold atom with 79 protons, 114 neutrons and 79 electrons
   d A uranium atom with 92 protons, 146 neutrons and 92 electrons

10 Figure 1.1.11 shows four different versions of what could have happened in Rutherford's gold foil and alpha particle experiment. **Identify** which diagram best represents:
   a what he observed in his experiment
   b what would have happened if the atoms were solid balls
   c if the nucleus and electron cloud were roughly the same size.

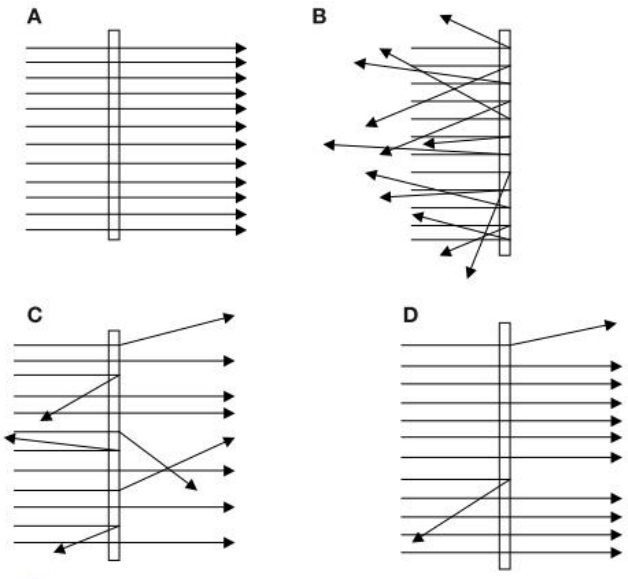


Figure 1.1.11

11 For each of the situations i–iv described below:
   a **name** the ion formed
   b **identify** its charge
   c **identify** the symbol for the ion formed.
      i Lithium (Li) loses an electron.
      ii Aluminium (Al) loses three electrons.
      iii Fluorine (F) gains an electron.
      iv Sulfur (S) gains two electrons.

Analysing

12 **Compare** protons with:

- **a** neutrons
- **b** electrons.

13 **Compare** the five lightest atoms by copying and completing the following table. N

Atom	Atomic number	Mass number	Number of protons	Number of neutrons	Number of electrons	Atomic symbol
Hydrogen	1			0	1	$^{1}_{1}H$
Helium		4		2		
Lithium	3			4		
Beryllium	4	9				
Boron						$^{11}_{5}B$

14 **Compare** elements with compounds.

15 **Calculate** the number of protons, neutrons and electrons in the following atoms. N

- **a** $^{4}_{2}He$
- **b** $^{16}_{8}O$
- **c** $^{28}_{14}Si$
- **d** $^{207}_{82}Pb$
- **e** $^{238}_{92}U$

16 **Compare** a sodium atom Na with its ion Na^{+}.

Evaluating CCT

17 **Propose** what causes a balloon to be attracted to a wall after being rubbed against your hair.

18 **Propose** why scientists have developed atomic symbols to help communicate their results.

Inquiring

1 Find and print a copy of the periodic table. Circle the elements whose chemical symbols don't appear to match their chemical names. Research these elements. Below their English names, write the names and the languages that their symbols have come from.

Present your research as an annotated copy of a periodic table.

2 Research the life of a scientist who has contributed to our understanding of the atomic model, including their education, contributions to the atomic model and other contributions to science.

Present your research as a short biography.

ADDITIONAL

3 Research how electrons arrange themselves in their shells. Find:

- how electron configuration relates to electron shells
- the electron configuration of the first 18 elements of the periodic table.

Present your findings as an introductory paragraph and a table of electron configurations.

ADDITIONAL

1.1 Practical investigations

1 Experimenting like Rutherford

Purpose

To use indirect observation to estimate the size of an unseen object.

Materials

- large cereal box with the top and bottom open
- objects of various shapes and sizes that can fit inside the box
- 5 marbles

Procedure

1. This activity requires you to work in pairs.
2. Place the open cereal box on the desk as shown in Figure 1.1.12.
3. One person places an object in the box without the other person seeing the object.
4. The other person then rolls the five marbles through the box and tries to estimate the size of the object.
5. Record your estimates in a table like the one in the Results section. Compare them to the real size of the object.
6. Repeat this process three more times, so that each member of the pair has two turns at determining the size of the hidden object.

Results

Record your measurements in a table like this one.

	Estimated size	Real size
Object 1		
Object 2		

Practical review

1. **Explain** how this experiment is similar to Rutherford's experiment.
2. **Propose** the factors that might have influenced the accuracy of your estimates.
3. **Propose** other properties of the object that may be determined by indirect observation using this technique.

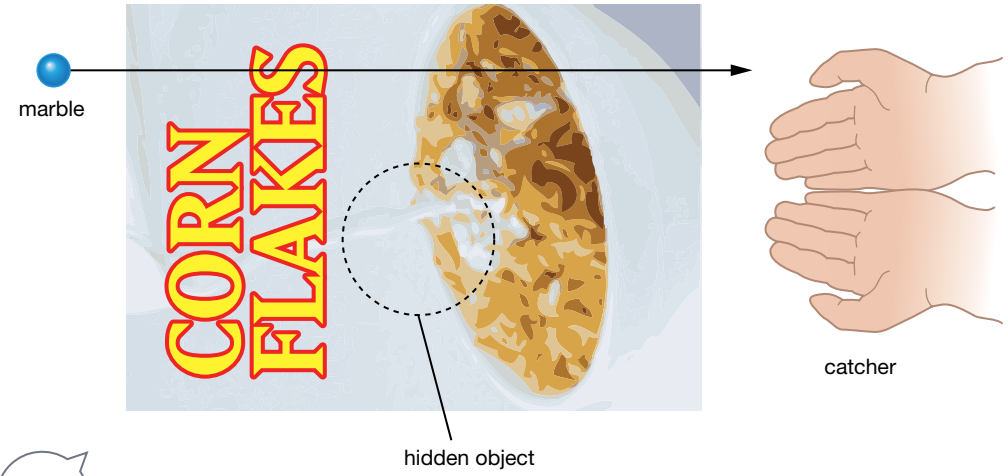


Figure 1.1.12

2 Detecting ions by indirect observation

Purpose

To determine whether common household compounds form ions.

Hypothesis

Which solutions do you think will contain ions—distilled water, salt water, a solution of sugar, coffee or tea, vinegar or vegetable oil? Before you go any further with this investigation, write a hypothesis in your workbook.

Materials

- distilled water
- salt water solution
- sugar (sucrose)
- tea bag
- coffee
- vinegar
- vegetable oil

- 250 mL beaker
- wires with alligator clips
- ammeter
- electrodes

SAFETY

A risk assessment is required for this investigation. Refer to the MSDS of all chemicals when constructing your risk assessment.

Procedure

1. Copy the table from the Results section into your workbook.
2. Use the wires to connect the voltage source, ammeter and electrodes in a circuit as shown in Figure 1.1.13.

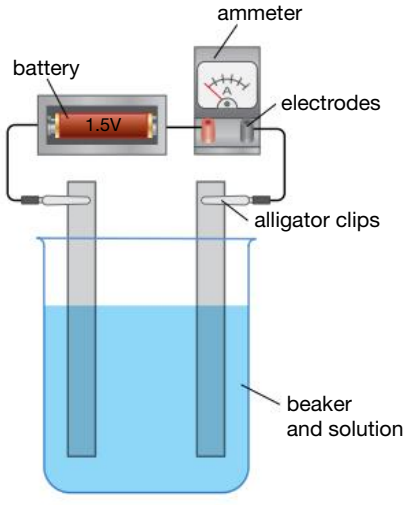


Figure 1.1.13

3. Fill the beaker with distilled water.
4. Place the electrodes in the water and record the current.
5. Replace the distilled water with a salt water solution and repeat the measurement with the ammeter.
6. Rinse the beaker and the electrodes with distilled water.
7. Make up separate solutions of sugar, coffee, tea and vinegar using distilled water. Also make up a mixture of vegetable oil and distilled water.
8. Repeat the measurement of current for these mixtures. Remember to rinse the beaker and electrodes with distilled water each time.

Extension

9. Repeat step 4 but try a globe in place of an ammeter. Will the globe light up?

Results

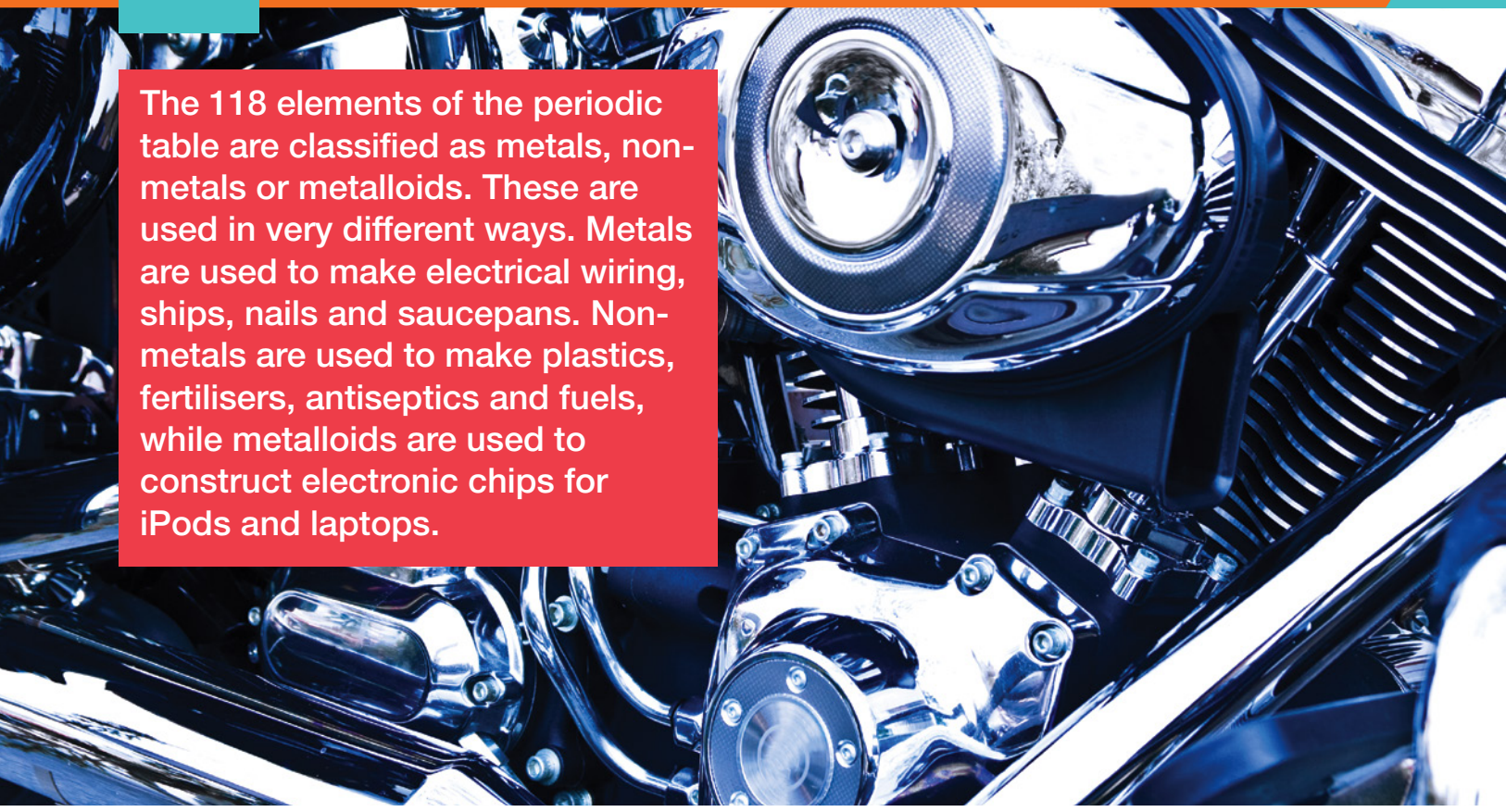
Record all your measurements in a table like this one.

Solution	Current detected? (Yes/No)	Ions present? (Yes/No)
Distilled water		
Salt water solution		
Sugar solution		
Coffee solution		
Tea solution		
Vinegar		
Vegetable oil		

Practical review

1. **List** all the solutions in which ions were present and all the solutions in which ions were not present.
2. **Explain** why a current flowing indicates the presence of ions.
3. a In the cases where no current flowed, **propose** whether the compounds form atoms, molecules or lattices in solution.
   b **Justify** your answer.
4. a **Construct** a conclusion for your investigation.
   b **Assess** whether your hypothesis was supported or not.

1.2 Metals, non-metals and metalloids



The 118 elements of the periodic table are classified as metals, non-metals or metalloids. These are used in very different ways. Metals are used to make electrical wiring, ships, nails and saucepans. Non-metals are used to make plastics, fertilisers, antiseptics and fuels, while metalloids are used to construct electronic chips for iPods and laptops.

KEY

- Non-metals
- Metals
- Metalloids

atomic number — 13
symbol — Al
name — aluminium

1 H hydrogen																2 He helium
3 Li lithium	4 Be beryllium											5 B boron	6 C carbon	7 N nitrogen	8 O oxygen	9 F fluorine	10 Ne neon
11 Na sodium	12 Mg magnesium											13 Al aluminium	14 Si silicon	15 P phosphorus	16 S sulfur	17 Cl chlorine	18 Ar argon
19 K potassium	20 Ca calcium	21 Sc scandium	22 Ti titanium	23 V vanadium	24 Cr chromium	25 Mn manganese	26 Fe iron	27 Co cobalt	28 Ni nickel	29 Cu copper	30 Zn zinc	31 Ga gallium	32 Ge germanium	33 As arsenic	34 Se selenium	35 Br bromine	36 Kr krypton
37 Rb rubidium	38 Sr strontium	39 Y yttrium	40 Zr zirconium	41 Nb niobium	42 Mo molybdenum	43 Tc technetium	44 Ru ruthenium	45 Rh rhodium	46 Pd palladium	47 Ag silver	48 Cd cadmium	49 In indium	50 Sn tin	51 Sb antimony	52 Te tellurium	53 I iodine	54 Xe xenon
55 Cs caesium	56 Ba barium	57–71 lanthanoids	72 Hf hafnium	73 Ta tantalum	74 W tungsten	75 Re rhenium	76 Os osmium	77 Ir iridium	78 Pt platinum	79 Au gold	80 Hg mercury	81 Tl thallium	82 Pb lead	83 Bi bismuth	84 Po polonium	85 At astatine	86 Rn radon
87 Fr francium	88 Ra radium	89–103 actinoids	104 Rf rutherfordium	105 Db dubnium	106 Sg seaborgium	107 Bh bohrium	108 Hs hassium	109 Mt meitnerium	110 Ds darmstadtium	111 Rg roentgenium	112 Cn copernicium	113 Uut ununtrium	114 Fl flerovium	115 Uup ununpentium	116 Lv livermorium	117 Uus ununseptium	118 Uuo ununoctium

Lanthanoids	57 La lanthanum	58 Ce cerium	59 Pr praseodymium	60 Nd neodymium	61 Pm promethium	62 Sm samarium	63 Eu europium	64 Gd gadolinium	65 Tb terbium	66 Dy dysprosium	67 Ho holmium	68 Er erbium	69 Tm thulium	70 Yb ytterbium	71 Lu lutetium
Actinoids	89 Ac actinium	90 Th thorium	91 Pa protactinium	92 U uranium	93 Np neptunium	94 Pu plutonium	95 Am americium	96 Cm curium	97 Bk berkelium	98 Cf californium	99 Es einsteinium	100 Fm fermium	101 Md mendelevium	102 No nobelium	103 Lr lawrencium

Figure 1.2.1 The periodic table displays all 118 known elements. There are roughly four times as many metals as there are non-metals and metalloids in the table, but in the universe the number of non-metallic atoms is far greater than the number of metallic atoms. This is because stars are made mainly of hydrogen and helium.

Elements

Elements are substances that are made up of only one type of atom. Each atom in an element has the same number of protons in its nucleus. This gives each element its own distinctive atomic number. For example, carbon (symbol C) is an element because all of its atoms are carbon atoms. Each carbon atom has 6 protons in its nucleus, giving carbon an atomic number of 6. Likewise, the element gold (Au) has an atomic number of 79 and so every gold atom contains 79 protons.

GO TO Pearson science NSW 10 Unit 4.1

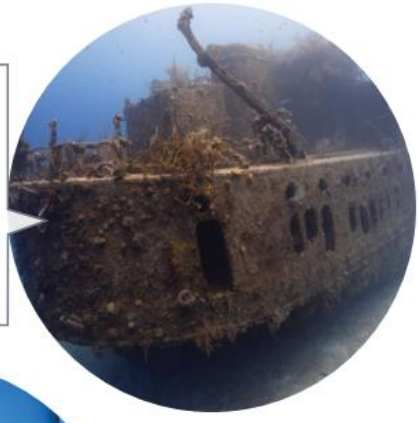
The periodic table

There are 118 different elements and therefore 118 different types of basic atoms. The **periodic table** is a list of all 118 known elements, arranged in order of their atomic number. As the periodic table in Figure 1.2.1 shows, elements are classified according to their properties as metal, non-metal or metalloid.

Metals

Metals are **lustrous** (they shine when polished), **malleable** (they can be bent into new shapes without breaking) and **ductile** (they can be stretched into wires). These are just three of the physical properties that have made metals invaluable to humans throughout history. They form the basis of much of our technology and art, from horseshoes, swords, electrical wiring and the frames of skyscrapers to jewellery, statues and the gold leaf on paintings.

Figure 1.2.2 outlines the physical properties shared by the metallic elements.



Metals are dense. Almost all metals are denser than water and so will sink when dropped into it. The only exceptions are lithium (Li), sodium (Na) and potassium (K). These float on water.

Metals are electrical conductors. They pass electricity along and through them.

Metals are thermal conductors. They pass heat easily along and through them.

Metals are malleable. They can be hammered and squashed to form new shapes.

Metals are lustrous. They shine when polished or freshly cut.

Metals are solid at room temperature. Mercury (Hg) is an exception because it is a liquid.

Metals are ductile. They can be stretched and drawn into long thin wires.

Figure 1.2.2 The physical properties of metals

Pure metals

Most metals cannot be used as pure elements because they have properties that make them impractical. For example, most pure metals are too soft to be made into anything useful. Table 1.2.1 shows metals that are often used in their pure form.

Alloys

Most of the metals around you are not pure elements but are alloys. An **alloy** is a metal (known as the **base metal**) combined with small amounts of other elements. The properties of the new alloy are usually an improvement over those of the base metal. For example, **steel** is much stronger and harder than its iron base metal, allowing it to be used in everything from paperclips, staples, nails and screws to cars, ship hulls and the frames of bridges and skyscrapers. Steel is an alloy of iron with small amounts of carbon added to it. Different amounts of carbon produce different steel alloys.

- Wrought iron contains almost no carbon and is the closest alloy to pure iron.
- Mild steel has only 0.5% carbon.
- Hard steel or tool steel has about 1% carbon.
- Cast iron has between 2.4% and 4.5% carbon. Cast iron is strong but **brittle**, shattering easily if hit or dropped.

Steel can be further improved by adding chromium and nickel to it. This addition produces rust-resistant **stainless steel**. Stainless steel is used in hot, wet and salty environments that would cause rapid rusting of other types of steel. This is why stainless steel is used in kitchens, on ships, for surgical instruments and for jewellery for body piercings like those in Figure 1.2.3.

Figure 1.2.3 High-grade stainless steel doesn't rust and so is ideal for body piercings.

Pure gold is so soft and fragile that any jewellery made from it would soon break. For this reason, silver and/or copper are added to it to create a stronger alloy. The **carat** scale measures the amount of pure gold in jewellery, with pure gold rated as 24 carat. Jewellery is often 18 carat, meaning that it is $\frac{18}{24}$ (three-quarters or 75%) gold.

Other alloys are shown in Table 1.2.2.

Table 1.2.1 Pure metals and their uses

Pure metal	Uses	Properties that make it particularly suited to its use
Aluminium Al	Overhead electricity cables, saucepans and cans, aluminium foil	Excellent conductor of heat and electricity, extremely light, non-toxic
Copper Cu	Electrical wiring, water pipes	Excellent electrical conductor, easily stretched into wires
Lead Pb	Flashing around windows and roofs to stop water entry	Very soft and easily bent, resists corrosion
Mercury Hg	Clinical thermometers, barometers, mercury switches	Liquid at room temperature, expands rapidly when heated, leaving tubes clean once it retreats, leaving no traces
Sodium Na	Nuclear reactor coolant, street lamps (as a vapour)	Good conductor of heat, melts at 98°C, allowing molten sodium to flow along pipes in the reactor
Tin Sn	Coating for steel cans used for storing food	Stops steel from rusting, doesn't react with food, non-toxic
Zinc Zn	Coating for iron and steel (galvanised iron)	Is more reactive than iron and so protects it from rusting

1.4 1.5 Prac 1 p21

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Gold isn't always gold!

Australian 'gold' $1 and $2 coins contain 92% copper, 6% aluminium and 2% nickel (and no gold). The 'silver' coins are 25% nickel and 75% copper. In contrast, the first circular 50-cent coins of 1966 were 80% silver. Eventually, this made them far more valuable as metal than as a coin!

Table 1.2.2 Alloys and their uses

Alloy	Composition	Uses	Advantages
Brass	70% Cu, 30% Zn	Hinges, door handles, fittings on boats and ships, musical instruments, e.g. trumpets and trombones	• Good looking • Doesn't corrode much • Stronger than its base metal (copper)
Bronze	95% Cu, 5% Sn	Statues, ornaments, bells	• Good looking • Doesn't corrode easily • Sonorous (makes a good ringing sound when struck) • Harder than brass • Stronger than its base metal (copper)
Duralumin	96% Al, 4% Cu, traces of Mg and Mn	Aircraft frames	• Very light • Stronger than its base metal (aluminium)
Solder	60–70% Sn, 30–40% Pb	Joining metals together, electrical connections, low-friction bearings	• Easy to melt • Easy to use
Cupronickel	75% Cu, 25% Ni	'Silver' coins (5, 10, 20 and 50 cents)	• Hard wearing • Looks like silver
EPNS (electroplated nickel silver)	46–63% Cu, 18–36% Zn, 6–30% Ni	Plated onto cutlery, plates and bowls	• Looks like silver • Cheaper than silver • Resists corrosion
Dental amalgam	43–54% Hg, 20–35% Ag, 10% Cu, 2% Zn, traces of Sn	Tooth fillings	• Hardens slowly after being mixed

SciFile

Mag wheels

Mag wheels (alloy wheels) are made from an alloy of magnesium and aluminium. This alloy is much lighter than the steel normally used for car wheels, making the car handle better. The alloy also conducts heat away from the brakes better than steel, keeping the brakes cooler and improving their performance.

INQUIRY science 4 fun

Rust away!

YES

Can you get steel to rust in one day?

Collect this…

- steel wool (plain, with no soap)
- vinegar
- liquid bleach
- screw-top glass jar

Do this…

1. Put a lump of steel wool in the bottom of the screw-top jar.
2. Pour in enough water to cover the steel wool.
3. Add a little vinegar and a little bleach.
4. Screw on the top of the jar and check what happens to the steel wool over the next day.

Record this…

Describe what happened.

Explain why you think this happened.

Non-metals

Most non-metals are found naturally as gases in the air. A few are solids found in the Earth's crust, such as the sulfur that occurs around volcanoes. The physical properties of non-metals are very different from those of metals. You can see these properties in Figure 1.2.4.

Non-metals are poor conductors of heat and electricity. They are thermal and electrical insulators.

Non-metals have relatively low melting and boiling points. Bromine is a liquid at normal room temperature. The other non-metals are gases or easily melted solids.

Non-metals are brittle. Solid non-metals tend to crumble into powders.

Non-metals are dull. They have little or no shine.

Figure 1.2.4 The physical properties of non-metals

Carbon wheels!

In 2010, Deakin University in Geelong (Victoria) and research firm CFusion released the world's first car wheel constructed from a *single* carbon fibre. Being incredibly light yet strong, the wheel promises to dramatically enhance car performance. It is to be used in one of the world's fastest cars, the Shelby Ultimate Aero.

SciFile

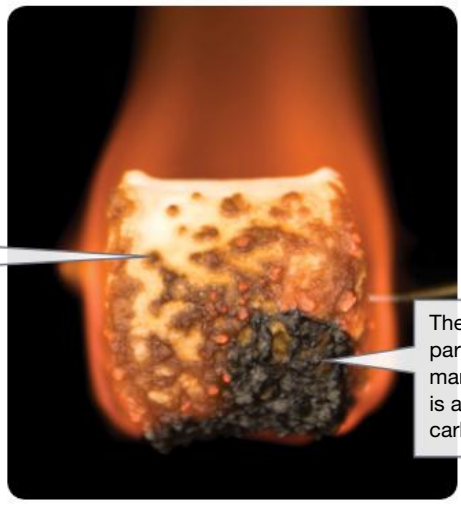
Carbon

Carbon is an unusual element because its atoms combine with other carbon atoms and with atoms of other elements (usually hydrogen and oxygen) to form lattices, long chains and rings. Over 90% of all known compounds contain carbon. Some of these compounds are essential to life on Earth. Carbon exists in molecules in every living thing and anything that was once part of a living thing.

Pure carbon exists in several different forms, called **allotropes**. Three common allotropes are:

- amorphous carbon
- diamond
- graphite.

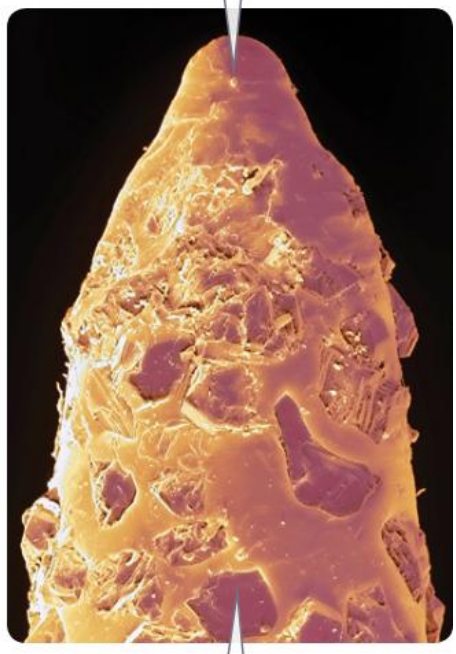
These are shown in Figure 1.2.5.



Amorphous carbon
Black powder and burnt bits you find on burnt toast, after bushfires, in charcoal and in coal.

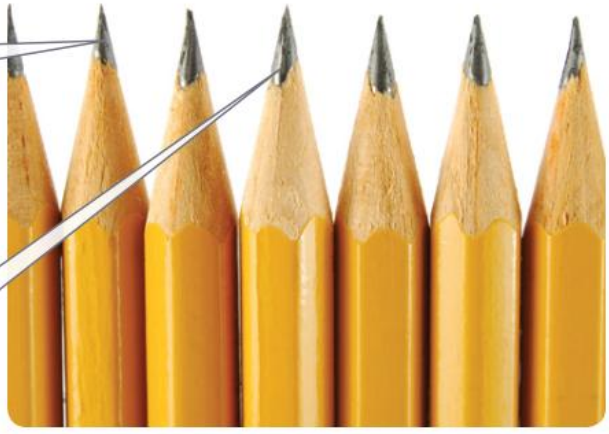
The black, burnt part of this marshmallow is amorphous carbon.

Diamond
The hardest known natural substance. Only 20% of diamonds are gem-grade. The rest are used to cut glass, metal and masonry or are crushed to make abrasives.



Graphite
A soft, slippery solid that conducts electricity. It is an excellent lubricant and forms the electrodes in many batteries and the connection brushes in electric motors.

The grey 'lead' in pencils is a graphite/clay mix.



Dental drills often have diamond tips. This is a scanning electron microscope (SEM) image of a diamond tip.

Figure 1.2.5 Some of the forms in which carbon exists

Diamond destruction!

SciFile

The English scientist Sir Humphry Davy (1778–1829) demonstrated that diamond was a form of carbon by burning a diamond that belonged to his wealthy wife! All that was left was carbon dioxide. Temperatures of about 800°C are required to convert diamond to graphite. Unfortunately it's much, much harder to turn graphite into diamond.

Prac 2 p22 Prac 3 p23

Metalloids

Metalloids (sometimes called semimetals) act like non-metals in most ways. However, they also have some properties that are more like those of metals. Most importantly, metalloids are semiconductors, meaning that they can conduct electricity under certain conditions. This ability has made silicon and germanium ideal materials from which to build electronic components like the one shown in Figure 1.2.6. These components are used in devices such as laptops, LED TVs and iPads.

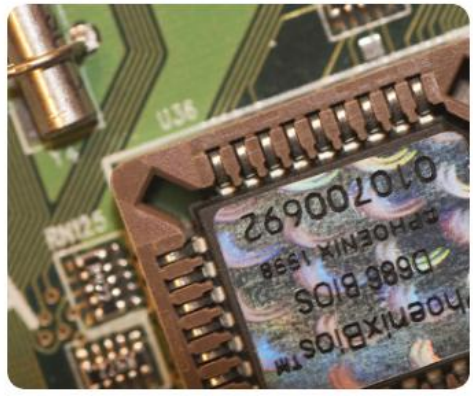


Figure 1.2.6 This electronic microprocessor chip is constructed from the metalloid silicon.

1.2 Unit review

Remembering

1 **State** the number of different elements.

2 **List** the names and symbols of three metals, three non-metals and three metalloids.

3 **Name** the only metal that is a liquid at normal room temperature.

4 **List** the different types of steel, from the lowest carbon content to the highest.

5 For stainless steel, **name** the:
- a base metal
- b added metals that give it rust resistance.

Understanding

6 **Explain** why most metals sink in water.

7 **Define** the following terms. L
- a lustrous
- b malleable
- c brittle

8 **Explain** why gold is rarely used in its pure form.

9 **Explain** why the slipperiness of graphite makes it ideal for use in grey-lead pencils.

Applying

10 **Identify** two physical properties that make metals the ideal material from which to construct electrical wires.

11 **Identify** the metal common to both the alloys brass and bronze.

12 **Calculate** the fraction and percentage of pure gold in a: N
- a 12-carat gold ring
- b 9-carat gold nose stud
- c 22-carat gold chain.

13 Wood, paper and food scraps all burn, leaving charcoal and ash behind. This suggests that they all have the same basic element in them. **Identify** what that element is.

14 Iron and steel rust in the presence of water and oxygen. **Use** this information to **predict** how much rusting would occur to steel in the:
- a body of a car left in the desert
- b hull of a sunken ship buried in mud so dense that there is no oxygen in it.

15 Below is a list of different atoms. Their element symbols have been replaced with the letters A–E.

$^{12}_{5}A$ $^{25}_{12}B$ $^{14}_{7}C$ $^{13}_{5}D$ $^{25}_{15}E$

- a **State** how many different elements are represented in the list. N
- b **Use** the periodic table on page 14 to **identify** the different elements represented in the list.

Analysing

16 **Compare** the number of elements that are metallic, non-metallic and metalloids.

17 **Classify** the following as normally properties of metals or non-metals:
- a ductile
- b normally gas or liquid
- c dense
- d malleable
- e brittle
- f lustrous
- g dull
- h most are solid
- i thermal and electrical insulators
- j excellent thermal and electrical conductors

Evaluating CCT

18 Cans that contain soup, dog food or vegetables are made predominantly of steel, yet are often called tins. **Propose** a reason why.

19 Graphite is carbon (a non-metal) but it conducts electricity like a metal. **Use** this information to **propose** a reason why carbon could be classified as a metalloid instead of a non-metal.

20 **Propose** what would be the base metal in a ferrous alloy. (Use the element symbols of metals to help you.)

Inquiring

Some people are now having the amalgam fillings in their teeth replaced with other materials. Research why.

Present your research as a brochure to give to dental patients.

1.2 Practical investigations

1 Making steel stronger

Heating changes the properties of steel because it changes the size of its crystals.

Purpose

To determine which treatment makes steel tougher.

Materials

- four steel hairpins
- steel wool

- Bunsen burner, bench mat and matches
- wooden peg
- beaker, tub or sink filled with cold water
- pliers (optional)

SAFETY

The hairpin will get red-hot so use a peg at all times to hold it. Water may spit when the hot pin is dropped into it so wear safety glasses at all times.

Procedure

1. Copy the table from the Results section into your workbook.
2. Count the number of times you can bend a hairpin before it snaps. One bend is out and in again. Enter the number in your table.
3. Hold another hairpin with the peg and heat the bend of the pin in a blue Bunsen burner flame until it is red-hot (Figure 1.2.7). Allow it to cool on the bench mat. This process is known as normalising or **annealing**.
4. Heat another hairpin in the same way, then cool it rapidly by dropping it into a beaker of water. This process is known as **quenching**.
5. Repeat step 4 with the remaining hairpin, then polish the bend with steel wool. Re-heat the bend of the pin, removing the pin occasionally to check whether the bend has gone blue. Once it has, remove the pin from the flame and allow it to cool on the mat. This process is known as **tempering**.
6. Bend each of the pins as before, counting the number of times you can bend the pin before it breaks. Record your counts in the results table.

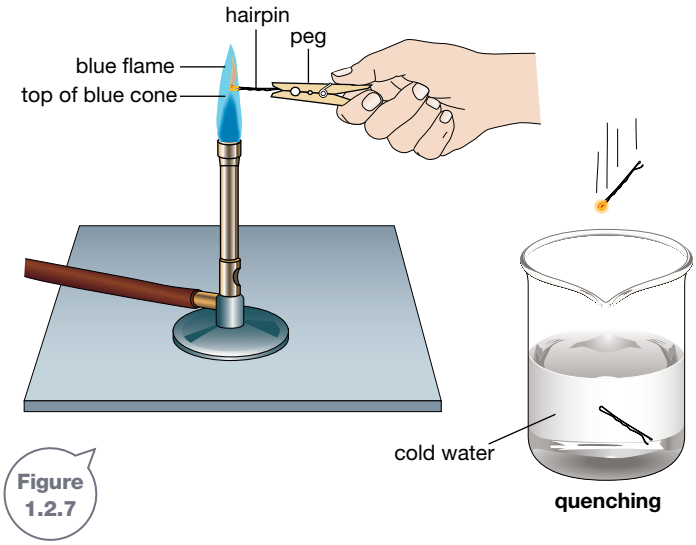


Figure 1.2.7

Results

Record all your observations in a table like this one.

Treatment	Number of bends needed to break pin	Did the treatment make the pin tougher?
No treatment		
Normalising/ annealing		
Quenching		
Tempering		

Practical review

1. **Outline** the processes of annealing, quenching and tempering.
2. **State** which treatment caused your hairpin to become more:
   a. brittle (easier to snap)
   b. malleable (more 'bendy' and less likely to snap).
3. Fast cooling produces small crystals; slow cooling produces bigger ones. **Predict** which of the treatments produced the biggest crystals.
4. **Propose** reasons why bigger crystals make steel tougher than small crystals.
5. Blacksmiths repeatedly heat, hammer and cool (quench) steel when making horseshoes. **Propose** a reason why.

2 Making oxygen

Purpose

To prepare and test oxygen gas.

Materials

- 5 mL hydrogen peroxide solution
- 1 g manganese(IV) oxide pellets

- 1 large test-tube, rubber stopper with opening and glass tube to fit
- hosing to fit glass tube
- 2 test-tubes with stoppers
- test-tube rack
- retort stand, bosshead and clamp
- large container (such as an ice-cream container)
- 10 mL measuring cylinder
- wooden splint
- electronic balance
- rubber gloves

SAFETY

Hydrogen peroxide burns and is toxic. It can explode when heated and may cause fires if in contact with combustible materials. Wear safety glasses, protective clothing and rubber gloves.

Procedure

Part A: Preparation of oxygen

1. Use the electronic balance to weigh out approximately 1 g of manganese(IV) oxide pellets.
2. Use the measuring cylinder to carefully measure out 5 mL of hydrogen peroxide.
3. Set up the equipment as shown in Figure 1.2.8.
4. Fill both the two smaller test-tubes with water. Put your thumb over the end on one, upend it and clamp as shown. Put the other one in the test-tube rack for later on.
5. Remove the rubber stopper and drop the manganese(IV) oxide pellets into the large test-tube.
6. Add the hydrogen peroxide and replace the rubber stopper.
7. The inverted test-tube should fill with oxygen gas. Remove the test-tube when full of gas, stopper it and place it in the rack.

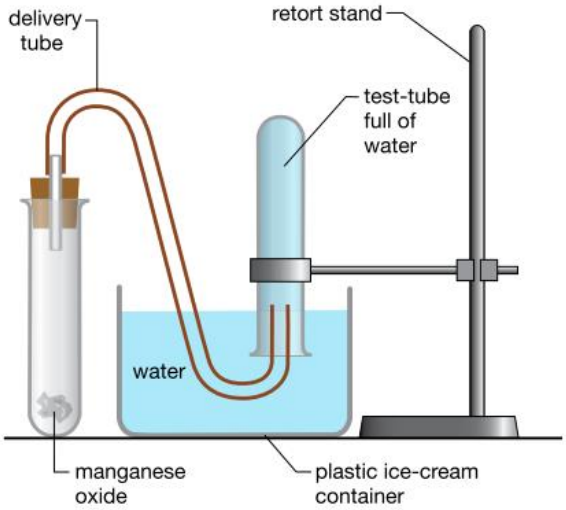


Figure 1.2.8

8. Fill the other test-tube with oxygen and store it in the rack.
9. The reaction in the large test-tube can be stopped by carefully adding water to it.

Part B: Testing oxygen

10. Use one tube of collected gas to make as many observations as you can about oxygen. For example, waft the gas towards you and attempt to smell it.
11. Light the wooden splint, allow it to burn for a few seconds and then blow it out. Insert the glowing end of the splint into the second test-tube of oxygen and record what happens.

Results

1. Construct a table to record your observations.
2. Record the state, colour and smell of oxygen gas and what it did to the glowing splint.

Practical review

1. **Use** your observations to **propose** why fanning a fire encourages it to burn.
2. **Propose** a reason why the burning splint doesn't burst into flame again when in air, despite air having oxygen in it.

STUDENT DESIGN

3 The better conductor

Purpose

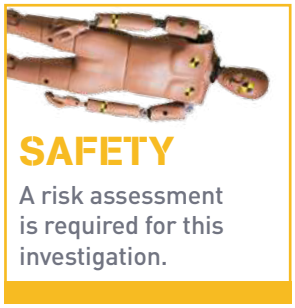
To find out whether wood or graphite is the better conductor of heat and electricity.

Hypothesis

Which substance do you think will conduct heat and electricity better—graphite or wood? Before you go any further with this investigation, write a hypothesis in your workbook.

Materials

- To be selected by students



SAFETY

A risk assessment is required for this investigation.

Procedure

1. Design an experiment that will test how well wood and graphite conduct heat and electricity.
2. Brainstorm in your group and come up with several different ways to investigate the problem. Select the best procedure and write it in your workbook. Draw a diagram of the equipment you need.
3. Before you start any practical work, assess all risks associated with your procedure. Refer to the MSDS of all chemicals used. Construct a risk assessment that outlines these risks and any precautions you need to take to minimise them. Show your teacher your procedure and your risk assessment. If they approve, then collect all the required materials and start work.

Hints

- The grey 'lead' in pencils is graphite.
- You will need to construct a simple electric circuit that includes a battery or low-voltage power pack and a light globe.

Practical review

1. a **Construct** a conclusion for your investigation.
   b **Assess** whether your hypothesis was supported or not.
2. **Evaluate** your procedure. Pick two other prac groups and **evaluate** their procedures too, identifying their strengths and weaknesses.
3. The handles of screwdrivers were once made of wood. **Use** the results of this investigation to **propose** a reason why.

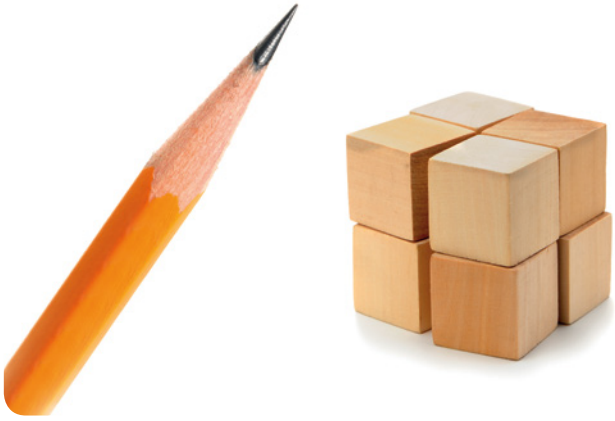
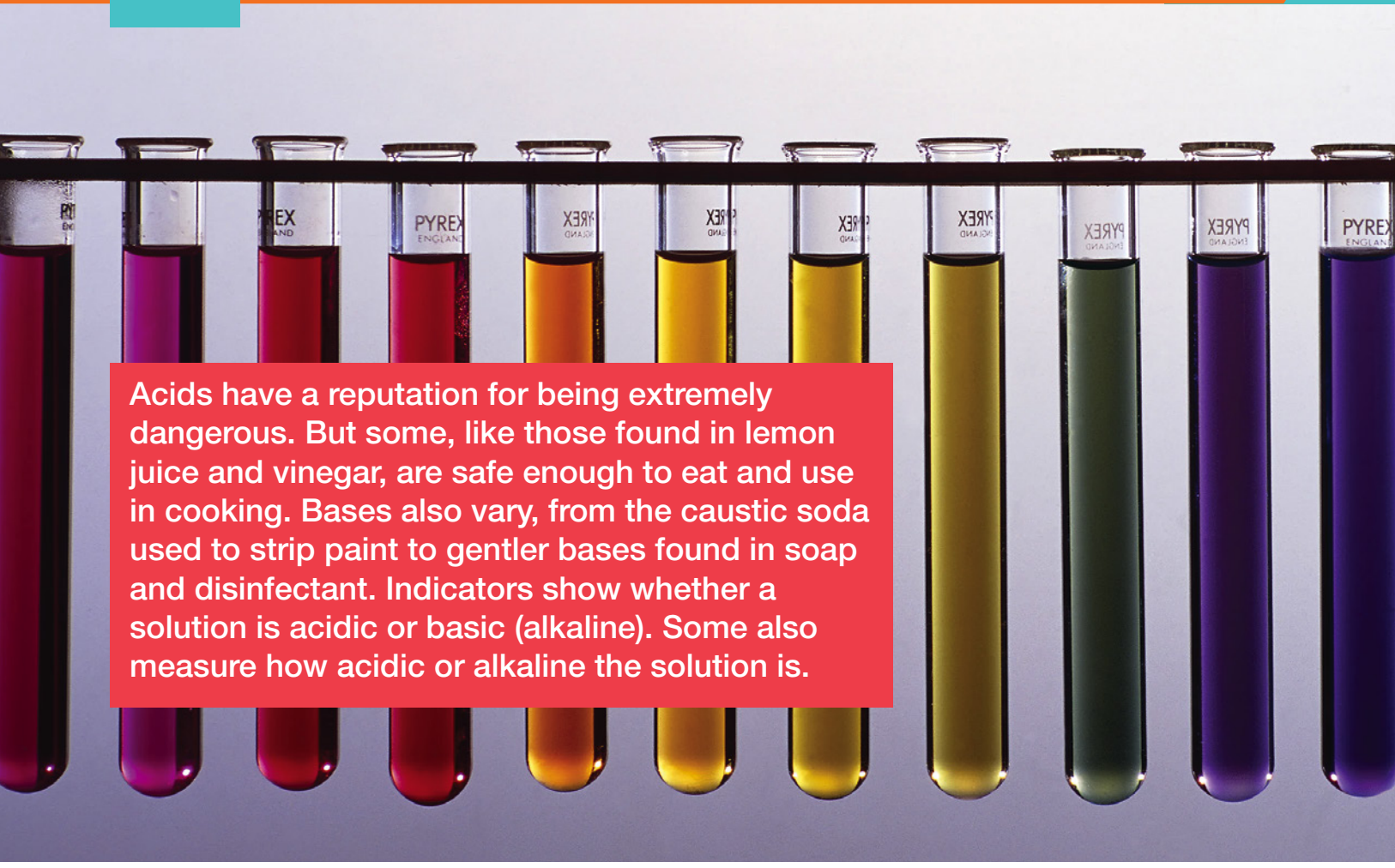


Figure 1.2.9 Which of these materials is the better conductor?

1.3 Acids and bases



Acids have a reputation for being extremely dangerous. But some, like those found in lemon juice and vinegar, are safe enough to eat and use in cooking. Bases also vary, from the caustic soda used to strip paint to gentler bases found in soap and disinfectant. Indicators show whether a solution is acidic or basic (alkaline). Some also measure how acidic or alkaline the solution is.

Acids

An **acid** is a substance that releases hydrogen ions (H^+) into an aqueous solution (containing water). Examples are the hydrochloric acid that's in your stomach and the acetic acid (ethanoic acid) found in vinegar.

Properties of acids

Acids have similar chemical properties. Acids:

- are corrosive. An acid burn is shown in Figure 1.3.1
- have a sour taste (think of the taste of vinegar)
- turn blue **litmus paper** red (shown in Figure 1.3.2)
- react with some metals, releasing hydrogen gas and leaving a salt behind
- conduct electricity
- are neutralised by bases, producing water and a salt.

Figure 1.3.1 Acid burns can be severe, particularly if the acid is spilt into sensitive tissue such as in the eye.

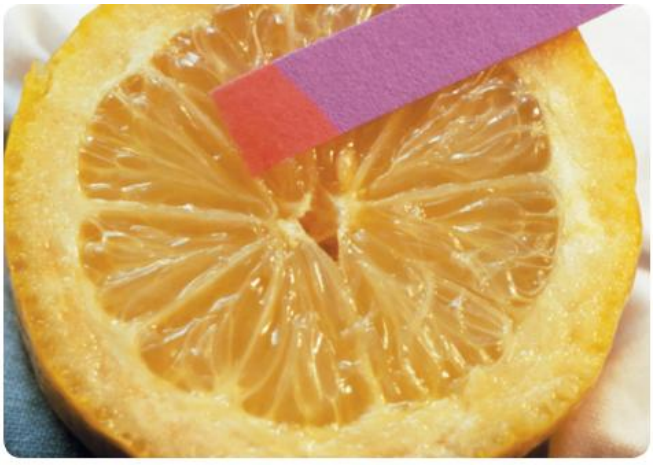


Figure 1.3.2 Acid turns blue litmus paper red.

Animal acids and bases

SciFile

A bite from a bull-ant hurts because the ant injects formic acid (also known as methanoic acid, HCOOH) into a cut made with its pincers. A bee sting also contains methanoic acid. Wasps and jellyfish inject a base. It's a different chemical but it still hurts!

Acids are molecular compounds made up of atoms from different elements. For example, a molecule of nitric acid (HNO_3) contains one hydrogen atom, one nitrogen atom and three oxygen atoms. Like nitric acid, all acids have hydrogen atoms in their molecules.

The acids you will work with in the laboratory (including nitric acid) are not pure substances but are solutions of acid mixed with water. When mixed with water, some of the hydrogen atoms in the acid molecule are released to form **hydrogen ions** (H^+).

The strength of an acid depends on how many hydrogen ions are released. An acid is strong if most of its molecules release hydrogen ions into solution. Nitric acid is an example of a strong acid, as are hydrochloric acid (HCl) and sulfuric acid (H_2SO_4). In contrast, an acid is weak if only a few of its molecules release hydrogen ions. An example of a weak acid is vinegar (ethanoic acid or acetic acid).

Figure 1.3.3 compares what solutions of hydrochloric acid and acetic acid would look like if you could see their ions. Other examples of strong and weak acids are listed in Table 1.3.1 on page 26.

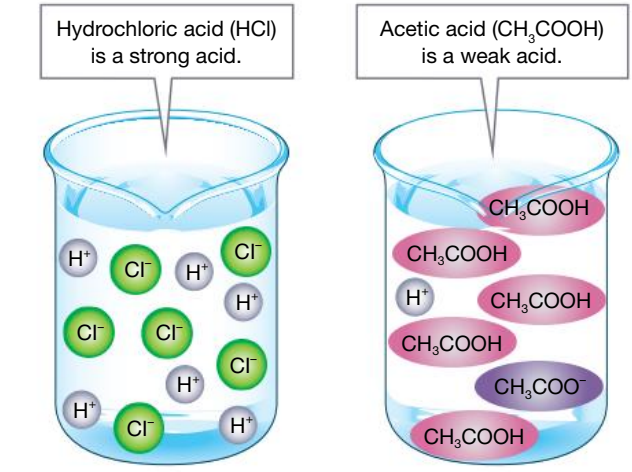


Figure 1.3.3 Strong acids such as hydrochloric acid release lots of H^+ ions into solution. Weak acids such as ethanoic acid (vinegar) release very few H^+ ions.

Table 1.3.1 Examples of acids

Strong acids		
Acid	**Chemical formula**	**Used for/found in**
Hydrochloric	HCl	• Cleaning mortar off bricks • Your stomach (part of its gastric juices)
Nitric	HNO_3	• Making fertilisers, dyes and explosives
Sulfuric	H_2SO_4	• Making other chemicals, dyes, fertilisers, synthetic fibres and plastics

Weak acids		
Acid	**Chemical formula**	**Use for/found in**
Ascorbic	$C_6H_8O_6$	• Vitamin C
Acetylsalicylic	$C_9H_8O_4$	• Making aspirin
Carbonic	H_2CO_3	• Rain water • Fizzy soft drinks and beer
Citric	$C_6H_8O_7$	• Citrus fruits (such as lemons, limes, oranges) • Tomatoes
Acetic (ethanoic)	CH_3COOH	• Vinegar
Malic	$C_4H_6O_5$	• Apples • Most unripe fruits
Lactic	$C_3H_6O_3$	• Milk, yoghurt • Your muscles after heavy exercise, making them hurt
Tannic	$C_{76}H_{52}O_{46}$	• Wood stains • Tea
Tartaric	$C_4H_6O_6$	• Grapes, bananas

Bases and alkalis

Ions are not always single 'charged atoms' like the hydrogen ions (H^+) that acids release. Ions can also be charged groups of atoms. This type of ion is known as a **polyatomic** ion (*poly* means 'more than one'). An example is the **hydroxide ion** (OH^-).

A **base** is a substance that releases hydroxide ions (OH^-). You use a weak base every time you use soap. If a base can be dissolved in water, it is also known as an **alkali**. The solution it forms is known as an **alkaline solution**. Bases such as caustic soda can burn you as badly as acids can, and so bases need to be treated with as much care as acids. All bases have similar chemical properties. Bases:

- are caustic
- have a soapy, slimy feel
- turn red litmus paper blue (shown in Figure 1.3.4)
- have a bitter taste
- conduct electricity
- are neutralised by acids, producing water and a salt.

Bases form hydroxide ions (OH^-) in solution. Strong bases produce lots of OH^- ions, while weak bases only produce a few. Some strong and weak bases are shown in Table 1.3.2.

Figure 1.3.4 Alkaline solutions turn red litmus paper blue.

Table 1.3.2 Examples of bases and alkalis

Strong bases/alkalis		
Base/alkali	**Chemical formula**	**Used for/found in**
Calcium hydroxide	$Ca(OH)_2$	• Cement, mortar and concrete • Stripping hair from hides to form leather • Paper production
Sodium hydroxide (caustic soda)	NaOH	• Producing soap • Paint stripper • Drain and oven cleaner

Weak bases/alkalis		
Base/alkali	**Chemical formula**	**Used for/found in**
Ammonia Ammonium hydroxide	NH_3 NH_4OH	• Household cleaners
Sodium hydrogen carbonate (sodium bicarbonate, bicarbonate of soda or baking soda)	$NaHCO_3$	• Baking, to make cakes rise
Magnesium hydroxide (milk of magnesia)	$Mg(OH)_2$	• Antacids
Sodium carbonate	Na_2CO_3	• Washing powders

pH

The concentration of hydrogen ions (H^+) in a solution is measured using the **pH** scale. In an acidic solution, there are more hydrogen ions than hydroxide (OH^-) ions. In contrast, an alkaline solution has more hydroxide ions than hydrogen ions.

Pure water is neither an acid nor a base. It is neutral, having equal numbers of hydrogen and hydroxide ions. It has a pH of 7. As Figure 1.3.5 shows, acids have a pH less than 7, while bases and alkaline solutions have a pH greater than 7.

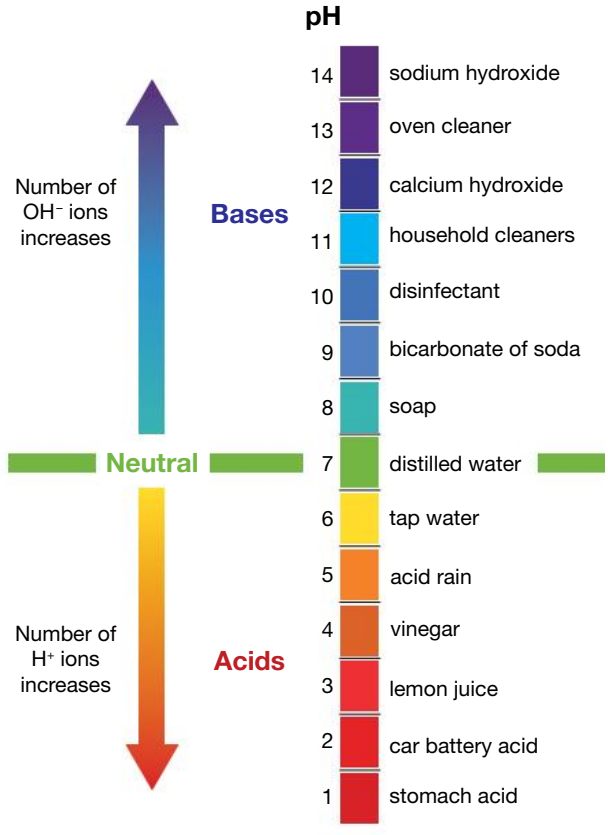


Figure 1.3.5 Neutral solutions have a pH of 7. Acidic solutions have a pH less than 7. Alkaline solutions have a pH greater than 7.

Blood pH

Human blood isn't neutral like pure water but is slightly alkaline, having a pH of between 7.3 and 7.4.

SciFile

Measuring pH

Indicators are chemicals that change colour to show whether a substance is acidic, neutral or basic. A common indicator is litmus paper, which turns red when dipped into acids and blue when dipped into a base. While litmus doesn't tell you what the pH of a solution is, other indicators such as universal indicator do.

As Figure 1.3.6 shows, different indicators change colour at different pH values.

Another way of measuring pH is to use a pH meter. One is being used in Figure 1.3.7.

Prac 1 p30 Prac 2 p31 Prac 3 p31 1.6

Indicator	Colour of indicator pH 1 2 3 4 5 6 7 8 9 10 11 12 13 14
Bromothymol blue	
Litmus	
Methyl orange	
Phenolphthalein	colourless
Universal indicator	

Figure 1.3.6 Different indicators have different colours, allowing pH to be determined accurately.

Figure 1.3.7 Pool water pH needs to be regularly monitored to ensure that the water is safe for swimmers.

INQUIRY science 4 fun

Testing household solutions

NO

What is the pH of different solutions around your home?

Collect this …

- samples of various household solutions (such as fruit juices, soft drink, sour and fresh milk, tap water, salad dressing, detergent, shampoo)
- litmus paper (blue and red)
- watch-glass or white tile

Do this …

1. Pour a little of each solution onto the watch-glass or white tile.
2. Touch one end of a small strip of litmus paper into the solution and then remove it.
3. Record the colour change.

Record this …

Describe what happened.

Explain what this tells you about each of the samples you tested.

1.3 Unit review

Remembering

1 **Name** the acid that is in:
- a vinegar
- b milk
- c lemons.

2 **Name** the following acid and bases.
- a CH_3COOH
- b NaOH
- c NH_3

3 **List** the names and chemical formulae of two strong:
- a acids
- b bases.

4 **Name** the base that is in:
- a paint stripper
- b cement
- c baking soda.

5 **Name** the type of ion formed by:
- a acids
- b bases.

Understanding

6 **Explain** why you have a sour taste in your mouth when you vomit.

7 **Predict** whether litmus paper will turn red or blue when dipped in:
- a washing powder (containing sodium carbonate)
- b orange juice (containing citric acid)
- c lemonade (containing H_2CO_3)
- d cleaner (containing NH_3).

8 **Explain** the main advantage that universal indicator has over litmus.

Applying

9 **Identify** an example of an ion that is:
- a a single atom that has become charged
- b polyatomic.

10 **Use** Figure 1.3.6 to **identify** the colour that the following indicators would be at pH 4.
- a blue litmus
- b phenolphthalein
- c universal indicator

Analysing

11 **Compare** the number of H^+ ions in a solution of nitric acid with the number found in ethanoic acid (vinegar) of the same concentration.

12 The most common isotope of hydrogen is ^1_1H.
A hydrogen ion H^+ is a hydrogen atom that has lost its single electron. **Analyse** this information and **identify** the subatomic particle that makes up a typical hydrogen ion.

Evaluating CCT

13 Heartburn has nothing to do with your heart. It is caused by gastric juices rising from the stomach into the oesophagus. **Propose** what is causing the pain of heartburn.

14 The pH of most public pools is measured using a pH meter, not an indicator. **Propose** reasons why.

15 Squashed ants have a distinctive smell. **Propose** what chemical causes the smell.

16 **Propose** reasons why bricklayers commonly wear gloves when working.

17 Nitric acid is a strong acid but a dilute solution of it might have exactly the same pH as a concentrated solution of vinegar, which is a weak acid. **Propose** a reason why.

Creating CCT

18 **Construct** a symbol (that uses no words) to be used on a sticker that would warn people that a bottle contained a concentrated solution of a strong acid like sulfuric acid.

Inquiring

1 Use the key words *acid base videos* to find internet videos on acids, bases and pH. ICT

2 Use the key words *acid base games* to find interactive games on the internet. One you should try to find is the GEMS Alien Juice Bar Game. ICT

1.3 Practical investigations

1 Red cabbage indicator

Purpose

To make an indicator from red cabbage.

Materials

- a few millilitres each of dilute (0.1 M) hydrochloric acid, dilute (0.1 M) sodium hydroxide solution, vinegar, salt solution, distilled water, soft drink and lemon juice
- 1 antacid tablet (such as Alka Seltzer)
- red cabbage leaves (or red flower petals such as carnation, rose or geranium)

SAFETY

Most chemicals in this prac are corrosive or caustic, so wear rubber gloves, protective clothing and safety glasses at all times.

- 250 mL beaker
- eyedropper
- hotplate or Bunsen burner, tripod, gauze mat and bench mat
- 8 test-tubes
- test-tube rack

Procedure

Part A: Making the indicator

1. Tear up one or two red cabbage leaves, and place them in the beaker with enough water so that the cabbage is just covered.
2. Heat the beaker until the water is gently boiling. Continue to boil the water until it has been strongly coloured red by the cabbage leaves.
3. Allow the water to cool and then filter, strain or pick out the cabbage leaves.

Part B: Testing the indicator

4. Place 7 test-tubes in the test-tube rack and divide your cabbage water equally between them. Top them up with water so that the test-tubes are about half full.
5. Use the eyedropper to put about 1 cm of the dilute (0.1 M) hydrochloric acid solution in the first of the cabbage water test-tubes. Record what colour it turns, in a table like the one in the Results section.

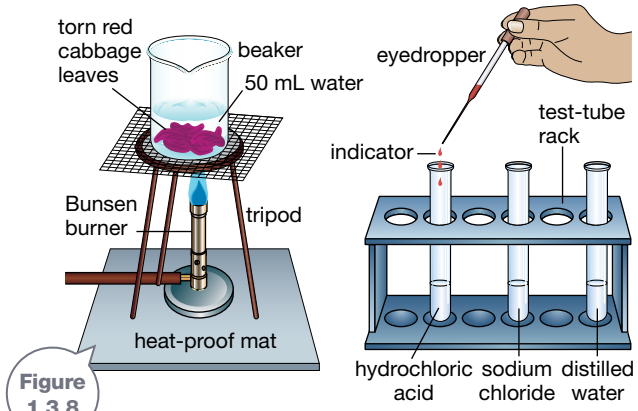


Figure 1.3.8

6. In the second cabbage water test-tube, put 1 cm of vinegar. In the third test-tube put distilled water, in the fourth test-tube put salt solution, and in the fifth test-tube put sodium hydroxide solution. Record the results of these tests in your table.

Part C: Testing unknowns

7. Add about 1 cm of lemon juice to the sixth test-tube.
8. Add about 1 cm of soft drink to the seventh test-tube.
9. Drop an antacid tablet into the eighth test-tube.

Results

Record your observations in a table like this one.

Test-tube/type of solution	Name of solution	Colour with red cabbage/ petal indicator
1 0.1 M strong acid	Hydrochloric acid solution	
2 Weak acid	Vinegar	
3 Neutral	Distilled water	
4 Weak base	Salt solution	
5 0.1 M strong base	Sodium hydroxide solution	
6 (Unknown 1)	Lemon juice	
7 (Unknown 2)	Soft drink	
8 (Unknown 3)	Antacid	

Practical review

From their colours, **identify** which acid or alkaline solution the lemon juice, soft drink and antacid were most similar to.

2 Green eggs

Purpose

To use indicators to turn the whites of fried eggs green.

Materials

- a few millilitres of cooking oil
- 1 raw egg
- red cabbage indicator from prac 1

- small aluminium foil pie dish
- eyedropper
- hotplate or Bunsen burner, bench mat, tripod and gauze mat
- digital camera or mobile phone

SAFETY

The eggs might not be fresh, so do not taste or eat them. Wash your hands thoroughly afterwards.

Procedure

1. Put a little oil in the aluminium foil pie dish and crack an egg into it. Try to keep the egg yolk intact.
2. Place the pie dish on the hotplate or over the Bunsen burner on a gauze mat and tripod.
3. Gently cook the egg without stirring. As *soon* as the clear liquid part of the egg starts to turn white, use the eyedropper to place a few drops of red cabbage indicator into it.

Results

Use a digital camera or mobile phone to record your observations in both parts of this experiment through photographs or film.

Practical review

Red cabbage indicator turns red in acid solution, purple in neutral solution and green in basic (alkaline) solution. **Identify** whether egg white (the material that surrounds the yolk) is acidic, neutral or alkaline.

3 pH column

Purpose

To construct a series of coloured layers of different pH.

Materials

- 2 or 3 rice-sized grains of solid sodium carbonate
- 10 mL vinegar
- universal indicator

- 100 mL measuring cylinder
- spatula
- long stirring rod (such as a chopstick)

Sodium carbonate is caustic, so wear rubber gloves, protective clothing and safety glasses at all times.

Procedure

1. Add 90 mL water and 10 mL vinegar to the measuring cylinder.
2. Add a drop of universal indicator.
3. Use the long stirring rod or chopstick to mix the solution well.
4. Use the spatula to add a small amount (about the size of a couple of rice grains) of solid sodium carbonate (Na_2CO_3) to the test-tube.
5. Stir again, but this time *lightly*.
6. Leave the measuring cylinder in a safe place where it won't be disturbed for at least a couple of days.

Results

1. After a day, four or five different-coloured layers should be clearly visible. Construct a diagram showing these layers.
2. Identify and label the pH of each band.

Practical review

1. **Describe** what happens to the pH as you move towards the top of the measuring cylinder.
2. **Explain** why the lower layers would be more basic (alkaline) and the top layers more acidic.

1.4 New materials

New materials are constantly being developed to make our lives easier, safer and healthier. From new types of plastics to carbon fibre, Kevlar and self-cleaning fabrics, these new materials show how chemistry can create new industries and transform the world. They even allow athletes without lower legs to compete in running events at the Paralympic and Olympic Games.

INQUIRY
science 4 fun

Velcro

NO

How does Velcro stick?

Collect this ...

- Velcro or clothing with Velcro fasteners
- stereomicroscope or hand lens

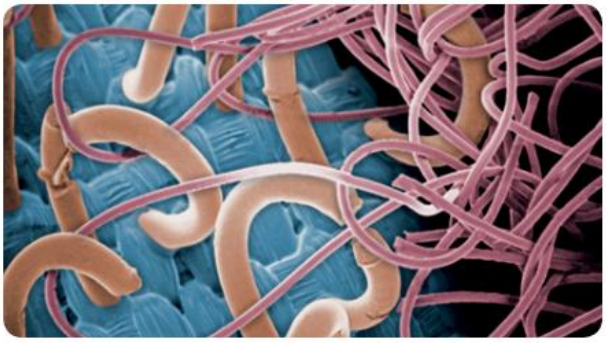
Do this ...

Velcro is made of two interlocking strips. Look at both strips under the microscope or hand lens.

Record this ...

Describe the features you observed.

Explain how the structure of Velcro makes it work.



Why develop new materials?

New materials are developed because there is a need for them. However, their development is restricted by the technology available at the time. For example, humans have always needed tools to hunt, grow crops and build shelters. The first tools were small flakes of rock chipped off with other rocks. As our understanding of materials and our technology grew, these simple stone tools were replaced by tools made of wood, bone, resin and fibre. These tools were eventually replaced with tools made from bronze and steel.

Likewise, materials such as plastics and carbon fibre could only be developed when chemists had discovered the chemical structure of substances.

Often, new materials are developed because of social, ethical and environmental needs.

Social needs

The development, manufacturing and sale of new materials provide work and income. New materials can give a company an advantage, allowing it to make more money.

Ethical needs

Ethics is an assessment of whether it is right or wrong to do something. Developing new materials because they make people's lives healthier or safer is obviously the right thing to do. For example, metals have been developed for artificial limbs and artificial joints, such as the one in Figure 1.4.1.

Figure 1.4.1 Artificial hip joints make life easier for people whose joints are worn and causing pain.

Shape memory alloys such as Nitinol change shape as temperature changes. Nitinol is used to construct small mesh sleeves called stents, which are used to keep open arteries that are in danger of bursting or blocking. The stent is cooled and crushed to make it thin enough to be surgically inserted into a vein in the groin. The stent is then pushed through the veins to the heart. As the body heats the alloy, the nitinol in the stent 'remembers' its original expanded state and opens up to widen the artery. Figure 1.4.2 shows a stent expanding when heated.

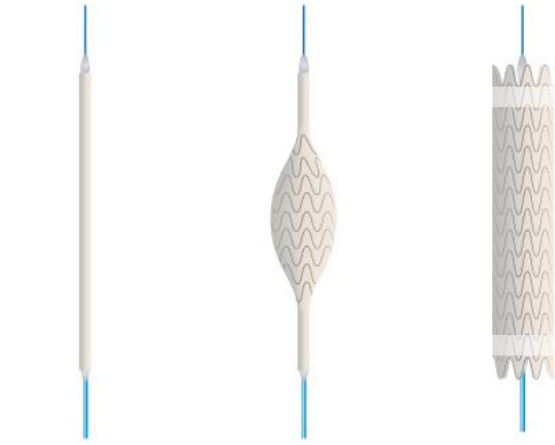


Figure 1.4.2 Stents are made of Nitinol, a shape memory alloy. When heated, these materials 'remember' what shape they were originally.

1.7

Environmental needs

New materials are also developed because they are better for the environment. For example, the metal rhodium is used in catalytic converters in car exhaust systems (Figure 1.4.3). Catalytic converters remove poisonous chemicals from the exhaust, making the air cleaner and healthier for people living near busy roads. Likewise, the development of biodegradable plastics that are able to decompose ensures a cleaner environment.

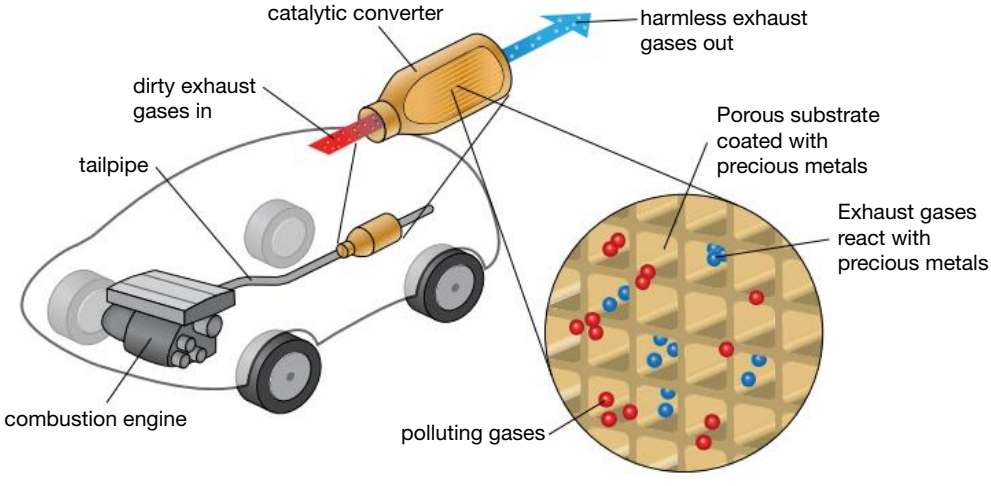


Figure 1.4.3 Catalytic converters help to protect the environment and our health by removing dangerous chemicals from the exhaust gases of cars.

Polymers and synthetic fibres

Polymers are molecules made of repeating units (called **monomers**) formed into long chains (Figure 1.4.4). Naturally occurring polymers include cellulose, proteins, starch, DNA and rubber. However, most polymers are synthetic—they are usually derived from oil. Plastics are **synthetic polymers**. Examples are nylon, polythene, PVC and aramid.

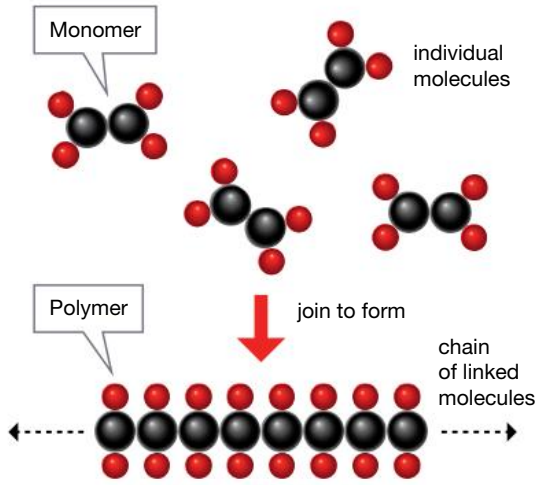


Figure 1.4.4 A polymer is a long-chain molecule made by repeatedly joining smaller molecules together.

Polymers can be made into fibres. A **fibre** is any substance that can be twisted into a rope, woven or knitted into a fabric or mixed with other substances to form a mesh. Fibres are solid with molecules arranged in long chains that are tangled together but not necessarily chemically bonded together. Some useful properties of polymers are shown in Table 1.4.1.

Self-cleaning fabric

Self-cleaning fabrics are coated in molecules of a polymer such as PFC (perfluorocarbon). This results in a rough surface that is highly water- and dirt-repellant. Nano-tex™ is a self-cleaning fabric that uses polymers to form 'whiskers' on the surface of the fabric. Figure 1.4.5 shows the whiskers as tiny branching polymer fibres that are stuck to the weave of the fabric. These fibres hold water droplets away from the surface of the fabric, preventing water from sticking to it. This makes the fabric hydrophobic.

A surface is classified as hydrophobic if it does not allow water to stick to it. A **hydrophobic** surface is highly water repellent and is commonly referred to as 'water-hating'. The opposite is **hydrophilic** or 'water-loving'.

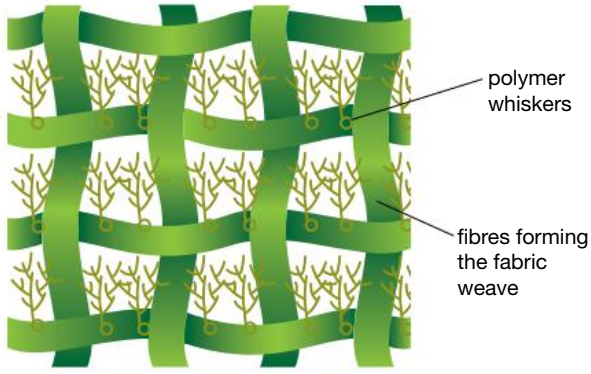


Figure 1.4.5 Nano-tex fabric uses tiny 'whiskers' of polymer stuck to the fabric surface to make the surface rough enough to stop water contacting the fabric surface.

Table 1.4.1 Properties and uses of some polymers

Polymer	Properties	Uses
Aramid (polyamide such as Kevlar)	High tensile strength	Racing sails, body armour
Nylon	Resilient and durable	Fabric, seat belts, carpet, rope
PET	Tough and transparent	Soft-drink bottles
PFC (perfluorocarbon)	Water repellent	Stain-resistant fabric (such as Nano-tex)
Polypropylene	Flexible	Plastic hinges, rope, ice-cream containers, straws
Polythene	Soft and flexible	Garbage bags, 'plastic' shopping bags, cling wrap
Polystyrene	Rigid and brittle	Yoghurt containers
PVC (polyvinyl chloride)	Hard, rigid	Plumbing pipes

On some hydrophobic surfaces, known as super-hydrophobic surfaces, water forms nearly spherical drops. You can see this in Figure 1.4.6. The angle a drop makes to its surface is known as the contact angle. For super-hydrophobic surfaces, the contact angle is almost 180°. On less hydrophobic surfaces, the drop is spherical but with a flattened base and a smaller contact angle. On hydrophilic surfaces, the drop is flattened with an even smaller contact angle.

As Figure 1.4.7 shows, superhydrophobic surfaces are self-cleaning—they allow water drops to pick up and carry dirt off the surface. Less-spherical drops on a smoother surface pick up the dirt but then re-deposit it back onto the surface.

Carbon fibre

An exciting area of current materials research is carbon nanotubes. A **carbon nanotube** is a tiny cylinder of carbon atoms about 100 nanometres long. A **nanometre** is one-billionth of a metre. About 25 nanotubes would fit across a red blood cell.

Carbon atoms can join with each other to form flat sheets of hexagons. These sheets can be rolled into tubes, like the one in Figure 1.4.8 on page 36. The properties of carbon nanotubes depend on how you roll the sheet. Rolling the sheet at different angles makes tubes with different properties and uses.

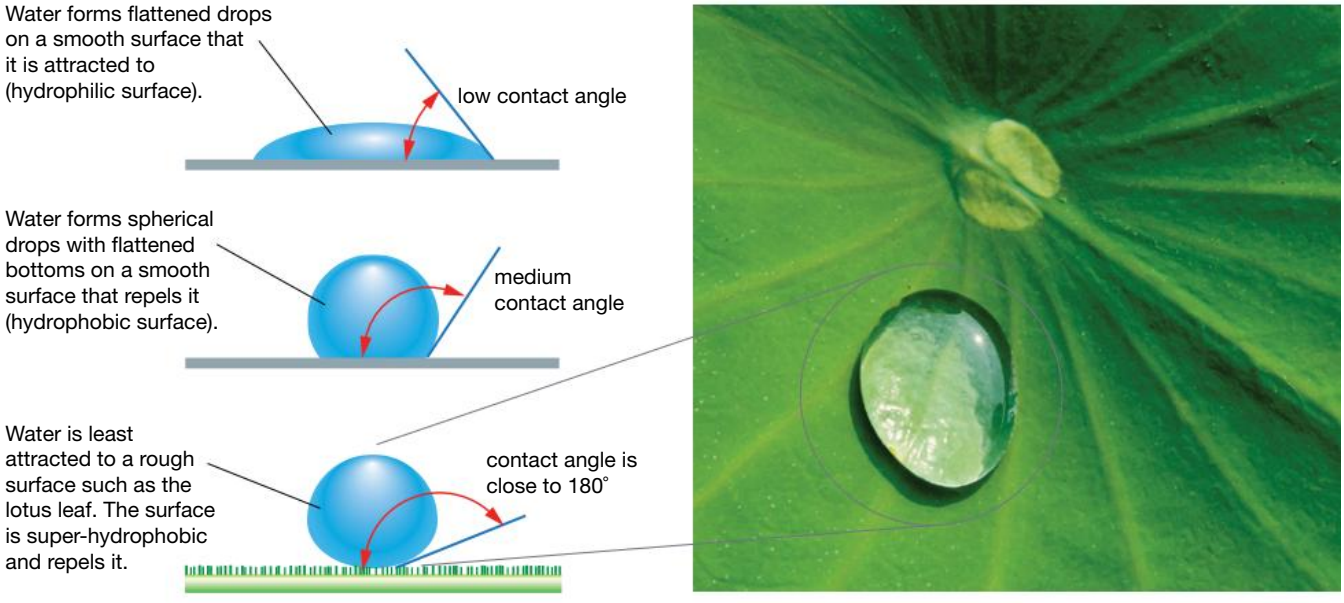


Figure 1.4.6 The shape of water droplets depends on whether they are attracted to or repelled by the surface they are on.

Prac 1 p39 Prac 2 p39

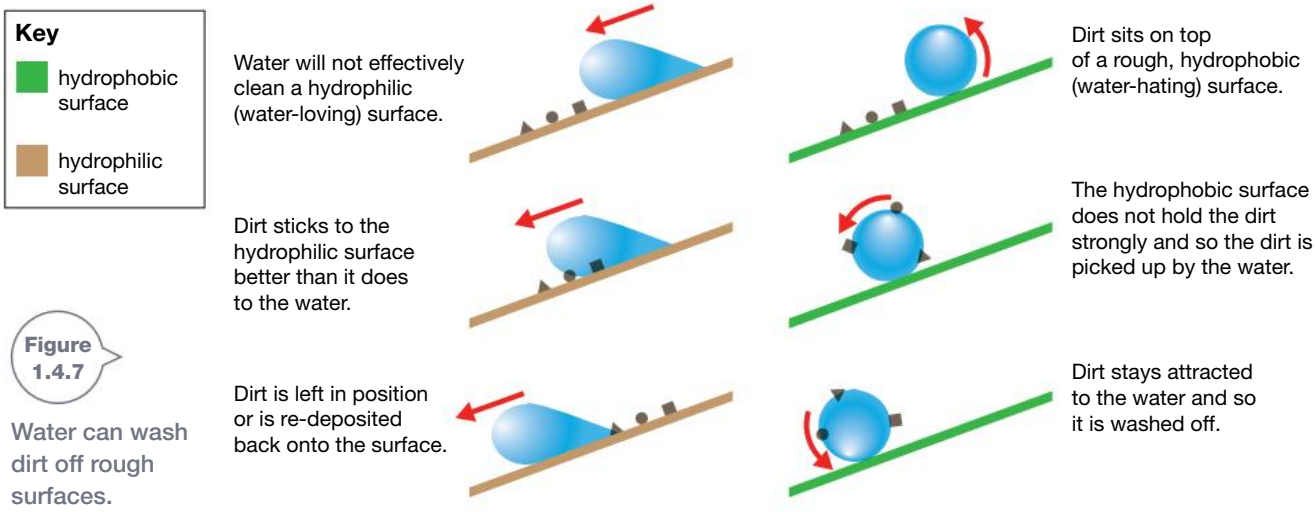


Figure 1.4.7 Water can wash dirt off rough surfaces.

Carbon nanotubes can be formed into fibres and are hundreds of times stronger than steel and much lighter. For this reason nanotubes are being researched for use in the structures of cars, aircraft and buildings. Carbon nanotubes are also being researched for possible use in electronic devices as semiconductors and microprocessors.

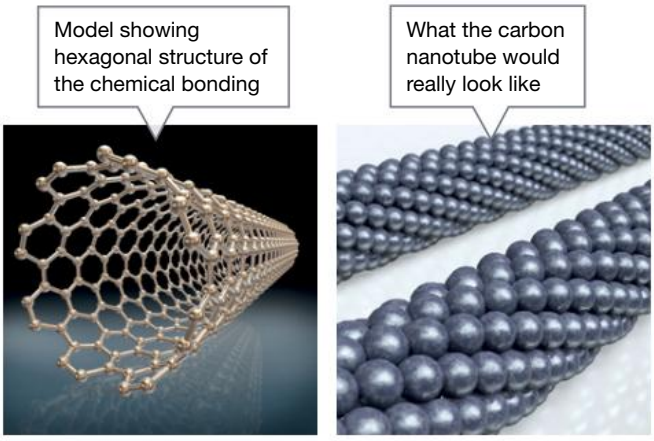


Figure 1.4.8 Carbon nanotubes are tubes formed from a rolled mesh of carbon atoms.

ADDITIONAL

Composite materials

Many **composite materials** are made of fibres embedded in a plastic matrix. For example, fibreglass is a composite material made by laying sheets of tangled glass fibres in liquid plastic, which then hardens around them. Fibreglass is used in many structures, such as swimming pools, storage tanks, car bodies and boats. Carbon fibre is used in a composite known as carbon-fibre-reinforced plastic or CFRP. The composite is made in layers such as in Figure 1.4.9.

Composites in aircraft

Composite materials such as carbon-fibre-reinforced plastics are typically strong, rigid and light. They also resist corrosion, resist cracking when vibrated and do not expand much when heated. These properties make composite materials ideal for use in aircraft bodies.

In aircraft, the main advantage of composites is that they are much lighter than traditional metals. For example, composites are about 20% lighter than aluminium, which is traditionally used to construct aircraft. In aircraft, weight is the major factor affecting fuel use and the load (passengers and cargo) that can be carried. This affects the amount of profit an airline makes.

High corrosion resistance is vital in an aircraft. Corrosion destroys the structure and strength of a material and can lead to it breaking under stress. This would be disastrous in the air.

Aircraft vibrate and flex, particularly on take-off and landing and during turbulence. Failure of a material under these stresses is called fatigue. This can be catastrophic in flight and so the materials used in aircraft need to be resistant to stress.

Where composites are used depends on the properties needed by that part of the aircraft (Figure 1.4.10).

Other materials can be added to the basic carbon fibre in composites. Materials such as Kevlar give the structure different properties, such as greater fracture toughness and impact resistance. These properties are useful in areas of the plane that could suffer an impact, such as hitting a bird in flight. The addition of carbon fibre plastics to fibreglass structures provides additional stiffness, useful, for example, in the wing, which must not flex too much.

1.8

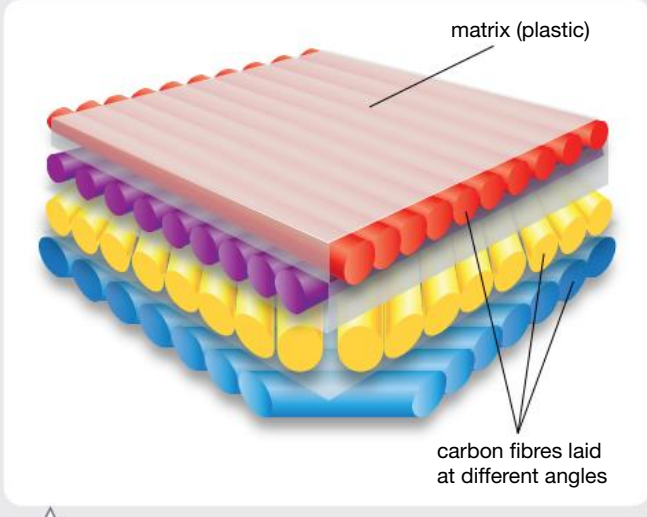


Figure 1.4.9 Carbon-fibre-reinforced plastic is made of layers of carbon fibre embedded in plastic. In each layer, the fibres point in different directions. This makes the composite extremely strong.

Figure 1.4.10 The Boeing 787 Dreamliner uses composites throughout its structure, replacing metals to make it lighter.

LEARNING ACROSS THE CURRICULUM

ETHICAL UNDERSTANDING

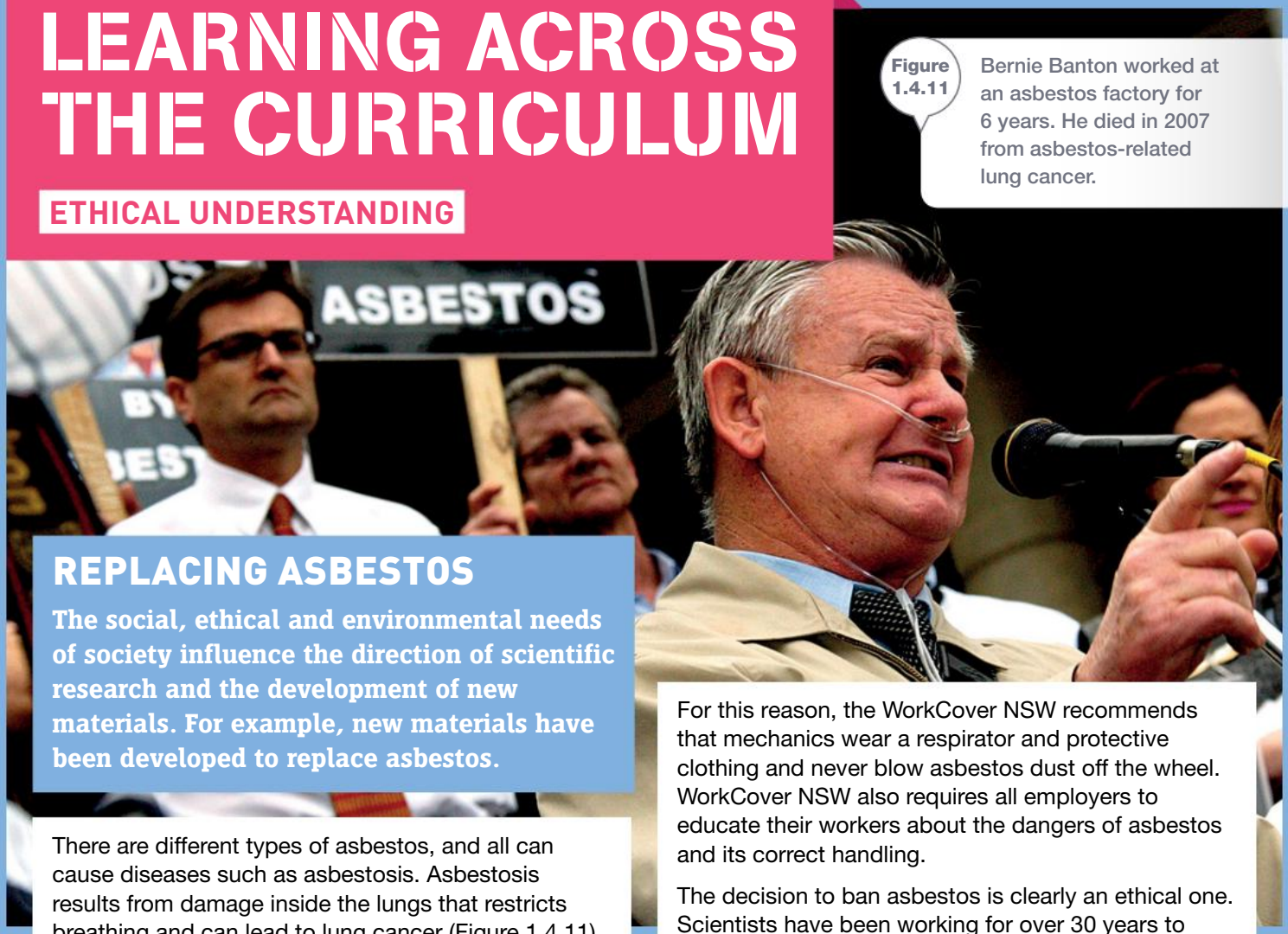


Figure 1.4.11 Bernie Banton worked at an asbestos factory for 6 years. He died in 2007 from asbestos-related lung cancer.

REPLACING ASBESTOS

The social, ethical and environmental needs of society influence the direction of scientific research and the development of new materials. For example, new materials have been developed to replace asbestos.

There are different types of asbestos, and all can cause diseases such as asbestosis. Asbestosis results from damage inside the lungs that restricts breathing and can lead to lung cancer (Figure 1.4.11). Two deadly types of asbestos, blue and brown, were banned from use in Australia by the mid-1980s. White asbestos (chrysotile) is carcinogenic (cancer causing) too and was banned from use in New South Wales in 2003. The ban did not cover asbestos already in place. Chrysotile was used in motor vehicles in engine gaskets and brake and clutch linings. Brakes containing chrysotile can still be found in older vehicles, posing a health risk for mechanics working on them (Figure 1.4.12).

GO TO Unit 7.3

Figure 1.4.12 Mechanics need to treat all brakes as if they contain asbestos.

For this reason, the WorkCover NSW recommends that mechanics wear a respirator and protective clothing and never blow asbestos dust off the wheel. WorkCover NSW also requires all employers to educate their workers about the dangers of asbestos and its correct handling.

The decision to ban asbestos is clearly an ethical one. Scientists have been working for over 30 years to develop replacement materials and many have been found. Most are more expensive than asbestos but the overall cost to society is less when health and safety are considered.

Carbon fibre, ceramics and polymers called aramids have replaced asbestos in brakes. Just like asbestos, these materials resist abrasion (wearing away), do not melt at high temperatures, do not easily catch fire and do not dissolve in organic solvents such as oil and petrol.

REVIEW

1. **Name** two illnesses caused by asbestos
2. **Describe** how mechanics can protect themselves in the workplace.
3. **Describe** how materials scientists responded to the dangers of asbestos, and name the materials they developed.
4. **Propose** why WorkCover NSW insists that workers be educated about safe handling of asbestos.

1.4 Unit review

Remembering

1 **List** four examples of:
   a natural polymers
   b synthetic polymers.

2 **List** the properties and uses of three synthetic polymers.

3 **Name** a self-cleaning fabric.

4 **State** the length of a nanometre. N

5 **State** two advantages of carbon nanotubes over steel.

Understanding

6 **Define** the term *polymer*. L

7 **Modify** the following statements to make them correct.
   a Polymers are long-chain synthetic compounds made by scientists.
   b The contact angles on super-hydrophobic surfaces are nearly 90°.

8 **Explain** what is meant by a fibre.

9 **Explain** how the structure of two surfaces of Velcro (shown in the science4fun on page 32) helps them stick to each other.

10 **Explain** how the hydrophobic nature of a surface affects how well water will wash dirt off it.

11 **Explain** how carbon nanotubes can be made with different properties.

Applying

12 a **Describe** how you could construct a model of a polymer from paperclips.
   b **Identify** the monomer in this model.

Analysing

13 **Compare** the properties of PVC and polythene and relate them to their uses.

14 **Contrast** the terms *hydrophobic* and *hydrophilic*. L

Evaluating CCT

15 **Assess** whether there are any social, ethical and environmental reasons for the development of a product to replace cigarettes.

16 a **Propose** reasons why a train is sometimes thought to be a good model for the structure of a polymer.
   b **Identify** what would be considered to be the monomer in this model.

Creating CCT

17 **Design** a way to compare hairy leaves with smooth leaves to determine if either type is hydrophobic.

18 **Construct** a promotional pamphlet for a university that is trying to encourage students to study chemistry because it can bring great benefits to society.

Inquiring

ADDITIONAL

1 Investigate a material or product and the claims that the manufacturers make on how it performs. Some materials you might investigate are Velcro, Teflon, carbon fibre, fibreglass, self-cleaning paint and glass, shape-memory alloys or 'age-defying' cosmetics. Use scientific evidence to evaluate the claims made in their advertisements.

   Present your findings in written form.

2 Investigate how synthetic fibres are used to produce the following three types of composite materials: carbon fibre reinforced plastics, ceramic polymer composites and aramid composites. In your answer:

   - describe the major differences in the chemical composition and structure of these composites
   - describe how the uses of the composite depend on the properties of the synthetic fibre
   - include images of each type of composite material.

   Present your answer in digital form. ICT

ADDITIONAL

1.4 Practical investigations

1 Observing water

Purpose

To compare how well water sticks to different materials.

Hypothesis

Which of the materials supplied do you think water will stick to the best and which will water stick to the least? Before you go any further with this investigation, write a hypothesis in your workbook.

Materials

- a selection of different materials such as aluminium foil, glass, plastic wrap, waxed paper, newspaper, raw timber, bark and different plant leaves
- water

- eyedropper
- beaker

Procedure

1. Place each of the materials flat on a table or bench.
2. Fill the eyedropper with water and carefully place a drop of water on each surface.
3. View the water drop on each surface from its side and draw the shape of the drop on the surface.

Results

1. Describe what you observed.
2. List the order in which you think the materials attracted water, from attracted most to attracted least.

Practical review

1 a **Construct** a conclusion for your investigation.
  b **Assess** whether your hypothesis was supported or not.

2 **Explain** how this experiment is relevant to real life.

STUDENT DESIGN

2 Stain-resistant fabrics

Purpose

To evaluate whether Nano-tex fabric has superior water and stain resistance.

Hypothesis

Of the fabrics you have been supplied with, which fabric do you think will have superior stain resistance? Before you go any further with investigation, write a hypothesis in your workbook.

Materials

- Nano-tex fabric
- a range of other fabrics (synthetic and natural)
- a range of food sauces in different beakers
- coffee
- vegetable juice

- eyedropper
- beaker
- detergent
- ice-cream container
- spoon

SAFETY

A risk assessment is required for this investigation.

Procedure

1. Design an experiment that will test the water and stain resistance of different fabrics.
2. Write your procedure in your workbook.
3. Before you start any practical work, assess all risks associated with your procedure. Construct a risk assessment that outlines these risks and any precautions you need to take to minimise them. Show your teacher your procedure and risk assessment. If they approve, then collect all the required materials and start work.

Results

Record your results in a table.

Practical review

1 a **Construct** a conclusion for your investigation.
  b **Assess** whether your hypothesis was supported or not.

2 **Evaluate** your experiment.

3 **Justify** whether or not you would buy the particular fabrics you tested.

1 Chapter review

Remembering

1 **Recall** the similarities and differences of the three subatomic particles that make up all atoms.

2 **Recall** how the atomic number and mass number of an atom are calculated by completing the following statements.

Atomic number = number of _____

Mass number = number of _____ + _____

3 **Name** the following chemicals.
- a CH_3COOH
- b H_2SO_4
- c NaOH

4 **Name** three indicators.

5 **State** the pH of pure water.

6 **List** the advantages of carbon nanotubes.

Understanding

7 **Define** the following terms. L
- a atom
- b molecule
- c crystal lattice
- d ion
- e cation
- f fibre

8 **Draw** a simple diagram that shows the structure of an atom.

9 **Explain** Rutherford's famous experiment and how it contributed to our current understanding of the atomic model.

10 **Describe** what must happen to an atom to make it:
- a a cation
- b an anion.

11 **Describe** the advantages that alloys have over their base metals.

12 **Explain** what a stent is, what it is made of and how it works.

13 **Describe** three examples where new materials made by chemists are of benefit to people's lives.

Applying

14 **Identify** the chemical formulae for these acids and bases.
- a hydrochloric acid
- b nitric acid
- c calcium hydroxide

15 **Use** examples to **demonstrate** that you understand what the following statement means.

New materials are developed because of social, ethical and environmental needs.

Analysing

16 **Classify** the following as elements or compounds.
- a Fe
- b NaOH
- c H_3PO_4
- d O_2

17 A solution was tested with different indicators. The colours they turned were:

Litmus = red

Methyl orange = yellow

Phenolphthalein = colourless

Bromothymol blue = blue
- a **Use** this information to **identify** the pH of the solution.
- b **Classify** the solution as acidic, neutral or alkaline.
- c **Predict** the colour that universal indicator would turn if it was added to the solution.

18 **Compare** acids with bases by listing their similarities and differences.

Evaluating CCT

19 Carbon has been known about for over 2000 years. **Propose** reasons why it was found much earlier than most other non-metals.

20 a **Determine** whether you can or cannot answer the questions on page 1 at the start of this chapter.
- b **Assess** how well you understand the material presented in this chapter.

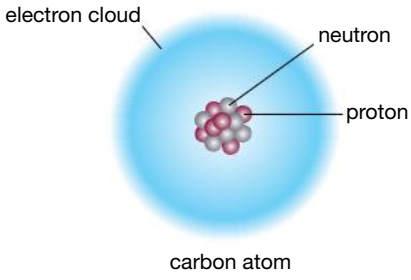
Creating CCT

21 **Use** the following ten key words to **construct** a visual summary of the information presented in this chapter.

metals
non-metals
acids
diamond
ions
carbon
hydrogen ion
alloys
atoms
hydroxide

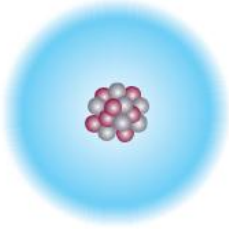
Thinking scientifically

Q1 Isotopes are atoms that have the same number of protons in their nucleus but a different number of neutrons. Determine which of the atoms below is an isotope of this carbon-12 atom.

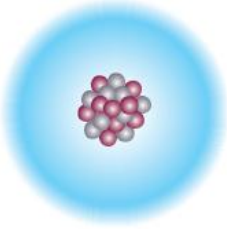


carbon atom

A



B



C

D

Q2 Acids release hydrogen ions (H^+) into solution.

Use this information to identify which of the following substances could *not* be an acid. CCT

A HCOOH

B Fe_2O_3

C H_2CO_3

D $NaHSO_4$

Q3 pH measures the concentration of hydrogen ions (H^+) in solution. The more concentrated the solution is in H^+ ions, the lower the pH is. CCT

An acidic solution has a pH of 5. Water is then added to it. Predict what will happen to the H^+ concentration of the solution.

A It will stay the same.

B It will increase.

C It will decrease.

D It will become the same as water.

Q4 Predict the pH of the new solution in question 3.

It will most likely be: CCT

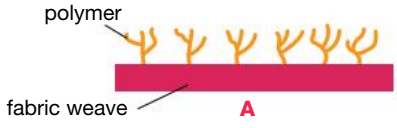
A 4

B 5

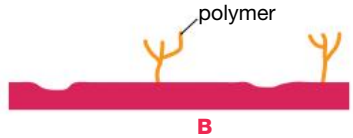
C 6

D 7

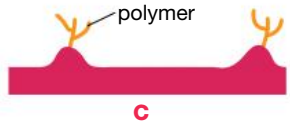
Q5 Researchers tested the type of surface that would work best in preventing stains. Their hypothesis was that a fabric will not stain if the staining substance is kept away from the fabric weave. They tested the surfaces shown below. Predict which surface would be best at resisting stains. CCT



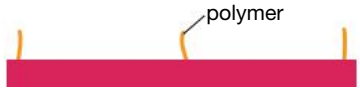
A



B



C



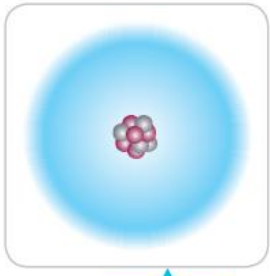
D

Glossary

Unit 1.1

Anion: an ion that has more electrons than protons and is negatively charged

Atom: the fundamental building block of all materials; it consists of a cluster of protons and neutrons surrounded by a cloud of electrons



Atom

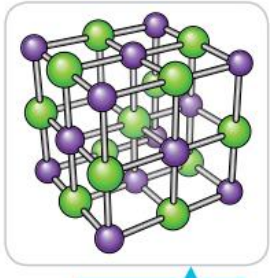
Atomic number: the number of protons in a nucleus; the atomic number determines what type of atom it is

Atomic symbol: a short-hand notation for describing an atom; it consists of the chemical symbol, atomic number and mass number

Cation: an ion that has more protons than electrons and is positively charged

Compound: a pure substance that is made up of two or more different types of atom chemically joined

Crystal lattice: a grid-like structure of atoms or ions in which each particle is bonded to all of its neighbouring atoms



Crystal lattice

Electron: a small, negatively charged particle; clouds of electrons surround the nucleus of an atom

Electron cloud: the region of negative charge surrounding the nucleus, containing the electrons

Electron shell: part of the electron cloud; it is a layer that surrounds the nucleus and can only hold a certain number of electrons

Element: a substance made up of only one type of atom

Ion: an atom that has gained or lost an electron

Mass number: the number of protons and neutrons in an atom

Molecule: a cluster of atoms that makes up an element or a compound

Neutral: having no overall charge

Neutron: a particle with no electric charge; it is found in the nucleus of an atom

Nucleus: a cluster of neutrons and protons at the centre of an atom

Proton: a positively charged particle found in the nucleus of an atom

Subatomic particles: the smaller particles that atoms are made of—protons, neutrons and electrons

Unit 1.2

Allotropes: different forms of the same element

Allotrope

Alloy: a mixture of a base metal and small amounts of other elements

Annealing: a process in which a metal is heated until red-hot, then allowed to cool naturally; also known as normalising

Base metal: the main metal in an alloy

Brittle: shatters if hit

Carat: a scale for measuring the purity of gold

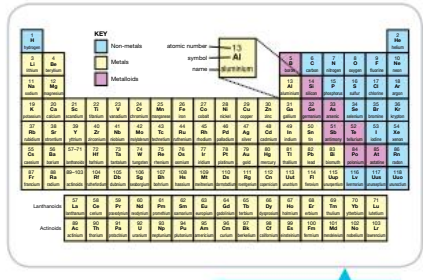
Ductile: able to be stretched into wires

Lustrous: shines when polished or freshly cut

Malleable: able to be hammered into new shapes

Metalloid: an element that usually displays the properties of a non-metal but conducts electricity like a metal under certain conditions; also known as a semi-metal

Periodic table: a list of all the known 118 elements



Periodic table

Quenching: a process in which a heated metal is cooled rapidly by dropping it into water

Stainless steel: a rustless alloy of steel that includes chromium and nickel

Steel: an alloy of iron and carbon

Tempering: a process in which a metal is heated, cooled rapidly (quenched) and then reheated

Tempering

Unit 1.3 L

Acid: a substance that releases hydrogen ions into an aqueous solution

Alkali: a base that dissolves in water

Alkaline solution: a solution made of a base/alkali and water

Base: a substance that releases hydroxide ions

Hydrogen ion: H^+, released by acids

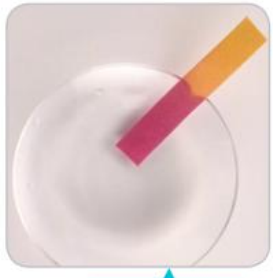
Hydroxide ion: OH^-, formed by bases

Indicator: a chemical that changes colour to show whether a substance is acidic, neutral or basic

Litmus paper: a common indicator that turns red in the presence of an acid and blue in the presence of a base

pH: a scale used to measure the concentration of H^+ ions in a solution

Polyatomic: containing more than one atom



Litmus

pH

Unit 1.4 L

Carbon nanotube: a tiny cylinder of carbon atoms about 100 nm long

Composite material: carbon fibres or polymer fibres embedded in a plastic matrix

Ethics: the study of whether a behaviour can be considered to be right or wrong

Fibre: a solid material with its molecules arranged in long chains that are tangled together but not necessarily chemically bonded together

Hydrophilic: a surface to which water is attracted

Hydrophobic: a surface that repels water

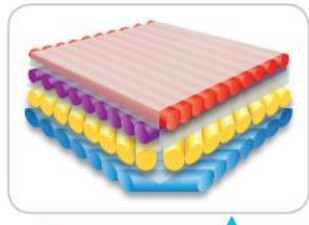
Monomer: the basic unit in a polymer

Nanometre: one-billionth of a metre

Polymer: a molecule made of repeating units formed into long chains

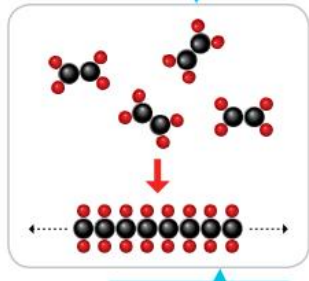
Synthetic polymer: a polymer that has been made from oil

Carbon nanotube



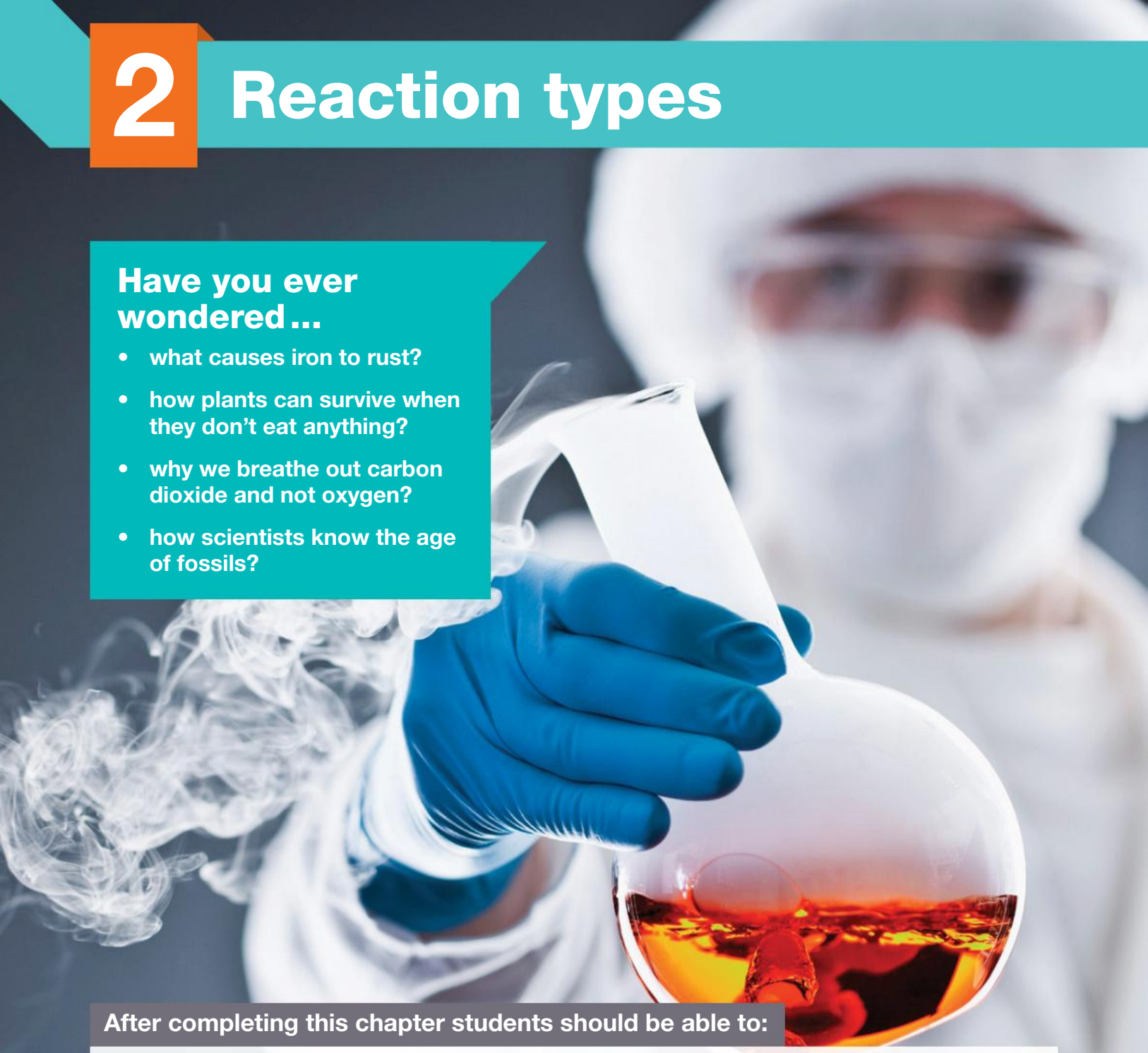
Composite material

Monomer



Polymer

2 Reaction types



Have you ever wondered ...

- what causes iron to rust?
- how plants can survive when they don't eat anything?
- why we breathe out carbon dioxide and not oxygen?
- how scientists know the age of fossils?

After completing this chapter students should be able to:

- recall that all matter is composed of atoms and has mass
- identify a range of compounds using their common names and chemical formulae
- classify chemical reactions as exothermic or endothermic
- investigate a range of types of chemical reactions including combustion, corrosion, neutralisation and the reaction of acids with metals and carbonates
- identify important chemical reactions that occur in living systems, including respiration and acid reactions in digestion
- construct word equations L
- deduce that new substances are formed during chemical reactions by rearranging atoms rather than by creating or destroying them
- compare combustion and respiration as chemical reactions that release energy at different rates
- identify that natural radioactivity arises from the decay of nuclei
- evaluate the benefits and problems associated with nuclear energy EU S CCT

ADDITIONAL

- balance a range of chemical equations
- research the development of ideas about the nature of radioactivity. L

2.1 Combustion and corrosion reactions

Chemical reactions happen continually around you. Two important types of chemical reactions are combustion and corrosion. Combustion happens when anything burns or explodes. Corrosion happens when a metal such as copper or an alloy such as steel changes into something else. Similar substances tend to undergo similar chemical reactions. These similarities allow you to predict what might happen if two chemicals are mixed. The similarities become more obvious when chemical reactions are expressed as chemical equations.

INQUIRY science 4 fun

Eating sherbet

YES

What does an endothermic reaction in your mouth feel like?

Collect this …

- ½ teaspoon of citric acid
- ¼ teaspoon of baking soda (bicarbonate of soda, $NaHCO_3$)
- 3 teaspoons of icing sugar
- clean mixing bowl, cup or mug
- teaspoon

Do this …

1. Add all the ingredients to the small mixing bowl or mug.
2. Use the back of the teaspoon to crush any lumps and to mix everything together.
3. Keep it in a dry place until ready to eat!

Record this …

Describe what happened in your mouth when you ate the sherbet.

Explain why you think this happened.

Endothermic and exothermic reactions

Chemical equations are used to explain what happens to substances when they undergo chemical change in a chemical reaction. **Reactants** are the substances you started with before the chemical reaction. **Products** are the substances that are formed by the chemical reaction.

In some reactions, the products have more energy than the reactants. These reactions need energy to proceed and they get their energy from their surroundings. Reactions like this are known as **endothermic** reactions. An example is what happens in a chemical cold pack that you apply when you have an injury. Packets of ammonium nitrate and water are broken, allowing these substances to mix and react. As they do so, they absorb energy from their surroundings, cooling the surroundings down. The sherbet in Figure 2.1.1 acts in a similar way.

Figure 2.1.1

Sherbet leaves your tongue cold and tingling because an endothermic reaction absorbs heat from your mouth.

GO TO Pearson science NSW 10 Unit 5.1

Combustion

While endothermic reactions absorb energy, **exothermic** reactions release energy. In exothermic reactions, the reactants have more energy than the products. During the reaction, the difference in these energies is released into the surroundings, usually as heat and/or light.

Combustion reactions are examples of exothermic reactions. **Combustion** occurs whenever something reacts with oxygen gas (O_2), burning or exploding as it does so. A bushfire is a series of combustion reactions. The chemicals in living plants and dead twigs and leaves burn in oxygen, releasing huge amounts of heat and light as they react.

That's shocking!

Explosions generate hot gases that suddenly expand at speeds of up to 8 kilometres per second! These expanding gases form blasts of wind called shockwaves, which can be as deadly as the explosion itself. A shockwave leaves a vacuum at the site of the explosion, and air flowing into this carries rubbish and debris.

SciFile

Writing word equations

To write a word equation, follow the steps below.

Step 1: Identify the reactants and products.

As an example, consider the chemical reaction between copper and sulfur dioxide. This reaction forms copper sulfide and oxygen gas. You started with copper and sulfur dioxide, so these are the reactants. Copper sulfide and oxygen gas were produced. These are the products.

Step 2: Write a word equation.

A **word equation** is a simple written description of what is happening in the reaction. The reactants are placed on the left side of the arrow and the products on the right.

reactants → products

copper + sulfur dioxide → copper sulfide + hydrogen gas

WORKED EXAMPLE

Writing word equations

Problem

A piece of aluminium was dropped into hydrochloric acid. The aluminium dissolved and reacted to form aluminium chloride. As it did so, hydrogen gas bubbled to the surface. Write a word equation for this reaction.

Solution

Step 1: Identify the reactants and products.

Reactants = aluminium, hydrochloric acid

Products = aluminium chloride, hydrogen gas

Step 2: Write a word equation.

reactants → products

aluminium + hydrochloric acid → aluminium chloride + hydrogen gas

Practice

Construct word equations for the following reactions.

1. Hydrogen peroxide splits to form water and oxygen gas.
2. Sodium reacts with iron(II) chloride to form sodium chloride and iron.
3. When propanol is burnt in oxygen gas, carbon dioxide and water are formed.

2.1 Prac 1 p52

Combustion of fossil fuels

Bunsen burners, gas stoves (like the one in Figure 2.1.2), water heaters and central heating furnaces produce a hot blue flame by burning methane or ethane gas in oxygen. The reactions are:

methane + oxygen gas → carbon dioxide + water vapour

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

ethane + oxygen gas → carbon dioxide + water vapour

$2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O$

Petrol is a mixture of highly combustible chemicals called **hydrocarbons**, the most important of which is octane. Octane combusts via the chemical equation:

octane + oxygen gas → carbon dioxide + water vapour

$2C_8H_{18} + 25O_2 \rightarrow 16CO_2 + 18H_2O$

Figure 2.1.2 A gas stove uses combustion to release its heat (and light).

SciFile

Suffocating fires

Fires consume oxygen, so there is less of it to breathe in the region of the fire. During World War II, the German city of Dresden was firebombed. Many of the 25 000 people killed in the attack are thought to have suffocated because of this lack of oxygen.

Incomplete combustion

The above combustion reactions all need oxygen fed into them. These reactions are known as **complete combustion**. If the oxygen supply is restricted, then other reactions occur instead. This is known as **incomplete combustion**. Incomplete combustion is still exothermic but does not release as much heat or light energy as complete combustion does.

The reactions below show what happens to methane if oxygen is restricted.

methane + oxygen gas → carbon monoxide + water vapour

$2CH_4 + 3O_2 \rightarrow 2CO + 4H_2O$

At the same time another reaction occurs.

methane + oxygen gas → carbon + water vapour

$CH_4 + O_2 \rightarrow C + 2H_2O$

Incomplete combustion reactions are 'dirty' because they produce carbon, which is left behind as soot, charcoal or smoke, like that seen in Figure 2.1.3. They also produce the poisonous gas carbon monoxide. In contrast, complete combustion reactions are 'clean'.

A Bunsen burner can show both complete and incomplete combustion. If the flow of oxygen to it is good (open airhole), then the flame is hot, clean and blue. If the air flow is restricted (closed airhole), then a cooler, dirty yellow flame is produced.

Figure 2.1.3 Smoke and soot are an indication of incomplete combustion.

Pollution and climate change

Water vapour and carbon dioxide are released into the atmosphere whenever fossil fuels such as gas, petrol, oil, coal, diesel and aviation fuel are burnt. Carbon dioxide is a greenhouse gas that traps heat within the atmosphere. Over the past 150 years, humans have burned huge quantities of fossil fuels to power their cars, ships and aircraft, and to heat their homes and generate electricity. For this reason, the amount of carbon dioxide in the atmosphere has increased to levels that most scientists agree are increasing the atmosphere's average temperature. If this view is correct, then the burning of fossil fuels could be affecting Earth's climate.

If the combustion of these fossil fuels is incomplete, then carbon monoxide and carbon are released.

GO TO Pearson science NSW 10 Unit 6.3

Carbon adds relatively harmless but dirty soot to the atmosphere. Carbon monoxide gas has no smell, but it is so poisonous that even small amounts of it can kill. Petrol also contains additives that release other poisonous chemicals when burnt. These include oxides of nitrogen and sulfur, both of which can combine with moisture in the air to form smog and acid rain.

GO TO Unit 2.2

Other combustion reactions

A much slower and controlled combustion reaction occurs within the cells of your own body. **Aerobic respiration** combines the sugar glucose from the digestion of your food with the oxygen you breathe in. This reaction releases the energy that the cells of your body need. A waste product is carbon dioxide, which you breathe out (Figure 2.1.4).

GO TO Unit 2.3

glucose + oxygen gas → carbon dioxide + water vapour

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$

Figure 2.1.4

Respiration gives your body the energy it needs. The reaction needs glucose (from your food) and oxygen (breathed in). You breathe out its product, carbon dioxide.

Not all combustion reactions produce carbon dioxide and water vapour. When burnt, magnesium reacts to form magnesium oxide. No other products form.

magnesium + oxygen gas → magnesium oxide

$2Mg + O_2 \rightarrow 2MgO$

You can see this reaction happening in Figure 2.1.5.

Figure 2.1.5

The light released by the combustion of magnesium is so bright that it can quickly damage your eyes.

Prac 2 p53 Prac 3 p54

Corrosion reactions

Most metals corrode when exposed to water, air or other chemicals. **Corrosion** is a chemical reaction that forms other compounds from these metals.

For example, the iron/steel body of a car slowly reacts with water and oxygen in the air and will corrode until all that is left is a pile of rust.

In a similar way, copper corrodes by reacting with gases in the air to form green **verdigris** (shown in Figure 2.1.6), a mixture of copper(II) hydroxide and copper(II) carbonate. The chemical equation is:

copper + water + carbon dioxide + oxygen gas → copper(II) hydroxide + copper(II) carbonate

$2Cu + H_2O + CO_2 + O_2 \rightarrow Cu(OH)_2 + CuCO_3$

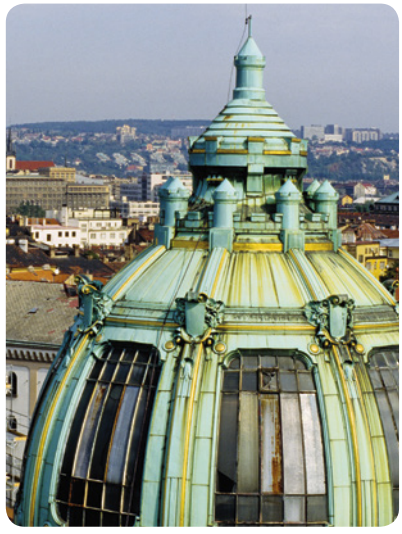


Figure 2.1.6

This copper roof has corroded to form a green coating called verdigris.

Pure silver reacts with sulfur to form a black coating called **tarnish** (silver sulfide). This sulfur comes from hydrogen sulfide in air pollution or from foods such as eggs, fish, onions and pea soup.

silver + hydrogen sulfide → silver sulfide + hydrogen gas

$2Ag + H_2S \rightarrow Ag_2S + H_2$

Pure sodium and potassium are such reactive metals that they react with just about anything. Their corrosion is very quick and often explosive because of the hydrogen gas that their reactions produce. Their chemical reactions with water are shown below.

sodium + water → sodium hydroxide + hydrogen gas

$2Na + 2H_2O \rightarrow 2NaOH + H_2$

potassium + water → potassium hydroxide + hydrogen gas

$2K + 2H_2O \rightarrow 2KOH + H_2$

Rusting

Iron and its alloy, steel, are common and relatively cheap, making them the most commonly used metals on Earth. Unfortunately, iron and most grades of steel react with air and water to form **rust**, known chemically as hydrated iron(III) oxide (chemical formula $Fe_2O_3 \cdot H_2O$). Rust is flaky and easy to dislodge. This allows the rusting process to continue into the next layer, making the iron or steel thinner and weaker. Figure 2.1.7 shows what can happen.

Although an extremely complex reaction, rusting can be summarised by the chemical equation:

iron + oxygen gas + water → hydrated iron(III) oxide

$4Fe + 3O_2 + 2H_2O \rightarrow 2Fe_2O_3 \cdot H_2O$

This equation is often simplified to:

iron + oxygen gas → iron(III) oxide

$4Fe + 3O_2 \rightarrow 2Fe_2O_3$

Figure 2.1.7 Rust forms when iron is exposed to oxygen and water.

Corrosion of aluminium

Aluminium is very reactive. The surface metal reacts almost immediately with the air, forming a fine layer of dull, grey aluminium oxide (Al_2O_3).

aluminium + oxygen gas → aluminium oxide

$4Al + 3O_2 \rightarrow 2Al_2O_3$

Unlike rust, this layer does not flake but acts instead like a tightly bound layer of paint, protecting the aluminium from further corrosion. **Anodising** is a process that deliberately builds up a layer of aluminium oxide to protect the aluminium underneath (Figure 2.1.8).

Figure 2.1.8 These cups are made of anodised aluminium. Their surface is a layer of aluminium oxide that was deliberately built up on the surface of the metal and then coloured.

ADDITIONAL

SKILL BUILDER

Writing balanced formula equations

Chemists use balanced formula equations to accurately show what is happening in a chemical reaction. To construct a balanced formula equation, follow the steps below.

Step 1: Write an unbalanced formula equation.

Replace the names of each substance in a word equation with their element symbols or chemical formulae. This gives you an unbalanced formula equation. Consider the reaction:

copper + sulfur dioxide → copper sulfide + oxygen gas

You need to know that copper has the element symbol Cu and the chemical formula of sulfur dioxide is SO_2, copper sulfide is Cu_2S and oxygen gas is O_2.

This gives you the following equation:

$Cu + SO_2 \rightarrow Cu_2S + O_2$

Step 2: Identify what elements are unbalanced.

An equation is unbalanced if it has unequal numbers of atoms of a particular element on both sides of the arrow. The above equation starts with one copper atom, one sulfur atom and two oxygen atoms. However, the equation ends up with two copper atoms, one sulfur atom and two oxygen atoms.

Skill builder continued on next page

Skill builder continued

This is shown below:

reactants	→	products
1 × Cu	→	2 × Cu
1 × S	→	1 × S
2 × O	→	2 × O

This suggests that a copper atom appeared from nowhere! That is impossible because atoms never just appear in chemical reactions. Nor do they disappear. They only change in the way they are arranged. This fundamental principle of chemistry is known as the **law of conservation of mass**. To describe accurately the rearrangement that is happening in the reaction, formula equations need to be balanced.

Step 3: Balance the equation.

A **balanced formula equation** has the same numbers of each type of atom on both sides of the arrow. The above reaction would be balanced if the reaction used up two atoms of copper instead of just one. When balancing an equation, you can only change the coefficients of each reactant or product. The coefficients are the big numbers that appear in front of some of the chemicals in a formula equation. Hence, the correct way of balancing the above equation is:

$$2Cu + SO_2 \longrightarrow Cu_2S + O_2$$

Figure 2.1.9 shows what is happening to the atoms in this reaction.

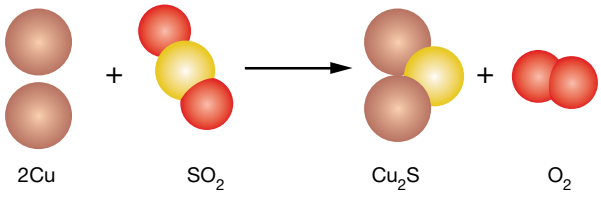


Figure 2.1.9 Atoms can't appear from nothing and can't disappear. This is why chemical equations must be balanced.

Step 4: Check your equation.

Your equation should now be balanced. To make sure that it is, check how many atoms of each element are on either side of the arrow.

reactants	→	products
2 × Cu	→	2 × Cu
1 × S	→	1 × S
2 × O	→	2 × O

GO TO Pearson science NSW 10 Unit 5.1

WORKED EXAMPLE

Writing balanced formula equations

Problem

Tin(IV) oxide (SnO_2) reacts with hydrogen gas (H_2) to form tin (Sn) and water (H_2O).

Construct a balanced formula equation for this reaction.

Solution

Step 1: Write the unbalanced formula equation.

$$SnO_2 + H_2 \longrightarrow Sn + H_2O$$

Step 2: Identify which elements are unbalanced.

reactants	→	products
1 × Sn	→	1 × Sn
2 × H	→	2 × H
2 × O	→	1 × O

Step 3: Balance the equation

Oxygen is unbalanced. By doubling the number of water molecules produced, oxygen becomes balanced. Hence change H_2O to $2H_2O$.

$$SnO_2 + H_2 \longrightarrow Sn + 2H_2O$$

Sometimes balancing one element causes another element to become unbalanced. This is what has happened here to hydrogen. The equation now has:

reactants	→	products
1 × Sn	→	1 × Sn
2 × H	→	4 × H
2 × O	→	2 × O

However, doubling the number of H_2 molecules reacting solves the problem:

$$SnO_2 + 2H_2 \longrightarrow Sn + 2H_2O$$

Step 4: Check your equation.

reactants	→	products
1 × Sn	→	1 × Sn
4 × H	→	4 × H
2 × O	→	2 × O

Practice

1 Calcium (Ca) burns in oxygen gas (O_2) to form calcium oxide (CaO). **Construct** a balanced formula equation for this reaction.

2 **Construct** balanced formula equations by adding coefficients where indicated.

a $CH_4 + O_2 \longrightarrow CO_2 + ...H_2O$

b $.....AgBr + GaPO_4 \longrightarrow Ag_3PO_4 + GaBr_3$

c $.....NaBr + Cl_2 \longrightarrow .....NaCl + Br_2$

d $SiCl_4 + ...H_2O \longrightarrow SiO_2 + ...HCl$

e $Au_2S_3 + ...H_2 \longrightarrow .....Au + ...H_2S$

2.2

ADDITIONAL

2.1 Unit review

Remembering

1 **State** what substance is always required for combustion to occur.

2 **Recall** the following reactions by writing the word equation and balanced formula equation.
- a combustion of octane
- b corrosion of copper

3 **Name** the process that is often used to protect aluminium from further corrosion.

Understanding

4 **Explain** how a Bunsen burner can display both complete and incomplete combustion.

5 **Explain** why the rusting of iron makes it get thinner and thinner.

Applying

6 The combustion of butene is shown by the following word and balanced formula equations.

butene + oxygen gas → carbon dioxide + water

$C_4H_8 + 6O_2 \rightarrow 4CO_2 + 4H_2O$

Identify:
- a the chemical formula for butene
- b reactants for the reaction
- c products of the reaction.

7 **Identify** the products formed when fossil fuels undergo:
- a complete combustion
- b incomplete combustion.

8 The steel body of an old car left in the desert will rust far less than one near the coast. **Use** the word equation for the rusting of iron to **explain** why.

Analysing

9 **Classify** the following reactions as endothermic or exothermic.
- a A bushfire burns down a forest.
- b A sparkler on a birthday cake is alight.
- c Sherbet tingles in your mouth.

10 **Contrast** the corrosion of iron with the corrosion of aluminium.

11 **Compare** combustion with corrosion.

Evaluating CCT

12 Magnesium is a metal but it burns in oxygen to form magnesium oxide. **Assess** whether this reaction could also be classified as a corrosion reaction.

13 Fires are combustion reactions that produce water. **Propose** a reason why this water does not extinguish the fire.

14 A flat sheet of paper burns quickly and with little smoke. In contrast, a tightly crumpled sheet of paper will smoulder, with few flames but a lot of smoke. **Propose** reasons why.

Creating CCT

15 **Construct** word equations for the following combustion reactions.
- a Benzene burns in oxygen gas to produce carbon dioxide and water vapour.
- b Carbon dioxide and water form when hexane burns in oxygen.

16 Zinc corrodes in air by reacting with oxygen gas. It forms a dull, grey substance called zinc oxide. Its balanced formula equation is:

$2Zn + O_2 \rightarrow 2ZnO$

- a **Use** this equation to **identify** the chemical formula for zinc oxide.
- b **Construct** a word equation to show what is happening in this reaction.

17 **Construct** word equations for the:
- a complete combustion of pentane
- b incomplete combustion of octane.

Inquiring

1 Use the key words *chemical reaction video*, *corrosion video* or *combustion video* to find internet videos of different types of chemical reactions. ICT

2 Use the key words *balancing chemical equations games* to find websites that do the balancing for you. ICT

2.1 Practical investigations

1 Conservation of mass

Purpose

To demonstrate that mass is conserved in a chemical reaction.

Materials

- 150 mL of 0.1 M copper sulfate solution
- 50 mL of 0.1 M sodium hydroxide solution
- 50 mL of 0.1 M sodium carbonate solution
- 50 mL of ammonia solution

- four 250 mL beakers
- marking pen
- electronic balance

SAFETY

All chemicals should be treated as toxic.

Do not taste any chemicals.

Procedure

1. In your workbook, construct a table like the one shown in the Results section.
2. Pour copper sulfate solution into one of the beakers until it reaches the 50 mL mark. Use the marking pen to label this beaker BLUE.
3. To the other beaker add 50 mL of sodium hydroxide solution.
4. Place both beakers on the electronic balance and determine their total mass. Record this mass in a table like the one in the Results section.
5. Carefully pour the copper sulfate into the sodium hydroxide and observe what happens.
6. Place the beaker with the solutions in it and the empty beaker labelled BLUE back on the electronic balance. Once again determine their total mass. Record their mass.
7. To a clean beaker, add 50 mL of sodium carbonate. Add another 50 mL of copper sulfate to the beaker labelled BLUE. Once again, find their total mass.
8. Carefully pour the copper sulfate solution into the sodium carbonate solution. As before, find the total mass of the full and empty beakers.
9. Repeat steps 6 and 7 but this time use ammonia solution instead of sodium carbonate.

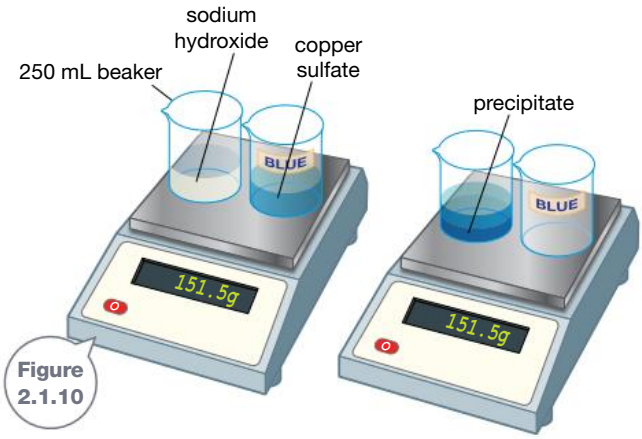


Figure 2.1.10

Extension

10. Allow each of the mixed solutions to settle. The powdery solid that settles on the bottom of the beaker is known as a precipitate. Design a way of filtering each solution so that you can determine the mass of the precipitate formed (trapped in the filter paper) and the filtrate (the liquid that passes through the filter paper).

Results

Record all your measurements in your results table.

	Total mass before mixing (g)	Total mass after mixing (g)	Observations
Sodium hydroxide + copper sulfate			
Sodium carbonate + copper sulfate			
Ammonia + copper sulfate			

Practical review

1. **List** evidence that chemical reactions took place once the solutions were mixed.
2. **Compare** the total masses before and after mixing.
3. **State** the law of conservation of mass.
4. **Assess** whether or not your results support this law.

2 Conservation of mass in combustion reactions

Purpose

To show that combustion reactions obey the law of conservation of mass.

Materials

- clean steel wool
- electronic balance

Part A: Combustion in the open air

- evaporating dish or watch-glass
- 9 V battery

Part B: Combustion in a sealed container

- large Pyrex test-tube
- test-tube tongs
- balloon
- Bunsen burner and bench mat

SAFETY

Sparks will fly in Part A. Make sure they don't hit you or your clothes.

In Part B if sparks enter the balloon it could partly melt or catch fire. Hence, keep it well away from you.

Procedure

Part A: Combustion in the open air

1. In your workbook, construct a table like the one shown in the Results section.
2. Tease out the strands of a small piece of steel wool (about 1 gram) and place it in an evaporating dish or watch-glass.
3. Use the electronic balance to find the combined mass of the evaporating dish/watch-glass and the steel wool. Record the total mass in a results table like the one shown in the Results section.
4. Pass an electric current through the steel wool by lowering a 9 V battery until both of its terminals touch the steel. Record your observations in the table.
5. Shift the battery around to other parts of the steel wool so that as much of the steel as possible is burnt.
6. When completed, find the mass of the evaporating dish or watch-glass and the burnt steel wool. Record the new mass in the table.

Part B: Combustion in a sealed container

7. Tease out a strand of steel wool (about 0.5 gram) and slide it into the test-tube.
8. Squeeze all the air out of the balloon and fit it over the opening of the test-tube, as shown in Figure 2.1.11.
9. Find the combined mass of the test-tube, balloon and steel wool and record it in your table.

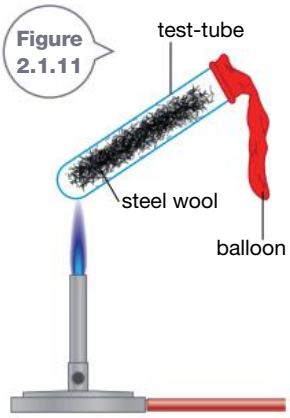


Figure 2.1.11

10. Use tongs to hold the test-tube over a blue Bunsen burner flame. Make sure that you move the test-tube back and forth in the flame and that the flame does not get near the balloon. Stop heating after about 5 minutes. Record what you saw happen in the test-tube and to the balloon.
11. Allow the test-tube to cool completely. When the test-tube is cool, again find the total mass of the test-tube, steel wool and balloon.

Results

Record all your measurements in your results table.

	Total mass before (g)	Total mass after (g)	Observations
Part A			
Part B			

Practical review

1. The reactions in both Part A and Part B were combustion reactions. **State** the other substance that is needed for combustion to occur.
2. The reactions in both Part A and Part B could also be classified as corrosion reactions. **Explain** why.
3. The total mass in Part A most likely increased. **Propose** where this increase in mass came from.
4. The total mass at the end of Part B was most likely the same or very similar to the total mass at the start. **Propose** reasons why.
5. **Assess** which set of results (Part A or Part B) best demonstrated the law of conservation of mass.

3 Cracker combustion

Purpose

To observe how combustion releases heat energy.

Materials

- dry biscuits (such as Clix crackers)

- large test-tube
- thermometer
- retort stand, bosshead and clamp
- bench mat
- metal tongs
- Bunsen burner
- electronic balance

SAFETY

An open flame can be dangerous. The room should be well ventilated.

Biscuits containing nuts or sesame seeds should not be used in case of allergies.

Procedure

1 In your workbook, construct a table like the one shown in the Results section.

2 Set up the apparatus as shown in Figure 2.1.12.

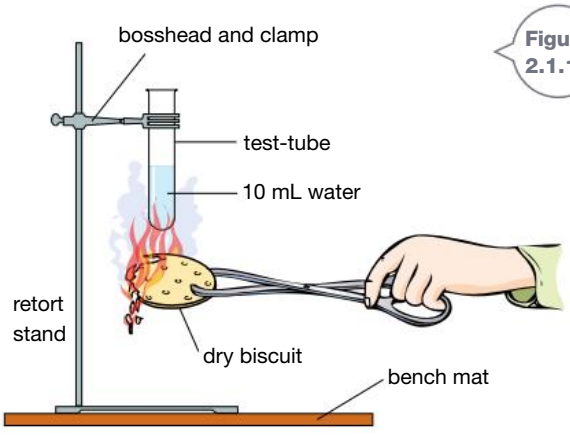


Figure 2.1.12

3 Use the measuring cylinder to measure out 10 mL of water. Add it to the test-tube.

4 Measure the temperature of the water in the test-tube. Record this temperature in a table like the one shown in the Results section.

5 Measure the mass of the dry biscuit.

6 Use the tongs to hold the biscuit in a blue Bunsen burner flame. Heat the biscuit until it catches fire.

7 Quickly hold the biscuit under the test-tube. Re-light the biscuit if it goes 'out'.

8 Measure the temperature of the water again once the biscuit has changed completely into ash.

9 Test what happens if the amount or number of biscuits is increased. For example, do two biscuits cause the temperature to rise twice as far?

Results

1 Record all your measurements in your results table.

	Number of biscuits		
	1	2	3
Mass (g)			
Temperature before (°C)			
Temperature after (°C)			
Temperature rise (°C)			
Energy absorbed (J) = temperature rise x 42			

2 Determine how much energy was absorbed by the water, by multiplying the temperature rise by 42. (It takes 42 J of heat energy to raise the temperature of 10 mL of water by 1°C.) N

Practical review

1 a **Identify** whether the biscuit underwent complete or incomplete combustion.

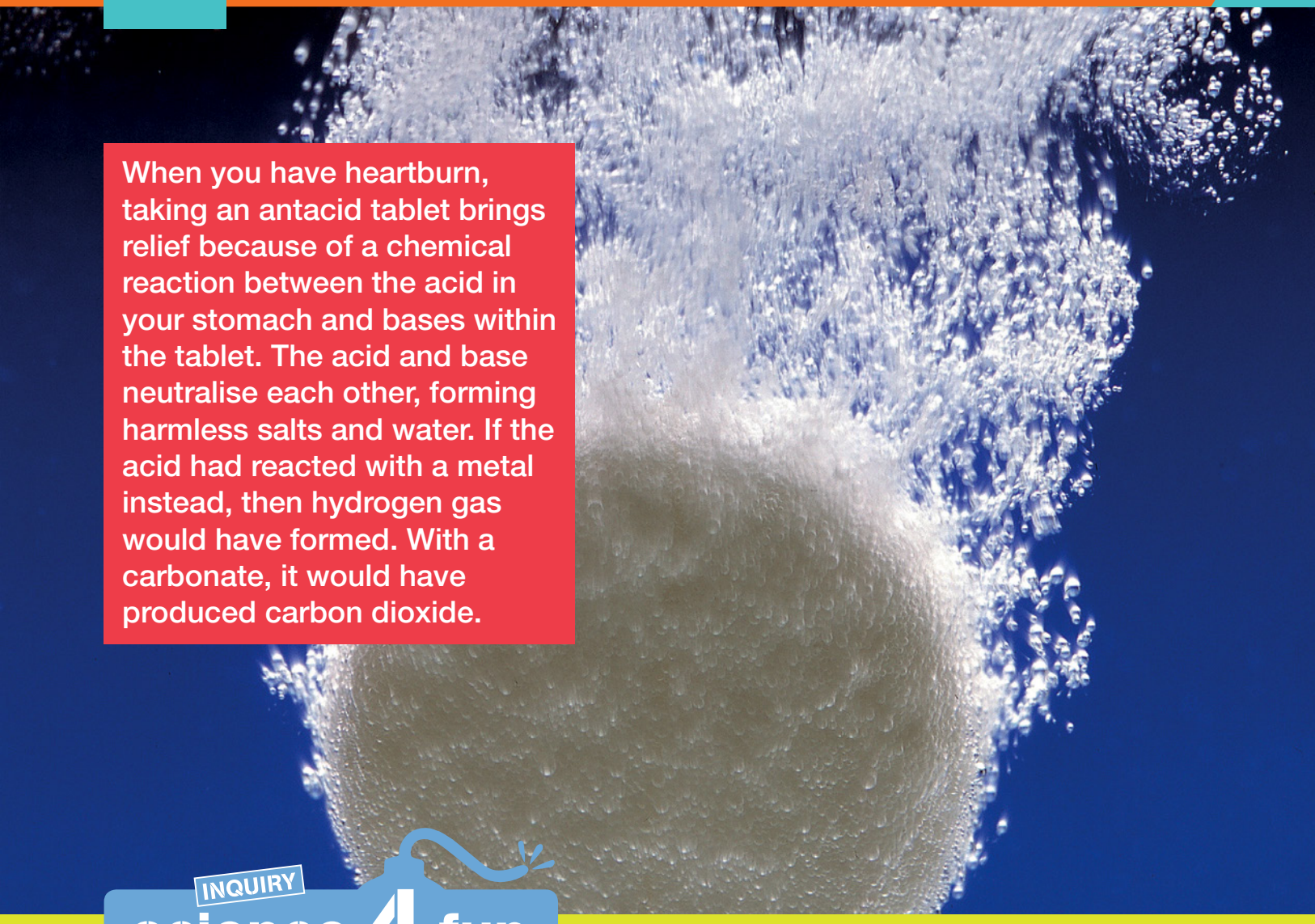
b **Justify** your answer.

2 The amount of energy absorbed by the water is less than the amount of energy released by the biscuit. **Explain** why.

3 **Construct** a conclusion for what happened when the mass or number of biscuits increased.

4 **Evaluate** your experiment to determine ways in which it could be improved.

2.2 Acid reactions



When you have heartburn, taking an antacid tablet brings relief because of a chemical reaction between the acid in your stomach and bases within the tablet. The acid and base neutralise each other, forming harmless salts and water. If the acid had reacted with a metal instead, then hydrogen gas would have formed. With a carbonate, it would have produced carbon dioxide.

INQUIRY

science 4 fun

Exploding bags

Can acids and bases mix together to produce a small explosion?

NO

Collect this ...

- baking soda (bicarbonate of soda)
- vinegar
- warm water
- zip-lock plastic bag
- a few squares of toilet paper
- tablespoon
- measuring cup

Do this ...

1. Measure out a tablespoon of baking soda and wrap it up in few sheets of toilet paper. Twist the paper to hold it all in place.
2. Pour ¼ cup of vinegar and ¼ cup of warm water into the zip-lock bag.
3. Zip up the bag but leave a gap big enough for your baking soda parcel to fit through.
4. Go outside and push the parcel in. Quickly zip up the gap and place it on the ground. Stand clear!

Record this ...

Describe what happened.

Explain why you think this happened.

Acids and metals

Acids can corrode metals, usually forming a salt and hydrogen gas. An example of this type of reaction is shown in Figure 2.2.1.

Figure 2.2.1 Iron reacts with hydrochloric acid, forming bubbles of hydrogen gas.

The general equation for the reaction between an acid and a metal is:

acid + metal → a salt + hydrogen gas

Examples are:

hydrochloric acid + magnesium → magnesium chloride + hydrogen gas

$2HCl + Mg \rightarrow MgCl_2 + H_2$

sulfuric acid + iron → iron(II) sulfate + hydrogen gas

$H_2SO_4 + Fe \rightarrow FeSO_4 + H_2$

Salt is normally the term used for sodium chloride (NaCl). However, in these reactions it is used in a much more general way. Here the term salt means any compound formed by a metal taking the place of the hydrogen atom in an acid. For example, potassium nitrate (KNO_3) is a salt because potassium (a metal) has taken the place of hydrogen in nitric acid (HNO_3). Likewise, magnesium sulfate ($MgSO_4$) and calcium chloride ($CaCl_2$) are salts because metals (Mg and Ca) have replaced hydrogen in sulfuric acid (H_2SO_4) and hydrochloric acid (HCl), respectively.

Prac 1 p62

Neutralisation reactions

Acids and bases neutralise each other when mixed, changing each other into harmless substances such as water and a salt. **Neutralisation** reactions take the form:

acid + base → a salt + water

Examples are:

nitric acid + potassium oxide → potassium nitrate + water

$2HNO_3 + K_2O \rightarrow 2KNO_3 + H_2O$

sulfuric acid + sodium hydroxide → sodium sulfate + water

$H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O$

Acids and carbonates

When the base is a carbonate, the reaction between it and an acid produces carbon dioxide as well as a salt and water. The general equation is:

acid + carbonate → a salt + water + carbon dioxide

Figure 2.2.2 shows the reaction between the calcium carbonate in chalk and hydrochloric acid. Its equation is:

hydrochloric acid + calcium carbonate → calcium chloride + water + carbon dioxide

$2HCl + CaCO_3 \rightarrow CaCl_2 + H_2O + CO_2$

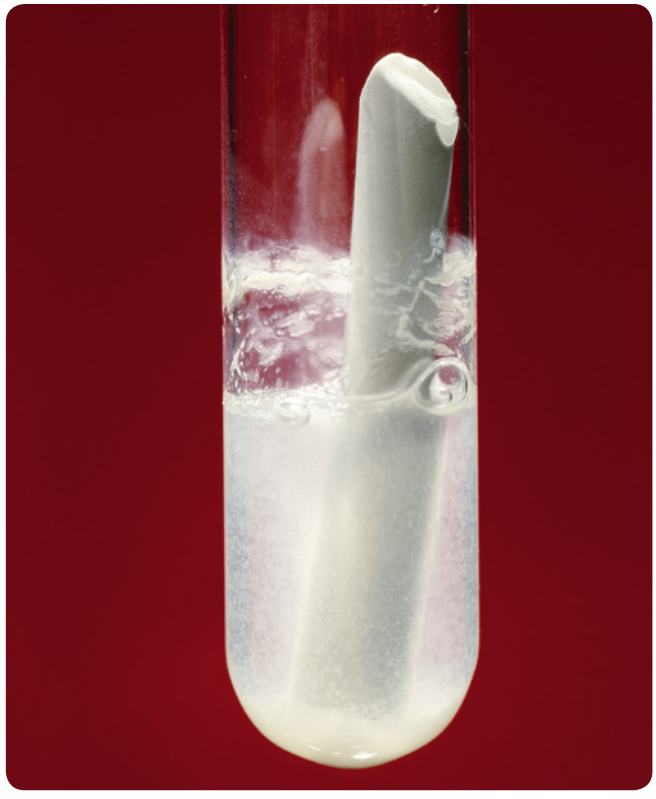


Figure 2.2.2 Chalk contains the base calcium carbonate. Here hydrochloric acid reacts with the calcium carbonate to form bubbles of carbon dioxide.

Carbon dioxide is also produced when acids react with hydrogen carbonates. For example, vinegar (ethanoic or acetic acid) and baking soda (sodium hydrogen carbonate) mix and form a froth of carbon dioxide bubbles. You can see this in Figure 2.2.3. Its equation is:

acetic acid + sodium hydrogen carbonate → sodium acetate + water + carbon dioxide

$CH_3COOH + NaHCO_3 \rightarrow NaCH_3COO + H_2O + CO_2$

Figure 2.2.3

Bicarbonate of soda (sodium hydrogen carbonate) is a base. Vinegar contains acetic acid. When mixed, these chemicals react rapidly, neutralising each other and producing lots of bubbles of carbon dioxide.

Ease the pain

SciFile

The acid of a bee sting should be relieved by neutralising it with a base, like bicarbonate of soda. Likewise, the alkaline sting of a wasp should be neutralised by vinegar or even urine. Unfortunately, these usually don't work because they rarely go deep enough into the tissues inflamed by the sting. There are also venom components that cause pain and can provoke (sometimes life-threatening) allergic reactions.

Acid reactions in digestion

Chemical digestion is the process that breaks down large molecules in food into smaller ones that can be absorbed by the body. Chemical digestion is done mainly through a series of chemical reactions, each reaction being sped up by helper chemicals called **enzymes**. Enzymes in saliva help digest starch, enzymes in your stomach help digest protein and enzymes in your duodenum help digest fat and any remaining carbohydrates and protein.

Enzymes are active only when their environment is suitable. For example, the enzymes in saliva are only active when your mouth has a pH of around 7 (neutral). Saliva is slightly alkaline (basic) and so it tends to neutralise acids in foods such as oranges and tomatoes and in drinks such as fruit juices and soft drinks.

An enzyme called pepsin helps digest proteins in your stomach. Pepsin needs a strongly acidic environment to form and to work. This can be seen in Figure 2.2.4. Gastric juice is produced by the lining of your stomach. It contains hydrochloric acid (HCl), giving the stomach a pH of between 0 and 3. This is the ideal environment for pepsin but is too acidic for the enzymes in saliva to keep working. Hence, digestion of starch stops in the stomach and digestion of protein begins. The acid also helps kill potentially harmful microorganisms that may have been in the food you ate.

GO TO Unit 1.3

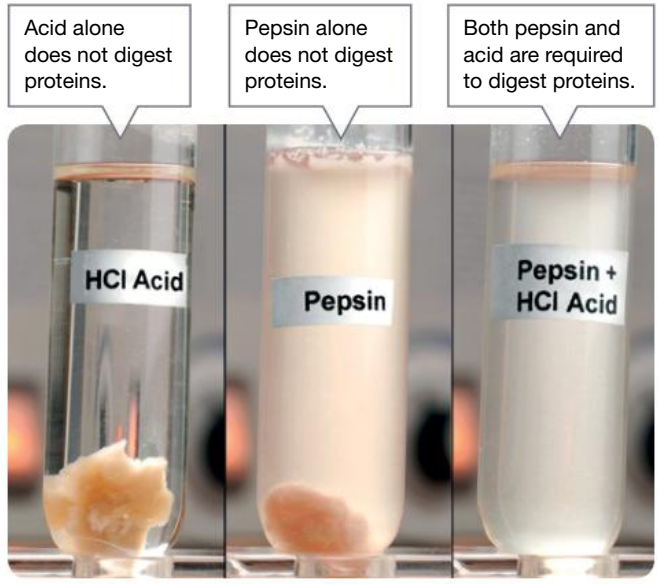


Figure 2.2.4

The proteins in meat only dissolve in the presence of pepsin and hydrochloric acid.

The part-digested material that emerges from the stomach is far too acidic for the rest of the digestive tract. Hydrochloric acid in this material is neutralised by sodium hydrogen carbonate, which is released by the pancreas if the pH in the duodenum drops below 5. The reaction is:

hydrochloric acid + sodium hydrogen carbonate → sodium chloride + water + carbon dioxide

$$HCl + NaHCO_3 \rightarrow NaCl + H_2O + CO_2$$

The duodenum now has a pH of between 7 and 8, which allows enzymes from the pancreas to digest the remaining starches, proteins and fats. Figure 2.2.5 summarises the role that acids, bases and pH play in digestion.

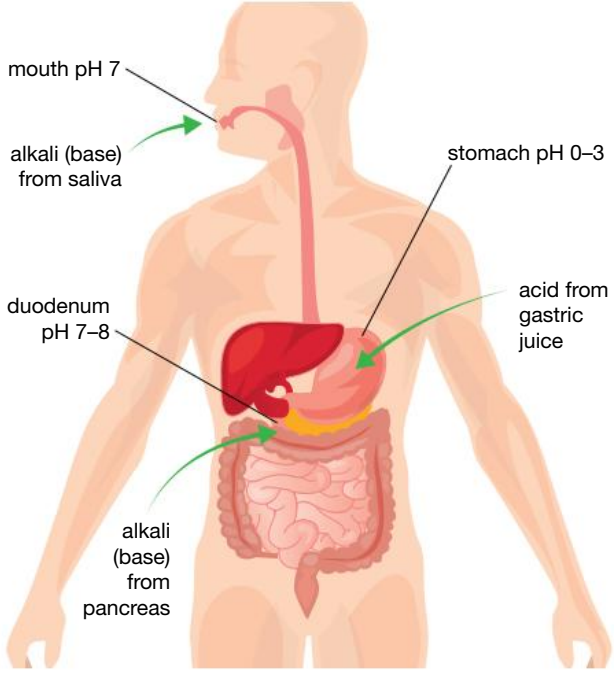
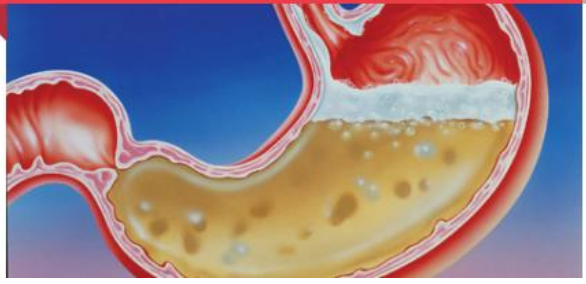


Figure 2.2.5 The stomach needs to be strongly acidic for digestion to occur there. The pancreas releases a base to neutralise this acid in the duodenum.

That feels better!

SciFile

Heartburn is caused by hydrochloric acid from your stomach rising into your oesophagus (foodpipe) and burning it. Antacid tablets contain bases (such as magnesium hydroxide and aluminium hydroxide) that neutralise the acid and bring quick relief.



INQUIRY science 4 fun

Acid rain

YES

White chalk contains calcium carbonate, the same compound that is in marble. Can you use it to imitate the action of acid rain on marble?

Collect this …

- 3 identical glasses
- 3 identical sticks or pieces of white chalk
- lemon juice
- vinegar
- water

Do this …

1. Fill the three glasses with identical amounts of lemon juice, vinegar and water.
2. Put a stick or piece of chalk in each glass, making sure each stick or piece is identical in size.
3. Leave the glasses where they won't be disturbed.
4. After three days (or more), inspect what has happened to the chalk in each glass.

Record this …

Describe what happened.

Explain why you think this happened.

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LEARNING ACROSS THE CURRICULUM

SUSTAINABILITY

Figure 2.2.6 Acid rain has killed many forests in North America and Europe.

ACID RAIN

Rainwater is naturally slightly acidic, with a pH between 5 and 6.

Rainwater is slightly acidic because it reacts with some of the carbon dioxide in the air to form carbonic acid.

water + carbon dioxide → carbonic acid

$H_2O + CO_2 \rightarrow H_2CO_3$

Pollution can cause rainwater to become even more acidic. The combustion of fossil fuels (particularly coal) releases carbon dioxide, sulfur dioxide (SO_2) and nitrogen oxides (mainly nitrogen dioxide, NO_2) as pollutants into the atmosphere. As a result, rainfall has more carbonic acid in it. It also has strong acids in it formed by the combination of sulfur dioxide and nitrogen dioxide with water vapour in the atmosphere. These form in a series of chemical equations that can be summarised as:

sulfur dioxide + water → sulfurous acid

$SO_2 + H_2O \rightarrow H_2SO_3$

sulfur dioxide + water + oxygen gas → sulfuric acid

$2SO_2 + 2H_2O + O_2 \rightarrow 2H_2SO_4$

nitrogen dioxide + water → nitrous acid + nitric acid

$2NO_2 + H_2O \rightarrow HNO_2 + HNO_3$

Rainwater dissolves these acids and returns them to Earth as **acid rain**. Depending on the weather, it may return instead as acid dew, fog, sleet, hail or snow. The pH of acid rain is much lower (more acidic) than that of normal rain (pH 6), and has been measured as low as 3.3 (strongly acidic).

Natural acid rain

SciFile

Volcanoes spew out huge quantities of sulfur and sulfur-based gases every time they erupt. Lightning produces nitrogen-based gases. These gases react with water vapour in the atmosphere and produce their own acids and acid rain. Studies of ancient ice samples from Antarctic glaciers show that some natural acid rain has always fallen.

THE EFFECT ON THE ENVIRONMENT

Although acid rain is not yet a significant concern in Australia, its effects are evident in highly populated and industrialised areas such as the United States, southern Canada, Europe and China.

- Acid rain has killed forests, as shown in Figure 2.2.6. It also leaches aluminium from the soil, which then runs into rivers and lakes and percolates downwards into the groundwater. These increased aluminium levels are often enough to kill the plants, animals and fish that use or live in that water.
- Acid rain has killed fish, frogs, water snails, insects and other organisms living in lakes or around lakes. These lakes have increased acidity (decreased pH). As Figure 2.2.7 on page 60 shows, pH has different effects on different animals.

- Acid rain has destroyed buildings and sculptures, like the one in Figure 2.2.8. Calcium carbonate is the major component of the marble and limestone that make up many old buildings and sculptures. Calcium carbonate is a base and so it reacts with the acids in rain, making the rock thinner and more likely to weather, flake and break off. A typical reaction is shown below.

calcium carbonate + sulfuric acid → calcium sulfate + water + carbon dioxide

$CaCO_3 + H_2SO_4 \rightarrow CaSO_4 + H_2O + CO_2$

Range of pH able to be tolerated by different animals

pH	7.0	6.5	6.0	5.5	5.0	4.5	4.0
Trout							
Bass							
Perch							
Frogs							
Yabbies							
Snails							

Figure 2.2.7 Frogs are least likely to be affected by acid rain. The eggs of most fish will not hatch at pH of less than 5.

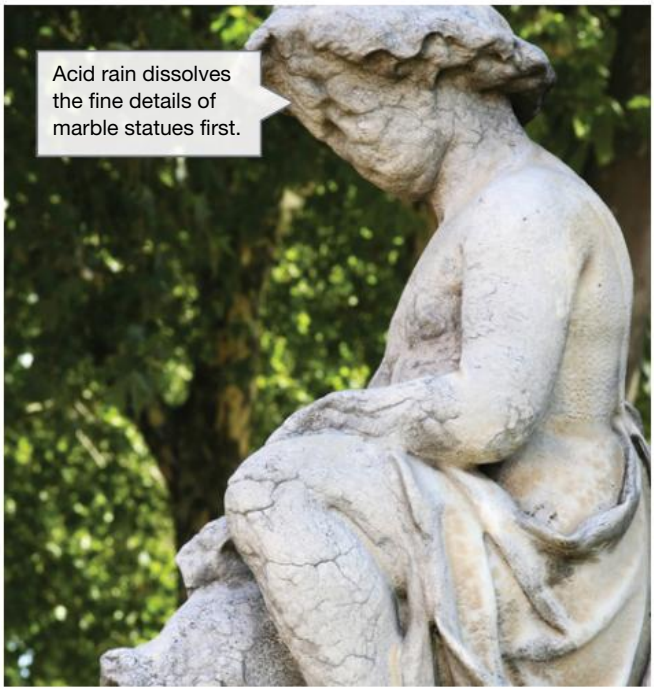


Figure 2.2.8 Marble is composed of the base calcium carbonate, which will react with any acid that it comes in contact with. This makes marble statues vulnerable to attack by acid rain.

CONTROLLING ACID RAIN

Taller chimneys (like those in Figure 2.2.9) mean that local areas are less likely to be affected by the chemicals released by them and the acid rain that forms. However, this does not solve the problem. It just pushes the problem onto more distant areas.

Coal-fired power plants are now fitted with 'scrubbers' that remove sulfur-based pollutants from the gases they release. In a similar way, modern cars use catalytic converters to remove nitrogen-based gases from their exhausts.

Figure 2.2.9 Pollution can cause acid rain to form. Tall chimneys minimise the damage in the area around them but increase the damage further away.

REVIEW

1 Write word equations to **describe** how acid rain forms.

2 **Predict** the order in which animals die when the acidity of a lake increases due to acid rain.

3 **Propose** reasons why forests are more likely to be damaged by acid rain if they are:

a near cities

b on the foggy upper slopes of mountains.

2.4

2.2 Unit review

Remembering

1 **Recall** acid reactions by copying and completing the following.
- a acid + metal ⟶ ..... + ...
- b acid + carbonate ⟶ ..... + ... + ...
- c nitric acid + potassium oxide ⟶ ..... + ...
- d acetic acid + sodium hydrogen carbonate ⟶ ..... + ... + ...
- e H_2SO_4 + Fe ⟶ ..... + ...
- f 2HCl + $CaCO_3$ ⟶ ..... + ... + ...

2 **State** the pH:
- a range of the stomach
- b that triggers the release of sodium hydrogen carbonate from the pancreas.

Understanding

3 a **Explain** what causes the pain of heartburn.
- b **Explain** how antacids work to relieve heartburn.

Applying

4 **Use** a word equation to **explain** why the plastic bag in the science4fun on page 55 explodes when the chemicals are allowed to mix.

Analysing

5 **Analyse** the following word and balanced formula equation.

phosphoric acid + aluminium ⟶ aluminium phosphate + hydrogen gas

$2H_3PO_4 + 2Al \longrightarrow 2AlPO_4 + 3H_2$

Identify:
- a the reactants
- b the products
- c the chemical formula for phosphoric acid
- d the name and chemical formula of the salt produced
- e whether the reaction is an example of an acid–metal reaction, a neutralisation reaction, or an acid–carbonate reaction.

Evaluating CCT

6 **Propose** reasons why the pH of the stomach varies.

7 **Propose** what happens to the carbon dioxide formed when acid is neutralised in the duodenum.

Creating CCT

8 **Construct** word equations for the reactions that happen when:
- a magnesium is added to sulfuric acid
- b aluminium hydroxide neutralises hydrochloric acid
- c hydrochloric acid and sodium carbonate are mixed.

9 **Construct** word equations for what you expect to happen in each of the three glasses in the science4fun activity on page 58.

10 **Construct** word equations for the following acid reactions.
- a Iron filings are sprinkled into a solution of hydrochloric acid. The iron dissolves. In doing so it forms a solution of iron(II) chloride. Bubbles of hydrogen gas rise from the iron filings as they react.
- b Copper reacts differently from other metals in acids. For example, copper dissolves in nitric acid to form copper nitrate and water. Instead of hydrogen or carbon dioxide forming, a poisonous brown gas called nitrogen dioxide is released.

Inquiring

1 Use the search terms *acid-base video* to find internet videos of different acid reactions. ICT

2 Some bacteria in the stomach can damage the stomach lining, causing it to become inflamed. Stomach acid can cause further damage, resulting in an ulcer. Research stomach ulcers and find:
- an image of an ulcer
- the name of the bacterium thought to cause ulcers
- why this bacterium is not killed by gastric juice
- typical symptoms of a stomach ulcer
- treatments for the ulcer, including recommended diet
- details of the Australian scientists who discovered that this bacterium was causing ulcers.

Present your findings as a pamphlet to be provided at doctors' clinics.

GO TO Unit 7.1

2.2 Practical investigations

1 Making hydrogen

Purpose

To prepare and test hydrogen gas.

Materials

- 5 cm strip of magnesium ribbon
- 2 M hydrochloric acid
- 1 test-tube, rubber stopper with opening and glass tube to fit
- 2 additional test-tubes
- test-tube rack
- eyedropper
- wax taper

SAFETY

2 M HCl is a strong and concentrated acid.

Wear safety glasses, a laboratory coat or apron and rubber gloves.

Procedure

1. Place the test-tube with the rubber stopper in the test-tube rack.
2. Roll the magnesium ribbon and drop it into the test-tube.
3. Use the eyedropper to add about 2 cm of hydrochloric acid.
4. Immediately turn another test-tube upside down and collect the hydrogen gas produced, as shown in Figure 2.2.10.
5. After about a minute, remove the upper test-tube, stopper it and stand it upside down in a test-tube rack.
6. Use the remaining test-tube to collect another sample of hydrogen gas. Stopper it and stand it upside down in a test-tube rack.
7. Stop the reaction by carefully adding water to the tube containing the acid.
8. Stand well away from the test-tube rack and light the wax taper.
9. Hold the flame to the mouth of the inverted test-tube of hydrogen gas and remove the stopper.
10. Record what happens.

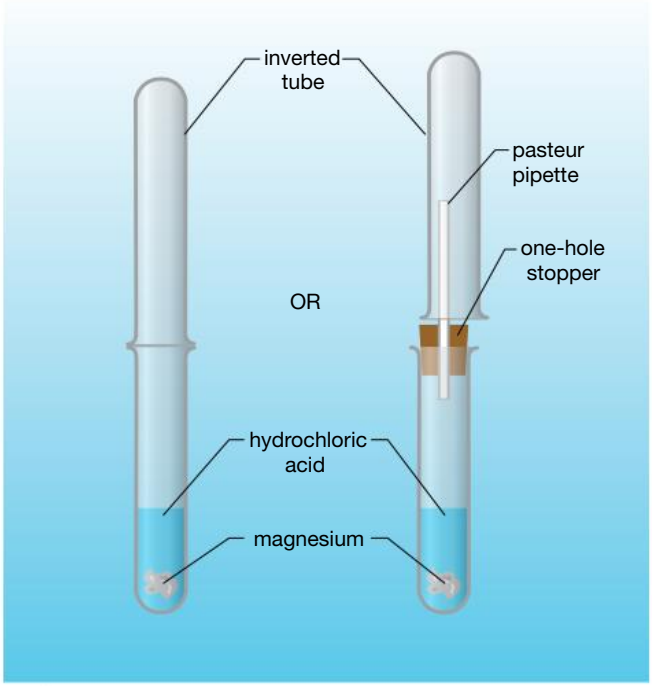


Figure 2.2.10

Results

Record all your observations, including the smell as hydrogen was wafted towards you.

Practical review

1. **Explain** how you knew this reaction was producing a gas.
2. **Identify** the type of reaction happening here. (Is it acid–base, acid–metal, neutralisation etc.?)
3. **Construct** a word equation and a balanced formula equation for this reaction.

2 Evaluating antacids

Antacids contain a base that neutralises some of the excess hydrochloric acid in your stomach.

Purpose

To evaluate how effective different antacids are at reducing acidity.

Materials

- different antacid tablets
- 0.1 M hydrochloric acid solution

- 250 mL beaker
- liquid universal indicator or pH meter
- eyedropper
- rubber gloves

SAFETY

Hydrochloric acid will burn and irritate open cuts and your eyes so wear rubber gloves and safety glasses at all times.

Do not taste any chemicals.

Procedure

1. Pour about 50 mL of hydrochloric acid into the beaker.
2. Measure the pH of the solution with the pH meter or by putting a couple of drops of the universal indicator in it. Record your observations and pH in a table like the one shown in the Results section.
3. Add an antacid tablet and allow it to dissolve completely.
4. Determine the new pH of the solution with the pH meter or by using the new colour of the solution.
5. Rinse out the beaker and then repeat the experiment with another antacid tablet.

Results

Record all your measurements in a table like this one.

	Tablet 1	Tablet 2	Tablet 3
Colour of universal indicator before antacid was added			
pH of solution before antacid was added			
Colour of universal indicator after antacid was added			
pH of solution after antacid was added			

Practical review

1. **Name** the acid that is in your stomach.
2. **Explain** how this acid can cause the pain known as heartburn.
3. **Analyse** your results and determine which antacid tablet was most effective.
4. Heartburn has nothing to do with the heart. **Propose** a reason why it got this name.

STUDENT DESIGN

3 Endothermic or exothermic?

Purpose

To determine whether a neutralisation reaction is endothermic or exothermic.

Hypothesis

What do you think a neutralisation reaction is—endothermic or exothermic? Before you go any further with this investigation, write a hypothesis in your workbook.

SAFETY

A risk assessment is required for this investigation. Vinegar and citric acid are mild irritants, so wear gloves and safety glasses to avoid contact with your skin and eyes. Refer to the MSDS for all chemicals when constructing your risk assessment.

Materials

- vinegar or citric acid
- baking soda (bicarbonate of soda or sodium hydrogen carbonate, $NaHCO_3$)
- materials as selected by students

Endo or exo? continued on next page

Endo or exo? continued

Procedure

1 Design an experiment to determine whether the reaction between vinegar or citric acid and baking soda (bicarbonate of soda or sodium hydrogen carbonate, $NaHCO_3$) is endothermic or exothermic.

2 Brainstorm in your group and come up with several different ways to investigate the problem. Select the best procedure and write it in your workbook. Draw a diagram of the equipment you need.

3 Before you start any practical work, assess all risks associated with your procedure. Refer to the MSDS of all chemicals used. Construct a risk assessment that outlines these risks and any precautions you need to take to minimise them. Show your teacher your procedure and risk assessment. If they approve, then collect all the required materials and start work.

Practical review

1 **Contrast** endothermic with exothermic reactions.

2 a **Classify** the reaction that happened here as endothermic or exothermic.

b **Justify** your choice.

3 a **Construct** a conclusion for your investigation.

b **Assess** whether your hypothesis was supported or not.

4 **Evaluate** your procedure. Pick two other prac groups and **evaluate** their procedures too, identifying their strengths and weaknesses.

STUDENT DESIGN

4 Acid–base rocket

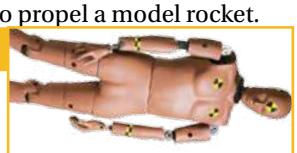
Purpose

To use a neutralisation reaction to propel a model rocket.

Materials

- vinegar
- baking soda (bicarbonate of soda or sodium hydrogen carbonate, $NaHCO_3$)

- materials as selected by students



SAFETY

A risk assessment is required for this investigation. Vinegar is a mild irritant, so wear gloves and safety glasses to avoid contact with your skin and eyes. Refer to the MSDS for both vinegar and sodium hydrogen carbonate when constructing your risk assessment.

Procedure

1 Search the internet for a design of a rocket that uses a mixture of vinegar and baking soda (bicarbonate of soda or sodium hydrogen carbonate, $NaHCO_3$) to propel it. ICT

2 Print out or save the instructions or video of the rocket you wish to build.

3 Before you start any practical work, assess all risks associated with your design. Refer to the MSDS of all chemicals used. Construct a risk assessment that outlines these risks and any precautions you need to take to minimise them. Show your teacher your design and your risk assessment. If they approve, then collect all the required materials and start work.

Practical review

1 **Recall** the reaction of vinegar and baking soda by writing its word equation and balanced formula equation.

2 **Name** the gas that 'powered' your rocket.

3 **Use** forces to **explain** how this gas caused your rocket to move.

2.3 Reactions of life

Almost all life on Earth depends on two processes called photosynthesis and respiration. Plants use photosynthesis to make glucose, which stores energy for later use. Respiration is needed to release that stored energy. Respiration is also used by animals (including humans) to release energy from the glucose they have absorbed from their food.

Photosynthesis

Photosynthesis is a series of chemical reactions that green plants use to produce the sugar glucose ($C_6H_{12}O_6$). **Glucose** is a molecule that stores energy that green plants absorb from sunlight. Glucose can be thought of as a plant's food.

Photosynthesis can be summarised by the word equation:

$$\text{carbon dioxide + water} \xrightarrow[\text{chlorophyll}]{\text{sunlight}} \text{glucose + oxygen gas}$$

or the balanced formula equation:

$$6CO_2 + 6H_2O \xrightarrow[\text{chlorophyll}]{\text{sunlight}} C_6H_{12}O_6 + 6O_2$$

As long as a plant has enough sunlight, carbon dioxide and water, it can manufacture all the food it needs. Photosynthesis takes place in any part of the plant that is green and exposed to sunlight. Leaves are the most exposed parts of a plant and so most photosynthesis takes place there. To maximise this exposure, most plants have flattened leaves that don't overlap. You can see this in Figure 2.3.1.

SciFile

Maximising, minimising

Exposure to sunlight also dries out plants. Different leaf shapes have evolved to maximise their exposure to the sun while minimising water loss. For example, plants in hot, bright environments often have small or needle-shaped leaves. Plants near the ground in dark, wet rainforests don't get much sunlight and so have large, flat leaves to capture as much light as possible. Most rainforest plants have large leaves with deep channels in them to drain heavy rainfall.

Figure 2.3.1 Leaves are arranged to catch as much sunlight as possible.

Obtaining the raw materials for photosynthesis

Photosynthesis needs carbon dioxide and water as reactants. It also needs sunlight to power its reactions. This process is shown in Figure 2.3.2.

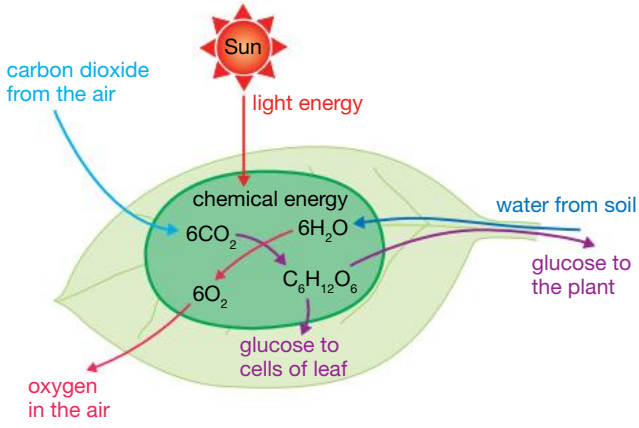


Figure 2.3.2 All the raw materials need to be brought together in the chloroplasts of the leaf cells before photosynthesis can take place.

Sunlight

Sunlight passes into the cells containing chloroplasts. Within the chloroplasts is a green-coloured chemical called **chlorophyll**, which helps convert light energy from sunlight into chemical energy that the plant can use. The chloroplasts also contain **enzymes**. These are helper chemicals that speed up the reactions of photosynthesis happening there.

Water

Water is carried from the roots up the plant's transport system and into the leaf. It moves from the transport system into the cells and then into the chloroplasts.

Carbon dioxide

Carbon dioxide moves by a process called **diffusion** from the air through tiny openings in the leaf called stomata (Figure 2.3.3). The concentration of carbon dioxide in the air is higher than in the leaf because photosynthesis has used it up in the leaf. Carbon dioxide continues to move by diffusion through air spaces in the lower part of the leaf to the chloroplasts in the cells of the upper layers.

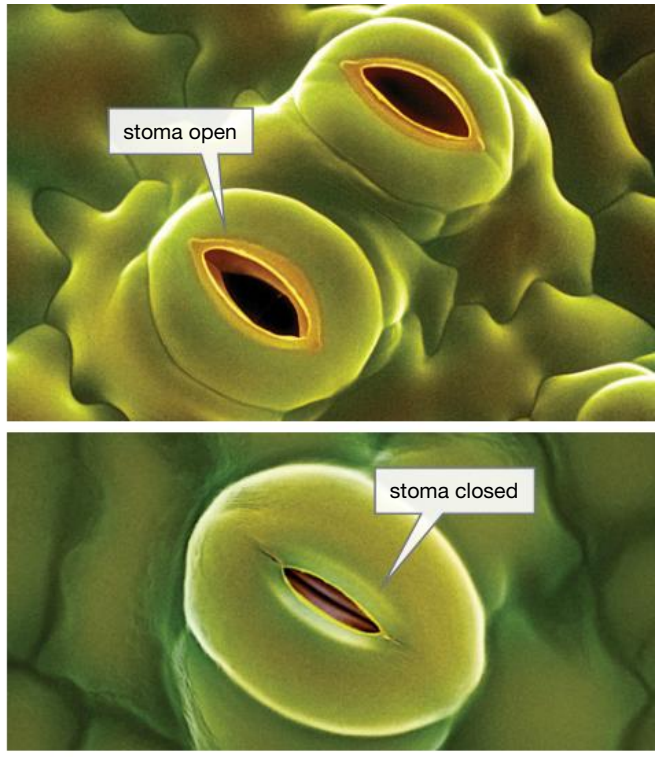


Figure 2.3.3 These stomata provide an entry for the carbon dioxide needed for photosynthesis. The stomata also provide an exit for the water vapour and carbon dioxide produced by respiration. In hot weather, the stomata close to stop the plant losing too much water and becoming dehydrated.

Prac 1 p70
2.5

Respiration

Plant and animal cells need a constant supply of energy in order to function. They get this from a process called **respiration**, which releases energy from glucose. Plants get their glucose from photosynthesis. Animals get glucose through digestion of the food they eat.

Glucose molecules are made up of carbon, hydrogen and oxygen atoms. Energy is released when these molecules are broken into smaller ones. This energy is then available to the organism for tasks such as growth, repair, movement and reproduction.

Plants use a form of respiration called aerobic respiration to release this energy. Animals also use aerobic respiration most of the time. Aerobic respiration needs a supply of oxygen as well as glucose. This is why you breathe. When exercising, the increased rate and depth of breathing removes carbon dioxide waste while supplying more oxygen to the bloodstream. This flow of gases is what is being measured in Figure 2.3.4.

The reaction can be represented by the following chemical equations:

glucose + oxygen gas → carbon dioxide + water + energy

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ + energy

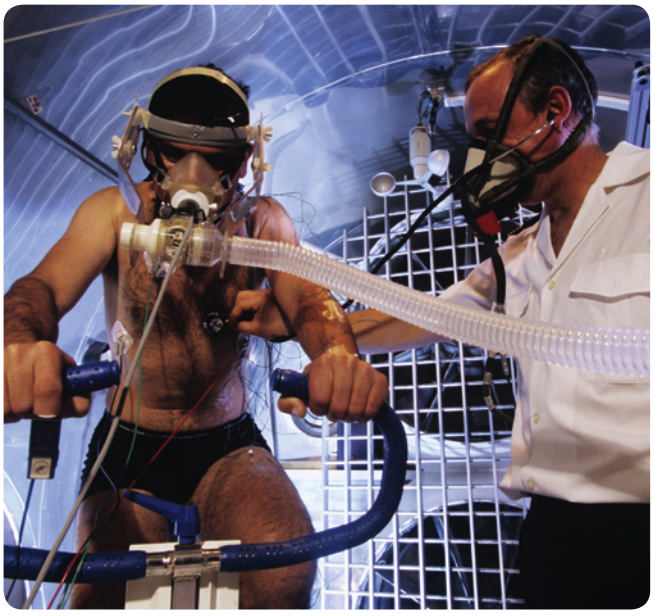


Figure 2.3.4 Aerobic respiration needs oxygen. Breathing provides oxygen and gets rid of the carbon dioxide produced.

Aerobic respiration begins once the oxygen and glucose get to the cells. The glucose and oxygen react together in parts of the cells called mitochondria. Carbon dioxide and water are produced and energy is released. Enzymes enable this reaction to occur at a rate that meets the cell's requirements.

Respiration in plants

Glucose is brought to the cells of a plant by the transport system. Oxygen diffuses into the plant from the atmosphere through specialised structures called **lenticels** in the stems and roots, and through stomata.

The products of respiration are carbon dioxide and water. Carbon dioxide diffuses out of the mitochondria into the cytoplasm, a thick liquid sap that fills much of the rest of the cell. Some of the carbon dioxide is taken in by the chloroplasts and used in photosynthesis. The rest leaves the cells and eventually exits the plant through the stomata.

Water also diffuses from the plant cell and evaporates. It exits the plant through the stomata in the form of water vapour.

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Carbon sinks

Plant respiration releases carbon dioxide back into the atmosphere, but in smaller quantities than that used by photosynthesis. This is because the glucose produced by a plant is not used just for respiration. As Figure 2.3.5 shows, glucose is also used to build the plant itself.

Specifically, glucose is:

- converted to starch for short-term storage. During the night the starch may be converted back into glucose and then used as a source of energy
- stored long-term as starch in the stems or roots of vegetables such as potatoes and sweet potatoes
- converted into cellulose for the manufacture of plant cell walls
- converted to substances used to make plant oils or proteins (Olive oil is formed this way.)
- converted into a more complex sugar called sucrose ($C_{12}H_{22}O_{11}$) and transported to parts of the plant where photosynthesis cannot occur (such as the roots). Sucrose is the sugar used to sweeten coffee and tea
- used in the process of making vitamins.

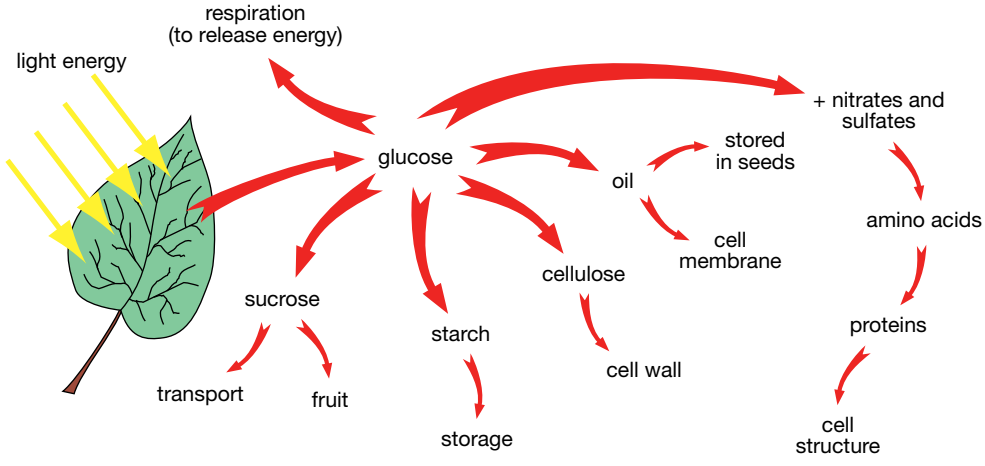

Figure 2.3.5 Glucose is not used just for respiration.

By doing all this, plants store carbon that has been removed from the atmosphere by photosynthesis. Every tree, forest, field and crop can therefore be thought of as a **carbon sink**, effectively 'burying' the carbon. For this reason, some environmentalists are encouraging the preservation of existing forests and the planting of new ones to reduce carbon dioxide in the atmosphere and to reduce the effects of climate change. When trees are killed by being chopped down or burnt, they cannot take in any more carbon. Rotting returns their carbon to the soil. Burning them releases much of the stored carbon back into the atmosphere as smoke, soot and carbon dioxide.

Respiration in humans

The bloodstream of animals such as humans carries glucose and oxygen to the cells. Glucose is one of the products of digestion of food. Oxygen is breathed in, then passes through narrower and narrower tubes until it diffuses through the lungs' alveoli into the blood. You can see this network of tubes in Figure 2.3.6.

Figure 2.3.6 The lungs supply the bloodstream with oxygen so that aerobic respiration can occur in the cells. They also provide an exit for waste carbon dioxide and some water vapour.

The blood also carries away the waste water and carbon dioxide from the cells. Some water is re-absorbed into the body. Some is removed by the kidneys to be stored in the bladder and later expelled as urine. Other water is breathed out as water vapour. Carbon dioxide diffuses from the blood into the alveoli in the lungs.
It too is then breathed out.

2.6

Comparing photosynthesis and respiration

The chemical equations for photosynthesis and respiration suggest that the two processes are exact opposites of each other. For example, photosynthesis makes glucose, and respiration uses it. Both processes also use an 'energy-storage' molecule called ATP (adenosine triphosphate). However, the two processes differ. Table 2.3.1 lists the similarities and differences between photosynthesis and respiration.

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Table 2.3.1 Comparison of photosynthesis and aerobic respiration

Photosynthesis	Aerobic respiration
Makes glucose	Uses glucose
Uses carbon dioxide	Makes carbon dioxide
Makes oxygen gas	Uses oxygen gas
Uses ATP	Uses ATP
Has two steps: light reaction and dark reaction	—
Enzymes speed up the reaction	Enzymes speed up and control the reaction
Occurs only in the chloroplasts of cells of green plants	Occurs in the mitochondria of cells of all living things
Shuts down at night	Happens continuously (day and night)

SciFile

How do mozzies breathe?

Mammals, birds, reptiles and amphibians such as frogs have lungs to draw in oxygen and expel carbon dioxide. Amphibians also exchange gases through their skin. Insects don't have lungs. Instead they have small tubes from the outside of their bodies feeding the gases directly into and out of their blood. Mosquito larvae (wrigglers) breathe through a tube that sticks out of the water.

2.3 Unit review

Remembering

1 **Name** the following chemicals.
   - a CO_2
   - b O_2
   - c $C_6H_{12}O_6$

2 **Name** the green pigment found in plants.

3 **Name** the opening in the leaf that allows gases to move in and out.

Understanding

4 **Describe** what an enzyme is and what it does.

5 **Explain** why sunlight and chlorophyll are placed above and below the arrow in the equation of photosynthesis and not on the side of the reactants.

6 **Explain** how aerobic respiration releases energy from glucose.

7 Sucrose (table sugar) comes from the stems of sugar cane. **Outline** how it got there.

8 Environmentalists sometimes talk about a *carbon sink*. **Explain** what this term means.

Applying

9 Equipment was set up as shown in Figure 2.3.7 to gather information about photosynthesis.
   - a **Identify** the gas that would be collected in the test-tube.
   - b **Demonstrate** how the rate of photosynthesis could be determined using this equipment.

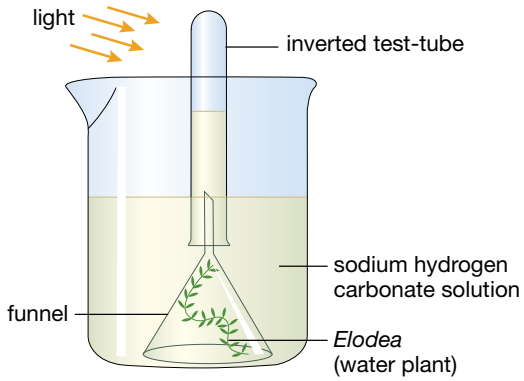

Figure 2.3.7

Analysing

10 **Contrast** the ways in which plants and animals get their glucose.

11 **Compare** photosynthesis and aerobic respiration by:
   - a writing their word equations
   - b writing their balanced formula equations
   - c listing the ways in which they are similar
   - d listing the ways in which they are different.

Evaluating CCT

12 Climate change may lead to increased ocean temperatures. **Propose** reasons why many environmentalists are very worried about this possibility.

13 It has been suggested that humans will need to take green plants along with them if they are ever to travel far into space. **Propose** reasons why.

Inquiring

1 Use the key words *respiration videos* to find clips on the internet to watch. ICT

2 a Research how our understanding of photosynthesis developed.
   b Identify the main people involved in the discovery.

   Present your research as a timeline with linked text and images.

3 Research anaerobic respiration.
   - Find the word equation and balanced formula equation that describes it.
   - Contrast anaerobic and aerobic respiration.
   - Propose with reasons when it is most likely to happen in humans.
   - List organisms that use anaerobic respiration to release energy.
   - Compare these organisms.

   Present your findings as a set of responses to the above tasks.

2.3 Practical investigations

1 Testing leaves for starch

Purpose

To test leaves for the presence of starch.

Materials

- 1 variegated leaf that has been in sunlight for several hours
- methylated spirits
- iodine solution

- beaker
- hotplate
- test-tube
- test-tube rack
- Petri dish
- tongs
- dropping pipette
- tweezers

SAFETY

Methylated spirits is flammable, so keep it well away from flames and the hotplate.

Wear safety glasses at all times.

Procedure

1. Sketch the leaf, showing where there is a lot of chlorophyll (the green parts) and where there is little (the paler or cream parts). Keep this sketch for later.
2. Place around 100 mL of water in the beaker and heat it on the hotplate until it boils. Drop the leaf in the water and heat it for about 30 seconds.
3. Use the tweezers to carefully remove the leaf from the water and place it in a test-tube. Keep the water in the beaker boiling.
4. Keeping well away from the hot plate, add methylated spirits to the test-tube so that the leaf is covered.
5. Place the test-tube into the beaker of boiling water and heat it until the green chlorophyll is removed from the leaf.
6. Using tongs, carefully remove the test-tube from the beaker of boiling water and remove the leaf from the test-tube.
7. Place the leaf back into the beaker of boiling water for a few minutes to soften it.
8. When the leaf is soft, remove it from the water and place it in a Petri dish.
9. Add 4 drops of iodine solution to the leaf.

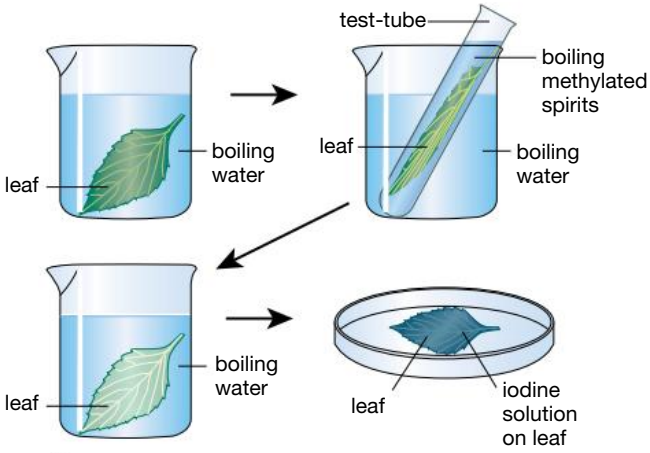

Figure 2.3.8

Extension

10. Tape black paper or aluminium foil onto another leaf that is still attached to the plant. Cut a 'window' in the paper or foil to expose part of the leaf.
11. After a few days, pick the leaf and test as above for the presence of starch.

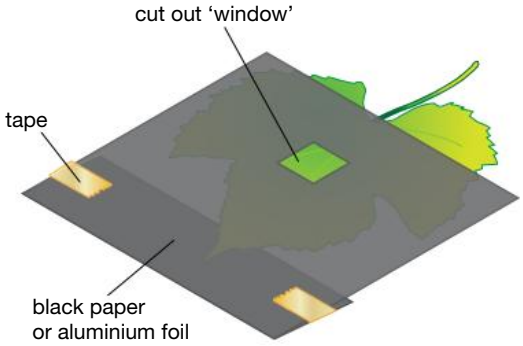

Figure 2.3.9

Results

Sketch the leaf, showing where starch is present and where it is absent.

Testing leaves for starch continued on next page

Practical review

1 **Name** the substance in the leaves with which iodine reacts.

2 a If you carried out the extension, **compare** the two diagrams you have made of the leaf.

b **Explain** what the diagrams tell you about starch production in the leaf.

3 a **Predict** the results you would have obtained if you had tested a leaf picked from the plant at dawn.

b **Justify** your prediction.

4 If you carried out the extension, **construct** an annotated diagram that explains what you observed.

2 Respiring plants

Purpose

To investigate respiration in plants.

SAFETY
Wear safety glasses at all times.

Materials

- 9 pieces of water plant such as *Elodea*
- bromothymol blue indicator
- 9 test-tubes
- 3 test-tube racks
- drinking straw
- 50 mL beaker

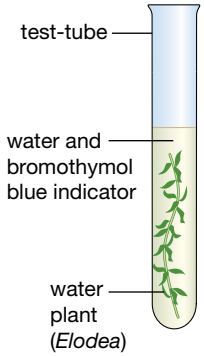

Figure 2.3.10

Procedure

1 In your workbook, construct a table like the one shown in the Results section.

2 Two-thirds fill each test-tube and the beaker with water. Add a few drops of bromothymol blue to give the solution an obvious blue colour.

3 Using the drinking straw, bubble exhaled air through the water in the beaker.

4 Observe and record the colour change of the indicator.

5 Label the test-tube racks: 'Dark', 'Low light', 'Bright light'.

6 Add the same amount of water weed to each test-tube.

7 Place three test-tubes into each of the test-tube racks.

8 Place the test-tube racks in an appropriate place.

- dark—a cupboard
- low light—a corner of the classroom away from the windows
- bright light—a window sill, but make sure the water does not get hot.

9 Leave the test-tubes for 24–48 hours.

10 Observe and record any changes in the colour of the indicator. Record your observations in a table like that shown in the Results section.

Results

1 Describe what happened when you bubbled exhaled air through the water containing bromothymol blue.

2 Record your observations in your results table.

Treatment	Indicator colour	
	Start	After 24 hours
Dark		
Low light		
Bright light		

3 Bromothymol blue is blue in an alkaline or a neutral solution. It turns green and then yellow in an acidic solution. Carbon dioxide dissolved in water produces a weak acid.

Use this information to identify whether each solution was alkaline, neutral or acidic.

Practical review

1 **Explain** the colour change that occurred when you bubbled exhaled air through the water with bromothymol blue.

2 **Describe** what happened in each of the test-tubes.

3 **Explain** why this happened.

2.3 Practical investigations

STUDENT DESIGN

3 Light and photosynthesis

Purpose

To demonstrate that light is needed for photosynthesis to occur.

Materials

- to be selected by students

Procedure

1. Design an experiment to demonstrate that light is necessary for photosynthesis to occur.
2. Brainstorm in your group and come up with several different ways to investigate the problem. Select the best procedure and write it in your workbook. Draw a diagram of the equipment you need.
3. Before you start any practical work, assess all risks associated with your procedure. Refer to the MSDS of all chemicals used. Construct a risk assessment that outlines these risks and any precautions you need to take to minimise them. Show your teacher your procedure and your assessment of its risks. If they approve, then collect your equipment and start work.

Hints

- Think about the product of photosynthesis that you can test easily.
- Consider how you will prevent light reaching plants and how long you will keep the plants in the dark.
- Think about other factors that you will have to control to make this a fair test.

Practical review

1. **Recall** the word equation and balanced formula equation that summarises the process of photosynthesis.
2. **Explain** how your observations confirm that light is needed for photosynthesis to occur.
3. **Evaluate** your procedure. Pick two other prac groups and **evaluate** their procedures too, identifying their strengths and weaknesses.

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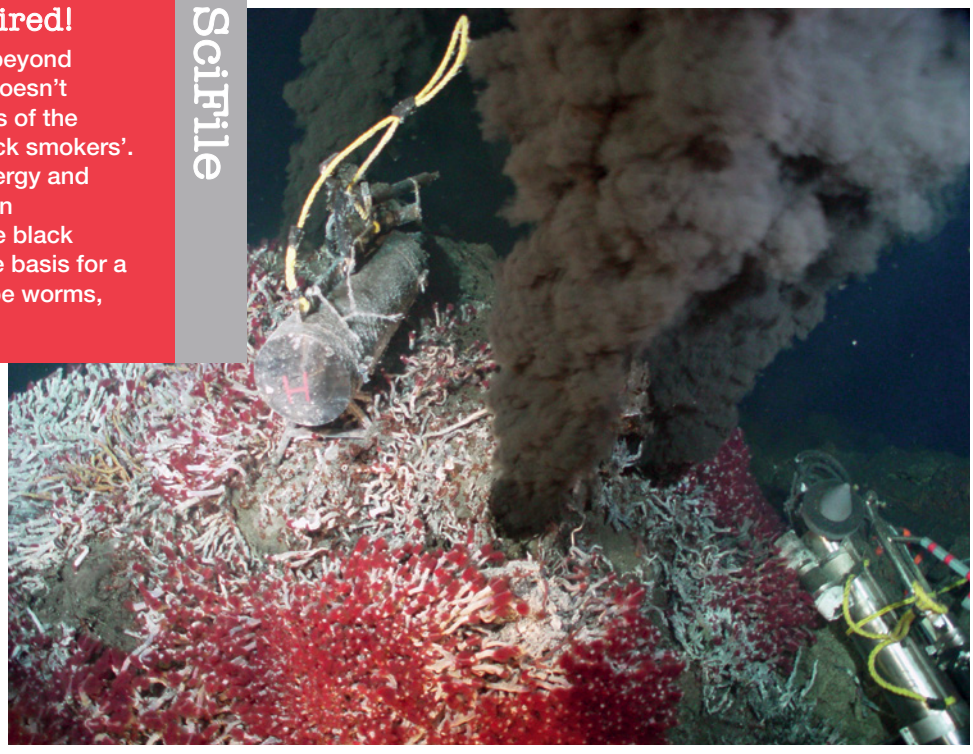
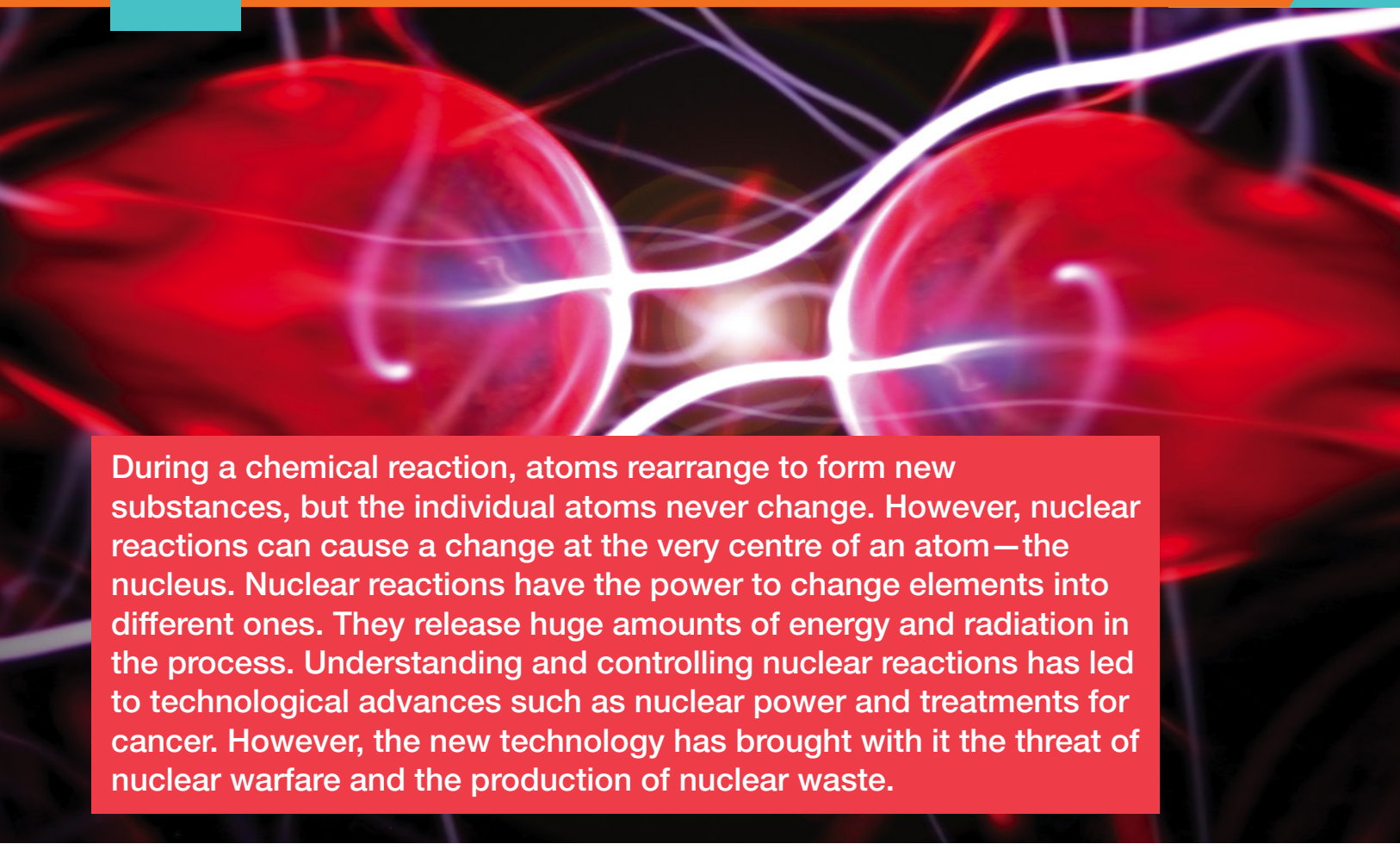
No photosynthesis required!

Sunlight can't penetrate the ocean beyond 300 metres and so photosynthesis doesn't happen there. However, at the edges of the tectonic plates are vents called 'black smokers'. Chemosynthetic bacteria collect energy and nutrients from chemicals dissolved in superheated water erupting from the black smokers. These bacteria provide the basis for a food chain, which includes giant tube worms, spider crabs and mussels.



2.4 Nuclear reactions



During a chemical reaction, atoms rearrange to form new substances, but the individual atoms never change. However, nuclear reactions can cause a change at the very centre of an atom—the nucleus. Nuclear reactions have the power to change elements into different ones. They release huge amounts of energy and radiation in the process. Understanding and controlling nuclear reactions has led to technological advances such as nuclear power and treatments for cancer. However, the new technology has brought with it the threat of nuclear warfare and the production of nuclear waste.

Nuclear decay

Combustion, corrosion, neutralisation, respiration and photosynthesis are all examples of chemical reactions that convert substances (reactants) into different substances (products). The products can have very different properties from the reactants, but the atoms remain the same. The atoms in the reactants just rearrange to form the products. To convert an atom into a different type of atom requires a change in the nucleus. This can only be achieved by a **nuclear reaction**.

The nucleus that sits at the centre of an atom is not just standing still. The protons and neutrons that make up the nucleus are constantly moving and rearranging. In some cases, these rearrangements can cause nuclei to emit (release) high-energy electromagnetic radiation and particles. This process is known as **nuclear decay**. Nuclear decay is a type of a nuclear reaction.

Nuclear decay can cause some atoms to change into completely different types of elements. This happens whenever the number of protons in the nucleus changes. For example, some sodium atoms decay by losing a proton. This converts them into neon atoms, as shown in Figure 2.4.1. The process of an atom converting to another type of atom is known as **transmutation**.

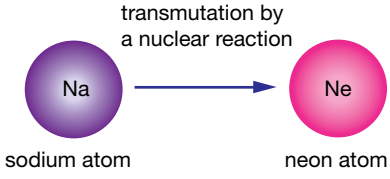


Figure 2.4.1 When a sodium (Na) atom undergoes nuclear decay, it changes into an entirely different atom—neon (Ne). This process is known as transmutation.

It is impossible for transmutation to occur through a chemical reaction. This is because chemical reactions do not involve changes in the nucleus. Instead, chemical reactions involve the electrons that surround the nuclei of the atoms.

Ambitious alchemists

SciFile

In the Middle Ages, people known as alchemists tried to turn lead into gold through magic and various chemical reactions. Today, scientists know the alchemists' attempts were pointless and that only a nuclear reaction could convert lead into gold.

Radioisotopes

Most of the atoms that make up the world around you contain **stable nuclei**. This means that the nuclei will never undergo nuclear decay. However, a tiny fraction of atoms have **unstable nuclei**. These unstable atoms could eject particles or electromagnetic waves from their nucleus at any moment and undergo nuclear decay. These unstable atoms are known as **radioisotopes**.

Isotopes are atoms that have the same number of protons but a different number of neutrons. Hence, isotopes have the same atomic number and belong to the same element but have different mass numbers. In other words, isotopes are different 'versions' of the same element.

Each type of atom may have several isotopes but only some isotopes are **radioactive**. For example, carbon has three naturally occurring isotopes called carbon-12, carbon-13 and carbon-14, as shown in Figure 2.4.2. They are all carbon atoms because they all contain 6 protons and have an atomic number of 6. However, carbon-12 has 6 neutrons (giving it a mass number of 12), carbon-13 has 7 neutrons (mass number 13) and carbon-14 has 8 neutrons (mass number 14). As extra neutrons are added to a nucleus, it becomes unstable. For example, carbon-12 and carbon-13 are stable but carbon-14 is unstable (a radioisotope) and therefore radioactive.

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GO TO Pearson science NSW 10 Unit 4.1

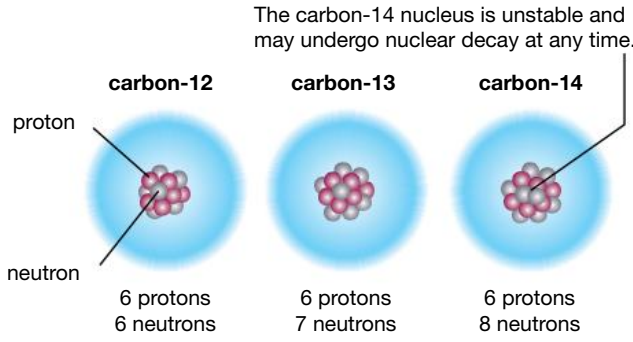


Figure 2.4.2 Carbon has three naturally occurring isotopes: carbon-12, carbon-13 and carbon-14. The nucleus of carbon-14 is unstable, so carbon-14 is a radioisotope.

Types of nuclear decay

There are three types of nuclear decay. These are alpha decay, beta decay and gamma decay. The three different types of decay are summarised in Table 2.4.1.

Alpha decay

During **alpha decay**, a nucleus ejects an **alpha particle**, which is a cluster of two protons and two neutrons. The alpha particle is given the symbol α. The particle is identical to a helium-4 nucleus, which has the symbol $^{4}_{2}\mathrm{He}$.

Alpha decay only occurs in atoms with very heavy nuclei—this is usually where the mass number (protons plus neutrons) is greater than 100. For example, the radioisotope uranium-238 ($^{238}_{92}\mathrm{U}$) undergoes alpha decay as shown in Figure 2.4.3.

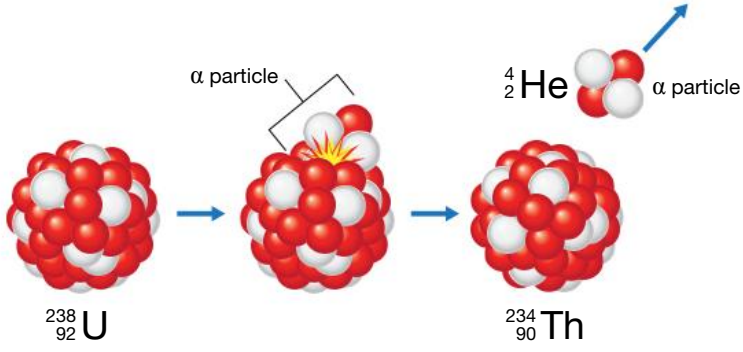


Figure 2.4.3 When a uranium-238 nucleus undergoes alpha decay, it becomes a thorium-234 atom. The atom of uranium has changed into an atom of thorium.

Initially, the uranium-238 atom has 92 protons and 146 neutrons. When the uranium-238 ejects an alpha particle, the nucleus loses 2 protons and 2 neutrons. Therefore, the atom becomes a thorium-234 atom with 90 protons and 144 neutrons. In other words, the atomic number has decreased by 2 while the mass number has decreased by 4. Through this nuclear reaction, a uranium atom becomes a thorium atom, an entirely different element.

Beta decay

Beta decay occurs when the nucleus ejects a **beta particle**, which is given the symbol β. Beta particles are identical to electrons and therefore are very small and have a negative charge. When a nucleus undergoes beta decay, a neutron is converted into a proton. This increases the atomic number by one, meaning a new element is formed. However, the mass number does not change because the total number of protons and neutrons stays the same.

Carbon-14 undergoes beta decay as shown in Figure 2.4.4. The carbon-14 atom has 6 protons and 8 neutrons. When the atom ejects a beta particle (β), one of the neutrons becomes a proton. This turns the atom into a stable nitrogen-14 atom with 7 protons and 7 neutrons.

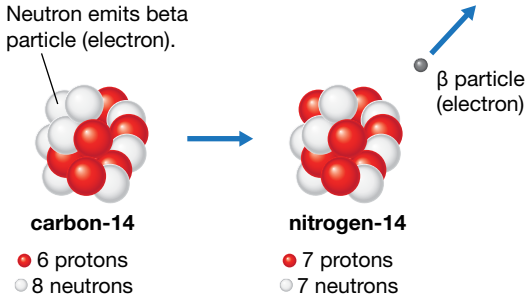


Figure 2.4.4 When a carbon-14 nucleus undergoes beta decay, it becomes a nitrogen-14 atom and emits a beta particle.

Gamma decay

Sometimes the protons and neutrons simply rearrange inside the nucleus but do not emit a particle. Instead they emit a form of electromagnetic wave known as a **gamma ray**. This process is known as **gamma decay**. Gamma rays are given the symbol γ. They are like X-rays but are more powerful.

Table 2.4.1 Summary of the products of nuclear decay

	Symbol	Equivalent to	Speed	Charge
Alpha particle	α	A helium nucleus	10% the speed of light	+2
Beta particle	β	An electron	90% the speed of light	−1
Gamma ray	γ	A high-energy X-ray	speed of light	0

Half-life

The rate at which nuclear decay takes place is measured by a radioisotope's **half-life**. The half-life of a radioisotope is the time it takes for half the nuclei to decay. For example, the radioisotope radon-222 decays into polonium-218 with a half-life of 4 days. This means that from 100 radon-222 atoms, 50 would decay over 4 days. Of the remaining 50 nuclei, 25 would decay over the next 4 days. And if you waited another 4 days, only 12 or 13 radon-222 atoms would remain. You can see this in Figure 2.4.5.

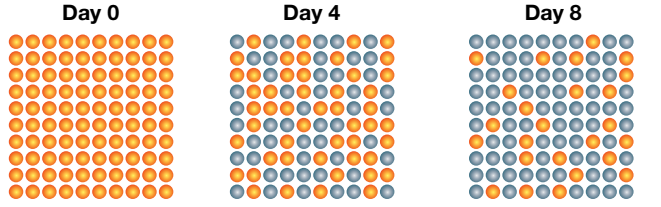


Figure 2.4.5 Radon-222 has a half-life of 4 days, so the number of radon atoms halves every 4 days.

The half-life of radioisotopes varies from a fraction of a second to millions of years. Table 2.4.2 lists the half-lives of some common radioisotopes.

Prac 1 p83 2.7

Table 2.4.2 Half-lives of common radioisotopes

Radioisotope	Half-life
Gold-200	48 minutes
Radon-222	4 days
Iodine-131	8 days
Cobalt-60	5.3 years
Americium-241	460 years
Carbon-14	5 730 years
Plutonium-239	24 000 years
Uranium-238	4.5 million years

Carbon dating

Understanding the half-life of radioisotopes has proved very useful to historians and archaeologists. The half-life of carbon-14 is used to determine the age of fossils (like the one in Figure 2.4.6) and ancient materials through a process known as **carbon dating**.

Figure 2.4.6

Archaeologists use carbon dating to determine the age of fossils and artefacts. Artefacts are objects made by humans, such as tools.

Carbon dating is based on the fact that all living things contain a small amount of carbon-14. The amount remains constant throughout the lifetime of the plant or animal. This is because carbon-14 is constantly being absorbed by the organism through its food and air. However, when the organism dies, carbon-14 is no longer absorbed. At that point, the small amounts of carbon-14 in the organism begin to decay into nitrogen-14 with a half-life of 5730 years. This decay is shown in Figure 2.4.7.

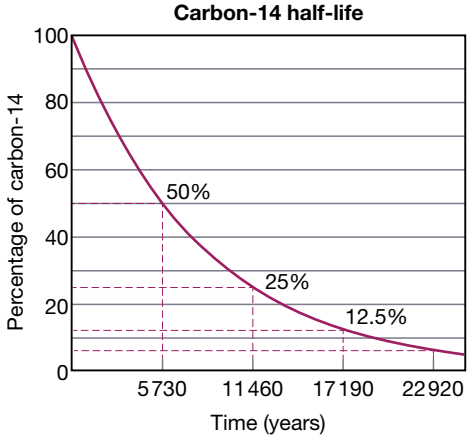


Figure 2.4.7

The percentage of carbon-14 atoms in a plant or animal halves every 5730 years after it dies.

This means an animal that died 5730 years ago will have half the amount of carbon-14 of an animal living today. An animal that died 11 460 years ago will have a quarter the amount of carbon-14 and so on. Therefore, by measuring the amount of carbon-14 in fossils and bones, scientists can get an accurate idea of when the animal lived. By 50 thousand years, so little carbon-14 is left that it no longer gives accurate dates.

Trees and other plants also contain carbon-14. This means that scientists can also use this technique to calculate the age of tools, paper and fabrics made from plants.

GO TO Pearson science NSW 10 Unit 2.2

Nuclear radiation

The term **nuclear radiation** describes any rays or particles emitted (released) by atomic nuclei. The term includes alpha particles, beta particles and gamma rays. Nuclear radiation can be extremely harmful, especially to living organisms. However, it can also be useful in medicine, industrial processes and scientific research.

Biological effects of radiation

Alpha particles, beta particles and gamma rays are particularly damaging to the cells of living organisms. This is because radiation destroys biological molecules and causes unwanted chemical reactions.

Alpha particles, beta particles and gamma rays are all types of **ionising radiation** because they can remove electrons from atoms and molecules. Exposing cells to ionising radiation can cause them to die or mutate.

Effects of cell death

Cell death occurs when ionising radiation enters the cell and destroys the biological molecules beyond repair. This may result in **radiation burns** or **radiation sickness**.

Radiation burns like the one in Figure 2.4.8 are caused by short exposure to a very large amount of ionising radiation. The radiation damages the cells on the surface of skin or other organs, causing redness and blistering. However, the side effects are not immediately obvious. It may take 1 or 2 days for itching and redness to appear and then 1–3 weeks before burns and blisters appear.

Radiation sickness may result from exposure to a large amount of radiation in a short amount of time, or a lower amount of radiation over a longer period of time. The symptoms include nausea, vomiting, fever, hair loss and diarrhoea. The symptoms may not appear immediately but will appear more quickly if the person has absorbed a larger amount of radiation.

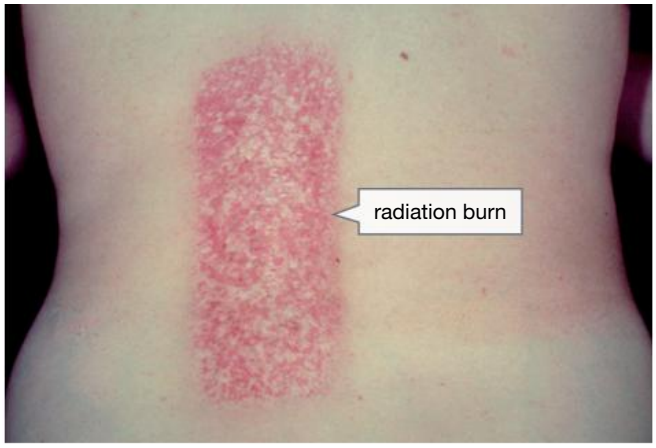


Figure 2.4.8 Radiation burns can be just as severe as burns caused by a fire.

Effects of cell mutation

Cell **mutation** occurs when the ionising radiation damages the DNA inside the cell without causing the cell to die. The DNA inside a cell contains all the genetic information that tells the cell how to function properly. If the DNA is damaged, the cell is reprogrammed and may cause the cell to develop into a cancer, like the skin cancer in Figure 2.4.9. A cell mutation can be caused by even a small amount of radiation. However, the likelihood of cell mutation increases as the exposure to ionising radiation increases.

If the ionising radiation causes a mutation in sperm or ova (egg cells), the offspring of the organism may be affected. This is known as genetic or inherited mutation. Different animals experience different levels of inherited mutations. For example, the mutations in the offspring of mice and fruit flies are increased significantly if the parents have been exposed to radiation.

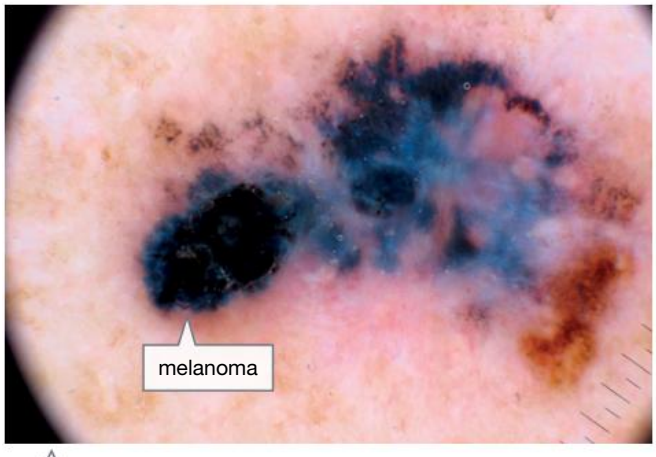


Figure 2.4.9 If ionising radiation damages the DNA in cells, it can cause them to turn into cancers. This malignant melanoma is one type of skin cancer.

However, in humans it is unclear whether large doses of radiation produce mutations in children. Scientists who studied the survivors of the nuclear bombs dropped on Nagasaki and Hiroshima in Japan in 1945 found that children of the survivors did not show an increase in genetic mutations. On the other hand, studies of men who worked with radioactive materials showed that the workers were more likely to have children with leukaemia.

GO TO Pearson science NSW 10 Unit 1.1

Mutants aren't monsters

SciFile

The mutations caused by radiation are not the monstrous creatures seen in science fiction movies. Instead, radiation exposure simply increases the frequency of naturally occurring mutations (such as albinism, which causes an absence of colour in the skin and hair). This peacock is an albino.

Properties of radiation

Alpha, beta and gamma radiation all have different properties (characteristics) that determine how much biological damage they can cause. Table 2.4.3 summarises some of these properties.

Table 2.4.3 Summary of nuclear radiation

Radiation	Mass of particles	Speed	Penetration depth	Ionisation ability
Alpha radiation	7000 times heavier than a beta particle	10% the speed of light	Stopped by dead skin or a layer of paper	20 electrons per α particle
Beta radiation	Same mass as an electron	90% the speed of light	Stopped by a 1 mm sheet of aluminium	1 electron per β particle
Gamma radiation	No mass	100% the speed of light	Stopped by several centimetres of lead or concrete	1 electron per γ ray

Alpha radiation

Alpha particles are large, heavy and slow compared to beta particles and gamma rays. This makes them 20 times better at ionising molecules. However, their large size also means that **alpha radiation** can only travel a few centimetres in air and is easily blocked by a thin sheet of paper or even a layer of dead skin. This is shown in Figure 2.4.10. As a result, radioisotopes that emit alpha radiation can be handled relatively safely. However, if isotopes emitting alpha radiation get inside the body, the effects can be fatal. Radioactive gases that emit alpha radiation are particularly dangerous when breathed into the lungs.

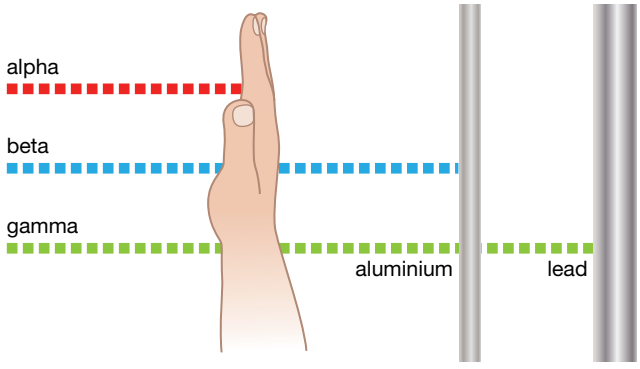


Figure 2.4.10 Alpha particles are stopped by a sheet of paper or dead skin. Beta particles are stopped by a 1 mm plate of aluminium. Gamma rays are only stopped by thick lead or concrete.

Deadly mines

SciFile

In the 1940s and 1950s it was discovered that the workers in uranium mines were twice as likely as other people to die of lung cancer. This was due to accumulation of the radioactive gas radon-222 in the mines. Radon-222 emits alpha radiation that damages the cells inside the lungs. Today, mines must be ventilated properly to prevent radon-222 accumulating.

Beta radiation

The beta particles that make up beta radiation are small and fast. This means that **beta radiation** penetrates (enters) the skin more deeply than alpha radiation. As a result, beta radiation is more likely to cause radiation burns to the skin and eyes, like the burns shown in Figure 2.4.11. However, beta radiation can be blocked by a thin plate of aluminium.

Figure 2.4.11 Beta and gamma radiation are the most likely source of radiation burns following a nuclear explosion. This person was burnt by radiation from the atomic bomb dropped on Hiroshima in 1945.

Gamma radiation

Gamma radiation can travel through skin, bone and aluminium, making it extremely dangerous to humans. Only a thick layer of concrete or lead will block the radiation. This is because gamma radiation is a form of **electromagnetic radiation**, made up of electromagnetic waves rather than particles. This means gamma rays do not have any mass or charge and travel at the speed of light. Other forms of electromagnetic waves include radio waves, microwaves, visible light, ultraviolet light and X-rays. However, only gamma rays, X-rays and certain types of ultraviolet light are powerful enough to ionise molecules and cause cell damage.

GO TO Unit 4.4

Useful radiation

While radiation should be handled with care, it can also be very beneficial if used correctly. Radiation is often used for medical treatments and diagnosis, industrial applications and scientific research.

Medical applications

Although radiation causes cells to become cancerous, it is also one of the most important tools for the treatment of cancers. This type of treatment is known as **radiotherapy**. During radiotherapy, the cancerous tumour is exposed to high concentrations of radiation. This radiation is used to kill the cells in the tumour and stop them multiplying. However, healthy cells may also be damaged. As a result, radiotherapy comes with serious side effects, including skin irritation, ulcers, swelling, nausea, hair loss, heart disease and secondary cancers.

Radioisotopes can also be used for medical diagnosis. For example, radioisotopes can be used to obtain detailed images of the organs inside the body, like the one in Figure 2.4.12. This process is called nuclear imaging. To obtain an image of the internal organs, radioisotopes are injected into the body. These radioisotopes collect in the organs and emit a very low dose of gamma radiation that can be detected outside the body to build up an image of the organs.

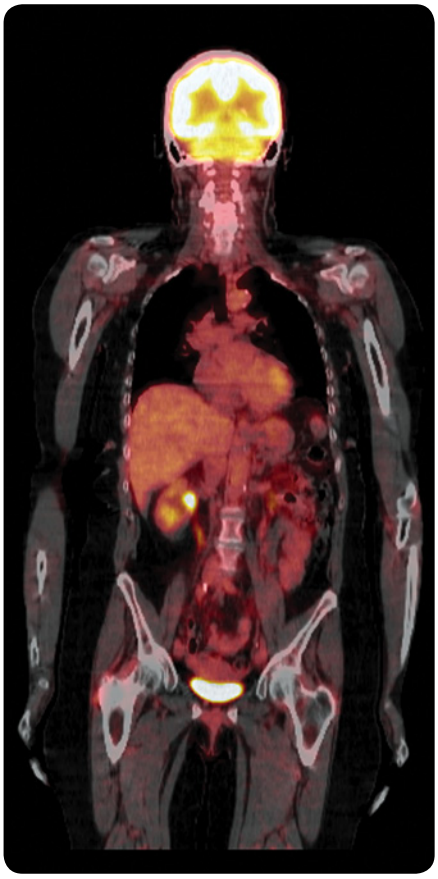


Figure 2.4.12

Doctors inject the patient with radioisotopes to obtain images of organs inside the body, like this false-coloured PET scan. Brighter areas show a build-up of radioisotope.

Industrial applications

There is a wide variety of industrial applications for radiation. Radiation is commonly used in the process of sterilisation to kill bacteria in medical equipment and even in food. This means that equipment such as bandages and needles can be sterilised without the need for harmful chemicals. Foods treated with radiation last longer before rotting or going stale.

Radiation can also be used to 'look' inside objects in the same way that X-rays can be used to look inside you. This is useful in exploring for minerals, oil, gas and water. A similar process is also used to determine the thickness of materials such as paper or metal foils, using the technique shown in Figure 2.4.13.

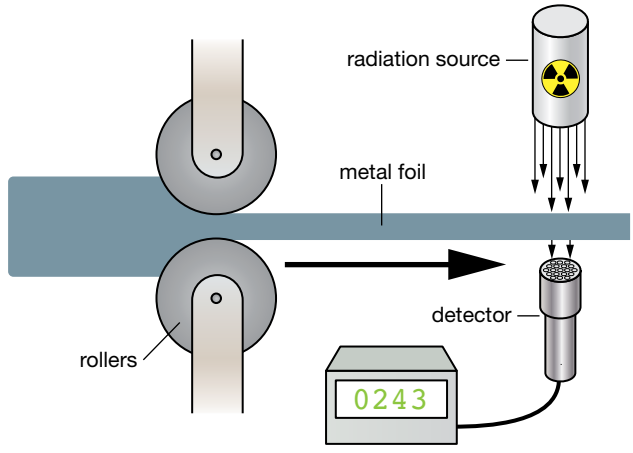


Figure 2.4.13

Engineers can accurately measure the thickness of materials by measuring how much radiation can pass through them.

You might even find radiation being used in your home! A certain type of smoke detector has a small amount of americium-241, which produces alpha radiation. If there is smoke in the air, the alpha particles are blocked and the alarm sounds (Figure 2.4.14).

Figure 2.4.14

Some smoke detectors use the radioactive element americium-241 to detect smoke particles in the air.

LEARNING ACROSS THE CURRICULUM

ETHICAL UNDERSTANDING

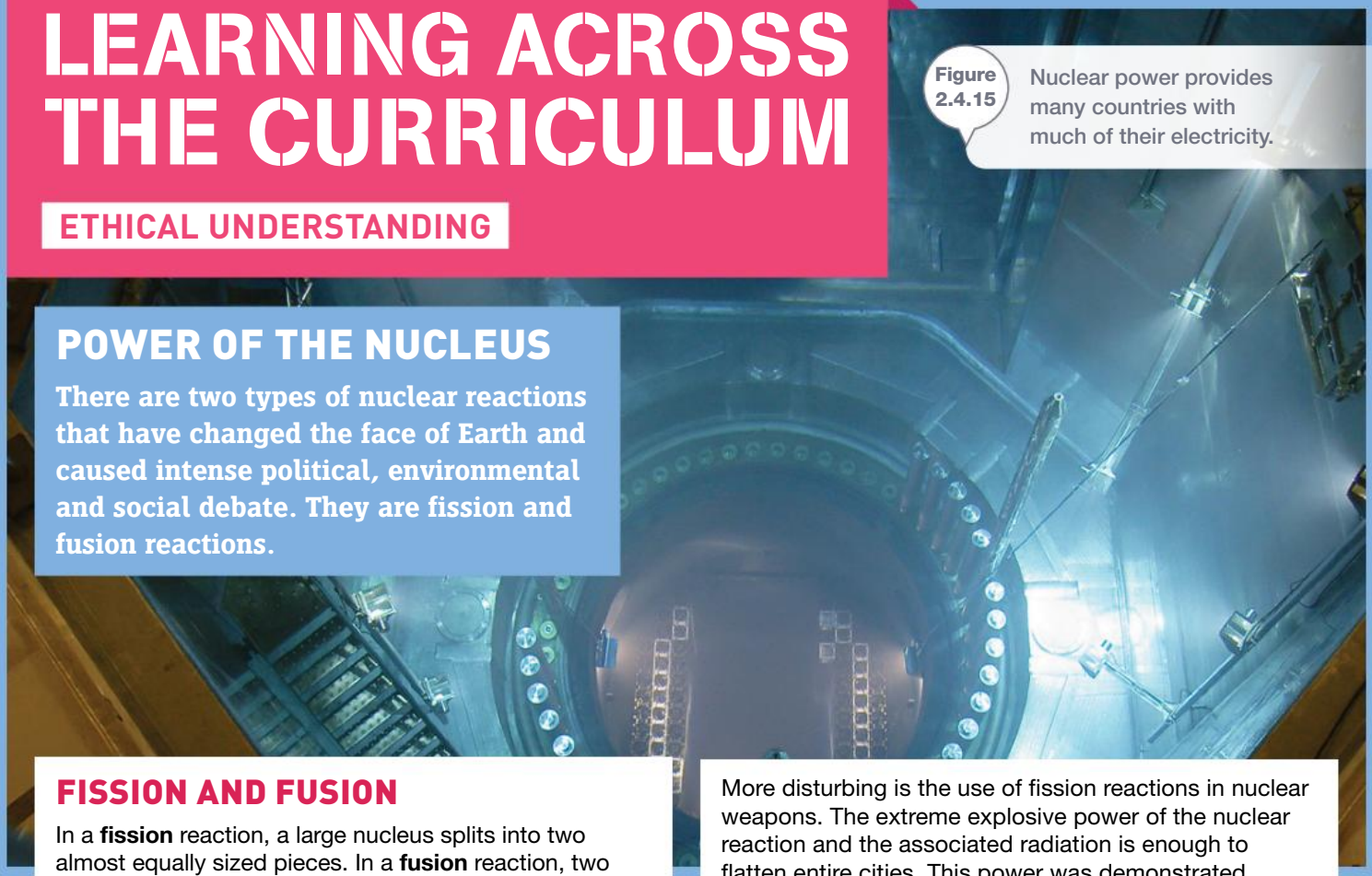


Figure 2.4.15 Nuclear power provides many countries with much of their electricity.

POWER OF THE NUCLEUS

There are two types of nuclear reactions that have changed the face of Earth and caused intense political, environmental and social debate. They are fission and fusion reactions.

FISSION AND FUSION

In a **fission** reaction, a large nucleus splits into two almost equally sized pieces. In a **fusion** reaction, two small nuclei come together to form a larger nucleus. Both reactions release huge amounts of energy that can be extremely useful or extremely destructive.

FISSION REACTIONS

The most famous fission reaction involves uranium-235. If this radioisotope absorbs a neutron, it forms the highly unstable isotope uranium-236. The uranium-236 then splits into two smaller atoms, krypton-92 and barium-141, releasing a huge amount of energy.

This reaction, shown in Figure 2.4.16, is used to supply 15% of the world's electricity demand and power military naval vessels. However, the reaction creates radioactive waste that cannot be destroyed and must be stored deep underground.

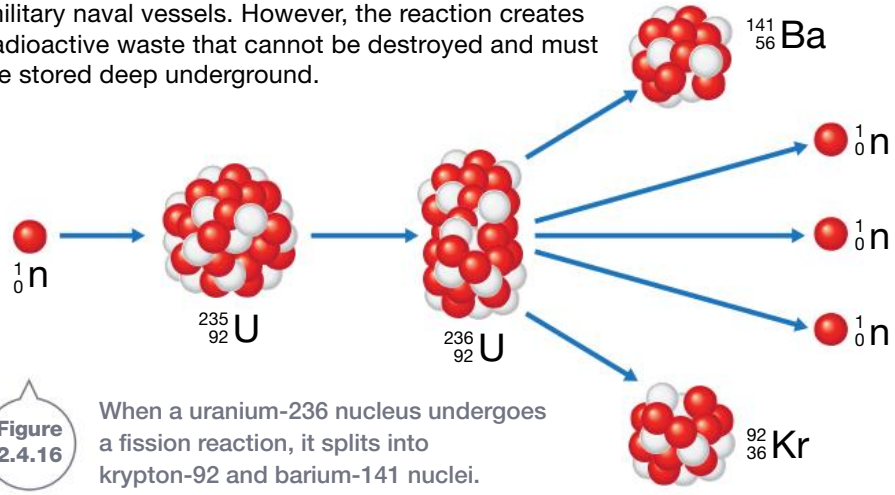


Figure 2.4.16 When a uranium-236 nucleus undergoes a fission reaction, it splits into krypton-92 and barium-141 nuclei.

More disturbing is the use of fission reactions in nuclear weapons. The extreme explosive power of the nuclear reaction and the associated radiation is enough to flatten entire cities. This power was demonstrated tragically during World War II when atomic bombs were dropped on the Japanese cities of Nagasaki and Hiroshima (Figure 2.4.17). The bomb blasts instantly killed about 100 000 people and almost the same number of people died in the following 2–4 months due to radiation exposure.

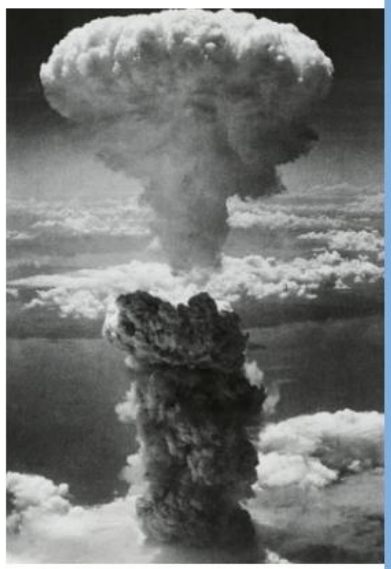


Figure 2.4.17 The extreme power of fission reactions was demonstrated when atomic bombs were detonated (exploded) over Nagasaki and Hiroshima during World War II.

FUSION REACTIONS

Without fusion reactions, there would be no life on Earth. This is because fusion reactions power the Sun and give us warmth and light. A fusion reaction occurs when two small nuclei combine to form a single nucleus. For example, if two hydrogen-2 nuclei collided, then they might form a helium-4 nucleus, as shown in Figure 2.4.18.

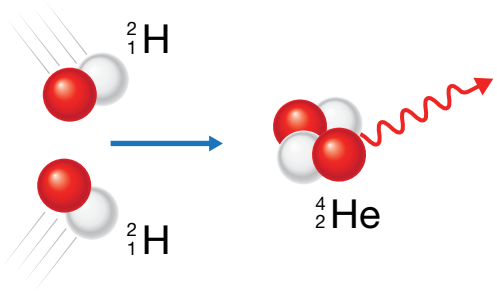


Figure 2.4.18 If two hydrogen-2 (deuterium) nuclei collide at high speed, then they may fuse together to form a helium-4 nucleus.

Figure 2.4.19 Fusion reactions occur at such high temperatures that scientists must hold the reaction in mid-air with strong magnetic fields that produce a 'magnetic bottle'.

However, the small nuclei strongly repel each other because they both have a positive charge. Therefore, fusion only occurs at extremely high temperatures—over 100 million degrees Celsius. There is no material on Earth that can withstand these temperatures, so scientists trying to create a fusion reactor must suspend the reaction in mid-air by using a powerful magnetic field like the one in Figure 2.4.19.

If fusion reactions could be controlled, they would provide an extremely powerful and clean source of energy. However, the power of fusion can also be used to create the most destructive weapons on Earth—hydrogen bombs. Fortunately, a hydrogen bomb has never been used in a military attack.

2.8

The Fukushima disaster

SciFile

Japan's first-hand experience of the devastating effects of nuclear weapons has made the people of Japan understandably wary about the use of nuclear power. Their fears were realised in March 2011 when three nuclear reactors in Fukushima went into meltdown after the shock of a magnitude 9.0 earthquake and tsunami. This disaster is considered the second-worst nuclear reactor meltdown after the one in Chernobyl, Ukraine, in 1986.

Figure 2.4.20 This is one-year old Yunna. She has her face covered to protect her from the radioactive dust sent into the air by the Fukushima meltdown.

REVIEW

1 **Recall** the percentage of the world's power supply that is provided by nuclear reactions.

2 **Explain** why there could be no life on Earth without nuclear fusion.

3 **Explain** why the number of deaths from a nuclear explosion is not easy to calculate.

4 **Propose** whether an atom with an atomic mass of 243 is more likely to undergo fission or fusion.

2.4 Unit review

Remembering

1 **List** three types of radiation in order from least penetrating to most penetrating.

2 **Recall** what happens to the atomic number and mass number of a nucleus when it undergoes:
- a alpha decay
- b beta decay.

3 **List** four uses of radiation.

4 Gamma rays are just one type of electromagnetic wave. **List** four others.

Understanding

5 **Define** the term *radioisotope*. L

6 **Explain** why alpha particles, beta particles and gamma rays are classified as forms of ionising radiation.

7 Alpha particles are 20 times more effective than beta particles or gamma rays at ionising molecules. **Explain** why they may be considered the least dangerous nuclear radiation.

8 **Define** the term *half-life*. L

9 **Explain** how radiation burns and radiation sickness are caused.

Applying

10 **Identify** the atomic symbols for the isotopes oxygen-16, oxygen-17 and oxygen-18. (Hint: All oxygen atoms have 8 protons.)

Analysing

11 **Contrast** stable and unstable nuclei.

12 **Compare** the properties of alpha particles, beta particles and gamma rays. N

13 **Calculate** the atomic number and mass number of the following nuclei after they undergo alpha decay.
- a $^{241}_{95}\text{Am}$
- b $^{240}_{94}\text{Pu}$
- c $^{210}_{84}\text{Po}$

14 **Calculate** the atomic number and mass number of the following nuclei after they undergo beta decay. N
- a $^{22}_{11}\text{Na}$
- b $^{14}_{6}\text{C}$
- c $^{137}_{55}\text{Cs}$

15 The half-life of carbon-14 is 5730 years. **Use** this to **calculate** the age of a fossil with a carbon-14 content that is: N
- a half the normal amount
- b one-quarter the normal amount
- c one-eighth the normal amount
- d one-sixteenth the normal amount.

Evaluating CCT

16 **Propose** the advantages and disadvantages of nuclear power plants and **list** them in a table.

17 **Propose** why radioisotopes that emit alpha radiation are not used for radio-imaging.

Creating CCT

18 **Construct** a pamphlet for health department workers advising them of the dangers of different types of radiation they may be exposed to in the workplace.

19 **Construct** a short story describing what you think it would be like to survive a nuclear bomb explosion and the effects of the radiation damage.

Inquiring

1 Research to find out the percentage of power that comes from nuclear power stations in Australia and five other countries such as the United States, France, Korea, Japan and Russia. Present your results as a bar or column graph, using a spreadsheet. ICT

ADDITIONAL

2 Research how our ideas of radioactivity (its uses and its dangers) have changed over time. Find out about the contributions of people such as the Curies, Roentgen, Becquerel, Rutherford, Chadwick and Einstein.

Present your research as an annotated timeline. L

ADDITIONAL

2.4 Practical investigations

1 Half-life

Purpose

To model radioactive decay and half-life.

Materials

- a packet of M&Ms (or Skittles or two-sided tokens)
- a clean tray or sheet of A3 paper
- a clean jar

SAFETY

It is unsafe to eat food in the laboratory, so do not eat any of the lollies.

Procedure

1. Copy the table from the Results section into your workbook.
2. Count the total number of M&Ms in the packet and put them into the jar.
3. Shake the jar up to mix the lollies around. Pour the jar of M&Ms onto the clean tray or A3 paper.
4. Count how many M&Ms show the letter M facing upwards. Record this number in the table.
5. Place only the M&Ms showing the letter M back into the jar and dispose of the other M&Ms appropriately.
6. Repeat steps 3–5 until there are no M&Ms left in the jar.

Results

1. Record your results in a table like this one.

Number of repeats	1	2	3	4	5
M&Ms showing the letter M					

2. Construct a graph of the number of M&Ms remaining (those that showed the letter M) versus the number of times the procedure was repeated.
3. Compile everyone's results into one table and plot the classroom total of M&Ms remaining with each repeat of the procedure.

Practical review

1. **Describe** the shape of the graphs that you produced.
2. **State** the half-life of your M&M sample by finding how many throws it took for the number of M&Ms in your sample to reduce to half.
3. a **Compare** your individual results with the class results.
   b **Propose** which of these results is more reliable.
   c **Justify** your response.
4. **Discuss** how this prac models the half-life of a radioactive element.

Figure 2.4.21 M&Ms can be used to model nuclear decay.

2 Chapter review

Remembering

1 **Name** the following chemicals.
   a $Fe_2O_3 \cdot H_2O$
   b HCl
   c $C_6H_{12}O_6$

2 **Name** the gas produced:
   a by incomplete combustion, and that is poisonous
   b when an acid reacts with a metal
   c when an acid reacts with a hydrogen carbonate.

3 **Recall** the following reactions by writing their word equations and/or balanced formula equations.
   a tarnishing of silver
   b combustion of octane
   c neutralisation of potassium oxide with nitric acid
   d photosynthesis

4 **Recall** the following reactions by completing their equations.
   a acid + base ⟶ ..... + ...
   b methane + oxygen ⟶ ..... + ...
   c $CaCO_3 + 2HCl \longrightarrow$ ..... + ... + ...
   d $C_6H_{12}O_6 + 6O_2 \longrightarrow$ ..... + ...

5 **List** three substances required for iron to rust.

6 **List** three types of ionising radiation.

7 **List** four ways in which radiation can be useful.

Understanding

8 Burning fossil fuels causes problems for our atmosphere. **Describe** these problems.

9 **Explain** why you breathe faster and deeper when exercising.

10 **Explain** why gamma radiation may be considered the most dangerous type of radiation, even though alpha radiation ionises more electrons for each particle.

11 **Explain** how ionising radiation causes:
   a radiation burns and radiation sickness
   b mutations.

Applying

12 A small fire will be extinguished if covered by something that doesn't burn. **Use** a word equation to **explain** why.

13 You discover a new element named jellium (Je) that has a half-life of 5 days. Your sample of jellium contains only 256 atoms. **Calculate** how many jellium atoms there will be after:
   a 5 days
   b 10 days
   c 15 days
   d 20 days.

Analysing

14 **Compare:**
   a combustion reactions with corrosion reactions
   b the reactions of acids with metals with the reactions of acids with carbonates
   c photosynthesis with aerobic respiration.

15 **Contrast** chemical reactions with nuclear reactions.

Evaluating CCT

16 You should never try to break open a smoke detector. **Propose** reasons why.

17 a **Determine** whether you can or cannot answer the questions on page 44 at the start of this chapter.
   b **Assess** how well you understand the material presented in this chapter.

Creating CCT

18 **Construct** word equations for the following reactions.
   a Nitric acid neutralises sodium hydroxide to form sodium nitrate and water.
   b Ethane produces carbon, carbon monoxide gas and water vapour when it burns in a poor supply of oxygen gas.
   c Lots of hydrogen bubbles rise from calcium as it reacts with water. The end result is a solution of calcium hydroxide.

19 **Use** the following ten key terms to **construct** a visual summary of the information presented in this chapter.

chemical reaction	exothermic
endothermic	photosynthesis
combustion	oxidation
glucose	oxygen gas
carbon dioxide	respiration

Thinking scientifically

Q1 Fiona dropped a stick of chalk (containing calcium carbonate, $CaCO_3$) into hydrochloric acid (HCl). It fizzed as the reaction produced carbon dioxide gas (CO_2), water (H_2O) and calcium chloride ($CaCl_2$). CCT

Identify the equation for this reaction.

A $CaCl_2 + H_2O + CO_2 \rightarrow CaCO_3 + 2HCl$
B $CaCO_3 + H_2O + CO_2 \rightarrow CaCl_2 + 2HCl$
C $CaCO_3 + 2HCl + H_2O \rightarrow CaCl_2 + CO_2$
D $CaCO_3 + 2HCl \rightarrow CaCl_2 + H_2O + CO_2$

Q2 Fiona measured the amount of carbon dioxide gas generated as the chalk in question 1 dissolved. She repeated the experiment, but this time she crushed the stick of chalk into a powder. Her results are shown in the table below. CCT

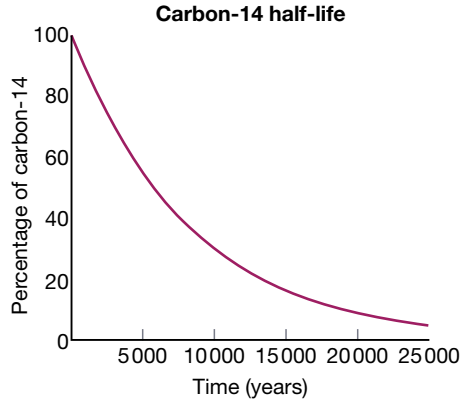
Time (s)	Volume of CO_2 generated (cm^3)	
	Stick of chalk	Crushed chalk
0	0	0
15	50	100
30	100	200
45	150	200
60	200	200
105	200	200

From these results, identify the best conclusion.

A Chalk and hydrochloric acid react together.
B Chalk always produces 200 cm^3 of carbon dioxide.
C Crushed chalk reacts faster than a stick of chalk.
D Hydrochloric acid burns.

Q3 An archaeologist working in Cairo, Egypt, discovers an old artefact and takes it back to the lab for carbon dating. The lab results show that there is only 16% of the carbon-14 that would have been found in a similar artefact made today. CCT

Use the graph of the carbon-14 half-life to determine which is the best estimate for the age of the artefact.



A 5000 years
B 10 000 years
C 15 000 years
D 20 000 years

Q4 A nuclear power plant worker comes into hospital after having an accident where he was exposed to high levels of radiation approximately 30 minutes before. Initially he seems fine but after an hour he starts to feel nauseated and begins vomiting. He is kept in for observation and after a few days develops diarrhoea. CCT

Use the table below to determine the likely dose of radiation that the worker was exposed to.

Dose (Sv)	Symptoms
0–0.5	No obvious effect
0.5–1.0	Vomiting and nausea for about 1 day in 10 to 20% of people. Tiredness, but no serious disability
1.0–2.0	Mild to moderate nausea in 50% of people, with occasional vomiting, setting in within 3–6 hours after exposure, and lasting several hours to a day
2.0–5.5	Nausea in 100% of people. Vomiting starting 0.5–6 hours after irradiation and lasting up to 2 days. Followed by other symptoms of radiation sickness, e.g. loss of appetite, diarrhoea, minor bleeding
5.5–10	Severe nausea and vomiting within 15–30 minutes, lasting up to 2 days, followed by severe symptoms of radiation sickness, e.g. loss of appetite, diarrhoea, minor bleeding.
10–20	Immediate nausea, diarrhoea and bleeding
> 20	Immediate disorientation and coma. Onset within seconds to minutes

A 0.5–1.0 Sv
B 1.0–2.0 Sv
C 2.0–5.5 Sv
D 5.5–10 Sv

Glossary

Unit 2.1

Aerobic respiration: a reaction that uses oxygen to release energy stored in glucose

Anodising: a way of protecting aluminium from corrosion, by deliberately creating a layer of aluminium oxide over it

Balanced formula equation: a chemical equation that has the same number of each type of atom on both sides of the arrow

Combustion: a rapid reaction with oxygen that releases energy in the form of heat and/or light

Combustion

Complete combustion: combustion that occurs when there is plenty of oxygen; it produces carbon dioxide and water vapour

Corrosion: the breakdown of metals due to their reaction with other chemicals

Endothermic: a chemical reaction that absorbs energy

Exothermic: a chemical reaction that releases energy

Hydrocarbons: highly combustible chemicals; petrol is a mixture of hydrocarbons

Incomplete combustion: combustion that occurs when oxygen is limited; produces carbon (soot, smoke) and carbon monoxide, and does not release as much heat or light as complete combustion

Incomplete combustion

Law of conservation of mass: atoms are not created or destroyed in a chemical reaction; they can only be rearranged

Products: chemicals produced in a chemical reaction; they are written on the right-hand side of the arrow

Reactants: chemicals that take part in a chemical reaction; they are written on the left-hand side of the arrow

Rust: hydrated iron(III) oxide; chemical formula $Fe_2O_3 \cdot H_2O$

Tarnish: a black coating of silver sulfide that is produced when silver reacts with sulfur in food or the atmosphere; chemical formula Ag_2S

Verdigris: a green coating of copper hydroxide that is produced when copper reacts with moisture, carbon dioxide and oxygen in the atmosphere; chemical formula $Cu(OH)_2$

Word equation: simple written description of what is happening in a reaction

Unit 2.2

Acid rain: rain that has acids such as nitric acid and sulfuric acid dissolved in it

Chemical digestion: the process that breaks down large molecules in food into smaller ones that can be absorbed by the body

Neutralisation: a reaction of an acid with a base, forming a salt and water

Neutralisation

Salt: the term commonly used for sodium chloride, but which covers any compound formed by a metal taking the place of the hydrogen atom in an acid

Unit 2.3

Carbon sink: a term used to describe materials that store carbon in their structures; plants and animals can be thought of as carbon sinks

Chlorophyll

Chlorophyll: the green chemical found in the chloroplasts of green plants that traps the Sun's energy for photosynthesis

Diffusion: the movement of chemicals from an area of high concentration to an area of low concentration

Enzyme: a helper chemical that speeds up chemical reactions in living things

Glucose: a simple sugar produced by photosynthesis; chemical formula $C_6H_{12}O_6$

Lenticels: structures on roots and stems that allow gas exchange to take place

Photosynthesis: endothermic reaction that takes place in green plants; uses energy from sunlight to combine water and carbon dioxide and produce glucose and oxygen gas

Respiration: a series of chemical reactions that releases energy from glucose; it takes place in the mitochondria inside cells

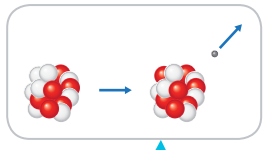
Unit 2.4

Alpha decay: a nuclear reaction in which a nucleus ejects an alpha particle

Alpha particle: a particle made up of two protons and two neutrons, making it identical to a helium nucleus

Alpha radiation: a form of ionising radiation made up of alpha particles

Beta decay: a form of nuclear reaction in which a nucleus ejects a beta particle



Beta decay

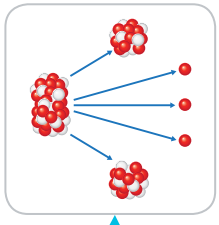
Beta particle: a small, negatively charged particle that can be ejected from a nucleus during a nuclear reaction; it is identical to an electron

Beta radiation: nuclear radiation that is made up of beta particles

Carbon dating: a method for judging the age of artefacts or fossils by analysing the amount of carbon-14 in the fossil

Electromagnetic radiation: radiation that travels through a vacuum as waves rather than particles

Fission: a nuclear reaction in which a very large nucleus splits into two smaller nuclei of similar mass number

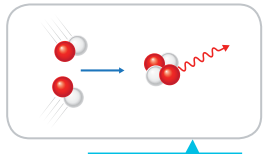


Fission

Fusion: a nuclear reaction in which two small nuclei come together to form one larger nucleus

Gamma decay: nuclear decay that involves the release of gamma rays

Gamma radiation: a form of ionising radiation made up of gamma rays



Fusion

Gamma ray: a very high-energy electromagnetic wave that is produced when the protons and neutrons in a nucleus rearrange

Half-life: the time it takes for half the nuclei to decay

Ionising radiation: any form of radiation that has the ability to remove electrons from atoms and molecules

Isotopes: atoms that have the same number of protons but a different number of neutrons

Mutation

Mutation: a change in the DNA of a cell that causes it to change how it works and reproduces

Nuclear decay: when a nucleus undergoes a nuclear reaction and emits radiation

Nuclear radiation: rays or particles that are emitted by a nucleus during a nuclear reaction

Nuclear reaction: a process that causes a nucleus to change, including alpha decay, beta decay, fission and fusion

Radiation burns: redness and blistering on the surface of the skin or other organs caused by intense exposure to ionising radiation

Radiation burns

Radiation sickness: a condition that results from a large dose of ionising radiation, causing significant cell death; symptoms include nausea, vomiting, fever, hair loss and diarrhoea

Radioactive: emitting radiation

Radioisotope: an isotope with a nucleus that may undergo a nuclear reaction

Radiotherapy: a cancer treatment in which tumours are exposed to high concentrations of radiation

Stable nuclei: nuclei that will never undergo a nuclear reaction

Transmutation: a nuclear reaction that converts one type of atom into a different type of atom

Transmutation

Unstable nuclei: nuclei that may undergo a nuclear reaction at any time

Look who is using science

PHOTOGRAPHER

My name is Rod Ash and I am a photographer. My interest in photography started when I was living and working in the Middle East and Europe. By documenting my travel adventures through photography, I developed a keen interest in the creative and practical processes involved with this art form.

My diverse background in a variety of service-based industries reflected my interest in working with people, and photography was a great medium to continue this. My work is both studio and location based and allows me to travel. I love the interaction with my clients and being involved in what is often some of the most important events of their lives.

In its very basic form, photography is very much about understanding light. I am always challenged by the science and technology associated with photography, and how I can apply this to creating an enjoyable photographic experience for my clients as well as the photographic art that reflects this experience.

PROJECTIONIST

My name is Ben Charter and I work as a technical supervisor at Village cinemas. I prepare films and project them onto a movie screen.

Most of my day is spent threading film into projectors, checking that sessions start on time and that everything runs smoothly. New-release movies arrive in boxes, on three 610-metre spools. I splice cues onto the film where the credits start, and these cues trigger the cinema lights to come up. I then splice the three reels together onto one 1800-metre spool and thread this onto a platter so the film is ready to run from start to finish.

I started working in the cinema as an usher and worked my way up in the business. I have moved around and worked in five cinemas across Australia. I enjoy my job and, best of all, I get free tickets to any movie I'd like to see!

RADIOGRAPHER

My name is Julian Ginn and I am a radiographer. I work in a hospital and capture different types of images using specialised equipment.

These images include general X-rays (including mammography and dental imaging), ultrasound and CT scans.

The image is recorded on an imaging plate, which is housed within a cassette. A CR (computed radiography) reader converts this recording into a digital image.

The image is sent through a PACs (Picture Archive Communication system) to a radiologist, for analysis.

The radiologist prepares and submits a report to the patient's doctor about the information revealed in the image.

3 Heat, light and sound

Have you ever wondered...

- why a doona keeps you warmer than just a sheet?
- how musical instruments make different sounds?
- why you cannot see clearly underwater?
- why diamonds sparkle?
- why tiles feel colder than carpet?

After completing this chapter students should be able to:

- use the particle model to explain conduction and convection of heat energy
- identify situations where waves transfer energy
- use the wave model to qualitatively describe wavelength, frequency and speed
- use the particle model to explain the transmission of sound in different mediums
- outline how the properties of different types of radiation in the electromagnetic spectrum relate to their uses in everyday life CCT
- describe absorption, reflection and refraction CCT
- discuss how the values and needs of contemporary society can influence the focus of scientific research S CCT EU

ADDITIONAL

- outline how scattering and dispersion of light relate to everyday occurrences
- use the equation for speed to calculate the depth of underwater objects. N

3.1 Heat

In cold weather, you seek extra jumpers or thicker doonas to keep warm. When it is really hot, you wear less clothing and cool yourself with a fan or by jumping in the pool. Heat is a form of energy that you sense through receptors in your skin. Heat is lost from your skin as you stand in front of a fan and is gained as your body absorbs radiant heat from the flames of a log fire.

INQUIRY 4 fun

Burning a balloon!

YES

Can you heat water in a balloon without bursting the balloon?

Collect this …

- two balloons
- matches
- candle

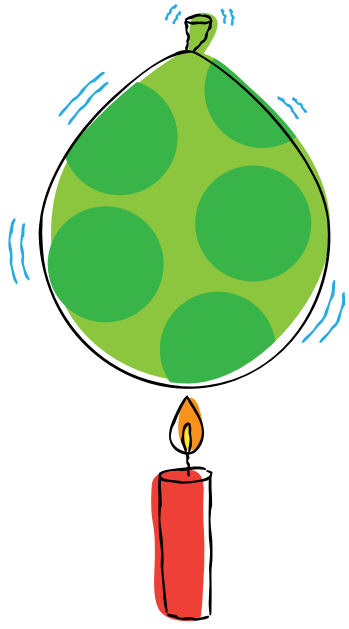
Do this …

1. Blow up a balloon and tie its end.
2. Hold a lit candle below the balloon.
3. Observe what happens.
4. Now hold another balloon under a tap and fill it up with water to about the size of a rockmelon.
5. Place a lit candle underneath this second balloon, and again observe what happens.

Record this …

Describe what happened.

Explain why you think this happened.



The particle model

Heat is a form of energy that can be transferred through solids, liquids and gases. To understand how this happens, you first need to understand the particle model of matter. In the particle model, atoms are considered as small, hard balls.

In a solid, the particles are closely packed. The particles vibrate on the spot but keep the shape of the substance they form. Particles in a liquid are packed closely together too. The particles vibrate but are also free to move or flow over each other.

The particles of a gas are not bound together at all and are free to move in straight lines until they collide with other gas particles, or the walls of the container in which they are held. Particle model diagrams for a solid, a liquid and a gas are shown in Figure 3.1.1.

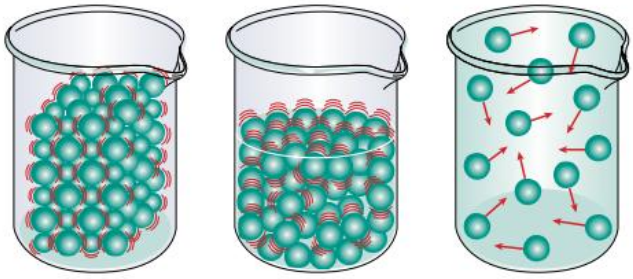


Figure 3.1.1 Particle model diagrams for a solid, a liquid and a gas

Heating substances

Heating a substance adds energy to its particles. Some of this energy is stored in the material itself as potential energy. The remaining heat energy increases the kinetic energy of the particles in the material. Kinetic energy is the energy of movement. So if the temperature of a substance increases, then its particles move faster and faster. This spreads the particles further apart and the substance expands. Similarly, if the temperature of a substance decreases, then its particles lose kinetic energy. The particles slow down and the substance contracts. Figures 3.1.2 and 3.1.3 show this relationship.

When sufficient heat energy is added to a solid or a liquid, the particles break free from each other and the substance changes state.

Temperature

The **temperature** of a substance is a measure of the average kinetic energy of its particles. The particles of hotter substances move faster than the particles of cooler substances. As the temperature drops, particles lose kinetic energy. Eventually the particles barely move at all. This happens at –273°C, at a point called **absolute zero**.

Temperature can be measured using a thermometer. A **thermometer** contains a liquid (alcohol or mercury) inside a narrow glass tube. This liquid expands when heated and contracts when cooled. Temperature is read from a scale on the thermometer corresponding to the expansion or contraction of the liquid. Temperature is commonly measured in degrees Celsius (°C).

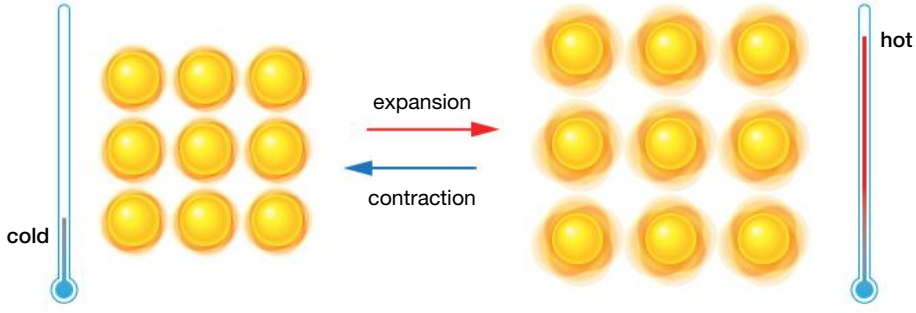


Figure 3.1.2 The particles in a solid vibrate more when heated. This causes the solid to expand.

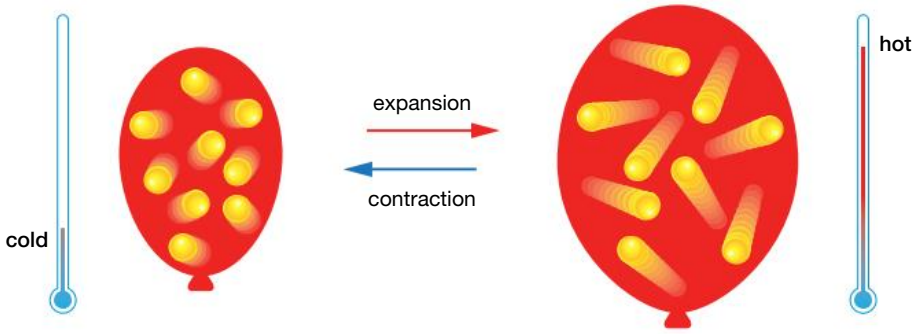


Figure 3.1.3 The particles of a gas travel faster when heated. They hit the sides of the container more frequently and with more force. A balloon has flexible walls so this force will cause it to expand.

The Fahrenheit (°F) and kelvin (K) scales are also used to measure temperature. The thermometers in Figure 3.1.4 compares these three scales.

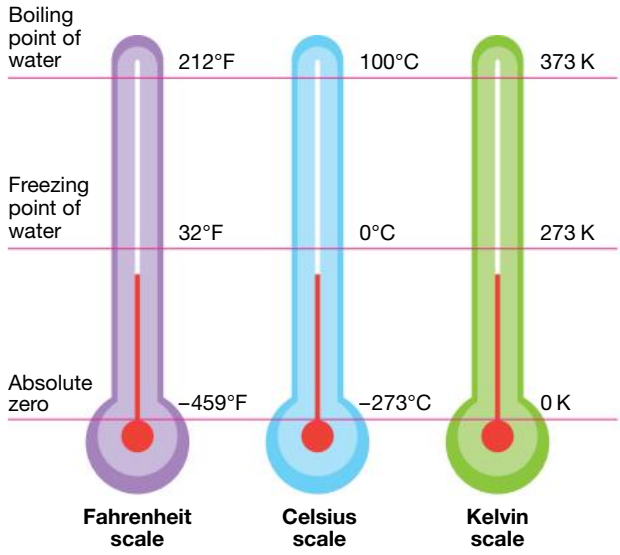


Figure 3.1.4 The three scales commonly used to measure temperature. They were proposed by Gabriel Fahrenheit (1686–1736), Anders Celsius (1701–1744) and Lord Kelvin (1824–1907).

Thermometers measure temperature but do not measure the heat of a substance. Heat is a form of energy and is a way of describing the total energy of all particles within an object. Saucepans A and B in Figure 3.1.5 both contain boiling water. Their temperatures are equal. However, saucepan B contains twice the volume of water and so it has twice the heat energy of saucepan A.

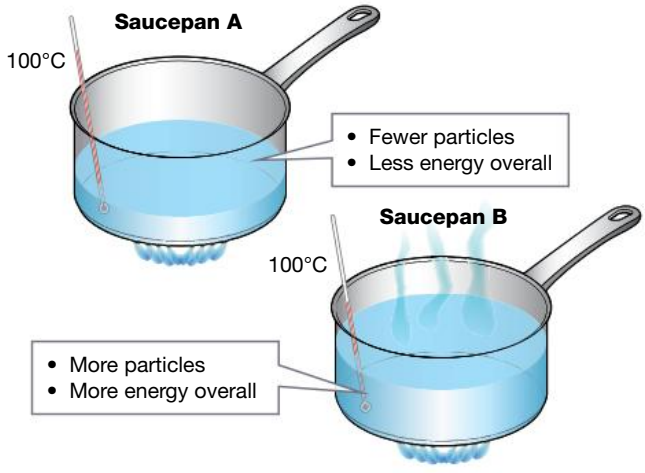


Figure 3.1.5 Both these saucepans are at the same temperature so the particles in both have exactly the same energy. However, saucepan B has double the number of particles of saucepan A. This gives saucepan B twice the *total* heat energy of saucepan A.

Heat transfer

Heat flows from areas of higher temperature to those of lower temperature. The greater the temperature difference, the faster the flow of heat from one object to another. This process of heat transfer can happen in three ways: conduction, convection and radiation.

Conduction

Hold an ice cube and your hand gets cold. This is because heat flows from your skin into the ice, lowering the temperature of your skin in the process. You know that the ice cube is absorbing this heat because it starts to melt. Heat has flowed from the higher-temperature hand into the lower-temperature ice cube. Figure 3.1.6 shows some examples of heat flow.

Figure 3.1.6 Heat flows from your hands into an ice block, and from a hot cup into your hands.

Hotter substances have particles that are moving faster than particles in cooler substances. Rapid jiggling or vibration of the particles in a hot mug of soup with a metal spoon in it makes the particles in the spoon vibrate faster too, increasing the temperature of the spoon. This vibration of particles is passed on from one particle to the particle next to it, and as this process continues along the spoon you may feel the handle getting hot. This process of heat transfer by vibrating particles is called **conduction** and is shown in Figure 3.1.7.

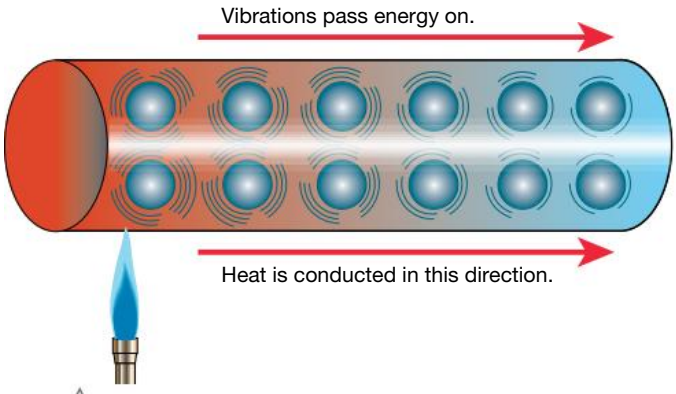


Figure 3.1.7 Particles near the flame vibrate more as they absorb heat energy. These vibrations transfer energy to conduct heat along the solid.

Conductors

Materials vary in how effectively they conduct heat. A glass of ice-cold lemonade feels much colder than a polystyrene cup of ice-cold lemonade. Glass is a better heat conductor than polystyrene. As a result, heat flows from your warm hand into the cooler glass and your hand feels cold. When holding the polystyrene cup, your hand is not losing heat and so it still feels warm.

Substances that transfer heat easily are known as **conductors**. Metals, such as the saucepan shown in Figure 3.1.8, are good conductors of heat.

Figure 3.1.8 Metals, particularly copper, silver, gold and aluminium, are good conductors of heat.

Insulators

Plastic, air, cloth, cork, wood and rubber are all very poor conductors of heat, and sometimes can block heat transfer completely. Such substances are known as **insulators**. The handles of a saucepan are usually made from insulating materials to allow you to lift them without burning your hands. An Esky uses insulating materials to keep food and drinks cool.

Gases are poor conductors of heat. Air trapped by woollen jumpers and blankets helps to insulate your body from losing heat. Ski parkas, doonas and sleeping bags are filled with cotton, feathers, wool and polyester that also traps air and helps to protect you from the cold, as seen in Figure 3.1.9. Similarly, animals living in cold climates (Figure 3.1.10) have adaptations that help them stay warm.

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Figure 3.1.9 Wool fibres and the fluffy polyester, down or cotton filling inside a ski parka trap air and help prevent heat loss from your body.

Figure 3.1.10 These animals must stay warm in very cold conditions. Polar bears rely on body fat and a thick coat of fur for insulation, whereas penguins have layers of fat and feathers that they can fluff up to trap more air.

Convection

As air is heated, its particles gain energy and move further apart. This hot air is less dense than cool air, and so it is pushed upwards by cooler air around it. This method of heat transfer is called **convection**. The air flow it creates is called a convection current. Such a current is shown in Figure 3.1.11, transferring heat from an open fire.

Heat is transferred by convection in liquids and gases because their particles can move around, rather than remaining fixed like those within a solid. Figure 3.1.12 shows how liquid in a saucepan is heated by convection.

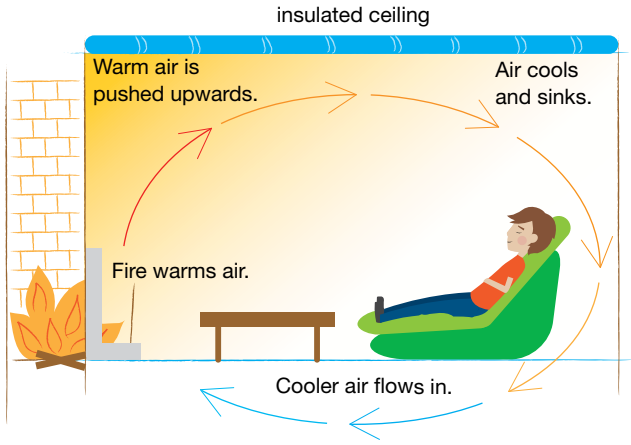


Figure 3.1.11 As air warms, it becomes less dense and is pushed up by cooler air that is sinking. These convection currents gradually spread heat from the open fire through the air in the room.

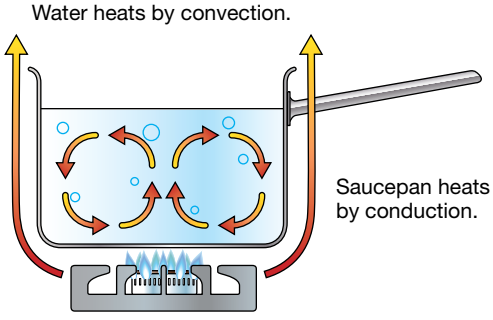
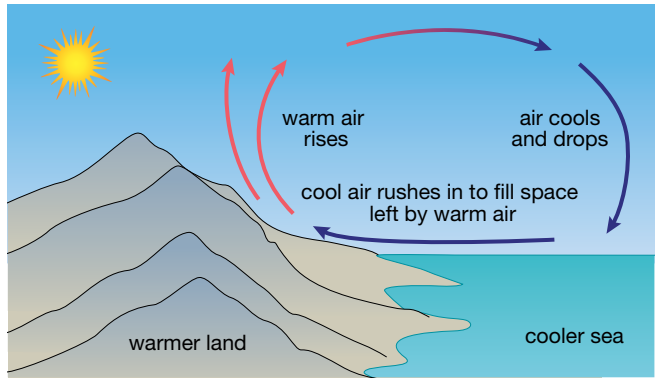
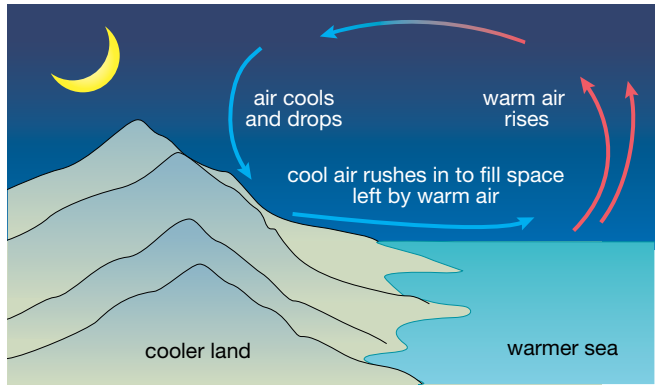


Figure 3.1.12 Particles gain heat from the hot base of the saucepan and rise. Cooler liquid sinks down, is heated and the cycle continues.

Convection explains the formation of a sea breeze during the day and a breeze towards the sea at night. This process is shown in Figure 3.1.13. Convection also circulates heat in a hot water system. You can see this in Figure 3.1.14.



A sea breeze during the day



A land breeze at night

Figure 3.1.13 In the daytime, land heats up more quickly than the sea. Hot air is pushed upwards by cooler air that flows in towards it, producing a sea breeze. At night, the sea retains its heat for longer than the land. Warm air is pushed upwards above the sea as cool air flows from the land towards it.

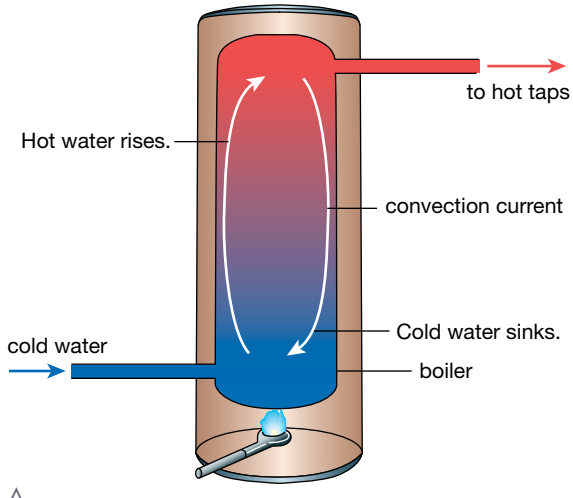


Figure 3.1.14 Convection assists in circulation of water in a hot water system.

INQUIRY

science 4 fun

Ups and downs!

NO

Can you see convection currents in action?

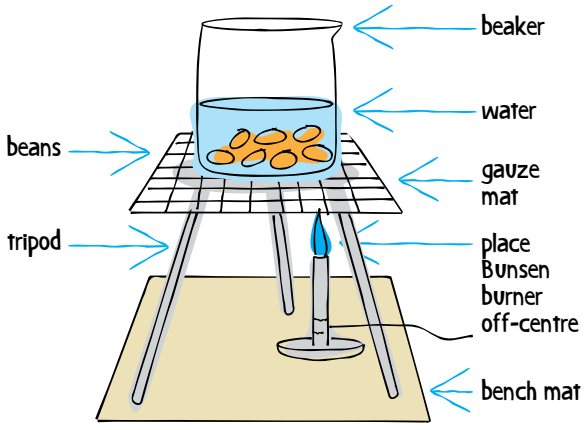
Collect this …

- dried beans, such as borlotti beans or chickpeas
- Bunsen burner, gauze mat, tripod and bench mat
- large beaker of water

Do this …

1 Add dried beans to cover the base of the beaker.

2 Heat this carefully over a Bunsen burner.



Record this …

Describe what happened.
Explain why you think this happened.

Radiation

When you go outside and into the sunlight, you can feel the heat from the Sun on your skin (Figure 3.1.15). Heat has travelled through empty space between the Sun and the Earth to reach you. It cannot be transferred by conduction or convection on its journey because there are no particles to vibrate or flow in the vacuum of space. The Sun transfers its heat energy through a process called **radiation**.

Radiation transmits heat as invisible waves that travel at the speed of light (around 300 000 km/s). Infrared radiation is heat energy that is transmitted this way. All objects emit (release) some infrared radiation.

GO TO Unit 4.3

Figure 3.1.15

Radiation from the Sun travels through the vacuum of space to reach us. It is cooler in the shade because this radiation has been blocked.

The hotter something is, the more heat it radiates. For example, a hot oven radiates more heat than an oven set at a lower temperature. Similarly, the red-hot coals of an open fire radiate such enormous amounts of heat that you cannot sit too close to them (Figure 3.1.16).

Figure 3.1.16 You can feel the radiant heat emitted from the glowing coals of an open fire.

When radiated energy hits a surface, the heat may be absorbed into the surface, reflected from the surface or transmitted through the surface. This is shown in Figure 3.1.17. Often radiation will be partially absorbed, reflected or transmitted according to the material and its colour.

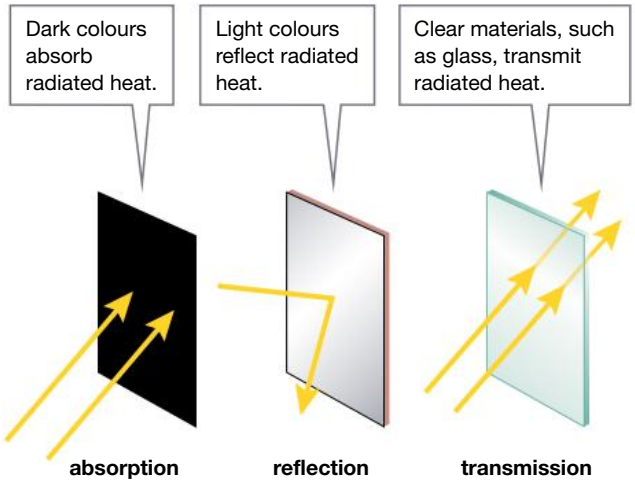


Figure 3.1.17 When radiation hits an object, it may be absorbed, reflected or transmitted.

For example, a dark-coloured car heats up more quickly in sunlight than a lighter-coloured car. This happens because dark-coloured objects are good absorbers of radiation, whereas lighter colours reflect much of it and don't heat up as rapidly. Darker objects also lose heat faster by radiation than lighter colours do. Solar hot water systems utilise this absorption of heat energy from the Sun by using black collection panels like those in Figure 3.1.18.

Prac 3 p101 3.2

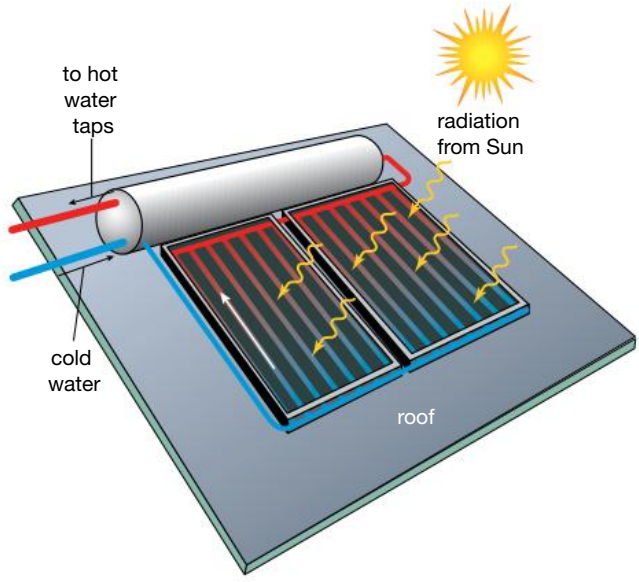


Figure 3.1.18 Heat energy radiated by the Sun is absorbed by the cold water within the black collection panels of a solar hot water system. Some systems rely upon the natural convection of the hot water to circulate the water without the use of a pump.

Home insulation

SciFile

Heat transfer in a home occurs by conduction, convection and radiation. In winter, warm air flows out of the house, and in summer, warm air flows in. Insulation added to the ceiling and walls of a home helps to stop this transfer of heat and makes your home more energy efficient.

3.1 Unit review

Remembering

1 **State** the temperature on the Fahrenheit, Celsius and kelvin scales at which water freezes. N

2 **Recall** how heat transfers by selecting the correct alternative in each statement.
- a Heat always flows from an object of *higher/lower* temperature to one of *lower/higher* temperature.
- b Insulators are *good/poor* conductors of heat.
- c Gases are *good/poor* conductors of heat.
- d On a warm day, a house is warmer upstairs because of *conduction/convection* currents.

3 **List** three insulators.

Understanding

4 **Describe** how the particles in a solid change as the solid is heated.

5 **Describe** how heat is conducted along a metal rod.

6 Imagine the water in saucepan A and saucepan B from Figure 3.1.5 on page 92 has cooled to room temperature. You supply an equal amount of heat energy to both saucepans. **Describe** how the temperature of the water in each will change.

7 A wetsuit traps a layer of water between the wearer and the fabric of the suit.
- a **State** whether water is a good or poor conductor of heat.
- b **Explain** how this design helps to keep the wearer of the suit warm.

8 **Explain** why the vents for a ducted heating system are usually placed near the floor and not the ceiling.

9 You lose a lot of heat from your head. For most people, their hair protects them from losing too much heat from their heads. **Explain** why hair is an effective insulator.

Applying

10 **Use** the particle model to **explain** why the following expand when heated.
- a A solid metal rod
- b A balloon

11 Heat transfer can occur by conduction, convection or radiation. **Identify** the main method of heat transfer in each situation below.
- a Your feet get hot when you walk on sand at the beach.
- b Your back feels warm when you sit in the sun.
- c You boil water in an electric kettle.
- d You feel cold when you dive into a swimming pool.
- e You feel warm air as you walk into a school disco held in a hall.

Analysing

12 **Compare** heat and temperature.

13 Two identical bathtubs are filled to the same level with water. The particles in bathtub A move with greater speed than the particles in bathtub B. **Analyse** this situation to answer the following.
- a **State** in which bathtub the water will be at a higher temperature.
- b **State** which bathtub has more heat energy.
- c As the water cools, each bath loses heat energy. **List** three places this heat energy could go.

14 Water absorbs a large amount of heat energy for a relatively small rise in temperature compared to other substances. **Use** this information to **analyse** why in the science4fun on page 90 the balloon does not burn when filled with water.

Evaluating CCT

15 You walk barefoot on carpet in the living room of your house and your feet feel warm, yet when you walk into the bathroom and stand on the ceramic tiles your feet feel cold. The carpet and tiles are at the same temperature. **Propose** an explanation for why this is the case.

16 On a hot day, you have a choice of travelling in a red car, a white car or a black car, all of the same model. All have been parked in the sunlight for three hours.
- a **Identify** which car you would choose.
- b **Justify** your choice.

17 Pyrex glass expands less than ordinary glass when heated. **Use** this information to **propose** a reason why Pyrex is used in cooking instead of ordinary glass.

3.1 Unit review

18 Figure 3.1.19 shows the experimental set-up for a radiation experiment. The same-sized black and white cardboard squares are attached to two thermometers close to an incandescent globe.

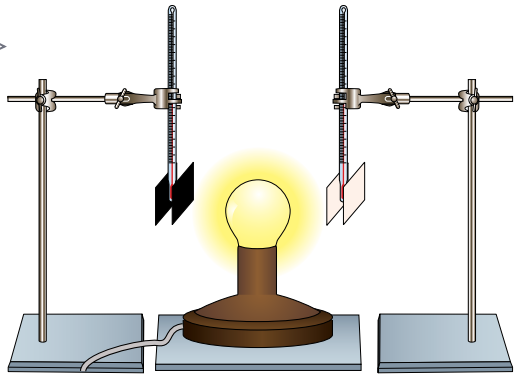
a **Propose** what the student performing the experiment is trying to test.

b **State** three variables that must be controlled to ensure a fair test.

c **Predict** which thermometer will show the highest reading after 5 minutes.

d **Discuss** reasons for your answer to part c.

Figure 3.1.19



Creating CCT

19 In the science4fun on page 95, a beaker of beans in water was heated. **Use** your knowledge of the particle model to **construct** a diagram showing how you expect the beans to move as they are heated.

20 a **Construct** a diagram of a new type of suit that will keep you warm in cold conditions.

b On your diagram, **label** what the suit is made from and how it keeps the heat in.

Feeling chilly?

SciFile

Naked mole rats are the only mammals known to not control their body temperature. Their bodies are warmed to the temperature of their burrows, about 30°C.

Inquiring

1 New homes must be constructed to comply with standards to improve energy efficiency. Double-glazed windows and insulation are two methods that improve the energy efficiency of a home. Research these methods and find:

- whether conduction, convection and/or radiation transfer heat through a window, allowing heat to escape out in winter and in during summer
- a diagram showing what a double-glazed window looks like
- why a double-glazed window is more effective in insulating a house than a regular window
- how insulation affects the energy efficiency of a home
- images of different types of insulation commonly used in walls and ceilings.

Present your findings as a poster to be displayed at a home show advertising double-glazed windows and insulation. ICT

2 An endotherm is an animal that that can maintain a constant body temperature. For the animal to stay healthy, this body temperature needs to remain fairly constant. Humans and animals have different ways of maintaining their body temperature, including:

- having hair or fur
- shivering when cold
- covering themselves in mud
- panting
- having goose bumps on their skin.

Choose one of these methods (or another method) and research how it assists in regulating temperature.

Present your findings as a multimedia display. ICT

3.1 Practical investigations

1 Comparing materials

Purpose

To compare how well plastic, wood and metal conduct heat.

Hypothesis

Which do you think will conduct heat better—a plastic spoon, a wooden stick or a metal spoon? Before you go any further with this investigation, write a hypothesis in your workbook.

Materials

- butter
- very hot water (from a kettle)

- plastic spoon
- metal spoon
- wooden icy-pole stick
- 250 mL beaker
- small beads or similar
- stopwatch
- ruler

SAFETY

Handle hot water with care.

Procedure

1. In your workbook, construct a results table like the one in the Results section.
2. Put a dob of butter near the top of the handle of the plastic spoon.
3. Push a bead onto the dob of butter.
4. Repeat steps 1 and 2 for the metal spoon and icy-pole stick. Make sure the beads are placed at equal heights and that the same amount of butter is used each time.
5. Carefully place the spoons and the icy-pole stick into very hot water in the beaker as shown in Figure 3.1.20.
6. Time how long each bead takes to fall off, and record your results in a table like the one shown in the Results section.

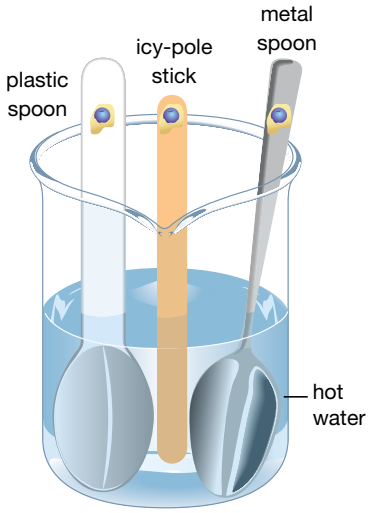


Figure 3.1.20

Results

Record all results in your results table.

Time taken to drop (seconds)		
Bead on plastic spoon	Bead on icy-pole stick	Bead on metal spoon

Practical review

1. **State** which of the materials used was the best conductor of heat.
2. **Assess** whether or not your hypothesis was correct.
3. **Assess** which material was the best insulator.
4. **Explain** why it was important to place the beads at the same height, and use the same amount of butter.
5. The thermal conductivity of a material is a measure of how well the material conducts heat. It has the unit W/(m °C). The higher this value is, the better the substance conducts heat.
   Use your results to **identify** which of the following thermal conductivities belong to the plastic spoon, the metal spoon and the wood icy-pole stick.

   0.17, 16, 0.19

2 Testing insulators

Purpose

To test how effective different materials are in insulating heat.

Hypothesis

Which of the materials that you have available for this prac do you think will keep water in a can the warmest? Before you go any further with this investigation, write a hypothesis in your workbook.

Materials

- a range of insulating materials, such as newspaper strips, cloth, cotton wool, foam, polystyrene beads, foam packing bullets, fibreglass insulation, carpet scraps
- thermometer or temperature probe
- cardboard box
- hot water
- beaker
- stopwatch or clock
- empty soft-drink cans

SAFETY

Handle hot water with care.

You may use a temperature probe to gather temperature data.

Procedure

1. In your workbook, construct a table like that shown below.
2. Carefully measure 200 mL of hot water using a beaker, and pour this into your can.
3. Place the can inside the box.
4. Record the initial (starting) temperature of the water, and then measure and record the temperature every 2 minutes for 10 minutes. Record all your measurements in a table like that shown below.
5. Repeat, using water at the same initial temperature and packing one of the insulating materials into the space between the can and the box, as shown in Figure 3.1.21.
6. Repeat the process, using a second insulating material.

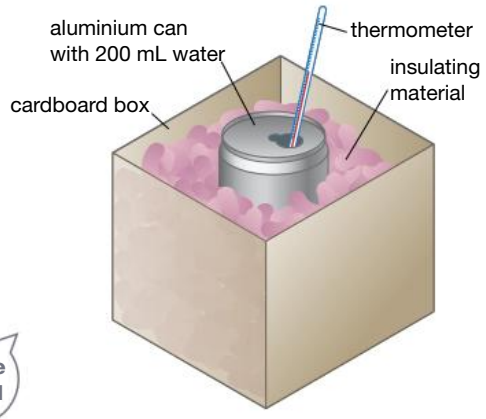


Figure 3.1.21

Time (minutes)	Water temperature (°C)		
	Can with no insulating materials (air only)	Can with insulating material A	Can with insulating material B
0			
2			
4			
6			
8			
10			

Testing insulators continued on next page

Results

1 In your results table, insert the names of two insulating materials you are going to test.

2 Record all measurements in your table.

3 Construct a line graph of temperature versus time for each sample tested, to show the temperature drop over time. Alternatively, use data-logging equipment to produce a graph.

Practical review

1 a **Construct** a conclusion about which material was the best insulator.

b **Assess** whether your hypothesis was supported or not.

2 **Explain** why it was important to test one can with no insulating materials.

3 **Identify** any sources of error in your experiment.

4 **Outline** any improvements that could be made to the design of the experiment.

STUDENT DESIGN

3 Comparing heat radiation

Purpose

To compare how silver, white and black cans radiate heat.

Hypothesis

Which colour aluminium can do you think will radiate more heat over time—silver, white or black? Before you go any further with this investigation, write a hypothesis in your workbook.

SAFETY

A risk assessment is required for this investigation. Be careful when handling hot liquids.

Materials

- silver, white and black aluminium cans
- thermometer or temperature probe

Procedure

1 Design a prac to compare the amount of heat that is radiated over time from silver, white and black aluminium cans.

2 Brainstorm in your group and come up with several different ways to investigate the problem. Select the best procedure and write it in your workbook. Draw a diagram of the equipment you need.

3 Before you start any practical work, assess all risks associated with your procedure. Construct a risk assessment that outlines these risks and any precautions you need to take to minimise them. Show your teacher your procedure and your risk assessment. If they approve, then collect all the required materials and start work.

Hints

Make sure:

- your cans all contain the same amount of water
- the water is at the same starting temperature.

Results

1 Write a report on your findings.

2 Construct a line graph to display your results.

Practical review

1 **Evaluate** your procedure. Pick two other prac groups and **evaluate** their procedures too, identifying their strengths and weaknesses.

2 a **Construct** a conclusion for your investigation.

b **Assess** whether your hypothesis was supported or not.

3.2 Sound

Indigenous Australians developed the didgeridoo thousands of years ago. The player blows air into the didgeridoo while vibrating his lips to produce a low rumbling sound. Musical instruments like violins, pianos and guitars produce sound using strings that vibrate. Other devices, such as ultrasound machines, rely on the reflection of sound waves to produce an image of the structures inside the human body.

INQUIRY

science 4 fun

Hear this!

YES

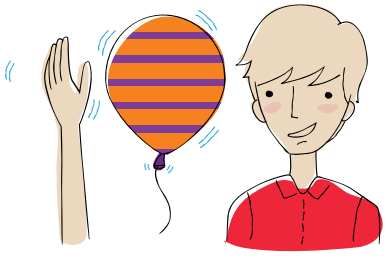
Sound vibrates air particles as it travels through them. What happens to a sound wave when you push air particles closer together?

Collect this …

- balloon

Do this …

1. Blow up the balloon and tie off the end.
2. Hold it close to one of your ears.
3. Have a partner lightly tap on the other side of the balloon.



Record this …

Describe what you could hear.

Explain what you think makes this happen.

What is sound?

Sound is produced when something *vibrates*, moving back and forth very quickly. Table 3.2.1 shows some common sounds and the objects that vibrate to produce them. When something vibrates, it passes the vibration into its surrounding environment, such as air. The vibration creates regions of space in which the air particles are bunched together, called **compressions**, and regions in which they are more spread out, called **rarefactions**. A **sound wave** is the movement of alternating compressions and rarefactions. This is shown in Figure 3.2.1. These sound waves travel away from the source of a sound, in the same way that ripples of water move outwards when a stone is dropped into a pond. Because a sound wave relies upon particles that vibrate for it to be transmitted, a solid (such as a railway track), a liquid (such as water in a swimming pool) or a gas (such as air) is needed for a sound to be produced.

Table 3.2.1 Common sounds and their sources

Sound	Vibrating source
Speech	Flaps of skin (called vocal cords)
Drum	Drum skin
Piano	String inside piano (when you strike a key, the string is struck by a hammer)
Saxophone	Reed inside the mouthpiece
Car stereo system	Speaker cone
A bell ringing	Metal casing of the bell (when struck)

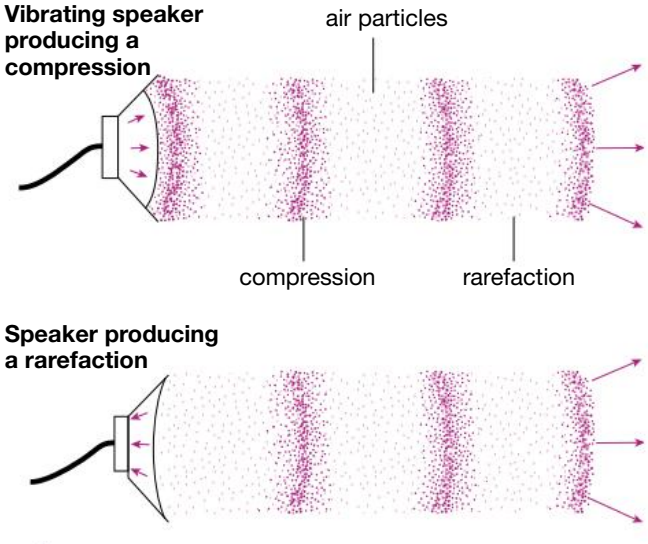


Figure 3.2.1 A vibrating speaker produces regions in which air particles are squashed close together (compressions) and regions in which air particles are spaced further apart (rarefactions). The energy moves through air as a sound wave.

Types of waves

A wave carries energy from one point to another. This can happen in a couple of ways. The energy carried by waves at a beach moves horizontally, but the particles making up the wave actually move in a vertical direction, as shown in Figure 3.2.2. This explains why a boat in the ocean bobs up and down as a wave travels to the shore. This type of wave is called a **transverse wave**. Radiated heat energy is transferred as a type of transverse wave.

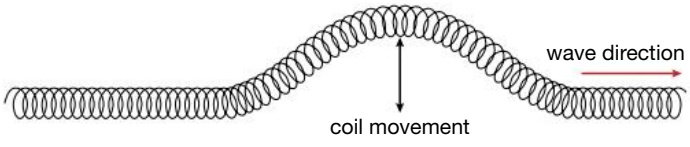


Figure 3.2.2 In a transverse wave, particles move at right angles to the direction of movement of the wave.

A sound wave differs from a transverse wave. In a sound wave, the particles that make up the wave move back and forth in the same direction as the wave is travelling. This type of wave is called a compression,or a **longitudinal wave**, and is shown in Figure 3.2.3.

Prac 1 p113

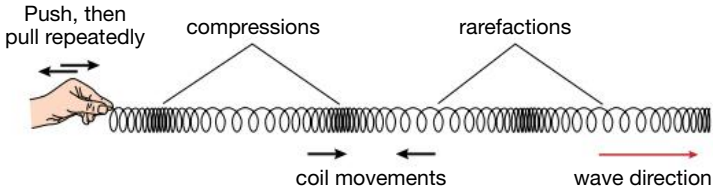


Figure 3.2.3 In a longitudinal wave, particles move in the same direction that the wave is moving.

GO TO Unit 4.1

Transmission of sound

Sound energy is transmitted through a material as longitudinal waves. The particles of the material vibrate as the sound energy flows through it. If you have ever been to a concert or stood near an aircraft that is taking off, then you will have physically felt the energy that can be transmitted by sound waves.

The speed at which sound transmits through a material depends upon the material through which the sound is travelling. In general, the more closely packed the particles are in the material, the faster the series of compressions and rarefactions will travel. As a result, sound travels faster through solids than through liquids, and faster through liquids than through gases.

Table 3.2.2 shows that sound travels much faster through glass or steel than through air. In addition to the type of material the sound is travelling through, the temperature of the material also affects the speed of sound transmission. The particles of warmer materials vibrate faster than particles in cooler materials. As a result, sound travels faster through warm air than through cool air and faster through warm water than through cold water.

Table 3.2.2 Speed of sound in various materials

Material	Speed of sound (metres/second)
Air (at 0°C)	331
Air (at 18°C)	342
Water	1440
Wood	4500
Steel	5100
Glass	5200

Reflection and absorption of sound

You can usually hear when people are at home in your house by noise in the kitchen, living room or bedrooms. Sound passes through thin walls and is transmitted short distances through most materials.

Hard surfaces, such as concrete or bathroom tiles, reflect sound waves. This reflected sound is heard as an **echo**. The time difference between sending and receiving sound waves can be measured. This difference can be used to calculate the depth of objects under water, using a technique called sonar (**so**und **na**vigation and **r**anging), shown in Figure 3.2.4.

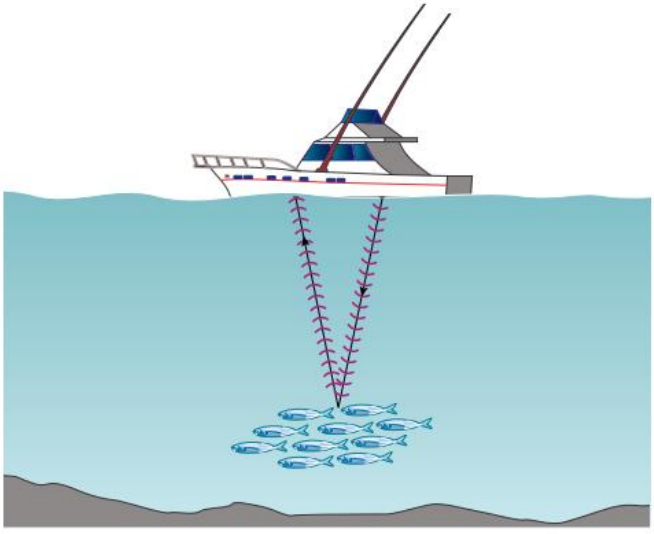
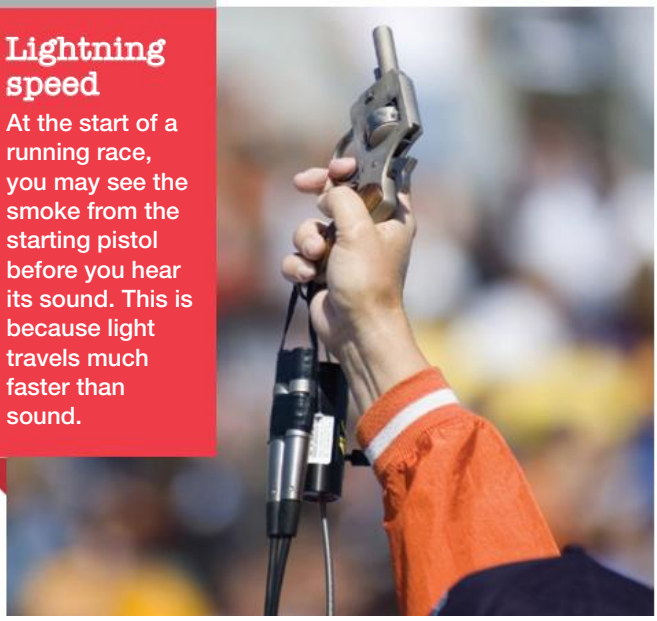


Figure 3.2.4 Sonar can be used to determine the depth of objects in the sea, such as this school of fish.

SciFile

Lightning speed

At the start of a running race, you may see the smoke from the starting pistol before you hear its sound. This is because light travels much faster than sound.



ADDITIONAL

Sonar calculations

Sound travels at about 1500 m/s in seawater. Sonar measures the time it takes for sound to return to the ship. This data may be used to calculate how deep the water is, or how deep a school of fish is.

To calculate depth:

1. Halve the time it takes for the sonar signal to return. This gives the time it takes for the signal to reach the bottom or the fish.
2. Multiply this by the speed of sound in seawater (× 1500).

WORKED EXAMPLE
Sonar calculations

Problem

Sound travels at a speed of about 1500 m/s in seawater.

a It took 0.4 seconds for a sound pulse sent from the ship in Figure 3.2.4 to return. Calculate the depth of the fish.

b If it took 1 second for the sound to return, calculate the depth of the fish.

Solution

a If it took 0.4 seconds for a pulse to return, then the sound reached the fish after 0.2 seconds. The sound pulse travelled at 1500 m/s, so this means that the fish are located 0.2 × 1500 = 300 m below the ship.

b If it took 1 second for the sound to return, then it reached the fish in 0.5 seconds. The fish are located 0.5 × 1500 = 750 m below the ship.

Practice

N

Pirates are searching for a treasure chest in deep, shark-infested waters. They assume that the speed of sound in water is 1500 m/s.

1. Given that it took 3 seconds for a sonar pulse fired from the pirate ship to return after rebounding from the chest, **calculate** the depth of the chest below the ship.
2. After finding the treasure, the pirates are hungry. They now use their sonar to locate a shark to hunt for lunch. Given that the sound takes 0.5 seconds to return to the ship, **calculate** the depth of the shark.

ADDITIONAL

Boom!

SciFile

Fighter jets regularly travel at supersonic speeds—faster than the speed of sound. As the jet catches up to and then overtakes the sound waves it has produced, a very loud 'sonic boom' is heard. Sonic booms can smash windows and damage the hearing of humans, birds and other animals.

Soft materials such as curtain fabric, carpet and cushions (Figure 3.2.5) absorb sound and convert it into heat. This reduces the reverberation, or length of time a sound is heard. Sound absorption like this is needed in concert halls, so that there is no overlap between the sounds being performed and their echoes, which would otherwise distort what you hear. Figure 3.2.6 compares how well some materials absorb sound.

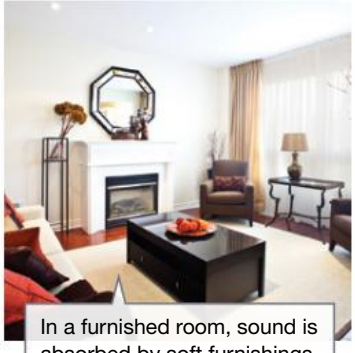


Figure 3.2.5 Different materials give a room different reverberation times.

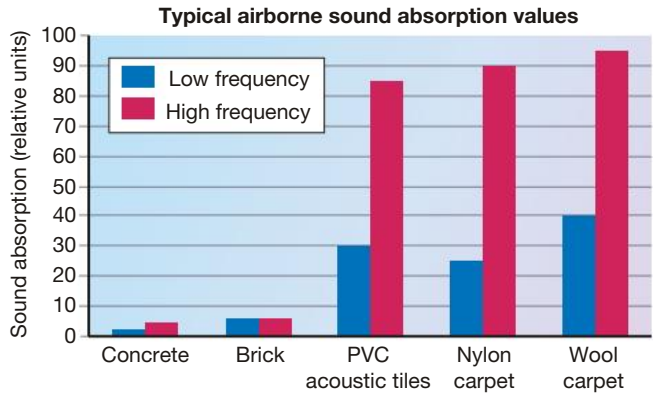


Figure 3.2.6 A comparison of the sound absorption levels of different materials

Frequency and pitch

A dog has a low-pitched growl, whereas a bird chirps with a high-pitched sound. The different sounds can be compared by analysing their sound waves using an oscilloscope (also known as a CRO), as shown in Figure 3.2.7.

Figure 3.2.7 An oscilloscope converts sound waves into electrical signals that can be viewed on a screen. The trace on the screen is a graph that shows how the pressure changes as the wave travels.

A source that vibrates rapidly produces sound of a higher pitch, or frequency, than one that vibrates more slowly. The number of vibrations a sound makes each second is called the **frequency** of a wave. Frequency is measured in **hertz** (**Hz**). The **wavelength** of a sound is the distance between successive peaks. It is measured in metres. Figure 3.2.8 on page 106 shows that graphs of louder sounds have larger peaks, meaning louder sounds have greater amplitude than softer sounds. Sounds with higher frequency produce sound waves that are shorter in wavelength with the compressions and rarefactions bunched closer together than sounds at a lower frequency, resulting in a shorter wavelength.

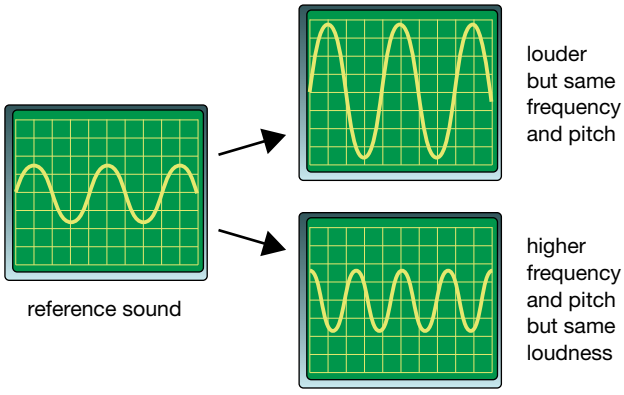


Figure 3.2.8 A loud sound has a taller graph on an oscilloscope than a quiet sound. Higher-frequency sound waves have a shorter wavelength.

In the same way, sounds with low frequency produce sound waves with wider-spaced compressions and rarefactions and so have a larger wavelength.

Our ability to hear higher frequencies of sound reduces as we age. Young people can typically hear a range of frequencies up to 20 000 Hz, yet most people over 65 years cannot hear frequencies above 5000 Hz. Hence, some mobile phone ringtones cannot be heard by older adults.

Many animals, such as dogs and cats, can hear sound frequencies that are outside our human range of hearing. Ultrasound is the name given to sound waves with frequencies above our hearing range. Bats emit ultrasound squeaks with frequencies up to 200 000 Hz, which reflect off surfaces around them and are used by bats to avoid obstacles and to locate food. Elephants can hear a range of frequencies lower than our own hearing range. These frequencies are called infrasound.

Computer analysis of the way ultrasound reflects from living tissue can be used to create an image, like the one shown in Figure 3.2.9.

Prac 2 p113

Figure 3.2.9 Ultrasound waves pass easily through fluids and soft tissue but are reflected from other layers within an organ or foetus. Echoes of these waves are detected and analysed by computer to create the image, such as this 3D image of a human fetus.

INQUIRY science 4 fun

Straw clarinets

YES

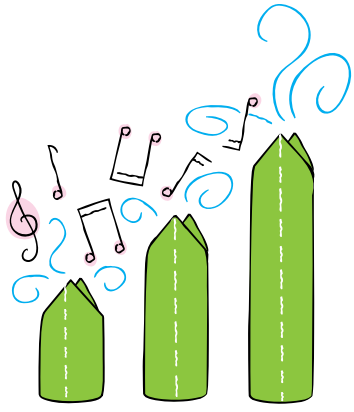
How does changing the length of a flute or a clarinet change the sound it produces?

Collect this …

- straw
- pair of scissors

Do this …

1. Squash the end of the straw and cut it to make a point.
2. Blow into the pointy end of the straw.
3. Try different positions until you get a buzzing sound.
4. As you are making the sound, have a partner carefully cut the other end of your straw.
5. Keep cutting, making the straw shorter and shorter.



Record this …

Describe how the sound changed as the straw got shorter.

Explain how you think the straw produced a sound.

Teenager repellent!

The Mosquito (or mosquito alarm) emits a high-frequency sound of around 17 000 Hz. This can typically be heard only by people under the age of 25. The device has been used to discourage youths from hanging around outside shops or railway stations. Now, teenagers use the sound of the mosquito alarm to signal incoming text messages.

SciFile

Musical instruments

All musical instruments produce sounds by vibrations (Figure 3.2.10). They do this in different ways and produce sounds of differing characteristic qualities. These differences can be compared by playing the sound into a microphone attached to an oscilloscope. Typical traces from some instruments are shown in Figure 3.2.11.

On a guitar, a violin and a piano, vibrations are produced by strings. Changing the length of the string alters the frequency of the sound produced. Longer strings vibrate more slowly, producing lower-pitched sound than shorter strings. When you press a string against the neck of a guitar, you shorten the effective length of that string.

In percussion instruments like drums, the skin stretched over the top of the drum vibrates when you hit it. In instruments like the triangle or the cymbal, the instrument itself vibrates.

Figure 3.2.10 Each of these musical instruments uses vibration to create its sound. Guitars use vibrating strings, saxophones use a reed and drums use a 'skin'.

Figure 3.2.11 Musical notes produce a smooth, repeating pattern on an oscilloscope. Different instruments produce different characteristic sounds. Background noise shows as an uneven mixture of waves.

In wind instruments, a column of air vibrates. When you play a flute or a recorder, the length of this vibrating column of air is increased when you cover holes along the tube, and shortened when you leave the holes open. A longer vibrating column of air produces a lower pitched sound than a shorter vibrating air column.

GO TO Unit 4.1

Hearing sounds

To hear a sound, the energy needs to be transmitted through your eardrum and delicate structures of the ear. Your ears collect sound waves as they enter the outer ear and travel through the ear canal. Vibrations of the sound wave strike the eardrum, causing the eardrum to vibrate. This vibration is then passed on to the three tiny bones of the middle ear, where they are converted into electrical impulses. Your brain interprets these electrical impulses as sound. Figure 3.2.12 on page 108 shows the parts of the ear and how they function.

Popping ears

As an aircraft takes off, or if you go up into hilly countryside, the air pressure outside your eardrum falls, but the air pressure inside your ear remains the same. This pushes against your eardrum. When your ears 'pop', the Eustachian tube opens and releases air through your nose and throat, which balances the air pressure on your eardrum.

SciFile

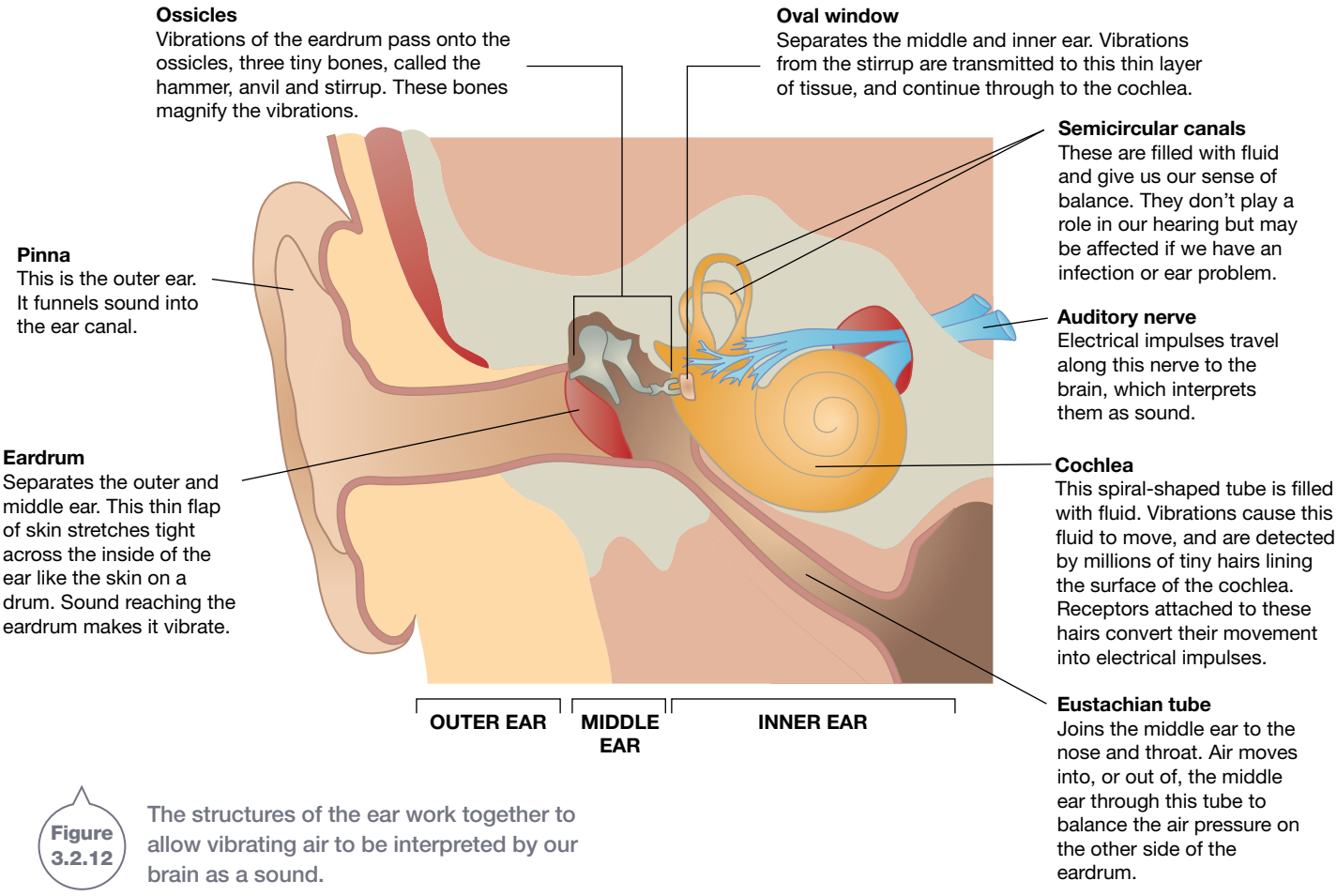


Figure 3.2.12 The structures of the ear work together to allow vibrating air to be interpreted by our brain as a sound.

Over 1 million Australians have a hearing disability, ranging from mild hearing loss to complete deafness. These problems can be because:

- the ear canal is blocked with wax, preventing the passage of sound waves
- the middle ear is filled with fluid
- the eardrum has been ruptured by an extremely loud noise or as the result of infection
- sensory cells of the ear have been damaged by loud noise
- a defect in the auditory nerve or the tiny hairs of the cochlea prevents sound impulses being transmitted correctly to the brain.

The cochlear implant, or bionic ear, has helped many people with serious inner-ear damage to hear sound for the first time. Figure 3.2.13 shows how it is fitted.

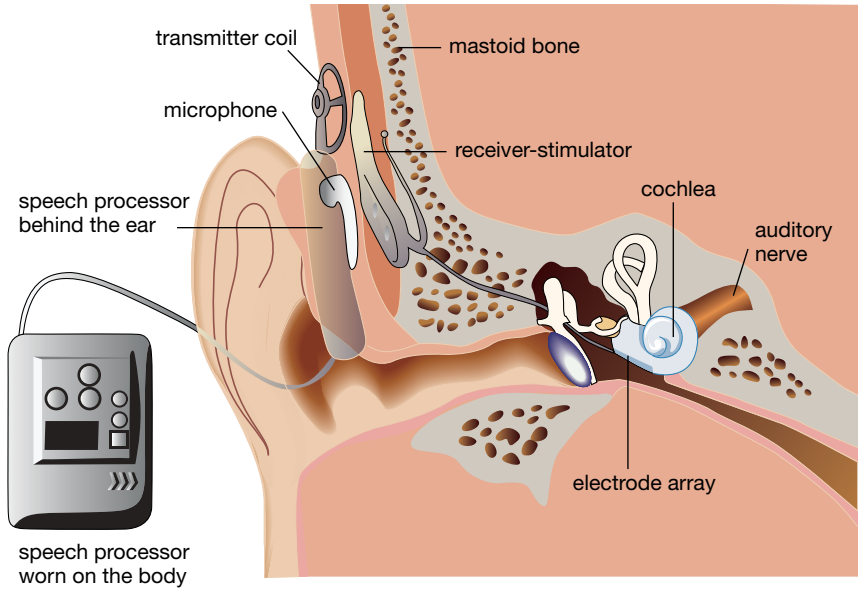


Figure 3.2.13 The cochlear implant is an Australian invention. It was developed in the 1970s by a group of scientists led by Professor Graeme Clark. It converts sounds into electrical impulses that are sent to the brain.

3.3

LEARNING ACROSS THE CURRICULUM

WORK AND ENTERPRISE

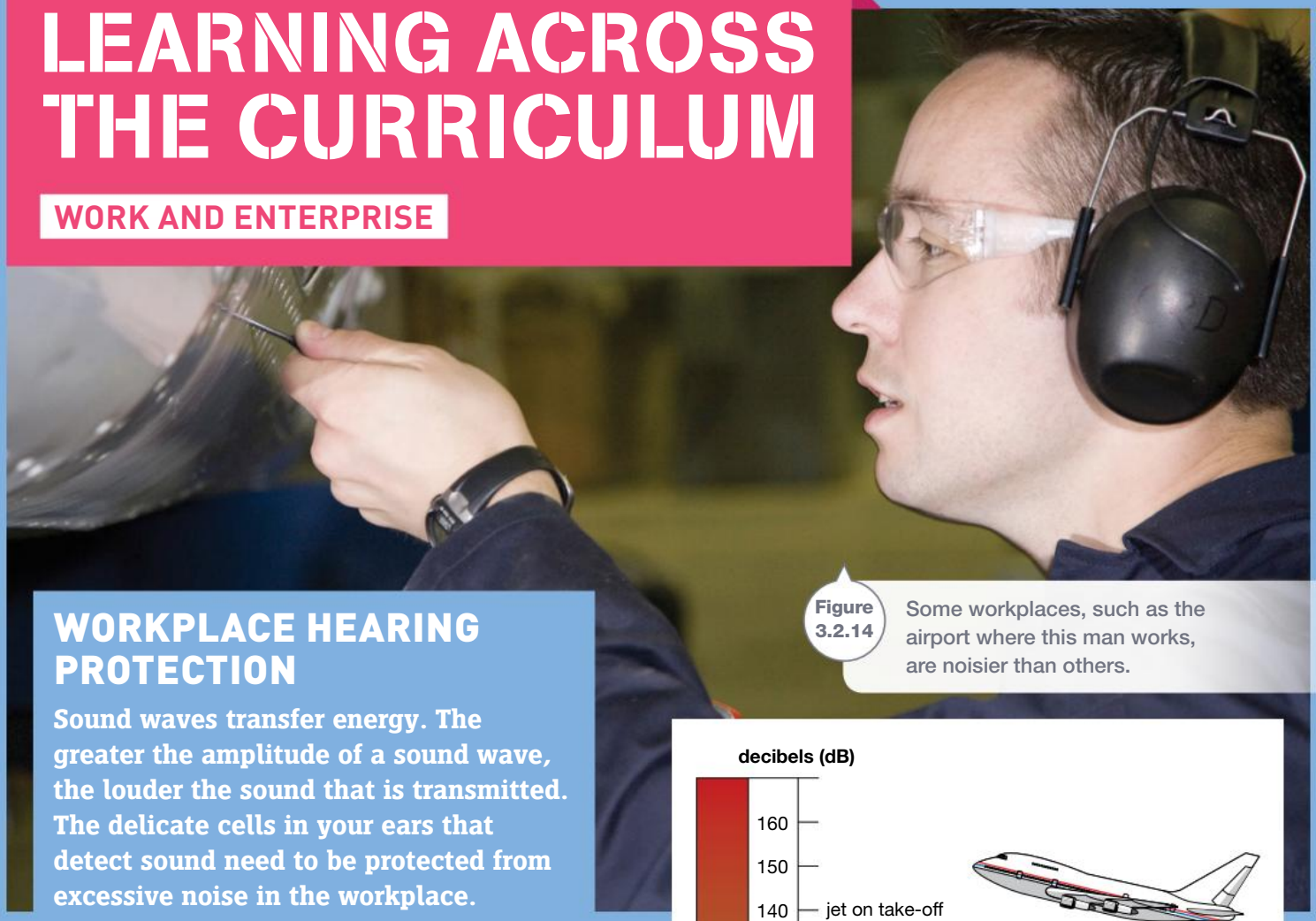


Figure 3.2.14 Some workplaces, such as the airport where this man works, are noisier than others.

WORKPLACE HEARING PROTECTION

Sound waves transfer energy. The greater the amplitude of a sound wave, the louder the sound that is transmitted. The delicate cells in your ears that detect sound need to be protected from excessive noise in the workplace.

Like the engineer in Figure 3.2.14, many people use noisy machinery at work. Loudness can be measured by a device called a sound level meter. Loudness is measured in **decibels** (unit symbol dB). The decibel scale is shown in Figure 3.2.15.

Exposure to noise levels above 85 dB for long periods can permanently damage your hearing. The degree of damage depends on how loud the noise is, and how long you are exposed to it. People spend much of their day in their workplace, and so exposure to constant loud noise can have a significant effect on their hearing.

Noise destroys delicate sensory cells in the inner ear, called hair cells. These cells detect vibrations and send electrical signals to the brain. Such damage can be seen in Figure 3.2.16 on page 110. If affected, these cells cannot be replaced.

Repeated exposure to loud noise can also lead to tinnitus, a condition in which a person hears a permanent ringing in their ears. Noise-induced hearing loss is recognised as a major industrial disease in Australia and around the world. It makes hearing higher-frequency sounds more difficult. In turn, this can lead to problems communicating, increased fatigue, stress and anxiety.

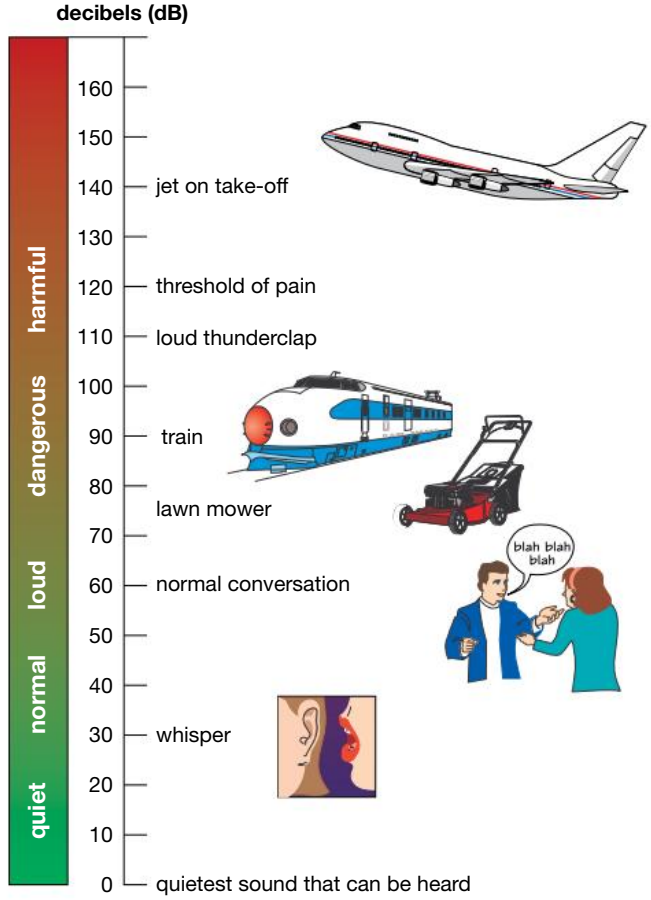


Figure 3.2.15 Sound intensity level, or loudness, is measured on the decibel scale.

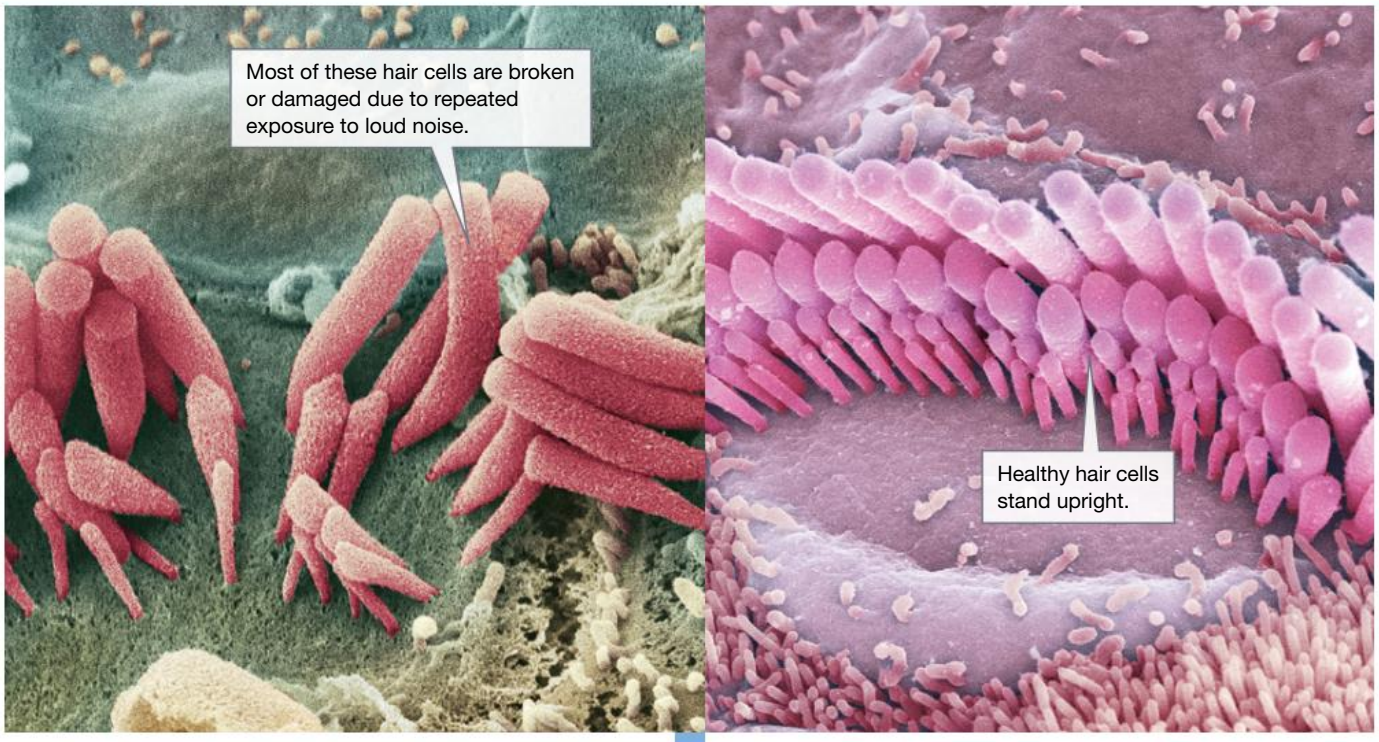


Figure 3.2.16 These images show the effect that loud sounds can have upon tiny hair cells in the inner ear.

A code of practice exists for maintaining noise within acceptable levels in workplaces. Workplaces are assessed for their noise levels. Employers operating worksites with high levels of noise are directed to:

- try to reduce noise levels by:
  - replacing outdated, noisy machinery with quieter alternatives where possible
  - ensuring that machinery is regularly maintained
  - reducing metal-to-metal contact in machinery by inserting materials to dampen sound
- block noise transmission by:
  - shifting noisy machinery to more remote areas of the workplace
  - fitting sound-absorbing materials to the ceiling or walls
  - using sound-absorbing curtains to screen off an area or machine
- ensure that all areas of loud noise are signposted as hearing protector areas
- ensure that workers are not exposed to sound intensity levels greater than 85 dB averaged over an 8-hour period
- ensure that affected workers wear personal hearing protectors, such as correctly fitted earmuffs or earplugs and that these workers undergo regular hearing tests to monitor their hearing.

REVIEW

1 **Describe** what is heard when the amplitude of a sound wave increases.

2 **Use** Figure 3.2.15 on page 109 to estimate the sound level intensity (in dB) of:
- **a** city traffic
- **b** two people arguing loudly
- **c** a chip packet rustling in a cinema
- **d** a car backfiring.

3 **Describe** the effect that repeated and prolonged exposure to noise above 85 dB has on a person's ears.

4 **List** three ways an employer could act to reduce the noise levels around machinery.

5 **a** Your hearing is usually muffled after a loud concert. **Propose** a reason why.

b Members of bands risk hearing damage more than the occasional concert-goer does. **Propose** a reason why.

6 **a** **Describe** what tinnitus is.

b **Explain** how it is caused.

7 iPods and similar portable music devices can produce sounds above 105 dB.

a **Use** this information to **propose** a reason why many doctors believe that tinnitus will become far more common in the future.

b **Assess** whether you are at risk of tinnitus in the future due to your current listening habits.

3.2 Unit review

Remembering

1 **State** whether the following are true or false.
- a Sound is produced by vibrations.
- b Regions of high air pressure are called rarefactions.
- c A sound wave can travel in a vacuum.
- d Waves at the beach are called transverse waves.

2 **Name** the unit that is used to measure the frequency of a sound wave. N

3 **List** the causes of four types of hearing loss.

Understanding

4 **Explain** why sound travels faster through solids than through liquids.

5 a **Describe** the function of the eardrum.
- b **Describe** the role of the ossicles in the ear.
- c **Explain** how electrical impulses travel from the ear to the brain.

6 **Predict** which of the straws in the science4fun on page 106 would produce:
- a the highest pitched sound
- b sound with the longest wavelength
- c sound of the highest frequency.

Applying

7 In the science4fun activity on page 102, a sound is heard when the balloon is tapped. **Use** the idea of particles and sound waves to **explain** why.

Analysing

8 Figure 3.2.17 illustrates three traces of sounds on an oscilloscope.

Identify the:
- a sound with the highest frequency
- b sound with the lowest frequency
- c loudest sound.

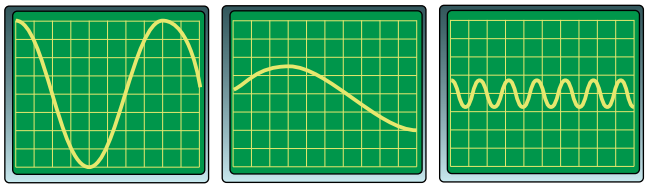


Figure 3.2.17

9 **Analyse** the oscilloscope patterns of the sound from a guitar, oboe and piano in Figure 3.2.11 on page 107.
- a **Identify** which instrument was being played the loudest.
- b **Identify** which instrument had the lowest pitch.
- c **Compare** the patterns of musical instruments with the shape of the trace that is shown for noise.

10 **Analyse** Figure 3.2.12 on page 108 to:
- a **explain** why the shape of the pinna suits the function of this part of the ear
- b **identify** where vibrations are converted to electrical signals.

Evaluating CCT

11 **Analyse** Figure 3.2.6 on page 105 to answer the following questions.
- a **State** which material listed best absorbs high-frequency sounds.
- b i **State** which material reflects the greatest proportion of sounds.
  - ii **Propose** a reason why this material does not absorb much sound.
- c **Explain** what happens to the sound energy absorbed by materials.

12 **Propose** how a speech recognition system would operate.

3.2 Unit review

13 Figure 3.2.18 compares the range of hearing of humans and different animals. **Use** it to answer the questions that follow. N

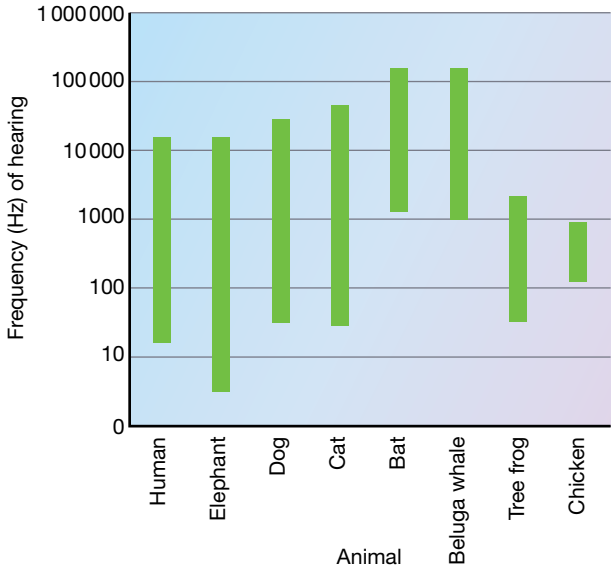


Figure 3.2.18 Note that the vertical scale is a logarithmic scale, meaning each division on the scale is ten times as large as the previous division.

a **Identify** which animal can hear the highest-frequency sounds.

b **Identify** which animal or animals can hear the lowest frequency.

c The bat and the beluga whale rely on echolocation using ultrasound. **Propose** why they need to have a higher hearing range than humans.

d Dog whistles are audible to dogs but not to humans. **Propose** the frequency range of such whistles.

e **State** whether a chicken can hear any of the sounds heard by a bat.

Creating CCT

14 **Construct** a diagram to **contrast** ultrasound with infrasound.

Inquiring

1 Research MP3 players and headphones and hearing damage associated with them. Find:

- the levels of loudness that are likely to cause long-term hearing damage
- how to reduce the chance of hearing loss associated with headphone use
- why some experts recommend a '60/60' rule: listen to music on an MP3 player at 60% of the maximum volume for 60 minutes and then have a break before listening again
- the risks associated with using earbud-style headphones compared to headphones that fit over the ear
- an estimate of the maximum recommended duration that it is safe to listen to an MP3 player at maximum volume before causing hearing damage

Present your research in a brochure or multimedia display to outline key recommendations on how to use an MP3 player without risking hearing loss. ICT

2 Some people are calling for devices such as the Mosquito alarm to be banned because it infringes human rights.

Research this issue and list arguments for and against such a ban.

ADDITIONAL

3 Find the depths of the following places and then calculate how long it would take for sonar to return from each. Assume the speed of sound in water is 1500 m/s. N

- The deepest point on Earth (Mariana Trench)
- The wreck of the *Titanic*
- The shallowest and deepest points in Sydney Harbour

Present your findings and calculations in written form.

4 Find the speed of light and the speed of sound in air. Use these values to:

- explain why you always see lightning before you hear the sound of its thunder
- estimate how far away a storm is if you hear thunder 6 seconds after you see the flash of lightning. N

Present your findings and calculations in written form.

ADDITIONAL

3.2 Practical investigations

1 Making waves

Purpose

To model transverse and longitudinal waves.

Materials

- slinky spring

Procedure

1. Hold one end of the slinky. A partner holds the other end.
2. Move your end of the slinky up and down at a regular speed, as shown in Figure 3.2.19a.
3. Sketch a side view of the waves you made. These are transverse waves, like water waves.
4. Try to alter how you produce the waves so that they are bunched closer together, with greater frequency.
5. You and your partner hold each end still.
6. Tap one end of the spring horizontally so that a pulse travels through the spring, as shown in Figure 3.2.19b.
7. Try to draw what is happening here from a side view. This is a longitudinal wave, like a sound wave.
8. Try to alter how you produce these waves to increase their frequency.

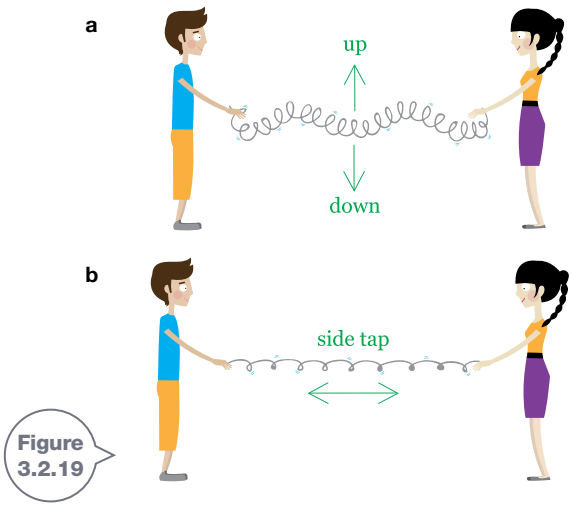


Figure 3.2.19

Practical review

1. **Describe** how the slinky moves when a:
   - a transverse wave passes through
   - b longitudinal wave is transmitted.
2. **Explain** how you were able to increase the frequency of the:
   - a transverse waves
   - b longitudinal waves.
3. **State** which of the two wave types you produced is more like a sound wave.

2 Good vibrations

Purpose

To investigate the differences in producing high-pitched and low-pitched sounds.

Materials

- water
- 5 beakers (or glasses) of the same size
- pen or a chopstick
- ruler

Procedure

Part A

1. Hold the ruler over the edge of a bench and flick it so it vibrates.
2. Listen to how the pitch changes as you reduce the length of ruler vibrating.

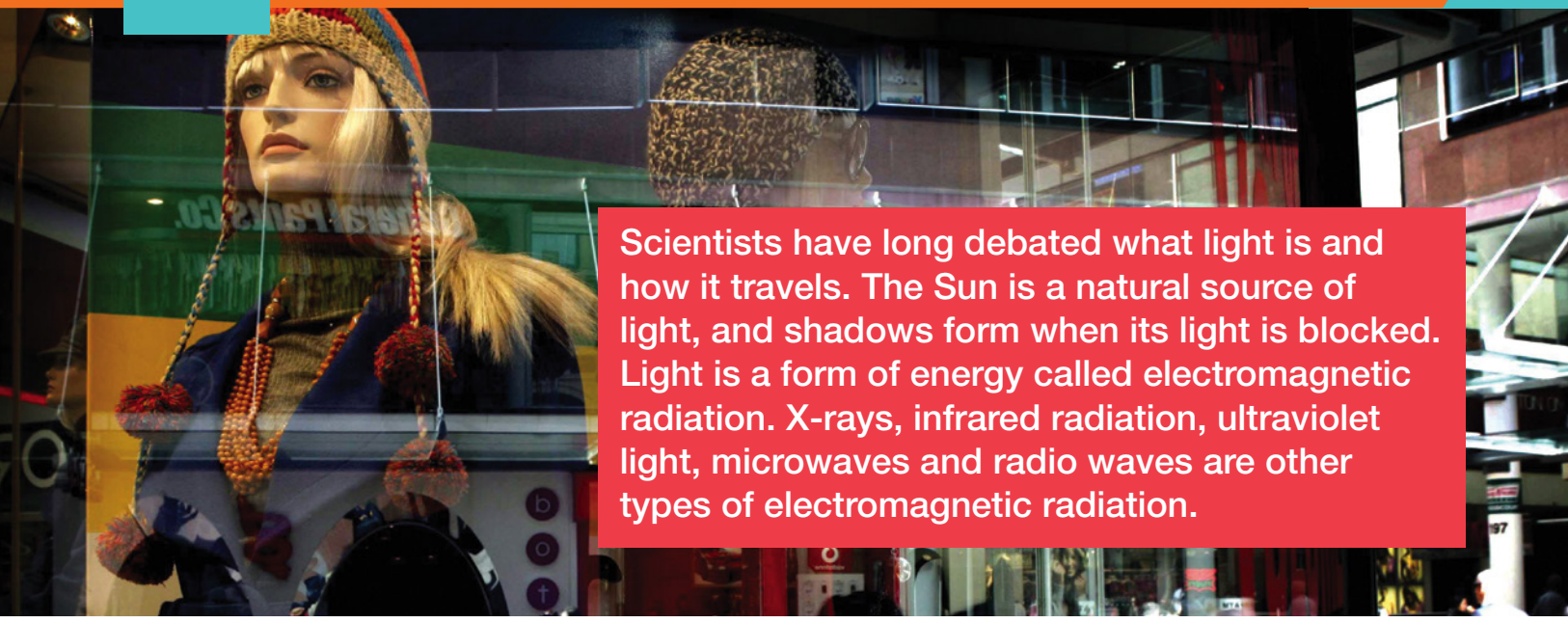
Part B

3. Line up the beakers (or glasses) on your bench.
4. Fill each beaker to a different depth with water.
5. Carefully tap the glass of each using the pen, chopstick or other object, and listen to the variation in pitch.

Practical review

1. **State** which length of vibrating ruler made the lowest sound and which made the highest sound.
2. **Construct** a diagram that shows the difference between sound waves produced.
3. **Describe** the pitch of sound produced by the beaker with the least amount of water.
4. **Deduce** how the length of the ruler and the depth of the water in the beaker are related to the pitch of the sound they produce.
5. **Explain** whether you think the vibrations would be faster or slower when producing high-pitched sounds.

3.3 Light



Scientists have long debated what light is and how it travels. The Sun is a natural source of light, and shadows form when its light is blocked. Light is a form of energy called electromagnetic radiation. X-rays, infrared radiation, ultraviolet light, microwaves and radio waves are other types of electromagnetic radiation.

Properties of light

Like infrared radiation, light is a form of energy called electromagnetic radiation. It travels as a wave, called an electromagnetic wave. This has a complex structure, shown in Figure 3.3.1. Like a sound wave, an electromagnetic wave has a specific frequency and wavelength. But unlike a sound wave, an electromagnetic wave does not require a material to transmit through. It can pass through a vacuum. For example, infrared radiation and light from the Sun travel through the vacuum of empty space to reach Earth. A sound wave in air may travel at around 340 m/s, whereas a light wave travels at an incredible 300 000 km/s.

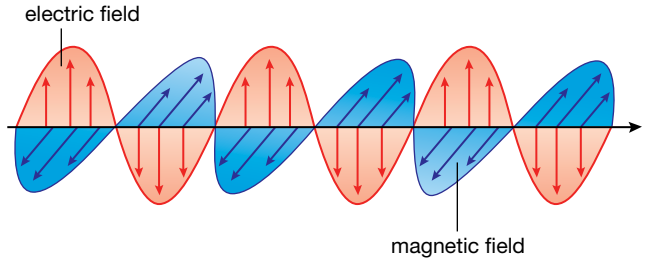


Figure 3.3.1 Light travels as an electromagnetic wave made of alternating electric and magnetic fields.

When light hits a surface, it may be:

- transmitted through it
- reflected off it, or
- absorbed into it.

Table 3.3.1 outlines examples of these three situations.

GO TO Unit 4.1
GO TO Unit 4.2

Table 3.3.1 Transparent, translucent and opaque materials

Light hits a surface and:	This material is called:	Examples	
• Almost all light is transmitted through the substance. • A clear image can be seen through it.	Transparent	Clear glass, shallow water	
• Some light may be reflected, and light that passes through is scattered. • An image seen through it is fuzzy.	Translucent	Tissue paper, fingernails, frosted glass	
• Light is either reflected from or absorbed into the substance • No light is transmitted. • No image can be seen through it.	Opaque	Brick, piece of wood, a desk, a football	

An object that releases or emits light is said to be **luminous**. However, most objects do not produce their own light. They are non-luminous. You see most objects, such as the Moon, because light bounces off them and then into your eyes. This process is called reflection and is shown in Figure 3.3.2.

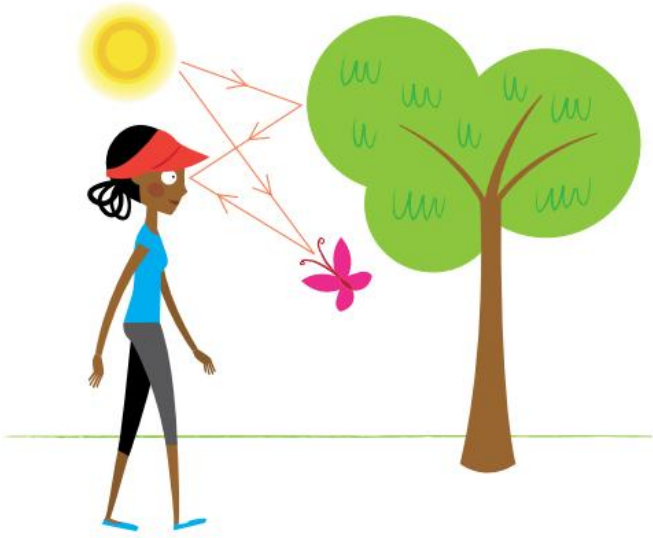


Figure 3.3.2 This girl can see the tree and the butterfly because light from the Sun is reflected from these objects and then enters her eyes.

Diffuse and regular reflection

When light reflects off a very smooth surface such as a mirror or a window, it undergoes regular reflection. This produces a clear image. As Figure 3.3.3 shows, all the light rays are reflected in the same direction.

The surfaces of most objects are quite rough when viewed up close. These surfaces reflect or scatter light in many directions, and do not form an image. This is called diffuse reflection and is shown in Figure 3.3.4.

Figure 3.3.3 Regular reflection occurs from very smooth surfaces and forms clear, sharp images.

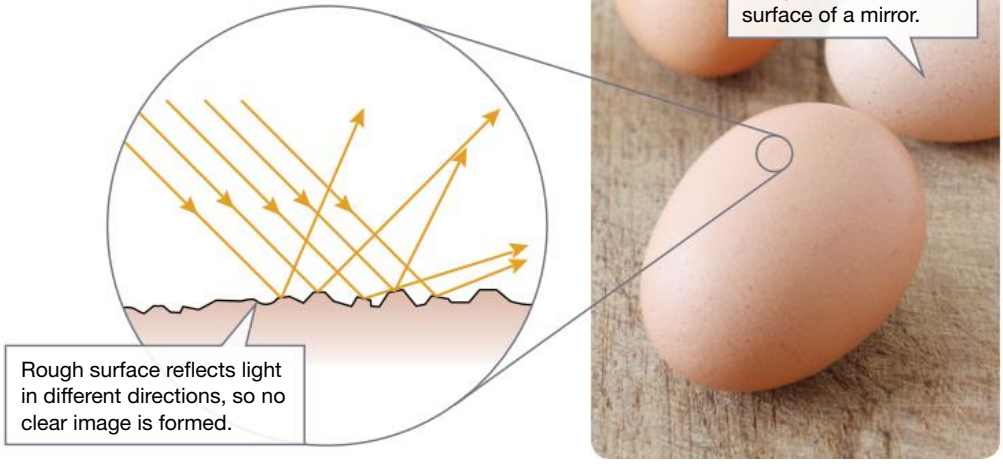


Figure 3.3.4 Diffuse reflection occurs from rough surfaces and no clear image is formed.

The law of reflection

When a billiard ball is hit at right angles to the cushion of the table, the ball bounces straight back along the same path. When the ball is hit at an angle to the cushion, it bounces off the cushion at the same angle. In the same way, an incoming ray of light, known as an incident ray, is reflected off a mirror at the same angle. This is called the law of reflection and is shown in Figure 3.3.5.

A dotted imaginary line, called the **normal**, is shown in Figure 3.3.5 at right angles to the surface of the mirror. This is used to measure the **angle of incidence** (shown as i) and the **angle of reflection** (r).

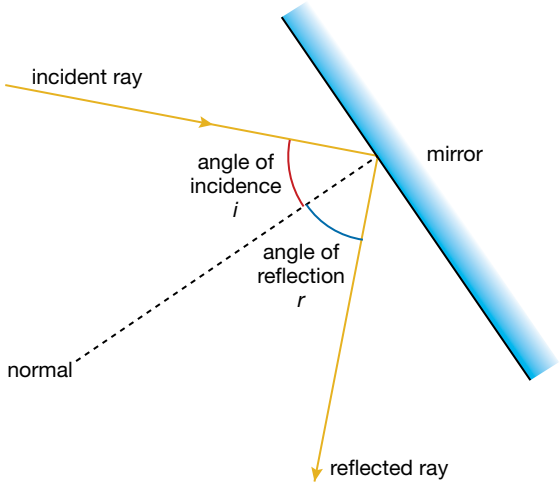


Figure 3.3.5 The law of reflection states that the angle of incidence of a light ray is equal to the angle of reflection.

According to the law of reflection:

angle of incidence = angle of reflection

$i = r$

Prac 1 p125

Mirror on the Moon

In 1969, Neil Armstrong and Buzz Aldrin left a device called a corner reflector on the Moon. Researchers have used the reflection of laser light from this device to accurately measure the distance from the Earth to the Moon, and have discovered that this distance increases by 4 cm each year.

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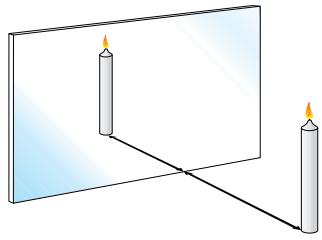
INQUIRY science 4 fun

Image finder

How far behind a mirror is an image located?

Collect this ...

- 2 birthday candles
- 2 dobs of Blu Tack
- sheet of glass
- sheet of paper



Do this ...

1. Draw a line down the middle of the sheet of paper.
2. Hold the glass so that it stands along this line.
3. Position a lit birthday candle with Blu Tack in front of the glass, as shown in the diagram.
4. Carefully look into the glass at the image formed.
5. Move an unlit candle behind the glass so that the image of the flame rests on its wick.
6. Measure the distance from each candle to the glass.

Record this ...

Describe what happened.

Explain why you think this happened.

Plane mirrors

A flat mirror is also called a **plane mirror**. When you stand in front of a mirror in a fitting room when trying on clothes, your image is the same size as you. It is the same distance behind the mirror as the distance you are standing in front of it. Your image is identical to you in every way except that it is reversed sideways: your right side appears in the mirror as your left, and vice versa, as the example in Figure 3.3.6 shows. This reversal is called **lateral inversion**.

Figure 3.3.6 Although this boy is brushing his teeth with his right hand, his image appears to hold the toothbrush in the left hand. The image is laterally inverted.

Forming an image

When a plane mirror produces an image of an object, such as a candle, the image looks as though it is really positioned inside or behind the mirror. Figure 3.3.7 shows why this happens. Light that has reflected from the candle reaches your eyes. Your brain is used to light travelling in straight lines, so it extends this light back inside the mirror to where it appears to have come from. As a result, the candle appears to be inside the mirror. This is called a **virtual image**, because the rays of light do not really meet to produce this image.

An image seen in a plane mirror:

- is upright (normal way up)
- is the same size as the object
- is laterally inverted (reversed sideways)
- is virtual
- appears to be located as far inside the mirror as the object is in front.

3.4

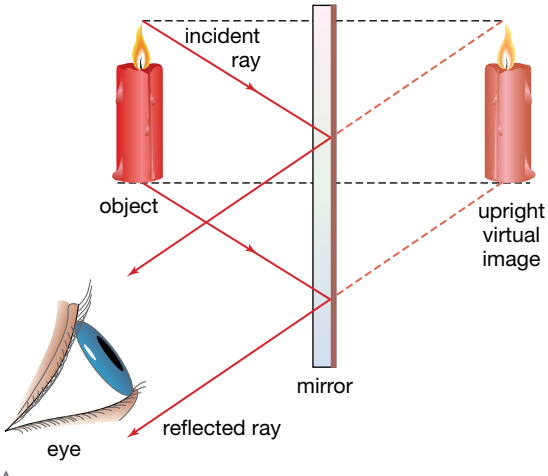


Figure 3.3.7 A plane mirror produces a virtual, upright image that is the same size as the object but laterally inverted.

Refraction

The straw resting in the glass shown in Figure 3.3.8 appears to be bent. The straw is not bent at all. It appears this way because light was bent as it travelled out from the water in the glass to the air. This bending of light is called **refraction**.

Figure 3.3.8 This straw appears disjointed at the surface of the water, when viewed through the water in the glass.

Light refracts when it travels from one transparent substance into another. Figure 3.3.9 shows light bending towards the normal as it enters a glass block, and bending away from the normal when it exits it.

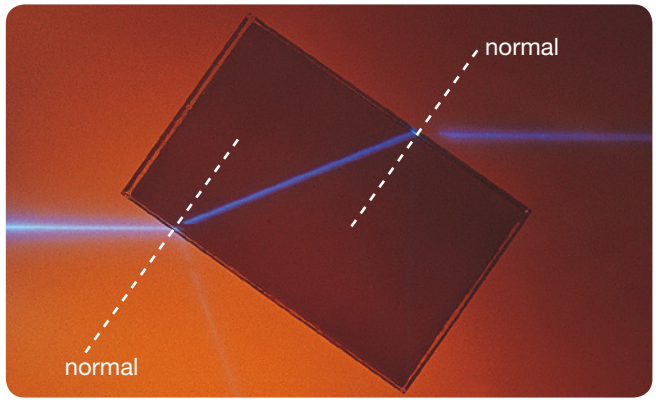


Figure 3.3.9 Light bends towards the normal when it enters this glass block and bends away from the normal when leaving.

Why does refraction occur?

Light travels at different speeds through different substances. The differences in its speed result in different amounts of bending, or refraction, as light passes from one substance into another. The **refractive index** is a measure of how easily light travels through a substance. The smaller the refractive index of a material, the faster light will travel through this material.

Light entering a glass block from air slows down and bends towards the normal. A car that meets a flooded section of road behaves in a similar way. The first wheel entering the water slows down while the other continues at the same speed, causing the car to slow down on one side and swerve inwards, towards the normal. This is what is happening in Figure 3.3.10. As light leaves a glass block, it speeds up and bends away from the normal.

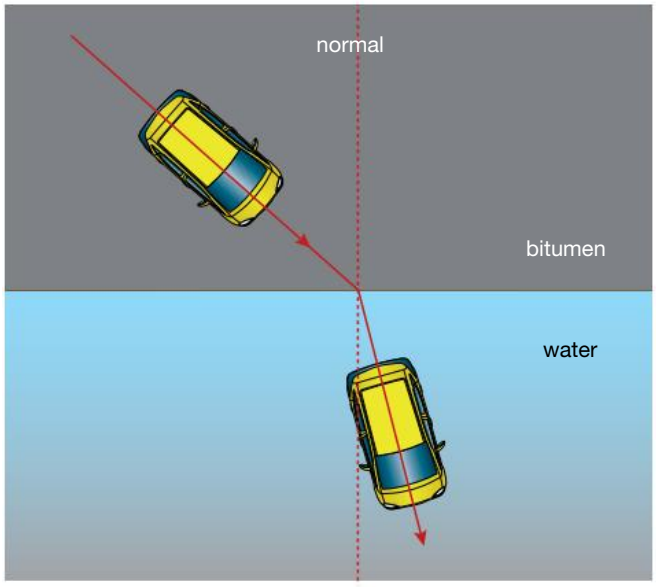


Figure 3.3.10 A car that enters a pool of water on a road slows down and its path bends towards a normal line.

The higher the refractive index of a substance, the more light bends when it enters the substance from air. Light travels more slowly in glass, water, diamond and Perspex than through air and so it bends as it enters them. Table 3.3.2 shows the speed of light in a few common substances, and the refractive index of each.

Table 3.3.2 Speeds of light in different media

Medium	Speed of light (km/s)	Refractive index
Air	300 000	1.00
Ice	231 000	1.31
Water	226 000	1.33
Perspex	200 000	1.49
Glass	197 000	1.52
Diamond	124 000	2.42

SciFile

Forensic refraction

Investigators can link pieces of broken glass to a window pane smashed at a crime scene if the refractive indices of both samples of glass match. Fragments of glass from car headlights left at a hit-and-run accident can be used to identify the model of the car they came from, and eventually its driver.

The angle an incoming ray of light makes with the normal is called the angle of incidence, *i*. The angle that the refracted ray makes with the normal is called the **angle of refraction**, *r*. Figure 3.3.11 shows that light bends towards the normal when entering a substance of higher refractive index, and bends away from the normal when entering a substance of lower refractive index. Light entering another substance head on is not bent, but continues straight through.

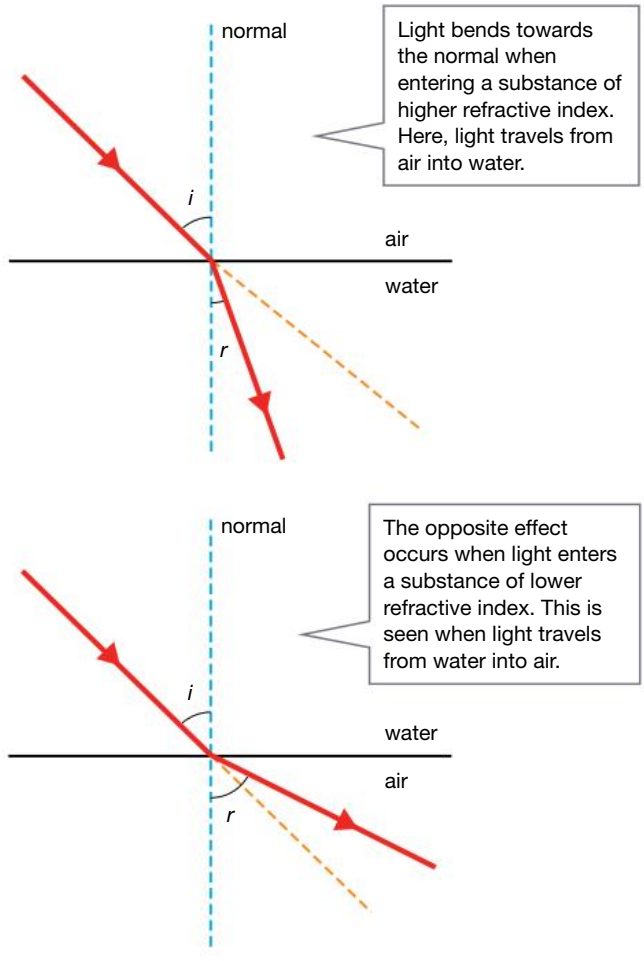


Figure 3.3.11 The way light refracts depends on the refractive indices of the substance it is coming from and the substance it is entering.

Depth illusions

When someone is standing in a swimming pool, their legs look shorter than normal. Similarly, rocks on the bottom of a stream always look as though they are in shallower water than they actually are. These depth illusions, like that seen in Figure 3.3.12, occur because light from an object under water is bent away from the normal when it leaves the water surface into air. When you look at this refracted light, your brain traces the light reaching your eyes back in a straight-line path. This makes the object appear to be positioned closer to the surface.

3.5

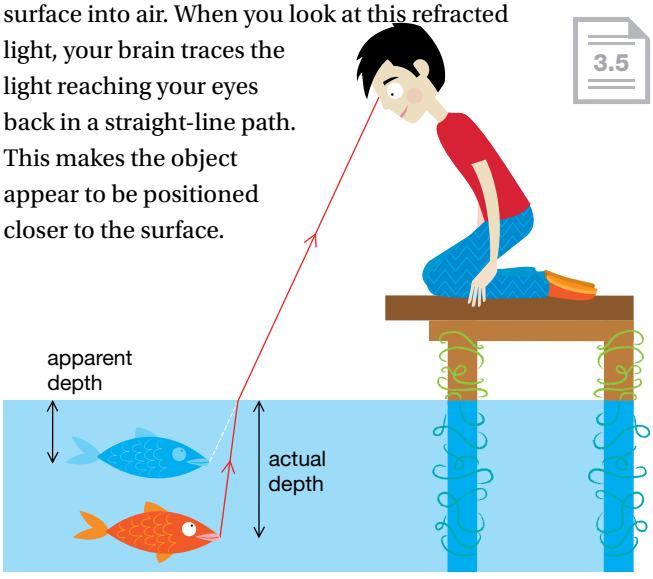


Figure 3.3.12 The depth of the fish (its apparent depth) is less than its true depth in the water. For this reason, hunters using spears to catch fish aim the spear slightly below where they see the fish in the water.

Underwater vision

When you are under water looking at objects without goggles or a mask, they appear blurry. Light reaching the corneas of your eyes from water doesn't bend as much as it would if it had come from air. As a result, you can't focus properly. If you wear goggles or a mask, light enters your eyes from air rather than from water. This makes everything clearer!

SciFile

Total internal reflection

When light enters a substance of lower refractive index, such as from glass into air, it is refracted away from the normal. Figure 3.3.13 on page 120 shows what happens to this ray as the angle of incidence increases. At an angle of incidence called the **critical angle**, light is refracted so far from the normal that it runs along the boundary of the two substances. For any angles of incidence greater than this, there is no refracted ray. Light is reflected from the boundary as though it was a mirror. This is called **total internal reflection**.

INQUIRY science 4 fun

The reappearing coin

YES

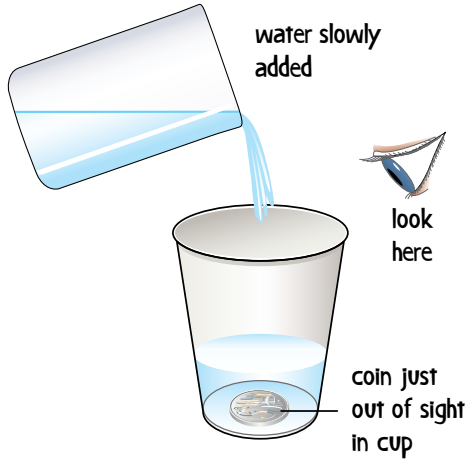
Can you make a coin appear before your eyes?

Collect this …

- coin
- opaque cup (one that is not see-through) or evaporating basin
- pencil or pen
- glass of water
- rectangular glass block

Do this …

1. Put the coin in the cup.
2. Move back until the coin is just out of sight.
3. Have your partner pour water into the cup from the beaker.
4. Can you see the coin again?
5. Now place the rectangular glass block on top of this page of your textbook.
6. Study the print through the block and compare this to when the block is removed.



Record this …

Describe what happened when you viewed the coin and when you looked through the glass block.

Explain why you think these things happened, using diagrams to assist your response.

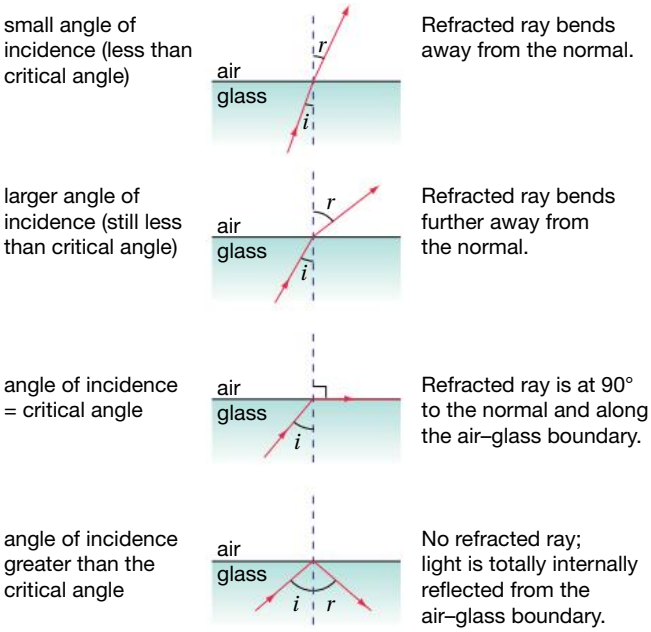


Figure 3.3.13 What light does at the air–glass boundary depends on its angle of incidence.

Total internal reflection of light explains why diamonds sparkle (Figure 3.3.14). It also explains the imaginary shark seen in Figure 3.3.15.

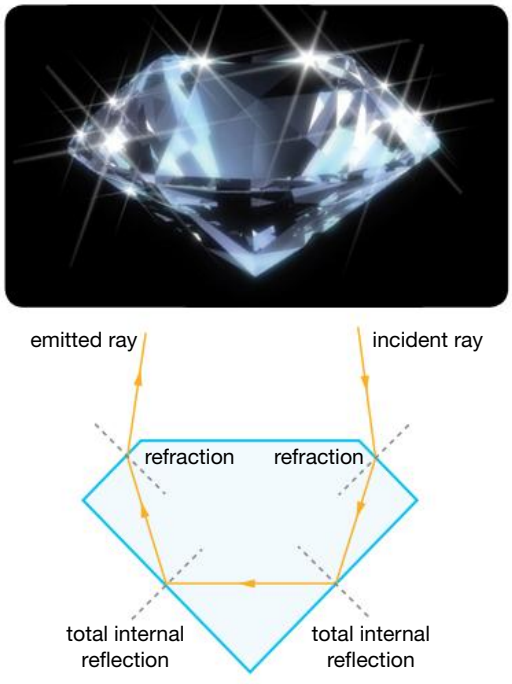


Figure 3.3.14 Diamond has a high refractive index and a low critical angle of about 23°. Jewellers cut the faces of a diamond so that most light falling on the diamond will strike the back of the diamond at an angle larger than the critical angle. This means the light is reflected twice within the diamond before it emerges, making it look more brilliant.

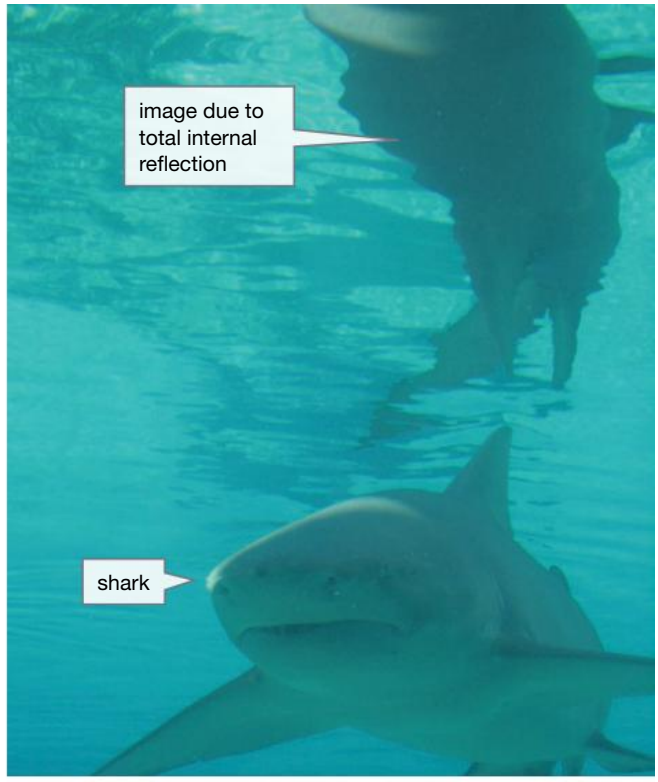


Figure 3.3.15 Light from this shark has been totally internally reflected at the surface of the water. This produces the illusion of a shark swimming upside down above the real one.

Prac 2 p126
3.6

Lenses

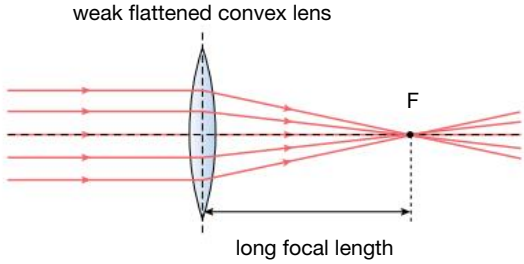
A lens is a transparent piece of plastic, glass or even jelly that is shaped to curve outwards or inwards. A lens refracts light and focuses it to form images in the eye and in devices such as cameras, telescopes, binoculars, microscopes, spectacles and contact lenses.

Convex lenses

A lens that bulges outwards is called a **convex lens**. These lenses, such as the one shown in Figure 3.3.16, cause light rays to come together, or converge. If a convex lens is held close to an object, it can be used as a magnifying glass. In this case, it produces an upright and enlarged (magnified) virtual image.

If light reaches a convex lens from a distance, the convex lens can be used to focus the light on a screen to form an image. Figure 3.3.17 shows two convex lenses of different strengths focusing light to a point called the focus of the lens (F). Light is focused to a point on a screen when you see a film at the movies. This is the type of image that is formed by the convex lenses in your eyes. This type of image is called a **real image**.

Figure 3.3.16 Lenses refract light to produce different types of images. A magnifying glass is a convex lens.



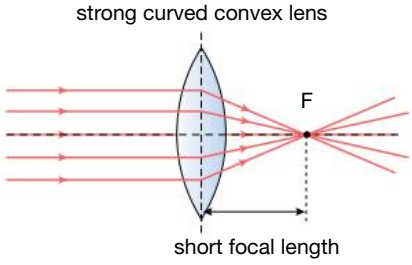


Figure 3.3.17 Parallel rays of light are brought together at a point called the focus (F) on the other side of a convex lens. The greater the curve of the lens, the stronger the lens is and the shorter its focal length, or distance between the lens and the focus.

Concave lenses

A lens that curves inwards is called a **concave lens**. These lenses cause light to diverge, or spread out. They spread parallel light rays as though the rays have come from a point behind the lens, as shown in Figure 3.3.18. A concave lens only produces images that are smaller, upright and virtual.

Prac 3 p127

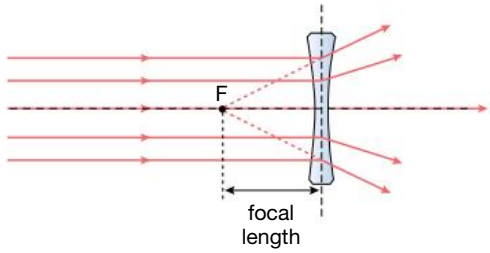


Figure 3.3.18 A concave lens causes light to diverge. To measure the focal length of a concave lens, you must trace the path of the rays leaving the lens to the single point where they appear to have come from. This point is the focus (F) of the lens.

INQUIRY

science 4 fun

Forming an image

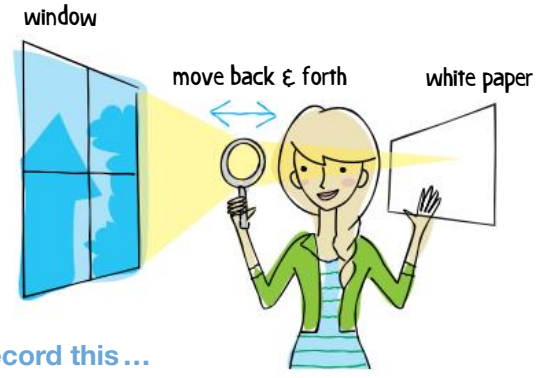
YES

Collect this …

- magnifying glass
- sheet of white paper

Do this …

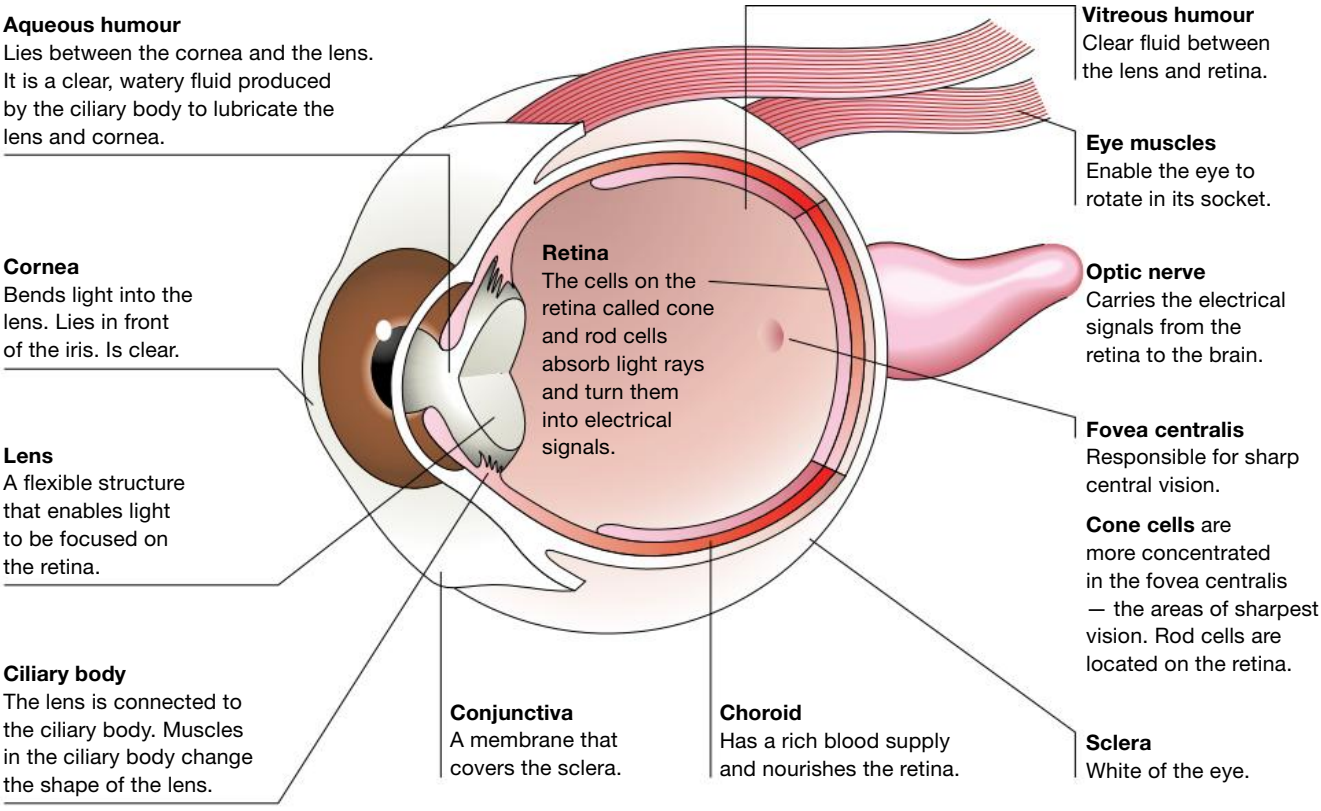
1. Hold the magnifying glass in front of a light source, such as sunlight through a window, a candle or a light globe.
2. Hold the sheet of paper as a screen in one hand and the lens in the other.
3. Try to focus an image on the sheet of paper by moving the lens back and forth.



Record this …

Describe what happened.

Explain why you think this happened, using a diagram to assist your response.



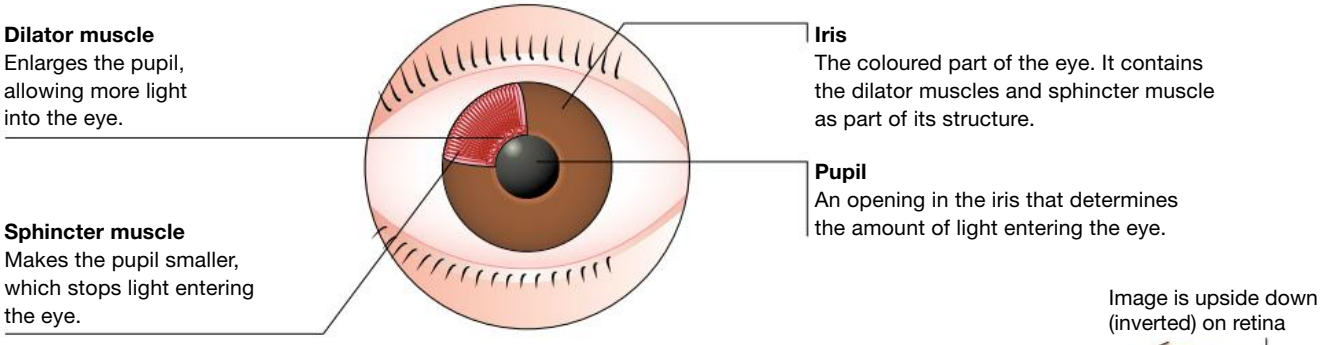


Figure 3.3.19 These structures of the eye work together to provide vision.

The eye

The most incredible optical instrument we have is the eye. Figure 3.3.19 shows the structure of the human eye. Light that enters the eye is refracted by the cornea and focused by the lens, which is convex. Figure 3.3.20 shows how incoming light is focused to form a clear, upside-down image on the retina, at the back of the eye. This image is converted into a series of electrical signals, which then travel along the optic nerve to the brain. The brain interprets this information as an image.

Prac 4 p127 3.7

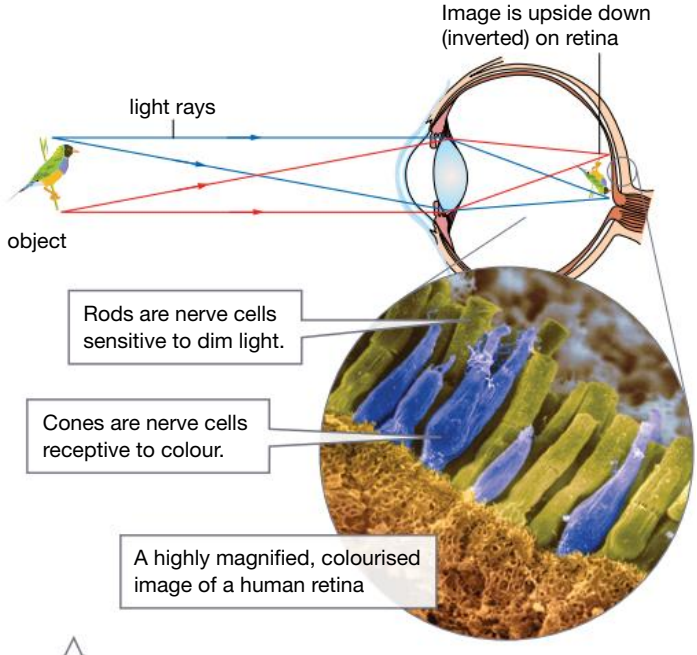


Figure 3.3.20 The brain interprets the upside-down image formed on the retina as an upright image. Specialised cells in the retina give information about its colour and shading.

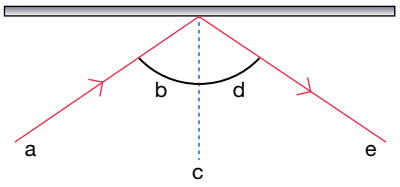
3.3 Unit review

Remembering

1 a **State** which letter in Figure 3.3.21 represents the:
   i incident ray
   ii reflected ray
   iii normal
   iv angle of incidence
   v angle of reflection.

   b **Name** the law that is demonstrated in Figure 3.3.21.

Figure 3.3.21



2 **List** five properties of an image formed by a plane mirror.

3 **State** which of the two alternatives makes each sentence true.
   a Light is refracted *away from/towards* the normal when it passes from glass into air.
   b Light travels at a higher speed through *glass/air*.
   c Total internal reflection can only occur when light attempts to pass from a substance of *lower/higher* refractive index.

4 **Recall** the language of lenses by matching the correct word from the list below to each of the statements that follow. (Note: Some words can be used more than once.)
   focus real virtual convex concave
   a In using a lens, this is the point at which distant light rays meet, or appear to meet.
   b This type of image cannot be produced on a screen or a sheet of paper.
   c This type of lens always produces upright, diminished, virtual images.
   d A convex lens produces this type of image from a distant object.

5 **State** which of the two alternatives makes each sentence true.
   a Light entering the eye is refracted by the lens and the *cornea/retina*.
   b To produce a clear image, light must be focused on the *retina/lens*.
   c The image travels as a series of *light/electrical* signals along the optic nerve to the brain.
   d The aqueous humour is a clear fluid that lies between the cornea and the *retina/lens*.

Understanding

6 If you were to double the distance of the candle from the glass in the science4fun on page 116, then **predict** where the image would now be located.

7 **Explain** why the boy shown in Figure 3.3.12 on page 119 thinks the fish is closer to the surface than it really is.

8 a **Explain** why everything looks blurry if you open your eyes under water.
   b **Describe** what you can do to make your underwater vision clear.

9 **Explain** why the pencils in Figure 3.3.22 seem to be broken in the middle.

Figure 3.3.22

Applying

10 **Identify** the property of light that makes the coin reappear in the science4fun on page 119.

11 **Use** Figure 3.3.11 on page 118 to help you to **identify** whether light will bend towards or away from the normal in each of the following situations.
   Light travels from:
   a water to glass
   b diamond to air
   c water to Perspex
   d water to ice
   e glass to diamond
   f air to Perspex.

3.3 Unit review

12 Figure 3.3.23 shows three rays of light hitting a mirror. **Use** this diagram to carry out the following tasks.

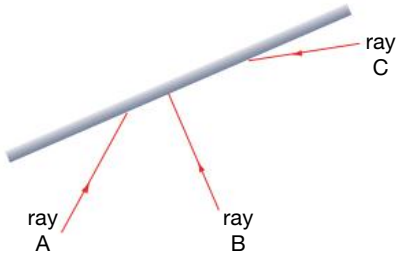


Figure 3.3.23

- **a** Copy the diagram and use a ruler to draw a normal at 90° to the mirror for each of rays A, B and C.
- **b** Extend where each ray will be reflected in front of the mirror.
- **c** **Use** a protractor to **determine** which ray has the largest angle of reflection.

Analysing

13 **Compare** the formation of the image in the science4fun on page 121 with the way the eye forms and image.

14 **Classify** the following objects as transparent, translucent or opaque.

- **a** a basketball
- **b** air
- **c** a pair of sheer pantyhose
- **d** shallow water
- **e** a piece of lightweight cotton fabric

Evaluating CCT

15 **Propose** why total internal reflection never occurs when light travels into a substance of greater refractive index.

16 If a sample of glass was found at the scene of a burglary, **propose** how this could be used as evidence in a criminal investigation.

Creating CCT

17 Copy each diagram in Figure 3.3.24 and draw the normal to the point where light meets each boundary. **Construct** a ray on each diagram to show the likely path of each ray through each material.

18 The critical angle of light passing from water into air is 48.6°. **Construct** a diagram to demonstrate how light bends when travelling from water into air at an angle of:

a 60° **b** 48.6° **c** 25°.

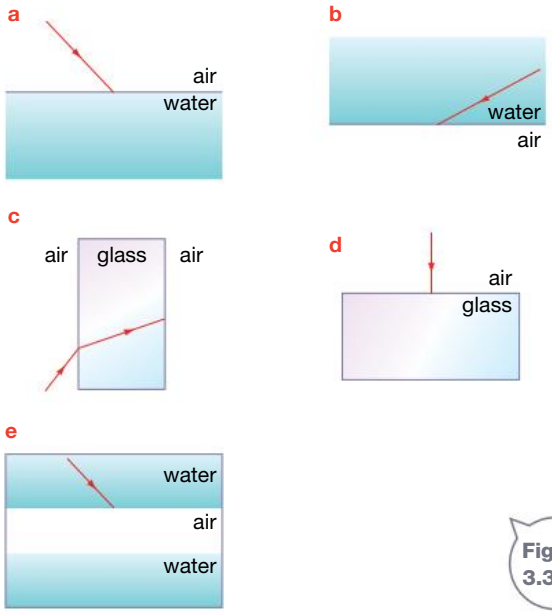


Figure 3.3.24

19 Copy the lenses shown in Figure 3.3.25 and **construct** the path the light rays will take as they pass through each lens.

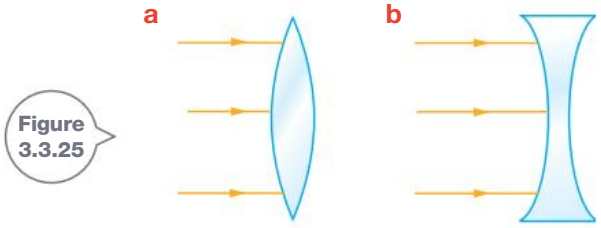


Figure 3.3.25

20 **Construct** a flowchart that lists the structures and fluids light travels through on its journey from entering your eye until it reaches your retina.

Inquiring

1 Find online images of optical illusions caused by refraction and total internal reflection like those seen in Figure 3.3.8 on page 117, Figure 3.3.15 on page 120 and Figure 3.3.16 on page 121.

Present your images as a digital slide show. ICT

2 Research an optical instrument such as a data projector, camera, telescope or microscope. Construct a labelled diagram that explains how it operates.

Present your findings as a poster.

3.3 Practical investigations

1 Law of reflection

Purpose

To verify the law of reflection.

Materials

- light box and power supply
- sheet of white paper
- plane mirror
- ruler
- pencil
- protractor

Procedure

1. In your workbook, construct a table like the one shown in your Results section.
2. Set up the equipment as shown in Figure 3.3.26, marking the positions of the back of the mirror and the normal line.

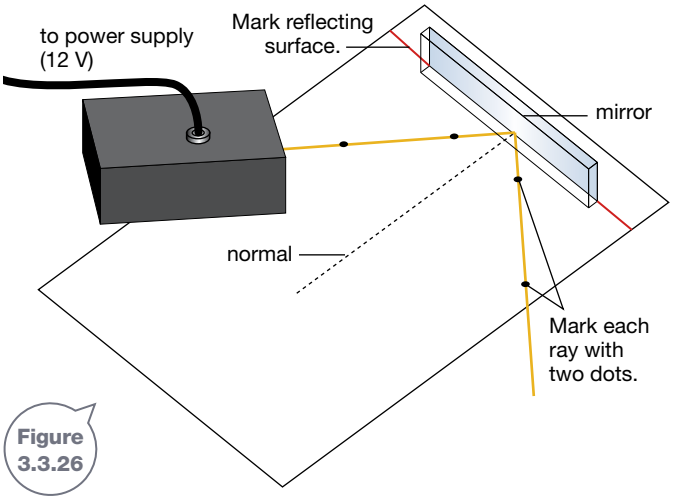


Figure 3.3.26

2. Direct a ray of light on an angle towards the centre of the mirror.
3. Mark the position of the incident and reflected rays using two dots, and then use your ruler to draw these rays on the paper. Label these 'ray 1.'
4. Repeat this process for three more rays of different angles.
5. Direct a ray at right angles into the mirror and observe its reflection. Record your observations in a table like the one shown in the Results section.

Results

1. Record all results in your table.

Ray	Angle of incident ray	Angle of reflected ray
1		
2		
3		
4		

2. Select a ray from your diagram and measure the angle that its incident ray (incoming ray) makes to the normal. Enter the angle in the table.
3. For the same ray, measure the angle that the reflected ray makes to the normal. Enter this angle in the table.
4. Complete the table for each ray tested.

Practical review

1. **Assess** whether your results support the law of reflection.
2. **Describe** what happened when you directed light at right angles to the mirror.
3. **List** at least three examples where you have observed the law of reflection in action (for example, at a cricket match when the ball bounces off the pitch).

Turning the world upside down SciFile

Experiments have been conducted in which people have worn lenses that flip the world upside down. After about a week of bumping into the furniture, they reported that their brain adjusted its view and perceived this view as the right way up. When the glasses were then taken off, everything was upside down again for a while!

3.3 Practical investigations

2 Bending light

Purpose

To observe and measure the refraction of light as it passes through a transparent block.

Materials

- plastic or glass rectangular block and semicircular block
- light box and single-slit slide
- 12 V power supply
- sheet of white paper
- protractor
- ruler
- pencil

Procedure

1 In your workbook, construct a table like the one shown in your Results section.

2 Set up the equipment as shown in Figure 3.3.27. Trace around the glass block with a pencil and use a protractor to rule a normal at 90° to the surface half-way along the edge.

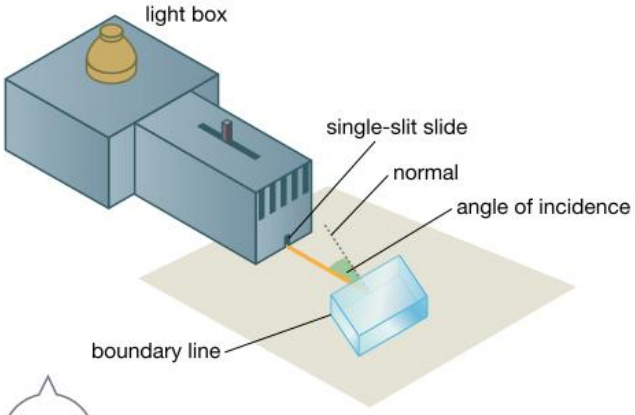


Figure 3.3.27

2 Direct a single ray of light at the centre of the block.

3 Mark a series of dots on the paper to trace the path of light incident on, refracted through and refracted out the other side of the glass block.

4 Remove the glass block and use a ruler to draw the path the light followed on the paper. Add a normal at the point where light left the glass block.

5 Make angle measurements with a protractor to complete a copy of the table shown in the Results section.

6 Replace the rectangular glass block with the semicircular block, with its curved side facing the incoming light.

7 Move the light box in an arc to alter the angle of incidence of light at the centre of the block. Find the critical angle for the semicircular block and investigate what happens for smaller and larger angles of incidence.

Results

Record all measurements in your table.

	Angle of incidence	Angle of refraction
Light entering glass from air		
Light entering air from glass		

Practical review

1 **State** whether light bends towards or away from the normal when it:
   a enters the glass block
   b leaves the glass block.

2 **Compare** the size of the angle at which light enters the glass block with the angle at which it leaves.

3 **Describe** whether all the light hitting the glass block was refracted through it, or whether some light followed a different path.

4 **State** the critical angle for the semicircular block.

5 **Describe** what you observed happening with the semicircular block when the angle of incidence was smaller or larger than the critical angle.

3 Comparing curved mirrors and lenses

Mirrors can be curved and can produce real and virtual images in a similar way to lenses. A concave mirror curves inwards like a cave, whereas a convex mirror bulges outwards. A concave mirror can be used to produce a real image. Concave mirrors are used in astronomical telescopes.

Purpose

To investigate how light is reflected and refracted from curved mirrors and lenses.

Materials

- light box with 12 V power supply
- multiple-slit slide
- set of curved mirrors and lenses of different strengths
- pencil
- several sheets of white paper

Procedure

1. Place a multiple-slit slide in the light box and position it on a sheet of white paper.
2. Place a concave mirror in the path of the light rays as shown in Figure 3.3.28.
3. Use a pencil to mark two dots for each incident and reflected ray on the sheet of paper.

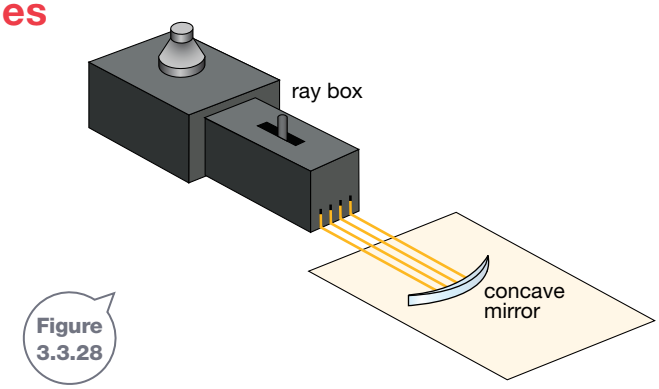


Figure 3.3.28

4. Remove the mirror and trace these rays onto the page. Also show the position of the mirror.
5. Repeat the procedure for a concave mirror of different curvature, two convex mirrors, two concave lenses and two convex lenses, all of different thickness. Use a new sheet of paper for each sketch.

Practical review

1. **Describe** differences between how the concave and convex mirrors reflected light.
2. **Describe** the effect of using a more curved mirror.
3. **Compare** the way light passed through the convex and concave lenses.
4. **Describe** the effect of using a thicker convex lens compared to a thinner lens.

STUDENT DESIGN

4 Pinhole cameras and blind spots

Purpose

To investigate the properties of light.

Materials

To be selected by students

SAFETY

A risk assessment is required for this investigation.

Procedure

1. Search the internet for instructions to: ICT
   a. make a simple pinhole camera
   b. test your blind spot.
2. Print or save the instructions you find. Before you start any practical work, assess all risks associated with the instructions. Construct a risk assessment that outlines these risks and any precautions you need to take to minimise them. Show your teacher your instructions and risk assessment. If they approve, then collect all the required materials and start work.

Practical review

1. **Use** the terms from this unit to **describe** the images formed with the pinhole camera.
2. **Construct** a diagram showing how the image with a pinhole camera is formed.
3. **Explain** what happened in the blind spot test.
4. **Propose** reasons why you do not normally notice your blind spots.

3 Chapter review

Remembering

1 **List** the three processes of heat transfer.

2 **Name** the only process that can transfer heat through the vacuum of space.

3 **State** whether sound travels fastest in a solid, a liquid or a gas.

4 **List** the parts that make up the middle ear.

5 A beam of light hits a plane mirror at an angle of 45°. **State** the angle at which it is reflected.

Understanding

6 **Explain** how a sea breeze forms.

7 **Describe** what is likely to happen to infrared radiation that hits a:

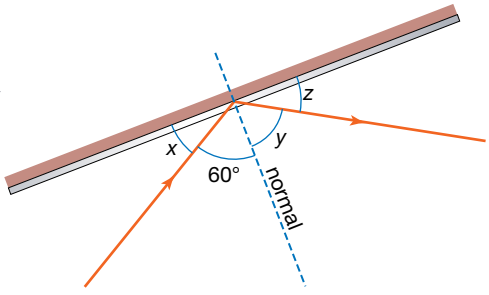
- **a** black plastic pot plant
- **b** white shade sail over a sandpit
- **c** glass window on a boat.

8 Kim toasts marshmallows on an open fire. Although she can't see any flames, she can still feel heat from the fireplace. **Explain** why.

9 **Describe** how the pitch of a violin string can be changed.

10 **Predict** the sizes of angles *x*, *y* and *z* in Figure 3.4.1.

Figure 3.4.1



11 **Explain** whether an image projected from a data projector onto a wall is real or virtual.

Applying

12 **Identify** what vibrates in each musical instrument below to produce a sound.

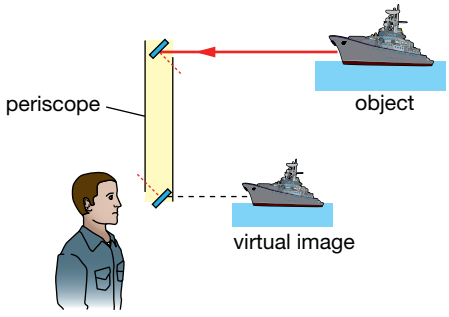
- **a** harp
- **b** trumpet
- **c** bongo drum

13 Perspex has a greater refractive index than ice does.

- **a** **Identify** in which material light travels faster.
- **b** If light travels from ice into Perspex, **state** whether it will bend towards or away from the normal.

14 A periscope is used in a submarine to allow sailors to see what is above the surface of the water. Copy Figure 3.4.2 and complete the path of a ray of light to **demonstrate** how this works.

Figure 3.4.2



15 A light ray travels through material X and hits the boundary of the transparent material Y at an angle of 40° to the surface. It is then refracted into material Y at an angle of 35°. **Identify** whether X or Y has the greater refractive index.

Evaluating CCT

16 **a** **Determine** whether or not you can answer the questions on page 89 at the start of this chapter.

b **Assess** how well you understand the material presented in this chapter.

Creating CCT

17 A seagull circling overhead spies a fish below, as shown in Figure 3.4.3. **Construct** a diagram to show where the fish appears to be when seen by the seagull.

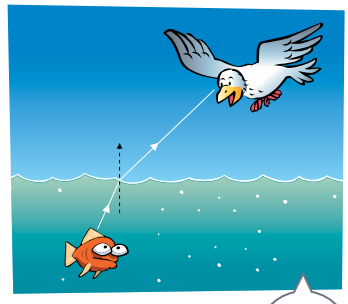


Figure 3.4.3

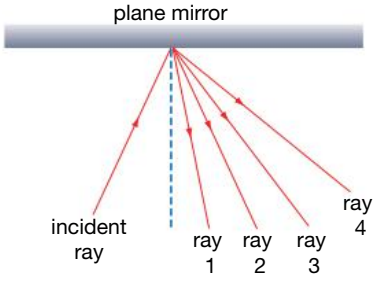
18 **Use** the following ten key terms to **construct** a visual summary of the information presented in this chapter:

heat	temperature
conduction	convection
radiation	sound
frequency	wavelength
light	image

3.8

Thinking scientifically

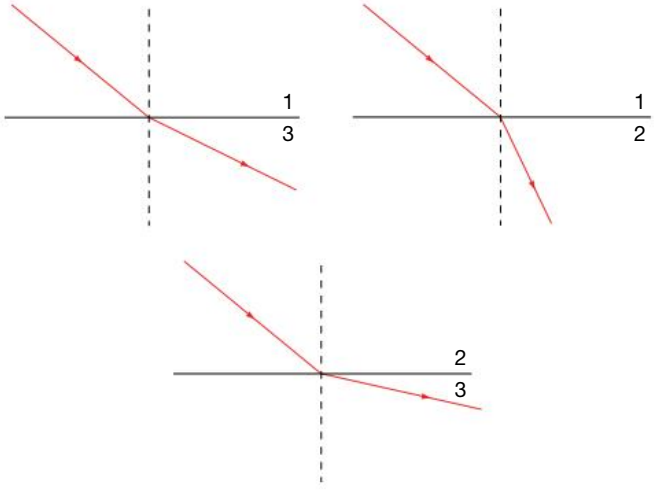
Q1 Light reflects from a plane mirror at an angle equal to the angle at which it hits the mirror. Josh directs a ray from a light box onto a plane mirror, as shown in the diagram. CCT



The reflected ray in Josh's experiment is:

A ray 1
B ray 2
C ray 3
D ray 4

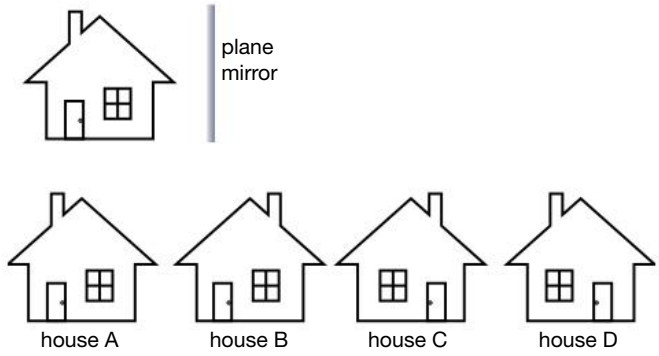
Q2 Light refracts (bends) towards the normal when it travels from one medium into another of higher refractive index. It bends away from the normal when travelling into a substance of lower refractive index. Study the ray diagrams as light travels between materials 1, 2 and 3. CCT



The materials listed from least to greatest refractive index are:

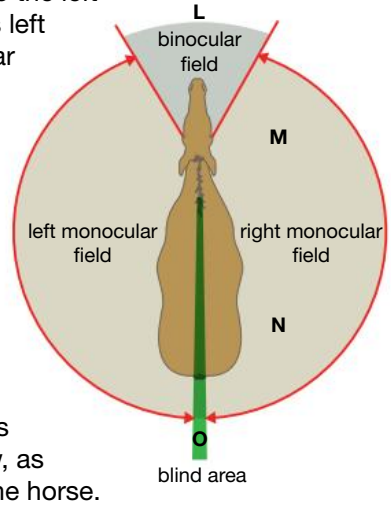
A 1, 2, 3
B 3, 1, 2
C 2, 1, 3
D 1, 3, 2

Q3 In a plane mirror, light is laterally inverted (reflected from left to right). Select the correct image of the house as it appears when reflected through a plane mirror. CCT



A house A
B house B
C house C
D house D

Q4 A horse has one of the largest pairs of eyes of any animal. The horse has binocular vision and therefore a limited field of view. In this field of view, the horse can easily judge distances between objects. It also has a wide field of monocular vision to the left and right, called its left and right monocular fields. The horse cannot judge distances as effectively between objects it sees in these fields. In a small region behind the horse, it has no vision.



The diagram shows these fields of view, as seen from above the horse.

Identify which of the 1-metre tall objects, L, M, N and O, can be seen by the horse without turning its head. CCT

A only L
B only M and N
C L, M and N
D only L and O

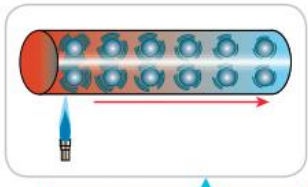
Glossary

Unit 3.1

Absolute zero: the lowest possible temperature, –273°C

Conduction: a method of heat transfer in which heat is passed by vibration of particles

Conductor: a substance that allows heat to flow through it



Conduction

Convection: transfer of heat in a liquid or gas due to less dense, warmer matter rising and denser, cooler matter falling

Insulator: a material that does not conduct heat well

Radiation: movement of heat in the form of electromagnetic waves, which can travel through a vacuum

Temperature: a measure of the average kinetic energy of particles in a substance that results in how hot or cold the substance is

Thermometer: an instrument used to measure temperature

Unit 3.2

Compression: a region of high pressure in which particles are close together

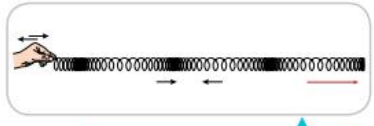
Decibel (dB): unit used to measure loudness

Echo: a sound that is reflected and heard a second time

Frequency: the number of waves passing a point every second

Hertz (Hz): the unit used to measure frequency

Longitudinal wave: a wave in which the vibration is in the same direction as the wave is travelling

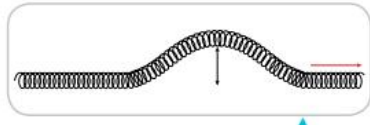


Longitudinal wave

Rarefaction: a region of low pressure in which particles are far apart

Sound wave: regions of high and low pressure originating from a vibrating object and transmitted through a medium

Transverse wave: a wave in which the vibration is at right angles to the direction the wave is travelling



Transverse wave

Wavelength: the distance from one peak of a wave to the next

Unit 3.3

Angle of incidence, *i*: the angle an incoming ray makes with the normal

Angle of reflection, *r*: the angle a reflected ray makes with the normal

Angle of refraction, *r*: the angle a refracted ray makes with the normal

Concave lens: a lens that curves inwards

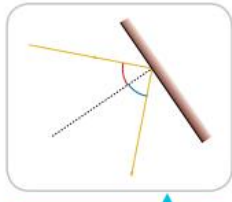
Convex lens: a lens that bulges outwards

Critical angle: the angle of incidence of light that produces an angle of refraction of 90°

Incident ray: incoming ray

Lateral inversion: the sideways or left-to-right reversal of an image in a plane mirror

Law of reflection: the law stating that light is reflected at the same angle that it is incident, or $i = r$



Law of reflection

Luminous: an object that releases or emits light

Normal: an imaginary line that is drawn at right angles to a surface that light is incident upon

Plane mirror: a flat mirror

Real image: an image formed when rays of light actually meet

Refraction: the bending of light as it passes from one substance into another substance

Refractive index: a measure of how easily light travels through a substance

Total internal reflection: when light is completely reflected from the boundary of two substances; it occurs when the angle of incidence is greater than the critical angle

Virtual image: an image formed in which the rays of light do not actually meet, but only appear to meet at a point inside the mirror

4 Electromagnetic radiation

Have you ever wondered...

- how an X-ray image is formed?
- why some objects glow in the dark?
- how night-vision goggles work?
- how 3D glasses work?

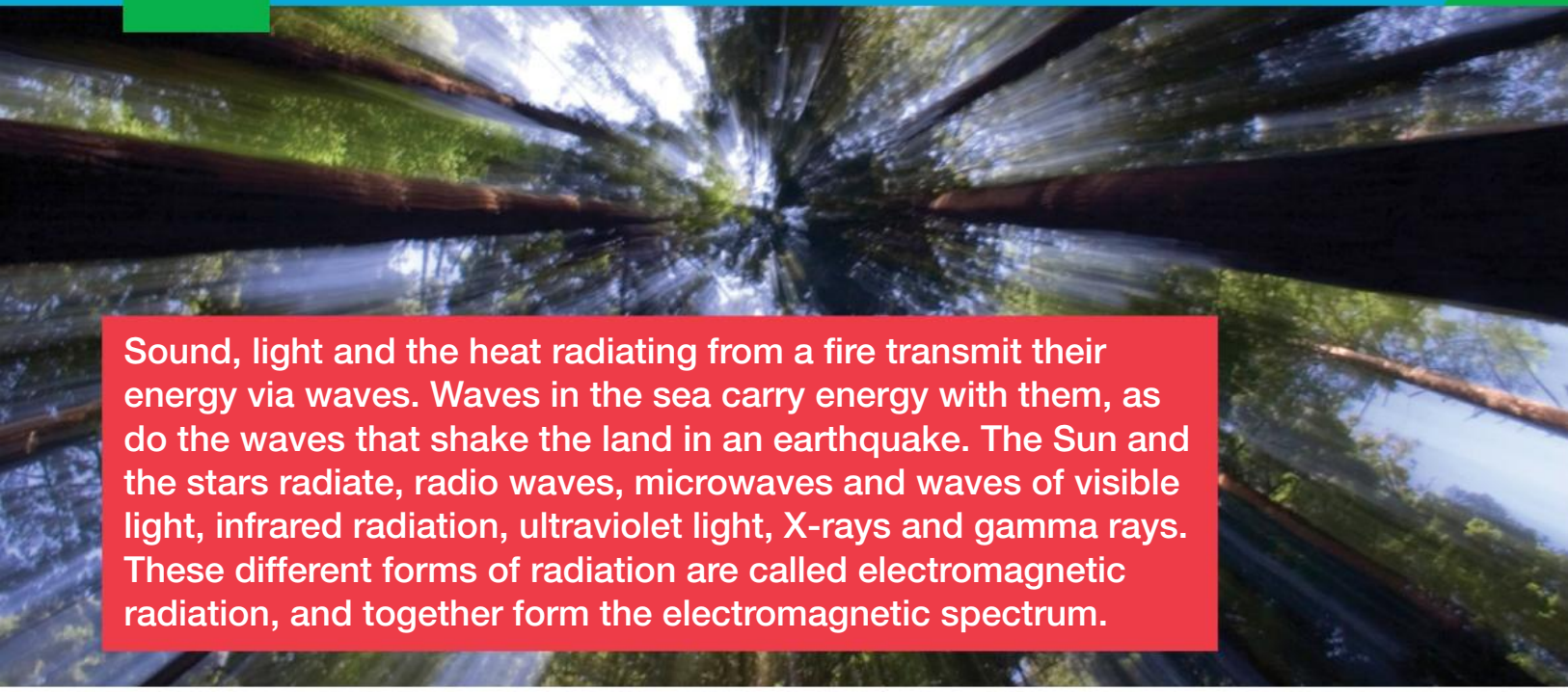
After completing this chapter students should be able to:

- identify situations where waves transfer energy
- use the wave model to qualitatively describe wavelength, frequency and speed
- describe the properties of different types of radiation in the electromagnetic spectrum, their uses in everyday life and communications technology CCT
- describe absorption, reflection and refraction CCT

ADDITIONAL

- investigate quantitatively frequency, wavelength and speed using $v = f\lambda$, and relate this to musical instruments N
- relate scattering and dispersion of light to everyday occurrences.

4.1 Waves



Sound, light and the heat radiating from a fire transmit their energy via waves. Waves in the sea carry energy with them, as do the waves that shake the land in an earthquake. The Sun and the stars radiate, radio waves, microwaves and waves of visible light, infrared radiation, ultraviolet light, X-rays and gamma rays. These different forms of radiation are called electromagnetic radiation, and together form the electromagnetic spectrum.

Wave motion

Figure 4.1.1 shows the wave motion of ripples created from a droplet of water. These ripples travel outwards from the point where the droplet hit the water. The energy of the impact travels outwards, but the actual water particles making up the wave only move up and down.

The transfer of energy without the transfer of matter is called **wave motion**. There are two types of waves that can transfer energy. The particles of a transverse wave vibrate at right angles to the direction of motion of the wave.

GO TO Unit 3.2

Figure 4.1.1 A water droplet hitting a pool of water triggers the spread of circular waves outwards from where it hit the surface.

Examples of transverse waves are the waves you see on the ocean and the waves you can flick along a rope, slinky spring or hose. In a longitudinal wave the particles vibrate backwards and forwards in the same direction as that of the wave. Sound waves are longitudinal waves. Both these types of wave are shown in Figure 4.1.2.

Prac 1 p139

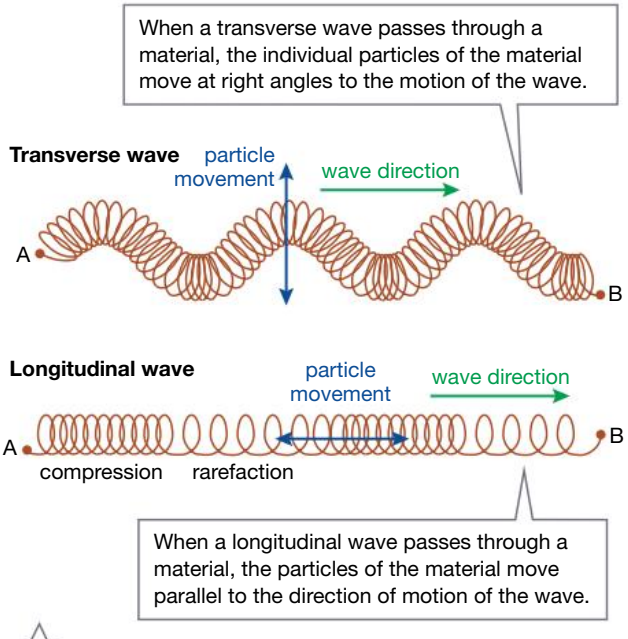


Figure 4.1.2 Transverse waves and longitudinal waves both transfer energy but in very different ways.

Wave properties

The number of waves produced each second is called the **frequency** of the wave. Frequency is measured in hertz (Hz), which means cycles (waves) per second.

Wavelength is the distance between two successive waves and is usually measured in metres. The wavelength of some radio waves is several kilometres, whereas the wavelength of visible light is less than one thousandth of a millimetre.

The **amplitude** of a wave is the maximum distance it extends beyond its middle position. Figures 4.1.3 and 4.1.4 show the wavelength and amplitude of transverse and longitudinal waves.

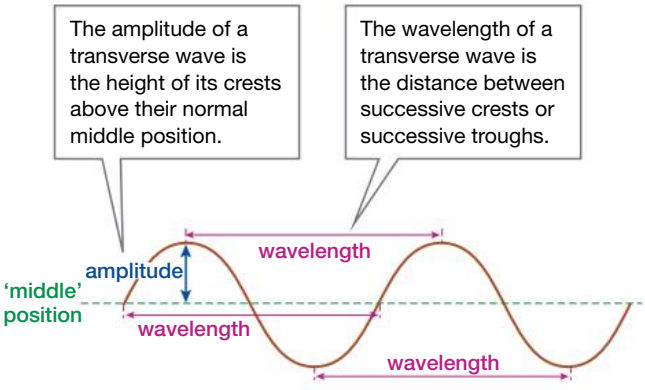


Figure 4.1.3 The amplitude and wavelength of a transverse wave. The number of these waves passing a given point each second is the frequency of the wave.

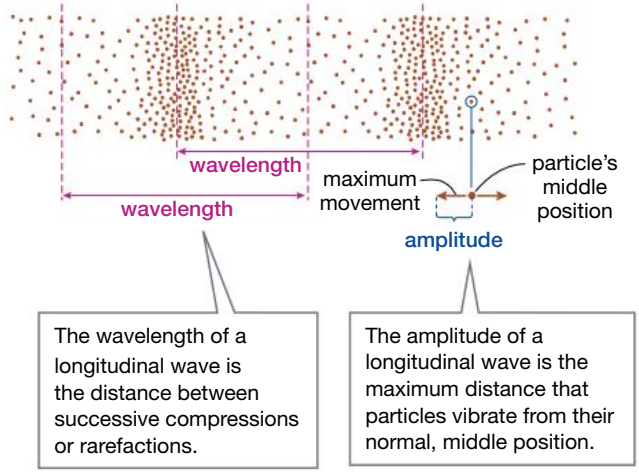


Figure 4.1.4 The amplitude and wavelength of a longitudinal wave. Its frequency is the number of waves passing a given point each second.

For two waves of the same frequency, the larger the amplitude of the wave, the more energy is carried by the wave. This relationship is shown in Figure 4.1.5.

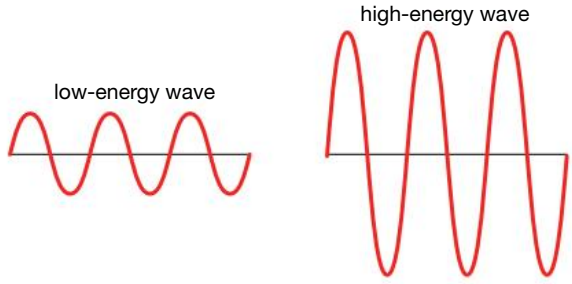
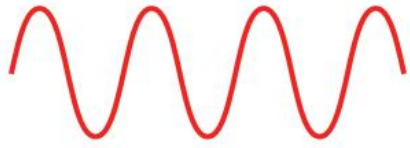


Figure 4.1.5 Both these waves have the same frequency and wavelength. The taller wave has the greater amplitude and so it carries more energy.

The wave equation

The speed, wavelength and frequency of a wave are linked by a special relationship. This is called the wave equation. This means that if the frequency of a wave increases, then its wavelength will decrease. Alternatively, if the frequency of a wave decreases, then its wavelength increases. This relationship is shown in Figure 4.1.6.

Wave A



Given that wave A and B are travelling at the same speed.
Wave A has a:
- higher frequency and
- shorter wavelength than wave B.

Wave B

Wave B has a:
- lower frequency and
- longer wavelength than wave A.

Prac 2 p140

Figure 4.1.6 Frequency is the number of waves passing every second. The more bunched up the waves, the higher their frequency and the shorter their wavelength.

ADDITIONAL

The wave equation

The speed, wavelength and frequency of a wave depend upon each other and are linked by a formula called the wave equation:

$$v = f\lambda$$

where: v = speed of wave (m/s)

f = frequency of wave (Hz)

λ = wavelength of wave (m)

(The symbol for wavelength is λ, a letter from the Greek alphabet. The letter is called lambda.)

The equation can be rearranged to calculate frequency:

$$f = \frac{v}{\lambda}$$

It can also be rearranged to calculate wavelength:

$$\lambda = \frac{v}{f}$$

Musical instruments and the wave equation

The wave equation determines what you hear when playing a musical instrument. For example, when you strike a guitar string, it vibrates to form a transverse wave. More correctly, it forms half a wave as shown in Figure 4.1.7.

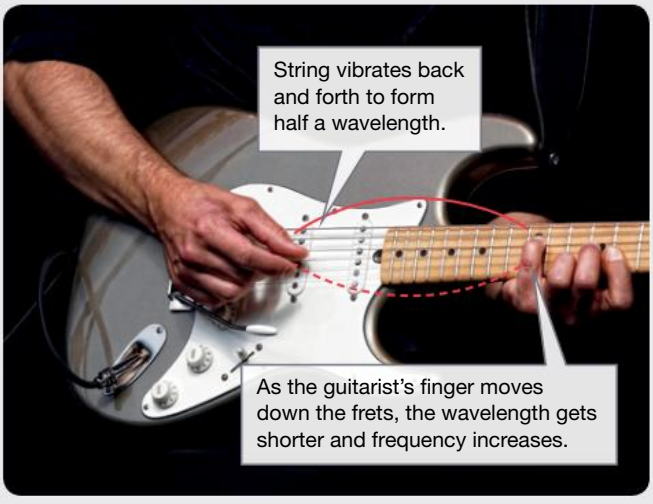


Figure 4.1.7 Wavelength decreases as you shorten a string, so the frequency of the note increases.

WORKED EXAMPLE

Wave equation calculations

Problem 1

At a beach, a wave hits the shore every 10 seconds. This means they have a frequency of $\frac{1}{10}$ Hz, or 0.1 Hz. If there is 6 m between successive waves, calculate the speed of the waves.

Solution

$f = 0.1$ Hz

$\lambda = 6$ m

Using the wave equation,

$v = f\lambda$

$= 0.1 \times 6$

$= 0.6$ m/s

Problem 2

The highest note produced on a typical piano has a frequency of 4100 Hz. Given that the speed of sound in air is 330 m/s, calculate the wavelength of this sound wave.

Solution

$\lambda = \frac{v}{f}$

$= \frac{330}{4100}$

$= 0.08$ m

This means the sound wave has a wavelength of 0.08 m or 8 cm.

Practice N

1. Goran strikes a tuning fork in class and produces a note of frequency 440 Hz. If the speed of sound is 330 m/s, then **calculate** the wavelength of the sound produced.
2. Felicity produces a sound of wavelength 2 m. If the speed of sound is 330 m/s, then **calculate** the frequency of this sound wave.
3. Gary flicks a hose twice every second to form a wave with a wavelength of 1.5 m. **Calculate** the speed of the wave as it travels down the hose.

By moving your finger along the frets you shorten the vibrating length of the string. Whatever note you play on a particular string, the speed of the wave along that string is the same. As the wavelength decreases, the frequency of the note (its pitch) increases.

Place your finger on exactly the same fret but on a different string and you get a note of a different frequency. This is because different strings have different thicknesses, are made from different materials and are under different tensions. This combination of factors alters the speed of the wave that travels down them when struck. The wavelength might be the same but the speed is now different and so its frequency is different too.

Other stringed instruments such as violins and cellos work in much the same way. Pianos and harps have many strings of different lengths. Each string vibrates to form a particular wavelength and a particular frequency.

Wind instruments such as trombones form longitudinal compression waves that travel down the tube of the instrument. This tube is filled with air and the speed of the sound wave travelling down it is always the same. Lengthen the tube and the wavelength in the tube increases (Figure 4.1.8). As a result, the frequency of waves produced decreases and deeper notes are heard. Other wind instruments such as recorders and clarinets do not physically alter the length of their tubes but instead let air escape through holes. Opening holes shortens the effective length of the tube and the wavelengths formed in it. As a result, the frequency of sound produced is increased and higher notes are heard.

4.1

Figure 4.1.8 Wind instruments form different notes by changing the length of their tubes.

ADDITIONAL

What is electromagnetic radiation?

When electric charges move, such as when electric current flows in a wire, a magnetic field is generated around the wire. Similarly, a changing magnetic field generates an electric field. This property is called electromagnetism. It is used to generate electricity in a typical power station and to run electric motors.

GO TO Unit 5.3

The Scottish scientist James Clerk Maxwell (1831–79) suggested that a changing electric field could create a changing magnetic field, which would in turn create a changing electric field. These fields would continue to generate each other. He proposed that changing magnetic fields and changing electric fields travel through space as transverse waves at right angles to each other. This is the structure of an electromagnetic wave. You can see it in Figure 4.1.9.

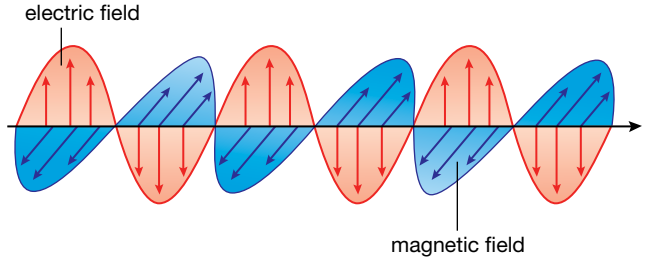


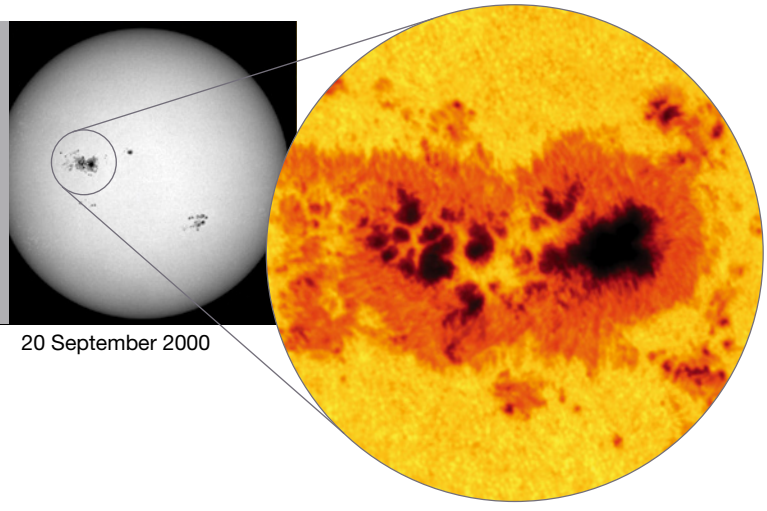
Figure 4.1.9 Electromagnetic waves travel as two interconnected electric and magnetic fields moving as transverse waves.

Electromagnetic waves are generated naturally in our upper atmosphere and from stars, including our Sun. Visible light, microwaves and X-rays are examples of **electromagnetic radiation**. These forms of energy travel through space as **electromagnetic waves**.

Solar flares

Solar flares are enormous explosions that occur on the surface of the Sun. They release incredible amounts of energy across the electromagnetic spectrum, including gamma rays, X-rays, and high-speed protons and electrons. One solar flare releases approximately ten million times more energy than that of an erupting volcano.

SciFile



20 September 2000

The electromagnetic spectrum

The entire range of frequencies of electromagnetic radiation that can be produced is called the **electromagnetic spectrum**. This ranges from low-energy radiation, such as radio waves, through to high-energy gamma radiation. As the energy of the radiation increases, the frequency of the electromagnetic waves increases, and the wavelength decreases. Electromagnetic waves all travel at the speed of light, which is 300 000 km/s. The electromagnetic spectrum is shown in Figure 4.1.10.

Electromagnetic waves can travel through empty space, gases, liquids and some solids. When a substance absorbs any kind of electromagnetic radiation, it also absorbs its energy. The substance may heat up or change in some way. For example, sunlight causes the sand on a beach to heat up and a solar cell can convert light into an electric current.

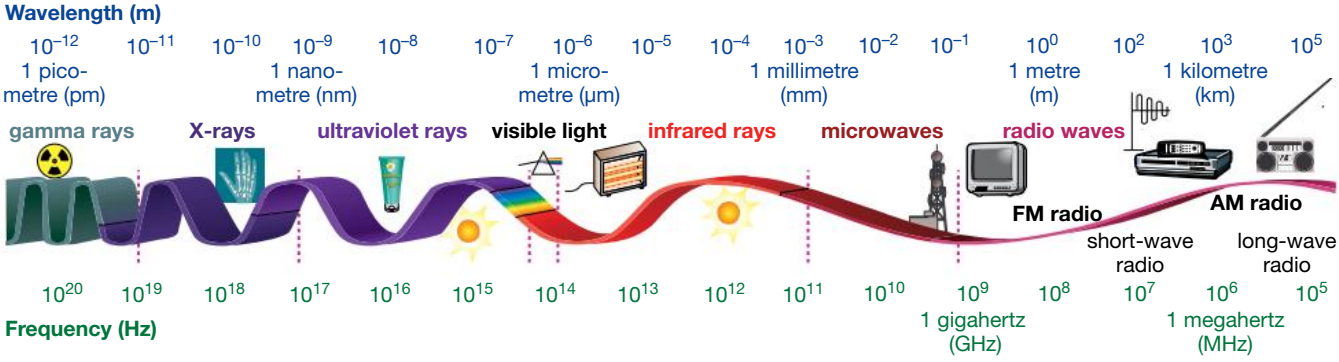


Figure 4.1.10 The electromagnetic spectrum shows the complete range of electromagnetic waves that are possible. All these waves travel at the speed of light. The shorter the wavelength and the higher the frequency, the more energy is carried by the radiation.

Using scientific notation

Scientific notation is an easy way to handle very large and very small numbers. In scientific notation, numbers are written as a product of a power of ten. For example, 10 000 can be written as 1.0×10^4 (or simply 10^4).

The number at the top right of the 10 is called the exponent. For example, in 10^{19}, 19 is the exponent. When the exponent is positive, to convert the number from scientific notation to a digit, you move the decimal point this many places to the right.

For very small numbers, the exponent is negative. This indicates that to convert the number to a digit, the decimal point is moved to the left. For example, 0.000 000 1 becomes 1.0×10^{-7} (or simply 10^{-7}).

WORKED EXAMPLE
Using scientific notation

Problem

State the following in scientific notation.

a 470 000

b 0.0006

Solution

a $470\,000 = 4.7 \times 10^5$

b $0.0006 = 6.0 \times 10^{-4}$

Practice

N

State the following in scientific notation.

a 21 000 000 000

b 0.000 000 000 009

4.1 Unit review

Remembering

1 **Recall** wave motion by selecting the correct alternative in each statement.
   - a Wave motion is a transfer of energy *with/without* matter.
   - b Particles of a *transverse/longitudinal* wave vibrate at right angles to the direction of motion of the wave.
   - c The *frequency/wavelength* of a wave is the number of waves produced every second.

2 **State** whether each statement below is true or false.
   - a The electromagnetic spectrum ranges from low-energy gamma rays to high-energy radio waves.
   - b As the energy of the radiation decreases, its wavelength increases.

3 A wave is transporting energy through air from right to left. The particles of the air move back and forth in a horizontal direction. **Recall** the name of this type of wave that is travelling.

4 Refer to the transverse wave shown in Figure 4.1.11.

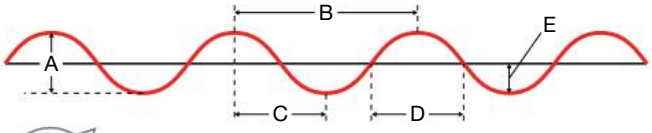


Figure 4.1.11

State the letter that corresponds to its:
   - a amplitude
   - b wavelength.

5 Julia and Skye are creating waves with a slinky spring that is stretched between them. They decide to halve the frequency of the waves they are producing. **State** what happens to the wavelength produced.

6 **State** which two types of field interact to produce an electromagnetic wave.

7 **List** five types of electromagnetic waves.

8 **State** the following in scientific notation: N
   - a 21 000
   - b 0.0085

Understanding

9 Fans in a sporting stadium sometimes move to create a wave around the stadium. **Describe** how they would need to move to create a:
   - a transverse wave
   - b longitudinal wave.

10 Atahan strikes a tuning fork of frequency 440 Hz and listens to the sound produced. Hema then strikes another tuning fork and hears a lower-pitched sound. Assuming that the speed of sound in air is constant, **describe** the difference between the wavelengths of each sound. N

11 Nisha whispers a comment to her friend Sally. **Describe** the movement of air particles as sound travels from Nisha's lips to Sally's ears.

Applying

12 **Identify** the rarefaction and compression in the sound waves created by the tuning forks in Figure 4.1.12.

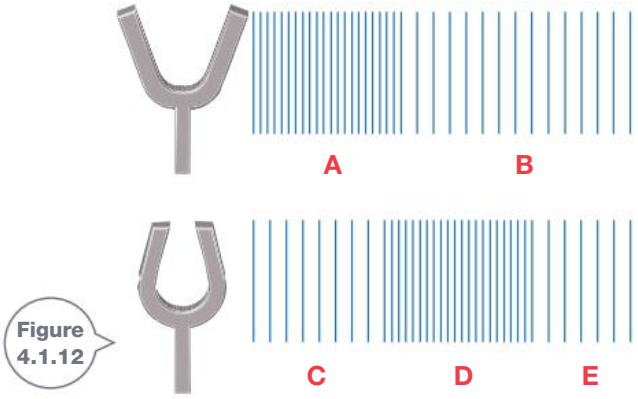


Figure 4.1.12

13 Look at the transverse wave shown in Figure 4.1.13.

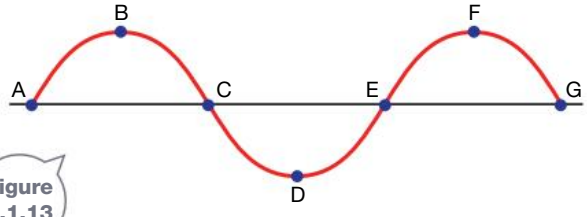


Figure 4.1.13

Identify any pairs of letters that are spaced one wavelength apart.

4.1 Unit review

14 A transverse wave in a string has an amplitude of 5 cm, a frequency of 60 Hz and a distance from crest to the next trough of 15 cm. **Identify** the wavelength of this wave. N

15 A nervous student paces up and down a corridor waiting to enter an exam room. She paces 10 times in 1 minute. **Calculate** the frequency of her pacing in hertz. N

16 **a** **Use** Figure 4.1.14 to **state** the wavelength and amplitude of: N

i wave A **ii** wave B.

b **Identify** which of these waves has the higher frequency.

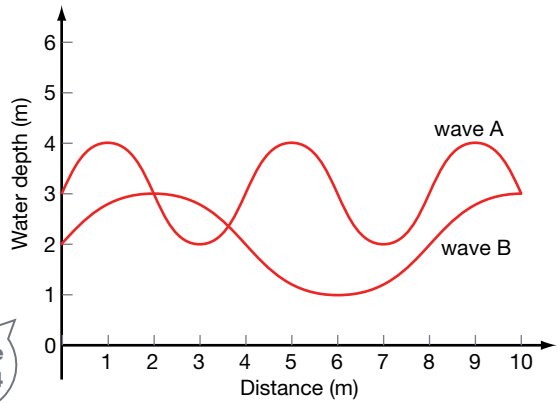


Figure 4.1.14

Analysing

17 Sound is a mechanical wave, which is different from an electromagnetic wave. **Compare** a sound wave with an electromagnetic wave.

18 **Use** Figure 4.1.10 on page 136 to **classify** the following frequencies of electromagnetic radiation. N

a **i** 1.0×10^{14} Hz **ii** 1.0×10^{22} Hz
iii 1.0×10^{10} Hz **iv** 1.0×10^{6} Hz
v 1.0×10^{16} Hz

b **Identify** which of the frequencies in part a has the greatest energy.

c **Identify** which of the frequencies in part a has the shortest wavelength.

Evaluating CCT

19 Ocean waves are continually crashing upon the shore. **Deduce** why beaches are not flooded with this continuous supply of incoming water and why the middle of the ocean does not run dry.

Creating CCT

20 **Construct** a diagram to show a transverse wave with:

a wavelength of 2 cm and amplitude of 3 cm

b wavelength of 6 cm and amplitude of 2 cm.

Inquiring

ADDITIONAL

1 If the speed and frequency of a sound wave are known, then the wave equation can be used to calculate the wavelength of the sound wave. N

- Research to find the frequency of the 'middle C' note on a piano. Express your answer in hertz (Hz).
- Given that the speed of sound in air is 340 m/s, use the wave equation to calculate the wavelength of this particular note. Express your answer in metres.
- Research to find the frequency of the C note one octave higher than middle C. Express this answer in metres.
- Given the speed of sound is 340 m/s, calculate the wavelength of sound of this note.
- The speed of sound in air is affected by temperature. Predict what would happen to the wavelength of this sound wave if the speed of sound decreased to 330 m/s.

Present your research and calculations as answers to the above tasks.

2 You can use the wave equation to calculate the wavelength of transmission of radio waves from radio stations. Research to find the frequency of transmission of your favourite radio station. N
For FM stations, this is stated in megahertz (MHz).
1 MHz = 1 000 000 Hz.

Use the wave equation stated in terms of wavelength:

$$\lambda = v/f$$

The speed of a radio wave is the same as the speed of light. This is 300 000 000 m/s.

Use speed (in m/s) and frequency (converted to Hz) to calculate the wavelength (in m) of transmission for five of your favourite radio stations.

Present your calculations in written form.

ADDITIONAL

4.1 Practical investigations

1 Making waves

Purpose

To observe how transverse waves behave in a ripple tank.

Materials

- transparent tank of water (ripple tank), with a lamp suspended over it and a screen below (or use an overhead projector and screen)
- eyedropper
- metre ruler
- block of wood
- cork

SAFETY

Be careful not to splash water near electrical power outlets

Procedure

1. Using the eyedropper, place a droplet of water into the middle of the tank.
2. Describe the shape of the wave that you see.
3. The wave crests appear as bright bands on the screen. Observe the motion of the wave as it spreads out.
4. Dip the edge of ruler into the water at one end of the tank as shown in Figure 4.1.15 and tap it up and down at regular intervals.
5. Describe the motion of the waves produced.
6. Count the number of waves passing a point on the tank in 10 seconds.

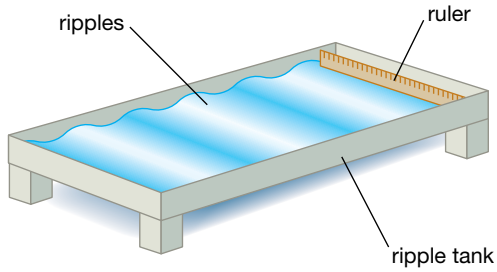


Figure 4.1.15

7. Increase the frequency of waves produced. Observe the effect this has on wavelength.
8. Place a cork in the centre of the tank, and repeat step 4. Observe the motion of the cork in the water.
9. Place a block of wood as a barrier in the path of the wave. Observe what happens as waves reach the barrier.

Results

Record your observations.

Practical review

1. **Describe** how the waves spread from a single droplet of water added to the tank.
2. **Calculate** the frequency of the wave produced in step 6.
3. **Describe** how the wavelength was affected when the frequency of waves produced increased.
4. **Construct** a conclusion for your investigation.

4.1 Practical investigations

STUDENT DESIGN

2 Wave motion

Purpose

To use materials to investigate wave motion in rope, string, water or a spring.

Materials

- Could include a slinky spring, rope, spring attached to a stand and clamp, stringed musical instrument such as a guitar, computer animation program

SAFETY

A risk assessment is required for this investigation.

Procedure

1. Design an experiment that will answer one of the following questions or another related question.
   - How does changing the frequency of a wave affect wavelength?
   - How does changing the tension of a string or spring affect the frequency of a sound wave?
   - How does the frequency of a wave change with increasing thickness and density of guitar string?
   - How does the frequency of a pendulum vary with the size of the hanging mass?
2. Brainstorm in your group and come up with several different ways to investigate the problem. Select the best procedure and write it in your workbook. Draw a diagram of the equipment you need.
3. Write a hypothesis for your investigation.
4. Before you start any practical work, assess all risks associated with your procedure. Construct a risk assessment that outlines these risks and any precautions you need to take to minimise them. Show your teacher your procedure and risk assessment. If they approve, then collect all the required materials and start work.

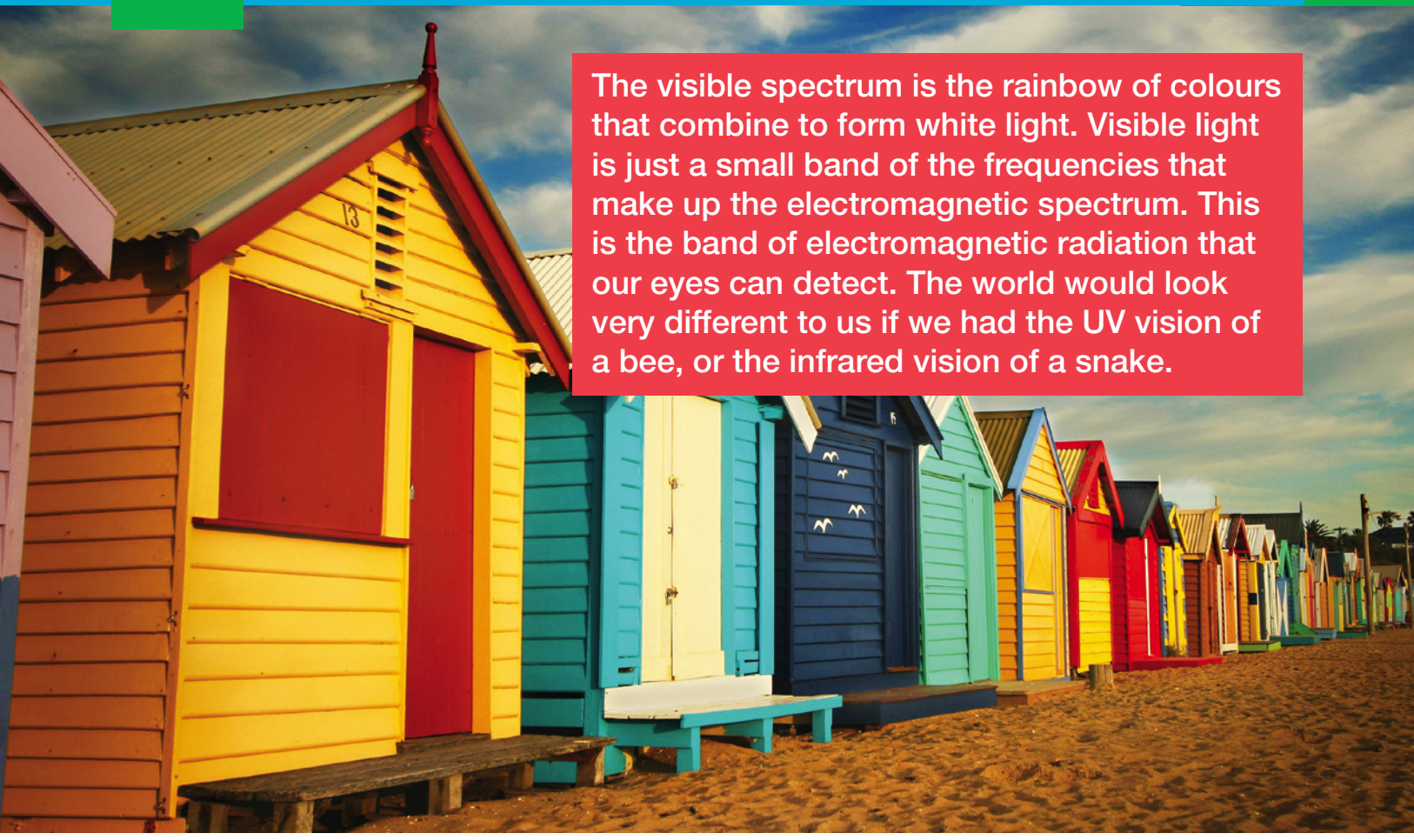
Results

1. Record your observations in written format, or photograph your wave motion.
2. Describe what you observed when changing variables in your investigation.

Practical review

1. **Construct** a conclusion for your investigation.
2. **Assess** whether your hypothesis was supported or not.
3. **Identify** any sources of error in your investigation.
4. **Evaluate** your procedure. Pick two other prac groups and **evaluate** their procedures too, identifying their strengths and weaknesses.

4.2 The visible spectrum



The visible spectrum is the rainbow of colours that combine to form white light. Visible light is just a small band of the frequencies that make up the electromagnetic spectrum. This is the band of electromagnetic radiation that our eyes can detect. The world would look very different to us if we had the UV vision of a bee, or the infrared vision of a snake.

Colour

In 1666, the English scientist Isaac Newton (1642–1727) passed a narrow beam of light through a glass prism. As the light exited the prism, Newton could see the colours of the rainbow, as shown in Figure 4.2.1. Newton realised that white light consists of all of the colours of the **visible spectrum**. He classed the colours making up this spectrum as red, orange, yellow, green, blue, indigo and violet. When all the colours shine at once, they produce white light.

Each colour of light has a different wavelength and frequency. These are shown in Figure 4.2.2 on page 142. The wavelengths of visible light are extremely small, ranging from violet light with wavelengths around 400 nm, through to red light with wavelengths around 700 nm. To get an idea of how small this is, consider that 1 nm (nanometre) = 1.0×10^{-9} m. This means that the wavelengths of visible light are less than one-thousandth of a millimetre long, or about one-hundredth the width of a human hair.

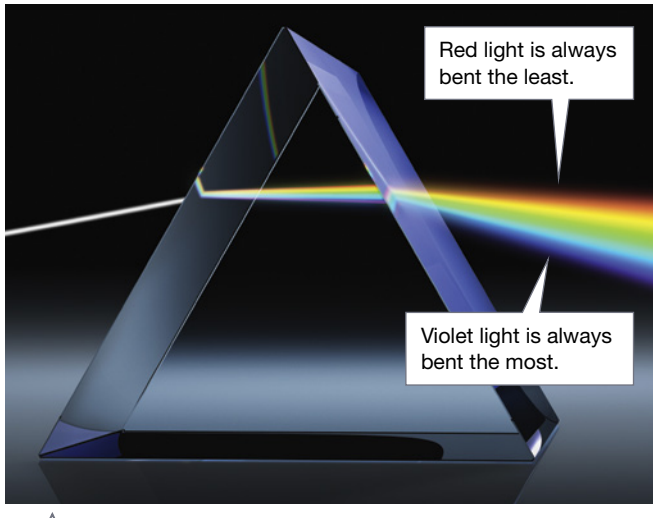


Figure 4.2.1 When white light passes through a prism, each individual frequency of light is refracted (bent) by a slightly different amount.

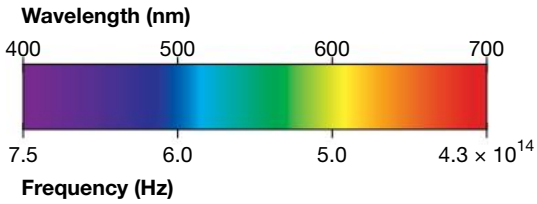


Figure 4.2.2 Visible light is a very small portion of the complete electromagnetic spectrum. It is the only band that is visible to our eyes. About 1000 waves of visible light fit into 1 mm.

Seeing in colour

Some apples are red, while others are green. This is because pigments on the surface of the apple determine its colour. An apple viewed under white light looks red if it reflects red light towards your eyes (like the apple in Figure 4.2.3) and absorbs orange, yellow, green, blue, indigo and violet light. In reality, the red apple may reflect a little orange light as well, but this just affects the shade of red that you see. In the same way, a blue yo-yo reflects blue light (and probably a little green and violet) and absorbs all other colours of light. A white car reflects most of the light and radiant heat that hits it. In comparison, a black car reflects very little light or radiant heat. Most of this radiant heat and light is absorbed. As a result, a black car heats up more rapidly than a white car on a fine day.

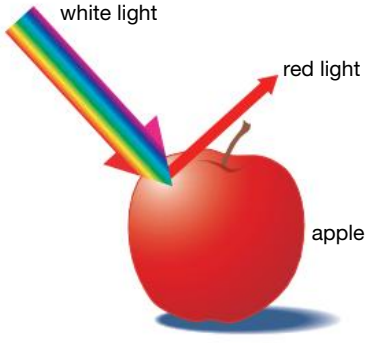


Figure 4.2.3 A red apple reflects red light and absorbs the other six colours of the visible spectrum.

Objects that are viewed under different coloured lights may look quite different from when they are viewed under white light. For example, compare the four candles in Figure 4.2.4 viewed under white light and then red light.

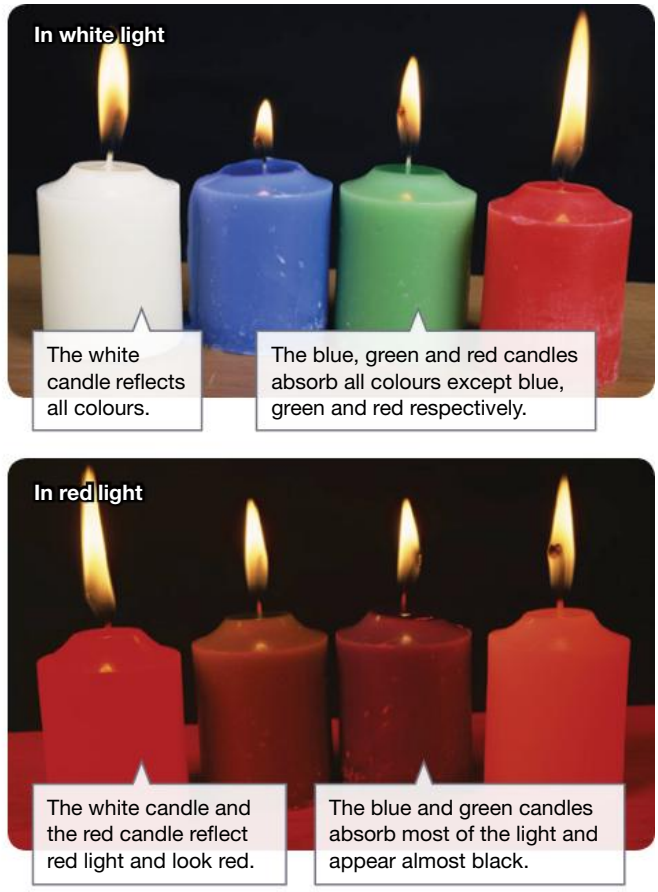


Figure 4.2.4 Coloured candles look very different under different-coloured lights.

Primary colours

White light can be produced by shining all colours together. White light can also be made by using just three colours of the spectrum—red, green and blue. For this reason, these are called the **primary colours** of the spectrum. When you combine light of the primary colours in pairs, the three **secondary colours**—magenta, cyan and yellow—are produced. These combinations are shown in Figure 4.2.5.

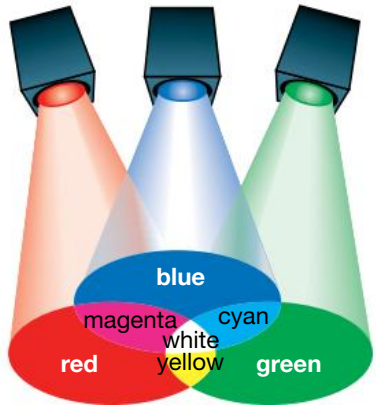


Figure 4.2.5 Red and blue light produce magenta light, red and green light produce yellow light, and blue and green light produce cyan light. Combinations of the primary colours of light (red, green and blue), produce white light.

Colour vision

Your eyes have three types of colour-sensitive photoreceptor cells, called cones. Each type of cone is sensitive to one of the three primary colours. Combinations of signals from these three types of cell give us our full colour view of the world. About 8 % of males have problems with colour vision and are said to be colour blind. This condition is rare in females. The most common form of colour blindness is confusion between shades of red and green. An Ishihara test card, similar to that shown in Figure 4.2.6, is used to test for colour blindness.

Colour filters

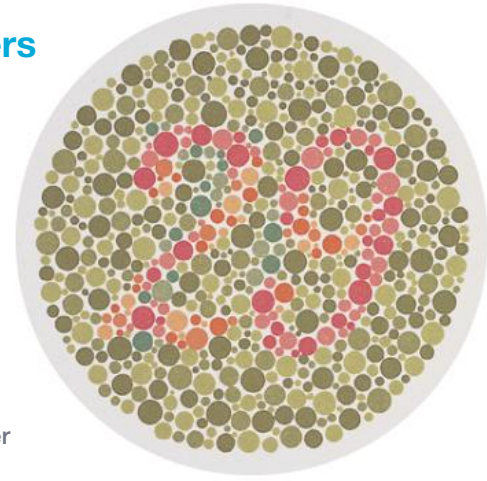


Figure 4.2.6 A person with normal vision will see a particular number in this test. What number can you see?

A red apple absorbs all colours of the visible spectrum except red light. Similarly, a red piece of cellophane absorbs all colours except red light, which passes straight through. The cellophane acts as a **colour filter**.

A colour filter only allows light of its particular colour to be transmitted. Figure 4.2.7 shows the way some combinations of light are transmitted or absorbed by a filter. Coloured filters are used widely in photography and the theatre to provide a range of lighting effects. Coloured filters are also used to create 3D effects, as shown in Figure 4.2.8.

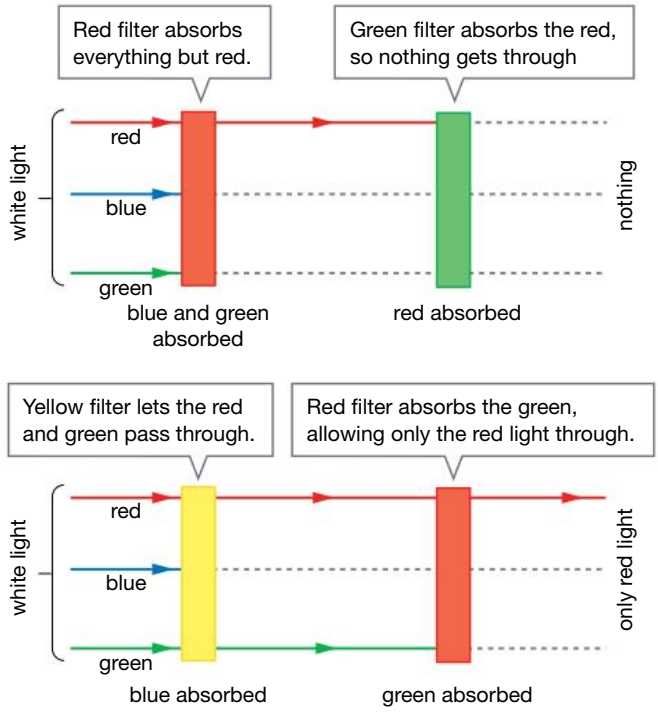


Figure 4.2.7 Different coloured filters absorb different colours, and so they affect what you see.

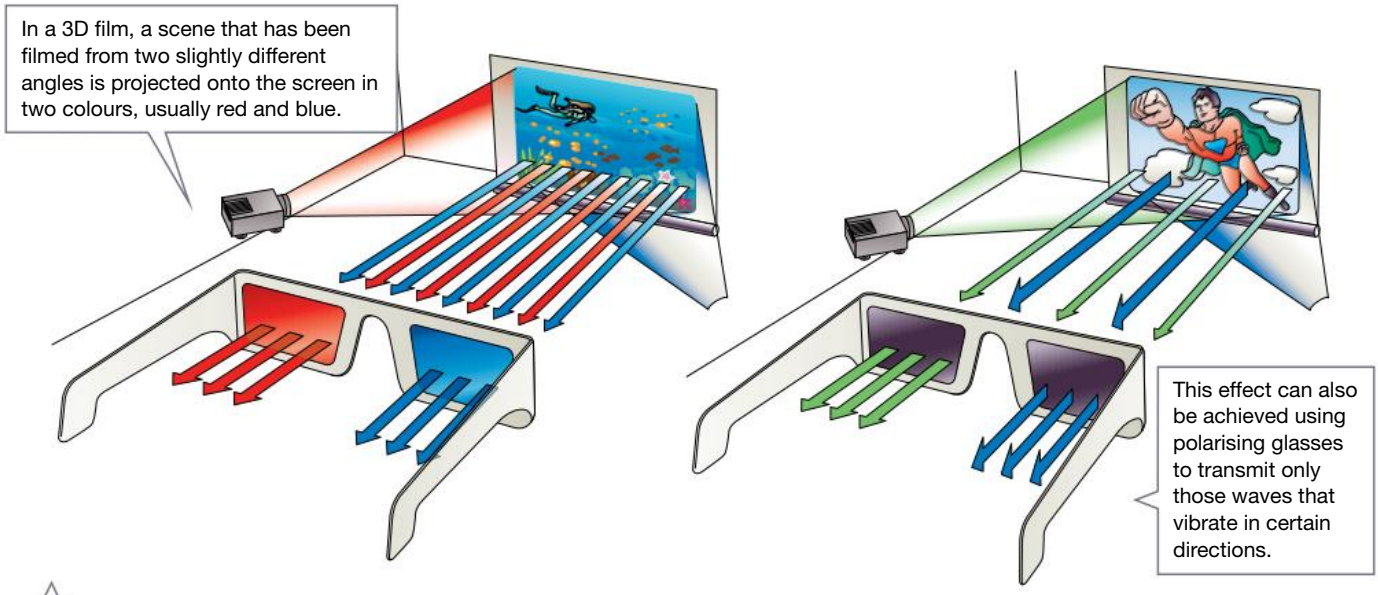


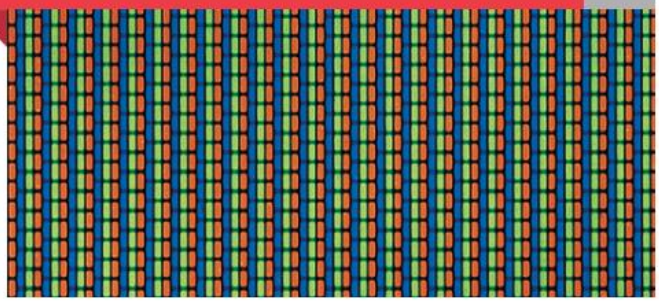
Figure 4.2.8 When you wear 3D glasses with a red and blue filter, each eye receives a slightly different view of the movie scene. Your brain interprets this as 3D vision.

Prac 1 p147 Prac 2 p148

Full colour?

SciFile

Televisions, video cameras, computers and mobile phones are just some of the devices that use an RGB (red, green, blue) colour model. Their displays consist of many tiny pixels of red, green and blue filters (for LCD screens) or phosphors (for plasma screens). Combinations of the red, green and blue light create the full colour display that you see.



Colour printing

When all the colours of light are added together, white light is produced. However, if you mixed every colour of paint pigment, then the final mixture would look dark and murky. As more paint pigments are added, more colours are absorbed rather than reflected. This type of colour combination is called subtractive colour mixing.

The three subtractive primary colours are cyan, magenta and yellow. Figure 4.2.9 shows how these three colours can produce all other colours. Black ink is also used in the printing process to increase the contrast of the printed image. Figure 4.2.10 illustrates the way colour printing operates.

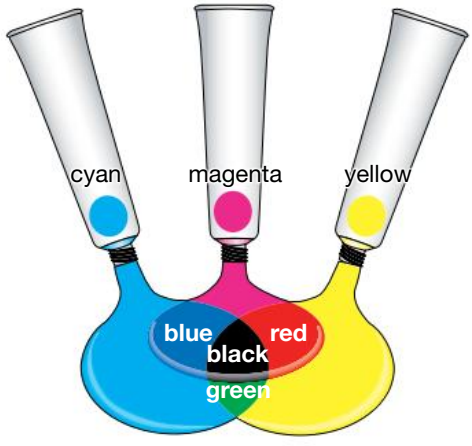


Figure 4.2.9 Combinations of the three subtractive colours, cyan, magenta and yellow, can produce every colour of the spectrum.

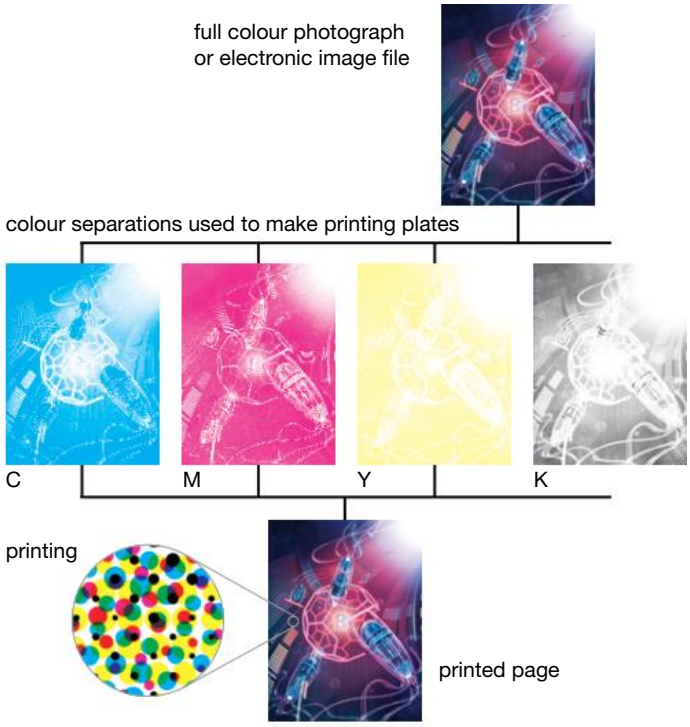


Figure 4.2.10 Colour printers produce a full spectrum of printed colour by using only four inks: cyan, yellow, magenta and black.

Polarisation of light

Light travels as an electromagnetic wave in three dimensions. Polaroid sunglasses absorb much of the light energy that hits them by using filters that only allow through waves vibrating in a certain direction. Waves vibrating in other directions are absorbed. The light has been **polarised**. This can be seen in Figure 4.2.11. Polarising filters absorb much of the incoming light energy, but allow enough light through for you to still see clearly.

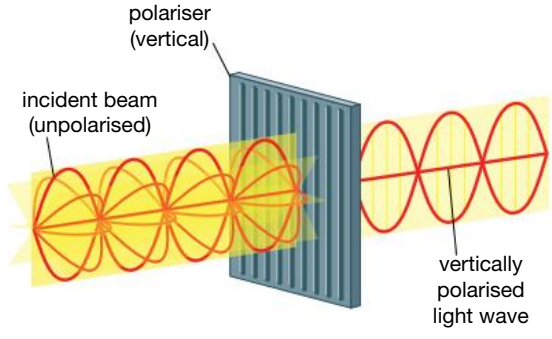


Figure 4.2.11 Electromagnetic radiation travels as a 3D wave, with electric and magnetic fields vibrating at right angles. A polariser only allows one plane of vibration to pass through it, the rest being absorbed.

You can test your sunglasses to see if they are polarised by holding another pair of polarised sunglasses in front of them. Rotate your sunglasses. If they are polarised, no light will pass through when the two pairs are perpendicular.

ADDITIONAL

Dispersion of light

When white light is passed through a prism, it splits into the colours of the visible spectrum. The splitting of white light into the colours that make it up is called **dispersion**. You can see dispersion effects whenever you notice a rainbow of colours. You may see such colours when you see a rainbow through a spray of water, or look at light reflecting from crystals or the pieces of glass of a chandelier.

To see a rainbow, individual droplets of water must be present in the sky and the Sun must be behind you. The water droplets act like tiny prisms. Sunlight enters the water droplets and is dispersed (split) into individual colours. This light is then totally internally reflected back out of the water droplet. You only see one colour from each droplet of water. The actual rainbow that you observe is unique to where you are standing. The rainbow you see consists of light that has reflected from many individual water droplets at many different heights in the sky. Figure 4.2.12 shows how this can produce a single and a double rainbow.

Scattering of light

Light interacts with particles in the Earth's atmosphere. If the light and the atmosphere did not interact, then our skies would be black. This interaction is called **scattering**. The amount of scattering depends on the colour and frequency of light being scattered. Light waves of higher frequency and energy are scattered more easily than waves of lower frequency and energy. This means that light from the blue end of the visible spectrum is scattered more than light from the red end of the visible spectrum. As a result, the sky appears blue in the daytime. However, at sunrise and sunset, the Sun is low in the sky, making light travel through a thicker layer of the atmosphere than in the middle of the day. This situation is shown in Figure 4.2.13. At sunrise and sunset, the blue wavelengths have already scattered and so the sky appears red.

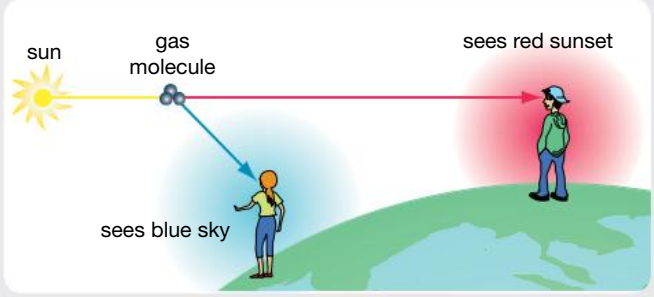


Figure 4.2.13 Sunlight travels a shorter distance to reach the girl. Blue light is scattered and she sees a blue sky. Sunlight travels further to reach the boy. Short wavelength light has already been scattered, so he sees the reddish sky of sunrise or sunset.

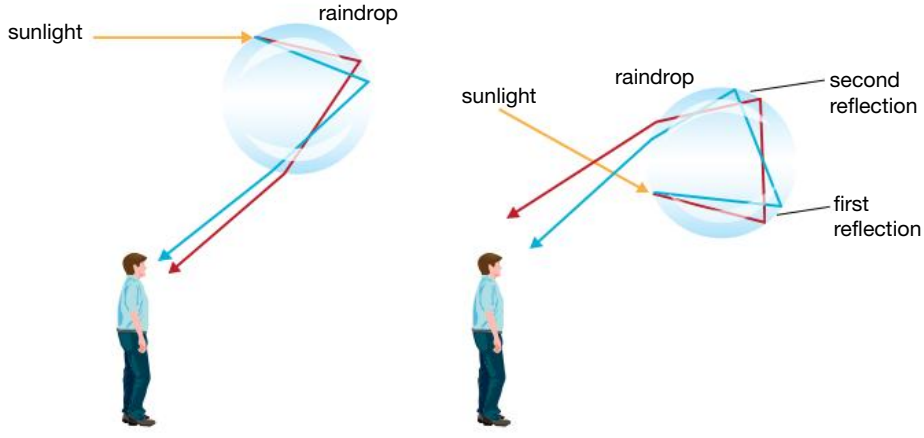


Figure 4.2.12 Sunlight is dispersed into different colours and is totally internally reflected back out of the water droplet. This produces a rainbow. Secondary rainbows are fainter and appear higher in the sky than primary rainbows and the order of their colours is reversed.

This observer sees blue light from this particular water droplet. The red light seen in this person's rainbow has been reflected from water droplets higher in the sky.

Depending upon the angle of sunlight entering the droplet, the light may be totally internally reflected twice before exiting the droplet. When this happens, a secondary rainbow is observed.

ADDITIONAL

4.2 Unit review

Remembering

1 a **List** all the colours of the visible spectrum.
b **State** what is produced if all these colours are shone together.

2 **State** the colour of visible light that has the:
a shortest wavelength
b lowest frequency.

3 **List** the three primary colours of the visible spectrum.

4 **List** the three secondary colours of the visible spectrum.

Understanding

5 **Explain** in terms of light reflected and light absorbed why a frog viewed in white light looks green.

6 Quentin looks at a black bowling ball through a red filter. He expected the ball to look red because this filter allows the transmission of red light. **Explain** to Quentin why the ball appears black.

7 **Explain** why you feel cooler when wearing white clothing in a very warm climate.

8 **Explain** how polarising sunglasses reduce glare.

9 **Explain** why a tricolour (three-colour) cartridge plus black ink is all that a computer printer needs to produce full colour prints.

Applying

10 For each of the three cases shown in Figure 4.2.14, **identify** the final colour (or lack of colour) that emerges.

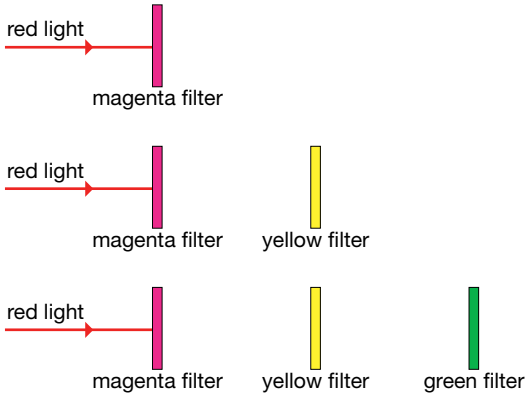


Figure 4.2.14

11 **Identify** the key colours reflected and absorbed when white light shines on the objects below.

Object	Colours reflected	Colours absorbed
Red convertible		
Yellow banana		
Blue jeans		
Black bowling ball		
White dove		

12 a **Identify** the colour a green frog would look under yellow light.
b **Identify** one colour of light that would make the green frog appear black.

13 Su-Lin and Sofia are dressed as shown in Figure 4.2.15, as they arrive at a night club. **Identify** what Su-Lin and Sofia's clothes look like in the nightclub's blue lighting.

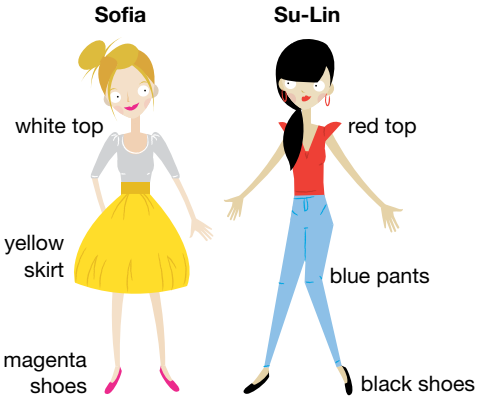


Figure 4.2.15

Evaluating CCT

14 **Use** two properties of light to **justify** the idea that light travels as a wave.

Inquiring

ADDITIONAL

Search for five images of the phenomena of primary and secondary rainbows, sunsets and a lunar rainbow (known as a 'moonbow'). Annotate each set of images with a diagram that show how the phenomenon is caused by reflection, refraction, scattering and/or dispersion of light.

Present your images as a digital slideshow. ICT

ADDITIONAL

4.2 Practical investigations

1 Combining colour

Purpose

To investigate combinations of coloured light and to explore the behaviour of coloured filters.

Materials

- light box
- power supply
- set of coloured filters
- set of coloured cards
- sheet of white paper

SAFETY

Allow time for the lamp of the light box to cool before handling it.

Procedure

1. Copy Tables A and B from the Results section into your workbook.
2. Connect the light box to a power supply and place it on a sheet of white paper.
3. Place a red filter and a blue filter in the light box and adjust the mirrored flaps to combine the colours, as shown in Figure 4.2.16.
4. Change the filters as necessary to combine the light to complete Table A.
5. Now use one coloured filter at a time and shine light of this colour onto red, blue, green, cyan, yellow and magenta pieces of card. In Table B, record what each card looks like when viewed in each colour of light.

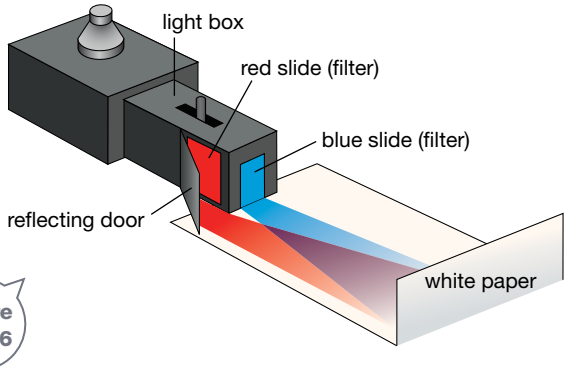


Figure 4.2.16

Results

Record all observations in your results tables.

Table A Mixing coloured light

First slide	Second slide	Third slide	Colour produced
Red	Blue		
Red	Green		
Green	Blue		
Yellow	Cyan		
Yellow	Magenta		
Cyan	Magenta		
Red	Blue	Green	
Cyan	Yellow	Magenta	

Table B Viewing cards in different coloured light

Colour of slide	Colour of card					
	Red	Blue	Green	Cyan	Yellow	Magenta
Red						
Blue						
Green						
Cyan						
Yellow						
Magenta						

Practical review

1. **List** any combinations of colours that produced white light.
2. **Discuss** whether your results for Table A were as you would have predicted.
3. **Explain** the results you obtained for Table B.
4. **Propose** any ways in which this prac could be improved or extended.

STUDENT DESIGN

2 Making a kaleidoscope

A kaleidoscope consists of mirrors in a tube with some brightly coloured objects. A kaleidoscope can be rotated to reveal changing, symmetrical patterns.

GO TO Unit 3.3

Purpose

To construct and test a kaleidoscope.

Materials

You could use the following or similar materials:

- 3 equal-sized rectangular mirrors (or smooth aluminium foil glued to cardboard)
- sticky tape
- 2 pieces of stiff cardboard
- Petri dish
- cardboard circle (same diameter as Petri dish)
- small coloured objects (such as glitter, sequins, confetti, cut cellophane, buttons and glass beads)
- strong rubber bands
- thin plastic bag or a piece of coloured cellophane

SAFETY

A risk assessment is required for this investigation.

Procedure

1 Design a kaleidoscope that will produce different patterns when the end piece is rotated. Figure 4.2.17 may give you some ideas for your design.

2 Write your procedure in your workbook.

3 Before you start any practical work, assess all risks associated with your procedure. Construct a risk assessment that outlines these risks and any precautions you need to take to minimise them. Show your teacher your procedure and your assessment of its risks. If they approve, then collect all the required materials and start work.

4 Once your basic kaleidoscope is built, investigate how the final image is affected by:

- increasing the number of mirrors used or their orientation
- using different colours of cellophane over the viewing hole.

Results

1 Describe the patterns that you saw through the kaleidoscope.

2 Describe the effect of changing the variables in your investigation.

Practical review

1 **Explain** how the kaleidoscope creates these images.

2 **Propose** any improvements to your design of the kaleidoscope.

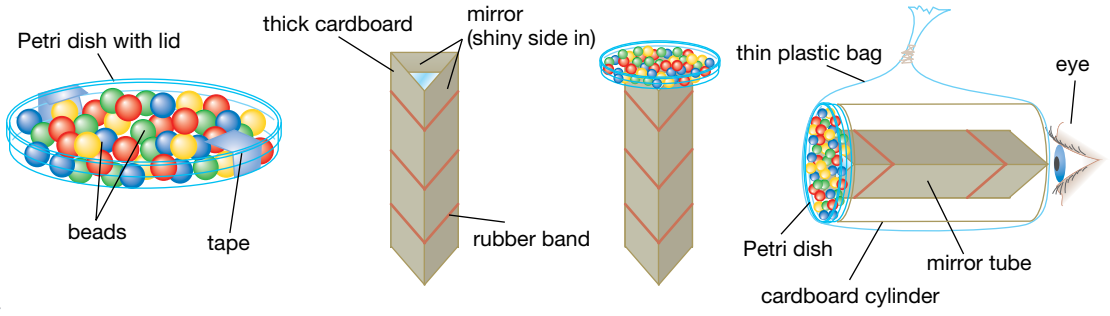


Figure 4.2.17

4.3 Low-energy radiation

The electromagnetic spectrum consists of a broad range of types of electromagnetic radiation. Electromagnetic radiation that has a frequency less than that of visible light is considered to be low-energy radiation. Our communications network relies upon forms of low-energy radiation, such as radio waves and microwaves. Microwave radiation is also used to cook and heat up food, while infrared radiation is the warmth you feel when in front of a fire and when the sun is on your back.

Radio waves

Television and radio networks transmit a signal using **radio waves**. These radio waves are produced through vibrating or oscillating electrons in a transmitting aerial (Figure 4.3.1). Radio waves have the longest wavelengths of all types of electromagnetic radiation. This can range from less than a centimetre to many kilometres. As a result, radio waves have the lowest frequency and are the lowest-energy form of electromagnetic radiation. Radio waves can travel large distances. They make electrons in the antenna of your television or radio vibrate, and this is converted into the sounds or images you see and hear when tuning in.

Short-wave and long-wave radio signals are also used in communications. Short-wave radio signals (wavelength about 30 m) can be transmitted long distances by beaming the waves upwards at an angle. The waves are reflected back to Earth by a layer of the atmosphere called the ionosphere, far away from where the transmitter is located.

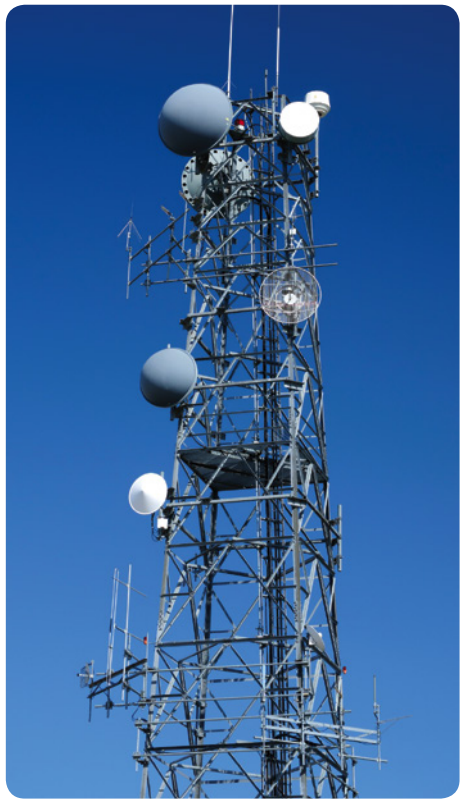


Figure 4.3.1 Radio and television stations broadcast radio waves that are produced by electrons oscillating (moving back and forth).

Long radio waves are used for communications because they bend around the Earth's surface when transmitted. These applications are shown in Figure 4.3.2.

Radio waves are also produced naturally. Objects in space, such as stars, emit radio waves.

AM and FM radio

Each radio station broadcasts signals at a particular frequency, which you receive when you tune your radio to this frequency. AM and FM radio waves involve using a wave called a carrier wave, shown in Figure 4.3.3. After being detected by the antenna of a radio, the carrier wave is subtracted from the signal, leaving only the original signal. This signal is amplified and directed to the speakers, where it is converted to sound once more. The process is summarised in Figure 4.3.4.

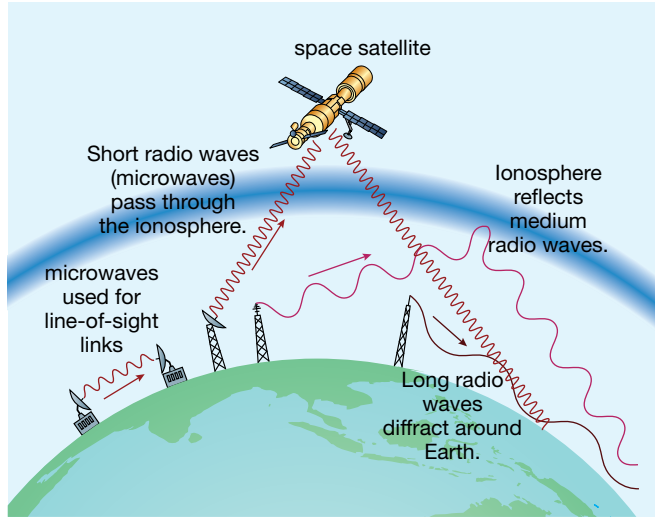


Figure 4.3.2 The wavelengths of radio waves can vary from kilometres to tens of centimetres. Long and short radio waves are useful for communication.

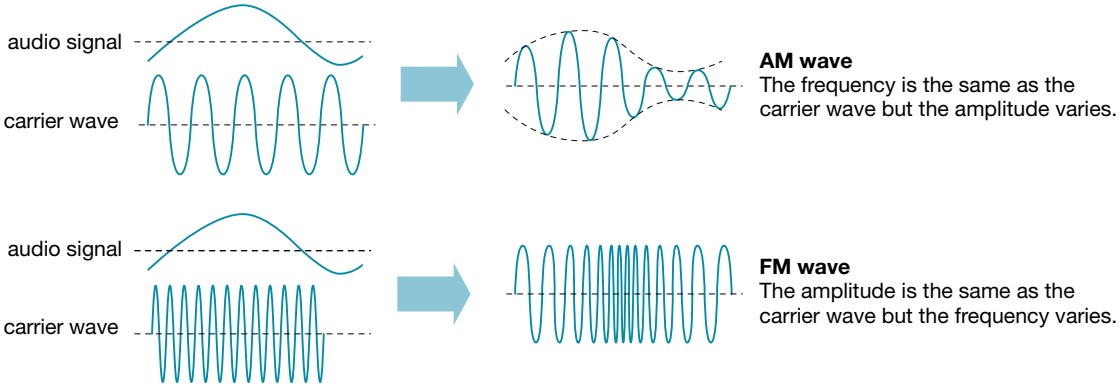


Figure 4.3.3 AM radio stations transmit waves that are amplitude modulated. In FM, the carrier wave is frequency modulated. Each radio user, such as CB radio, the police or a radio station, operates on its own specific frequency.

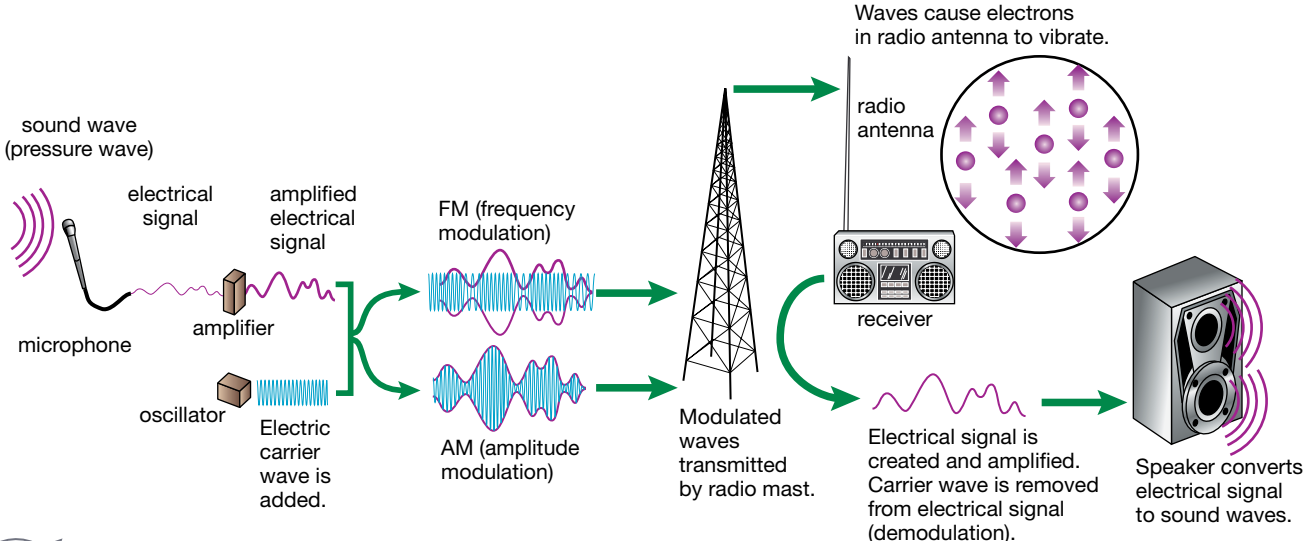


Figure 4.3.4 The steps used when broadcasting and receiving a radio signal.

An FM signal has a wavelength of around 3 metres, whereas an AM signal has wavelengths longer than 100 metres. The longer AM radio waves can bend around large obstacles such as buildings, trees and hills more easily than the smaller FM waves can. This bending around obstacles is called *diffraction*. AM signals travel further than FM signals, but they are of lower quality and are more likely to suffer from interference. You may have noticed this when listening to an AM radio near electrical equipment.

SciFile

Digital radio

Digital radio transmits multiple VHF (very high frequency) signals, filtering these for interference and then recombining the signals, digital radio delivers a cleaner, higher-quality sound that is free of crackles.

Microwaves

Microwaves have shorter wavelengths than radio waves and are used in radar and communication systems. Shorter microwaves with wavelengths of about 0.1 mm are used in cooking (Figure 4.3.5). Microwaves are absorbed by water, fats and sugars in food, causing the food molecules to vibrate and heat up. Because the heating occurs inside the food without warming the surrounding air, the food cooks quickly but sometimes unevenly. Glass, paper and many plastics don't absorb microwaves, and metal reflects microwaves.

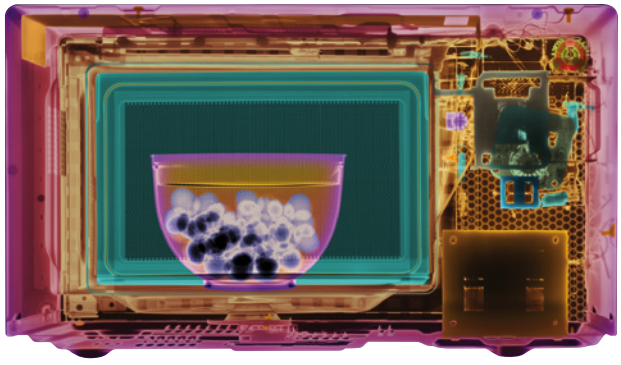


Figure 4.3.5 The wavelengths of microwaves make the particles in food vibrate, which causes the food to heat up.

INQUIRY science 4 fun

Remote signals

YES

Remote controls emit infrared rays, which are detected by sensors on devices such as TV or DVD players.

Collect this …

- TV, CD, DVD or HDD remote control
- its associated player

Do this …

1. Point your remote control directly at your device to turn it on.
2. Vary the direction at which you point the remote control. Which unusual directions will still be effective at turning on the device?

Record this …

Describe what happened.

Explain why you think this happened.

Infrared radiation

Heat is transferred from the Sun to Earth as **infrared radiation**. Infrared rays are given this name not because they are red, but because they are next to red light in the visible spectrum. 'Infra' means below, and infrared radiation has a lower frequency than red light.

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GO TO Unit 3.1

You cannot see this radiation, but can detect its presence as warmth on your skin. All objects with a temperature above absolute zero (0 K or –273°C) emit infrared radiation. The hotter something is, the more infrared radiation it emits. Infrared radiation can be detected using an infrared camera, as shown in Figure 4.3.6 on page 152.

4.3

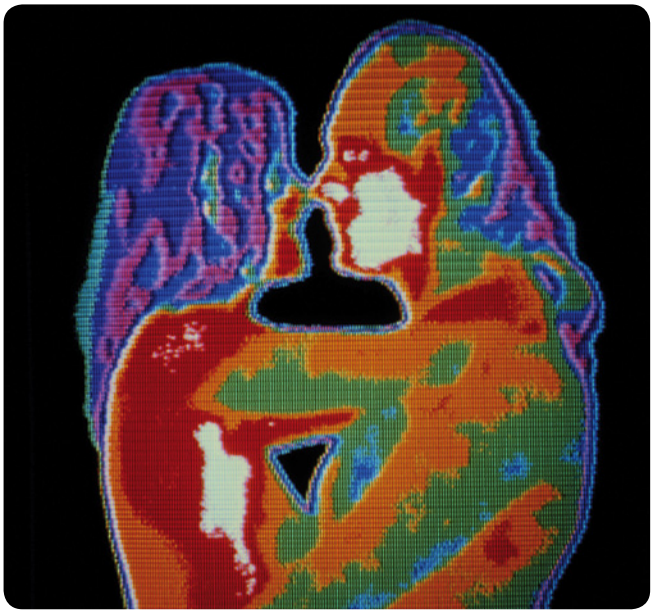


Figure 4.3.6 In this false colour image, different intensities of infrared radiation are assigned different colours. White corresponds to the hottest regions, while the coolest regions appear turquoise.

Modern communications networks

Modern communications networks carry vast amounts of data from landline telephones, mobile phones, radio, TV and the internet. Data such as downloaded files, voice conversations and satellite images are relayed.

Analogue or digital signals

Some mediums, such as the copper wires connected to landline phones, are designed to carry an **analogue signal**. The voltage of such a signal is determined by the speaker's voice. You can see a typical analogue signal in Figure 4.3.7. Analogue signals are limited because they suffer from signal loss and interference as they travel.

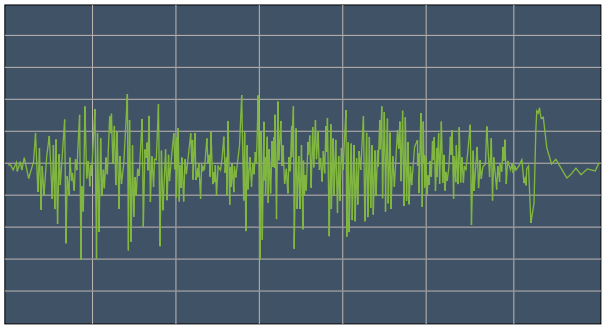


Figure 4.3.7 An analogue signal replicates the message it transmits.

Most communications systems that we use regularly, such as television and the internet, rely on a **digital signal**. A modem connects a computer to a telephone line and converts the digital computer signal into an analogue signal that the phone line transmits. This process of coding the signal into a different format is called *modulation*. Our mobile phone network is digital, as is the music we listen to on CD or MP3 player. A digital signal can still be read even when interference disturbs the message.

Instead of relying upon a number system with ten digits, the digital system uses a **binary number system**, consisting of only two digits, 0 or 1 (or, in the case of light pulses, 'on' or 'off').

Increasing capacity

Until relatively recently, all telephone signals were sent along copper wires. To limit signal interference, twisted-pair copper wires were used. These consist of a pair of insulated copper wires twisted around each other. A 600-pair copper cable can carry 600 two-way conversations. These cables are inexpensive and do not suffer much signal loss when used over short distances.

Coaxial cable (Figure 4.3.8), can carry more data than twisted-pair cables. Australian cities have been linked by underground coaxial cables since the 1960s. Two cables of 50 tubes can carry 2700 two-way conversations. Such cable is used with repeaters positioned every 45 km to reinforce the signal.

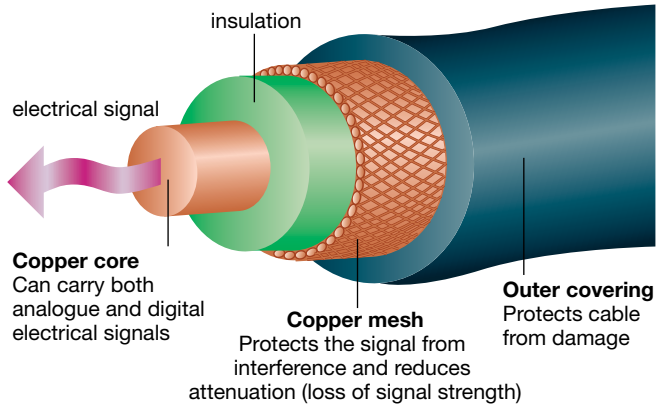


Figure 4.3.8 The inner core of this coaxial cable transmits analogue and digital signals. The outer layers protect the signal from interference and loss of strength.

To enable the transmission of more data along a copper wire, different signals are sent along the wire at the same time. This is possible when using carrier waves of different frequencies. At the receiving end, these different frequencies are sorted back into separate signals. This is called frequency division multiplexing (FDM).

Digital signals are transmitted by a technique called time division multiplexing (TDM). In this process, data is broken up into smaller chunks and interwoven together, then transmitted at a single frequency as a data stream. This datastream is sorted into its components after transmission. In fact, a combination of FDM and TDM can be used to further increase the amount of data that can be carried. The amount of data that can be carried is known as the **bandwidth** of the channel.

Channels of communication

Optical fibre

The increasing use of computers leads to ever greater demand for bandwidth. In Australia from the late 1980s, a new network was laid next to the underground coaxial cable that linked cities. This network was made from **optical fibre**. Optical fibres are thin, flexible tubes made of silica glass or plastic. Each optical fibre consists of a central core of pure silica glass surrounded by a layer of less dense glass, called the cladding. This layer is coated with a plastic jacket to minimise interference. The structure of fibre optic cable is shown in Figure 4.3.9.

A laser produces a narrow beam of light waves that are said to be **coherent**, or in step with each other. Such coherent light is illustrated in Figure 4.3.10. Laser light is coded into digital language as strings of binary numbers and is sent as a series of millions of light flashes down the optical fibre. This light is totally internally reflected as it travels along the tube. An optical receiver at the other end of the fibre converts these pulses back into a digital signal. Much higher frequency signals can be sent along a fibre optic system than can be sent through copper wires. As a result, a fibre optic system has much greater bandwidth than a copper system. A single optical fibre can carry over 30 000 telephone calls. This bandwidth can be expanded by sending signals of different wavelength along the fibre at the same time. In addition, optical fibre is lighter and more flexible than copper cable. A signal can be transmitted around 200 km without any signal loss, and it suffers less interference than signals sent along a copper network.

Prac 2 p159

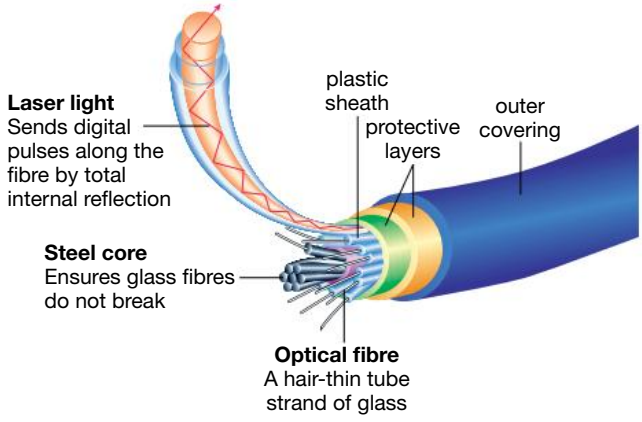


Figure 4.3.9 A fibre optic cable is made up of many single optical fibres.

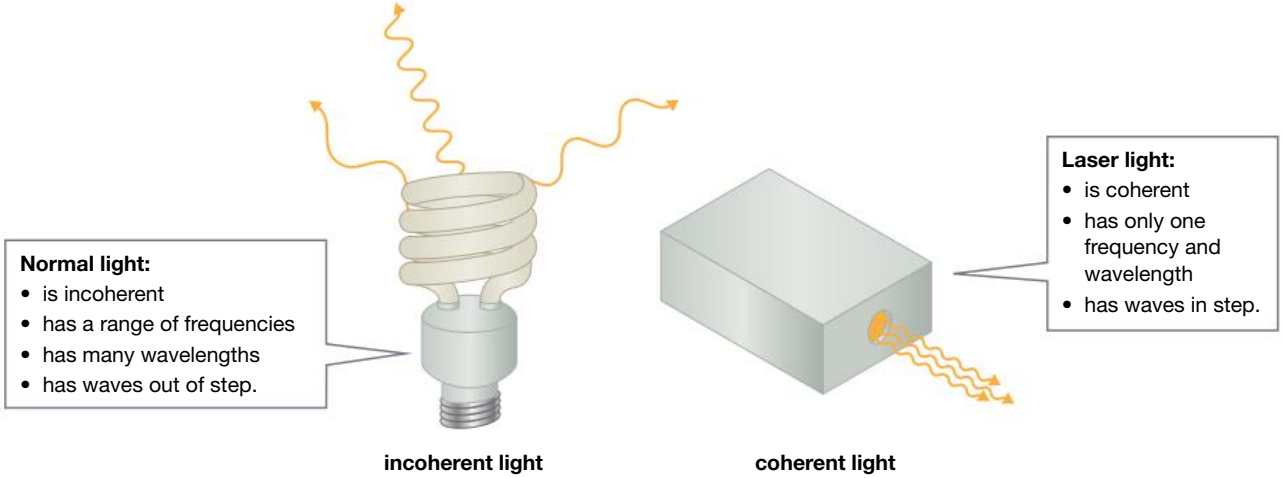


Figure 4.3.10 Light from an ordinary light globe produces light with a range of frequencies. A laser produces light of one frequency that is coherent.

Slippery cables

Fibre optic cables manufactured for use in Australia have a unique outer nylon jacket. This jacket protects the cabling from termites, which are unable to grip its slippery outer surface.

SciFile

INQUIRY

science 4 fun

Bendy light

YES

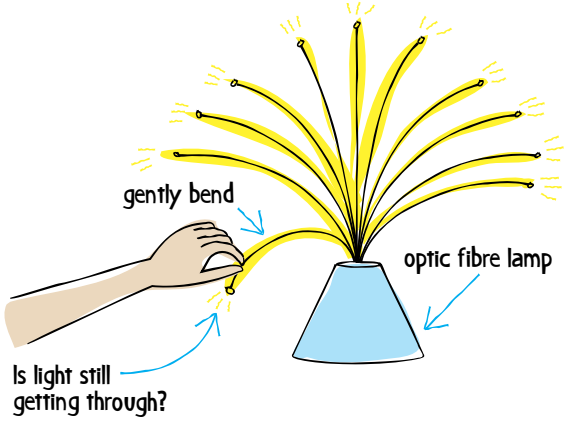
Light travels in straight lines. So can you make it turn a corner?

Collect this…

- fibre optic lamp

Do this…

1. Turn on the lamp.
2. Carefully bend a single optical fibre, as shown in the diagram.
3. See how far you can bend the fibre but still see light coming out of its end.



Record this…

Describe what happened when you bent the fibre.

Explain why you think this happened.

Microwave links

Microwave signals are directed in short, straight-line paths. About 2000 phone conversations can be carried using such a system, with repeater towers required every 50 km. Microwave satellite links are used for long-range mobile communications and for communications in remote areas.

Mobile phone networks

Mobile phone networks send a digital signal of your voice through microwaves transmitted through the air. This system relies upon an interconnected series of base stations. These base stations are where antennas receive and transmit mobile phone signals. Each base station is located in the centre of a hexagonal region called a cell. Each cell uses a different frequency to transmit its signal, and no adjacent cells use the same frequency. When you dial a number, the base station in the cell that receives the strongest signal directs your call to the telephone exchange. The exchange then directs the call to the appropriate base station of the cell in which the receiving phone is held. This complex arrangement is shown in Figure 4.3.11.

What a yolk!

Debate has raged over the question of whether mobile phone use may be linked to cancer. In 2000, a website claimed that an egg was hardboiled in 65 minutes while positioned between two operating mobile phones. Public outcry followed, with people wondering what their own phones were cooking inside their heads. The 'experiment' was later proved to be a hoax.

SciFile

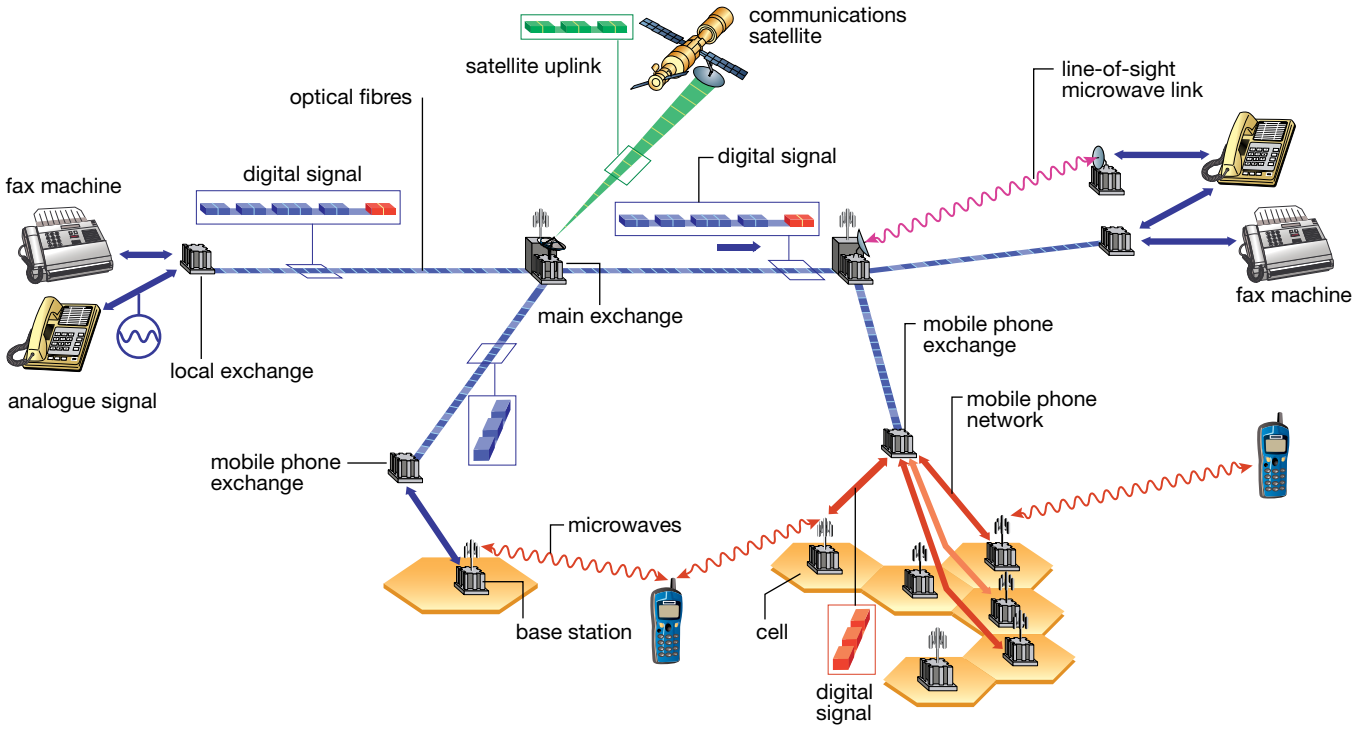


Figure 4.3.11 A modern communications network relies upon a number of channels of transmission, including copper cable, microwave links, satellite links and optical fibre. The short connections from a house to the communications network are usually made with copper wire.

The internet

Using the internet, you can connect with people around the world in an instant. Documents that in the past would take days to reach a destination can be downloaded in seconds. A *router* is a device that manages the connection between your computer and your internet server. It is this device that is responsible for making sure your message reaches where it is meant to go.

Data to be sent as a downloaded file or email is first split into a 'packet' made up of about 1500 bytes. These packets then travel over a 'packet-switching network' in which each individual packet is directed along the best pathway for it to reach its destination. The router selects the best pathway by examining where the packet is to go and the type of network it is using. It directs the traffic in a way that eases congestion on major routes. The individual packets or snippets of the original message are reassembled when they reach their destination.

Wireless internet networks

Wireless internet is a method of transmitting an internet connection using radio waves. It allows a Wi-Fi (wireless fidelity) enabled device such as a mobile phone, laptop, tablet, video game console, Bluetooth or MP3 player to connect to the internet when within range of an access point. An example is shown in Figure 4.3.12. This occurs in a similar way to mobile phones connecting to a wireless telephone network. Wi-Fi is a wireless alternative for internet access within local area networks (LANs). A Wi-Fi signal does not have a long range, only about 30 metres indoors and 100 metres outdoors. In regions further away from a wireless network that is connected to the internet, the Wi-Fi device cannot pick up a signal. In such cases, Wi-Fi is not an alternative to an internet system that operates using coaxial cable or optical fibres.

Figure 4.3.12 This WLAN (wireless local area network) card enables the laptop to link to a wireless broadband internet network.

LEARNING ACROSS THE CURRICULUM

WORK AND ENTERPRISE

WI-FI HELPS CSIRO SCIENTIST WIN TOP AWARD

The technology that made wireless internet possible was developed by a team of Australian scientists.

Figure 4.3.13 Dr John O'Sullivan

Almost two decades after pioneering high-speed wireless now used by almost a billion people each day, John O'Sullivan has won one of Australia's top science gongs [awards].

The CSIRO scientist was awarded the prestigious Prime Minister's Prize for Science for 2009 for his WiFi technology now found in millions of laptops, printers, wireless access devices and even Nintendo's Wii.

One of Australia's most significant scientific breakthroughs, Dr O'Sullivan and his team found a way to speed up wireless networks in 1992—a problem that had previously stumped [confused] international scientists.

The idea has since generated a massive windfall for the CSIRO to the tune of $205 million and counting.

Dr O'Sullivan was given $300,000 at a gala event in Canberra on Wednesday.

Prime Minister Kevin Rudd said the award recognised Dr O'Sullivan's major contribution to astronomy as well as his groundbreaking WiFi technology.

'While looking for exploding black holes Dr O'Sullivan created a technology that cleaned up intergalactic radio waves,' Mr Rudd said.

'Then in 1992, he and his colleagues at CSIRO realised that the same technology was the key to fast reliable wireless networking in the office and home.'

'Their patented invention is now built into international standards and into computers, printers, smart phones and other devices used by hundreds of millions of people every day.'

Mr Rudd called it one of the most significant achievements in CSIRO's 83-year history and said it illustrated how scientific research can be turned into real and practical solutions.

Dr O'Sullivan and the CSIRO team beat 22 international labs to solve the 'multipath' problem—or the interference caused by reflected radio waves which slows down network speeds.

They found a way to accelerate them by splitting radio channels apart, essentially turning a one-lane road into a super highway and making wireless about five times faster.

Dr O'Sullivan said the idea was born out of a need to 'cut the wires'.

'And to cut the wires, we needed to make it as fast as the wires,' he told AAP.

Seeing the technology in use in millions of devices around the globe, 'I can't help but feel proud,' he said.

'Even though we thought it had huge potential, I'm just blown away with how many applications there are now.'

Among the other winners, Michael Cowley took out the Science Minister's Prize for Life Scientist of the Year for breaking the link between fat and diabetes, while Amanda Barnard was named the Physical Scientist of the Year for her work in nanotechnology.

The Age 28 October 2009 © 2010 AAP

REVIEW

1 **Name** the prize that Dr John O'Sullivan was awarded in 2009.

2 **Describe** what the prize was awarded for.

3 **List** devices that use this technology.

4 **Describe** what Dr John O'Sullivan was looking for when he created the new technology.

4.3 Unit review

Remembering

1 **State** whether the following statements are true or false.
   a Radio waves have the longest wavelengths of any type of electromagnetic radiation.
   b Microwaves are reflected off water, fats and sugars in food.
   c The hotter an object is the less electromagnetic radiation it will emit.

2 **List** three types of low energy electromagnetic waves.

3 **Name** a natural source of radio waves.

4 **State** the typical wavelength of an AM radio signal.

5 **Recall** the number system that is used in digital communications.

6 **State** two disadvantages associated with analogue signals compared with digital signals.

7 **Recall** the term that describes the amount of data a communication channel can carry. L

8 **State** how far apart repeater towers are positioned in microwave surface links.

9 **List** four common devices that may be Wi-Fi enabled.

10 **State** the indoor and outdoor range of a Wi-Fi signal.

Understanding

11 **Explain** why AM radio waves travel further than FM radio waves. L

12 **Define** the meaning of the term *amplitude modulated*.

13 **Explain** how a signal is transmitted along an optical fibre.

14 **Explain** the function of a modem.

Applying

15 **Deduce** which property of waves is necessary for a person to bounce an infrared signal off a wall to a TV.

Analysing

16 **Compare** normal light with laser light.

17 a **Compare** frequency division multiplexing (FDM) with time division multiplexing (TDM).
   b **Explain** the purpose of these techniques.

18 **Compare** the number of two-way conversations that can be carried by a typical twisted pair cable, coaxial cable and fibre optic cable.

19 **Draw** a diagram to **compare** AM with FM radio waves.

Evaluating CCT

20 **Propose** why food may cook quickly but unevenly in a microwave oven.

21 **Propose** why both coaxial cable and optic fibres are wrapped in an outer plastic jacket.

Creating CCT

22 **Construct** a design for a new application of wireless internet technology; for example, the projection of a 3D replica of your body shape into a changing room to allow virtual fitting of clothing while internet shopping.

Inquiring

1 Research and construct a timeline to outline the history of the development of one of the following technologies:
- the USB device
- iPods
- MP3 players
- social media
- email
- the world wide web. ICT

Present your research as a Prezi or a poster. Include in your report a summary of key people who contributed to the development of your technology.

2 Heating in a microwave oven can be quite uneven. This has led to people receiving serious burns from 'super-heated' liquids. Research to:
- find out what 'superheating' is
- describe how this happens in a microwave oven
- develop a list of precautions to prevent such burns from occurring.

Present your findings as a newspaper ad or plan for a TV commercial warning of the dangers and providing helpful advice.

4.3 Practical investigations

1 Heating the Earth and the sea

Purpose

To investigate whether soil heats up at the same rate as water.

Hypothesis

Which do you think will heat up faster—soil or water? Before you go any further with this investigation, write a hypothesis in your workbook.

SAFETY

Do not touch the hot globe.

Wear rubber gloves when handling soil.

Materials

- enough soil to fill two Petri dishes
- 2 or 3 large leaves with a small amount of stem attached
- water
- 3 identical Petri dishes
- incandescent desk lamp
- 3 thermometers or temperature probes
- rubber gloves

Procedure

1. Construct a table similar to the one shown in the Results section.
2. Turn on the desk lamp and leave it to warm up for several minutes.
3. Fill two Petri dishes with soil.
4. Push the stems of the leaves into one of the soil samples.
5. Measure the soil temperature.
6. Run the hot and cold taps to obtain water at approximately the same temperature as the soil.
7. Fill the third Petri dish with water at this temperature.
8. Position the three dishes 10 cm below the light source, as shown in Figure 4.3.14.

Hint

Make sure all three dishes are the same distance from the light source.

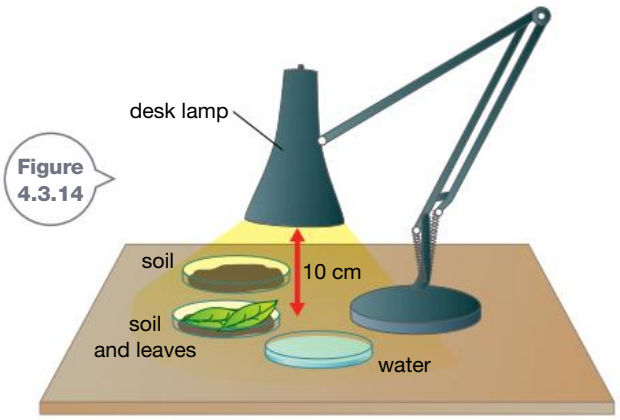


Figure 4.3.14

Results

1. Record the initial temperature of the three samples, and then their temperature every 5 minutes for 30 minutes.

Time (min)	Temperature (°C)		
	Soil sample	Soil and vegetation	Water
0			
5			
10			
15			
20			
25			
30			

2. Construct a graph showing the temperature variation of the three dishes over the 30 minutes, using a single set of axes. N

Practical review

1. **Describe** how the three samples heated up.
2. **Use** your results to **propose** whether open surfaces of land, land with vegetation or oceans would heat up more rapidly from the Sun.
3. **Propose** one improvement you could make to the design of this experiment.
4. a **Construct** a conclusion for your investigation.
   b **Assess** whether your hypothesis was supported or not.

2 Using light

Purpose

To model how light is totally internally reflected along an optical fibre.

Materials

- length of optical fibre
- light box
- power pack
- 3 glass prisms

SAFETY

Ensure that the light box has cooled before handling it.

Procedure

1. Connect the light box to the power source and direct a single beam of light at a glass prism.
2. Rotate the prism. Look at what happens to the incident ray as you do this.
3. Find a position in which all the light is reflected from the inside glass surface. This is called *total internal reflection*, and will only occur when rays hit the glass at an angle larger than a specific critical angle.
4. Place a second prism in the path of the reflected beam and rotate it so that the beam is totally internally reflected again by the second prism.
5. Repeat this process once more, using a third prism. You should be able to make the ray of light travel in the opposite direction to its original pathway using these three prisms. Use Figure 4.3.15 as a guide.
6. Sketch the orientation of your three prisms and the reflected rays of light.
7. Curve an optical fibre into a shape that is similar to that of the light pathway that you have just drawn. Direct light along the fibre.
8. Change the shape of the fibre to see if the light can be transmitted through it.

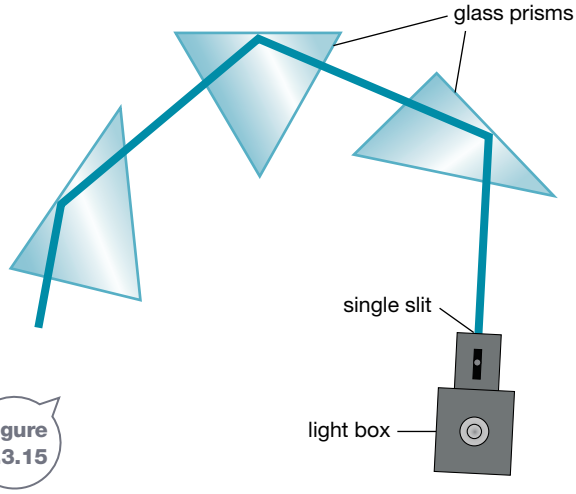
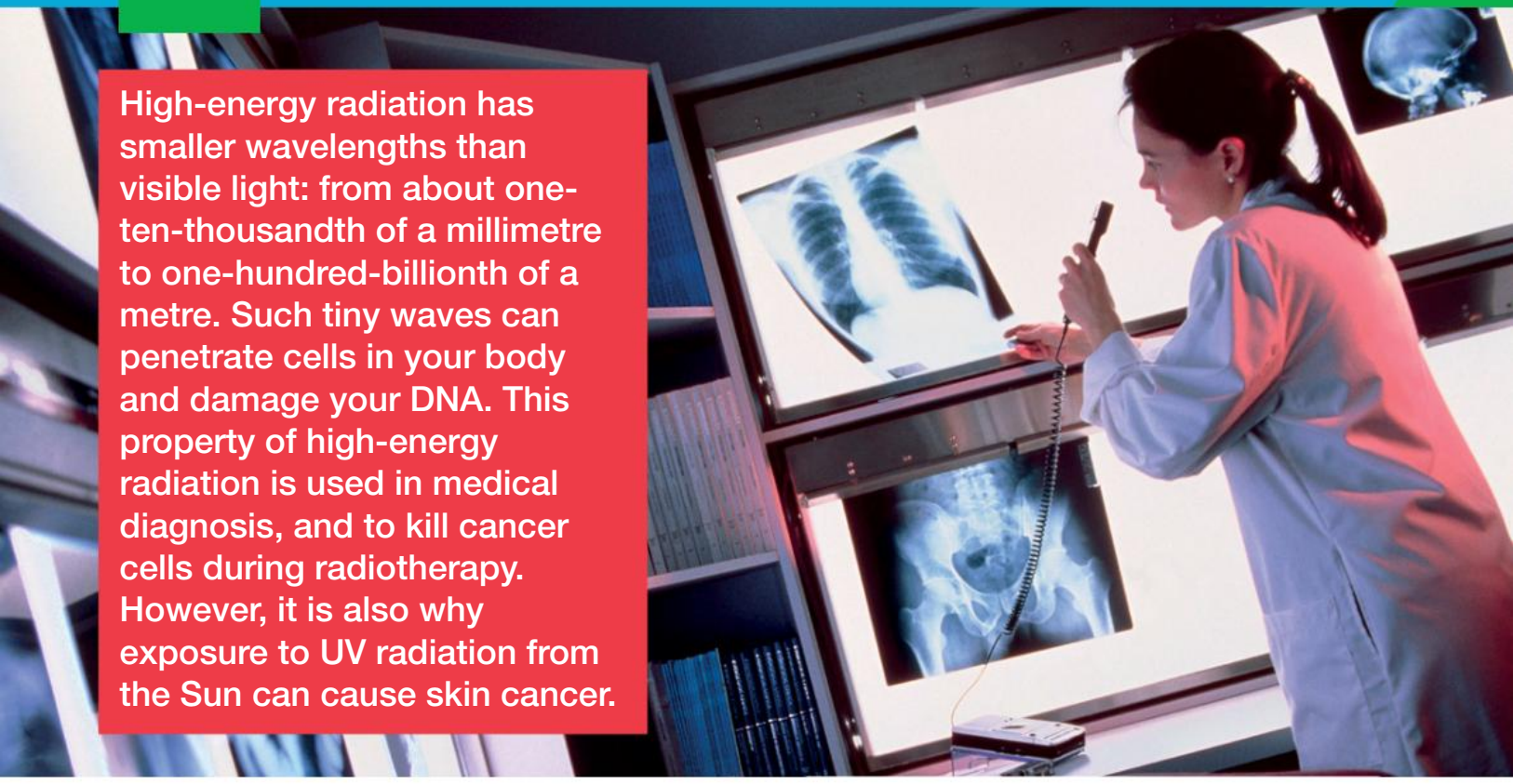


Figure 4.3.15

Practical review

1. **Describe** what you observed happen to the ray of light as you rotated the first prism.
2. **Explain** how total internal reflection of light could be useful in communication.
3. **Construct** a diagram to show what you observed when you tried to shine light through the optical fibre.
4. **Discuss** what you found when you tried to direct the light through the fibre when bent in different directions.
5. **Identify** features of an optical fibre that make it a useful channel of communicaton using light.

4.4 High-energy radiation



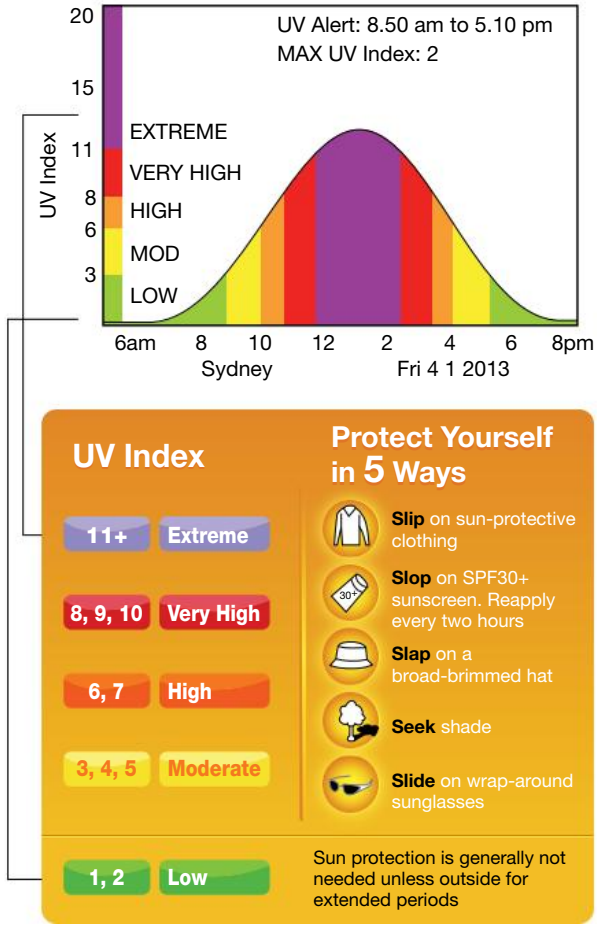
High-energy radiation has smaller wavelengths than visible light: from about one-ten-thousandth of a millimetre to one-hundred-billionth of a metre. Such tiny waves can penetrate cells in your body and damage your DNA. This property of high-energy radiation is used in medical diagnosis, and to kill cancer cells during radiotherapy. However, it is also why exposure to UV radiation from the Sun can cause skin cancer.

Ultraviolet light

Ultraviolet (UV) light is radiation with a higher frequency than violet light ('ultra' means 'beyond'). Sunlight contains UV light in addition to infrared and visible light. Your body needs some exposure to UV light to produce vitamin D. Although you cannot see UV light, it can tan or burn your skin. High exposure to UV light can cause skin cancers such as melanoma. UV light can also cause cataracts in your eyes. Approved sunglasses and sunscreens can offer us some protection from these rays.

The Bureau of Meteorology issues daily UV index forecasts like the one shown in Figure 4.4.1 to help you take precautions to protect yourself against damage from UV radiation.

Prac 1 p165



The Bureau of Meteorology issues daily Sunsmart UV alerts for each capital city in Australia.

Figure 4.4.1

Skin cancer alert

Australia has the highest rate of skin cancer in the world. Each year, 1300 people in Australia die from the disease.

SciFile

Some substances fluoresce when hit by UV light, such as the rocks shown in Figure 4.4.2. This means they absorb UV light and emit visible light. White paper, teeth whiteners and some laundry powders add fluorescent particles to take advantage of this property. The particles make the paper, teeth or clothes appear brighter. UV light is also used to sterilise objects.

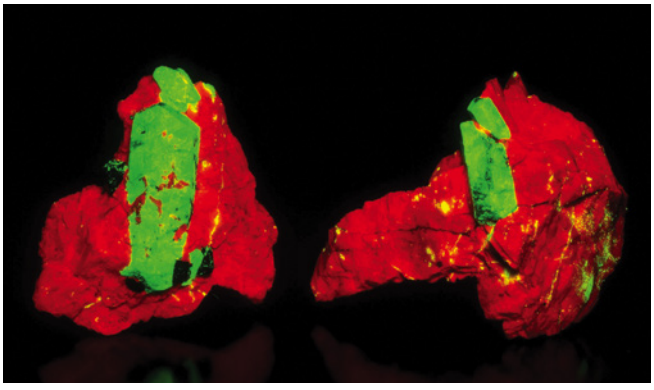


Figure 4.4.2 Many rocks, including calcite, gypsum, ruby, talc, opal, quartz and fluorite, are fluorescent and glow under UV light.

Glowing notes

After a major counterfeit operation involving the circulation of fake notes in Australia in 1966, many new security features have been added to today's notes. If you hold any Australian bank note under a UV light, its serial numbers and a patch below its denomination (value) glow. This is because they are printed in fluorescent ink.

SciFile

X-rays

X-rays have great penetrating power and so are used to investigate the structure of objects and to find flaws in metals. This radiation has such high energy that it can damage cells and tissues, and also the genetic material inside cells. X-rays are produced when electrons hit a metal surface. This happens inside an X-ray tube. X-rays are used in radiology, to produce images of bones, like that shown in Figure 4.4.3. They are also used in radiotherapy, in which X-rays are targeted at cancer cells to kill them or stop them from multiplying.

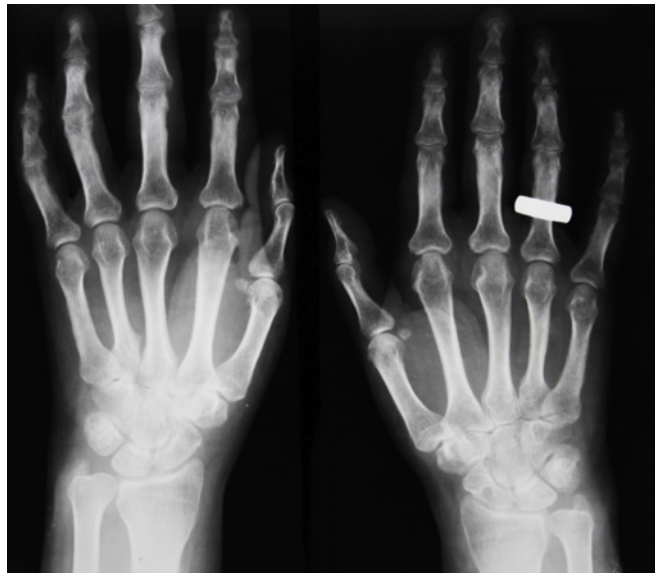


Figure 4.4.3 X-rays travel through human flesh, but not through bone. This makes them useful in producing images of the structures inside the body.

When a patient undergoes a computed tomography (CT) scan, the X-ray sources and detectors rotate around the person. Computers then analyse the data from the CT scanner to create images of organs in the body.

Because of the high energy of X-rays, it is important that people who work with them use protective lead shields and monitor their exposure levels. This is done using a personal radiation monitoring device, such as the one shown in Figure 4.4.4. The device is worn for up to three months. The total, or accumulated, radiation dose is then measured. The employer must ensure that this remains below a certain value, to protect the worker from possible harm.

Figure 4.4.4 A personal radiation monitoring device measures a person's exposure to X-rays, gamma rays, neutrons and beta particles.

Figure 4.4.5 shows a baggage X-ray inspection system. This is a machine used to screen luggage for dangerous items. A generator inside the machine produces low-to-medium-energy X-rays, which are directed at the luggage as it passes through on a conveyor belt. These X-rays pass more easily through less-dense items than through items of high density. Sensors behind the luggage detect variation in penetration of X-rays through the sample. These differences in densities can be displayed as different colours so that any items of concern can be identified. An example is shown in Figure 4.4.6.

4.4

4.5

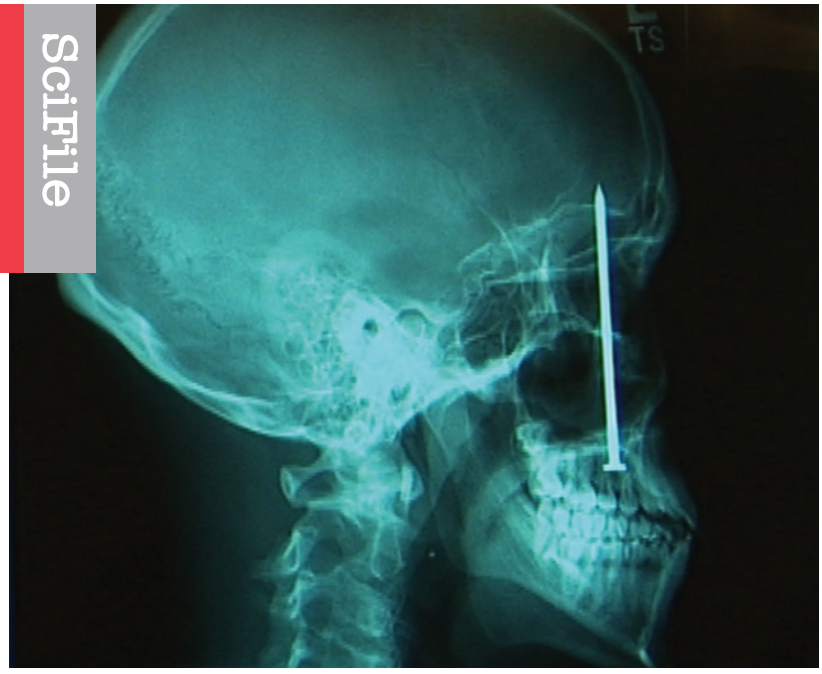
Figure 4.4.5 X-ray baggage inspection systems are widely used to screen luggage at airports.

Figure 4.4.6 Variations in the density of luggage items mean that X-rays penetrate samples to different extents. Such variations are used to build an image.

Sharp pain!

In January 2004, Patrick Lawler of Denver, USA, visited a dentist, complaining of tooth pain and blurred vision. The dentist found the problem: a 10 cm nail that the construction worker had unknowingly fired through the roof of his mouth 6 days earlier! The nail was safely removed.

SciFile



Gamma rays

Gamma rays have wavelengths of about one-hundred-billionth of a metre. Only a thick sheet of lead or a concrete wall will stop them. Gamma rays are produced in making nuclear power and nuclear bombs, and can be detected with photographic film or a machine called a Geiger counter. Their high energy allows gamma rays to interact with matter. Gamma rays can free electrons from their atoms, making them into ions. These in turn ionise surrounding atoms. This ionising ability is used in radiotherapy to target and kill cancer cells in patients.

Gamma rays are also useful in medical diagnosis. In the technique of positron emission tomography (PET), a patient is injected with small amounts of a short-lived radioactive material. This emits gamma rays, which are detected by a PET scanner or camera. This data is converted using computer analysis into a three-dimensional image. These scans allow doctors to study how parts of a patient are functioning, giving metabolic information. The scan in Figure 4.4.7 was produced by a PET scanner in combination with a computer tomography (CT) scanner.

GO TO Unit 2.4

4.6

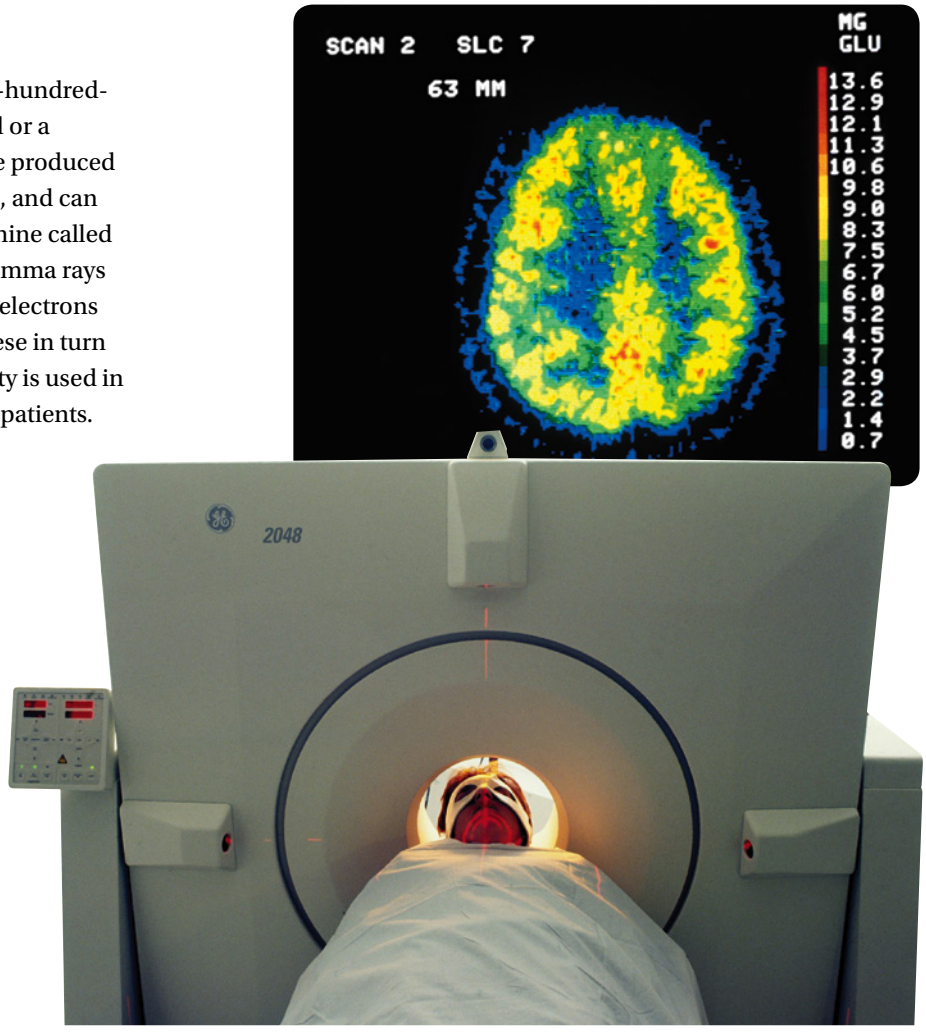


Figure 4.4.7 PET scans allow doctors to study how parts of a patient are functioning. They are often viewed together with a CT (computed tomography) scan, which provides anatomic information regarding their body structure.

4.4 Unit review

Remembering

1 **List** three uses of X-rays.

2 **Name** the damaging rays that are emitted in a nuclear explosion.

3 **Recall** which vitamin your body can only produce after some exposure to UV light.

4 **List** five ways you can protect yourself from harmful UV radiation.

5 **Name** the machine that detects gamma rays.

6 **Specify** what type of barrier is needed to stop the penetration of gamma radiation.

Understanding

7 **Define** the term *fluoresce*. L

8 **Explain** why some laundry detergent manufacturers claim that their product will leave washing brilliantly white.

9 **Explain** why a patient is injected with a short-lived radioactive material before having a PET scan.

10 Sydney Airport checks baggage through an X-ray machine with a conveyor belt (Figure 4.4.8). **Explain** how X-ray baggage scanning machines work.

Figure 4.4.8 An airport X-Ray machine and monitor

Applying

11 **Identify** whether infrared or ultraviolet radiation has greater wavelength.

12 The Sun emits a range of UV frequencies. UVA is the 'safest', UVC is the most dangerous while UVB is somewhere in between. **Identify** which form of UV radiation would have the:

- a longest wavelength
- b highest frequency
- c highest energy.

Evaluating CCT

13 a **Infer** what happens to the energy of electromagnetic radiation as its wavelength decreases.

b **Justify** your answer to part a.

14 Full-body X-ray scanning machines have been used to screen passengers before aircraft flight. These machines use low-energy ionising X-rays. The amount of radiation delivered to a person being scanned is equivalent to the radiation dose a passenger absorbs in a few minutes of flying. Some people argue that these machines should be banned. **Propose** arguments for or against the use of these machines.

15 a **State** the purpose of radiotherapy.

b **Propose** why patients undergoing radiotherapy usually suffer unwanted side effects to their treatment.

16 Some banknotes and passports include text and images that can only be seen under UV light. **Propose** how these security measures work.

Inquiring

A number of techniques of medical diagnosis or treatment are possible using forms of electromagnetic radiation. These include: radiology, radiotherapy, CT scans and PET scans.

Select one of these techniques and research to find:

- the type of electromagnetic radiation involved
- how this radiation is utilised
- any precautions that need to be taken when using this technique
- conditions the technique is most commonly used to treat or diagnose.

Present your findings as an information brochure for a radiography or doctor's clinic.

4.4 Practical investigations

STUDENT DESIGN

1 UV protection

Purpose

To test how effectively different materials block UV radiation.

Materials

- UV colour-changing beads or a UV sensor
- a range of materials to test, such as Polaroid sunglasses, cellophane of different colours, glass, transparent plastic, shadecloth, various clothing fabrics, and other items

SAFETY

A risk assessment is required for this investigation.

Figure 4.4.9 Wearing a wide-brimmed hat, sun-protective clothing and SPF 30+ sunscreen will help to protect this child's delicate skin from harmful UV rays.

Procedure

1. Design a test that will investigate how well different samples block UV radiation.
2. Brainstorm in your group and come up with several different ways to investigate the problem. Select the best procedure and write it in your workbook. Draw a diagram of the equipment you need.
3. Before you start any practical work, assess all risks associated with your procedure. If using chemicals, then refer to their MSDS. Construct a risk assessment that outlines these risks and any precautions you need to take to minimise them. Show your teacher your procedure and your risk assessment. If they approve, then collect all the required materials and start work.

Results

Record all your results in a table.

Practical review

1. **List** the materials you tested from most effective at blocking UV to least effective.
2. **Analyse** any sources of error in your experiment.
3. **Evaluate** your procedure. Pick two other prac groups and **evaluate** their procedures too, identifying their strengths and weaknesses.

4 Chapter review

Remembering

1 **State** the type of electromagnetic radiation that is emitted by radioactive materials.

2 **State** the approximate wavelength of an FM radio wave.

3 **State** whether AM or FM radio waves are more likely to experience static.

4 **Recall** which secondary colour is produced when red light and blue light are combined.

5 A hummingbird flaps its wings 120 times in a second. **State** the frequency of its beating wings. N

Understanding

6 **Describe** two uses of microwave radiation.

7 a **List** three products that may contain fluorescent additives.
b **Explain** why these are added to these products.

8 a **Define** the term *Wi-Fi*. L
b **List** three situations in which such technology is useful. N

9 Su-Ann sits on a beach and watches the waves roll in. She calculates that the waves are arriving every 5 seconds, with a frequency of 0.2 Hz. A short while later Su-Ann calculates that the waves are arriving every second. **Describe** how the frequency has changed.

Applying

10 Huong and Callum are relaxing on a beach. Huong is wearing red-tinted sunglasses and Callum wears yellow-tinted ones. Emily jogs past them wearing a white T-shirt, green shorts and a magenta cap. **Identify** the apparent colours of Emily's clothes to Huong and Callum.

Analysing

11 **Compare** a transverse wave and a longitudinal wave.

12 **Contrast** infrared and ultraviolet radiations.

13 **Use** Figure 4.1.10 on page 136 to **classify** each of the following electromagnetic wavelengths into a type of electromagnetic radiation. N

a 2 cm
b 3 km
c 0.0008 m
d 0.000 000 3 m

14 **Classify** the following UV Index readings as extreme, very high, high, moderate or low.

a 2
b 7
c 12

15 Pigment X reflects mostly orange light with a little red and yellow, but absorbs other colours. Pigment Y reflects mostly green light, with some blue and yellow, but absorbs all other colours. You dye your favourite socks in a mixture of X and Y. **Analyse** this information to **predict** the new colour of your socks.

Evaluating CCT

16 **Propose** how the world would be different if optical fibres had never been invented.

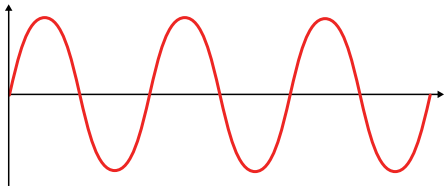
17 **Propose** reasons why a mobile phone is sometimes referred to as a *cell* phone.

18 a **Determine** whether you can or cannot answer the questions on page 131 at the start of this chapter.
b **Assess** how well you understand the material presented in this chapter.

Creating CCT

19 Tony plays a scale on his flute and ends on a note of frequency 220 Hz. The pressure variation of this sound is represented by Figure 4.5.1. **Construct** a diagram of a note that he then plays that has a frequency of 440 Hz and is twice as loud as the original sound. N

Figure 4.5.1



20 **Use** the following ten key terms to **construct** a visual summary of the information presented in this chapter.

electromagnetic radiation
electromagnetic waves
electromagnetic spectrum
gamma rays
infrared radiation
ultraviolet light
microwaves
visible light
X-rays
radio waves

4.7

Thinking scientifically

Q1 Sheena is carrying out an experiment using three tin cans. These are identical except that one is black, one is white and one is light grey. Sheena's teacher tells her that dark colours are better than lighter colours at absorbing infrared radiation. The air temperature in each can is 20°C at the start of the experiment. The cans are placed near a heater. CCT

Select the likely temperature of the black, silver and white cans after an hour.

A black 30°C, light grey 40°C, white 50°C
B black 50°C, light grey 20°C, white 40°C
C black 50°C, light grey 40°C, white 30°C
D black 30°C, light grey 50°C, white 40°C

Q2 The unit of measurement for radiation dose is the millisievert (mSv). The following table reveals the effective radiation dose involved in particular medical procedures and diagnostic tests. CCT

Procedure	Effective radiation dose (mSv)
CT abdomen and pelvis	10
Radiography spine	1.5
CT head	2
Bone densitometry	0.001
Mammography	0.7

CT: computed tomography

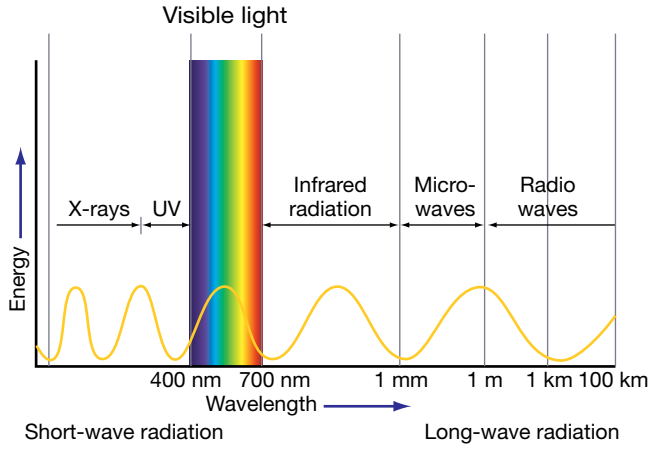
Which of the following lists the effective radiation dose absorbed by a person in order of increasing dose?

A bone densitometry, CT head, CT abdomen and pelvis, radiography spine, mammography
B CT head, CT abdomen and pelvis, radiograph spine, mammography, bone densitometry
C bone densitometry, mammography, radiography spine, CT head, CT abdomen and pelvis
D CT abdomen and pelvis, CT head, radiography spine, mammography, bone densitometry

Q3 Jimmy listens at close range to a trumpet being played. If the final note of the tune has a frequency of 440 Hz, calculate the number of sound waves passing Jimmy each second. CCT

A 110
B 440
C 220
D 880

Q4 Study this diagram, which shows the energy and wavelength of various types of electromagnetic radiation. CCT



Identify which list ranks this radiation in order from longest to shortest wavelength.

A X-rays, infrared radiation, microwaves, radio waves
B X-rays, visible light, UV light, infrared radiation
C radio waves, UV light, microwaves, infrared radiation
D radio waves, infrared radiation, UV light, X-rays

Q5 Infrared radiation has a band of energies just below those of visible light. Given that red light has a wavelength of approximately 4.0×10^{-7} m, predict which wavelength would be classed as infrared radiation. CCT

A 2.0×10^{7} m
B 2.0×10^{3} m
C 2.0×10^{-9} m
D 2.0×10^{-5} m

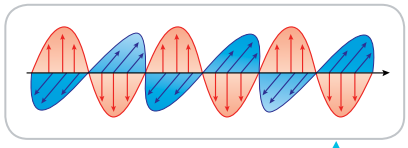
Glossary

Unit 4.1

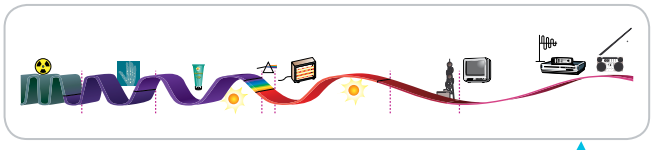
Amplitude: the maximum distance a wave extends beyond its middle position

Electromagnetic radiation: a range of electromagnetic waves consisting of oscillating electric and magnetic fields travelling at the speed of light

Electromagnetic spectrum: the entire range of frequencies of electromagnetic radiation, from high-energy gamma rays to low-energy radio waves



Electromagnetic radiation



Electromagnetic spectrum

Electromagnetic wave: transverse electric and magnetic fields positioned at right angles to each other and travelling through empty space at the speed of light

Wave motion: the transfer of energy without transferring matter

Unit 4.2

Colour filter: a transparent material that allows light of a particular colour to pass through

Dispersion: splitting of white light into separate colours

Polarised: electromagnetic radiation that is travelling in a single plane

Primary colours of light: red, green and blue

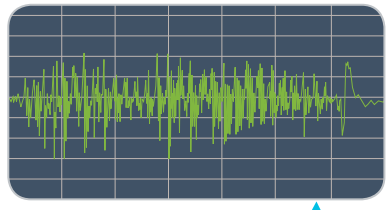
Scattering: the interaction of light with particles in the atmosphere, depending on colour and frequency of the light

Secondary colours of light: cyan, yellow and magenta

Visible spectrum: the range of colours that can be seen by the eye (red, orange, yellow, green, blue, indigo and violet)

Unit 4.3

Analogue signal: a continuous signal that varies in amplitude or frequency with the information being transmitted



Analogue signal

Bandwidth: the amount of data that can be transmitted through a communication channel

Binary number system: number system consisting only of two digits: 0 and 1

Coherent: light waves that are 'in step'

Digital signal: a discrete signal consisting of a series of 'on' or 'off' pulses

Infrared radiation: electromagnetic radiation with energies just below those of visible light, detected by our skin as heat

Microwaves: electromagnetic radiation with wavelengths ranging from fractions of a millimetre to tens of centimetres, used in communication and cooking

Optical fibre: a narrow tube of glass or plastic used to transmit pulses of light

Radio waves: electromagnetic radiation with wavelengths ranging from less than a centimetre to hundreds of kilometres, used in communication

Wireless internet (Wi-Fi): a method of transmitting an internet signal using radio waves

Unit 4.4

Fluoresce: absorbs UV light and emits visible light

Gamma rays: extremely high-energy electromagnetic radiation emitted by radioactive materials

Ultraviolet light: electromagnetic radiation with energies just above those of visible light, contained in sunlight

X-rays: high-energy electromagnetic radiation that can penetrate materials

5 Electrical energy

Have you ever wondered...

- how energy is carried around an electric circuit?
- what the difference is between current and voltage?
- how the electric circuits in your home are arranged?
- why electricity is transmitted from power stations at extremely high voltages?

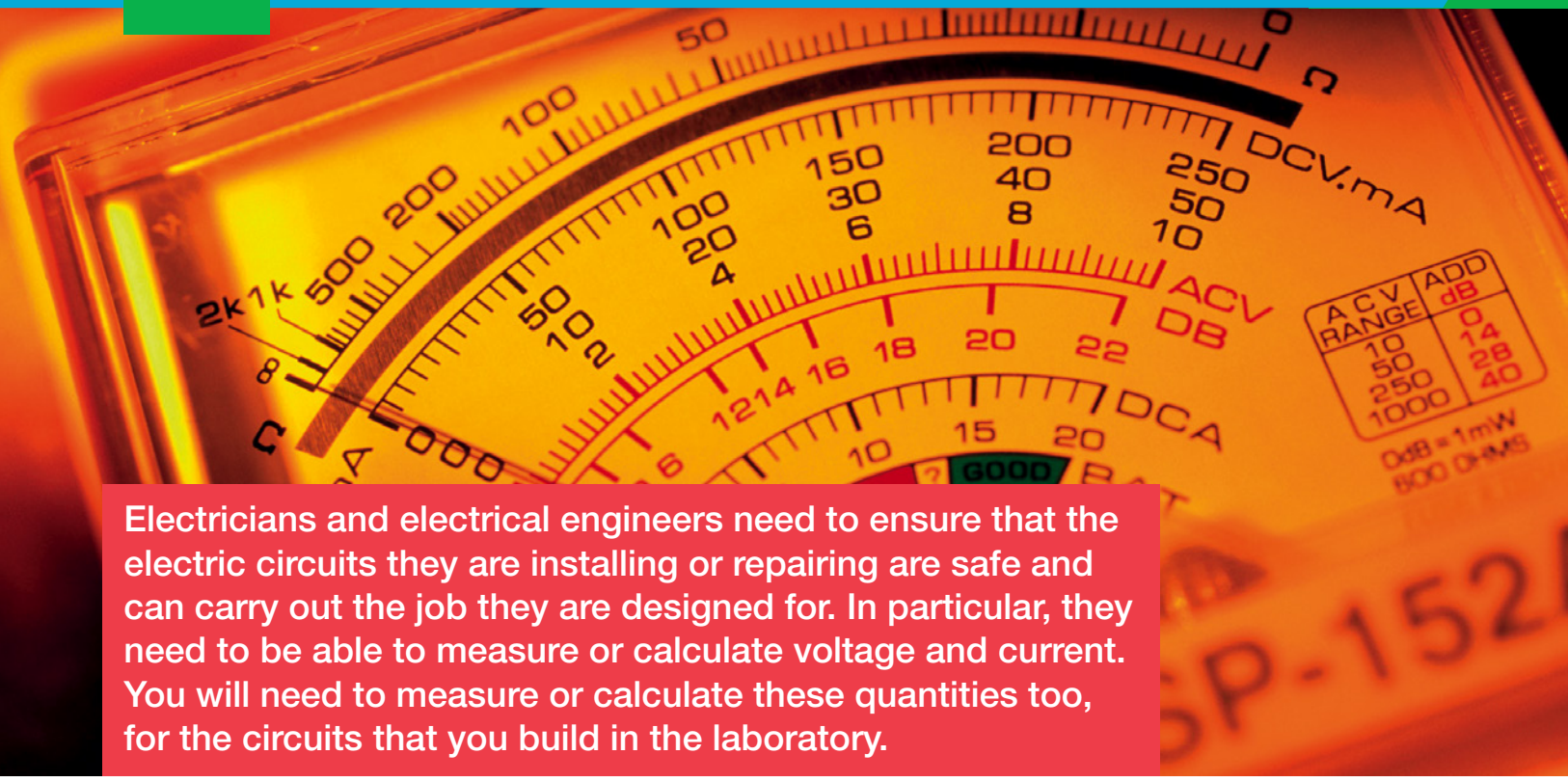
After completing this chapter students should be able to:

- describe voltage, current and resistance
- describe qualitatively the relationship between voltage, resistance and current
- compare series and parallel circuits
- outline developments in low-emission electricity generation and reduction in atmospheric pollution CCT PSC L
- apply the law of conservation of energy
- describe how usable energy is reduced, making a system less than 100% efficient
- discuss how the values and needs of contemporary society can influence scientific research into increasing efficiency of the use of electricity CCT S EU
- discuss choices that need to be considered when making decisions about the use of non-renewable energy resources S EU CC CCT

ADDITIONAL

- use Ohm's law to explain the relationship between voltage, resistance and current N
- use fruit to construct simple electrochemical cells
- research the structure of portable electrochemical cells such as mercury cells and rechargeable batteries L
- research scientific concepts that are used when designing energy-efficient devices CCT WE
- investigate the energy efficiency of appliances and relate this to a household energy account.

5.1 Measuring electricity



Electricians and electrical engineers need to ensure that the electric circuits they are installing or repairing are safe and can carry out the job they are designed for. In particular, they need to be able to measure or calculate voltage and current. You will need to measure or calculate these quantities too, for the circuits that you build in the laboratory.

Electric circuits

An **electric circuit** is a closed loop that provides a path for the transfer of electrical energy from a battery or power point to an electrical component. That component then converts the electrical energy into other forms of energy such as light, heat, sound or the kinetic energy of movement.

An electric circuit needs:

- a source of electrical energy, such as a battery or power point
- a component that converts electrical energy into another form of energy. A **component** is anything that is part of an electric circuit. Examples are resistors, globes, heating elements and motors
- wires to form a loop, connecting the component to the energy source.

To make the circuit easier and safer to use, it can also have:

- switches that control the flow of energy to the whole circuit or some of its branches
- fuses or safety switches that deliberately break the circuit in an emergency.

Circuit diagrams

A **circuit diagram** shows how the different components are arranged in the circuit. Figure 5.1.1 shows the circuit diagram for a simple battery-powered torch. The circuit diagram doesn't look anything like the real circuit but is a shorthand version of it. Figure 5.1.2 provides a key that allows you to determine what each component in the circuit is.

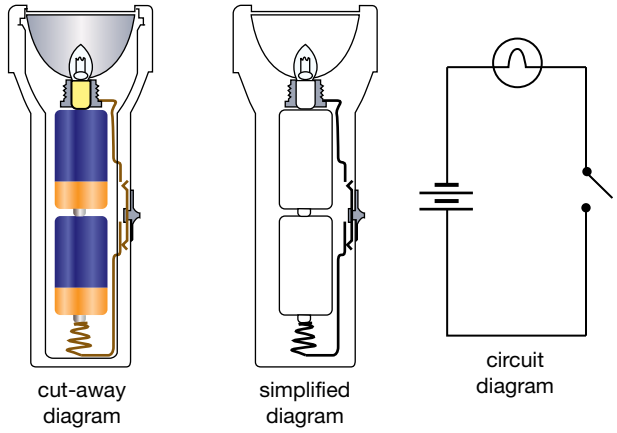


Figure 5.1.1 A torch has a battery, a globe and a switch.

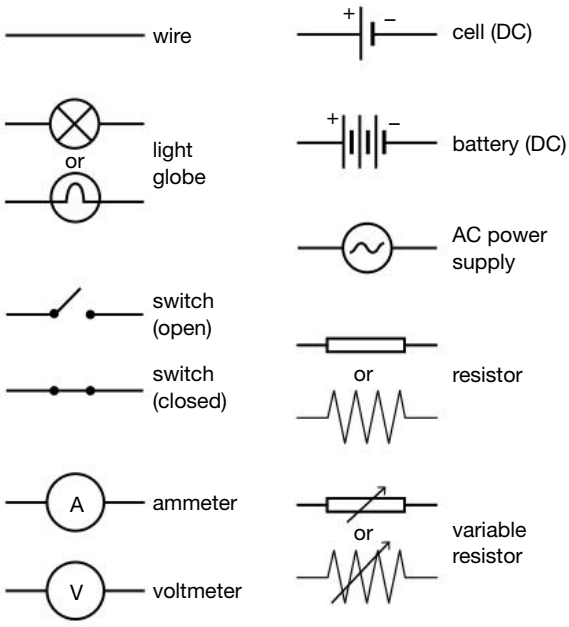


Figure 5.1.2 Symbols used for circuit components

Current

An electric current is formed whenever charge flows from one spot to another. In an electric circuit, this flow of charge is made up of electrons moving along the wires.

These electrons and the current they form carry energy around the circuit from the battery or power point to the different components that use it.

Electric current is measured using an **ammeter**. An ammeter measures the amount of charge that flows through it every second. The current is high if a lot of charge flows through it in one second, and low if only a small amount of charge flows through it.

Current is measured in **amperes** (unit symbol A), which is often shortened to 'amps'.

Nervous about electricity?

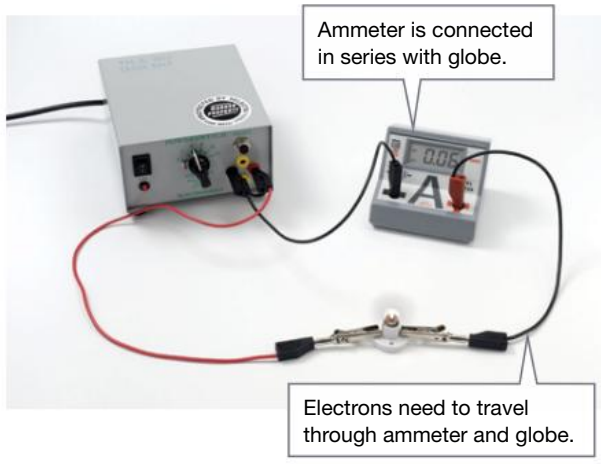
SciFile

Your muscles are activated by electrical impulses sent along your nerves. The same happens in other animals too. A platypus uses sensors within its bill to detect electric currents from the muscle movements of yabbies, fish and frogs.

Connecting up an ammeter

BUILDER

Electrons must pass through an ammeter for the charge to be detected. Therefore, the ammeter needs to be in line with the rest of the circuit's components. This arrangement is known as being in series and is shown in Figure 5.1.3.



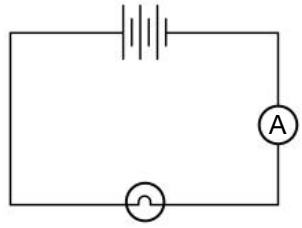


Figure 5.1.3 Ammeters measure the current that passes through them. An ammeter needs to be in line (in series) with the rest of the circuit.

Voltage

Voltage is a measure of the amount of energy:

- supplied to the charges by the voltage source (the supply voltage)
- used by the charges as they pass through a component such as a light globe (voltage drop).

Voltage is measured using a **voltmeter**. The voltage is high if the electrons are supplied with a lot of energy or are losing lots of energy. The voltage is low if the electrons lack energy or lose very little. If the voltage is zero, it means the battery is dead, the power point is turned off or the electrons are losing no energy in that part of the circuit.

Voltage is measured in **volts** (unit symbol V).

Connecting up a voltmeter

A voltmeter compares the energy of electrons before and after they pass through a component such as a light globe. For this reason, voltmeters are connected in parallel. This means they are not part of the circuit itself, but instead attach across the component being measured, piggy-backing it. This arrangement is shown in Figure 5.1.4.

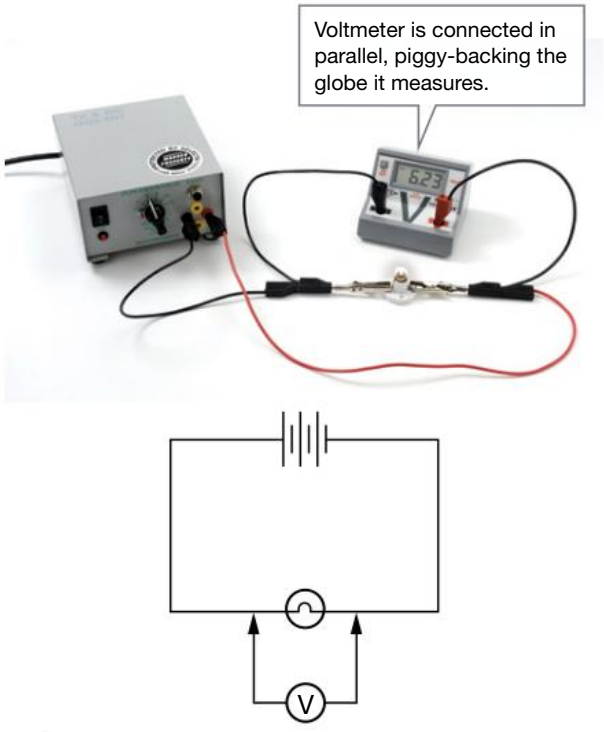


Figure 5.1.4 Voltmeters measure how much energy is used by charges as they pass through an energy converter such as a light globe. The voltmeter is connected in parallel with the component whose voltage it is measuring.

Supply voltage

Electrons get the energy they carry around the circuit from the circuit's energy source. Each energy source has its own voltage. Higher supply voltages give the electrons a bigger 'push' than low supply voltages.

Mains power

In Australia, power points supply 240 V to the electrons in any circuit plugged into them. Sometimes a **transformer** (like the one in Figure 5.1.5) is used to reduce the voltage from a power point to a more manageable voltage. For example, laptops typically only need a supply of 19 V, mobile phones need 6 V to recharge and digital cameras 6.5 V.

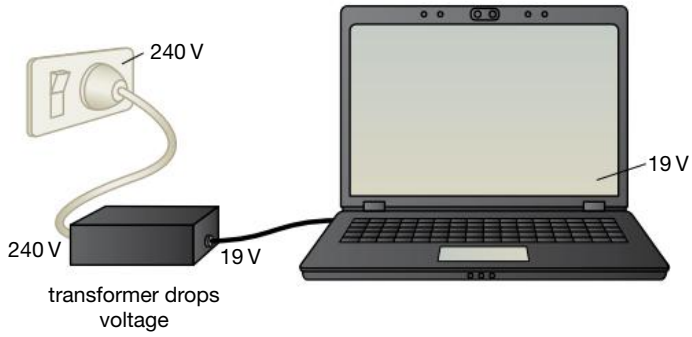


Figure 5.1.5 A step-down transformer reduces the 240 V provided by a power point to the 19 V that a laptop needs.

In the laboratory, power packs reduce the 240 V from a power point to the voltages required in experiments. Most power packs can be adjusted to supply a range of voltages from 1.5 V to 6 V or 12 V.

Batteries

As you can see in Figure 5.1.6, batteries come in different sizes and shapes and different batteries provide different voltages. The voltage of batteries can be further increased by placing a number of them end to end. For example, eight 1.5 V AA batteries arranged head to tail give the same 12 V as supplied by a car battery.

Prac 1 p178

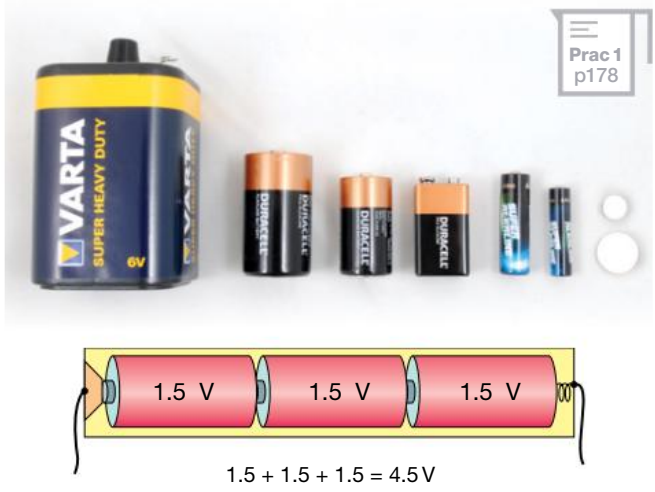


Figure 5.1.6 Dry cell batteries come in different shapes and voltages. Higher voltages can be obtained by arranging the batteries end to end in series.

INQUIRY

science 4 fun

Investigating batteries

What voltages do batteries supply?

YES

Collect this ...

- range of battery-operated appliances, such as wristwatches, cameras, toys and torches

SAFETY

Do not use a car battery in this activity.

Do this ...

1. Open up the back of the battery-powered appliances.
2. Take note of the voltage of the battery or batteries and how many batteries are being used.

Record this ...

Describe the different batteries, their voltages and combinations you found in each appliance.

Explain why you think batteries come in different sizes, shapes and voltages.

Voltage drop

Electrons lose energy as they pass through a component such as a light globe, a heating element or a motor. This results in a voltage drop across the component. This voltage drop depends on the resistance of the component.

5.1

Resistance

As electrons pass along the wires of an electric circuit, their path is restricted a little by the atoms that make up the wires. This restriction is known as **resistance**. Resistance measures how difficult it is for an electric current to flow through a material or a component. A high resistance means it is difficult for electrons to pass through the material. A low resistance means that it is easy for the electrons to pass through the material.

The energy and voltage lost by electrons as they pass through a component depends on the resistance of the material in the component. Electrons don't bump into much as they pass through low-resistance materials, and so they lose almost no energy and almost no voltage. In contrast, in high-resistance materials there are obstacles in the way of the electrons. A little energy is lost every time the electrons are bumped off-course. Overall, a lot of electrical energy and voltage is lost as all the electrons pass through.

Resistance also affects the current flowing through a circuit. As the resistance of a component increases, fewer electrons get through it every second. This reduces the current flowing through it.

The resistance of a wire depends on the:

- type of material the wire is made from. For example, metals generally have low resistance, whereas rubber has an incredibly high resistance
- length of the wire. Doubling the length of a wire doubles the number of obstacles that the electrons must pass through. This doubles its resistance
- thickness of the wire. It is more difficult for electrons to pass along thin wires than to pass along thick wires.

Resistance is measured in **ohms**. The unit symbol for ohms is the Greek letter omega, Ω. Resistance can be measured by a multimeter, like the one in Figure 5.1.7.

Figure 5.1.7 A multimeter combines an ammeter and a voltmeter, and can also measure resistance.

Conductors

Metals are **conductors**. This means that an electric current will pass through them. However, some metals are better conductors than others. It all depends on their resistance.

Copper is an excellent conductor. It has a very low resistance and almost no energy is lost from it. It is also relatively cheap. For these reasons, copper wires are used in most electric circuits around the home, in factories and in cars. Another excellent, low-resistance conductor is aluminium. Aluminium is much lighter than copper. This is why aluminium is used for high-voltage transmission lines strung between distant pylons (poles), like those in Figure 5.1.8.

Figure 5.1.8 Transmission lines need to be made of a low-resistance, light metal. Copper would be far too heavy, so aluminium is used instead.

Tungsten and nichrome alloy are metals and so they conduct electricity too, but not as well as copper or aluminium do. Tungsten and nichrome have relatively high resistances and so electrons passing through them lose much of their energy and voltage. This energy is converted into heat and sometimes light. This makes them ideal to use as heating elements in electric kettles, hair dryers, electric blankets and the filaments of old-fashioned incandescent light globes like the one in Figure 5.1.9.

Figure 5.1.9 Tungsten and nichrome wires conduct electricity but have a high resistance. This old-fashioned light globe uses a tungsten filament. Its resistance converts electrical energy into light and heat.

Insulators

Some materials have such a high resistance that they can block electric current completely. These materials are said to be **insulators**. Examples are rubber, plastics, wood, glass and ceramics. Figure 5.1.10 shows how plastic is used to wrap electric wires and cables to insulate them from their surroundings. Glass and ceramics are used to insulate high-voltage power lines so that current doesn't pass into the poles that are holding them up.

Prac 2 p178

Figure 5.1.10 Plastic coating is used to insulate each of the three wires in an electric cable. More plastic coating wraps all the three wires together, insulating them even further.

Relating current, voltage and resistance

Current, voltage and resistance are all related to one another. Change one of them and at least one of the others will change too. For example, if the:

- current remains the same, then the voltage drop (and energy lost) will increase as the resistance of a component increases. This is similar to what happens in a car. The rougher and steeper the road, the more petrol (chemical energy) the car will use
- supply voltage remains the same but the resistance of a component is increased, then less current will flow through the component. This is because it is harder for the electrons to get through. This is similar to what happens to the traffic on a road. If there is roadwork or an accident restricting traffic, then fewer cars will get through
- supply voltage is increased, then the current flowing around the same circuit will increase. Similarly, the number of cars that can pass every hour over a bridge increases if the cars travel faster, with more kinetic energy.

5.2

ADDITIONAL

Ohm's law

The relationship between current, voltage and resistance can be summarised by Ohm's law, which states:

voltage = current × resistance

or

$V = IR$

where V = voltage (measured in volts V)

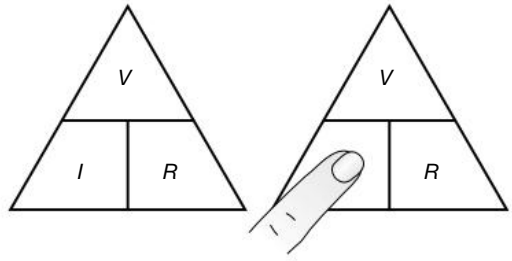
I = current (measured in amperes A)

R = resistance (measured in ohms Ω).

- For a constant current, voltage varies directly with resistance. This means that if the resistance of a component doubles, then the voltage drop (and energy lost) will double too.
- For a constant supply voltage, current varies inversely with resistance. This means that if the resistance of a component doubles, then only half the current will flow through it.
- For a constant resistance, voltage varies directly with current. This means that if the current through a component doubles, then the voltage drop (and energy lost) will double too.

Using Ohm's law

Figure 5.1.11 shows one easy way of using Ohm's law. Cover the quantity you need to calculate. You then do the calculation that is left exposed.



To calculate current, cover I with your finger. This tells you that $I = \frac{V}{R}$.

Figure 5.1.11 An easy way to use Ohm's law

WORKED EXAMPLE
Using Ohm's law

Problem

An unknown resistor carries a current of 5 A. A voltmeter connected across it shows 10 V. Calculate the resistance of the resistor.

Solution

To find the resistance, cover the symbol R. This gives you the formula $R = \frac{V}{I}$.

$$\text{Hence } R = \frac{V}{I}$$

$$= \frac{10}{5}$$

$$= 2\ \Omega$$

Practice

N

1 A 3 Ω resistor has a current of 2 A passing through it. **Calculate** the voltage lost over it.

2 A 4 Ω resistor has 12 V applied to it. **Calculate** the current passing through it.

3 A current of 2 A passes through a resistor. The voltage drop is 12 V. **Calculate** its resistance.

Prac 3 p179 5.3 5.4

ADDITIONAL

5.1 Unit review

Remembering

1 **Recall** the following terms by matching each term (a–c) with its correct description (i–iii).

a	current	i	Measures how difficult it is for charges to pass through a material
b	voltage	ii	Measures the flow of charge passing through the circuit
c	resistance	iii	Measures the energy provided to or used by charges

2 **Recall** units and unit symbols by copying and completing the table.

Quantity	Unit	Unit symbol
Current		
Voltage		
Resistance		

3 **List** three things that resistance depends on.

4 **List** two examples of an electrical:
- a conductor
- b insulator.

5 **Name** two metals that have:
- a low resistance
- b high resistance.

Understanding

6 **Explain** what a transformer is used for.

7 **Explain** why copper is used for the wiring around a house but aluminium is used for high-voltage transmission lines.

Applying

8 **Calculate** the total supply voltage of the battery arrangement shown in Figure 5.1.12. N

The following key applies to questions 9 and 10.

Key
- A 0 A (current is blocked)
- B 1 A
- C 2 A
- D 4 A

N

9 The circuit in Figure 5.1.13 was set up. The ammeter shows the current flowing through the globe. The supply voltage was then increased to 12 V. **Use** the above key to **predict** the new ammeter reading.

10 The globe in Figure 5.1.13 was swapped with one of greater resistance. **Use** the above key to **predict** the new ammeter reading. N

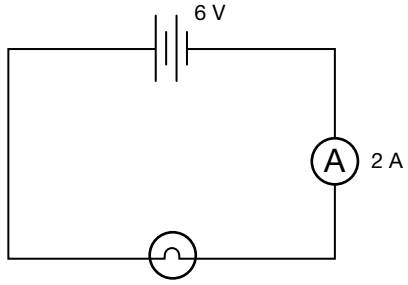


Figure 5.1.13

Analysing

11 **Contrast** a conductor with an insulator.

12 **Contrast** the ways in which an ammeter and a voltmeter are connected into a circuit.

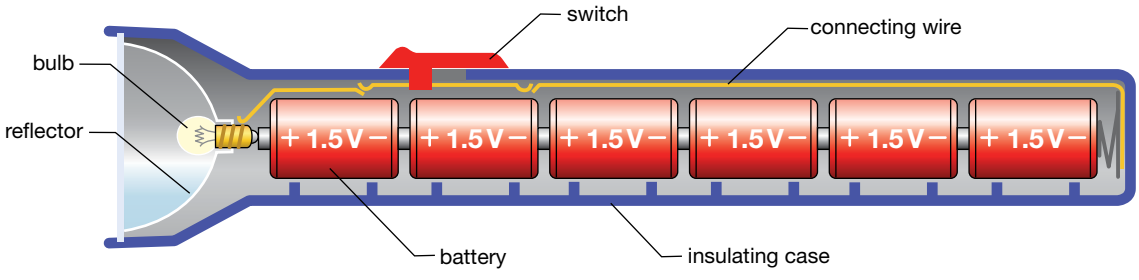


Figure 5.1.12

Evaluating CCT

13 An analogy is a model that compares something that is difficult to understand with something that is easier to understand. For example, electrons moving along a wire are impossible to see and difficult to imagine. they are often compared to something easier to understand, such as cars driving along a road.

- a In this analogy, **state** what would represent:
  - i electric current
  - ii resistance.
- b **Analyse** the flow of cars along a busy single-lane road that:
  - i widens with extra lanes
  - ii is blocked by a broken-down car.
- c **Use** this analogy to **predict** what would happen to current if a light globe were replaced by:
  - i a copper wire
  - ii an insulator.

14 An electric current can flow when different metals touch each other.

- a If you place aluminium against an amalgam filling in your tooth, you will feel pain in the tooth. **Propose** reasons why.
- b Builders often work with different metals. For example, they use steel nails and screws, aluminium foil and copper wires. **Propose** ways in which they can keep themselves safe when working with different metals.

15 AA and AAA batteries are different sizes but both supply voltage of 1.5 V. **Propose** a reason why batteries come in different shapes and sizes, even when some of them supply the same voltage.

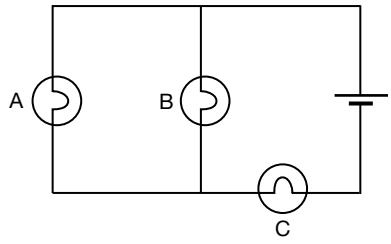
Creating CCT

16 **Construct** a circuit diagram that has a battery, a resistor, a switch and connecting wires. Include an ammeter that measures the current flowing through the resistor and a voltmeter that measures the voltage drop across it.

17 **Construct** a circuit diagram like that shown in Figure 5.1.14 but add:

- a a switch that would turn all three globes on and off
- b a switch that will only turn globe B on and off
- c an ammeter that would measure the total current through the circuit
- d an ammeter that would measure the current that flows only through globe A
- e a voltmeter that would measure the voltage lost by charges as they pass through globe B.

Figure 5.1.14



Inquiring

1 what a superconductor is and what it can be used for.

Present your research as a digital document that includes images. ICT

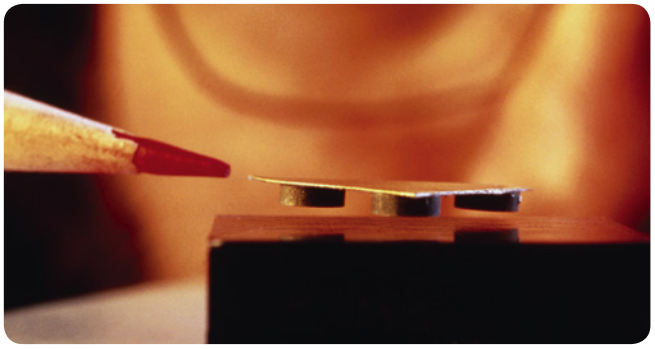


Figure 5.1.15 Superconductors have the ability to levitate or float in the air.

2 Research Georg Ohm, the physicist after whom the unit of resistance is named. Find:

- biographical details such as his date and places of birth and death
- information regarding his life
- information regarding his scientific achievements
- whether he developed Ohm's law or whether it was named after him
- another of his laws that has been since disproven.

Present your findings as short biography.

5.1 Practical investigations

1 Dry cell voltages

Purpose

To measure the supply voltages of different batteries.

SAFETY

Do not use a car battery in this activity.

Materials

- selection of batteries with some charge left in them
- voltmeter or multimeter

Procedure

1. In your workbook, construct a table like the one shown in the Results section.
2. Set the voltmeter or multimeter to its least-sensitive scale.
3. Attach or touch the voltmeter or multimeter terminals or probes to the terminals of each battery. For most batteries, their terminals will be their ends. Record your measurement in the results table.
4. Record the voltage printed on the battery.

Results

Record your measurements in a table like this one.

Battery type	Voltage printed on battery (V)	Measured voltage (V)

Practical review

1. **Use** your results to **assess** the accuracy of this statement. *The supply voltage of batteries is always a little lower than the voltage printed on them.*
2. Batteries have a resistance (their internal resistance) and so they use up some of the supply voltage. **Use** this fact to **explain** your results.

2 Graphite light globe

Purpose

To construct a light bulb using a pencil refill.

SAFETY

The pencil refill will get very hot, so do not touch it once it is connected into the circuit.

Materials

- refill for a mechanical pencil
- cardboard tube
- 9 V battery
- 2 wires with alligator clips
- large beaker, glass jar or drinking glass
- electrical insulation tape
- scissors
- digital camera or mobile phone (optional)

Procedure

1. Set up the apparatus shown in Figure 5.1.16. The pencil refill will break easily so take care when handling it.
2. Connect the wires to the terminals of the battery.

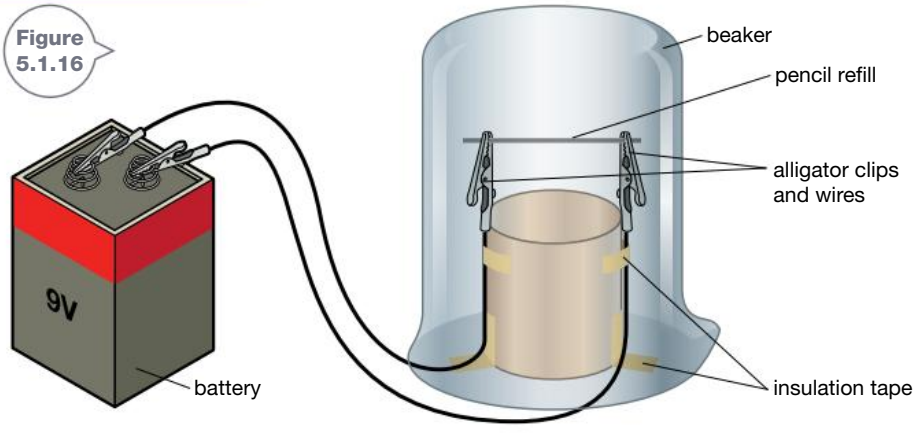
Results

Record what happens.

Practical review

1. Pencil refills are made from graphite mixed with clay. **Deduce** whether the graphite–clay mix is a conductor or insulator.
2. **Deduce** whether the graphite–clay mix has a higher or lower resistance than the copper wires.

Figure 5.1.16



3 Ohm's law

Purpose

To determine whether a light globe obeys Ohm's law.

Materials

- adjustable power pack (up to 12 V)
- connecting wires
- 12 V light globe and holder
- ammeter
- voltmeter

SAFETY

The globe will get hot so do not touch it.

Ensure that the ammeter and voltmeter are connected as shown.

Procedure

1. Copy the table from the Results section into your workbook.
2. Construct the circuit shown in Figure 5.1.17.
3. Set the power pack on the lowest possible voltage.
4. Record the ammeter and voltmeter readings in the table.
5. Set the power pack on a different supply voltage and repeat your measurements.
6. Repeat until you have tested all possible voltage settings on your power pack or have five different sets of current/voltage measurements.

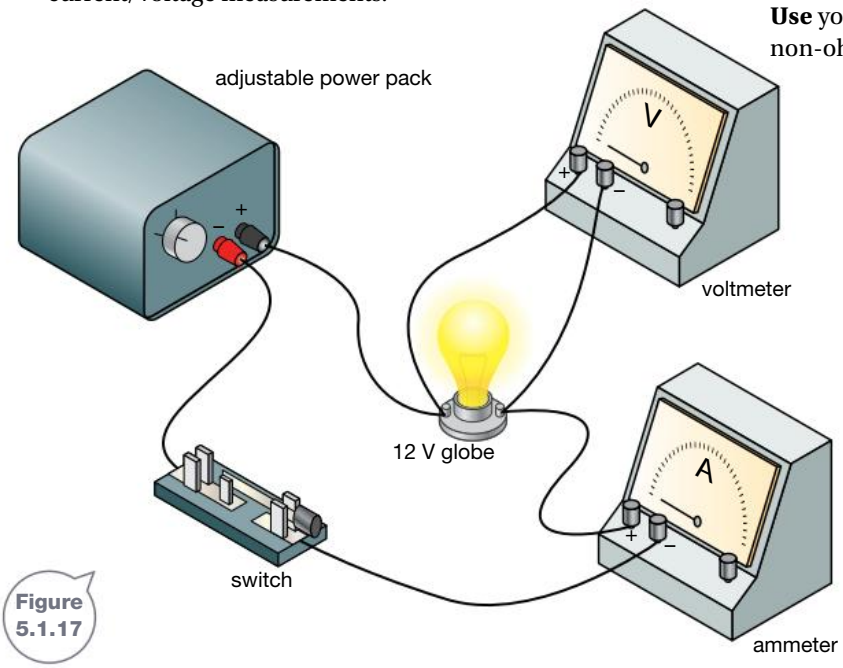


Figure 5.1.17

Results

1. Record your results in a table like this one.

Supply voltage (V)					
Current (A)					
Voltage (V)					
Calculated resistance of globe (Ω)					

2. Ohm's law can be used to calculate resistance of the globe.

   Use $R = \frac{V}{I}$.

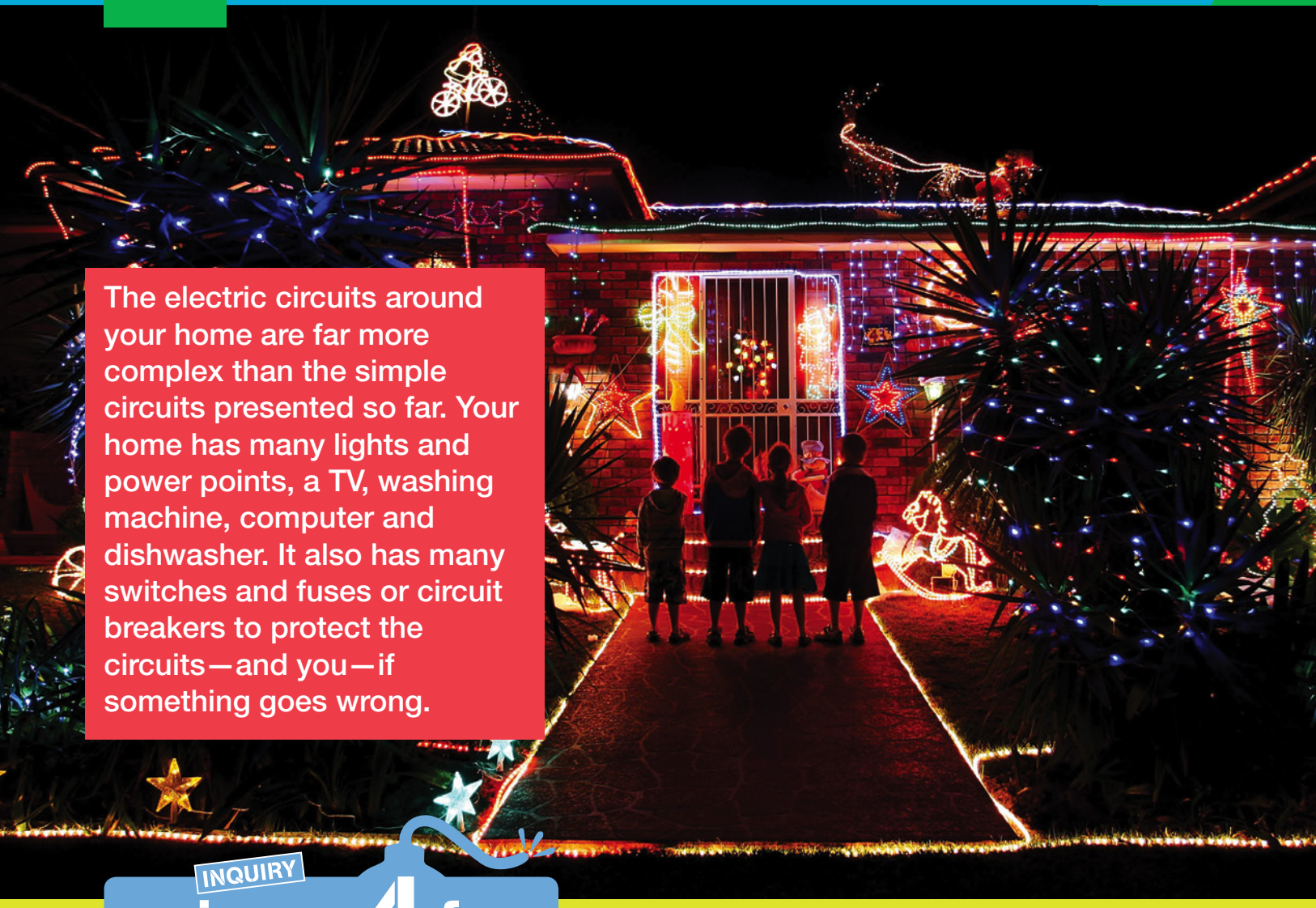
   Calculate the resistance of the light globe for each set of measurements and add to your table.
3. Plot a graph of voltage versus current (place voltage on the vertical axis and current on the horizontal). Draw a line of best fit or a smooth curve through the middle of your results.

Practical review

1. **Construct** a circuit diagram for Figure 5.1.17.
2. A component is ohmic if its resistance is approximately the same for all voltages and currents and its voltage/current graph is a straight line.

   Use your results to **classify** the light globe as ohmic or non-ohmic.

5.2 Practical circuits



The electric circuits around your home are far more complex than the simple circuits presented so far. Your home has many lights and power points, a TV, washing machine, computer and dishwasher. It also has many switches and fuses or circuit breakers to protect the circuits—and you—if something goes wrong.

INQUIRY

science 4 fun

Tongue circuits

YES

Collect this...

- clean, new nail
- clean copper wire

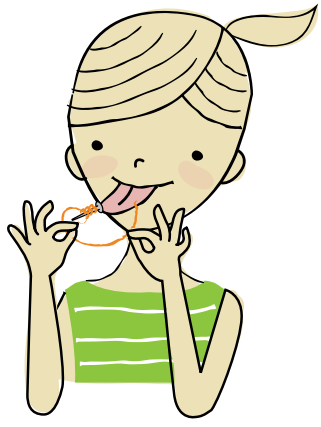
Do this...

1. Wind one end of the copper wire around near the head of the nail.
2. Place the sharp end of the nail and the free end of the copper wire on your tongue (be careful not to cut yourself).

Record this....

Describe what you felt.

Explain what you think caused this feeling.



Series circuits

In a **series circuit**, all the components of the circuit are connected up one after another to form a single loop. Series circuits are the easiest of all the circuits to connect up. Figure 5.2.1 shows a typical series circuit, in which two identical light globes are connected in series.

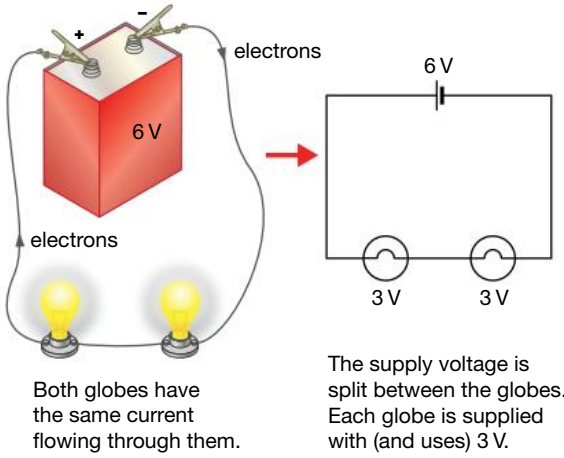


Figure 5.2.1 This series circuit has two light globes arranged one after the other.

When the charges leave the battery, they carry a full load of energy (in this case 6 V). Very little energy is lost in the wires because they have a very low resistance. This leaves 6 V worth of energy to be shared equally by both globes. Each globe therefore loses 3 V worth of energy. To get back to the battery, the current must pass through both globes.

Series circuits are easy to connect up but are often not very practical. This is because:

- the globes cannot be controlled individually with a switch. A switch would turn them all on or all off
- current stops flowing around them if any of the globes 'blow'. This breaks the circuit and causes all the other globes to go out too, making it extremely difficult to locate which globe is the faulty one
- adding more globes to the circuit reduces how brightly they glow. The supply voltage is shared by more globes, so each globe is duller than before. This effect is shown in Figure 5.2.2.

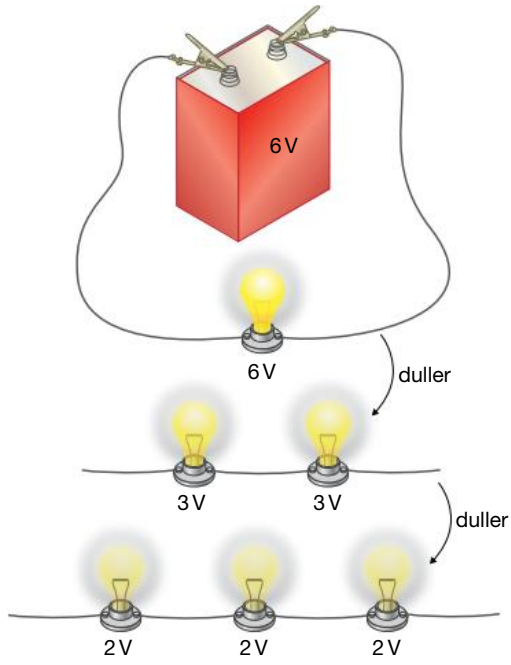


Figure 5.2.2 Globes get duller and duller as you add more of them to a series circuit.

Parallel circuits

A **parallel circuit** has a number of branches, each branch having its own components. A typical parallel circuit is shown in Figure 5.2.3.

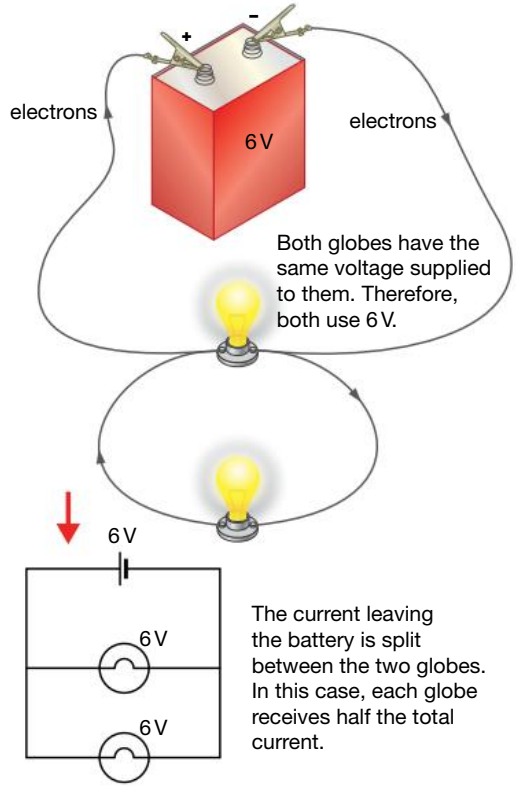


Figure 5.2.3 This circuit has two globes in parallel.

In this parallel circuit, the current leaving the battery splits into two, with half going down each branch. An individual electron cannot pass through both globes and so loses its energy in the one globe it passes through. Therefore, each globe receives the full 6 V supplied by the battery.

Although more difficult to construct, parallel circuits have many advantages over series circuits. In parallel circuits:

- each branch can have its own switch. This allows each globe to be turned on or off independently of the others
- only one branch is affected if a globe 'blows'. All the others keep working. This also makes it easy to find the faulty globe
- adding extra globes does not affect their brightness. This is shown in Figure 5.2.4. Each branch always receives the full supply voltage, regardless of how many globes there are.

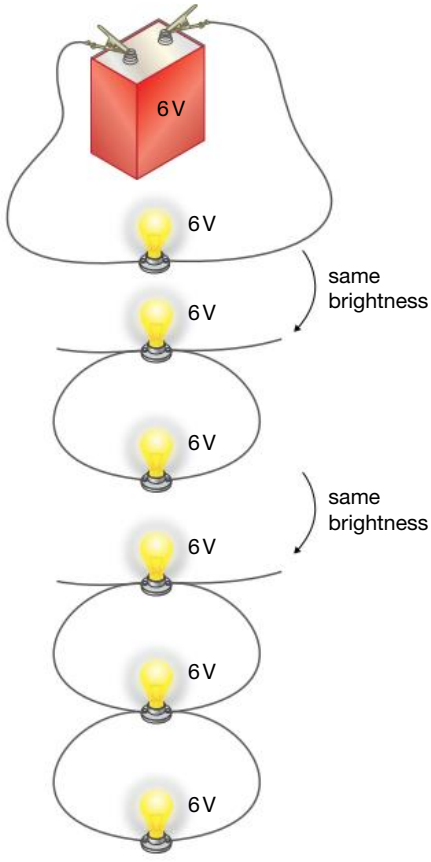


Figure 5.2.4 There is no change in the brightness of globes in a parallel circuit when more of them are added.

In summary:

- components in a series circuit have the same current through them but split the voltage between them
- components in a parallel circuit have the same voltage across them but split the current between them.

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Combination circuits

Sometimes some components in a circuit are arranged in series and other components in parallel. Consider the circuit in Figure 5.2.5. In this circuit, two globes (B and C) are in series with each other. These two globes are in parallel with globe A.

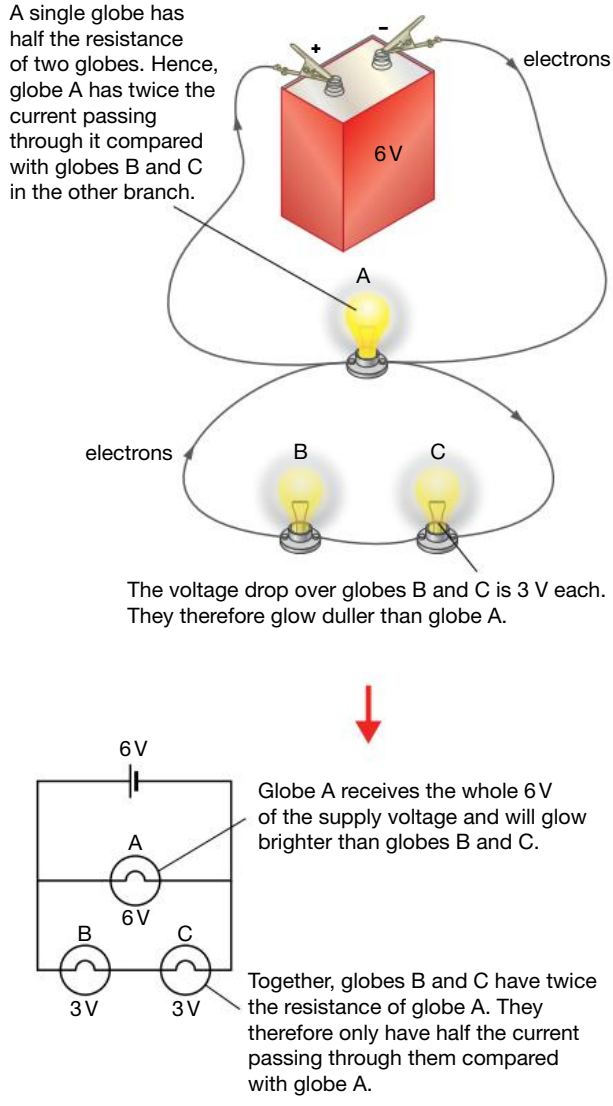

Figure 5.2.5 This circuit has both series and parallel components.

5.5

Household wiring

The electrical wiring in a house or an apartment is one large parallel circuit, with each light and power point located on its own branch with its own switch. Each receives the full supply voltage of 240 V, allowing each to work at full power. A simplified version of a typical household circuit is shown in Figure 5.2.6.

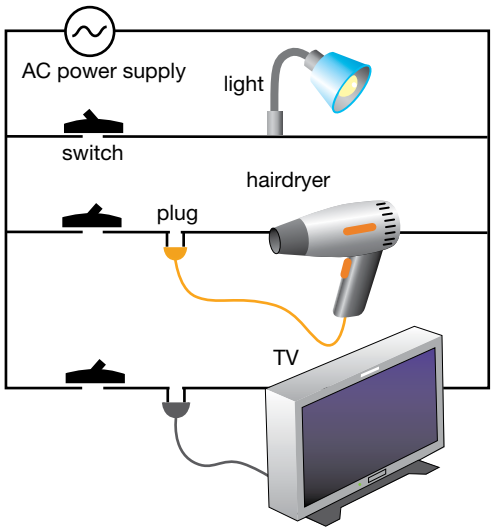

Figure 5.2.6 The circuits around your home are connected in parallel. This allows everything to be controlled independently and provides everything with 240 V.

The electrical cables supplying power points are made of three separate wires. The **active wire** (coated in brown plastic) carries current to the power point, and the **neutral wire** (blue) carries current away from it. However, 240 V can be deadly if the current finds a way out of the wires and through you. This might happen if part of the circuit within an appliance breaks, allowing a wire to touch the casing or switch. You can then become part of the circuit and current will flow through you instead of down the neutral wire! The result would be an electric shock or possibly **electrocution** (death by electricity).

Colour changes

Old wiring may have red (active), black (neutral) and green (earth) wires. Up to 8% of electricians are red/green colour blind and cannot tell the difference between a red active wire and a green earth wire. These two wires are deadly if swapped! For the safety of everyone, the colours have been changed to brown, blue and green/yellow.

SciFile

To avoid this possibility, power points have a third wire, called the **earth wire** (coated in green and yellow plastic). This wire connects the power point (and any metal part of an appliance connected to it) to the earth beneath you. This provides a way for dangerous stray currents to flow out of the appliance without passing through you. The arrangement of active, neutral and earth wires within an extension lead is shown in Figure 5.2.7.

Electrical safety

Most practical circuits also have a device that deliberately breaks the circuit if a faulty appliance allows an abnormally high current to flow. This current might otherwise end up passing through you or setting the house on fire. Abnormally high currents cause wires to heat up rapidly. This might melt their plastic coatings. They can then set fire to the fluff and dust trapped with the wires in the walls and roofspace. For this reason, old worn wiring, such as that in Figure 5.2.8 on page 184, should be replaced.

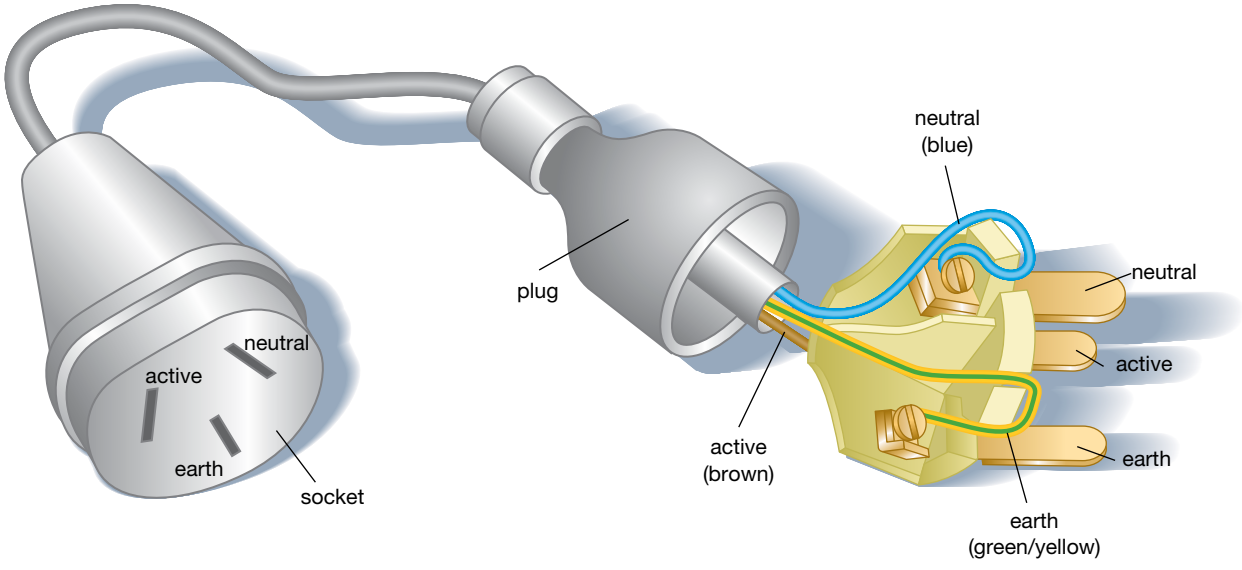

Figure 5.2.7 Power points and cables have three wires. The active and neutral wires carry the current to and from the appliance. The earth wire is included only for emergencies. Stray currents caused by faulty appliances will pass along the earth instead of through you.

Figure 5.2.8 Old or faulty electrical wiring is the most common cause of house fires.

Fuses

A **fuse** is a wire of high resistance and low melting point. It will melt if too much current flows along it. Melting breaks the circuit and stops the current. Fuses are common in older houses, and are still used in cars and trucks and electronic devices such as music and home theatre systems. A typical car fuse box is shown in Figure 5.2.9.

Prac 2 p188

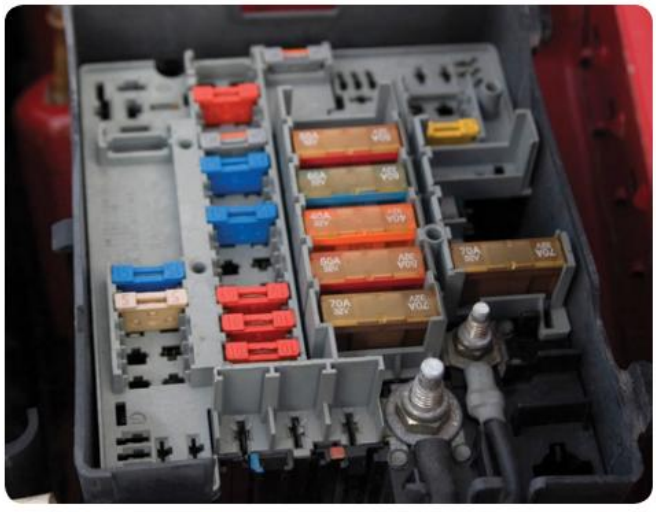

Figure 5.2.9 Cars commonly use fuses to break a circuit if something goes wrong in it. Each colour fuse will melt at a different temperature and current.

Circuit breakers

New houses generally use circuit breakers instead of fuses. A **circuit breaker** is a switch that is activated by a higher-than-normal current. When this happens, it switches 'off', breaking the circuit. Figure 5.2.10 shows a typical household switchboard or junction box. Each circuit breaker controls a different circuit. One controls the lights while another circuit breaker controls the air conditioner. Others control the circuits of different clusters of rooms such as the family room, kitchen and bedrooms.

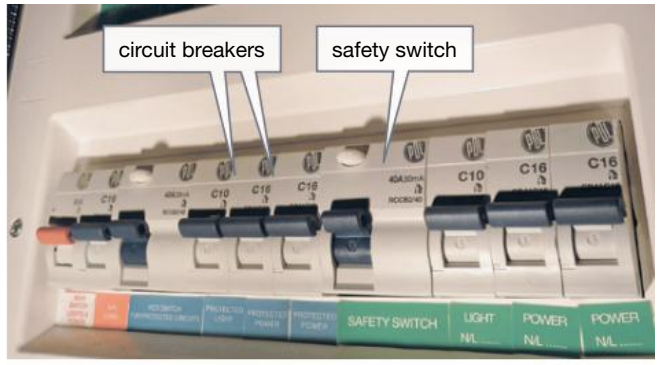

Figure 5.2.10 You will probably find your home's switchboard near the front door. Those in most newer homes look like this one, with a set of circuit breaker switches and safety switch.

Safety switches

Modern home switchboards also have a **safety switch** on their lighting and power circuits that monitors how much current is flowing through them. The current flowing into the house through the safety switch should be the same as the current flowing out of the house through the same safety switch. If they are different, then current is likely to be 'leaking' either into a faulty appliance or into you. When the safety switch detects a leak, it breaks the circuit within 0.03 seconds. This stops any further current from flowing. In this time, you will still receive a nasty shock but the current should be switched off fast enough to stop you being electrocuted.

Some power points around a home may also have their own safety switch, protecting you from any faulty appliances attached to it. These power points have a small blue reset/test button, as seen in Figure 5.2.11.

A safety switch is also known as a residual current device (RCD).

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Figure 5.2.11 Some power points have their own safety switch.

SciFile

Strike insurance

A surge protector keeps your appliances from 'blowing' if there is an unexpected increase in the current through them. This mostly happens when there is a lightning strike on your home or on a powerline or transformer nearby. The surge protector breaks the current to any appliances attached to them.

5.2 Unit review

Remembering

1 **List** the advantages and disadvantages of a series circuit.

2 **State** the colours of the following wires used in household wiring.
- a active
- b neutral
- c earth

3 **State** the time it takes for a safety switch (RCD) to activate.

Understanding

4 **Describe** the advantages of a home being wired as a parallel circuit instead of as a series circuit.

5 **Draw** a circuit diagram for the circuit shown in Figure 5.2.12.

6 **Define** the term *electrocution*. L

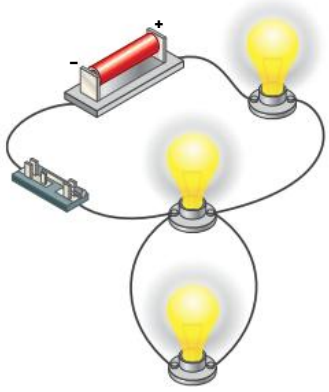


Figure 5.2.12

7 **Describe** how electrical faults can cause house fires.

8 **Describe** how a safety switch (RCD) detects a problem in the circuit.

Applying

9 **Use** the key below to complete the following statements. Options can be used more than once.

Key
- A don't change
- B don't light up
- C shine brighter
- D shine less brightly

- a If another globe is added to a series circuit, then the globes _____.
- b If another globe is added to a parallel circuit, then the globes _____.
- c If one globe in a series circuit 'blows', then the others _____.
- d If one globe in a parallel circuit 'blows', then the others _____.

Analysing

10 **Analyse** the circuit in Figure 5.2.13, then **use** the key below to complete the following statements. Options can be used more than once.

Key
- A the same as
- B twice
- C half
- D three times

- a The current through globe A is _____ the current through globe B.
- b The current through globe B is _____ the current through globe C.
- c The voltage across globe A is _____ the voltage across globe B.
- d The voltage across globe B is _____ the voltage across globe C.

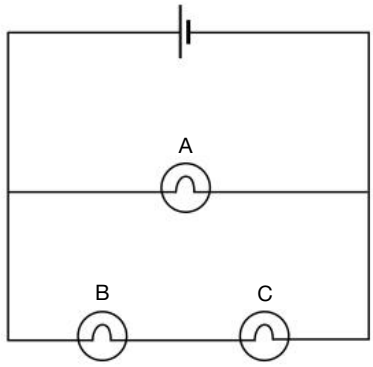


Figure 5.2.13

11 **Compare** a fuse with a circuit breaker by listing their similarities and differences.

12 **Compare** a safety switch with a surge protector.

5.2 Unit review

13 **Analyse** the circuit in Figure 5.2.14 to complete the table below, indicating which globes would be on or off.

Note: *Closed* means that current can flow through the switch. *Open* means that current cannot flow through the switch.

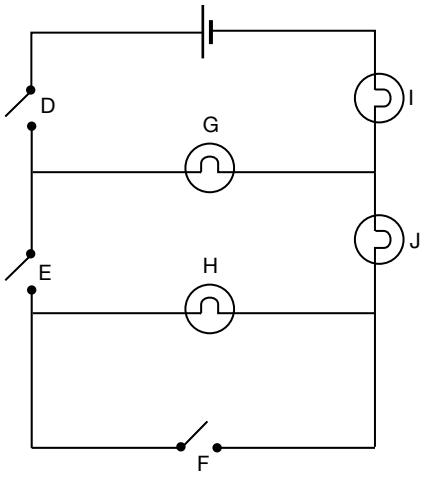


Figure 5.2.14

	Switch			Globe			
	D	E	F	G	H	I	J
a	closed	closed	open				
b	open	closed	closed				
c	closed	open	closed				
d	closed	closed	closed				

14 **Predict** the order of brightness (from brightest to dullest) of the globes in Figure 5.2.15. Assume that both ammeters have very little resistance and so have very little effect on the circuit.

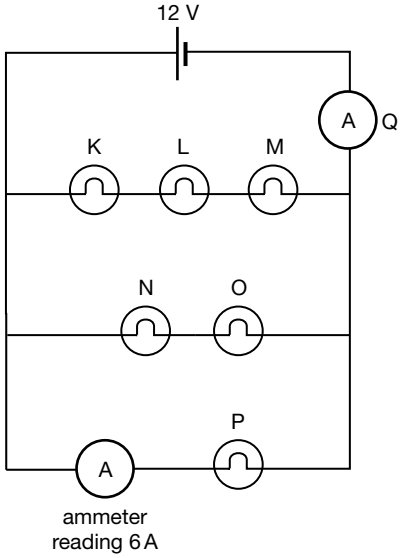


Figure 5.2.15

15 **a** **Analyse** the circuit shown in Figure 5.2.15 to complete the following table.

	Globe					
	K	L	M	N	O	P
Current (A)						
Voltage (V)						

b **Calculate** the current through ammeter Q.

Evaluating CCT

16 **Propose** what would happen if a car had all its electrical components (such as windscreen wipers, headlights, blinkers, internal light, radio) wired up in series, not parallel.

17 A primitive battery can form when two different metals touch each other or if they both touch something that is salty and moist. **Use** this information to **propose** a reason why your tongue tingles in the science4fun activity on page 180.

Creating CCT

18 **Construct** a circuit diagram like that shown in Figure 5.2.13 on page 185, but add a switch that would turn on and off: N

a all globes in the circuit

b globe A only.

Inquiring

1 Use the key words *electricity mania* to find interactive games in which you need to connect up household circuits. ICT

2 Some schools have a software package called Crocodile clips which allows you to construct and test electric circuits. If your school has this package, test your skills in circuit construction. ICT

3 Not all power points and plugs around the world are the same. Research the different types used in different countries.

Present your findings as a world map with attached photos or diagrams.

5.2 Practical investigations

1 Series and parallel circuits

Purpose

To compare series and parallel circuits.

Materials

- 3 globes (preferably 6 V)
- power pack
- connecting wires
- switch
- ammeter
- voltmeter

SAFETY

The globes will burn out if more than 6 V is applied across them. Hence, do not go higher than 6 V when using a power pack of variable voltage.

Procedure

1. In your workbook, construct a table like the one in the Results section.
2. Connect up the basic circuit shown in Figure 5.2.16.
3. Measure the current flowing through the globe, and the voltage lost across it.
4. Add another globe to construct the series circuit shown in Figure 5.2.16.
5. Note the brightness (very bright, bright, dull or very dull) of the globes, and measure the current and voltage.
6. Remove the second globe and reconnect it so that it is in parallel (as shown in Figure 5.2.16).
7. Note the brightness of the globes, and measure the current and voltage.

Results

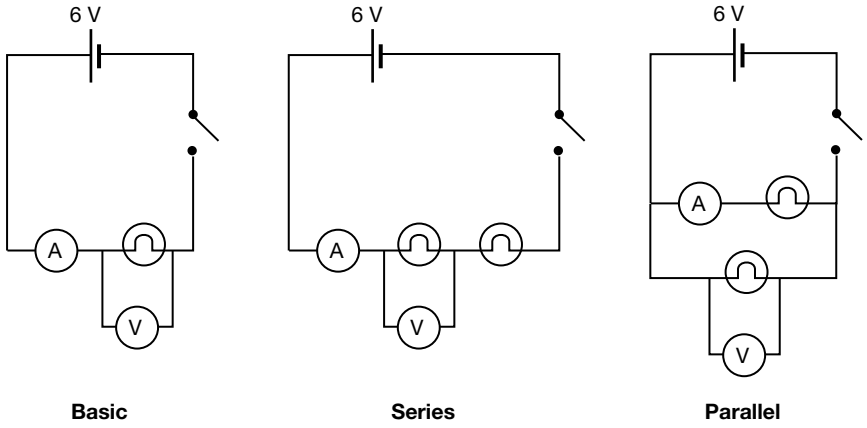
Record your results in a table like this one.

	Single globe	Globes in series	Globes in parallel
Brightness			
Current (A)			
Voltage (V)			

Practical review

1. **Describe** what happened to the current when another globe was added in series.
2. **Use** your knowledge of resistance to **explain** why this happened.
3. Adding another globe in series makes all the globes duller. **Explain** why.
4. **Explain** why adding globes in parallel makes no difference to their brightness.

Figure 5.2.16



5.2 Practical investigations

2 Fuses

Purpose

To construct and test a fuse.

Materials

- cork
- steel wool
- 2 dry cell batteries
- globe
- connecting wires
- sticky tape or electrical tape
- screwdriver with insulating handle
- access to pliers

SAFETY

The current will try and find its way to earth via you if you use any uninsulated metal to cause the short circuit. Hence, do not use a nail or screw. Your screwdriver must have an insulating handle to hold onto, stopping you from touching the bare metal.

Procedure

1. Tape the two batteries end to end as shown in Figure 5.2.17.
2. Use the pliers to strip a short section of insulation off the ends of two connecting wires and a short section of the insulation halfway down each connecting wire.
3. Construct the circuit shown in Figure 5.2.17.
4. To construct the fuse, tease out a strand of steel wool and wind it around the ends of the connecting wires.
5. Deliberately short-circuit this circuit by touching the screwdriver across the two stripped sections of the connecting wires as shown. As you do so, watch the fuse.
7. Thicken the wad of steel wool used as a fuse, and repeat.

Practical review

1. **Explain** the purpose of a fuse in a circuit.
2. **Describe** what the fuse did here when there was a short circuit.
3. **Describe** what happened when thicker 'fuses' were used.

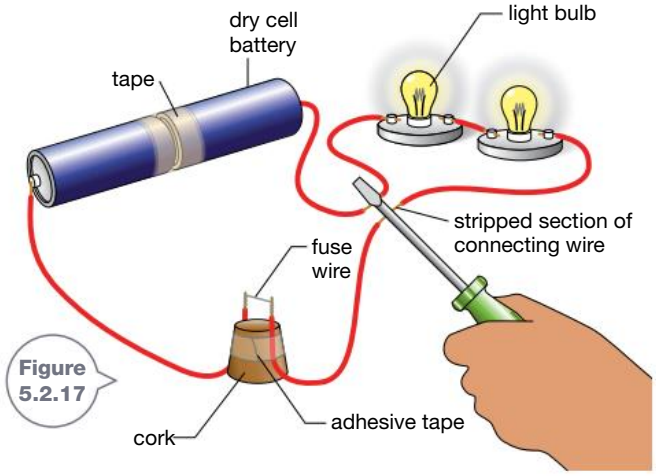


Figure 5.2.17

3 Binary counting

A switch can turn a circuit off (given the symbol 0) or on (given the symbol 1). These 0 and 1 numbers are called binary numbers.

Purpose

To construct a simple circuit that can count from 0 to 3.

Materials

- dry cell battery, batteries or power pack
- 2 globes (of a lesser voltage than battery pack or battery)
- 2 switches
- connecting wires with alligator clips

Procedure

1. Copy the table on the next page into your workbook.
2. Analyse the circuit in Figure 5.2.18 and predict whether each globe will be off (0) or on (1) when the switches are in the positions shown in the table. Record your predictions in columns 4 and 5 of your table.
3. Construct the circuit and test your predictions. Write your observations in column 5 and 6.

Results

1. Predict what each globe will do in each case below. Write your predictions in columns 4 and 5 of your table.
2. Write your observations in columns 6 and 7.

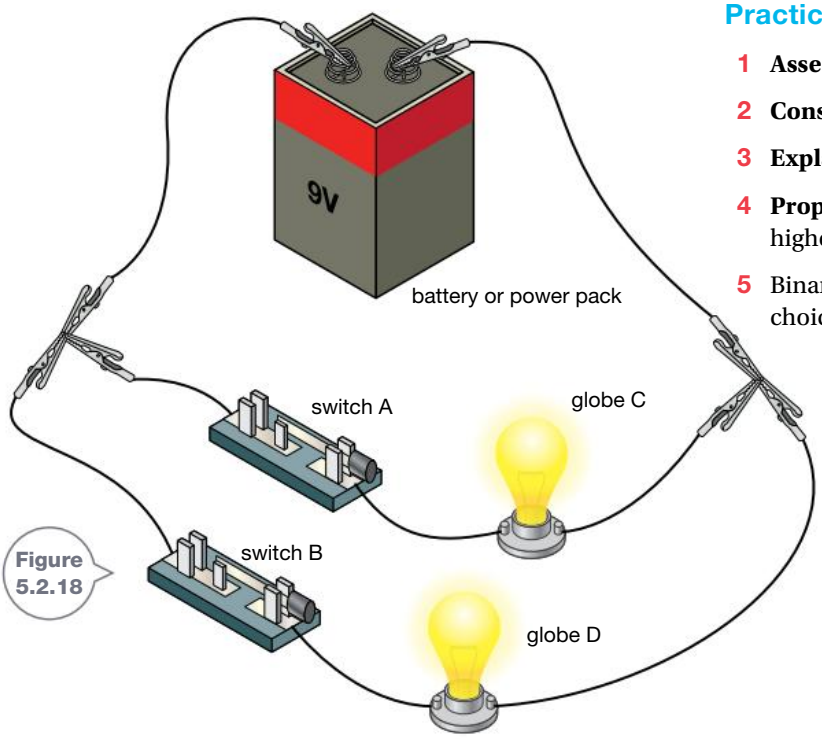


Figure 5.2.18

Practical review

1. **Assess** how accurate your predictions were.
2. **Construct** a circuit diagram for Figure 5.2.18.
3. **Explain** how this circuit counts from 0 to 3.
4. **Propose** how this circuit could be adapted to count higher than 3.
5. Binary is a word describing anything that has only two choices. **Explain** how switches are binary.

Switching arrangement	Switch A	Switch B	Predicted		Observed	
			Globe C	Globe D	Globe C	Globe D
0 (start)	0 (off)	0 (off)				
1	0	1 (on)				
2	1	0				
3	1	1				

STUDENT DESIGN

4 Morse code

Purpose

To build a telegraph circuit that sends messages in Morse code.

Materials

- to be selected by students

SAFETY

A risk assessment is required for this investigation.

Method

1. Use the internet to find: ICT
   - the dots and dashes that make up Morse code
   - a design for a simple telegraph circuit that could be used to send messages back and forth using Morse code.
2. Copy the telegraph circuit that you intend to build and show your teacher to check that it is safe and that you have the appropriate materials.
3. Once you have constructed your circuit, send messages back and forth between you and your prac partners.

Practical review

1. The first telegraph in New South Wales was opened in 1857. **Propose** a list of 'technologies' used to send messages before then.
2. **Propose** reasons why the telegraph (and its related printout called a telegram) eventually stopped being used.

5.3 Electromagnets, motors and generators

Electricity and magnetism are related to each other. The relationship explains how electricity is produced, how electric motors, electromagnets and transformers work and why spectacular auroras like this one only appear at Earth's poles.

Magnetism

Around a permanent magnet is an invisible force field called a **magnetic field**. This field exerts forces on:

- materials containing large quantities of iron (or cobalt or nickel). This explains why magnets can be used to separate steel nails and screws from plastic and scrap
- other magnets nearby. Each magnet has a north pole (N) and a south pole (S). What two magnets do depends on the orientation of their poles: unlike poles (N/S) attract and like poles (N/N or S/S) repel.

The direction and strength of a magnetic field is shown by its **field lines**. Field lines show the direction of the force on iron filings and compass needles. For example, the iron filings in Figure 5.3.1 have aligned (lined up) with the field lines of the bar magnet.

The needle of a compass is also a magnet and it too is attracted and repelled by the field of Earth and of nearby magnets.

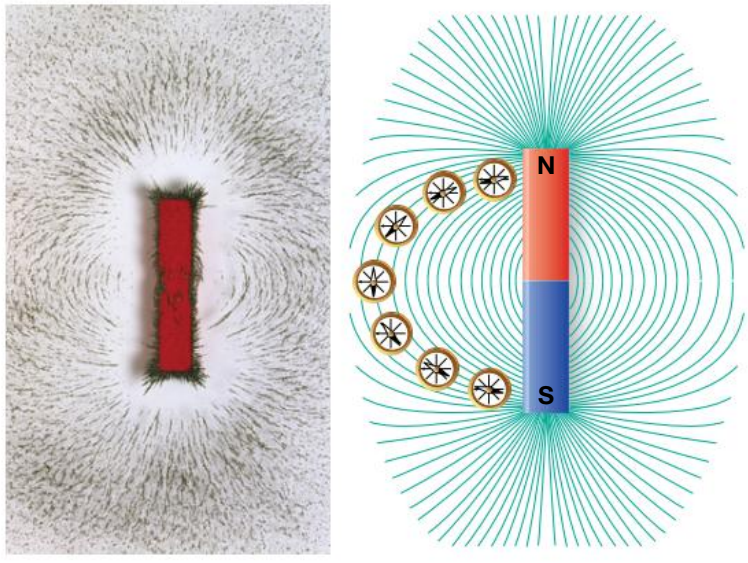


Figure 5.3.1 Iron filings clearly show the shape of a magnetic field.

Electromagnetism

A magnetic field is also produced when an electric current flows along a wire. When compasses are placed around the wire, their needles align with the magnetic field around the wire. As Figure 5.3.2 shows, the field produced is a set of concentric circular rings. In this case, electricity has caused magnetism. The phenomenon is known as **electromagnetism**.

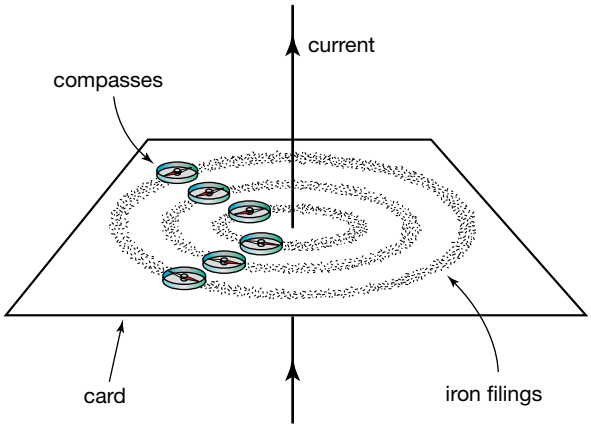


Figure 5.3.2 The magnetic field around a current-carrying wire forms concentric rings.

Electromagnets

If a current-carrying wire is twisted around to form a loop, the magnetic field down its centre is reinforced and made stronger. If the wire is wound many times to form many coils, then the magnetic field down its core is reinforced even more. This looped current-carrying coil is known as a **solenoid**. The magnetic field it creates is shown in Figure 5.3.3. The magnetic field down the core of the solenoid is made even stronger when an iron rod is placed down it. This device is known as an **electromagnet**.

The magnetic field of an electromagnet depends on the current flowing through it. This means that an electromagnet can be controlled in ways that are not possible with a permanent magnet. Table 5.3.1 compares an electromagnet with a permanent magnet.

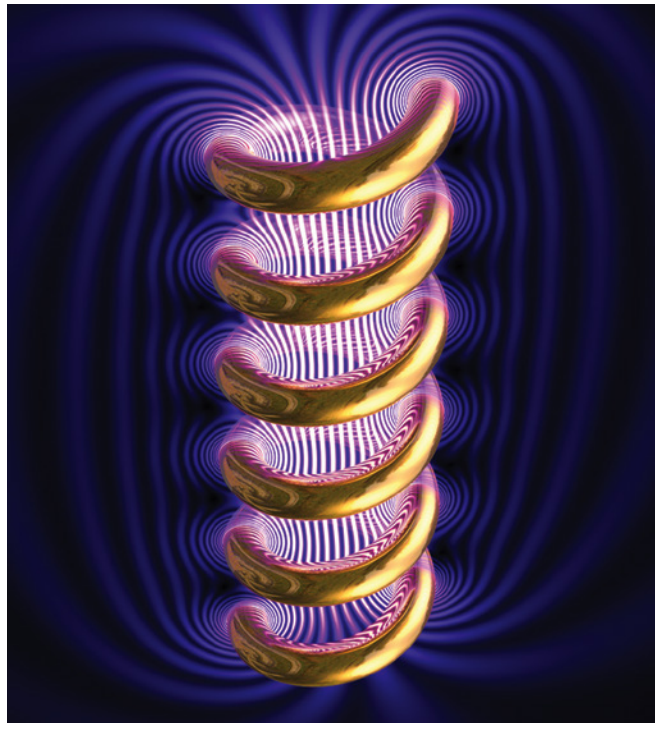


Figure 5.3.3 A solenoid has a magnetic field similar to that of a bar magnet. Insert an iron rod down the core and you get an electromagnet.

Using electromagnets

Electromagnets are used in many ways. They are used to separate iron and steel metal in junkyards, in car starter motors, and to operate bells and automatic latches. If too much current flows through a house circuit, electromagnets in circuit breakers pull the switch open. This cuts the current through it.

You use electromagnets every day when you listen to your MP3 player or watch TV. Within every speaker, earplug or headphone is a cone that is connected to an electromagnet. As Figure 5.3.4 on page 192 shows, a speaker has a permanent magnet and an electromagnet. The current fed into the electromagnet changes as the music changes its pitch and volume. The two magnets either attract or repel each other, causing the cone of the speaker to vibrate. These vibrations in turn cause the sounds you hear.

Table 5.3.1 An electromagnet compared with a permanent magnet

Properties of magnet	Electromagnet	Permanent magnet
Magnet on or off	'On' if current flows through it 'Off' if no current flows through it	Always 'on'
Strength of the magnet	Can be increased by increasing its current	Cannot be adjusted
Direction of the magnetic field	Can be changed by changing the direction of the current passing through it	Can only be changed by flipping the magnet end to end

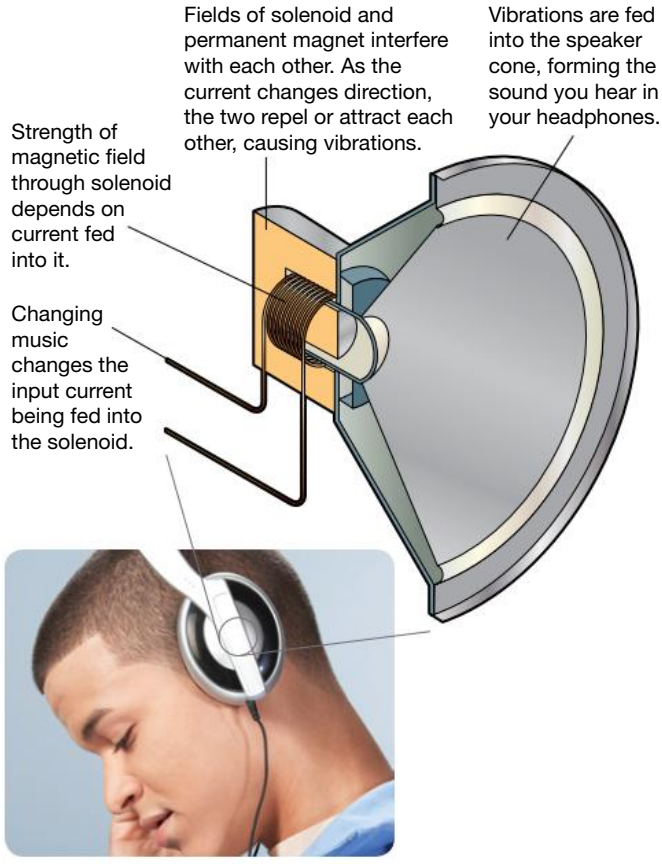


Figure 5.3.4 Speakers, headphones and earphones work because two magnetic fields attract or repel each other, causing the speaker to move.

Electric motors

Two magnets experience a force when placed within each other's field. Likewise, a current-carrying wire experiences a force and moves whenever it is placed in a magnetic field. In this case, electricity has caused a magnetic field that then causes movement. This too is part of the phenomenon of electromagnetism.

An electric **motor** spins because of electromagnetism. A current-carrying coil is placed within the magnetic field of a permanent magnet. The two magnetic fields interact and the coil then spins because of the forces on it. This forms the basis of a simple motor, as shown in Figure 5.3.5.

Simple motors like this are commonly used in toys such as slot-cars because these toys don't require much speed or power. Appliances such as hairdryers and power drills need stronger motors and use stronger solenoids instead of permanent magnets. As Figure 5.3.6 shows, they also use multiple planes of coils.

Prac 1 p196 Prac 2 p197

INQUIRY

science 4 fun

Pick-me-up!

YES

Collect this ...

- paperclips
- C cell battery
- insulated copper wire
- access to pliers

Do this ...

1. Cut off 15–20 cm of electrical wire and use the pliers to strip the wire of its insulating plastic.
2. Wind the wire around a bolt, a large nail or a screw.
3. Hold the ends of the wire against the ends of a C battery. As you do so, try and use it to pick up a paperclip.

Record this ...

Describe what happened.

Explain why you think this happened.

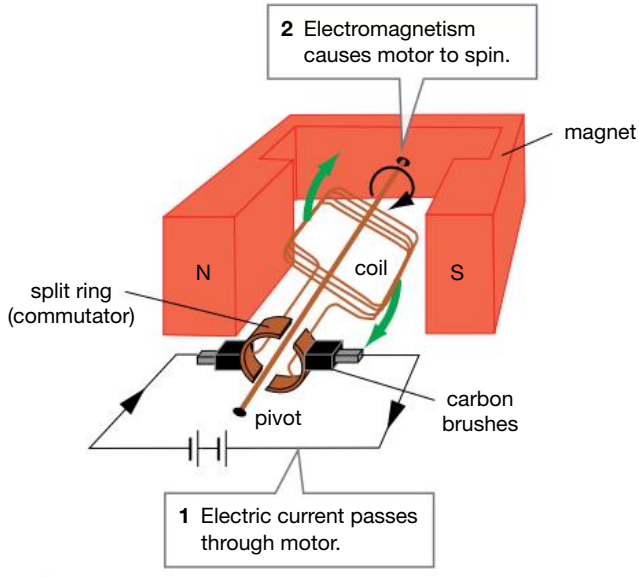


Figure 5.3.5 In an electric motor, current is passed through a coil. The magnetic field it produces interacts with the permanent magnetic field of the motor, causing the coil to spin.

Figure 5.3.6

Heavy-duty motors like the one in this electric fan use electromagnets instead of permanent magnets.

SOS!

Electricity is difficult to supply to the outback. For this reason, outback cattle stations once used bikes to power their emergency radios. One person would pedal while another person would use the radio. Solar panels and diesel and petrol generators now provide these stations with the electricity they need.

SciFile

Generators

The electricity available from batteries is useful for portable devices. However, the voltages and currents are far too low for most purposes around the home and in industry. This is when a generator is needed. A **generator** uses electromagnetism to generate electricity in a similar way to how motors use electromagnetism to produce spin. A simple generator is shown in Figure 5.3.7. Table 5.3.2 compares an electric motor with a generator.

Table 5.3.2 Comparing motors and generators

	Electric motor	Generator
Needs	A coil	A coil
	A magnet	A magnet
	An electric current	Spinning movement
Produces	Spinning movement	An electric current

A **dynamo** is a small generator that spins its magnet instead of its coils. Dynamos are often used to power the front lights on bicycles. As Figure 5.3.8 on page 194 shows, the wheel spins a magnet alongside a coil, which then generates current. Dynamos are also used in remote locations to recharge batteries in mobile phones, torches, simple laptop computers and portable radios like the one in Figure 5.3.9 on page 194. A handle is turned to produce the power required.

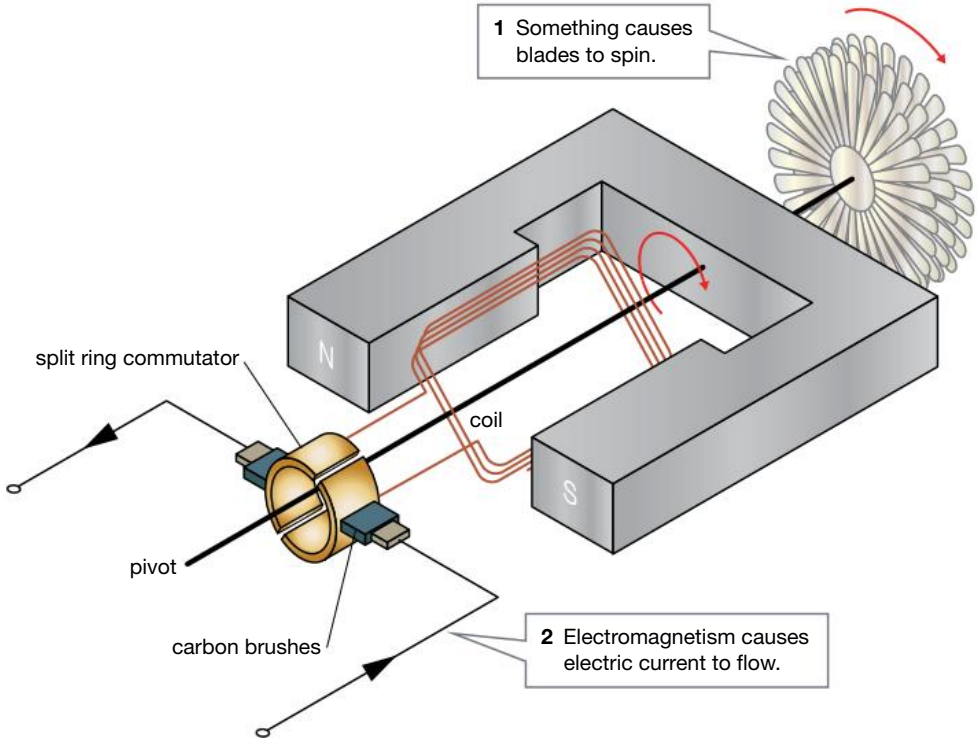


Figure 5.3.7

A simple generator shares many of the features of a simple motor. This is an example of a wind-driven generator.

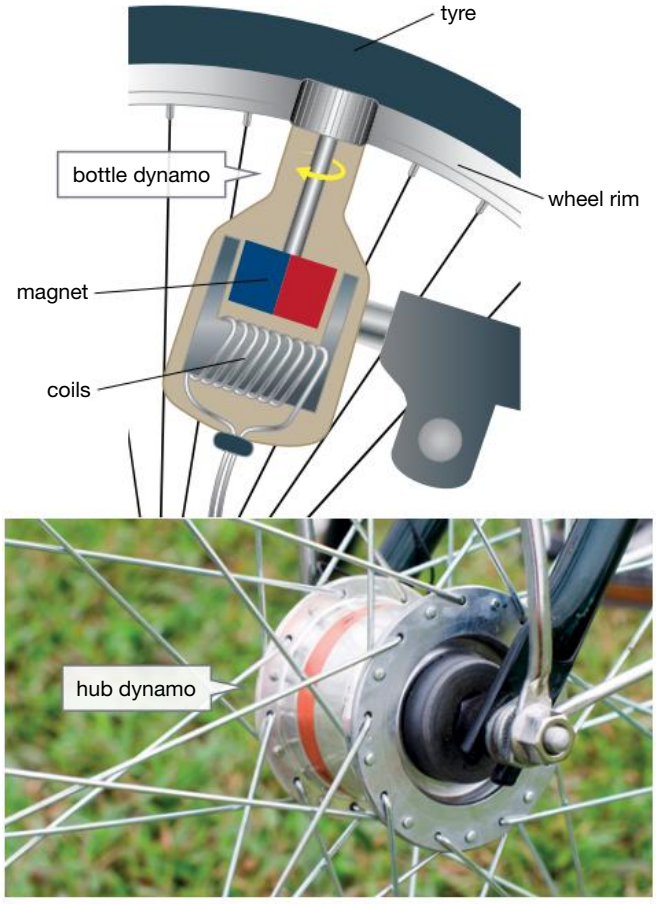


Figure 5.3.8 Bikes can use hub dynamos or bottle dynamos to generate the current needed to run their front lights.

Figure 5.3.9 This portable radio uses a combination of solar cells and a hand-turned dynamo to recharge its batteries.

INQUIRY

science 4 fun

Solenoid generators

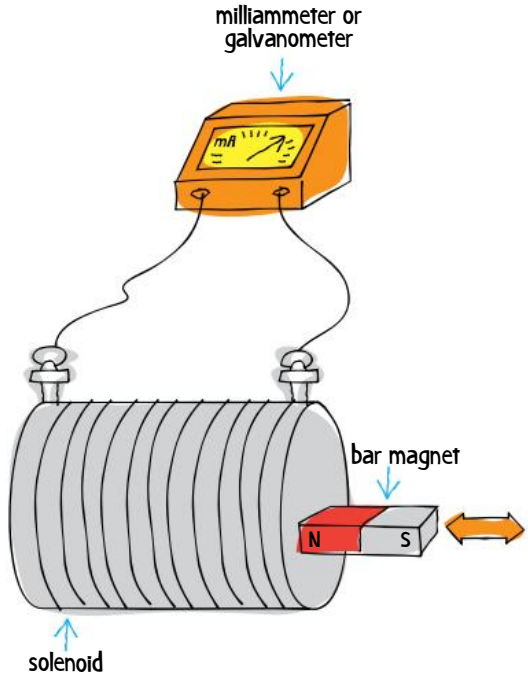
NO

Collect this ...

- solenoid or coil of wire
- milliammeter or galvanometer
- connecting leads with alligator clips
- bar magnet

Do this ...

1 Connect the solenoid to the milliammeter or galvanometer.



2 While watching the milliammeter or galvanometer, quickly insert the bar magnet into the solenoid.

3 Leave the magnet there and then quickly remove it. Watch what happens.

4 Find out what happens when you insert the magnet more slowly, or when two magnets are used instead of one.

Record this ...

Describe what happened.

Explain why you think this happened.

5.3 Unit review

Remembering

1 **State** whether the following combinations of magnetic poles attract or repel.
   - a N/N
   - b S/S
   - c N/S

2 **List** the advantages an electromagnet has over a normal, permanent magnet.

3 **List** five uses for electromagnets.

Understanding

4 **Describe** how you can make the field lines around a magnet visible.

5 **Explain** why toys use small permanent magnets but power drills and hairdryers use electromagnets.

6 To generate current, a coil and magnetic field must move relative to each other. **Predict** whether current will be generated in a solenoid like the one in the science4fun on page 194 when the magnet is:
   - a pushed into the coil
   - b left stationary within the coil
   - c pulled out of the coil.

Applying

7 Electricity can be used to create magnetism and magnetism can be used to generate electricity. **Identify** the term that describes these phenomena. L

8 **Identify** what is being constructed in the science4fun on page 192.

Analysing

9 **Compare**:
   - a a solenoid with an electromagnet
   - b an electric motor with a generator.

10 **Compare** a bike dynamo with a simple generator.

Creating CCT

11 **Construct** a Venn diagram like the one shown in Figure 5.3.10. Then identify which of the following terms describe a motor only, a generator only or both. Place the terms in the Venn diagram.

uses a coil	uses a magnet
needs movement	needs electric current
produces movement	produces electric current

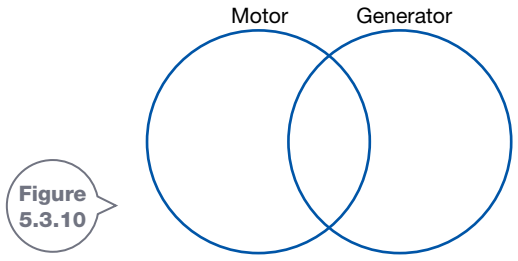


Figure 5.3.10

Inquiring

1 Electromagnetism explains why auroras only happen near the north or south poles. Research auroras and find:
- images that show the different colours that are displayed in auroras
- the difference between aurora borealis and aurora australis
- the particles that cause auroras, where these particles come from and why they light up in the atmosphere
- a diagram or animation that explains how electromagnetism causes the particles to funnel towards the poles.

Present your research as a digital presentation. ICT

2 Laptop computers are often useless in developing countries where mains power is not available or is so unreliable that batteries cannot be recharged. Simple laptops have been developed that use hand-turned dynamos to provide the power they need. Research these dynamo-powered laptops and find:
- images of at least one type
- a list of countries that are using them
- the name of an organisation that funds schemes providing these types of computers
- whether they use a hard disk or another way to store information.

Present your findings as a brochure to be given out at a shopping mall to raise funds for the organisation providing them.

5.3 Practical investigations

1 Force on a wire

Purpose

To demonstrate electromagnetism.

Materials

- aluminium foil
- small sheet of cardboard
- scissors
- sticky tape
- retort stand, bosshead and clamps
- wires with alligator clips
- switch
- power pack with circuit breaker or auto cut-off
- horseshoe magnet

Procedure

1. In your workbook, construct a table like the one shown in the Results section.
2. Cut a 'picture frame' out of the cardboard and stick a single thin strip of aluminium foil across it.
3. Construct the apparatus as shown in Figure 5.3.11 and set the power pack at its lowest voltage.
4. Hold the horseshoe magnet as shown and quickly close then open the switch. Record what happens in a table like the one shown in the Results section.
   Note: The power pack might 'trip'. If it does, you will need to wait until it resets before attempting the rest of the prac.
5. Reverse the terminals on the power pack and repeat step 3.
6. Reverse the orientation of the magnet (i.e. swap poles) and repeat step 3.

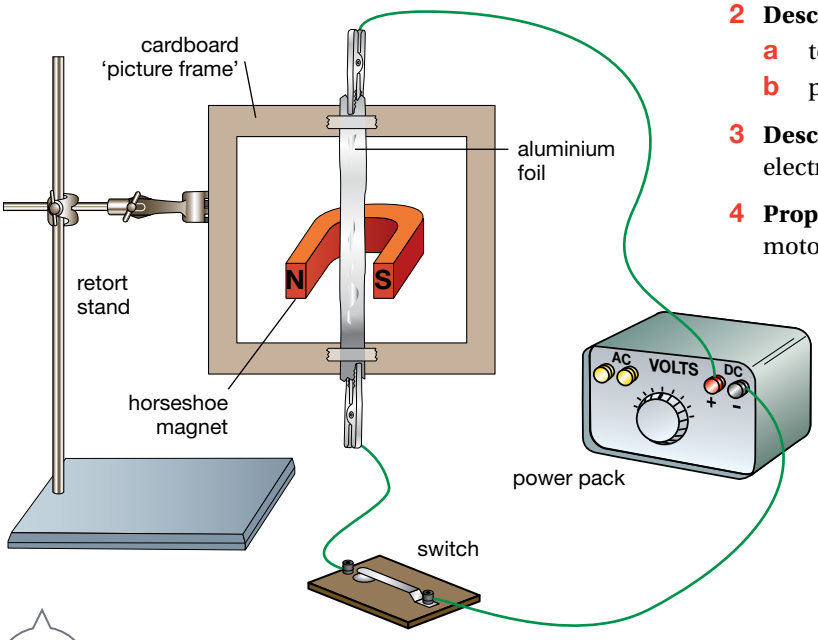


Figure 5.3.11

Results

Record your observations in a table like this one.

Terminals of power pack	Magnet poles	Direction aluminium strip moves (in, out, left or right)
As shown	As shown	
Reversed	As shown	
As shown	Reversed	
Reversed	Reversed	

Practical review

1. **Identify** the purpose of the aluminium foil in this experiment.
2. **Describe** what happened when the:
   a. terminals of the power pack were reversed
   b. poles of the magnet were swapped.
3. **Describe** how this experiment demonstrates electromagnetism.
4. **Propose** how this experiment relates to an electric motor.

2 Make your own motor

Purpose

To build a simple electric motor.

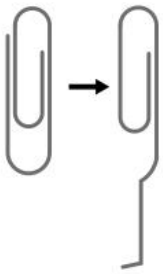
Materials

- solid copper wire (without strands and insulating plastic)
- small piece of sandpaper
- 2 large paperclips
- 2 insulated connecting wires with alligator clips on one end
- access to pliers
- bar magnet
- plastic or paper cup
- sticky tape
- 1.5 V AA battery
- rubber band

Procedure

1 Straighten one end of both paperclips, as shown in Figure 5.3.12, and tape the paperclips to the top of the cup.

Figure 5.3.12

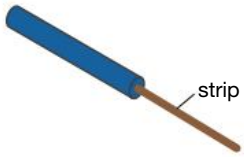


2 Lightly sand the ends of the copper wire. Then wind the copper around your little finger to form a coil. Leave two straight sections about 1 cm long on each side. It should look like Figure 5.3.13. Place your coil in the holder formed by the paperclips.

Figure 5.3.13

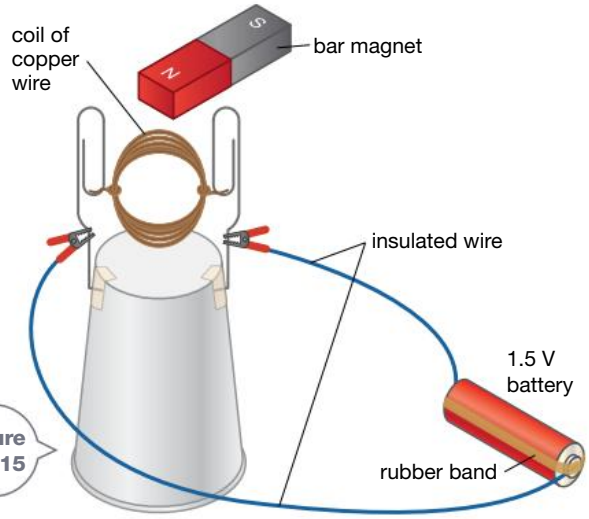
3 Strip about 1 cm of insulating plastic off the ends of both connecting wires as shown in Figure 5.3.14.

Figure 5.3.14



4 Use the rubber band to secure these stripped ends to each end of the battery. Your set-up should look like Figure 5.3.15.

Figure 5.3.15



5 When your set-up is ready, attach the alligator clips to the paperclips. Meanwhile, hold the bar magnet close to the coil. If your motor doesn't spin:

- try giving the coil a small flick
- remove the coil and twist it so that the straight parts are exactly central.

Practical review

1 A motor changes the form of energy. **State** the type of energy that is provided:
   a to the motor
   b by the motor.

2 **Describe** what the passage of current creates down the core of the coil.

3 The motor will not spin without a magnet nearby. **Explain** why.

5.4 Making, transmitting and using electricity

Batteries are a good portable source of electric power, but most cannot provide the voltages required to operate kettles, washing machines and air conditioners. Even if they did, they would soon need to be replaced or charged. Most of the electricity used in homes and factories is generated by the turbines of a power station.

Electricity from chemicals

Batteries are an excellent source of portable electrical power. Batteries are made of smaller 'mini-batteries' known as **electrochemical cells**. These cells use chemicals to generate electricity.

Electrochemical cells and the batteries they make up can be wet or dry. You can see examples in Figure 5.4.1.

Electrochemical cells create an electric current by a type of chemical reaction known as an oxidation–reduction (or redox) reaction. In a redox reaction, electrons transfer from one chemical reactant to another. As Figure 5.4.2 shows, an electrochemical cell is constructed using two half-cells.

Each half-cell contains a solid electrode and an **electrolyte** (a solution or wet paste containing dissolved chemicals). Each half-cell contains only one reactant. This keeps the reactants apart and prevents electrons from transferring between them and the chemical reaction taking place. However, electrons *will* transfer if a wire connects the electrode of one half-cell to the electrode of the other half-cell. This flow of electrons can be used to power devices such as torches or mobile phones. Ions moving within the electrolyte complete the circuit. When disconnected, the electrochemical cell stores its reactant chemicals for future use. The cell will 'go flat' when the reactants in it are used up.

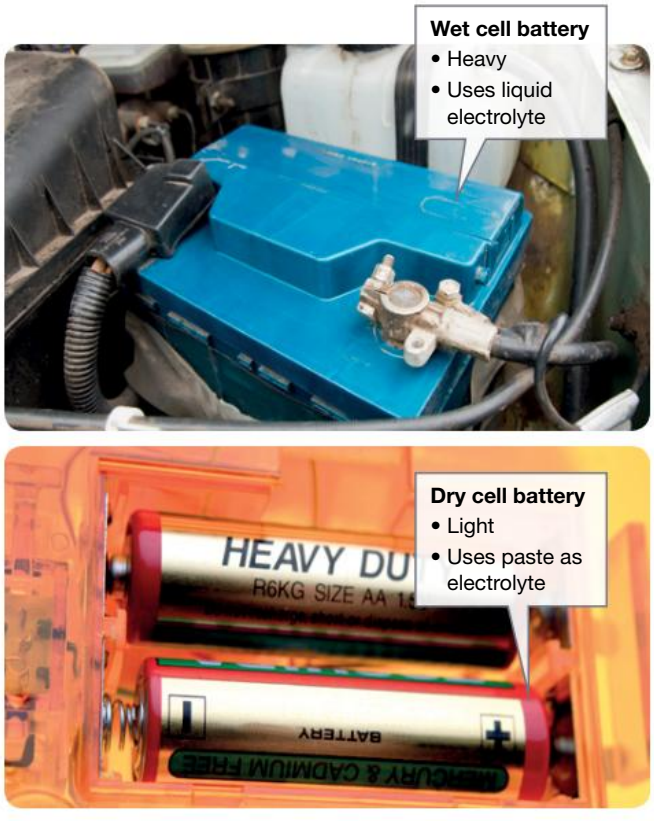


Figure 5.4.1 Wet cell batteries leak if turned upside down. They can be used in for cars and boats but not in torches or TV remote controls. For these devices, dry cell batteries are used instead.

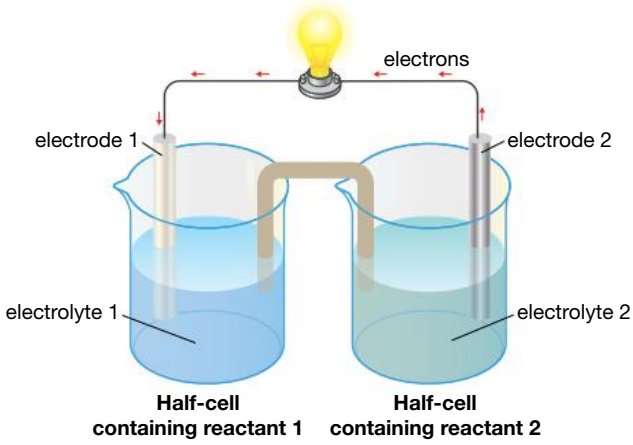


Figure 5.4.2 An electrochemical cell uses two half-cells to produce an electric current.

Prac 1 p209

Electricity from the Sun

Photovoltaic cells (or solar cells) convert solar energy directly into electrical energy. Energy in the sunlight knocks electrons off semiconducting silicon crystals within the cell. These electrons move away from the crystal, forming an electrical current that can be used to power appliances such as calculators, road signs and public telephones. Alternatively, the current can be used to recharge batteries for later use. For example, the solar garden light in Figure 5.4.3 uses batteries that are recharged by photovoltaic cells during the day.

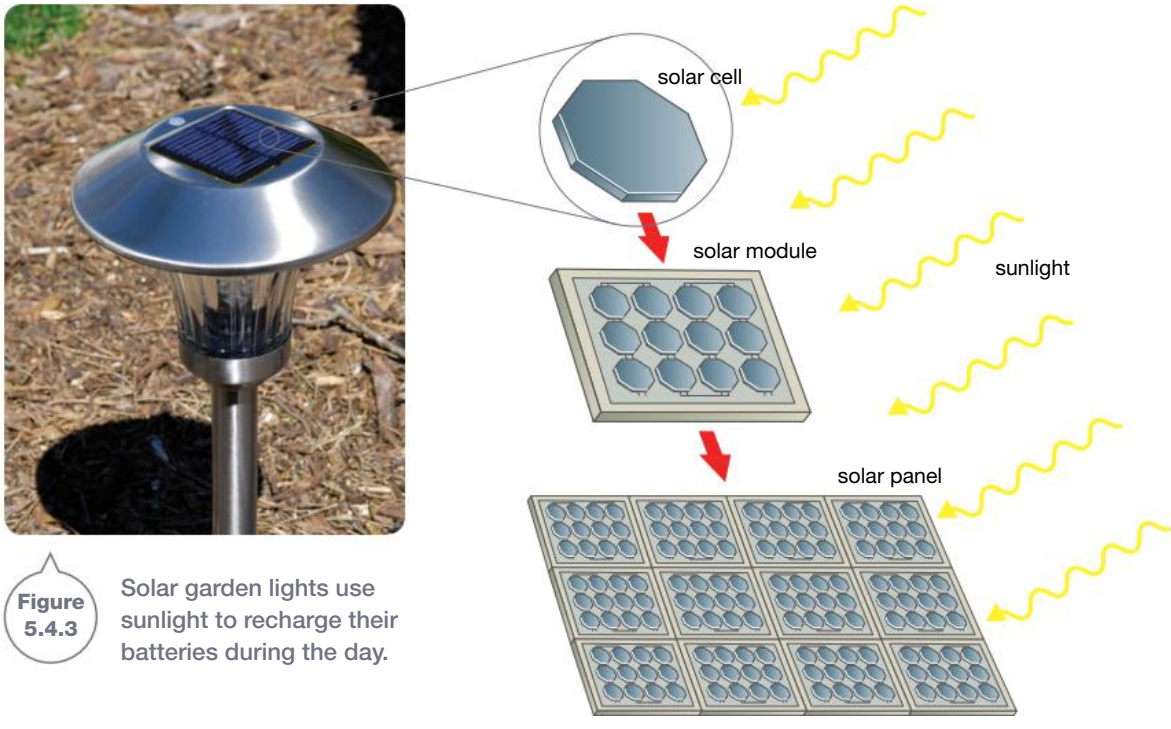


Figure 5.4.3 Solar garden lights use sunlight to recharge their batteries during the day.

Many homes now have banks of solar panels made of many photovoltaic cells, to provide them with a source of renewable energy that releases no greenhouse gases. Any excess power generated by the panels is fed back into the electrical grid of the community and earns the household money. If insufficient power is generated at any time, then the house draws electricity from the grid just like any other house.

Photovoltaic power plant

SciFile

The world's largest photovoltaic power plant is to be built near Mildura (in Victoria). The plant will use arrays of mirrors to reflect sunlight (concentrating it 500 times) onto a tower of solar cells. This is very different from existing large-scale solar power plants. They use the reflected sunlight to boil water to turn turbines to make electricity.

Electricity from electromagnetism

The most common way of generating electricity is electromagnetism. Electromagnetism creates a current whenever a magnet and coil move relative to one another.

A **turbine** is a large generator that creates current by spinning its magnet within fixed sets of coils.

Turbines need to be spun at high speeds, and different methods can be used to spin them. Figure 5.4.4 shows a turbine that is turned by the wind. More commonly, moving water or steam is used.

Figure 5.4.4
Wind turbines use a renewable resource to generate electricity.

Moving water

There are a number of ways in which water can be made to spin a turbine.

- Hydroelectricity is generated by water falling onto the blades of the turbines, spinning them like old-fashioned but very fast water wheels.
- Wave power uses the regular swells of the ocean to rock the turbines back and forth.
- Tidal power uses the massive flows of water from the twice-daily changes of the tides to spin turbines. One design is shown in Figure 5.4.5.

Prac 2 p210

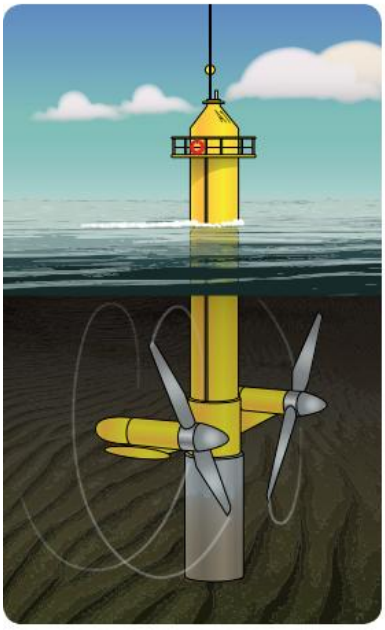


Figure 5.4.5
The tidal movement of water can spin turbines and generate electricity. This design resembles an underwater wind turbine.

INQUIRY science 4 fun

Milk carton turbine

Most turbines are like a water wheel, but some turbines spin by forcing water or steam through holes. Can you use this idea to get a milk carton spinning?

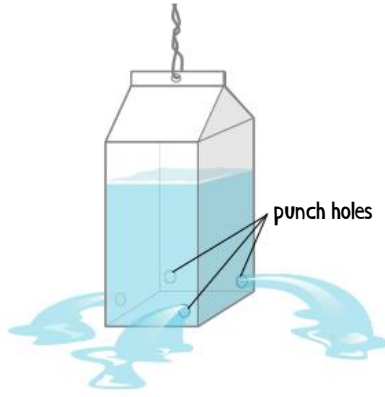
YES

Collect this ...

- cardboard milk carton
- nail or skewer
- tape
- string

Do this ...

1. Use the nail or skewer to make a hole in the bottom-left corner of each side of the carton. Then tape each hole up.
2. Punch another hole in the middle of the 'fold' at its top.
3. Put water into the carton until it is nearly full.
4. Pass the string through the top hole and tie it to a support outside or over a sink.
5. Rip the tape off each of the holes and let go of the carton.



Record this ...

Describe what happened.

Explain why you think this happened.

That's fast!

In Australia, AC electricity changes direction 50 times every second. This means that the turbines that make it are spinning 50 times every second!

SciFile

Steam

Most power stations around the world are basically big kettles, because they boil water and change it into high-pressure steam. This steam then spins the turbines. Afterwards, the steam is usually released via cooling towers, like those in Figure 5.4.6. The heat required to run the 'kettle' can come from a variety of sources, including:

- burning fossil fuels such as coal or gas
- burning biomass. Biomass is any biological material that comes from living or recently dead organisms. It includes wood, leftover woodchips, sugarcane waste, methane gas produced by human and animal waste, and biofuels (petrol and diesel substitutes that are 'brewed' from sugar cane, wheat, soy or maize)
- geothermal energy in which heat from deep in the Earth's crust is used to heat water that is pumped underground
- nuclear power in which a controlled nuclear reaction produces the heat necessary to generate steam
- solar power in which sunshine is reflected from mirrors onto a central furnace through which water flows.

All these methods of generating power have advantages and disadvantages. For example, burning coal is an easy and cheap way of generating steam (and therefore electricity) but it emits huge quantities of the greenhouse gas carbon dioxide (CO_2). In contrast, nuclear power emits almost no greenhouse gases but it produces wastes that are radioactive for many thousands of years.

A summary of these advantages and disadvantages is shown in Table 5.4.1 on page 202.

Figure 5.4.6 Cooling towers release steam after it has been used to spin turbines.

Wasted energy

Energy can take many forms, such as light, heat, sound, electrical energy and kinetic energy (the energy of movement). It can also be stored as gravitational potential energy and chemical energy. When energy changes from one form into another, the total energy before and after is exactly the same. No extra energy is created and none is destroyed. This is known as the **law of conservation of energy**. However, only a percentage of the total energy is converted into *useful* forms. This percentage is known as **efficiency**. The rest of the energy is 'wasted', usually being converted into 'useless' heat, sound or both.

For example, only 25–30% of the chemical energy stored in the petrol used by a car actually gets it moving, giving it kinetic energy. The rest is wasted as sound and heat, most of which is released via the car's radiator (Figure 5.4.7). Hence, a car has an efficiency of only 25–30%. A car that was 100% efficient would convert *all* the energy in petrol into movement. The car would be absolutely silent and require no radiator.

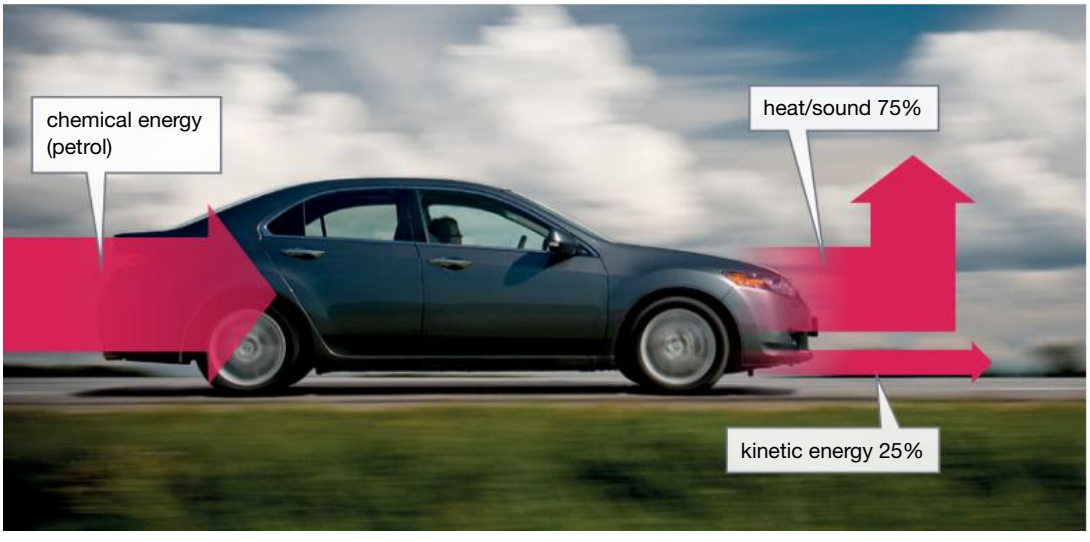
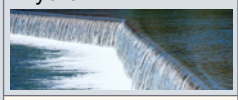
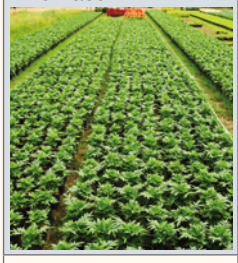


Figure 5.4.7 Cars are only 25–30% efficient: this means that 70–75% of the petrol they use is converted into heat and noise.

Table 5.4.1 Comparison of different methods of turning a turbine

	Method	Efficiency	Renewable?	Clean? (emitting minimal CO_2)	Advantages	Disadvantages
Uses wind	Wind	35%	✓	✓	• Energy is 'free' • Can be located close to where power is needed	• Output changes as wind changes • Turbulence from one turbine can affect nearby turbines • Noisy
Uses water	Hydro 	90–95%	✓	✓	• Quick to start up • Can be used to 'top up' power supply when needed	• Valleys need to be dammed
	Tidal	90%	✓	✓	• Energy is 'free' • Reliable	• Must be on the coast • Needs very large tides and so can only be used in a few places
	Wave	8%	✓	✓	• Energy is 'free' • Minimal environmental impact • Can be located near coastal cities	• Largely experimental • Output changes as waves change
Uses steam	Fossil fuels	35–40%	✗	✗	• Coal is abundant • Coal is relatively cheap	• Power station needs to be located near coal mines • Emits huge amounts of CO_2 • Open-cut mining devastates the environment
	Biomass 	35%	✓	?	• Removes waste and CO_2 from the environment • Can be located near where electricity is needed • Individual houses, farms and factories can power themselves	• Large amounts of CO_2 emitted • Biofuels use crops or agricultural land that could instead be used as food
	Geothermal	15%	✓	✓	• Energy is 'free'. • Small geothermal plants can be built anywhere there is a significant increase in underground rock temperature	• Only countries on fault lines or which have deep 'hot rocks' can have large geothermal stations
	Nuclear	40%	✗	✓	• Clean when operating normally • Uses very little nuclear fuel	• Waste remains radioactive for many thousands of years • Disastrous if something goes wrong
	Solar power	20%	✓	✓	• Energy is 'free' • Can provide power to inland cities	• Needs to be in sunny areas • Needs mirrors to track the Sun • Takes up wide areas of flat landscape

The generation of electricity involves converting one form of energy into electrical energy. Like all energy conversions, this process is not 100% efficient, so energy is wasted. Figure 5.4.8 summarises the efficiency and the wastage of the different methods of generating electricity.

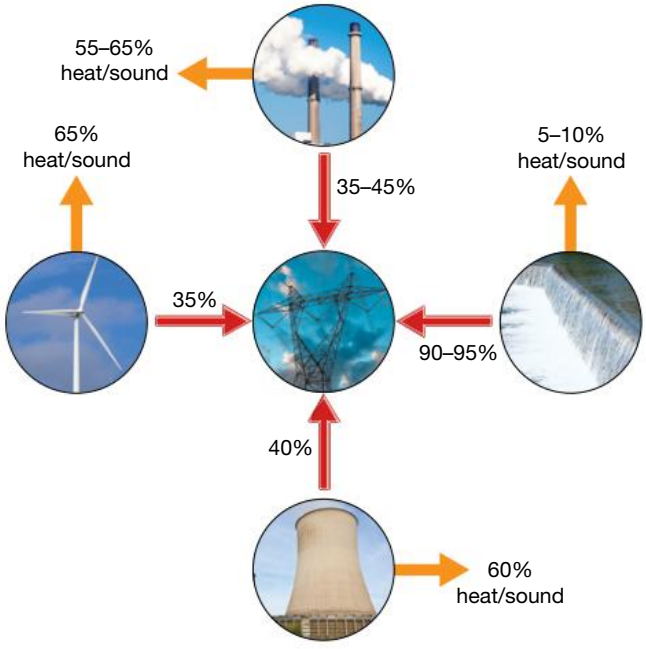


Figure 5.4.8 No process is ever 100% efficient. Depending on the method of generating electricity, 5–85% of the energy is wasted, usually as heat.

5.6

Transmission of electricity

Most power stations are located near their energy source. For example, coal-fired power stations need to be near coal mines and hydroelectric power stations need to be near suitable rivers. Hence, in New South Wales most coal-burning power stations are in the coal-mining regions of the Hunter and Central Coast and most hydro stations are on rivers in the Snowy Mountains. The electricity that is generated is then transmitted to cities and towns. This long-distance transmission causes more energy to be lost. To understand how this loss is minimised, you first need to understand the difference between AC and DC electricity.

AC/DC

AC/DC is one of Australia's most famous rock bands, but AC and DC also describe electric current. Batteries and solar cells produce **direct current** (**DC**). In DC, all the electrons move in one direction and with one voltage. Turbines produce **alternating current** (**AC**). In AC, the electrons regularly change their direction and so just shuffle back and forth along the wire. The electricity you obtain from a power point is AC and it changes direction 50 times every second, at a frequency of 50 hertz, or 50 Hz. The voltage also changes. Its 'average' voltage (called RMS voltage) is 240 V, but 100 times a second it climbs to 340 V and then drops to –340 V. Figure 5.4.9 shows how.

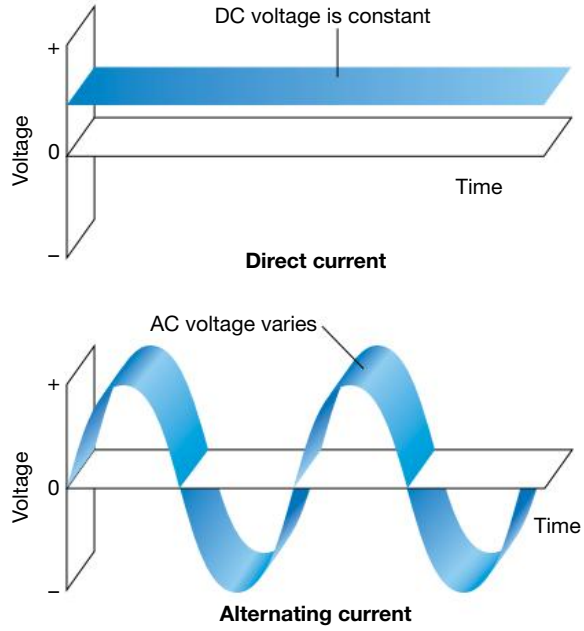


Figure 5.4.9 DC provides a constant voltage and all its electrons move in one direction. AC provides a varying voltage and its electrons move back and forth along the wire.

AC is produced because it can generate more power than DC, is easier to transmit and its voltages can be boosted or dropped using transformers.

Reducing transmission losses

Most power stations produce AC voltages of around 20 000 V. This electricity must then be transmitted far away to the cities and towns that need it. All electrical wires have a resistance, and energy is wasted when current passes along them. One way to reduce wasted energy and increase efficiency is to use a transformer that boosts the AC voltage until it is an incredible 220 000 to 500 000 V. This voltage boost is accompanied by a decrease in current. Less current means less energy being lost from the power line, making long-distance transmission more efficient.

A transformer is a device that steps up AC voltage (increasing it) or steps down AC voltage (reducing it). Transmission voltages are far too high for users at the other end, and so a series of transformers reduce the voltage until it is the 240 V that is fed into your home.

The final transformer is probably up a pole at the end of your street. Other transformers inside your home reduce the voltage even further to the levels needed for halogen light globes and electronic equipment such as computers or mobile phone rechargers.

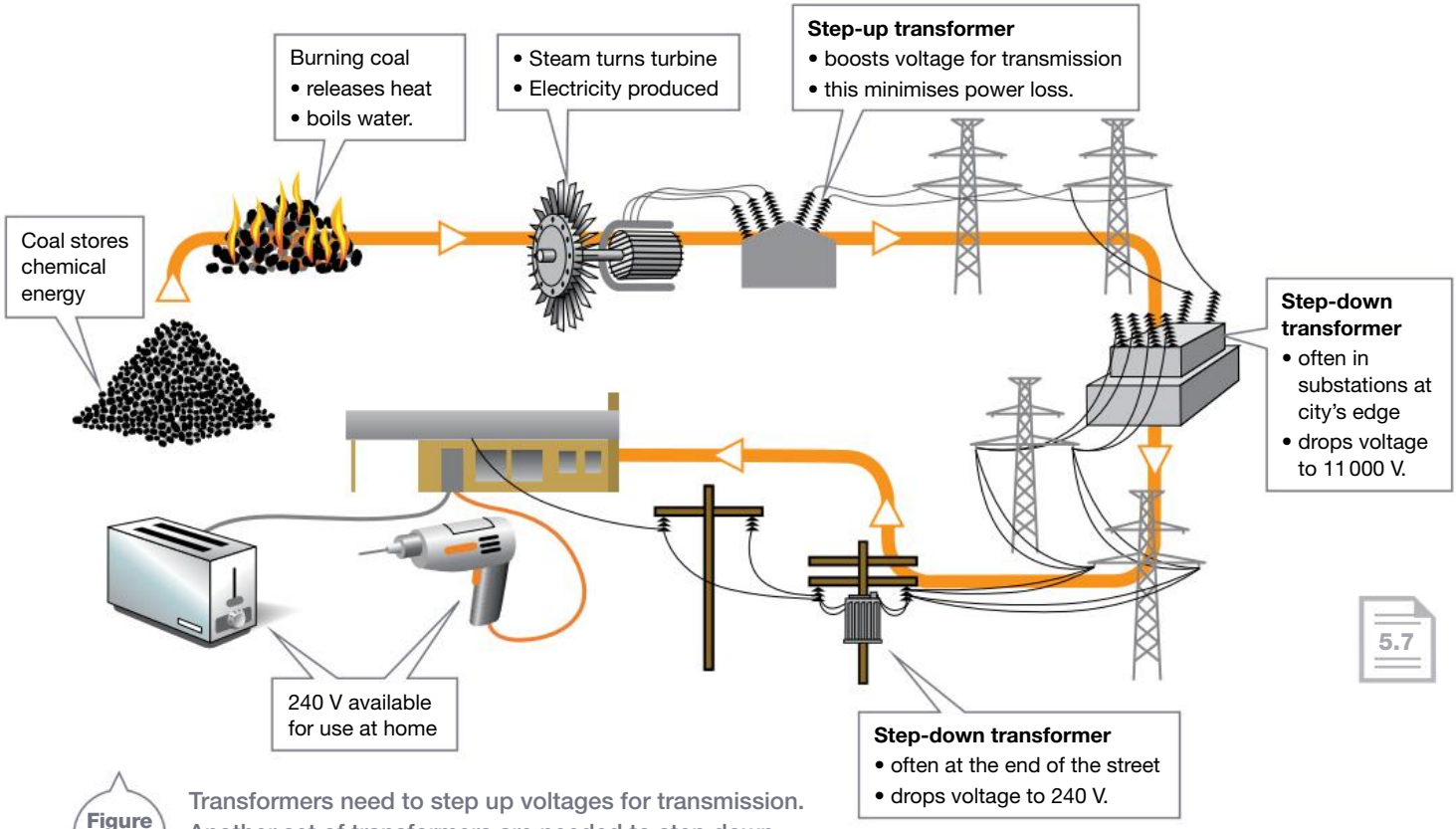
Figure 5.4.10 shows where transformers are commonly used in transmission lines.

About 7% of electrical energy is lost in transmission from the power station through the various transformers, high-voltage power lines and substations. Depending on where you live, another 7–9% might then be lost in the lower-voltage local distribution systems.

Using electricity

More electrical energy is lost when you use an electrical appliance. Put your hand near a computer or TV that has been operating for a while and you will feel some of the heat that it releases as wasted energy.

Old-fashioned incandescent light globes are only about 10% efficient. This means that 90% of the electrical energy the globe uses is 'wasted' as heat! For this reason, Australia began to phase out the sale of incandescent globes in 2009. They are gradually being replaced by other types of light globes that have been engineered to be more efficient. Figure 5.4.11 compares the efficiency of different types of globes now available in Australia.



5.7

Figure 5.4.10 Transformers need to step up voltages for transmission. Another set of transformers are needed to step down the voltage to what is needed in the home.

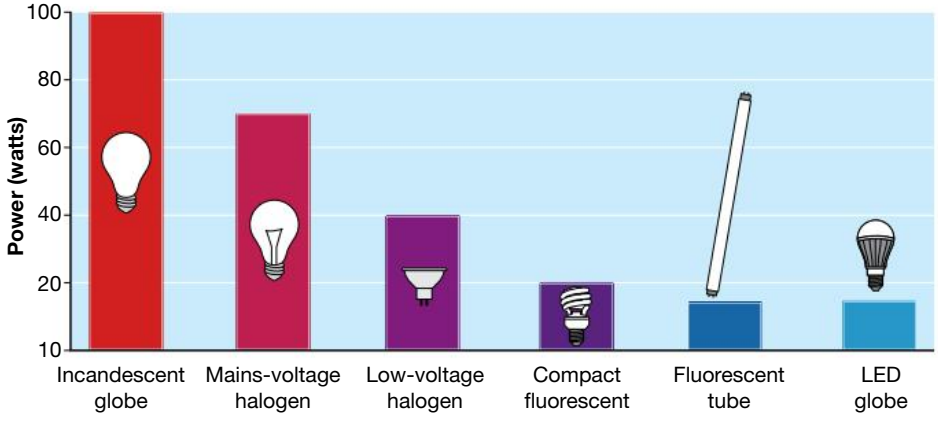


Figure 5.4.11 Each of these light globes produces exactly the same amount of light but each uses very different amounts of electrical power. The higher the power used, the less efficient the globe is.

LEARNING ACROSS THE CURRICULUM

SUSTAINABILITY

Figure 5.4.12 The brown coal from this open-cut mine is used to generate electricity.

POWER TO AUSTRALIA

Seventy years ago, the average Australian home was about half the size of most of those being built today. There were no computers, plasma or LCD TVs, iPods, Xboxes, DVDs or Blu-rays. There were no freezers, dishwashers, clothes dryers, hairdryers or air conditioners and no central heating. All these appliances require energy (usually electricity) to run, and all contribute to the release of greenhouse gases.

Australians now produce more greenhouse gases per person than any other nation on Earth, even the United States. As a nation, we need to find ways of conserving energy. We also need to find better ways of generating electricity from renewable sources and produce less (or ideally no) greenhouse gases.

POWER SOURCES

Australia has plenty of coal (Figure 5.4.12) and gas, is very flat and has few large rivers. For these reasons, nearly 80% of our electrical energy comes from coal-fired power plants. Other sources of electrical energy in Australia are shown in Figure 5.4.13.

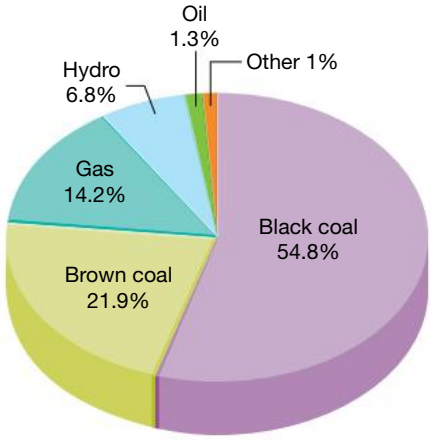


Figure 5.4.13 This pie chart shows Australia's dependence on coal for its electricity. Only Greece and Denmark rely on coal as much as we do.

COAL-FIRED PLANTS

In New South Wales and Queensland, high-quality black coal is used to generate electricity. In Western Australia and South Australia, a lower-quality black coal is used. In Victoria, an even lower-quality brown coal is used.

'Clean-coal technologies' are currently being developed that burn coal more efficiently. These technologies generate electricity more efficiently and with less pollution and carbon dioxide emissions. One technology involves converting coal into a gas called syngas that burns more efficiently than solid coal. Other technologies burn a combination of coal and gas, increasing the power station efficiency to 50–55%. Waste heat can also be captured to heat local homes and factories, further increasing the total efficiency of the energy conversion to around 80%. Regardless of which method is used, coal is being burnt and so there are major environmental concerns arising from them.

HYDROELECTRICITY

Australia has a limited number of hydroelectric power plants. Most plants are in the mountains of New South Wales (the Snowy Mountains), Victoria (Kiewa Valley and Dartmouth) and Tasmania (Gordon River and Devil's Gate). Others are located on major rivers that carry huge amounts of water, such as the Barron, Tully and Brisbane Rivers (Queensland) and the Ord River (Western Australia). You can see a typical dam used for the generation of hydroelectricity in Figure 5.4.14.

Figure 5.4.14 Hydroelectricity uses water falling from dams to spin turbines.

NEW TECHNOLOGIES

To reduce our dependence on coal and gas, and to reduce the amount of carbon dioxide being released, various 'green' technologies are currently being built or tested around Australia.

- *Wind farms* are becoming more common in Australia, particularly along the coast of Victoria and South Australia, where winds from the Southern Ocean are most fierce. In 2008 an estimated 42 wind farms consisting of around 650 wind turbines were already generating electricity. Many more are planned. Although wind farms provide roughly 1% of the nation's electricity needs, South Australia draws 15% of its electricity from wind farms.
- *Solar reflector generators* are currently used to generate electricity in Liddell (New South Wales), Whyalla (South Australia), Cloncurry (Queensland) and the remote Indigenous communities of Hermannsberg, Yuendumu and Lajamanu (Northern Territory).
- Australia does not lie on any major fault lines (unlike New Zealand, Iceland, Japan, the Philippines and Indonesia) and so large-scale *geothermal power plants* cannot be built here. However, a temperature difference always exists between the rocks deep underground and the surface. This difference allowed a small geothermal power plant to be built in Birdsville (Queensland). Sites in South Australia and New South Wales are being tested for their suitability for geothermal power production. A trial geothermal plant is being built outside Geelong (Victoria). This plant will eventually provide power for 120 000 homes.
- Like most places in the world, Australia's tides are generally not large enough to be used to generate electricity. One place where the tides are large enough is Broome (Western Australia). However, the region is relatively unpopulated and there are no plans for *tidal generators* to be built there.
- Australia is ringed by sea and is constantly being battered by waves. Experimental *wave-powered generators* are being tested at Port Kembla (New South Wales), Douglas Point (South Australia) and Albany (Western Australia).

In 2011 the Australian Government introduced the Renewable Energy Target (RET), a scheme that uses incentives and a price on carbon dioxide emissions to shift electricity production from fossil fuels to renewable sources. By 2020, it is planned that 20% of Australia's electricity will come from renewable sources such as large wind farms and smaller, domestic solar systems. By 2012, the demand for electricity from coal-fired power stations had already dropped enough to shut down the Munmorah station in New South Wales, the Playford B station in South Australia and one turbine at Yallourn in Victoria.

REVIEW

1. **Compare** the black coal of New South Wales with the brown coal of Victoria.
2. **Explain** why hydro is not used more often in Australia.
3. **Assess** whether 'clean-coal' technologies are really clean or not.
4. Electricity drawn from power stations has decreased in recent years. **Propose** reasons why.
5. **Explain** what RET is and how it works.

5.4 Unit review

Remembering

1 **List** the advantages and disadvantages of electricity that is:
   - **a** AC
   - **b** DC.

2 **List** three ways in which water (not steam) can be used to directly spin turbines.

3 Steam is often used to spin turbines. **List** three commonly used ways in which a power station changes water into steam.

4 **State** the typical voltages:
   - **a** produced by power stations
   - **b** at which electricity is transmitted long distances.
   - **c** available from a power point.

5 **State** where transformers are commonly used:
   - **a** around the home
   - **b** in transmitting electricity from the power station to home.

6 Incandescent globes are very inefficient. **State** the percentage of electrical energy 'wasted' as heat by them. N

Understanding

7 **Predict** what will happen to the milk container in the science4fun on page 200 when water pours out of the four holes made near its base.

8 **Explain** why electricity is transmitted over long distances at low currents and high voltages.

9 **Outline** some of the developments that have increased the efficiency and reduced atmospheric pollution involved in the generation, transmission and use of electricity. CCT PSC L

10 **Discuss** what needs to be considered when making decisions about using non-renewable energy resources such as fossil fuels for electricity generation. S EU CC CCT

Applying

11 **Identify** whether AC or DC electricity is used to power a:
   - **a** tablet computer
   - **b** washing machine.

12 **Use** Table 5.4.1 on page 202 to **rank** the different methods of generating electricity from most efficient to least efficient.

13 **Use** Figure 5.4.11 on page 204 to **rank** the different types of light globe from most efficient to least efficient.

Analysing

14 **Compare** the function of step-up and step-down transformers.

15 **Use** Figure 5.4.11 on page 204 to **calculate** how much more efficient a compact fluorescent globe is compared to: N
   - **a** an incandescent globe
   - **b** a low-voltage halogen.

16 The table below shows the average size of new homes in different countries. N
   - **a** **Identify** which country has the largest average new home.
   - **b** **Compare** the size of an average new home in Australia with one in the:
     - **i** United Kingdom
     - **ii** USA.

Country	Average size of a new house (m^2)
Australia	215
United States	202
New Zealand	196
Denmark	137
Greece	126
United Kingdom	76

Evaluating CCT

17 **Propose** reasons why the efficiencies of power stations using solar power, geothermal power or wind power are of less concern than the efficiencies of power stations using fossil fuels.

18 **Use** Table 5.4.1 on page 202 to **evaluate** whether renewable and non-renewable energy sources should be used to generate electricity.

5.4 Unit review

19 The proportion of Australia's electricity being generated by wind farms and solar panels is increasing every year. This has caused a drop in the amount of power required from coal-fired power stations.

a **Propose** reasons why these changes are happening.

b **Discuss** how the values and needs of society influence the preferred methods of electricity generation.

c **Discuss** how this might affect the focus of scientific research.

Creating CCT

20 **Construct** a labelled diagram to **summarise** the transmission of electricity from power station to the city.

Inquiring

1 Research the power stations and transmission system of New South Wales. Find:

- their location
- the method each uses to generate electricity
- the main transmission lines across the state.

Present your research as a labelled map.

2 Australia has 23% of the world's uranium, the main fuel used for nuclear power stations. Find a list of countries we export uranium to, how much we export to each (in tonnes or as a percentage) and the reasons why we export it to some countries but not others.

Present your research as an article for a newspaper or news website. Include a table or graph in your article. A DD

3 Research a recent example of a scientific or technological development in electricity generation that has reduced emissions or reduced atmospheric pollution. You might investigate syngas, geosequestration, or a renewable method of generating power such as tidal or wave generators. Whatever you choose:

- outline what the development is
- explain how the development reduces emissions and pollution
- identify the branches of science, engineering and technology involved in the research that led to the development.

Present your research in digital form. ICT

ADDITIONAL

4 Research different types of batteries including those that use wet cells and dry cells (including mercury cells) and those that are rechargeable. For each type, find:

- their typical voltages
- their advantages
- their disadvantages
- common uses
- images showing their structure
- the names of the substances used for their electrodes and electrolytes
- how these substances are kept apart.

Present your research as a brochure that includes appropriate images. L

5 Energy-efficient devices don't just happen. They need to be designed by engineers. Research how science is used in this design process.

Present your research as a timeline showing important stages in the development of the device. CCT WE

6 Research five similar electrical appliances, such as different types of TV (plasma, LCD, LED, 3D) or different makes and sizes of refrigerator. Find:

- images of each appliance
- the power of each appliance (in watts, symbol W)
- their star rating
- their other features (such as size, screen clarity, bottom or top freezer etc.).

Present your research as an article for a website or consumer magazine in which you compare the different appliances and the cost of running them and recommend one of them for purchase.

ADDITIONAL

5.4 Practical investigations

1 Lemon cells

Purpose

To construct a cell and a battery using fruit.

Materials

- lemon and/or other fruits and vegetables (such as kiwi fruit, apple, tomato, melon)
- copper nail, small sheet of copper or length of stripped copper wire
- iron nail (can be galvanised) or small sheet of iron
- milliammeter, multimeter or LED (light-emitting diode)
- connecting wires with alligator clips
- paper towel

Procedure

1 Soften the inside of the lemon a little by squeezing it. Don't break it.

2 Insert the copper nail, sheet or wire into the lemon. Do the same with the iron nail or sheet.

3 As shown in Figure 5.4.15, connect the copper electrode to either the positive terminal of the milliammeter or multimeter or the long terminal of the LED.

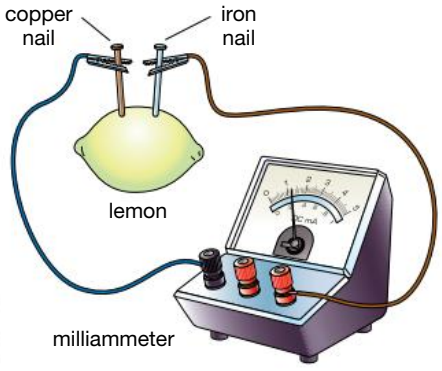


Figure 5.4.15

4 Connect the iron electrode to the negative terminal of the milliammeter or short terminal of the LED. A current should flow immediately. Record the current flowing or describe how brightly the LED shines.

5 Remove the electrodes and pat them dry with paper towelling. Repeat the experiment but with different fruits and vegetables.

6 Increase the energy supplied by connecting up a series of the same types of fruit, as shown in Figure 5.4.16. Start with two pieces of fruit, then three and so on. Once again, record the current or brightness of the LED.

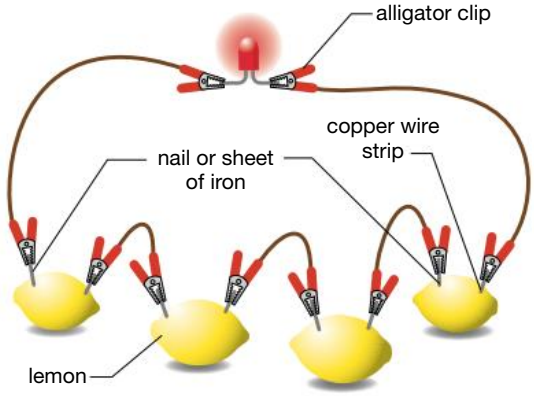


Figure 5.4.16

Results

Record your results in a table like this one.

Type of fruit	Number of pieces of fruit	Current (mA)	Brightness of LED
Lemon	1		
Lemon	2		

Practical review

1 a **Classify** these fruit batteries as wet or dry cells.
b **Justify** your answer.

2 **Identify** the electrolyte (conducting liquid) in these fruit batteries.

3 **Propose** a reason why it was recommended that you soften the inside of the lemon a little before the experiment started.

4 **Describe** the energy transfer happening in this experiment.

2 Power from water

The height of water above a hole or tap referred to as its *head height*.

Purpose

To test whether the speed of water squirting out of a hole in the side of a container depends on head height.

Materials

- straight-sided container such as a cardboard milk or fruit juice carton
- nail
- scissors
- chair, table or some other stand
- 30 cm plastic ruler
- 1 m ruler

Procedure

1. Copy the table from the Results section into your workbook.
2. Cut the top off the container and use the nail or skewer to make a hole in the side, about 1 cm above its base. Widen the hole a little with the nail or skewer.
3. Tape the ruler inside the container. Make sure that the zero marking of the ruler is aligned with the hole.
4. Go outside and perform the rest of the prac in a place where it does not matter if it gets wet. Place the container on a chair, table or some other stand, ensuring that the container is vertical.
5. Put the 1 m ruler on the ground, making sure its zero marking is directly below the hole in the container. Your apparatus should look like Figure 5.4.17.
6. Place your finger over the hole and fill the container with water. In your table, record the height of the water above the hole (its head height).
7. Release your finger and let the water flow for a second or so, then plug it once more.
8. Record how far the water went.
9. Repeat this method for at least five different head heights of water.
10. Verify your results by repeating the whole experiment at least once more.

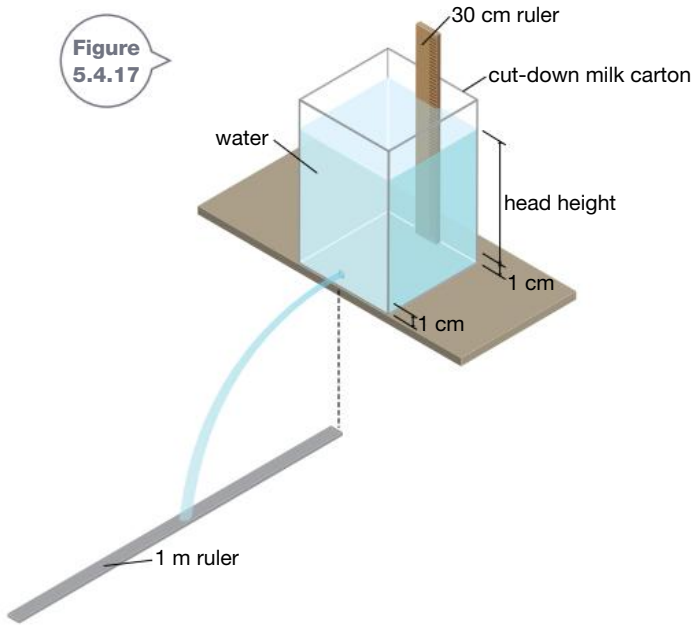


Figure 5.4.17

Results

1. Record your results in a table like this one.

Head height (mm)	Distance water went (mm)			
	Trial 1	Trial 2	Trial 3	Average

2. Calculate the average distance the water went for each head height.
3. Plot a line graph of average distance versus head height. Place average distance on the vertical axis and head height on the horizontal. Draw a line or curve of best fit through the centre of your points.

Practical review

1. **Describe** what happened when the water level (head height) dropped.
2. If the water went further, then it flowed out the hole faster. **State** whether big head heights caused the water to flow faster or slower.
3. Hydroelectricity is generated using falling water. **Propose** what happens to the amount of hydroelectricity produced as the water levels in dams drop.
4. **List** factors that might cause water levels in dams to drop.

5 Chapter review

Remembering

1 **State** whether the following statements are true or false.
- a Energy converters have resistance.
- b A current is flowing when a spark jumps from one object to another.
- c Radiation spins the turbine in a nuclear reactor.
- d Australia has no geothermal power plants.

2 **Name** the components shown in Figure 5.5.1.

a b c

Figure 5.5.1

3 **State** what the following do if an abnormally high current passes through them.
- a fuse
- b circuit breaker

4 **State** the unit and unit symbol used to measure resistance. N

5 Coal is Australia's main source of electrical energy. **List** its advantages and disadvantages.

Understanding

6 **Define** the following terms. L
- a electrolyte
- b resistance
- c solenoid

7 **Predict** the expected current and voltage of each of the globes in Figure 5.5.2. N

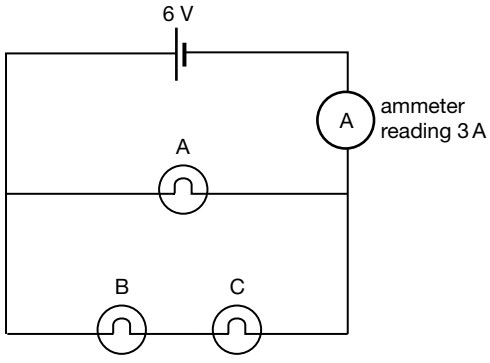


Figure 5.5.2

8 **Explain** why a wet cell is suitable for a car but not for a tablet computer.

9 **Explain** the advantages of having all your home appliances connected in parallel rather than in series.

10 Voltage is boosted before electrical power is transmitted long distances. **Explain** why.

11 **Explain** why laptops need a transformer when plugged in.

Applying

12 **Identify** three appliances around your home that use an electric motor.

13 **Identify** three energy sources used to generate electricity that are:
- a renewable
- b non-renewable.

Analysing

14 **Contrast** the electron flow and voltage of AC electricity and DC electricity.

15 **Compare** a dynamo with a turbine.

Evaluating CCT

16 a **Identify** which renewable way of generating electricity would be best for your area in New South Wales.
- b **Justify** your choice.

17 a **Determine** whether you can or cannot answer the questions on page 169 at the start of this chapter.
- b **Assess** how well you understand the material presented in this chapter.

Creating CCT

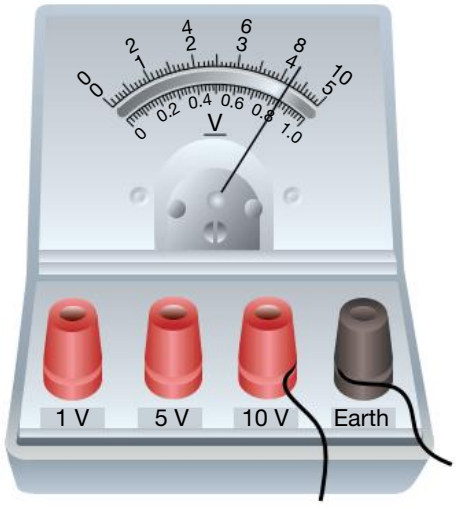
18 **Use** the following ten key words to **construct** a visual summary of the information presented in this chapter.

current	voltage	resistance
ammeter	voltmeter	magnet
coil	motion	
motor	generator	

5.8

Thinking scientifically

Q1 Analogue voltmeters have a needle and a dial. Many have different terminals along their base, with each terminal measuring a different maximum voltage. CCT



The voltmeter shown here was used to measure the voltage over a light globe. Its measurement is shown. State which of the following voltage readings is most likely to be correct.

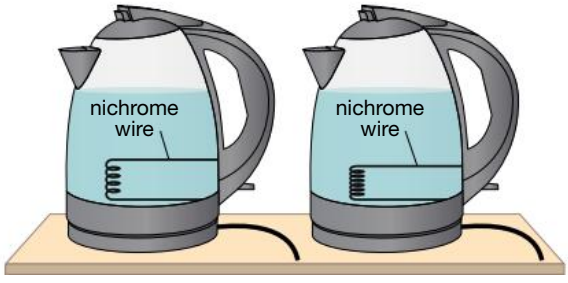
A 0.84 V
B 4.2 V
C 8.2 V
D 8.4 V

Q2 The actual supply voltage of a 3 V battery is to be measured using the voltmeter above. CCT

Assess which set of terminals would give the most accurate reading of this battery's voltage.

A 1 V and earth
B 5 V and earth
C 10 V and earth
D earth only

Q3 Marge tested how long each of these electric kettles took to boil water. CCT



The kettles were almost identical. Identify what is different between them.

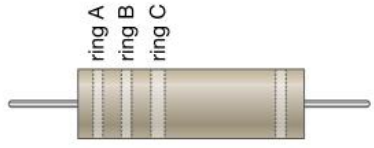
A the amount of water each held
B the voltage of the heating element
C the type of wire used as a resistance
D the resistance of each heating element

Q4 To run a fair test on the kettles in question 3, identify which of the following Marge would have to keep constant. CCT

A the position of the lid (up or down)
B the amount of water each held
C the temperature of the water at the start
D all of the above

Q5 Resistors are electronic components. Their resistance is marked on them as a series of coloured bands. What each colour band means is shown in the table below. CCT

Colour	Ring A	Ring B	Ring C
Black	0	0	× 1
Red	2	2	× 100
Yellow	4	4	× 10 000
Blue	6	6	× 1 000 000



State the most likely resistance of this resistor.

A 40 Ω
B 400 Ω
C 20 Ω
D 2 000 000 Ω

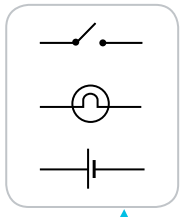
Glossary

Unit 5.1

Ammeter: an instrument that measures current

Ampere: the unit of current; symbol A

Circuit diagram: shows how all components in the circuit are connected



Components

Components: the parts of a circuit

Conductor: a material that allows a current to pass

Current: the flow of charge

Electric circuit: the path down which charge flows

Insulator: a material that blocks current

Ohm: the unit of resistance; symbol Ω

Resistance: a measure of how difficult it is for current to pass; measured in ohms (Ω)

Transformer: a device that increases or reduces voltage

Voltage: a measure of the amount of energy provided to charges or used by them; measured in volts (V)

Voltmeter: an instrument that measures voltage

Volts: the unit of voltage; symbol V

Unit 5.2

Active wire: a wire that carries current to a component; it is coated in brown plastic

Circuit breaker: a switch that turns off a circuit if too much current flows through it

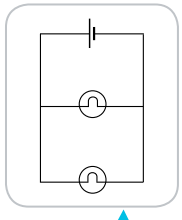
Earth wire: a wire through which current only flows when there is a leak of current in an appliance; it is coated in yellow and green plastic

Electrocution: death by electricity

Fuse: a wire of high resistance; it will melt if too much current flows in the circuit

Neutral wire: a wire that carries current away from the component; it is coated in blue plastic

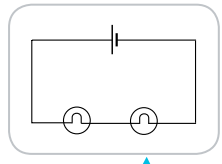
Parallel circuit: a circuit that has a number of branches, each with its own components



Parallel circuit

Safety switch: a device that turns all household circuits off if it detects a leak in current; it is also known as a residual current device (RCD)

Series circuit: a circuit with all its components arranged in a line, forming a single loop



Series circuit

Unit 5.3

Dynamo: a small generator that spins its magnet instead of its coils

Electromagnet: a solenoid with an iron rod in its centre

Electromagnetism: the relationship between electricity and magnetism

Field lines: lines that show the direction of the force on iron filings and compass needles

Electromagnet

Generator: uses electromagnetism to produce electricity; it needs a spinning coil and a magnet

Magnetic field: an invisible force field around a magnet

Motor: a machine that uses electromagnetism to spin; it needs a current-carrying coil and a magnet

Solenoid: a current-carrying loop of wire

Unit 5.4

Alternating current (AC): the current generated by electrons changing the direction in which they move

Direct current (DC): the current generated by electrons always moving in one direction

Efficiency: the percentage of energy that is converted into useful forms

Electrochemical cell: a 'mini-battery' that uses chemicals and redox reactions to generate electrical current

Electrolyte: a solution or wet paste containing dissolved chemicals that conducts electricity and completes the circuit in an electrochemical cell

Law of conservation of energy: the amount of energy before and after a change is the same; no energy is created and none is destroyed

Photovoltaic cell: a solar cell; directly converts solar energy into electrical energy

Turbine: a large-scale electricity generator

SCIENCE TAKES YOU PLACES

Look who is using science

VET

Hi, I am Glenn Linstead, a vet working in a private practice. My official title is veterinary surgeon. I did a five-year university degree to become a vet. I love my job, and it would be hard to imagine a better one because I have always been fascinated by animals.

I am a 'small animal' vet, which means I treat mainly pets, including dogs, cats, rabbits and birds. This job is interesting because of the variety of animals and conditions. I perform surgery such as repairing torn ligaments in legs and removing foreign objects such as balls or sticks from intestines. There are many other duties, including vaccinations, stitching cuts, desexing, cleaning or extracting teeth, diagnosing illnesses, and administering cures such as drug treatments.

The thrill of curing animals and seeing the delight of their owners makes you feel great. If you like science and animals, consider being a vet.

PHYSIOTHERAPIST

I'm Kelly Sheffield, a senior physiotherapist in a hospital. I did a Bachelor of Science in Physiotherapy for 4 years at university. I gain a lot of satisfaction from my job by being able to help people and I enjoy working closely with medical staff.

The human body is an amazing machine. Learning about its complexities is very interesting. My work is extremely varied and includes working with newborn babies and children, treating women after childbirth, and treating people on ventilators in critical care units.

I rehabilitate people who have balance disorders and problems with their inner ear vestibular system. I teach exercises to patients after surgery or accidents and help people to do the things we all take for granted, such as sitting up, standing and walking.

I use science every day in my job and I am very glad that I chose to be a physiotherapist.

HORTICULTURIST

Hello, my name is Cheryl Commens, and I work as a horticulturist. Horticulture is the science of growing plants. To do this effectively requires a knowledge of plant reproduction, soil chemistry and pest and disease management.

To become a horticulturist I had to study for a Diploma in Applied Science, Horticulture. I have worked in many different fields of horticulture, including landscaping, retail and wholesale plant nurseries and agriculture.

Working as a horticulturist allows you to spend most of your working life outdoors. This gives you a great sense of freedom and love and respect for the environment. If you like similar things, then perhaps you should consider horticulture as a career.

6 Body coordination

Have you ever wondered...

- how parts of your body can work without you having to think about it?
- why your heart beats really fast and you are red in the face during and after exercise?
- why you are able to act quickly in response to sharp or hot objects?
- why you get 'butterflies' in your stomach when you are nervous, or feel shaky when frightened?

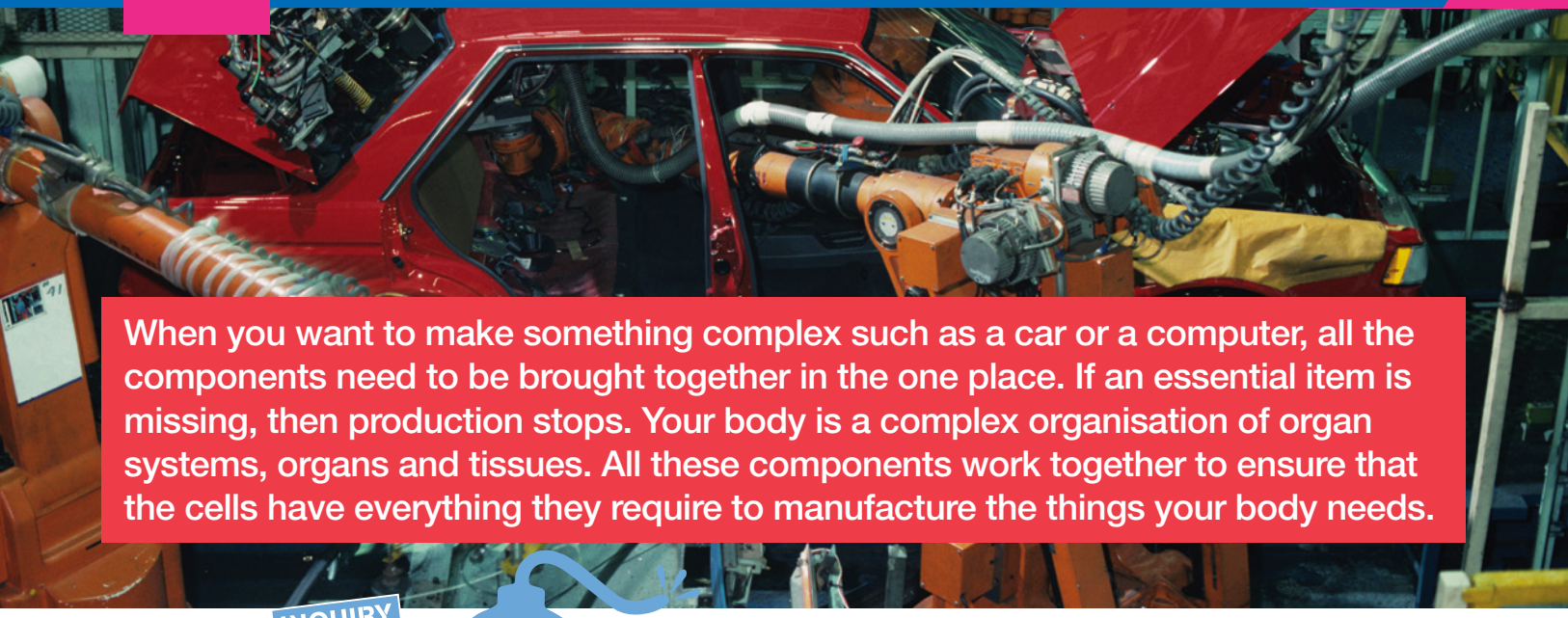
After completing this chapter students should be able to:

- describe ways that multicellular organisms respond to changes in their environment
- describe how coordinated body systems provide cells with the requirements for life
- describe how the coordinated systems maintain humans as functioning organisms
- discuss how the values and needs of contemporary society can influence the focus of scientific research PSC CCT EU

ADDITIONAL

- describe the range of functions carried out by some endocrine (hormonal) glands in humans L
- describe examples of advances in science in areas that involve biological science, such as biomedical engineering. CCT L WE

6.1 Coordinated body systems



When you want to make something complex such as a car or a computer, all the components need to be brought together in the one place. If an essential item is missing, then production stops. Your body is a complex organisation of organ systems, organs and tissues. All these components work together to ensure that the cells have everything they require to make the things your body needs.

INQUIRY science 4 fun

It smells!

YES

How long does it take for a scent to travel across a room?

Collect this ...

- spray can of perfumed deodorant or air freshener
- partner
- stopwatch or watch with a second hand

Do this ...

1. Close all the windows and doors in the room to reduce air movement.
2. Stand on one side of the room, facing the wall with your eyes closed.
3. Your partner gives a short spray of deodorant into the air and records the time.
4. Call out as soon as you can smell the scent. Record the time.
5. Repeat the experiment using twice the amount of deodorant. However, you will have to wait until all the scent has cleared from the room before you do this.

Record this ...

Describe what happened.

Explain why you think this happened.

Metabolism

A large number of chemical reactions take place within your cells. Collectively these reactions are known as **metabolism**—the chemical processes that maintain life and allow organisms to grow and reproduce, maintain their structures and respond to their environments.

The chemical reactions of metabolism are divided into two groups:

- reactions that break down organic matter—examples are respiration, which breaks down the glucose molecule to release energy, and the breakdown of wastes into harmless substances for excretion
- reactions that build complex molecules from simpler substances—an example is the construction of new cells and cell components such as proteins and genetic material (Figure 6.1.1).

Figure 6.1.1

These plants are able to grow because their metabolism builds simple chemicals into the complex components of new cells.

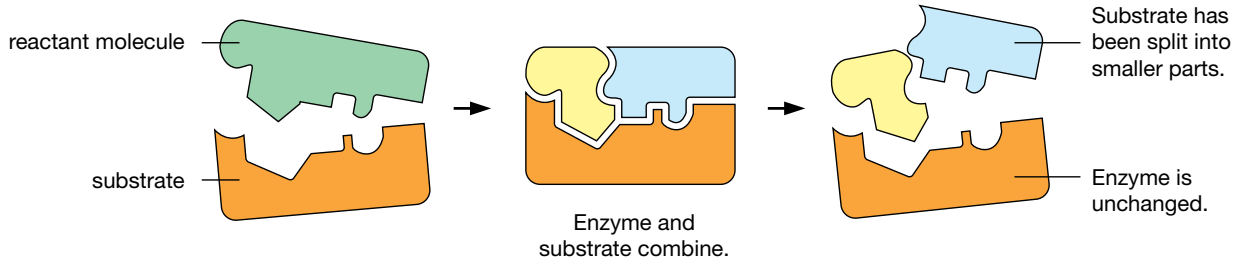


Figure 6.1.2 The 'lock-and-key' model explains the action of enzymes. In this diagram a larger molecule has been split into smaller ones. The opposite reaction can also occur with other enzymes, where smaller molecules are joined to form a larger one.

Enzymes

All the reactions in your body are helped along by **enzymes**—chemicals that speed up the rate of a reaction without being used up in the process. Without the help of enzymes, many reactions would occur too slowly to maintain life.

There are over 700 enzymes in the human body and each one is specific to one particular chemical reaction. Scientists have constructed a model of how enzymes work. This model is known as the 'lock-and-key' model, shown in Figure 6.1.2.

Each enzyme has a particular shape that allows it to attach to a specific molecule or molecules, known as the **substrate**. The substrate is what will be changed by the chemical reaction. In a reaction, the enzyme and the substrate join together and the substrate is then changed in some way.

Prac 1 p225

That's fast!

Enzymes can increase reaction rates by up to ten billion times. That's like taking a minute to do something that otherwise would take 18 000 years!

SciFile

Getting nutrients

The food you eat is the source of many of the raw materials your body needs for metabolism. When you chew on an apple or a slice of bread, the nutrients it contains are not always in a form that your body can use. It is the job of the digestive system to chemically change the complex molecules in the apple and the bread into simple chemical substances your body can use.

The food you eat contains complex carbohydrates, proteins and lipids. Through the reactions of chemical digestion, they are progressively broken down, so that when the food reaches the small intestine it is in the form of simple chemical substances.

- Carbohydrates are broken down into glucose.
- Proteins are broken down into amino acids.
- Lipids (fats and oils) are broken down into fatty acids and glycerol.

These simple chemical substances are small enough to pass through the thin walls of the villi lining the small intestine (Figure 6.1.3). They then pass through the thin walls of capillaries and into the bloodstream.

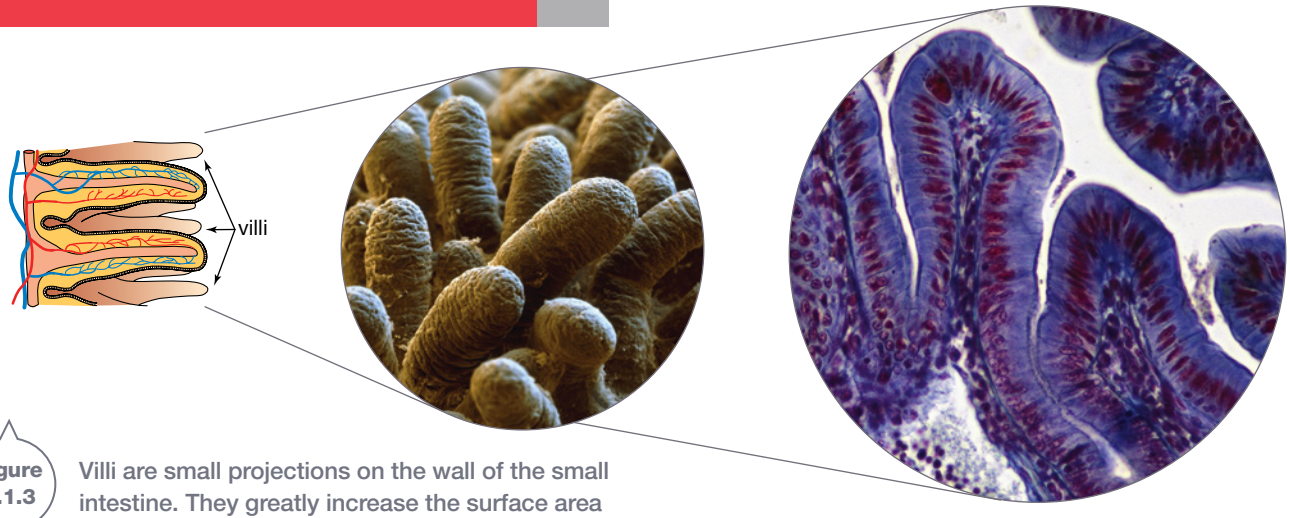


Figure 6.1.3 Villi are small projections on the wall of the small intestine. They greatly increase the surface area through which nutrients can be absorbed.

Diffusion

The simple chemical substances produced by digestion are very small particles. They move by diffusion through the cells of the villi and capillaries. **Diffusion** is the movement of particles of a substance from an area of high concentration of that substance to an area of low concentration of that substance. In simpler terms it means that the particles move from an area where there is a lot of that type of particle to an area where there is not much at all. Diffusion takes place in liquids and gases where the particles have enough energy to move around.

Figure 6.1.4 models how diffusion works. The particles are moving around, bumping into each other on both sides (A and B) of the container. However, they are separated from one another by the barrier. Side A has a higher concentration of red particles than side B. Side B has a higher concentration of yellow particles than side A. If the barrier between the two sides is removed, then the particles can move freely. Without the barrier to stop them, red particles are able to move into the right-hand part of the container. Eventually the red particles are evenly distributed across the whole volume. In the same way, more yellow particles are able to move to the left. Eventually they too are evenly distributed across the whole volume.

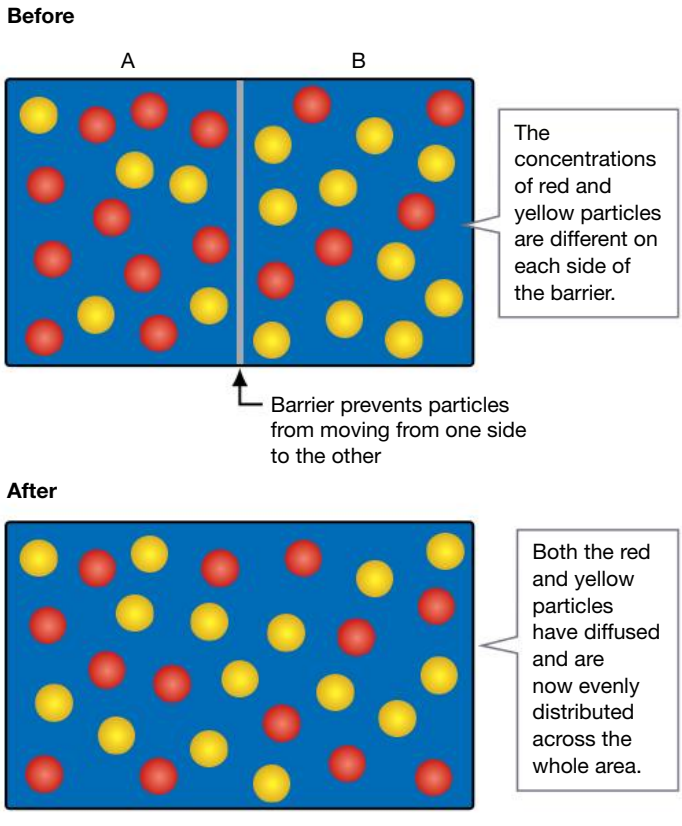


Figure 6.1.4 The process of diffusion

After eating, there are high concentrations of glucose, amino acids, fatty acids and glycerol in the small intestine. In the bloodstream, there are low concentrations of these molecules. Most of the molecules move by diffusion from the small intestine, through cell membranes and into the blood capillaries in the villi.

The flow of blood in the capillaries quickly carries the digested materials away, so there is always a higher concentration in the small intestine and lower concentration in the blood. Hence, diffusion continues.

Prac 2 p226

Getting oxygen

The air you breathe enters your respiratory system through your nose and mouth. It passes down the trachea, bronchi and bronchioles, ending up in the alveoli. As Figure 6.1.5 shows, the walls of the alveoli are only one cell thick and are surrounded by blood capillaries. Oxygen dissolves at the moist surface of the alveoli and moves by diffusion across the short distance from the space inside an alveolus to the blood.

Once in the blood, the oxygen combines with haemoglobin in the red blood cells. The flow of blood carries the oxygen away, so the concentrations in the alveolus and the blood never become equal. In this way, oxygen continues to move into the blood.

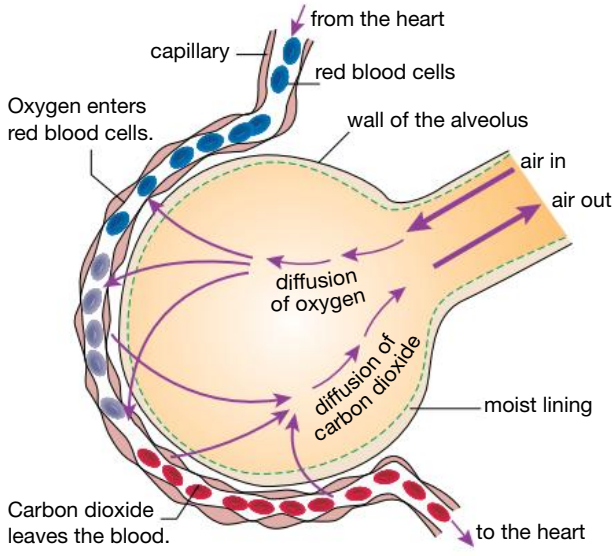


Figure 6.1.5 The walls of the alveoli and blood capillaries are only one cell thick. The ideal situation for gas exchange is where the surface of the alveolus and the blood capillary are in contact.

Circulation

The circulatory system of arteries, capillaries and veins carries materials to and from every cell of your body. The heart is the pump that keeps the blood moving and without it the cells would soon be starved of the materials they need to function.

Heartbeat

The heart is made up of cardiac muscle. Cardiac muscle naturally contracts and relaxes without any input from the nervous system. The rhythm of the heartbeat is initiated by a small patch of muscle, called a pacemaker (or SA node), shown in Figure 6.1.6.

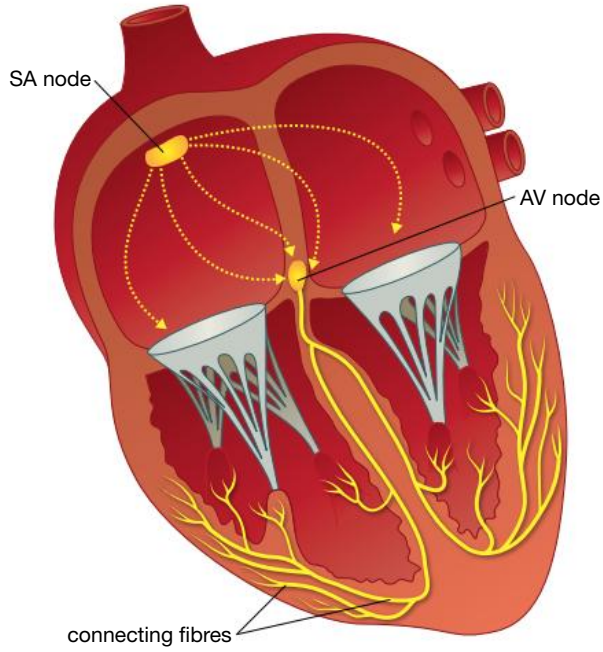


Figure 6.1.6 The heart has two specialised areas of muscle (the SA node and the AV node) that control and synchronise the heartbeat.

The rhythm of relaxation and contraction of the pacemaker sets the rhythm for the heartbeat. The pacemaker stimulates both atria to contract simultaneously. When the stimulus reaches the tissue between the atria and the ventricles, another small patch of specialised tissue (the AV node) stimulates both ventricles to contract. An electrocardiograph of a normal heartbeat is shown in Figure 6.1.7.

If the impulses in the ventricles become disorganised because the stimulus is not picked up correctly, the muscles of the ventricle begin to twitch spasmodically. This is a condition known as ventricular fibrillation. Blood flow stops and unless the heart rhythm is restarted, death will follow swiftly.

A defibrillator is used to give the heart a jolt with electric current, in an attempt to restore the heart's natural rhythm and save the person's life. That is what is happening in Figure 6.1.8. Defibrillators are found in hospital emergency rooms, ambulances, commercial aircraft, shopping centres and surf lifesaving clubs.

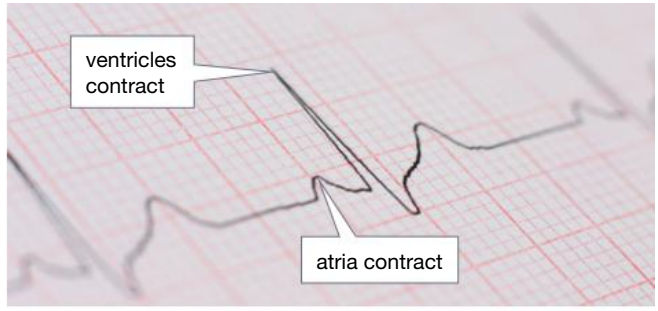


Figure 6.1.7 An electrocardiograph creates an image of the heartbeat. The lower peak is the contraction of the atria. The high peak is the contraction of the ventricles. Then the heart rests.

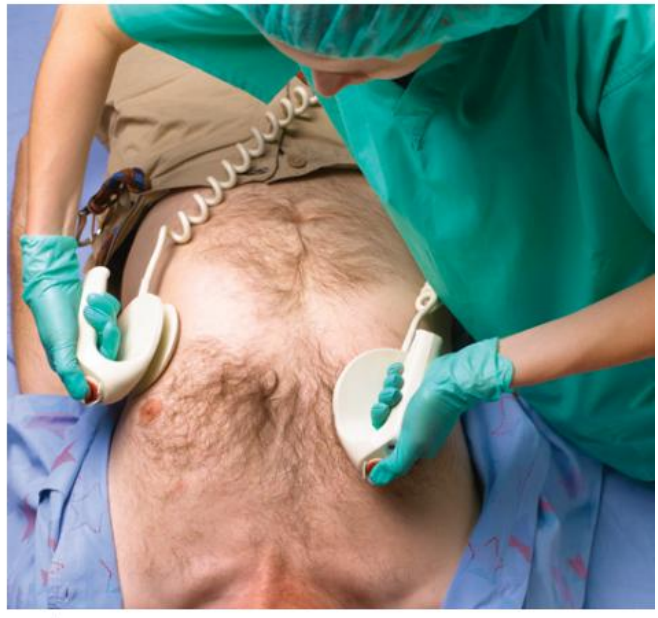


Figure 6.1.8 Defibrillators are used to restart the heart of a person who has suffered heart failure.

Changes to heart rate

The rate at which your heart beats changes according to the needs of your body.

Stress or fear causes the body to produce a hormone called noradrenalin. **Hormones** are chemicals that act as messengers in the body. Noradrenalin affects the heart in two ways, both of which increase blood flow. It increases the:

- rate at which the heart beats
- strength of the contractions.

Noradrenalin can stimulate the heart to pump up to five times as much blood per minute as normal.

Vigorous exercise, such as the cross-country race shown in Figure 6.1.9, increases the heart rate in two ways.

- As cellular respiration increases, so does the carbon dioxide (CO_2) level in the blood. This change is detected by receptors. **Receptors** are specialised cells that dectect stimuli changes. In this case, receptors in the carotid artery (in your neck) and aorta (the artery leading from your heart) detect the increased CO_2 concentration and send messages to the brain. Nerves then stimulate the heart to beat faster.
- As muscular activity increases, more blood is pumped back to the right atrium. The atrium wall stretches to hold the extra blood. Stretch receptors in the wall of the atrium send nerve impulses to the brain, which stimulates the heart to beat faster.

Figure 6.1.9 When you exercise, receptors in your body detect changes. The nervous system is stimulated to send impulses to muscles that respond in ways that meet the changed needs of your body.

When you stop exercising vigorously, receptors in the aorta and the carotid artery send messages to the brain to slow the heart rate.

In the cells

Your body is made up of billions of microscopic cells. Within each cell are smaller structures known as organelles, many of which can only be seen using an electron microscope. You can see some in Figure 6.1.10.

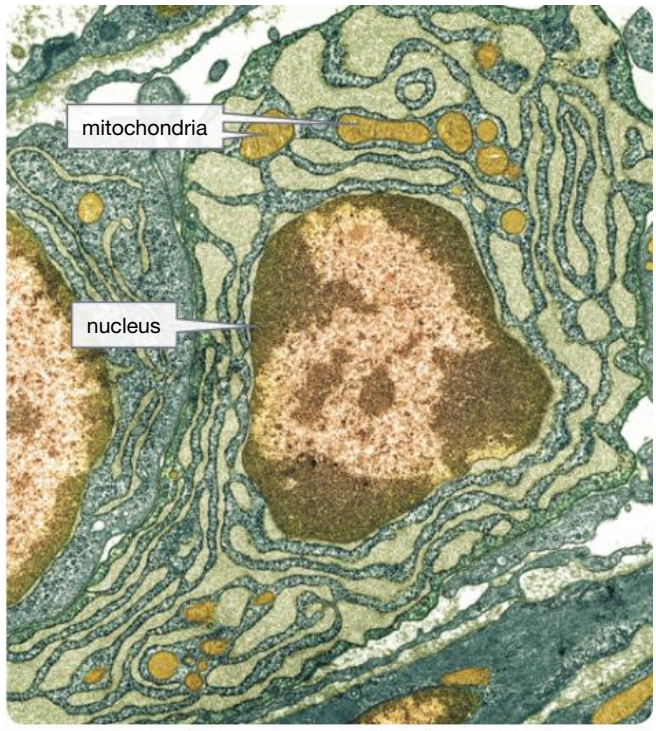


Figure 6.1.10 Most organelles are so small that they can only be seen clearly when magnifications of over 100 000 are used.

Mitochondria are the organelles in which cellular respiration takes place. Oxygen and glucose enter the cell from the blood capillaries and move through the cytoplasm to the mitochondria where they are used in cellular respiration. Cellular respiration is a series of chemical reactions assisted by enzymes. These chemical reactions release energy from glucose.

While the reactions of respiration are taking place in the mitochondria, chemical reactions to produce proteins are occurring on the surfaces of structures called **ribosomes**. At the ribosomes, amino acids from the proteins you have digested are reassembled into proteins your body can use. Enzymes and hormones are proteins, as are parts of cell membranes and muscle fibres.

Lysosomes are organelles that treat wastes within cells. Cells and organelles within your body are replaced continuously. Lysosomes digest dying cells, damaged organelles, and viruses or bacteria that have invaded the cell. The products of lysosome digestion move from the cell to the bloodstream.

Removing wastes

The liver is your largest internal organ. Its position is shown in Figure 6.1.11. It carries out many different functions, some of which are related to waste treatment. The liver:

- breaks down hormones
- breaks down haemoglobin (from dead red blood cells), creating products that are added to bile and then disposed of through the digestive system
- breaks down or modifies toxic substances and most medicines—an excess of toxins such as alcohol may cause permanent damage to the liver
- converts ammonia to urea.

Apart from the end-products of the breakdown of haemoglobin, other wastes are carried from the liver to the kidneys and are excreted in the urine.

6.1

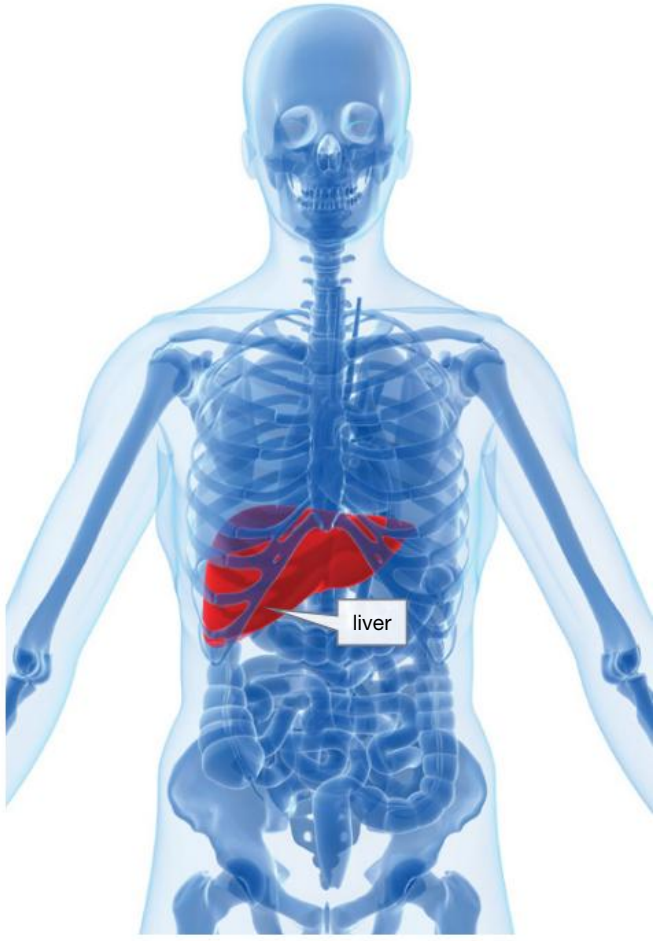


Figure 6.1.11 The liver is a very important internal organ. It has many functions, only a few of which are related to waste disposal.

Interdependence of systems

The systems of your body are interdependent. Each system depends on the others in a variety of ways and cannot function without them. Figure 6.1.12 shows the interrelationships between the excretory, digestive, circulatory and respiratory systems. The nervous and endocrine systems control the activities of these systems.

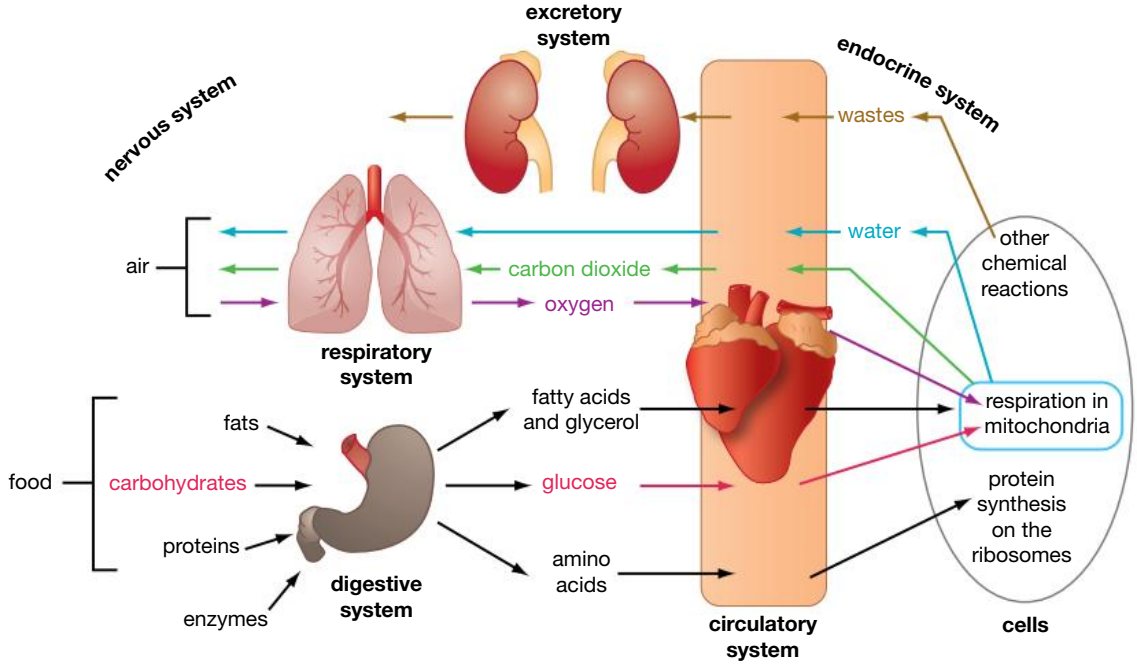


Figure 6.1.12 The interrelationships between the systems of your body

LEARNING ACROSS THE CURRICULUM

WORK AND ENTERPRISE

ARTIFICIAL PACEMAKERS

In 1899 the *British Medical Journal* reported experiments that John A. McWilliam had carried out on the human heart.

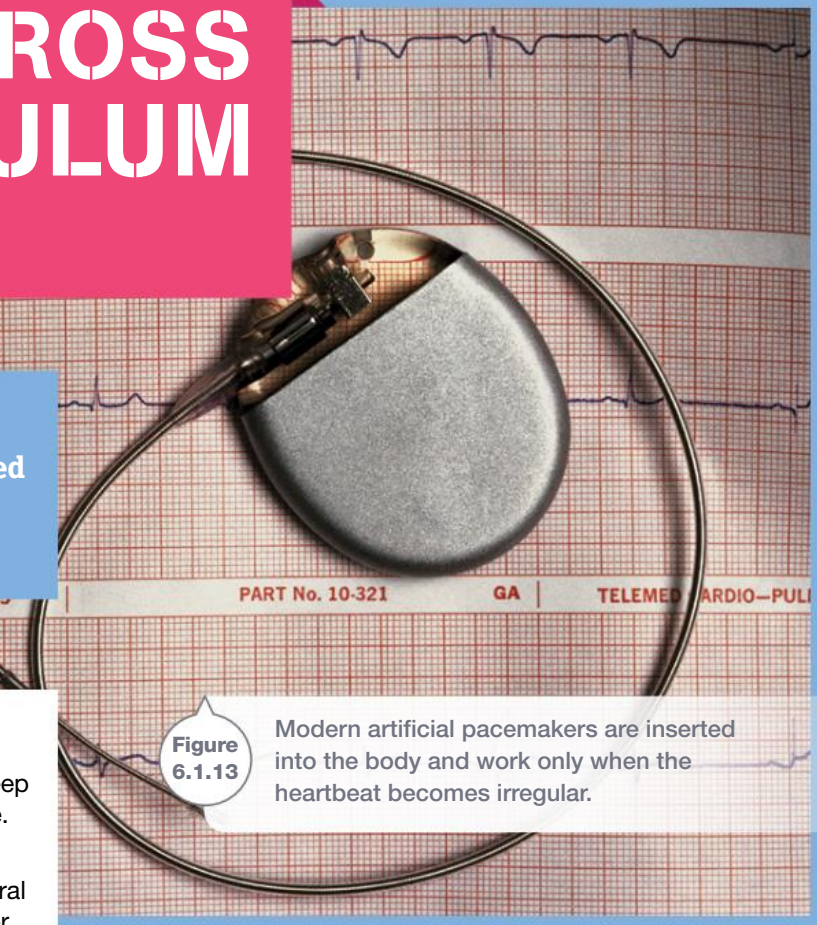


Figure 6.1.13 Modern artificial pacemakers are inserted into the body and work only when the heartbeat becomes irregular.

McWilliam used electrical impulses to make the heart muscle contract. By stimulating the heart at the rate of 60–70 electrical impulses per minute, he was able to keep the heart muscle contracting at 60–70 beats per minute.

This research preceded the development of artificial pacemakers—instruments used when the heart's natural pacemaker is defective. A defective natural pacemaker may cause the heart to beat too slowly, too quickly or in an irregular fashion. Any of these can cause health problems. Artificial pacemakers (like the one in Figure 6.1.13) have been developed to help control abnormal heart rhythms.

The first artificial pacemaker was invented by Australian anaesthesiologist Dr Mark C. Lidwell. He used his device to resuscitate a newborn baby at the Crown Street Women's Hospital, Sydney, in 1926. Lidwell did not patent his device and chose to remain anonymous because research of this nature was very controversial at the time. However, two years later, Lidwell worked with a physicist, Edgar H. Booth of the University of Sydney, to develop a portable artificial pacemaker that plugged into a light socket. The circuit was created by applying a pad soaked in strong salt solution to the skin and inserting a needle insulated except at its point into one of the ventricles of the heart.

Refinement of artificial pacemakers continued, but the biggest breakthrough came with the development of the silicon transistor in 1956. From that time, there was rapid development towards pacemakers that were wearable and then to ones that could be implanted in the body.

Swedish scientists pioneered the use of pacemakers in 1958, when Arne Larsson was the recipient. The first device failed after only three hours. A second device lasted two days. In total, Arne received 26 different pacemakers over a period of 43 years. He died in 2001 at the age of 86.

Modern artificial pacemakers are small devices placed in the chest or abdomen that use batteries to send electrical pulses to prompt the heart to beat at a normal rate. An electrode is placed next to the heart wall and small electrical charges travel through a wire to the heart.

Most pacemakers have a sensing device and send out signals to the heart only when necessary. The sensing device turns the signal on when the heart beats too slowly. When the heart is beating normally, the sensing device turns the signal off.

REVIEW

1 **State** the rate of:
   - **a** a normal heartbeat
   - **b** electrical impulses from an artificial pacemaker needed to maintain that heart rate.

2 **a** **Name** the Australian inventor of the artificial pacemaker.
   - **b** **State** the year in which he first trialled his invention.

3 **State** the breakthrough that enabled development of the wearable artificial pacemaker.

4 **Summarise** the way that modern pacemakers work to control the heart rate.

6.1 Unit review

Remembering

1 **Name** the process by which:
- a oxygen moves from the lungs into the bloodstream
- b food is broken down into molecules small enough for the body to use
- c energy is released from glucose

2 **Recall** the word used to describe each of the following.
- a the chemical processes that maintain life
- b chemicals that speed up the rate of reaction
- c the movement of particles of a substance from an area of high concentration of that substance to an area of low concentration of that substance
- d a molecule that is going to be changed by a chemical reaction

3 Copy the following table into your workbook and **recall** the information required to complete it.

Complex molecule	Simple molecule following digestion
lipid	
	amino acid
	glucose

4 **Name** the hormone that causes the changes in your body when you are frightened. L

Understanding

5 **Explain** why complex molecules such as proteins in your food have to be broken down into simpler chemical substances such as amino acids.

6
- a **Describe** the function of the SA node and the AV node in the heart.
- b **Explain** what is happening when the heart is fibrillating.
- c **Explain** why a defibrillator is used in that circumstance.

7 **Describe** how the lock-and-key model of enzyme action explains the specific nature of enzyme action.

8
- a **Explain** how villi make the small intestine more efficient.
- b Each villus has a good blood supply. **Explain** how this helps the digestive system supply the cells with the nutrients they need.

Applying

9 **Use** diagrams similar to those in Figure 6.1.2 on page 217 to **demonstrate** a reaction where two small molecules are joined to create a larger molecule.

10 **Use** annotated diagrams to **demonstrate**:
- a how diffusion occurs
- b the roles of the circulatory system and diffusion in the movement of nutrients from the small intestine
- c the interdependence of the roles of the circulatory system, the respiratory system and diffusion in removing carbon dioxide from the body.

Analysing

11 The chemical reactions of metabolism are divided into two groups. **Contrast** these two groups.

12
- a **Analyse** the information provided in this unit to **identify** the systems involved in getting nutrients to the cells of your body.
- b **Demonstrate** how the systems work in an interdependent way to achieve this task.

Evaluating CCT

13 In your body, there are many enzymes and each is specific to a reaction.
- a **Deduce** the benefit to your body's functioning of having specific enzymes.
- b **Propose** the effect on your body if enzymes were not specific to a reaction.

14 Imagine you did not have a circulatory system and that substances such as oxygen, nutrients, hormones and wastes moved through your body by diffusion instead. **Propose** why it would be impossible for your body t o function.

Creating CCT

15 **Construct** a flow diagram of the heartbeat, starting and ending with contraction of the atria.

16 **Construct** a flow diagram of the changes that take place in your body as you take part in vigorous exercise.

17 **Construct** an outline of the human body, making it fill an A4 page.

a Sketch in the parts of the body involved in making the energy in your food available to your cells.
b Join the parts with arrows showing the direction in which substances or information is moving.
c Label the arrow with the name of what is moving and the effect it is going to have.

Inquiring

1 Research the work done in the body by the liver.
- List the functions of the liver.
- Explain how each function helps your body to work.
- Describe ways in which lifestyle can affect the functioning of the liver.

Present your findings as an information pamphlet of the type available in doctors' waiting rooms or in digital form. ICT

2 Research the life and work of the Australian heart surgeon Victor Chang.
- List his major achievements.

Figure 6.1.14 Victor Chang

- Explain how his work helped improve the survival rate of heart transplant patients.
- Describe Dr Chang's contribution to the Australian medical profession.

Present your research as a feature article for a magazine or as a web page. ICT

3 Find out who Mark Dorrity is and why he suffers from a condition known as rhabdomyolysis.
- Describe what Mark Dorrity was doing that caused him to become ill.
- Describe the changes that took place in his body as a result of his activity.
- Explain what rhabdomyolysis is, how it can be caused and the long-term effects on his body.
- Explain why this story is still relevant many years after the event.

Present your research as a digital presentation for young athletes. ICT

4 Drugs can improve the performance of athletes and many drugs are banned because they provide an unfair advantage. Some of the drugs also have long-term effects on people who take them.

Steroids are one group of banned drugs. Research:
- the sports in which steroids have been proven to be used
- the changes they make in the body that improve athletes' performance
- their long-term effects on the body
- reasons why steroids are banned in sport
- arguments used by people who do not think they should be banned.

Present your findings in a pamphlet to be handed out to aspiring athletes your age.

6.1 Practical investigations

1 Enzyme activity

Amylase is an enzyme that converts starch to glucose.

Purpose

To demonstrate the action of enzymes.

Hypothesis

Which do you think will react faster—a reaction with an enzyme present or the same reaction without an enzyme? Before you go any further with your investigation, write a hypothesis in your workbook.

Materials

- 50 mL starch solution
- amylase
- iodine

- 2 × 50 mL beakers
- stirring rod
- Tes-Tape™
- labels
- 50 mL measuring cylinder
- water bath at about 30°C

SAFETY

Iodine stains. Avoid contact with skin and clothes.

Procedure

1. Label the 50 mL beakers 'Enzyme' and 'No enzyme.'
2. Using Tes-Tape, test the starch solution for the presence of glucose.
3. Add a few drops of iodine to the solution until the starch is showing a distinct blue-black colour.
4. Add 20 mL of the coloured starch solution to the two 50 mL beakers. Your set-up should look like Figure 6.1.15.
5. Add amylase to the beaker labelled 'Enzyme.' (Use an amount equivalent to a match head.)
6. Stir the amylase and starch solution mixture.
7. Place both beakers in the water bath.
8. After about 10 minutes, note any colour change in the beakers.
9. Using the Tes-Tape, test both beakers for glucose.

Results

1. Record any change in appearance of the beakers.
2. Record whether glucose was present in either of the beakers.

Practical review

1. If glucose was present in either of the beakers, **explain** where the glucose came from.
2. **Account** for any colour change that occurred.
3. **Explain** why the beakers were heated to 30°C.
4. **Summarise** the results of this experiment, relating any changes to the action of amylase.
5. a **Construct** a conclusion for your investigation.
   b **Assess** whether your hypothesis was supported or not.

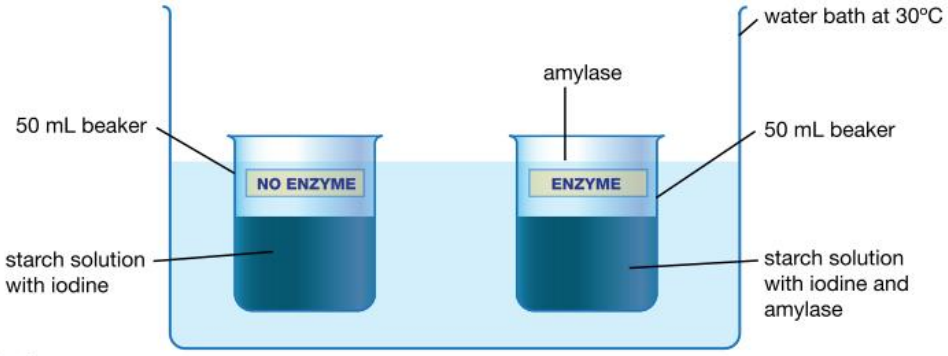


Figure 6.1.15

2 Diffusion

Purpose

To demonstrate the process of diffusion in cells.

Hypothesis

Which do you think will leak colour most quickly—dialysis tubing filled with strongly coloured water or tubing filled with faintly coloured water? Before you go any further with your investigation, write a hypothesis in your workbook.

Materials

- food colouring
- water

- 3 pieces of dialysis tubing 15 cm long
- 3 × 500 mL beakers
- 3 × 50 mL beakers
- stirring rod
- string
- 3 retort stands with clamps
- stop watch

Procedure

1 Add 300 mL of water to each of the 500 mL beakers. Set them up on the bench with a retort stand behind each one (see Figure 6.1.16).

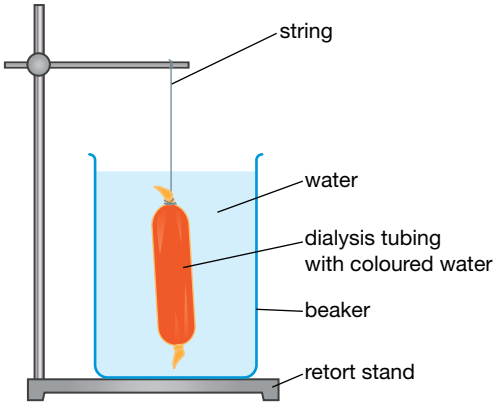


Figure 6.1.16

2 Let the water settle.

3 Add 25 mL of water to each of the 50 mL beakers. Label the beakers 1, 2 and 3.

4 Create solutions of different concentrations using the food colouring. Add 10 drops of food colouring to beaker 1, 20 drops to beaker 2 and 40 drops to beaker 3.

5 Run water from the tap over the three lengths of dialysis tubing.

6 Tie one end of each piece of tubing in a tight knot.

7 Rub the other end of the tubing to open it up.

8 Fill one piece of tubing with the coloured water from beaker 1.

9 Close the end of the tubing by tying it with string.

10 Rinse off the dialysis tube 'sausage' you have created so that there is no coloured water on the outside.

11 Using the other end of the string, tie the 'sausage' to the retort stand and suspend it over one of the large beakers.

12 Repeat steps 8–11, adding the other solutions to the dialysis tubing.

13 Carefully lower the dialysis tubing into the large beakers, taking care to disturb the water as little as possible.

14 Observe any changes.

Results

Record the time it takes for the:

a colour to 'leak' out of the dialysis tubing

b colour to move half way across the water in the beaker

c water in the beaker to become uniformly coloured.

Practical review

1 **Compare** the rate of movement of the coloured solutions in the three beakers.

2 **Explain** any differences in terms of the concentration of the original solutions.

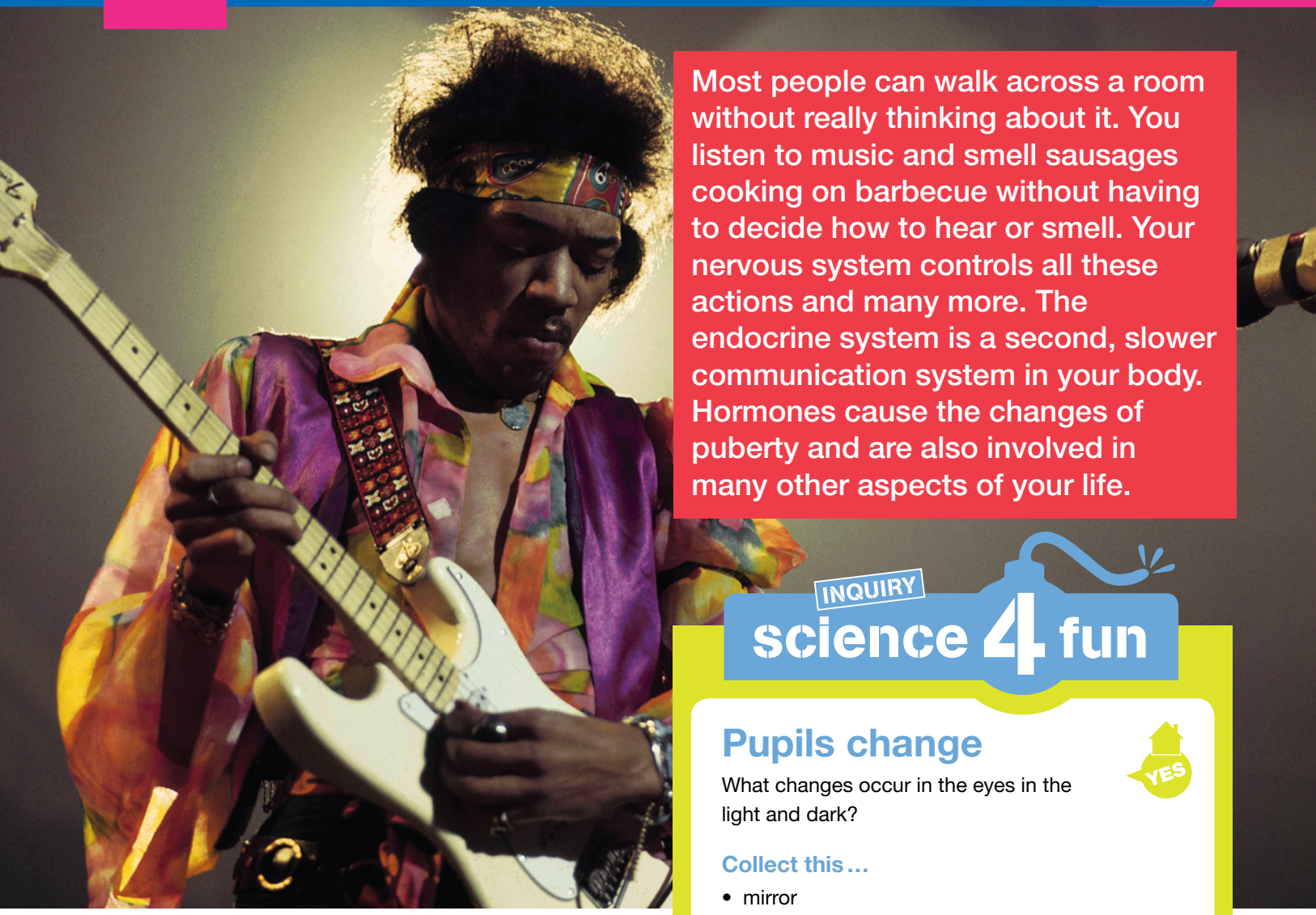
3 **Identify** the part of the model that represents the cell.

4 **Propose** an aspect of diffusion of oxygen in the lungs, or nutrients in the digestive system, that is not demonstrated by this model.

5 a **Construct** a conclusion for your investigation.

b **Assess** whether your hypothesis was supported or not.

6.2 Control systems



Most people can walk across a room without really thinking about it. You listen to music and smell sausages cooking on barbecue without having to decide how to hear or smell. Your nervous system controls all these actions and many more. The endocrine system is a second, slower communication system in your body. Hormones cause the changes of puberty and are also involved in many other aspects of your life.

Nervous system

The nervous system is a communication network that controls all the other systems of your body, such as the digestive and circulatory systems. The human nervous system has two main parts. These are shown in Figure 6.2.1 on page 228.

The two parts of the nervous system are the:

- **central nervous system (CNS)**, made up of your brain and your spinal cord. The CNS receives information from all over the body, processes that information, and then sends out messages telling the body how to respond
- **peripheral nervous system (PNS)**, made up of the nerves that carry messages to and from the CNS and other parts of your body.

GO TO Unit 6.3

INQUIRY

science 4 fun

Pupils change

YES

What changes occur in the eyes in the light and dark?

Collect this …

- mirror
- strip of dark cloth

Do this …

1. Stand in front of the mirror in a room with good light.
2. Look at your eyes—especially notice the size of the pupils.
3. Close your eyes and cover them gently with the dark cloth. Do not press on your eyes.
4. Keep your eyes closed for two minutes.
5. Remove the cloth and open your eyes. Look in the mirror immediately.
6. Observe the pupils of your eyes.

Record this …

Describe what happened.

Explain why you think this happened.

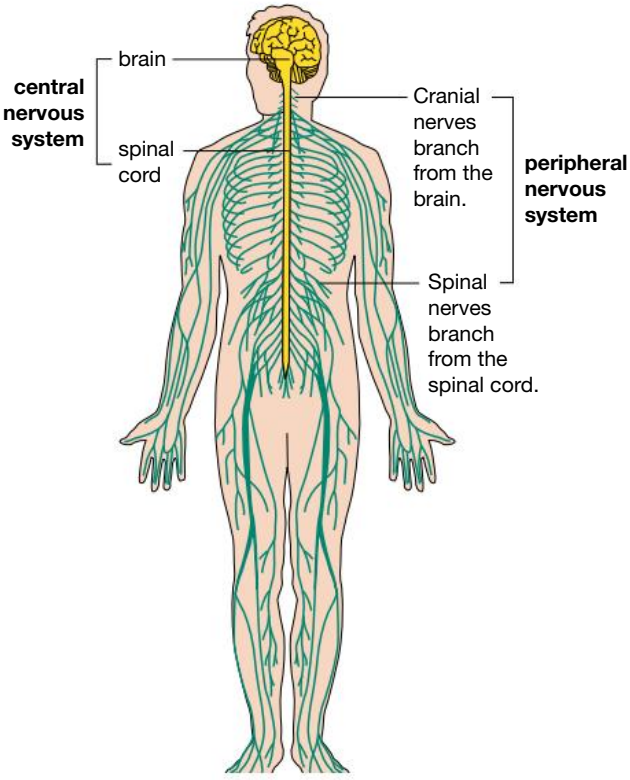


Figure 6.2.1 The relationship between parts of the human nervous system

Nerve cells

The nervous system is made up of trillions of nerve cells or **neurons**. Neurons carry electrical messages, called **nerve impulses**, from one part of your body to another at very high speed. These nerve impulses can travel in only one direction.

As you can see in Figure 6.2.2, a neuron has four main parts: a cell body, dendrites, axon terminals and an axon. The **cell body** contains the nucleus, which is the control centre of the cell. The **dendrites** branch out from the cell body and receive messages from other nerve cells, which are then sent on to the cell body. The **axon** or nerve fibre sends nerve impulses in only one direction—away from the cell body. The axon terminals pass the message on to the next neuron.

Two common types of neurons are:

- **motor neurons**—these carry messages from the CNS to **effectors**. Effectors are muscles or glands (tissues that secrete hormones) that put the messages into effect
- **sensory neurons**—these carry messages from cells in the sense organs (such as your eyes, ears, tongue and skin) to the brain and spinal cord.

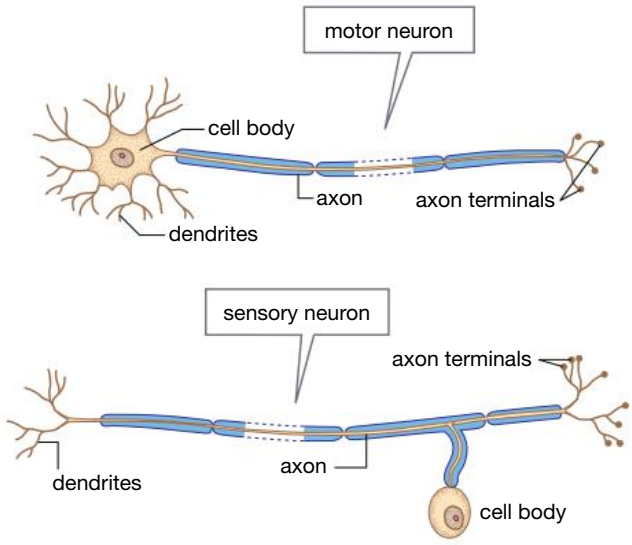


Figure 6.2.2 Two types of neuron

The messages sent along the neuron are electrical. If all the neurons in your body touched one another, stimulating one nerve ending would be like turning on one switch in your house and having all the lights and appliances come on. Your body needs to control which nerves 'fire' at a certain time.

When the nerve impulse reaches the axon terminals at the end of an axon, a chemical called a **neurotransmitter** is released into the space between the neurons. This space is called a **synapse** (Figure 6.2.3). The neurotransmitter carries the message from the axon of one neuron to the dendrite of the next neuron. The dendrite receives the chemical message and sends off an electrical signal.

6.2

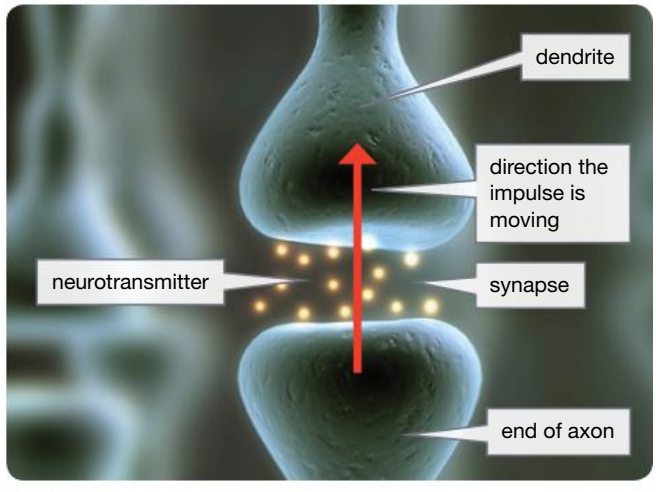


Figure 6.2.3 At the synapse, the electrical signal of the nerve is converted into a chemical signal and then back into an electrical signal again.

About 50 different neurotransmitters have been found that carry electrical impulses across these gaps. These neurotransmitters control which nerves fire and when.

In your body, the neurons are bundled together to form nerves, as shown in Figure 6.2.4. Neurons are covered with an insulating layer called a **myelin sheath**. The myelin sheath electrically insulates the neurons from each other and increases the speed of the nerve impulse.

The parts of the CNS that contain neurons covered in myelin are called white matter. The parts that contain mainly cell bodies are called grey matter. The outer parts of the brain are made up mainly of grey matter.

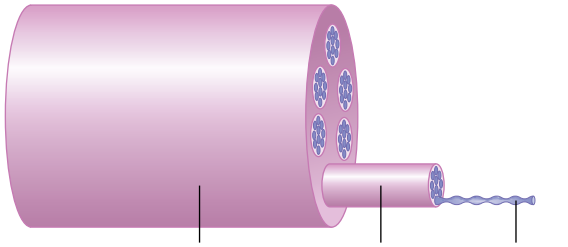


Figure 6.2.4 A nerve is made up of a large number or neurons, each of which is surrounded by a myelin sheath.

What a nerve!

The longest neuron in your body extends from your big toe to the middle part of your spine and is about a metre long. A giraffe's longest nerve is in its neck and is up to 5 metres long!

SciFile

Responding to stimuli

A simple model of your nervous system is a stimulus–response model. You can see it in Figure 6.2.5. Receptors stimulate the sensory nerves. The sensory nerves send a message to the brain. The brain works out the response that is required, then sends a message along motor nerves to the effectors.

Prac 1 p233

Reflex actions: a rapid response

If you touch something hot or sharp, you automatically pull your hand away. Arm muscles, which are normally under voluntary control, react very fast, without waiting for instructions from the brain. This action, called a **reflex action**, protects your body from danger.

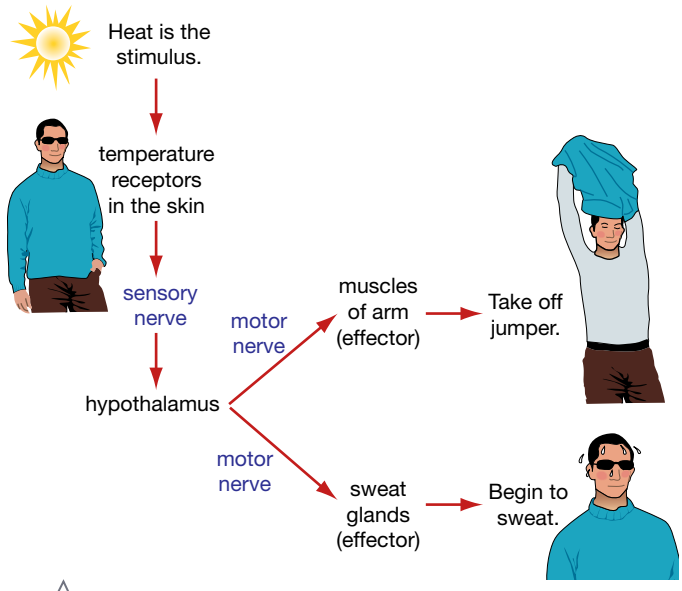


Figure 6.2.5 This stimulus–response diagram represents your body's reaction to being too hot.

Consider what happens when you touch a hot object. Receptors detect the temperature of your skin. This activates a sensory neuron, which sends nerve impulses to the spinal cord. Within the spinal cord, a relay neuron passes the message directly to a motor neuron, which sends impulses to the arm muscles, which are the effectors. The arm muscles contract, lifting your hand away from the hot object. A message is sent to the brain shortly afterwards. Only then can the brain register pain.

The nerve pathway operating in a reflex action is called a **reflex arc**. Figure 6.2.6 shows an example of a reflex arc. Most reflex actions involve only a few neurons and are therefore very rapid.

6.3

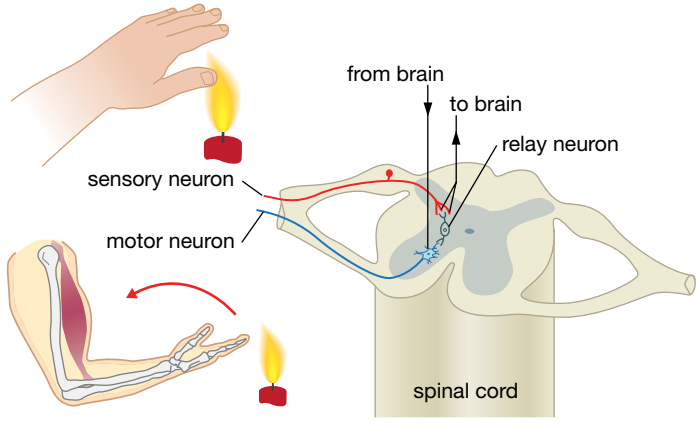


Figure 6.2.6 The reflex arc allows you to react very rapidly to protect your body from harm.

Endocrine system

The **endocrine system** is a communication system that controls the internal environment of the body. The amount of water and glucose in your blood and your body temperature are controlled by the endocrine system, as are the changes the body goes through during puberty and pregnancy.

Hormones are chemical substances that act as messengers in the body. They are produced in **endocrine glands**, which release their hormones directly into the bloodstream. As Figure 6.2.7 shows, the endocrine glands are scattered throughout the body. Together, all these glands form the endocrine system.

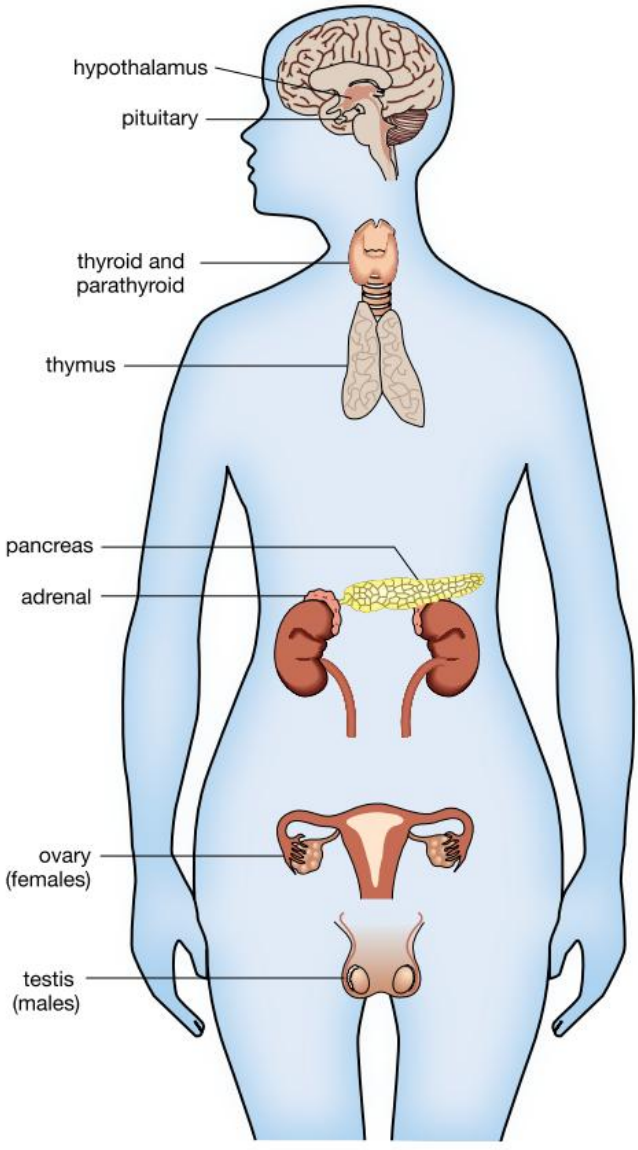


Figure 6.2.7 The main human endocrine glands

The endocrine system is coordinated by the **pituitary gland**, which responds to information from the hypothalamus. The **hypothalamus** is a portion of the brain. You can see its location in the brain in Figure 6.2.8. It constantly checks the internal environment—that is, the conditions within the tissues, organs and systems of your body. If these conditions change, the hypothalamus responds.

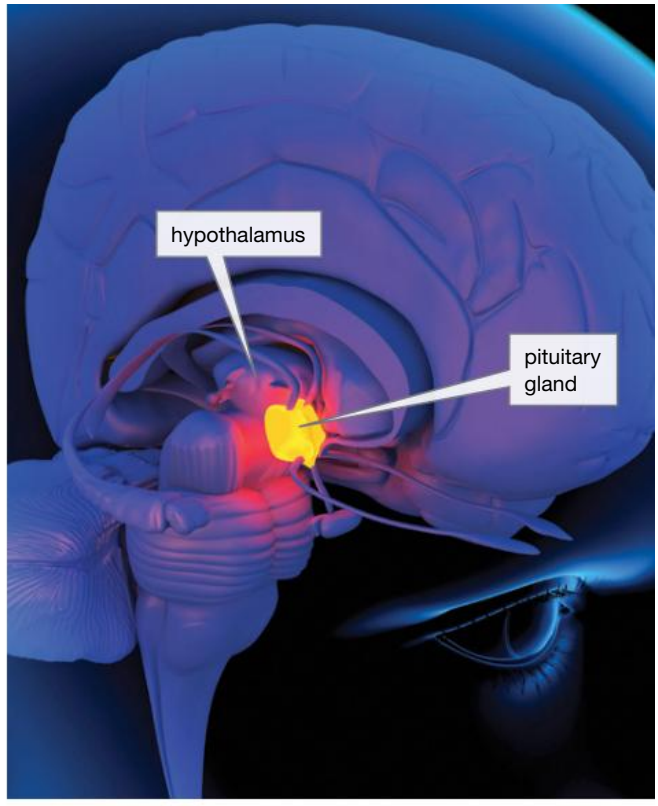


Figure 6.2.8 Two parts of the endocrine system: the hypothalamus, and the pituitary gland that attaches to it. These are located deep within the skull, where they are well protected.

The most important function of the hypothalamus is to link the nervous system and the endocrine system. It secretes hormones that act on the pituitary gland. The pituitary gland responds by either secreting other hormones or producing less of the hormones. Through its action on the pituitary gland, the hypothalamus controls important aspects of the body such as body temperature, rate of metabolism and water content.

The pituitary gland is often called the 'master gland' because it controls the activities of other endocrine glands such as the ovaries, the testes and the thyroid gland. It is about 1 cm in diameter.

How hormones work

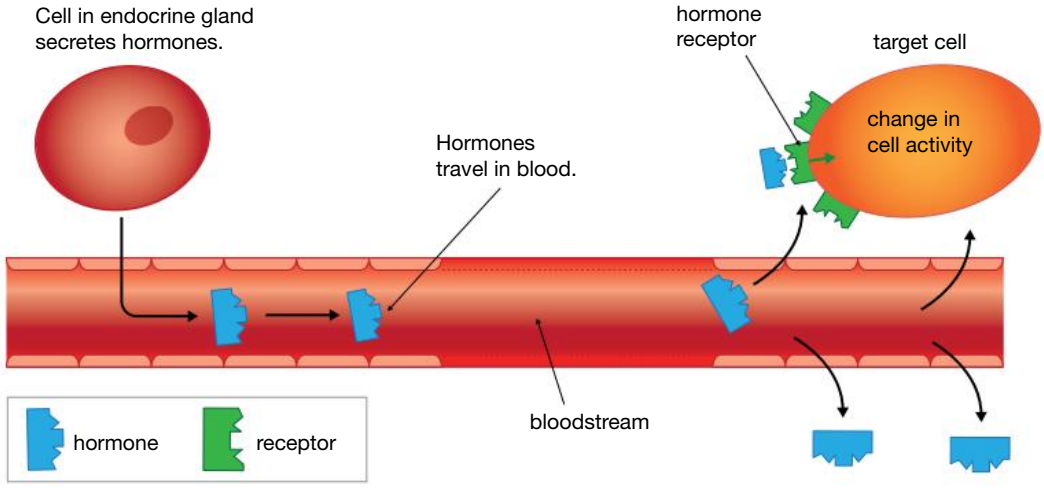
Hormones are produced in very small amounts and travel through the blood, reaching all your body cells. However, they do not affect all the cells. Hormones are specific. This means that they only act on particular cells in the body. These are the **target cells**.

Different hormones have different chemical structures. This means that their shape varies. It is the shape of the hormone that makes it specific. Within cells are receptors. A hormone is only active in cells that have receptors that fit the shape of the hormone (Figure 6.2.9).

Figure 6.2.9

Hormones are only active in cells where the shape of the hormone and the shape of the receptors fit together like pieces of a jigsaw.

GO TO Unit 6.4



Controlling the internal environment

Your body works most efficiently when the internal environment is reasonably constant. This means that factors such as temperature, water content, available energy, available oxygen and concentration of wastes in the blood are all controlled. The process of maintaining a relatively constant internal environment is known as **homeostasis**.

Homeostasis involves receptors that are sensitive to a particular stimulus, and effectors that have an effect on the same stimulus. This type of control is known as a feedback system.

To understand this, consider a reverse-cycle air conditioner like the one shown in Figure 6.2.10 as an example of a machine that maintains a constant environment. A sensor called a thermostat is set at a particular temperature range, such as 21–23°C. If the temperature of the room goes above 23°C, the air conditioner switches on and cools the room until the required temperature is reached. The sensor detects this and then the air conditioner switches off until it once more detects a rise in temperature. If the sensor detects a lower temperature than 21°C, the heating system turns on. The temperature in the room rises and the heater turns off once the set temperature range of 21–23°C is reached.

The means of controlling the temperature used by a reverse-cycle air conditioner is a feedback system. The output from the system (warm or cool air) becomes the input into the sensor of the air conditioner. In other words, the output feeds back into the system and then controls the operation of the system.

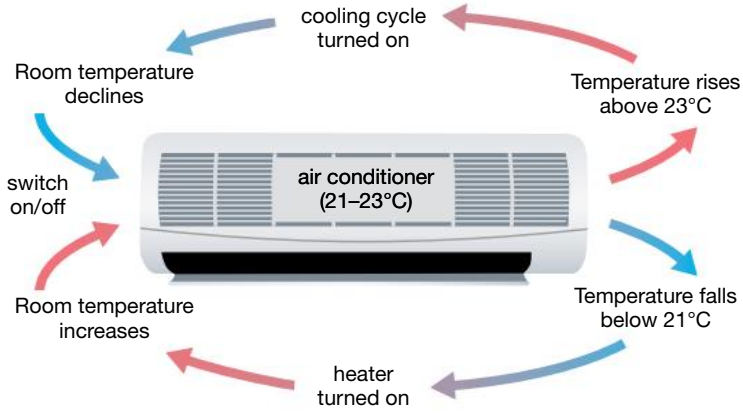


Figure 6.2.10

A reverse-cycle air conditioner maintains a preset temperature in a room by heating or cooling the air in response to temperature detectors.

Prac 2 p234 Prac 3 p234

6.2 Unit review

Remembering

1 **Name** the three main parts of a neuron.

2 **List** the parts of the central nervous system.

3 **Name** the layer of insulation found on nerves.

4 **Recall** the terms used to describe the cells that respond to hormones.

5 **List** three endocrine glands.

6 **Name** the process of maintaining a relatively constant internal environment in the human body.

Understanding

7 a **Describe** the function of dendrites.
b **Explain** how their structure suits their function.

8 **Describe** the function of neurotransmitters.

9 **Describe** the relationship between hormones and the endocrine system.

10 a **Describe** the function of the hypothalamus.
b **Explain** why the hypothalamus can be thought of as part of both the nervous system and the endocrine system.

Applying

11 **Use** the diagram of the reflex arc in Figure 6.2.6 on page 229 to **outline** how your foot is pulled away from a sharp object.

12 **Identify** the endocrine glands labelled A, B and C in Figure 6.2.11.

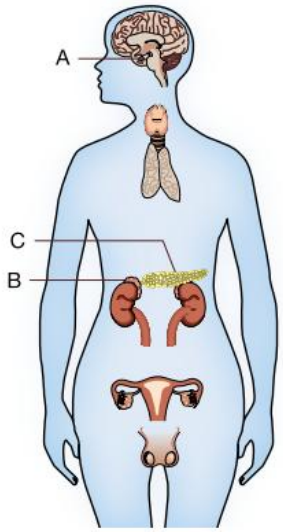


Figure 6.2.11

Analysing

13 **Compare** the roles of a sensory neuron and a motor neuron.

14 **Contrast** a stimulus and a response.

15 **Compare** the roles of receptors and effectors.

Evaluating CCT

16 Think about the time it takes for your eyes to react to the change from dark to light.
a **Deduce** whether this reaction is caused by the nervous system or the endocrine system.
b **Justify** your response.

Creating CCT

17 **Construct** a model or create a digital animation to demonstrate the action of hormones. Begin with the hormones being produced in the gland and end with the target cells responding.

Inquiring

Spina bifida, multiple sclerosis (MS) and Alzheimer and Parkinson diseases all affect the nervous system. Diseases such as diabetes affect the endocrine system. All have support groups that increase public awareness about the conditions and to raise funds for scientific research into them.

Research one such support group or campaign that deals with a condition of the nervous or endocrine system or in some way affects body coordination.

- Find how the support group or campaign raises money or awareness.
- Discuss how such support groups or campaigns influence the way contemporary society thinks about the condition.
- Discuss whether the general public would know about the condition if such support groups or campaigns did not exist.
- Discuss how such support groups or campaigns influence the focus of scientific research.

Present your findings in written form or as a Word document. ICT

6.2 Practical investigations

1 Sensitivity

When you feel two points from two toothpicks placed 2 mm apart, two nerves have been stimulated. This means that the receptors are no more than 2 mm apart. Feeling only one point indicates fewer receptors, spaced more widely.

Purpose

To investigate whether touch receptors are evenly distributed in the skin.

Hypothesis

Which parts of your skin do you think will be most sensitive—your palm or fingertips, the back of your hand, your upper arm or the back of your neck? Before you go any further with this investigation, write a hypothesis in your workbook.

Materials

- 3 toothpicks per student
- sticky tape

Procedure

1. Tape 2 toothpicks together as shown in Figure 6.2.12.
2. Work in pairs to test different surfaces of the body. One student is the tester. The other is the subject.

SAFETY

The toothpicks should just touch the surface of the skin. They should not be pressed hard enough to cause pain. Each student must only use their own set and discard after use.

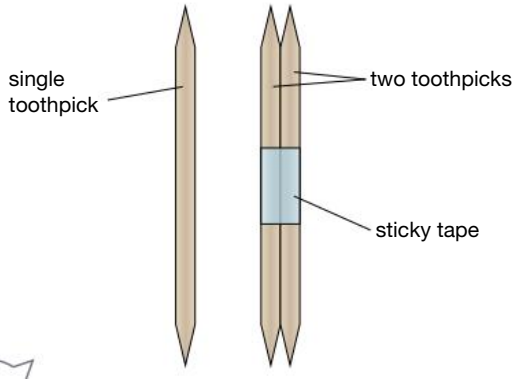


Figure 6.2.12

3. Holding the toothpicks upright, the tester gently touches the skin of the subject. Test sometimes with one toothpick and sometimes with two.
4. Test various parts of the body, such as the:
   - back of the hand
   - palm of the hand
   - fingertips
   - upper arm
   - back of the neck.
5. When the toothpicks touch the skin, the subject should indicate whether they can feel two points or one.
6. Test each part of the body five times, sometimes with one toothpick and sometimes with two toothpicks.
7. The tester records the results, noting carefully whether one or two toothpicks were used in the test.
8. The tester and the subject change places and repeat the experiment.

Results

Construct a table to record your results.

Practical review

1. **Compare** the sensitivity of the various parts of your body. (Remember: It is only the points with two toothpicks that will indicate levels of sensitivity.)
2. **Analyse** the relationship between the level of sensitivity and the function of the body part.
3. **Draw** conclusions about the distribution of touch receptors in your skin.
4. a **Construct** a conclusion for your investigation.
   b **Assess** whether your hypothesis was supported or not.

Extension

Temperature receptors in the skin can detect heat gain (warmth) and heat loss (cold). Design an experiment to investigate the distribution of temperature receptors in the skin. Before you begin, determine exactly what you want to test (warm, cold or both) and how you will do this. Record your results and compare these with the distribution of touch receptors.

2 Model feedback system

Purpose

To demonstrate a feedback system, using people.

Materials

- blindfold
- chairs and desks to create an obstacle course, or an area of the school that includes some obstacles

SAFETY

Do not put the subject into any dangerous situations.

Procedure

1. Work in pairs. One person is the controller and the other is the subject.
2. The subject is blindfolded and follows the course in response to commands provided by the controller.
3. The controller directs the subject as quickly and accurately as possible around the course, using only the commands 'left' or 'right'.
4. On completing the course, the controller and the subject change position. In this second trial the controller may also use the words 'forward', 'back' and 'stop'. This represents a more sophisticated form of feedback.

Practical review

1. **Propose** what is being controlled in this system.
2. a **Compare** a natural feedback system with this model.
   b **Identify** the part represented by the controller.
   c **Identify** the part represented by the subject.
3. **Compare** the success of the feedback system in the first trial with that in the second trial, when more information was provided to the subject.
4. **Compare** the model with how you think a natural feedback system would work. An example for you to think about is temperature control in your body or control of the amount of water in your blood through drinking and urination.

STUDENT DESIGN

3 Model neuron

Purpose

To construct a model of a neuron.

Materials

- as selected by students (could include string, balloons and drinking straws)

SAFETY

A risk assessment is required for this investigation.

Procedure

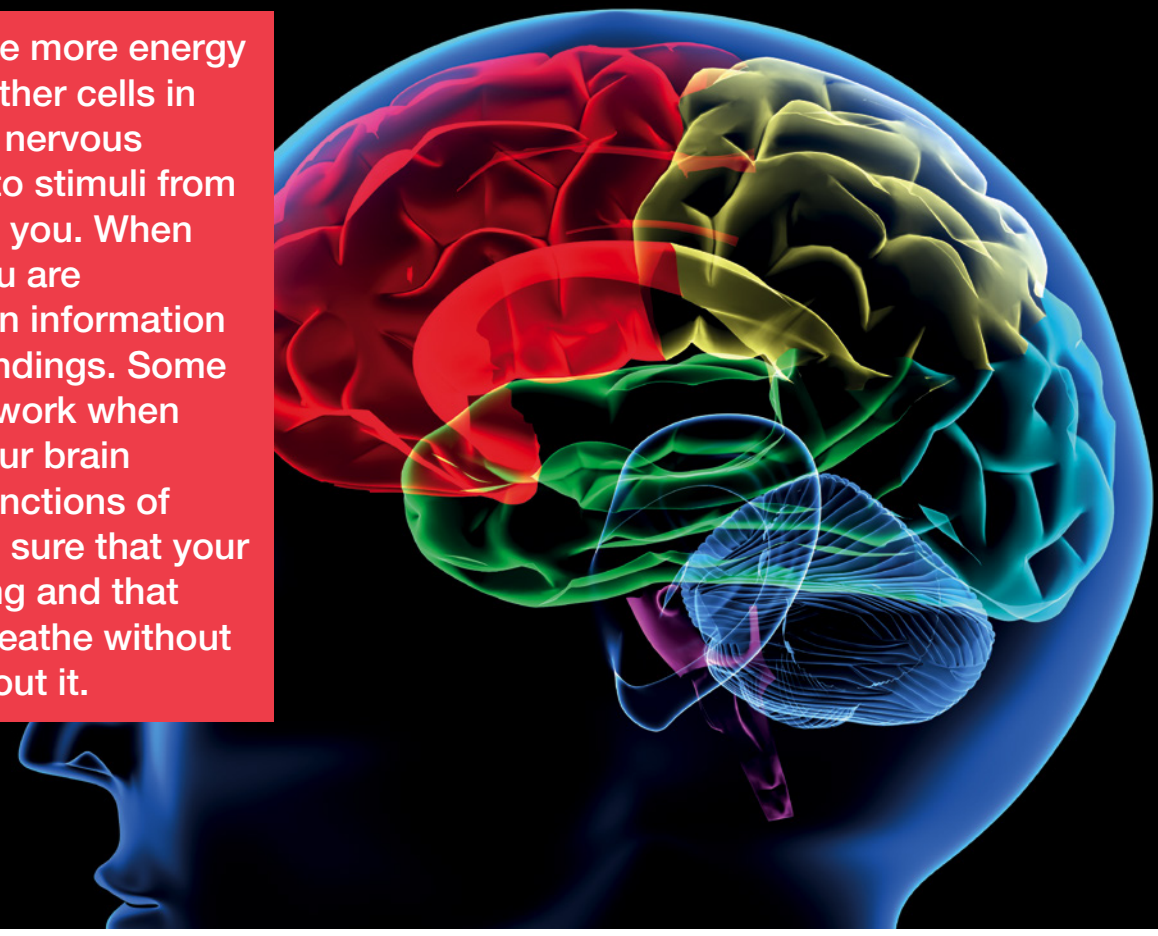
1. Brainstorm in your group different materials that could be used to represent different parts of the neuron. Select the best materials and use them to construct your model.
2. Design and construct a model of a neuron.
3. Attach labels indicating the neuron's important parts and the functions of those parts.

Practical review

1. **Identify** the type of neuron you have constructed (motor or sensory neuron).
2. **Evaluate** your model. Pick two other models and **evaluate** them as well. **Identify** the strengths and weakness of the models and how well they represent the neuron.

6.3 Nervous control

Your brain cells use more energy than most of the other cells in your body as your nervous system responds to stimuli from outside and inside you. When you are awake, you are constantly taking in information about your surroundings. Some senses are still at work when you are asleep. Your brain manages all the functions of your body, making sure that your heart keeps beating and that you continue to breathe without having to think about it.



INQUIRY science 4 fun

I'm scared

YES

What changes happen in your body when you are surprised or frightened?

Do this ...

Ask a family member or friend to give you a surprise or fright.

Record this ...

Describe the changes in your body.

Explain why these changes occurred.

The brain: communication centre

Humans have a very large brain for their body size, compared with other animals. The human brain contains about 100 billion neurons, and has an average volume of 1200–1400 mL.

The brain controls and regulates body functions. Without it, you cannot survive. Amazing new medical imaging techniques can now look inside a living brain. For example, MRI (magnetic resonance imaging) uses strong magnetic fields to distinguish different types of body tissue. This is useful in diagnosing brain tumours and finding areas of brain injury. Damage to the brain is repaired slowly. Sometimes other parts of the brain take over the function of the damaged parts, but there are situations where brain damage is permanent.

The cerebrum

When you think of what a human brain looks like, you are probably thinking of the **cerebrum**. You can see it in Figure 6.3.1. It occupies more than 80% of the brain and contains over 10 billion neurons. Its many folds increase its surface area by three times. It is here that the higher intellectual functions of humans take place. The cerebrum controls your conscious thoughts and the intentional (voluntary) movement of every body part. It also receives sensory messages from all body parts.

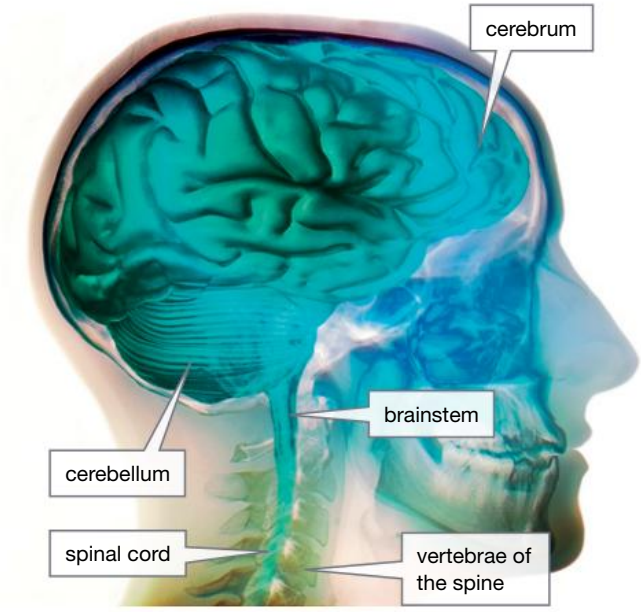


Figure 6.3.1 Computer-enhanced X-ray showing the external structure of a human brain

The cerebrum is made up of two parts, called the right and left cerebral hemispheres. When it comes to intended actions such as walking or hitting a ball, the right hemisphere controls the left side of your body and the left hemisphere controls the right side of your body (Figure 6.3.2). Each half of the brain can work independently, but you use both cerebral hemispheres for most activities. One side usually dominates in a particular task. For example, in most people the left side has more control over language and logical thinking, such as mathematical ability. The right side is the more creative and emotional side. Musical and artistic abilities depend on the right side of the brain.

Figure 6.3.3 uses images of the brain created using both MRI and PET (positron emission topography). Together these scans reveal the parts of the brain that are active during various activities. They show that the left-hand side of the brain is active during activities that involve language. They also show that different parts are active

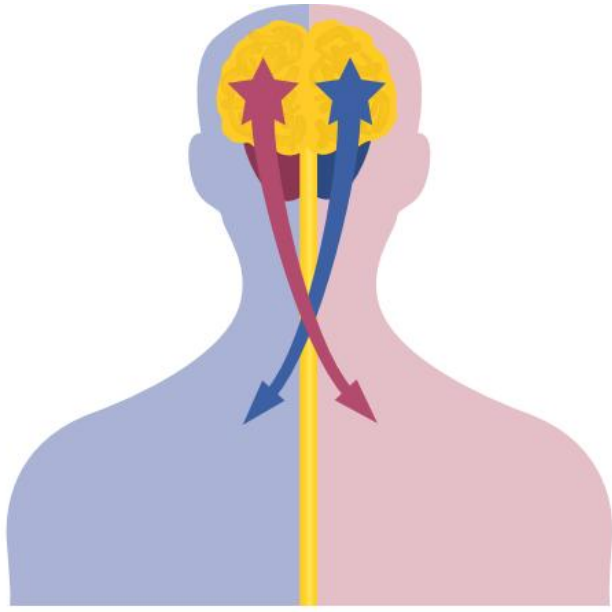


Figure 6.3.2 The right and left sides of the brain control the opposite sides of the body.

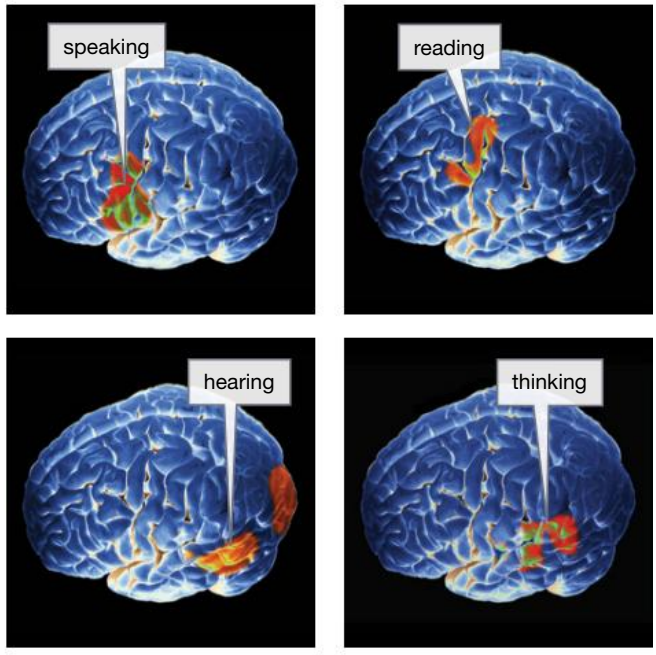


Figure 6.3.3 The red and green areas in these images show the areas of your brain that are active during various activities.

when listening, speaking, reading or just thinking about words.

At the base of the cerebrum, where you can feel your skull curve inwards, is the **cerebellum**. Its position is shown in Figure 6.3.4. The cerebellum is responsible for coordination and balance. Without it, walking would be impossible.

The lower part of the **brain stem** or **medulla** can be seen where the spinal cord widens just after it passes into the skull. It controls the body's vital functions, such as breathing, blood pressure and heart rate. Damage to this area can be fatal.

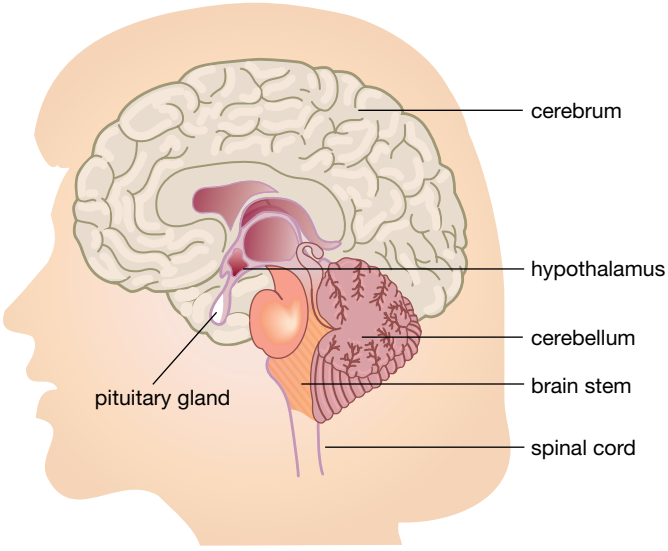


Figure 6.3.4 Vertical section through the brain

Prac 1 p244 Prac 2 p245

Peripheral nervous system

The PNS has two separate parts: the somatic nervous system and the autonomic nervous system.

Somatic nervous system

All animals, including humans, need information about their surroundings. The **somatic nervous system** collects this information through receptors in sensory organs such as the eyes and ears. The somatic nervous system also coordinates movement of the body.

The somatic nervous system's sensory organs detect changes in the environment. The changes stimulate the nerve endings to send messages to your brain. Something that you can detect using your sense organs is a **stimulus**. Stimuli in your environment include temperature, light, touch, smell and sound.

In your body, there are different types of receptors. Mechanoreceptors are sensitive to stimuli such as touch. They also make you aware of muscles being stretched, for example when your bladder becomes full. Photoreceptors in the eye are sensitive to light. Thermoreceptors respond to changes in temperature. Chemoreceptors are sensitive to chemicals, such as those found in food. Chemoreceptors tell you if food is sweet or bitter.

The sensitive skin

The skin responds to many different sensations, such as touch, pain and temperature. One of the ways that your body protects itself from the outside world is by being very sensitive to touch. Receptors in your skin alert you to a hot surface or a biting mosquito. You can see these receptors in Figure 6.3.5.

6.4

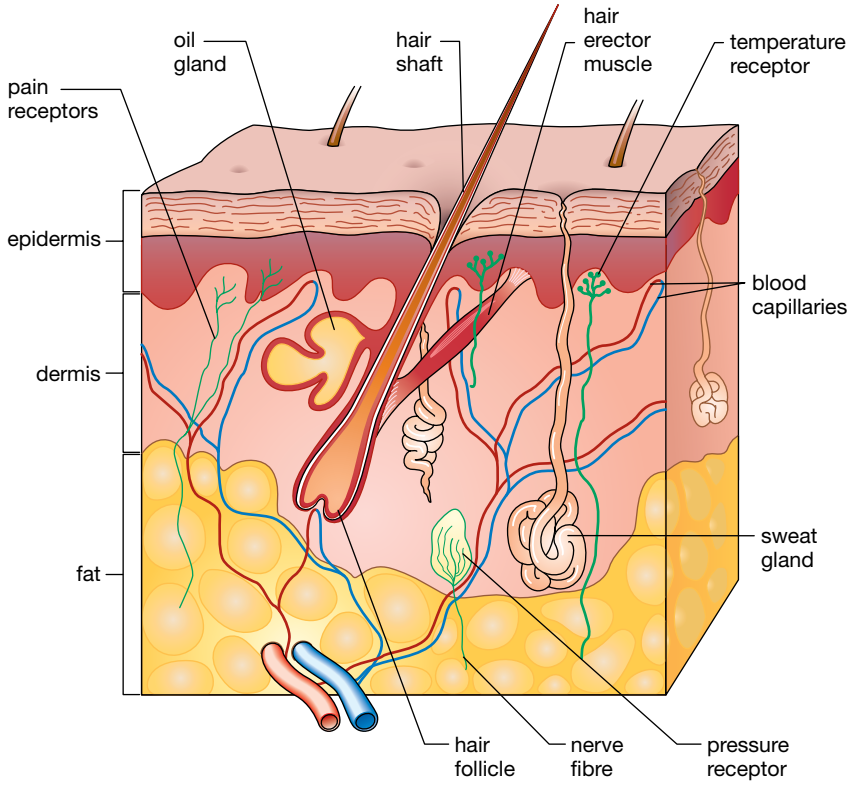


Figure 6.3.5 The skin has many receptors and provides you with a lot of information about your surroundings.

The sense of hearing

Sometimes receptors are grouped together to form a sense organ. An example is the receptors in the ear. The ear not only senses sound, but also helps you to keep your balance.

In your inner ear are fluid-filled semicircular canals. These are shown in Figure 6.3.6. If you suddenly lean in one direction, the fluid in one of the canals moves against tiny sensory hairs in the canal lining. A nerve impulse is sent to the brain, and the brain then sends messages to the muscles to help you balance.

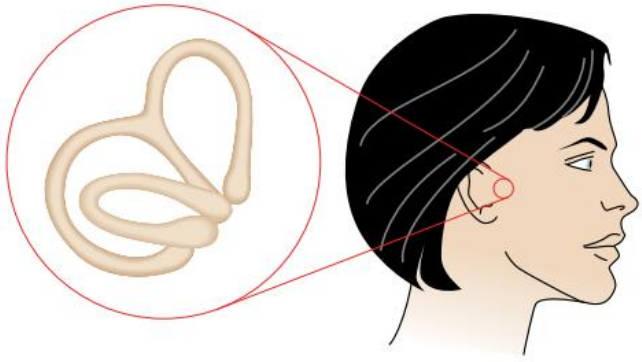


Figure 6.3.6 Nerves in the semicircular canals of the inner ear respond to gravity and help you maintain your balance.

The sense of sight

Only about one-sixth of the eye is visible. Most of it is protected within the skull. The pupil is an opening that allows light to pass through the lens and into your eye (Figure 6.3.7). The lens bends (refracts) light to help focus the light rays onto the photoreceptors in the retina at the back of the eye. Messages are sent from the photoreceptors via the **optic nerve** to the brain for interpretation. This is what is called vision.

In the retina, there are two types of photoreceptors: rods and cones. Rods work in dim light and are responsible for night vision. Cones work in bright light and are responsible for colour vision. People with colour blindness have difficulty distinguishing between certain colours because they have fewer cones than normal.

The sense of smell and taste

The chemoreceptors for taste and smell work together. Food never tastes as good when you cannot smell it. The receptor cells for taste are taste buds. You have about 10 000 taste buds scattered on the surface of your tongue. You can see some in Figure 6.3

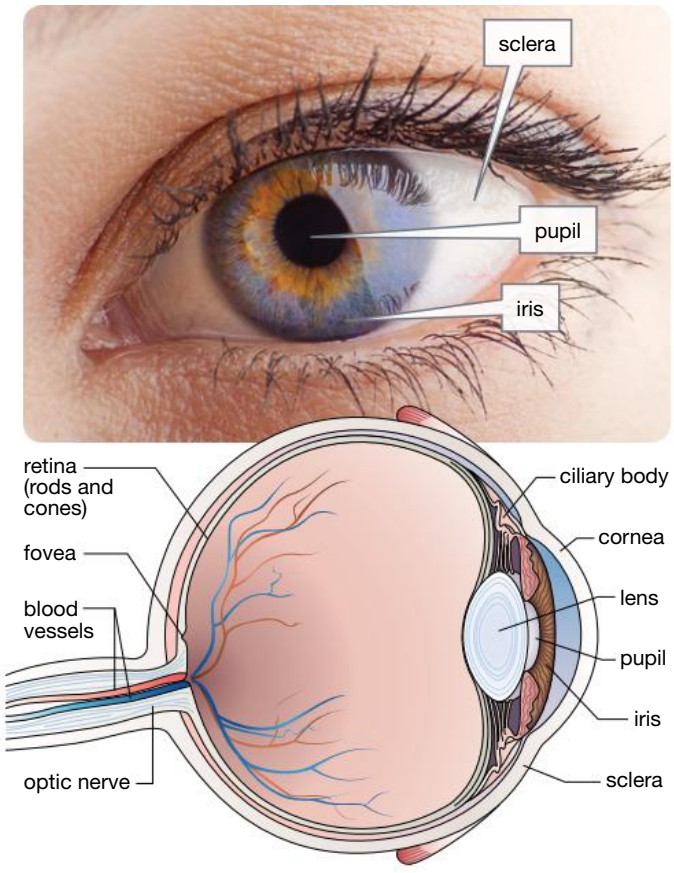


Figure 6.3.7 The structure of the human eye

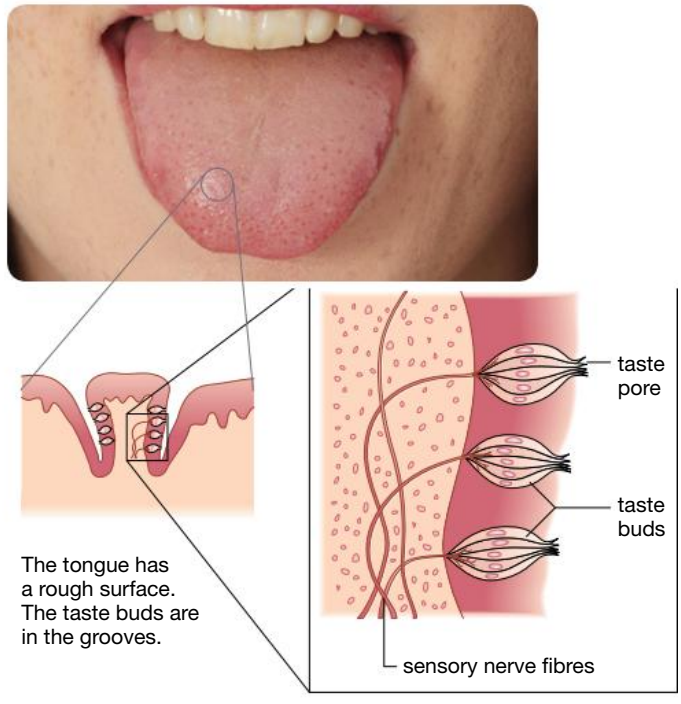


Figure 6.3.8 Taste buds are arranged in groups to form a taste pore, through which taste receptors extend. Chemicals bind to the taste receptors and stimulate sensory nerves. Messages sent to the brain give the sensation of taste.

You spoke?

Have you ever heard girls complain that boys do not listen to them? There is a scientific basis for this. Researchers in the United Kingdom have found that male and female voices stimulate different parts of the brain and that deciphering a female voice is a more complex process.

SciFile

Tastes good

Humans can distinguish sweet, sour, salty and bitter tastes. In 2002, umami (savoury) was added as a fifth sense. In 2010, researchers from Deakin University, Victoria, discovered that humans can detect a sixth taste—fattiness.

SciFile

Autonomic nervous system

Some of the activities of your body happen without you realising it, such as the beating of your heart, the movement of food in your intestines, sweating and changing pupil size. These activities are controlled by the **autonomic nervous system**.

Two parts of the autonomic nervous system are the sympathetic nervous system and the parasympathetic nervous system.

The sympathetic and parasympathetic nervous systems can be thought of as opposites that complement each other. The **sympathetic nervous system** speeds up the functions of the body and makes it work more efficiently. It is the system that prepares your body for emergencies by making you more alert and ready to act (Figure 6.3.9). The **parasympathetic nervous system** slows everything down. It is the system in control when you are resting.

Figure 6.3.9 It is the actions of the sympathetic nervous system that cause the sensations associated with fear or stress.

To prepare your body for intense activity, the sympathetic nervous system diverts blood away from areas that will not be used in the action, such as the digestive system. It diverts the blood to areas that will be used, such as the muscles. The sympathetic nervous system:

- diverts blood flow away from the digestive tract and the skin
- stops peristalsis—the muscular action that mixes food in the intestines
- maintains blood flow to the lungs and the muscles of the skeleton—blood flow to the muscles may be increased by up to 120%
- opens the bronchioles (airways to the lungs)—this increases the amount of air able to enter the lungs, increasing the supply of oxygen to the body
- increases heart rate, thereby increasing blood flow to the muscles of the skeleton
- relaxes the muscles in the eye and dilates the pupils, allowing more light to enter the eye and improving distance vision
- increases blood flow to the heart.

The functioning of the parasympathetic nervous system:

- increases blood flow to the digestive tract
- stimulates the salivary glands and increases the rate of peristalsis, in support of digestion
- reduces the diameter of the bronchioles when there is a reduced need for oxygen
- controls the heartbeat
- contracts the muscles of the eye and reduces the diameter of the pupil to allow close vision.

Figure 6.3.10 shows how the parts of the human nervous system relate to one another.

6.5 6.6

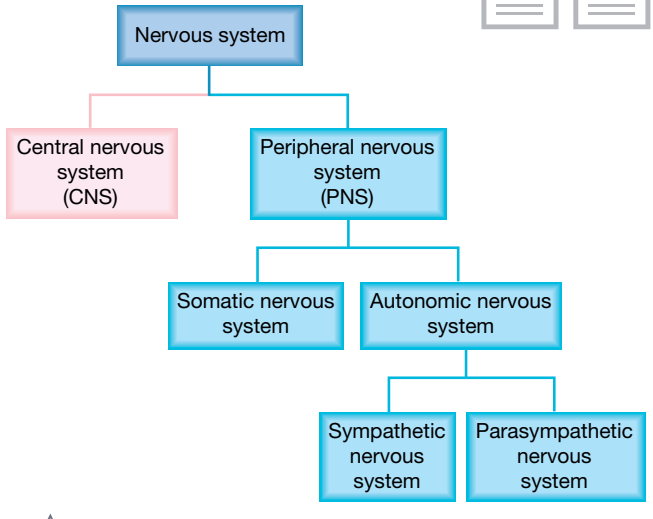


Figure 6.3.10 The relationship between different parts of the human nervous system

LEARNING ACROSS THE CURRICULUM

WORK AND ENTERPRISE

THE BIONIC EAR AND EYE

The cochlear implant or 'bionic ear' was developed by an Australian scientist, Professor Graeme Clark.

Figure 6.3.11 A cochlear implant

THE BIONIC EAR

Professor Clark (Figure 6.3.12) was born in country New South Wales in 1935. His father was partially deaf, and this sparked Professor Clark's interest in the causes of deafness. He became a surgeon, specialising in otolaryngology, which is the study of diseases of the ear and throat. There was very little money available for his research, as most people believed it was impossible to restore hearing to the deaf.

Figure 6.3.12 Professor Graeme Clark (right) developed the cochlear implant, which allows some deaf people to hear again.

The cochlear implant mimics the way that the cochlea receives sounds. A microphone and a speech processor are placed behind the ear. They pick up sounds and turn them into electrical signals. These signals pass into the implant, which is placed in the skull and connected to the cochlea. The cochlea then stimulates the auditory nerve to send messages to the brain.

In 1978, Clark successfully implanted the first bionic ear into a man named Rod Saunders, who had lost his hearing in a car accident. Clark's success has been recognised worldwide.

The Australian bionic ear (shown in place in Figure 6.3.13) has now provided hearing to more than 150 000 people in more than 120 countries.

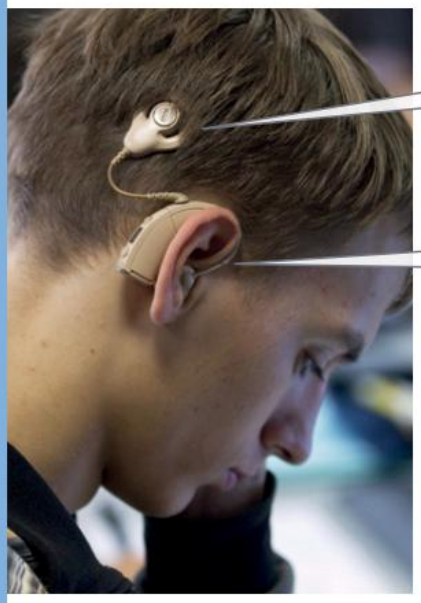


Figure 6.3.13 The bionic ear is worn behind the ear.

THE BIONIC EYE

The bionic eye is being developed by Bionic Vision Australia researchers at the University of New South Wales.

About 1.5 million people worldwide have a disease called retinitis pigmentosa, and about one in 10 people over the age of 55 have age-related macular degeneration. Both diseases cause cells in the retina of the eye to gradually die and the person becomes vision impaired or blind.

The bionic eye is still in the experimental stage, but it is hoped that it will be able to help people with these conditions. The bionic eye is a device that consists of a camera attached to a pair of glasses. How the device works is described in Figure 6.3.14.

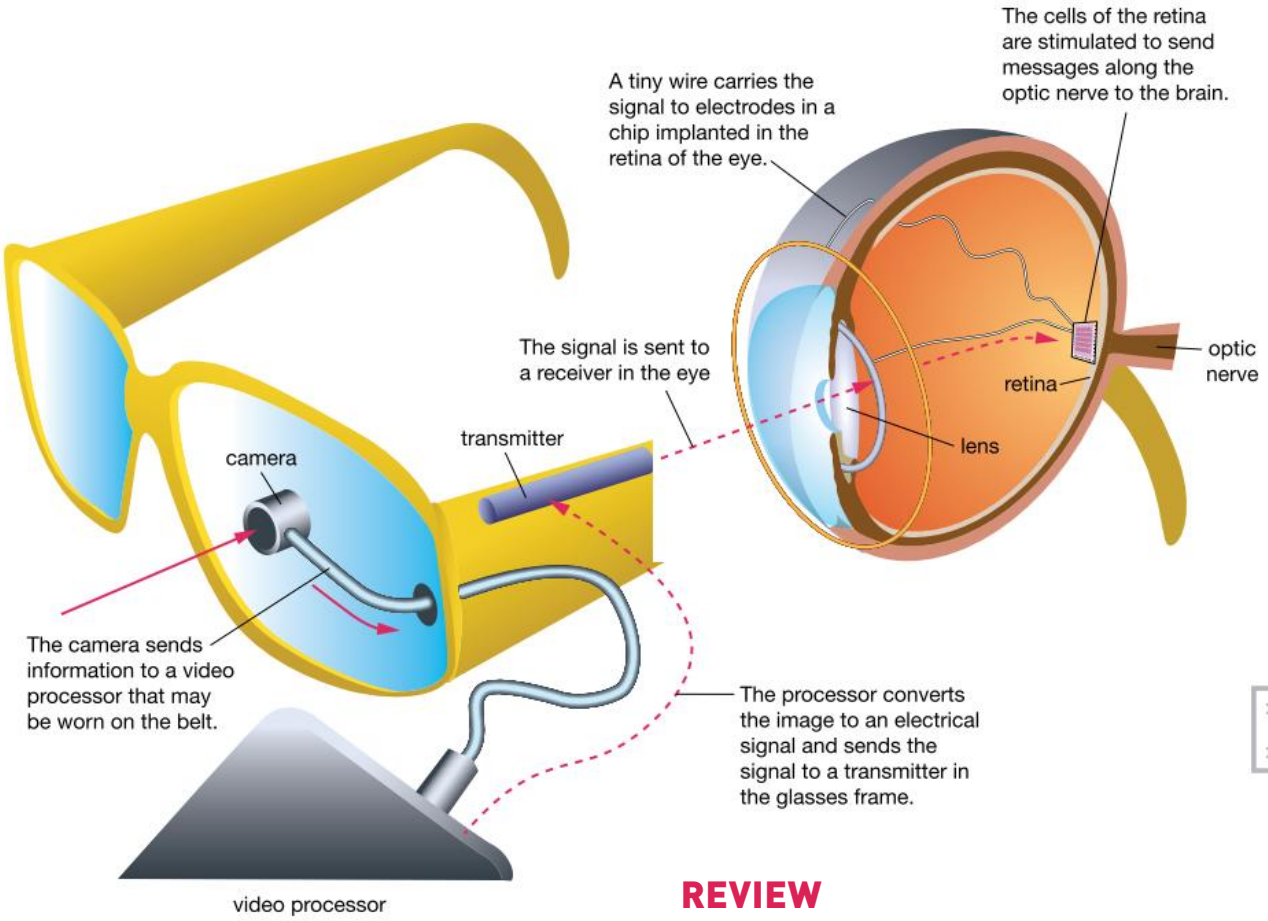


Figure 6.3.14 How a bionic eye works

One version of the bionic eye is designed to enable a person to distinguish light from dark. This will help the person move around large objects such as buildings, parked cars and benches or rubbish bins on footpaths.

A second version of the bionic eye will have many more electrodes. With it, the person may be able to recognise faces and read large print (Figure 6.3.15).

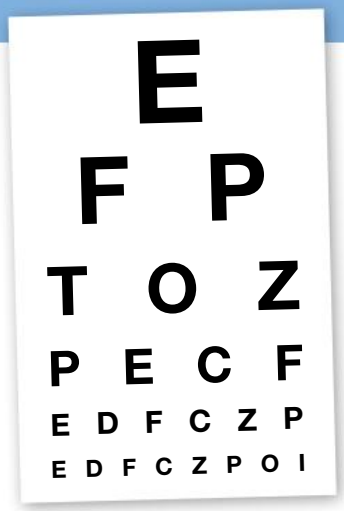


Figure 6.3.15 It is hoped that people fitted with the second version of the bionic eye will be able to read the letters on the third line of a Snellen chart, such as the one shown here.

6.7

REVIEW

1 **Identify** the events that led to Professor Clark's interest in the causes of deafness.

2 **State** the branch of medicine concerned with diseases of the ear and throat.

3 **Describe** what a cochlear implant does.

4 **Construct** a flow diagram that shows the steps from a sound being made to a person with a cochlear implant hearing it.

5 **Compare** the bionic ear and the bionic eye by listing their similarities and differences.

6 **Propose** advantages for a patient of having a bionic eye. Include those mentioned in the text.

6.3 Unit review

Remembering

1 **List** three types of receptors found in the skin.

2 **Name** two parts of the autonomic nervous system.

3 **Name** the types of activities that the right side of the brain has more control over.

4 **Recall** the functions of the cerebrum.

5 **Name** the part of the nervous system that causes the changes that occur in your body when you are frightened.

Understanding

6 **Outline** the difference between a receptor and a stimulus.

7 **Explain** why an injury to the left side of the brain often affects the right side of the body.

8 **Describe** an example of how your brain controls an activity inside your body without your knowing about it.

9 **Describe** the function of the somatic nervous system.

Applying

10 **Use** information from the science4fun activity on page 235 to **identify** changes that occur in your body when you are scared.

11 **Identify** the parts of the eye labelled A, B and C in Figure 6.3.16.

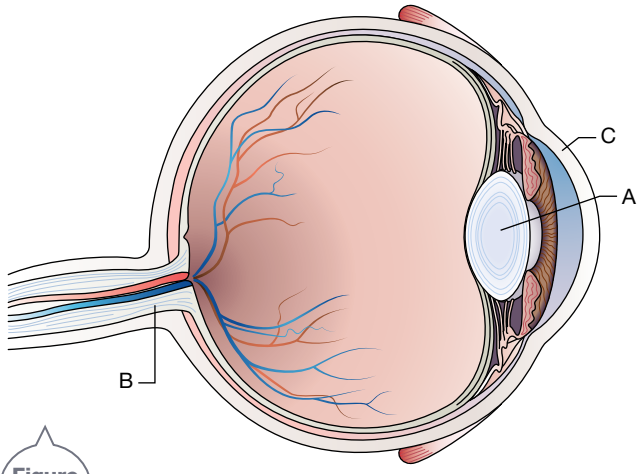


Figure 6.3.16

12 a **Identify** the arrow in Figure 6.3.17 (A or B) that represents an impulse passing along the sensory nerve.

b **Use** your knowledge of stimulus and response to **identify** the effector in this example.

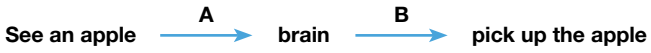


Figure 6.3.17

Analysing

13 **Contrast** the sympathetic and parasympathetic nervous systems.

14 **Compare** rods and cones.

15 **Contrast** the eyes of people who have normal vision with those of people who are colour blind.

16 **Discuss** the possible changes in the functioning of your body if you only had the sympathetic nervous system without the parasympathetic nervous system.

Evaluating CCT

17 **Propose** why severe damage to the neck region is often fatal.

18 **Propose** why many quadriplegic patients who are paralysed from the neck down can still maintain normal body functions such as breathing and digestion.

19 During a medical test called a PET scan, a sugar solution containing a radioisotope is injected into the patient. The most active brain cells use the most sugar, and so they absorb more of the radioisotope. A picture of the brain's activity is produced, based on where the radioisotope collects. **Deduce** how a PET scan could be used to determine whether a person's brain is functioning normally.

Creating CCT

20 **Construct** a model of the semicircular canals in your ears to demonstrate how they provide the information you need to keep your balance.

Inquiring

1 Spina bifida is a birth defect that involves damage to the spine and spinal cord. Research spina bifida and:

- compare the spine and spinal cord of a person with spina bifida and a person without spina bifida
- describe the effects of the differences on the functioning of the:

Present your findings as a poster with text and annotated diagrams.

2 Multiple sclerosis (MS) is a disease of the nervous system. Research MS and find:

- the cause of the disease
- how the symptoms of the disease are linked to its cause
- the short- and long-term effects it has on the body
- current research being undertaken to find a treatment or cure.

Present your research as a web page or an article for a popular science magazine. ICT

3 Research paraplegia and quadriplegia.

- Compare the two conditions by listing their similarities and differences.
- Describe the changes to the nervous system that cause each condition.
- Find the main causes of each condition in Australia.
- Explain why there is currently no cure for these conditions.

Present your research as a poster or PowerPoint presentation to be displayed at the local swimming pool or gym. ICT

4 Find different games that allow you to measure your reaction times online. ICT

- Most of the games you find will be based on how quickly you detect a change of colour on the screen. Find one of these 'colour-change' games and record your first ten reaction times using it. Calculate the average of these first ten reaction times. Record your best-ever reaction time using this game.
- Some online games use methods that are not based on a change in colour to determine your reaction time. Find one of these games and record your first ten reaction times using it. Calculate the average of these first ten reaction times. Record your best-ever reaction time using this game.
- Compare your results from each type of game and with the result from Practical investigation 2 if you perform it.

Present your reaction times from the different games (and from Prac 2 if performed) in a table or spreadsheet. ICT

5 Research what the Stroop effect is. Find:

- an online demonstration of the effect ICT
- different explanations of what causes the effect.

Present your findings as a written description of the effect and its causes.

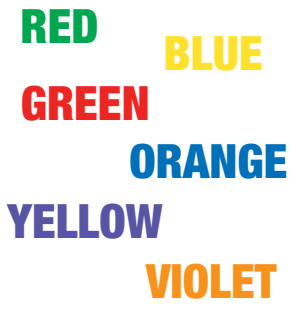


Figure 6.3.18 The Stroop effect: say the colours, not the names of the colours. Say them as quickly as you can.

6.3 Practical investigations

1 Brain dissection

Purpose

To investigate the structure of a brain.

Materials

- 1 partly frozen lamb's brain

- scalpel
- dissecting scissors
- dissection board
- newspaper
- disinfectant

SAFETY

Take extreme care with scalpels and dissecting scissors. Wear rubber gloves, safety glasses and a laboratory coat or an apron at all times.

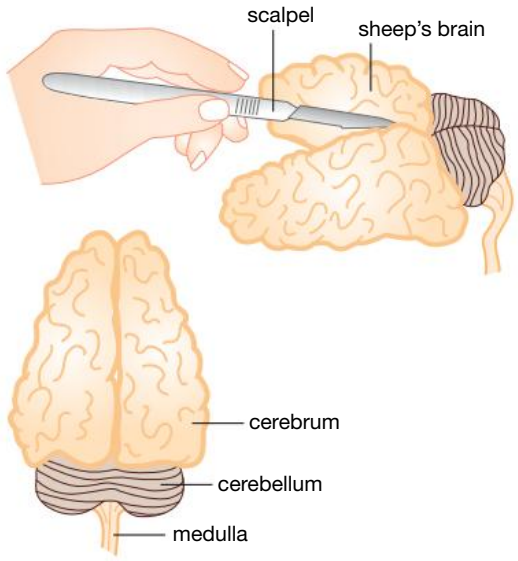
Procedure

1. Cover your workbench in newspaper and place the dissection board on it.
2. Carefully inspect the surface of the brain. Use Figure 6.3.19 to identify the cerebrum, cerebellum, brain stem (medulla) and spinal cord.
3. The brain has a fine membrane or 'skin'. If possible, use the edge of your scalpel to lift and peel it off the brain.
4. Slice the brain in half, separating the right and left hemispheres.
5. Remove the cerebellum and brain stem (medulla).
6. If it is still sufficiently frozen, then slice the brain into thin slices. Use Figure 6.3.4 on page 237 and Figure 6.3.19 to help you identify the pituitary gland and hypothalamus.
7. Dispose of the remains and clean the dissecting board and equipment according to your teacher's instructions.

Results

Construct a table like the one below to summarise your observations about the size, colour, texture and consistency of everything you identified.

Part	Size	Colour	Texture	Consistency
Cerebrum				
Cerebellum				



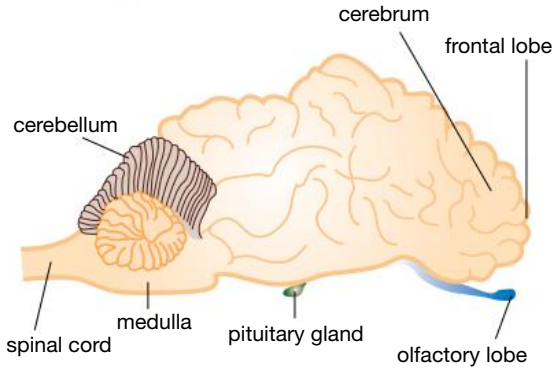


Figure 6.3.19

Practical review

1. **Propose** a reason why a frozen brain was dissected and not a fresh brain.
2. **Explain** how you identified which hemisphere was the left one and which was the right.

Using a scalpel

When using the scalpel:

- make many light cuts instead of one deep cut
- cut away from the hand holding the brain in place.

2 Reaction times

Purpose

To calculate the reaction time for a simple task.

Materials

- metre ruler
- materials required to create the selected distraction

Procedure

1 Work in pairs. The person being tested (the subject) should sit with their elbow resting on the edge of a table.

2 The other person (the investigator) holds the ruler by the 100 cm mark so that it hangs vertically, with the 0 cm mark between the thumb and forefinger of the dominant hand of the subject (Figure 6.3.20).

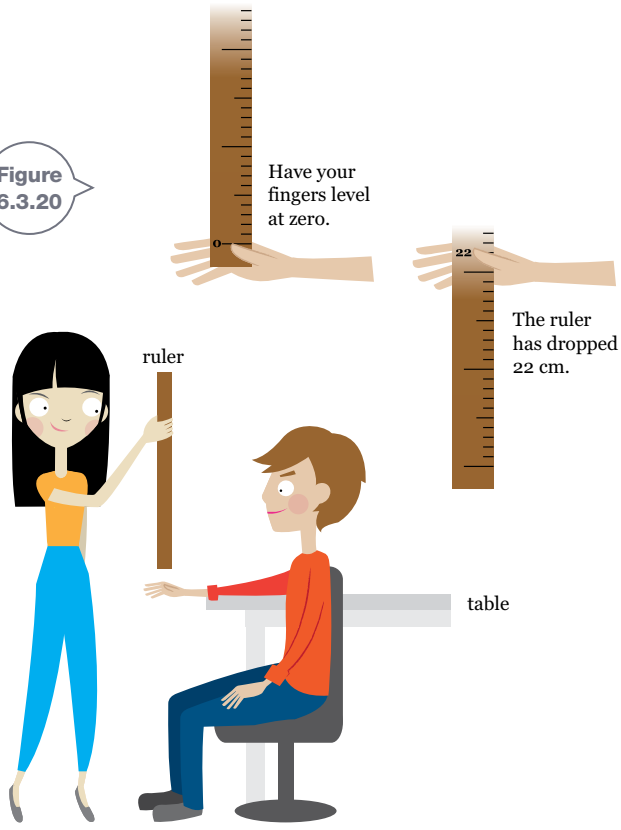


Figure 6.3.20

3 When the investigator releases the ruler, the subject tries to catch it as quickly as possible, using just their thumb and finger.

4 Record the distance the ruler has fallen, and convert it to 'time' using the graph shown in Figure 6.3.21. N

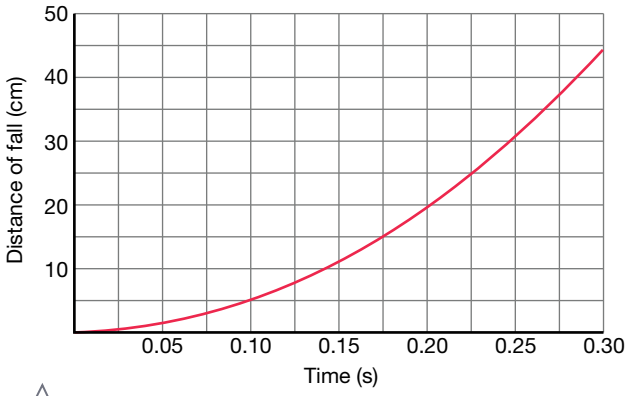


Figure 6.3.21 Graph of reflex time versus distance

5 Repeat the experiment five times to determine an average reaction time.

6 Repeat the experiment when a distractor is in place. This could be any one of the following suggestions or an idea of your own:

- constant background sound, such as music
- intermittent loud noises
- someone talking to the subject
- shutting one eye
- standing rather than sitting
- wearing gloves.

Results

Enter the data for both parts of the experiment into a suitable table or spreadsheet, and calculate the average reaction time without distraction and the average reaction time with distraction. N

Practical review

1 **Compare** your reaction times in both circumstances.

2 **Propose** reasons for any differences.

3 **Propose** how different types of distractions might affect your reaction time. For example, consider whether constant music has the same effect as intermittent noise.

4 **Deduce** how distractions could affect your reaction times when you are cycling, skateboarding or involved in another activity where you have to be very aware of your surroundings.

ADDITIONAL

6.4 Chemical control

The glands of the endocrine system and the hormones they release control the functions of your body that occur slowly. Hormones are responsible for the changes of puberty but are also involved in less obvious ways on a daily basis throughout your life. For example, hormones control your kidneys and the amount of glucose in your blood.

Controlling body temperature

Digestion, growth and repair, respiration and manufacture of hormones are some of the chemical reactions taking place inside your body. All these reactions together are known as your metabolism. The heat they produce as a by-product maintains your body temperature regardless of the temperature of your surroundings. This is illustrated in Figure 6.4.1. Because you can maintain a constant body temperature, you are said to be **endothermic**. However, if the temperature inside your body was to increase by more than a few degrees above 37°C, your metabolism would stop, and you would die. If your body temperature fell below 37°C, your metabolism would slow down.

Hormonal control of temperature

The hypothalamus acts on the pituitary gland to control body temperature through the action on another endocrine gland—the thyroid gland.

The hypothalamus receives information from temperature receptors in the skin and from internal receptors, including the hypothalamus itself.

Figure 6.4.1 Your body temperature stays the same regardless of the temperature of the environment. There are things you can do to help your body, such as adding clothing when it is cold, and removing clothing and using shade when it is very hot.

If the hypothalamus detects a fall in body temperature, it produces a hormone that causes the pituitary gland to secrete more thyroid-stimulating hormone (TSH). TSH stimulates the thyroid to release more of the hormone thyroxine. Thyroxine travels in the blood to all cells and causes the rate of metabolism in the cells to increase. Increased metabolism generates more heat and warms the body.

Producing the hormones that cause these changes takes time, and therefore the endocrine system does not have immediate control over body temperature.

Nervous control of temperature

Body temperature is also controlled by the nervous system and this is a more immediate response. When the hypothalamus detects a drop in temperature, it sends nerve impulses to muscle groups around vital organs such as the heart and lungs. Small shaking movements begin in these muscles. Eventually the shaking movements extend to the large muscles of the arms and legs, and you begin to shiver. Shivering increases the activity of muscle cells, producing heat and raising body temperature. This is the body's way of creating warmth by using energy.

Another aspect of nervous control is the process that reduces blood flow to your skin when you are cold. The sympathetic nervous system causes a narrowing of the blood vessels near the surface of the skin. This reduces blood flow and therefore heat flow to the skin. If the external temperature is very low, the blood flow to the extremities (fingers, toes, nose and ears) is reduced further and you can lose feeling in them—your toes and fingers go numb.

When the hypothalamus detects a rise in body temperature, nerve messages are sent to the sweat glands and blood vessels. Blood vessels close to the skin dilate (increase in diameter) so that more blood (carrying heat) can reach the skin surface. The extra blood near the surface makes your skin more red.

The message from the hypothalamus causes the sweat glands to produce more sweat (Figure 6.4.2). Heat from your body causes the sweat (which is mostly water) to evaporate. The rate at which heat is lost by evaporation depends on the difference in temperature between the body and the surrounding air, and the relative humidity of the air.

Prac 1 p251 6.8

Figure 6.4.2

It takes a lot of heat to evaporate a small amount of water. This makes sweating a very effective cooling mechanism.

Water balance

The kidneys are important organs in homeostasis. They control both salt and water balance within the body. You take in water and salts through food and drink. The body also manufactures about 350 mL of water per day as a product of cellular respiration.

You lose some water in the air you breathe out. You lose water and salts through sweat and in the faeces you produce; however, most salts and water are lost through urine. The body needs to balance its losses and gains. The kidneys are the organs that control the amount of water and salt lost. The balance between gains and losses is shown in Figure 6.4.3.

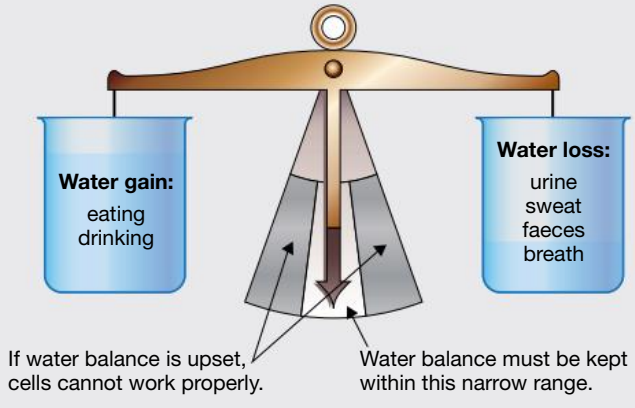


Figure 6.4.3

Gains and losses of water by the body must be balanced. If there is too much or too little water in the body, then it will not function correctly.

About a quarter of the blood from every heartbeat passes through the kidneys—about 50 litres/hour. Of this about 7 litres is processed by millions of microscopic filters within the kidney. These filters remove harmful wastes (such as urea), salts and water from the blood. The kidney returns to the blood the salts, glucose and water needed by the body. Wastes, excess salts and excess water pass from the kidneys into the bladder, where they are stored before being released from the body as urine.

If you drink a lot more water than your body requires, you produce large amounts of light-coloured, dilute urine. If your water intake is inadequate, you produce dark-coloured, concentrated urine. The amount of water in urine is controlled by **antidiuretic hormone (ADH)**. ADH causes the kidneys to reabsorb water directly from the renal tubules of the kidney. Salts and waste products are concentrated in the liquid, which will eventually become urine. ADH is secreted by the pituitary gland under the control of the hypothalamus. The hypothalamus monitors the volume of blood passing through it and the concentration of water in the blood. Dehydration increases the production of ADH and water is retained in the body.

Figure 6.4.4 illustrates the relationship between the parts of the body involved in water balance. Figure 6.4.5 demonstrates the feedback system involved in this process.

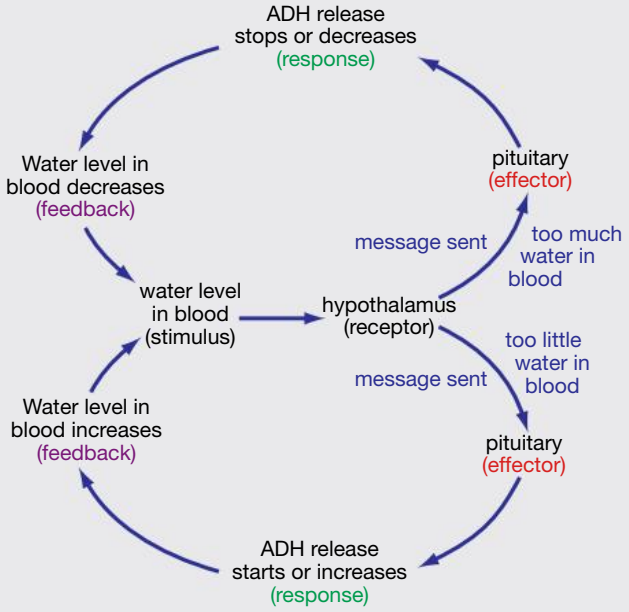


Figure 6.4.5 Homeostasis is achieved through negative feedback systems. In this type of system, the response of the system (in this example the amount of ADH produced) works to change the inputs to the system (in this case the amount of water in the blood).

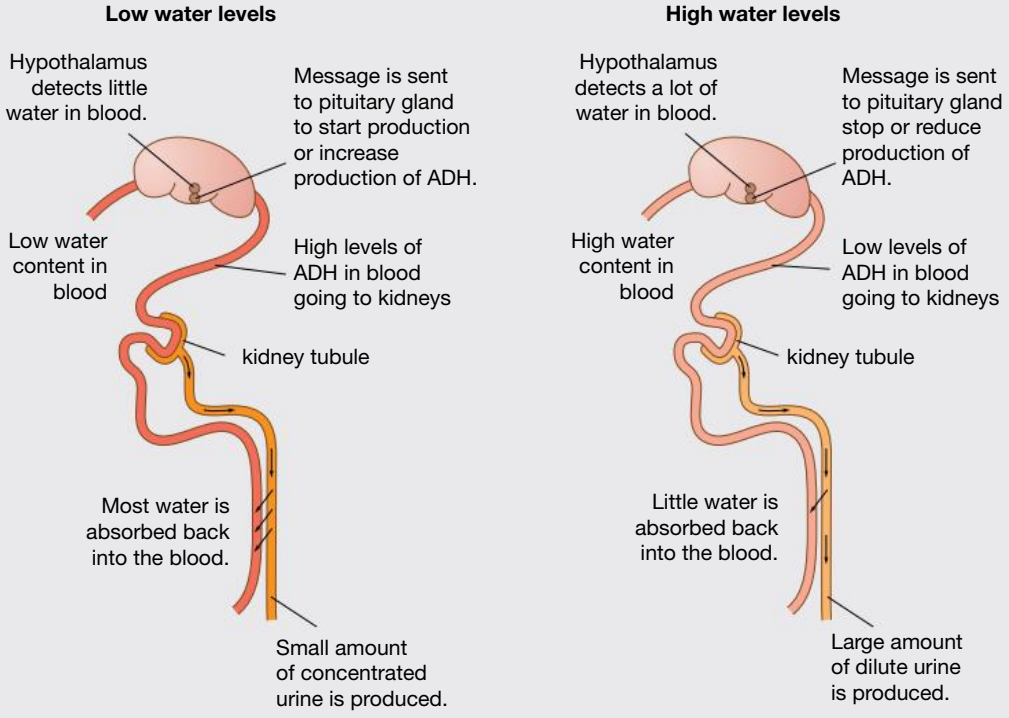


Figure 6.4.4 The volume of urine excreted by the kidneys is controlled by antidiuretic hormone (ADH) in a negative feedback system.

Blood sugar control

To provide energy for your body throughout the day, your cells need a continuous supply of glucose for cellular respiration. Too much glucose makes your blood thick, meaning that it can move only slowly through your blood vessels. Too little glucose makes you feel dizzy because you have insufficient energy. Glucose is carried around the body dissolved in the blood plasma. It enters the blood from the digestive tract and is absorbed by most body cells. Despite this intake and usage, glucose levels in the blood remain fairly constant at about 0.8–1 mg/mL. The steady concentration is due to the action of two hormones: insulin and glucagon (Figure 6.4.6). These hormones are made by groups of specialised cells in the pancreas, called 'islets'.

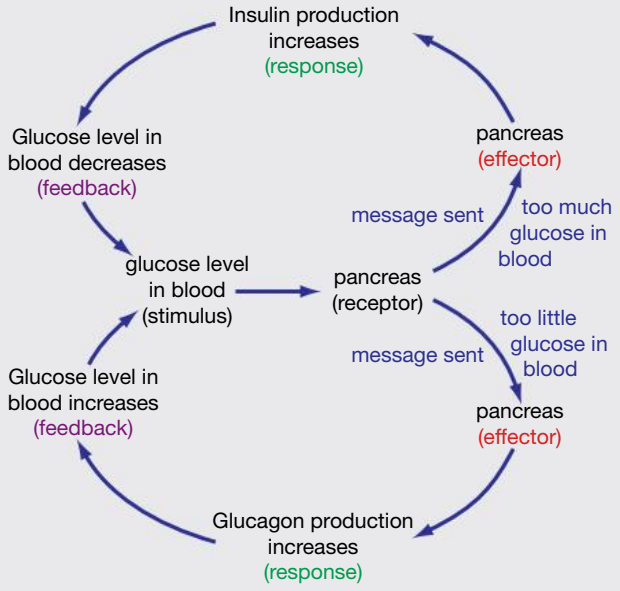


Figure 6.4.6 Control of glucose in the blood is by a negative feedback system. The body responds to increased glucose levels in the blood by producing insulin. Insulin causes glucose to be removed from the blood. When glucose levels in the blood fall, glucagon allows the glycogen in the liver to be released and glucose is returned to the blood.

An increase in blood glucose levels after eating is detected by receptors in the pancreas. The pancreas then releases the hormone **insulin**. Insulin causes the liver and muscles to extract glucose from the bloodstream and convert it into a larger molecule called **glycogen**. The glycogen is stored in the liver and glucose levels in the blood are reduced.

When glucose is taken from the bloodstream during activity, the pancreas detects this and responds by releasing another hormone, called **glucagon**. Glucagon has the opposite effect to insulin. So, by the controlled release of the two hormones, glucose levels are kept fairly constant.

If someone has the disease diabetes, then either they are not able to produce insulin or their tissues are not able to respond to it.

Responding to stress

If you are in a frightening or stressful situation, your nervous system registers this and sends messages to the **adrenal glands** situated on your kidneys. They produce a hormone known as **epinephrine** (commonly called **adrenalin**).

Epinephrine causes your heart rate to increase, blood vessels to contract and air passages to dilate (open up). This reaction of the body to adrenalin makes you more alert and prepares your body to act in an emergency. The response is triggered by the sympathetic nervous system.

Nearly all body tissues are target cells for epinephrine. However, the effect of the hormone varies from tissue to tissue. The smooth muscles of the airway relax, allowing more oxygen to be taken into the body. But the smooth muscles of the blood vessels contract, increasing blood pressure.

Epinephrine inhibits insulin secretion by the pancreas. Glucose therefore remains in the blood where it can be taken up by the cells, especially muscle cells, and used to release energy.

Once the hormones have done their job and the frightening situation is past, the hormones break down quickly. Constant high levels of this hormone in the body can do harm.

Figure 6.4.7 Both your nervous system and your endocrine system react to stress and fear. People with large amounts of epinephrine in their bloodstream can do things they would not normally be able to do, such as leap over a fence.

ADDITIONAL

6.4 Unit review

Remembering

1 **Name** the hormones that control glucose levels in the blood.

2 **Recall** the term used to describe having a relatively constant body temperature.

3 **Name** the hormone that controls:
- a the amount of water in urine
- b the level of glucose in the blood
- c your response to fear.

Understanding

4 **Describe** the relationship between:
- a the pituitary gland and the hypothalamus
- b antidiuretic hormone and the colour of urine.

5 **Explain** why sweating is an efficient way for the body to lose heat.

6 a **Explain** why it is important that your body temperature remains constant.
- b **Describe** two involuntary reactions that keep your body temperature from rising.
- c **Describe** one involuntary reaction that prevents your body temperature from falling.

Applying

7 About 7 litres of blood is filtered by the kidneys in every hour. **Calculate** the number of times your blood would be filtered each day. Assume you have 5 litres of blood. N

Analysing

8 **Compare** the way that glucose levels and temperature are controlled in the body.

9 **Discuss** the need for two hormones to control glucose levels in the blood rather than just one.

Evaluating CCT

10 **Propose** how the information in the table below would differ if the data came from a person who:
- a ate a lot of salty food
- b had been out in the sun for a long time
- c ate a large amount of sugar.

Substance	Amount in blood (%)	Amount in urine (%)
Water	90–93	95
Glucose	0.1	0
Salts	0.37	0.5
Urea	0.03	2

11 **Propose** why it is important that glucose is not excreted in the urine.

12 Changes in hormones in response to a decrease in body temperature are described on pages 246–7. The changes in response to a rise in temperature are not described. **Propose** what these changes might be. There are no different hormones involved.

Creating CCT

13 a **Construct** a sketch line graph showing the expected changes in your blood glucose levels after eating some lollies. N
- b **Describe** what causes the glucose levels to change.

14 **Construct** a flow diagram showing the reaction of your body to fear.

Inquiring

Research the thyroid gland.

- Identify the hormone produced by the thyroid gland.
- List the functions of the thyroid gland.
- Describe the effects of having in overactive thyroid.
- Describe the effects of having an underactive thyroid.

Present your findings as a set of responses to the above tasks.

6.4 Practical investigations

1 Changing temperature

Purpose

To investigate the effect of exercise on body temperature.

Hypothesis

What do you think happens to your skin and internal body temperatures as you exercise? Before you go any further with this investigation, write a hypothesis in your workbook.

Materials

- electronic clinical thermometer (if available, data-logging equipment could be used for this experiment)
- area of the school where you can run around

SAFETY

Students with health problems may not be able to take part in this activity.

Procedure

1. Work in pairs. One person is the subject and the other is the recorder.
2. Record the skin temperature of the subject at the start of the experiment. Measure the skin temperature by holding the thermometer inside a bent elbow. Measure the internal temperature at the ear using an electronic clinical thermometer.
3. The subject undertakes 10 minutes of vigorous exercise, enough for them to feel hot and possibly turn red in the face.
4. The recorder records the subject's skin temperature and internal temperature.
5. Observe and record any other changes resulting from the exercise in an appropriate table.

Results

Record all measurements and observations.

Practical review

1. **Describe** the changes to the skin temperature during the experiment.
2. **Describe** the changes to the internal body temperature during the experiment.
3. **Compare** the changes in skin temperature with the changes in internal body temperature.
4. **Describe** any other changes that were observed.
5. **Propose** ways in which these other changes could contribute to the observed changes in temperature.
6. a **Construct** a conclusion for your investigation.
   b **Assess** whether your hypothesis was supported or not.

6 Chapter review

Remembering

1 **Name** the 'master gland' of the endocrine system.

2 **Name** the two parts of the human nervous system.

3 **Name** the system in the body that:
- a delivers materials to cells
- b gets oxygen into the body
- c removes wastes from the body.

Understanding

4 **Explain** the relationship between proteins and amino acids.

5 **Define** the term: L
- a metabolism
- b homeostasis.

6 **Explain** why the human body needs the following systems.
- a digestive system
- b respiratory system
- c excretory system
- d nervous system
- e endocrine system
- f circulatory system

7 a **Describe** the role of the 'pacemaker' in the heart.
- b **Propose** what could happen to the heart rate if the pacemaker stopped working.

8 **Describe** two situations in your body where substances move from one place to another by the process of diffusion.

9 a **Describe** the function of enzymes.
- b **Explain** why many different enzymes are required by the body.

Applying

10 **Use** the concept of diffusion to **explain** the process of oxygen and carbon dioxide exchange in the lungs.

11 **Use** the example of a reverse-cycle air conditioner to **explain** the term *negative feedback*.

12 a **Describe** the changes that occur in your body as you start to do some vigorous exercise.
- b **Identify** the systems that are causing the changes.
- c **Explain** how the changes are brought about.
- d **Explain** how the changes help your body maintain that level of activity.

13 **Use** Figure 6.1.13 on page 221 to **demonstrate** that multicellular organisms rely on coordinated and interdependent internal systems.

Analysing

14 a **Contrast** the roles of the sympathetic and parasympathetic nervous systems of the body.
- b **Explain** why both systems are required.

Evaluating CCT

15 a **Assess** each of the statements below and decide whether they are true or false.
- i Motor neurons carry messages from muscles and glands to the central nervous system.
- ii The peripheral nervous system has two main parts: the somatic nervous system and the autonomic nervous system.
- iii The digestive system can work independently of the other systems of the body.
- iv The kidneys are the only organs involved in removing wastes from your body.

b For each statement you decided was false, **justify** your decision.

16 a **Determine** whether you can or cannot answer the questions on page 215 at the start of this chapter.
- b **Assess** how well you understand the material presented in this chapter.

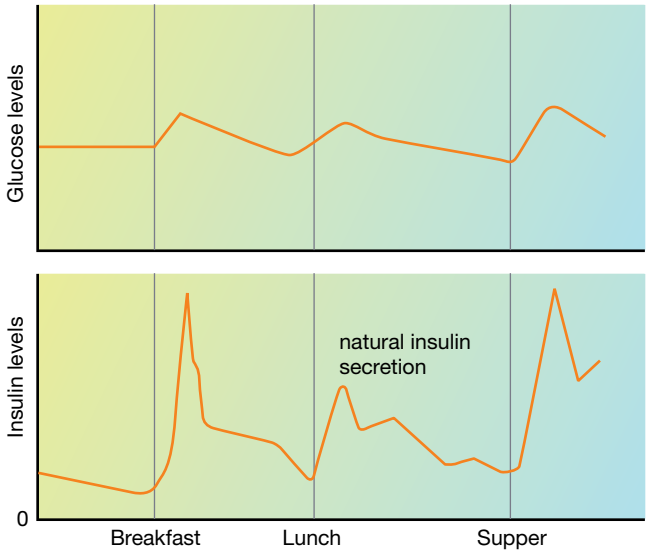
Creating CCT

17 **Use** the following ten key terms to **construct** a visual summary of the information presented in this chapter.

central nervous system	axon
peripheral nervous system	receptors
nervous system	metabolism
neurotransmitter	homeostasis
diffusion	reflex actions

Thinking scientifically

Q1 The graphs below show the relationship between glucose and insulin levels in the blood.



From this data, levels of insulin are highest:

A when glucose levels are increasing

B when you are eating a meal

C when glucose levels are highest

D a short time after the peak in glucose levels.

Q2 The volume of urine produced was measured for two groups of people every half hour. Each group did a different activity during that time. The following results were obtained. CCT

Time (min)	Volume of urine produced (mL)	
	Group 1	Group 2
0	50	50
30	53	50
	Vigorous exercise for 30 minutes	Sat in the sun for 30 minutes
60	60	30
90	10	20
120	8	20
150	35	25
180	40	23

Select the statement that is most likely to be true.

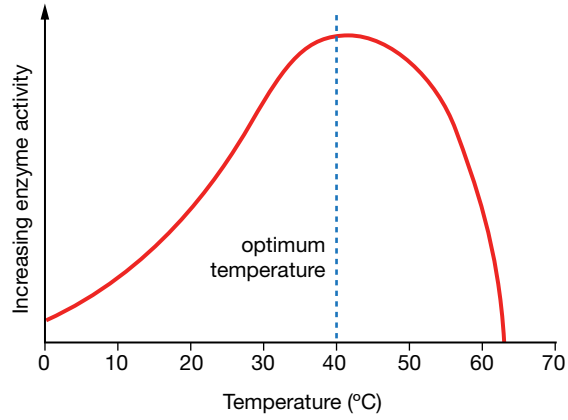
A The group who were sunbaking produced less urine after sunbaking.

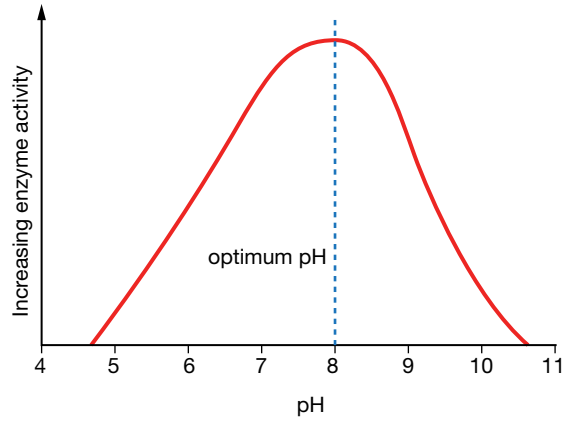
B The group who were exercising produced less urine after exercising.

C Both groups produced the same amount of urine in total.

D There was a steady decline in the amount of urine produced by both groups.

Q3 The following graphs show the level of activity of a human enzyme at different temperatures and pH.





The normal internal temperature of the human body is 37°C. The pH of the mouth is about 7.5, in the stomach it is about 3, and in the small intestine it is about 8.

Select the statement that best fits all the data presented.

A The enzyme works best at low pH and high temperature.

B Temperature and pH have no effect on activity of the enzyme.

C The enzyme would be able to function best in the small intestine.

D The enzyme is most likely a digestive enzyme from the stomach.

Glossary

Unit 6.1

Diffusion: the movement of particles of a substance from an area of high concentration to an area of low concentration

Enzyme: a chemical that speeds up a rate of reaction

Hormones: chemical substances that act as messengers in the body

Metabolism: all the chemical reactions occurring in the cells

Mitochondria: organelles where cellular respiration occurs

Receptor: a specialised cell that detects stimuli (changes)

Ribosome: the structure where proteins are manufactured

Substrate: the molecule that is going to be changed by a chemical reaction involving an enzyme

Unit 6.2

Axon: a nerve fibre that sends nerve impulses away from the cell body

Cell body: the part of the neuron that contains the nucleus

Central nervous system (CNS): the brain and spinal cord

Dendrites: branches from the cell body that receive messages from other neurons

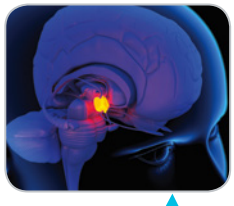
Effectors: muscles or glands that put the messages into effect

Endocrine glands: glands that produce hormones

Endocrine system: all the endocrine glands of the body

Homeostasis: the process of maintaining a constant internal environment

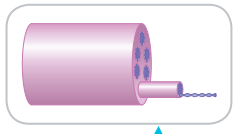
Hypothalamus: a portion of the brain that constantly checks the internal environment of the body



Hypothalamus

Motor neurons: nerve cells that carry messages from the CNS to effectors

Myelin sheath: the insulating layer that covers a neuron



Myelin sheath

Nerve impulse: the electrical message carried by a nerve cell

Neuron: a nerve cell

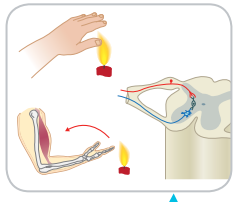
Neurotransmitter: a chemical message released at the end of an axon to be received by the next neuron's dendrites

Peripheral nervous system (PNS): the nerves that carry messages to and from the central nervous system and other parts of the body

Pituitary gland: the endocrine gland that controls the activities of other endocrine glands; it is often called the 'master gland'

Reflex actions: quick, automatic actions that protect the body from danger; also known as reflexes

Reflex arc: the nerve pathway operating in a reflex action

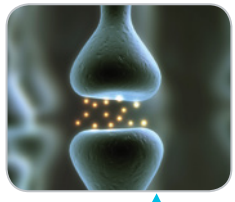


Reflex arc

Sensory neurons: nerve cells that carry messages from cells in the sense organs to the CNS

Synapse: the space between two neurons

Target cells: the cells on which a hormone acts



Synapse

Unit 6.3

Autonomic nervous system: the system controlling involuntary actions such as heartbeat

Brain stem: the part of the brain where the spinal cord enters the skull; it controls the body's vital functions, such as breathing, blood pressure and heart rate

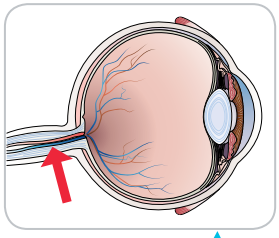
Cerebellum: the part of the brain that is responsible for coordination and balance

Cerebellum

Cerebrum: the part of the brain that controls conscious thoughts, and the movement of every body part, and receives sensory messages from each body part

Medulla: the lower half of the brain stem

Optic nerve: the nerve that carries messages to the brain from the retina at the back of the eye



Optic nerve

Parasympathetic nervous system: part of the nervous system that slows the body down and controls it when it is resting

Somatic nervous system: the part of the nervous system that coordinates the movement of the body and receives information from the sensory organs

Stimulus: any factor that stimulates a receptor and brings about a response

Sympathetic nervous system: part of the nervous system that speeds up the functions of the body and makes the body work more efficiently

Unit 6.4 L

Adrenal glands: endocrine glands situated on the kidneys

Adrenalin: the common name for the hormone epinephrine

Antidiuretic hormone (ADH): a hormone that controls the volume of urine produced by the body

Endothermic: able to maintain a constant body temperature

Endothermic

Epinephrine: a hormone produced in the adrenal glands; it is commonly known as adrenalin

Glucagon: a hormone that has the opposite effect to insulin; it releases glucose from stores in the liver and muscles

Glycogen: the chemical store of glucose in the liver and muscles

Insulin: a hormone produced in the pancreas that causes the liver and muscles to extract glucose from the bloodstream and store it in the liver and muscles

7 Disease

Have you ever wondered...

- why you get sick?
- what things you could do to try to keep yourself healthy?
- why you need to wash your hands after going to the toilet?
- why it is so important to eat fresh fruit and vegetables?

After completing this chapter students should be able to:

- outline responses of the human body to infectious and non-infectious diseases
- discuss how the values and needs of contemporary society can influence the focus of research into diseases, epidemics and lifestyle-related non-infectious diseases PSC ICT EU
- describe how biological understanding has advanced, allowing the development of vaccines ICT EU PSC

ADDITIONAL

- describe examples of advances in science and technology in areas that involve biological science. ICT L WE

7.1 They make us sick!

Everyone gets sick at some time or another. When you get sick, you expect to get better quickly. Colds and upset stomachs are *diseases*. So are more serious and long-term illnesses.

Bacteria

A **disease** is anything that causes your body to stop working properly. One cause of disease is bacterial infection.

Bacteria are microscopic, unicellular (one cell) organisms. Thousands of different species of bacteria have been discovered. However, scientists are finding so many new species of bacteria that they believe that most have not yet been discovered.

Bacteria are an important part of the natural environment. They are decomposers, converting dead plant and animal matter and wastes into nutrients that plants use to grow (Figure 7.1.1). Bacteria living in the intestines of herbivores such as cows and kangaroos help with digestion. Bacteria help control insects. Humans use bacteria to make medicines and to break down pollutants such as oil and plastics. A small percentage of known bacteria cause disease. These bacteria are known as **pathogenic bacteria** or **pathogens**.

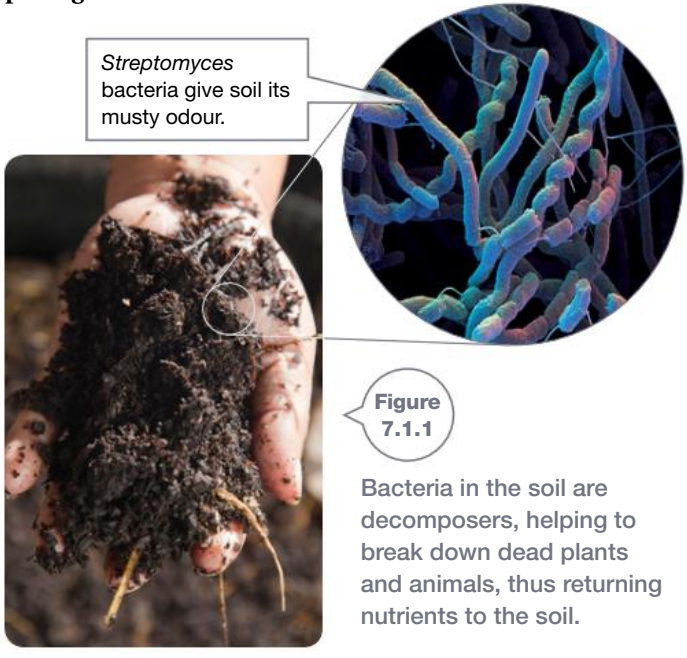


Figure 7.1.1

Bacteria in the soil are decomposers, helping to break down dead plants and animals, thus returning nutrients to the soil.

INQUIRY

science 4 fun

Is it clean?

Where in the house would you find harmful bacteria?

Collect this ...

- magnifying glass

Do this ...

1. Think about the places in the kitchen where harmful bacteria could lurk.
2. Wipe the bench surfaces over until you think they are clean.
3. Use the magnifying glass to look at the surfaces, in corners and on ledges. You will not be able to see bacteria, but you may be able to see dust or grime that could be a home for bacteria.

Record this ...

Describe what you could see.

Explain why the surfaces may not have been as clean as you thought.

On me?

There are more living organisms on the skin of a single human being (even a clean one) than there are human beings on the surface of the Earth!

SciFile

Bacterial diseases

Pathogenic bacteria cause hundreds of diseases, such as whooping cough, tetanus, diphtheria, impetigo (school sores), pneumococcal and meningococcal disease, and typhoid fever. These are all **infectious diseases**—they are diseases that can be spread.

Some infectious diseases are easier to spread than others. Those that are easiest to spread are described as **contagious**. Figure 7.1.2 shows impetigo, a contagious disease that is more common in children than in adults. Touching someone with impetigo could result in you becoming infected. For this reason infected children are put into **quarantine**—they are isolated from healthy people to prevent the spread of the disease. They are not allowed to attend school or day care centres until they have started treatment for the disease. Even then they can only return to school if the sores are covered with watertight dressings. Quarantine is used to prevent the spread of disease within a community, between communities and between countries.

Figure 7.1.2 If they are not treated, the oozing sores of impetigo remain infectious until they are healed. Once treatment starts, the sores should begin to heal in about three days.

Bacterial infections are treated with **antibiotics**—substances that kill or prevent the growth of bacteria. The first successful antibiotic was **penicillin**. Penicillin was made from *Penicillium* mould (Figure 7.1.3). Penicillin was not in common use until the late 1940s. Before the development of antibiotics, you would have had to depend on your own body's **immune system** to fight off infections. Even today, antibiotics don't always work.

Some people are allergic to penicillin, and not all types of bacterial infections can be treated with it. For these reasons, other antibiotics have been developed. Penicillin and these other antibiotics have saved the lives of millions of people since they were discovered.

Prac 1 p264 7.1 7.2

Figure 7.1.3 *Penicillium* is a common mould that forms on bread. It was from this mould that the first antibiotics were made.

Accidents that work

SciFile

Penicillin was discovered in 1928 by accident. The Scottish scientist Alexander Fleming left some culture plates on which he was growing bacteria on a bench while he went on holiday. Mould grew among the plates. Where one particular mould grew, the bacteria didn't. In 1940, the Australian scientist Howard Florey and Ernst Chain developed penicillin into a useful medicine.

The immune system

Pathogens can enter your body in a number of ways, as shown in Table 7.1.1.

Table 7.1.1 Methods of entry of pathogens

Method of entry	Examples of disease
Food and water	Food poisoning, cholera
Breathing in	Flu, pneumonia, tuberculosis
Cuts and wounds	Tetanus, blood poisoning
Sexual contact	Gonorrhoea, syphilis, HIV
Other contact	Anthrax, leprosy

Your body has three lines of defence against disease. The first line of defence is to prevent the pathogens from entering the body:

- Skin is an effective barrier against pathogens and protects the internal organs from harmful chemicals in the environment and from sunlight.
- Fluids such as tears and saliva have mild antiseptic properties and help to wash away dust and harmful substances from openings to the body.
- Air entering through the nose is filtered by hairs in the nostrils. Other unwanted particles in the air are then trapped in the mucous lining of the trachea (windpipe). Coughing and sneezing help to get rid of these foreign particles.
- Pathogens entering the digestive system are usually killed by the acid in the stomach. Vomiting is a quick way of getting rid of something undesirable in the stomach. Diarrhoea is a rapid way of ridding the body of pathogens that have got past the stomach.

Once a pathogen enters the body tissues, the second line of defence gets started. The affected area becomes red, hot and swollen—it is inflamed. Inflammation is a response of the body to infection. Damaged cells release a **histamine**, a chemical that causes more blood to flow to the infected area. Within the blood are special white blood cells called **neutrophils**. You can see these in Figure 7.1.4. Neutrophils consume bacteria.

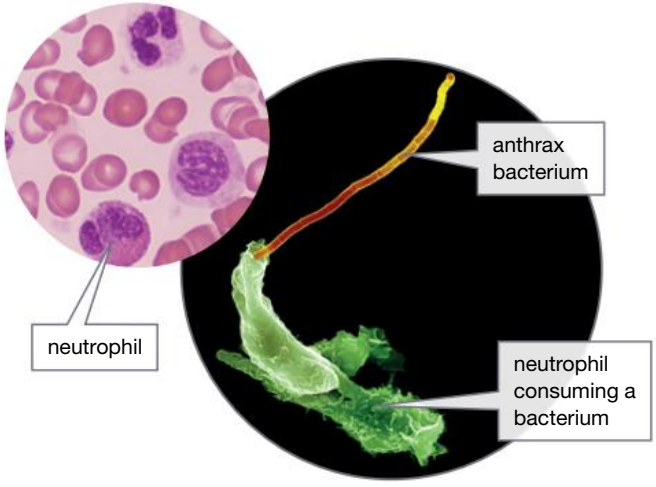


Figure 7.1.4 Neutrophils are white blood cells that have many nuclei, which you can see stained purple in some cells here. Neutrophils can change shape as they hunt for and consume bacteria.

Many neutrophils are killed as a result of consuming large numbers of bacteria. Dead neutrophils form the yellow pus that collects around infected wounds. This has happened in the wound shown in Figure 7.1.5.

Figure 7.1.5 Once the skin is broken, the first line of defence is breached. The second line of defence can be seen at work here. The skin is inflamed and the yellow pus indicates that neutrophils have been at work.

If the pathogens are still active, then the third and last line of defence is activated. The last line of defence is the lymphatic system. The lymphatic system is a series of vessels and capillaries that carry fluid fro m around your cells back to your heart. In areas of the lymphatic system there are swellings or nodes (lymph nodes).

Lymph nodes contain a large number of different types of white blood cells, called lymphocytes and macrophages. The function of these white blood cells is to destroy pathogens and to help protect the body in the future.

Macrophages are similar to neutrophils in that they consume and destroy the pathogens. A macrophage is shown in Figure 7.1.6. **Lymphocytes** respond by making a chemical called an **antibody**. Antibodies cause pathogens to clump together, allowing the macrophages to destroy more of the pathogens at any one time.

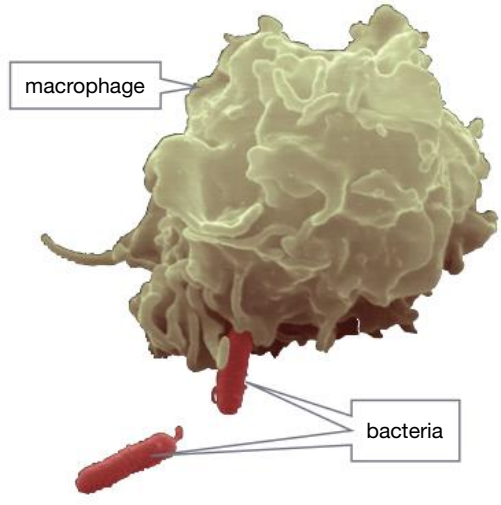


Figure 7.1.6 Macrophages are large white blood cells found in the lymph glands. This macrophage is consuming bacteria.

Each pathogen has a specific antibody that acts on it. The first time the lymphocytes meet a particular pathogen, they make antibodies that work on that pathogen. This takes some time, and meanwhile you may get sick. The next time your immune system meets the same pathogen, it is able to make the same antibodies quickly and the pathogen is destroyed before it can make you unwell. You are now **immune** to that pathogen and should stay healthy if you meet it again.

When the lymphocytes and macrophages are working hard, the lymph nodes closest to the site of infection become enlarged and tender. You may be able to feel them in your neck, armpits and groin.

To help you fight an infection, your body's thermostat is set higher than normal and you develop a fever. Pathogens that enter your body function best at normal body temperature. When your body temperature is higher, the pathogens are not able to function as well and your immune system can fight them more easily.

The body's three lines of defence are summarised in Figure 7.1.7.

Vaccination

Some diseases are so serious that you don't want to rely on your body developing immunity by itself. To help it out, vaccines are used. **Vaccines** are chemicals that cause your body to react as if it had met a pathogen.

A vaccine is created by taking a small amount of the poison produced by the bacterium and making it inactive, or by using weakened or dead bacteria. The inactive poison and the dead bacteria are harmless, but your immune system responds to the vaccine by making antibodies and you become immune to the pathogen.

7.3

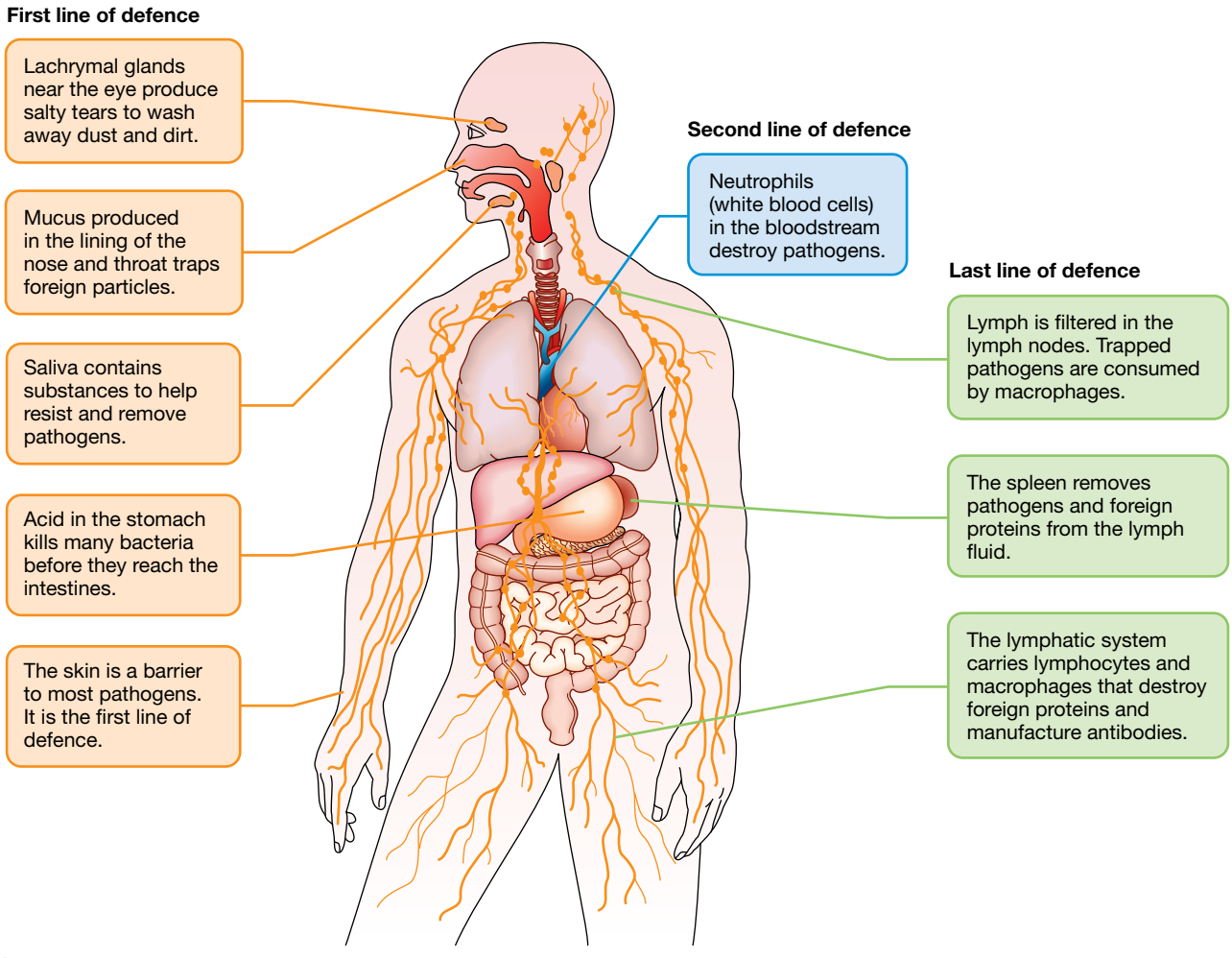


Figure 7.1.7 The function of the three lines of defence is to protect the body from pathogens.

In Australia, young children are routinely injected with vaccines against tetanus, diphtheria and whooping cough (pertussis). This process is known as being vaccinated or immunised. Other bacterial diseases for which vaccines are available include meningococcal and pneumococcal disease and typhoid fever.

Tetanus

Tetanus is a bacterial infection caused by a bacterium called *Clostridium tetani*. These bacteria (Figure 7.1.8), live where there is very little air—deep in the soil, or deep in the body. They can enter your body through puncture wounds, the sort you would get from standing on barbed wire or a rusty nail. As the bacteria multiply within your body, they produce a poison that causes the muscles to become stiff and to tighten suddenly (spasm). The spasms begin in the jaw, causing the jaw to lock shut. This symptom gives the disease its common name, lockjaw. A **symptom** is an indicator of a particular disease.

The vaccine against tetanus gives you immunity for up to ten years. After that you need a booster.

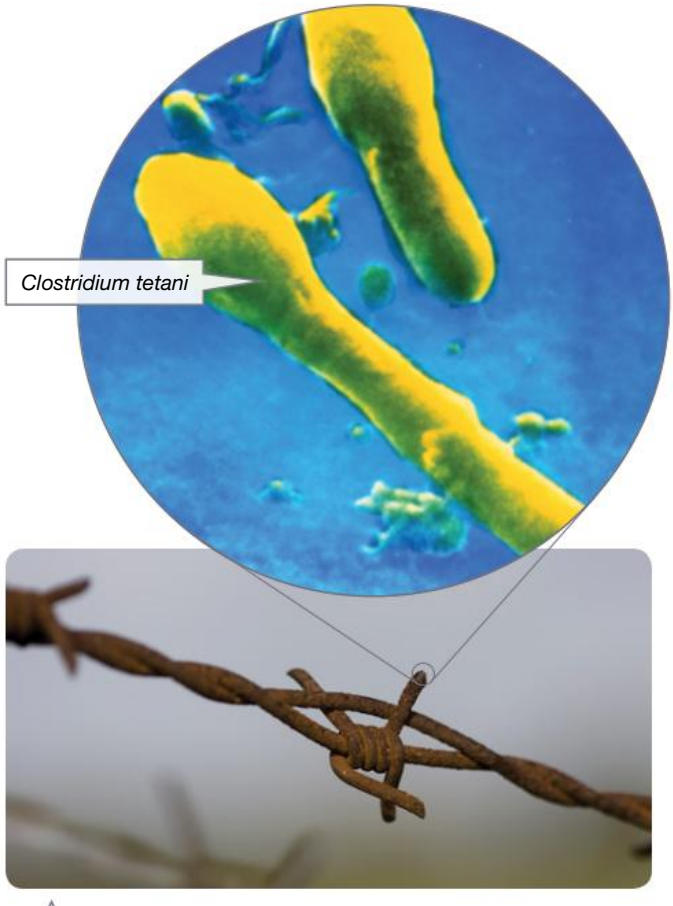


Figure 7.1.8 Barbed wire can cause deep puncture wounds that allow *Clostridium tetani*, tetanus bacteria, to enter the body.

Hygiene

Some diseases can be prevented by practising good hygiene. If you wake up one morning feeling sick in the stomach and then start vomiting, you could be infected with *Salmonella enteritidis*—a bacterium that causes gastroenteritis. This bacterium is shown in Figure 7.1.9.

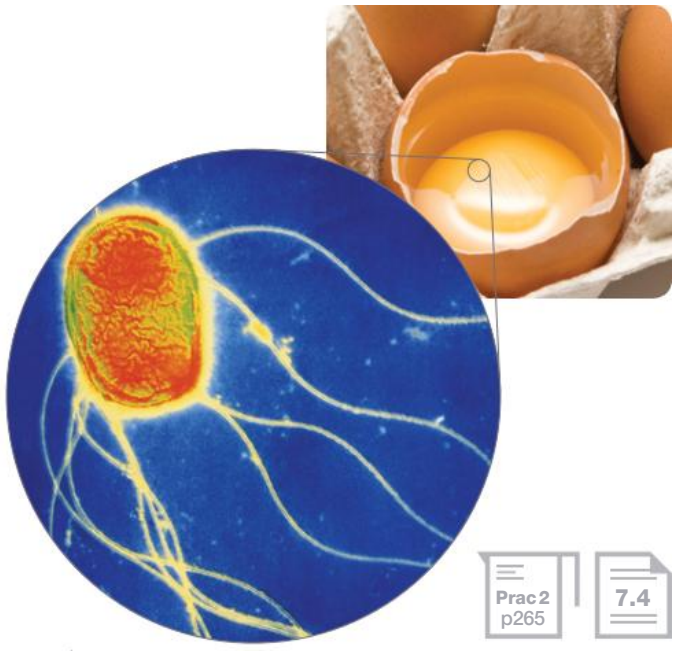


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Figure 7.1.9 *Salmonella enteritidis* bacteria are found naturally in faeces and on dirty surfaces such as egg shells. *Salmonella* bacteria are responsible for over 9000 cases of gastroenteritis per year in Australia.

Salmonella enteritidis bacteria live naturally in the bowels of humans and other animals, especially birds. If the bacteria get into food you eat, then they will multiply in your stomach, producing poisonous wastes as they do so. The poisons cause fever, headache and stomach pains. Your body tries to get rid of the poisons as quickly as possible through vomiting and diarrhoea. Vomiting and diarrhoea cause you to lose a lot of water, so dehydration (a lack of water in the body) may become an additional problem. So no matter how ill you feel, you must drink plenty of water.

Gastroenteritis is a disease that can be avoided if you:

- wash your hands thoroughly and frequently, after handling animals, and going to the toilet, and before handling food
- thoroughly wash all surfaces on which food is prepared
- keep foods such as meat, fish and dairy products refrigerated and separate from one another.

LEARNING ACROSS THE CURRICULUM

WORK AND ENTERPRISE

STOMACH PAINS

Stomach ulcers occur when the lining of the stomach has been damaged. The stomach normally produces strong acid, and when this comes in contact with the damaged area, the result is pain.

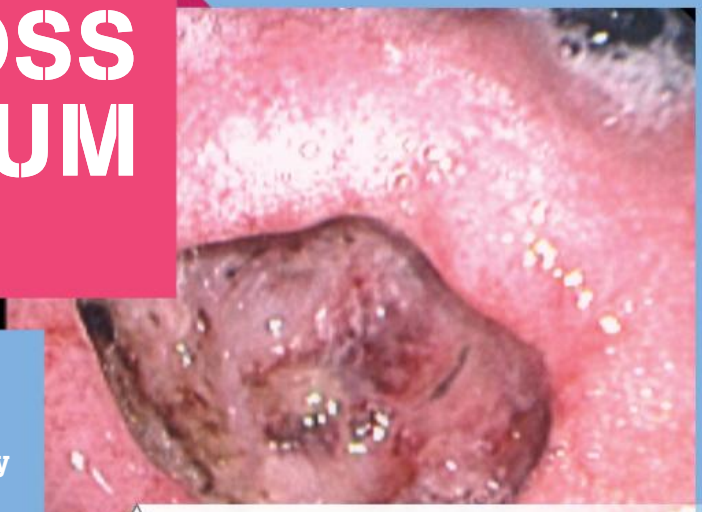


Figure 7.1.10 This stomach ulcer has eaten away the lining of the stomach, leaving the tissue underneath exposed to the strong acid of the stomach. This will cause intense pain and can lead to life-threatening bleeding.

Ulcers in the stomach and lower in the intestines, such as the one shown in Figure 7.1.10, have been a major medical problem throughout the world. Doctors thought that stress, poor diet, alcohol, smoking or too much caffeine could all be part of the cause.

In 1979, Dr Robin Warren was working as a pathologist at the Royal Perth Hospital. Pathologists study the causes and effects of disease. Dr Warren found that an unusual bacterium was common in the stomachs of patients suffering from ulcers. Up until then, people in the medical profession were so sure that stress and diet caused ulcers that they were very sceptical about the link between a bacterium and stomach ulcers that Dr Warren had suggested. They did not believe that a bacterium could survive in the acidic environment of the stomach.

Dr Barry Marshall is a gastroenterologist—a doctor who studies diseases of the stomach and intestine. In 1981, he and Dr Warren isolated this strange bacterium from the stomach and cultured (grew) it in the laboratory. It was a new species of bacterium, which they called *Helicobacter pylori* (*H. pylori*) (shown in Figure 7.1.11). The two doctors were convinced that *H. pylori* was causing ulcers, but the rest of the medical profession were still sceptical.

Figure 7.1.11 *Helicobacter pylori* was identified as a new species of bacterium and the cause of stomach ulcers.

Dr Marshall decided to test his hypothesis by infecting himself with the bacterium. He swallowed a culture of the bacterium, and a week later he began to suffer the symptoms of gastritis, the infection that comes before an ulcer develops. He then treated himself with antibiotics to destroy the bacteria, and he recovered.

The discovery of the link between *H. pylori* and ulcers has been described as possibly the most significant event in medicine in Australia in the past 20–30 years. It was now possible to cure a disease that doctors had previously considered incurable.

In 2005, Dr Robin Warren and Dr Barry Marshall were awarded a Nobel Prize for their contribution to medicine.

REVIEW

1 **Explain** what a stomach ulcer is.

2 **Explain** why many doctors were unwilling to accept the idea that bacteria were the cause of stomach ulcers.

3 **Summarise** the evidence that Dr Warren and Dr Marshall used to suggest a link between the bacterium and ulcers.

4 **Explain** why the discovery of *Helicobacter pylori* is considered such a significant event for Australian science.

5 **Construct** a flow diagram showing the major events between Dr Warren observing the bacterium and the awarding of the Nobel Prize.

7.1 Unit review

Remembering

1 **State** the general name for bacteria that cause disease. L

2 **Name** the system of the body that fights disease.

3 **Name** two common diseases caused by bacteria.

4 **State** the function of antibiotics.

5 **List** diseases that health authorities advise all Australian children be immunised against.

Understanding

6 **Define** the term *disease*. L

7 **Explain** why severe cases of gastroenteritis can cause dehydration.

8 **Outline** the process used to make a vaccine.

9 **Explain** how vaccines work.

10 **Explain** what it means to be *immune* to a disease such as tetanus.

11 **Explain** why it is important that you wash your hands after playing with pets or going to the toilet.

Analysing

12 **Compare**:

a a contagious disease and an infectious disease

b antibiotics and vaccines.

13 **Compare** the way you become immune through natural reactions of your body and through administering a vaccine.

Evaluating CCT

14 Some parents think that immunisation is not necessary because the diseases it is used against are so rare in Australia.

a **Evaluate** whether this attitude is reasonable or not.

b What would you **recommend** if someone asked you whether or not they should be immunised against a disease?

15 Three friends went for a meal at a restaurant. Next day all were feeling very ill and were diagnosed as having gastroenteritis. **Propose** the possible causes of the illness.

16 **Propose** what could happen if kitchen benches are not cleaned regularly and thoroughly.

Creating CCT

17 **Construct** a series of diagrams to demonstrate how a tetanus vaccine protects you against the disease.

18 **Construct** a poster to inform people about tetanus and how it can be prevented.

Inquiring

1 In your workbook, construct a table like the one at the bottom of the page.

- In the table, list the diseases that you have been vaccinated or immunised against. (You may have to ask your parents to help you with this list.)
- Research the information needed to complete the rest of the table.

ADDITIONAL

2 Find out more about the discovery of penicillin. Information to look for includes:

- where the research was carried out and by whom
- the timeline for the discovery
- the contribution each person made to the discovery
- other scientific research they were involved in.

Present your findings as a written report. L WE

3 Investigate the work of Australian scientists Fiona Wood and Marie Stoner on artificial skin.

- Summarise the significant events in their research.
- Describe the types of injuries they have been able to treat.
- Describe how this treatment has affected the lives of their patients.
- Describe the benefits to society of this research.

Present your research in digital form. ICT WE

ADDITIONAL

Disease	Symptoms of the disease	Prevalence in Australia	When the immunisation was developed	Age at which immunisation is given	Frequency of immunisation

7.1 Practical investigations

1 Growing bacteria

Purpose

To show that bacteria are common in our environment.

Hypothesis

Which area of the school do you think would have the largest number of bacteria—your classroom, the library, outside or somewhere else? Before you go any further with this investigation, write a hypothesis in your workbook.

Materials

- prepared agar plates
- marker pen
- zip-lock bag
- access to an incubator

SAFETY

Treat all bacteria as potentially dangerous.

All plates must be completely sealed with tape.

Do not open the lids of the agar plates once you have grown the bacteria. Your teacher will dispose of the plates correctly. As an added precaution, the agar plates could be sealed within a zip-lock plastic bag, as shown in Figure 7.1.12.

Procedure

1. Take one agar plate for each group of three or four students.
2. As a group, decide where in the school you are going to expose the plates. Do not touch the plate or expose it where dangerous pathogenic organisms may exist (for example, the toilets). Do not cough or sneeze on the plate.
3. Each group should go to a different part of the school, such as the canteen, sports oval and classrooms.
4. Go to your chosen site and open the agar plate. Wave it gently through the air for about one minute.
5. Replace the lid on the plate and seal it with tape. Mark the bottom of the plate with the name of your group and the place where the plate was exposed.
6. Place the plate top down in an incubator at 20–25°C and leave it overnight. If no bacterial colonies are visible, leave the plate for another 3–4 days.

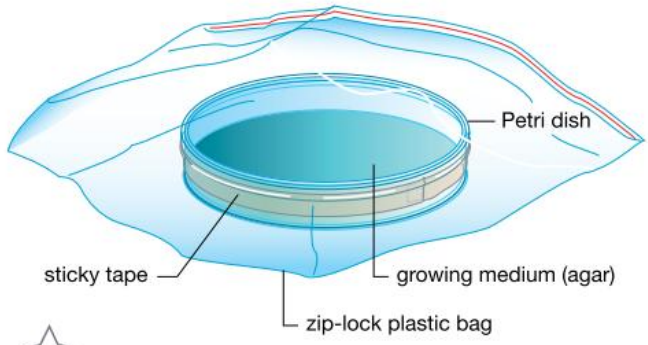


Figure 7.1.12

Results

1. Count the number of different colonies on the plate, using the following characteristics as a guide.
   - Bacterial colonies tend to be smooth and round.
   - Different bacteria may have different colours.
   - Fluffy areas like cotton wool are colonies of fungi.
2. Gather results for other groups in the class and construct a table that compares the number and variety of colonies from different parts of the school.

Practical review

1. **Describe** the appearance of the colonies on your group's plate.
2. **Compare** the number of colonies found in the different parts of the school.
3. **Compare** the variety of colonies found in different parts of the school.
4. **Explain** the differences you identified.
5. a **Construct** a conclusion for your investigation.
   b **Assess** whether your hypothesis was supported or not.
6. **Discuss** the idea that one area of the school is more of a health hazard than another area.

2 The milk's off!

Bottled milk in the supermarket has been pasteurised. This means that most of the bacteria present in the milk have been killed. Some remain, however, and in the right conditions for growth they will multiply rapidly and cause the milk to spoil and clot. Acid produced by bacteria causes the clotting.

Purpose

To see how quickly milk spoils under different conditions.

Hypothesis

How will heating affect how fast milk goes off—will heating make milk spoil quicker or slower? Before you go any further with this investigation, write a hypothesis in your workbook.

Materials

- full-cream milk
- universal indicator paper
- access to a refrigerator
- 3 tall, heat-resistant beakers
- plastic wrap
- 3 rubber bands
- saucepan
- spoon
- electric hotplate or stove
- measuring cup
- masking tape
- access to a marking pen

SAFETY

When conducting experiments with micro-organisms, treat them all as if they could cause disease.

Do not touch the milk. If you do, wash your hands thoroughly.

Do not taste, drink or sniff any of the milk.

Procedure

1. Use the masking tape to label each beaker 'Cold', 'Room temp/Control' or 'Boiled'.
2. Test the milk with universal indicator paper and record its colour. Note the results—acid, base or neutral—by comparing the colour of the wet strip with the chart provided with the indicator strips.
3. Pour one cup of milk into the beaker labelled 'Cold'. Cover it in plastic wrap secured with a rubber band. Place this in the refrigerator.
4. Pour one cup of milk into the beaker labelled 'Room temp/Control'. Cover it in plastic wrap secured with a rubber band. Place this in an area at room temperature where it will not be disturbed.
5. Pour one cup of milk into the saucepan and bring the milk to a simmer.
6. Stir continuously while letting the milk simmer for one minute.
7. Test the boiled milk with universal indicator paper and record the colour of the paper.
8. Pour the hot milk into the beaker labelled 'Boiled'. Cover it in plastic wrap secured with a rubber band. Place this in an area at room temperature where it will not be disturbed.
9. Record the appearance of each milk sample every day for 4–5 days. Do not remove the plastic wrap or shake the beaker.
10. At the end of the experiment, when at least one of the samples of milk has separated, open the samples with care. There may be large quantities of bacteria in the milk. The samples should not be shaken and you should not sniff the milk.
11. Place an indicator strip in each beaker and note the colour of each strip.

Results

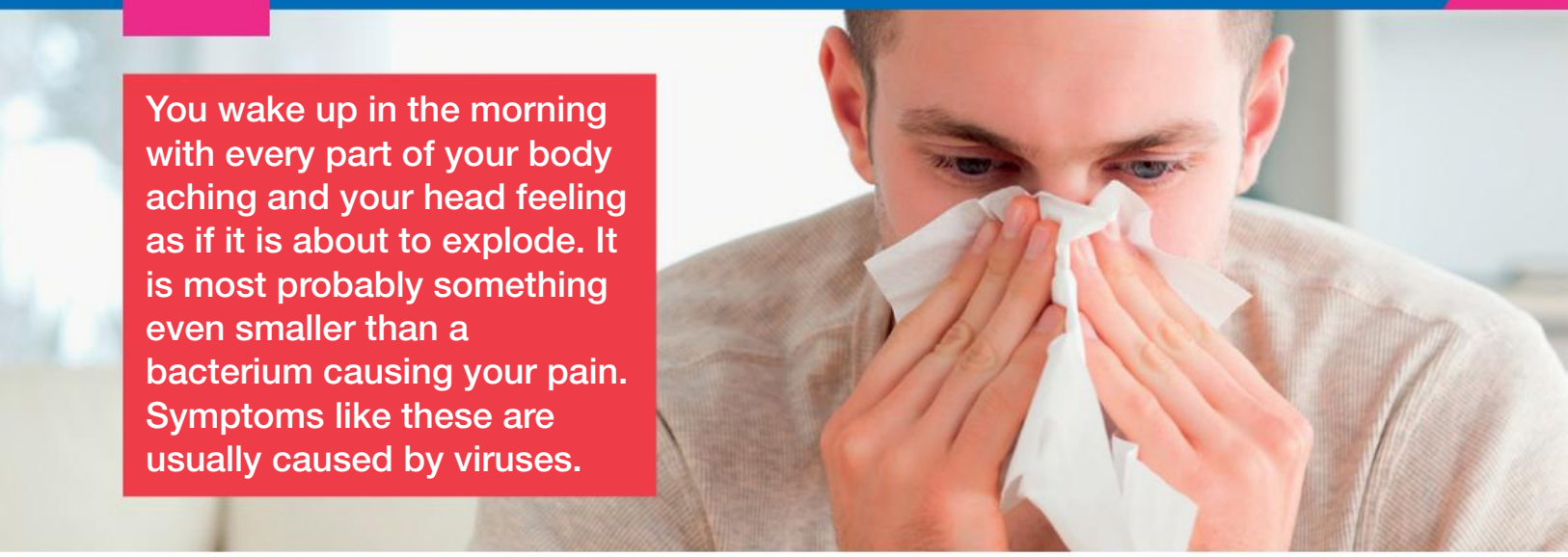
1. Construct a table in which your observations can be recorded.
2. Compare the colour of each strip of indicator paper with the chart provided with the indicator strips. Classify each as acidic, basic or neutral.

Practical review

1. **Describe** what happened in each beaker of milk.
2. **Explain** why you think this happened.
3. **Use** your results to **explain** why milk needs to be kept refrigerated.
4. **Use** your results to **explain** why foods 'go off' faster in warm weather than in cool weather.
5. **Propose** what would have happened to unrefrigerated milk if you lived in a cooler climate.
6. From these results, **propose** recommendations on how other food products such as meat and cream should be stored.
7. a **Construct** a conclusion for your investigation.
   b **Assess** whether your hypothesis was supported or not.

7.2 Other sources of infection

You wake up in the morning with every part of your body aching and your head feeling as if it is about to explode. It is most probably something even smaller than a bacterium causing your pain. Symptoms like these are usually caused by viruses.



Viruses

Viruses cause many common diseases, such as colds and flu. They also cause measles, mumps, rubella, polio, cold sores (herpes), chickenpox and warts like the ones shown in Figure 7.2.1.

Viruses are pathogens and are about 100 times smaller than bacteria. They are so small that they were not seen until the invention of the electron microscope in 1931. Since then, more than 5000 types of viruses have been described in detail.

Scientists debate whether viruses are living things or not. This is because viruses can only grow and reproduce inside cells they have invaded—**host cells**. A virus uses the host cell to make thousands of copies of itself. The host cell is destroyed when it bursts open and releases new viruses that spread throughout the body, infecting and then destroying other cells.

Figure 7.2.1

Warts are abnormal growths caused by a virus that infects skin cells.

Colds and flu

Over 200 different viruses cause colds. There can be thousands of microscopic virus particles in a droplet that is sneezed or coughed out by an infected person. You can see them in Figure 7.2.2. If you breathe in an infected droplet, then the virus has entered your body. Catching a cold is as easy as that.

Although colds are difficult to avoid, you can reduce your chances of catching one or spreading it to others by:

- covering your mouth when you cough or sneeze
- washing your hands frequently
- not sharing personal items if you or the other person are ill
- avoiding close contact with people who are coughing or sneezing or have a runny nose
- staying at home if you are sick so that you do not infect other people.

Figure 7.2.2

Coughing and sneezing pass viruses onto others nearby, quickly spreading the cold through a class, school and eventually your classmates' families.

Atishoo!

The droplets in a sneeze travel out of your mouth at over 160 km/h!

SciFile

The cold virus attacks the lining of the nose and throat. Extra mucus is produced, so your nose keeps running or becomes so blocked up that you feel as though you cannot breathe. Your throat gets sore and red, and you feel unwell.

You can catch flu (influenza) in the same way as catching a cold—by breathing in air containing virus particles, such as those in Figure 7.2.3. Or you may have put your hands near your mouth after touching contaminated surfaces. Flu is not the same as a cold. Both are caused by viruses, but flu develops more quickly and can be more severe. Infection with the flu virus causes a high temperature, and your whole body aches. However, your nose will not run as much as it would with a cold.

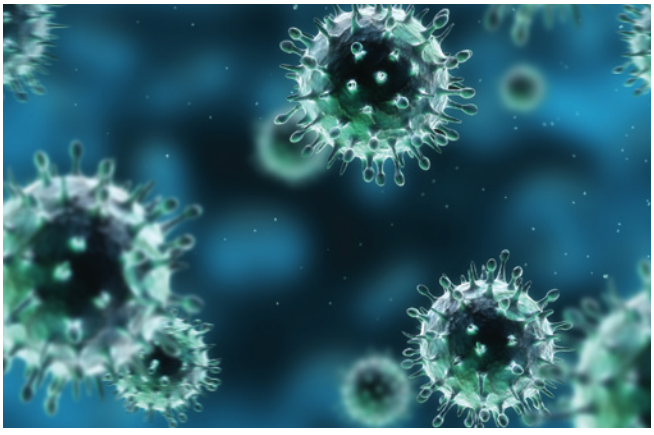


Figure 7.2.3 An artist's impression of the virus that causes flu. The symptoms that you have the disease are a high temperature and aching muscles.

Antibiotics do not work against viruses. However, sometimes when you have a viral infection, bacteria invade the body and cause secondary infections. These can be treated with antibiotics. Coughing up green phlegm indicates a bacterial infection. Bronchitis and pneumonia are common secondary bacterial infections of a body weakened by fighting a virus.

Your body develops immunity to flu viruses, but you can get flu more than once. This is because viruses are able to change quickly and new strains can appear. For each new strain of flu virus, the body has to make new antibodies.

Also, medical researchers have to make different vaccines because vaccines can only be made for strains of a virus that are known.

Flu infections are usually treated as a nuisance, but they can be fatal for people with low immunity (for example, the elderly or the very young) or with other illnesses. Flu causes more than 4000 deaths in Australia each year.

7.5

Childhood diseases

When you are born, your body has not yet had the chance to build up the antibodies you need to keep you healthy. This is why children tend to come down with lots of diseases that rarely affect adults.

Measles

Measles is a viral disease spread by infected people coughing and sneezing. It starts with a runny nose and sore eyes. A couple of days later a rash like the one in Figure 7.2.4 appears. In the past, doctors did not worry about this common childhood illness, but now they are aware of serious side-effects. Severe cases of measles can result in permanent hearing problems or brain damage.

When European settlers first came to Australia, they brought measles with them. The Aboriginal population had no natural immunity, and measles killed a large number of them, especially children.

Measles is one of the most contagious diseases. Since 1966, children have been routinely immunised, resulting in the disease becoming very rare in Australia.

Figure 7.2.4 Measles rash

Chickenpox

The chickenpox virus causes a runny nose and a slight fever, followed by a rash of small, very itchy blisters. Scratching the blisters can lead to permanent scarring or to secondary bacterial infections of the blister.

After a person has been infected, the chickenpox virus can remain inactive in the nerve cells of their body for many years. Twenty, thirty or even forty or more years later, the virus can become active again, causing shingles—a very painful rash that can last for weeks. Figure 7.2.5 shows what the blisters of chickenpox and the rash from shingles look like.

Routine immunisation against chickenpox did not start until 2006, so infections still occur. However, the number of infections should decline as more and more children are immunised.

Figure 7.2.5 Immunisation against chickenpox protects you from getting chickenpox. It also protects you from developing shingles later in life.

Parasitic diseases

A parasite is an organism that lives on or in the body of another organism (the **host**) and takes nutrients from it. The host gets nothing in return and may be harmed. Some parasites can cause serious disease in humans.

Malaria

Malaria is an infection caused by a parasitic protozoan organism called *Plasmodium*. Mosquitoes, such as the one shown in Figure 7.2.6, carry the *Plasmodium* from one host to another. As the mosquito pierces the skin, it injects a chemical (an anticoagulant) into the host's body to prevent the blood from clotting. The *Plasmodium* is injected along with the anticoagulant.

Malaria is one of the most widespread human diseases caused by a parasite. In the 1950s, there were 250 million cases of malaria each year, with 2.5 million deaths.

Figure 7.2.6 Mosquitoes carry the *Plasmodium* (a member of the protist kingdom) from one host to another, infecting a new host as it bites them and sucks their blood.

Then the World Health Organization (WHO) coordinated efforts to control the disease. It was eradicated from many areas, including Europe, North America and Australia. In Australia, complete eradication was declared in 1981. This means that you cannot become infected with malaria in Australia. In 1988 'only' 110 million new cases were reported worldwide, but this trend has changed and now there are up to 220 million new cases of malaria each year.

Malaria has not returned to Australia, but mosquitoes capable of transmitting the disease live in northern Australia above the latitude of 19°S (Figure 7.2.7). About 700–800 people are hospitalised with malaria in Australia each year. These people were all infected elsewhere, mostly in Papua New Guinea.

Figure 7.2.7 Travellers to Papua New Guinea sometimes bring malaria back into Australia.

Preventing infection means preventing mosquito bites in areas where the disease could return. If visiting northern Australia or South-East Asia:

- wear protective clothing
- use insect repellent
- if your windows are not screened, use a mosquito net when sleeping
- empty any standing water where mosquitoes could breed.

Insecticides can be used to control mosquito numbers. However, insecticides may also kill useful insects such as bees, so they should be used with caution.

Target blue

Mosquitoes are attracted to the colour blue more than twice as much as any other colour!

SciFile

Amoebic dysentery

Most of Australia is supplied with fresh, clean water, and sewage is treated effectively. This protects you from many diseases found in other parts of the world. You only come into contact with these diseases if you travel overseas, or if some disaster at home damages the sewage system or contaminates the drinking water (Figure 7.2.8). One disease spread through contaminated water is amoebic dysentery. This disease causes 50 000–100 000 deaths per year worldwide.

Figure 7.2.8 There is a greater chance of contracting amoebic dysentery when there is poor (or no) sewage treatment and the water supply is contaminated.

Amoebic dysentery is caused by a single-celled organism that is most common in tropical areas. People become infected by swallowing a cyst containing the parasite in contaminated food or water. The cyst is one stage in the life cycle of the parasite.

People who contract the disease can remain infectious for years, so it is best to prevent infection in areas where amoebic dysentery occurs. When travelling in these areas, only drink boiled water or sealed, bottled water, don't have ice in your drinks and don't eat fruit or vegetables that may have been rinsed in tap water and not cooked.

Fungi

Fungi such as mushrooms are useful as a source of food. Others are decomposer organisms in the environment. Some fungi cause disease. Very few of the diseases they cause are life-threatening. Most are simply a nuisance.

Fungi disperse (spread) by **spores**, which are made of a single cell with a tough skin. Fungal spores are everywhere. A cloud of spores can be seen leaving the puffball fungus in Figure 7.2.9. The spores just need to find a warm, moist environment and they will start to grow. The warmest, most sweat-prone parts of the human body are the feet and the groin. It is there that pathogenic fungi such as tinea and thrush are most likely to grow.

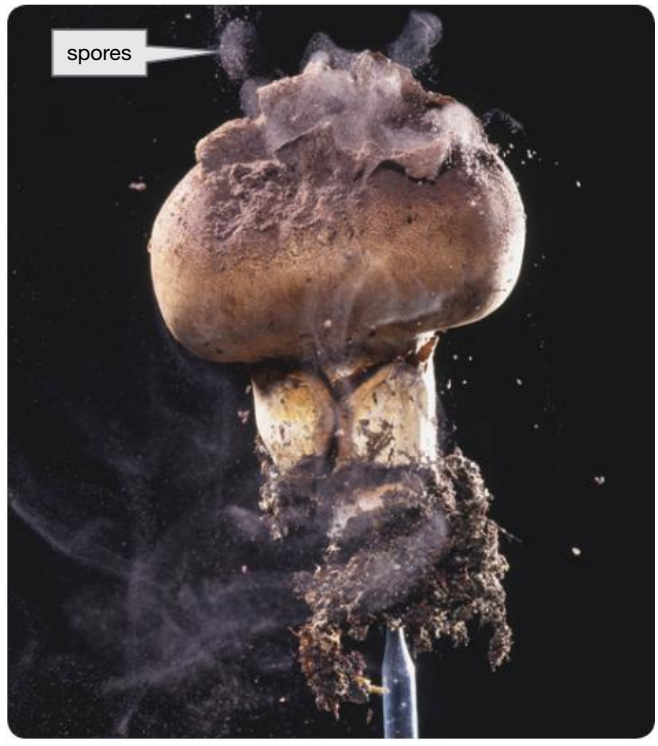


Figure 7.2.9 This large puffball fungus does not cause disease. However, like all fungi, it releases spores that are light and easily blown about in the wind.

Fungal infections are contagious. They can be passed from one person to another through skin-to-skin contact, the sharing of towels, or walking on floors that an infected person has walked on.

INQUIRY science 4 fun

Where do spores come from?

YES

Collect this …

- mushroom that is open, with dark brown gills under the cap
- sheet of white paper

SAFETY

Dispose of the mushroom and the paper in the bin when you are finished.

Wash your hands well after handling the mushroom.

Do this …

1. Place the mushroom on the sheet of paper with the gills facing down.
2. Leave it in an area where it will not be disturbed for two days.
3. Without moving the paper, lift the mushroom carefully off the sheet of paper. There should be a deposit of black spores on the paper.

Record this …

Describe the pattern on the paper. You could draw a picture or take a photograph.

Explain where the spores came from and what would normally happen to them.

Prac 1 p274 Prac 2 p274

Tinea

Tinea is a fungus that can grow on the skin, hair or nails. It grows out from a centre, producing a red, inflamed ring of skin, as shown in Figure 7.2.10. Tinea infection is often called ringworm, but no worms are involved. The tinea fungus feeds on dead skin cells. When it runs out of dead cells it will attack the living cells, causing the skin to become red and itchy. If not treated, the skin will crack and bleed. Figure 7.2.11 shows an example. The infection can be treated with a **fungicide**—a chemical that kills fungi.

Figure 7.2.10

Tinea infection is often called ringworm because of the shape of the inflamed area.

Figure 7.2.11

Tinea infection between the toes

Thrush

Thrush infection is caused by fungus that is normally found in your body. Sometimes it grows out of control, causing problems. Thrush is not serious, but is very itchy and uncomfortable. It can be found as white patches on the tongue (as you can see in Figure 7.2.12) or inside the cheek, causes nappy rash in babies, and may infect the vagina.

Thrush sometimes develops when you are taking antibiotics because the bacteria that naturally control fungi have been destroyed by the antibiotics.

Figure 7.2.12

An oral thrush infection causes the tongue to be white.

LEARNING ACROSS THE CURRICULUM

INTERCULTURAL UNDERSTANDING

NATURAL DISASTERS AND DISEASE

Natural disasters can affect thousands or millions of people. Nine hundred thousand people were forced to leave their homes when monsoonal floods swamped the northeastern Indian state of Assam in June 2012. Two months later, 3.4 million people in the Philippines were affected by flooding (Figure 7.2.13). Earthquakes made over one million people homeless in southwestern China in September 2012.

Figure 7.2.13 Following a natural disaster, homes are destroyed and living conditions may not be hygienic.

When major disasters cause large numbers of people to be displaced, the threat of disease quickly follows. Damage to water treatment plants leads to a lack of safe drinking water. If affected areas cannot be accessed, then the sick and injured will not receive medical attention.

Cholera is caused by the bacterium *Vibrio cholerae*, shown in Figure 7.2.14. It is spread through contaminated food and water. Where sewage treatment and health standards are good, cholera is not a problem and people who contract the disease can be treated successfully. When major floods and earthquakes damage sewage treatment plants, untreated sewage can enter the floodwaters or rivers from which drinking water is collected.

In September 2012, the African country of Niger was facing a severe outbreak of cholera. Floods through the months of July, August and September affected over 500 000 people. Homes and public buildings were destroyed, along with large quantities of food. People displaced by the floods were being accommodated in schools and mosques. Cholera spread quickly through the community, killing over 80 individuals and causing nearly 4000 people to become sick.

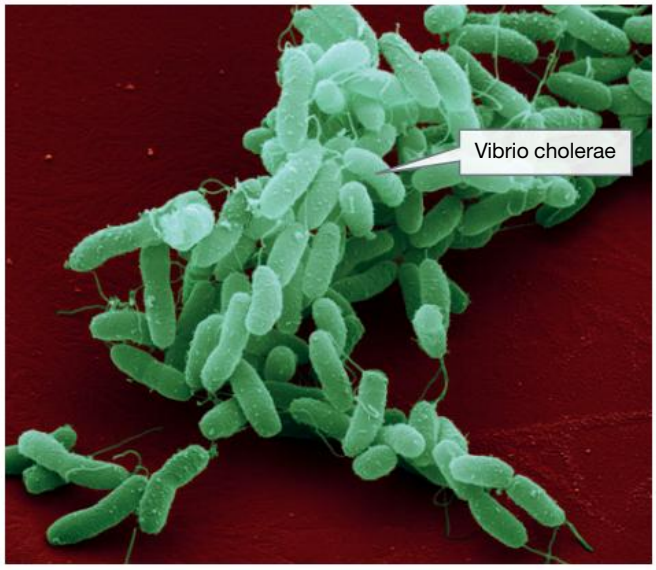


Figure 7.2.14 The bacteria that cause cholera are spread through contaminated food and water.

A vaccine against cholera is available and most people in Australia have received the vaccination. However, in many poorer countries such as Niger, the population is not vaccinated. When an epidemic occurs, it is too difficult and expensive to vaccinate the number of people required to prevent the spread of the disease.

In the hot, humid conditions following floods in places such as India and the Philippines, dengue fever and malaria can spread easily through camps where people made homeless have taken refuge. Dengue fever is a parasitic disease carried by the *Aedes aegypti* mosquito. People who have lost their homes in floods can find it difficult to protect themselves against mosquito bites. The conditions they experience can be seen in Figure 7.2.15.

- They often do not have a building to sleep in.
- They do not have anything to which a mosquito net could be attached.
- During the wet season the nights are hot and humid, so it is difficult to keep children covered while they sleep.
- Insect repellent would only be effective if it was reapplied every few hours.
- Pools of stagnant water created as the floodwaters drain away are ideal places for mosquitoes to breed.

REVIEW

1 **Outline** why disease often becomes a problem following a natural disaster.

2 **Explain** why cholera is likely to spread after a severe flood.

3 a **Deduce** whether or not a cholera epidemic could occur if there was a major natural disaster in Australia.

b **Justify** your response.

4 **Explain** why malaria and dengue fever are more likely to affect survivors of a flood in a tropical country than in a cooler place.

5 a **Assess** the reasons for malaria and dengue fever spreading through populations of flood victims. **List** the reasons in order from the most significant to the least significant.

b **Justify** the order of your list.

Prac 3 p275

Figure 7.2.15 The conditions in camps for people displaced by floods are often crowded. In these situations, disease can spread easily.

7.2 Unit review

Remembering

1 **Name** two diseases caused by viruses.

2 **Name** the type of organism that causes malaria.

Understanding

3 **Describe** the relationship between spores and fungi.

4 **Explain** the role (function) of the host cell in a viral infection.

5 **Outline** how malaria is spread.

6 **Explain** how the virus that causes colds is spread.

7 **Explain** how someone can get the flu even though they were vaccinated against it.

8 a **Explain** why taking antibiotics for a viral infection is a waste of time.
b **Describe** a situation where it is appropriate for a doctor to prescribe antibiotics for someone with a viral infection.

9 **Explain** why measles caused so many deaths when it was first introduced to the Australian Aboriginal population.

Applying

10 **Use** diagrams to **demonstrate** how walking barefoot can spread tinea.

Analysing

11 **Compare** bacteria and viruses.

12 **Contrast** colds and flu.

Evaluating CCT

13 The mosquito is rated by many as the most dangerous animal on Earth. **Justify** why the mosquito is often considered more dangerous than crocodiles, sharks or lions.

14 Jan said that mosquitoes cause malaria. Kai said that was not a true statement.
a **Evaluate** the statement and decide who is more accurate.
b **Justify** your answer.

15 A family in northern Queensland knows that dengue fever is carried by mosquitoes and that there are cases of it their area. **Propose** ways they could protect themselves from the disease.

16 **Propose** reasons why there will never be a vaccine to stop you from catching a cold.

17 **Deduce** why fungi can start growing wherever conditions are suitable when there do not appear to be any other fungi in the area.

Creating CCT

18 **Construct** the scenario (story) for a 30-second television advertisement that makes people aware of how viral or fungal infections are spread, and ways they can prevent the spread. L

Inquiring

1 Gather information about viral diseases such as dengue fever, ebola, Murray Valley encephalitis, Ross River fever, rubella, poliomyelitis and AIDS.

Find out:

- where in the world these diseases are a problem
- how these diseases are transmitted
- what is being done on a local or worldwide scale to control these diseases.

Identify the disease you think should have most resources allocated for future research. Explain your decision.

Present your findings as a written report. L

2 Find the names of diseases carried by mosquitoes. For these diseases, gather information about:

- symptoms of the disease
- possible treatments and expected outcomes
- the number of cases of the disease each year
- the distribution throughout the world
- any control or eradication programs.

Present your findings in digital form. ICT

ADDITIONAL

3 Professor Ian Frazer was named Australian of the Year in 2006. Research:

- why he received this award
- the benefit to society of his medical research.

Present your findings in digital form. ICT WE

ADDITIONAL

7.2 Practical investigations

1 Growing fungi

Purpose

To investigate what causes fruit to rot and to find out if all fruits rot in the same way.

Hypothesis

Which do you think will rot faster—cut fruit or whole fruit? Before you go any further with this investigation, write a hypothesis in your workbook.

Materials

- a selection of fruit including:
  - 2 apples
  - 2 pieces of soft fruit such as a strawberry
  - 2 lemons
- paper towel
- marker pen
- 2 plastic boxes such as take-away containers

SAFETY

Dispose of all the fruit used in this investigation according to your teacher's instructions.

Wash your hands thoroughly after handling the fruit.

Procedure

1. Read through all the steps of this procedure before you do anything.
2. Use the marker pen to label each container 'Cut fruit' or 'Whole fruit'.
3. Wash all the fruit carefully and pat it dry with the paper towel. Do not bruise the fruit.
4. Place one apple, one of the soft fruits and one lemon into the plastic container labelled 'Whole fruit'.
5. Using a clean, sharp knife, make a cut in the skin of the other apple. Wash the knife and then make a cut in the lemon. Be sure to cut through the skin into the segments. Wash the knife and then cut the soft fruit.
6. Place the cut fruit into the container labelled 'Cut fruit' cut side up.
7. Leave the fruit in a well-ventilated area for 3–5 days.

Results

1. Write what you predict will happen to the fruit in the two different treatments.
2. Each day, observe the fruit and record any changes in its appearance. You could use photographs to support your notes.

Practical review

1. **Compare** the changes in the whole fruit with the changes in the cut fruit.
2. **Suggest** what could have caused the changes.
3. **Compare** the changes in the apple and the lemon.
4. **Compare** the changes in the apple and the soft fruit.
5. **Explain** what caused the changes in the fruit.
6. **Explain** why the changes were not the same for all the fruit.
7. a **Construct** a conclusion for your investigation.
   b **Assess** whether your hypothesis was supported or not.

STUDENT DESIGN

2 Floor free of fungi

Tinea is a fungus spread by spores.

Purpose

To test a variety floor coverings to find out if they are all able to spread fungal spores to the same extent.

Materials

- a selection of different floor coverings such as carpet, wood, tiles (rough and smooth) and vinyl
- prepared agar plates as required

Procedure

1. Design an experiment that will test whether different floor surfaces will harbour fungal spores and therefore spread infection.

SAFETY

A risk assessment is required for this investigation.

2 Brainstorm in your group and come up with several different ways to investigate the problem. Select the best procedure and write it in your workbook.

3 Before you start any practical work, assess all risks associated with your procedure. Construct a risk assessment that outlines these risks and any precautions you need to take to minimise them. Show your teacher your procedure and risk assessment. If your teacher approves, then collect all the required materials and start work.

Hints

- Use a damp cotton bud or tissue to collect samples from the different surfaces.
- Ask your teacher how to prepare agar plates.

Results

Record the number of fungal colonies that were grown from the different surfaces tested.

Practical review

1 **List** the variables that you controlled (kept constant) during this experiment.

2 **State** the variable that you changed.

3 **Describe** the way in which this variable changed.

4 **Use** the differences between the floor surfaces to **explain** your results.

5 **Deduce** whether a floor surface could be produced that would not allow fungal spores to spread.

6 **Evaluate** your procedure. Pick two other practical groups and **evaluate** their procedures too, identifying their strengths and weaknesses.

STUDENT DESIGN

3 Alcohol-based handwash

Purpose

To test the effectiveness of alcohol-based handwashes as a means of controlling disease.

Hypothesis

Do you think alcohol-based handwashes are as effective as washing your hands with hot water and soap? Before you go any further with the investigation write a hypothesis in your workbook.

Materials

- alcohol handwash
- soap
- prepared agar plates if required

SAFETY

A risk assessment is required for this investigation.

Procedure

1 Design an experiment that will test whether alcohol-based handwashes are effective in controlling the spread of disease.

2 Brainstorm in your group and come up with several different ways to investigate the problem. Select the best procedure and write it in your workbook.

3 Before you start any practical work, assess all risks associated with your procedure. Construct a risk assessment that outlines these risks and any precautions you need to take to minimise them. Show your teacher your procedure and your risk assessment. If they approve, then collect all the required materials and start work.

Results

Construct a table to record the number of bacterial and fungal colonies in different samples.

Practical review

1 **List** the variables that you controlled (kept constant) during this experiment.

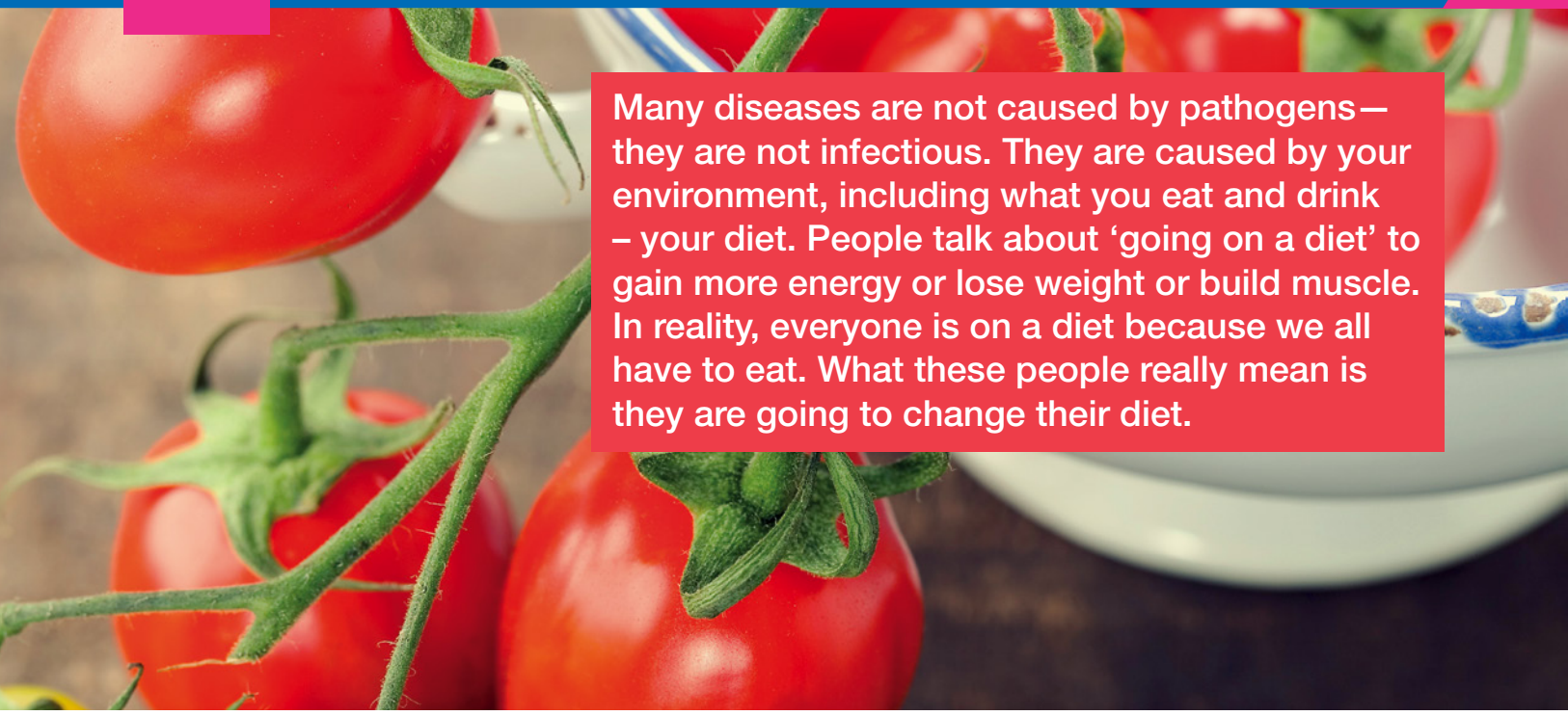
2 a **State** the variable that you changed.
b **Describe** the way in which this variable changed.

3 **Construct** a conclusion for your experiment.

4 **Assess** whether your hypothesis was supported or not.

5 **Evaluate** your procedure. Pick two other practical groups and **evaluate** their procedures too, identifying their strengths and weaknesses.

7.3 Non-infectious diseases



Many diseases are not caused by pathogens—they are not infectious. They are caused by your environment, including what you eat and drink – your diet. People talk about 'going on a diet' to gain more energy or lose weight or build muscle. In reality, everyone is on a diet because we all have to eat. What these people really mean is they are going to change their diet.

Nutrition

What everyone needs from their diet is **nutrition**—the food necessary for health and growth. **Nutrients** are substances essential for healthy growth and maintenance of your body. The nutrients you need from your food are proteins, carbohydrates, fats, minerals and vitamins. Water is also an essential part of any diet.

- **Protein** is used for growth and repair and comes from meat, fish (Figure 7.3.1) and dairy products.
- **Carbohydrates** are your main source of energy. Starches and sugars found in grains (such as wheat and oats) as well as in fruit and vegetables are carbohydrates.
- **Fats** provide twice the amount of energy as carbohydrates. Your body stores energy as fat. Oils and the fat found in meat and dairy products such as cheese are sources of fat.
- **Minerals** such as iron, calcium, sodium, potassium and phosphorus do not provide energy but they are important for your health. Iron is part of haemoglobin in red blood cells. Calcium and phosphorus build strong bones and teeth. Phosphorus is essential for effective metabolism. Sodium and potassium balance the water content of your body. Nerves and muscles, including the muscles of your heart, need sodium to work effectively.
- **Vitamins** control many of the chemical reactions in the body. They are required in only minute amounts.
- Water provides no energy or other form of nutrition but it is essential for health. Your body is more than 60% water. All the chemical reactions of metabolism take place in the watery environment of your cells. Water in the blood carries nutrients around the body to where they are used.

Prac 1 p285

Figure 7.3.1

This meal of salmon and rice will provide protein and carbohydrates.

Water of life

If you lose 10% of the water in your body, then you will become ill. Losing 20% usually means death. You can survive up to 40 days without food but no more than 3 days without water.

SciFile

INQUIRY

science 4 fun

Look at the labels

YES

Collect this ...

- labels of four of your favourite snack foods or drinks

Do this ...

1. Read the nutrition information on each label.
2. Identify which essential nutrients each snack or drink provides.

Record this ...

Describe the snacks in terms of the nutrients they provide.

Explain which snack you would choose to eat and why.

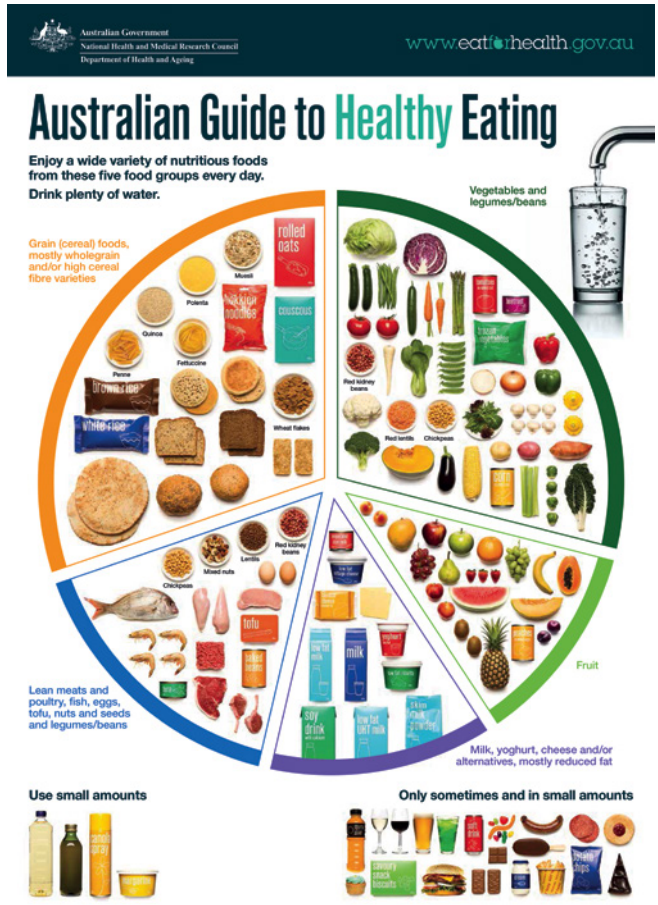


Figure 7.3.2 Enjoy food from each sector of the plate every day. The size of the sector indicates the relative amount of each group to include in your diet.

Healthy diet

Disease occurs when people do not get enough to eat. It can also be the result of eating too much or eating the wrong things. The Australian Government has produced *The Australian Guide to Healthy Eating* to provide guidance on what to eat and how much to eat in a healthy diet. This guide classifies foods into five groups:

- bread, cereals, rice, pasta, noodles
- vegetables, legumes
- fruit
- milk, yoghurt, cheese
- meat, fish, poultry, eggs, nuts, legumes.

Food should be eaten from each of the five groups every day. However, you do not need equal quantities from each group. The proportions of the sectors on the plate in Figure 7.3.2 indicate the relative amounts of each food group that should be consumed.

Sweets, cakes and hot chips can be part of a healthy diet as long as they are eaten only occasionally.

Eat your veggies!

One in ten adults in Australia does not eat the recommended five serves of vegetables per day, and half the adult population does not eat the recommended two serves of fruit.

SciFile

Under-nutrition

Malnutrition occurs when the nutrition provided by diet does not meet the needs of the body. Malnutrition can mean not having enough of the nutrients the body requires. This is called **under-nutrition**. Many children in the world are not healthy because they do not get enough food and so lack the nutrients needed for normal growth and development and the energy required to play normally.

Kwashiorkor

When food is in short supply, it is often protein that is missing from the diet. Without protein the body cannot build up muscle and brain development is slowed. Children lacking protein may develop a disease called **kwashiorkor**. The child in Figure 7.3.3 has kwashiorkor as shown by the pot-belly, which is caused by weak stomach muscles. Other symptoms include hair loss, swollen legs and no energy. Kwashiorkor kills 60% of the children who suffer from it.

Figure 7.3.3

A child with kwashiorkor looks as if they are fat because of their swollen belly. In reality they are starving.

Scurvy

Sailors are often at sea for very long periods of time. In the past, many of them developed a disease called **scurvy**. Their gums bled, their teeth fell out (Figure 7.3.4), their joints became sore and swollen, and wounds were slow to heal and became infected. Scurvy is caused by a lack of vitamin C, a vitamin found in many fruits and some vegetables. Especially high quantities of vitamin C are found in blackcurrants and in citrus fruits.

Figure 7.3.4

This man has scurvy, caused by a lack of vitamin C.

Rickets

Children lacking vitamin D and calcium may develop **rickets**, a disease that causes the bones to remain relatively soft. When babies learn to walk, their legs are carrying weight for the first time. If a baby has rickets, then the bones bend outwards and the legs take on the shape seen in Figure 7.3.5. This is typical of a person suffering from rickets.

Figure 7.3.5

The femur (thigh bone) and the tibia (shin bone) are bent outwards in this person with rickets.

It makes your mouth water

The average human produces almost one litre of saliva every day! This adds up to about 38 000 litres in a lifetime. You need saliva though. If your mouth was completely dry, then you would not be able to taste the difference between meat or bread, chocolate cake or an apple.

SciFile

Calcium hardens the bones and vitamin D helps the body to use the calcium. Calcium is found in milk and green vegetables. Vitamin D is found in fish oils. Your body can also manufacture vitamin D in the lower layers of the skin by using the ultraviolet rays of sunlight.

SciFile

Captain Cook's cure

In the time of Captain James Cook, fresh fruit and vegetables were scarce on long voyages. Captain Cook managed to reduce the prevalence and severity of scurvy on his ships by encouraging his men to have cabbage or lemon and orange juice, which are good sources of vitamin C.

Over-nutrition

Over-nutrition is another form of malnutrition. It is when the body gets so much nutrition that it does not work properly.

Over-nutrition results from eating too much, eating too many of the wrong things, not exercising enough, or taking too many vitamins or other dietary replacements. Over-nutrition can lead to many **chronic diseases** such as diabetes and high blood pressure. Chronic diseases last for a long time. Some cannot be cured. They can only be managed.

Overweight and obese

The human body is designed to conserve energy. If the diet provides more energy than the body needs, then the extra energy is stored as fat under the skin and around internal organs such as the heart. Storing too much (because you need some stored fat to be healthy) energy as fat leads to an unhealthy increase in weight. Too much stored fat leads to being overweight and more fat storage leads to obesity.

The number of people who are overweight or obese is increasing very rapidly in Australia. Figures 7.3.6 and 7.3.7 show the change in numbers of overweight and obese children (5–17 year olds) in the years from 1985 to 2007–08.

The children who were 5–17 years old in 1995 were in the 18–30-year age group in 2007–08. Figure 7.3.8 on page 280 shows how the statistics for this group had changed.

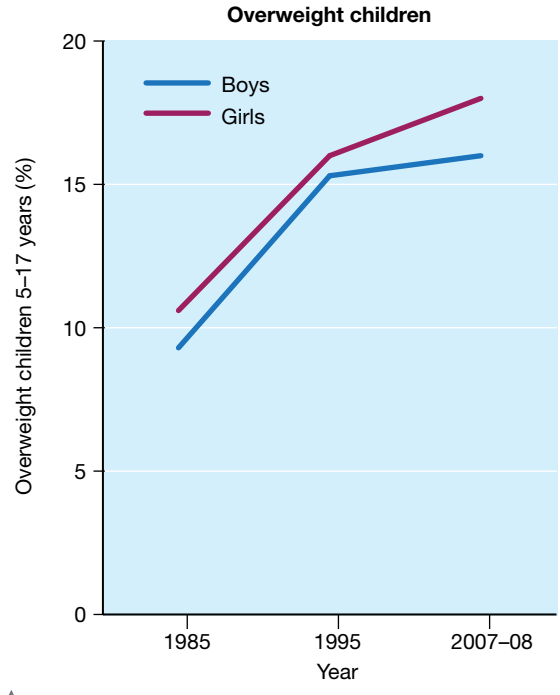


Figure 7.3.6 The percentage of overweight boys and girls increased significantly from 1985 to 1995, and then increased at a lower rate from 1995 to 2007–08.

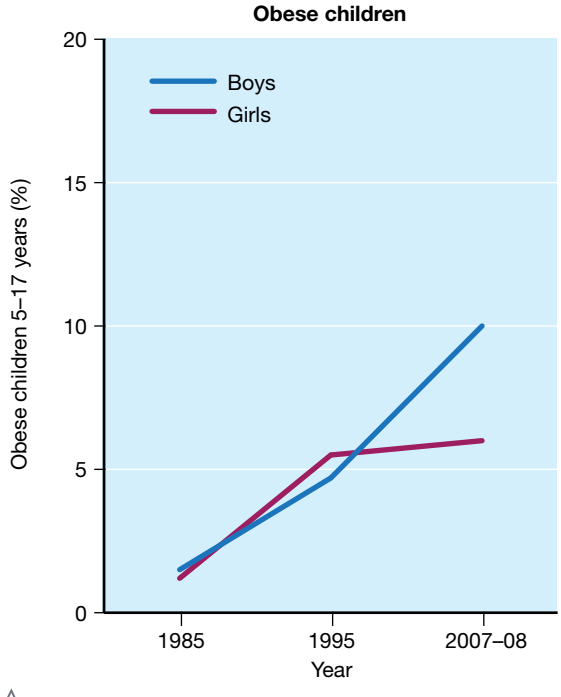


Figure 7.3.7 The percentage of obese boys and girls has increased since 1985. In 1995, the rate of increase changed for both sexes but in different ways.

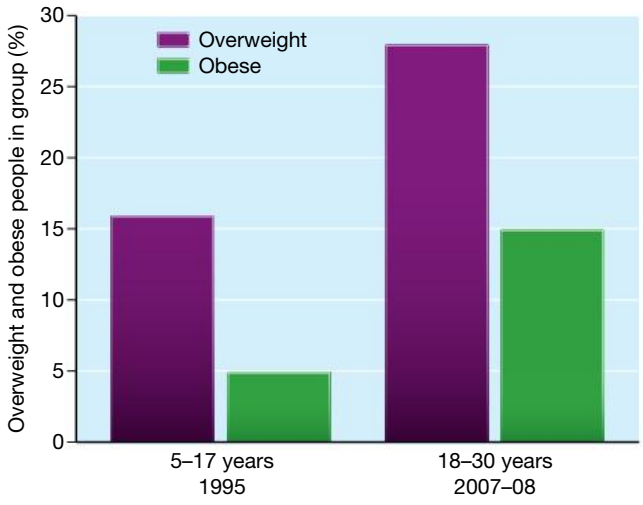


Figure 7.3.8 As the group of 5–17 year olds in 1995 have aged, the percentage that is overweight has increased 1.75 times. The level of obesity has trebled.

Since 1985, Australians have increased their energy consumption. At the same time, they have reduced their energy needs because they are not so physically active. For many, watching television, surfing the internet, social media and playing computer games take up more time than sport and lighter exercise such as walking. If the Australian population is to remain healthy, then this trend has to change.

Too much salt

For many people the first thing they do when they sit down to a meal is add salt to the food. A small amount of salt is important in your diet. Your kidneys need salt to balance the water and salt in your body. This balance ensures that there is the correct amount of water in your cells and tissues and the correct volume of blood circulating around your body.

Fruit and vegetables have salts in their cells and there is salt in meat and whole grains. By eating these foods, you gain all the salt your body requires.

Many processed foods have a high salt content and you can taste the salt. A small bowl of breakfast cereal like the one in Figure 7.3.9 has about the same amount of salt as a small packet of plain chips, and some sweet biscuits have as much salt as savoury biscuits.

Figure 7.3.9 Simple processed foods such some breakfast cereals contain considerable amounts of salt.

Most Australians consume eight to nine times the amount of salt that they need each day and 75% of this comes from processed foods. Lots of salt makes the kidneys work overtime and can lead to kidney failure. It is also linked to high blood pressure.

Prac 2 p286
Prac 3 p287
7.6
7.7

High blood pressure

Your heart is the pump that causes your blood to circulate within your body. Your heart beats, forcing blood out of the heart. Your blood is under pressure when it enters your arteries. Between heartbeats the pressure in your arteries falls. During exercise your heart works very hard and your blood pressure increases and then falls again when you rest. Therefore, it is normal for your blood pressure to vary throughout the day.

When the pressure in the arteries stays high between heartbeats and during rest, the person is suffering from **high blood pressure**. The constantly high pressure strains the artery walls. It also causes fats from the blood to stick to the artery walls. The arteries become clogged, causing the heart to pump even harder to get the blood through. The blood pressure increases further.

Doctors regularly check patients' blood pressure because high blood pressure does not produce symptoms (Figure 7.3.10). Without diagnosis, people may not know they have high blood pressure until something major happens such as:

- **heart attack**—when part of the heart muscle is damaged or dies because the blood supply is blocked or severely reduced
- **stroke**—when part of the brain is damaged or dies because the blood supply is blocked or severely reduced.

Figure 7.3.10 Regular measurements are needed to ensure that blood pressure is within healthy limits.

SciFile

Long way

The human heart creates enough pressure to squirt blood 9 metres. This could happen to you if you cut a major artery. Thankfully, your major arteries are protected deep inside your body.

Caffeine

Caffeine is a drug, a stimulant that acts on the brain to speed up the rate at which messages move around the body. It is found in coffee, tea, chocolate, cola and energy drinks and is part of everyday life in Australia for most adults and many children (Figure 7.3.11).

The specific effect of caffeine depends on age, body size and general health. If you consume caffeine only occasionally, then it may affect you differently from someone who consumes it regularly. The side-effects of caffeine include increased breathing and heart rates, restlessness, dizziness and headaches. Children who consume energy drinks containing caffeine might experience sleep problems and anxiety.

Figure 7.3.11 Caffeine is found in coffee and energy drinks. It is a stimulant that can keep a person more active for up to 12 hours and may have some long-term effects if consumed in large quantities.

Diabetes

Diabetes is a complex disease caused by a lack of insulin or an insensitivity to insulin. A person who suffers from diabetes is a **diabetic**. **Insulin** is the hormone that lowers the level of glucose in the blood.

The energy your body uses comes from glucose produced by the digestion of the food you eat. Glucose moves from the digestive system into the blood. From the blood glucose moves into the cells, where it is broken down in the process of cellular respiration to release energy. The process is shown in Figure 7.3.12. The hormone insulin moves the glucose from the blood to the cells. Without insulin, glucose remains in the blood and the energy needed for growth, repair, and other essential functions is not released.

There are two main types of diabetes—type 1 and type 2.

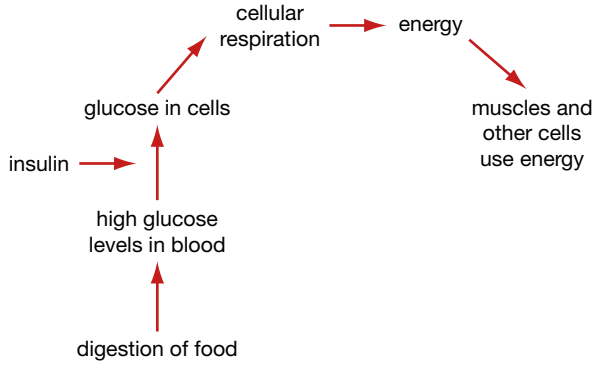


Figure 7.3.12 The hormone insulin controls the movement of glucose into the cells where it can be used.

Type 1 diabetes

In **type 1 diabetes**, the body stops making insulin. Reasons for this are not known. A person with type 1 diabetes may eat well but their body is undernourished because they cannot release any energy from their food. Part of the treatment for people with type 1 diabetes regularly test the levels of glucose in their blood (Figure 7.3.13) and then inject themselves with insulin to replace the insulin that their body fails to make. The diabetic can then get the nutrition they need from the food they eat.

Figure 7.3.13 People with diabetes must check the glucose levels in their blood regularly so they know how much insulin to take.

Type 1 diabetes accounts for 10–15% of cases of diabetes in Australia. It is usually found in people under the age of 30. There could be a genetic link to type 1 diabetes, meaning that the disease is caused by inherited characteristics. Type 1 diabetes is not linked to lifestyle, but eating well and exercising regularly is essential for managing the disease.

Type 2 diabetes

In **type 2 diabetes**, the body has become resistant to insulin. The levels of insulin in the blood are normal or may be higher than normal but the body cannot use the insulin. This is the form of diabetes found in 85–90% of people with diabetes.

Glucose levels in the blood of type 2 diabetics are permanently high. When the blood glucose level gets to a certain point, the body converts the glucose to fat. People with type 2 diabetes can therefore gain weight very easily. When the disease is first diagnosed, people with type 2 diabetes can often control the problem with diet and exercise (Figure 7.3.14). Later they will also have to inject themselves with insulin just as people with type 1 diabetes do.

Type 2 diabetes may have a genetic link. However, it is also closely connected to lifestyle. A diet high in fat, sugar and refined foods increases the risk of type 2 diabetes.

7.8

Figure 7.3.14 Taking regular exercise is a way of preventing type 2 diabetes. Just half an hour of walking a day will dramatically reduce the risk of developing type 2 diabetes and is a means of controlling it if the disease develops.

Environmental disease

Our environment can affect our health. It is not just the pathogens in our environment that we have to be careful of. Naturally occurring minerals and human-made chemicals can be harmful to our health. For example, asbestos is a naturally occurring mineral that can cause severe health problems.

GO TO Unit 1.4

Asbestos miners, people who worked with asbestos products and people who lived in mining areas developed illnesses with very similar symptoms. They had a persistent cough, shortness of breath and blue colour to their lips.

These people were diagnosed with **asbestosis**, which is a lung disease caused by breathing in asbestos fibres. Asbestos fibres are shown in Figure 7.3.15. Each asbestos fibre is 50–200 times thinner than a human hair and when the fibres are floating in the air they cannot be seen. When the fibres are breathed in, they remain in the lungs and cause inflammation and scarring. The hard, inflexible scar tissue makes it difficult to get enough oxygen into the body, causing the lips to turn blue.

Asbestos can also cause mesothelioma—a cancer that develops 30–40 years after exposure to asbestos.

Asbestos had been mined and used widely for a long time before any danger was recognised. However, from 31 December 2003 the use of all forms of asbestos was banned in Australia. Although asbestos cannot be used in new buildings, it is still found in old buildings and is gradually being replaced by safer materials. Anyone working with asbestos needs to wear safety clothing like that shown in Figure 7.3.16.

Figure 7.3.16 Workers removing asbestos from buildings must wear safety clothing and a mask.

Figure 7.3.15 Fibres of asbestos look like cotton wool, but they are not soft. Asbestos fibres are fire-resistant and very strong. They were used to make corrugated roofing, water pipes, fabrics, and brake linings.

7.3 Unit review

Remembering

1 **List** the nutrients required in any diet.

2 **State** the function in the body of:
- a vitamins
- b calcium
- c iron
- d protein.

3 a **Name** two diseases caused by a lack of vitamins.
b **Name** the vitamin that is lacking in both diseases.

Understanding

4 **Define** the term: L
- a diet
- b malnutrition
- c chronic disease.

5 **Explain** why water is an important part of any diet.

6 **Describe** the sort of information that you can get from *The Australian Guide to Healthy Eating*.

7 **Describe** a scenario that could lead to a child in Australia having rickets.

Applying

8 a **Use** the information in Figure 7.3.6 on page 279 to **calculate** the change in percentage of overweight boys between 1985 and 2007–08. N

b **Use** the information in Figure 7.3.7 on page 279 to **compare** the change in obesity levels for boys and girls in the years 1995 to 2007–08. N

9 **Identify** two health problems that occur when there is too much salt in the diet.

10 **Identify** reasons why an adult could develop mesothelioma even though they had not been near asbestos since they were a child.

Analysing

11 **Contrast** over-nutrition and under-nutrition.

12 **Compare** a non-infectious disease and an infectious disease.

Evaluating CCT

13 a In the graph in Figure 7.3.17 the line for type 1 diabetes is relatively flat. **Explain** what a line like this means.

b **Propose** a reason for the line for type 1 diabetes being this shape.

c **Deduce** from the graph the age group that is most seriously affected by type 2 diabetes.

d **Use** your knowledge of type 2 diabetes to **propose** what this graph might look like in 20 years time if Australians do not change their eating habits.

e **Propose** a reason for type 1 diabetes having less effect on the health of the population.

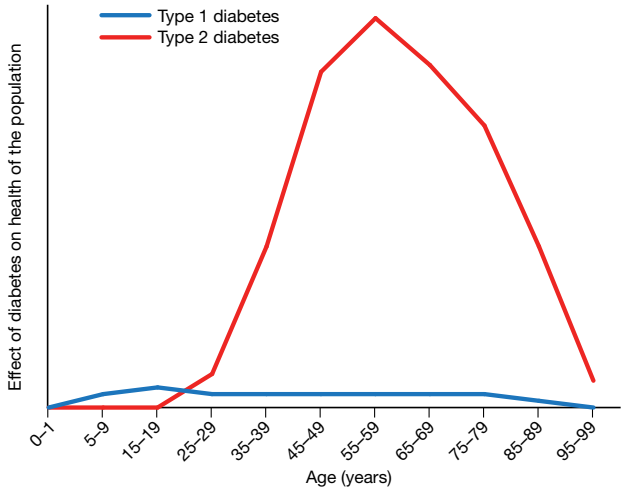


Figure 7.3.17 The more diabetes there is in a population, then the greater the effect diabetes has on the functioning of that population.

Creating CCT

14 **Construct** a flow diagram that shows what happens when a person eats more food than they require through to that person gaining weight.

Inquiring

1 Research caffeine.
- Use the nutrient labels on different brands of energy drinks, cola, tea and coffee to compare the amount of caffeine they contain.
- Find the effects of caffeine on different age groups.

Present your findings in a pamphlet or poster for a gym. Include a table comparing the different drinks.

7.3 Practical investigations

1 Testing for nutrients

Purpose

To carry out standard tests for fats, carbohydrates (starch and glucose) and protein.

Materials

- 10% glucose solution
- 10% gelatine solution (protein)
- 10% starch solution
- vegetable oil
- iodine solution
- water

- white tile
- Albustix™ paper
- Tes tape
- brown paper
- eyedropper

Procedure

Water test (control)

1. Use the eyedropper to place one drop of water in three places on the white tile and one drop onto a piece of brown paper.
2. Test the water using the Albustix, Tes tape and iodine solution.

Glucose test

3. Use the eyedropper to place one drop of glucose solution on the white tile.
4. Dip the end of the Tes tape in the solution. Note the colour change.
5. Wash the eyedropper thoroughly in water.

Starch test

6. Use the eyedropper to place one drop of starch solution on the white tile.
7. Add a drop of the iodine to the starch solution. Note the colour change.
8. Wash the eyedropper thoroughly in water.

Protein test

9. Use the eyedropper to place one drop of gelatine solution on the white tile.
10. Dip the end of the Albustix in the solution. Note the colour change.
11. Wash the eyedropper thoroughly in water.

Fat test

12. Use the eyedropper to place one drop of vegetable oil on the brown paper.
13. Leave the paper for a few minutes and then note any change in the paper.

Results

Record your observations from each test.

Practical review

1. **Modify** the following statements by completing them.
   - a Starch solution turned from _____ to _____ when iodine was added.
   - b Tes tape changed colour from _____ to _____ in the presence of glucose.
   - c Albustix turned from _____ to _____ when protein was present.
   - d A translucent stain was left on brown paper when _____ was present.
   - e When water was tested _____.
2. **Explain** why it was important to know how water reacted to the tests.

7.3 Practical investigations

2 A balanced diet

Purpose

To compare your diet with a recommended diet.

Materials

- a list of the food eaten each day for four days

Procedure

1. Construct a blank version of the 'Healthy food plate' to fit an A4 page. Use Figure 7.3.18 as a guide.
2. Over the next four days, record everything you eat and drink (including all snacks). Place a cross in the appropriate segment of the plate to represent each serve of food in that category. Use Table 7.3.1 as a guide.

Figure 7.3.18

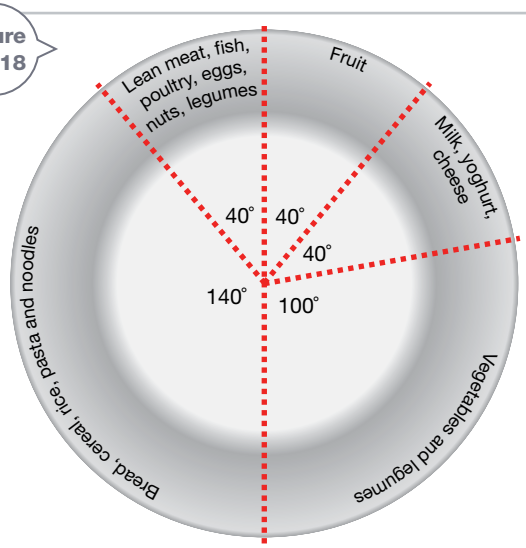


Table 7.3.1 Size of one serving of different foods

Food	Serving size
Bread	1 slice
Roll	1
English muffin or hamburger bun	½
Rice, pasta, cooked cereal	½ cup
Ready-to-eat cereal	¾ cup
Chopped fresh fruit	½ cup
Canned fruit	½ cup
100% fruit juice	¾ cup
Raisins or dried fruit	¼ cup
Cooked vegetables	½ cup
Chopped, raw vegetables	½ cup
Raw, leafy vegetables	1 cup
Vegetable juice	¾ cup

Food	Serving size
Cooked lean meat, fish or poultry	60–90 grams, size of palm of hand
Egg	1
Peanut butter	2 tbsp, 30 grams
Cooked dried peas or beans	½ cup
Nuts, seeds	⅓ cup
Milk	1 cup
Yoghurt	1 cup
Cheese	1 slice, 30 grams
Cottage cheese	½ cup
Ice-cream	½ cup
Vegetable oil	1 tsp
Butter	1 tsp
Peanut butter	1 tsp
Ripe olives	8
Salad dressing	1 tbsp

Results

1. Calculate the percentage of the 'Healthy food plate' occupied by each food type. Measure the angle of the segment—for example, the angle of the fruit sector is 40°. The complete circle is 360°; therefore, the fruit segment occupies $\frac{40}{360}$. Convert this into a percentage: N

$$\frac{40}{360} \times \frac{100}{1} = 11\%$$

2. Use the following table to add up all the crosses you have placed on the plate and then calculate the percentage of your diet represented by each food type. N

	Angle of segment (°)	% of plate	Number of crosses	% of diet
Fruit	40	11		
Vegetables				
Lean meat, fish, poultry, eggs, nuts and legumes				
Milk, yoghurt and cheese				
Fat				
Bread, cereal, rice, pasta and noodles				

Practical review

1. **Explain** why the information for this activity was collected over four days rather than only one day.
2. **Compare** the diet you have recorded with the recommended diet.
3. **Assess** the quality of your diet.
4. **Discuss** the differences you have identified. What changes would be required to bring your diet closer to the recommended diet?

STUDENT DESIGN

3 Nutrients in food

Purpose

To test a range of foods for fats, carbohydrates (starch and glucose) and protein.

Materials

- samples of various foods (such as apple, cheese, milk, egg white, butter, meat, orange juice, potato, bread, boiled lolly and sweet biscuit)
- equipment as chosen by students

SAFETY

A risk assessment is required for this investigation. Do not use foods that contain nuts.

Procedure

1. Design an experiment that will test all the selected foods for fat, sugar, starch and protein.
2. Brainstorm in your group and come up with several different ways to investigate the problem. Select the best procedure and write it in your workbook.
3. Before you start any practical work, assess all risks associated with your procedure. Refer to the MSDS of all chemicals used. Construct a risk assessment that outlines these risks and any precautions you need to take to minimise them. Show your teacher your procedure and your risk assessment. If they approve, then collect all the required materials and start work.

Hint

- Practical investigation 1 may provide you with some ideas for your experiment.
- For dry foods such as bread, biscuit, meat and cheese, you will need to grind the food in a mortar and pestle with a few drops of water before testing.
- Make sure that you use clean equipment for each test.

Results

Construct a table to show the nutrients present in each food sample.

Practical review

1. **Assess** which food contained the most nutrients.
2. **Assess** which food contained the fewest nutrients.
3. **Assess** the contribution each food makes to a balanced diet.
4. **Discuss** the idea that it is better to eat foods containing more than one nutrient than foods containing only one nutrient.
5. A negative test for a particular nutrient does not necessarily mean that the nutrient is not present. **Deduce** why.
6. **Evaluate** the effectiveness of the procedure you used and suggest any improvements that could be made.

7 Chapter review

Remembering

1 **Name** two different types of pathogens.

2 **Recall** the names of two diseases caused by single-celled organisms other than bacteria.

3 **State** the cause of tinea and thrush.

4 **State** the cause of:
- a scurvy
- b kwashiorkor.

Understanding

5 **Explain** how washing your hands can protect you from disease.

6 **Outline** ways a viral disease may be transmitted from an infected person to a healthy one.

7 **Explain** the term *contagious*, using one contagious and one non-contagious disease in your explanation.

8 **Explain** how vaccination is able to control the spread of contagious diseases.

9 The skin, gastric juices and mucous membranes are sometimes called the body's first line of defence. **Explain** why this is an appropriate description.

10 **Describe** the role of white blood cells in the immune system.

11 **Explain** the relationship between chickenpox and shingles.

12 **Explain** how a person who eats a good diet can be suffering from malnutrition.

13 **Explain** the concept of *blood pressure*.

14 **Explain** why few people in Australia should have rickets.

15 Water is not a nutrient. **Explain** why water is such an important part of a healthy diet.

16 **Explain** the link between asbestos mining and the disease mesothelioma.

Applying

17 **Demonstrate** how the following behaviours would protect you from disease.
- a Protect yourself from amoebic dysentery by eating fruit only if it can be peeled before eating.
- b Avoid tinea infection by not sharing towels.
- c Use insect repellent to avoid malaria.

Analysing

18 **Discuss** the possibility of amoebic dysentery occurring in Australia.

19 **Compare** a neutrophil and a macrophage.

20 **Classify** the following as things that cause disease, or things that are part of the immune system.

pathogens, macrophages, viruses, neutrophils, skin, nose hairs, gastric juices, *Plasmodium*

21 As you grow, you gain weight. **Compare** this weight gain with the weight gain that leads to someone becoming overweight.

Evaluating CCT

22 **Propose** why some vaccinations against viral diseases such as polio give you lifelong immunity, whereas it is recommended that you get a flu vaccination each year.

23 Some non-infectious diseases were described as chronic diseases.
- a **Define** a chronic disease. L
- b **Propose** a situation where an infectious disease could be described as a chronic disease.

24 a **Determine** whether you can or cannot answer the questions on page 256 at the start of this chapter.
- b **Assess** how well you understand the material presented in this chapter.

Creating CCT

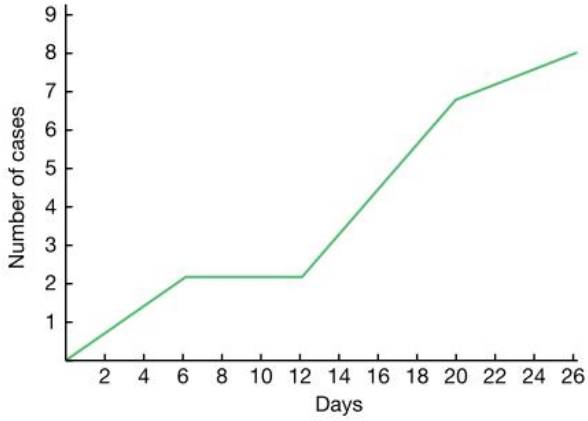
25 **Use** the following ten key words to **construct** a visual summary of the information presented in this chapter.

pathogen	immunity
virus	bacteria
vaccination	over-nutrition
under-nutrition	lymphocytes
disease	chronic disease

Thinking scientifically

Questions 1 and 2 refer to the following information.

During an outbreak of flu the local doctor was recording the number of people in the area diagnosed each day. Below is the graph the doctor created.



Key

A Days 0–6
B Days 6–12
C Days 12–20
D Days 20–26

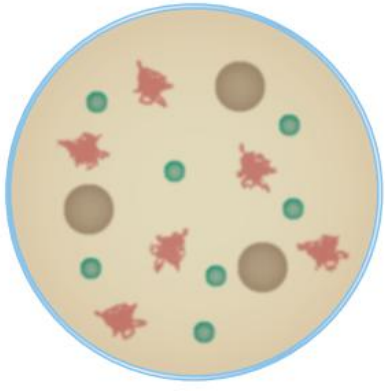
Q1 Use the key to identify the period of time when there were no more cases of flu diagnosed. CCT

Q2 Use the key to identify the period of time when the number of cases increased most rapidly. CCT

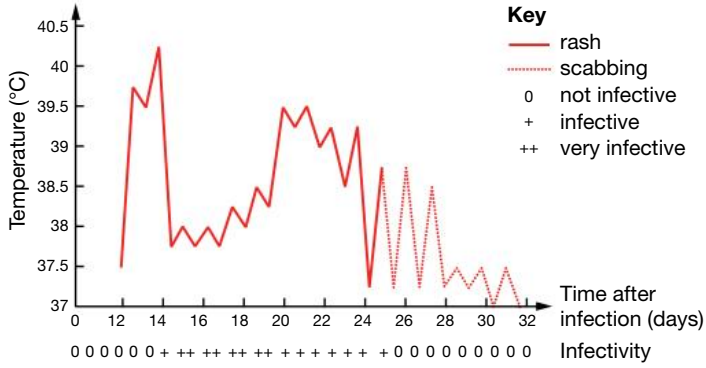
Q3 A class of students was arguing about the number of colonies of bacteria they had on the agar plate they had exposed on the windowsill of their classroom. Below is a drawing of the plate.

How many bacterial colonies can be seen on the plate? CCT

A 3
B 6
C 7
D 10



Q4 Below is a graph of the temperature of a person suffering from smallpox. CCT



Identify the statement that is consistent with the data presented.

A The person was most infective when their temperature was highest.
B Once the scabs started to form, the temperature was consistently lower than when the rash was present.
C The total rise in temperature from day 12 to day 14 was almost 3°C.
D Thirty days after infection, the temperature was consistently back to normal.

Q5 Bacteria in the mouth can cause bad breath. The bacteria in a mouth were counted before and after using four mouthwashes. The results are given in the table below. CCT

Mouthwash	Bacterial count	
	Before	After
1	25	10
2	80	25
3	45	6
4	60	15

Calculate which mouthwash killed the greatest percentage of bacteria.

A 1
B 2
C 3
D 4

Glossary

Unit 7.1

Antibiotic: a substance that kills bacteria or prevents the growth of bacteria

Antibody: a chemical made by the immune system that makes it easier for white blood cells to destroy pathogens

Bacteria: microscopic, single-celled organisms

Contagious: very easy to spread; used to describe a disease

Disease: anything that causes your body to stop working properly

Histamine: a chemical that is made by cells in response to injury

Immune: able to make the antibodies to a pathogen before it can make you unwell

Immune system: the system in your body that fights infections

Infectious disease: a disease that can be spread

Lymphocyte: a white blood cell that makes antibodies

Macrophage: a white blood cell that consumes pathogens

Neutrophil: a type of white blood cell that consumes pathogens

Pathogen: an organism that causes disease

Pathogenic bacteria: bacteria that cause disease

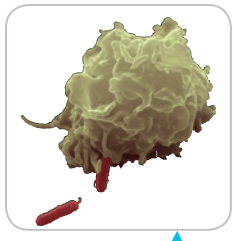
Penicillin: an early antibiotic

Quarantine: isolation to prevent the spread of a disease

Symptom: indicator of a particular disease

Vaccine: a chemical that causes your body to react as if it had encountered a pathogen

Infectious disease



Macrophage

Unit 7.2

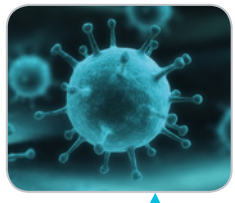
Fungicide: a chemical that kills fungi

Host: the organism a parasite lives in

Host cell: a cell invaded by viruses

Spore: a single cell used by fungi to spread

Virus: a pathogen about 100 times smaller than a bacterium



Virus

Unit 7.3

Asbestosis: a lung disease caused by breathing in asbestos fibres

Caffeine: a stimulant drug that acts on the brain

Carbohydrates: nutrients used as the main source of energy for the body

Chronic disease: a disease that lasts for a long time

Diabetes: a complex disease caused by a lack of or insensitivity to insulin

Diabetic: a person who has the disease diabetes.

Fats: nutrients used as a source of energy and an energy store in the body

Heart attack: when part of the heart muscle is damaged or dies because the blood supply is blocked or severely reduced

High blood pressure: when the blood pressure in the arteries remains high between heartbeats and during rest

Insulin: the hormone that lowers the level of glucose in the blood

Kwashiorkor: a disease caused by a lack of protein

Malnutrition: when the nutrition provided by the diet does not meet the needs of the body

Minerals: nutrients required for various functions in the body

Nutrients: protein, carbohydrate, fats, minerals and vitamins

Nutrition: the food necessary for health and growth

Over-nutrition: a form of malnutrition in which the body is getting more nutrients than it requires

Proteins: nutrients used for growth and repair of the body

Rickets: a disease caused by a lack of vitamin D

Scurvy: a disease caused by a lack of vitamin C

Stroke: when part of the brain is damaged or dies because the blood supply is blocked or severely reduced

Type 1 diabetes: a form of diabetes in which the body stops producing insulin

Type 2 diabetes: a form of diabetes in which the body has become resistant to insulin

Under-nutrition: a form of malnutrition in which the body is not getting enough of the essential nutrients

Vitamins: nutrients that control many functions in the body

8 Ecosystems

Have you ever wondered...

- what it is like for an animal living in the wild?
- why wilderness areas are worth saving?
- if humans could be damaging the Earth?
- whether humans have a responsibility to protect the environment?

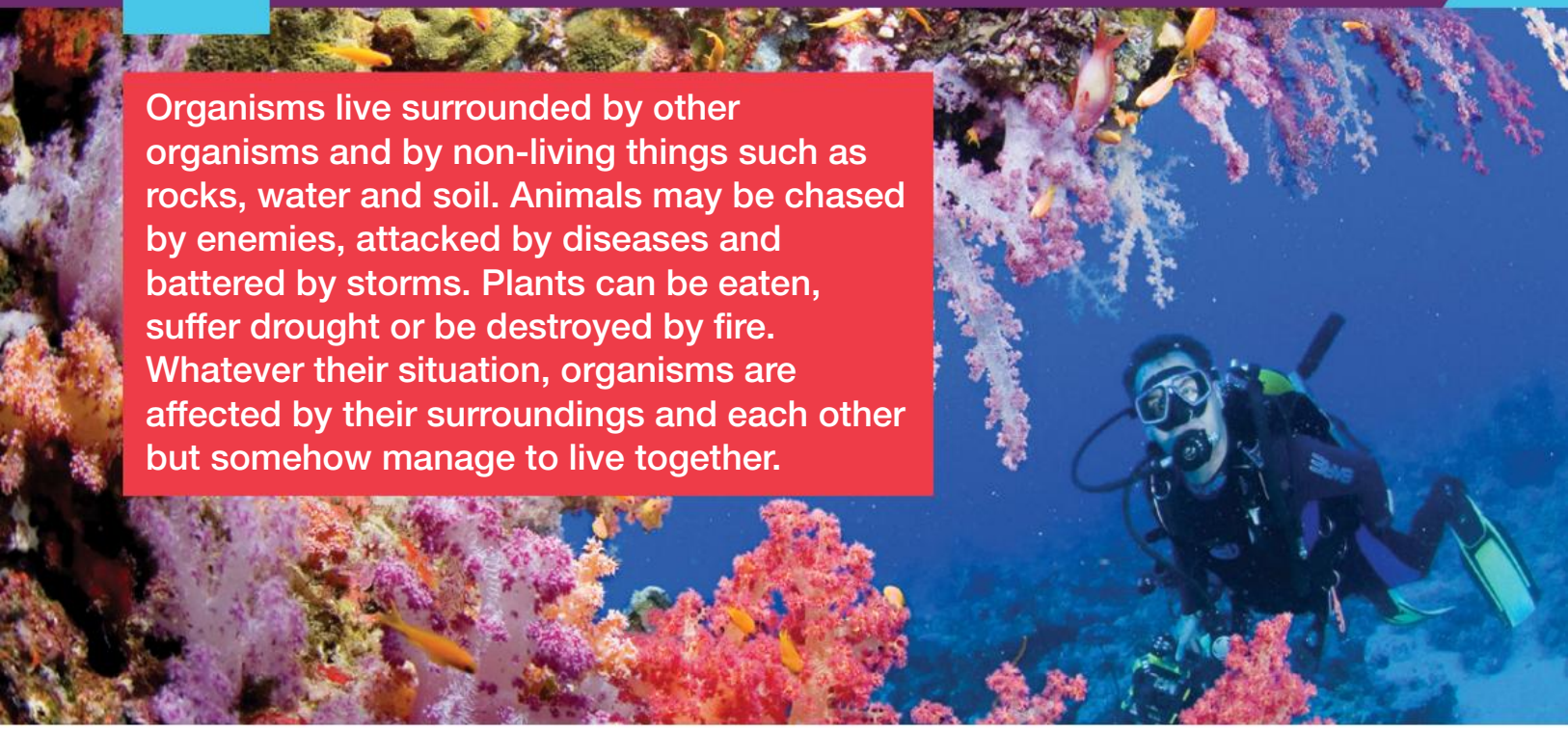
After completing this chapter students should be able to:

- recall that ecosystems consist of communities of interdependent organisms and abiotic components
- outline how matter such as nitrogen is cycled through ecosystems
- describe how energy flows through ecosystems and food webs
- analyse how changes in biotic and abiotic components affect populations and communities CCT
- assess how Aboriginal and Torres Strait Islander peoples' cultural practices and knowledge of the environment contribute to sustainable ecosystems AHC S
- evaluate strategies used to balance conserving, protecting and maintaining the environment with human activities and needs CCT PSC EU S

ADDITIONAL

- debate why any investigation affecting animals must be humane, justified and ethical CCT EU
- use models to predict the changes in populations due to environmental changes CCT L
- discuss the strengths and limitations of using models to make predictions about changes in biological systems CCT
- describe examples of advances in science and technology in areas such as environmental science. CCT L WE

8.1 Components of an ecosystem



Organisms live surrounded by other organisms and by non-living things such as rocks, water and soil. Animals may be chased by enemies, attacked by diseases and battered by storms. Plants can be eaten, suffer drought or be destroyed by fire. Whatever their situation, organisms are affected by their surroundings and each other but somehow manage to live together.

Interdependence

Living things affect each other's survival. For example, termites depend on microscopic organisms called flagellates (Figure 8.1.1). Flagellates live in the termite's intestines and digest the wood for the termite. The termite needs the flagellates to do this because it cannot digest wood even though this is all the termite eats. The termite provides a moist, stable place for the flagellates to live and so the flagellates also depend on the termite.

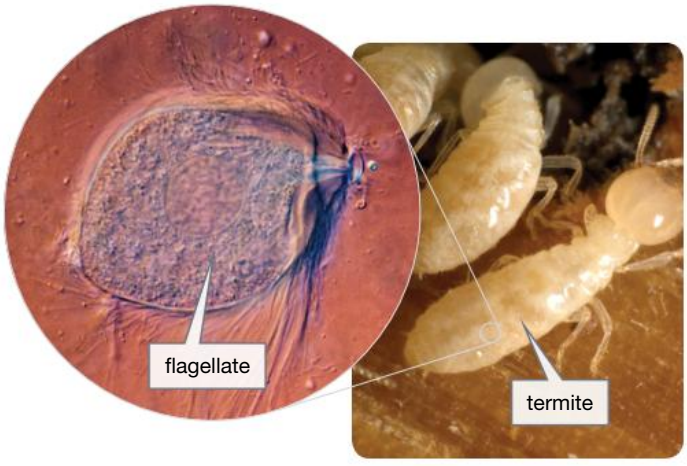


Figure 8.1.1 Termites and the flagellates that live in their intestines are interdependent. They rely on each other for survival.

Unlike the termite and flagellate, organisms do not always help each other to survive. A hawk that kills and eats a mouse is dependent on the mouse for its survival. The mouse is dependent on plants for its food. Therefore, the hawk also depends on the plants because they keep its food source alive. The hawk, mouse and plant are therefore interdependent, because a change affecting one will affect all three. **Interdependence** means that all organisms in a food web are interconnected, affecting each other's survival in helpful and harmful ways.

Prac 1 p301

The environment

When biologists talk about the **environment**, they are talking about all the factors in an organism's surroundings that affect its survival. Some of these factors are very visible, such as the landscape and the types of rock, soil, plants and animals found there. The environment also includes less visible factors such as the number of days of sunshine, the amount of rainfall and the number of predators in the area. Every organism has its own unique environment.

Ecology

Ecology is the study of how organisms interact with each other and with their non-living surroundings. To interact means to affect each other, in either harmful or helpful ways. These interactions are just some of the factors that form the environment in which an organism lives. Scientists who specialise in ecology are known as ecologists.

Ecosystems

To help understand how organisms live where they do, ecologists classify the surroundings into two components:

- the physical surroundings (such as rocks and water)
- the living organisms (animals, plants, fungi, bacteria and other microorganisms)

Together these components make up an ecosystem. An **ecosystem** is a place where the organisms and their physical surroundings form an environment that is different from other environments nearby.

Natural ecosystems can exist on their own. They are balanced, meaning that they keep working without any outside help from humans. The lake in Figure 8.1.2 is an example. Humans can create artificial ecosystems such as the aquarium in Figure 8.1.3, but these need to be managed to keep them balanced. This may involve adding food materials and removing wastes.

Figure 8.1.2 A freshwater lake is a natural ecosystem.

Figure 8.1.3 An aquarium is an artificial ecosystem. Without human help, it quickly becomes unbalanced.

Factors influencing organisms

Organisms in an ecosystem are affected by two main sets of environmental factors:

- **abiotic factors**: These are non-living factors such as air quality and humidity, the amount of sunlight, rainfall, wind, tides, waves, lightning and fires. Abiotic factors are also known as physical factors.
- **biotic factors**: These are living factors such as predators, parasites, fungi, infectious organisms, competitors for food and shelter and collaborators (such as a breeding partner).

Some abiotic and biotic factors in the human environment are shown in Figure 8.1.4.

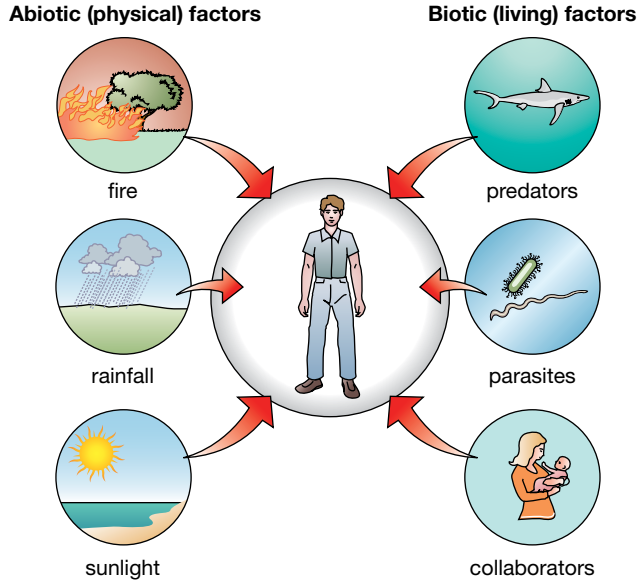


Figure 8.1.4 Abiotic and biotic factors affect all organisms, including humans.

Abiotic factors

Water, temperature, fire, light, soil type and oxygen levels are important abiotic factors for most organisms.

Water

Water is essential for all living organisms. It is the solvent for all materials in cells and allows the chemical reactions of life to occur. Chemicals must move around to participate in chemical reactions—water allows this movement to occur. When water is limited, chemical reactions within the cells cannot occur and cells die. As a consequence, the organism also dies.

Water affects any organisms that live in it, such as fish, sponges, seaweed and algae. Water does not evaporate from their body surfaces as it does from land organisms. Instead, aquatic animals and plants lose water through diffusion. Water diffuses out of their body cells into the ocean, river or lake.

INQUIRY science 4 fun

Fish shapes

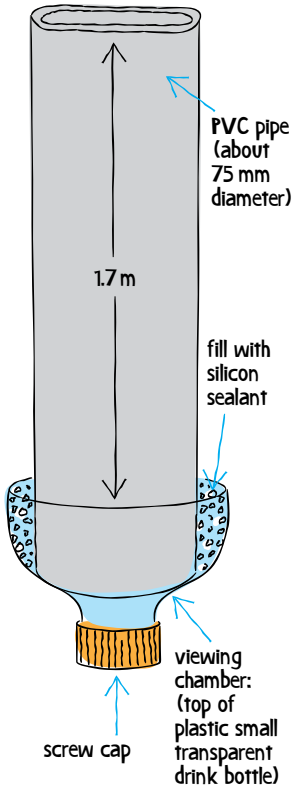
What is the best shape for a fish?

Collect this ...

- water
- test container as shown
- plasticine
- bucket
- timer

Do this ...

1. Make the test container as shown in the diagram. It will need to be 1.7 m in height.
2. Cut five cylinders of plasticine about 2 cm wide by 2 cm long.
3. Use the plasticine to make a fish shape (with tail) and different shapes such as a sphere, cube, pyramid and rectangle. These should all be approximately the same size.
4. Fill the test container with water. Drop the shapes into the top of the container and time how long it takes each to reach the bottom.



Record this ...

Describe how the shape affected the movement through water.

Explain the advantage of fish being a particular shape.

Water provides buoyancy (uplift), so organisms that live in water need less support for their bodies than creatures that live on land. However, water is very difficult to move through and so marine animals are usually streamlined to minimise water resistance.

Temperature

Heat affects the rate (speed) of chemical reactions in the cells. As temperature increases, the rate of a reaction usually increases too.

The body temperature of fish, amphibians and reptiles (like the one in Figure 8.1.5) depends on the temperature of the environment. Biologists use the term **ectothermic** to describe these animals, rather than 'cold blooded'. This is because many of these animals are not 'cold' but have body temperatures that vary as the environment warms and cools. These animals can also regulate their temperatures by lying on warm rocks or in sunlight to heat up, or by hiding in burrows if they need to cool down. Ectothermic means the organisms must obtain body heat from the environment rather than by generating it internally through body chemistry.

Birds and mammals such as humans and kangaroos are **endothermic**. Endothermic means that the organisms are warm blooded—they have the ability to generate heat internally and control heat loss to keep their body temperature constant.

Prac 2 p301

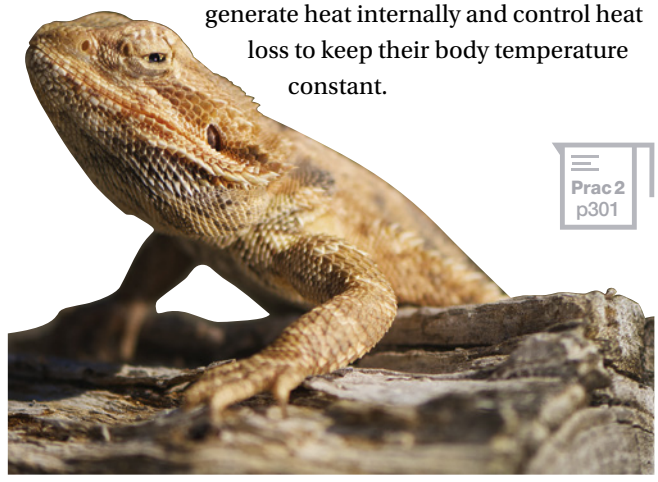


Figure 8.1.5 A reptile is ectothermic. Its body temperature will be very low overnight and on cold mornings, and high after it has been lying in the sunlight.

The price of being an endotherm

Up to 80% of food consumed by an endothermic animal (like you) goes to generating heat to maintain a constantly warm body. This means an endothermic animal must find and consume much more food than a comparable ectothermic animal.

SciFile

Fire

Some fires start because of lightning hitting trees, or because of human activity. Australian Aborigines have used fire for many thousands of years to keep the bush open and to improve the growth of plants. They knew that many Australian plants re-grow quickly after fire.

A bushfire like the one in Figure 8.1.6 can kill some plants, but it may help others. Some plants flower better after a fire and some drop their seeds. Many Australian plants will germinate after a fire in response to the chemicals released in the smoke.

Figure 8.1.6 Fire can kill some organisms but help others.

8.1 Prac 3 p302

Light

Light is necessary for photosynthesis. **Photosynthesis** is the process by which plants manufacture their food materials using water, carbon dioxide and light. Changes in the amount of light over the seasons trigger plant growth and flowering in many species.

As Figure 8.1.7 shows, hilly ground can affect the amount of light reaching plants. The Sun's rays do not penetrate into valleys early in the morning or in the late afternoon so plants growing in valleys receive less light than plants growing on hilltops.

In places outside of the Tropics of Capricorn and Cancer, the Sun never passes directly overhead during the day. For example, all of New South Wales lies below the Tropic of Capricorn and so the Sun never passes directly overhead. Instead, it moves across the sky in a path that lies towards the north. This path shifts north in winter and is more overhead in summer. For this reason, plants on the south side of hills in New South Wales receive less sunlight than those on the northern side. Hence, plants tend to grow taller on the northern slopes of hills and only plants that can survive with less light will be found on the southern slopes.

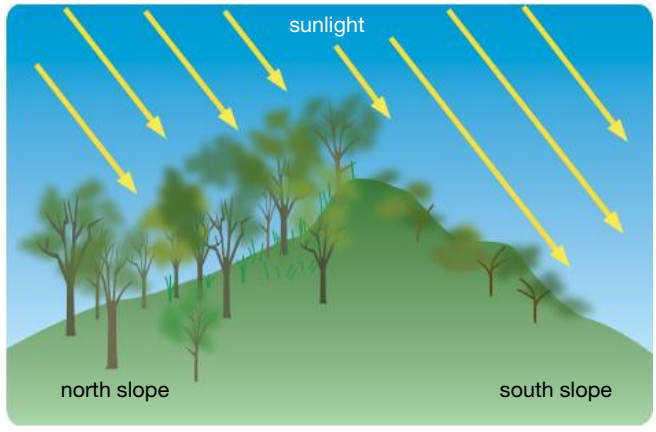


Figure 8.1.7 Plants on a north slope usually grow larger because they receive more sunlight over a year.

The amount of light influences the flowering of most plants. Plants sense how much light they receive every day. As winter progresses into spring, the number of daylight hours and the amount of light increase. Many plants respond by flowering (Figure 8.1.8). As summer progresses into autumn and the hours of daylight become shorter, some plants respond by changing colour and dropping their leaves.

Figure 8.1.8 Plants such as this waratah detect the change in daylight with the seasons and respond by flowering.

Light also affects animal behaviour. For example, rock lobsters (crayfish) avoid bright moonlight. Many other animals stay out of direct sunlight during the hottest part of the day to avoid overheating.

Soil type

Plants usually grow in soil that provides them with the water and minerals they need to help make their food. Not all soils are the same—they differ in mineral content, water-holding ability and acidity.

Two nutrients needed by plants are nitrate and phosphate. Where there are only tiny amounts of these in the soil, only specially adapted species such as banksias can survive.

Loam soil usually contains more plant nutrients than sandy soil because the clay particles in loam have more plant nutrients in them than sand grains do. While fertilisers stick to the clay particles in loam, they are often washed away and lost from sandy soils.

Some soils hold more water than others. Loam soils hold onto water more strongly than sandy soils. Therefore, it is more difficult for a plant to extract the water it needs from loam soils than it is from sandy soils.

Acidity and alkalinity of soil are also important to plants (Figure 8.1.9). Plants such as azaleas, camellias and most Australian native plants need acidic soils. High alkalinity will kill them or prevent them growing well. Other plants, such as some acacias (wattles) and eucalypts (gum trees), grow better in alkaline soils.

Figure 8.1.9

Testing soil for acidity (pH level) is useful because it helps decide whether a particular plant will grow well in it.

GO TO Unit 1.3

Oxygen levels

The amount of oxygen in the environment affects most organisms because they require oxygen to carry out respiration, the reaction that provides their cells with energy. There is usually enough oxygen in the air for land-based organisms, but the amount dissolved in water can change greatly and affect aquatic organisms living there.

The amount of oxygen in water depends on several factors.

- **Temperature**: there is more oxygen in cold water than warm water.
- **Movement**: moving water dissolves a lot of gases from the air. Hence, a fast-flowing stream has more oxygen than a swamp.
- **Depth**: as water gets deeper, there is less mixing of water with the air, which reduces the amount of oxygen available. Animals living in the depths of the ocean (such as the anglerfish in Figure 8.1.10) tend to move slowly because the energy available from respiration is limited by a lack of oxygen.

GO TO Unit 2.3

Figure 8.1.10

Anglerfish are slow-moving fish that live in the deep ocean where there is limited oxygen available.

Biotic factors

Organisms rarely live alone—they are surrounded by other plants, animals and microorganisms. All the living things in an ecosystem are known as a **community**. Different relationships exist between the organisms in a community and these relationships are classified by how the organisms interact.

There are many different interactions between living organisms. These interactions involve biotic factors, and they play an important role in the survival of all species. Sometimes organisms assist each other, and sometimes they harm each other.

Competition

Organisms are said to be in **competition** when they both try to obtain the same resource, which may only exist in limited amounts. Competition occurs between members of the same species (like the chicks shown in Figure 8.1.11), and between different species. There is only a limited supply of food and resources, and so some individuals will not survive. In natural communities, competition is often fierce. There is a constant struggle for survival, and many die, especially the young, the old and the weak.

Figure 8.1.11 Baby birds compete with each other for food by trying to attract their mother's attention.

Predation

When one organism kills and eats another, the attacker is called the predator and the one being eaten is called the prey. This feeding relationship is known as **predation**. An example is shown in Figure 8.1.12.

Mutualism

Mutualism is a relationship where two organisms live closely together and both benefit. The flagellates in a termite's guts are a good example. Without the flagellates, the termite would not have any food. The flagellates receive food and the correct temperature and moisture levels for survival. Both organisms depend upon each other.

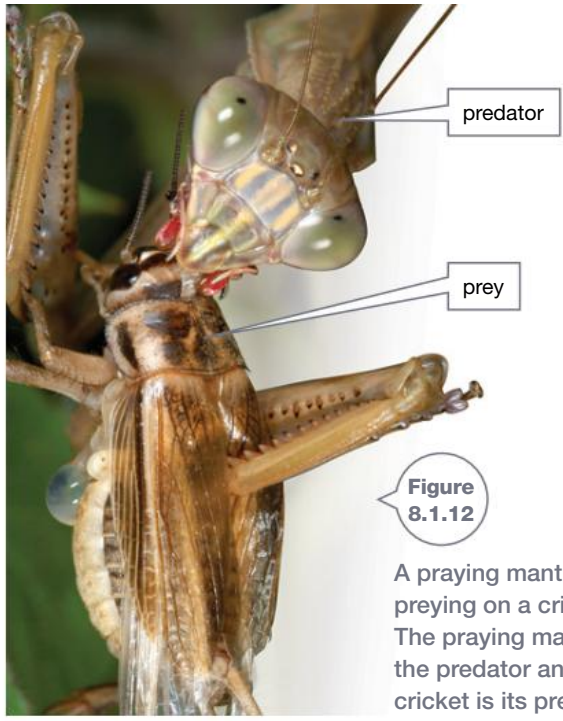


Figure 8.1.12 A praying mantis preying on a cricket. The praying mantis is the predator and the cricket is its prey.

The cleaner shrimp shown in Figure 8.1.13 eats parasites on the skin of the fish. Both the cleaner shrimp and the fish it cleans benefit, so this is an example of mutualism.

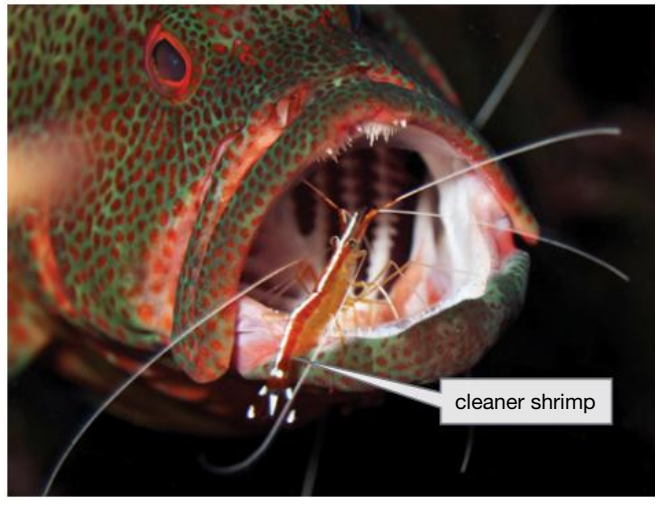


Figure 8.1.13 Cleaner shrimp and the fish they clean are an example of mutualism.

Pollination is another example of mutualism. Many flowering plants depend on animals (like the honeyeater in Figure 8.1.14 on page 298) to pollinate them. Pollination is the transport of pollen (containing the male sex cells) to the female parts of the flower. Pollination results in seeds. The honeyeater benefits from the relationship by obtaining food in the form of a sugary liquid (nectar).

Figure 8.1.14 Flowering plants rely on pollinators such as this honeyeater to transfer pollen, which enables the plants to make their seeds.

Parasitism

Parasitism is a relationship where one organism (the parasite) lives on or in another organism (the host) and feeds off it. The parasite cannot survive without the organism in which it lives. The parasite usually harms the host, but rarely kills it. The caterpillar in Figure 8.1.15, which has been attacked by a wasp parasite is an example of parasitism killing the host.

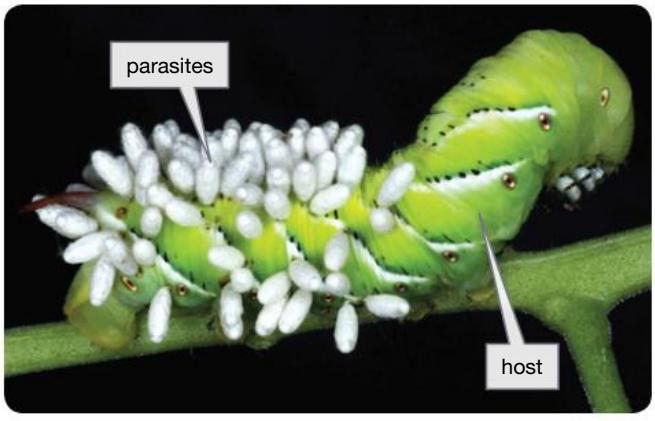


Figure 8.1.15 A parasitic wasp has laid its eggs on this caterpillar. They will hatch and eat the caterpillar.

River blindness

River blindness is caused by a parasitic worm that lives in human eyeballs. The worm is transmitted by a bite from a type of fly called a blackfly. The worm is estimated to have made about half a million people blind.

SciFile

Commensalism

Commensalism is a relationship in which one organism benefits and the other is unaffected. An example of commensalism is the relationship between a whale and the barnacles it carries, shown in Figure 8.1.16. The barnacles attach themselves to the outside of the whale, but do not harm the whale or gain food from it. The barnacles collect their food by filtering microscopic animals out of the water as the whale swims. The whale does not eat the same animals as the barnacles and so is unaffected by them.

Figure 8.1.16 Barnacles attached to the tail of this whale collect food but do not harm the whale. This relationship is an example of commensalism.

Environmental changes and populations

Changes in the environment affect the population sizes of all species living in it. These changes involve both biotic and abiotic factors. The most common environmental changes are those due to seasonal changes in abiotic factors such as temperature, light and water.

In southern Australia, native plants have a growth spurt in spring when there is adequate water and light and temperatures are around 20°C. Many plants also flower at this time, providing food for animals that drink nectar or eat flowers. Therefore, the changes in abiotic factors affect the biotic factors. Increased quantities of plant matter result in increased numbers of herbivores (plant-eaters) and the carnivores (meat-eaters) that feed on the herbivores and on each other.

The size of a population changes because environmental factors affect the rates of birth, death, immigration and emigration. Some examples are shown in Table 8.1.1.

Defining relationships

Scientists sometimes reclassify relationships as more research is carried out and they learn more about them. An example is the relationship between clownfish and anemones (Figure 8.1.17).

Figure 8.1.17 Clownfish in a sea anemone

Anemones are related to jellyfish, and have stinging tentacles. They kill small animals and eat them. The clownfish are immune to the stings and feed on the anemone's leftover food, and receive protection from predators.

1. Recent research has shown that some anemones grow better if clownfish live in them. So there must be a benefit to those anemones. Some species of clownfish scare away butterfly fish, which can eat anemones. Both the anemone and the clownfish benefit and so the relationship is mutualism.
2. In aquariums, one type of clownfish catches small fish and drags them over to the anemone. The anemone stings the small fish and kills them. Both the clownfish and the anemone then feed on the dead fish. Both benefit, so once again the relationship is mutualism.
3. It is not clear whether all clownfish and their anemones show mutualism. Some species of anemones may neither benefit nor be harmed by the clownfish. Only the clownfish is benefiting, and so the relationship is one of commensalism.

Table 8.1.1 Factors that affect population size in an area

Factor	Example
Birth rate	The number of animal births often increases when food is plentiful. Adults have more energy and breed. More breeding adults can survive because more food is available.
Death rate	Plentiful food reduces the number of animals that die, which keeps the population high. In contrast, exposure to unusually low temperatures can increase the death rate (Figure 8.1.18).
Immigration	More animals move into an area when there are more resources such as food and water.
Emigration	Animals usually move out of an area when they do not have enough food and water.

8.2 8.3

Figure 8.1.18 Emperor penguin adults and young huddle together to keep warm in an Antarctic blizzard. Very low temperatures increase the death rate, decreasing the size of the population.

8.1 Unit review

Remembering

1 **List** the two main components of any ecosystem.

2 **List** five different abiotic (physical) factors that affect organisms.

Understanding

3 **Define** the terms: L
- a environment
- b ecology
- c parasitism
- d commensalism.

4 **Describe** three abiotic factors of soil that affect land plants.

5 Farmers find that adding fertilisers to loam soils increases crop yield, while adding them to sandy soils does little. **Explain** why.

6 **Predict** the shapes of fish that would drop fastest and slowest in the science4fun on page 294.

7 **Explain** how seasonal changes in abiotic factors can alter the rate of birth, death, immigration and emigration.

8 **Explain** why birds and mammals are not affected by cold weather as much as reptiles are.

9 **Explain** how fire can be beneficial in the Australian bushland.

Applying

10 **Use** the relationship between clownfish and anenomes to **demonstrate** that relationships can sometimes be classified in different ways.

11 **Demonstrate** how a eucalypt depends on both its biotic and its abiotic environment.

Analysing

12 **Compare**:
- a a community with an ecosystem
- b abiotic and biotic factors
- b predator and prey
- c parasite and host.

13 a **Discuss** five biotic factors and five abiotic factors in your environment.
- b **Compare** these factors with those for a kangaroo.

14 Most of the land animals found in the Arctic and Antarctica are birds or mammals. Few are reptiles or frogs. **Compare** these animals and **explain** this observation.

15 **Compare** the effects of the following five abiotic factors on plants in beach sand dunes and plants in a rainforest: temperature, humidity, soil moisture, sunlight and wind.

Evaluating CCT

16 a **Classify** a human as endothermic or ectothermic.
- b **Justify** your answer.

17 a **Classify** each of the relationships listed below as examples of competition, predation, parasitism or commensalism.
- b **Justify** your answers.
  - i falcon and budgerigar
  - ii tick and bobtail lizard
  - iii human and pet budgerigar
  - iv tinea and human
  - v lion and cheetah
  - vi sheep and bacteria in its gut
  - vii rabbits, foxes and wedge-tailed eagles
  - viii soldier ant and worker ant in a colony

18 **Propose** a reason why mosses are more likely to grow on the southern side of trees in Australia than on their northern sides.

19 Fewer crayfish are caught on nights when the moon is full and the sky is clear than on nights that are overcast or when there is no moon in the sky. **Propose** a reason why.

Creating CCT

20 **Design** an experiment to test the response of a slater, mealworm or millipede to light.

Inquiring

ADDITIONAL

Research the use and humane treatment of animals in scientific research. Once you have gathered your findings, hold a class debate on why an investigation involving or affecting animals must be humane, justified and ethical. CCT EU

ADDITIONAL

8.1 Practical investigations

1 Termite guts

Purpose

To investigate what lives inside termite guts.

Materials

- 0.6% saline solution (non-iodised salt) in dropper bottle
- termite

- small watchglass
- fine forceps
- Petri dish
- microscope slides
- coverslips
- monocular microscope with 40× objective lens
- razor blade
- dissecting needle

SAFETY

Be extremely careful with the razor blade, needle and forceps.

Wash your hands carefully after the dissection.

Procedure

1. This involves killing a termite. If you don't want to do this, then ask your teacher to do it. Grasp a termite with fine forceps and drop it into the saline solution in the watchglass.
2. Using the razor blade, remove the termite's head. Hold the thorax with fine forceps and use a dissecting needle to pull out the abdomen and puncture the gut.
3. Place a drop of saline on a slide and dip the gut into it. Then put the gut back in the Petri dish. Add a coverslip and observe the slide with a light microscope. Observe first on low power, then on high power with a 40× objective.

Results

1. Describe the organisms you see and record how many different ones there are.
2. Sketch the different flagellates you find.

Practical review

1. **Explain** why the flagellates are essential to the survival of the termite.
2. **Classify** the relationship between the termite and the flagellates.

STUDENT DESIGN

2 Temperature and activity

Purpose

To test how temperature affects animals.

Hypothesis

What effect do you think temperature will have on animals? Before you go any further with this investigation, write a hypothesis in your workbook.

Materials

- animals such as slaters, ants, mealworms or other insects
- access to hot and cold water
- ice

- thermometer
- at least four containers such as beakers and Petri dishes
- marking pens

SAFETY

A risk assessment is required for this investigation.

Procedure

1. Design an experiment that will test the effect of temperature on the activity of animals.
2. Brainstorm in your group and come up with several different ways to investigate the problem. Select the best procedure and write it in your workbook. Draw a diagram of the equipment you need.
3. Before you start any practical work, assess all risks associated with your procedure. Construct a risk assessment that outlines these risks and any precautions you need to take to minimise them. Show your teacher your procedure and your risk assessment. If they approve, then collect all the required materials and start work.

Hints

As part of the planning process, decide which animals you will use in the activity. Remember that you must not harm the animals. To design your experiment, you must consider:

- what activity you will measure
- how to change the temperature
- what equipment you will need.

Temperature and activity continued on next page

Temperature and activity continued

Results

Present your data in a suitable way.

Practical review

1 **Describe** any pattern or patterns you found in the data.

2 **Summarise** the relationship between temperature and animal activity.

3 **Explain** the relationship between temperature and activity.

4 a **Construct** a conclusion for your investigation.
b **Assess** whether your hypothesis was supported or not.

5 **Evaluate** your procedure. Pick two other prac groups and **evaluate** their procedures too, identifying their strengths and weaknesses.

STUDENT DESIGN

3 Plants and fire

Some Australian native plants germinate after a fire because of a chemical in the smoke and not because of the heat from the fire. The chemical is released into the air in smoke and can also be found in ash produced after a fire.

Purpose

To test whether ash makes seeds germinate rather than the heat of the fire.

Materials

- as selected by students (probably wattle seeds, featherflower (*Verticordia*) or fringe myrtle (*Calytrix*) seeds, containers, matches, newspaper or leaves to burn, can, beakers, water)

SAFETY

A risk assessment is required for this investigation.

Fires must only be lit outside the classroom in an appropriate container. Teachers must supervise at all times.

Procedure

1 Design an experiment that will test whether it is the ash or the heat from a fire that causes seeds to germinate.

2 Brainstorm in your group and come up with several different ways to investigate the problem. Select the best procedure and write it in your workbook. Draw a diagram of the equipment you need.

3 Before you start any practical work, assess all risks associated with your procedure. Construct a risk assessment that outlines these risks and any precautions you need to take to minimise them. Show your teacher your procedure and your risk assessment. If they approve, then collect all the required materials and start work.

Hints

Your team will need to decide aspects of your design such as:

- how you will test the effect of heat on the seeds (putting them directly in a fire will kill them)
- whether you will subject the seeds to a fire (which would need to be done in a tin can outside the classroom) or some other source of heat such as hot or boiling water
- how you will capture chemicals from ash so that you can then use on the seeds (capturing smoke is a bit difficult in a school setting without special equipment).

Results

Construct a table showing your results and the results of other prac teams.

Practical review

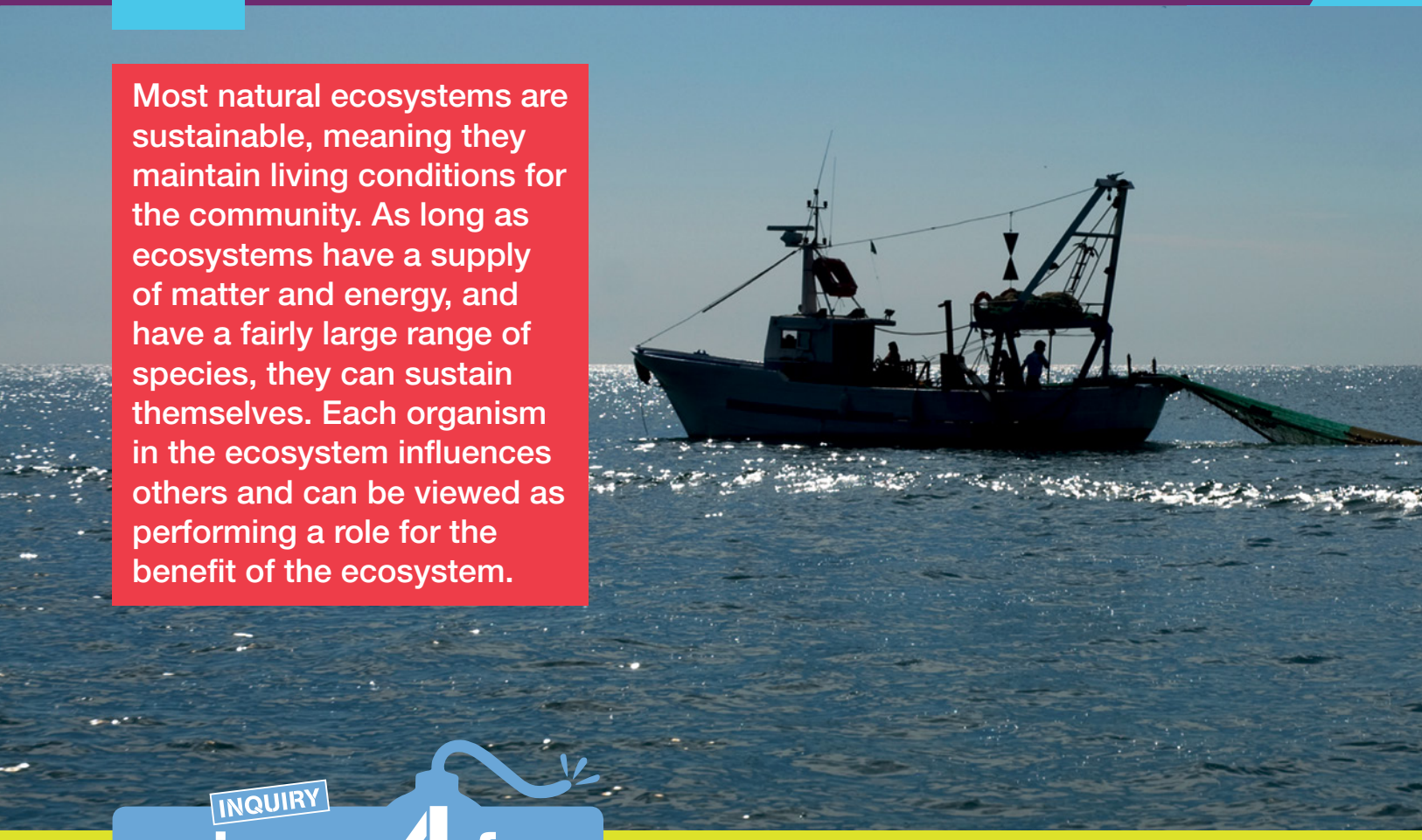
1 **Construct** a report on the experiment.

2 **Propose** how the results could be of use in repairing ecosystems.

3 **Evaluate** your procedure. Pick two other prac groups and **evaluate** their procedures too, identifying their strengths and weaknesses.

8.2 Sustainability

Most natural ecosystems are sustainable, meaning they maintain living conditions for the community. As long as ecosystems have a supply of matter and energy, and have a fairly large range of species, they can sustain themselves. Each organism in the ecosystem influences others and can be viewed as performing a role for the benefit of the ecosystem.



INQUIRY science 4 fun

Ant food

YES

Do ants eat sugar?

Collect this …

- 5 mL of sugar water (about 10% sugar)
- food colouring in dropper bottles (several different colours)
- waxed paper 10 cm square (taped to cardboard to resist wind)
- digital camera or mobile phone with camera (with zoom function)

SAFETY

Some ants give a painful sting. Do not touch them. Try not to step on a nest.

Do this …

1. Add about 10 drops of the food colouring to the sugar water. Different groups can use different colours.
2. Go outside with your equipment and find an ant nest or ant trail.
3. Place the paper next to the nest or in the trail.
4. Add about 5 drops of different-coloured sugar water to the paper (you can swap colours with other groups). Space the drops about 2 cm apart.
5. Observe what the ants do for several minutes. Observe their abdomens carefully for evidence that they drank the liquid. Take a close-up digital photo if you can.
6. Look carefully at the photos you took. Zoom in to see their abdomens more clearly.

Record this …

Describe what happened.

Explain why this happened.

Food in ecosystems

In any ecosystem, food is vital. Food contains the matter and energy required by living organisms. To understand how ecosystems function, it is important to understand the feeding relationships between organisms. Each organism performs a role in the ecosystem. The organisms do not know they have a role, or that it will support the ecosystem. They are simply trying to survive. However, their interactions result in a balanced system.

Producers

Every community must have a source of food, which is made by organisms known as **producers**. Most producers are green plants such as flowering plants, conifers, moss and algae, although some are bacteria. Producers are essential for the community. Without them there would be no life, because other organisms such as animals and fungi cannot make their own food.

All the organisms that require a ready-made source of food are called consumers. Humans are consumers because we cannot produce food without the help of plants. All the food people 'make' comes from plant or animal products. For example, bread comes from wheat seeds. Many animals that we eat (such as chickens and cows) are raised on plants or their seeds. Even some animals that are carnivores (such as tuna) are part of a chain of other animals that started with plant eaters. All food was originally made by a producer.

Figure 8.2.1 Trees are producers. They make their food by photosynthesis.

Apart from some bacteria, all other producers make food by **photosynthesis** (Figure 8.2.1). This is a chemical process that takes place inside cells containing a green pigment called chlorophyll. Photosynthesis is a complicated process of many chemical reactions, but it can be summarised in a word equation or balanced formula equation:

$$\text{carbon dioxide + water} \xrightarrow{\text{sunlight, chlorophyll}} \text{glucose + oxygen}$$

$$6CO_2 + 6H_2O \xrightarrow{\text{sunlight, chlorophyll}} C_6H_{12}O_6 + 6O_2$$

GO TO Unit 2.3

For land plants, the carbon dioxide gas (CO_2) is absorbed from the air, and water (H_2O) is absorbed through the roots. When sunlight falls on the cells containing chlorophyll, the cells start making a sugar called glucose ($C_6H_{12}O_6$).

The glucose made by photosynthesis is vital to the plant. It is used to make all the other materials that a plant needs, such as proteins, fats and vitamins. Often the sugar is turned into starch and stored in the leaves until it is needed. Many plants also store starch in seeds. This is why wheat is used to make bread and other foods.

Prac 1 p314

Food chains and webs

A **food chain** is a sequence of organisms feeding on each other. An example is shown in Figure 8.2.2.

In this food chain, the food materials made by the grass (such as proteins, fats and vitamins) are passed to the grasshopper when it eats the grass. The grasshopper uses these food materials to build and maintain its own body. When the grasshopper is eaten by the frog, the food materials in the grasshopper's body are used by the frog to build and maintain its body. Similarly, when the frog is eaten by the snake, food materials pass to the snake. So the grasshopper, the frog and the snake all depend on the grass to make the food materials they need. Without grass, the snake has no food.

There are many food chains in communities and they are all interconnected. All the connected food chains are known as a **food web**. An example is shown in Figure 8.2.3. Food webs are usually complex, with each organism appearing in many food chains. For example, the mouse and snake are in four food chains.

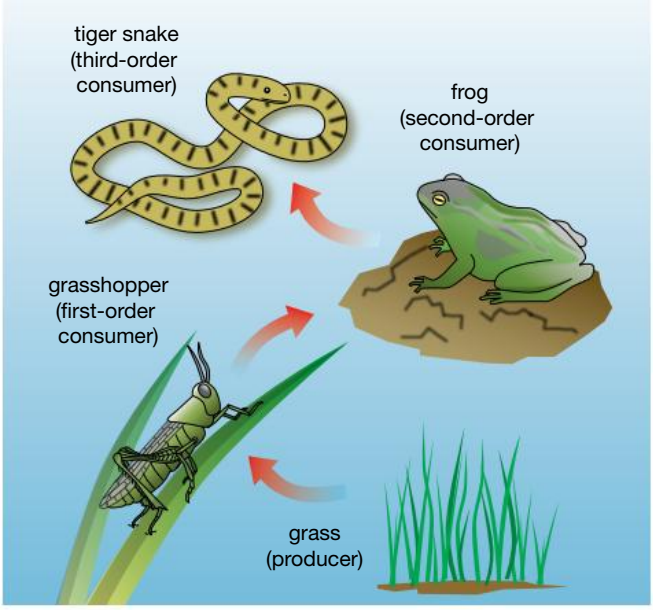


Figure 8.2.2 A food chain starts with plants. Plants produce their own food and so are known as producers. First-order consumers consume (eat) plants. Second-order consumers eat first-order consumers, third-order consumers eat second-order consumers, and so on up the food chain.

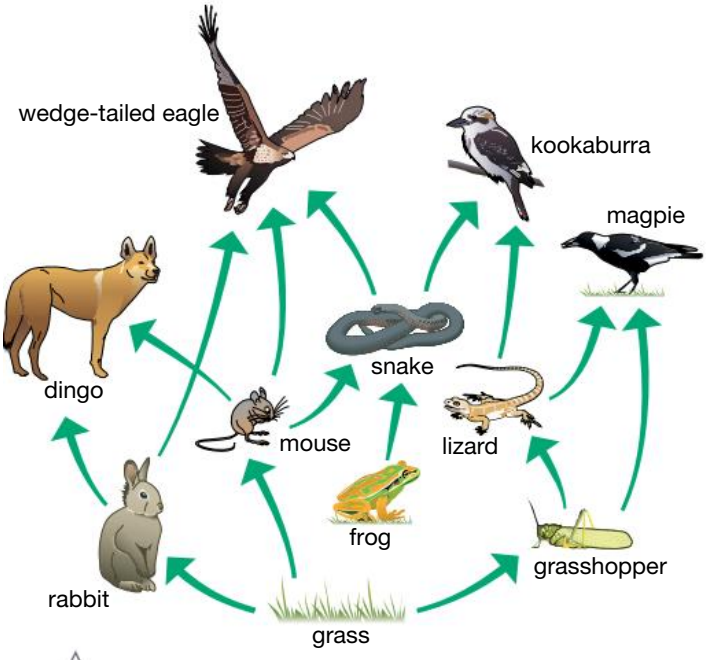


Figure 8.2.3 Part of a food web in a eucalypt woodland community

Recycling in nature

A vital group of organisms in any ecosystem is the **decomposers**. These organisms are bacteria and fungi (like the ones in Figure 8.2.4) that break down dead bodies and wastes, and recycle matter for the producers to re-use.

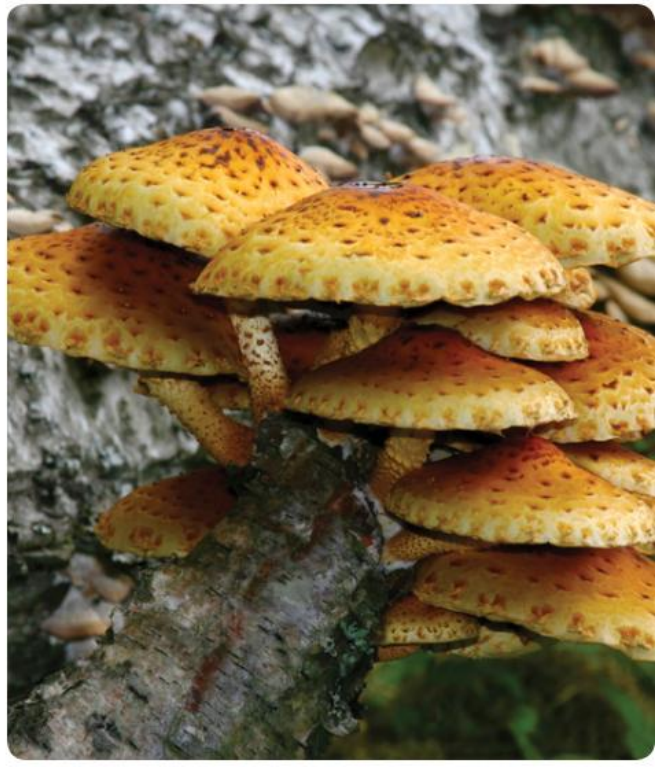


Figure 8.2.4 Decomposers like these fungi are vital for the ecosystem to keep functioning.

You can see this process in Figure 8.2.5. Without them, ecosystems would run out of resources.

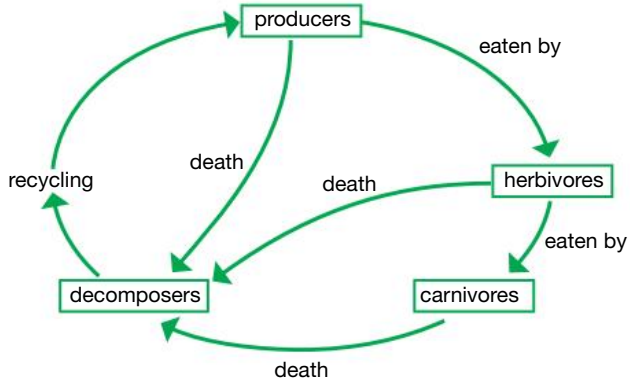


Figure 8.2.5 Decomposers recycle materials back to the ecosystem for re-use.

Cycling of matter

One way to understand the cycling of matter in ecosystems is to focus on how individual elements such as nitrogen move around. Nitrogen is an element that is found in all living organisms, mainly in their proteins. Proteins are the substances from which the organisms' bodies, organs and body systems are built. Nitrogen is also found in some lipids (fats and oils) and in vitamins such as folic acid (vitamin B9) and thiamine (vitamin B1).

As Figure 8.2.6 shows, nitrogen cycles through the physical surroundings and through the organisms that make up a community. You can begin anywhere in the cycle to follow where nitrogen goes, but a good starting point is nitrogen in the atmosphere. Some soil bacteria (known as **nitrifying bacteria**) absorb nitrogen gas from the air in the soil and use it to make nitrogen-containing compounds such as ammonia (NH_3). This process is known as nitrogen fixing, or **nitrification**. Nitrifying bacteria convert the ammonia into proteins and other compounds that contain nitrogen. These nitrifying bacteria live freely in the soil and in nodules on the roots of a group of plants known as **legumes** (Figure 8.2.7). Native Australian legumes include wattles and many of the plants that have seed pods that look like pea pods. Many of the plants used for crops and pastures are legumes too. Examples are clover, peas and beans.

GO TO Pearson science NSW 10 Unit 6.1

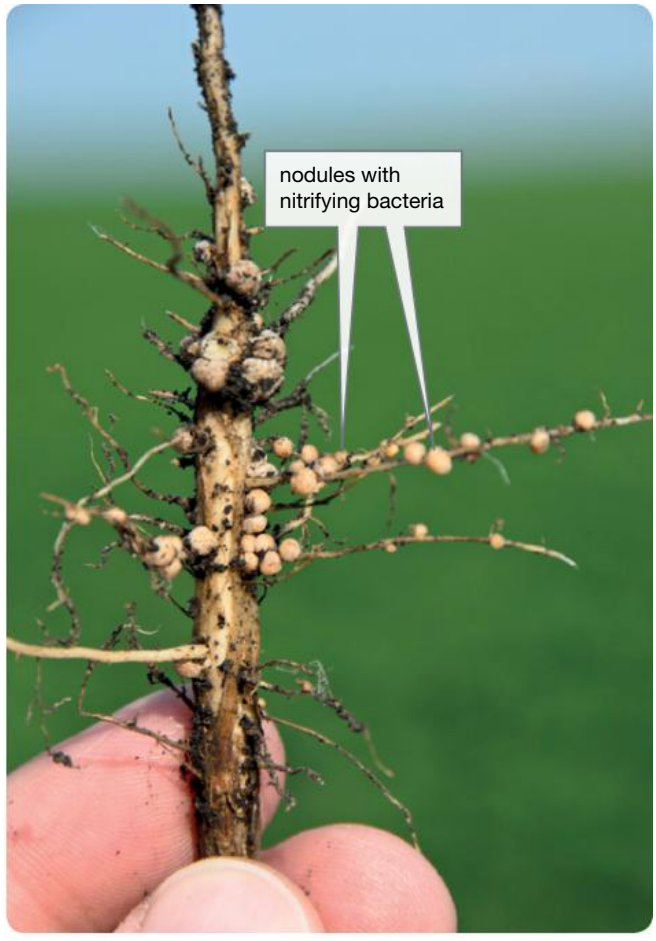
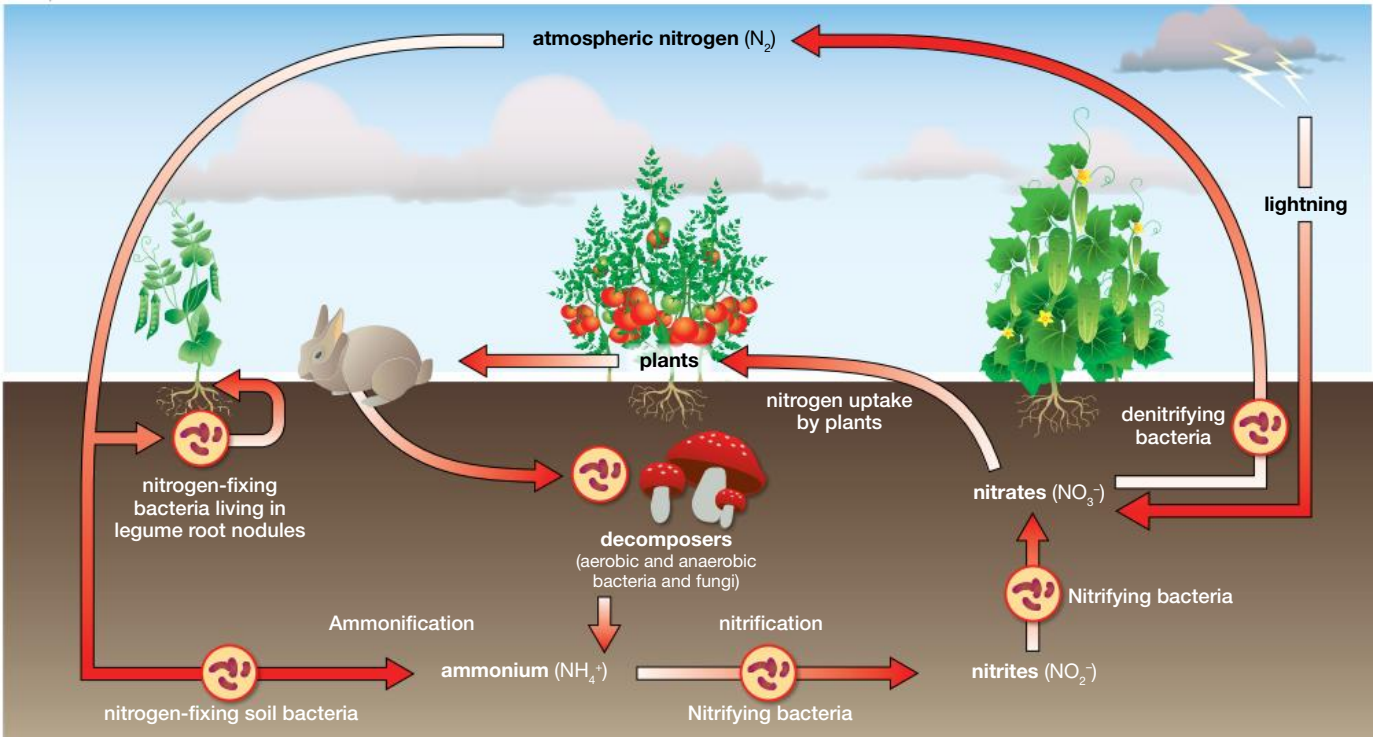


Figure 8.2.7 Legumes have nitrogen-fixing bacteria in nodules on their roots. These plants play a vital role in the nitrogen cycle.

Figure 8.2.6 Like all matter, nitrogen cycles through an ecosystem.



From there, other species of bacteria change the ammonia into chemicals called nitrites and then into nitrates. Nitrates are then absorbed by plants through their roots. The nitrates are made into the proteins and other nitrogen-containing compounds in the plant.

When an animal eats a plant, it also takes in the plant's nitrogen. In the animal's body, most of this nitrogen is used to construct the proteins and other compounds that become part of the animal. The plant compounds not needed by the animal are excreted by the animal in wastes such as urea. In this way, some nitrogen returns to the soil where it is again used by soil bacteria and converted back into ammonia.

Nitrogen also finds its way into the soil and water in other ways.

- When organisms die and decay, they release ammonia.
- Volcanoes release ammonia.
- Lightning acts on nitrogen gas (N_2) in the atmosphere, producing nitrogen oxides, which dissolve in atmospheric water to form nitric acid (HNO_3). This then falls as acid rain.

Some nitrogen is lost from the soil and water in a process called **denitrification**. This happens when bacteria (known as denitrifying bacteria) convert nitrates back into nitrogen gas, which is then released into the air. Denitrification reduces the fertility of the soil and is a major problem for farmers. Small amounts of nitrogen can also end up in sedimentary rocks where it remains locked until sediments are exposed and weathered. However, there is usually so little in rocks and soil that many farmers need to apply nitrogen fertilisers to their crops to boost production. Unfortunately, these fertilisers lose some of their benefit because of denitrification.

Energy flow in ecosystems

Energy does not cycle through ecosystems like matter does. Instead, energy flows continuously through the ecosystem, being lost as fast as it is gained.

To understand how energy flows through ecosystems, think about what you eat. You eat food for two reasons:

- to build new cells needed for growth and repair
- to provide energy for movement and internal processes.

In ecosystems, energy flows from one organism to another as it is eaten. The food material available to each organism is only that which is in the body cells of the organism it eats. The food materials that an organism has used for energy are not available to the organism that eats it. Therefore, the energy is lost from the community.

Figure 8.2.8 shows that the energy in 1000 kg of grass can only sustain about 100 kg of grasshoppers feeding on that grass. This is because each grasshopper uses up about 90% of its food for energy, rather than for making chemicals that form part of its body cells.

The 100 kg of grasshoppers can only feed about 10 kg of frogs. The frogs use 90% of its food materials to maintain themselves and, again, only about 10% of the energy ends up in the cells of the frogs. The same losses of energy occur when the frogs are eaten by the snakes.

So, the 1000 units of energy originally in the grass ends up as only 1 unit of energy in the snakes. This food chain demonstrates that there is a great loss of energy along it.

The progressive loss of energy along food chains explains why the chains are short—there is little energy available to the organisms at the end of the chain. It also explains why there are fewer higher-order consumers such as snakes than lower-

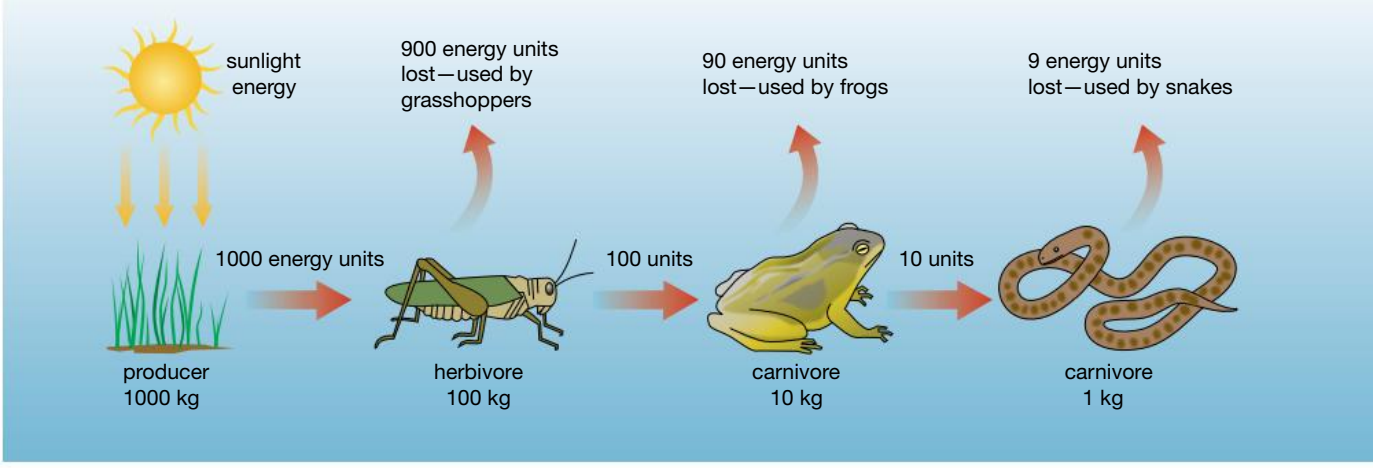


Figure 8.2.8 Energy flow through food chains results in energy losses.

order consumers such as insects—there is not enough energy available to keep high numbers of large organisms alive. Since kookaburras eat snakes (Figure 8.2.9), you can expect to find fewer kookaburras than snakes in the ecosystem.

Figure 8.2.9

Kookaburras will have less total energy available in food than the snakes had.

8.4

Humming along

Hummingbirds use energy faster than any other animal. Hummingbirds have to drink their weight in nectar every day. They are about as small as an endothermic animal can be. If they were any smaller, then they could not consume enough food to generate the heat to maintain their body temperature.

SciFile

Pyramids of biomass

Ecologists construct diagrams called **pyramids of biomass**, which show the total mass of organism at each stage of a food chain. The area of each rectangle represents the mass of organism at each stage. For the food chain in Figure 8.2.8 on page 307, a pyramid of biomass would look like the one shown in Figure 8.2.10.

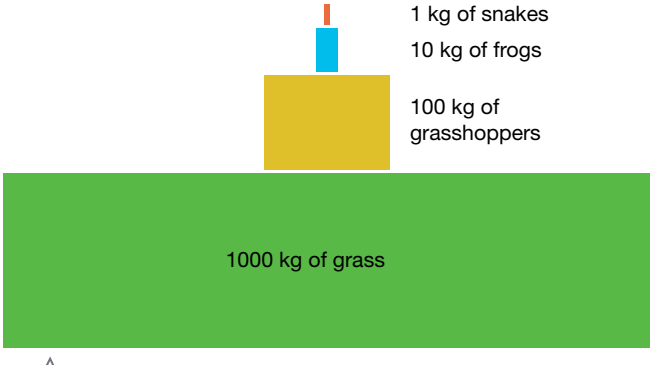


Figure 8.2.10

A pyramid of biomass shows the mass of organisms at each level in a food chain.

Pyramids of biomass are a result of the progressive loss of energy along food chains. With less energy available at each stage in a food chain, less total mass of living tissue can be built and maintained.

Pyramids of biomass are useful, because they allow ecologists to understand the total productivity of an area. **Productivity** means how well an area supports life. Pyramids of biomass can be used to compare different ecosystems, and are useful in farming, fisheries and wildlife conservation.

Biodiversity

Biodiversity refers to the range of different species in a community. High biodiversity means that a large number of different species live in the ecosystem. The coral reef in Figure 8.2.11 is an ecosystem that has high biodiversity.

Figure 8.2.11

Coral reefs are one of the most biodiverse ecosystems on Earth. A large number of different species are found in a small area.

An ecosystem with many different species is likely to remain stable and is less likely to be disrupted by environmental changes. There are many reasons why. Consider the invasion of an ecosystem by species from other countries, such as weeds invading an area of Australian bush (Figure 8.2.12). It is much harder for weeds to invade a community that has many species than to invade a community with only a few species. With only a few species, it is likely that weeds could out-compete the native plants for resources. In a community with many different native species, it is less likely that the weeds will be superior to them all and so the weeds are less likely to invade.

Figure 8.2.12 When an introduced species such as this Paterson's curse invades an ecosystem, the ecosystem is more likely to resist the invasion if there are many different species in the ecosystem.

Biodiversity also helps stabilise the ecosystem when physical conditions change. Look at the food web in Figure 8.2.13. A change in the weather might lead to an unusually heavy flowering of eucalypts. This is likely to lead to an increase in the number of bees. This is because more food is available and so more bees can survive. If the number of bees increases, then there is more food for honeyeaters, Jacky winters and rainbow bee eaters like the one in Figure 8.2.14. Numbers of these birds increase, and the bee population is gradually reduced again. As the bee numbers start dropping again, it becomes harder for the birds to find food. So the bird numbers decrease as the birds die or migrate away.

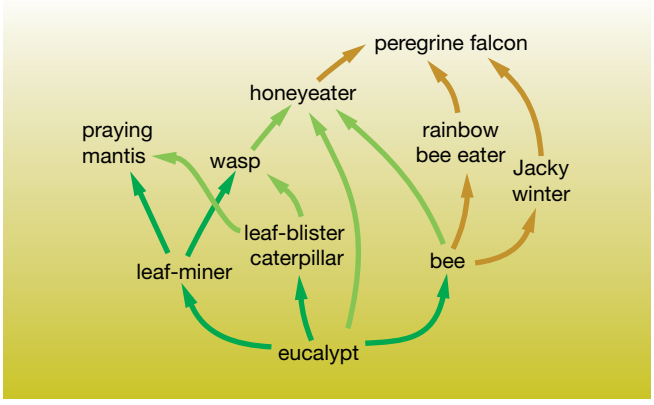


Figure 8.2.13 In a food web, each organism can appear in many food chains.

Figure 8.2.14 Rainbow bee eaters are predators that eat bees and so affect the population size of bees in an ecosystem.

So the numbers of a predator and its prey tend to change as they affect each other. You can see this in Figure 8.2.15. A rise in prey numbers is followed by a rise in predator numbers. As the predator numbers increase, the prey numbers decrease. The predator numbers then decrease, which triggers another rise in the prey.

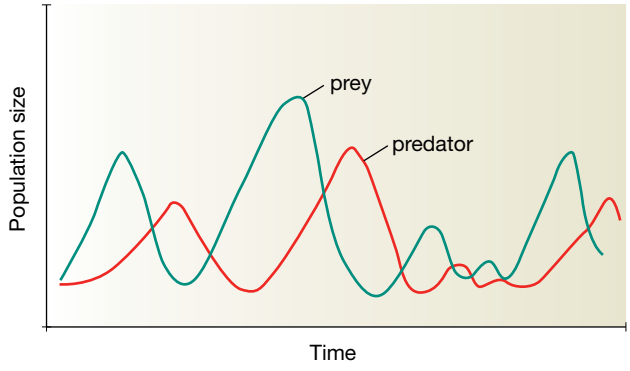


Figure 8.2.15 Predator and prey numbers affect each other.

Food webs with few species are very susceptible to changes in any one of the species. That one species may have been supporting a large part of the food web. In a food web with more species, if one source of food is lost, then there will be others available.

Prac 2 p314
8.5

LEARNING ACROSS THE CURRICULUM

SUSTAINABILITY

PROTECTING ECOSYSTEMS

Sustainable living describes humans acting in a way that maintains the living conditions of our environment. It involves careful use of resources so that they do not run out, and ensuring that natural ecosystems that keep us alive are not damaged by our actions.

The idea that we should protect our environment rather than just exploit it is fairly new in European and Western civilisations. Only recently have scientists realised that some civilisations such as Australian Aboriginals and African Bushmen had the balance right between protecting and using the environment.

One recent discovery of ecologists is that there are **keystone species** that are critical to the survival of the whole ecosystem. For example, earthworms enrich the soil and enable plants to grow, and so support all the other organisms. If earthworms were to disappear, the ecosystem would be in danger of collapsing. Research into keystone species is essential if we are to understand how to better manage ecosystems.

Figure 8.2.16 Ecotourism is one way ecosystems can be protected.

Another recent idea for measuring sustainable living is ecological footprint analysis. The **ecological footprint** of a population is the area of land and water required to supply the resources the population needs and to cope with the wastes produced by it. As Figure 8.2.17 shows, the area of land needed to support each Australian is about 7.5 hectares. The world average is about 2.2 hectares. Ecologists have suggested that Australians need to reduce their ecological footprint to about 2 hectares by changing how they live.

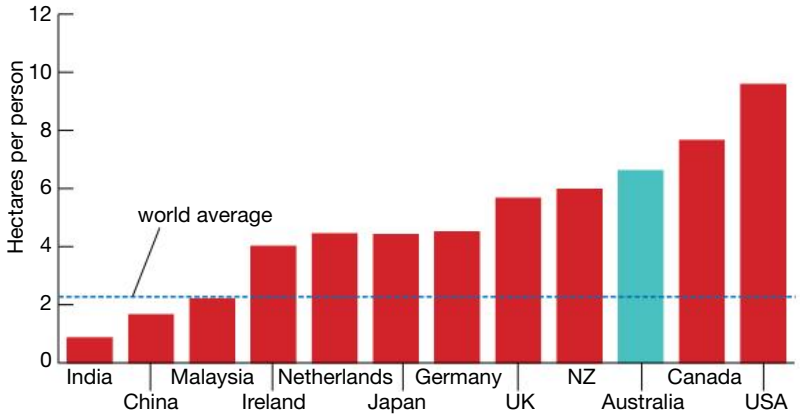


Figure 8.2.17 Australia's ecological footprint is among the highest in the world.

WHY PROTECT ECOSYSTEMS?

Compassion

Compassion is humans feeling sympathy for other organisms (Figure 8.2.18). The philosophy of compassion is that all organisms have a right to live, and that humans have no right to exterminate any species. It recognises that humans are the only organism on Earth capable of understanding the possible fate of all life. Humans therefore have a responsibility to make wise decisions.

Figure 8.2.18 This whale became stranded on a beach and was rescued by compassionate humans.

Cultural value

Some species have a value as part of our culture. They are part of our national view of ourselves. The Australian coat of arms in Figure 8.2.19 has a kangaroo and an emu on it. Imagine how most Australians would feel if these animals were hunted to extinction. Many animals and plants are a source of wonder, interest and enjoyment and would be deeply missed.

Figure 8.2.19 The Australian coat of arms shows some of the organisms we value as part of our culture.

Economics

Many previous generations exploited the environment to make money but gave little thought to protecting ecosystems. The concept of the ecosystem was only developed in the early 20th century. Now there is an increased awareness that money can be made and the environment protected at the same time.

One source of income from ecosystems is tourism. People like to holiday in Australia so they can see its wildflowers, forests and animals. This creates many jobs in the tourism industry.

Another source of income is from farming or cropping commercial native species such as eucalyptus (gum) trees, prawns or kangaroos. Conserving these species while still cropping them ensures that they will always be there to use.

Many useful pharmaceutical drugs have been produced from plants that were previously not used by humans. Conserving species means that new discoveries could be made as new needs arise. Also, certain animals could be possible biological control agents for controlling new pests. In the future, many animals and plants may be used for cross-breeding experiments to improve the health of existing farm animals and crops.

Survival

The survival of humans as a species depends on making smart decisions about the environment. For example, clearing much of the world's forests for timber could cause the climate to change. If the ocean fisheries are disrupted or destroyed by over-fishing or chemical pollution, then human food resources would be seriously reduced. Clearing trees means that soils are destroyed through erosion and salting of the land. This in turn reduces the productivity of the land, so less pasture and crops can be grown. Less food can be produced and people could starve.

REVIEW

1 **Define** the term *sustainable living*. L

2 **State** an example of a keystone species.

3 **Compare** the ecological footprint of Australia with the ecological footprints of USA, India and Germany.

4 **Describe** four ways in which protecting ecosystems can also give people an income.

5 **Explain** why protecting ecosystems could be necessary for our survival.

8.2 Unit review

Remembering

1 **Recall** photosynthesis by writing a word equation and balanced formula equation.

2 **Name** the group of organisms that makes the food for an ecosystem. L

Understanding

3 **Predict** what will happen when droplets of sugar water are placed near a trail of ants in the science4fun on page 303.

4 **Explain** why photosynthesis is so important to ecosystems.

5 **Explain** why decomposers are vital for a sustainable natural ecosystem.

6 **Explain** how energy enters an ecosystem, and what happens to it immediately after it enters plants.

7 a **Define** the term *biodiversity*. L
b **Explain** why biodiversity is important in an ecosystem.

Applying

8 **Identify** the term that means *the range of different species in a community*. L

9 Consider the following suggestions from a pamphlet designed to help farmers protect and encourage native animals.

- Fence off from the stock any native vegetation remaining on the farm on land that cannot be used.
- Plant many different trees and shrubs native to the area.
- Leave old trees standing, especially those with hollows in them.
- Form corridors of vegetation between bushland areas on the farm and neighbouring farms.

Discuss how each of these suggestions may help protect and encourage native animals in farming areas.

10 **Use** Figure 8.2.13 on page 309 to **name**:
a three animals that compete for bees as a food source
b two animals that compete for leaf-miners as a food source.

11 **Identify** what level of consumer you are in a food chain when you eat:
a beef
b an apple.

12 **Use** a pyramid of biomass to **describe** energy flow for one of the food chains from Figure 8.2.13 on page 309.

13 **Use** Figure 8.2.8 on page 307 to **calculate** how much energy would be available to kookaburras that ate snakes. N

Analysing

14 Consider the food web in Figure 8.2.13 on page 309. **Analyse** how the populations of the following species may be affected as seasonal changes cause eucalypts to stop flowering and slow down their growth.
a bees
b honeyeater
c peregrine falcon
d carnivorous wasps

15 If the amount of wattle in the food web in Figure 8.2.20 increased, **discuss** what you think would happen to each of the following populations.
a leaf hoppers
b wasps
c honeyeaters
d beetles

16 **Contrast** the flow of matter and energy through a natural ecosystem.

Evaluating CCT

17 **Propose** a reason why producers are not found in caves.

18 Consider the nitrogen cycle in Figure 8.2.6 on page 306. Imagine a large bushfire occurring in an area that killed many of the wattle trees and native pea plants. Consider the effect this would have on the cycling of nitrogen in the ecosystem.
a **Propose** how the fire could have a negative short-term effect on the ecosystem.
b **Justify** your answer to part a by referring to the cycling of matter.

19 Recent research has suggested that some nitrogen-fixing bacteria live in a mutualistic association with live coral. Some coral reefs are being killed by sunlight and high water temperatures in a process called coral bleaching. **Propose** how the death of corals will affect the cycling of nitrogen.

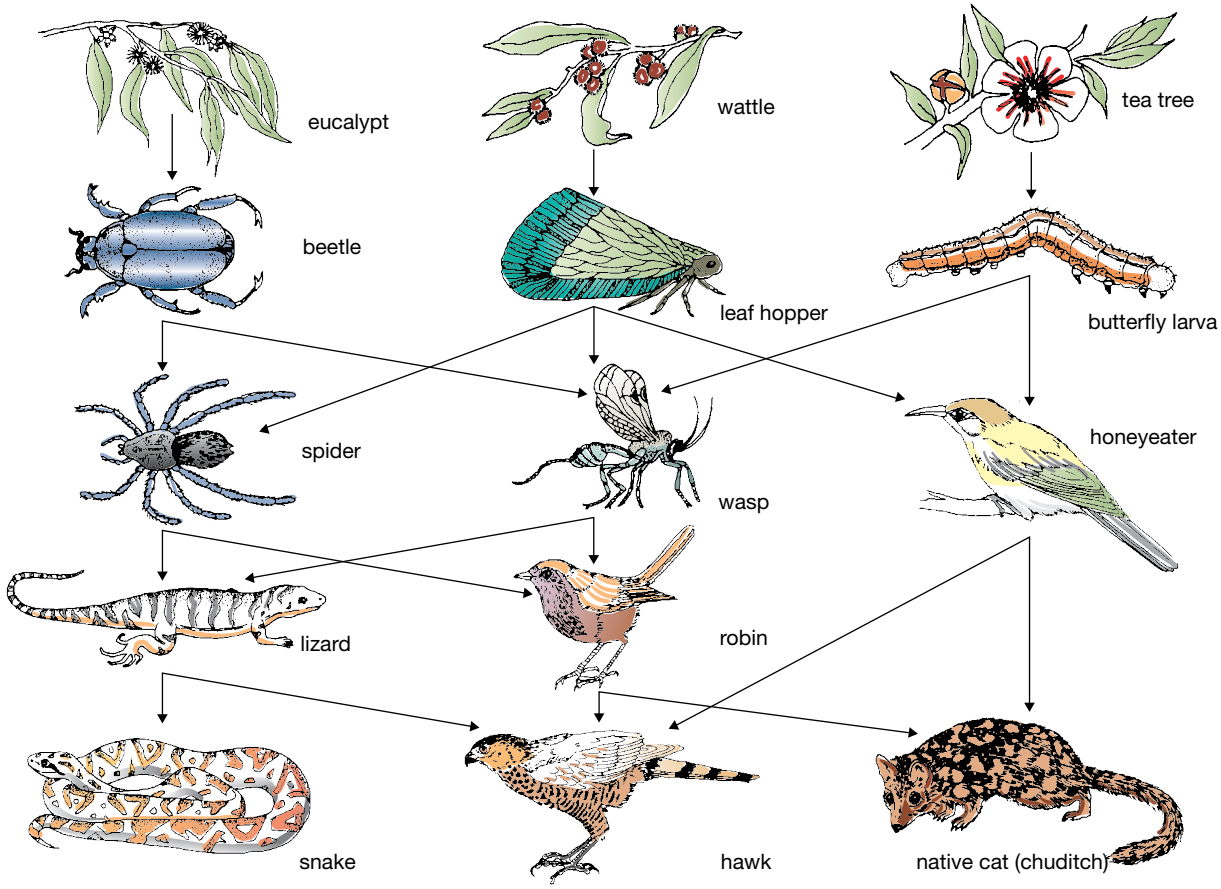


Figure 8.2.20

Creating CCT

20 **Use** your knowledge of energy flow in ecosystems to **construct** a scientific argument that it is more efficient to feed the world's population on plants than on animals.

Inquiring

1 Research five species, including some threatened plants and animals. For each species:

- show on a map where it can be found, naming any national parks in the area
- include a picture of the species
- state the known population size
- if it is threatened, state the main reason for its threatened status.

Present your findings in digital form. ICT

ADDITIONAL

2 Investigate how scientific models can be used to predict the changes in populations of native animals due to environmental changes. In your answer give an example of a model and also discuss the strengths and limitations of using models to make predictions about changes in ecosystems. CCT

3 Research five examples of advances in science and technology that have made important contributions to the study and practice of environmental science. Present your findings as a PowerPoint or similar digital document. ICT

ADDITIONAL

8.2 Practical investigations

1 Photosynthesis

Purpose

To determine whether carbon dioxide and light are necessary for photosynthesis.

Materials

- 150 mL of dilute bromothymol blue solution
- 2 small plants or shoots (for example, clover, soursob, geranium)

- 3 × 250 mL conical flasks and stoppers to fit
- aluminium foil
- straw
- lamp

SAFETY

Bromothymol blue is toxic if swallowed.

Wear safety glasses and avoid contact with skin.

Procedure

1. Your teacher will blow through the bromothymol blue solution until it turns yellow. Blowing adds carbon dioxide to the water.
2. Label the flasks 1–3. Add 50 mL of the yellow bromothymol blue to each conical flask.
3. Add a plant to flasks 1 and 3. Stopper all flasks.
4. Wrap flask 3 in aluminium foil so that light cannot enter. Your set-up should look like Figure 8.2.21.
5. Place all three flasks in the light until the next day. If you can, put them in sunlight during the day and leave them under a lamp overnight.
6. Observe the flasks the next day.

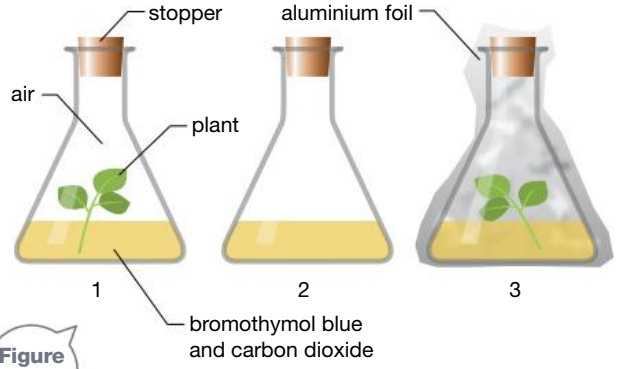


Figure 8.2.21

Results

Record your results in a table.

Practical review

1. **State** the colour of bromothymol blue when carbon dioxide is present and when it is absent.
2. **Identify** the flasks that had no carbon dioxide left at the end of the experiment.
3. **Deduce** what happened in flask 1 by comparing flasks 1 and 2.
4. **Deduce** what happened in flask 1 by comparing flasks 1 and 3.
5. **Explain** what this experiment has shown you about photosynthesis.
6. **Explain** how this prac is relevant to understanding ecology.

2 Studying a leaf litter environment

Purpose

To investigate the relationship between the community and the abiotic conditions in a leaf litter environment.

Materials

- 2 strips of blue cobalt chloride paper in a plastic bag, or a moisture meter
- 3 plastic bags
- margarine container
- thermometer
- binocular microscope
- Petri dish
- fine forceps
- mounted needle
- diagram sheet of soil organisms

SAFETY

Do not go near long grass or possible hiding places for snakes.

Do not pick up animals with your bare hands, as some may bite or sting. Use containers to pick them up.

Studying a leaf litter environment continued on next page

Procedure

1 Take the bags, margarine container, thermometer, cobalt chloride paper and forceps to an area around the school that has a natural leaf litter cover.

2 Check the air temperature about 1 m above the soil and record it in your notes.

3 Carefully push the end of the thermometer into the leaf litter but not into the soil. Be very careful not to break the thermometer. Record the temperature in your notes. Replace the thermometer in its case.

4 Remove a piece of cobalt chloride paper with forceps and hold it in the air for 1 minute. Record the colour in your notes. (Alternatively, use the moisture meter.)

5 Place the other piece of cobalt chloride paper deep in the litter layer for 1 minute and then record its colour in your notes.

6 Quietly observe the surface of the leaf litter for a minute or so. Look for any small invertebrate animals moving near the surface. If you can catch them, put them into one of the bags. Do not try to collect vertebrates like lizards or frogs. Try not to kill any of them.

7 Scrape off some of the fresh litter from the surface and place it in the bag with the animals already collected. Try not to dig down into the lower layers of decaying leaves. Now scrape up the darker decaying litter layer into another bag. Finally, scrape up about half a cup of soil and place it into the third bag.

8 Return to the classroom and use the microscope and books to identify any animals in the three layers. Some leaf litter animals are shown in Figure 8.2.22.

Practical review

1 **Describe** the main abiotic conditions of temperature, light and water in the leaf litter layer.

2 Fresh leaves fall each year, but the litter layer tends to stay the same thickness. **Explain** this observation.

3 The breakdown of the leaf litter begins with fungi, bacteria and certain animals. You probably found some animals from each of the following two groups. Choose one animal in each group and **explain** why it lives in the litter.

- Group A: springtails, millipedes, symphylids, bristle tails, earwigs, slaters, white worms, amphipods, mites
- Group B: spiders, centipedes, flatworms, pseudoscorpions, fly larvae, beetle larvae

4 **Propose** why it is necessary to have biodiversity in a leaf litter community.

5 **Propose** how this activity is relevant to our lives.

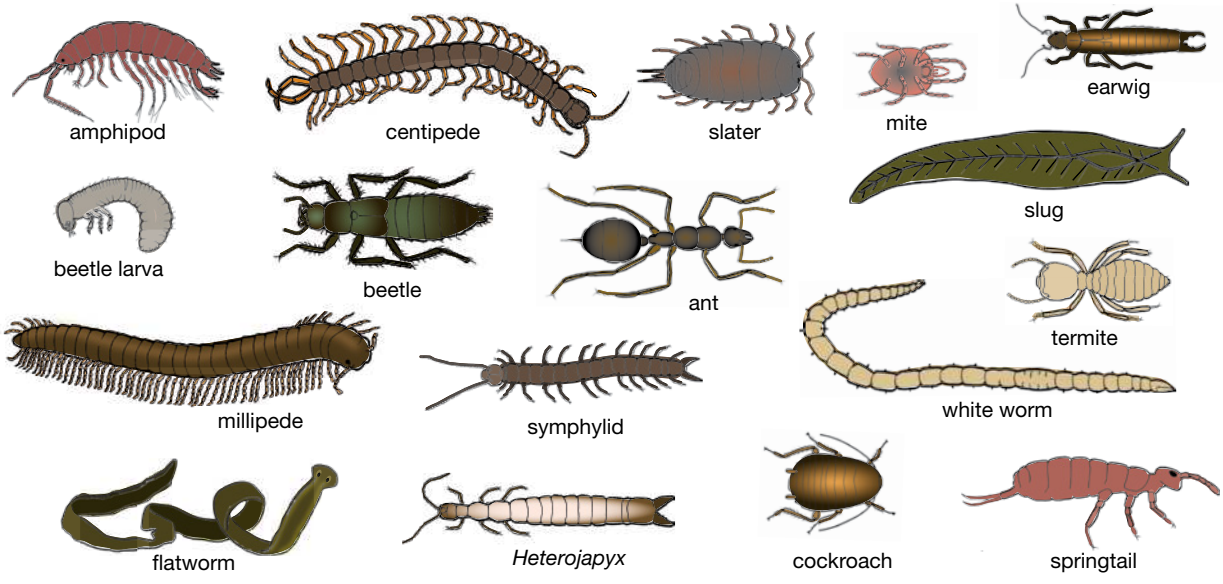


Figure 8.2.22

8.3 Managing human impact

Understanding how human activities cause damage to ecosystems helps scientists, governments and the general community to minimise the damage while still allowing human needs to be met. Around Earth, societies have developed strategies to protect ecosystems, showing that conserving and maintaining ecosystems is considered essential.

INQUIRY science 4 fun

Boosting germination

Does a commercial wildflower seed starter pack help seeds germinate?

YES

Collect this ...

- wildflower seed starter pack (vermiculite granules soaked in smoke water)
- 20 seeds (*Calytrix, Banksia paludosa, Solanum centrale*)
- potting mix
- 2 plant pots

Do this ...

1. Fill each pot with potting mix and push 10 seeds about 0.5 cm into the soil.
2. In one of the pots sprinkle the vermiculite granules on top of the potting mix after sowing the seeds.
3. Water the potting mix.
4. Observe the seeds for the next 2 weeks.

Record this ...

Describe your results.

Explain your results.

Human impacts

Humans affect ecosystems by destroying habitat, introducing new species, adding chemical pesticides and by polluting and overcropping them.

Habitat destruction

The term **habitat destruction** describes any damage done to the environmental factors that an organism depends on for survival. Examples of habitat destruction are mining, logging and land clearing like that seen in Figure 8.3.1. These activities don't necessarily destroy habitats permanently—ecosystems can be repaired if there is enough knowledge about the environment.

Animals such as the bilby, woylie (brush-tailed bettong, shown in Figure 8.3.2), rat kangaroo, potoroo and regent honeyeater have declined in numbers as a result of agricultural development. However, some animal populations have increased because farms, orchards and grazing land have increased their food supply. These animals include kangaroos, locusts and emus.

Figure 8.3.1 Land clearing for farms has destroyed much habitat.

Figure 8.3.2 Woylie (brush-tailed bettong) populations have declined, partly due to habitat destruction.

Introduced species

Animals and plants brought to Australia from other countries are known as **introduced species**. Some of these animals are predators that kill native animals. Some just compete with the native species for food, while others destroy habitat.

Introduced animals that have become established in the wild are referred to as **feral animals**. Feral cats and foxes (Figure 8.3.3) are predators that have had a devastating effect on wildlife.

Rabbits, camels, donkeys, horses, goats, mice, rats and pigs have also been introduced and can all be found running wild. They compete with native animals for food and shelter, and so fewer native animals survive.

Figure 8.3.3 Feral cats and foxes threaten native wildlife.

The situation is just as bad with introduced plants. Many of these have become weeds and compete with native plants for limited resources. Examples are watsonia, blackberry, veldt grass and the lantana shown in Figure 8.3.4. These plants currently cover large areas of native bush.

Figure 8.3.4 Lantana has become a problem weed in much of northern Australia.

Chemical insecticides

Insecticides are chemicals that kill insects. Some of the insecticides developed have been found to be dangerous to more than just insects. DDT is one example of this. Research in the 1970s found that DDT was present in all the organisms in a food chain, like the one shown in Figure 8.3.5 on page 318. The amount of DDT increases along the food chain. The reason more DDT was found in the clam than in the plankton was that the clam consumed a lot of plankton. Almost all the DDT in the plankton was stored in the clam's body, and little was lost during consumption. The gull ate many clams and stored most of the DDT in its body. So the gull contained a higher concentration of DDT. Poisons that build up in organisms in this way are known as cumulative poisons, because they accumulate (build up).

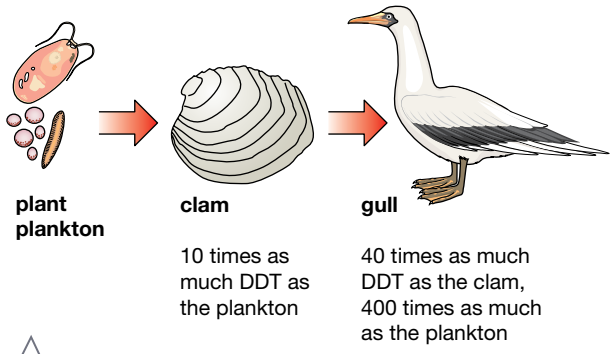


Figure 8.3.5 Food chain showing pesticide accumulation

The accumulated DDT had serious effects on some types of birds, especially peregrine falcons and eagles at the end of the food chain. DDT caused these birds to lay eggs with thin shells, which broke when the adult sat down to incubate them. So fewer young were produced, and the population decreased as adults died and were not replaced by young.

The discovery that DDT accumulated in humans (especially in breast milk) was also very worrying. No one knew what effects it might have on human health. Research has since shown that it is linked to many diseases such as cancer, diabetes, hormonal disruption and reproductive problems. DDT use was banned in Australia in 1987. However, it is still used in many poorer countries, particularly those that have a malaria problem. In these countries, DDT levels in breast milk are extremely high.

Not all insecticides accumulate in organisms as DDT does. However, they can still cause problems if they are not used carefully.

Useful insects such as bees, which pollinate flowers (Figure 8.3.6), or predatory wasps that kill insect pests, can be killed if the spray drifts away from crops, or if the farmer sprays at the wrong time.

Studies have shown that the insects can now withstand much stronger sprays than when spraying began years ago. The insects have become resistant to the chemicals.

Insects become resistant to these chemicals by a process called natural selection. As insecticides become less effective, higher and higher concentrations are needed to kill the pests.

GO TO Pearson science NSW 10 Unit 3.2

Figure 8.3.6 Pollination of flowers can be affected when insecticides kill bees.

SciFile

Go organic

Organic farming is based on the idea that many chemicals can cause problems. Organic farmers try to let insects be controlled naturally by the insects' enemies, rather than by using insecticides. The farmers also use recycled animal wastes instead of artificial fertilisers to enrich the soil. Another aim is to reduce contamination of the food by chemicals. Organically grown foods fetch high prices.

Chemical pollution

Any chemical waste that is allowed to enter the environment from industry, power stations, farms, sewerage systems and transport must be considered as **chemical pollution**. Some pollutants, such as the oil in Figure 8.3.7 that was spilt from a ship, are very obvious.

The effects of many other chemical pollutants are less obvious. For example, many scientists argue that carbon dioxide gas is polluting the Earth's atmosphere and causing it to get hotter. The general opinion is that the atmosphere is warming.

Figure 8.3.7 A volunteer helps to save a bird affected by oil from an oil spill.

Increased production of carbon dioxide gas by human activities is thought to be contributing to global warming, a process known as the **enhanced greenhouse effect** (Figure 8.3.8).

Carbon dioxide absorbs some of the heat radiated from the Earth, warming the atmosphere.

One likely result of raising the Earth's temperature is that the ice caps of Antarctica and Greenland will melt, causing sea levels to rise.

A warming atmosphere could also change wind and rainfall patterns. These changes could have large-scale effects on agricultural production and could lead to the extinction of many plant and animal species. Many governments have responded to this problem by trying to limit emissions of greenhouse gases, especially carbon dioxide.

Monitoring our environment to safeguard us against dangerous chemicals is an important job for health authorities and the environmental protection agencies of government.

GO TO Pearson science NSW 10 Unit 6.3

Prac 1 p325 Prac 2 p326

SciFile

Minamata disease

In the 1950s, over 100 people living near Minamata Bay in Japan died or suffered nerve damage. A chemical company had released mercury wastes into the bay, and these wastes were accumulating in the food chains in the sea. People eating the local fish absorbed large doses of these mercury compounds.

Figure 8.3.8 Combustion reactions release carbon dioxide, a greenhouse gas that is considered by almost all scientists to be responsible for global warming.

GO TO Unit 2.1

Overcropping

Overcropping of animal populations happens when more animals are killed than can be replaced by the normal breeding cycle. This results in a decrease in the population. Many of the world's whale populations have declined dramatically because of overcropping. The population of the blue whale (shown in Figure 8.3.9) in the 1980s was only about 5% of the population earlier last century. Blue whales are now totally protected, and populations are recovering very slowly.

Figure 8.3.9 The blue whale was almost hunted to extinction in the 20th century. Numbers of blue whale are still very low.

Strategies minimising human impact

There are many strategies that can be used to minimise the impact that humans have on the environment. These six strategies are among the most important.

Laws protecting threatened species

In New South Wales, there are laws to protect threatened species. These are the species with such small populations that they are likely to become extinct in the near future. There are over 950 threatened species, including the barking owl, Camden white gum and koala. The laws are set out in the Threatened Species Priorities Action Statement (PAS).

The PAS sets out strategies that can be used to create a recovery plan. A **recovery plan** is a detailed plan of how the population of a threatened species will be returned to a safe level to ensure its survival.

A recovery plan includes information on:

- where the species lives
- threats to the species
- management strategies such as protecting habitat and controlling fires
- community education programs.

The PAS lists 34 different strategies that can be used in the recovery of a species or to remove threats to species that are presently secure. These strategies include control of feral animals, weeds and fire, collection from the wild and reintroduction of endangered species to areas where the species used to exist.

Environmental impact statements

The Federal Government has a big influence on activities that could affect the environment. The mine in Figure 8.3.10 is one such activity. State governments also control development activities in each state. Any group wanting to undertake an activity that is large enough to cause environmental change must prepare an environmental impact statement, which must describe:

- what the existing environment is like
- the likely effects of the activity on the environment
- alternatives to the activity and their effects
- proposed safeguards and monitoring of the environment for damage.

The public can usually examine the impact statement and object to it. One problem is that the issues regarding the project may not be communicated to the public clearly enough for people to be aware of the activity or that they have the right to object.

Figure 8.3.10 Proposals for mining development such as this dredge mine require an environmental impact statement.

Protected areas

There are many types of **protected areas**. These are set aside to conserve a range of important ecosystems in New South Wales. These areas include World Heritage sites, nature reserves, national parks, wilderness areas and aquatic reserves. The level of legal protection varies for each type of protected area. For example, Wollemi National Park is a World Heritage site. Its main role is to protect the threatened Wollemi pine.

There are strict rules about who can enter protected areas and the types of activities that are allowed. This helps preserve the habitats in them.

Fishing and hunting controls

The New South Wales Government controls fishing and hunting in the state. Laws govern how many fish and animals of each type may be caught, when they can be caught and what size or age they must be. For example, mulloway is currently being overfished in New South Wales and a recovery plan has been proposed. The total catch allowed needs to be reduced by at least 50–70% to stop overcropping and to allow the population to stabilise by replacing itself through breeding.

Wondrous Wollemi

SciFile

The Wollemi pine was discovered in 1994 by David Noble, a New South Wales parks and wildlife officer. He was bushwalking in the Blue Mountains when he saw a tree that he did not recognise. He took a piece to botanists, who were amazed when they compared it with fossils of a similar tree. They found that the Wollemi pine had a history dating back 90 million years. Only 100 trees survived to the present day (Figure 8.3.11).

Figure 8.3.11 The Wollemi pine is a threatened species that is totally protected in the wild.

8.6

Laws on land clearing

Property owners such as farmers need permission from the government before they can remove bushland or forest. They are not allowed to plough up native vegetation, thin out bushland, spray native vegetation or remove vegetation beneath trees. These laws enable scientists to limit how much habitat is destroyed. They also allow scientists to manage associated environmental damage such as salting of land.

Destroying introduced pests

Introduced pests such as rabbits, foxes, blackberry and fireweed are removed where they are a serious threat to natural ecosystems or to agricultural production. Foxes are controlled using a poison known as 1080 ('ten eighty') that is laid in baits either on the ground or by air. Large areas of New South Wales are baited in this way, mainly in areas where foxes are impacting on threatened species.

Biological control is the use of a natural enemy against a pest species. An example is the waterweed *Salvinia*. *Salvinia* is a floating fern and is one of the most damaging waterweeds in the world. It can double the area it covers in a few days. It floats on the water surface and forms mats about a metre deep. This blocks all light from entering the water. The plant's roots also remove oxygen from the water, which results in the death of aquatic animals.

Lake Moondarra in Queensland became covered in the weed in 1980. Australia's CSIRO (Commonwealth Scientific and Industrial Research Organisation) searched for a natural enemy that would act as a biological control for the weed. In its natural habitat in Brazil, a species of weevil (Figure 8.3.12) feeds on the plant. These weevils were released onto Lake Moondarra and 14 months later the weed coverage was reduced to almost nothing. A similar problem with *Salvinia* occurred on the Sepik River in Papua New Guinea. Again the weevils were released and managed to clear the river of the weed. You can see the results in Figure 8.3.13.

8.7 8.8

Figure 8.3.12 The weevil that is a biological control agent for *Salvinia*

Figure 8.3.13 The Sepik River, Papua New Guinea, before and after the weevil was released to control *Salvinia*

LEARNING ACROSS THE CURRICULUM

ABORIGINAL AND TORRES STRAIT ISLANDER HISTORIES AND CULTURE

ABORIGINAL PEOPLE, FIRE AND ECOSYSTEMS

Australia's Aboriginal people have been here for over 50 000 years. Research is continuing into how their use of fire to improve hunting affected the vegetation and fauna of the country. Burning of the bush was viewed differently by the early Europeans and the Aboriginal people. The early Europeans seem to have been frightened of fires, whereas in some areas the Aboriginal people burned bushland regularly to improve hunting.

Figure 8.3.14 Fire is used to manage the landscape today, much like it was 50 000 years ago.

Today, widespread burning is conducted by government departments to protect houses in fire-prone areas. Burning is also conducted to keep the amount of plant litter low, in order to prevent larger fires that could damage the bush as well as properties. Research indicates that keeping plant litter levels low helps in the management of hot fires.

Figure 8.3.15 A painting by Joseph Lycett showing Aboriginal people using fire to hunt in New South Wales in 1817

Research into the effect of fire on native plants such as banksias has revealed that even the earliest plant fossils dating back to 40 million years ago were adapted to fire. Researchers concluded that Aboriginal people could not have affected the characteristics of these plants. However, Aboriginal land-management practices may have affected where the plants grew. Most researchers agree that Aboriginal people in many areas of the country used a hunting method called '**firestick farming**'. Fires were deliberately lit to create conditions suited to plant regrowth (Figures 8.3.15 and 8.3.16). The fresh growth attracted herbivorous animals to the area to feed, and made hunting easier. The fire also recycled nutrients back into the soil, which helped rejuvenate the land and made it more productive as a food source for humans. In some areas, small fires were lit to produce smoke, which frightened animals out of the undergowth and made them easier to catch.

Some recent research using satellite imaging of land being managed by the Martu people in the Western Desert has demonstrated that using a regular pattern of small fires changes the plant species that grow in grassland areas. The vegetation in areas that had

regular small burns is different from areas where lightning strikes started the fires. The main effect was that areas subjected to firestick farming had greater diversity of species. These research results support views proposed by ecologists many decades ago. Early last century, ecologists discovered that fire affects the germination of some species but not others, and that species favoured by fire become more common in areas that are burned.

Some recent evidence contradicts the idea that the use of fire by Aboriginal people had a major impact on the vegetation in forest areas. A research study headed by Dr Scott Mooney from the University of New South Wales looked at 223 sites around Australia and surrounding countries. The study compared charcoal deposits from the past 70 000 years with climate records. The study concluded that the major factor affecting fires was variations in climate between hot and cold periods. Fire activity was high between 70 000 and 28 000 years ago, then decreased between 28 000 and 18 000 years ago. It increased again after 18 000 years ago, and even more after European settlers colonised the country. This evidence seemed to indicate that climate rather than human activity was the main factor in fire history over a long period of time.

Research is continuing, and the debate about burning to control species diversity and to reduce the intensity of fires will probably continue for some time.

REVIEW

1 **State** how long Aboriginal people have been in Australia.

2 **Compare** the views of the early settlers and the Aboriginal people regarding fire.

3 Controlled burns are still done regularly in many places in Australia. **State** the aims of this burning.

4 **List** the evidence that the Aboriginal people of Australia did not change the characteristics of plants through their use of fire.

5 **Describe** the main aim of firestick farming and the beneficial effect it had on burnt areas.

6 **Assess** the impact of the use of fire by the Martu people in the spinifex grasslands of the Western Desert.

7 **Assess** the impact of firestick farming on forest areas.

Figure 8.3.16 An Aboriginal man and his son using firesticks to burn off grassland in Arnhem Land, Northern Territory

8.3 Unit review

Remembering

1 **List** six strategies that are used to limit the damage caused by human activities in ecosystems.

2 **State** three examples of habitat destruction.

3 **State** an example of damage to ecosystems caused by chemical:
- a insecticides
- b pollution.

Understanding

4 **Define** the term: L
- a threatened species
- b overcropping.

5 **Explain** what is meant by a recovery plan, including some of the main types of information included in a plan.

6 **Explain** how overcropping can lead to the extinction of a species.

7 **Explain** how the clearing of land for farming has affected natural communities.

8 **Explain** how introduced animals (such as rabbits, foxes, cats and wild pigs) affect native animals.

9 **Explain** how the greenhouse effect may cause problems in the future.

Applying

10 Wildflowers often bloom better after a bushfire has passed through the area. **Use** this information to **predict** what might happen in the science4fun on page 316.

11 **Identify** the environmental problem caused by human activities that each of the following strategies attempts to solve.
- a National parks and reserves
- b Fishing licences
- c Environmental impact statements

12 **Demonstrate** how each of the strategies listed in question 11 achieves the goal of limiting the human impact on ecosystems.

Analysing

13 **Discuss** whether the waterweed *Salvinia* would cause problems for:
- a other plants in the water.
- b consumers that live in the water.

Evaluating CCT

14 When cropping native fish species such as the mulloway, there are laws that control:
- what size the fish must be
- how many can be caught.

Justify how each of these laws may assist in the conservation of the mulloway.

15 Large areas of the Amazon rainforest are being cut down. **Propose** what effect this could have on the Earth's climate.

16 The navy intercepts any fishing vessels from overseas that come inside Australian territorial waters. **Propose** why this is done.

17 CSIRO scientists found it very difficult to find the place of origin of the weed *Salvinia*. Eventually they found small amounts of it in a small river system leading into the Amazon in Brazil. Considering *Salvinia* can cover large areas in a short time, **propose** reasons why was it hard to find the weed in its natural environment.

Creating CCT

18 **Construct** a food web to **explain** how a cumulative poison sprayed onto crops could kill predatory birds such as wedge-tailed eagles..

Inquiring

Research examples of Aboriginal and Torres Strait Islanders:
- understanding the relationships between organisms, and between organisms and their physical environment
- using cultural practices and knowledge to conserve and manage ecosystems sustainably
- thinking differently from European settlers regarding their use of the environment.

Present your findings in digital form. ICT

8.3 Practical investigations

1 Wastes

Yeast is a microscopic fungus found in water and on land. When it has food, it uses oxygen for respiration and to grow.

Purpose

To investigate the effect of wastes on water communities.

Hypothesis

What do you think will happen to the oxygen content of a yeast–water mixture if you give the yeast some milk? Before you go any further with this investigation, write a hypothesis in your workbook.

Materials

- 5 mL of each of 25%, 50%, 75% and 100% milk solutions
- methylene blue indicator solution in a dropper bottle
- dry yeast

- teaspoon
- 20 mL measuring cylinder
- 5 small test-tubes
- test-tube rack
- 100 mL beaker
- marking pen
- timer with a split button
- stirring rod

SAFETY

Methylene blue is toxic if swallowed and irritating to the eyes and skin. Wear safety glasses at all times.

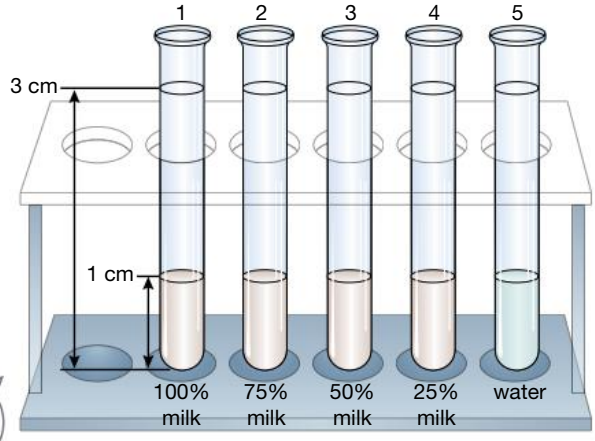


Figure 8.3.17

Procedure

1. Mix half a teaspoon of yeast and 20 mL of warm water in the beaker. Leave this to stand.
2. Mark each test-tube with a line 1 cm from the bottom and a line 3 cm from the bottom. Number the test-tubes from 1 to 5.
3. Pour the 100% milk solution into test-tube 1 up to the 1 cm mark.
4. Repeat the process with the 75%, 50% and 25% milk solutions in test-tubes 2–4 respectively.
5. In test-tube 5 place tap water up to the 1 cm mark.
6. Add 8 drops of methylene blue to each test-tube and mix well. The tubes should appear blue because there is plenty of oxygen in the water. Methylene blue turns colourless when there is no oxygen.
7. Pour the yeast solution into each test-tube up to the 3 cm mark and mix each test-tube well. Do this as quickly as possible. Each tube should be done at the same time. If this is not possible, then record the time when each tube was mixed.
8. Use the split button on the timer to record how long each test-tube takes to lose its blue colour.

Results

Record your times in a suitable table.

Practical review

1. **Explain** what caused the colour change from blue to colourless.
2. **Describe** the relationship between milk concentration and time taken to lose the blue colour in the test-tube.
3. a **Construct** a conclusion for your investigation.
   b **Assess** whether your hypothesis was supported or not.
4. **Explain** what could happen in a swamp ecosystem if human food wastes got into the water and the microorganisms reacted like the yeast in this prac.

8.3 Practical investigations

STUDENT DESIGN

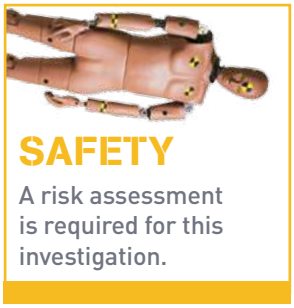
2 Detergents and plants

Purpose

To investigate the effect of detergent on water plants.

Materials

- materials as selected by students



SAFETY

A risk assessment is required for this investigation.

Hypothesis

How do you think detergent entering rivers and lakes will affect aquatic plants living in them? Before you go any further with this investigation, write a hypothesis in your workbook.

Procedure

1. Researchers suspect that water plants could be damaged by detergents entering our waterways. Design a way of testing whether this is true.
2. Brainstorm in your group and come up with several different ways to investigate the problem. Select the best procedure and write it in your workbook. Draw a diagram of the equipment you need.
3. Before you start any practical work, assess all risks associated with your procedure. Refer to the MSDS of all chemicals used. Construct a risk assessment that outlines these risks and any precautions you need to take to minimise them. Show your teacher your procedure and your risk assessment. If they approve, then collect all the required materials and start work.

Hints

In your group, decide on aspects of your design, such as:

- how you will decide that plant health is damaged
- how you will apply the detegent and how much you will use
- how many plants to use and how long the experiment will last.

Results

Collect all the results in the class.

Practical review

1. a **Construct** a conclusion for your investigation.
   b **Assess** whether your hypothesis was supported or not.
2. **Evaluate** your procedure. Pick two other prac groups and **evaluate** their procedures too, identifying their strengths and weaknesses.

8 Chapter review

Remembering

1 **List** the components of an ecosystem.

2 **List** the major ways in which humans are damaging the environment.

3 a **Name** five feral animals in Australia.
b **Specify** the type of damage they do in ecosystems.

Understanding

4 **Explain** why biodiversity is important.

5 **Explain** why all organisms in an ecosystem are interdependent.

6 **Discuss** ways of protecting and managing ecosystems.

7 **Discuss** why it is important to protect ecosystems.

8 **Explain** why termites are important in Australian ecosystems, and how they manage to perform their role.

9 **Explain** how seasonal changes in temperature, water availablity and sunlight can affect ecosystems.

Applying

10 a **Identify** five biotic factors and five abiotic factors that affect you.
b **Explain** how they affect you.

11 **Use** energy in ecosystems and pyramids of biomass to **explain** why food chains are usually fairly short, with perhaps only four levels of consumer.

Analysing

12 A dingo and a wedge-tailed eagle both prey on rabbits. The dingo is infested with fleas. **Classify** the relationships between the dingo, eagle, rabbit and fleas as parasitism, predation or competition.

13 **Compare** the effect that any two biotic and abiotic factors have on you and on a plant in your garden.

14 Choose an ecosystem close to where you live.
a **Name** two different species of animals in the ecosystem.
b **Identify** an environmental factor that you think affects the two species.
c **Compare** how the two species are affected by that particular environmental factor.

15 a **Compare** the concepts of sustainability and protection of the environment (conservation).
b **Discuss** how they are interdependent.

16 The ecological footprint of Australia is about nine times greater than that of India. **Analyse** what this means for the sustainability of our lifestyles in Australia.

17 Figure 8.4.1 shows the changes in oxygen content in a lake. Assume temperature changes had minimal effect on the amount of oxygen dissolved. **Interpret** the changes in oxygen content over the 24 hours.

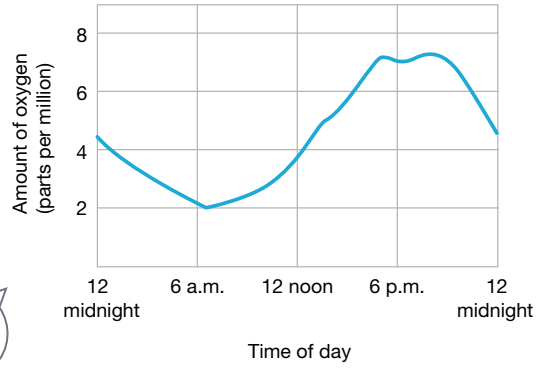


Figure 8.4.1

18 **Discuss** the following statement.

Maintaining a sustainable environment requires scientific understanding of interactions in and of the flow of matter and energy through ecosystems.

Evaluating CCT

19 **Justify** the argument that photosynthesis is the most important process in ecosystems.

20 a **Determine** whether you can or cannot answer the questions on page 291 at the start of this chapter.
b **Assess** how well you understand the material presented in this chapter.

Creating CCT

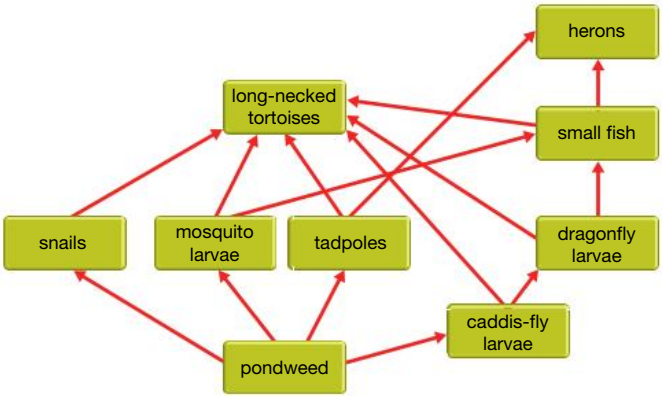
21 **Use** the following ten key terms to **construct** a visual summary of the information presented in this chapter.

biotic factors
abiotic factors
environment
interdependence
biodiversity
conservation
human impacts
energy flow
sustainability
cycling of matter

8.9

Thinking scientifically

Questions 1–4 are based upon the following food web.



Q1 Identify which of the relationships in the following table is correct. CCT

	Predation	Competition
A	Small fish and mosquito larvae	Tadpoles and dragonfly larvae
B	Snails and pondweed	Herons and small fish
C	Herons and small fish	Herons and long-necked tortoises
D	Long-necked tortoises and tadpoles	Tadpoles and small fish

Q2 If the lake was sprayed to control mosquitoes, identify the most likely effect. CCT

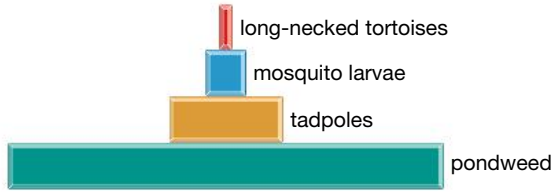
A The biomass of pondweed would decrease.
B The tadpole population would decrease.
C Most of the herons would migrate out of the area.
D The population of small fish would decrease.

Q3 If a disease killed most of the long-necked tortoises, identify a likely short-term change in the ecosystem. CCT

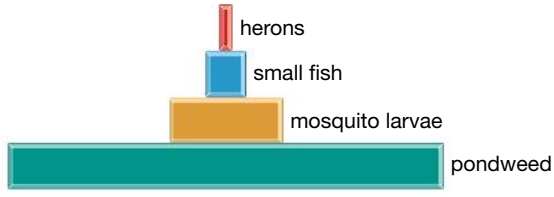
A rapid increase in the numbers of small fish
B decrease in the numbers of heron
C rapid increase in the biomass of pondweed
D no change in the biomass of caddis-fly larvae

Q4 Identify which of the following is a correct pyramid of biomass that could be drawn for this ecosystem. CCT

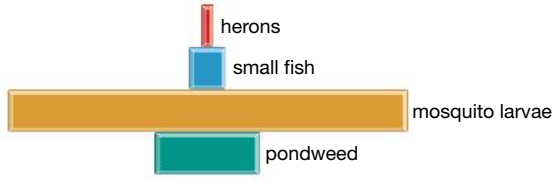
A



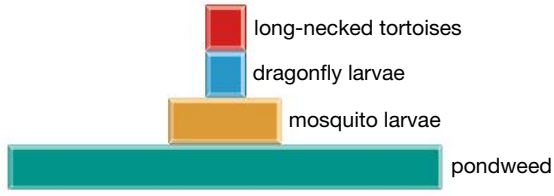
B



C



D



Glossary

Unit 8.1

Abiotic factor: a non-living factor of the environment, also known as a physical factor

Biotic factor: a living factor of the environment

Commensalism: relationship where one organism benefits and another organism is unharmed

Community: all the living organisms in an ecosystem

Competition: relationship between organisms that are trying to use the same limited resource

Competition

Ecology: the study of how organisms interact with each other and with their non-living surroundings

Ecosystem: a place where organisms and their physical surroundings form an environment that is different from others nearby

Ectothermic: animals that obtain body heat from outside their body

Endothermic: animals that can generate body heat internally

Environment: all the factors in an organism's surroundings that affect its survival

Interdependence: relationship between organisms, where each affects the other's survival

Mutualism: relationship between two organisms living closely together, where each benefits

Parasitism: relationship where one organism lives on or in another organism and feeds off it

Photosynthesis: the process by which plants make their food

Predation: relationship where one organism kills and eats another organism

Unit 8.2

Biodiversity: the range of different species in a community

Decomposers: organisms that break down the bodies of dead organisms and animal wastes and recycle material

Denitrification: the loss of nitrogen from soil and water to the air when bacteria convert nitrates to nitrogen

Ecological footprint: the area of land and water needed to provide resources necessary for survival

Food chain: a sequence of organisms feeding on each other

Food chain

Food web: connected food chains showing who eats whom in a community

Keystone species: species that are critical to the survival of an entire ecosystem

Legumes: a group of plants with root nodules where nitrogen-fixing bacteria live

Nitrification: the process of converting nitrogen in the air to compounds such as ammonia by soil bacteria

Nitrifying bacteria: soil bacteria that convert nitrogen in the air to compounds such as ammonia

Producers: organisms that make food for the community

Productivity: how well an area supports life

Pyramid of biomass: a diagram that shows the total mass of organisms at each stage of a food chain

Sustainable living: humans living in a way that ensures that resources do not run out and the natural ecosystems are not damaged

Unit 8.3

Biological control: the use of a natural enemy of a pest to control the numbers of that pest

Chemical pollution: chemicals escaping into the environment that can damage ecosystems

Enhanced greenhouse effect: the part of global warming due to human activities

Feral animal: an introduced species of animal that has become established in the wild

Global warming: the increase in the temperature of the Earth's atmosphere

Habitat destruction: damage caused to the factors in the environment needed for survival

Introduced species: species not native to Australia

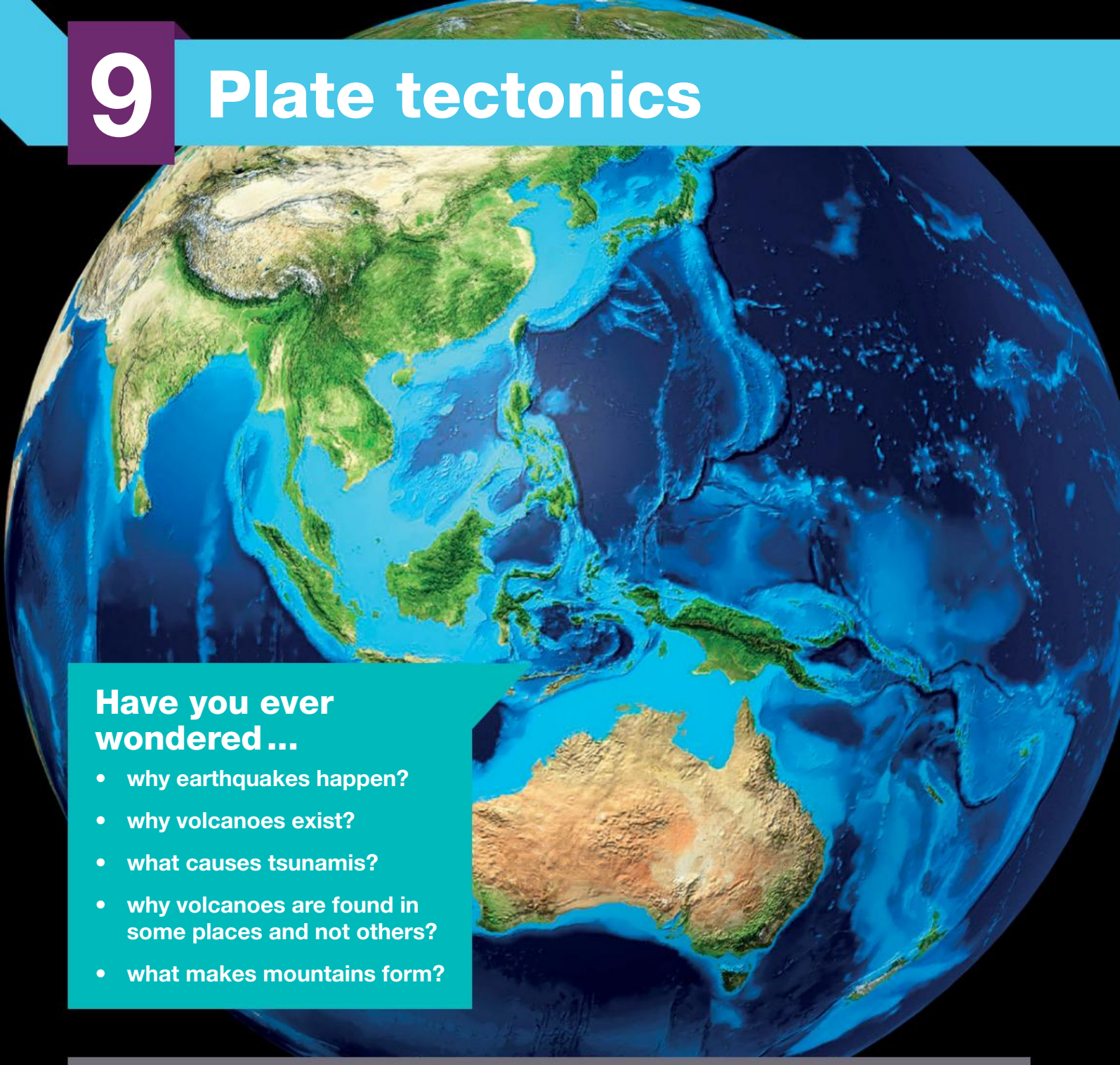
Overcropping: removing more individuals from a population than can be replaced by breeding

Introduced species

Protected area: an area set aside to conserve ecosystems, especially to protect the habitat of species in the area

Recovery plan: a plan detailing how the population of a threatened species can be returned to a safe level to ensure its survival

9 Plate tectonics



Have you ever wondered...

- why earthquakes happen?
- why volcanoes exist?
- what causes tsunamis?
- why volcanoes are found in some places and not others?
- what makes mountains form?

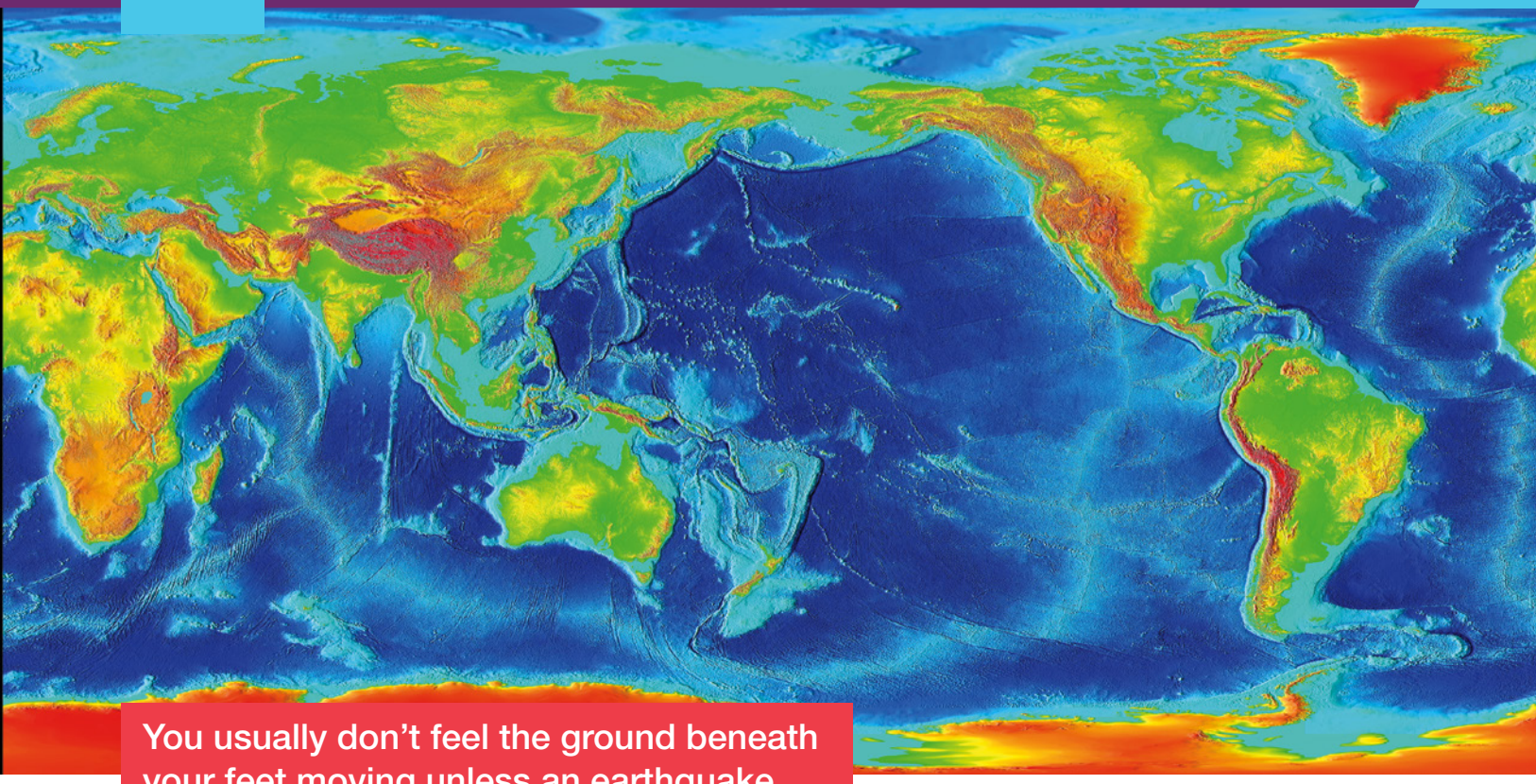
After completing this chapter students should be able to:

- outline how the theory of plate tectonics changed ideas about the structure of Earth
- use convection and gravity to explain the movements of Earth's plates
- outline how the theory of plate tectonics explains earthquakes, volcanic activity and formation of new landforms A
- describe how technological developments have increased our understanding of geological activity, including in the Asia–Pacific region A CCT

ADDITIONAL

- discuss technological developments that have extended the ability of scientists to collect information about the natural world CCT
- outline examples of advances in science generating new career opportunities in geophysics and vulcanology WE
- use an equation for speed to calculate the age of oceans. N

9.1 Moving continents



You usually don't feel the ground beneath your feet moving unless an earthquake happens. However, there are movements that are much slower and less noticeable than earthquakes. Geologists have collected a large amount of evidence to show that whole continents are moving.

Continental drift

A revolutionary new theory about Earth was proposed in 1912. In that year, the German meteorologist and geophysicist Alfred Wegener (1880–1930), claimed that the continents were once connected to each other. He called the large landmass Pangaea, and concluded that the continents must somehow have separated and drifted across the oceans. His theory was called **continental drift.**

Wegener based his conclusions on two main observations. The first observation was that the continents seemed to fit together like a jigsaw. You can see this in Figure 9.1.1. The second observation was that fossils of the same prehistoric species were found on continents that were a long way apart. He could see no way that the organisms could cross the oceans to reach all of these places. Instead, he thought that the continents themselves had shifted. As they shifted, they took the fossils with them. Wegener rearranged the continents, joining them so that the distribution of the fossils matched up across the continents. This can be seen in Figure 9.1.2 on page 332.

Figure 9.1.1 Africa and South America seem to fit together like pieces of a jigsaw.

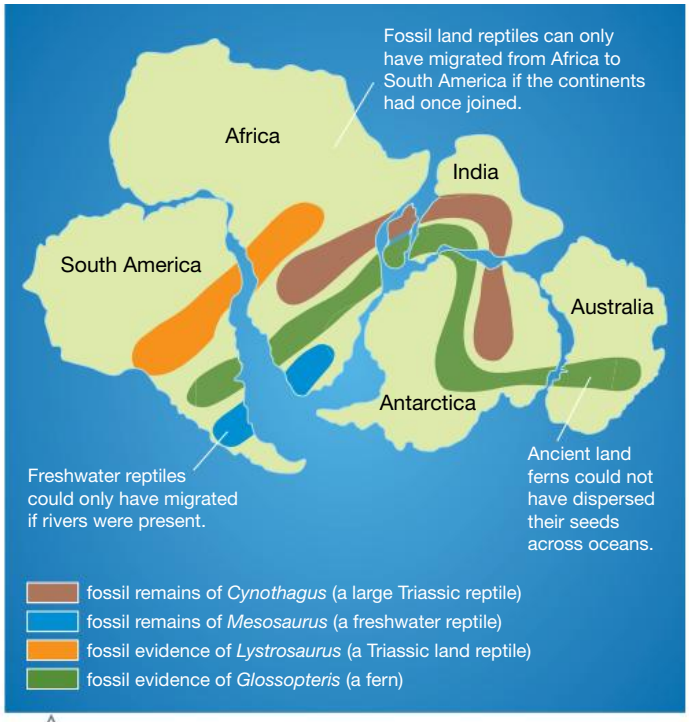


Figure 9.1.2 Fossil distribution makes sense if the continents were once connected as shown here.

At the time, few scientists agreed with Wegener's theory. The main reason was that there was no mechanism known by which huge continents could move. There was also no way of measuring whether the continents moved or not. Wegener died in 1930, before the discovery of new evidence that would prove him correct.

9.1

Seafloor spreading

In 1872, scientists were surveying the ocean floor for an undersea telegraph cable to be laid between North America and Europe. They measured ocean depth by dropping down very long cables and measuring their length. In the middle of the Atlantic Ocean, they discovered a large mountain ridge that extended a long way south. The extent of the ridge was not investigated then. However, in 1925, German scientists used sonar (echo sounding) to confirm that this ridge ran the entire length of the Atlantic Ocean.

GO TO Unit 3.2

After 1945, further studies using sonar showed that the underwater ridge continued into other oceans and around Earth. In 1953, the ridges were found to have a series of huge cracks along them. The cracks are called **rifts** and so the system was named the Great Global Rift system. You can see some of it in Figure 9.1.3.

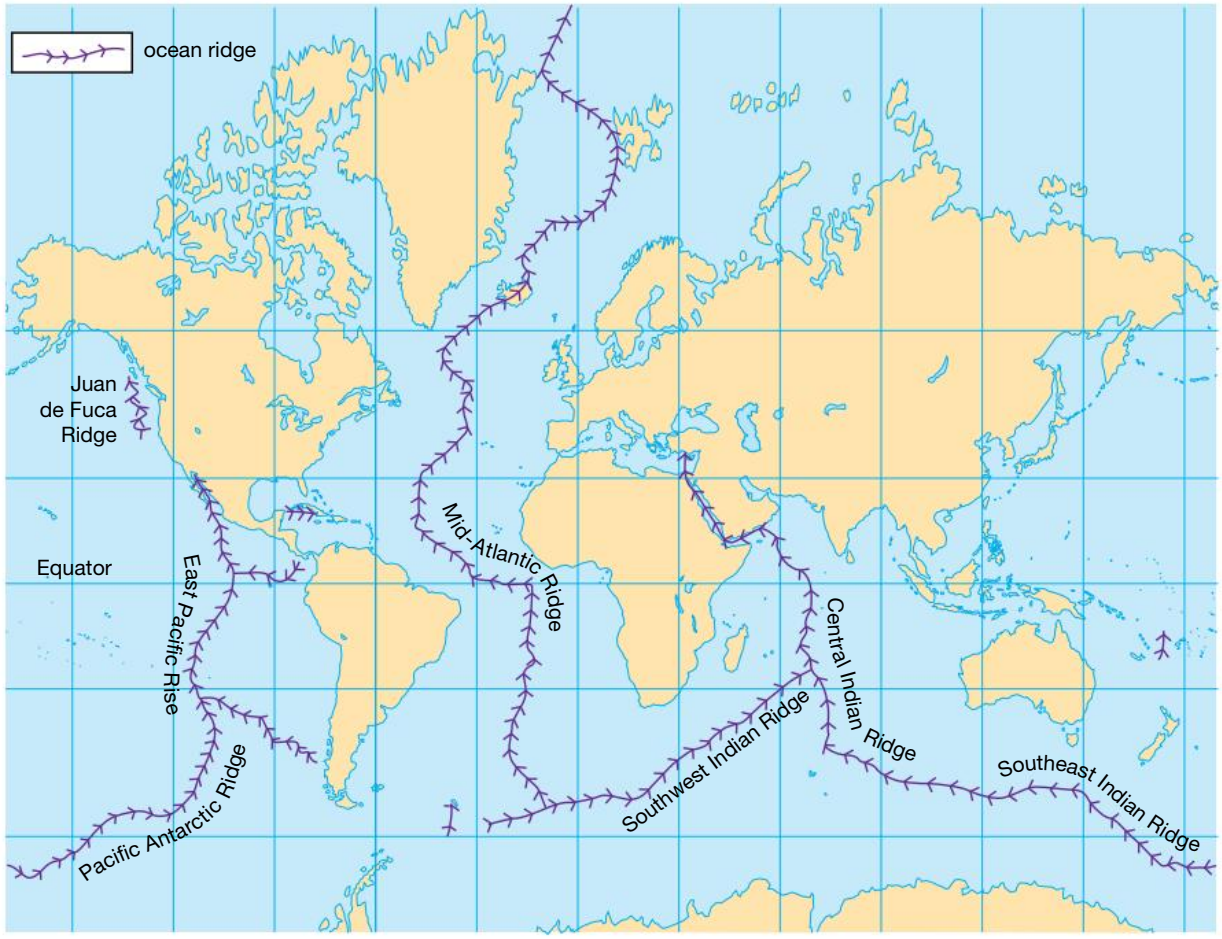


Figure 9.1.3 The Great Global Rift system of ocean ridges

In 1962, an American geologist Harry Hess (1906–69), tried to explain what was happening at the ocean ridges. While serving the US navy during World War II (1939–45), Hess had used sonar to map the floor of the Pacific Ocean. There he had discovered many underwater, flat-topped mountains. When the Great Global Rift was found, he thought back to his discoveries of mountains under the sea.

Hess proposed that new rocky crust was being formed at the ocean ridges and spreading outwards. This process was later called **seafloor spreading**. Hess proposed that the crust was sinking down into Earth, forming **ocean trenches**. The process of the crust sinking down like this is called **subduction**. You can see these processes of forming new crust and destroying it in Figure 9.1.4.

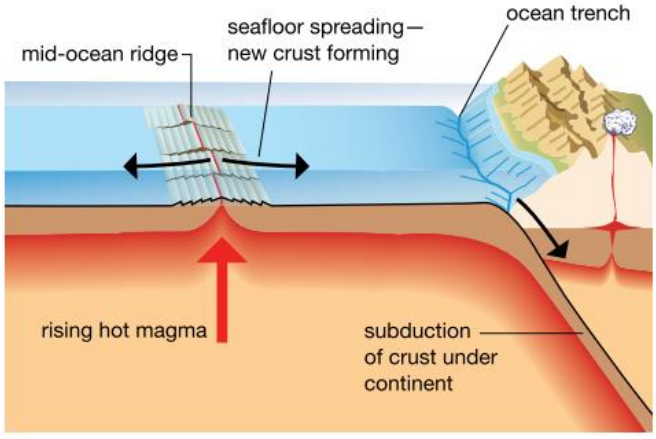


Figure 9.1.4 Seafloor spreading forms new crust and subduction eventually destroys it.

Support for Hess's theory

The theory of seafloor spreading proposed by Hess is supported by three important pieces of evidence:

- magnetic striping
- age of the sea floor
- sediment thickness.

Magnetic striping

In the 1950s, scientists discovered that many rocks contained the magnetic iron oxide mineral called magnetite. Magnetite has a north-seeking pole and a south-seeking pole, just like a compass needle.

When molten rock solidifies, all the magnetite particles in it line up with Earth's magnetic field to point in the same direction. In this way, the direction of Earth's magnetic field at the time is preserved in the rock.

The direction of the magnetic field of these magnetite particles can be detected with a device called a magnetometer. During World War II, US navy magnetometers showed that there were bands of alternating strong and weak magnetism on the sea floor. These bands were parallel to the mid-ocean ridges. You can see this in Figure 9.1.5.

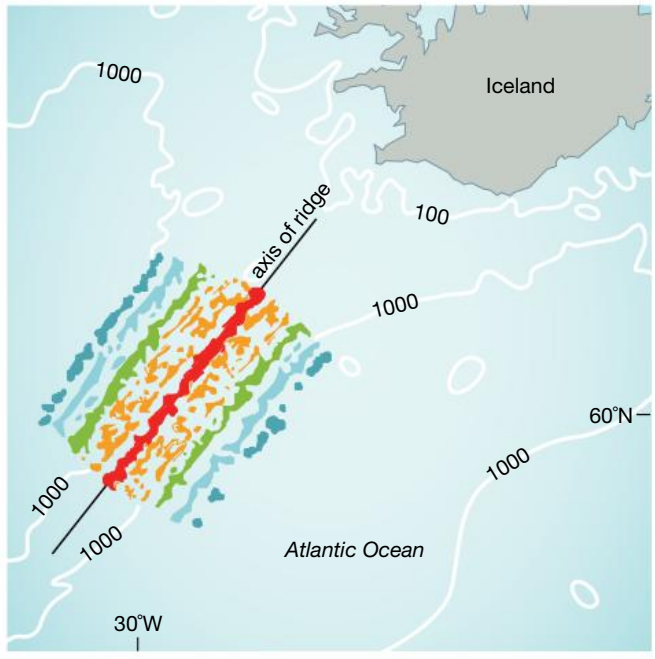


Figure 9.1.5 The magnetism in the rocks on each side of the mid-ocean ridges is symmetrical—it consists of alternating bands of strong and weak magnetism.

Geologists found that as they went away from the ridge, the magnetic field preserved in the rocks kept changing. At the start, the rocks had north pointing in the correct direction (towards what is now Earth's north pole). Suddenly the direction of north changed to the opposite direction. North became south, then changed back again. This was very puzzling, because there was no way that the rocks could have spun around. The conclusion was that Earth's magnetic field had changed every few million years.

These patterns of strips of rocks with alternating magnetism are called **magnetic striping**. The patterns on either side of the ridge are symmetrical—rocks at a particular distance from the ridge on one side always have their magnetic fields pointing in the same direction as rocks the same distance away on the other side. That is, their magnetic fields both point to the current position of north, or both point to the current south.

INQUIRY science 4 fun

Making a compass

YES

Can you make a compass?

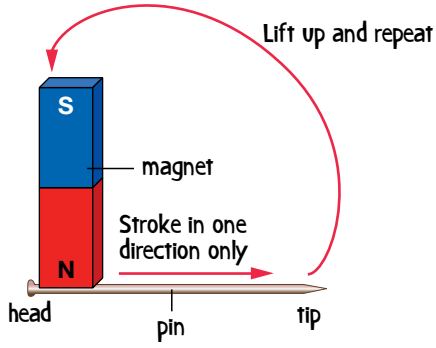
Collect this …

- small steel nail or pin
- bar magnet
- 20 cm of cotton
- compass
- sticky tape

Do this …

1 Place the pin on the desk and stroke it ten times from head to tip with the north-seeking pole of the bar magnet. Lift the magnet up and place it back at the head of the pin after each stroke.

2 Tie or sticky tape the piece of cotton firmly in the middle of the pin so it hangs horizontally, and let it hang down and spin freely. Make sure you are further than 2 metres away from any metal object and the magnet.



3 Note which direction the pin tip points in. Spin it around a few times to see if it always points in the same direction. Compare the direction with a compass if you have one.

4 Repeat step 1 but use the opposite end of the magnet. Note any differences this time.

Record this …

Describe what happened.

Explain why you think this happened.

More research into magnetic striping led geologists to support Hess's theory about seafloor spreading. They concluded that there were great cracks in the crust and that magma rose up and added to each side of a crack to form new crust on the seafloor. New seafloor was being added equally on each side of the ridge.

This is why the pattern of magnetism was symmetrical—the rocks at equal distances on each side of the ridge were formed at the same time and so had their magnetic fields pointing in the same direction. As Earth's magnetic field changed over many millions of years, so did the magnetic direction preserved in the rocks (Figure 9.1.6).

Prac 1 p338 9.2

Age of the sea floor

More evidence supporting the theory of seafloor spreading came from the dating of rocks on the sea floor:

- The further the rocks of the sea floor were from the ridges, the older they were. This is exactly what you would expect if new rocks form near the mid-ocean ridge and move outwards away from it.

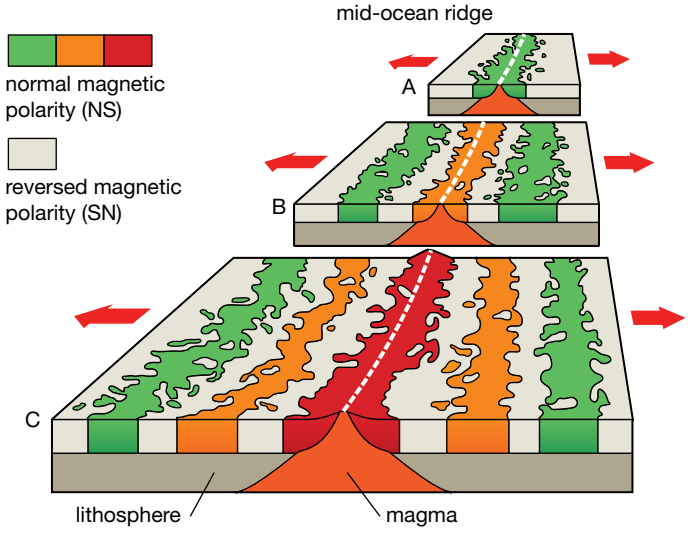


Figure 9.1.6 Magnetic striping is due to new sea floor forming on each side of a crack in the crust. The time sequence here goes from A to C.

- The oldest seafloor rocks found were only about 200 million years old. Some of the rocks in the continents were thousands of millions of years old. So the sea floor was very young compared with the continents.

Sediment thickness

When the sedimentary rock layers on the ocean floor were studied, it was found that the layers became thicker as you moved away from the ridges. This was interpreted by geologists as showing that sediments had been falling for longer on the rocks on the sea floor furthest away from the ridges.

Glomar Challenger

SciFile

Studying the thickness of sediments on the bottom of the ocean is not easy. The solution was to use a special drilling ship called the *Glomar Challenger*. This used extremely long 'drill strings'. The motor was in the ship and the drill bit cut the rock over 5 km below.

Tectonic plates

The picture that scientists now have of Earth supports Wegener's original view of continental drift. Scientists have concluded that Earth consists of several layers with different physical properties. The current view of its structure is shown in Figure 9.1.7.

The crust consists of many huge, cracked plates that are larger than continents. These plates are known as **tectonic plates**. They 'float' on a layer of semi-liquid rock in the upper mantle called the **asthenosphere**. Rock in the asthenosphere is very hot and is referred to as being plastic—it is like hot plastic in that it is gooey, can change shape very slowly and flow from place to place.

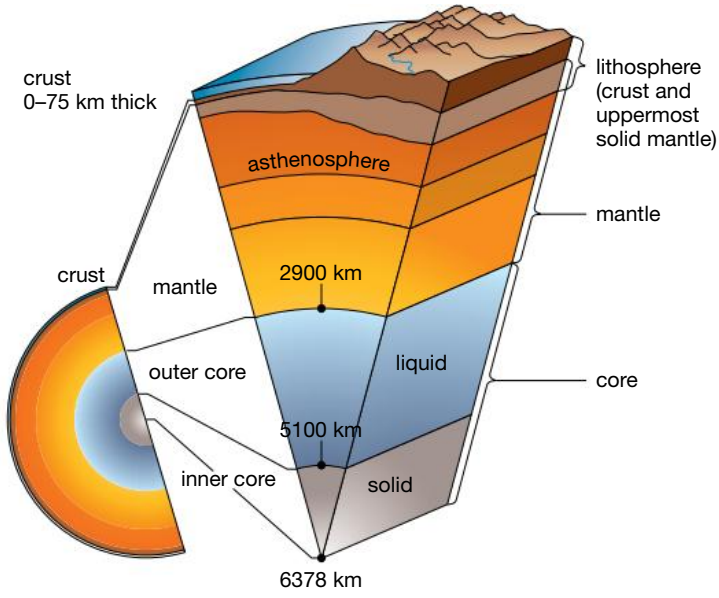


Figure 9.1.7 Earth consists of layers. The asthenosphere is like a very thick, slow-moving liquid that allows tectonic plates to move on it.

Convection currents

There are two main theories for how the plates move on the asthenosphere. One is that plates are dragged along as the hot magma in the asthenosphere rises up and then flows under the plates, creating convection currents. As the liquid rock flows, the friction between it and the tectonic plates above may be enough to move them. Figure 9.1.8 shows the convection currents that might carry the plates along.

GO TO Unit 3.1

Prac 2 p339

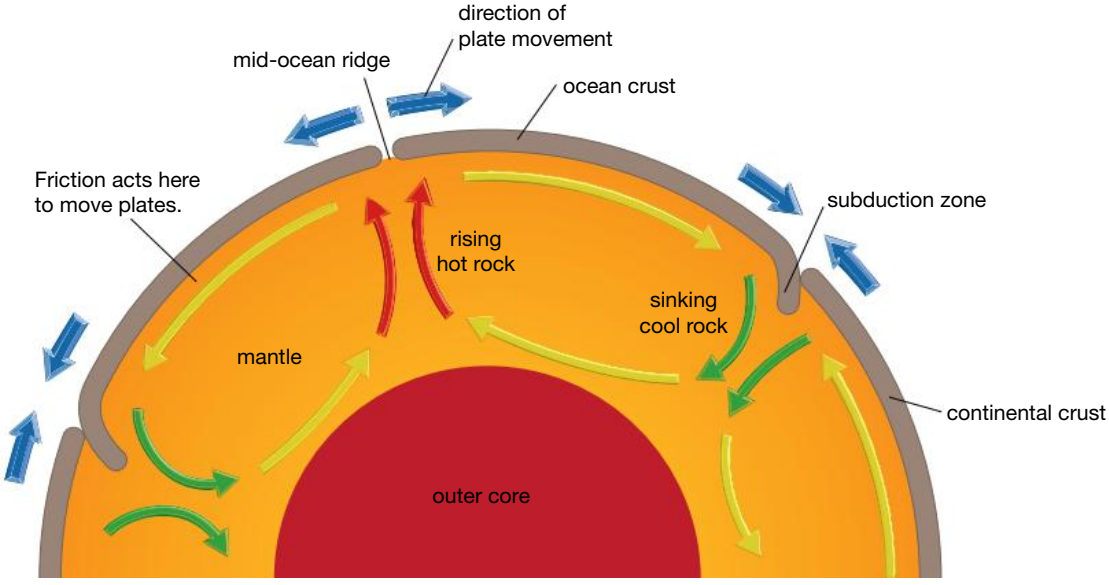


Figure 9.1.8 Convection currents may be enough to move tectonic plates.

Gravity

The other theory is that gravity is involved in moving tectonic plates. This could happen in two very different ways. Both are shown in Figure 9.1.9.

Slab pull

The plates at subduction zones are denser than those near the mid-ocean ridges. This theory proposes that gravity pulls the heavy and dense plate downwards at the subduction zone. This then pulls the plate into the trench and away from the ocean ridges. The end result is that the plates are pulled apart.

Ridge push

Since the new ocean crust forming at the ridges is above the rest of the crust, gravity pulls the new crust downwards. This would push on the older crust below it and to its sides. This force may be enough to move the plates sideways.

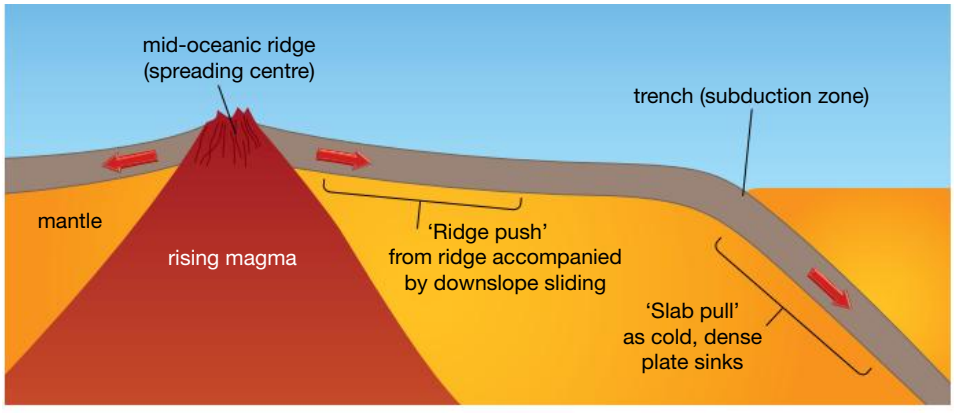


Figure 9.1.9 Slab pull and ridge push are two proposed ways in which gravity moves tectonic plates.

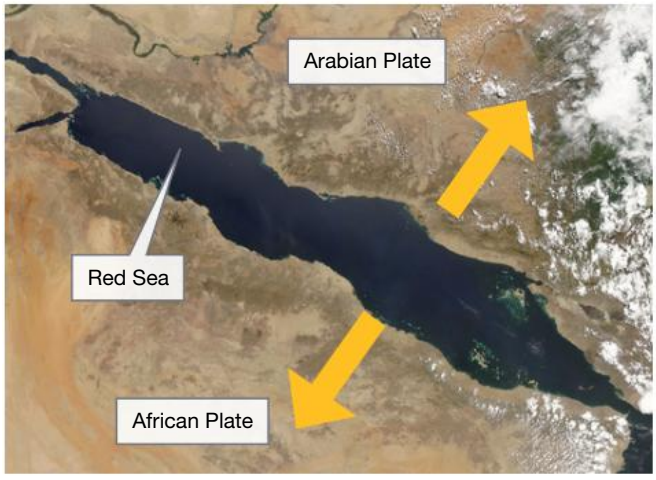


Figure 9.1.10 This satellite image shows the Red Sea, a giant water-filled rift valley at the edge of two tectonic plates.

Rifting and continental drift

Wegener's theory of continental drift had no known mechanism by which the continents could move. Wegener had proposed that gravity and the spinning of Earth could be involved. He thought the continents just scraped across the ocean floors.

Hess's theory of seafloor spreading offered a much more likely mechanism for movement of the continents. He believed that the continents broke up by a process called **rifting**. The crust cracked and subsided, allowing in water from the oceans. One such water-filled rift is the Red Sea, shown in Figure 9.1.10.

Then the process of seafloor spreading occurred. As new crust formed at the ridges, the continents moved along with the ocean floor as it spread away from the ridges. This is shown in Figure 9.1.11.

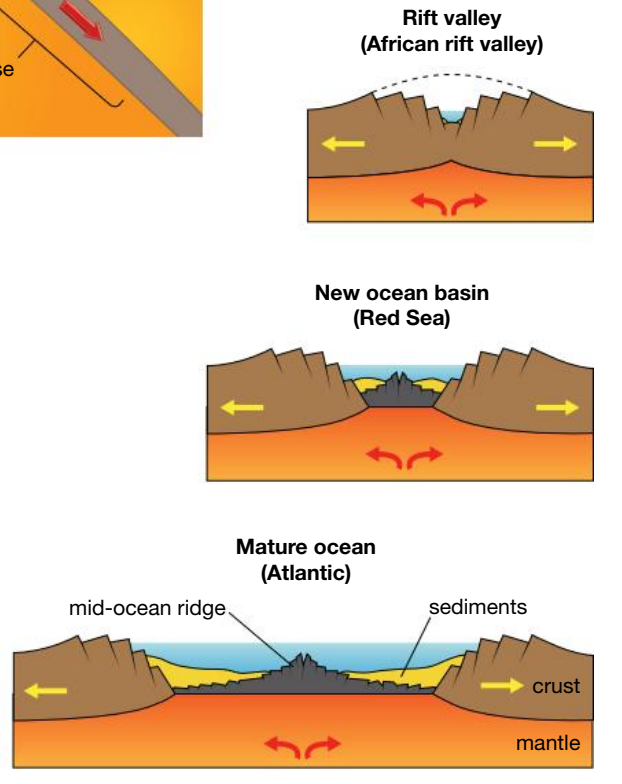


Figure 9.1.11 Continents can split apart by rifting and new ocean basins form. Seafloor spreading provided a mechanism to explain Wegener's idea of drifting continents.

9.1 Unit review

Remembering

1 **Name** the scientist who proposed:
   - **b** continental drift
   - **a** seafloor spreading.

2 **State** the observation that first led to the theory of seafloor spreading.

3 **List** the characteristics of the asthenosphere.

Understanding

4 **Define** the following terms. L
   - **a** subduction
   - **b** seafloor spreading

5 **Outline** the two main observations that led Wegener to propose the theory of continental drift.

6 **Explain** how Wegener deduced what Pangaea looked like.

7 **Explain** Hess's theory of seafloor spreading.

8 **Describe** three types of evidence that now supports the hypothesis of seafloor spreading.

9 A simple compass can be made by a process like that shown in the science4fun on page 334. **Explain** how this 'pin' compass could be used to find north.

Applying

10 **Use** the theory of plate tectonics to **explain** why Africa and America are older than the sea floor of the Atlantic Ocean.

11 **Use** Figure 9.1.6 on page 334 to **explain** the process of magnetic striping.

12 **Use** Figure 9.1.8 on page 335 to **explain** how convection and gravity may be involved in the movement of crustal plates.

Analysing

13 **Compare** the theories of continental drift and plate tectonics.

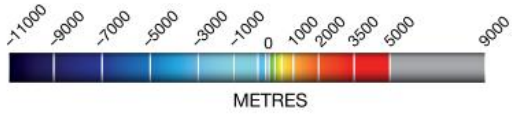
14 **Distinguish** between magnetic striping and magnetic field reversal.

15 **Compare** Figures 9.1.10 and 9.1.11, and **use** them to **explain** how the Red Sea formed.

Evaluating CCT

16 The large photo on page 331 is a satellite image of Earth's topography using sensors that detect various wavelengths of light. Geographic features are colour-coded by their height. You can see the coding in Figure 9.1.12.
   - **a** **Use** this colour coding to **identify** the mid-ocean ridges, trenches and large mountain ranges.
   - **b** **Use** these images to **evaluate** whether there is any relationship between the topography and the positions of the rifts.

Figure 9.1.12



17 There is an ocean trench separating Indonesia and Australia. There is an ocean ridge half way between Australia and Antarctica. **Use** this information to **justify** why geologists believe Australia is moving north.

Creating CCT

18 **Construct** a three-column table to **summarise** the evidence supporting the theory of plate tectonics. **Use** the headings *Feature*, *Description* and *Sketch*. A simple sketch of each feature alongside its description will help you remember it. Remember to include Wegener's observations.

Inquiring

ADDITIONAL

New technological developments allow scientists to collect data from which they can propose new ideas about planet Earth. Research sonar/echo sounding and magnetometers and find:

- how they work
- when they were invented
- other applications for these technologies.

Present your research in digital form. Include in your presentation a discussion of the importance of newly developed technologies in the collection of scientific data about the natural world. ICT CCT

ADDITIONAL

9.1 Practical investigations

1 Magnetic striping

Purpose

To model the magnetic striping patterns found in the rocks from seafloor spreading.

Materials

- 2 A4 sheets of plain paper
- compass
- bar magnet
- red and yellow pencils
- 2 clothes pegs
- sticky tape

Procedure

1. Tape the two A4 paper sheets together at one end so you have one long piece of paper. Rule a line across the open end of each sheet 10 cm from the end. Close the paper so the two A4 sheets are face to face with the ruled lines on the inside face of each paper.
2. Push two desks together, leaving a gap of a few millimetres.
3. Push the taped end of the paper down into the gap between the desks until you reach the ruled line. Leave 10 cm of the paper projecting above the desktop.
4. Place a compass on the desktop, next to the top edge of the paper. Place a magnet on the desk about 5 cm away from the compass. Have the north end of the magnet pointing away from the compass.
5. Gently fold the ends of the paper down, one end on each desk, and put a peg on each to weigh each end down (see Figure 9.1.13).
6. Under the desk, gently push up on the taped end of the papers until about 2 cm of paper has come out above the desk. Hold the paper still and use the red pencil to colour the 2 cm strip between the opening in the desk and the line on the paper. You should have a 2 cm red strip on each side of the opening in the desk. Your set-up should look like Figure 9.1.13.
7. Spin the magnet around so that the north end is pointing at the compass.

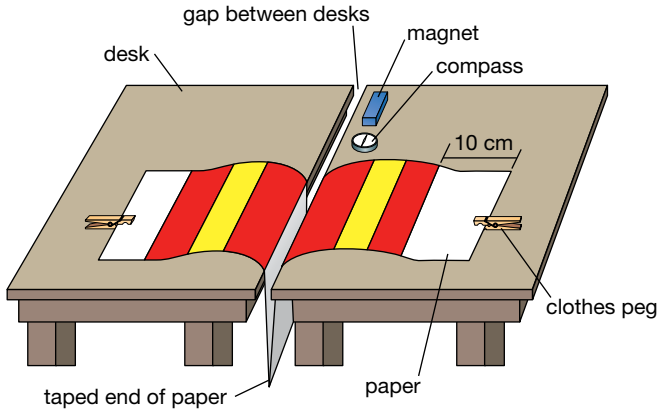


Figure 9.1.13

8. Repeat step 6, but use the yellow pencil to colour in the 2 cm strip. You now should have a red strip and a yellow strip on each side of the opening in the desk.
9. Repeat steps 6–8 until you have three red lines and three yellow lines on each side of the opening in the desk. For step 7, spin the compass around so the north pole is to the top of the desk.
10. On each of your sheets, number the layers 1–6 in the order that they formed. Write on the oldest layer of rock the word 'oldest', and on the youngest layer, the word 'youngest'.

Practical review

1. In this model, **identify** what is represented by the:
   - a gap between the desks
   - b two sheets of paper
   - c magnet
   - d red colour on the paper
   - e yellow colour on the paper.
2. **State** the number and position of the layer that was the youngest on each sheet, and the layer that was the oldest on each sheet.
3. **Explain** how this model helps you understand magnetic striping along the ocean ridges.

2 Convection

Purpose

To model the convection currents in the asthenosphere.

Materials

- 5 potassium permanganate crystals
- small coloured ice cube (water with food colouring)
- 200 mL of water

- 2 × 250 mL beakers
- tweezers
- hotplate or Bunsen burner, tripod, gauze mat and bench mat

SAFETY

Potassium permanganate stains—only handle it with tweezers.

Wear safety glasses.

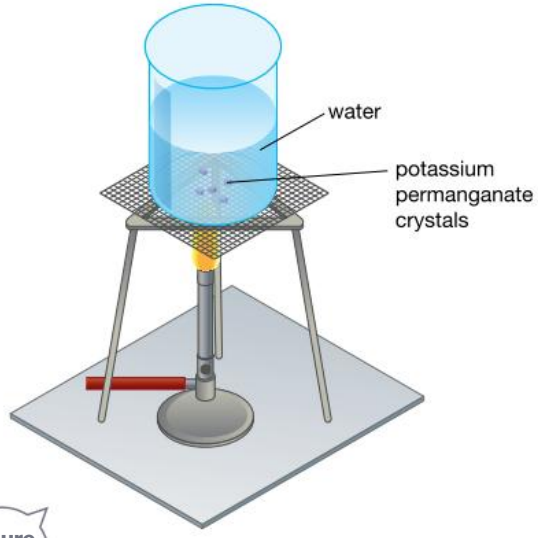


Figure 9.1.14

Procedure

1. Place 200 mL of water in a 250 mL beaker on the hotplate or gauze mat on the tripod.
2. Using tweezers, gently drop about five potassium permanganate crystals into the centre of the beaker. Do not move the beaker.
3. Gently heat the beaker. (If using a Bunsen burner, use a cool flame directly below the crystals.)
4. Carefully observe what happens to the streams of purple colour that come off the crystals. (It should happen within a minute or two.)
5. Fill the other beaker with 200 mL of tap water.
6. Use tweezers (because food colouring stains) to place a coloured ice cube into the beaker of cool water.

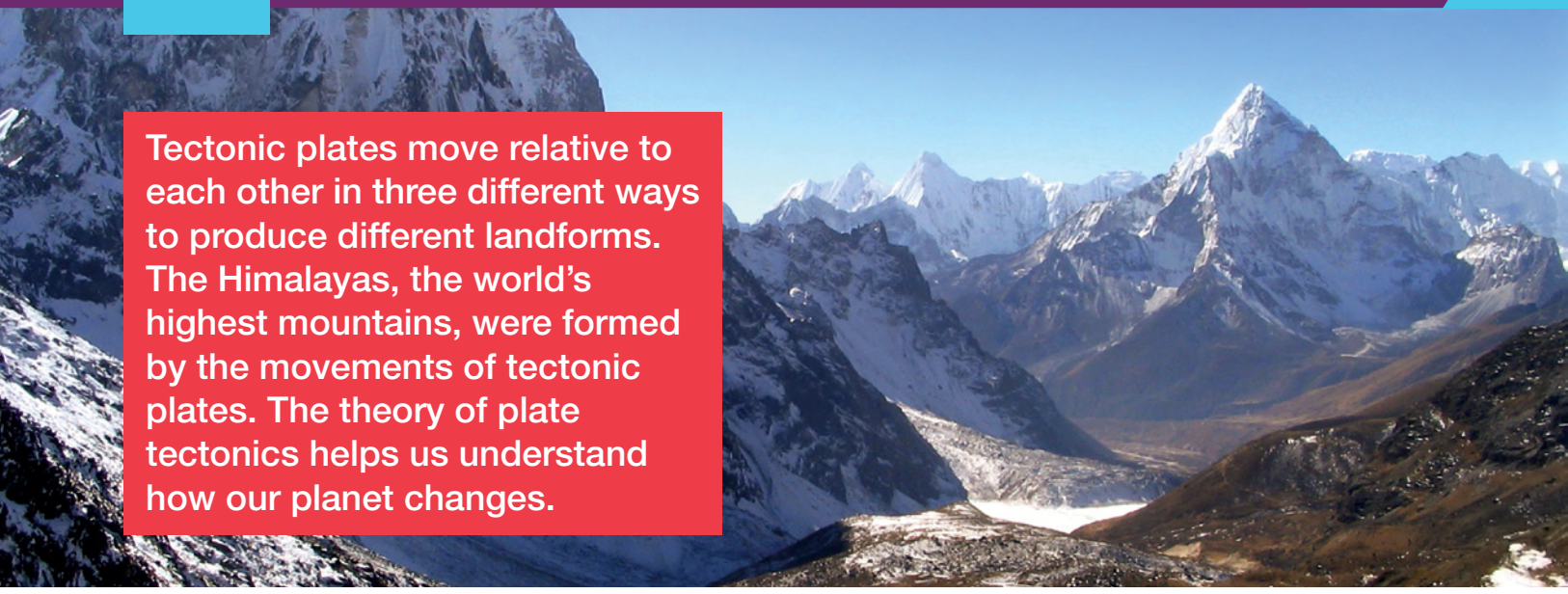
Results

Record your observations for steps 4 and 6 as labelled sketches.

Practical review

1. **Explain** why the stream of purple colour behaved as it did when you heated the water.
2. **Explain** why the coloured ice cube behaved as it did.
3. **Use** the behaviour of the coloured ice cube to **propose** why the purple-coloured water sinks after reaching the surface of the beaker.
4. **Explain** how this experiment helps you understand what happens with magma in the asthenosphere.
5. **Propose** a way of testing your answer to question 3 by using a bag of ice, purple crystals, a beaker and water.

9.2 Plate movements



Tectonic plates move relative to each other in three different ways to produce different landforms. The Himalayas, the world's highest mountains, were formed by the movements of tectonic plates. The theory of plate tectonics helps us understand how our planet changes.

Where are the plates?

There are many tectonic plates of varying sizes. There are seven extremely large ones that are bigger than most continents. There are another ten or so medium-sized ones, and about 60 smaller plates. The larger plates are splitting into smaller ones in many places. Some of these plates can be seen in Figure 9.2.1.

Types of crust

There are two types of crust—continental and oceanic. The **oceanic crust** is found on the ocean floor generally below sea level. The **continental crust** is the crust forming the continents and so projects above sea level. Oceanic crust is a darker colour and much thinner than continental crust. Oceanic crust is also denser than continental crust.

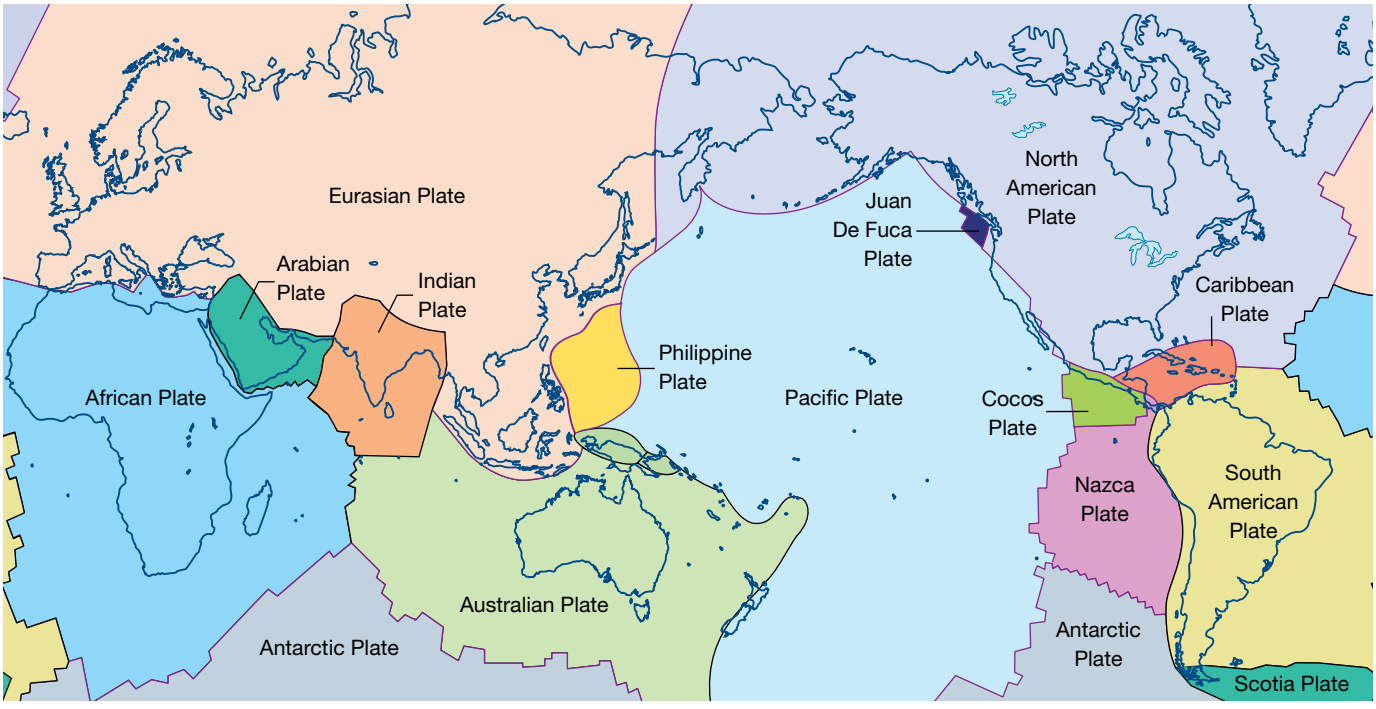


Figure 9.2.1 There are many tectonic plates of differing sizes. This map shows 15 of the major plates. Many of these are split into other smaller plates.

This is because oceanic crust has less silicon and more of the heavier elements such as iron and magnesium. Continental crust has a lot of aluminium and silicon. The densities of these types of crust are important when the plates are moving near each other.

Types of plate movement

As Figure 9.2.2 shows, the tectonic plates move in three different ways at the boundaries between them.

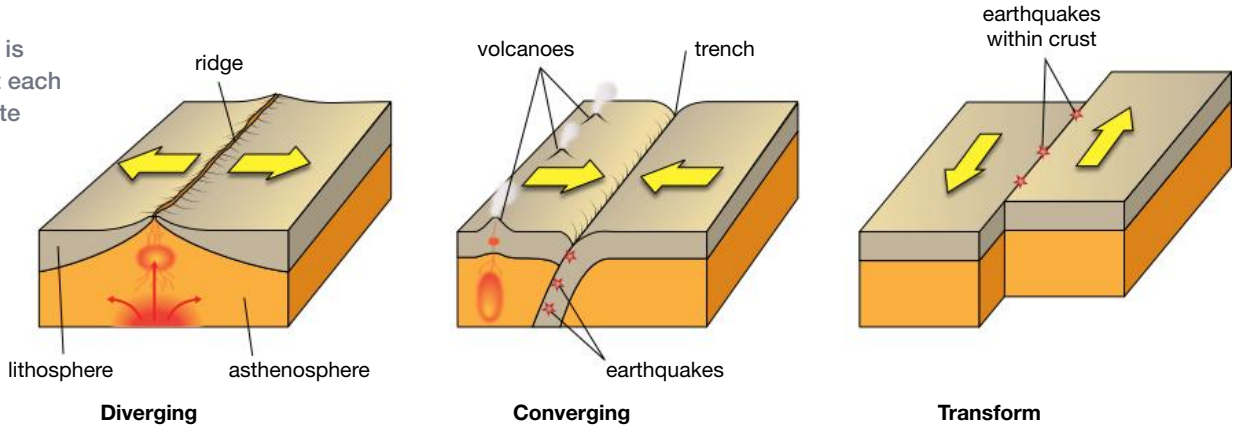
These boundaries are:

- diverging boundaries—where the plates are moving apart from each other
- converging boundaries—where the plates are colliding with each other
- transform boundaries—where the plates are sliding past each other.

The locations of each type of boundary are shown in Figure 9.2.3.

Figure 9.2.2

Movement is different at each type of plate boundary.



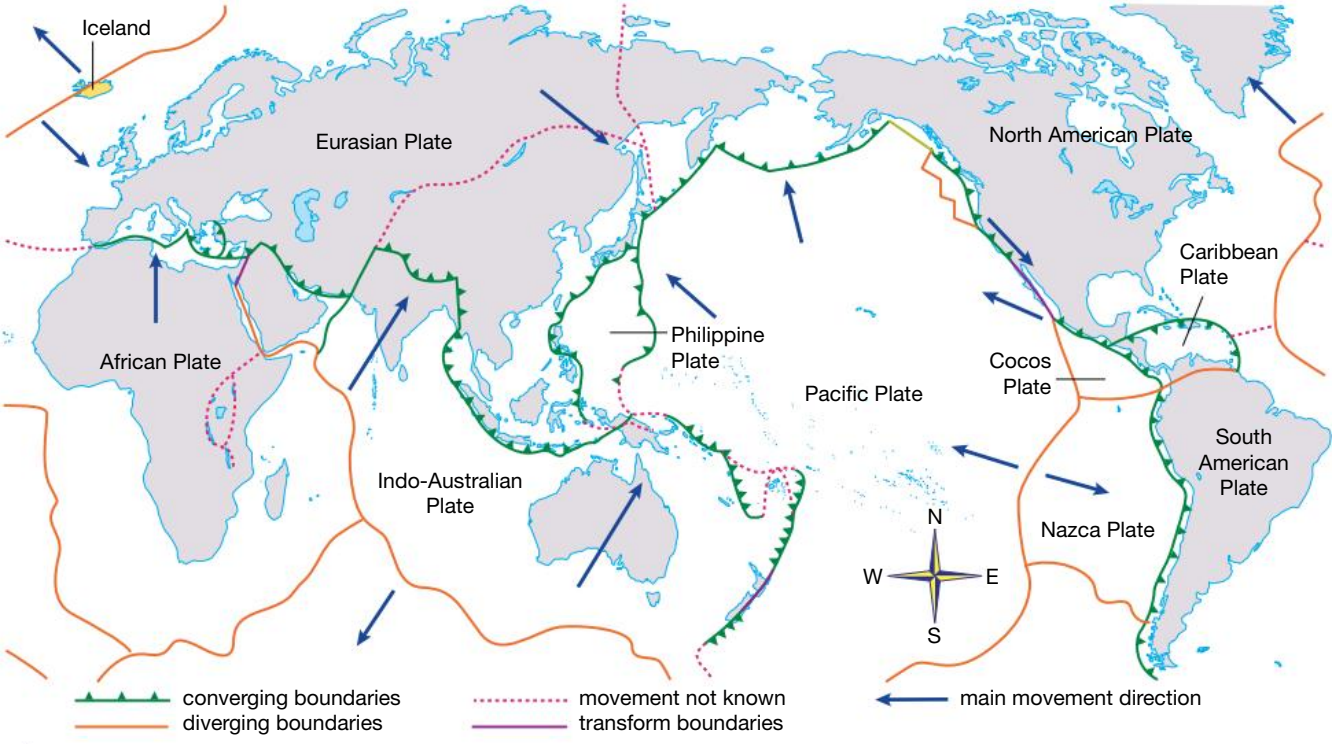


Figure 9.2.3 Locations of the three different types of boundaries

Diverging boundaries

Diverging boundaries are where tectonic plates are moving apart from each other in opposite directions. To *diverge* means to separate.

When the plates separate, they leave a rift (deep crack) between them. Magma from the asthenosphere rises up into the rift and solidifies as it cools. This forms new crust, and so diverging boundaries are also known as constructive boundaries. The mid-ocean ridges form a diverging boundary and the ridge itself is evidence that new crust is being constructed.

Diverging boundaries also occur on land. As you can see from Figure 9.2.4, the Mid-Atlantic Ridge runs right through the island of Iceland. As a result, the island is widening as new crust is formed. Iceland has constant volcanic eruptions as the magma spews up into the rift. The rate of widening has been measured to be about 2–5 centimetres per year. That may not seem like much, but this spread has formed the Atlantic Ocean.

Figure 9.2.4 Iceland is located on the Mid-Atlantic Ridge and so the island is steadily growing wider.

Another place where diverging boundaries seem to be forming is in East Africa. As Figure 9.2.5 shows, the Great Rift Valley, runs along the eastern part of the African continent. At present there is no obvious crack or rift in the crust with magma welling up into it, but the land is subsiding and volcanoes occur in several places. Geologists have proposed that this could be where the next ocean will form on Earth.

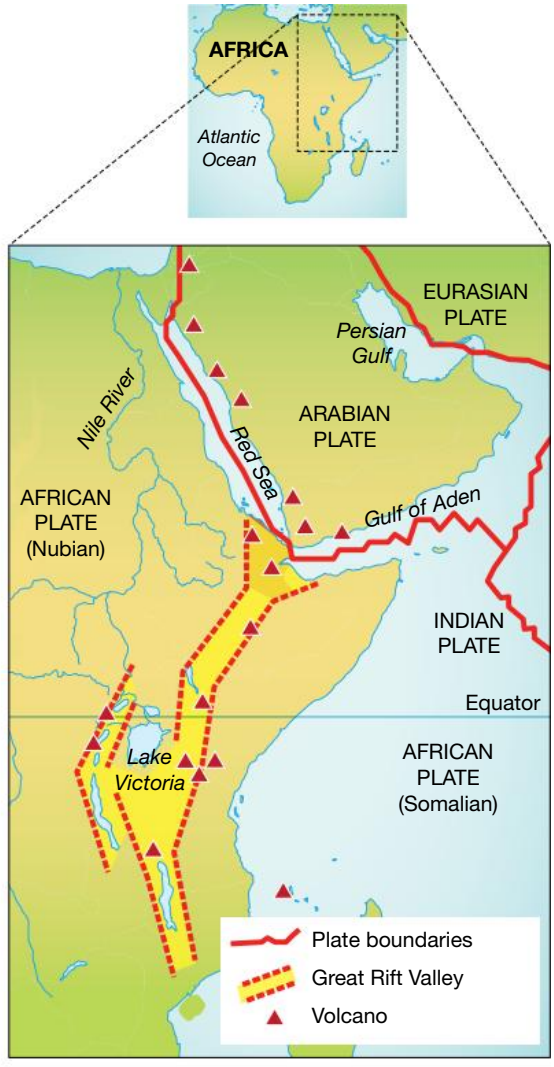


Figure 9.2.5 The Great Rift Valley of Africa could be the site of the next ocean to form on Earth. The dashed lines show where the edges of the rifts (cracks) are.

Converging boundaries

Converging boundaries occur when two plates are colliding head-on into each other. To *converge* means to come together. Rock is destroyed at converging boundaries, and so these boundaries are also known as destructive boundaries. These collisions form an assortment of land features such as mountains, chains of islands and underwater trenches. The features that are formed depend on what types of crust collide.

Mountains, volcanoes and trenches

If oceanic crust is colliding with continental crust, then the denser oceanic plate sinks under the lighter continental plate. This is subduction, and can be seen in Figure 9.2.6. The continental plate becomes distorted, forming

fold mountains and volcanoes. Where the oceanic plate subducts under the continental plate, a deep ocean trench is formed. A good example is where the Nazca Plate collides with South America. The Andes Mountains have been formed along the west coast of South America, and the 8000-metre deep Peru–Chile Trench has formed.

The plate that subducts dives down deep into the mantle, which is extremely hot. The friction of the plates colliding also generates heat. This heat is enough to melt the crust and form magma. So crust is being destroyed as it subducts.

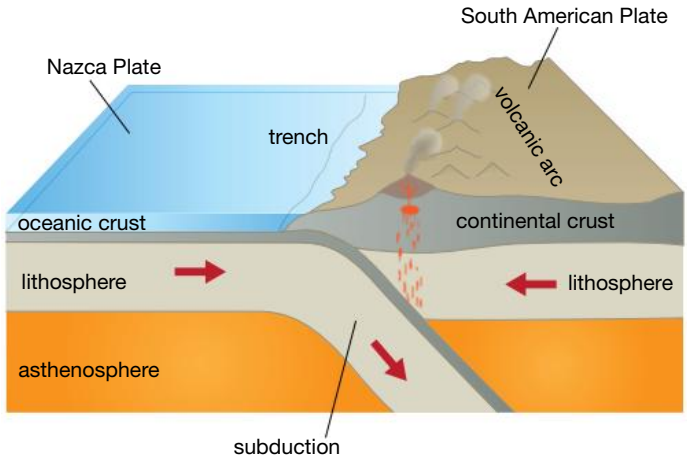


Figure 9.2.6 Subduction of an oceanic plate under a continental plate

SciFile

Into the depths

In 1960, the Mariana Trench was investigated by Donald Walsh and August Picard in a submarine called the *Trieste*. The enormous pressure cracked a window at 9000 metres on the descent and the nervous explorers spent only 20 minutes at the bottom. There they saw some fish—the first time scientists knew that vertebrate organisms could live at extreme depths.

High mountain systems

When two continental plates collide, both are pushed upwards because neither is denser than the other. This upwards push forms very high mountain systems. The best-known example of this is where the Indian Plate is colliding with the Eurasian Plate. This has formed the highest mountain range on Earth, the Himalayas (Figure 9.2.7). The highest mountain, Mt Everest at 8848 metres above sea level, was formed by this process.

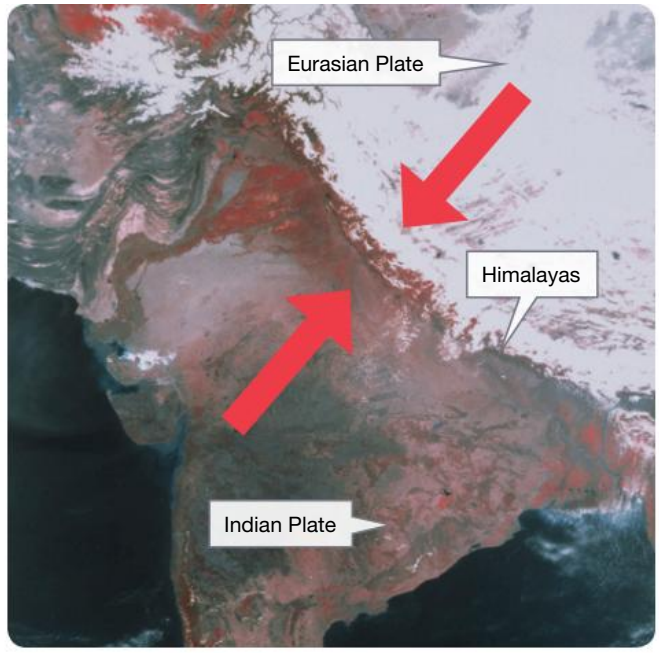


Figure 9.2.7 The Himalayas were formed by the collision of two continental plates: the Indian Plate and the Eurasian Plate.

Island arcs

When two oceanic plates collide, the faster-moving plate always subducts under the other. This forms a deep trench (Figure 9.2.8). The descending plate melts and is destroyed. A chain of volcanic islands (called an **island arc**) appears as the magma formed by the subducting plate rises up to the surface.

The Mariana Trench is the deepest ocean trench yet discovered. It occurs where the Pacific Plate collides with a small plate called the Mariana Plate (part of the Philippine Plate). The trench is 10 911 metres deep. A string of volcanic islands forms an island arc along the boundary.

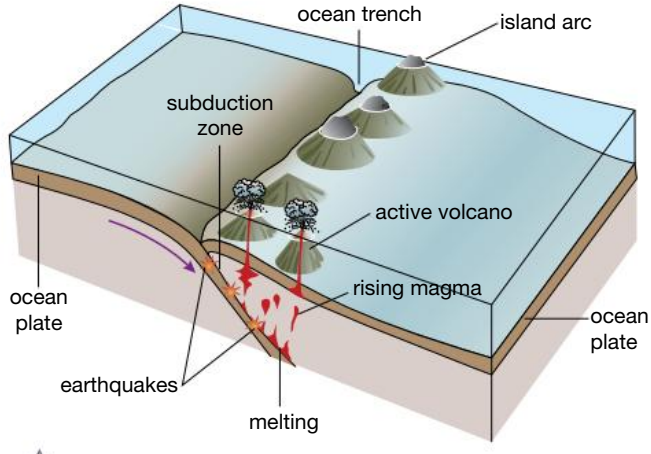


Figure 9.2.8 Colliding oceanic plates form ocean trenches and arcs of volcanic islands.

INQUIRY

science 4 fun

Simulating subduction

YES

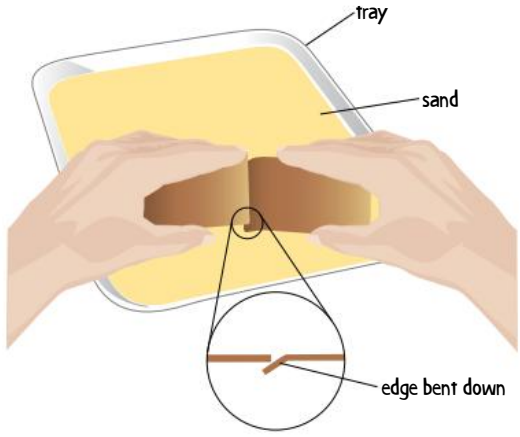
Can you simulate subduction using cardboard and sand?

Collect this ...

- dry, clean sand
- tray
- 2 sheets cardboard, 12 cm × 10 cm, 1–2 mm thick

Do this ...

1. Fill the tray with sand almost to the top.
2. Bend the edge of one sheet of cardboard down, as shown in the diagram.
3. Place the two sheets of cardboard on the sand.
4. Slowly push the two pieces of cardboard together, making sure the piece with the bent edge sinks below the other sheet.



5. Repeat the process several times. Try to make the results of the simulation more like the real process. Where you hold the cardboard could make a big difference.

Record this ...

Describe what happened.

Explain how this simulates subduction.

ADDITIONAL

SKILLBUILDER

Calculating the age of oceans

Geologists can estimate the age of geological features such as the ocean basins, rift valleys or continental islands. To do this, they use the rate of movement of tectonic plates.

For example, they can calculate the age of the Atlantic Ocean. Iceland is widening at about 2–5 cm/year. The Atlantic Ocean is about 4000 km wide between the parts of Africa and South America that appear to have been joined.

This information can be used to calculate how long it took to form the Atlantic Ocean.

First convert the distance across the ocean into centimetres.

$$4000\text{ km} = 400\,000\,000\text{ cm}$$

Now divide the rate of widening of the plates into this distance.

$$\frac{400\,000\,000}{2} = 200\,000\,000\text{ years}$$

$$= 200\text{ million years}$$

So if the rate of movement of the plates has been averaging 2 cm/year, then the Atlantic Ocean is 200 million years old. However, if the rate of widening is 5 cm/year, then the Atlantic Ocean is about 80 million years old.

WORKED EXAMPLE

Calculating the age of oceans

Problem

Iceland is about 250 km wide. Calculate how long the island may have existed if the average rate of movement is 2 cm/year.

Solution

$$250\text{ km} = 25\,000\,000\text{ cm}$$

$$\frac{25\,000\,000}{2} = 12.5\text{ million years}$$

Practice

N

1. The ocean between Australia and Antarctica is widening at about 7.5 cm/year. It is about 4000 km wide. **Calculate** when the ocean may have formed.
2. India and Africa are about 4000 km apart and are moving apart at a rate of about 3.4 cm/year. **Calculate** how many years ago Africa and India were connected.
3. The distance between Australia and the Indonesian island of Java is about 500 km. The Indo-Australian Plate is moving about 7 cm towards Java per year. **Calculate** how long it will be before Australia crashes into Java.

ADDITIONAL

Transform boundaries

A **transform boundary** is where two plates are sliding parallel to each other but in opposite directions. The plates usually move very slowly past each other but then suddenly slip quickly. When this happens, there is an earthquake. Whether on land or under the ocean, a transform boundary usually has fold mountains along its length. There are also many cracks in the rock, called fault lines. Fault lines usually do not form one continuous crack in the crust along the plate boundary. Instead there are many cracks parallel to each other.

The San Andreas Fault in California (USA) is a transform boundary. This is where the Pacific Plate and the North American Plate move past each other. The cities of Los Angeles and San Francisco are built near the fault line. This fault has moved in the past and has caused massive earthquakes, such as in 1989, and in 1906 when much of San Francisco was destroyed.

Another transform fault runs right through New Zealand. Meeting at this fault are the Indo-Australian Plate (moving north-east) and the Pacific Plate (moving south-west). Movement of this transform boundary created the mountains of the South Island of New Zealand. You can see this transform fault in Figures 9.2.9 and 9.2.10.

Prac 1 p348 Prac 2 p348 9.3

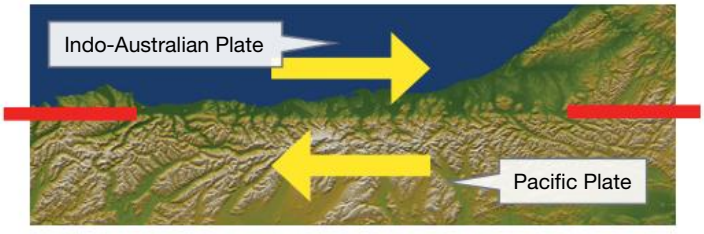


Figure 9.2.9 This satellite image shows New Zealand's Alpine Fault.

Figure 9.2.10 Milford Sound in the South Island of New Zealand sits next to the transform fault that runs along the west coast.

Pre-history of Australia

Pangaea was the original land mass of Earth. This mega-continent gradually broke into two major landmasses, Laurasia in the north and Gondwana in the south. Australia was part of Gondwana.

Reconstructions of how the land masses appeared in the past are shown in Figure 9.2.11.

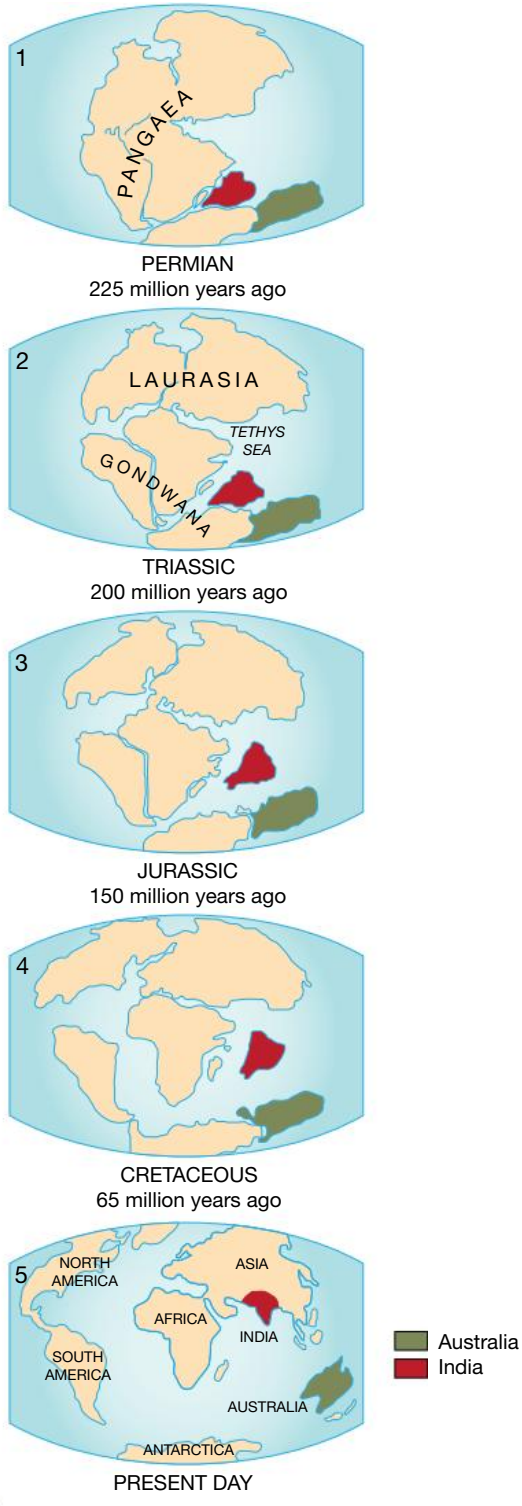


Figure 9.2.11 Reconstruction of the break-up of Pangaea, Laurasia and Gondwana.

- About 65 million years ago, Australia began to separate from Gondwana. This was the Cretaceous period and about the time the dinosaurs were becoming extinct. Australia's landforms and climates changed as it moved northwards on the Indo-Australian tectonic plate.
- About 125 million years ago, Australia was still connected to Antarctica. Almost all of the centre of Australia was covered by a sea that separated the country into four landmasses.
- About 85 million years ago, the sea level dropped, exposing more land.
  Australia slowly moved northwards, but still remained connected to Antarctica at the South Tasman Rise, a small area of land near Tasmania.
- About 40 million years ago, the South Tasman Rise separated, and Australia became an island continent.

Measuring plate movement

Scientific instruments such as sonar and magnetometers gave scientists information about Earth that led first to the theory of continental drift and eventually the theory of plate tectonics. Newer technology now shows that the plates do move as the theory suggested they should.

Various techniques can directly measure how fast tectonic plates are moving. The most widely used technique uses satellites and the global positioning system (GPS). A **GPS ground station** is a receiver and computer that is placed on top of a stand (Figure 9.2.12). The legs of the stand are fixed into the rock. Scientists have installed many such GPS ground stations on tectonic plates around Earth.

A group of 24 satellites orbiting Earth sends radio signals to the GPS ground stations. If a ground station detects at least three satellites, then the ground station can calculate how far it moves and in which direction. If four satellites can be detected, then the ground station can also determine how far it moved vertically. The ground station computer works out where it is, then sends the data by a communications satellite link to the scientists' home base. By comparing all the data from different ground stations, scientists can determine how far the ground stations have moved compared with the others.

The best GPS ground stations are accurate to a few millimetres. Measurements from these stations show that rates of plate movement vary greatly between plates and even between parts of the same plate. Using data from many GPS ground stations gives an accurate picture of how the ground is moving.

9.4

SciFile

Fast and slow plates

The fastest moving plate is a part of the Pacific Plate near Easter Island, which is moving at 15 cm/year. The slowest moving plate, part of the Antarctic Ridge, is moving at 2.5 cm/year.

Figure 9.2.12 A GPS ground station and satellite dish used to send data for analysis.

9.2 Unit review

Remembering

1 **Name** the three types of plate boundary.

2 **Name** the two types of crust that form the tectonic plates.

3 **Name** one place where the following type of plate boundary can be found.
- a diverging boundary
- b converging boundary
- c transform boundary

Understanding

4 **Describe** the process of subduction.

5 **Explain** how the movement of tectonic plates can be measured.

6 **Predict** what will happen when the two sheets of cardboard are moved across the sand in the science4fun on page 344.

Applying

7 **Identify** the type of plate boundaries where the following may occur.
- a subduction
- b ocean trenches
- c fold mountains
- d rifting under the sea
- e island chains (island arc)
- f an ocean trench next to a continental mountain range

8 **Identify** the two plates that make up the larger Indo-Australian plate.

Analysing

9 **Draw** simple sketches to **compare** the directions tectonic plates move at divergent, convergent and transform boundaries.

10 **Compare** subduction when two ocean plates converge with subduction when an oceanic and continental plate converge.

11 **Analyse** Figure 9.2.11 on page 345 and **explain** the origin of the Himalayas.

Evaluating CCT

12 **Propose** what evidence could help you decide whether two plates had converged in the past to form a continent.

13 At diverging boundaries, seafloor spreading is occurring as new crust is continually created.
Propose a reason why Earth's crust is not getting any bigger despite this.

14 **Propose** a reason why fossils of sea creatures have been found near the top of Mt Everest (8848 m above sea level).

15 The oldest known fossils in the ocean floor are about 180 million years old, yet fossils from continents have been found that are 3400 million years old. **Propose** reasons why.

16 **Propose** reasons why it took scientists so long to agree that Alfred Wegener was correct about the continents moving around over the surface of Earth.

Creating CCT

17 **Construct** a table (or **modify** your table from Unit 9.1) to **summarise** the evidence found so far that supports the theory of plate tectonics.

Inquiring

1 Find an animation or video on how Earth may look in 100 million years from now. Use the animation to describe what has happened to Africa, Australia and the Mediterranean Sea.

Present your findings as a diagram with notes attached. ICT

ADDITIONAL

2 The Red Sea and Mediterranean Sea are located on plate boundaries. Find:
- which of the two are getting narrower as the plates move
- the rate of narrowing.

From this data, calculate the time it will take for the sea to shut completely. N

Present your data and calculations in written form.

ADDITIONAL

9.2 Practical investigations

1 Paper plate tectonics

Purpose

To model plate tectonics.

Materials

- paper template. To obtain this, type into a web browser: 'Sea-floor spreading and subduction model by John C Lahr' ICT
- cardboard or shoebox
- sticky tape
- scissors
- coloured pencils

Procedure

1. Colour in the paper templates provided.
2. Construct the model using the instructions provided. Alternatively, make your 'shoebox' from flat sheets of cardboard stuck together.
3. With a partner, operate the model. This represents seafloor spreading where there are also fault lines perpendicular to the rift. The sea floor is separating away from the central rift, but it is doing it in three separate strips. Your partner must gently keep holding the three paper strips below the top. You hold the two side pieces and slowly pull them apart, watching the magnetic strips as they appear.
4. Imagine what would be happening in real strips of ocean crust as their inside edges slide past each other like the paper strips.

Hint

The measurements on your print-out are in inches: 1 inch = 2.54 cm.

Practical review

1. **Describe** what the model shows about seafloor spreading.
2. **Describe** where the three transform faults are on the seafloor spreading and subduction model.
3. a **Identify** the following features of the seafloor spreading and subduction model.
   - i subduction
   - ii convection currents
   - iii volcanic islands
   - iv seafloor spreading
   - v magnetic striping

   b **Justify** your answer in each case.

2 Types of crust

Purpose

To calculate the density of granite and basalt.

Materials

- granite and basalt (to fit in a displacement can)
- displacement can
- scales or triple-beam balance
- 100 mL measuring cylinder
- beaker
- cotton

Procedure

1. Measure the mass of the basalt and the granite. Record them in a table.
2. Place the granite in a displacement can and measure the volume of water displaced.
3. Place the basalt in a displacement can and measure the volume of water displaced.

Results

Calculate the density of the basalt and the granite using: N

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

Hint

1 cm^3 = 1 mL water (at 20°C)

Practical review

1. **Compare** the density of basalt and granite.
2. If the oceanic crust is high in basalt and the continental crust is high in rocks like granite, **explain** why oceanic crust subducts under continental crust at a collision boundary between these two types of plate.

9.3 Volcanoes and earthquakes

Volcanoes are among the most awesome sights on the planet. The largest explosion in recorded history was from a volcano. Earthquakes can also be deadly. Earthquakes and volcanoes provide evidence of the interior processes of the Earth. They provide information that supports the theory of plate tectonics.

Volcanic eruptions

A **volcano** is a place where extremely hot material from inside Earth erupts at Earth's surface. This material can include:

- gas such as steam and hydrogen sulfide
- ash (fine particles of rock)
- **lava** (molten rock)
- lumps of solid volcanic rock such as scoria.

Volcanoes form where extremely hot molten rock called **magma** has accumulated below weak spots in Earth's crust. This magma is occasionally pushed upwards under great pressure into the volcano.

The magma reaches the surface, and is now known as lava. It erupts white hot at a temperature of over 1200°C. The lava changes colour as it cools, from white through yellow, orange and red, until it finally hardens and solidifies into black rock.

Prac 1 p357

SciFile

Victims of Vesuvius

In 79 CE the volcano Mount Vesuvius erupted and covered the Italian city of Pompeii with hot ash. About 16 000 people died. The ash covered bodies and hardened into rock. When each body decayed, it left a cavity in the rock. Scientists poured plaster into the cavity to make a cast of each body. The outside layer was then chipped away, leaving the cast.

Volcanoes and plate boundaries

A comparison of Figure 9.2.3 on page 341 and Figure 9.3.1 shows that most volcanoes are at or near the edges of tectonic plates. This is because the movement of the plates creates weaknesses in the crust and also generates intense heat that can melt rock.

Diverging plate boundaries create weaknesses in the crust because the separating plates thin the crust. This lowers the pressure on the underlying hot rocks of the asthenosphere and they melt. The magma formed then finds its way up through the weaknesses in the crust.

Krakatoa

SciFile

Krakatoa (also called Krakatau) is a volcanic island in Indonesia. In 1883, it exploded, blowing two-thirds of the island to pieces. It is the largest explosion ever witnessed by humans. A total of 21 cubic kilometres of land was blown into the air. The sound was clearly heard over 5000 km away and 36 000 people died.

Figure 9.3.1

Most volcanoes form near the edges of the tectonic plates. This observation provides further support for the theory of plate tectonics.

Converging plates, especially where subduction occurs, create weaknesses in the crust and generate a lot of heat. If the colliding boundaries occur under the ocean, then chains of volcanic islands (island arcs) can form at the edges of the tectonic plates (Figure 9.3.2). An example is the Lesser Sunda Islands, Indonesia. They are shown in Figure 9.3.3.

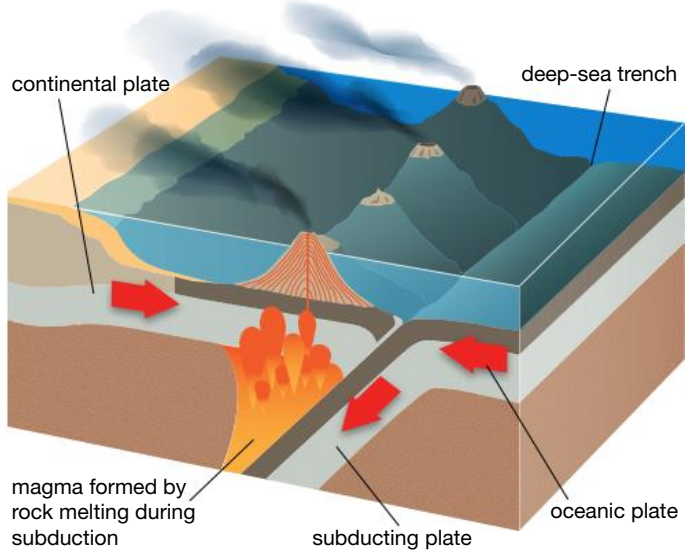


Figure 9.3.2

Subduction results in weakness in the crust and generates of a lot of heat. A string of volcanic islands (an island arc) is evidence for colliding tectonic plates.

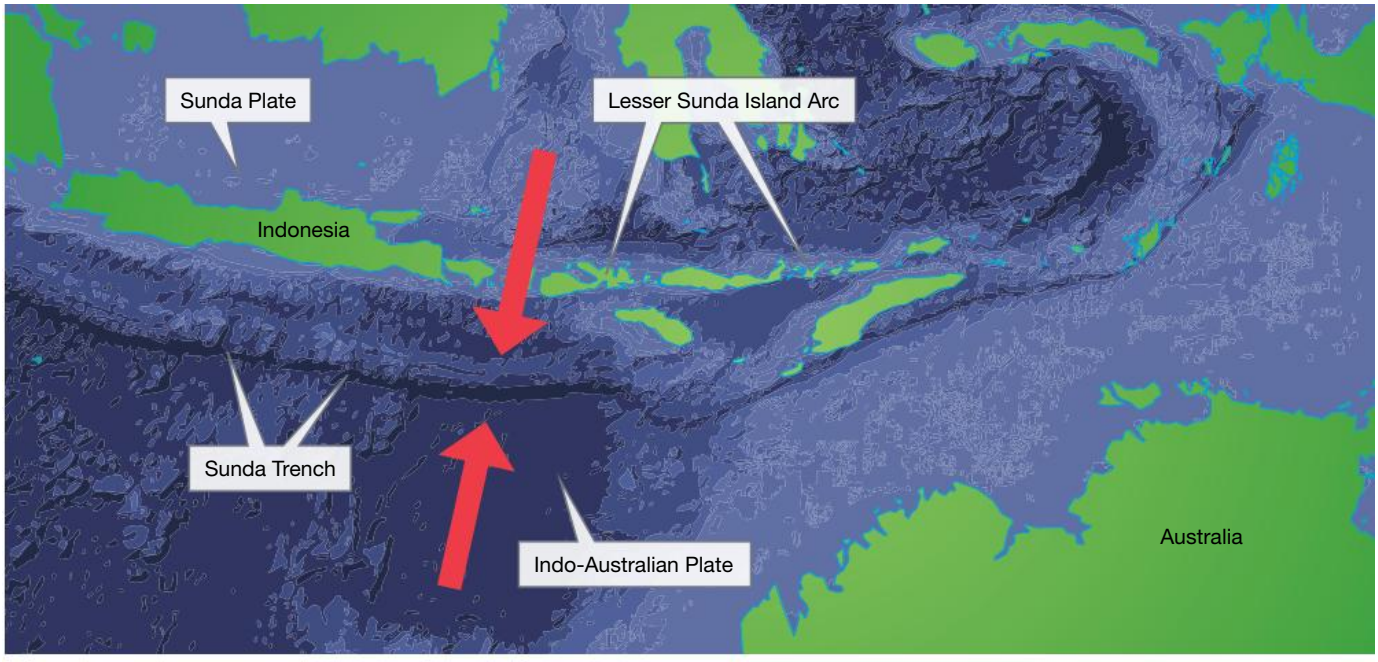


Figure 9.3.3 The Indo-Australian Plate is moving north and colliding with the Sunda Plate, creating an island arc called the Lesser Sunda Islands (Indonesia).

Hot spot volcanoes

While most volcanoes form near plate boundaries, some form well away from the edges of the plates. These volcanoes sit over 'hot spots' in Earth's crust. **Hot spots** are isolated weak spots in the crust where a lot of hot magma is being created. They can occur under oceanic or continental plates. Geologists are not sure why these hot spots exist.

In the ocean these volcanoes occur in chains of islands. In each chain, there is always one island with an active volcano, while all the other islands have dormant (inactive) volcanoes. Geologists realised that the formation of these volcanoes could be explained by the theory of plate tectonics. Each island formed as it sat over the hot spot. As the plate moved, the island went with it and so the island no longer sat over the hot spot. A new part of the plate was now above the hot spot and this gradually formed a new volcano. The Hawaiian islands are a good example of an island chain over a hot spot. Their formation is shown in Figure 9.3.4.

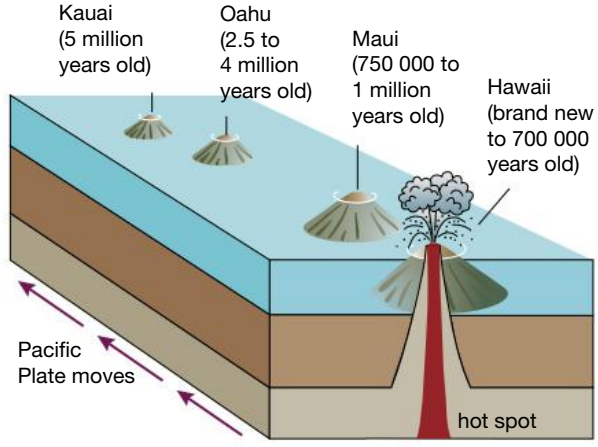


Figure 9.3.4 The Hawaiian islands have been formed by movement of the Pacific Plate over a single hot spot in Earth's mantle.

Earthquakes

An **earthquake** is the rapid movement of the ground, usually back and forth and up and down in a wave motion. It is caused by the rapid release of energy as the tectonic plates move. Friction between the plates must be overcome before they can move. When the force is great enough, the plates suddenly move as friction can no longer hold them. This sudden movement sends out waves of energy through the rock and the water. The ground and water then shake as the waves of energy pass through them.

Detecting earthquakes

Earthquakes are measured using an instrument called a **seismometer**. Old-style seismometers consisted of a pen on a moving drum. They used the principle of inertia. The heavy mass attached to the pen has a lot of inertia, meaning it tends to stay still. The rest of the seismometer moves with the vibrations of Earth.

GO TO Pearson science NSW 10 Unit 8.3

There are many designs for seismometers. You can see two designs in Figures 9.3.5 and 9.3.6. Modern seismometers are electronic. The trace of a seismometer is called a seismograph.

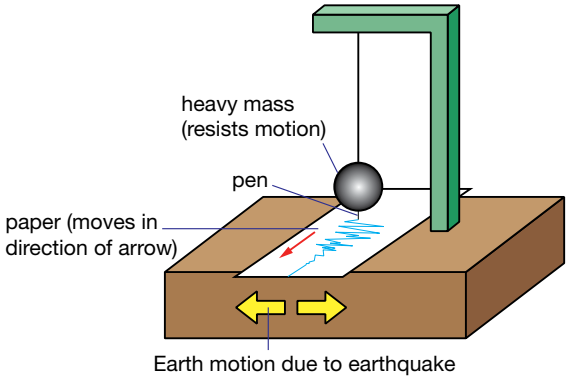


Figure 9.3.5 This seismometer uses a swinging pendulum. The pen does not move much. The supporting arm and the recording paper vibrate back and forth with the ground.

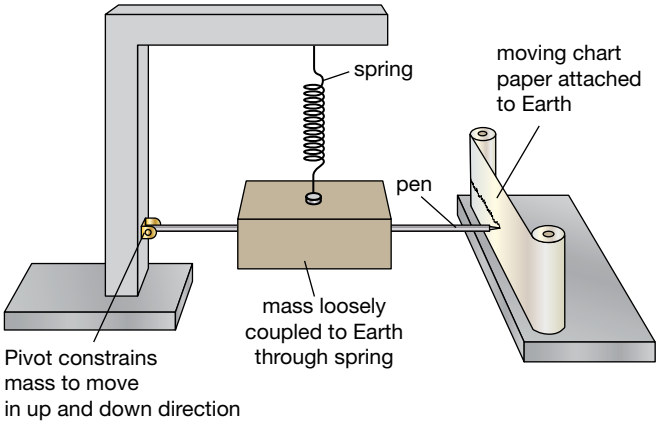


Figure 9.3.6 In this vertical-mounted seismometer, the pen stays fairly still, while the recording paper and the support move up and down with Earth.

Seismic waves

The movement of the ground in an earthquake occurs in a shaking back-and-forth motion called a wave. These waves in Earth caused by earthquakes are called **seismic waves**.

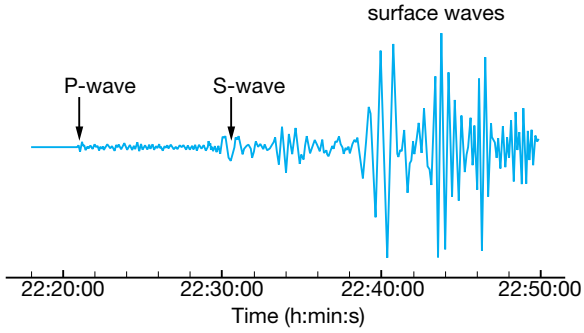


Figure 9.3.7 This seismograph was recorded in the UK from a distant earthquake. It shows the pen trace when S-waves, P-waves and surface waves reach the seismometer.

Three main types of seismic waves can be detected (Figure 9.3.7).

- **Primary waves (P-waves)** are longitudinal waves that travel fast through Earth.
- **Secondary waves (S-waves)** are transverse waves that travel slightly slower than P-waves through Earth.
- **Surface waves** are the slowest waves and cause the most destruction.

S-waves and P-waves travel deep under the ground and then bend upwards to reach the surface of the crust. P-waves shake the ground up and down. S-waves shake the ground sideways, back and forth.

Surface waves travel along the crust near the surface. They travel more slowly than P-waves and S-waves, but they can be much larger. They are particularly destructive if the earthquake is near Earth's surface.

GO TO Unit 3.2
GO TO Unit 4.1
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Where earthquakes occur

Nearly all earthquakes start at the edges of the tectonic plates. Compare Figure 9.3.8 with Figure 9.2.3 on page 341 and you can see that the locations of earthquakes align with the boundaries of the tectonic plates. The strongest earthquakes occur near converging boundaries. This distribution of earthquakes provides further evidence for the theory of plate tectonics.

Epicentre and focus

Earthquakes happen at particular places under the ground where Earth slips, usually along a fault. The place where the quake starts is called its **focus**. This may be many hundreds of kilometres deep in Earth. The point on Earth's surface directly above the focus is called the **epicentre**. Buildings near the epicentre are usually the most heavily damaged.

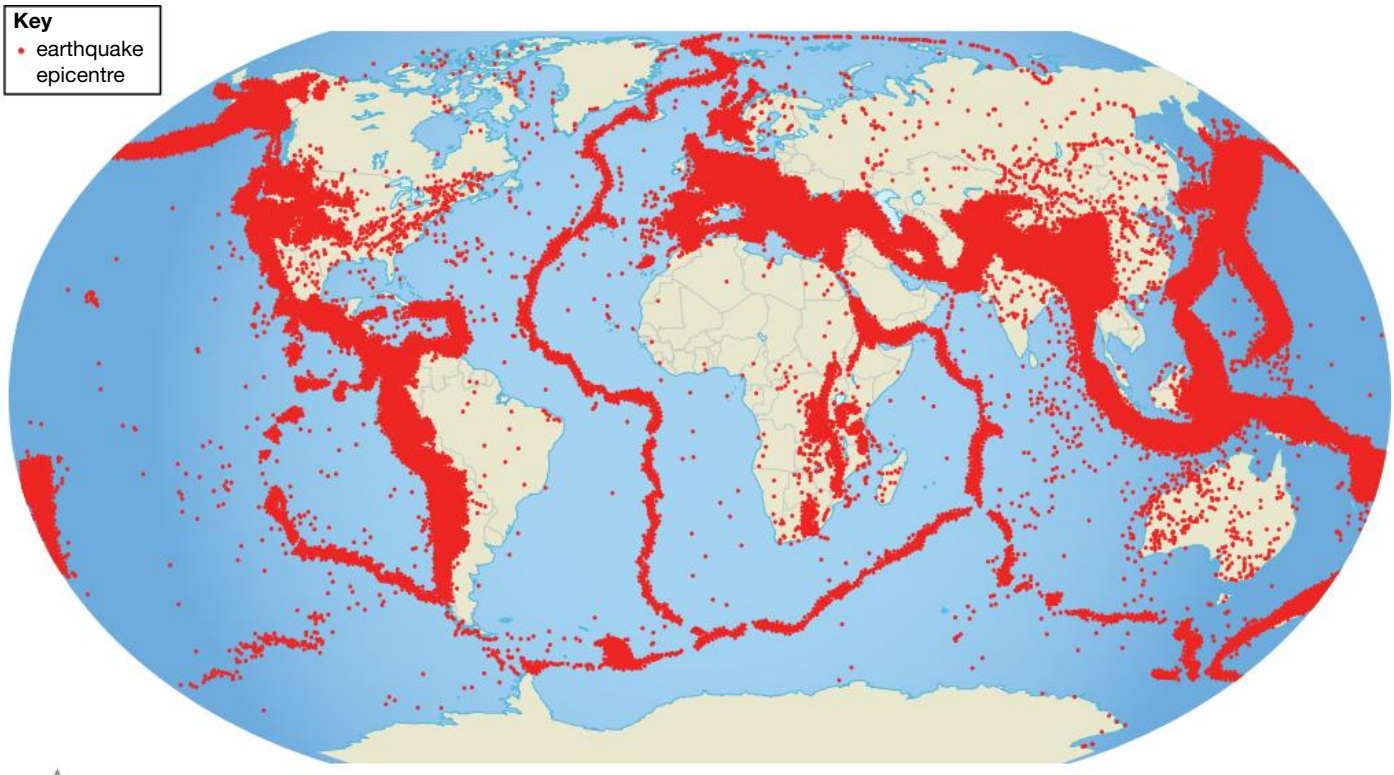

Figure 9.3.8 Earthquakes nearly all occur near the boundaries of the tectonic plates. However, some types of boundaries have more earthquakes.

The severity of an earthquake is calculated in several different ways. One early method, still used today, is measured on the Richter scale. This scale is an open-ended scale but usually finishes at 10. Each successive number is ten times greater than the previous number. So an earthquake measuring 5.0 is ten times more destructive than one measuring 4.0.

SciFile

Big quakes

The largest earthquake ever recorded was one of magnitude 9.5 in Chile in 1960.

The world's deadliest recorded earthquake occurred in 1556 in central China. It killed an estimated 830 000 people. In 1976, another deadly earthquake struck in Tangshan, China, where more than 250 000 people were killed.

Effects of earthquakes

Earthquakes damage buildings and can cause landslides. However, they also cause destruction in the ocean. An earthquake under the ocean can cause a huge wave called a **tsunami**. You can see one in Figure 9.3.9.

These waves can be 100 metres high and cause massive destruction if they collide with the land near where people are living. You can see this in Figure 9.3.10 on page 354.

9.5

Figure 9.3.9 A tsunami hit the north-east coast of Japan in 2011, after a massive magnitude 9.0 earthquake occurred 129 km east of the town of Sendai.

Figure 9.3.10 A tsunami can be devastating when it reaches land.

Building design

Buildings need to be designed and built to withstand earthquakes in places where earthquakes are common, such as Los Angeles (USA), Tokyo (Japan) and Christchurch (New Zealand). Engineers have found that the most effective solution is vibration control. This uses:

- base isolation—springs, ball bearings and pads (like those in Figure 9.3.11) isolate the building from the waves passing through the ground underneath it. This allows the building to remain in position rather than vibrate with Earth
- dampers—structures that move in opposition to the waves and oppose their effect (Figure 9.3.12).

Figure 9.3.11 Base isolation involves placing structures such as these rubber bearings under a building.

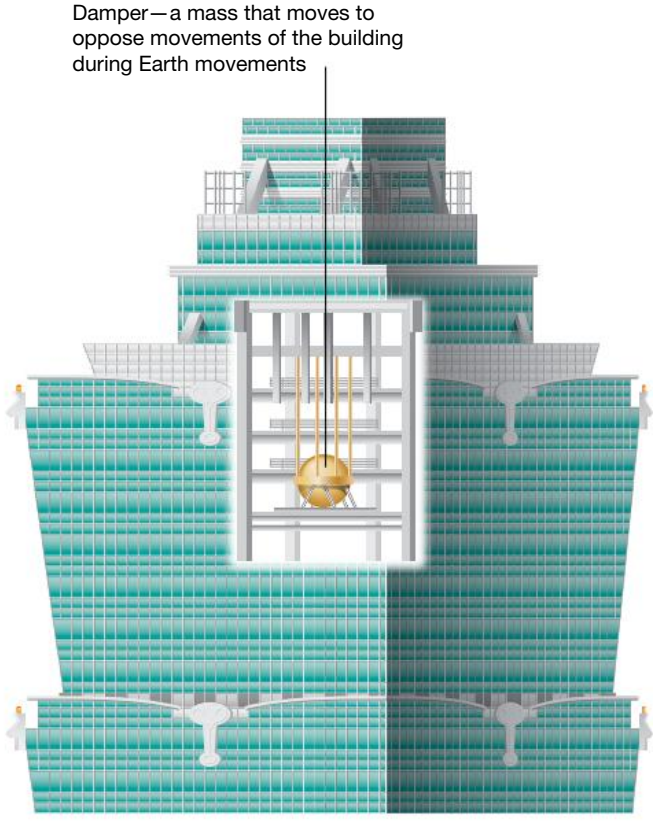

Figure 9.3.12 A damper is a structure in a building that moves and opposes the wave motion pushing on the building. This cross-section shows the damper in Taipei 101, one of the world's tallest buildings, in earthquake-prone Taiwan.

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LEARNING ACROSS THE CURRICULUM

CIVICS AND CITIZENSHIP

Figure 9.3.13 Earthquakes cause much destruction but they also tell scientists about the structure of Earth.

SCIENTIFIC RESEARCH AND DISASTER WARNINGS

To understand threats posed by earthquakes, volcanoes and tsunamis and to provide some warning of them, scientists first need to know what Earth is like beneath the crust.

To understand Earth's structure, scientists have to rely on indirect observation and data, then construct theories and models from these. These theories and models are constantly changing as new evidence emerges.

SEISMIC WAVES

Seismologists use seismometers to study Earth, and have learnt about Earth's structure by studying earthquakes. For example, the behaviour of S-waves and P-waves has enabled seismologists to construct the layered model of Earth shown in Figure 9.3.14.

Seismologists had observed that there was a 'shadow zone' where no S-waves were recorded at the surface after an earthquake. From experiments, it was known that S-waves would not travel through liquids, but would travel through solids. So seismologists proposed that there is a liquid layer around the core of Earth. This would stop the S-waves passing through.

Seismologists also tried to explain why there was an area where few P-waves are detected. After much research studying many earthquakes, they proposed that this was due to the P-waves refracting (bending) as they passed through the liquid outer core. The waves bent down into the liquid core and this directed them away from the weak P-wave area at the surface. Further discussion and debate among seismologists led to the proposal that some P-waves bent because they had reflected off a solid inner core.

GO TO Unit 3.3

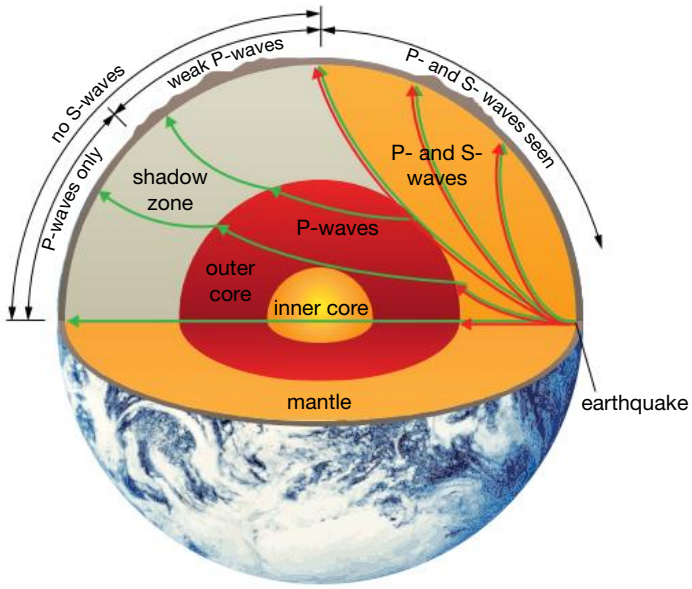


Figure 9.3.14 The behaviour of S-waves and P-waves during earthquake activity helped scientists create the layered model of Earth's structure.

REVIEW

1 **Outline** a reason why scientific research on Earth's structure is important in any society.

2 **Describe** a possible future benefit of improved understanding of the structure of Earth.

3 **Explain** the observations that led seismologists to propose that the centre of Earth has a:
   - **a** liquid outer core
   - **b** solid inner core.

4 Besides public safety, **propose** other benefits of scientific research into the structure of Earth.

9.3 Unit review

Remembering

1 **List** the materials found in volcanic eruptions.

2 **Name** a tectonic process that generates heat at the boundaries of the plates.

3 **Name** the instrument used to measure earthquakes.

4 **Recall** an outcome of an earthquake under the ocean.

Understanding

5 **Define** the terms: L
   a earthquake
   b seismic wave.

6 **Outline** evidence that shows that the following are found mainly at or near the edges of tectonic plates.
   a volcanoes
   b earthquakes

7 **Explain** why volcanoes are often found near the edges of converging tectonic plates.

8 **Explain** how island chains form from hot spots below the ocean crust.

9 **Explain** the cause of earthquakes.

10 **Describe** two features of building design that prevent damage by earthquakes.

Applying

11 The Australian Plate forms a converging boundary with the Indonesian island of Java at the Sunda Trench (also called the Java Trench). Java is one of the most volcanically active places on Earth. **Use** your knowledge of plate tectonics to **explain** the presence of these volcanoes.

12 **Use** the theory of plate tectonics to **explain** why earthquakes and volcanoes are mainly found near plate boundaries.

Analysing

13 **Compare** the formation of an island arc with the formation of an island chain from a hot spot.

14 **Compare** S-waves and P-waves.

15 **Distinguish** between the focus and the epicentre of an earthquake.

Evaluating CCT

16 **Propose** what evidence could help you decide whether a chain of islands was formed by a hot spot.

17 **Propose** why Japan has many active volcanoes.

18 **Use** Figure 9.3.8 on page 353 to **justify** the statement *Australia is a very geologically stable country*.

Creating CCT

19 **Construct** a table to **summarise** the evidence that supports the theory of plate tectonics. Otherwise, **modify** and add your evidence to the tables you constructed in Units 9.1 and 9.2.

Inquiring

1 Research volcanoes in Australia. Find out:
- any evidence of volcanoes in the past, indicating their position on a map
- descriptions of the geology or landforms associated with at least three of the sites
- how the volcanoes are thought to have occurred.

Present your findings as a PowerPoint presentation. ICT

2 Research an earthquake such as the 1989 Newcastle earthquake or the 2011 Christchurch earthquake. Include:
- descriptions of the geology of the area around the epicentre
- reasons why the earthquake probably occurred
- whether the disaster had any effect on recommended building designs for the area.

Present your findings as an article for a newspaper or newspaper website. ICT

ADDITIONAL

3 Research how advances in geology have significantly affected people's lives in:
- creating new jobs in areas such as geophysics and volcanology
- protecting homes and lives
- generating goodwill between Australia and its Asian neighbours such as Indonesia. A

Present your findings in digital form. ICT

ADDITIONAL

9.3 Practical investigations

1 Model volcanoes

Purpose

To build a model volcano and observe its eruptions.

Materials

- baking soda
- vinegar
- food dye
- cornflour
- Alka-Seltzer tablets

- cardboard
- aluminium foil
- newspaper
- plastic tape (for example, duct tape)
- white laboratory tray or newspapers
- glass stirring rod
- scissors
- 100 mL beaker
- reaction vessel (for example, small jar)

SAFETY

Vinegar can damage your eyes, so wear safety glasses at all times. Food dye can stain your skin, so wear gloves.

Procedure

1. Fold the cardboard into a cone shape with a base diameter of about 30 cm, but leave a hole at the top large enough to hold the reaction vessel. Tape the cardboard to form the cone shape.
2. Insert the reaction vessel and tape it in securely. Seal around the edges of the cardboard with plastic tape or aluminium foil.
3. Cover the cardboard with aluminium foil to waterproof it. Tape the foil to seal it.
4. Place the volcano in a laboratory tray or on about 20 sheets of newspaper.
5. Decide how much baking soda and vinegar to use for your first mix. Measure these out. Place the baking soda in the reaction vessel. Add a couple of drops of food dye. Add your measured amount of vinegar.
6. If the result was disappointing, explore different amounts of vinegar and baking soda to see if you can improve the effect. Video the experiment on your mobile phone if given permission.
7. An alternative mixture to try is a thin paste of cornflour and water and Alka-Seltzer tablets.

Results

Record your observations.

Practical review

1. **Construct** a word equation for the baking soda and vinegar reaction.
2. **Compare** your model with a real volcano.

STUDENT DESIGN

2 Seismometers

Purpose

To build and test a model seismometer.

Materials

- retort stands and clamps
- metal rod
- string
- metal weights or brick
- pen and paper
- other materials as selected

SAFETY

A risk assessment is required for this investigation.

Procedure

1. In a team, decide on your seismometer design. Construct a diagram and provide a list of necessary materials to your teacher.
2. Before you start any practical work, assess all risks associated with your procedure. Refer to the MSDS of all chemicals used. Construct a risk assessment that outlines these risks and any precautions you need to take to minimise them. Show your teacher your procedure and your risk assessment. If they approve, then collect all the required materials and start work.
3. Build your seismometer. Test the seismometer by gently bumping the desk without moving the desk.

Seismometers continued on next page

Seismometers continued

Hint

You will have to pull the paper by hand as the pen moves over it.

Practical review

1 **Compare** your seismographs with those of other groups, and **evaluate** the effectiveness of the different designs.

2 **Propose** how you could improve your design.

STUDENT DESIGN

3 Earthquakes and buildings

Purpose

To test how three variables may affect the performance of a building in an earthquake area. The three variables are:

1 distribution of weight in a building

2 width of the building or sections of the building

3 base isolation of the building.

Hypothesis

How do you think the three variables will affect the performance of a building in an earthquake area? Before you go any further with the investigation, write a hypothesis for each variable in your workbook.

Materials

- Plasticine
- hardcover book
- pencils
- wooden blocks, styrofoam blocks, cardboard boxes
- ice-cream container
- ball bearings, marbles, sand, 'hundreds and thousands'
- other materials as selected

SAFETY

A risk assessment is required for this investigation.

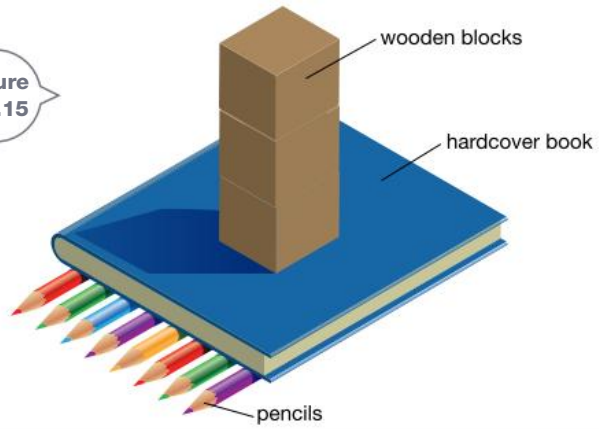


Figure 9.3.15

Procedure

1 In your team, decide how you will make your 'earthquake generator', which is a way of rocking your model buildings back and forth. A hardcover book on pencils (shown in Figure 9.3.15) is the simplest solution, but you will need to consider this as an experimental variable and control its effect.

2 Your buildings must be made in three or four sections. Use different sections (floors) about 10 cm high and a base of about 5 cm by 5 cm for each section. You can change this if there is enough material available. You will need to make the sections from different materials such as wood or styrofoam to test variable 1. To test variable 2, some sections will need to be different widths.

3 To test variable 3, base isolation, you can use the ice-cream container and different materials such as ball bearings, sand, marbles and 'hundreds and thousands'. If you want to try anything else, ask your teacher.

4 Build your first model building to test one of the three variables. Place the model building on your earthquake generator and test its performance. Remember that how you operate your earthquake generator is a variable. Record your observations.

5 Test the other two variables.

Practical review

1 **Explain** how you kept the earthquake generator as a controlled variable in your three different tests.

2 a **Construct** a conclusion for each variable you tested in your investigation.

b **Assess** whether each of your hypotheses were supported or not.

3 **Evaluate** the importance of the three variables on building design in earthquake areas.

4 **Evaluate** the experimental procedure you used and, if necessary, **recommend** any improvements.

9 Chapter review

Remembering

1 **Name** the first person to propose that the continents moved.

2 **List** ten major tectonic plates.

3 **List** the evidence that supports the hypothesis of seafloor spreading.

Understanding

4 **Define** the following terms. L
   a lithosphere
   b asthenosphere

5 **Explain** the process of seafloor spreading and subduction, and how these relate to convection and gravitational force.

6 **Describe** the three types of tectonic plate movements and the effects these have on the crust.

7 **Account** for the relationship between the places where earthquakes and volcanoes occur and where convergent and divergent tectonic plate boundaries exist.

Figure 9.4.1

8 **Account** for the great age and geological stability of Australia compared with many other continents.

9 **Describe** how technological developments (such as magnetometers, echo sounders and GPS) have increased scientific understanding of global patterns in geological activity.

Applying

10 **Use** the theory of plate tectonics to **explain** how new landforms such as mountain ranges, volcanic islands and ocean trenches develop.

11 **Use** the theory of plate tectonics to **explain** why geologists predict that the Great Rift Valley in Africa will be the site of an ocean millions of years in the future.

Analysing

12 **Compare** the characteristics of oceanic crust and continental crust.

13 **Compare** the effects of subduction when oceanic plates meet, with the effects when oceanic and continental plates meet.

14 **Compare** Alfred Wegener's continental drift theory with our current understanding of plate tectonics.

Evaluating CCT

15 **Justify** the view that mountains form because of plate tectonics.

16 **Justify** the view that oceans form from rifting.

17 a **Determine** whether you can or cannot answer the questions on page 330 at the start of this chapter.
   b **Assess** how well you understand the material presented in this chapter.

Creating CCT

18 **Construct** a poster to display in your science room, adding illustrations and notes on the evidence that supports the theory of plate tectonics.

19 **Use** the following ten key terms to **construct** a visual summary of the information presented in this chapter.

seafloor spreading

magnetic striping

converging boundary

diverging boundary

transform boundary

ocean trench

mountains

island arcs and chains

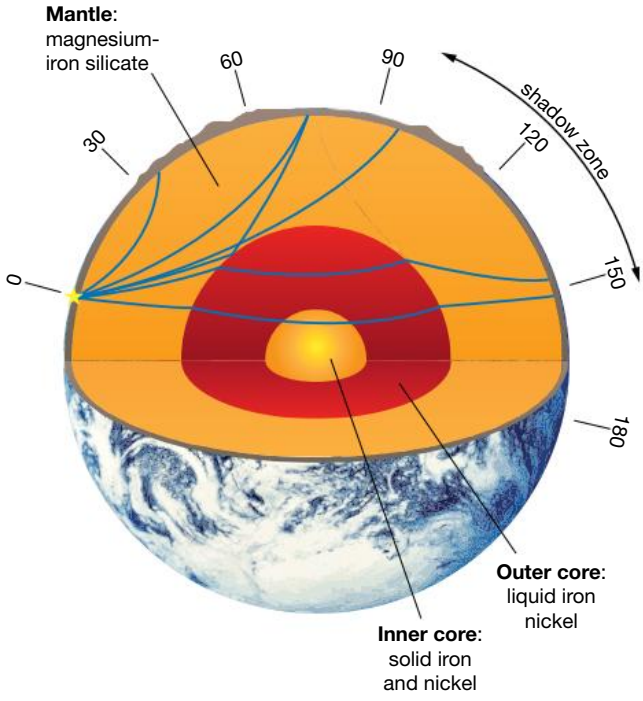
volcanoes

earthquakes

9.6 9.7

Thinking scientifically

Q1 Consider the following diagram. CCT



This diagram is presenting evidence of:

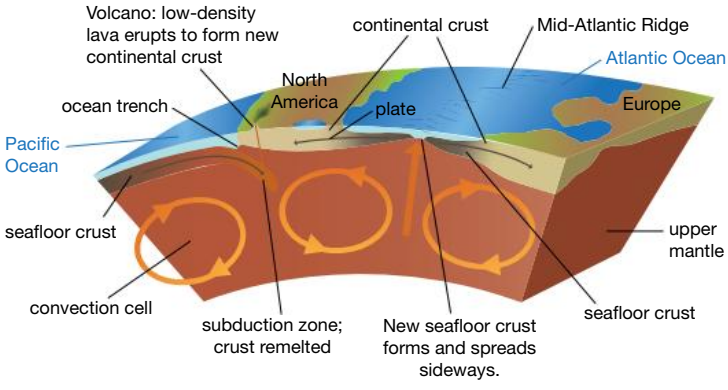
A volcanic activity in the crust due to tectonic plate movement

B the existence of earthquakes caused by subduction

C the interior structure of Earth based on measurements of earthquakes

D how drilling has determined the chemical composition of the layers of Earth.

Questions 2 and 3 refer to the following diagram.



Q2 The diagram is being used to show that: CCT

A Earth is composed of layers

B continents are formed by seafloor spreading

C plate tectonics can change Earth's climates

D tectonic plates move due to convection currents.

Q3 From the diagram, you could deduce that subduction and seafloor spreading together: CCT

A cause the convection currents

B show that the crust is recycled and therefore does not grow larger

C explain the formation of North America and Europe

D explain why volcanoes form from magma originating in the crust.

Q4 Consider the following data on the composition of the crust. CCT

Mineral group	% of crust	Approximate density of mineral (weight compared with water)
Feldspars	49	2.5–2.7
Quartz	21	2.6
Pyroxene, olivine and others	15	3–4.3
Micas	8	2.7–3
Magnetite	3	5.2
Other minerals	4	varies greatly

Basalt has a density of about 2.9 g/cm^3, whereas granite is about 2.6 g/cm^3. Which of the following is a likely deduction from this information?

A Continental crust is heavier than ocean crust.

B Basalt probably has more feldspars and quartz than granite has.

C Basalt is largely made of magnetite.

D There is probably more magnetite, pyroxene and olivine in basalt than in granite.

Glossary

Unit 9.1

Asthenosphere: a layer of 'plastic' semi-solid rock in the lower mantle

Continental drift: the separating of continents by drifting across Earth's surface

Continental drift

Magnetic striping: patterns of magnetism trapped in rocks on each side of plate boundaries

Ocean trench: a deep channel in the ocean floor where crust is sinking downwards

Plate tectonics: the theory that Earth's crust is cracked into many large pieces that move on the asthenosphere

Rifting: the process of continents breaking up, subsiding and allowing in water from the sea

Seafloor spreading: the process of new crust forming at the ocean ridges and spreading outwards

Subduction: when one plate sinks below another plate during a collision

Unit 9.2

Continental crust: the crust that forms the continents

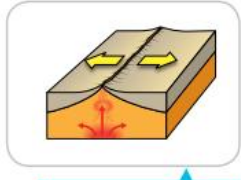
Converging boundary: where plates are colliding with each other

Converging boundary

Diverging boundary: where plates are moving apart from each other in opposite directions

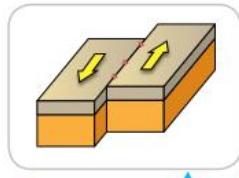
GPS ground station: a receiver and computer that can detect satellite signals and calculate position on Earth's surface

Island arc: a chain of islands formed at the edges of colliding tectonic plates where one plate subducts


Diverging boundary

Oceanic crust: the crust that forms the ocean floor

Transform boundary: where plates are sliding parallel to each other but in opposite directions


Transform boundary

Unit 9.3

Earthquake: the rapid movement of the ground, usually back and forth and up and down in a wave motion, due to the movement of tectonic plates

Epicentre: the point on Earth's surface directly above the focus of an earthquake

Focus: the place below ground where an earthquake starts

Hot spots: isolated places away from plate boundaries where a lot of hot magma is collecting

Hot spot

Lava: molten rock that has erupted onto Earth's surface

Magma: molten rock below Earth's surface

Primary wave (P-wave): a longitudinal seismic wave that travels fast through Earth

Secondary wave (S-wave): a transverse seismic wave that travels through Earth

Seismic wave: the shaking, wave-like movement of the ground in an earthquake

Tsunami

Seismometer: an instrument that detects the seismic waves from an earthquake

Surface wave: a seismic wave that travels along the surface of the Earth in the crust

Tsunami: a huge wave in the ocean caused by an earthquake occurring on the seafloor

Volcano

Volcano: a place where extremely hot material from inside Earth erupts at the surface

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