nelson iscience 9

for the Australian Curriculum • NSW Stage 5

Anna DAVIS • Robert FARR • Karen LAMPMAN • Bill MATCHETT • Ruth MILLER • Rebecca SMYTH

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Key: atomic number / Symbol / element name

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H hydrogen																	2 He helium
2	3 Li lithium	4 Be beryllium											5 B boron	6 C carbon	7 N nitrogen	8 O oxygen	9 F fluorine	10 Ne neon
3	11 Na sodium	12 Mg magnesium											13 Al aluminium	14 Si silicon	15 P phosphorus	16 S sulfur	17 Cl chlorine	18 Ar argon
4	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
5	37 Rb rubidium	38 Sr stronium	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
6	55 Cs caesium	56 Ba barium	57–71 lanthanides	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
7	87 Fr francium	88 Ra radium	89–103 actinides	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		114 Fl flerovium		116 Lv livermorium		

57 La lanthanium	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
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

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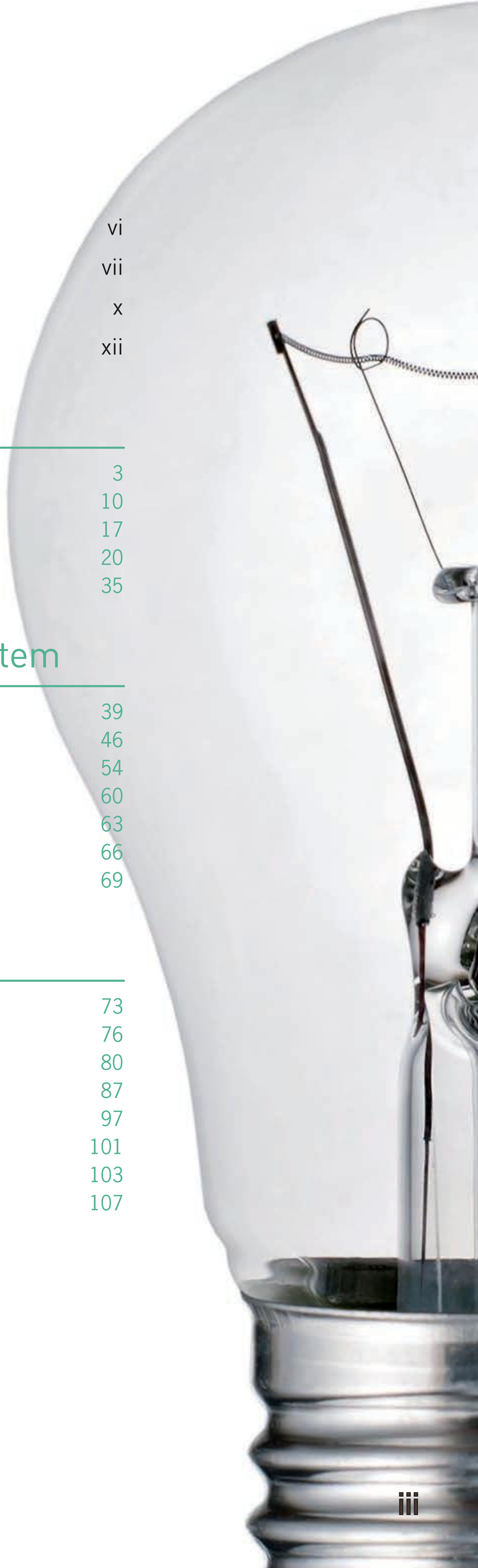


4 Atomic theory

5 The chemistry of new substances

6 Chemical reactions

7 Waves

8 Global patterns

Introduction

The New South Wales Syllabus for the Australian Curriculum – Science provides the opportunity to immerse students in the wonder and awe of science. It emphasises that science is a creative and collaborative human endeavour that helps students make sense of their world. Having an understanding of science assists students to be effective and successful members of society, especially in this rapidly changing technological world. More than this, the new syllabus enables students to gain practical and thinking skills that they can benefit from throughout their life.

The authors of the *Nelson iScience for NSW* series have embraced the New South Wales Syllabus for the Australian Curriculum – Science and produced a truly 21st-century science resource for students. *Nelson iScience* provides a resource that fully integrates the strands and aims of the new syllabus into the fascinating story of Science.

Nelson iScience for NSW combines higher-order thinking tools and ICT to promote innovative and creative problem-solving and approaches to learning science. It builds on the collaborative nature of learning by enabling students to learn with and from one another by sharing their work, ideas and thoughts through the vast capabilities of ICT.

Nelson iScience for NSW has adopted a differentiated practical approach to the learning of science, providing many opportunities for hands-on and minds-on activities. Many of these activities challenge students, assisting them in organising their thoughts and understandings. Many others require students to unpack information and ideas and repackage or manipulate them to show their understanding. It provides each student with many and diverse opportunities to excel.

Whether students continue with the study of science or not, they are sure to learn lifelong and valuable lessons and skills that are transferrable from the *Nelson iScience for NSW* series.

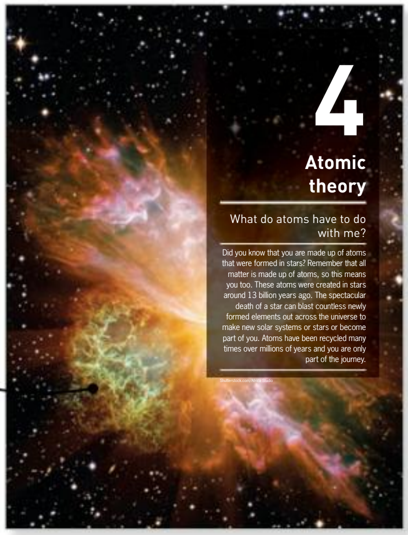
How to use *Nelson iScience for NSW*

The *Nelson iScience for NSW* series has been authored by practising teachers from across Australia to meet the requirements of the New South Wales Syllabus for the Australian Curriculum – Science. The *Nelson iScience* series integrates the three strands of the Australian Curriculum, while integrating the depth and full scope of the NSW syllabus.

Nelson iScience for NSW has been designed for use by the students of the 21st century. It seamlessly integrates the use of ICT in the science classroom to research, analyse, record, collaborate and present material. Higher-order thinking skills are developed and reinforced throughout the series, providing students with strategies to manipulate information and ideas to tackle issues and assist with problem-solving.

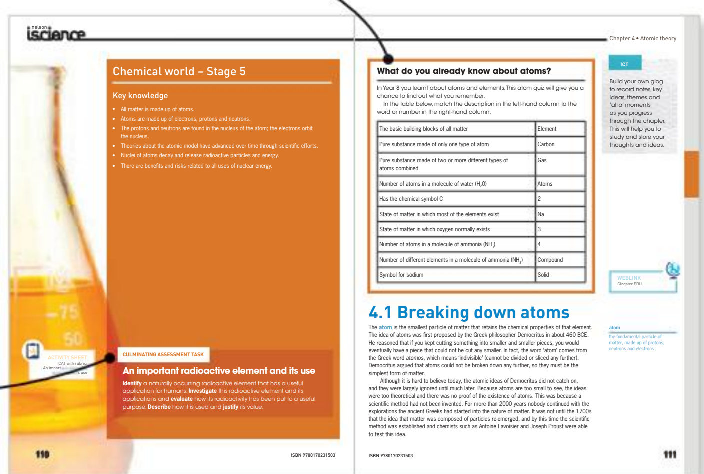
The *Nelson iScience for NSW* series has a clear, uncluttered and easy-to-follow design.

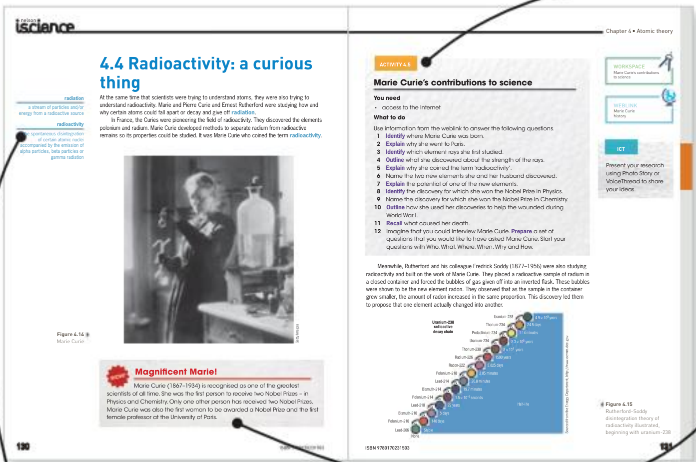
Each chapter begins with a chapter opening page that features a chapter question based around one of the overarching ideas of the NSW Syllabus for the Australian Curriculum – Science. The chapter question is designed to ignite student curiosity. It also provides a framework on which teachers build students' knowledge. Each idea is further developed in subsequent chapters, showing that these key aspects of science bridge scientific knowledge and understanding across all levels and disciplines of science.



Students are challenged to think by the What do you already know about …? at the start of each chapter. This is designed to determine what understandings and skills each student brings to each topic, and enables teachers to customise the chapter to build on their students' current knowledge and skills.

The culminating assessment task is presented towards the beginning of each chapter so that students can plan their time to complete the task. The culminating assessment task is designed to assess the understandings and skills presented in each chapter. Each culminating assessment task is accompanied by an assessment rubric so that students are aware of the criteria on which they will be assessed.



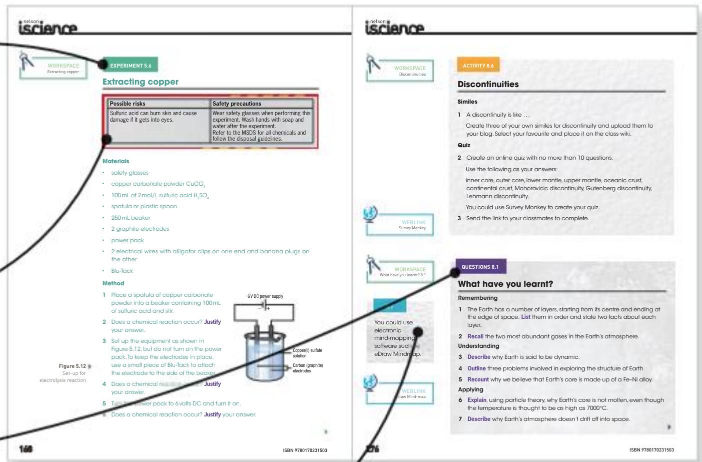


ACTIVITY 4.5

Activity boxes occur throughout each chapter, providing practical minds-on or hands-on activities to reinforce student's learning. Activity boxes build and reinforce valuable skills related to the science inquiry skills strand. Many activities are suitable for homework or extension exercises.

WOW! boxes provide interesting and engaging information related to the content of the chapter.

Glossary terms are conveniently located in the margins as students meet new scientific words.



EXPERIMENT 5.6

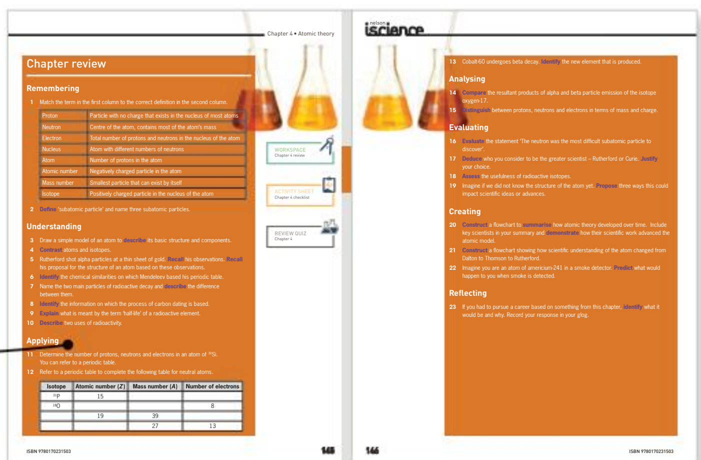
Experiments allow students to follow procedures, collect data, perform guided experiments and analyse results. Experiment – Investigations challenge students to test their own hypotheses by designing and performing their own experiments. Safety audit boxes alert teachers and students to some of the risks associated with completing the experiment. Experiments build and reinforce valuable skills related to the science inquiry skills strand.

QUESTIONS 8.1

What have you learnt? boxes break the chapter content into smaller chunks. They allow students to review and assess their learning. Questions are categorised according to Bloom's Revised Taxonomy, designed to extend each student's thinking and understanding.

ICT

ICT boxes throughout the chapters give optional suggestions on how ICT applications can be used to assist with the delivery or presentation of content and student learning.



The end-of-chapter review consists of an interactive autocorrecting review quiz, a chapter checklist to assist students with revising for a test, and a set of end-of-chapter review questions. These questions, similar to other questions throughout the chapters, are categorised according to Bloom's Revised Taxonomy to extend each student's thinking and understanding.

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NelsonNet is your protected portal to the premium digital resources for Nelson textbooks located at www.nelsonnet.com.au. Once your registration is complete, you will have access to exciting and stimulating digital resources that supplement and complement each chapter. They include the following.

WORKSPACES are provided throughout each chapter. These are spaces in which students can complete the work required within the chapter. Workspaces can be either printed out or filled in on-screen and submitted electronically to the teacher.

ACTIVITY SHEETS provide extra activities, literacy exercises, questions and more that can be used either within class or as homework and extension material. Activity sheets can be either printed out or filled in on-screen and submitted electronically to the teacher.

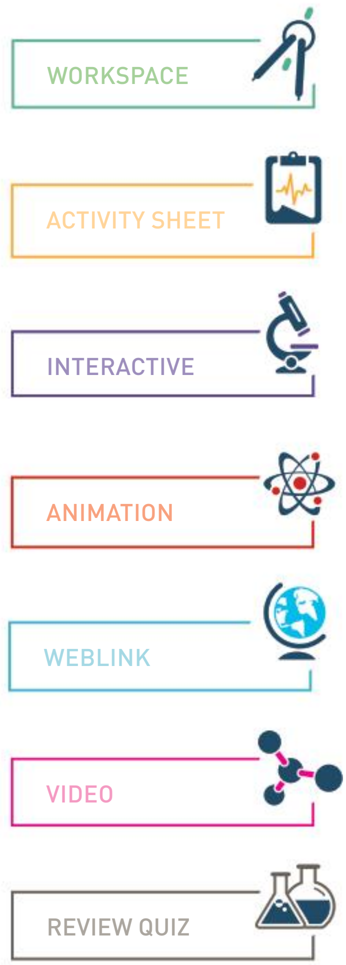
INTERACTIVES provide learning objects that the student can interact with and use at their own pace to reinforce their learning.

ANIMATIONS provide students with animated illustrations from the student text.

WEBLINKS link students to websites on the Internet.

VIDEO links students to video clips to aid with learning and understanding.

REVIEW QUIZZES appear at the end of each chapter. Each quiz contains 10 multiple-choice items and is interactive and autocorrecting.



Nelson iScience for NSW NelsonNetBook

NelsonNetBook is a web-based downloadable ebook for secondary schools, friendly to interactive whiteboards and computers. Optional ICT functionality enables class groups and individuals to add highlights, annotations, audio clips and weblinks. Visit the NelsonNet portal at www.nelsonnet.com.au to find out more, to register or to log in if already registered.

NelsonNetBook allows both teachers and students to personalise the book and for teachers to share their enriched version with groups of students, or a group of teachers, in the school. Alternatively, students can simply use the resource independently without being in a group. The creation and membership of the groups is entirely in the hands of the teacher, and the shared environment is protected through individual access codes and school registration.

The NelsonNetBook becomes central to everything the students do. It loads onto the screen with toolbars down the side and along the bottom (can be interchanged as per the user's preference). The icons on the toolbars correspond to editing features, such as highlighting, note-taking, inserting weblinks, bookmarking, inserting video links and inserting worksheets, as well as for more personalised activities.

Nelson iScience for NSW teacher companion site

The teacher will have access to assessment material and detailed curriculum grids that map in detail the chapters to the science curriculum strands, teaching plans for each chapter and a pdf of the student book.

Key question words

These key words are drawn from Bloom's Revised Taxonomy for the cognitive learning domain. They have been applied throughout this series in chapter questions. Many of these appear frequently in HSC documents and examinations. Introducing students to specific key words used similarly in HSC examinations across various subjects helps them to better prepare for HSC study. Importantly, the key words always have the same meaning. Students understand these words and what is expected.

In classrooms, teachers who consistently use these words will better prepare their students for tests and examinations.

Account Give an account of: report on a sequence of events or transactions; account for: express an explanation or justification for

Analyse Separate into components and identify how these relate to each other; use implications to infer

Apply Implement or employ in a specific context; put into use

Appreciate Recognise, judge or appraise the value or worth of

Assess Apply a value judgement; evaluate in terms of quality, size, results or outcomes

Calculate Determine or identify from relevant, available data; score or quantify

Clarify Break down to make plain; simplify

Classify Categorise, arrange or organise into groups or classes, as in a taxonomy

Compare Emphasise similarities or differences between; compare with: compare essentially similar things; compare to: compare essentially different things

Construct Create or design; combine existing items into something new; build arguments or plans

Contrast Emphasise and identify differences between things

Critically analyse Analyse in great depth with scepticism and objectivity; use knowledge and understanding, logic, reflection and questioning in analysis

Critically evaluate Evaluate with precision and scepticism; carefully consider; apply elements of logic, reflection and questioning to assess

Deduce Conclude or infer; derive an answer

Define Identify or denote the meaning, implications or essence of

Demonstrate Perform, indicate or show something by example

Describe State attributes and characteristics; answer 'what?'

Design Create or build something for a purpose; come up with a plan for a purpose

Discuss Engage in conversation about; consider issues and problems; describe; argue for and/or against

Distinguish Make distinct from; reveal differences or disparities between

Evaluate Apply criteria, reasons or evidence to judge or identify the value of

Examine Inspect or investigate in great depth; take stock of

Explain Give reasons for; demonstrate relationships between; show cause and effect; answer 'why?' and 'how?'

Extract Select a relevant and appropriate part of the whole

Extrapolate Predict, infer and conclude from given information

Identify Name, label or recognise; diagnose a problem; determine a cause

Illustrate Use examples to make plain, simplify or prove

Interpret Define; translate or make sense of something

Investigate Scrutinise, question and explore thoroughly; plan an inspection into; measure; make conclusions

Justify Legitimise or substantiate an argument or conclusion; prove the validity or accuracy of

List Arrange items, words or names one after the other, sometimes in a specific order

Modify Make small changes to something, especially to improve

Outline Summarise the main characteristics of; describe in general terms

Predict Use available information to anticipate a possible outcome

Propose Nominate or recommend an action; present an idea, argument, point of view or suggestion for consideration

Recall Share recollections of relevant ideas and experiences; draw on remembered facts

Recommend Approve or advocate for; give reasons to justify a suggestion

Recount Give a detailed account of a sequence of events; retell as a narrative

Relate Identify and describe the links between two or more things, or people

Show Make something evident in a clear way, possibly using examples

Summarise State only the essential details; provide a succinct overview of

Synthesise Combine a variety of parts into a harmonious whole

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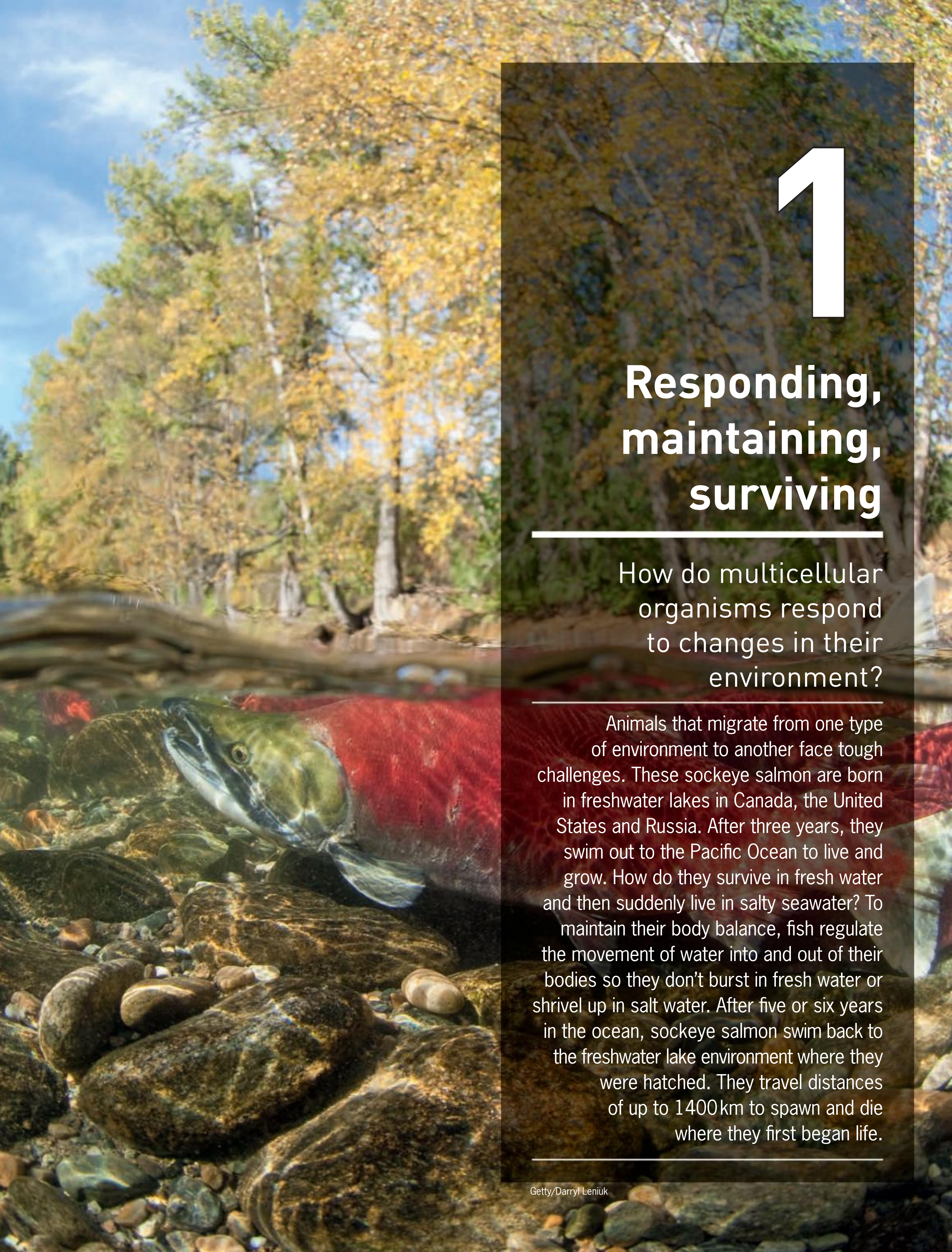

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1

Responding, maintaining, surviving

How do multicellular organisms respond to changes in their environment?

Animals that migrate from one type of environment to another face tough challenges. These sockeye salmon are born in freshwater lakes in Canada, the United States and Russia. After three years, they swim out to the Pacific Ocean to live and grow. How do they survive in fresh water and then suddenly live in salty seawater? To maintain their body balance, fish regulate the movement of water into and out of their bodies so they don't burst in fresh water or shrivel up in salt water. After five or six years in the ocean, sockeye salmon swim back to the freshwater lake environment where they were hatched. They travel distances of up to 1400 km to spawn and die where they first began life.

Living world – Stage 5

Key knowledge

- Multicellular organisms respond to environmental changes.
- Multicellular organisms use internal systems to remove metabolic wastes and to obtain the requirements for life, such as water, gases and nutrients.
- The endocrine and nervous systems work together to maintain humans as functioning organisms in a changing environment.

ACTIVITY SHEET
CAT with rubric:
Type 1 diabetes

CULMINATING ASSESSMENT TASK

Type 1 diabetes

Type 1 diabetes is also known as insulin-dependent diabetes or *Diabetes mellitus*. Be very clear about the distinction between type 1 and type 2 diabetes. This task relates to type 1 diabetes only.

Create a tri-fold brochure, suitable for use in doctors' surgeries or public health centres, to **summarise** and **outline** blood sugar regulation, type 1 diabetes and how to cope with the condition.

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What do you already know about coordinating human body systems?

Think about what happens when you have been running fast or playing sport. After intense physical activity you can feel very hot, quite thirsty and maybe hungry too, but you don't stay like this – your body eventually returns to its normal state.

In groups of two or three, create a summary diagram to **outline** the steps from *either* thirsty *or* hungry back to normal. Use a large sheet of paper and try to incorporate answers to these questions:

- How do you know you are hungry or thirsty?
- Why does your body get hungry or thirsty?
- Which organs or systems are required to respond to hunger or thirst and then return to normal?
- What happens to the food or water you take in? How do you know when you have had enough?

WORKSPACE
What do you already know about coordinating human body systems?

1.1 Why do multicellular organisms need to respond to their environment?

External environments change regularly. Day turns into night, rain comes and goes, and the outside temperature fluctuates with latitude, season and time. Living things have many ways to cope with these changes in order to survive. The challenge is to keep their internal body environment balanced, despite outside changes. Multicellular organisms, such as animals and plants, have specialised systems to detect changes and carry out coordinated responses, to keep their bodies functioning efficiently.

Detecting change

In order to respond to changes in the external environment, multicellular organisms must detect the change. When you enter an air-conditioned building on a summer day, you detect the change in temperature through **receptors** (**thermoreceptors**) on your skin. The colder temperature acts as a **stimulus** to the receptors. If the change is minor, such as a small drop in temperature, you can do simple things like putting on more clothes. If the change

receptor
part of a cell or organ that responds to a specific signal such as light, heat or a particular chemical

thermoreceptor
a receptor that responds to heat and cold

stimulus
anything that activates a sensory cell in the nervous system or a response in the endocrine system

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photoreceptor

a specialised receptor that is sensitive to light; in vertebrate animals, the photoreceptors are the rods and cones in the retina of the eye

ACTIVITY SHEET
Investigating our sensory system

Getty/Photo Researchers

Figure 1.1 Receptors (photoreceptors) in plants detect light and respond by growing towards it or away from it.

affects core body temperature, you activate more significant responses, such as shivering. If the change is potentially life-threatening, your reflexes kick in and respond before you are even aware of it.

Receptors (**photoreceptors**) in plants detect light and respond by growing towards it or away from it. Animals have photoreceptors in their eyes. Receptors (chemoreceptors), like those in moth antennae, can detect chemicals that stimulate a mating response. *Cercropia* moths, for example, can detect this stimulus from 1500 metres away.

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Figure 1.2 Receptors (chemoreceptors), like those in *Cercropia* moth antennae, can detect chemicals that stimulate a mating response.

Fast responses – the nervous system

Plants and fungi detect and respond to change, but they don't have a nervous system. Both **invertebrates** and **vertebrates** (including fish, amphibians, reptiles, birds and mammals) can respond rapidly to their environment. This type of coordination relies on the nervous system, which is unique to animals. The nervous system is made up of the brain, spinal cord and a large network of nerves. These specialised cells detect stimuli and

invertebrate

an animal that does not possess a backbone

vertebrate

an animal that has a backbone

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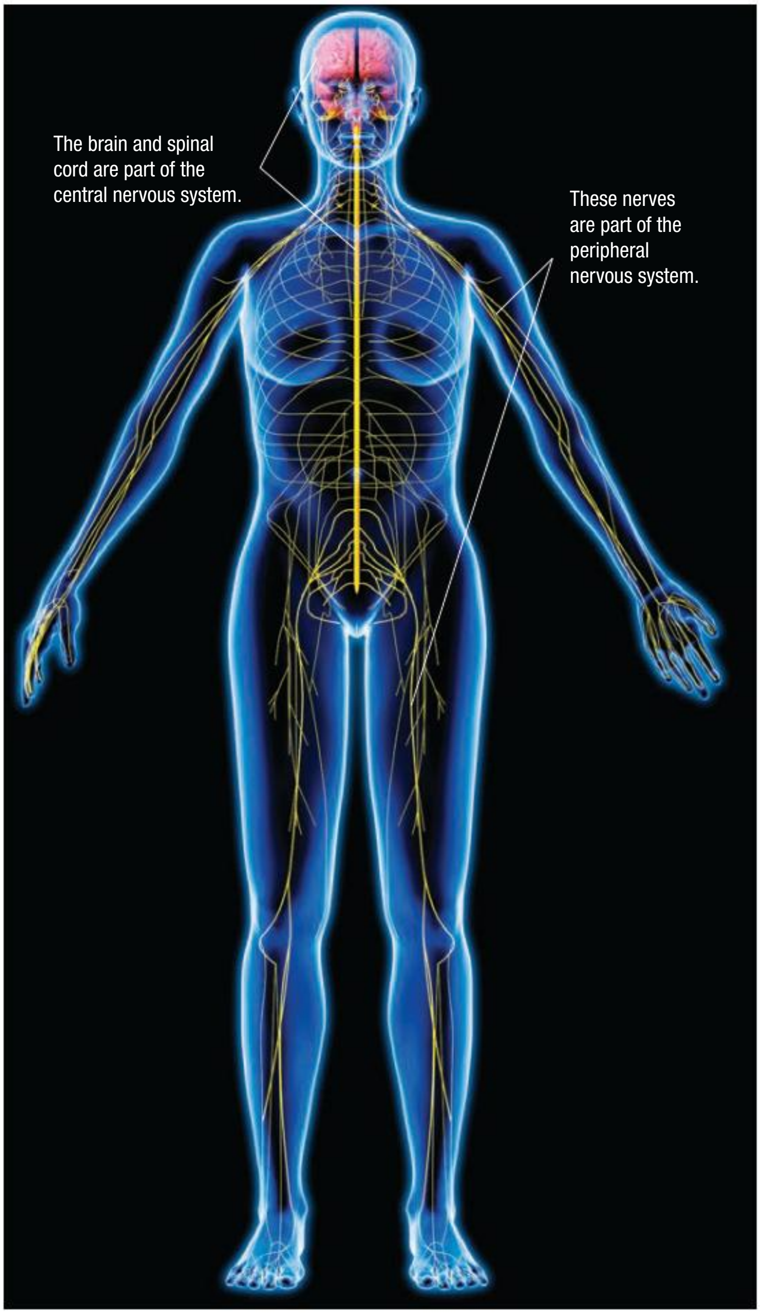

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Figure 1.3
The relationship between the central nervous system (brain and spinal cord) and the peripheral nervous system (other nerves and neurons).

VIDEO
The nervous system

WEBLINK
The human body: nervous system

respond quickly in a coordinated way. Fast communication, however, comes at a price. All the cells involved need to be kept alive whether they are being used or not, and a large amount of energy is used whenever nerve cells communicate. The human brain, which consists largely of nerve cells, is estimated to use approximately one quarter of our entire energy intake.

In complex animals, including all vertebrates, the nervous system is divided into two parts:

- the **central nervous system (CNS)**, which consists of the brain and spinal cord
- the **peripheral nervous system (PNS)**, which extends out to the rest of the body as a system of **nerves**. Each nerve consists of many individual nerve cells called **neurons**.

central nervous system (CNS)
the brain and spinal cord

peripheral nervous system (PNS)
all parts of the nervous system except the brain and spinal cord

nerve
a bundle of nerve fibres (neurons)

neuron
a single nerve cell

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WEBLINK
Mimosa pudica leaf responses

WOW!

A nervous plant?

Plants do not have a nervous system, but *Mimosa pudica* leaves can still sense touch and respond with movement. This movement is a result of rapid water movement from large, thin cells located at the base of each leaf. The leaves curl up when touched, which prevents insects resting on them to eat!


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The neuron

Nerves are made up of many individual neurons, bundled together. Neurons are the functional units of the nervous system (Figure 1.4). Messages can only travel in one direction along a neuron. This is why there are several types of neurons that work together to ensure our body's response is fast and organised.

There are three main types of neurons.

1. Sensory neurons transmit messages from our sense organs. For example, they pick up the sensations of touch, pressure, heat or cold from our skin, or light detected by our eyes; even sound vibrations in our inner ear are detected by sensory neurons. Their job is to send this information as an electrical impulse to the CNS.
2. Motor neurons carry the message from the CNS (brain or spinal cord) out to the **effectors** of the body (muscles or glands).
3. Connector neurons are found in the brain and spinal cord. They act as the link between other neurons so that messages are passed on correctly. They are also called interneurons or relay neurons.

All neurons have some similarities in structure. They all have a **cell body** that contains the nucleus and organelles and two kinds of branches, **dendrites** and **axons** (see Figure 1.4).

Dendrites receive nerve impulses and get their name from a Greek word meaning 'tree'. They even look 'tree-like' with their many branches. Different neurons have different numbers of dendrites. Their job is to help form communication webs, particularly in our brains. It is the dendrites (and the cell bodies) that make up most of the 'grey matter' of the brain.

Axons are the long fibres of the neurons. Most neurons have only one axon. An axon can be as long as your leg. Axons make up most of the 'white matter' of the brain. Axons are

effector
a structure or organ that brings about a response, e.g. muscles and glands

cell body
the enlarged part of a neuron that contains the nucleus

dendrite
the branching neuron extension that brings impulses towards the cell body

axon
the neuron extension that conducts impulses away from the cell body

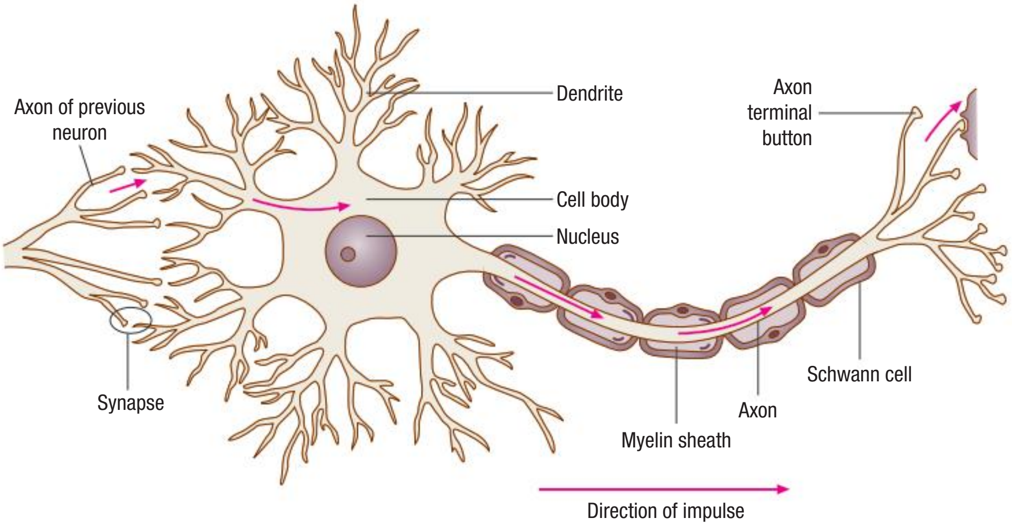

Figure 1.4 Structure of a neuron

ISBN 9780170231503

important because they enable neurons to conduct electrical impulses (nervous messages) from one cell to another throughout the entire body.

Wrapped around the axons of some neurons are specialised cells called **Schwann cells**. These cells secrete a fatty insulating layer called the **myelin sheath**. This layer speeds up the transmission of the message and ensures that the electrical signal only travels along its intended axon. The myelin sheath prevents the message crossing to other axons that might be nearby.

It takes about 7 milliseconds for a nervous message to travel along an axon and then about 1.5 milliseconds before the next message can be transmitted. This short delay is necessary for the chemicals of the neuron to reset and be ready for the next impulse. Interestingly, a neuron can only send a full response signal or no signal at all. Like a light that is either on or off, with no in-between settings, the action potential is an **all-or-nothing response**.

Schwann cell
a specialised cell that rolls its membrane around axons to form the myelin sheath

myelin sheath
a fatty covering around the axon that insulates it; produced by Schwann cells

all-or-nothing response
a response that either happens or it doesn't

Superfast responses – the reflex arc

The **reflex arc** is a special nerve pathway for rapid automatic responses. Reflex arcs are the fastest of all responses in the human body, and include responses such as blinking when an object is coming towards your eye and the size of the pupil decreasing in response to light. The reason these responses can be so rapid is that they do not usually involve brain cells. A reflex arc travels directly from the receptor to the spinal cord and then to the effector. We often only realise these responses have happened after the event. We never need to 'think' about the knee jerk reflex, which is processed in the spinal cord and helps us balance whenever we stand or walk. Reflex arcs are particularly important in the body when a superfast response is needed to keep us safe.

Consider the reflex arc pathway shown in Figure 1.5. When you put your hand on a tack, the pain stimulus makes you pull your hand away. All three types of neurons are used to transmit the message from the pain receptors to the muscle effector.

reflex arc
the nerve pathway that regulates a simple, automatic response (reflex action)

ACTIVITY SHEET
Testing reflex actions

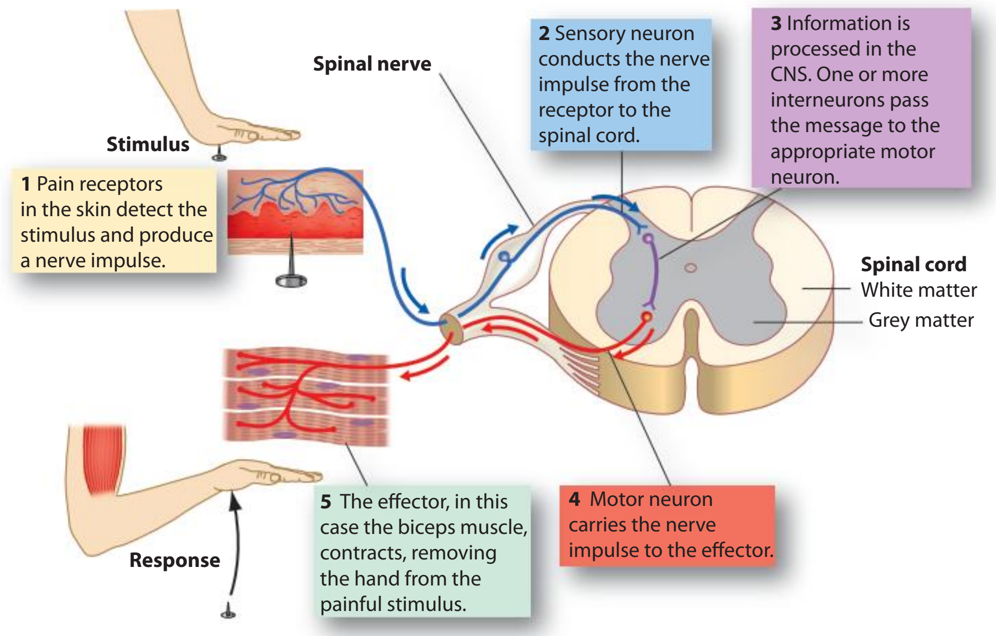

Figure 1.5 The neurons involved in the pathway of a reflex arc. In this example the impulses enter and leave the spinal cord by the same spinal nerve. This is not always the case.

Messages between neurons

Nerve messages can go in one direction only (Figure 1.4).

The process starts when a dendrite receives a signal that is large enough to cause a change in the neuron. This is called the threshold stimulus. Messages are then transmitted

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action potential

a 'wave' of electrical charge passing along a neuron

synapse

a tiny gap separating two neurons

neurotransmitter

a chemical that diffuses across synapses to transmit a message

presynaptic membrane

the membrane that releases neurotransmitters

along the neuron as a 'wave' of electrical charge, called an **action potential**. Where two neurons meet there is a tiny gap called a **synapse**. For a nervous message to cross this gap, the electrical message must be converted and transmitted using chemicals. These chemicals, called **neurotransmitters**, are released from the end of an axon. They diffuse across the synapse and bind to the membrane of the next neuron to pass the message along.

The membranes on axons and dendrites are different. If you looked at the end of an axon with a powerful electron microscope, you would see many fluid-filled bubbles (vesicles) near the membrane bordering the synapse (**presynaptic membrane**). These vesicles contain neurotransmitters. When an action potential arrives, the vesicles fuse with the membrane and spill neurotransmitter molecules into the synapse.

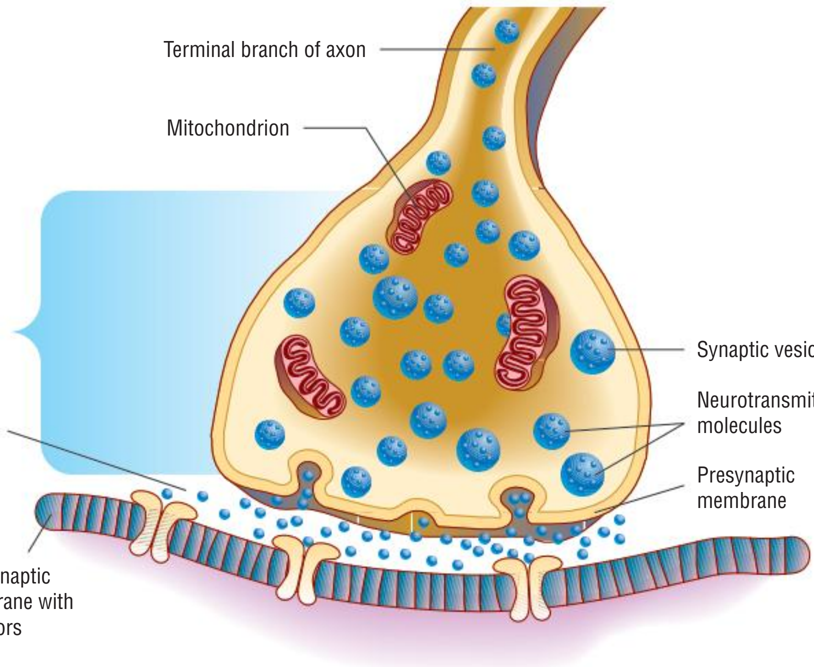

Figure 1.6 A detailed view of a synapse

postsynaptic membrane

the membrane that receives neurotransmitters

enzyme

a biological catalyst; a protein that speeds reactions without being used up

The **postsynaptic membrane** of the dendrite in the receiving neuron is covered with receptors that detect the neurotransmitter. The chemical message is then converted back to an electrical wave. The used neurotransmitter is acted on by **enzymes** and returned to the presynaptic membrane for reuse.

ACTIVITY 1.1

Modelling a message

In a group of five or six, develop a role play to model the action of a nervous message crossing a synapse. Think about how to **show** the change of signal from electrical to chemical and back to electrical message. Include the arrival of the nervous impulse, the release of neurotransmitters and their receipt by the next neuron in the chain.

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Neurotransmitters can also control the movement through the body of a nervous message. If insufficient neurotransmitter is released, the nervous message may stop at the end of the axon. However, if large amounts of neurotransmitter are released into the synapse, then one neuron may cause several others to fire in response.

Message interruption

Drugs and some poisons can also affect the transmission of messages from one neuron to the next. Some drugs may speed up the transmission of the nervous message across the synapse, or they may slow them down or even stop them altogether. Many painkillers, such as paracetamol, work by interrupting the transmission of neurotransmitter across the synapse. They block the release of neurotransmitter from the vesicles, interact with the neurotransmitter molecules in the gap or block the neurotransmitter from joining with the postsynaptic membrane. All of these actions can prevent a nervous message travelling through the body. This is particularly helpful when you have a site of pain as it prevents the transmission of the 'pain' messages given out by the cells.

WOW!

Beautiful, but deadly

Some animals and plants have deadly neurotoxins. Poison dart frogs of Central and South America have neurotoxins that are released through their skin. These frogs are beautiful, but deadly. Some have enough neurotoxin to kill 60 men or 400 mice! Local indigenous people often hunt using some of this toxin rubbed onto arrow points.

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ACTIVITY SHEET
Deadly neurotoxins

Multiple sclerosis

Multiple sclerosis (MS) is a disease that causes gradual loss of the myelin sheath around the axons of neurons. This interferes with the ability of the neurons in the brain and spinal cord to communicate with each other.

ACTIVITY SHEET
Multiple sclerosis

ISBN 9780170231503

WORKSPACE
What have you learnt? 1.1

QUESTIONS 1.1

What have you learnt?

Remembering

1 **Define** these terms.
   a Synapse
   b Neurotransmitter
   c Reflex arc

2 Draw and label a neuron.

Understanding

3 **Identify** an example of:
   a an effector
   b a receptor
   c a type of neuron.

4 **Outline** the benefits of the myelin sheath.

Applying

5 After neurotransmitters have bound to their receptors they are removed and broken down by enzymes.
   a **Predict** what could happen if neurotransmitters stayed attached to the receptors at the synapse.
   b Insecticides such as malathion damage the enzymes that cut up neurotransmitters. **Explain** the consequences of this for insects.
   c Some drugs, such as nicotine in cigarettes, act as neurotransmitters. **Explain** how this causes the stimulatory effects the smoker feels.
   d **Discuss** the advantages and disadvantages of having painkillers that block the transmission of messages across the synapse.

6 **Explain** how tipping over the first domino in a row of upended dominoes models the all-or-nothing response in neurons.

Reflecting

7 Begin a concept map to **summarise** your knowledge so far.

1.2 Slow responses

You might think that slow responses are not very useful to a living thing but this would be incorrect. Many plants, for example, rely on change happening slowly. Their changes may be timed to coincide with the seasons or with periodic changes in soil quality or the amount of rainfall. Many animals rely on slow change to enable them to use the environmental conditions to their best advantage. Slow responses may also assist an organism by allowing it to grow or develop at an appropriate rate.

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Many plants flower in spring because this will give them the best chance of being fertilised and reproducing. The flowers, however, have taken time and resources to develop – a slow change.

Slow changes are usually controlled by chemicals released into the transport system of the organism. These chemicals are called **hormones**. In humans, hormones travel in the blood stream to the cells where they cause an effect. Human growth hormone and the sex hormones like oestrogen and testosterone are good examples.

hormone

a chemical produced by a gland or organ that produces an effect on another part of the body

Plants also secrete hormones. Plant hormones generally occur in much higher concentrations than animal hormones. Some plant hormones cause the plant to grow in size by stimulating the cells to get longer (cell elongation). Other hormones cause the plant to form buds, flowers or fruit. Still other plant hormones act to control or regulate the responses of the plant. Some of the different hormones found in plants and their effects are:

- auxins – maintenance of cell wall, seasonal responses
- cytokinins – cell division and multiplication, budding and flowering
- gibberellins – cell elongation and growth (particularly in dwarf plants)
- abscisic acid – inhibition of the action of auxins, gibberellins and cytokinins, and the stimulation of ripening, leaf fall and dormancy
- ethylene – stimulation of ripening and flowering.

Manipulating the hormones of a plant may also be helpful to gardeners in speeding up a plant's growth or encouraging a plant cutting to grow roots. Knowing about plant hormones may also help you keep your fruit fresh.

Figure 1.7 Examples of the effects of some plant hormones **a** cytokinins, **b** abscisic acid and **c** ethylene

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WORKSPACE
Observing a plant's responses to gravity (gravitropism)

EXPERIMENT 1.1

Observing a plant's responses to gravity (gravitropism)

Aim

To observe the changes that occur in the growth of the roots and shoots of a seed in response to gravity

Materials

- 1 large seed (such as a bean seed), a Petri dish with lid, cotton wool, retort stand, and Boss head and clamp

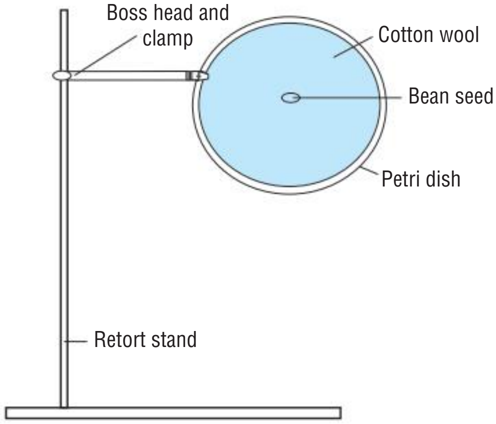

Figure 1.8 Experimental set-up

Method

1. Set up a Petri dish with a layer of damp cotton wool in it.
2. Place a large seed such as a bean seed onto the cotton wool.
3. Put the lid on the Petri dish.
4. Clamp the Petri dish onto a retort stand in a vertical position.
5. Place the stand in a warm dark place until germination.
6. Once the seed germinates, observe the growth of its roots and shoots over the next two to three weeks and record your observations. Rotate the Petri dish 90° clockwise once a week.

Results

Draw a diagram of your bean seed before each rotation. Clearly label the roots and the shoots of the plant.

Discussion

1. **Describe** any effects you observed in the growth of your seedling as the experiment progressed.
2. **Compare** the response of the roots with the response of the shoots. **Propose** the stimulus that triggers this response of the roots and the shoots.
3. **Identify** problems with your experiment that could be improved upon in further investigations. (Hint: What makes an experiment reliable?)

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Conclusion

Address the aim of your experiment in your conclusion. What changes did you see in the seedling's growth in response to gravity?

Extension: Student investigation – A plant's response to gravity is called gravitropism.

Investigate any other 'tropisms' that plants exhibit. **Design** an experiment to **demonstrate** another plant response.

WOW!

Ripe bananas

Some fruit is ripened artificially using ethylene gas. Bananas give off ethylene as they ripen. This chemical can affect other nearby fruit and stimulate a ripening response. If you want to eat that mango or avocado sooner, put it beside bananas!

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Slow communication in humans – the endocrine system

Just like in plants, some responses in the human body are slower. For example, we grow slowly over many years. We gradually mature from babies into children, teenagers and then into adults. The body must make slow and regular changes during this time to ensure that all systems develop in a coordinated manner. These slower responses are controlled by the endocrine system.

The endocrine system is made up of many glands. **Endocrine glands** make and secrete the chemical messengers, called hormones. Hormones are released into the bloodstream and travel throughout the body. Only certain cells will be affected by the hormones. These are called the target cells. Specific hormones affect specific target cells.

The **pituitary gland** is found in the brain. It makes many hormones and controls some of the other glands in the body. It is about the size of a pea but is essential for survival. One of the hormones made by the pituitary gland is growth hormone. This hormone targets many cells but one example is its effect on the liver. In response to growth hormone, cells in the liver produce more of the building blocks needed for the body to make proteins. Proteins make up many of the structural parts of our bodies and without them we wouldn't grow. In this example the hormone is growth hormone and the target cells are cells of the liver. The response is more proteins and ultimately growth. Hormonal systems can be turned on and off as needed, and only tiny concentrations of most hormones have major effects, making them energy efficient.

endocrine gland

a gland without ducts that releases hormones straight into the circulatory system

pituitary gland

an endocrine gland located in the centre of the brain

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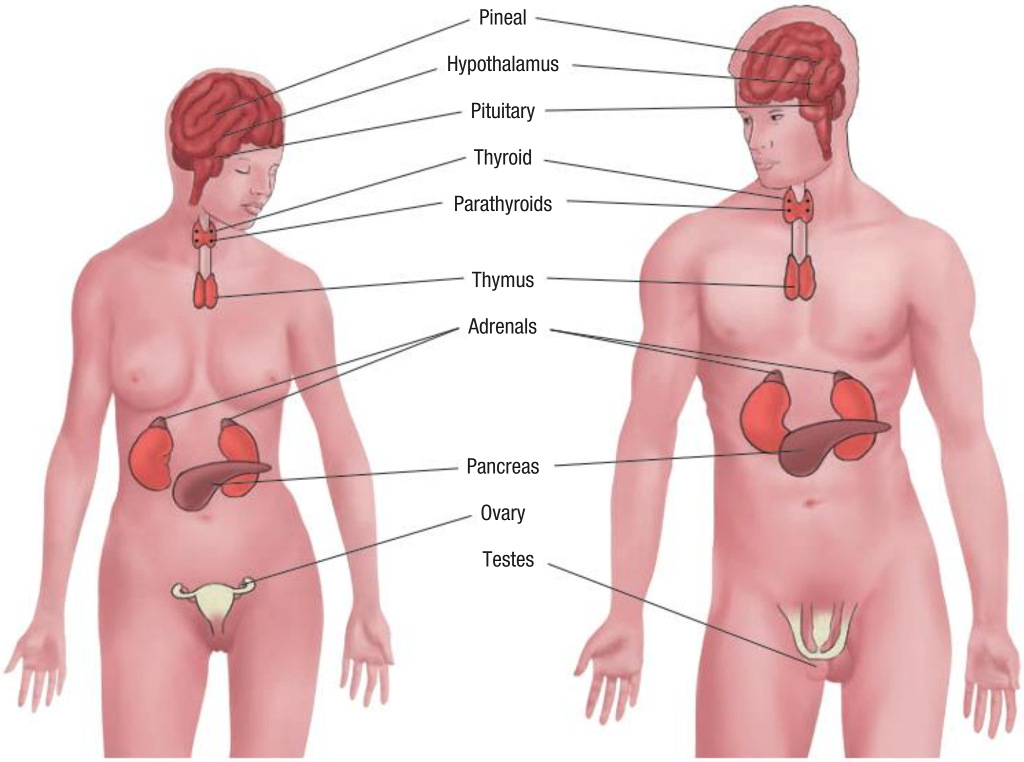

Figure 1.9 The endocrine system in humans. Together, the endocrine glands produce dozens of hormones that interact with each other to control our body systems.

Not so slow hormone communication

Did you know that not all hormones cause a slow response? One hormone in particular is often called the fight or flight hormone. Adrenalin is produced by the adrenal glands. These glands sit on top of the kidneys as shown in Figure 1.9. Adrenalin is released into the bloodstream when a person is excited or stressed to ready the body for attack (fight) or to run away (flight). Its target cells include the muscles of the heart, the muscles controlling the size of the pupil of the eye and the muscles that control the diameter of the air passages. The responses include an increased heart and breathing rate, dilated pupils and greater flow of oxygen to the muscles, to allow the body to respond.

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Figure 1.10 Prey use the fight or flight response to escape predators.

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Comparing the nervous system and endocrine system

The nervous system and the endocrine system continuously work together to coordinate body responses. These interactions enable our bodies to respond to the environment and all its changes in both fast and slow ways. When all parts communicate effectively, stable conditions in the body are easily maintained.

When running a race, muscles are required to work harder. Their cells therefore require more glucose and oxygen for **respiration**. To meet this need, the heart must pump harder to move materials around the body in the blood, breathing must increase to add oxygen to the blood and remove carbon dioxide, and glucose must be made available from body stores in the liver. The nervous system increases the heart and breathing rates and the endocrine system stimulates the release of nutrients into the blood. In this way, it isn't long before muscles have gained the energy they need to keep functioning – a well-coordinated response!

Table 1.1 compares the nervous system and the endocrine system.

respiration

a series of chemical reactions that releases chemical energy (and water and carbon dioxide) for use by an organism

Table 1.1

The nervous and endocrine systems

Nervous system	Endocrine system
• Composed of the brain, spinal cord and nerves • Acts via nervous impulses travelling along the neurons • Requires **diffusion** of neurotransmitters across the synapse • Provides relatively faster responses (reflex arcs being the fastest) • Causes effectors to respond, e.g. muscles to contract or glands to secrete hormones	• Composed of glands • Acts via the release of hormones into the bloodstream • Requires diffusion of hormones from the blood into target cells and tissues • Provides relatively longer lasting responses • Causes targeted responses, e.g. control of metabolic reactions, growth, development and reproduction

diffusion

passive movement of molecules from regions of higher concentration to regions of lower concentration

ACTIVITY 1.2

Five-minute fact find

Search the Internet to discover how the endocrine and nervous systems can interact.

1 **Identify** which endocrine glands respond to nerve signals.

2 **Identify** which hormones affect the nervous system.

3 **Propose** advantages of communication between the two systems.

4 Brainstorm your examples with members of your class. **Identify** some general conclusions.

WORKSPACE
Five-minute fact find

ISBN 9780170231503

WORKSPACE
What have you learnt? 1.2

QUESTIONS 1.2

What have you learnt?

Remembering

1 **Define** the term 'endocrine'. Use a dictionary to write a definition. **List** other examples of the use of the prefix 'endo' in science.

2 **Identify** the two systems involved with coordinating responses around the body.

3 **Identify** two advantages of coordinating an organism using hormones.

4 **Outline** why growth hormone is considered a banned drug for professional athletes.

Understanding

5 Cells in children with the inherited disease achondroplasia, particularly the cells of their upper arms and legs, are less sensitive to growth hormone. **Explain** how this is likely to affect their adult shape.

6 Create a Venn diagram to **compare** and **contrast** the endocrine and nervous systems.

Analysing

7 a Research a number of sources to **identify** one hormone that has a general effect on the body and one that has a specific effect.
b Determine which of these hormones will have more target cells.
c **Assess** the effectiveness of the two hormones you described. (In this answer you will need to clearly state your view and then give evidence from your research to support your view.)

Evaluating

8 Search the Internet to find an example of the problems humans have with too much or too little growth hormone. **Justify** the use of scientific research into these kinds of diseases. Present your information using images.

Creating

9 **Discuss** whether it might be possible for a multicellular organism to exist without a communication system within its body.

Reflecting

10 Revisit your concept or mind map to add further details.

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1.3 Homeostasis – coordinating body systems

Multicellular organisms, like us, must have body systems that work in a coordinated way. The boy in Figure 1.11 could not do these moves without his muscles, nerves, senses and balance all working together. The human body has many cells and these are specialised for different functions. Cells are grouped into tissues, and tissues into organs. Organs are the main components of our body systems such as the digestive, endocrine and circulatory systems. The body and the environment are in constant communication. This is part of the body's process of sensing and responding. There is also a constant exchange between the different parts of the body and between the body and the external environment. These exchanges could be labelled as inputs, processes and outputs (Figure 1.11).

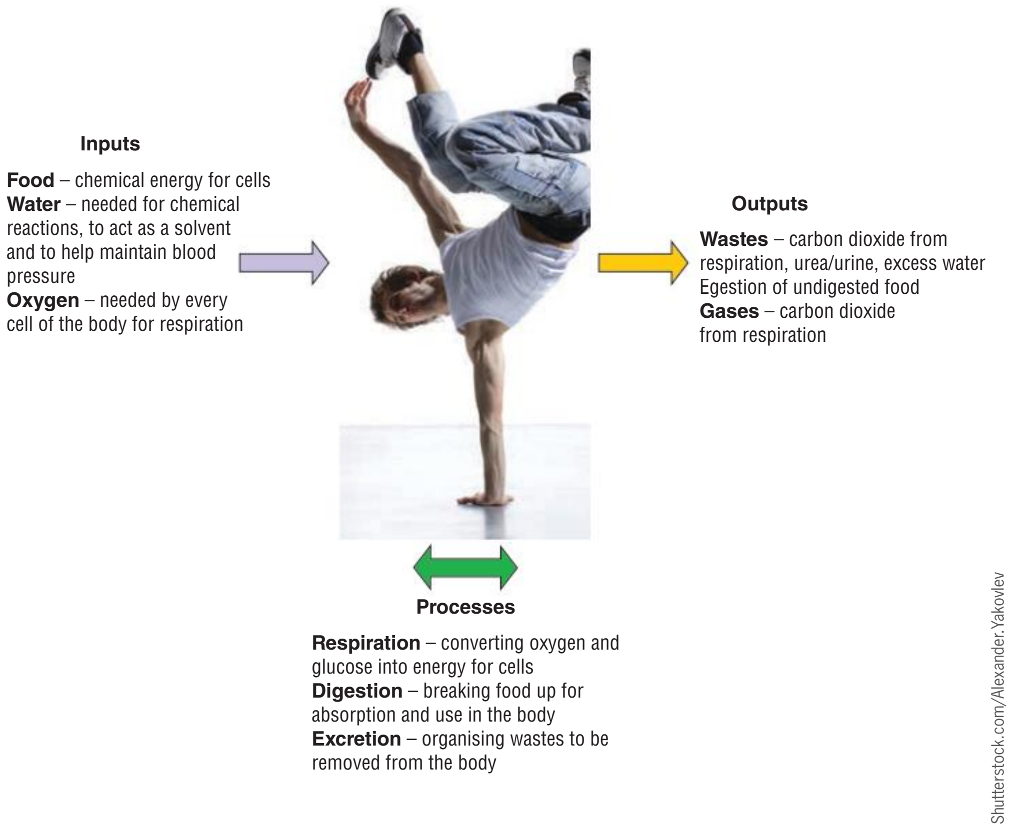

Figure 1.11 A number of body systems coordinate to allow these moves to be performed.

All organisms, including humans, take in gases and nutrients (inputs), process these internally (metabolism) and excrete wastes (outputs). In complex multicellular organisms, every cell relies on a range of body systems to provide it with its requirements. These requirements then need to be processed and the wastes created during metabolism removed (excretion). Many body systems have to interact to coordinate the smooth running of the body.

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Maintaining body temperature

homeostasis

the process for maintaining the internal 'steady state' in an organism

set point

the narrow range within which organisms function at their best

feedback

a system in which the response to a stimulus modifies the stimulus

endotherm

an animal that generates heat to maintain its body at a constant warm temperature; also called warm-blooded animals

sensor

a structure or organ that detects changes in the internal or external environment

negative feedback

a process in which the response cancels or lowers the original stimulus

capillary

a minute blood vessel that extends throughout tissues, from which materials can be exchanged with cells by diffusion

The process for balancing internal conditions inside an organism is called **homeostasis** (from the Greek *homoios*, meaning 'similar', and *stasis*, meaning 'standing still'). Homeostasis aims to keep internal conditions within a narrow range called the **set point**. This set point is the best or optimal condition for efficient body reactions. Some of the body conditions controlled by homeostasis include body temperature, pH levels, glucose concentrations, and salt and water levels. In order for the body to maintain these optimum states, it relies on constant analysis of body conditions, detection of changes and **feedback** to enable rapid responses.

Responding to changes in the environment is very important for survival. Humans and other **endotherms** adjust to these changes using mostly internal mechanisms. We can also adjust to changed conditions by altering our behaviour, such as sitting in the shade or having a cool drink. Endotherms control their body temperatures using internal processes, relying on **sensors** in the brain and the nervous and endocrine systems to keep body temperature stable.

A well-coordinated body is able to keep the internal conditions within very narrow limits. For example, human body temperature should always be about 37°C, but during any one day it could vary from as low as 36.1°C to as high as 37.8°C. If the body temperature drops below 35°C a person may fall into a coma and even die. This is called hypothermia and may occur if a person is lost for a long period outdoors or at sea. If the body temperature rises above 38°C then a person may be unwell, sweaty, pale, feverish and even dehydrated. A high body temperature could be due to infection, injury or medication and is known as hyperthermia. At very high temperatures there may be damage to the body's organs and tissues.

Receptors in the hypothalamus of the brain constantly check the temperature conditions of the body and use a **negative feedback** system to control it. These detectors recognise that body temperature has increased and so cooling responses are activated. These include sweating, increased heart rate and opening (dilation) of **capillaries** near the skin. As the water in the sweat evaporates from your skin it uses heat from your body. When the muscles that control capillary diameter relax, more blood can flow to the skin where heat can radiate away from your body. This is why your face and skin will often go red when you are hot. Your heart rate increases to move blood around the body more rapidly so that it also passes by the skin more often and so loses heat. During these responses the hypothalamus continues to monitor the temperature of the body. Feedback is given to the brain to identify whether the body temperature has dropped back to its optimal level. If the body temperature is still too high then the nervous and endocrine systems will continue to cause cooling mechanisms to work. If the body temperature has dropped then the cooling responses will be turned off. Sweating will stop and your skin colour, capillaries and heart rate will all return to normal. The effectors (muscles and glands) stop acting. Optimum body temperature has once again been achieved. The brain will continue to monitor body temperature to ensure it stays at its set point.

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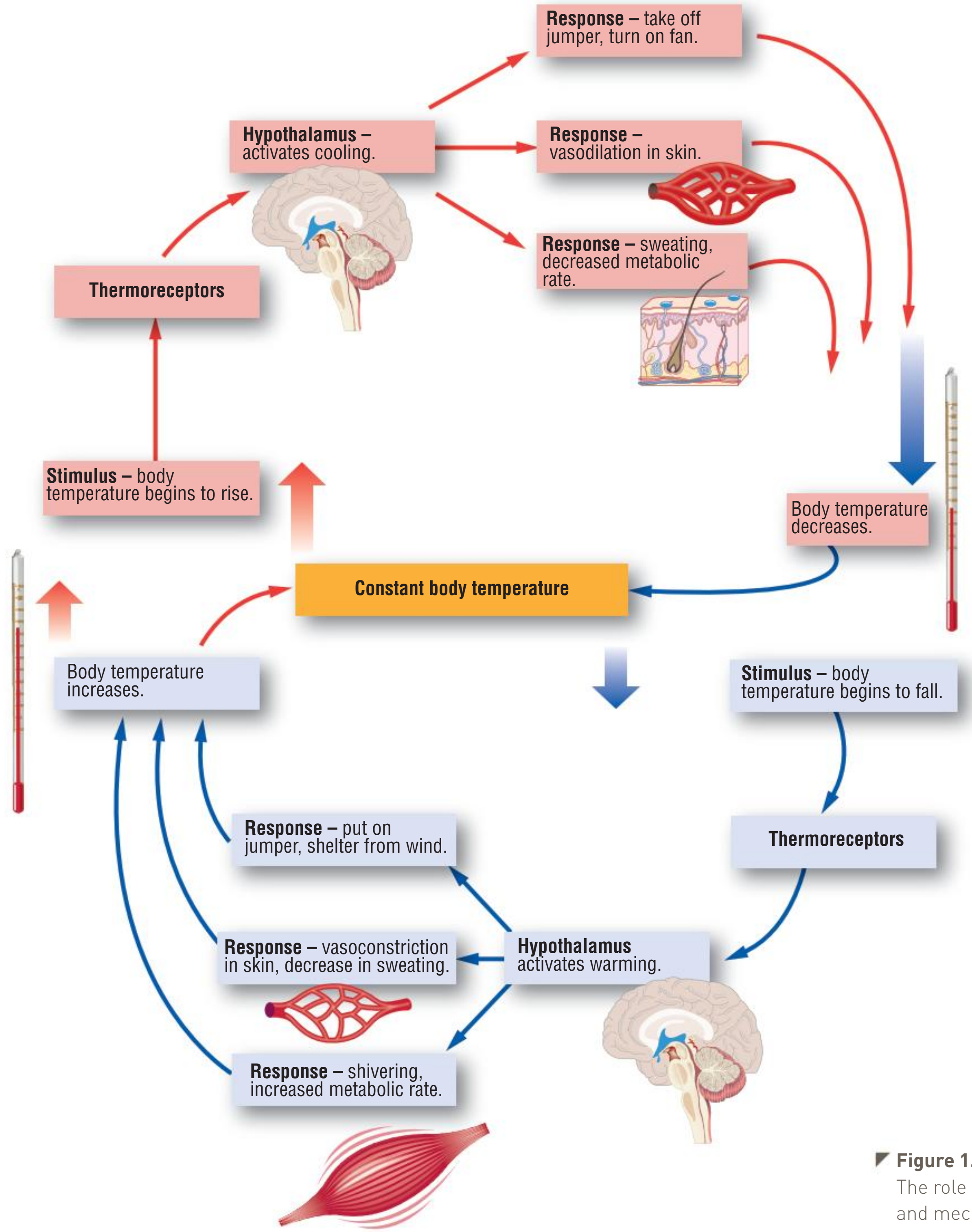

Figure 1.12 The role of the hypothalamus and mechanisms involved in maintaining a constant body temperature

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WORKSPACE
What have you learnt? 1.3

QUESTIONS 1.3

What have you learnt?

Understanding

1 **Describe** the aim of homeostasis.

Applying

2 **Compare** a thermostat in a refrigerator to a negative feedback system in a human.

3 Use a diagram of a negative feedback loop to **illustrate** how blood sugar concentration is maintained within narrow limits after a carbohydrate and sugar-rich meal. Include this in your culminating assessment task.

On your diagram, **identify**:

a the stimulus
b the effector
c the response.

Reflecting

4 Revisit your concept or mind map, adding details that you now understand about homeostasis.

1.4 Internal systems in multicellular organisms

There are many requirements for life. The feedback loops of homeostasis allow multicellular organisms to control their internal environment by monitoring levels of oxygen, carbon dioxide, glucose, water and other requirements.

Requirements for life – gas exchange

All living things require gases. Without oxygen, for example, we wouldn't be able to respire efficiently. Without carbon dioxide, plants wouldn't be able to carry out **photosynthesis**. Oxygen and carbon dioxide are the two main gases in the bodies of living organisms.

In animals such as humans, oxygen is used for **cellular respiration**. Respiration must occur all the time to release energy for use in the cell. As a word equation it can be written as shown below, but it is really a series of many steps.

$$\text{Oxygen} + \text{Glucose} \xrightarrow{\text{Enzymes}} \text{Water} + \text{Carbon dioxide} + \text{Energy}$$

Every cell requires energy, which is released by respiration. It is why oxygen is so important to our bodies and why we need food (to provide glucose). Carbon dioxide is a waste

photosynthesis
a series of chemical reactions in plants that convert light energy into usable chemical energy and produce glucose

cellular respiration
a series of chemical reactions that release chemical energy (and water and carbon dioxide) from nutrients for use by an organism

ISBN 9780170231503

product of respiration. As every cell respires, it also makes carbon dioxide. This waste gas must be removed from the body. Carbon dioxide is mostly carried in the blood as a dissolved product. When carbon dioxide dissolves in water it makes a slightly acidic solution of carbonic acid (H_2CO_3). Hence too much carbon dioxide in the body can make the blood more acidic. A rise in acidity may cause enzymes to malfunction and prevent cellular processes from occurring efficiently. This is why it is important to maintain carbon dioxide levels in the body within narrow limits.

How essential gases are exchanged with the environment

When the body needs to take in more oxygen or to get rid of carbon dioxide, it exchanges these gases between the air spaces in the lungs and the blood. Inside an organism, everything that is required or produced by cells is transported in liquids. Consequently, gases must dissolve in water before they can enter cells. Oxygen enters our blood from the air moving into the alveoli. Carbon dioxide leaves our blood to be moved via our exhaled air from the alveoli. Without moist lungs we wouldn't be able to exchange these gases with the liquids of our blood. That is why our lungs are found inside our bodies where they can remain moist all the time.

Breathing supplies our bodies with oxygen and removes carbon dioxide at the same time. The activity 'Investigating the effect of CO_2 and exercise on breathing rate' explores this relationship under different conditions. It is important to remember that gases must be balanced whether or not the organism is active.

ACTIVITY SHEET
Investigating the effect of CO_2 and exercise on breathing rate

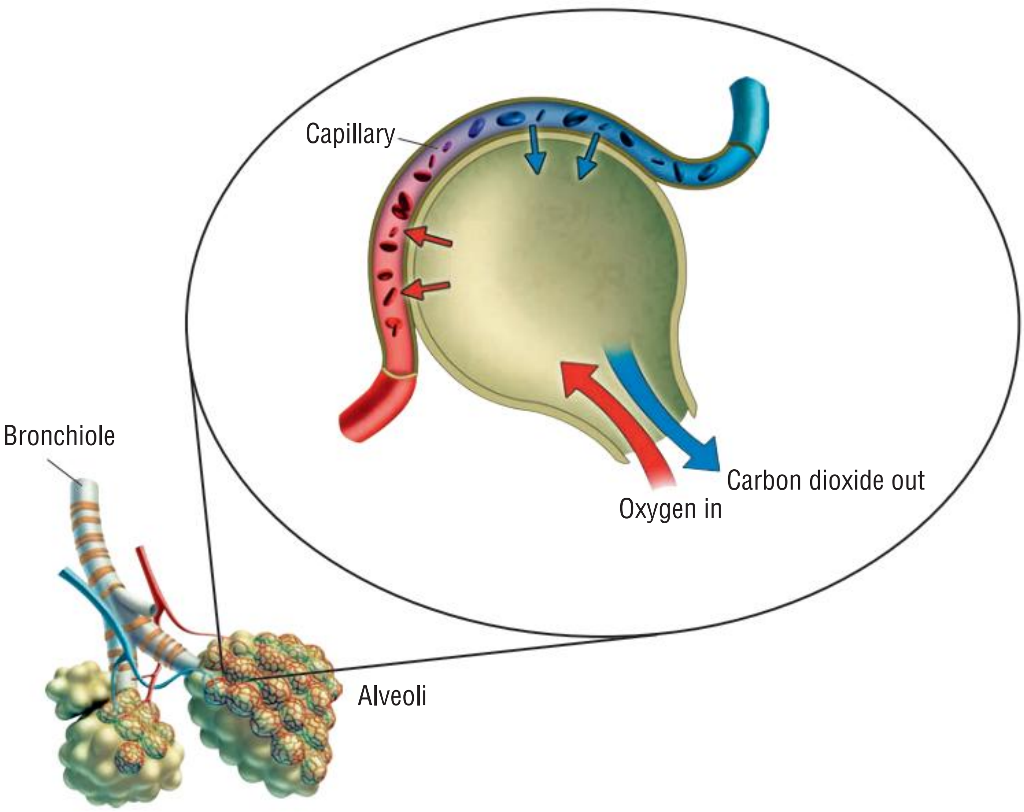

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Figure 1.13 Oxygen enters our blood from the air moving into the alveoli. Carbon dioxide leaves our blood to be moved via our exhaled air from the alveoli.

Gases of different kinds dissolve in water at different rates. For example, carbon dioxide is much more water-soluble than oxygen. This means that carbon dioxide will enter water more easily than oxygen. How fast a gas dissolves may also be affected by the temperature of the water. Cold water can hold much more dissolved gas than warm water. You have probably seen the effects of this in a soft drink that has warmed up. Much more gas will escape when you take the lid off the bottle, often causing the drink to spray everywhere!

WORKSPACE
Investigating the solubility of gases in water

EXPERIMENT 1.2

Investigating the solubility of gases in water

Possible risks	Safety precautions
Although the acid provided is dilute (1.0 M HCl) it may burn if you splash any on your skin or in your eyes.	Wear safety glasses at all times. Wash accidental splashes with copious water.

Aim

To **investigate** the solubility of air (with oxygen) and carbon dioxide in water

A: Dissolving air in water

Air is made up of 20% oxygen and 80% nitrogen.

Materials

- 2 small glass vials with plastic caps

Method

1 Two-thirds fill the first vial with normal tap water.

2 Two-thirds fill the second vial with water that has been boiled and cooled to the same temperature as the tap water.

3 Seal each vial with a plastic cap and shake it vigorously for 30 seconds.

4 Hold each vial upside down and slowly loosen the cap. Create a table to record your observations.

B: Dissolving carbon dioxide in water

Materials

- 2 small glass vials with plastic caps

Method

1 A carbon dioxide generator (see Figure 1.14) can be made by reacting dilute hydrochloric acid (1 mol/L) and marble chips (or sodium carbonate).

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EXPERIMENT 1.2

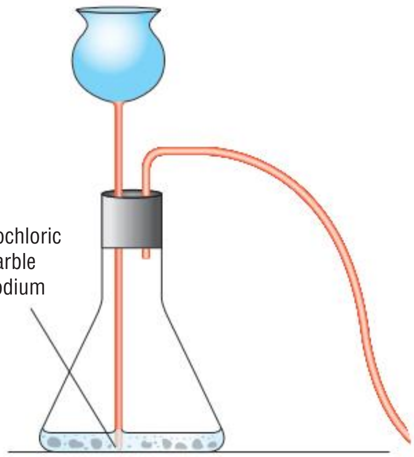

Figure 1.14
Carbon dioxide generator

2 Two-thirds fill the vials with tap water.

3 Run gas from the CO_2 generator above the liquid in one vial for about 15 seconds.

4 Seal both the vials with the plastic caps and shake them vigorously for 30 seconds.

5 Holding the vials upside down over a sink, slowly loosen the caps. Create a table to record your observations.

Results

1 Collect the results for air and carbon dioxide from two other groups and count these as replicates of the experiment.

2 Write a summary statement of what was observed in each of the tests (A and B).

Discussion

1 **Describe** and **explain** how boiling the water affected gas solubility.

2 **Compare** the solubility of the gases tested.

3 **Interpret** what your observations may mean for gas transport in organisms, which are at least 70% water.

4 On very hot days, fish can sometimes be seen swimming near the surface of ponds and even gulping air. **Apply** your knowledge to try to **explain** this behaviour.

ISBN 9780170231503

Gas exchange in aquatic organisms

aquatic
living in water

For **aquatic** organisms, oxygen and carbon dioxide are already dissolved in the water in which they live. The gases they need for life simply diffuse into or out of their bodies or across their gills. Fish gulp water into their mouths and then pass this oxygenated water across and out of their gills. The gills extract the oxygen from the water as it passes across them. Fish gills have very thin surfaces and a rich supply of blood. Dissolved oxygen moving through the gills in the water is easily extracted by the large surface area of the gills. Diffusion into the blood of the gills is very efficient. Gills are much more efficient than lungs. This is necessary because there is less oxygen available in water than in air.

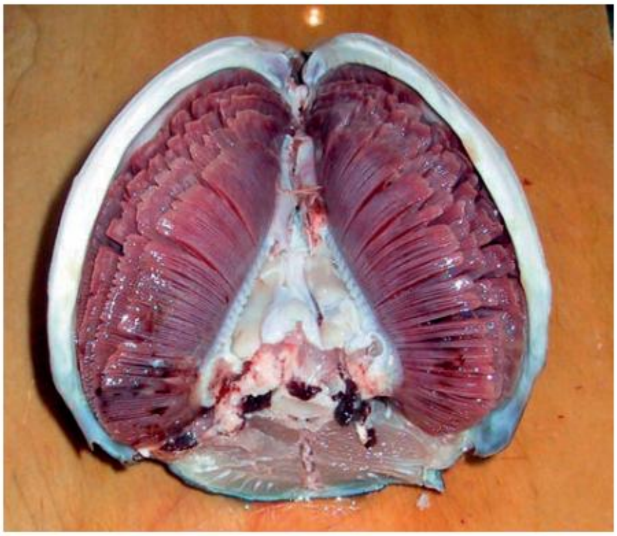
Wikimedia Commons/Chris 73

Figure 1.15 Fish gills are thin and have a rich blood supply that helps to maximise gas exchange between the fish and the water.

The movement of water through the gills holds them open. When the fish is out of water, however, the gills stick together and so have a very small surface area. When the gills dry out the oxygen in the air cannot dissolve to move into the fish's blood. This makes their gills so inefficient that the fish cannot get enough oxygen into their blood, even though there is plenty available in the air. This is one reason fish cannot live out of water.


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Figure 1.16 Plants that grow under water exchange gases directly with the water.

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Underwater plants have thin leaf surfaces. These aquatic plants need to obtain carbon dioxide and oxygen from the water. These dissolved gases move into and out of the leaves by diffusion. As the leaf surface is thin, the gases can reach their target tissues in the leaf quickly.

Gas exchange in terrestrial organisms

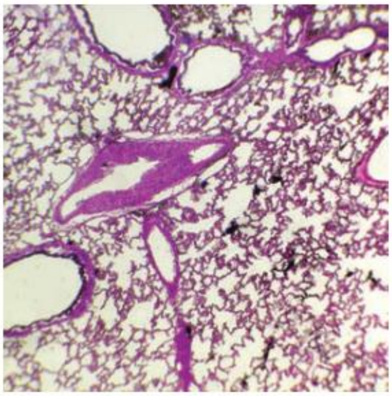
In **terrestrial organisms**, gases need to be exchanged between air and their internal liquid environment. This means that gases must be dissolved in water first. Figure 1.17 shows the exchange surfaces in a mammal, a plant and an insect. In all these organisms the moist exchange surfaces are internal, minimising evaporation to the atmosphere. The thin walls increase the speed with which gases can exchange. The branching structures increase the surface area available for gas exchange. These have a dense network of blood vessels to collect and distribute diffused gases. These are critical features of all exchange surfaces: they are thin, moist, have a large surface area and a high blood supply.

terrestrial organism
an organism that lives on land

Substances are normally exchanged with the environment by diffusion. The molecules simply move from an area of high concentration to an area of low concentration.

- In animals, carbon dioxide is a waste product. It dissolves easily in water and is transported from body cells dissolved in the blood plasma. It eventually diffuses out of the blood across the surface of the alveoli in the lungs.
- In plants, carbon dioxide and oxygen gas diffuse into and out of leaves through stomata. These gases then move through the air-filled spaces in the spongy mesophyll tissue to the cells. In the cells the gases dissolve and diffuse into the cells to be used for photosynthesis (CO_2) or respiration (O_2). These gases also diffuse out of plants by the same pathway.

a



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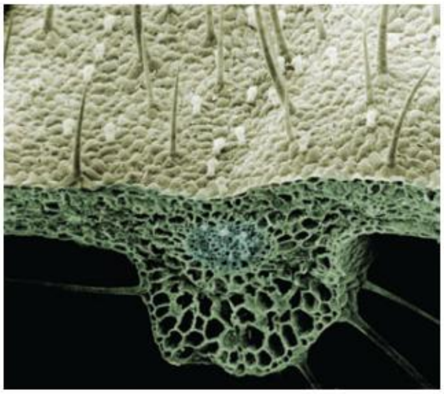

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c

Visuals Unlimited, Inc./Dr. Robert Calentine

Figure 1.17
a Inside the lungs of a mammal – the holes with pink-stained edges are blood vessels. **b** Internal structure of a geranium leaf – the large open tissue below the leaf surface contains air spaces and the spongy mesophyll where gases are exchanged. **c** Branching tracheae in a damselfly – tracheae are the structures through which insects carry gases.

ACTIVITY SHEET
Exploring diffusion and osmosis

WEBLINK
Osmosis and diffusion

haemoglobin

a transport protein in which oxygen is temporarily and reversibly held by iron 'haems' giving these organisms a reddish colour

red blood cell

a smooth, flattened, elastic, biconcave disc-shaped blood cell that is packed with haemoglobin

Inactive organisms such as plants and fungi have low energy requirements and therefore low oxygen requirements and low carbon dioxide outputs. They can function adequately by relying on diffusion to exchange oxygen and carbon dioxide.

Active organisms, particularly mammals and birds, need more energy to move and keep their bodies warm. They must respire more to get this energy so their oxygen needs are higher. They still exchange gases by diffusion, but they need extra transport mechanisms for oxygen to ensure enough is delivered because its solubility in water is lower than that of carbon dioxide. They have a circulatory system that moves oxygen around the body to all their cells, through the blood. Special transport proteins, such as **haemoglobin** (Figure 1.18), packaged inside **red blood cells**, increase the blood's ability to carry oxygen by up to 20 times.

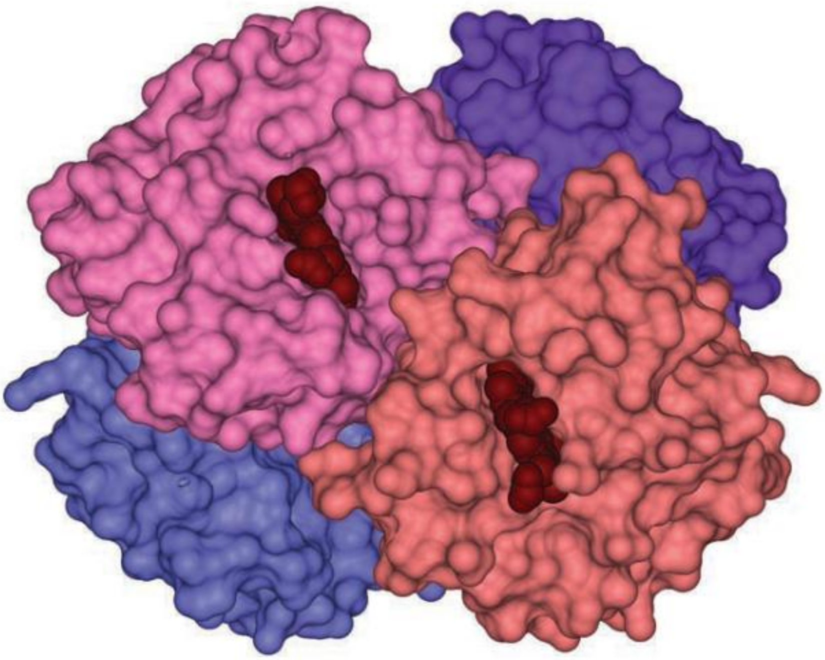

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Figure 1.18 A haemoglobin protein. Each of the four subunits can bind one oxygen molecule (O_2).

haemocyanin

a transport protein in which oxygen is temporarily and reversibly held by copper 'haems', giving these organisms a bluish colour

WOW!

True blue bloods!

Haemoglobin is usually packaged inside red blood cells. Blue invertebrates, such as squid, crabs and some snails, use **haemocyanin**. This is a copper-based protein that works in the same way, carrying up to two oxygen molecules. It is usually dissolved in the plasma and it makes their blood blue.

Regulation of gas levels in blood

Maintaining a balance in the body is vital, not just of body temperature but also of gases such as oxygen and carbon dioxide. The levels of oxygen and carbon dioxide in the blood must remain within very narrow limits. Homeostatic processes operate constantly to assess the conditions of the body and respond to changes. For example, when the concentration of carbon dioxide in the blood is high, receptors in the brain will be triggered. These will stimulate the

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response – our need to inhale. Interestingly, it is high levels of carbon dioxide and not low levels of oxygen that usually cause this response. When we breathe in, oxygen is taken into the alveoli and diffuses into the blood (see Figure 1.13, page 21). Normally, we do not use all the oxygen we breathe in. We breathe about 80% of it out again. This is why the first aid practice of giving mouth-to-mouth resuscitation (expired-air resuscitation) is effective.

Use the following weblink and interactive to refresh your understanding of the mechanics of breathing, and the respiratory system.

WEBLINK
Gas exchange in the lungs

INTERACTIVE
Body parts: respiratory system

Diving reflex and the ama

In Japan and parts of Korea, women collect seafood by skindiving hundreds of times a day, to depths of about 20 m. This custom goes back at least 2000 years (Figure 1.19). The women, or *ama*, traditionally carry little more than a knife and a net basket. (In Japanese, *ama-san* means 'sea-woman'.) *Ama* spend up to 7 hours a day in the sea, up to 2 hours on the bottom. Today, the tradition is vanishing, with fewer than 1000 *ama* remaining.

Figure 1.19
The traditions of the *ama* are passed on from mother to daughter.

Many years of training, beginning at the age of about 11, enable *ama* to develop special physical abilities. Teenage divers, or *cashido,* dive unassisted up to 60 times an hour. Each time, a *cashido* spends about 15 seconds gathering sea urchins and shellfish at 5–7 m, about the depth of an Olympic diving pool. As well as improving her general fitness, over many years this training gradually increases the *cashido*'s lung capacity. This improves her ability to exchange gas when she breathes. Swimming face down in the cold sea also triggers a diving reflex that results in **apnoea** and **bradycardia**. This is how the *ama*'s heart rate slows down, and her body uses less oxygen than normal. The diving reflex occurs in other mammals, like seals and in birds, like penguins.

When aged in her 20s, the diver is experienced enough to become a *funado. Funado* dive vertically to about 20 m. Before descending, the *funado* hyperventilates to clear dissolved

apnoea
a suspension of breathing

bradycardia
an abnormal slowing of the heart rate, seen in diving marine mammals

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hyperventilation
an increase in depth or rate of breathing

carbon dioxide from her blood. **Hyperventilation** is when you take many quick, deep breaths over a short period of time. Hyperventilation before diving can cause drowning. High concentrations of CO_2 in blood trigger sensors in the brain to stimulate the need to inhale. Hyperventilating clears carbon dioxide from the blood. By the time blood carbon dioxide concentrations have built up to levels where the brain again stimulates breathing, oxygen may have dropped enough to cause loss of consciousness. She holds a weight to speed her descent. The enormous water pressure collapses her lungs and squeezes red blood cells from her spleen. This slightly increases her blood haemoglobin levels, improving her body's capacity to store oxygen. Marine mammals, which have much higher amounts of haemoglobin than humans, have an extreme version of this ability. The very cold seawater also causes the *funado*'s blood to redistribute from her extremities to her essential organs, the heart and brain. Is the reason Japanese divers were all women simply physiological? Women's bodies have a higher fat-to-muscle ratio than most men's bodies and so are better insulated. They also use relatively less oxygen.

After spending about 30 seconds working on the seafloor, the *funado* tugs the rope that attaches her weights to her boatman. This signals him to pull her to the surface quickly, protecting her against potentially fatal blackouts. She never dives alone.

WARNING: Do not attempt to develop these skills yourself. Untrained divers who practise hyperbaria (breath-hold diving) risk a medical condition called pulmonary oedema. This condition fills lung tissue with fluid and the alveoli with blood.

ACTIVITY SHEET
Life at the top

WOW!

High society can be deadly

Oxygen levels decrease as you go higher. At altitudes of 5000 m, air pressure is half that at sea level, reducing oxygen to about a tenth of that at sea level.

In 1875, three Frenchmen attempted to set an altitude record in a balloon. As the *Zenith* rose above Paris, the men began to pant and feel a sense of euphoria. This was the first sign of oxygen deprivation. Soon, their arms became paralysed. Then, they could no longer read their instruments, or speak. They had brought an emergency oxygen supply, but were too disoriented to use it. Many hours later, G. Tissandier recovered consciousness in the descending balloon. He had survived an altitude of 8600 m, but both his companions had died.

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Requirements for life – glucose

One of the main nutrients needed by the body is glucose. Homeostasis mechanisms keep our body glucose levels stable. We can measure these levels as our blood sugar. Blood sugar levels usually rise after a meal. During the night as we sleep, blood sugar levels can drop. It is dangerous for the body to have blood sugar levels that are too high or too low.

Glucose is necessary for respiration and it must be continually supplied to our cells so that they can use it as a source of energy. Blood sugar levels in our body are controlled by a feedback system involving the hormones **insulin** and **glucagon**. Receptors in the nervous system identify changes in blood sugar levels and notify the brain. The brain then triggers the release of hormones from the glands of the endocrine system. In this way, the nervous system and the endocrine system are acting together to coordinate body function.

VIDEO
Blood sugar levels

insulin
a hormone that acts to decrease blood sugar levels

glucagon
a hormone that acts to increase blood sugar levels

Requirements for life – water

If your body was without food, it could last approximately three weeks. If your body was without water, it would only last about three days. As we cannot store water in our bodies, we must drink water or take it in with our food to survive.

The main role of water in our bodies is as a solvent in which sugars, salts and gases can dissolve. The body is about 70% water. This water makes our blood a liquid so that it can flow to each and every cell. It is a part of many chemical reactions and helps to transport wastes. Water is used to make sweat, which can keep us cool. It is important for cells to contain water so that they hold their shape. Too little water and a cell may shrivel up. Just like our body temperature and blood sugar, water must be balanced in the body. The balancing of water is carried out by our kidneys.

Requirements for life – removal of wastes

The body produces many wastes. It is important for the body to get rid of these wastes because their build up could be harmful. This is the job of the **excretory system**.

The main organs of our excretory system are the kidneys, which excrete excess water, salts and **urea**, and the lungs, which excrete carbon dioxide.

Urea is a chemical that forms when the body breaks down proteins. It is toxic and changes the blood acidity. It is one particular waste that must be excreted. We often call it our nitrogenous waste because 46% of urea is nitrogen. All vertebrates have to get rid of nitrogenous waste. Fish dissolve it in water as ammonia, birds secrete it as white uric acid, and humans excrete it dissolved in water as urine.

excretory system
a system that removes waste gases, heat and solutes from the body

urea
the main end product of nitrogen (in protein) metabolism; produced in the liver from ammonia

ACTIVITY SHEET
Kidney dissection

The kidney

The kidney is the main organ involved in the removal of urea from the body. It also balances water and salt levels.

Most people have two kidneys located just above the waist, towards the back of the body. All the blood in the circulatory system passes through the kidneys every few minutes.

The kidney consists of three very distinct regions.

- The outer **cortex** is dark red because it contains many capillaries and contains the glomeruli (singular, **glomerulus**).
- The **medulla** is pale pink because it has few capillaries.
- The cream-coloured **renal pelvis** collects urine from the collecting duct on its way to the bladder.

cortex
the dark outer part of the kidney that is rich in glomeruli

glomerulus
a network of capillaries inside the Bowman's capsule

medulla
the central or middle part of an animal organ such as the kidney

renal pelvis
the funnel-shaped part of the kidney that collects urine

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nephron
the functional unit of the kidney

Bowman's capsule
the part of the kidney that contains the glomerulus and filters small molecules out of the blood

artery
a thick, elastic blood vessel that branches out from the heart, carrying blood at high pressure and volume to major organs and appendages (legs and arms)

arteriole
a small artery

solute
a dissolved substance in a solution

semi-permeable
allowing some substances to pass through but not others

osmosis
the diffusion of water through a semi-permeable membrane

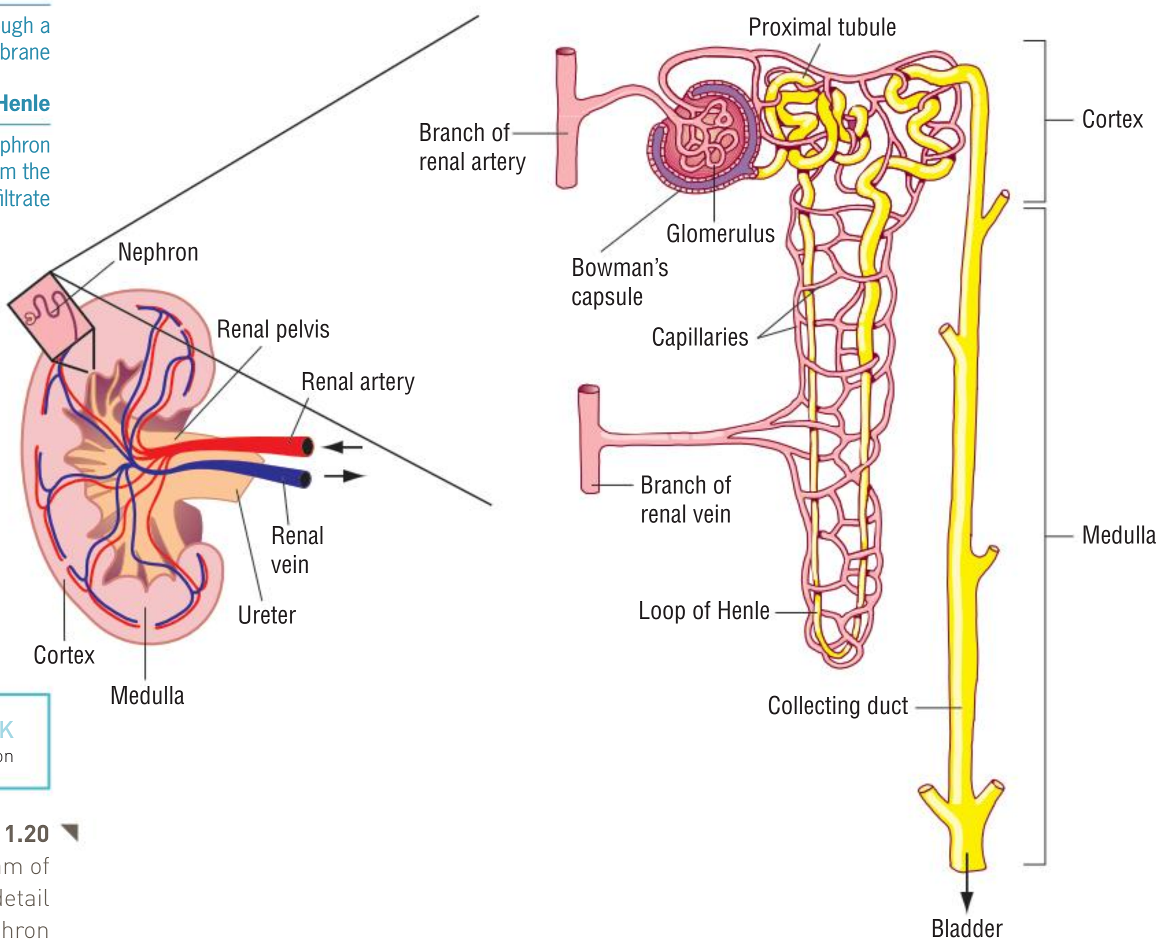
loop of Henle
a U-shaped part of the nephron that reabsorbs water from the glomerular filtrate

Filtering water and solutes

The functional unit of the kidney is a microscopic structure called the **nephron**. Each kidney contains about a million nephrons. Nephrons filter the blood and balance its composition (see Figure 1.20). Each nephron contains a **Bowman's capsule** – a structure that acts a little like a sieve. The blood enters the kidney straight from the heart via the renal **artery**. It is still under strong pressure. The renal artery branches into smaller vessels called **arterioles** that branch into even smaller vessels called capillaries. Each tiny capillary enables the wastes from the blood to be filtered out into the part of the nephron called the **loop of Henle**. The loop of Henle is a long, U-shaped part of the nephron that reabsorbs water and sodium chloride from the urine. All small molecules such as amino acids, water, salts, glucose and urea are filtered. Blood cells and proteins remain in the blood capillaries because they are too large to pass through the capillary walls.

Reabsorption

Some of the substances that are filtered by the kidney are needed by the body. These are not lost in urine; they are reabsorbed back into the blood. Glucose, amino acids, chloride ions and other essential nutrients are actively transported back into the bloodstream, a process that uses energy. Water follows the **solutes** passively back into the bloodstream by osmosis. Recall that the diffusion of water through a **semi-permeable** membrane is called **osmosis**. Urea is not reabsorbed; it remains in the filtrate. The filtrate becomes our urine. This is how urea is removed from our blood.



WEBLINK
Function of the nephron

Figure 1.20
A schematic diagram of the kidney and detail of a nephron

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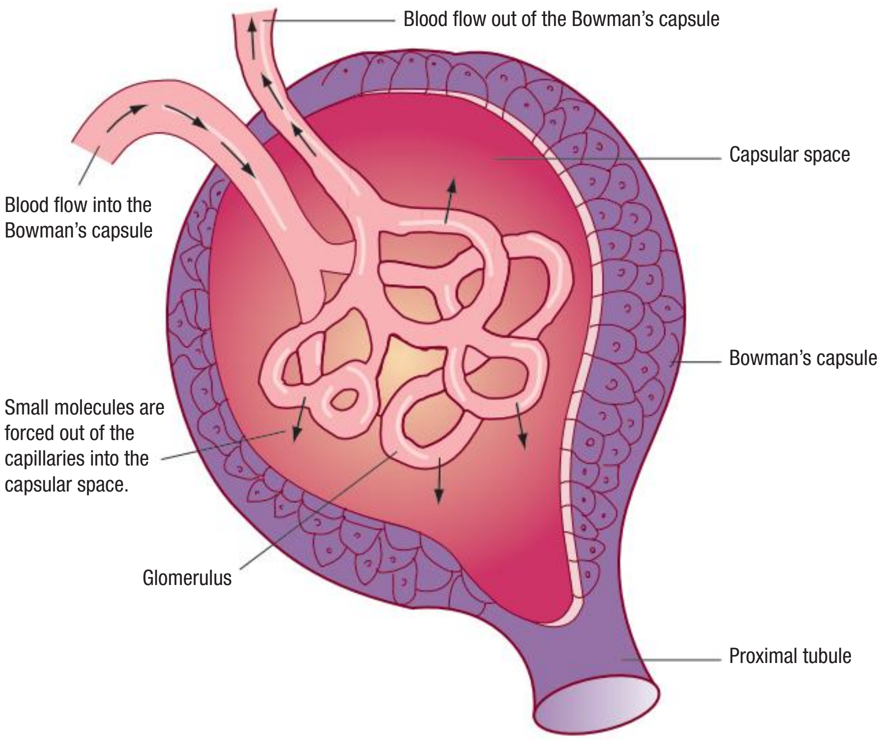

Figure 1.21 The Bowman's capsule and glomerulus

Balancing water and salt levels

It is during reabsorption that the kidney balances water and salt levels. As blood passes through the brain, the hypothalamus monitors the solute concentration of the blood. This enables the brain to coordinate reabsorption to ensure the body has what is needed and only excretes in the urine what is waste. If the water concentration of the blood is too low, receptors detect this and cause effectors to release **antidiuretic hormone (ADH)**. This hormone causes more water to be reabsorbed from the kidney filtrate. It also triggers our feelings of thirst. When the brain detects that the water concentration of the blood is back within normal settings, it will turn off the release of ADH. This is another example of the nervous and endocrine systems working together to coordinate the body as a whole.

When the body has limited water, the urine is more concentrated. The spinifex hopping mouse is a desert animal that only gets water from its food and from metabolic reactions. It has very long loops of Henle in its nephrons to maximise the reabsorption of water. As a result, the spinifex hopping mouse produces very concentrated urine and conserves body water.

antidiuretic hormone (ADH)
a hormone responsible for the reabsorption of water from the nephron into the bloodstream

ACTIVITY 1.3

Journey through the nephron

Using the information under the heading 'Filtering water and solutes', create a diagram to visually represent the journey of blood through the nephron. This diagram can be hand drawn or electronic. Upload your diagram to your blog.

VIDEO
Controlling body fluids

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WEBLINK
Homeostasis

ACTIVITY 1.4

Survival of salmon

On the chapter opening page, you were introduced to salmon and how they are able to survive their changing environments. Create a diagram to visually represent a salmon's journey from fresh water to the sea and back to fresh water. **Investigate** how its body maintains a balance in regards to water (and ions/solutes if you choose). Upload your diagram to your blog.

Practise understanding homeostasis and negative feedback with the 'Homeostasis' weblink.

WORKSPACE
Importance of homeostasis

ACTIVITY 1.5

Importance of homeostasis

How would you rate the importance of homeostasis in terms of bodily processes on a scale of 1 to 10 (where 1 is not very important and 10 is the highest importance)? **Justify** your response on your blog.

WORKSPACE
What have you learnt? 1.4

QUESTIONS 1.4

What have you learnt?

Understanding

1 **Recall** a reason why fluctuations in our blood pH could be harmful.
2 **Identify** the functional unit of the kidney.
3 Draw a diagram of a human kidney, cut longitudinally. **Identify** the main sections, and **describe** what happens in each of the sections.
4 **List** at least three functions of water in our bodies.
5 **Compare** and **contrast** diffusion and osmosis.
6 **Compare** the efficiency of lungs and gills at obtaining oxygen.

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QUESTIONS 1.4

Applying

7 People with very high blood pressure often suffer kidney damage, and people with damaged kidneys often develop high blood pressure. **Propose** an explanation for how these two symptoms may be linked.


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Figure 1.22
High blood pressure can be due to kidney damage.

Analysing

8 Table 1.2 summarises the concentration of various solutes in the glomerular filtrate at various locations along a human nephron.
 a **Identify** which solute is not filtered by the glomerulus.
 b All the glucose was filtered from the blood by the glomerulus. **Explain** why there is no glucose in the collecting duct.
 c **Explain** why chloride ions, ammonia and urea are not reabsorbed.

Table 1.2
Concentrations (g/100 mL) of solutes in the glomerular filtrate

Nephron component	Solute				
	Protein	Urea	Glucose	Chloride	Ammonia
Glomerulus	7.5	0.03	1.0	0.37	0.0001
Bowman's capsule	0	0.03	1.0	0.37	0.0001
Loop of Henle	0	1.50	0	0.45	0.0001
Collecting duct	0	1.90	0	0.60	0.04

9 **Explain** why materials such as urea, water and dissolved gases can diffuse across cell membranes, but other substances such as proteins cannot.

10 **Explain** why haemoglobin is necessary for birds and mammals but not fish and reptiles.

11 In goldfish kidneys, the nephron tubule (where reabsorption occurs) is very short. In desert rodents, it can be very long. **Propose** an explanation for how the length of the tubule helps these animals survive in their environments.

12 **Investigate** other gas exchange surfaces such as fish gills, insect tracheae and frog skin. **Identify** what all these gas exchange surfaces have in common and write a short description.

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QUESTIONS 1.4

Creating

13 Marine mammals such as seals are exceptional deep divers. Search a number of sources to **identify** and **explain** some physical adaptations that give them this ability.

Getty/Alastair Pollock Photography

Figure 1.23 Seals can dive to great depths.

14 **Investigate** what is meant by the letters GI when referring to foods and blood sugar. **Compare** a range of similar foods like breads to **identify** those with lower GI ratings. What characteristics do lower GI foods share?

Reflecting

15 Revisit your concept or mind map, adding details that you now understand about homeostasis.

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Chapter review

Remembering

1 **Define** these terms.
   a Homeostasis
   b Neurotransmitter
   c Thermoregulation
2 **List** three types of:
   a neurons
   b receptors
   c plant hormones.
3 **Recount** the pathway of a reflex arc using your own example.

Understanding

4 Give examples of where the following processes are used to assist in coordinating a body system.
   a Diffusion
   b Osmosis
   c Chemical signal
   d Solubility
5 **Compare** the advantages of using hormones or using nerve networks for coordination.
6 **Explain** the difference between a reflex response and a negative feedback response such as one used in homeostasis.
7 **Explain** the difference between a nerve and a neuron.
8 **Compare** the structure and function of sensory and motor neurons.
9 **Describe** how messages travel between two neurons, across a synapse.
10 **Describe** the features of glands that classify them as endocrine glands.
11 **Identify** at least five endocrine glands in the human body.
12 **Identify** the stimulus, receptor, effector and response when the human body gets too cold.

Applying

13 **Predict** how the following diets might change the composition of your urine.
   a A high protein diet
   b A very high salt diet
   c A diet based on a fruit such as watermelon
14 Healthy people do not have blood or glucose in their urine. Refer to the function and structure of the kidney to **explain** why.
15 Botox® is a toxin that can disrupt the transmission of messages to muscles. The appearance of a smooth face is a result of the paralysis of facial muscles. **Deduce** the basic mechanism of this toxin on nerves and neurotransmitters. **Justify** your idea.

WORKSPACE
Chapter 1 review

ACTIVITY SHEET
Chapter 1 checklist

REVIEW QUIZ
Chapter 1

ISBN 9780170231503

16 **Describe** how adrenalin prepares the body for 'fight or flight'.

17 **Explain** why removal of CO_2 from the body is a bigger trigger to breathe than need for O_2.

18 **Identify** whether these substances are filtered, reabsorbed or both in the nephron of the kidney:

a glucose
b proteins
c amino acids
d red blood cells
e urea
f oxygen

Analysing

19 Consider the three loops of Henle shown in Figure 1.24. Which organism A, B or C do you think lives in a desert environment? Give reasons for your choice based on kidney structure and function.

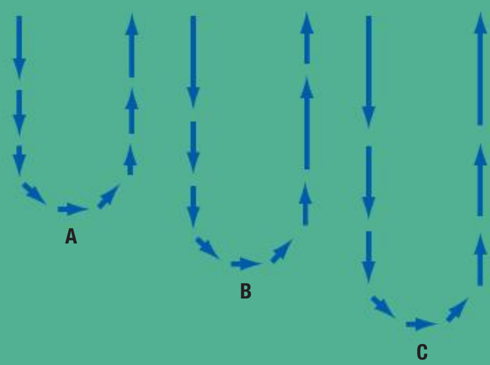

Figure 1.24 Loop of Henle of three different mammals

Evaluating

20 **Assess** the two main systems of coordination – the endocrine system and the nervous system. Which do you think is more effective? **Discuss** your point of view.

21 **List** the structures in this chapter that were probably named after their discoverers.

22 Do all multicellular organisms – fungi, plants and animals – preserve their 'steady states' in similar ways? **Explain** your answer.

23 If you touch a hot iron, you quickly pull your hand away to avoid burning it. **Identify** the name of this type of response and **describe** how it acts to assist in keeping us alive and healthy.

24 **Evaluate** the use of urine testing for athletes to detect drugs banned in sport.

Creating

25 Healthy humans maintain a constant internal body temperature of 36.8°C through a negative feedback system. Blood temperature is monitored by the brain. If the temperature is too high, then certain responses occur to assist in cooling the blood, such as increased perspiration. If the blood temperature is too low, then we begin to shiver, which increases muscle activity and cellular respiration – converting chemical energy to heat energy.

Draw a negative feedback diagram to **illustrate** how a constant body temperature is maintained in a human.

Reflecting

26 Go to your blog. **Identify** three things that you found interesting in this chapter, three things you learned and three things you still wonder about.

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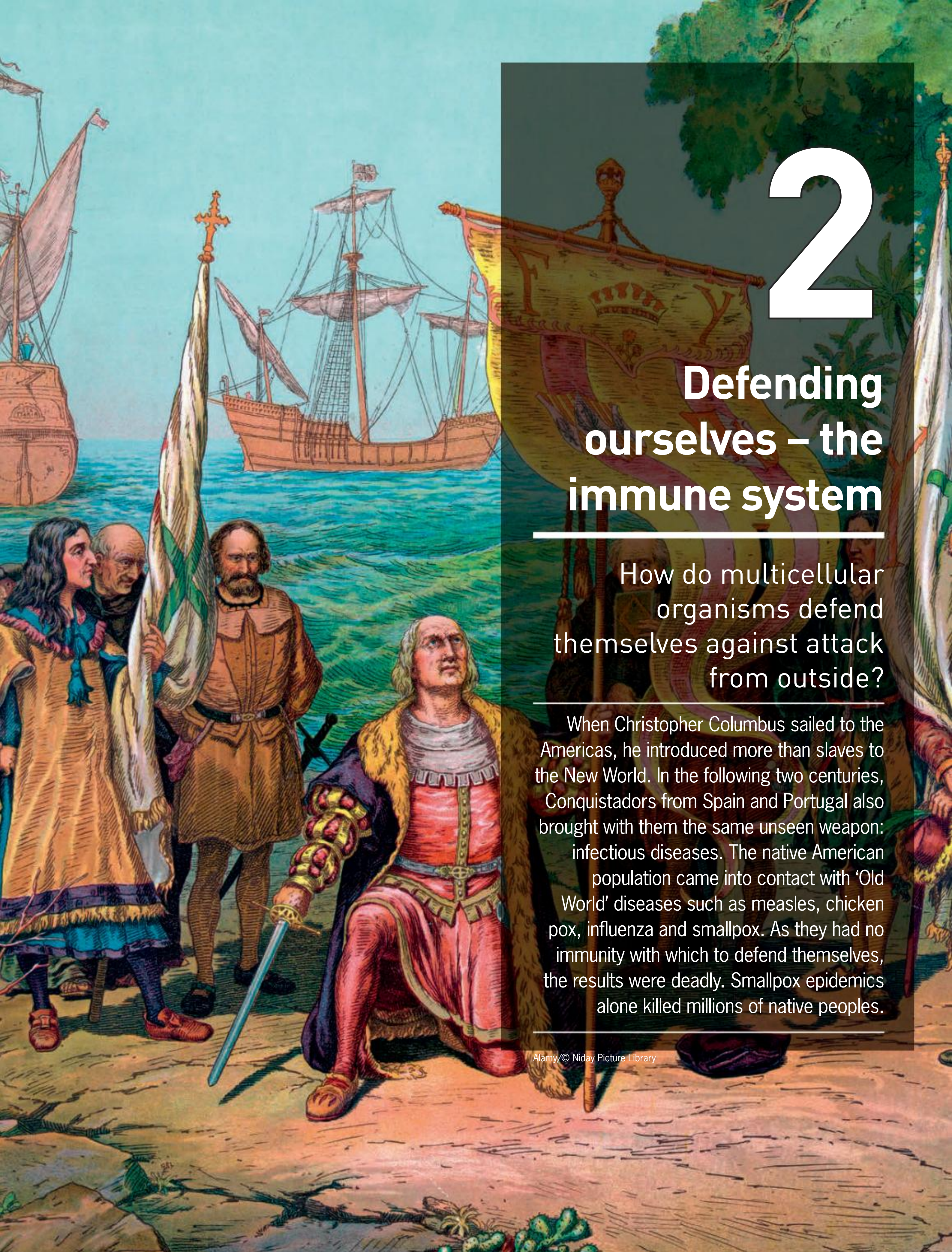

2

Defending ourselves – the immune system

How do multicellular organisms defend themselves against attack from outside?

When Christopher Columbus sailed to the Americas, he introduced more than slaves to the New World. In the following two centuries, Conquistadors from Spain and Portugal also brought with them the same unseen weapon: infectious diseases. The native American population came into contact with 'Old World' diseases such as measles, chicken pox, influenza and smallpox. As they had no immunity with which to defend themselves, the results were deadly. Smallpox epidemics alone killed millions of native peoples.

Living world – Stage 5

Key knowledge

- The human body responds to infectious and non-infectious diseases using coordinated internal systems.
- Epidemic or pandemic diseases can influence the focus of scientific research with regard to human, animal and plant diseases, and society's need for lifestyle-related non-infectious disease research can be driven by what is considered important by the general public.
- Disease research into treatment and prevention is advancing with new scientific technologies such as drug delivery systems using nanotechnology.

ACTIVITY SHEET
CAT with rubric: Stopping an epidemic

CULMINATING ASSESSMENT TASK

Stopping an epidemic

In 2009, Australians were warned about the possible outbreak of a swine flu epidemic. **Investigate** the strategies that were used to limit this outbreak and **apply** this knowledge to your task.

Create a plan to **demonstrate** your understanding of how infectious diseases are transmitted and how the spread can be minimised. You must provide a strategy at each level of alert.

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What do you already know about defending the body?

1. With a partner, write down what you think the phrase 'infectious disease' means.
2. **List** the first 10 infectious diseases you can think of in 3 minutes. (Hint: the common cold is an example of an infectious disease.)
3. Next to as many diseases as you can, write down what you think causes the disease and how you think the disease is transmitted, or spread.
4. Choose one disease and **list** as many symptoms of the disease as you can.
5. Share your lists with the class and upload the combined class list to the class wiki.
6. Review the combined class list at the end of the chapter to see what you have learned.

WORKSPACE
What do you already know about defending the body?

2.1 Disease – the body in trouble

A **disease** is any condition that interrupts your normal organ or body function. Disease can be classified as either a **non-infectious disease** or an **infectious disease**. Asthma is an example of a non-infectious disease, because it cannot be transmitted directly from person to person. Other non-infectious diseases include heart disease, stroke, Alzheimer's disease, diabetes and various cancers.

Infectious diseases are caused by something that can be transmitted from one organism to another. These diseases are caused by **pathogens**. The common cold, chicken pox, bubonic plague, tuberculosis and AIDS are all infectious diseases.

disease
any condition that interrupts the normal organ or body function

non-infectious disease
a disease that cannot be transmitted directly from one organism to another

infectious disease
a disease caused by a pathogen and able to be passed on from one organism to another

pathogen
a disease-causing organism, such as a bacterium or virus

Pathogens – the invaders

Pathogens are disease-causing organisms. Some bacteria, viruses, fungi, parasitic worms and protozoa are pathogens and these can be a threat to multicellular organisms like ourselves. They can cause disease when they are transmitted from one organism to another. Transmission may be via the air (inhaled), food or water (ingested), or by direct contact. Some organisms, such as fleas, ticks, mosquitoes, bats or dogs, can transmit pathogens when they bite or feed on other organisms.

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Figure 2.1 Some viruses, such as those that cause rabies, are transmitted by animal bite **(a)**. Others, such as those that cause yellow fever, are transmitted by mosquito bite **(b)**.

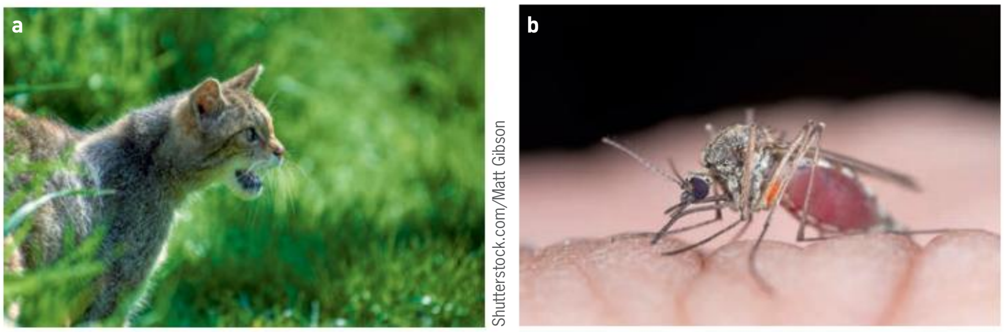

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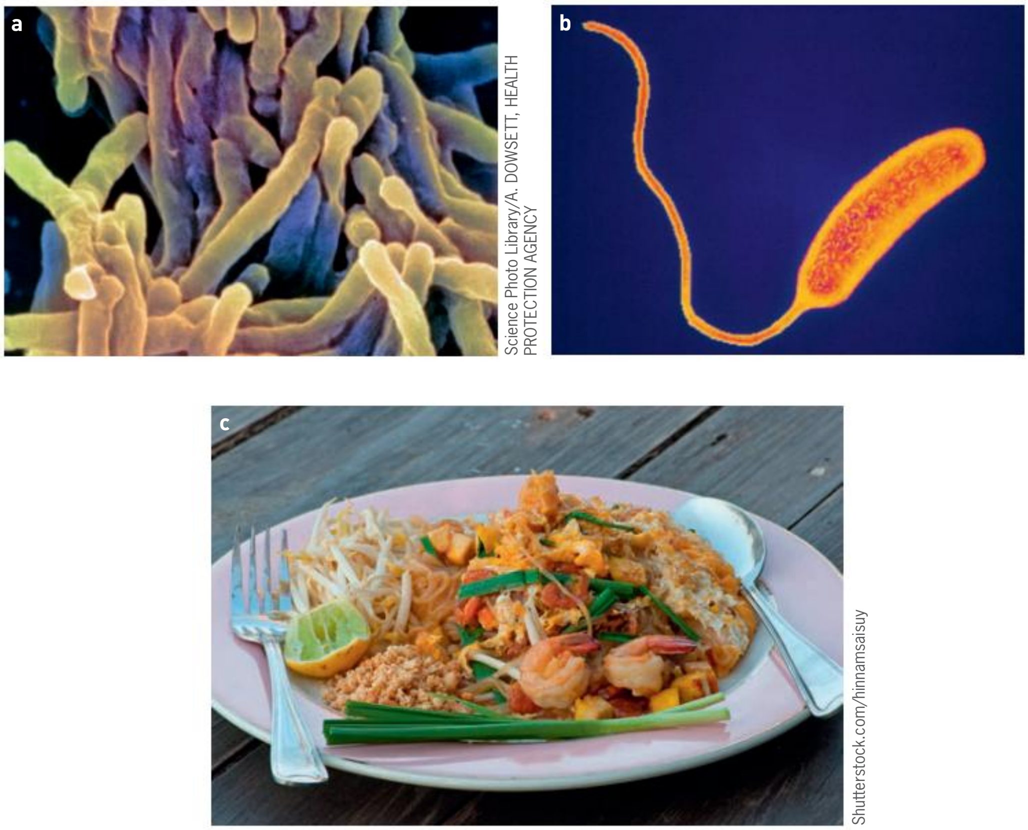
Figure 2.2 Some bacteria, such as those that cause tuberculosis, are transmitted through air **(a)**. Others, such as those that cause cholera, are transmitted through water **(b)**. Other bacteria, such as those that cause typhoid fever, can be transmitted through contaminated food **(c)**.



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bacteria

single-celled organisms, some of which cause disease

antibiotic

extract from fungus that is capable of killing disease-causing bacteria

virus

a small infectious pathogen that can only reproduce inside living cells

prion

an infectious agent that is composed entirely of protein

Bacteria, viruses and prions

Most of the infectious diseases you can name are caused by pathogenic bacteria or viruses. **Bacteria** are small, single-celled organisms that are found in just about every environment and on and in other organisms. A doctor will prescribe **antibiotics** to kill the bacteria that cause these infections. Some infectious diseases caused by bacteria include cholera, strep throat, anthrax and bacterial pneumonia.

Viruses are even smaller than bacteria. Viruses need to invade a host cell to reproduce themselves, so by definition they are not living organisms. As viruses are not living, antibiotics are not effective against them.

Prions are unusual proteins that can make the normal protein in your body change to prion protein. This is the cause of what is commonly called 'mad cow disease' and kuru. In this disease the brain gradually becomes spongy and motor control is lost.

ISBN 9780170231503

ACTIVITY 2.1

Body versus castle

WORKSPACE
Body versus castle

Five-minute task: Imagine a castle under siege. Think about how you would defend it. **Propose** three layers of defence and **identify** why each layer is needed. Now, if the castle is a metaphor for your body, suggest three ways we defend ourselves against invading pathogens such as bacteria.

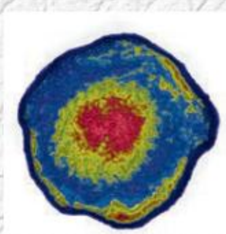
iStockphoto/duncan1890

Figure 2.3
A castle under siege by swarming army

ACTIVITY 2.2

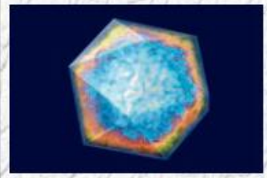
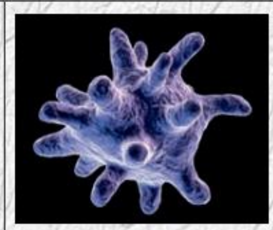
Sketching them small

How small is small? Step outside to your local footpath and try to draw these organisms and cells to scale to get the measure of them! You will need some chalk, a metre ruler and a 25 m tape measure.

Organism or cell	Actual size (diameter)	Size to draw	Looks like
Chicken pox virus	0.0003 mm	30 cm	 Alamy/© BSIP SA

ISBN 9780170231503

ACTIVITY 2.2

Organism or cell	Actual size (diameter)	Size to draw	Looks like
Polio virus	0.00002 mm	2 cm	 Alamy/© BSIP SA
E. coli bacterium	0.0005 mm	0.5 m	 Shutterstock.com/ Sebastian Kaulitzki
Cold virus	0.000023 mm	2.3 cm	 Shutterstock.com/dream designs
Bubonic plague bacterium	0.00075 mm	75 cm	 Shutterstock.com/MichaelTaylor
Red blood cell	0.0008 mm	80 cm	 Shutterstock.com/DTKUTOO
Macrophage	0.021 mm	21 m	 Shutterstock.com/Sebastian Kaulitzki

ISBN 9780170231503

WOW! Fear of fomites!

A **fomite** is any inanimate object that is capable of transmitting an infectious disease from one person to another. Door knobs, handholds in trains, railings, keys, pens, money, taps and on and on! Cold and flu viruses can still transmit infection after up to 8 hours on a fomite.

Shutterstock.com/Lemonpink Images

fomite

an inanimate object that is capable of passing on disease-causing organisms

WEBLINK
10 facts on malaria

WEBLINK
Malaria lifecycle summary

Parasites and protozoa

A **parasite** is any organism that lives on or in the body of another organism, the host, and gets its nutrition from the host without the host benefitting. Ectoparasites (on the outside of host) include ticks, fleas, mites and leeches. As they feed on blood from their host, some can transmit infectious diseases. Lyme disease, typhus and bubonic plague can all be passed to a host in this way. Endoparasites such as hookworms, roundworms and tapeworms are found inside the host's body. Depending on the type of worm, these can burrow into the foot, be ingested with food or contaminated water, or be transmitted by insect bites. Tiny parasitic worms can be transmitted by mosquito bite to cause the disease lymphatic filariasis (Figure 2.4).

Pathogenic protozoa can cause deadly diseases such as malaria, which is spread by the bite of an infected mosquito. Somewhere in the world a child dies from malaria every minute.

Science Photo Library/John Greim

Figure 2.4 A person with lymphatic filariasis (elephantiasis). This disease is caused by tiny parasitic worms transmitted by mosquito bite. It results in disfiguring swelling of the limbs and other parts of the body.

parasite

any organism that lives on or in the body of another organism, the host, and gets its nutrition from the host without the host benefitting

WOW! Zoonoses!

Zoonoses ('zoo-noh-seez') are diseases that can be transmitted from animals to humans. There are more than 200 known zoonoses. Anthrax, bird flu, rabies, toxoplasmosis, ringworm, Q fever and Lassa fever are just some examples.

Shutterstock.com/Zagorodnaya

ISBN 9780170231503

WORKSPACE
Looking at pathogens

EXPERIMENT 2.1

Looking at pathogens

Possible risks	Safety precautions
Wet specimens can be in various chemicals, such as ethanol or formaldehyde, that can be harmful to skin or if inhaled.	Do not open jars of wet specimens or touch preserved specimens. Consult MSDS for known preservatives used. Wear latex gloves.

Aim

To **examine** examples of pathogens to relate their structure to their function

Materials

- light microscope and dissecting microscope
- prepared slides of pathogens, including round-shaped bacteria (cocci) such as staphylococcus and rod-shaped bacteria such as *E. coli*, amoeba, macrophage, *Aspergillus* fungi
- resin-embedded or prepared slides of mosquito tick flea
- wet or preserved specimens of parasitic worms such as dog heartworm, hookworm/*Ascaris*, tapeworm

Method

Group A: Microscopic

1 **Examine** three to four examples of microscopic pathogens, including spherical bacteria, rod-shaped bacteria, fungi and amoeba. **Compare** these with white blood cells if possible.

2 **Describe** the main features in your results table and draw one example. Be sure to note the magnification.

Group B: Ectoparasites

3 **Examine** two to three examples of ectoparasites including flea, tick and mosquito if possible.

4 **Describe** the main features in your results table and draw one example. Be sure to note the magnification.

Group C: Endoparasites

5 **Examine** two to three examples of endoparasites including tapeworm, heartworm and hookworm if possible.

6 **Describe** the main features in your results table and draw one example. Be sure to note the magnification, if using a microscope.

ISBN 9780170231503

EXPERIMENT 2.1

Results

Category	Common or scientific name	Key structures	Disease	Drawing
Microscopic	Bacteria – spherical *Staphylococcus* sp.	Microscopic, round, can clump	Pneumonia, food poisoning	
	E. coli	Microscopic, rod-shape, flagella for swimming		
Ectoparasite				
Endoparasite				

Discussion

1 Rank these from the smallest to largest: staphylococcus bacteria, a pork/beef tapeworm, a virus, a tick. **Discuss** how size relates to its form of attack or where it lives.

2 **Identify** all of the pathogens you examined that must breach our first barrier of defence. **Outline** how they do this. **Propose** additional ways to defend ourselves against ectoparasites and the pathogens they may introduce.

3 Beef tapeworms can grow to 3 m long in a human gut. Consider our defence system and **describe** how you think tapeworms get into us and how they survive despite our defences. **Propose** ways we could avoid tapeworm infection.

4 **Evaluate** whether you think the human body has better defence systems to keep invaders out or to kill them from within? **Describe** examples.

Conclusion

Refer back to the aim and write a statement that **summarises** whether or not pathogens were found to have structures related to their function.

QUESTIONS 2.1

What have you learnt?

WORKSPACE
What have you learnt? 2.1

Remembering

1 **Recall** three types of ectoparasite that could transmit infectious diseases.

2 **List** four examples of infectious diseases.

3 **List** three ways a pathogen can enter the body.

ISBN 9780170231503

QUESTIONS 2.1

Understanding

4 **Contrast** these terms:
  a disease and pathogen
  b infectious and non-infectious.

5 **Explain** why antibiotics cannot be used to kill viruses.

Applying

6 Mosquito-borne diseases are particularly hard to control. **Outline** the steps you could take to prevent yourself from getting malaria if you were travelling in an area where it existed.

Analysing

7 There is a high rate of infectious disease in the Kenyan slum pictured below. **Deduce** five reasons why this could be the case. **Propose** at least three changes that would help people here stay healthy.

Shutterstock.com/africa924

Figure 2.5 A Kenyan slum

2.2 Defending the body

In the previous chapter, you learnt the ways in which the body maintains a stable internal environment. You also learnt how interrelated systems in your body communicate their responses to change to maintain stability. Imagine then, how your body may respond to an attack by a pathogen.

Complex multicellular animals such as humans have three levels of defence against attacking pathogens: barriers, non-specific immune cells and specific immune cells. Plants and simple animals such as insects only have one or two levels of defence.

ISBN 9780170231503

First line of defence – barriers

Surfaces are very important for individual cells and complex organisms. In most organisms, the skin or **epidermis** acts as a physical barrier to pathogens. Broken skin is a very common site of infection in all organisms. Burns victims who have lost their skin and people with open wounds are at extremely high risk of infection. In openings to the body, waxes (such as the ear) or hairs (such as the nose) block entry to some potential threats. Fish have overlapping scales and a layer of mucus to protect them from infection. Handling fish can remove their protective barrier of scales and mucus, and make them vulnerable to infection.

epidermis
a layer of tissue (usually one cell thick) on the surface of organisms


Shutterstock.com/Andrew G. Davis

Figure 2.6 Fish with bacterial infection

As well as physical barriers, there are chemical barriers to help form the first line of defence. Sweat and tears can repel harmful invaders on the outside, and stomach acids can destroy some ingested pathogens. Animals also produce mucus and chemicals such as **lysozyme**. Lysozyme is an enzyme that ruptures the cell walls of disease-causing bacteria to prevent their spread. Inside our respiratory tract, cells may be covered with hair-like structures called **cilia** (singular 'cilium'). The cilia beat together in coordinated waves, sweeping mucus up to your throat, where it is either coughed out or swallowed, and removing trapped pathogens and dust with it.

lysozyme
an enzyme found in mucus, urine, tears, saliva and other body secretions that kills harmful bacteria by rupturing their cell walls

cilia
hair-like projections from the surfaces of some cells that by beating together cause cell movement or push external fluids

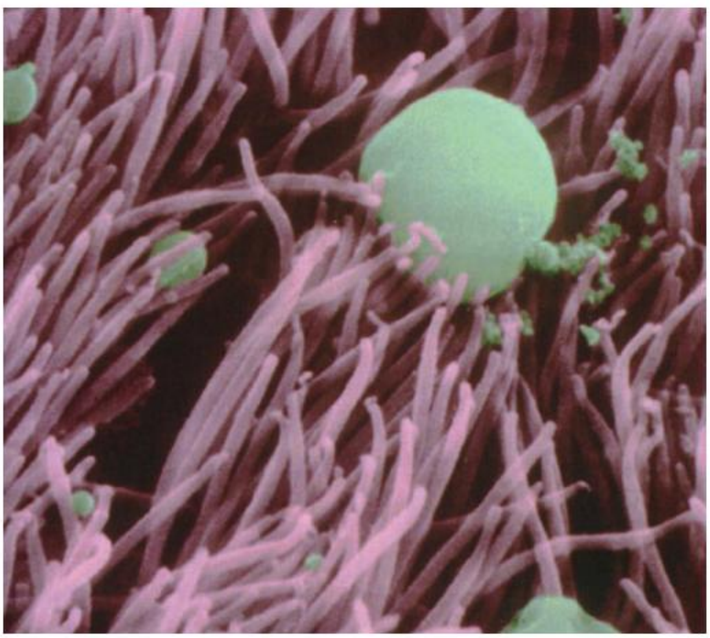

Science Photo Library/J.L.Carson, Custom Medical Stock Photo

Figure 2.7 Finger-like cilia in the trachea trap dirt and bacteria.

ISBN 9780170231503

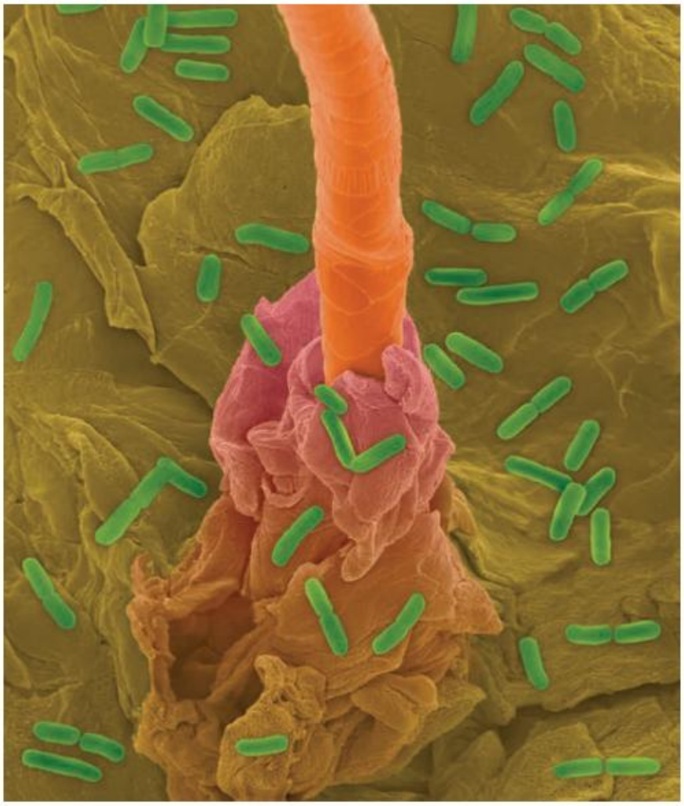
Earwax: your body's insecticide

WOW!

Earwax, or cerumen, helps protect our vulnerable ear opening from invaders. It acts as part of our first line of defence. Earwax is made from shed skin and secretions from oil and sweat glands. It also contains large amounts of fatty acids and waxes, which have antiseptic and insecticidal effects. Moving your jaws helps push the cerumen outwards, lubricating and cleaning our outer ears.

Shutterstock.com/Gang Liu

Additional protection is provided by a blanket of good bacteria covering the surface of most organisms. In fact, there are ten times more bacteria on you than the total number of cells in your body. Between 200 and 1000 species of beneficial or harmless bacteria live on our skin or line our guts or mouths. Some are permanent residents, but many are short lived. This barrier of bacteria allows little room for invaders to enter.



Visuals Unlimited, Inc./Dennis Kunkel Microscopy, Inc

Figure 2.8 A covering of harmless bacteria helps to keep disease-causing organisms from breaching the first line of defence.

ISBN 9780170231503

The human appendix is often presented as infection-prone and unnecessary. New research is suggesting it may protect our health by maintaining the bacteria mix in our gut by providing useful bacteria.

Hospital records of hundreds of patients suggest that removing the appendix seems to leave the gut more vulnerable to infection. Records showed a recurrence of pathogenic bacteria in 45% of people who had had appendectomies, but only 18% of people who had not had the operation.

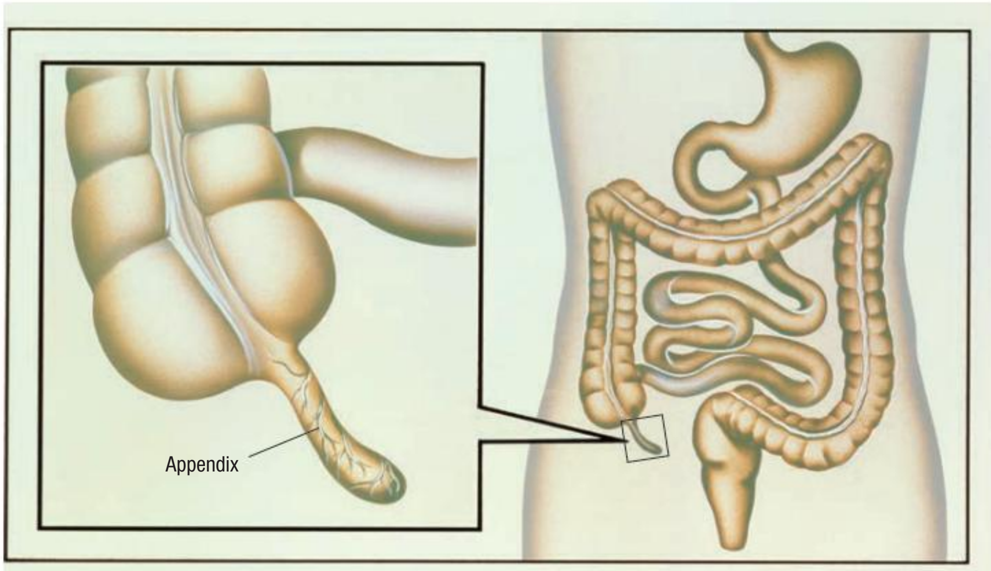


Figure 2.9
The appendix may be more important to our health than previously thought.

WORKSPACE
Student investigation: Does antibacterial handwash kill 99.9% of bacteria?

EXPERIMENT 2.2

Student investigation: Does antibacterial handwash kill 99.9% of bacteria?

Many manufacturers of antibacterial handwash claim that their product is effective in killing 99.9% of bacteria on our skin. This sounds like a good thing, but is it? We know that the skin needs good bacteria to fight off invading harmful bacteria, and we know that bacteria breed very quickly. Can we really remove 99.9% of them?

You are part of a team of scientists working for *Choice Magazine* and want to test this claim.

Possible risks	Safety precautions
Harmful bacteria and fungi are likely to grow on your agar plates.	Make sure your agar plates are securely taped (top to bottom) once they have been swabbed. Do not open your plates, and give them to your teacher for autoclaving and disposal at the conclusion of the experiment.

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EXPERIMENT 2.2

Your task

Work in a group of four. **Design** an experimental investigation to test the claim that antibacterial handwash kills 99.9% of bacteria. There are different ways to design this test, so don't worry about what other groups are doing.

This might help

Follow the scientific method when you are developing your experiment. Remember that you need replicates and a control. How will you collect your bacteria? How will you measure the growth or lack of growth of bacteria? What will you **compare** if you test the handwash? How will you label your agar plates? How many plates will you need? Draw your results table now to double-check your experimental design. Refer to activity sheet 'Sterile technique' for help.

ACTIVITY SHEET
Sterile technique

1 Wipe down or spray your work area with ethanol to sterilise the benchtop.
2 Collect agar plates from your teacher. Do not open them until you are ready to start! Agar is a nutrient medium on which bacterial colonies can grow. Label them with the date, treatment, your initials.
3 If you are collecting bacteria from your skin, use sterile swabs to collect bacteria.
4 Carefully wipe these swabs over the surface of the agar.
5 Make sure your agar plates are securely closed (tape the top to the bottom all around the side) once they have been swabbed with bacteria. Never open your agar plates once they have been exposed and taped.
6 Incubate your plates at 37°C for 48 hours.
7 Photograph your plates next to a ruler to provide a scale.
8 At the end of the experiment dispose of your agar plates according to your teacher's instructions.

Figure 2.10 Advertising on the bottle claims that some handwashes can kill up to 99.9% of bacteria.

Alamy/David J. Green

Things to think about

1 **Identify** the independent variable.
2 **Identify** the dependent variable.
3 **Identify** at least five variables you need to keep constant.

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EXPERIMENT 2.2

4 **Identify** the materials you need.

5 **Identify** a control.

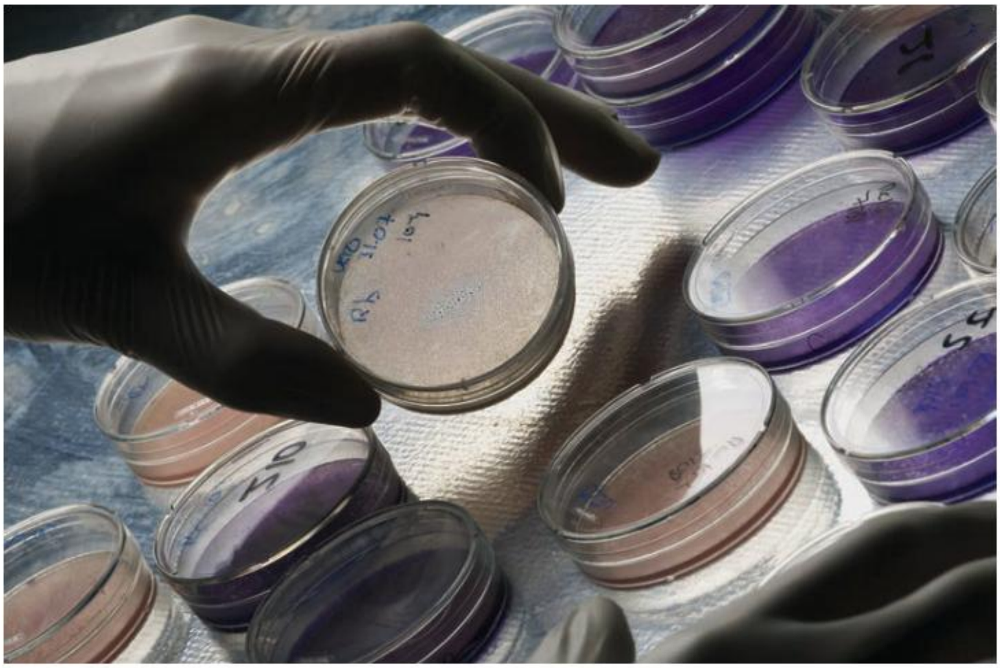
6 Write out your Aim, Hypothesis, Materials and Method.

Results

6 Take photos of your agar plates at the beginning and end of the experiment.

7 **Describe** the amount of bacterial growth on each. Quantify the amount of bacterial growth in some way (per cent coverage, or number of colonies perhaps), and record your results in an organised fashion.

8 **Identify** whether anything else grew on the plates (e.g. fungi).



Science Photo Library/Massimo Brega, the Lighthouse

Figure 2.11
Agar plates containing nutrient medium can be used to grow bacterial colonies.

Discussion

9 **Compare** your results with the claims made by the manufacturer.

10 **Justify** whether you think using an antibacterial handwash is better for your health.

Presenting your results

Write up your experiment as a formal scientific report (see Appendices). Include the photos you took of your agar plates.

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Second line of defence – non-specific immune cells

Imagine that your skin, part of the first line of defence, is damaged. Perhaps you fell and scraped your knee. Now your blood and tissues are contaminated with dirt, bacteria, and perhaps even fibres from the clothes you wore.

Shutterstock.com/Candace Hartley

Figure 2.12 The first line of defence has been breached.

Shutterstock.com/CHEN WS

Figure 2.13 The inflammation seen in this finger is a result of an infection. The finger would be painful and feel warm. Inside, neutrophils and macrophages are battling the infection.

neutrophil
the most abundant type of white blood cell in mammals

macrophage
a type of white blood cell that destroys invading particles by engulfing them

inflammation
a response of a tissue to injury characterised by increased blood flow to the damaged tissue

All animals, invertebrates as well as vertebrates, have a second line of defence made up of non-specific immune cells. These cells try to engulf and digest particles that are foreign to the body. They are not specific in what they attack. Non-specific immune cells will try to destroy anything that invades, such as splinters, dirt or bacteria. The cells involved are specialised white blood cells called **neutrophils** and **macrophages**. These cells migrate to any area where there is cell damage and cause **inflammation**. You know there is inflammation when the damaged area becomes painful, red, hot and swollen. This is due to the increased healing activity occurring below the skin surface.

Neutrophils detect cell damage and move to the site of infection within minutes. They can block the spread of toxins by getting into tissues and causing swelling. When they die, neutrophils form the major part of pus. Our bone marrow replaces these important cells at a rate of 80 million per minute.

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Macrophages are large, mobile cells that arrive at the infected site after the neutrophils. Both are able to surround bacteria and engulf them (Figure 2.14a). This process is called **phagocytosis** (literally 'eating cells'). When macrophages or neutrophils touch a foreign object, they quickly surround it by extending parts of their cytoplasm, which then fuse together. The foreign object is trapped inside a small bubble of membrane, and carried deeper into the cell, where it is digested by enzymes (Figure 2.14b).

Macrophages are able to squeeze between cells in tissues as well as in the circulatory system. Macrophages are considered general 'rubbish collectors', but often work with other parts of the immune system.

phagocytosis

the process in which a large cell extends its cytoplasm around a foreign object and draws it inside, later destroying it with enzymes

WEBLINK
Macrophage engulfing bacteria

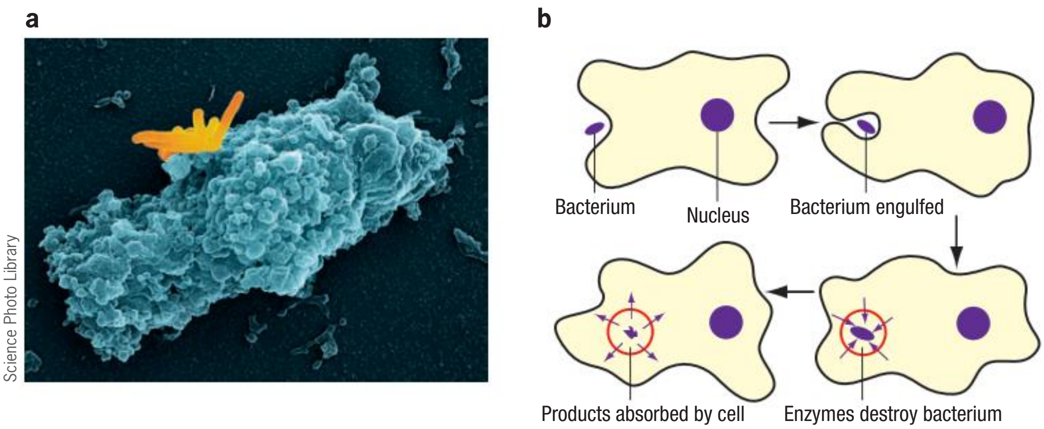

Figure 2.14
a A macrophage engulfing a bacterium. **b** Phagocytosis is a simple and direct way to defend against unwanted particles.

ACTIVITY 2.3

Lunch?

Compare the feeding behaviour of an *Amoeba* with that of a neutrophil engulfing a bacterium. **Describe** the ways these processes are similar. **Contrast** the ways in which they are different. Record your thoughts on your blog.

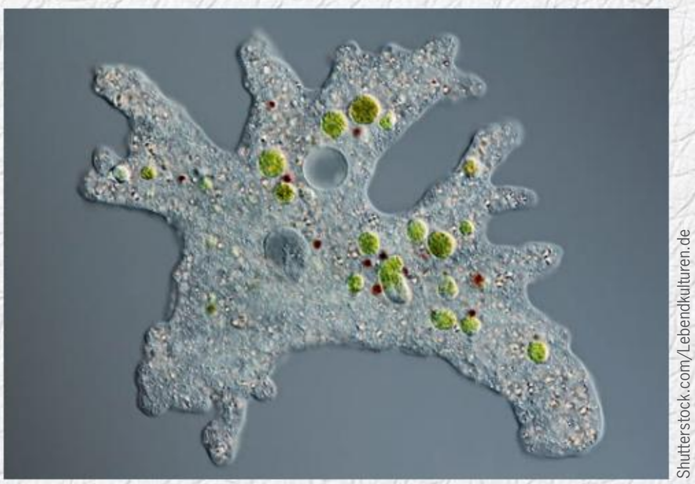

Figure 2.15
An *Amoeba*

Create your own animation of phagocytosis. You could use Pencil animation, SketchUp or a program of your own choice. Or, instead of animation, you could create a flip book of the basics of phagocytosis.

WORKSPACE
Lunch?

WEBLINK
Neutrophil

WEBLINK
Amoeba

WEBLINK
Pencil animation

WEBLINK
SketchUp

ISBN 9780170231503

WORKSPACE
What have you learnt? 2.2

QUESTIONS 2.2

What have you learnt?

Remembering

1 **List** the two different types of barriers that our body uses to keep out invaders.

2 **Summarise** two lines of defence that complex organisms use against invasion.

3 **Recall** examples of cells that use phagocytosis.

4 **List** two similarities between neutrophils and macrophages.

Understanding

5 **Describe** the purpose of inflammation.

6 You are walking through a dusty field. **Outline** the ways your body keeps the dust from invading your lungs.

Applying

7 **Discuss** how our increased use of antibacterial handwash can be related to the decreased health of local fish.

2.3 Third line of defence – specific immune cells

Vertebrates, including humans, have a third line of defence as part of the immune system. As well as helping us resist thousands of different diseases, our immune system helps us fight infectious diseases we have already had. Specialised white blood cells can 'remember' if they have met a specific pathogen before. They can recognise pathogens by the unique markers on their surface.

antigen
a substance that is foreign to the body and causes an immune response

All cells have proteins on their surfaces called **antigens**. These antigens identify cells, in the same way that the coloured jerseys on a football player identifies the team they are on. Our cells have our own antigens, or 'self' antigens, to signal that they are on our team. This prevents our immune system from attacking them. Cells that are foreign to our bodies, such as invading bacterial cells, are recognised as being foreign, just as opposing football teams recognise each other by their different jerseys. The foreign antigens on invading bacteria signal to our immune cells that they do not belong to us. Virus particles attach to the outside of cells they invade and this changes the 'self' marker to 'foreign'.

Fighting a virus

ANIMATION
Reproduction in viruses

Infection

Going home from school on the bus, Alex inhales a spray of droplets containing some rhinoviruses (common cold virus). Unknown to him, a passenger with a cold had coughed a few minutes before. As Alex had stayed up late finishing an assignment the night before, he is tired and his general defences are down. Some of the rhinovirus particles infiltrate a few cells along his throat, and begin to multiply.


Shutterstock.com/leungchopan

Figure 2.16 Alex catches a cold.

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Response by specific immune cells

The surface of the cells infected by the rhinovirus starts to change. New antigens appear on the outside of infected cells. This makes the virus-infected cells appear different and foreign from Alex's normal cells.

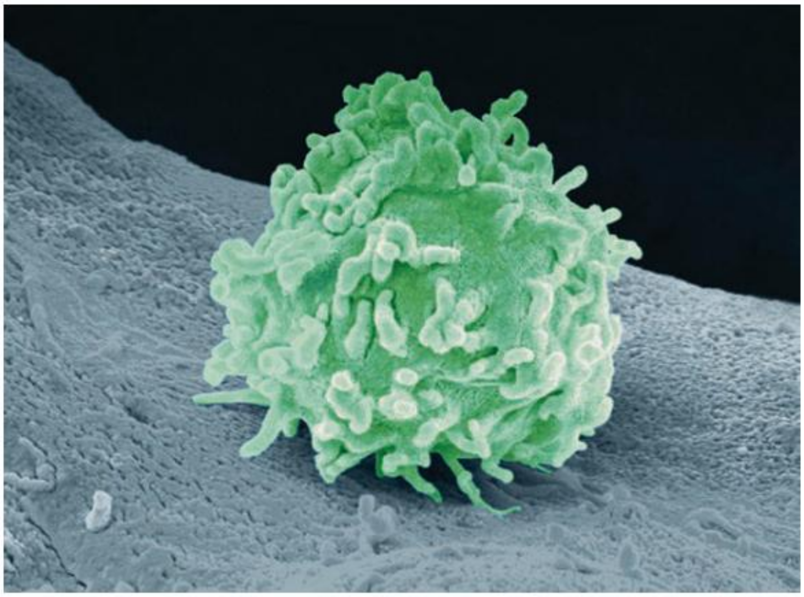
Small, clear white blood cells called **lymphocytes** begin to gather around the site of infection (Figure 2.17). Lymphocytes develop in bone marrow and their surfaces contain different proteins – called **antibodies**. Only a few of the hundreds of thousands of lymphocytes in Alex's entire circulatory system will have the right antibodies to match the antigens on the virus-infected cells, connecting like a key to a lock. When this happens, the lymphocytes begin to divide and so increase in number.

lymphocyte

a type of white blood cell involved in adaptive immunity

antibody

a specialised protein found in the plasma that binds to an antigen



Getty Images/Science Photo Library

Figure 2.17
Human lymphocytes such as this one are produced in bone marrow. Their role is to fight infection.

Within days of an infection, there will be thousands of identical lymphocytes circulating in the blood, where they make and secrete antibodies. The antibodies lock on to the surface of pathogens or virus-infected cells. They immobilise and clump the pathogens so that macrophages can find and engulf them. By now, Alex will be suffering all the symptoms of a cold.

Gradually, the antibody and virus are cleared from Alex's blood by the lymphocytes. Some will have been eaten by macrophages. The lymphocytes stop dividing and, over the coming weeks, most of these lymphocytes will die. A very small number will survive as 'memory' lymphocytes for decades after the infection. They will be ready to respond to a further challenge by the same virus. If Alex catches this same strain of cold virus again, the immune system will be quick to respond. The cold will be very mild or even go undetected by Alex. If Alex catches a different strain of cold, the immune system will again respond. **Vaccination** relies on this basic process to protect us from a wide range of diseases. Vaccination is the artificial introduction of antigens to the body to cause the body to stimulate an immune response.

vaccination

the administration of live or dead antibodies to stimulate an immune response to that disease

ISBN 9780170231503

Immunity

immunity
having biological defences against a specific disease

VIDEO
Microbes and disease

Immunity is the resistance to a specific infectious disease. Mothers pass on natural immunity to their baby in utero and via breastmilk. If you have fought off a virus such as the common cold, you will be naturally immune to the virus next time.

You can also receive artificial immunity through vaccination. Less than a century ago, infectious diseases such as diphtheria, measles, polio and whooping cough were very common causes of death. Today they are rare, thanks to vaccination programs.

Smallpox was the first and only human infectious disease to ever be eradicated through vaccination.

Although they were unaware of the process by which organisms developed lifelong immunity, the ancient Chinese and Indians developed early inoculation techniques. They exposed people to the smallpox virus by wiping cuts or skin with material that had touched a scab or nostril of someone with a minor smallpox infection. Much later, Edward Jenner (1749–1823), an English doctor, observed that milkmaids did not become infected with smallpox if they had previously had the related, milder animal cowpox. In 1770, he began to deliberately expose people to cowpox. His patients developed memory cells (immune cells) to the cowpox infection and were protected from the deadly smallpox for life.

Figure 2.18 This girl has the smallpox virus.

Corbis/CDC/Phil

WOW! Human guinea pig

James Phipps was a poor 8-year-old boy back in 1796. At the same time, Edward Jenner was eager to test his new smallpox vaccination technique and he needed human subjects. So, James became the first recipient (victim?) of the risky method, being infected first with cowpox and later smallpox. Luckily, he was only mildly ill and he survived. Jenner was thrilled and went on to experimentally vaccinate other poor labourers and their children, as shown in the painting. In appreciation of James Phipps' participation, Jenner awarded James a house for his family when he was grown and married.

Bridgeman Art Library/Archives Charmet

VIDEO
History of vaccination

ISBN 9780170231503

Understanding the details of how pathogens and toxins work has extended the range of techniques that can be used to immunise people against their effects (Table 2.1).

Table 2.1
Immunisation techniques

Type of immunity	Method of immunisation	Example treatments or vaccinations
Passive: a person without antibodies is given them directly	Antibodies are also supplied to babies in their mother's breastmilk. Antibodies are extracted from another organism and injected into person needing them.	Diphtheria Rabies Snakebite Tetanus
Active: the person produces their own antibodies	Antibodies are produced naturally as a result of an infection.	Cold viruses (rhinoviruses) Chicken pox
	Antibodies are produced through deliberate exposure to harmless versions of living pathogens via vaccination.	Measles Poliomyelitis
	Antibodies are produced through deliberate exposure to 'dead' pathogens. Boosters will be required to maintain antibodies.	Influenza Whooping cough
	Antibodies are produced through deliberate exposure to pieces of viruses.	Hepatitis B virus Human papilloma virus

ACTIVITY SHEET
Understanding disease transmission

ACTIVITY 2.4

Disease – what if . . .?

Select one of the diseases from the timeline on the weblink. What if this disease was still common?

1 **Predict** a problem this disease poses that needs a solution.
2 **Identify** what allows the disease to thrive.
3 **Outline** strategies put in place to minimise the disease.
4 **Describe** what happened when this strategy was developed and put in place.
5 **Explain** what has to happen to ensure that this disease stays under control.

WORKSPACE
Disease – what if . . .?

WEBLINK
Timelines for vaccines of several infectious diseases

INTERACTIVE
Body parts: immune system

ISBN 9780170231503

WORKSPACE
The National Immunisation Program

WEBLINK
The National Immunisation Program

ACTIVITY 2.5

The National Immunisation Program

Go to the weblink 'The National Immunisation Program' to see which diseases it recommends that all infants (0–4 years) be immunised against.

1 Determine the aim of this program.
2 **Explain** why infants need to receive repeat doses of some vaccinations, such as diphtheria.
3 **Predict** the possible outcome if no infants were immunised according to the schedule.
4 **Evaluate** the rights of the parents, children government program officials and the community of other families in deciding on whether or not to vaccinate children according to the National Immunisation Program.

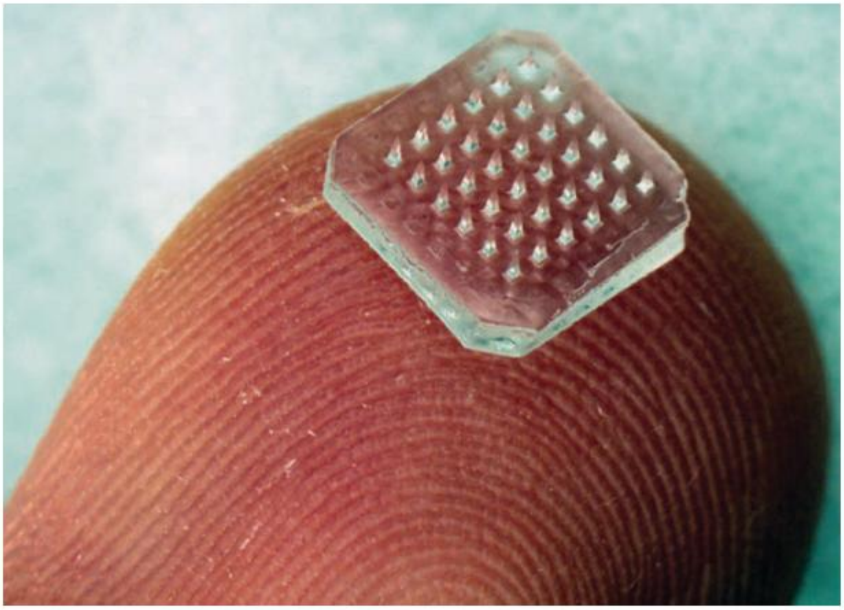
Delivering vaccines with nanotechnology

Nanotechnology deals with developing materials or devices in the size range 1–100 nanometres (nm). A **nanometre** is one-billionth of a metre. Nanotechnology has been used to develop a vaccine-delivery patch based on hundreds of microscopic needles that are able to dissolve into the skin. This is a painless and needleless way to administer a vaccine and provide immunisation against diseases such as influenza. Tests have shown that the dissolving microneedles appear to provide better immunity to influenza than vaccination with the hypodermic needles currently used.

nanotechnology
an emerging science that deals with developing materials or devices in the size range 1–100 nanometres (nm)

nanometre
one-billionth of a metre

WEBLINK
Nanovaccine to protect cattle



Jeong-Woo Lee, Georgia Institute of Technology

Figure 2.19 This patch consists of an array of 36 dissolving microneedles that can deliver a vaccine and provide immunisation against diseases such as influenza.

ISBN 9780170231503

QUESTIONS 2.3

What have you learnt?

Remembering

1 **Identify** the third line of defence our bodies employ to keep us safe from invaders.

2 **List** the two types of immunity.

Understanding

3 **Distinguish** between lymphocytes and antibodies.

4 **Describe** what antibodies are and what they do.

Applying

5 Imagine that you were running barefoot across a lawn and stood on a sharp piece of metal. Bacteria from the metal enter your bloodstream and you are at risk of blood poisoning.

Construct a flow diagram to **show** how your body would react to keep you safe from invaders.

6 **Explain** why we continue to catch a cold every winter even though our body has built up immunity to the cold we caught last winter.

7 a **Describe** how the immune system of a human would respond to a virus such as measles.

b **Explain** why you would not catch measles again later in life.

8 **Investigate** three scientific advances in the area of immunology in Australia. **List** them with a simple explanation.

Evaluating

9 **Predict** how our world might be different if Edward Jenner had not experimented with cowpox.

10 **Assess** whether or not you think spending research funding on delivering vaccines using nanotechnology is a good use of taxpayers' money. **Justify** your views.

WORKSPACE
What have you learnt? 2.3

ISBN 9780170231503

2.4 Epidemics and pandemics

pandemic

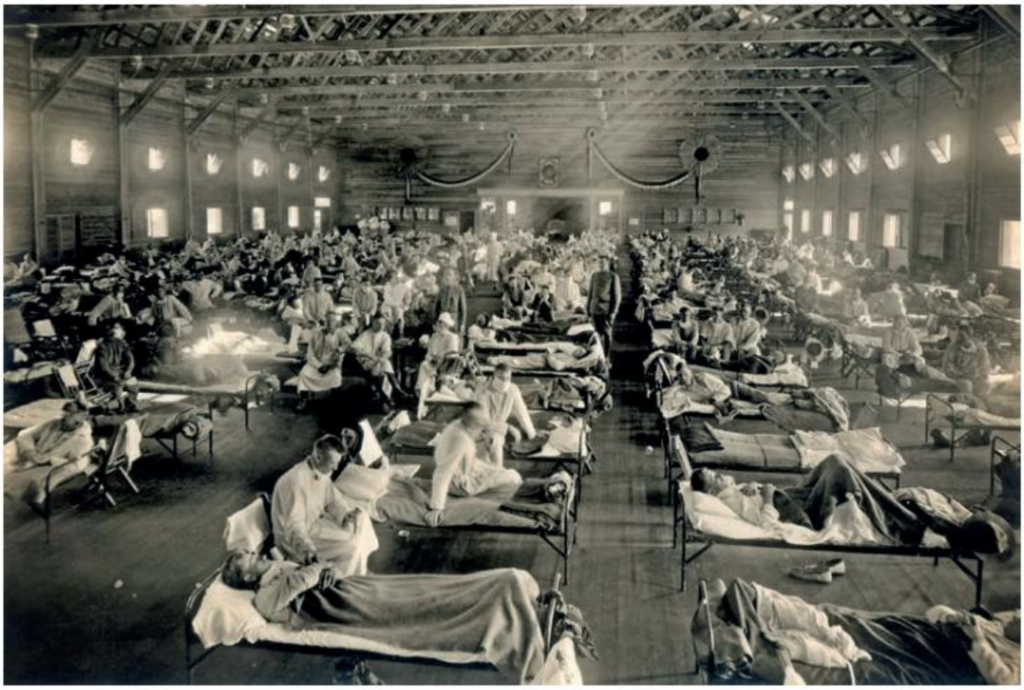
a severe disease outbreak that is widespread, perhaps over continents or the world, or the incident rate increases greatly in a region

epidemic

a disease outbreak that occurs suddenly in a region or group and affects more people than expected

The 1918 influenza ('Spanish flu') **pandemic** killed more than 50 million people worldwide. At least 500 million were infected. That was almost 30% of the global population at the time. When a disease outbreak occurs suddenly in a region or group and affects more people than expected, it is called an **epidemic**. When a serious disease outbreak is widespread, perhaps over continents or the world, or the incident rate increases greatly, it is referred to as a pandemic. The 1918 influenza pandemic killed indiscriminately across Europe, Africa, North America, up to the Arctic, and down to Australia and the Pacific Islands.

One of the reasons this epidemic became a pandemic was due to the severe nature of the particular strain of virus. This deadly strain killed 1 in 5 people infected, whereas typical flu viruses only kill 1 in 1000 people.



Science Photo Library/National Museum of Health and Medicine

Figure 2.20 Spanish flu patients filled the hospitals.

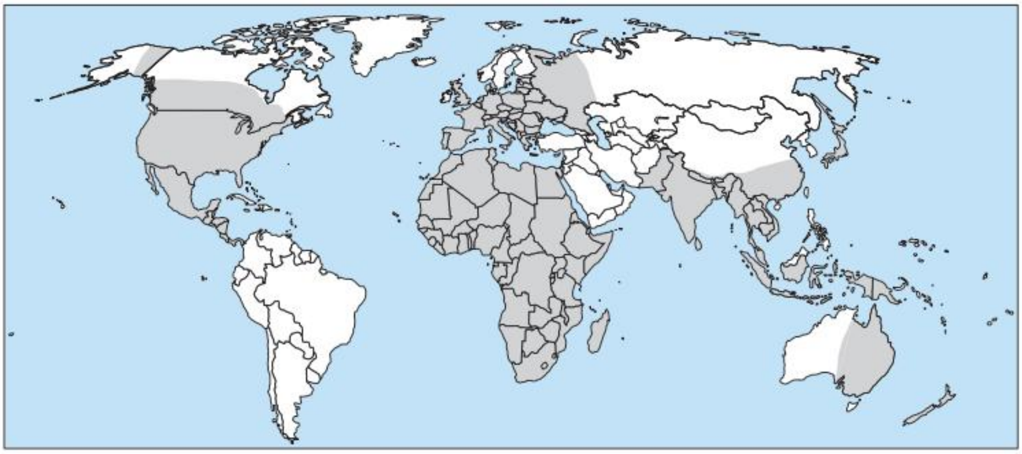


Figure 2.21 This map indicates (shaded grey) the extent of the Spanish flu pandemic.

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ACTIVITY 2.6

She cooks! She kills!

Mary Mallon, aka 'Typhoid Mary', was accused of causing at least three deaths and more than 50 infections by spreading typhoid. At one point, six of the people of the house where she cooked became ill. Did she know she was to blame? Could she be stopped? Did she deserve what she got?

Investigate the tragic case of Typhoid Mary to learn of her story and her treatment. **Recount** briefly how she infected people and how she was finally stopped. **Evaluate** her case. In two to three paragraphs, **discuss** whether or not you think she was to blame and whether she got what she deserved.

Try the weblink 'Typhoid Mary: villain or victim?' and find others for more information about Mary.

WORKSPACE
She cooks! She kills!

WEBLINK
Typhoid Mary: villain or victim?

Emerging diseases

Today, government departments and health organisations around the world monitor disease outbreaks to avoid another pandemic. The source and form of transmission are identified as quickly as possible. Measures to contain the spread are quickly put into place. As you saw with Mary Mallon, it took some detective work to trace the source of death and illness back to her. Isolating carriers or infected people was a common strategy then and it is still used today.

Severe acute respiratory syndrome (SARS) emerged as a new disease in Hong Kong in November 2002. In weeks, it had infected people in 37 countries. There was no vaccine and no cure. By March 2003, the World Health Organization (WHO) issued a public alert. An international effort involving quarantining infected people, as well as those in contact with them, was combined with disinfecting airplanes and timely communication of cases. By July 2003, 774 people were dead, but the outbreak had been stopped.

New diseases will continue to emerge. The deadly Ebola virus jumped from animals to humans to emerge in 1976 in central Africa. The epidemic was quick and had a mortality rate of almost 90%.

Alamy/© Peter Treanor

Figure 2.22
Masks were a common sight during the SARS epidemic.

Viruses and bacteria can both mutate into new forms of unknown severity. Modern technology has given us great tools to run computer simulations of hypothetical epidemics, map cases and communicate rapidly. At the same time, our modern world can speed up the spread of emerging disease thanks to international travel, shipping food and goods and living in high density. Changes to environments, such as contaminating water supplies and clearing land can lead to outbreaks of diseases such as cholera and to mosquito-borne diseases such as malaria and dengue fever. As of December 2012, the Dadaab refugee camp in Kenya was the largest in the world. There were more than 450 000 Somali refugees and more arriving every day. Managing the health of such a dense human population in filthy conditions is almost impossible. Bird flu, jaundice and cholera have all broken out at various times.

To see updates on Dadaab by the United Nations High Commissioner for Refugees go to the weblink 'UN refugee statistics'.

WEBLINK
UN refugees statistics

WORKSPACE
What have you learnt? 2.4

QUESTIONS 2.4

What have you learnt?

Remembering

1 **Define** the terms 'epidemic' and 'pandemic'.

2 **Recall** how typhoid can be transmitted.

Understanding

3 **Outline** how environmental changes may assist the spread of infectious diseases.

Analysing

4 There are several different free apps relating to epidemics that are available for mobile phones, tablets and computers. Choose one and play it to **analyse** the accuracy of the scientific features. **Discuss** the representation of the epidemic spread, and be sure to mention the forms of transmission, the type of pathogen and the strategies for defeating the disease.

Evaluating

5 **Synthesise** your knowledge from this section to **explain** why it might be more difficult to stop an emerging viral disease rather than a bacterial disease.

6 Epidemics are more likely to begin in developing countries than in developed countries. **Justify** or refute this statement.

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2.5 Responding to non-infectious diseases

Multicellular organisms, including humans, are also vulnerable to **non-infectious diseases**. Non-infectious diseases cannot be spread from one person to another. The cause of non-infectious diseases may be genetic, due to environmental factors, normal ageing, poor nutrition or other lifestyle-related reasons. Cystic fibrosis is an example of a genetic non-infectious disease, whereas the non-infectious diseases of heart disease, bowel cancer or obesity can be due to a combination of factors. Globally, almost two-thirds of deaths are due to non-infectious diseases.

In Australia, cardiovascular disease is the biggest killer, with a rate of one person dying about every 12 minutes. Heart disease, stroke and all other blood vessel diseases are referred to as cardiovascular diseases. At the same time, the fastest growing disease in Australia is diabetes. With almost half of women and two-thirds of men being overweight or obese (Figure 2.23) in this country, these statistics are not surprising. Being overweight interferes with healthy bodily functions and can increase the risk of developing cardiovascular disease, diabetes and other life-threatening conditions. Although fat is useful for cellular function, storing energy, absorbing some vitamins, protecting our organs and insulating our bodies, there are many health implications for excess fat. As fat accumulates around the torso, it can interfere with breathing, blood circulation and organ function, and even put pressure on joints. Since we rely on coordinated body systems, it is essential to maintain good health. The healthier we are, the less vulnerable we are to disease.

non-infectious disease

a disease not caused by a pathogen and not transmissible from person to person; also known as a non-communicable disease

Shutterstock.com/Bangkokhappiness

Figure 2.23 Obesity is a non-infectious disease that can be caused by a combination of nutritional, lifestyle and genetic factors.

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It takes your breath away

Asthma is a non-infectious disease that causes the sufferer to have trouble breathing. The airways of the respiratory system narrow and breathing becomes difficult. There are no invading pathogens, but foreign material from the environment, for example tobacco smoke or pet hair, may trigger an asthma attack in some sufferers. These **irritants** trigger the body to respond as best it can to rid itself of the material.

irritant
an agent (can be chemical, biological or mechanical) that causes a painful response

When an asthma attack occurs, the muscles around the airways tighten. This is the beginning of the body's response. Then the airways become swollen or inflamed. The diameter of the airways is now smaller, so it is difficult to breathe. Normal mucous in the membranes lining the airways begins to build up, causing shortness of breath and wheezing. The body has been triggered to respond, but it does not turn off the trigger. Some attacks can be so severe that they are fatal. Asthma is a lung disease without a cure, so the symptoms must be managed. The body can be helped by using preventative drugs delivered by an inhaler. The drugs interrupt the body's response to inflammation. Other inhaler drugs reduce inflammation and clear mucus when used during an asthma attack.

WEBLINK
An asthma attack in action

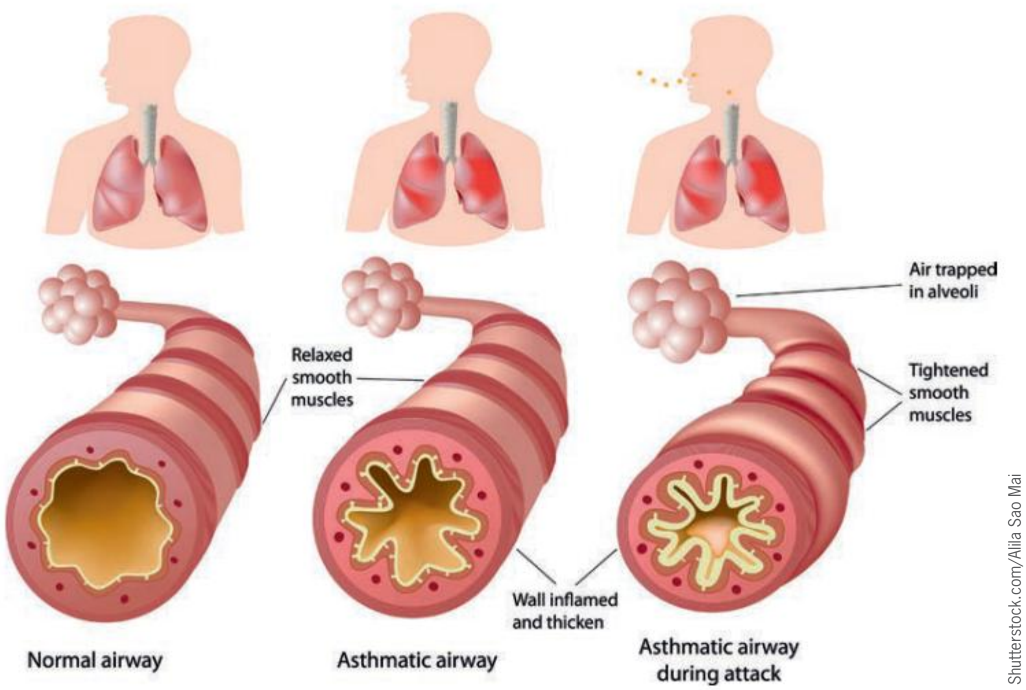

Figure 2.24 Inflammation response during an asthma attack

The killer inside you

Cancer is a common disease in the developed world. It results when cells start to divide uncontrollably, forming a **tumour**. This may occur because of a mutation due to a viral infection, exposure to radiation, inhalation of carcinogenic substances, a suppressed immune system or other reasons. Tumours can develop anywhere in the body. There are over 200 different types of cancer known so far: breast, ovarian, cervical, prostate, lung and colon cancer are probably ones that you have heard about.

tumour
a clump of cells that are dividing uncontrollably

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Cancer cells are produced from our own cells. Most will be destroyed within the first 24 hours by natural killer (NK) cells. These are generalist immune cells that circulate around our bodies destroying abnormal cells, such as virus-infected and cancerous cells. The NK cells kill cancer cells on contact. They inject a toxin that ruptures the cell membrane and breaks up the cell, killing it. Sometimes, cancer cells can occur further from the target tumour and evade destruction. If the NK cells and immune system are compromised, tumours can continue to grow. Some cancer cells are able to produce substances to fool the immune system that it is not a threat. Researchers at the Peter MacCallum Cancer Centre are currently working on a way to overcome these substances so the immune system can destroy the cancer cell.

WEBLINK
Immune system – natural killer cells

WOW!

Using nanocells to kill tumours

Australian scientists have developed a device (they have named EDV) that uses nanocells to penetrate and enter cancer cells. This device delivers drugs directly into cancerous tumour cells. This means that much less drug is required and there are fewer side effects, such as nausea and hair loss, than with conventional chemotherapy.

ACTIVITY 2.7

Which disease research to fund?

There are many diseases that affect humans. How do research institutes and governments decide which disease research to fund?

For this activity you need to work in groups of three. You are a team of medical researchers working at the University of Sydney. For the past three years you have been studying a specific disease that affects humans but your funding is about to run out. You need to apply for an extension of your funding so you can continue your research.

One group in the class will be allocated the role of Research Review Panel to **evaluate** each proposal for funding. There is a $100 000 grant available for disease research. The Research Teams will determine the focus of their research, which could be drug trials, education, prevention, transmission, or any other ideas they might have. They will then **propose** the research focus and justification to the review panel. It is a competition. There is only funding available for one project, or the panel may divide it between two projects.

WORKSPACE
Which disease research to fund?

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ACTIVITY 2.7

Your teacher will allocate each of the other groups a disease from the following list or you might be able to choose your own disease.

- AIDS
- Malaria
- Bird flu
- Tuberculosis
- Measles
- Alzheimer's disease
- Childhood obesity
- Breast cancer
- Cystic fibrosis
- Heart disease

What to do

Research teams	Research Review Panel
• Research an overview of the disease • **Identify** the focus for research priority. • **Summarise** a justification for funding, including statistics/data.	• Determine the criteria for **evaluating** and selecting the team that will receive the funding. • Prepare questions to ask the research teams to help you decide.

WORKSPACE
What have you learnt? 2.5

QUESTIONS 2.5

What have you learnt?

Understanding

1 **Distinguish** between infectious and non-infectious diseases.

2 **List** four factors that could influence the development of a non-infectious disease.

3 **Describe** how our immune system deals with a cancerous tumour.

Creating

4 **Construct** a flowchart to **show** the onset and treatment of an asthma attack.

2.6 Can plants get sick?

Members of the plant kingdom are also susceptible to invasion by pathogens. Bacteria, fungi, viruses and parasitic worms can all ruin the health of a plant. Unlike animals, plants do not have a circulatory system, so they do not have an army of killing and engulfing cells protecting them from the inside. But, like animals, they have physical and chemical barriers in their first line of defence. The external boundary of many plants is covered with slippery waxes and hairs to help fight off invading microbes. Any infected cells tend to die as a way of limiting the spread of infection. Disease resistance can occur in some strains of plants. Breeding, or engineering, for resistance is one way to protect important plants, such as crop foods, from becoming infected. In Australia, plant diseases can cost the agricultural industry more than $700 million per year.

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ACTIVITY 2.8

Quarantine matters!

In some ways, the airports and seaports of Australia are like our first line of defence against disease. It is important to take measures to keep new diseases out of Australia and to keep local disease from spreading between the states or territories.

Check the national and state government websites to learn more about quarantine rules at airports and borders. **Investigate** how we protect our borders and ourselves and complete the table below. Aim for two examples in each box.

Table 2.2
Australian quarantine rules and disease risks

At risk	Potential diseases or pathogens	Potential risk material or form of transmission
Humans		
Plants		
Animals/livestock		

WORKSPACE
Quarantine matters!

WEBLINK
Australian quarantine rules

WEBLINK
State quarantine rules

Invasion by bacteria: fire blight

Fire blight is a disease of apples (genus *Malus*) and pears (genus *Pyrus*). It is caused by the fire blight bacteria *Erwinia amylovora*, which attack the blossoms, flowers and twigs of a tree. Infected flowers turn brown and wilt; twigs shrivel and blacken, the ends often curling. In more advanced cases of infestation, cankers (discoloured oozing patches) form on branches. The reddish ooze contains masses of bacteria. This disease makes the apples or pears from the infected crop unsuitable for sale.

Sebastian Stabinger/Wikipedia, Creative commons

Figure 2.25
This shrivelled apple is affected by fire blight.

Fire blight was first recorded in 1794 on apples in New York. It has now spread to most of the world's apple-growing areas, including Canada, Mexico, New Zealand, United Kingdom, most of the European Union, Eastern Europe and parts of the Middle East. Fire blight was detected in

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the Melbourne Royal Botanic Gardens in 1997 but it was quickly eradicated. Australia is currently considered to be free of this disease.

Fire blight is easily spread by rain splashes, birds, insects and animals. An infected plant rubbing against another plant can also spread the bacteria. If plant tissue such as shoots or branches is damaged by hail or frost, then the normal defence mechanism is breached and the bacteria can invade the plant cells.

WORKSPACE
Fire blight – what do you think?

WEBLINK
New Zealand apples

quarantine
the strict isolation of people or countries to reduce the risk of unwanted pests and diseases entering a specific place

ACTIVITY 2.9

Fire blight – what do you think?

In 2011, the Australian Government agreed to allow the importation of apples from New Zealand. The government claims that our strict **quarantine** regulations will keep fire blight out of Australia, and protect our valuable apple-growing industry.

Read the articles at the adjacent weblinks. What do you think about the decision to allow New Zealand apples into Australia? Give reasons to support your point of view.

WORKSPACE
What have you learnt? 2.6

QUESTIONS 2.6

What have you learnt?

Remembering

1 **Identify** the physical barriers that plants use to defend themselves against invasion by disease-causing organisms.

2 **List** at least four ways in which plant diseases can be spread between plants.

Understanding

3 **Discuss** the statement: Plants do not have an immune system.

4 **Compare** airport security to our immune system.

Applying

5 **Explain** how you think fire blight would impact on the local commercial honey industry.

Evaluating

6 All permanent visa applicants aged 11 and over who wish to enter Australia *must* undergo a chest X-ray to check for tuberculosis. Those aged 15 and over *must* also undertake an HIV/AIDS test before being allowed entry. **Assess** whether or not you think these requirements are ethical and justified. **Discuss** whether or not Australia should keep these in place.

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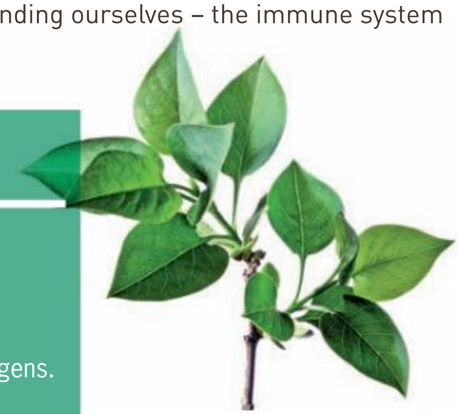

Chapter review

Remembering

1 **Describe** the three lines of defence that complex organisms use against invasion.

2 **Identify** three different barriers the human body creates to protect itself from pathogens.

3 **Describe** the advantages of delivering vaccines via nanotechnology.

Understanding

4 **Compare** and **contrast**:
- a macrophages and natural killer cells
- b natural and artificial immunity
- c how humans and plants combat invasion by disease-causing organisms.

5 **Recount** how foreign invaders are detected by cells in the human body.

6 You have cut your arm and after a while the skin goes red around the cut. **Explain** what is likely to be happening and how this assists in the healing process.

7 **Outline** how immunisation occurs, both naturally and via vaccination.

Applying

8 Rheumatoid arthritis is an example of an autoimmune disease, in which immune cells attack their own body cells. **Identify** which aspect of the immune system may have been damaged for this to happen. **Justify** your answer.

9 **Describe** at least three ways that you can help your body prevent an invasion by pathogens.

10 People often worry about 'germs' on food. However, all food that has been exposed to air, even food on a plate in the kitchen, is likely to be covered with millions of bacteria.
- a **Propose** reasons why these bacteria do not harm us when we eat them.
- b You might have heard of the 'three-second rule': as long as you pick up dropped food within three seconds of it hitting the ground it is still safe to eat. **Justify** or **refute** the validity of the three-second rule.

11 Re-read the information about the appendix on page 49.
- a **Identify** the hypothesis being suggested by the hospital records.
- b **Assess** whether or not the difference in the recurrence rates of patients with and without appendices could relate to the supply of beneficial bacteria stored in the appendix.
- c **Propose** some alternative explanations for the data, based on your knowledge of health.

Analysing

12 Our immune system makes memory cells that protect us from diseases we have had before. **Propose** an explanation for why we can still catch colds every year.

WORKSPACE
Chapter 2 review

ACTIVITY SHEET
Chapter 2 checklist

REVIEW QUIZ
Chapter 2

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13 Newborn babies are supplied with antibodies via their mother's milk. **Explain** why this is called passive immunity.

14 Diseases such as whooping cough were once common in Australia, but vaccination had almost eradicated them. However, whooping cough is becoming more common again.
   a **Investigate** the causes of this trend. **Summarise** your findings.
   b **Explain** why very young babies are most at risk from whooping cough today.

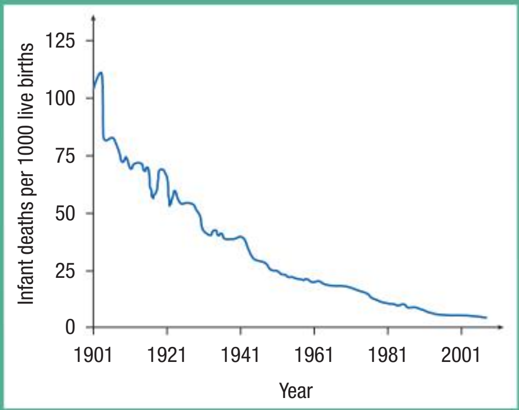

Figure 2.26 Infant mortality rate in Australia

15 The graph in Figure 2.26 shows infant mortality in Australia from 1901 to 2001.
   a **Describe** the trend shown in the graph.
   b **Propose** at least five reasons to **explain** the trend in the graph.
   c There are small increases in infant mortality around 1920 and 1940. How do you **account** for these increases?
   d Use resources to **compare** the rate of infant mortality in 1801 with the rate in 1901. **Account** for the difference.

Evaluating

16 **Critically evaluate** the problem of antibiotic resistance that has resulted from overuse and incorrect use of antibiotics. **Discuss** why you think members of the general public continue to insist on antibiotics when they have the flu.

Creating

17 Draw a flowchart to **show** the progress of a bacterial disease once it enters the human body. **Describe** the response by the human body to the bacterial infection.

Reflecting

18 **Identify** two things that have most surprised you about pathogens and how vertebrates respond to disease.

19 **Outline** how your views towards controlling human diseases have changed.

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3

Interactions in ecosystems

Why are interactions in ecosystems important?

The wet, tropical rainforests of Australia and Papua New Guinea are full of tall trees and shrubs that burst into bright flowers and, later, have large and small colourful fruits. Many tropical trees with large fruits can only disperse their seeds if their fruits are eaten by cassowaries. As cyclones, weeds and feral pigs disturb these ecosystems, the interaction of cassowary and fruit tree is placed more and more at risk. What will become of our tropical ecosystems if we cannot conserve this essential interaction?

Nature Picture Library/© Kevin Schafer

Living world – Stage 5

Key knowledge

- Ecosystems are made up of communities of organisms interacting with the abiotic factors in the environment.
- Matter such as carbon, nitrogen and phosphorus is cycled through ecosystems.
- Energy flows, but does not cycle, through food webs and ecosystems.
- Biotic and abiotic factors can affect populations and communities in an ecosystem.
- Sustainable practices used by Aboriginal and Torres Strait Islander peoples can be applied to ecosystem management.
- Sustainable use of the environment can be balanced with other human activities such as mining and recreation.

ACTIVITY SHEET
CAT with rubric: Science news team

CULMINATING ASSESSMENT TASK

Science news team

You will work in a small group. Choose a recent major event that caused changes to one or more ecosystems. This could be an oil spill, an earthquake, a cyclone, a flood or a fire, for instance.

Prepare a video of your news report(s), or perform it live for the class. You may choose to prepare a single five-minute news spot, or a series of one- or two-minute items to report on the initial devastation and later updates, including a follow-up. Be sure to **discuss:**

- the cause of the change
- reasons why we should be concerned
- how the change could affect the ecosystem and humans
- what action people could take if necessary.

Investigate thoroughly and **explain** the situation and impacts for a general audience. You must ensure that you have evidence to back up any claims you make.

Remember, people can change the channel easily, so be engaging and keep people watching. You can enhance your report with photographs and/ or an interview with an expert.

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What do you already know about ecosystems?

Think, pair, share

Part A

1 **Recall** what you have previously learned about ecosystems. **Propose** an example of an ecosystem you are familiar with from anywhere in the world and **identify** examples of the following:
  a a food chain and a food web
  b a producer and a consumer in the food chain
  c the habitat for one of the consumers
  d a population
  e three biotic and three abiotic factors
2 **Discuss** your thoughts with a classmate.
3 Combine your shared thoughts with the class to **define** each term.

As you progress through this topic, add important facts to your choice of graphic organiser. This will become a summary of all the important points in the chapter and will be useful when you review the main topic points.

WORKSPACE
What do you already know about ecosystems?

3.1 What is an ecosystem?

An **ecosystem** is a community of organisms and their non-living environment. A **biome** is a collection of ecosystems with similar climatic conditions. Major Australian biomes are water (fresh and salt), **rainforest**, **savannah**, **grasslands** and **deserts**. Other major world biomes are the **tundra**, **taiga** and **deciduous forests** that circle the northern hemisphere. Ecosystem and biome patterns are shaped by climate, and climate depends on geography (see Figure 3.1).

Biomes can have different ecosystems within them, depending on the species present. By definition, an ecosystem is the result of the interactions between all the **communities** of living organisms (**biotic** factors) in an area and their physical environment (**abiotic** factors).

The Australian Alpine ecosystem

The combination of snow gums (*Eucalyptus pauciflora*) and snow (Figure 3.2a) can only be found in an Australian alpine ecosystem. Many other alpine plants – mosses, buttercups and grasses – are adapted to alpine ecosystems in other countries. The plants support an assorted group of animals, including **endemic** species such as the mountain pygmy possum and the corroboree frog. These are some of the biotic components of our alpine ecosystems.

ecosystem
a community of organisms and the non-living environment in which they live

biome
a collection of ecosystems with similar biotic and abiotic factors

rainforest
a dense evergreen forest with a very high annual rainfall

savannah
grassland with small, widely spaced trees

grassland
wide, open ecosystems dominated by low vegetation, particularly grasses

desert
a landscape that receives less than 250 mm precipitation or rain annually

tundra
a treeless biome north of taiga, with only low vegetation and permafrost

taiga
a large terrestrial biome characterised by coniferous forests

deciduous forest
a forest in which a majority of the trees lose their foliage at the end of the typical growing season

community
a collection of organisms (different species) in one place

biotic
a living part of the environment or ecosystem

abiotic
a non-living part of the environment or ecosystem

endemic
occurring only in a specific region

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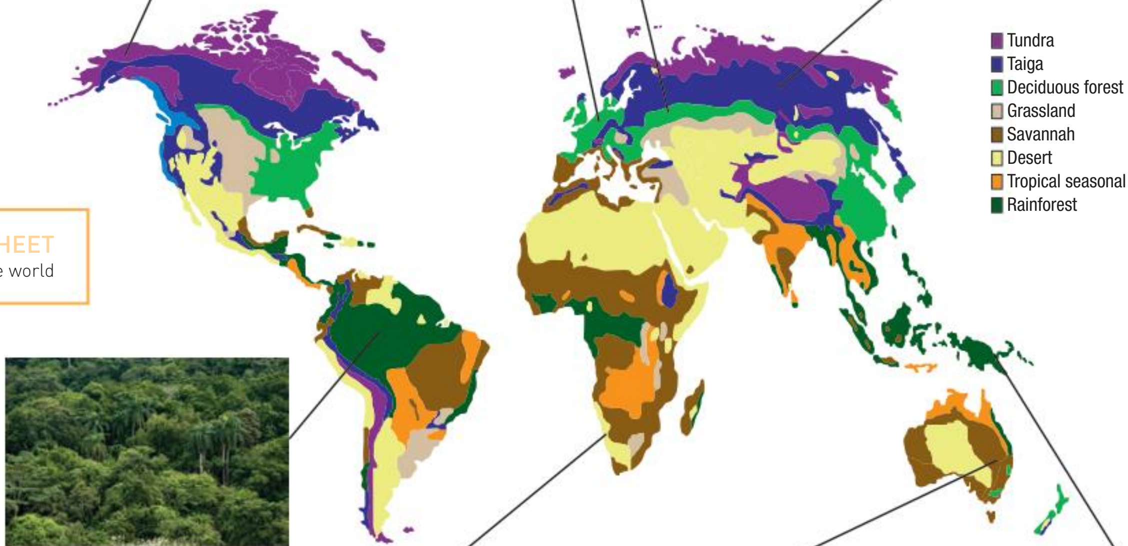

ACTIVITY SHEET
Biomes of the world

ACTIVITY SHEET
Who, what, why, when, where and how?

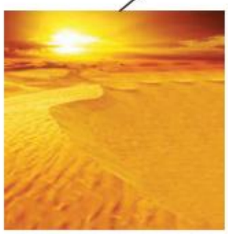

Figure 3.1
Major biomes of the world

a

Shutterstock.com/shawshot

b

Getty Images/Paul Sinclair Photography

Figure 3.2
a Winter and **b** summer in the Australian Alps

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To survive in this environment organisms must be adapted for life within a temperature range of –7 to 29°C. As well as temperature, other abiotic factors such as soil type and water availability determine what vegetation can survive. This then determines which animals can survive here.

Although the winter cold prevented humans living in the Australian Alps permanently, the region's deep Aboriginal history is revealed in its place names. The *bogong* (which means 'mountain' in a regional Aboriginal language) were an annual destination for *cori*, a migratory moth that avoids the summer heat by sheltering in cool cracks in the Alps' granite boulders. Bogong moths hang together in their thousands, and are easily harvested and prepared for eating by roasting.

Over at least 20000 years, during Australia's rich pre-European history, the moths provided humans with an important source of protein. Annual moth feasts attracted dozens of tribes, several from up to a 100 km away. Undertaking these journeys required diplomacy and often involved trade. Many, many thousands of people attended these cultural gatherings every year.

WEBLINK
Mountain pygmy possum feeding on Bogong moths

Simpson Desert ecosystem

The drainage area of The Great Artesian Basin in central Australia includes the huge Simpson Desert ecosystem. This diverse environment includes **ephemeral** salt lakes such as Lake Eyre. The plants are all drought-resistant due to the limiting abiotic factor of water availability. Examples are canegrass and spinifex, deep-rooted coolabah trees (*Eucalyptus coolabah*) and mulgas (species of *Acacia*). Invertebrate animal species, such as ants and scorpions, number in their thousands.

ephemeral
temporary, lasting only a short time

Shutterstock.com/Light & Magic Photography

Figure 3.3
Deserts are not necessarily barren: they support many organisms that are highly adapted for conserving water.

The secret of the desert's high biodiversity is that individual species are adapted to the extreme abiotic features of this ecosystem. High daytime temperatures and cool night temperatures, along with sparse water and abundant sunlight make this environment a challenge for most organisms. Some have adapted by being tiny. Others, such as annual plants or the brine shrimp found in Lake Eyre, can survive decades of drought as seeds or eggs.

ICT

Use Google Earth to locate each of the Australian biomes mentioned in this section. In what state(s) are they located?

ISBN 9780170231503

WORKSPACE
Australian biomes

ACTIVITY 3.1

Australian biomes

1 For the alpine and desert ecosystems described in this section, **identify**:
   a a producer and a consumer
   b a climatic factor that is different between desert and alps
   c the biome to which each ecosystem belongs.

WORKSPACE
What have you learnt? 3.1

QUESTIONS 3.1

What have you learnt?

Remembering

1 **Define** biome.

2 **List** the major Australian biomes.

Understanding

3 **Explain** the relationship between ecosystem, climate and geography.

4 **Predict** whether or not a snow gum tree could survive in a rainforest ecosystem. **Outline** some survival challenges it might face if it was moved to this tropical ecosystem.

3.2 The components of ecosystems

The term 'ecosystem' can apply to an area as small as a pond or as large as Earth itself. In order to understand ecosystems, we look at the biotic and abiotic features and study the interactions within and between these features.

ACTIVITY SHEET
Measuring temperature and humidity

ACTIVITY SHEET
Measuring soil pH

Abiotic factors

Abiotic factors are the non-living components in an ecosystem. These include features such as temperature, water availability, light levels, nutrient availability, soil type and soil pH. Abiotic factors account for many of the reasons for the distribution of vegetation on Earth, as well as many of the adaptations of organisms in that environment. The distribution of vegetation in Earth's biomes shows the importance of abiotic factors such as temperature, light levels and rainfall. As well as these geographic features, plants and all the organisms they support through food webs depend on a variety of nutrients.

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Table 3.1
Examples of key abiotic factors

Temperature	Temperature plays a major role in determining what can survive in an ecosystem. Many organisms cannot survive when temperatures drop below the freezing point of water. As temperatures increase it is often water availability, rather than heat, that restricts life.
Water availability	Water availability incorporates precipitation (rain, hail, snow) and humidity (water vapour in the air). Plants can absorb and use water vapour from the air, even if the soil is dry. When water is in short supply plant growth is limited.
Light availability	Sunlight provides the energy for almost all life on Earth, so its availability directly limits what can grow. Deep in a forest with a dense canopy, light availability will determine what life can be sustained. Plants that live in dense forest may have large leaves, to catch what little sunlight penetrates. In aquatic ecosystems, light does not penetrate far through water, and any particles or **turbidity** in the water restrict this even further. This limits plant and producer growth in water.
Nutrient availability	Plants rely on air, water and sunshine for their energy and carbon requirements. However, they must also obtain other elements from the soil, most importantly nitrogen and phosphorus, for making DNA and proteins.
Soil type	Soil type can determine the nutrient availability and water retention of the soil. The main types of soil, such as clay or **loam**, are defined by their particle size. The pH of soil determines the availability of some of its nutrients, as well as what can grow there.

ACTIVITY SHEET
Student investigation: How does salinity affect plant growth?

Biotic factors

Biotic factors are the members of the community within an ecosystem; that is, all the living components in an ecosystem, without the abiotic components. They include all of the members of each **population** of each species. In general terms, this includes producers, consumers and decomposers. More specifically, these members could be classified in a variety of ways: parasites, scavengers, **competitors**, **predators**, **prey**, pollinators, herbivores, carnivores, frugivores (fruit eaters) and more.

From your previous studies, you should recall that plants are known as **producers**. This is because they produce their own simple sugars using the energy from the sun. A rabbit is a first-order **consumer** as it eats the producer. A predator of the rabbit, such as a fox, is a second-order consumer. This relationship can be shown as a simple **food chain**. Many food chains in an ecosystem can be interlinked to form a **food web**. Food webs show the feeding relationships within an ecosystem.

turbidity
cloudiness of a solution

loam
soil with a mixture of sand, clay and organic matter

population
a number of individuals of one species living together

competitors
organisms that require the same resources from the same habitat

predator
an organism that kills and eats other animals

prey
an organism that is used as food

producer
an organism that creates its own chemical energy store from simple substances such as carbon dioxide and water through photosynthesis; also known as an autotroph

consumer
an organism that must consume other organisms to gain chemical energy; also known as a heterotroph

food chain
a single linear diagram that shows the way energy is transferred from producer to consumer

food web
a group of food chains interlinked to show how energy is transferred through an ecosystem

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pyramid of numbers
a diagram that shows the number of organisms that exist at each successive level of a food chain

trophic level
an organism's position in a food chain

Food chains can also be represented as a **pyramid of numbers** to show the number of organisms at each **trophic level** (Figure 3.4). A trophic level is a feeding level in a food chain, such as producer, first-order consumer and second-order consumer. Typically, there are more organisms at the first trophic level than at the fourth level. For instance, there are many plants, which are eaten by many types of invertebrates, which are eaten by fewer insectivores, and which, in turn, are eaten by even fewer carnivores.

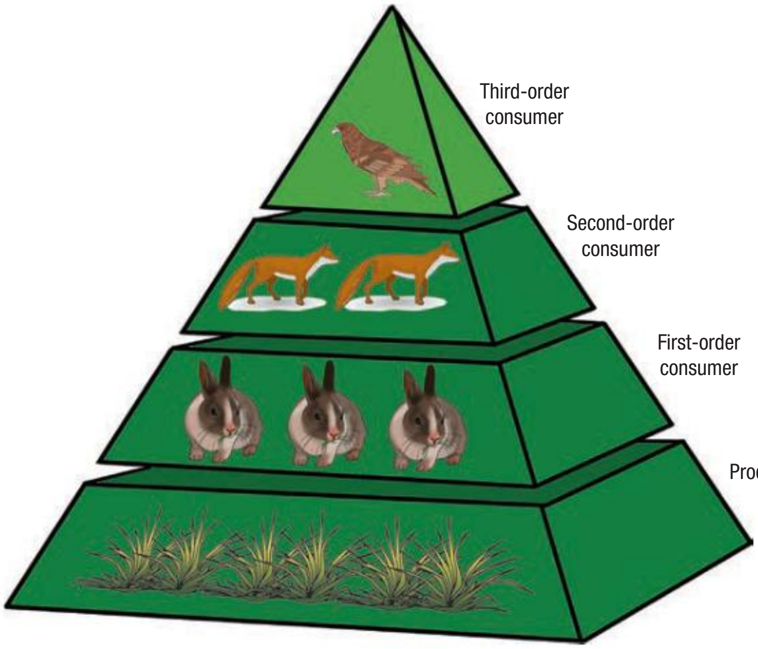

Figure 3.4 Each level in this pyramid represents a trophic level in the food chain.

Measuring biotic factors in an ecosystem

distribution
where organisms live

abundance
how many organisms there are

transect
a strip of land used for estimating population and distribution

quadrat
equal-sized areas that cover a representative sample of the area being studied

To record what has been happening in an ecosystem, we need to try to measure what lives where (species **distribution**) and how many there are (species **abundance**). However, biotic factors, being living, are often harder to measure than abiotic ones. Organisms reproduce or die all the time, and in the case of animals, movement, immigration and emigration occur too. Many animals hide in burrows, avoid humans, or range over vast areas. In the case of insects the numbers are often so vast we cannot possibly count them all. We tend to make estimates rather than actual counts of population sizes.

The distribution of organisms changes significantly as factors, in particular abiotic factors, change; for instance, as you move up a mountain from the lowlands. **Transects** are used to measure the distribution and abundance of species or members of populations along a line. To estimate a population's size we count what we believe is a representative sample and then extrapolate to estimate the population in the total area in question. We can measure a sample within a series of **quadrats**. If the organisms being counted are small enough, such as new seedlings or ants, quadrats can be as little as a quarter of a square metre. If the organisms are sparse, rare or large, for example trees, the quadrats could be larger than 100 m^2.

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Figure 3.5
Transect lines can give information about how the distribution of organisms changes, as well as their abundance.

ACTIVITY SHEET
Transects in the tropics

ACTIVITY SHEET
Critters in the litter

The **capture–mark–recapture method** is frequently used to estimate the size of a population whose members move. A number of animals are captured and marked in some way. The animals are then released back into the area. After allowing time for the marked animals to disperse randomly through the population, a second group of animals is then collected and counted. The population is then calculated using the formula:

capture–mark–recapture method
a method for estimating populations of mobile organisms like animals

$$\text{Population size} = \frac{\text{number of animals in first sample} \times \text{number of animals in second sample}}{\text{number of animals recaptured (marked animals in second group)}}$$

ACTIVITY SHEET
Capture–mark–recapture

Figure 3.6
This bird has been captured and is being marked with a band around its leg before being released again.

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WORKSPACE
What have you learnt? 3.2

QUESTIONS 3.2

What have you learnt?

Remembering

1 **Identify** five biotic factors that occur within an ecosystem.

2 a **Identify** the abiotic components in the list below.

Wind	Parasites	Nitrifying bacteria
Mycorrhizae	Sunlight	Oxygen levels
Soil chemistry	Acidity (pH)	Pollinators
Altitude (height)	Legumes	Water availability

b For each abiotic factor in the list, **describe** how you would measure it.

Understanding

3 **Explain** the difference between abundance and distribution and **describe** how you would determine each one.

Applying

4 Would you **classify** pollutants as biotic or abiotic factors? **Explain** your answer.

Analysing

5 Different methods are used to estimate different populations of organisms. For each of the following populations **identify** the best method for estimating their population and **explain** your choice.

a Pygmy possums
b Spinifex grass
c Cane toads
d *Streptomyces* bacteria, which live in the soil

3.3 Relationships within ecosystems

Competition

niche
the very particular place within the habitat, and the role in the environment in which an organism lives

The term **niche** applies to an organism's role in the ecosystem. Two different types of organisms cannot occupy the same niche without competing. Competition is greatest between members of the same species because they have exactly the same requirements. They compete for the same food, shelter and mate resources.

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A **habitat** is the place in an environment in which an organism lives; for example, a tree hollow. There is both **intraspecific** and **interspecific competition** for tree hollows across Australia. Because there is usually great competition for available feeding and breeding sites, the availability of habitats can limit the size of a population or its distribution.

habitat

the place in an environment where species are found in an ecosystem (such as soil, leaf litter, tree tops)

Auscape/© Jean-Paul Ferrero

Auscape/© John Shaw

Figure 3.7
a Intraspecific competition – yellow-bellied gliders compete with each other for tree hollows.
b Interspecific competition – yellow-bellied gliders compete with powerful owls for tree hollows.

Organisms can reduce intraspecific competition in several ways.

- They migrate at different times of the year. For example, when coral spawning occurs on Ningaloo Reef, large numbers of whale sharks converge on the area to feed. However, when food is not so abundant, the whale sharks live alone in the open ocean.
- The organisms use different niches at different times of their life cycle. For example, tadpoles are only aquatic and eat vegetation, but frogs can be found on land as well and are carnivorous. In this way, they do not compete for food with members of their own species.

As populations grow, competition for shelter and food increases between members of a species.

intraspecific competition

competition between members of the same species

interspecific competition

competition between members of different species

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EXPERIMENT 3.1

Student investigation: Competition experiment

Choose *one* of the following tasks.

A **Investigate** what happens when two organisms (different species) compete for the same conditions. Select two organisms, preferably plants, and **design** an experiment that **compares** their growth using different initial starting populations as your experimental variable.

OR

B **Compare** the growth of two similar organisms under different environmental conditions, starting with the same population size.

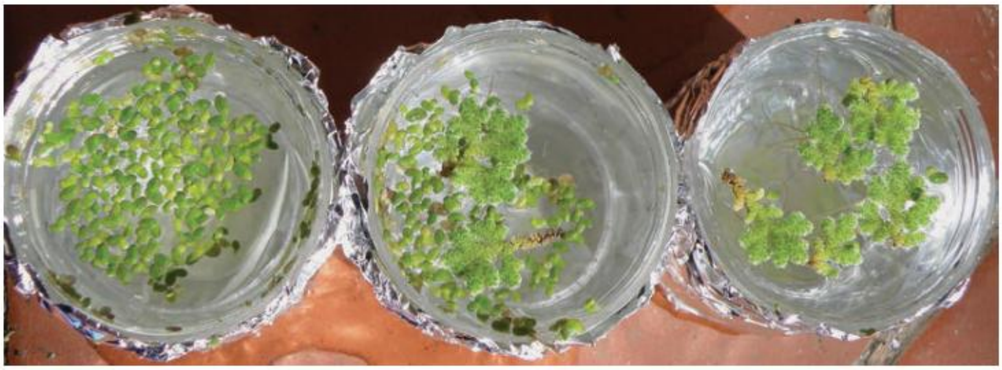

Figure 3.8 Water plants such as the fern *Azolla* and duckweed could be used for this investigation. Grasses or grains, such as rye or oats, are also good possibilities.

The weblinks may assist you in setting up your experiment.

WEBLINK The virtual greenhouse

WEBLINK The virtual field

WEBLINK Effects of rabbit predation on two species of plants

Hints

1 Refer to the appendix to follow the scientific method.

2 Determine your aim, hypothesis, independent variable, what you will measure (for example, leaf height, leaf surface area or biomass), the variables you must control, and the duration of your experiment.

3 **Design** your method. If you will be destroying some of your samples during periodic harvests, ensure you have enough. How many replicates will you need? Take photos or make sketches along the way.

Presenting your results

It is common for scientific conferences to include 'poster sessions', where delegates can visit several presenters who discuss their research.

Your investigation report on your poster must include all of the standard scientific report categories, from aim to conclusion. In your discussion, as well as **analysing** your results, be sure to **discuss** how your findings apply to real Australian ecosystems.

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Symbiosis

Symbiosis refers to a close physical relationship between two organisms that benefits at least one of them. Symbiotic relationships include **mutualism**, **commensalism** and **parasitism**.

Mutualism

Mutualism is a relationship in which two organisms live together and each benefits from the other. These are quite common. One example is the relationship between **mycorrhizae** fungi and the plants whose roots they colonise. The fungus, unlike the plant, is able to extract phosphorus from the soil, which it shares with the plant. The plant in return provides the fungus with glucose from photosynthesis.

Many **lichens** are also the product of a mutualistic relationship. They are made of a fungus and an alga, living together. The fungus protects the alga from dehydration and it is able to extract nutrients from the rock on which it lives. The alga photosynthesises and feeds the fungus in exchange for these nutrients.

symbiosis
interaction between two organisms that live in close proximity, benefitting at least one of them

mutualism
a close physical relationship between species in which both benefit

commensalism
a close physical relationship between species in which only one benefits and the other is not harmed

parasitism
a close physical relationship between species in which only one benefits and the other is harmed

mycorrhizae
fungi that live symbiotically on plant roots, helping the absorption of nutrients

lichen
a composite organism that is made from a fungus and an alga

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Figure 3.9 Lichen is an example of a mutualistic relationship.

Nitrogen-fixing bacteria, which will be covered in more detail later, also have mutualistic relationships with the plants whose roots they inhabit.

About 80% of flowering plants depend on other organisms such as birds and insects to distribute their pollen. Plants have mutualistic relationships with **pollinators**. The plant provides nectar (food) to the pollinator and the pollinator carries pollen from one plant to another to allow fertilisation (Figure 3.10). Approximately a third of the global human diet directly consists of food that is pollinated by honeybees. This estimate becomes very much higher if we include food that indirectly depends on bee pollination, such as meat that is raised on commercially grown alfalfa (which is pollinated by bees).

nitrogen-fixing bacteria
bacteria that incorporate nitrogen gas to form compounds such as nitrates that can be absorbed by plants

pollinator
an organism that assists in the transfer of pollen from the male part (anther) of a flower to the female part (stigma) of a flower

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WEBLINK
Bees and deceitful plants

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Shutterstock.com/gallimaufry
Shutterstock.com/David Schnerch

Figure 3.10 Four examples of pollinators. **a** Plants that rely on flies for pollination often smell of rotting flesh. **b** Bird-pollinated flowers are often red in colour. **c** Flowers pollinated by mammals usually have a yeasty smell, particularly at night. **d** Buzz pollination uses the vibrations of flying bees to release pollen.

WORKSPACE
C&S bees?

extinct
having no living members

VIDEO
How rhododendrons dominate a habitat

ACTIVITY 3.2

C&S bees?

The purpose of a consequence and sequence (C&S) analysis is to explore various time frames for consequences of an action. In this case, consider the consequences if bees were to become **extinct**.

1 **Describe** the immediate consequences of bees becoming extinct.
2 **Describe** the short-term consequences (1–2 months) of bees becoming extinct.
3 **Describe** the medium-term consequences (3–5 years) of bees becoming extinct.
4 **Describe** the long-term consequences (10+ years) of bees becoming extinct.

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Commensalism

Commensal relationships benefit one organism and leave the other unharmed. These relationships are much rarer than mutualism or parasitism, and are often disputed. One example is the relationship between cattle and cattle egrets. The egrets sit on cattle and eat the insects they stir up as they walk, and have no impact on the cattle. Another example is that of clownfish living among the arms of stinging anemones. The clownfish are protected from predation, but the anemones do not gain any benefit. Some sources, however, say that the clownfish and anemone relationship is a mutualistic one.

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Figure 3.11 These clownfish on the Great Barrier Reef benefit by sheltering in the stinging tentacles of the anemones.

Parasitism

This type of relationship benefits one organism at the expense of another. Mistletoe is a parasitic plant that sucks the sap from the tree that hosts it, depriving the tree of water and nutrients. Tapeworms, fleas, mosquitoes and leeches are all parasitic.

Science Photo Library/CLOUDS HILL IMAGING LTD

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Figure 3.12 Parasitic relationships benefit only one partner in the association. In these examples, how is the other species in the relationship being harmed? **a** Mistletoes do not have roots, but special structures tap into the water-conducting tissues of host trees. **b** This tapeworm is one example of an internal parasite. It uses the hooks at the top to attach itself to the intestinal wall and it feeds on the host's food. **c** The Australian koel lays its eggs in the nests of red wattlebirds, friarbirds and magpie-larks, which then feed and raise the chicks with their own.

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Predation

Parasites rarely kill their host because, if they do, they too will die. Predators, however, do kill and eat their prey. If the prey population increases, more predators can be supported; but this then reduces the numbers of prey again, which reduces the number of predators. However, the relationship is not simply about the numbers of each organism, and this will be looked at in more detail in the section on energy flow.

WORKSPACE
What have you learnt? 3.3

WEBLINK
Killer whales hunting greys in Alaska

QUESTIONS 3.3

What have you learnt?

Understanding

1 **Identify** the niche each of the following organisms would occupy in an ecosystem.
   a Kangaroo
   b Eucalypt tree
   c Eagle
   d Fungus

2 **Define** the term 'trophic level'.

3 **Explain** how a trophic level is different from a niche.

4 Are all the animals in the weblink 'Killer whales hunting greys in Alaska' on the same trophic level? Determine the types of feeding behaviours that are represented.

Applying

5 **Classify** the following symbiotic relationships as parasitic, commensalistic or mutualistic. **Explain** your choice.
   a Remoras attach themselves to sharks, manta rays and other large ocean predators with their modified dorsal fin, which acts like a sucker. They scavenge leftover food and sometimes faeces from their hosts.
   b Pygmy possums feed on nectar and pollen from *Banksia* and eucalypt plants, among other things. They are important as pollinators of *Banksias*.
   c Goby fish often live with burrowing shrimp in a burrow. The shrimp are almost blind, but dig and clean the burrow. The goby fish acts as a watch dog, warning the shrimp of potential danger by touching it.
   d Phytophthora is a disease caused by the soil fungus *Phytophthora cinnamomi*. The fungus grows through the root system (and sometimes the stem) of a plant, feeding on it, destroying it and preventing the plant from absorbing water and nutrients.
   e Epiphytes such as orchids are plants that grow on the trunks of trees. They benefit by capturing light energy and precipitation (rain) and appear to do no harm to the trees.

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3.4 Matter cycling and energy flow in ecosystems

Carbon cycle

All life forms on Earth are carbon based. Carbon cannot be created or destroyed, so it is cycled through the ecosystem. Plants take in carbon as carbon dioxide from the air. They combine it with water from the soil (or air), using **chlorophyll** and light energy from the sun, to build glucose by photosynthesis. Glucose made by plants serves three purposes.

1. Plants use it as a source of energy, which is later released by **respiration**. They use this energy to actively transport nutrients in through their roots, to make other chemicals for use in their cells, and for other processes such as mitosis and reproduction. Respiration returns carbon to the atmosphere as carbon dioxide.
2. Plants use glucose as a building block for their bodies. The cells that make up all plants are made from chemicals built primarily from carbon, hydrogen and oxygen, and these are supplied by the glucose made in photosynthesis.
3. Glucose that is not needed to build the plant or to be respired for energy is stored as starch or oils.

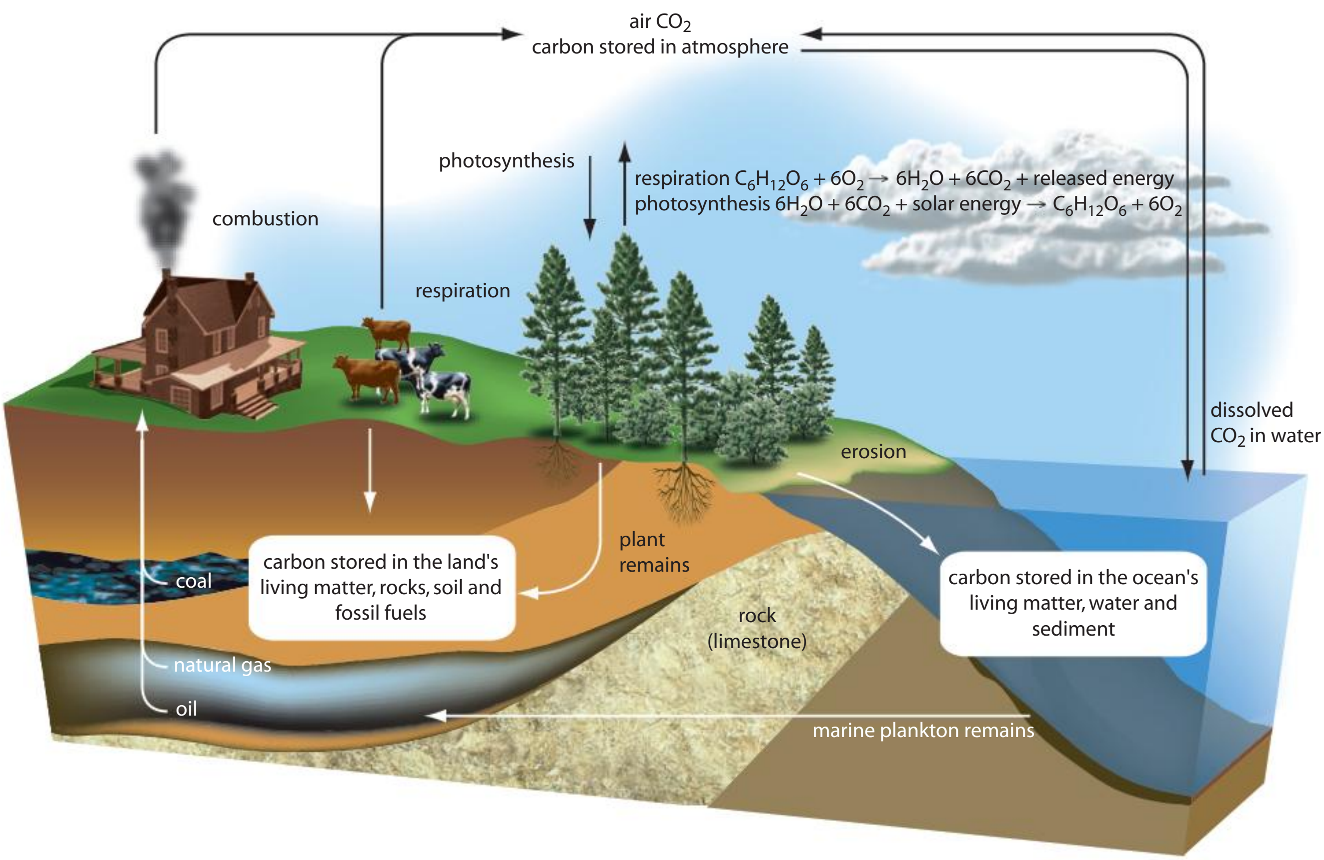
chlorophyll
the green photosynthetic pigment in chloroplasts of plants

respiration
a series of chemical reactions that release chemical energy (and water and carbon dioxide) for use by an organism

WEBLINK
Photosynthesis

WEBLINK
The carbon cycle

Figure 3.13 The carbon cycle shows how carbon is moved through the ecosystem. Photosynthesis is the major means by which it enters the ecosystem.



As well as carbon, hydrogen and oxygen, there are other trace elements that are necessary for life. The most important of these are nitrogen and phosphorus. These are obtained from the soil.

Nitrogen cycle

All organisms use nitrogen to build the proteins and nucleic acids (DNA and RNA) that are essential for life. But where do they get their nitrogen from?

Although nitrogen gas (N_2) forms 80% of the atmosphere, very few organisms can access and use it in this form. Most consumers need to obtain nitrogen from their food. Plants (producers) can only take in nitrogen as ammonium (NH_4^+) or nitrate (NO_3^-) ions. The formation of these ions from nitrogen gas is called **nitrogen fixation**. Once incorporated into plants, nitrogen flows through the food web as animals eat plants or other animals. Nitrogen from animal wastes, including dead animals, is recycled when it is returned to the soil as nitrates or ammonium ions by decomposers. Plants can then absorb it through their roots.

nitrogen fixation
the process of incorporating nitrogen gas from the atmosphere into compounds such as nitrates that can be absorbed by plants

Nitrogen fixation is done by lightning or microbes.

WOW!

It's raining fertiliser

Electrical storms fix about 5% of the Earth's nitrogen. The intense energy in lightning combines nitrogen and oxygen gas to produce nitrogen oxides. These compounds dissolve in rain, forming nitrates. In an electrical storm it really does rain fertiliser!

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Microbes are the most important natural source of nitrogen in ecosystems. Several types of nitrogen-fixing bacteria contribute to nitrogen fixation.

- Cyanobacteria (sometimes called 'blue-green algae') fix nitrogen in aquatic ecosystems, such as ponds and rivers.
- *Rhizobia* bacteria live in the root nodules of peas and beans (Figure 3.14) and fix nitrogen in terrestrial ecosystems. In this mutualistic relationship, plants protect the *Rhizobia* and supply them with nutrients, and in return receive nitrogen compounds that the bacteria have made from nitrogen in the air.

Human activity can also provide ecosystems with nitrogen, mostly as synthetic fertilisers, which boost food production. The amount of nitrogen supplied by fertilisers is now similar to the amounts produced by legumes. This has almost doubled the nitrogen available to ecosystems, and increased productivity.

Nitrogen is returned to the atmosphere by **denitrifying bacteria**, which convert the nitrogen compounds back to atmospheric nitrogen. These reactions are enhanced in **anaerobic** conditions, such as waterlogged soils or polluted water bodies.

denitrifying bacteria

bacteria that break down nitrogen compounds, producing nitrogen gas

anaerobic

without oxygen

Science Photo Library/Dr. Jeremy Burgess

Figure 3.14
Rhizobia in root nodules can fix nitrogen from the atmosphere.

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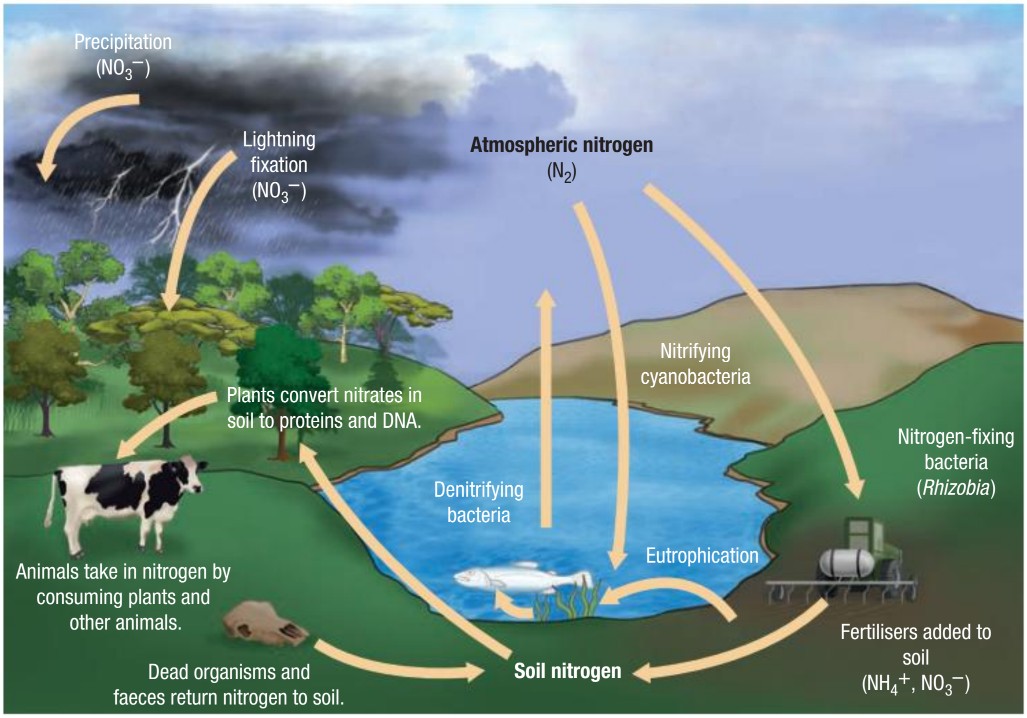

VIDEO
The nitrogen cycle

Figure 3.15 A visual representation of the nitrogen cycle in an ecosystem

The phosphorus cycle

Phosphorous also cycles through ecosystems. All organisms use phosphorus in their cell membranes and nucleic acids, and in the molecules that transfer energy in cells. Vertebrates also use phosphorus with calcium in their bones and teeth. Phosphates originally come from rocks. They enter ecosystems when rocks containing phosphate minerals are weathered, releasing phosphate ions into soil or water. Phosphate is absorbed into plants through their roots. Once incorporated in plants, phosphate flows through the food web as organisms consume other organisms.

Getty Images/Science Photo Library

Figure 3.16 Many Australian plants have mycorrhizae fungi to help them absorb phosphates. This Banksia, however, has proteoid roots, which have a very large number of filaments and hairs that absorb the scarce nutrients in the soil without the help of fungi.

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Figure 3.17 Fertilisers are added to the soil to replace nitrogen and phosphorus.

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ACTIVITY 3.3

The iron cycle

In most ecosystems, iron is a micronutrient. Based on what you learnt about oxygen carriers in Chapter 1, how might iron be used in krill, a type of pink crustacean that lives in the Southern Ocean?

Getty Images/Science Photo Library

Figure 3.18 Krill

Go to the weblink 'Iron whales' to follow the flow of iron in the food chain.

1 Sketch a diagram that **outlines** the iron cycle in the Southern Ocean.
2 If humans were to harvest krill in large quantities, **predict** how this could change the iron cycle.

WORKSPACE
The iron cycle

WEBLINK
Iron whales

Energy flow in ecosystems

Food chains and food webs always start with producers because they are the organisms that can trap carbon dioxide from the atmosphere and turn it into useable organic carbon compounds by photosynthesis. This also traps energy in a usable form. Producers also bring other elements into the **biosphere**, like nitrogen and phosphorus. Other organisms rely on plants to do this. In a food web, the trophic level refers to the position an organism occupies, starting with producers. **Herbivores** are first-order consumers. **Carnivores**, **scavengers** and **decomposers** can occupy a range of levels. It is not only matter (carbon, oxygen, hydrogen, nitrogen and phosphorus) that passes from the producers to the consumers and finally through to the decomposers; energy follows this path too. However, unlike matter, it is not recycled. Energy flows, matter cycles. Once converted or lost in the ecosystem, the energy cannot be recaptured. More energy must enter the ecosystem by photosynthesis.

biosphere
the land, water and gas around Earth that is habitable by living organisms

herbivore
an organism that feeds solely on plants

carnivore
an organism that feeds solely on animals

scavenger
an animal that eats meat that has been abandoned by predators, rather than hunting for itself

decomposer
a micro-organism, such as a fungus or bacterium, that breaks down dead matter

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Plants are very efficient with the energy they trap. They do not move much or generate much body heat, and so only a small portion of the glucose they make in photosynthesis is required. The rest is used to build their bodies, or stored as starch or oil. It is the energy stored in their bodies that is available to the next trophic level. Luckily for us, plants make a lot more glucose than they really need themselves, so plants can support almost all other life on the planet.

Animals are much less energy efficient than plants. They respire at a much higher rate, particularly mammals and birds, which must maintain their body at a constant warm temperature. Most of the food they eat is respired to provide energy for body heat and movement, and for cellular processes such as active transport, mitosis and the manufacture of the chemicals of life. Most of the carbon that animals obtain from their food is ultimately breathed out as carbon dioxide.

WORKSPACE
Carnivores and their prey

ACTIVITY 3.4

Carnivores and their prey

1 Draw a line to match the carnivore in the left-hand column to the prey in the right-hand column.

Cat	Feral pig
Saltwater crocodile	Moth
Eastern longneck tortoise	Mouse
Grey wagtail	Lizard
Fox	Yabby
Kookaburra	Cricket
Microbat	Rabbit
Scrub python	Bandicoot
Antechinus (marsupial mouse)	Spider, small insects

2 For every predator in the table, try to find an organism that preys on it.

At every trophic level, energy is lost. Any predator that eats an animal will not have the benefit of all the energy in all the food its prey consumed in its lifetime. It will only be able to extract energy from what was converted into the body of the prey.

We might expect organisms to get smaller as we go up the food chain, as less energy is available to them, since the organisms they eat have respired most of what they ate. Or we might expect higher level consumers to become fewer in number. However, there is no clear-cut relationship between size or number of organisms and trophic level. Sometimes organisms at the top of a food chain are much smaller and more plentiful than the organisms they feed upon. Sometimes they are larger or fewer, such as whale sharks feeding on plankton.

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Figure 3.19
The whale shark is one of only three shark species that eat plankton.

For this reason the concept of **biomass** is introduced. Biomass is the total mass of living things, whether it is an individual species, such as fleas or whales, or a community, such as all the top level predators in one ecosystem. The total biomass decreases as you go up in trophic levels. The total mass of a whale is much smaller than the total mass of the plankton it eats. We call this a pyramid of biomass.

biomass
the total mass of living things

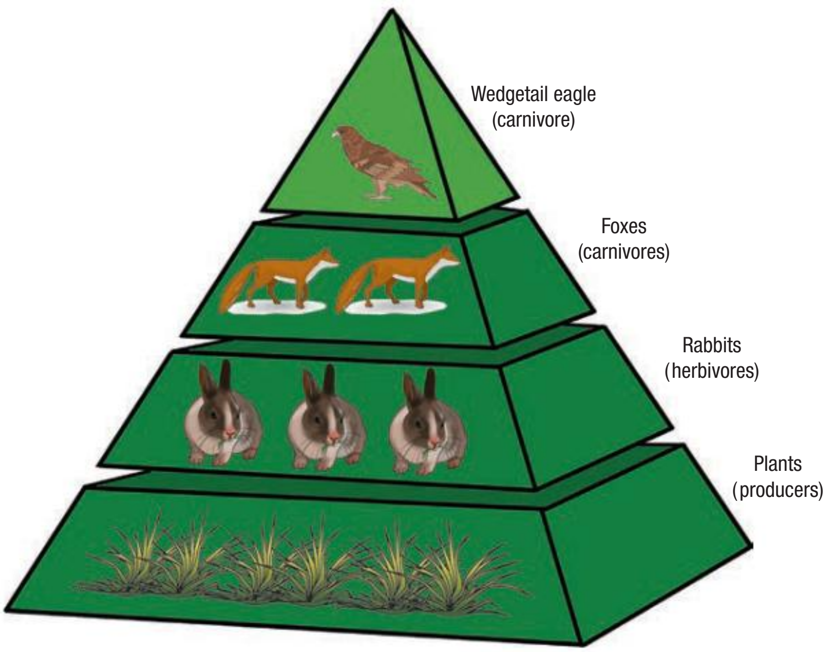

Figure 3.20
A biomass pyramid. The total mass of the grasses would be greater than the total mass of the rabbits. The total mass of the eagles would be the smallest because the rabbits and foxes used most of the energy gained from the grass in moving and keeping warm.

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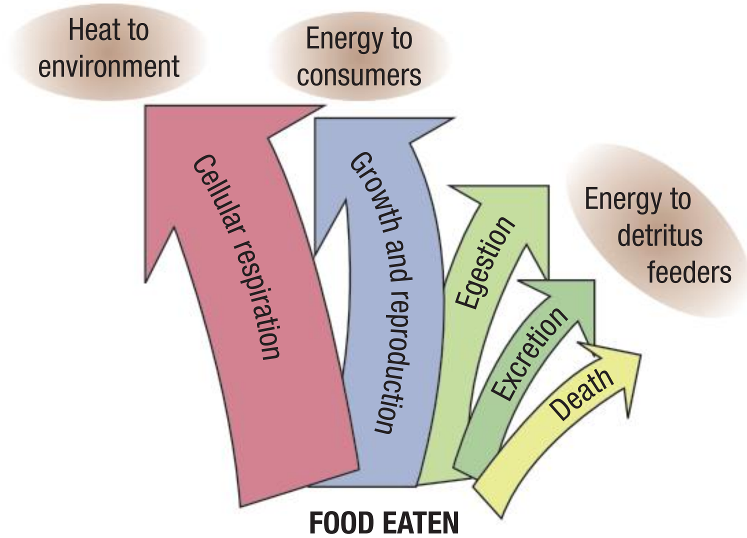

Figure 3.21 This Sankey diagram describes how the energy captured by producers is used by different types of consumers in the food web. The amount of energy is indicated by the relative sizes of the arrows.

WORKSPACE
Modelling energy flow in ecosystems

EXPERIMENT 3.2

Modelling energy flow in ecosystems

Chemical energy is difficult to visualise. This experiment attempts to model how the energy in ecosystems is used as it passes from one trophic layer to the next.

Assume that at each level of the food chain about 90% of the energy consumed is not incorporated into the organism's biomass. This number is an average.

Aim

To model how the energy in ecosystems is used or lost as it passes from one trophic level to the next

Materials

- 100 mL of water coloured with food dye (the colour represents energy)
- 100 mL measuring cylinder, or graduated pipette
- 5 large (100 mL) test tubes or clear containers

Method

1. Number the test tubes 1 to 5.
2. Make a **serial dilution** as follows.
   a. Place 90 mL of the coloured liquid into test tube 1.
   b. Place 10 mL of the coloured liquid and 90 mL of water in test tube 2. Mix this.
   c. Place 10 mL of the mixed liquid from test tube 2 and 90 mL of water into test tube 3. Mix this.

serial dilution
a stepwise dilution of a substance in solution, usually keeping the dilution factor the same

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EXPERIMENT 3.2

d Place 10 mL of the mixed liquid from test tube 3 and 90 mL of water into test tube 4. Mix this.

e Place 10 mL of the mixed liquid from test tube 4 and 90 mL of water into test tube 5. Mix this.

Results and discussion

1. **Identify** what the decreasing colour of the test tubes represents.
2. **Identify** the trophic levels in your food chain model.
3. **Describe** what happened to the 'energy' available as you move up the 'food chain' in your model.
4. **Outline** what actually happens to the energy in a real food chain when it does not pass to the next 'trophic level'. Provide an example.
5. **Propose** a food chain that could be represented by this model.
6. Can a food chain have an infinite number of trophic levels? **Explain** your answer.

ACTIVITY SHEET
Stranded on a desert island

ACTIVITY 3.5

Setting up a model of an aquatic ecosystem

The food supplied with kits for growing brine shrimp (sea monkeys, Figure 3.22) contains cyanobacteria. These bacteria are adapted to living in extremely saline environments.

Figure 3.22 A brine shrimp, sometimes known as a sea monkey, commonly found in salty water

Investigate to find the best conditions to enable the cyanobacteria to grow at a rate that can support a reproducing population of brine shrimp in a small jar (100 mL).

Record your method. Ensure you have followed the scientific method.

WORKSPACE
Setting up a model of an aquatic ecosystem

ISBN 9780170231503

WORKSPACE
What have you learnt? 3.4

QUESTIONS 3.4

What have you learnt?

Remembering

1 **Identify** two compounds in your body that include nitrogen.

2 **Identify** two ways in which atmospheric nitrogen is brought into the living part of the ecosystem.

3 **Identify** two molecules in your body that include phosphorus.

4 **Identify** the original source of phosphorus in the ecosystem.

5 **Identify** the original source of carbon in the ecosystem.

Understanding

6 **Describe** how nitrogen flows through a food web.

7 a **Identify** the process that captures energy in ecosystems.
b **Identify** the organelle involved.
c **Identify** the original source of energy in an ecosystem.

8 a **Identify** the main process that releases energy for use in living organisms.
b **Identify** the organelle involved.

Applying

9 A limiting nutrient is one that is so rare that it restricts population size. **Explain** why phosphorus is a limiting nutrient in most ecosystems.

10 Nitrogen and phosphorus stimulate the growth of plants. **Predict** the impact of this on the carbon cycle.

11 **Describe** the relationship between photosynthesis and respiration.

12 **Explain** why it is unlikely that a pyramid of biomass ever goes past a sixth-order consumer.

Analysing

13 Nitrogen and phosphorus are often limiting nutrients in an ecosystem. In a cave there can be high quantities of nitrogen and phosphorus from bat droppings. **Explain** why caves generally do not support large and complex ecosystems even though nitrogen and phosphorus are plentiful.

14 Gardeners growing Australian plants have to be careful about the fertiliser they put on their plants. **Explain** why the phosphorus in most fertilisers will kill Australian plants.

15 Are there limits to growth? **Explain** your answer.

Creating

16 **Draw** an IPO (input, processing, output – see page 17) diagram for photosynthesis and cellular respiration.

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3.5 Changes to ecosystems

Ecosystems are always changing. They are dynamic; full of organisms that live, move, reproduce and die. Weather changes throughout the year, season, day and even hourly. Both natural and human impacts will continue to change the abiotic and biotic factors in ecosystems.

Abiotic factors

Humans change abiotic factors deliberately: we apply fertilisers to soil in Australia in huge quantities, because the soil here is so poor. We irrigate widely, making water available on land where it previously was not. And we change the atmosphere by adding significant quantities of carbon dioxide whenever we burn fossil fuels. We raise hard-hoofed cattle and sheep that erode and compact our fragile soils. All these are affecting ecosystems.

Eutrophication

Eutrophication is an increase in the nutrient levels in waterways. This may occur naturally, especially after significant floods or dust storms, but it can be a result of human activity. When fertilisers run off the land and enter waterways, or when sewage is released into waterways, the excess nutrients provide the perfect opportunity for small, rapidly growing organisms such as algae and cyanobacteria to proliferate. This can be a problem in itself, as the bacteria may release toxins, which make the water poisonous to organisms that live in it or drink it. Alternatively, an algal bloom on the surface of the water will prevent light reaching plants lower down in the waterway. These plants die, as do many of the algae as soon as the nutrient levels drop. The dead matter sinks to the bottom of the waterway, where the decomposers consume it and respire. This uses up the oxygen in the water, and causes fish and other aquatic organisms to die. Additionally, this releases nutrients that fall to the bottom of the waterway, where plants cannot survive as there is inadequate light. This means the nutrients are not cycled through the system any further and the productivity of the ecosystem drops.

eutrophication
an increase in the nutrient levels of waterways

Newspix/Andy Tyndall

Figure 3.23 While increasing the nutrients in waterways may sound like a good idea, it can be disastrous. Eutrophication resulted in this algal bloom in the Swan-Canning Estuary during February 2000.

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Effect of floods on ecosystems

Just as bushfires are a key component of living in Australia, floods are also a regular occurrence. In January 2011, devastating floods occurred in north-eastern Australia. Much of this water flowed into the ocean at the ports of Bundaberg, Gladstone and Brisbane. Such a huge volume of fresh water, containing sediments, nutrients and pesticides, poses a large threat to marine environments. Flood plumes such as this have a significant impact on seagrass beds, covering them with silt and reducing their ability to photosynthesise. High concentrations of nutrients can cause algal blooms, which cover large areas of the surface of the ocean, reducing the amount of light and oxygen reaching marine plants. Animals such as dugongs (Figure 3.24) and sea turtles that rely on these seagrass beds may be unable to find an alternative food source. This can lead to malnutrition, disease and death, and removal of a significant number of organisms from the food web.

Auscape/Jurgen Freund

Figure 3.24 Dugongs depend on seagrass beds for survival.

Lake Eyre in South Australia has one of the world's largest basins, covering 1.2 million square kilometres, almost one-sixth of Australia. It is 12–17 m below sea level and is the end point for many inward-draining rivers. Lake Eyre is a salt lake; its edges are crusted with white crystals. It has an annual rainfall of just 120 mm and much of the time it is empty or has low water levels. As flood water from Queensland made its way to Lake Eyre, the region also received heavy rainfall, approximately 450 mm in 2010. This combined influx of water into the lake resulted in an increase in populations of the birds and mammals living there (Figure 3.25). Pelicans and Eyrean grasswren flocked to the lake to feed on the plentiful water life. Populations of small mammals increased dramatically, resulting in an abundance of predators such as the letter-winged kites (*Elanus scriptus*). The flooding filled rabbit burrows, forcing rabbits to the surface and provided plentiful food for eagles and dingoes. Coolabahs (*Eucalyptus coolabah*), native Australian eucalypts made famous by poet Banjo Paterson, finally germinated. Coolabahs are very resistant to drought and their seeds only germinate after flooding. This ensures that seedlings are only produced when there is enough water for them to become established.

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Auscape/Wayne Lawler

Figure 3.25
The flooding of Lake Eyre in 2010 resulted in an abundance of bird life, such as these pelicans.

ACTIVITY 3.6

Effect of climate change on our environment

1 Go to the weblink 'Climate change and the Queensland floods' and read the article about the Queensland floods.
2 Many science-based newspaper articles are a mixture of fact and opinion. It is sometimes difficult to determine between the two. Use activity sheet 'Fact or opinion?' to try to tease out the fact from the opinion in this article.

WEBLINK
Climate change and the Queensland floods

ACTIVITY SHEET
Fact or opinion?

VIDEO
Threat to Antarctic wildlife

Surviving and thriving in Australia

Human ingenuity has produced ways of making the best use of resources with the technology available. Aboriginal people discovered how to remove toxins from food such as the water fern *Marsilea drummondii* (Figure 3.26). The spore cases contain an enzyme that destroys thiamine (vitamin B1). This vitamin is present in very small doses in our bodies, but we cannot live without it. Aboriginal people knew how to prepare *nardoo* for safe consumption, but the European explorers Burke and Wills famously did not, and it contributed to their deaths in 1861.

© M.Fagg, Australian National Botanic Gardens

Figure 3.26
The bean-shaped spore cases of the water fern *Marsilea drummondii* (*nardoo* or *ngardu* in regional Aboriginal languages) contain an enzyme that destroys vitamin B1.

Aboriginal people also developed trapping techniques that maintained fresh food supplies for long periods (Figure 3.27). This knowledge enabled Aboriginal people to live sustainably for tens of thousands of years.

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Figure 3.27 Along the Australian coast some of the most substantial structures built by Aboriginal people were fish traps. These traps in the Coorong National Park of South Australia could hold large fish stocks for months.

ICT

Download Google Earth and locate the Coorong National Park in South Australia. Upload this map to the class wiki. Provide a caption for the map.

WORKSPACE
Who were Burke and Wills?

ACTIVITY 3.7

Who were Burke and Wills?

Getty Images

Figure 3.28 Robert O'Hara Burke and William John Wills led an expedition from Melbourne to the Gulf of Carpentaria.

1. Research Burke and Wills and **construct** a Venn diagram to **compare** and **contrast** Burke and Wills with a modern-day explorer of your own choosing.
2. Upload your Venn diagram to the class wiki and write a brief explanation of who they were and who your modern-day explorer is.
3. **Discuss** the ways in which science has assisted modern-day explorers.

WOW!

Pollen database uncovers Australia's ecosystem history

Pollen in sediments can be used to reconstruct the biomes of the distant past. Records suggest that 20 000 years ago, the southern regions of Australia were much drier and the tropics were cooler. Aboriginal people survived these climate changes, but did not cause them.

Shutterstock.com/Sebastian Kaulitzki

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QUESTIONS 3.5

What have you learnt?

Understanding

1 **Outline** the ways that Indigenous Australians used the resources around them to survive.

2 **Define** eutrophication.

3 **Outline** three causes of eutrophication.

4 **Outline** how eutrophication results in the death of life in a waterway.

Reflecting

5 What is your reaction to the information that has been presented so far in this chapter? **Explain** your reaction in a paragraph on your blog.

WORKSPACE
What have you learnt? 3.5

3.6 The shock of the new and other challenges

The impact of European settlement on Australian ecosystems can be compared to that of a spaceship filled with aliens arriving from another planet. This was not just a few new plants or insects arriving sporadically on Indonesian trading vessels. Europeans brought with them technologies, animals and plants designed to reconstruct the way of life of the northern hemisphere. When attempts to introduce organisms failed, reinforcements could be called upon, over and over again. Rabbits, for example, arrived with the First Fleet in 1788 but did not become established on mainland Australia until settler Thomas Austin released 12 animals on his Victorian property in 1859.

Every introduced organism that becomes established changes the balance of the original ecosystem. Invasive producers use sunlight, nutrients and water that were previously available for native plants. The introduced plants often grow well and look green and lush. However, native consumers can find them inedible and so the energy these plants capture through photosynthesis is not processed through the food web.

ANT Photos.com.au/John Carnemolla

Figure 3.29 Thomas Austin released 12 rabbits on his property in southern Victoria in 1859 for sporting purposes. Now they are a major ecological threat in Australia.

The effects of invasive consumers are less predictable. Herbivores such as rabbits compete with native animals for food but also contribute to the diets of their predators, including introduced foxes. Toxic animals such as cane toads have killed many native animals but now seem to have become a new food source for a small number of native snakes.

VIDEO
Threat to rainforest communities

WORKSPACE
What have you learnt? 3.6

QUESTIONS 3.6

What have you learnt?

Understanding

1 The arrival of Europeans has been compared to 'a spaceship filled with aliens'. **Propose** reasons why this might be.

2 **List** the characteristics that help introduced organisms become established.

Analysing

3 Introduced plants often grow well and look green and lush. However, native consumers can find them inedible and so the energy these plants capture through photosynthesis is not processed through the food web. **Explain** what this means.

4 Figure 3.31 shows an Australian rainforest food web. **Outline** the effects on this food web if the following introduced species were released into the area.

a Foxes
b Cats

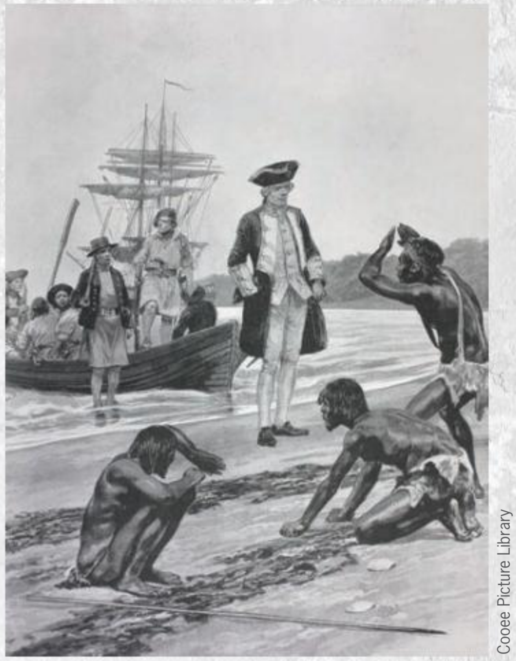

Figure 3.30 European arrival in Australia

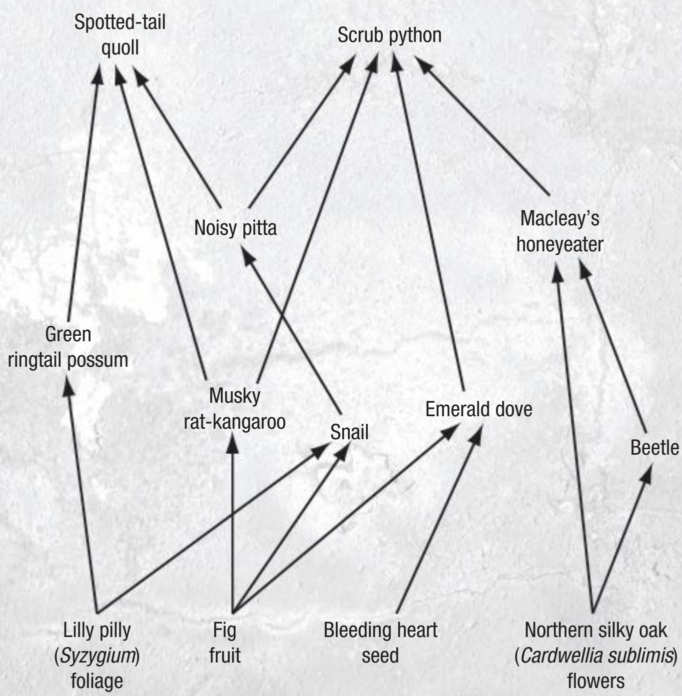

Figure 3.31 Rainforest food web

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QUESTIONS 3.6

Evaluating

5 a Regional rainforest herbivores found in Indonesia and Malaysia include the Asian macaque (a kind of monkey) and various squirrels. **Describe** how they might change the food web in Figure 3.31 if they were introduced to this area.

b From your answer to part **a**, do you think the changes that would occur in the food web would improve the ecosystem? **Explain** your answer.

3.7 Conserving ecosystems

Management strategies

The Australian Government has strategies to manage ecosystems, including control of the country's national parks and wildlife reserves. However, governments are susceptible to pressure from large corporations such as mining companies and developers, and from special interest groups such as hunters and 4-wheel-driving clubs to prioritise profit or recreation over conservation. Often it is only when faced with further species extinction that action is taken. As cane toads moved from Queensland across the Northern Territory many animals died from cane toad poison. Threatened with extinction, quolls and other small mammals were captured and relocated to isolated islands free from the toads to ensure the species' survival, but their populations are smaller and much more vulnerable as a result.

Individuals or private organisations make major contributions to conservation and ecosystem management. Farmers set aside tracts of land as reserves and wildlife corridors, conservationists buy areas of land to be set aside purely for conservation and regeneration purposes. Groups raise awareness of the plight of endangered species and what can be done.

Preserving habitat has the greatest effect on conservation. However, with an ever increasing population this becomes harder and harder.

ACTIVITY SHEET
Science career – environmental engineer

ACTIVITY 3.8

Creating habitats near your school

Which organisms have their populations limited by habitat availability in your environment?

Carefully designed fauna boxes can make a difference to a range of species, including insectivorous bats, possums, gliders and a variety of birds (Figure 3.32).

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ACTIVITY SHEET
Non-government conservation organisations

feral

having returned to the wild from being domesticated

WEBLINK
David Attenborough: How many people can live on planet Earth

ACTIVITY 3.8

Getty Images/Jason Edwards

Figure 3.32 This nesting box will be used by Australian possums and cockatoos at different times of the year.

1 As a group or a class **design** and make a fauna box to place in your school environment. Check with your local environmental group for design advice. You must avoid attracting undesirable **feral** species.
2 Take a digital image of your finished fauna box and load it onto the class wiki.
3 Monitor your fauna box for signs of habitation such as fur, bedding material or droppings. Do not touch animals or their droppings; instead take a digital image to **compare** to images of known animal droppings on the Internet.

Aboriginal and Torres Strait Islander management techniques

fire-stick farming

the Aboriginal practice of using fire to burn vegetation regularly in order to change the composition of plant and animal species in the area

greenhouse gas

any gas that traps heat in the atmosphere

Aboriginal people understood Australia's low productivity and remained nomadic, rather than settling to intensely cultivate one area of land. This allowed plant and animal populations to remain stable and not be depleted by intense harvesting, and thus allowed the Aboriginal population to also remain stable. **Fire-stick farming** is another Aboriginal land-management practice. It involves burning small patches of land at regular intervals. It is still a common technique in northern Australia. In the Top End of Australia the dry season can extend for up to eight or nine months, and high-intensity fires at the end of the dry season are catastrophic. Fires started by lightning (very common in the late dry season) could burn for many weeks at high intensity if undergrowth is still high. This is devastating to wildlife and releases enormous quantities of **greenhouse gases**. Because the land is so sparsely populated and inaccessible only wet-season rains can extinguish these fires.

Frequent low-intensity fires early in the dry season, while the land and plants are still wet, keeps undergrowth low, reducing fuel loads. The fires burn slowly, allowing wildlife to escape, and reduce the likelihood of extremely devastating high-intensity fires. Aboriginal people deliberately started these fires as a land-management practice. A patchwork of ecosystems at different stages of growth supports high biodiversity. Unburnt sections act as game reserves. Grasses sprout in recently burnt areas, attracting large herbivores such as kangaroos. Fire is also used to clear undergrowth, herd wild animals and discourage snakes and insects.

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Over time, fire-stick farming transformed Australia's ecosystems. Plants such as eucalypts have the ability to sprout new branches from **epicormic buds** located underneath the bark (Figure 3.33) or from underground **lignotubers**.

epicormic bud

an area under tree bark that can sprout new growth if the tree is damaged

lignotuber

a swollen root that helps some plants regrow after being burnt

Shutterstock.com/Jarrod Boord

Figure 3.33
Eucalypts are highly adapted to survive and regenerate after bushfires. The new growth on the trunks of these trees comes from dozens of epicormic buds found deep under the bark.

Other species, such as *Banksia* and *Acacia*, produce seeds that need to be exposed to fire or smoke before they will germinate. Fire-resistant and fire-dependent plants benefited from fire-stick farming and these species became dominant in Australian landscapes. Moist rainforest areas dwindled, but fragments of fire-sensitive ecosystems remain.

It is not certain whether human activities contributed to the extinction of Australian megafauna, as happened in other parts of the world. The fossils of diprotodons and other giant marsupials have been found together with human tools in layers 27 000–37 000 years old.

ACTIVITY SHEET
Testing Australian plants' response to heat

WEBLINK
Megafauna

Getty Images/Science Photo Library

Figure 3.34
Acacia seeds require fire to germinate.

WORKSPACE
What have you learnt? 3.7

QUESTIONS 3.7

What have you learnt?

Understanding

1 **Define** the term 'sustainable'.

2 **Identify** five things you, personally, can do to build a more sustainable environment.

3 **Describe** fire-stick farming. How does this practice assist Indigenous Australians to obtain food?

4 **Outline** how fire-stick farming changes the environment.

5 What evidence is used to show that the environment has changed over the last 30000 years?

Applying

6 When land is cleared for housing or when street trees are cut down, the remaining habitats are placed under further pressure. **Propose** two ways of reducing the pressure placed on the native fauna.

Analysing

7 The first orange roughy were discovered by New Zealand fishermen in the late 1970s. Further discoveries off Australia followed in 1985. The deepwater shoals were easy to harvest from the undersea mountains called 'seamounts' on which they gather.

Today, there are still about 30 orange roughy fisheries operating in the southern hemisphere. Yet within 25 years the boom harvests have declined (Figure 3.35).

a **Identify** what fishermen need to know in order to fish sustainably.

b An FIP (first important priorities) is a tool that helps to prioritise things that are important. Complete an FIP that you could share with the fishermen to help them understand what they need to know in order to fish sustainably. **Explain** your choice of priorities and **describe** how they will positively impact on orange roughy sustainability.

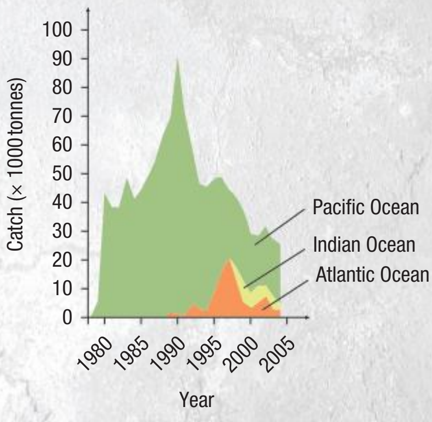

Figure 3.35 Orange roughy catch size over time in three oceans

Reflecting

8 Think about how life might be different if we never did any conservation. **Predict** what would change and how it would change.

9 Add more information to your graphic organiser.

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Chapter review

Remembering

1 **Identify** the original source of energy in ecosystems.

2 Plants can't take in nitrogen from the air and some nitrogen compounds in the soil can't be used. **Identify** the nitrogen-containing compounds plants can take in from the soil.

3 **Outline** where plants and animals get their carbon from.

4 **Identify** one land-management practice used by Aboriginal and Torres Strait Islander peoples.

Understanding

5 **Explain** the difference between the following pairs of words.
- a Biotic and abiotic
- b Photosynthesis and respiration
- c Biosphere and ecosystem
- d Quadrat and transect
- e Competitor and parasite
- f Eutrophication and algal bloom

6 Plant fertilisers usually contain NPK (nitrogen, phosphorus and potassium).
- a **Explain** why fertilisers are used.
- b **Identify** the uses of nitrogen and phosphorus by living organisms.
- c **Explain** how nitrogen and phosphorus enter the biosphere in the absence of fertilisers.

Applying

7 **Explain** how artificial nesting boxes can make a difference when new suburbs are built.

8 **Explain** why improvements to soil fertility as a result of using lucerne (a plant with a mutualistic relationship with nitrogen-fixing bacteria) are likely to be sustainable.

9 Commercial mixtures of fungal spores from mycorrhizae are often applied to help rehabilitate disturbed land such as mine sites. **Describe** how this might work.

10 Dunnarts are marsupials that live and breed in family groups in burrows in the desert. **Explain** how you would determine how many dunnarts lived in an area of several square kilometres of Australian bushland. **Justify** your choice of population estimation method.

11 **Identify** two uses of energy in an organism, and **explain** how they account for the differences in biomass shown between different feeding levels on a food chain.

Analysing

12 Scientists studying a food web based in an Arctic pond during spring found that the total mass of microscopic water plants was less than that of the microscopic animals that ate the plants. **Explain** how a food web with this structure could survive.

WORKSPACE
Chapter 3 review

ACTIVITY SHEET
Chapter 3 checklist

REVIEW QUIZ
Chapter 3

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13 The following data shows the population of three different species, X, Y and Z, in an area.

Time (months)	Population		
	Species X	Species Y	Species Z
0	185	35	410
2	160	35	370
4	230	35	250
6	240	40	215
8	220	45	265
10	175	70	385
12	140	105	420
14	140	115	395
16	210	80	300
18	255	60	250
20	230	45	290

a Plot a graph of this information, with time on the *x* axis and population on the *y* axis. Remember to include a key for each species.

b **Calculate** the average populations for the three organisms and draw a horizontal line on your graph for each one. Remember to label this.

c **Identify** the most likely food chain for these organisms. Use this food chain to answer the following questions.

d **Describe** the changes occurring in the first four months in the population of:

i species X   ii species Z.

e **Explain** the changes described in question 3, using your food chain from question 2.

f **Identify** when the number of producers was greatest.

g **Explain** why the population of species Y is always smaller than the population of species X.

h **Predict** the approximate population numbers of each of the species in month 24.

Evaluating

14 Aboriginal people have used fire to manage the ecosystem for many thousands of years. **Discuss** the impact of this on the species that survive in Australia.

15 **Explain** two ways in which you could change your behaviour to help conserve natural ecosystems.

Creating

16 Create a concept map with the word 'ecosystems' in the centre. Branch as many ideas off from this concept as you can. Make as many connections and links between ideas as you can.

Reflecting

17 Imagine you are able to make one law to protect and maintain the ecosystems of Australia sustainably.

a **Describe** the key ideas you would need to take into account.

b **Propose** the law you would make.

b **Explain** how you would enforce this law.

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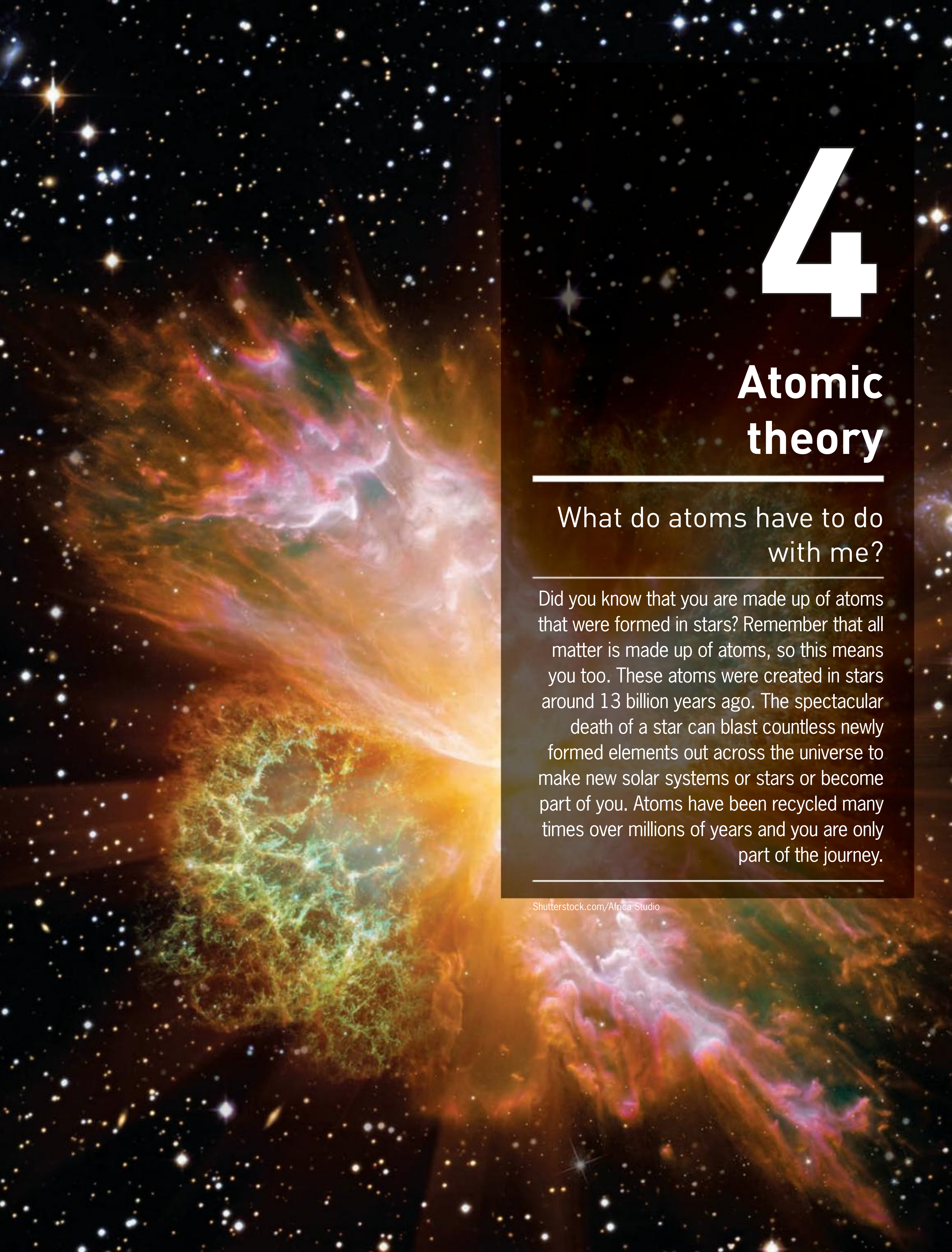

4

Atomic theory

What do atoms have to do with me?

Did you know that you are made up of atoms that were formed in stars? Remember that all matter is made up of atoms, so this means you too. These atoms were created in stars around 13 billion years ago. The spectacular death of a star can blast countless newly formed elements out across the universe to make new solar systems or stars or become part of you. Atoms have been recycled many times over millions of years and you are only part of the journey.

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Chemical world – Stage 5

Key knowledge

- All matter is made up of atoms.
- Atoms are made up of electrons, protons and neutrons.
- The protons and neutrons are found in the nucleus of the atom; the electrons orbit the nucleus.
- Theories about the atomic model have advanced over time through scientific efforts.
- Nuclei of atoms decay and release radioactive particles and energy.
- There are benefits and risks related to all uses of nuclear energy.

ACTIVITY SHEET
CAT with rubric:
An important radioactive element and its use

CULMINATING ASSESSMENT TASK

An important radioactive element and its use

Identify a naturally occurring radioactive element that has a useful application for humans. **Investigate** this radioactive element and its applications and **evaluate** how its radioactivity has been put to a useful purpose. **Describe** how it is used and **justify** its value.

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What do you already know about atoms?

In Year 8 you learnt about atoms and elements. This atom quiz will give you a chance to find out what you remember.

In the table below, match the description in the left-hand column to the word or number in the right-hand column.

The basic building blocks of all matter	Element
Pure substance made of only one type of atom	Carbon
Pure substance made of two or more different types of atoms combined	Gas
Number of atoms in a molecule of water (H_2O)	Atoms
Has the chemical symbol C	2
State of matter in which most of the elements exist	Na
State of matter in which oxygen normally exists	3
Number of atoms in a molecule of ammonia (NH_3)	4
Number of different elements in a molecule of ammonia (NH_3)	Compound
Symbol for sodium	Solid

ICT

Build your own glog to record notes, key ideas, themes and 'aha' moments as you progress through the chapter. This will help you to study and store your thoughts and ideas.

WEBLINK
Glogster EDU

4.1 Breaking down atoms

The **atom** is the smallest particle of matter that retains the chemical properties of that element. The idea of atoms was first proposed by the Greek philosopher Democritus in about 460 BCE. He reasoned that if you kept cutting something into smaller and smaller pieces, you would eventually have a piece that could not be cut any smaller. In fact, the word 'atom' comes from the Greek word *atomos*, which means 'indivisible' (cannot be divided or sliced any further). Democritus argued that atoms could not be broken down any further, so they must be the simplest form of matter.

Although it is hard to believe today, the atomic ideas of Democritus did not catch on, and they were largely ignored until much later. Because atoms are too small to see, the ideas were too theoretical and there was no proof of the existence of atoms. This was because a scientific method had not been invented. For more than 2000 years nobody continued with the explorations the ancient Greeks had started into the nature of matter. It was not until the 1700s that the idea that matter was composed of particles re-emerged, and by this time the scientific method was established and chemists such as Antoine Lavoisier and Joseph Proust were able to test this idea.

atom
the fundamental particle of matter, made up of protons, neutrons and electrons

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Figure 4.1 Antoine Lavoisier

INTERACTIVE
The elements: elements analyser

Lavoisier and the elements

French chemist Antoine Lavoisier (1743–94) is known as the 'father of modern chemistry'. He wrote the first 'modern' chemistry textbook, entitled *Elements of Chemistry*, in which he proposed that an element should be defined as a substance that cannot be broken down into any simpler substances. In his book he listed the 23 elements known at that time. Thus the term 'element', as we currently use it today, was defined. Of course, today many more elements are known. In June 2012, elements 114, flerovium (Fl), and 116, livermorium (Lv), were added to the official international version of the periodic table.

You may have heard the phrase 'matter can neither be created nor destroyed'. This means that all matter that currently exists was always here in some form and always will be. So, even if you burn a piece of paper, it has to go somewhere. In chemistry, the idea that the total mass of substances in a chemical reaction remains constant was formulated and tested in 1789 by Lavoisier. By carefully sealing fruit in a closed container and weighing it before and after it became a rotted mess, he showed that no mass was lost. This idea has become one of the fundamental laws of chemistry – the law of conservation of mass. You will meet this law again in Chapter 5.

The law of conservation of mass – When different substances combine to produce a new substance, the total mass of the new substance equals the sum of the masses of the original substances.

Another important law in chemistry relates to the idea that substances always combine in the same proportion. A simple analogy could involve baking 24 muffins using a recipe for a dozen muffins. You would need to double all of the ingredients, proportionally, if you wanted to make 24 muffins. In chemistry, the proposal that substances only ever combine in very precise proportions was first established by another French chemist, Joseph Proust (1754–1826), in 1799. This idea became the other fundamental law of chemistry – the law of definite proportions.

The law of definite proportions – Substances only ever combine in very precise proportions; for example, water will always be H_2O (two atoms of hydrogen and one atom of oxygen).

WOW!

Off with his head!

Lavoisier was a powerful man of both science and politics in France. He was accused of many crimes during the Reign of Terror in the French Revolution. His positive contributions were ignored and he was tried and found guilty of treason. Lavoisier was executed by guillotine in 1794. Less than two years later, he was pardoned by the French government for wrongful conviction.

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Dalton and the atom

Figure 4.2
John Dalton

The English chemist John Dalton (1766–1844) examined the facts and figures accumulated by many chemists, including Lavoisier and Proust, as well as the results of his own experiments. Dalton was a scientist and so he tried to find a logical way to explain these principles. His conclusion was startlingly simple – the early Greek philosophers had been right. Even though atoms cannot be seen, all matter must be made of separate, tiny particles. In 1808 John Dalton published a book, *New System of Chemical Philosophy*, to explain his theory. In advocating his atomic theory, he also recommended that symbols be used to represent different atoms.

It is almost impossible to understand how small an atom is. Millions of carbon atoms would fit side by side on the full stop at the end of this sentence. It is only now that scientists have the technology to obtain images that show the atoms that make up matter.

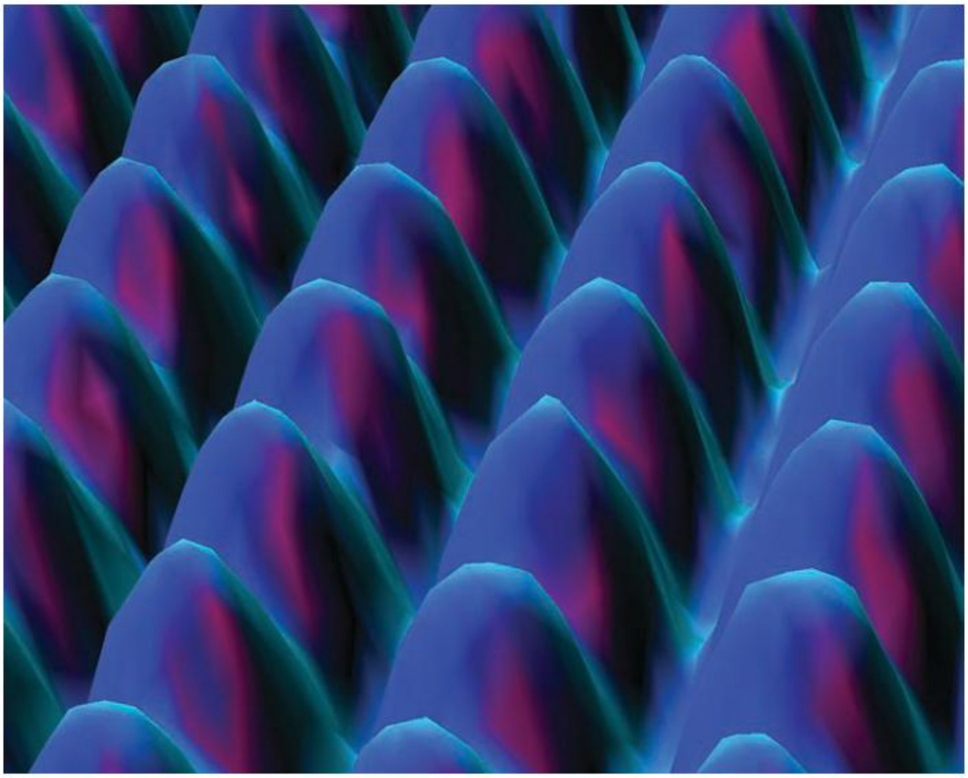

Figure 4.3
This image was taken with a scanning tunnelling microscope. It shows the regular arrangement of atoms on the surface of a piece of nickel.

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The main ideas of John Dalton's theory that have been accepted by today's scientists are shown in Figure 4.4.

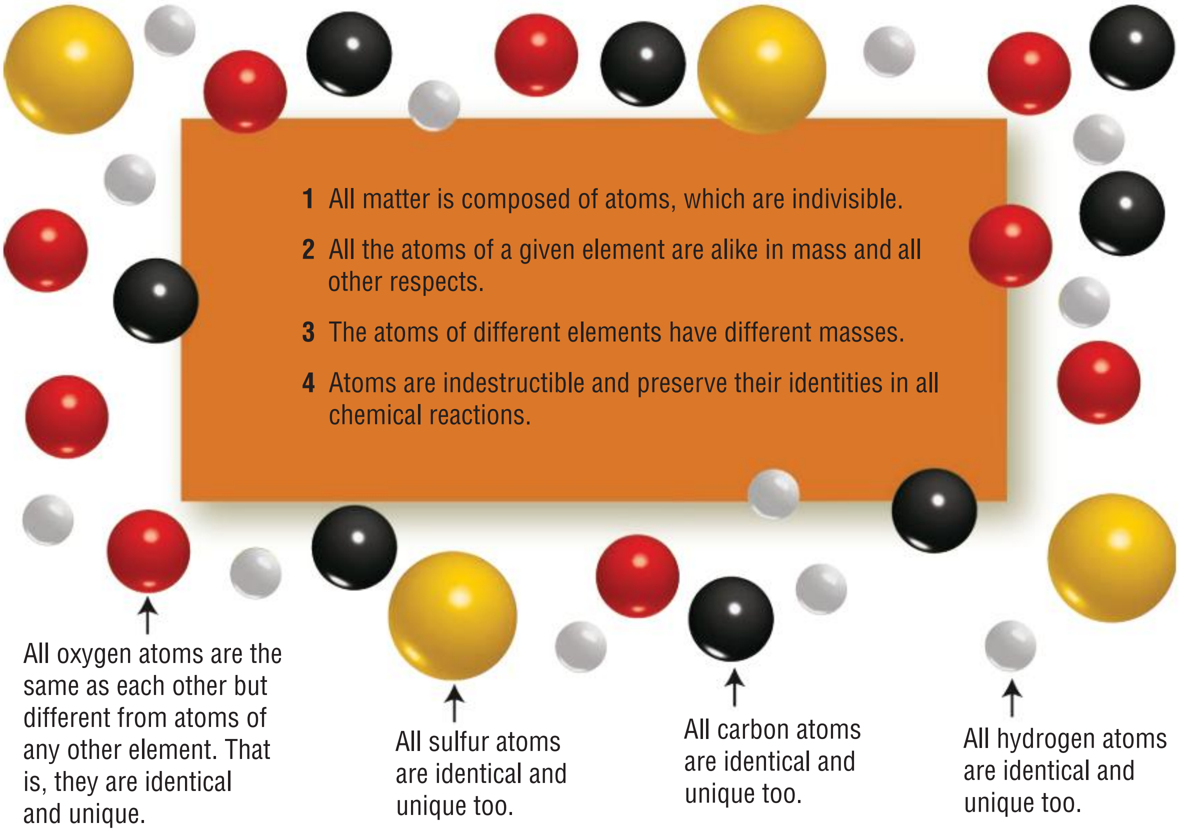


Figure 4.4 Accepted ideas from John Dalton's theory

WOW! Seeing red!

John Dalton was colour blind and had difficulty seeing red (the image below is part of a test for colour blindness). He proposed that his eyes must contain a blue liquid, which was the reason for his abnormal vision. In his will he directed that after his death his eyes be removed and their fluids examined for blueness. His wishes were carried out but the fluids were found to be normal and colourless.

Getty Images/SSPL

VIDEO
What are atoms?

ISBN 9780170231503

QUESTIONS 4.1

What have you learnt?

Remembering

1 **Recall** the definition of an atom.

2 **Recall** the two latest elements to be added to the periodic table.

3 **Recall** the law of conservation of mass.

4 **Summarise** Dalton's theory of the atom.

Understanding

5 **Explain** why Democritus' idea of atoms was dismissed.

6 **Explain** why Dalton's theory was accepted.

Applying

7 **Describe** one piece of experimental evidence that supported Dalton's proposal.

8 **Contrast** an atom and an element.

Analysing

9 **Relate** the two fundamental laws proposed by Lavoisier and Proust to Dalton's atomic theory.

Evaluating

10 In 1676, in a letter to Robert Hooke, Isaac Newton wrote: 'If I have seen further it is by standing on the shoulders of giants'. He was referring to having built on the ideas and work of others, such as Hooke.

a **Justify** whether this quote could also apply to Dalton.

b **Evaluate** whether or not the statement applies to most scientists.

Creating

11 **Construct** a timeline to capture the developmental understanding of the atom. Continue to add to this as you work your way through this chapter.

WORKSPACE
What have you learnt? 4.1

ICT

You could use Timetoast or similar to create your timeline.

4.2 Historical development of atomic theory

Organising the elements: the periodic table

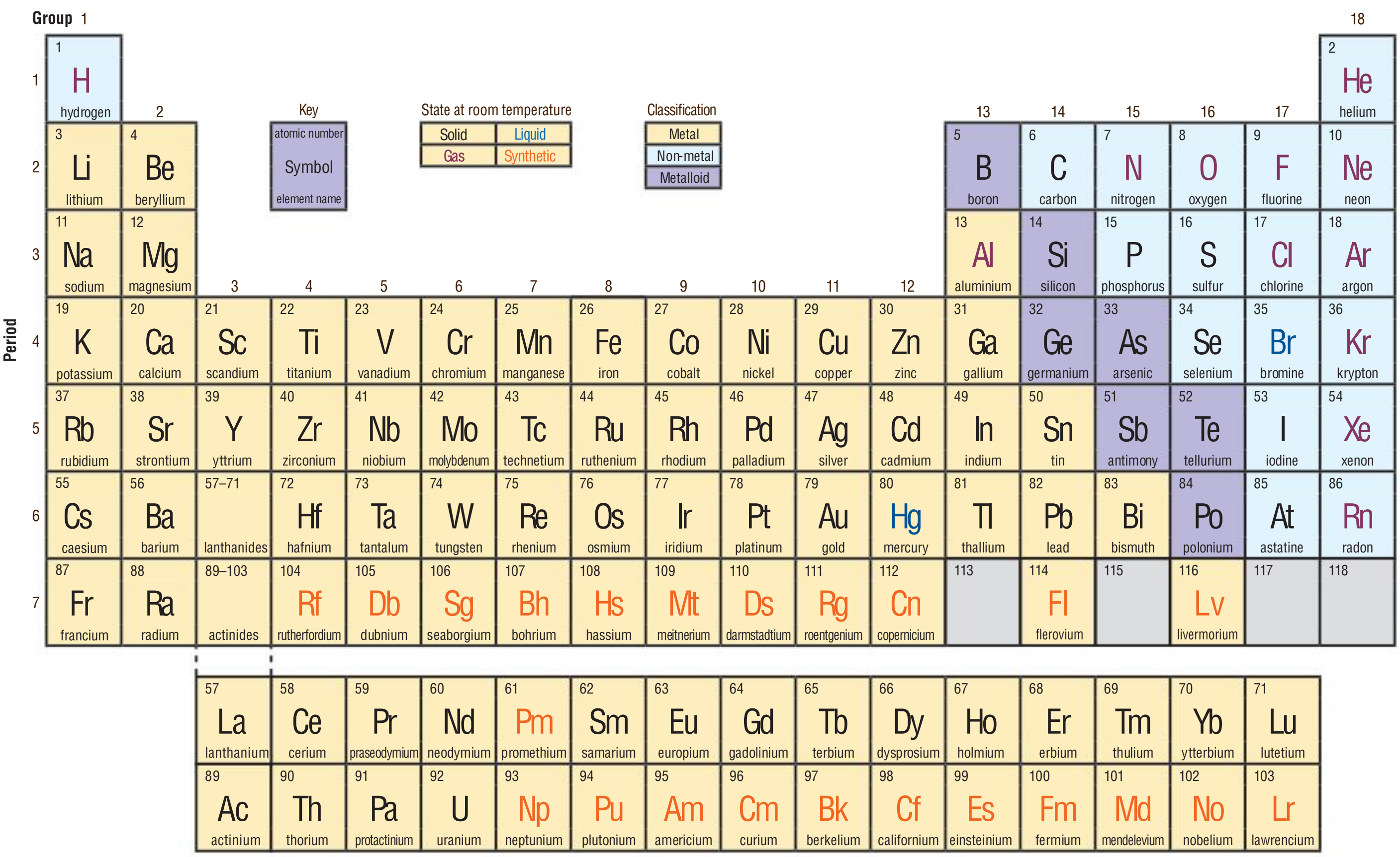
ACTIVITY SHEET
Visual periodic table

The periodic table of elements is one of the great intellectual achievements of humankind. It was originally developed by Russian chemist Dmitri Mendeleev (1834–1907). It catalogues all the different kinds of matter in our universe, the 114 elements that make up all matter, everything we see and touch. The arrangement of elements in the periodic table also gives patterns and clues as to how the different elements combine.

The periodic table we see and use today is not the same as the one originally developed by Dmitri Mendeleev. It has changed over time as scientists have discovered new elements and developed a greater understanding of the atoms that make up elements.

Many chemists were developing an organisational structure for the periodic table at the same time as Mendeleev in 1869. Mendeleev understood that elements could be grouped on the basis of chemical similarities that stay constant and so he was able incorporate all 62 known elements into his columns and rows. He even predicted that new elements would be discovered,

Figure 4.5 The modern periodic table consists of 114 elements and includes elements that Mendeleev predicted should exist.



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such as germanium, gallium and scandium, and left gaps for them in the table; he also proposed the **densities** and **atomic weights** of these elements. When some of his predictions proved to be correct, he cemented his place in history as the 'father of the periodic table'.

Mendeleev made many wrong predictions. This was not surprising considering that only half of the elements had been discovered when he was formulating his table. Later discoveries showed that some of the elements had been placed in the wrong columns and rows. However, Mendeleev did the important work of establishing the basic structure of the periodic table.

density

the mass of a substance in a specific volume, measured in kg/m^3

atomic weight

the mass of protons, neutrons and electrons that make up an atom

ACTIVITY 4.1

Seeing is believing

Imagine if all scientists needed to see everything before believing it. **Predict** and **discuss** the possible implications for scientific advancement in Chemistry. **Identify** how this could also be problematic in Biology and Physics. Record your thoughts on your glog.

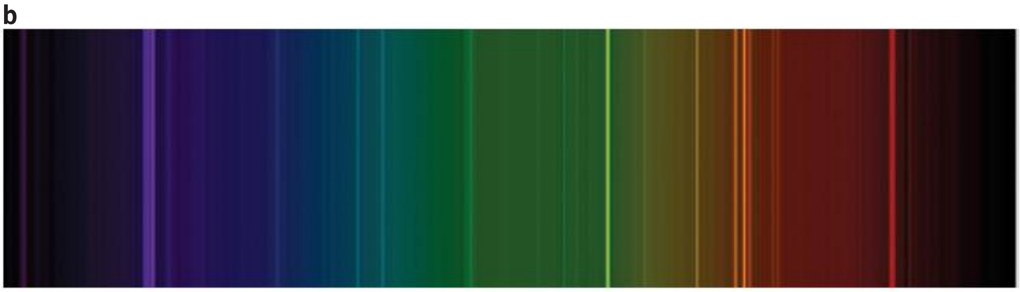
Seeing the elements

In the 1850s, German chemist Robert Bunsen (1811–99) discovered that each element produces a unique set of coloured bands, or atomic spectrum, when heated. In order to study elements, he invented two devices that made him famous – a spectroscope to study the bands of coloured light and the Bunsen burner to heat the elements to a high temperature. Using these devices, we can identify individual elements by the spectrum of light they emit when heated. Hydrogen, for example, always emits violet, blue, cyan and red bands of light. The element mercury, however, emits bands of violet, blue, green and orange–yellow light.

a

Wikipedia Commons/Jan Homann

b



Alamy/© Phil Degginger

Figure 4.6 Visible atomic emission spectra of **a** hydrogen and **b** mercury

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WORKSPACE
Identifying elements

EXPERIMENT 4.1

Identifying elements

Possible risks	Safety precautions
Copper and barium compounds are toxic.	Safety glasses must be worn at all times. Be extremely careful when using these chemicals. Direct only a short puff of the very fine mist directly into the flame so that the chemical is not inhaled and cannot drift onto someone else's skin or a surface in the room. If any chemical does contact the skin, wash it off immediately with soap and water.
Bunsen burners can cause burns.	To prevent any accidental burns, ensure any burner not in use is turned to the visible yellow flame or turned off altogether. Ensure that long hair is tied back.

In this experiment, you will observe the characteristic flame colours of different elements. In the case of chemical compounds, the colour of the flame is determined by the metal, which is the first element in the compound's name; for example, barium is the metal in barium chloride.

Aim

To use flame colour to **identify** an unknown substance

Materials

- fine-mist spray bottles containing solutions of barium chloride, calcium chloride, copper chloride, copper sulfate, lithium chloride, potassium chloride, sodium chloride, strontium chloride, zinc chloride

  Alternatively, icy pole sticks or clean flame loops dipped in the solutions could be used. Set up stations with solution and clean loop to avoid contamination. Students rotate around stations.
- clean Bunsen burner
- bottles (different one for each pair) of unknown element to be identified
- box of matches
- heat-proof mat
- safety glasses and protective clothing

Method

1 Work with a partner. Place the Bunsen burner on the heat-proof mat and light it. Set up the spray bottles next to the mat ready to start.

2 **Construct** a table in which to record the name of the substance and the colour of the flame for each solution.

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EXPERIMENT 4.1

3 Adjust the burner to the blue flame, select a spray bottle and spray a very short puff of the chemical into the flame while your partner observes the colour of the flame and records the observations.

4 **Describe** the flame colour you observed for the first substance in your results table.

5 Repeat steps 3 and 4 for each of the other spray solutions.

6 Obtain a sample bottle of an unknown substance and spray a little of it into the flame. Record the colour.

7 Use your results to **identify** the unknown substance.


Getty/Dorling Kindersley

Figure 4.7 Flame test being performed using flaming loop dipped in solution. Which metal has made this flame colour?

8 Turn off the burner and pack the chemicals away according to your teacher's instructions.

Results

1 Complete your table. **Summarise** any trends you notice.

Discussion

2 **Extrapolate** from your findings to decide whether or not the colour of the flame for sodium fluoride would be the same as that for sodium chloride. **Justify** your answer.

3 **Synthesise** your current knowledge of atoms and **propose** a possible explanation for why different substances produce different colours when heated.

4 **Propose** a useful scientific application of this process.

Conclusion

5 State whether or not this test can be used to distinguish some elements.

Extension

6 **Investigate** the explanation for what causes the flame colour in this test and **describe** it with the aid of a simplified labelled diagram.

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Describing the atom

After the publication of Mendeleev's periodic table in 1869, chemists continued to add columns and move elements around. They were particularly interested in what caused inconsistencies in the table's organisation. Most groups are arranged in order of increasing atomic weight of elements, but this is not always the case. For example, according to weight nickel should be placed before cobalt, but chemists swapped them so that cobalt was in the column of cobalt-like elements and nickel was in the column of nickel-like elements.

atomic number (*Z*)
a number that is equal to the number of protons in the nucleus (and is the same for every atom of that element)

To get around this problem, scientists assigned each element an **atomic number (*Z*)** so that they could be placed in the correct order. At that time, no one really understood what the atomic number actually was.

Electrons discovered

In 1897, British scientist JJ Thomson (1856–1940) was experimenting with the cathode ray tube. Scientists at the time knew that when an electric current was passed through a vacuum tube, a stream of glowing materials would be seen. Thomson showed that the stream could be bent by electric and magnetic fields. He concluded that the rays consisted of charged particles (which he called 'corpuscles') that were later confirmed to be negatively charged **electrons**. This confirmed that atoms were not solid balls of matter, as was thought at the time, because electrons could leak out.

electron
a negatively charged particle in the atom, which moves in space around the nucleus

Atoms are usually electrically neutral, so the fact that they contained negative particles meant they also had to contain the same number of positive particles. Thomson proposed that the negatively charged electrons were contained inside a positively charged sphere – like fruit spread through a Christmas pudding or chocolate chips in a muffin. In fact, Thomson's model of the atom is often referred to as the 'plum pudding' model.

Models are useful because they can help us to visualise something that is too small to see, but they aren't always perfect. In further studies of science you will learn how scientists have developed different models to explain other phenomena related to atoms.

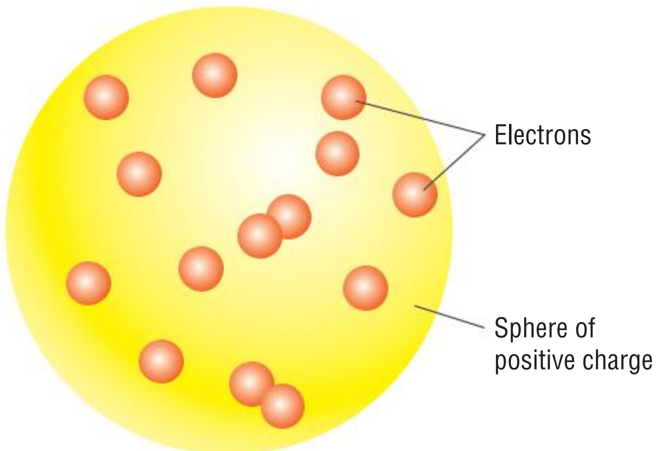

Figure 4.8
a JJ Thomson's model of the atom; **b** a plum pudding

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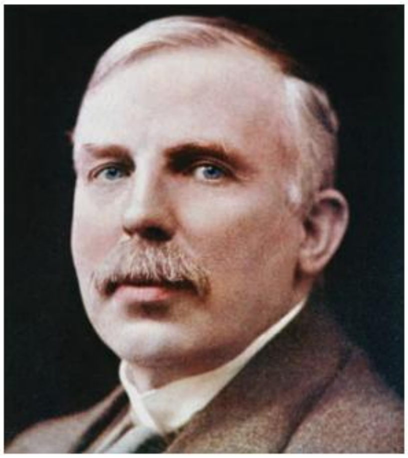
Nucleus and protons discovered

Ernest Rutherford (1871–1937) was born in New Zealand and worked in the United Kingdom. He was interested in discovering what was in atoms. Rutherford was an expert on **alpha particles**. These are particles that are made up of two protons and two neutrons, so they are positively charged. In an experiment to test Thompson's model of the atom, Rutherford fired alpha particles at a thin gold foil target. Gold was easy to use because it is the most **malleable** of all metals. This means it can be hammered until it is a very thin sheet (about 400 atoms thick) without breaking.



Getty Images

Figure 4.9 Ernest Rutherford

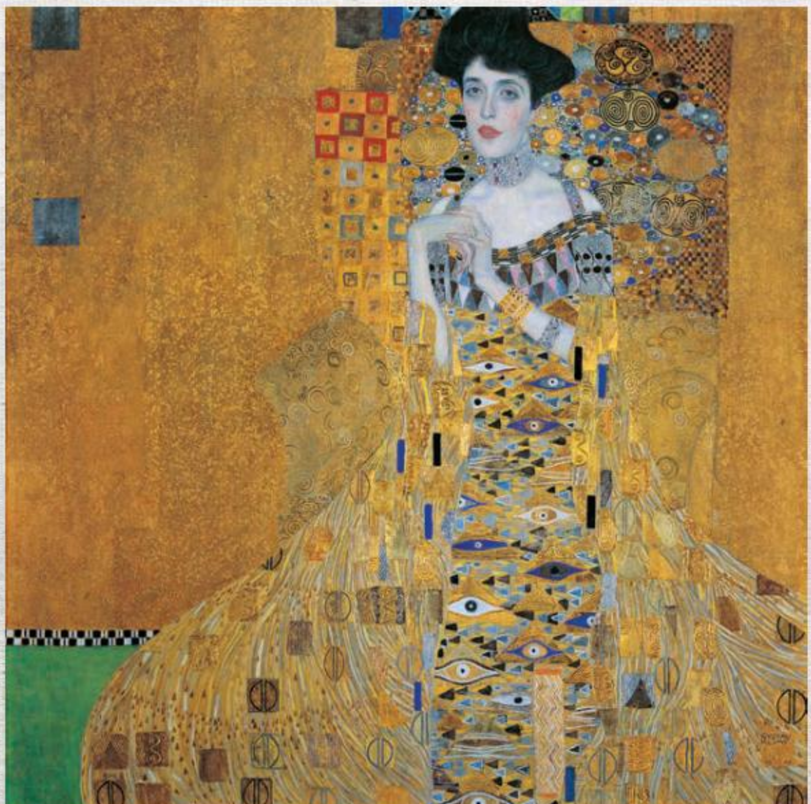
alpha particle
the helium nucleus emitted when an unstable larger nucleus decays

malleable
relating to metals, having the property that it can be hammered until it is a very thin sheet without breaking

WOW!

Gilded in gold!

A 6 cm × 6 cm cube of gold can be hammered and rolled out to almost 100 m long. Gold foil, like aluminium foil, is about 0.025 mm thick. Thin sheets of gold leaf are about 500 times thinner! Gold leaf is used for gilding objects, statues, picture frames and artwork. It can be 22-karats (92% gold) or 24-karats (pure gold). Austrian artist Gustav Klimt used gold leaf in his paintings.



Klimt, Gustav (1862–1918)/Bridgeman/De Agostini Picture Library/E. Lessing

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According to the plum pudding model, the gold atoms had a positive charge (from protons) throughout, with a few negatively charged electrons spread here and there. Rutherford hypothesised that if the model was correct, the positive alpha particles would be deflected (change direction) only a small amount.

The results of his experiment shocked him. Although most of the alpha particles did exactly as predicted, a small number were deflected almost 90°.

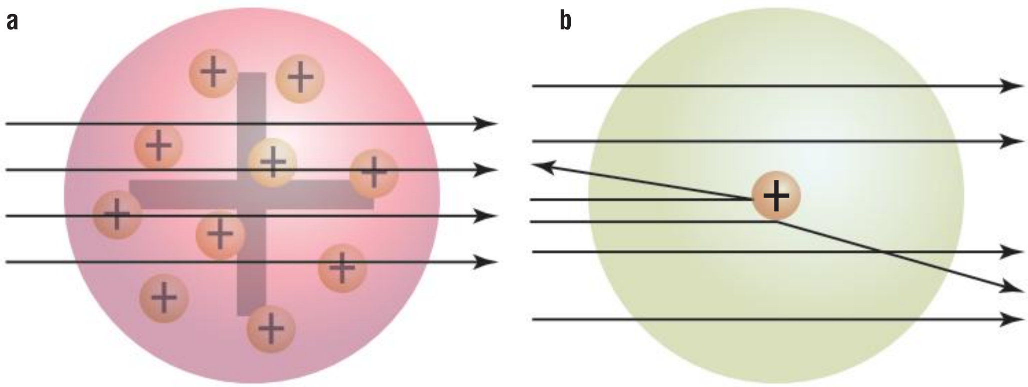

Figure 4.10 Rutherford's experiment with alpha particles. **a** Rutherford expected the alpha particles to pass straight through the foil. **b** In his experiment some particles were deflected straight back or off at large angles.

WEBLINK
Rutherford's gold foil experiment – the nucleus of an atom

Rutherford used this evidence and that from other experiments to propose a new model of the atom. He put forward the idea that atoms:

- were mostly empty space
- had positively charged protons in a compact nucleus
- had negatively charged electrons outside the nucleus.

WEBLINK
Powers of ten

ACTIVITY 4.2

The size of things

A single molecule can be one million times smaller than a grain of sand. An atom can be about 10 million times smaller than a grain of sand! To get an idea of the size of an atom, go to the weblink and zoom in.

Rutherford's idea was too radical for many scientists and it was another 2 years before his model was accepted. This happened when one of Rutherford's students, Henry Moseley (1887–1915), who was only 25, was able to link an element's place in the periodic table to the positive charge on its nucleus.

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The atomic number now made sense – it was the number of positive charges (protons) in the nucleus. So, for example, each lithium atom contains three protons, as its atomic number is 3. This discovery demonstrated that it was the number of protons rather than the mass of the atom that determined the correct order of elements in the periodic table.

But there were still problems to be solved, such as why elements with a smaller atomic number weigh more than those with a bigger atomic number.

Neutrons discovered

The puzzle of atomic mass was solved in 1932, when James Chadwick (another of Rutherford's students) discovered the electrically neutral **neutron**.

A neutron, found in the nucleus, has the same mass as a proton but it has no electric charge. It will make an atom heavier but does not affect its atomic number. Irregularities in the periodic table, such as cobalt having greater mass than nickel but having a smaller atomic number, could now be explained – cobalt had more neutrons!

neutron

a particle found in the nucleus of an atom and does not have an electrical charge

The structure of the atom

The discovery of the neutron led to a refinement of Rutherford's 'solar system' model to produce a model of the atom that, with some improvements, is the basic model of the atom most people can identify today.

VIDEO
The structure of the atom

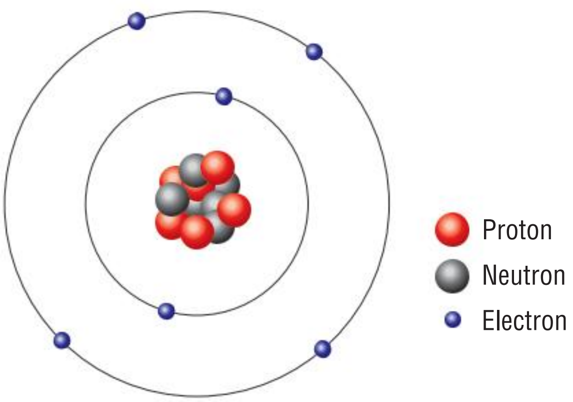

Figure 4.11
The 'solar system' model of the carbon atom

Table 4.1 summarises the properties of the particles found inside an atom. These particles are referred to as **subatomic particles**. The charge and mass are relative to each other.

subatomic particle

a particle found inside an atom, such as a proton, a neutron and an electron

Table 4.1
The properties of particles in an atom

Subatomic particle	Symbol	Where found in the atom	Charge	Relative mass
Proton	p	Nucleus	+1	1
Neutron	n	Nucleus	0	1
Electron	e	Around the nucleus	−1	$\frac{1}{1840}$

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WORKSPACE
Student investigation: How understanding of the atom has changed over time

ACTIVITY 4.3

Student investigation: How understanding of the atom has changed over time

You need

- access to the Internet

What to do

Investigate how scientists' understanding of the atom has changed over time. Use the following list as a guide for your research.

- The classical elements
- The alchemists
- Antoine Lavoisier
- Joseph Proust
- John Dalton
- JJ Thomson
- Ernest Rutherford
- James Chadwick

Corbis/David Lees

Figure 4.12 The alchemists contributed to early understandings of science, although many of their goals, such as turning common metals into gold and making the philosopher's stone, were never achieved.

1. For each idea that you research, **outline**:
   a. a brief description of the idea
   b. the date when the idea was proposed
   c. the name of the person who came up with the idea, if possible.
2. For each idea, **propose** two questions of your own.
3. **Summarise** information on the timeline you began in section 4.1 by including the information you have gathered in Question **1**.
4. **Clarify** how this person developed their idea by briefly **describing** an example of one experiment that was done.

Extension

5. Consider the chemists Lavoisier, Proust, Dalton, Thomson, Rutherford and Chadwick. **Evaluate** their work. In your opinion, who made the most significant contribution to science with respect to atomic theory? Write a persuasive answer to **justify** your opinion.
6. Submit a report to your teacher. You may choose how to present this.

WEBLINK
Development of atomic theory

ISBN 9780170231503

QUESTIONS 4.2

What have you learnt?

WORKSPACE
What have you learnt? 4.2

Remembering

1 Draw a line to match the scientist in the first column with their contribution in the second column.

Dalton	Discovered the electron and proposed the plum pudding model
Democritus	Published the model that atoms were hard spheres
Rutherford	Realised the smallest part of matter was an atom
Thomson	Developed the periodic table
Mendeleev	Performed a gold foil experiment that demonstrated that atoms had a nucleus

Understanding

2 Complete the following paragraph to check your understanding.

The number of ____________ in the nucleus of an atom is the atomic ____________ of that element. Because atoms are electrically neutral, the number of protons and the number of ____________ are equal. The total number of ____________ and neutrons in an atom is the mass number.

3 Complete the following table.

Subatomic particle	Symbol	Where found in the atom	Charge	Relative mass
Proton				
Neutron				
Electron				

4 Determine whether each statement is true or false. Rewrite any false statements to make them true.

a Scientists have always believed that everything is made of atoms.
b Atoms are composed solely of protons and neutrons.
c Protons have a negative charge and are found in the nucleus.
d Electrons are the smallest particle found in the atom and are positively charged.
e Neutrons are uncharged.
f The nucleus of an atom contains protons and electrons.
g The atomic number of an element is determined by the number of protons.

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QUESTIONS 4.2

5 Of the three particles protons, neutrons and electrons, **identify** which are responsible for most of the mass of an atom.

Applying

6 **Complete** the following sentence:

The modern periodic table has elements placed in increasing order of ____________ ____________.

7 a **Illustrate** Rutherford's 'solar system' model by drawing a labelled diagram of an atom that has three protons, four neutrons and three electrons.

b Draw a labelled diagram of the same atom to **illustrate** Dalton's model. **Explain** what you should and shouldn't include in this drawing and why it is important.

Analysing

8 During the flame test experiment, Sanja says to her partner that the flame colours remind her of fireworks. Her teacher says she is right, they are related. Suggest the similarities they share.

Creating

9 Imagine that you wake up one morning and discover that you have shrunk to an incredibly small size and are trapped inside a carbon atom in your pillow case. **Describe** what you would see. Be sure to include all relevant facts about atomic structure.

10 A neutron is found in the nucleus and has the same mass as a proton but no electric charge, so it will make an atom heavier but does not affect the atomic number.

Construct a comic strip to visually represent your understanding of this sentence. Upload your comic strip to the class wiki.

4.3 Atoms and isotopes

As mentioned earlier, the discovery of the neutron meant that problems related to atomic number, atomic mass and the position of the elements in the periodic table could be explained.

But there was another problem that had scientists puzzled. Moseley (of atomic number fame) had proved that lead-204 (lead with a mass of 204) had the same number of protons as lead-206 (lead with a mass of 206). This meant that different atoms of the same element could have different atomic masses. Scientists proposed a number of explanations but none of them answered all the questions.

Once again the discovery of the neutron solved the problem. It meant that atoms with the same number of protons (the same atomic number) could have different masses because they had different numbers of neutrons. These atoms were called **isotopes** of the element. Isotopes are atoms that have the same number of protons but a different number of neutrons.

isotopes
atoms with the same number of protons but a different number of neutrons

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For example, the gas hydrogen has three isotopes. The most common isotope of hydrogen has a nucleus that is made up of one proton and no neutrons. More than 99% of hydrogen exists as this isotope, which is sometimes called **protium**. A hydrogen atom that has one proton and one neutron is called **deuterium**. Water made from deuterium is called heavy water because the extra neutron makes it heavier. It is the water used in nuclear reactors. The third isotope of hydrogen is **tritium**. It has one proton and two neutrons in the nucleus and is radioactive. Tritium is formed when gases in the upper atmosphere interact with cosmic rays.

Each isotope of hydrogen has one electron.

protium

an isotope of hydrogen with one proton and no neutrons

deuterium

an isotope of hydrogen with one proton and one neutron

tritium

an isotope of hydrogen with one proton and two neutrons

Describing isotopes

A convention for writing and naming isotopes was developed. Isotopes are named by their **mass number** (which is the same as atomic mass). The atomic number is also represented by the symbol *Z* and the mass number by the symbol *A*.

For example, carbon has three isotopes, which are referred to as carbon-12, carbon-13 and carbon-14. The diagrams in Figure 4.13 show these three isotopes.

mass number

the total number of protons and neutrons in an atom; also known as atomic mass

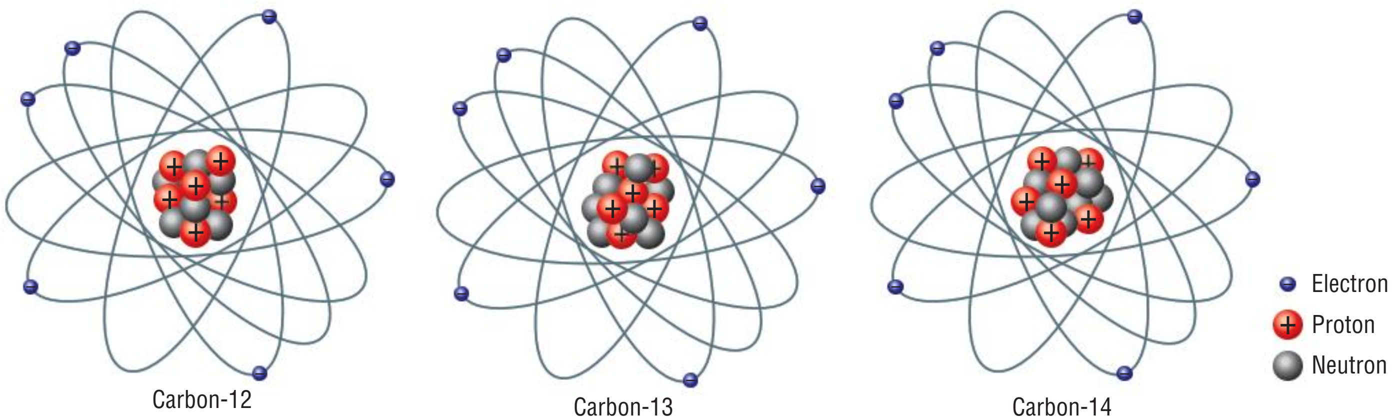

Figure 4.13
The three isotopes of carbon

The information shown in the diagrams is summarised in Table 4.2. This shows that the atomic number remains constant but the mass number depends on the number of neutrons.

Mass number = number of protons + number of neutrons

Table 4.2
Isotopes of carbon

Element	Atomic number (*Z*)	Number of protons	Number of neutrons	Mass number (*A*)
Carbon-12	6	6	6	12
Carbon-13	6	6	7	13
Carbon-14	6	6	8	14

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WEBLINK
Let's scatter neutrons for science

The symbol for carbon is C, so the information for carbon-12 in Table 4.2 can also be represented symbolically as:

Mass number → 12
Atomic number → 6

$$^{12}_{6}\mathrm{C}$$

Some other examples are:

- chlorine-35, which has the symbol $^{35}_{17}\mathrm{Cl}$
- copper-65, which has the symbol $^{65}_{29}\mathrm{Cu}$
- oxygen-16, which has the symbol $^{16}_{8}\mathrm{O}$.

WORKSPACE
Modelling isotopes

ACTIVITY 4.4

Modelling isotopes

Materials

- small coloured marshmallows or foam balls
- toothpicks
- digital camera

Method

1 Read the background information and fill in the following table.
2 Pick three different coloured marshmallows or balls to represent protons, neutrons and electrons and record your choices.

Isotope	Number of protons	Number of neutrons	Number of electrons
Protium			
Deuterium			
Tritium			

3 Using the numbers from the table, collect the correct number and colour of marshmallows/balls to **construct** the three isotopes of hydrogen.
4 Use the marshmallows/balls and toothpicks to **construct** your models.

Results

1 In your workspace use photographs or drawings to record what your models look like.

Discussion

2 **Justify** or refute this statement: 'An isotope is an atom.'
3 **List** the correct symbols for each of the three isotopes of hydrogen.

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WORKSPACE
What have you learnt? 4.3

QUESTIONS 4.3

What have you learnt?

Remembering

1 **Define** the terms 'isotope', 'heavy atom' and 'light atom'.

2 **Recall** the missing terms to complete the following statements.

a The number of protons in an atom is known as the__________ __________.

b The number of __________ in an atom determines which element it is.

c The mass number of an atom is the number of __________ plus the number of __________ in the nucleus of the atom.

d In an electrically neutral atom, the number of __________ must equal the number of __________.

Applying

3 **Compare** the isotopes uranium-235 and uranium-238.

4 The correct symbol for nitrogen-15 is $^{15}_{7}N$.

a The number 15 is the __________ number.

b The number 7 is the __________ number.

c The number of neutrons in nitrogen-15 is __________.

Analysing

5 The symbol for one of the isotopes of uranium is $^{235}_{92}U$.

a **Identify** how many protons it has.

b **Calculate** how many neutrons it has.

c Determine how many electrons it has.

d **Identify** the mass number.

e **Identify** the atomic number.

6 **Predict** the isotope notation for the following.

a A boron atom that has 5 protons and 6 neutrons

b An atom of sulfur-32

Evaluating

7 A teacher gave a group of students the following information.

'One atom with an atomic number of 6 has six protons, eight neutrons and six electrons. Another atom has six protons, six neutrons and six electrons.'

She then asked: 'Do these two atoms represent the same element?' One student replied 'Yes they do' while another student replied 'No, they don't.' **Evaluate** each claim and **explain** which student you agree with and why.

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4.4 Radioactivity: a curious thing

radiation

a stream of particles and/or energy from a radioactive source

radioactivity

the spontaneous disintegration of certain atomic nuclei accompanied by the emission of alpha particles, beta particles or gamma radiation

At the same time that scientists were trying to understand atoms, they were also trying to understand radioactivity. Marie and Pierre Curie and Ernest Rutherford were studying how and why certain atoms could fall apart or decay and give off **radiation**.

In France, the Curies were pioneering the field of radioactivity. They discovered the elements polonium and radium. Marie Curie developed methods to separate radium from radioactive remains so its properties could be studied. It was Marie Curie who coined the term **radioactivity**.

Getty Images

Figure 4.14 Marie Curie

Magnificent Marie!

WOW!

Marie Curie (1867–1934) is recognised as one of the greatest scientists of all time. She was the first person to receive two Nobel Prizes – in Physics and Chemistry. Only one other person has received two Nobel Prizes. Marie Curie was also the first woman to be awarded a Nobel Prize and the first female professor at the University of Paris.

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ACTIVITY 4.5

Marie Curie's contributions to science

You need

- access to the Internet

What to do

Use information from the weblink to answer the following questions.

1 **Identify** where Marie Curie was born.
2 **Explain** why she went to Paris.
3 **Identify** which element rays she first studied.
4 **Outline** what she discovered about the strength of the rays.
5 **Explain** why she coined the term 'radioactivity'.
6 Name the two new elements she and her husband discovered.
7 **Explain** the potential of one of the new elements.
8 **Identify** the discovery for which she won the Nobel Prize in Physics.
9 Name the discovery for which she won the Nobel Prize in Chemistry.
10 **Outline** how she used her discoveries to help the wounded during World War I.
11 **Recall** what caused her death.
12 Imagine that you could interview Marie Curie. **Prepare** a set of questions that you would like to have asked Marie Curie. Start your questions with Who, What, Where, When, Why and How.

WORKSPACE
Marie Curie's contributions to science

WEBLINK
Marie Curie history

ICT

Present your research using Photo Story or VoiceThread to share your ideas.

Meanwhile, Rutherford and his colleague Fredrick Soddy (1877–1956) were also studying radioactivity and built on the work of Marie Curie. They placed a radioactive sample of radium in a closed container and forced the bubbles of gas given off into an inverted flask. These bubbles were shown to be the new element radon. They observed that as the sample in the container grew smaller, the amount of radon increased in the same proportion. This discovery led them to propose that one element actually changed into another.

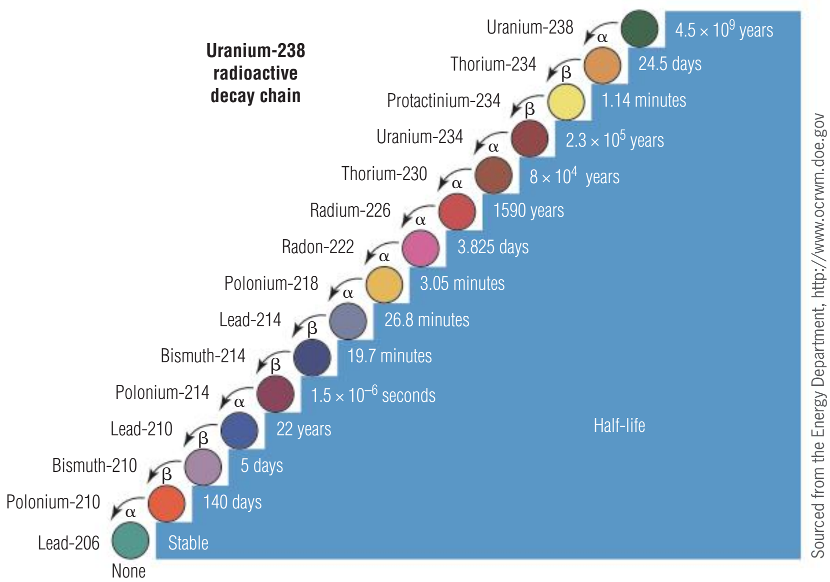

Figure 4.15 Rutherford–Soddy disintegration theory of radioactivity illustrated, beginning with uranium-238

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beta particle
an electron or positron (which has the same mass as an electron but the opposite charge) emitted when an unstable nucleus decays

Rutherford was an experimental scientist. His theories were the result of careful laboratory experimentation and observations. This is reflected in one of his famous quotes: 'If your experiment needs statistics, you ought to have done a better experiment.'

By studying the weight difference between decaying elements and their products, Rutherford identified that little bits flew off radioactive atoms. He called these alpha particles. Through careful investigation he was able to determine that alpha particles were actually helium nuclei. He also discovered **beta particles,** but could not explain their nature.

Rutherford helped classify the radiation that had been identified into common types. He used letters from the Greek alphabet to label them alpha (α), beta (β) and gamma (γ) decay. At the time, scientists knew that alpha and beta were particles and gamma was energy.

WOW!

Another Nobel Prize winner

Rutherford won the 1908 Nobel Prize in Chemistry for his investigations into the disintegration of substances and the chemistry of radioactive substances. During his acceptance speech he announced that he had discovered that an alpha particle is a helium nucleus.


University of Canterbury NZ

As an experimentalist Rutherford knew that great research did not just support or disprove theories, it also raised more questions to be investigated. As well as winning a Nobel Prize himself, he mentored and trained 11 future prize winners!

Making sense of radioactive atoms

Here again, the discovery of the neutron played an important role – the nature of radioactivity suddenly made sense. When a radioactive element undergoes alpha decay, an alpha particle is released so that the decaying element is converted into a different element. This occurs because it has lost two protons.

Similarly, beta decay could be explained as the conversion of neutrons to protons or vice versa. This conversion changes the number of protons in the nucleus so the atomic number changes; therefore, beta decay converts an atom of one element into an atom of a different element.

Natural radioactivity

natural radioactivity
the result of spontaneous disintegration of naturally occurring radioactive elements

Natural radioactivity occurs when naturally occurring radioactive elements undergo spontaneous disintegration. So why are elements or some isotopes of elements radioactive?

To understand this we need to go back to the nucleus. Remember, the nucleus is a bundle of positively charged protons and neutral neutrons crowded together. The neutrons help to reduce the repulsive forces between the protons. For a nucleus to be stable, the number of neutrons and protons must be balanced.

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WOW! Radioactive bananas?

Bananas are naturally radioactive because they contain the radioisotope of potassium, K-40. One BED – banana equivalent dose – is the dose of radiation equal to eating one banana. One BED will not cause you harm, but 80 million will. Fifty BEDs is equivalent to receiving a dental X-ray and 500 million BEDs is a dose equal to that received by standing beside a nuclear meltdown for 10 minutes!

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Types of radioactive decay

Elements with a lighter atomic mass tend to maintain an equal number of neutrons and protons. This makes the atom stable. If an atom has more neutrons than protons, then it is unstable. This means it will decay and this releases energy. The decay products are neutrons and high-energy gamma radiation.

An example of this type of decay is that of the radioactive isotope of carbon, carbon-14. The main isotope of carbon, carbon-12, is stable. When carbon-14 (which has six protons and eight neutrons) decays, one of its neutrons is converted to a proton and a negatively charged beta particle is given off (emitted). The new nucleus has seven protons and seven neutrons because it has gained a proton and lost a neutron. It has been converted to another element, nitrogen, because the number of protons has changed.

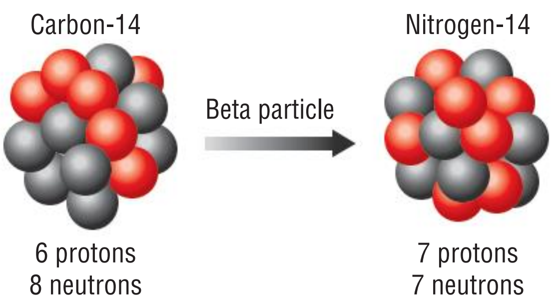

Figure 4.16 The decay of carbon-14 to nitrogen occurs when a neutron is converted to a proton.

This knowledge is used by scientists in the process of carbon dating of archaeological samples of biological origin, such as bone, wood and other plant material. Carbon-12 and carbon-14 exist in a known ratio in the atmosphere. Plants and animals incorporate both isotopes and therefore they are maintained in living organisms in about the same proportion as in the atmosphere. Throughout an organism's life, as the carbon-14 within the organism decays, it is replaced and the ratio remains relatively constant. When the organism dies, the carbon-14 in its tissues decays to nitrogen at a known rate and is no longer replaced. Hence, by comparing the ratio of carbon-12 to carbon-14 in a fossil, scientists can determine its age (see Figure 4.17 on page 134).

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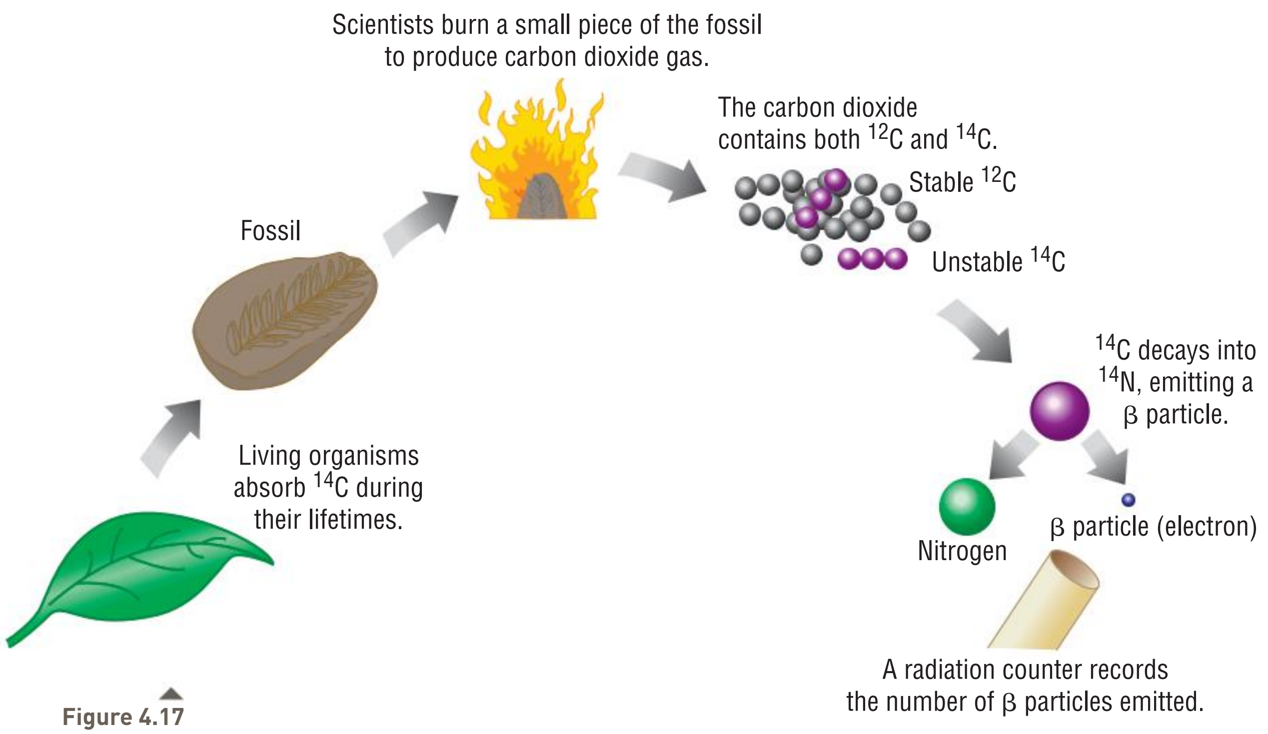

Figure 4.17
Carbon dating. Carbon-14 decays at a known rate. Scientists can determine the age of a fossil by measuring the amount of carbon-14 it contains.

ACTIVITY 4.6

Careers in carbon dating


Shutterstock.com/dtopal

Figure 4.18
An archaeologist uncovering an ancient burial site

Identify a career that involves carbon dating. **Investigate** that career. **Construct** a voki that **explains** what that career is and how it uses carbon dating. Upload your voki to the class wiki.

WEBLINK
Voki

Are you falling apart?

In the average human, more than 200000 potassium-40 nuclei disintegrate each minute. The body emits 20000 gamma rays by this process alone.

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Heavier elements have more protons so they must also have more neutrons to help stabilise the nucleus. For elements with an atomic number greater than 50, the ratio of neutrons to protons increases to 3:2.

Elements with an atomic number greater than 83 (bismuth) have no stable isotopes. This means every element above bismuth in the periodic table will spontaneously decay, giving off radioactivity. So radioactive elements dominate the bottom section of the periodic table.

Once this discovery was made, it became obvious to chemists why it was difficult to find elements to fill the empty positions in the periodic table. Many of them no longer existed naturally or existed in only very small amounts. Astatine is the scarcest natural element. In the 6 million billion billion kilograms that is the mass of the Earth, there is a total of only 28 g of astatine.

Uranium and radium are heavy elements that have many positively charged protons bound in their tiny nuclei. The neutrons act as buffers to stabilise the nucleus. Uranium-238 is unstable and will emit an alpha particle (a helium nucleus) to form thorium-234. Similarly, radium-226 (which has 88 protons and a mass number of 226) will undergo alpha decay to form radon-222, which has:

$$88 - 2 = 86 \text{ protons}$$

and a mass number of:

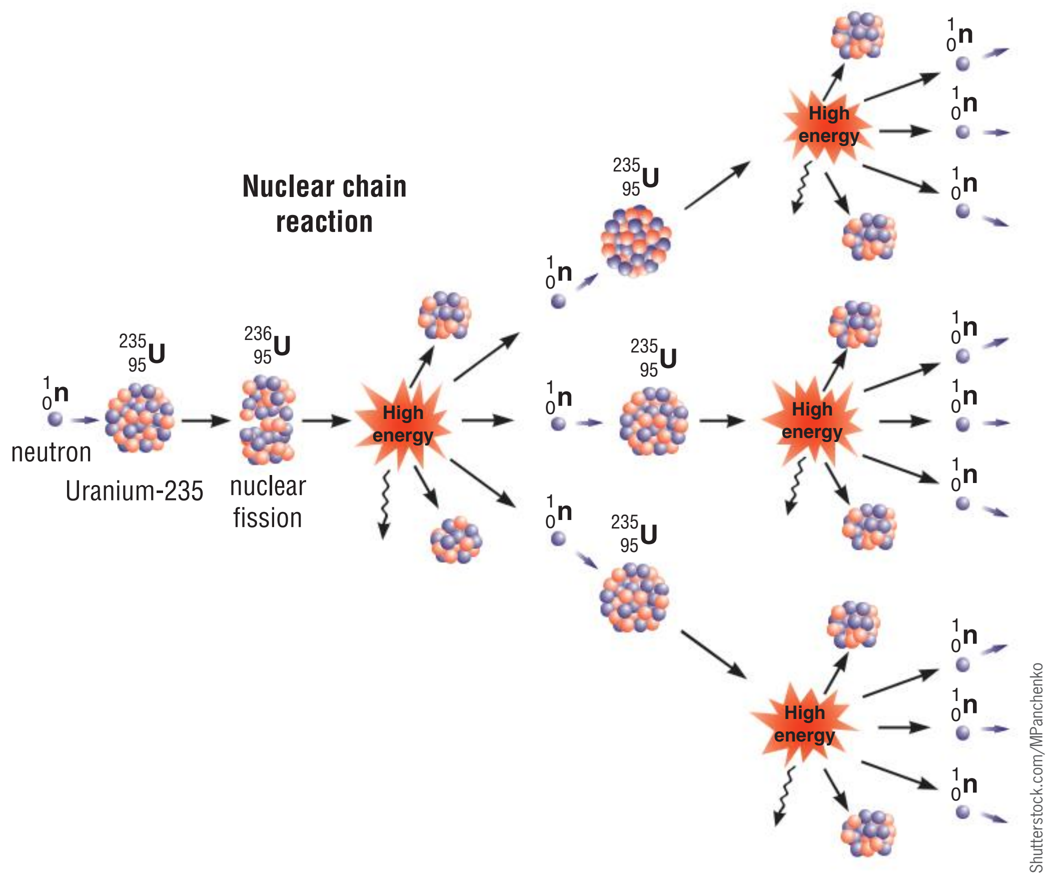
$$226 - 4 = 222$$

Radioactive isotopes that emit alpha particles often emit gamma rays as well.

Nuclear reactors

If the atoms of heavy elements are bombarded with neutrons, they can be split into two lighter atoms of roughly equal size. This process is called **nuclear fission**.

nuclear fission
the splitting of a nucleus into two smaller pieces



ANIMATION
Chain reaction

ICT

Download Google Earth and use it to locate 10 of the world's nuclear reactors. Mark these locations on a map. Upload your map to your glog.

Figure 4.19
A chain reaction – the neutrons generated by the nuclear fission initiate fission in other atoms.

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chain reaction

a reaction that is self-sustaining as a result of one step starting another step

The lighter atoms need fewer neutrons to make them stable, so extra neutrons are released during fission. Sometimes those neutrons are absorbed by nearby heavy atoms, which become unstable and release more neutrons. This process continues, creating a **chain reaction**.

If the number of neutrons builds up rapidly, it can cause more reactions to occur in a chain reaction. The release of an enormous amount of energy is enough to create an atomic explosion.

However, if most of the neutrons are absorbed by another material and only one neutron is allowed to carry on the reaction, then a steady controlled release of energy occurs. This is how nuclear reactors work. They can be used to produce electricity or to produce radioactive isotopes for medical or industrial purposes.

WEBLINK
All about isotopes

Half-life of radioactive elements

An important property of radioactive isotopes is their stability. This is defined as how long they survive before completely decaying into other isotopes. Stability is measured by the **half-life**, which is defined as the time it takes for half the atoms of a given sample to decay.

half-life

the time it takes for half of an isotope to decay

The rate at which radioactive isotopes decay varies greatly. Fluorine-20 decays in a matter of hours, while gold-198 takes a few days to decay. Others, such as radium-226, will not decay for tens of thousands of years.

Consider this example of sodium-24, which has a half-life of 15 hours. If initially there were 10 g of sodium-24, after 15 hours there would only be 5 g because half the sample would have decayed. After a further 15 hours (30 hours from the beginning), there would be 2.5 g. After another 15 hours (45 hours later), there would be 1.25 g. This process would continue until there was hardly any of the original radioactive isotope left.

ACTIVITY SHEET
Isotope review

WORKSPACE
Simulating radioactive decay

EXPERIMENT 4.2

Simulating radioactive decay

Aim

To model radioactive decay using pieces of coloured paper to simulate the process

Materials

- 50 pieces of paper (approx. 2 cm square) with one colour on one side and a different colour on the other side
- plastic container with lid

Method

1 Place the pieces of paper in the container.

2 Place the lid tightly on the container.

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EXPERIMENT 4.2

3 Shake the container, turning it upside down several times.

4 Remove the lid and empty out the pieces of paper. Choose one of the colours of the paper and remove all the pieces that have that coloured side up. Count how many pieces were removed. Return the rest to the container.

5 Repeat steps 2–4, removing the same colour each time until no pieces of paper are left in the container.

6 If possible, use Excel to create a data table to record the number of pieces removed in each trial. If not, use the data table provided below. **Calculate** the number of pieces remaining and record this in the second column.

Results

1 **Construct** two graphs side by side or draw both graphs on the same set of axes. Put the trial number on the horizontal axis and the number of pieces of paper on the vertical axis. Draw a graph for the number of pieces remaining and another for the number of pieces removed.

Data table

Trial	Number of pieces remaining	Number of pieces removed
0	50	0
1		
2		
3		
4		
5		
6		
7		

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EXPERIMENT 4.2

Discussion

2 **Identify** what the pieces of paper represent.

3 **Identify** what the two different coloured sides represent.

4 **Identify** what the shaking of the container represents.

5 **Explain** the relationship between the lines on your graph(s).

6 **Explain** the ways in which this activity simulates radioactive decay.

7 **Predict** if there will eventually be no paper left.

Conclusion

8 Write a conclusion for this activity.

Extension: Student investigation

9 **Design** a different experiment that could simulate radioactive decay. Conduct your experiment. Record your findings. **Compare** your method with the one above.

WORKSPACE
What have you learnt? 4.4

QUESTIONS 4.4

What have you learnt?

Remembering

1 **Identify** Marie Curie's major scientific accomplishments.

2 **Recall** the charge carried by a beta particle.

3 **Recall** what an alpha particle is.

4 **Recall** the mass of an alpha particle.

5 **Identify** the type of radiation emitted during alpha and beta decay.

6 **Define** the term 'half-life'.

Applying

7 Iodine-131 undergoes beta decay. **Identify** the new element produced.

8 Uranium-238 undergoes alpha decay. **Identify** the new element produced.

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QUESTIONS 4.4

Analysing

9 A radioactive isotope has a half-life of 2.0 minutes. **Construct** a graph of the mass of the sample against time for 8 minutes, starting with a sample of 24.0 g.

- **a** **Calculate** how much of the sample would be left after 10 minutes.
- **b** If the original sample had been 48.0 g, **predict** whether the half-life would increase, decrease or remain constant.

10 Ernest Rutherford said: 'If your experiment needs statistics, you ought to have done a better experiment.' **Explain** what you think this means.

Creating

11 Return to your timeline and add your increased understanding of the atom.

4.5 Radioactivity: What is it good for?

Advances in the understanding of radioactivity and radioactive isotopes have been used to generate new applications. These in turn have led to new technologies and new career opportunities.

Radioactivity in medicine

Radiation has many uses in medicine, both in finding out what is wrong with a patient and in treating an illness such as cancer.

Nuclear medicine follows what happens to certain chemicals as they pass through the body and so can be used to check if an organ is functioning properly. These chemicals, called tracers, are made with radioactive isotopes and so their path through the body can be followed by monitoring the radiation they emit (see Figure 4.20 on page 140).

It is important that isotopes used in medicine only have short half-lives so that patients do not stay radioactive any longer than necessary. Technetium-99 is widely used because it emits only gamma radiation. It is used to diagnose heart, bone, lung, brain, thyroid and blood flow problems. Fluorine-18 is used to study brain function and to diagnose epilepsy, heart disease and certain types of cancer (see Figure 4.21 on page 140). Iodine-123 is used in the diagnosis of thyroid diseases and some cancers.

nuclear medicine
the branch of medicine that uses radioactive isotopes to diagnose, manage and treat diseases

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Figure 4.20 Chemical tracer containing a radioactive isotope

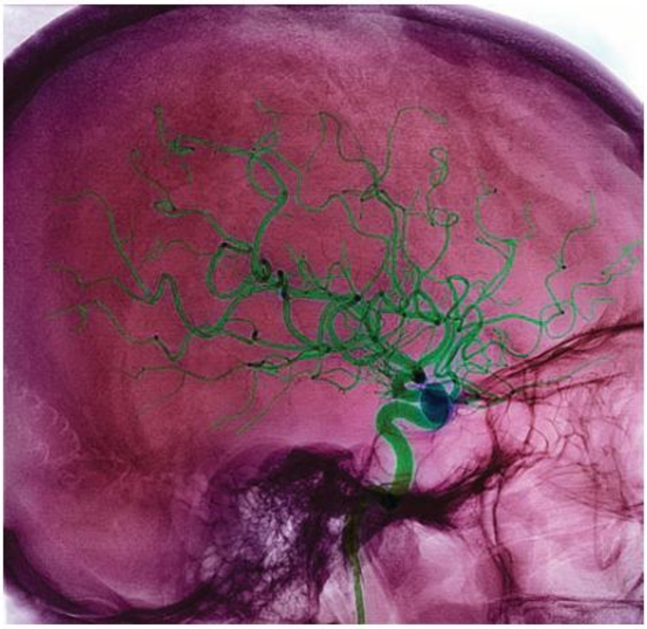

Figure 4.21 Arterial brain scans involve injecting a radioactive isotope such as fluorine-18 into a blood vessel and taking an image.

radiotherapy
the treatment of cancer by radiation

The use of radiation in the treatment of cancer is called **radiotherapy**. It works because cancer cells are actively dividing and so are more susceptible to radiation than healthy cells. This means that cancer cells can be killed by radiation while healthy cells will recover. Radiotherapists must be very careful with the dosage to ensure only the cancer cells receive the high dose of radiation and are highly trained to do this.

Many radiotherapy machines use cobalt-60 as a source of gamma radiation. Cobalt-60 has a half-life of 5.2 years. It does not need to have a short half-life as it is not inside the patient but in a radiotherapy machine.

Other radioactive isotopes used in medicine are iodine-131, which is used in the treatment of diseases of the thyroid, and iridium-192, which is used as an internal radiation source when a small amount is implanted in the body.

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ACTIVITY 4.7

Ethics in science

Imagine you are on the Bioethics Committee at Nelson Children's Hospital. An oncologist presents a case in which the parents of Lily, a child diagnosed with cancer, want Lily treated with radiotherapy without telling her she has cancer.

1 In a small group, **examine** the ethical considerations of this scenario.
2 **Discuss** the rights of the child, the parents and the doctor. Together, **list** as many ethical issues as you can. **Assess** whether or not the age of the child is relevant.
3 **Critically evaluate** the issues and write a persuasive essay (300–500 words) to **explain** your point of view in this case.

WORKSPACE
Ethics in science

Radioactivity in industry

Radioactive isotopes have a number of industrial applications. Caesium-137 is used to determine the thickness of steel sheets, paper, aluminium foil and plastic film. The caesium-137 is placed on one side of the material and a detector, which measures the amount of radiation, is placed on the other. Thicker materials absorb more radiation, so the amount received by the detector is less.

Gold-198 is used as a tracer to follow the movement of sewage and other wastes through waterways in a similar way to how tracers are used in medicine.

Leaks can be detected in underground water pipes or oil lines by adding a radioactive isotope, such as sodium-24, and following the passage of the tracer in the pipe with a detector. The places where radiation is detected indicate the site of the leak.

Domestic smoke detectors contain a small amount of americium-241. To understand how these work, go to the interactive 'Where there's smoke'.


Alamy/Mode Images

Figure 4.22
An ionising smoke detector

INTERACTIVE
Where there's smoke

Radioactivity issues

Despite the benefits of many of the applications of radioactive isotopes, there are a number of problems associated with their uses.

Environmental contamination

As mentioned earlier, one of the most important properties of radioactive isotopes is their stability and this is dictated by their half-life. Tied in with this is the possibility of causing short- or long-term harm to the environment or living organisms, including humans.

Shutterstock.com/Sergey Kamshylin

Figure 4.23 Forest contaminated with radioactivity inside the 30 km exclusion zone around Chernobyl

Radioactive contamination of the environment results from the unintentional release of radioactive materials. Such contamination could be due to human error, accidental leaks, natural disaster or the deliberate release by humans. Design flaws and poor procedures resulted in the catastrophic disaster at the Chernobyl nuclear facility in 1986 in the Ukraine. An earthquake and tsunami led to the accidental release of radioactive materials from the Fukushima nuclear power plant in Japan in 2011. The deliberate dropping of atomic bombs on Nagasaki and Hiroshima during World War II caused not only immediate deaths, but also left widespread devastation and lingering radioactivity. In each of these examples, the radioactivity was not contained at the site. After the Chernobyl disaster, wind, rain and waterways spread radioactive materials across an estimated 200 000 square kilometres of Europe. Radiation also crept into local food chains. High levels were also found in fish and reindeer in Sweden, and food production was prohibited within 30 kilometres of the site.

ACTIVITY SHEET
Fukushima nuclear reactor

Human health effects

Radiologists, airline flight crews and uranium miners are all examples of radiation workers. Occupations like these mean that the workers are exposed to a higher level of radiation and must take precautions to prevent radiation effects on their health. Uranium miners, for example, had an increased rate of lung cancer before safety regulations were put in place.

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Figure 4.24
Radiologist technician wearing protective clothing when treating patient

The health risk associated with exposure to radiation is due to the damage that can occur to cells. The amount of damage depends on how far into the tissue the form of radiation can penetrate. These forms are alpha and beta particles and gamma rays. Alpha particles lose energy quickly and cannot pass through the thickness of a piece of paper or a layer of skin. But if these particles are inhaled they can damage cells. Beta particles can penetrate through skin and damage living cells. Gamma rays can penetrate deeply into living tissue and cause serious damage to cells. The radiation can damage and disrupt the production of new cells during cell division. In some cases, mutations to genes or chromosomes can occur, resulting in cancer or birth defects in offspring. High doses of radiation can cause nausea, vomiting, fever and hair loss. Over the long-term, bone marrow can be destroyed, mutations can occur and cancers can develop. Radiologists protect themselves from risk of repeated high levels of exposure by standing behind leaded glass or wearing safety clothing.

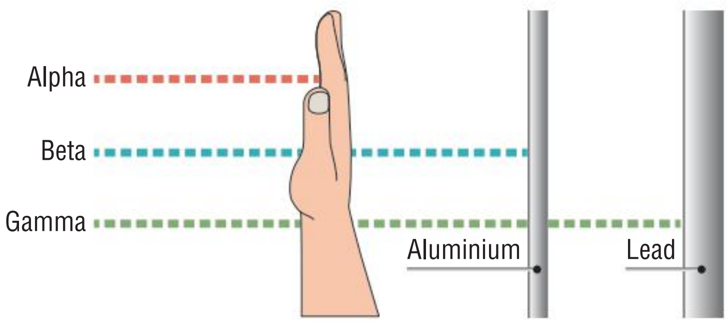

Figure 4.25
Alpha particles cannot pass through the thickness of a sheet of paper or layer of skin. Beta particles are stopped by a 1 mm plate of aluminium, but gamma rays are only stopped by thick lead or concrete.

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The disaster at Chernobyl released radiation more than 200 times that of the atomic bombs dropped on Nagasaki and Hiroshima combined. Nearby there has been a 200% increase in both breast cancers and birth defects, and a 2400% increase in the incidence of thyroid cancer.

WORKSPACE
What have you learnt? 4.5

QUESTIONS 4.5

What have you learnt?

Remembering

1 **Define** the term 'radiotherapy'.

2 **Identify** three uses of radioactive isotopes in medical diagnosis or treatment.

3 **Identify** three uses of radioactive isotopes in industrial settings.

Understanding

4 **Explain** why isotopes used in nuclear medicine must have a short half-life.

5 Marie Curie died from radiation-related illness. **Account** for how this may have occurred. **Propose** two precautions she could have taken to protect herself from radiation.

Analysing

6 **Explain** how radiation can cause cancers, but can also be used to treat cancer.

Evaluating

7 Gold is usually thought of as a precious metal, yet gold-198 is used to track the pathway of sewage through waterways. Gold-198 has a half-life of 2.7 days. Considering this, **critically evaluate** the degree of risk this is to local waterways. **Discuss** the risks and benefits and **justify** your view on whether or not the risks outweigh the benefits.

8 **Construct** a plus minus table to **compare** the positives and negatives of detecting leaks in underground pipes using radioactive isotopes. Determine which of these is the most important and **explain** your answer.

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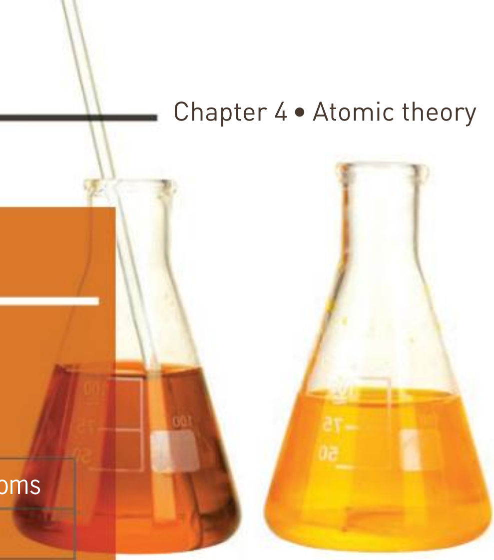

Chapter review

Remembering

1 Match the term in the first column to the correct definition in the second column.

Proton	Particle with no charge that exists in the nucleus of most atoms
Neutron	Centre of the atom, contains most of the atom's mass
Electron	Total number of protons and neutrons in the nucleus of the atom
Nucleus	Atom with different numbers of neutrons
Atom	Number of protons in the atom
Atomic number	Negatively charged particle in the atom
Mass number	Smallest particle that can exist by itself
Isotope	Positively charged particle in the nucleus of the atom

2 **Define** 'subatomic particle' and name three subatomic particles.

Understanding

3 Draw a simple model of an atom to **describe** its basic structure and components.

4 **Contrast** atoms and isotopes.

5 Rutherford shot alpha particles at a thin sheet of gold. **Recall** his observations. **Recall** his proposal for the structure of an atom based on these observations.

6 **Identify** the chemical similarities on which Mendeleev based his periodic table.

7 Name the two main particles of radioactive decay and **describe** the difference between them.

8 **Identify** the information on which the process of carbon dating is based.

9 **Explain** what is meant by the term 'half-life' of a radioactive element.

10 **Describe** two uses of radioactivity.

Applying

11 Determine the number of protons, neutrons and electrons in an atom of ^{30}Si. You can refer to a periodic table.

12 Refer to a periodic table to complete the following table for neutral atoms.

Isotope	Atomic number (Z)	Mass number (A)	Number of electrons
^{31}P	15		
^{18}O			8
	19	39	
		27	13

WORKSPACE
Chapter 4 review

ACTIVITY SHEET
Chapter 4 checklist

REVIEW QUIZ
Chapter 4

ISBN 9780170231503

13 Cobalt-60 undergoes beta decay. **Identify** the new element that is produced.

Analysing

14 **Compare** the resultant products of alpha and beta particle emission of the isotope oxygen-17.

15 **Distinguish** between protons, neutrons and electrons in terms of mass and charge.

Evaluating

16 **Evaluate** the statement 'The neutron was the most difficult subatomic particle to discover'.

17 **Deduce** who you consider to be the greater scientist – Rutherford or Curie. **Justify** your choice.

18 **Assess** the usefulness of radioactive isotopes.

19 Imagine if we did not know the structure of the atom yet. **Propose** three ways this could impact scientific ideas or advances.

Creating

20 **Construct** a flowchart to **summarise** how atomic theory developed over time. Include key scientists in your summary and **demonstrate** how their scientific work advanced the atomic model.

21 **Construct** a flowchart showing how scientific understanding of the atom changed from Dalton to Thomson to Rutherford.

22 Imagine you are an atom of americium-241 in a smoke detector. **Predict** what would happen to you when smoke is detected.

Reflecting

23 If you had to pursue a career based on something from this chapter, **identify** what it would be and why. Record your response in your glog.

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5

The chemistry of new substances

How are new substances made?

Baking a cake is an example of a chemical reaction. We mix together specific amounts of egg, butter, sugar, flour and other ingredients, and then put the mixture in the oven to cook. When we take the mixture out of the oven, it looks very different from when we put it in. A new substance has been formed. It is now a cake. We cannot reverse the reaction and get back the individual ingredients. They have been changed. A chemical reaction has occurred.

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Chemical world – Stage 5

Key knowledge

- All matter is composed of atoms and has mass.
- Compounds can be identified by both common names and chemical formulas.
- Corrosion, decomposition and precipitation are important chemical reactions that occur in non-living systems.
- Corrosion, decomposition and precipitation are chemical reactions that involve the transfer of energy.
- Chemical reactions can be represented as word equations.
- Atoms are rearranged during chemical reactions to produce new materials.

ACTIVITY SHEET
CAT with rubric: Important chemical reactions

CULMINATING ASSESSMENT TASK

Important chemical reactions

Work with a partner. Choose one chemical reaction that occurs in your body, or in industry, nature or your home. You must **describe** the general chemistry involved in this reaction. Imagine and **outline** the possible consequences of this reaction not existing. Present the chemistry and your justification of its importance to your class.

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What do you already know about new substances?

During your study of science and in your everyday experience, you will have seen examples of chemical reactions. Some of these reactions occur naturally and some take place either in the home or in industrial processes. Baking a cake is one such example.

Use your knowledge to create a list that **describes** some examples of chemical reactions you encounter from when you get up in the morning until you go to bed at night. Think of substances that you use or things that you are involved in. Make your descriptions as precise as you can. You can also **list** any chemical reactions you know of.

Share your list with the class, or put it on the class wiki.

WORKSPACE
What do you already know about new substances?

5.1 Chemical reactions involve energy

Chemicals can undergo two types of change – physical change and chemical change. Both of these can involve energy. An example of a physical change is sugar dissolving in water. This is called a physical change because the molecules of sugar and the molecules of water have not changed – they have just packed in near each other just like table tennis balls can pack in near basketballs. The table tennis balls and basketballs haven't changed into any new substance, nor have the sugar molecules and water molecules. We can separate them out again by distillation, in which water boils and moves through the condenser, where it condenses to form liquid water again. Crystals of sugar are left in the flask.

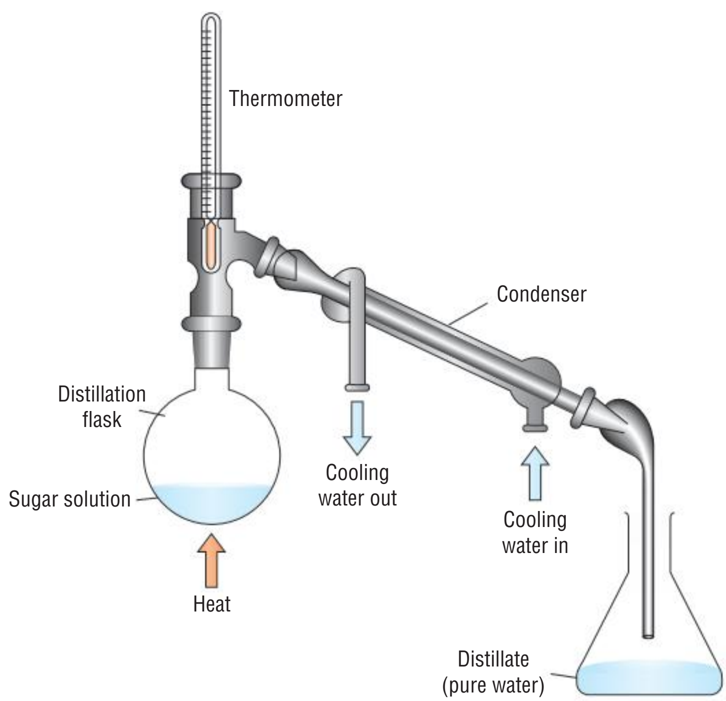

Figure 5.1 Distillation is a physical change, such as sugar being separated from water.

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Chemical change, however, involves the formation of new substances. The molecules are not just packing in near each other, they are rearranged. Atoms within the chemicals rearrange in definite proportions to produce new substances, during a chemical reaction. Sometimes many chemical reactions are needed to produce a specific product. Chemical reactions occur in nature and in industry. A chemical reaction is always needed to form a new substance.

An example of a chemical change is the production of plastic from crude oil. A new substance has been formed – plastic. It is not a physical change since the plastic cannot be changed back into crude oil, a chemical change has occurred.

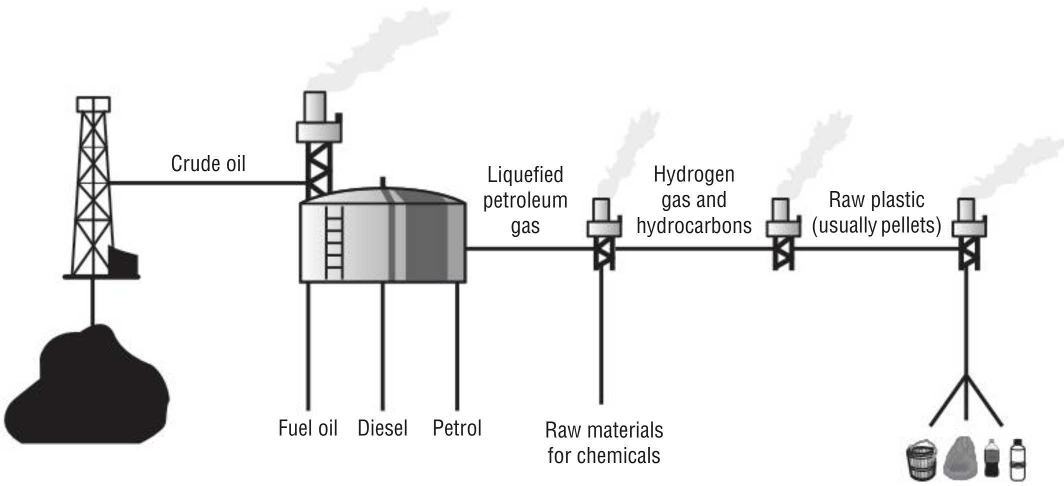

Figure 5.2 An example of a chemical change – making plastics from crude oil

chemical reaction
a reaction in which a new chemical is formed

A **chemical reaction** is a process that changes or transforms one set of chemicals into another. During this process energy is either used or released.

WORKSPACE
Energy transformations

ACTIVITY 5.1

Energy transformations

1 Chemical reactions can involve energy transformations (see Question **2** for some examples of energy transformations). **Explain** each of the energy transformations in Question **2** to someone younger. Write a definition of each transformation and upload them to the class wiki.

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ACTIVITY 5.1

2 Consider the items on the shelves at your local supermarket or hardware store. How are the non-edible items sorted or classified in the aisles and on the shelves? With this in mind, **identify** a **list** of products that involve the following energy transformations. Use the workspace to **list** four products and include images under each of the headings.
   - **a** Electrical energy → chemical energy
   - **b** Chemical energy → electrical energy
   - **c** Chemical energy → heat energy
   - **d** Chemical energy → light energy

3 **Justify** or refute this statement: 'Non-edible supermarket items are sorted according to energy transformations'. Record your response on your blog.

Getty Images/Paul Burns

Figure 5.3 How are the items in a supermarket or hardware store sorted?

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WORKSPACE
Student investigation: A simple fruit battery

EXPERIMENT 5.1

Student investigation: A simple fruit battery

Part A

Aim

To **construct** the best battery possible using different metals and fruits or vegetables

(The best battery is the one that has the largest voltage as measured using a voltmeter.)

Materials and method

This is a safe experiment but you should carry out your own risk assessment.

You will need to borrow a voltmeter and a couple of electrical wires from your teacher, but all other equipment should be able to be found around your home.

1 Take digital images as you make your fruit battery.
2 Write a detailed set of instructions, including digital images on how to make your battery.
3 A simple set-up for the experiment is shown in Figure 5.4.
4 Determine which metals to use. Is it better to use two of the same metal or two different metals?
5 Which fruits or vegetables could you use? Is it better to use one piece of fruit or vegetable or several?
6 Should the pieces of metal be placed close together or far apart?

Part B

Materials and method

1 Make another battery, but this time change one of the variables, such as using different fruit and the same metals or different metals and the same fruit.
2 Develop a flowchart as a set of instructions on how to make this battery.

Discussion

1 **Compare** the two batteries.
   - In what way did changing the fruit or the metal make a difference?
   - Was one battery better than the other?
   - What were the variables?
   - What conclusions can you draw from your investigation?

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EXPERIMENT 5.1

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Figure 5.4
A simple fruit battery

- Do you need to make another battery to draw conclusions?
- How could you improve on your experiment?

2 **List** different ways to vary your battery in an attempt to increase the voltage. Sequence the changes you would like to make. That is, use the same fruit but change the quantity, use the same fruit but change the metal, use a combination of fruits and so on.

3 Develop a list of the questions you have as you proceed with your experiment.

4 **Identify** the conditions that were necessary for a voltage to be recorded.

5 **Describe** the combination of factors that produced the greatest voltage.

6 **Describe** the energy transformation that occurred during this investigation.

7 **Identify** the ways in which you worked scientifically.

8 **Outline** ways in which you could improve the way you worked.

9 What would you keep the same? **Explain** why.

10 What questions do you have about this investigation?

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Using word equations to represent chemical reactions

When looking at a chemical reaction, we generally use the following terms.

reactant
a chemical that is put into a chemical reaction

product
a chemical that comes out of (is produced in) a chemical reaction

- **Reactants** are the substances that we start with – that is, the substances that are put into the reaction.
- Reaction conditions are what we need to do for the reaction to occur.
- **Products** are the substances that we have at the end – that is, what is produced.

Let's analyse the example of making a cake.

- The reactants are specific quantities of eggs, butter and flour (and any other ingredients).
- The reaction conditions are mixing the ingredients for a certain time, then putting them in a cake tin in the oven at a specific temperature and for a specific time period.
- The product is the cake.

A chemical equation is a way of presenting information about chemical reactions:

$$\text{Reactants} \rightarrow \text{products}$$

A chemical equation always has:

- reactants written on the left-hand side of the arrow
- products written on the right-hand side of the arrow
- the arrow always pointing towards the products.

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Figure 5.5 Reactants are substances we start with – in this case, eggs, butter and flour.

Sometimes a chemical reaction also has the reaction conditions written on top of the arrow.

If there is more than one reactant, then a '+' symbol is put between the reactants, for example A + B. The same is true if there is more than one product. We do not use an '=' symbol in chemical equations; we use an arrow symbol, which means 'goes to'.

Making a cake can be written as a chemical equation:

$$\textbf{(eggs} \quad + \quad \textbf{flour} \quad + \quad \textbf{butter)} \xrightarrow{\textbf{heat in oven}} \textbf{cake}$$

(reactants) **(product)**

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ACTIVITY 5.2

Scrambled eggs

1 Write a recipe for scrambled eggs, including the ingredients and method.
2 Write a 'chemical equation' for scrambled eggs.
3 Think of an example of your own of a chemical reaction that is non-food related. Write the reaction in detail and then as a chemical equation. Upload this to the class wiki.


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Figure 5.6 Cooking scrambled eggs

WORKSPACE
Scrambled eggs

EXPERIMENT 5.2

Making elephant's toothpaste

WORKSPACE
Making elephant's toothpaste

Possible risks	Safety precautions
This experiment is safe, but very messy.	Set up the equipment in a sink or large container such as an equipment container, or conduct the experiment outside.
The hydrogen peroxide could splash in your eyes or on your skin or clothes.	Wear eye protection and a laboratory coat to protect your clothing when using chemicals. If chemicals splash onto your skin, wash them off immediately with soap and water.

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EXPERIMENT 5.2

Materials

- safety glasses
- 1.25 L soft-drink bottle
- funnel
- 250 mL beaker
- stirring rod
- 125 mL of 6% hydrogen peroxide H_2O_2
- 1 sachet of dry yeast (this is a catalyst – it speeds up the chemical reaction)
- 1–2 mL of dishwashing detergent
- 1 mL of food colouring (not cochineal)
- 50 mL of warm water
- digital video camera (optional)

Method

1 Place the funnel in the rinsed soft-drink bottle and pour the hydrogen peroxide in.

2 Add the dishwashing liquid and food colouring to the soft-drink bottle.

3 Pour the dry yeast into the beaker, add the warm water and stir.

4 Pour the yeast solution into the soft-drink bottle and remove the funnel. Watch what happens.

Results

1 Record or video your observations.

Discussion

2 **Identify** the signs that a chemical reaction occurred.

3 The word equation for this chemical reaction is:

Hydrogen peroxide → water + oxygen

Use the word equation and your observations to **explain** what happened in this chemical reaction.

4 The detergent did not take part in the chemical reaction. **Explain** the purpose of using the detergent in this activity.

5 Repeat the activity without adding the detergent. **Assess** whether your explanation to Question **4** is correct.

6 What questions do you have about this activity?

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There are many different types of chemical reactions. Some reactions do not need any extra energy to get them started, they are **spontaneous**. Examples of spontaneous reactions are making elephant's toothpaste and corrosion, which we will look at later in this chapter. Others only occur when we put in energy, such as heat or electricity. We will see examples of this when we look at **decomposition** reactions later in this chapter and combustion reactions in Chapter 6.

spontaneous

a reaction that occurs at room temperature; it does not require any extra energy to get it started

decomposition

a chemical reaction in which a more complex substance (compound) is broken down into simpler substances

WORKSPACE
What have you learnt? 5.1

QUESTIONS 5.1

What have you learnt?

Remembering

1 **Distinguish** between a chemical change and a physical change.

2 **Identify** the term used to describe substances that are put into a chemical reaction.

3 **Identify** three types of energy that can be produced during a chemical reaction.

Applying

4 Nail polish remover, ethyl acetate, is produced by reacting ethanol with acetic acid. Water is also produced.

   a **Identify** one of the products in this reaction.
   b Write a word equation for this reaction.

5.2 Law of conservation of mass

All matter is made of atoms. The atom is the smallest quantity of matter. Some substances are elements, e.g. oxygen and aluminium. Other substances are compounds, e.g. water and sugar. Some substances are natural, such as water and rocks. Others are manufactured, for example plastics and medicines.

In Year 8, you learnt to write simple chemical formulae.

Compounds are made up of definite amounts of different elements. Chemical formulae are used to write the names of compounds. They give us information about:

- the names of the elements that are present in a compound
- the number of atoms of each of the elements that are present in the compound.

ACTIVITY SHEET
Writing chemical formulae

For example, water has the formula H_2O. This tells us that water has 2 atoms of hydrogen and 1 atom of oxygen in it.

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In the late 1700s, French chemist Antoine Lavoisier (1743–94) conducted many experiments. Through his work, he was able to collect evidence that supported the idea that mass is conserved during a chemical reaction. This means that the total mass of the reactants that are put in at the beginning of an experiment will be the same as the total mass of the products that are collected at the end of the experiment.

Law of conservation of mass
Total mass of reactants = total mass of products

You will recall from Chapter 4 that Lavoisier's idea about the conservation of mass is now known as the law of conservation of mass. Scientists have performed many more experiments over the last 200 years and the results all reinforce the finding that mass is conserved during a chemical reaction. You cannot end up with more or less than you started with; you must end up with the same mass.

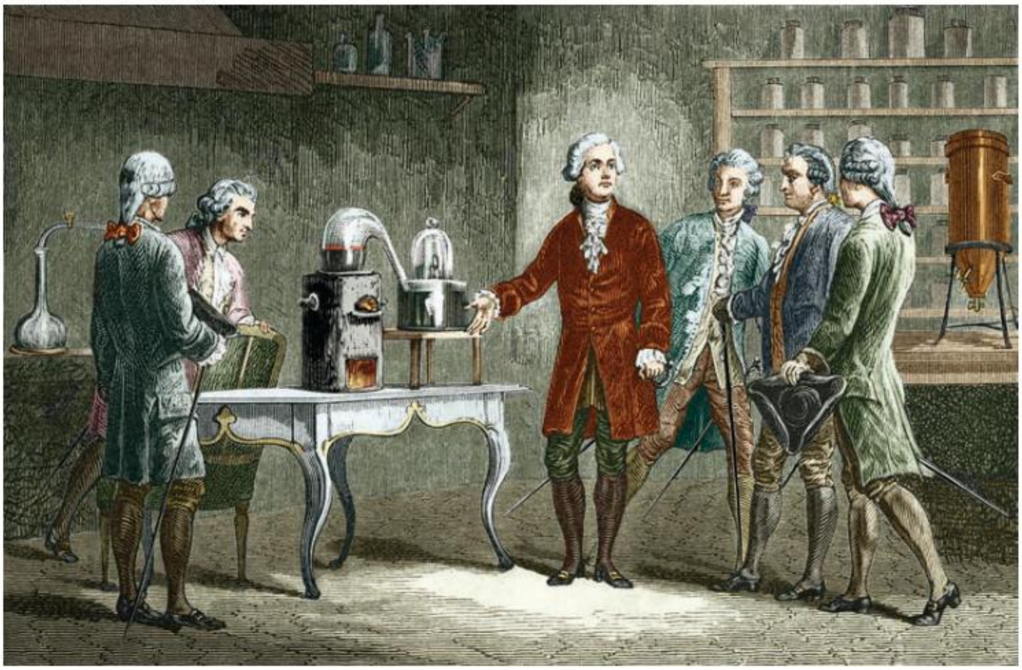

Figure 5.7 Antoine Lavoisier (1743–94) discovered that mass is conserved in chemical reactions.

WORKSPACE
Conservation of mass

EXPERIMENT 5.3

Conservation of mass

Possible risks	Safety precautions
Lead nitrate is toxic. It could get into your eyes or onto your skin.	Wear safety glasses. Wash hands with soap and water after the experiment. Refer to the MSDS for all chemicals and follow the disposal guidelines.

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EXPERIMENT 5.3

Part A

Materials

- 2 × 100 mL beakers
- electronic balance
- 20 mL of potassium iodide KI solution (0.1 mol/L)
- 20 mL of lead nitrate $Pb(NO_3)_2$ solution (0.1 mol/L)

Method

1. Pour 20 mL of potassium iodide into beaker 1 and 20 mL of lead nitrate into beaker 2.
2. Place both beakers onto the electronic balance and find the total mass.
3. Pour the contents of beaker 1 into beaker 2 and find the total mass of both beakers.
4. Dispose of chemicals as instructed by your teacher.

Discussion

1. **Describe** the features that told you that a chemical reaction had occurred.
2. **Deduce** whether your results indicate that mass is conserved during a chemical reaction.

Part B

Materials

- 100 mL beaker
- watch glass
- electronic balance
- spatula or plastic spoon
- 20 mL of vinegar CH_3COOH
- 5 g of solid bicarbonate of soda $NaHCO_3$

Method

1. Pour 20 mL of vinegar into the beaker.
2. Measure 5 g of bicarbonate of soda onto the watch glass.
3. Place the beaker and the watch glass onto the electronic balance and find their combined mass.
4. Pour the bicarbonate of soda into the beaker of vinegar and find the total mass of the beaker and its contents and the watch glass.

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EXPERIMENT 5.3

Discussion

1 **Describe** the features that told you that a chemical reaction had occurred.

2 **Deduce** whether your results indicate that mass is conserved during a chemical reaction.

Extension

3 Complete a five whys analysis on the following question:

'Why is it important to understand that mass is conserved in a chemical reaction?'

Upload your final answer to the class wiki.

WORKSPACE
Antoine Lavoisier

ACTIVITY 5.3

Antoine Lavoisier

Antoine Lavoisier is known as 'the father of chemistry'. **Justify** this description by researching Lavoisier's contribution to our understanding of chemistry.

Imagine that you are Antoine Lavoisier. Create your own coat of arms divided into four sections:

- significant events in your life
- interesting things that you have discovered
- things you are good at
- things you are proud of.

WORKSPACE
Student investigation: Conservation of mass

EXPERIMENT 5.4

Student investigation: Conservation of mass

Aim

To **demonstrate** that mass is conserved during a chemical reaction using bicarbonate of soda and vinegar

Materials and method

1 **Identify** the shortcomings in the method for Part B of Experiment 5.3.

2 **Explain** how you can **modify** the method to overcome these shortcomings.

3 **Identify** the equipment you will need for this investigation.

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EXPERIMENT 5.4

4 **Outline** ways in which you can you perform this investigation carefully. **Identify** the risks in the method and indicate how you will overcome or minimise each risk. **Show** this as a safety audit.

5 **Show** your method to your teacher and get it signed off before you perform your investigation.

Discussion

1 **Analyse** your results. Do your results indicate that mass is conserved during a chemical reaction?

2 **Assess** whether you need to make further modifications to your method. If so, how?

QUESTIONS 5.2

What have you learnt?

Understanding

1 **Identify** the energy transformations that occur in the following situations.

a Batteries in torches and calculators

b A coal-fired power station

c A fireworks display on New Year's Eve

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Figure 5.8 A New Year's Eve fireworks display

2 **Identify** the main components of a chemical equation.

WORKSPACE What have you learnt? 5.2

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QUESTIONS 5.2

3 Write word equations for each of these reactions.
   a Lead nitrate and potassium iodide react to form lead iodide and potassium nitrate.
   b Vinegar and bicarbonate of soda are placed in a beaker. Sodium acetate is one product. The other products are carbon dioxide and water.
   c Chlorine gas reacts with carbon monoxide to form phosgene ($COCl_2$).

4 **Recall** the law of conservation of mass.

Applying

5 6.3 g of lead nitrate was added to 6.3 g of potassium iodide to form 8.8 g of lead iodide and some potassium nitrate. **Calculate** the mass of potassium nitrate that was formed. **Justify** your answer.

6 Nail polish remover contains the compound ethyl acetate (ethyl ethanoate), which has four atoms of carbon, eight atoms of hydrogen and two atoms of oxygen. Write the chemical formula for ethyl ethanoate.

Analysing

7 The table lists some mineral ores and their chemical formulas.

Mineral ore	Chemical formula
Sphalerite	ZnS
Cassiterite	SnO_2
Stibnite	Sb_2S_3
Sphene	$CaTiSiO_5$
Rhodochrosite	$MnCO_3$

   a Write the information contained in the formula for rhodochrosite in a complete sentence.
   b **Identify** the elements present in cassiterite.
   c **Identify** the metal in sphalerite.
   d Determine the number of atoms of silicon present in sphene.
   e **Identify** the elements present in stibnite.

Reflecting

8 Go to your blog and write about two things that you were surprised to learn in this section.

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5.3 Types of chemical reactions – Part A

There are millions of chemical reactions that occur in both nature and industry. Scientists have analysed these reactions and placed them into categories. As you know, we can have physical changes or chemical changes. Chemical changes (chemical reactions) can be split into a number of different categories – this will help us to remember the reactions.

For example, sometimes bigger molecules are broken down into smaller molecules. This occurs during mining when we extract metals from their ores. Mining is one of Australia's biggest industries. We have large deposits of iron ore. During mining, the iron is extracted from the iron ore. This is an example of a decomposition reaction. Iron can be used for many things, including building. The Eiffel Tower (Figure 5.9a) is 324 m tall and made of iron. Steel can be made using iron and it is a common building material today. Skyscrapers such as the 319 m Chrysler Building (Figure 5.9b) in New York are built of steel.

a

b

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Figure 5.9
a The Eiffel Tower in Paris is made of iron. **b** The Chrysler Building in New York has an internal steel frame.

Sometimes, smaller molecules react together to form bigger molecules. This is called a **synthesis reaction**. Making plastic is an example of a synthesis reaction.

Chemical reactions can be categorised into five main types of reactions:

1 decomposition
2 synthesis
3 single displacement
4 double displacement
5 combustion.

These can be further classified, as you will learn in this chapter and in Year 10.

synthesis reaction
a chemical reaction in which a more complex chemical is produced from simpler chemicals

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WEBLINK
Five major chemical reactions

ACTIVITY 5.4

Types of chemical reactions

1 Open the weblink and watch the video on the five major chemical reactions.

2 Choose one of the five types of chemical reactions and work in a group to develop a role-play to **demonstrate** your understanding. Perform your role-play to the class or video it and upload the video to the class wiki.

3 Use bubbl.us or similar to create a mind map of the different types of chemical reactions.

4 Throughout the topic, add to your mind map by including information about the various types of reactions.

Decomposition reactions

When substances decompose, they break down into simpler substances from which they were made. Potassium chloride (KCl), for example, is a compound that is made up of potassium (K) and chlorine (Cl). When it decomposes, it breaks down into solid potassium (K) and chlorine gas (Cl_2). When plants and animals die, they decompose or chemically break down into the simpler substances from which they were made. Coal, natural gas and petroleum are all products of decomposition reactions.

Decomposition reactions can be represented by the simplified equation:

$$AB \longrightarrow A + B$$

Decomposition does not just happen to animals and plants. Decomposition is the name given to any reaction in which a more complex chemical (compound) is broken down into simpler chemicals (elements and/or compounds). Only compounds can decompose. Elements cannot undergo decomposition reactions because they cannot be chemically broken down into simpler chemicals. Elements are already the simplest chemicals. For decomposition reactions to occur, they generally require the input of energy.

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ACTIVITY 5.5

Decomposition

1 **Describe** how can you tell that decomposition is occurring.
2 **Identify** the conditions necessary for decomposition to occur.
3 Is decomposition a slow or fast process? **Justify** your answer.

WORKSPACE
Decomposition

EXPERIMENT 5.5

Decomposing copper carbonate

WORKSPACE
Decomposing copper carbonate

Possible risks	Safety precautions
Bunsen burners will get hot and can cause burns.	Observe the rules for using a Bunsen burner. Let the equipment cool down before you put it away.

Materials

- safety glasses
- side-arm test tube with a rubber stopper
- rubber tube to fit the side-arm test tube
- test tube two-thirds full of limewater $Ca(OH)_2$ solution
- solid copper carbonate $CuCO_3$
- heating equipment – heat-proof mat, Bunsen burner, 2 retort stands, boss heads and clamps
- spatula or spoon
- digital video camera (optional)

Method

1 Clamp the side-arm test tube above the Bunsen burner.
2 Put copper carbonate into the test tube to a depth of about 2 cm.
3 Place a stopper in the top of the side-arm test tube.
4 Clamp the test tube containing limewater to the other retort stand.
5 Attach one end of the rubber tubing to the side arm of the test tube. Place the other into the test tube containing the limewater. Ensure the rubber tubing is in the limewater.
6 Gently heat the copper carbonate.

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EXPERIMENT 5.5

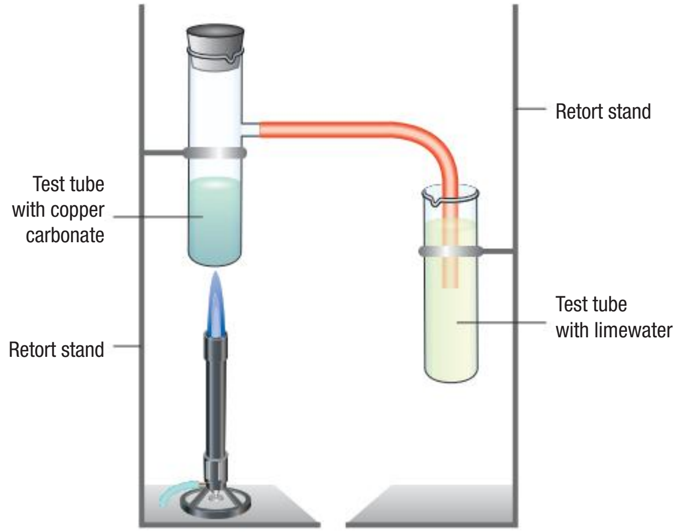

Figure 5.10 Set-up for the decomposition of copper carbonate

Results

1 Record all observations by either writing down what you see or recording with a digital video camera.

Discussion

2 **Explain** how you could tell that *two* chemical reactions occurred.

3 Look at the formula for copper carbonate. **Identify** the names of the simpler substances that were formed from the copper carbonate.

4 **Explain** why we used limewater in this experiment.

Applications of decomposition reactions

We can use decomposition reactions to obtain useful chemicals. This is the type of reaction that occurs when useful metals are extracted from their ores, such as when:

- copper (Cu) is extracted from chalcopyrite ($CuFeS_2$)
- aluminium (Al) is extracted from bauxite (a mixture of different chemicals that can occur in varying amounts, so it is shown as $Al_2O_3 + SiO_2 + TiO_2 + Fe_2O_3$)
- iron (Fe) is extracted from haematite (Fe_2O_3).

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Ore	Metal extracted
 Shutterstock.com/Karol Kozlowski Chalcopyrite	 Shutterstock.com/Kotomiti Okuma Copper
 Shutterstock.com/Denis Selivanov Bauxite	 Shutterstock.com/Simbad Aluminium
 shutterstock.com/michal812 Haematite	 Shutterstock.com/Margaret M Stewart Iron

Figure 5.11
Some ores and the metals extracted from them

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WORKSPACE
Extracting copper

EXPERIMENT 5.6

Extracting copper

Possible risks	Safety precautions
Sulfuric acid can burn skin and cause damage if it gets into eyes.	Wear safety glasses when performing this experiment. Wash hands with soap and water after the experiment. Refer to the MSDS for all chemicals and follow the disposal guidelines.

Materials

- safety glasses
- copper carbonate powder $CuCO_3$
- 100 mL of 2 mol/L sulfuric acid H_2SO_4
- spatula or plastic spoon
- 250 mL beaker
- 2 graphite electrodes
- power pack
- 2 electrical wires with alligator clips on one end and banana plugs on the other
- Blu-Tack

Method

1 Place a spatula of copper carbonate powder into a beaker containing 100 mL of sulfuric acid and stir.

2 Does a chemical reaction occur? **Justify** your answer.

3 Set up the equipment as shown in Figure 5.12, but do not turn on the power pack. To keep the electrodes in place, use a small piece of Blu-Tack to attach the electrode to the side of the beaker.

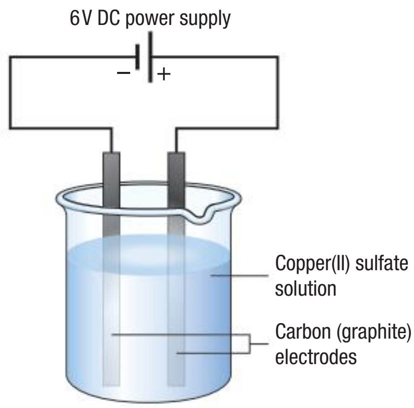

Figure 5.12 Set-up for electrolysis reaction

4 Does a chemical reaction occur? **Justify** your answer.

5 Turn the power pack to 6 volts DC and turn it on.

6 Does a chemical reaction occur? **Justify** your answer.

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ACTIVITY 5.6

Why extract copper?

Visit the weblink and complete all of the activities.

1 **Identify** the main copper ores.

2 **Describe** how copper is extracted.

3 **Describe** the uses of copper.

4 **Discuss** whether copper should be extracted from its ore or recycled.

5 What if we could no longer mine copper? **Outline** the short-term consequences of this (1 month). **Outline** the medium-term (1 year) and the longer-term consequences. Complete a C&S chart to answer this 'what if' question.

WORKSPACE
Why extract copper?

WEBLINK
Copper activities

WOW!

Mining in Australia

Australia is the world's largest iron ore exporter. In Australia, iron ore is mainly found in rocks that are more than 600 million years old. Ninety-five per cent of Australia's iron ore deposits occur in Western Australia.

Australia produces about 40% of the world's bauxite and more than 30% of the world's alumina, making it the largest producer of bauxite and alumina. Bauxite is mined from open-cut operations at Weipa (Queensland), Gove (Northern Territory) and the Darling Range (Western Australia).

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WORKSPACE
Australia's iron ore mining industry

ACTIVITY 5.7

Australia's iron ore mining industry

1 Go to the workspace and complete the question grid based on the topic 'Australia's iron ore mining industry.'
2 Upload your question grid to the class wiki.

Corrosion – a synthesis reaction

In a synthesis reaction, two or more simpler chemicals (elements or compounds) react to form a single more complex chemical (compound). You can represent a synthesis reaction using the simplified equation:

$$A + B \longrightarrow AB$$

Corrosion is an example of a synthesis reaction. It sometimes involves a metal reacting with oxygen to form a metal oxide (Figure 5.13). This generally leads to the metal degrading and losing strength. Rusting is an example of a corrosion reaction. The iron reacts with oxygen to form iron oxide. The rust flakes off the surface of the metal and the iron underneath continues to corrode.

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Figure 5.13 This nail reacted with oxygen and corroded. Iron oxide has been produced.

WORKSPACE
Student investigation: Factors that affect the rusting of iron

EXPERIMENT 5.7

Student investigation: Factors that affect the rusting of iron

Aim

To find out what conditions are necessary for iron to rust

This might help

Start with new iron nails – make sure the nails are not galvanised.

Materials and method

1 **Identify** your independent variable in this investigation.
2 **Identify** your dependent variable (what will you measure in this investigation to determine whether iron corrodes or not).
3 **Identify** what variables you will need to control to ensure that your investigation is a fair test.

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EXPERIMENT 5.7

4 **Discuss** how you will ensure that your results are reliable.

Discussion

1 **Identify** the conditions that are necessary for corrosion to occur.

2 Write a word equation for the corrosion of iron.

It is important to understand which metals corrode and under which conditions they corrode. Metals are used extensively to build structures, such as the Sydney Harbour Bridge and the dome on the Queen Victoria Building in Sydney. They are also used for hand rails, fly screens and window frames. However, metals are not just used in industrial or domestic situations, they are also used in our bodies.

Metals are used to replace or reinforce broken bones in our bodies. Sometimes metal screws are inserted to reattach tendons to bones. Metal plates are inserted to help the bones in arms and legs to mend. Sometimes, metals are used to replace bones, for example in hip replacements where the ball and socket joint is replaced by an implant. Medical implants are a major industry, and involve an understanding of the properties of the different materials to ensure that the appropriate material is chosen. It also involves an understanding of the chemistry of the human body to ensure that the material is compatible with the body's chemical environment. Scientists also have to take into account the forces that the material must withstand, we don't want to use materials that will break as soon as we stand up!

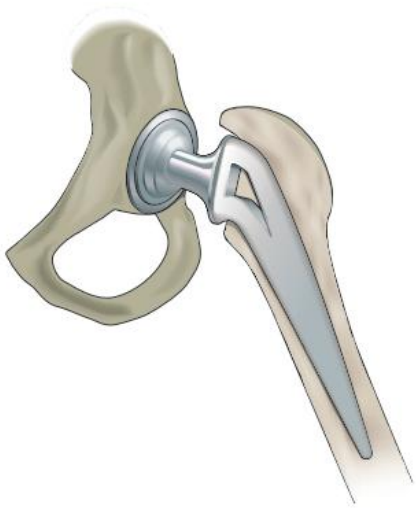

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Figure 5.14
An artificial hip joint

ACTIVITY 5.8

Metals used in the human body

1 **Assess** whether corrosion could occur in the human body.

2 **Identify** the metals used in artificial hips.

3 **Describe** the properties of each of the metals used in artificial hips.

4 **Justify** why these metals are used for hip replacements. In your response, you should **relate** the properties of the metal to its suitability to be used in the body's chemical environment.

5 **Identify** other examples of metals being used in the human body.

WORKSPACE
Metals used in the human body

ISBN 9780170231503

WORKSPACE
Student investigation: Corrosion of metals

EXPERIMENT 5.8

Student investigation: Corrosion of metals

Aim

To find out if all metals corrode

Materials and method

1 **Identify** your independent variable in this investigation.

2 **Identify** your dependent variable (what will you measure in this investigation to determine whether a metal corrodes or not).

3 **Identify** what variables you will need to control to ensure that your investigation is a fair test.

4 **Discuss** how you will ensure that your results are reliable.

Discussion

1 **Justify** whether all metals corrode.

2 Write word equations for any of the metals that corroded during this investigation.

Extension

3 Do rust treatments really prevent rusting? Devise a scientific experiment to test this. Get your method signed off by your teacher before you perform the experiment. Make sure you consider all of the safety issues involved.

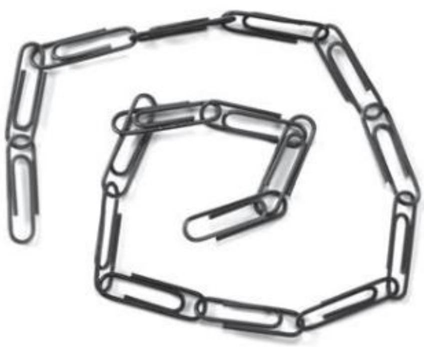
Other examples of synthesis reactions

polymer
a large molecule made up of repeating units

monomer
a single unit, or molecule, that can bind together with similar units to form a polymer

There are many other synthesis reactions. Making both plastics and medicines involve a number of synthesis reactions.

Polymers are very large chemicals that are made by reacting many simpler chemicals together. The word ‘polymer’ comes from *poly*, which means ‘lots of’, and *mer*, which means ‘units’. So polymers are made up of lots of the same units (**monomers**). Figure 5.15 shows lots of paper clips joined together in a chain. This is a model to show how lots of molecules of the same chemical can join together to form a polymer.



Shutterstock.com/Emelyanov

Figure 5.15 Each paper clip represents a monomer of the same chemical joining to form a polymer.

WEBLINK
Fabricating fabric: profile of nylon

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a

Shutterstock.com/John Kasawa

b

Shutterstock.com/Filip Obr

c

Shutterstock.com/discpicture

d

Shutterstock.com/heromen30

e

Shutterstock.com/Oleksiy Mark

f

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Figure 5.16 Some examples of polymers: **a** plastic lunch bags made from polythene (polyethylene), **b** the non-stick surface of frying pans made from Teflon (polytetrafluoroethene), **c** styrofoam cups made from polystyrene, **d** natural rubber and synthetic rubber, **e** soft-drink bottles made from PET (polyethylene terephthalate) and **f** fishing nets made from nylon

ISBN 9780170231503

WOW! Plastics forever?

If you lined up all the polystyrene foam cups made in just one day, they would circle the Earth.

When buried, some plastic materials may last for 700 years. Over 18 000 pieces of plastic debris float on every square kilometre of ocean.

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ACTIVITY 5.9

Polymer research

Research a polymer of your own choice. You may want to choose from the examples in Figure 5.16.

Use Glogster or Prezi to present information about your polymer to your peers. Your poster or presentation must include:

- the name of your polymer
- a diagram showing the structure of part of your polymer
- a diagram showing the simple chemical(s) that are used to make your polymer
- the properties and uses of your polymer. To **demonstrate** a deeper understanding, try to link specific properties to specific uses.

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ACTIVITY 5.10

Designing a new product

WORKSPACE
Designing a new product

Scientists from the Massachusetts Institute of Technology (MIT) have developed a material, called LiquiGlide, that can be coated on the inside of bottles so that sauce will just slide out. LiquiGlide is a non-toxic, extra slippery material. It is estimated that just using it on sauce bottles will save over 900 000 tonnes of food waste each year. Imagine the savings if it is also used for bottles containing other substances.

Propose a new product for the home, or an item of clothing that uses polymers. Use the polymer you researched in Activity 5.9 as the basis for this task. It may have been nylon, vinyl/PVC, Teflon, natural rubber, polystyrene or PET. **Outline** its benefits and uses in a mock-up advertisement. Include graphics to convey your idea. Upload your idea/advertisement to the class wiki.

Shutterstock.com/GorillaAttack

Figure 5.17 The residue left inside sauce bottles accounts for a great deal of food waste. Sauce will slide right out of bottles that have been coated with LiquiGlide.

Medicines are also complex substances. They require many chemical reactions to finally produce them. Aspirin, paracetamol and codeine are three common medicines that are produced using synthesis reactions.

Aspirin's origins can be traced back to early remedies. In the Middle Ages, an extract from willow bark was used for pain relief. However, it tasted horrible and irritated the lining of the stomach. Willow bark contained salicin, which your body converts to salicylic acid. In 1897, Felix Hoffmann developed a chemical process to convert salicylic acid to acetyl salicylic acid – more commonly known as aspirin. Aspirin retained the pain-relieving properties of salicylic acid, but it had a more pleasant taste and was less irritating to the stomach.

ACTIVITY 5.11

Medicine formulae

WORKSPACE
Medicine formulae

1 Use the Internet or printed resources to determine the chemical formula of each medicine (the structural formulae are shown in Figure 5.18).

2 **Examine** the symbols in the structural formula for each medicine to determine what elements are used in their formation.

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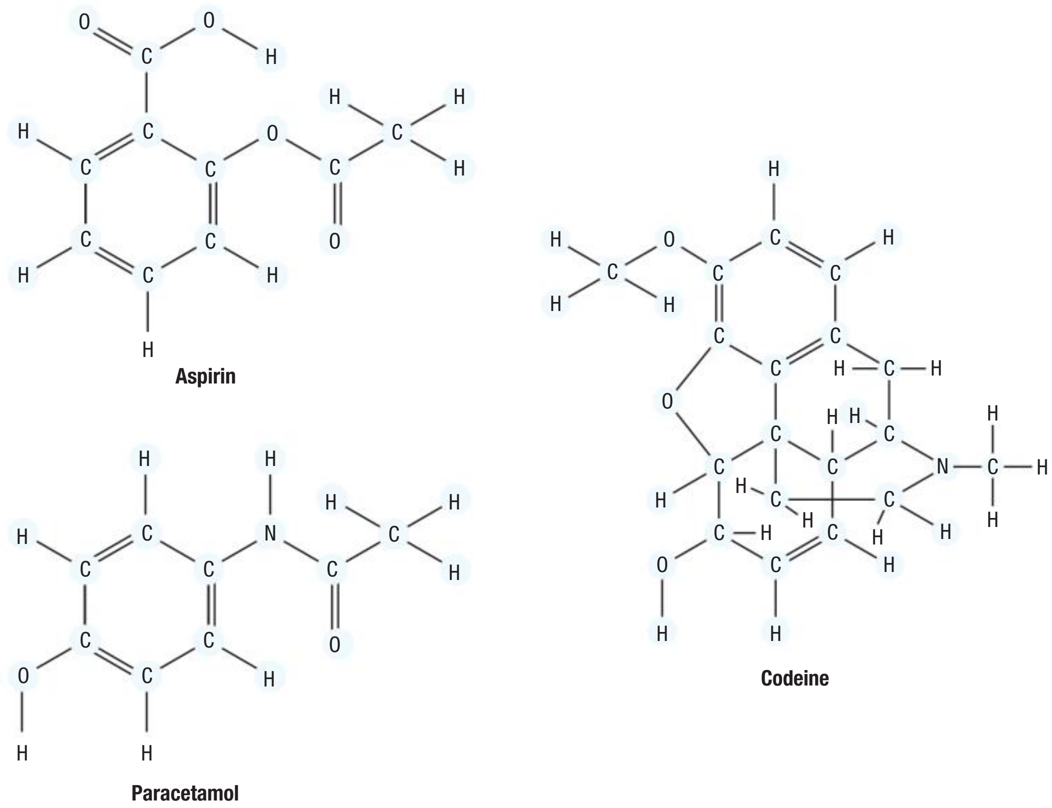

Figure 5.18 Aspirin, codeine and paracetamol are three common medicines.

WORKSPACE
What have you learnt? 5.3

QUESTIONS 5.3

What have you learnt?

Understanding

1 Look at the following decomposition equation.

$$2H_2O(l) \longrightarrow 2H_2(g) + O_2(g)$$

   a Write a word equation for this reaction.
   b **Describe** the chemical test for oxygen.

2 Look at the following decomposition equation.

$$2NH_3(g) \longrightarrow N_2(g) + 3H_2(g)$$

   a **Identify** the compound that is decomposing.
   b **Identify** the products of this decomposition.
   c **Describe** an experiment you could perform to identify one of the products in this reaction.
   d Name two ways in which a compound can be made to decompose.

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QUESTIONS 5.3

3 Write a word equation for each of the following reactions.
 a Copper oxide is formed when copper carbonate is heated with a Bunsen flame. The other product is carbon dioxide.
 b Carbon dioxide can be tested for by bubbling it into a solution of calcium hydroxide (limewater). If carbon dioxide is present, then the limewater becomes milky. The milky substance is calcium carbonate. The other product is water.

Creating

4 Go to your mind map and add information about decomposition reactions to it.

Reflecting

5 Complete the sentence:
I think that understanding decomposition will affect my life by . . .

5.4 Types of chemical reactions – Part B

Single displacement reactions

Single displacement reactions are substitution reactions. A reaction between an acid and a metal, such as magnesium, is an example of a single displacement reaction. The magnesium starts as a metal. It reacts with the acid to form a compound. The hydrogen starts as part of the acid compound and ends up as an element, hydrogen gas. The magnesium and hydrogen swap places.

single displacement reaction
a reaction in which one element takes the place of another element in a compound; more commonly referred to as a substitution reaction

Magnesium + hydrochloric acid ⟶ magnesium chloride + hydrogen gas

It is easier to see that the magnesium and hydrogen have swapped places by looking at the balanced chemical equation:

$$Mg + 2HCl \longrightarrow MgCl_2 + H_2$$

You can see in this equation that the magnesium starts off as an element – it is not bonded to any other substance – but ends up in a compound with chlorine. The hydrogen, however, starts off in a compound with chlorine and ends up as an element. The magnesium and hydrogen swap places. This is a single displacement reaction, or substitution reaction, since the magnesium takes the place of the hydrogen. We will look at this in more detail in Chapter 6.

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A simple way of remembering single displacement reactions is to remember that one element replaces another in a compound. A single-displacement reaction can be shown using the simplified formula:

$$\mathbf{A + BC \longrightarrow B + AC}$$

Notice that C is paired with B before the reaction but with A after the reaction has occurred.

The thermite reaction is an example of this. This reaction is too dangerous to be done in schools but you can view the reaction in the weblink.

The thermite reaction occurs between aluminium metal and iron oxide. The word equation is written as:

Aluminium + iron oxide → aluminium oxide + iron
(metal) (metal)

WEBLINK
Thermite reaction

In this reaction, we started with a metal and a compound and we produced a metal and a compound. The iron was originally attached to the oxide; however, a substitution reaction occurred and the iron and aluminium swapped places.

WORKSPACE
Single displacement reactions

EXPERIMENT 5.9

Single displacement reactions

Possible risks	Safety precautions
Do not get the solutions on your skin.	Use tongs to remove metals from the salt solutions. If you do get solutions on your skin, wash the area thoroughly with soap and water. Refer to the MSDS for all chemicals and follow the disposal guidelines.

Materials

- 16 clean 150 mL beakers
- sandpaper to clean your metals before you start if necessary
- approximately 5 cm clean strips of the following metals:
  - magnesium
  - copper
  - zinc
  - iron (nail)

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EXPERIMENT 5.9

- 200 mL of each of the following 1 mol/L solutions:
  - magnesium sulfate
  - copper sulfate
  - zinc sulfate
  - iron(II) sulfate

Method

1 Pour 50 mL of each solution into separate beakers. Add a strip of magnesium to each beaker.

2 Repeat for all metals, using clean beakers.

3 Dispose of the chemicals as instructed by your teacher.

Results

1 **Construct** a table to record your results and observations for each of the metal–solution combinations.

Discussion

2 **Identify** the combinations of chemicals that produced chemical reactions. **Justify** your answer.

3 Write word equations for each chemical reaction that occurred.

4 Determine if there is any observable pattern to which metals displace those in the solution.

Precipitation – a double displacement reaction

Double displacement reactions are those in which two compounds react to form two new compounds. Common examples are the precipitation reactions. A double displacement reaction can be shown using the simplified formula:

$$AB + CD \longrightarrow AD + CB$$

Many salts (ionic compounds) are soluble – they dissolve in water to form ions. The metal part of the salt forms positive ions in solution while the non-metal part forms negative ions. There are strong electrostatic forces of attraction between the positive ions and

double displacement reaction
a reaction in which two compounds react to form two new compounds

negative ions. Dissolving is all about forces. If the electrostatic forces between the ions are stronger than the forces between the water and the ions, then a precipitate will form. If the forces between the water and the ions are stronger, then the compound will break down and the salt will dissolve in the water.

The reaction that you conducted earlier between lead nitrate and potassium iodide was an example of a double displacement reaction. Below is the word equation for this reaction.

$$\text{Lead nitrate} + \text{potassium iodide} \longrightarrow \text{lead iodide} + \text{potassium nitrate}$$

In this reaction, the lead ions were with the nitrate ions and the potassium ions were with the iodide ions. Both of these were clear solutions. However, when they were added together, the clear solution had small solid yellow particles (the precipitate) suspended in it (Figure 5.19). This indicates that a chemical reaction occurred. The chemicals changed – there was a rearrangement of the ions (Figure 5.20). The lead is now with the iodide. The potassium cannot still be with the iodide, nor can it be with the lead, so it must be with the nitrate. We started with two compounds and ended up with two different compounds – this is a double displacement reaction.

Getty Images/Charles D Winters

Figure 5.19 The precipitation of lead iodide

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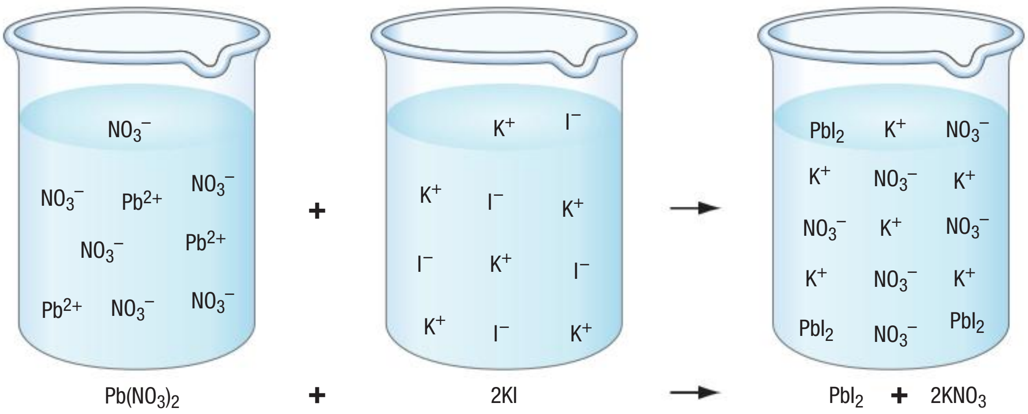

Figure 5.20 The reaction between lead nitrate and potassium iodide

ANIMATION
Reaction of lead nitrate with potassium iodide

WORKSPACE
Precipitation reactions

EXPERIMENT 5.10

Precipitation reactions

Possible risks	Safety precautions
You could get chemicals in your eyes or on your skin.	Wear safety glasses. If you do get chemicals on your skin, wash the area thoroughly with soap and water. Refer to the MSDS for all chemicals and follow the disposal guidelines.

Materials

- Safety glasses
- dropper bottles of each of these 1 mol/L solutions:
  - sodium chloride $NaCl$
  - sodium sulfate Na_2SO_4
  - sodium carbonate Na_2CO_3
  - sodium hydroxide $NaOH$
  - potassium iodide KI
  - calcium nitrate $Ca(NO_3)_2$
  - magnesium nitrate $Mg(NO_3)_2$
  - copper nitrate $Cu(NO_3)_2$
  - lead nitrate $Pb(NO_3)_2$
  - zinc nitrate $Zn(NO_3)_2$
  - silver nitrate $AgNO_3$

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EXPERIMENT 5.10

- the grid below photocopied and enlarged if necessary on an overhead transparency and placed on a dark background

Method

- Look at each of the starting chemicals – are they soluble or insoluble? Add one drop of each of the chemicals to the relevant boxes in the grid.
- Only take the lid off one dropper bottle at a time so that you do not contaminate the solutions.
- Rinse the plastic sheet with water at the end.

Results

1 Record your observations in a table.

	Sodium chloride	Sodium sulfate	Sodium carbonate	Sodium hydroxide	Potassium iodide
Calcium nitrate					
Magnesium nitrate					
Copper nitrate					
Lead nitrate					
Zinc nitrate					
Silver nitrate					

Discussion

2 **Identify** which combinations of chemicals produced chemical reactions. **Justify** your answer.

3 Write word equations for each chemical reaction that occurred.

4 Given the following rules, **identify** the name of the precipitate in each of your chemical reactions.

- All nitrates are soluble.
- All sodium salts are soluble.
- All potassium salts are soluble.

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EXPERIMENT 5.10

Extension: Writing chemical equations using chemical formulae

5 Use the ion cut-outs on the activity sheet to **construct** chemical formulae for your chemicals in the activity.

6 Use your chemical formulae to **construct** a balanced chemical equation for each of the chemical reactions in the activity.

The following might help.

- The overall charge for any chemical must be zero, i.e. the positive and negative charges must balance.
- The number of each element must be the same on both sides of the equation; that is, if one zinc is put into the reaction as a reactant, then one zinc must come out of the reaction as a product.
- An example of a balanced chemical equation is given in Figure 5.21.

ACTIVITY SHEET
Ion cut-outs

ANIMATION
Ion builder

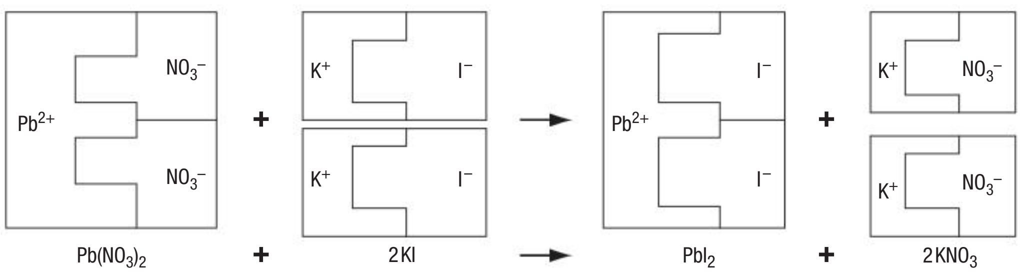

Figure 5.21 Balanced chemical equation for the reaction between lead nitrate and potassium iodide

Applications of precipitation reactions

Precipitation reactions are commonly used to test water quality. Drinking water must be of a particular standard so that we don't get sick when we drink it. Hence, it must be tested for the presence of chemicals that may make us sick. If these chemicals are present in the water, then the water must be treated to remove them before the water can be declared safe to drink.

Precipitation reactions are **qualitative tests** – they tell us if particular chemicals are present. They do not tell us how much of each chemical is present. For that, we need to use **quantitative tests**. These are more expensive and so are only used once it is known that the specific chemical is present.

qualitative test
a chemical test that identifies whether a substance is present or not

quantitative test
a chemical test that identifies how much of a substance is present

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WORKSPACE
What have you learnt? 5.4

QUESTIONS 5.4

What have you learnt?

Understanding

1 **Identify** three observations you have seen that indicate a chemical reaction has occurred.

Applying

2 Use the table to answer the questions that follow. ✓ means that the chemical is soluble. ✘ means that a precipitate forms.

	Sulfate	Hydroxide	Chloride	Nitrate
Sodium	✓	✓	✓	✓
Potassium	✓	✓	✓	✓
Calcium	✘	✓	✓	✓
Silver	✘	✘	✘	✓
Copper	✓	✘	✓	✓
Zinc	✓	✘	✓	✓
Lead	✘	✘	✘	✓
Strontium	✘	✓	✓	✓
Magnesium	✓	✘	✓	✓

a **Identify** three insoluble chemicals.
b Determine whether a chemical reaction occurs between potassium hydroxide and copper chloride. **Justify** your answer.
c **Identify** the precipitate that will form when zinc chloride reacts with calcium hydroxide.
d Write the word equation for the reaction between potassium sulfate and strontium chloride.

Creating

3 Go to your mind map and add information about synthesis, single and double displacement reactions to it.

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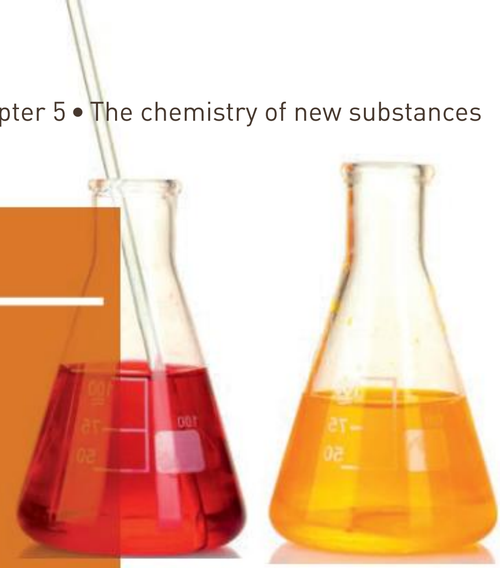

Chapter review

Remembering

1 **Define** the following types of reactions.
  a Corrosion
  b Decomposition
  c Precipitation

Understanding

2 **Identify** 10 natural substances.

3 **Identify** 10 synthetic substances.

4 **Explain** what is meant by the law of conservation of mass.

5 Write an example of a word equation for each of the following types of reactions.
  a Decomposition
  b Corrosion
  c Single displacement reaction
  d Precipitation

6 **Identify** the energy transformations that may occur during decomposition reactions.

Applying

7 **Identify** the type of reaction for each of the following.
  a Lead nitrate reacts with sodium chloride.
  b Iron reacts with oxygen.
  c Copper carbonate is heated and a black powder is formed.
  d Magnesium reacts with oxygen.
  e Lots of propylene molecules are added together.
  f Carbon dioxide and water react in the presence of light and chlorophyll to form glucose and oxygen.
  g Potassium sulfate reacts with silver nitrate.

8 Write word equations for the following.
  a Lead nitrate reacts with sodium chloride.
  b Iron reacts with oxygen.
  c Copper carbonate is heated and a black powder is formed.
  d Magnesium reacts with oxygen.
  e Carbon dioxide and water react in the presence of light and chlorophyll to form glucose and oxygen.
  f Potassium sulfate reacts with silver nitrate.

9 **Explain** why elements can't decompose.

WORKSPACE
Chapter 5 review

ACTIVITY SHEET
Chapter 5 checklist

REVIEW QUIZ
Chapter 5

ISBN 9780170231503

Analysing

10 When silver nitrate ($AgNO_3$) is mixed with potassium chloride (KCl), a white solid is formed.
- **a** **Identify** the type of reaction that has occurred.
- **b** Write the word equation for this reaction, showing the reactants and products.
- **c** **Identify** what the white solid is made of.

Evaluating

11 'Chemical reactions have had a positive impact on society.' **Discuss** this statement.

12 'Decomposition reactions are more important than synthesis reactions.' **Discuss** this statement by using examples of each of these reactions.

Creating

13 Hydrogen peroxide (H_2O_2) decomposes into water (H_2O) and oxygen gas (O_2). Devise a way to **explain** this reaction to a Year 7 student. For example, you could use different coloured Smarties.

14 Use the information in the table to answer this question.

✓ means that the chemical is soluble. ✗ means that a precipitate forms.

	Sulfate	Hydroxide	Chloride	Nitrate
Sodium	✓	✓	✓	✓
Potassium	✓	✓	✓	✓
Calcium	✗	✓	✓	✓
Silver	✗	✗	✗	✓
Copper	✓	✗	✓	✓
Zinc	✓	✗	✓	✓
Lead	✗	✗	✗	✓
Strontium	✗	✓	✓	✓
Magnesium	✓	✗	✓	✓

Labels have come off three chemical bottles and are lying on the floor. A student picks up the labels and sees that the chemicals are potassium hydroxide, silver nitrate and strontium chloride.

Design an experiment that the student could perform to identify the chemicals in each of the bottles so that the labels can be put back on the bottles.

Reflecting

15 **Explain** why you think it is important that you understand chemical reactions. Give at least three reasons.

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6

Chemical reactions

How are chemical reactions useful?

Jellyfish are beautiful sea creatures; but they can be deadly. Within their tentacles they have tiny nematocysts that store venom to immobilise their prey. These stinging cells can be triggered chemically by the pH of their victim. Millions of nematocysts release venom from tiny barbed harpoons, causing severe pain, or even death. Box jellyfish, or stingers, have enough toxin in two tablespoons of venom to kill 60 people! Queensland beaches have vinegar on hand for washing the sting site and neutralising nematocysts. This chemical reaction stops the stinging cells from firing.

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ACTIVITY SHEET
CAT with rubric: Effects of acid rain

Chemical world – Stage 5

Key knowledge

- Compounds can be classified into groups on the basis of their chemical characteristics.
- Combustion is an important chemical reaction that occurs in non-living systems.
- Acids reacting with metals is an important chemical reaction that occurs in non-living systems.
- Neutralisation reactions, including acids reacting with carbonates, are important chemical reactions that occur in non-living systems.
- Combustion, neutralisation and reactions of acids with metals and carbonates are chemical reactions that involve the transfer of energy.
- Respiration and digestion are examples of chemical reactions that involve energy transfer and occur in living systems.
- Chemical reactions that involve energy transfer can be classified as endothermic or exothermic.
- Reactions that release energy, such as combustion and respiration, occur at different rates.

CULMINATING ASSESSMENT TASK

Effects of acid rain

The effects of acid rain are a significant issue worldwide. Your task as an investigative journalist is to develop a story for a newspaper or a podcast for a current affairs program about the effects of acid rain. You must address both how acid rain is formed and the effects of acid rain on the natural and the made environments using a real example.

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WORKSPACE
What do you already know about chemical reactions?

What do you already know about chemical reactions?

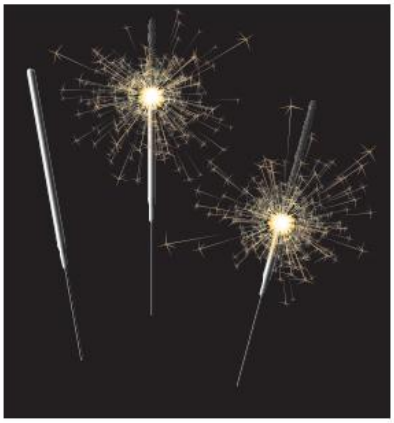
1 **Define** and **compare** 'physical change' and 'chemical change' (also called a chemical reaction).

2 Look at each picture below. **Identify** whether or not a chemical reaction is occurring. **Describe** briefly what is occurring.

a

Shutterstock.com/Neale Cousland

b



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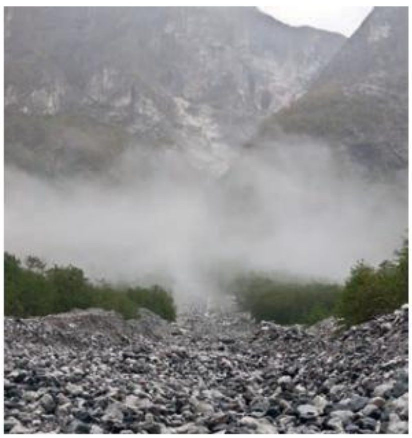
c

Shutterstock.com/kzww

d



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e

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6.1 Classifying compounds based on chemical characteristics

When you look at someone, you notice their appearance. You notice things such as hair colour, eye colour and height. These are all examples of the physical characteristics of that person. We can then use these physical characteristics to place people into groups. For example, in class, you could ask all of the students who write with their left hand to stand on one side of the room and all of the students who write with their right hand to stand on the other side of the room. Then you could use another physical characteristic to classify the students in your class, such as all of the boys on one side of the room and all of the girls on the other side of the room. Groups change depending on the characteristic that is being used to classify them.

Similarly, when we've looked at chemicals such as magnesium and water in earlier years, we've looked at their melting points, boiling points, colour, electrical conductivity, ability to conduct heat and whether they are soluble in water. These are all examples of the physical characteristics of those chemicals. We can group the chemicals according to whether they are solids, liquids or gases. We can group them according to whether they dissolve in water or not. The groups of chemicals change depending on the characteristic that is being used to classify them.

However, chemicals also have other characteristics, called chemical characteristics. Chemical characteristics affect how the chemical reacts with other chemicals. Their chemical characteristics relate to the chemical reactions that they take part in. We saw in Chapter 5 that some chemicals would corrode in the presence of oxygen and moisture. This was a chemical characteristic of these chemicals. Similarly, we looked at decomposition reactions. We can classify chemicals based on whether they can undergo decomposition or not. Compounds are a group of chemicals that can be decomposed. Elements are a group of chemicals that cannot be decomposed. The chemicals have been placed into groups according to the chemical characteristic of decomposition.

Here, we will classify other chemicals according to their chemical characteristics. We will classify them as acids or bases.

Acids – a group of compounds

acid
a substance that produces hydrogen ions in solution; acids neutralise bases

Acids are a group of compounds that are found in many common substances in our bodies and homes. DNA is an acid that is found in our bodies. It is the genetic material that codes for many of our characteristics. Its chemical name is deoxyribonucleic acid. Vinegar is an acid that is found in the home. Its chemical name is ethanoic (or acetic) acid (CH_3COOH). It is used in many recipes, for example in salad dressings and sweet and sour sauce. Acids such as hydrochloric acid (HCl) are found in the school laboratory.

Our understanding of acids continues to develop over time as further information becomes available. The definition of an acid has changed several times over the last 250 years. French scientist Antoine Lavoisier (1743–94) was one of the first to try to establish what an acid is. As more research and experiments were done and more evidence became available, the definition of an acid changed.

ISBN 9780170231503

The definition that we will use is that acids occur in solution, where they form hydrogen ions (H^+). Vinegar can form hydrogen ions. This can be written as:

$$\underset{\text{vinegar}}{CH_3COOH(aq)} \rightarrow CH_3COO^-(aq) + H^+(aq)$$

Figure 6.1 Common types of vinegar used at home

Besides forming hydrogen ions, acids have other common properties to help classify them. They feel sticky, taste sour and can conduct electricity.

WOW!

Exploding cotton!

German chemist Christian Schönbein was investigating acids in his kitchen one day, when he accidently invented exploding cotton, or guncotton! After cleaning up a spill of nitric and sulfuric acid with his wife's cotton apron, he hung it to dry. It spontaneously burst into flames and disappeared. This nitrocellulose mixture has many applications today in different forms, including 'flash paper' used by magicians.

Alamy/© Ted Foxx

ACTIVITY 6.1

Blabber

Each *Nelson iScience for NSW* chapter has suggested graphic organisers to **summarise** your learning as you go. You may recall using mind maps or Glogster for example. For this chapter you will be asked to create a number of blabbers. A blabber is a talking, animated picture. You are to choose a photo, upload this, animate the mouth and add a voice; it is that simple! You will need to either link to the Blabberize website where your blabber will be hosted or embed the URL into your blog to share your summary with your teacher or classmates.

WEBLINK
Blabberize

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WORKSPACE
Acids in the home

ACTIVITY 6.2

Acids in the home

Group challenge

1 **List** the names and uses of at least 10 acids found either in our bodies or around our homes. Add a photo of each example.

2 Share your list with the rest of the class and upload the combined list to the class wiki.

Extension

3 Include the chemical formula (such as CH_3COOH) for the acids you have found as part of the group challenge.

WORKSPACE
Changing ideas about acids

ACTIVITY 6.3

Changing ideas about acids

1 **Investigate** to find out Lavoisier's definition of an acid.

2 **Outline** the evidence that became available that meant that Lavoisier's definition had to be updated.

3 **Identify** the main scientists who contributed to the changing definition of an acid over the last 250 years.

4 Draw a timeline for the development of our understanding of acids over the last 250 years. This timeline could be drawn on graph paper or by using a spreadsheet program such as Excel, Numbers or NeoOffice, or a Web 2.0 program such as Timetoast.

Extension

5 **Outline** the most recent definition of an acid.

6 **Explain** how we know when a definition is final.

7 Research to find out who decides that a definition is 'official'.

8 **Identify** the criteria that must be met before something goes into a dictionary.

9 When we translate some words into different languages, the meaning also changes. There are some words that cannot be translated into some languages. **Propose** some issues this might pose for scientific definitions.

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WOW!

Why do onions make us cry?

Onions contain a number of chemicals that are kept separate in the cells of the onion. When the onion is cut, these chemicals react and form propanethiol S-oxide that wafts up to the eyes. The gas reacts with the water in your eyes to form sulfuric acid. This produces a burning sensation that causes the tear ducts to release tears.

Bases – a group of compounds

A **base** is a group of compounds that are the chemical opposite of acids. They feel slippery and taste bitter, but they also conduct electricity. Bases too are found in the home. Bleach is a common base found in the home. Its chemical name is sodium hypochlorite (NaOCl). Sodium hydroxide (NaOH) (caustic soda or Drano) is another common base found in both the home and the school laboratory. Hydroxides, oxides and carbonates are other common bases found in the school laboratory.

base
a substance that forms hydroxide ions, oxide ions or carbonate ions in solution; bases neutralise acids

Figure 6.2
Bases in the home

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pH – a chemical characteristic

pH
a number that indicates how acidic or basic a substance is

The **pH** scale gives an indication of how acidic or basic a substance is. The scale is commonly between 0 and 14.

- A substance with a pH of less than 7 ($pH < 7$) is classified as acidic.
- A substance with a pH of 7 ($pH = 7$) is classified as neutral.
- A substance with a pH of greater than 7 ($pH > 7$) is classified as basic.

Sometimes we need to know not only if the substance is acidic or basic but also how acidic or how basic it is. This is when we use the pH scale. A substance that has a pH of 3 is more acidic than a substance that has a pH of 5. Similarly, a substance that has a pH of 12 is more basic than a substance that has a pH of 9.

	Concentration of hydrogen ions compared to distilled water		Examples of solutions at this pH
	10 000 000	pH = 0	Battery acid, strong hydrofluoric acid
	1 000 000	pH = 1	Hydrochloric acid secreted by stomach lining
	100 000	pH = 2	Lemon juice, gastric acid, vinegar
Increasing acidity	10 000	pH = 3	Grapefruit juice, orange juice, soda water
	1000	pH = 4	Tomato juice, acid rain
	100	pH = 5	Soft drinking water, black coffee
	10	pH = 6	Urine, saliva
Neutral	1	pH = 7	'Pure' water
	1/10	pH = 8	Sea water
	1/100	pH = 9	Baking soda
	1/1000	pH = 10	Milk of magnesia
Increasing basicity	1/10 000	pH = 11	Ammonia solution
	1/100 000	pH = 12	Soapy water
	1/1 000 000	pH = 13	Bleach, oven cleaner
	1/10 000 000	pH = 14	Liquid drain cleaner

Figure 6.3 The pH scale

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Acid–base indicators – a group of compounds

Acid–base **indicators** are chemical substances that change colour when an acid or a base is added to it (Figure 6.4). Some indicators are special compounds only found in science laboratories. Others can be made from common substances found around the home.

Indicators commonly found in the school laboratory are litmus, phenolphthalein, methyl orange, bromothymol blue and universal indicator. Each of these indicators change colour, and each indicator has its own specific colours.

indicator
a substance that changes colour under different acidic or basic conditions

a

Getty Images/Science Photo Library

b

Shutterstock.com/Sabine Kappel

Figure 6.4
a Universal indicator exhibits several colour changes along the pH spectrum.
b The colour of indicator paper shows the pH of the liquid.

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WORKSPACE
Student investigation: Household indicators

EXPERIMENT 6.1

Student investigation: Household indicators

Aim

To find a substance that can act as an acid–base indicator

Method

1 Research, using secondary sources, three common substances that can be used as acid–base indicators. **Describe** how to prepare the indicator from each of these common substances.

2 Choose one of the substances and make up a solution of the indicator.

3 Plan an investigation to test how effective your indicator is for identifying acids and bases.

4 **Describe** any safety issues that you need to be aware of and manage.

5 Keep some of your indicator to use in other activities later in this chapter.

WORKSPACE
Student investigation: Indicators found in the science laboratory

EXPERIMENT 6.2

Student investigation: Indicators found in the science laboratory

Possible risks	Safety precautions
Hydrochloric acid and sodium hydroxide solution can be harmful if they come in contact with skin or eyes.	Wear safety glasses while performing this activity. Wash your hands thoroughly at the end of the experiment.

Aim

To plan and perform an investigation to **classify** household substances as acids, bases or neutral using indicators

Materials

- dilute hydrochloric acid solution
- water
- dilute sodium hydroxide solution

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EXPERIMENT 6.2

- phenolphthalein indicator
- methyl orange indicator
- bromothymol blue indicator
- universal indicator
- your household indicator from Experiment 6.1
- household substances such as shampoo, lemonade, milk, bleach, bread, orange or lemon juice, vinegar and a bathroom creamy cleanser

Method

1 For each household substance, **predict** whether it will be an acid, base or neutral and record it in a table.

2 **Identify** the colour of each indicator in hydrochloric acid, water and sodium hydroxide.

3 Use the indicators and your household indicator to **classify** a variety of substances found around the home as acids, bases or neutral. Water is an example of a neutral substance – it is neither an acid nor a base.

4 Dispose of the chemicals as instructed by your teacher.

Results

1 Record your observations for each household substance tested in the table with your predictions.

Discussion

2 **Justify** which of these indicators was most useful for classifying these substances as acids, bases or neutral.

3 For each of the substances tested, **predict** whether its pH would be:

- less than 7
- equal to 7
- greater than 7.

4 **Compare** your results for cleaning products and foods. **Identify** any trends in the pH range for these categories.

Extension

5 **Predict** whether or not hand soap would be acidic or basic. **Explain** your reasoning.

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ACTIVITY 6.4

More blabber

Create a blabber that **explains** in your own words the meaning of the terms 'acid', 'base' and 'indicator'. Upload the link or embed the URL into your blog.

WORKSPACE
Understanding pH

ACTIVITY 6.5

Understanding pH

As well as indicating which substance is more acidic or more basic, the pH scale gives a mathematical indication of how much more acidic or basic a substance is. Each division on the pH scale is a difference of 10 times. So a substance that has a pH of 3 is 10 times more acidic than a substance that has a pH of 4.

What do you think?

1 You have two substances. Substance A has a pH of 2. Substance B has a pH of 6.
   a **Identify** the substance that is more acidic.
   b Determine by how much this substance is more acidic. **Justify** your answer.

2 **Compare** the acidity of two substances with a pH of 5 and a pH of 8.

WOW!

The 'Meeting of the Waters'

The Rio Negro (the name means 'Black River') and the Amazon River meet near Manaus, Brazil. The Rio Negro has a pH of 3.5 and an average temperature of 28°C while the Amazon River has a pH of 7 and an average temperature of 22°C. The Amazon River flows more than twice as fast as the Rio Negro; hence the two rivers converge and flow side by side for about 8 km without mixing.

Corbis/Kazuyoshi Nomachi

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ACTIVITY 6.6

Rio Negro – a case study

Use the Internet or other resources to research information on the Rio Negro.

1 **Explain** the conditions that cause the Rio Negro to be so acidic.

2 **Outline** the impacts on the local communities and the environment of the Rio Negro having such a low pH.

WORKSPACE
Rio Negro River – a case study

ICT

Download Google Earth and locate the Rio Negro. Upload a screen grab of this to your blog.

Scientists sometimes use pH meters or probes to measure pH, instead of indicators. pH meters have a glass electrode that can be inserted into a liquid to record its pH. Old pH meters used an analogue scale. Today, most pH meters have a digital scale. pH probes are similar to pH meters, except they connect to a computer so that readings can be taken continuously.

a b

Science Photo Library/Andrew Lambert Photography

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Figure 6.5
a A pH meter and
b a pH probe

EXPERIMENT 6.3

Using pH meters/probes

WORKSPACE
Using pH meters/probes

Use a pH meter or probe to test and record the pH for each of the substances used with the indicators in Experiment 6.2.

1 **Identify** the substance that was the most acidic.

2 **Identify** the substance that was the most basic.

3 **Compare** the use of the pH meter or probe with the chemical indicators used in terms of:

a accuracy

b sample size needed for test

c types of substances for which it can be used.

4 **Discuss** whether the indicators or pH meter or probe are more useful for testing substances.

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EXPERIMENT 6.3

Extension

5 Complete a five whys analysis on the question: 'Why is it important to understand the pH of substances?'

6 Upload your five whys analysis to your blog and your final answer to the class wiki.

WORKSPACE
What have you learnt? 6.1

QUESTIONS 6.1

What have you learnt?

Remembering

1 **Define** these terms.
- a Acid
- b Base
- c Indicator

Understanding

2 **Identify** three acids, their chemical formulae and their uses.

3 **Identify** three bases, their chemical formulae and their uses.

4 **List** three examples of indicators.

5 **Describe** the pH scale in your own words.

6 **Outline** how you use the pH scale to classify an acid and a base.

7 **Describe** the purpose of an indicator.

Applying

8 Suggest how you think universal indicator is made.

9 **Classify** the following substances as acidic, basic or neutral.

Substance	pH	Acidic, basic or neutral
Milk	6.5	
Rain	5.6	
Vinegar	2.9	
Soapy water	12	
Toothpaste	9.9	
Oven cleaner	13	

10 Add another column to the table and **predict** the colour the substance would turn in universal indicator.

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QUESTIONS 6.1

Evaluating

11 Give two reasons why it is important to understand acids and bases.

12 **Identify** which is more useful for identifying the pH of substances – a pH probe or an indicator? **Justify** your choice.

13 'It is important to know and maintain the pH of the environment.' **Discuss** this statement with reference to specific examples.

6.2 Neutralisation reactions

Sometimes we need to **neutralise** acids, or stop an acid from working as an acid (and a base from working as a base). To do this, we add a substance that is the chemical opposite of an acid – that is, a base. Bases found in the school laboratory include hydroxides, oxides and carbonates. Each of these substances can be added to an acid to neutralise it.

Acids are transported in tankers, a bit like petrol tankers. If there is an accident and the acid leaks from the tank, then bicarbonate of soda is used to neutralise the acid spill.

neutralise

to cancel out the effect of an acid by adding a base, or cancel out the effect of a base by adding an acid

ACTIVITY 6.7

Neutralising acid spills

Look up the material safety data sheets (MSDS) for bicarbonate of soda and sodium hydroxide. **Investigate** why bicarbonate of soda is used to neutralise acid spills rather than sodium hydroxide.

WORKSPACE
Neutralising acid spills

Neutralisation is a chemical reaction that is important in our bodies as well as in our lives. Different chemical reactions can be used depending on the type of base:

$$\text{Acid} + \text{hydroxide/oxide} \rightarrow \text{salt} + \text{water}$$

$$\text{Acid} + \text{carbonate} \rightarrow \text{salt} + \text{water} + \text{carbon dioxide}$$

In both cases, a **salt** and water are formed. However, when a carbonate is added, carbon dioxide is also formed.

'Salt' is a general term used to describe compounds that are composed of both metals and non-metals. The first name of the salt comes from the first name of the base while the last name of the salt comes from the acid that is used.

- Hydrochloric acid forms chlorides.
- Nitric acid forms nitrates.
- Sulfuric acid forms sulfates.

salt

an ionic compound

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Examples of neutralisation reactions are shown in Figure 6.6.

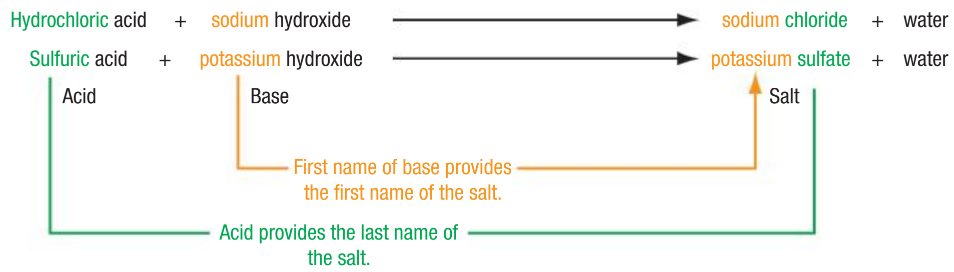

Figure 6.6 Naming salts of bases

ACTIVITY SHEET
Acids and bases

WORKSPACE
Neutralisation reactions

EXPERIMENT 6.4

Neutralisation reactions

Aim

To **investigate** neutralisation reactions

Materials

- small beaker
- 0.1 mol/L sodium hydroxide
- 0.1 mol/L hydrochloric acid
- universal indicator in a dropper bottle or a pH probe attached to a data logger

Part A

Perform either Method 1 or Method 2.

Method 1

1. Place 10 mL of 0.1 mol/L sodium hydroxide into a small beaker.
2. Add a few drops of universal indicator.
3. Measure out 10 mL of 0.1 mol/L hydrochloric acid and slowly add it to the beaker.
4. Record your observations as the hydrochloric acid is added.

Method 2

1. Place 50 mL of 0.1 mol/L sodium hydroxide into a small beaker.
2. Place the pH probe into the beaker.

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EXPERIMENT 6.4

3 Measure out 50 mL of 0.1 mol/L hydrochloric acid and slowly add it to the beaker.

4 Record your observations as the hydrochloric acid is added.

Results

1 What can you conclude?

2 Write a word equation for the reaction that has occurred.

Part B

1 **Predict** what will happen if 1 mL of hydrochloric acid were added to the final solution in Part A.

2 Add 1 mL of hydrochloric acid to the final solution.

3 Record your observations.

Discussion

Was your observation consistent with your prediction? **Explain** why or why not.

Part C

1 **Predict** what will happen if 2 mL of sodium hydroxide were added to the final solution from Part B.

2 Add 2 mL of sodium hydroxide to the final solution from Part B.

3 Record your observations.

Discussion

1 Was your observation consistent with your prediction? **Explain** why or why not.

2 **Explain** the pH changes that were occurring in the beaker.

Neutralisation in living systems

Neutralisation is a chemical reaction that is important in all organisms. Maintaining the correct pH is essential for maintaining living systems. Different organisms or even parts of organisms need different chemical environments. For example, our eyes have a pH of 7.2. Hence, the pH of a swimming pool should be checked regularly to ensure that the pH is maintained at 7.0–7.6. If the pH is not in this range, swimmers could experience stinging, burning eyes. This means that chemicals should be added to the pool to adjust the pH to bring it back to the optimal range.

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Figure 6.7 Adjusting pH is part of regular pool maintenance.

The pH of an aquarium is also important. Most freshwater fish require a pH of 6.8–7.5 and most saltwater fish require a pH of 8.2–8.4. Products, such as 'pH Up', are available for adjusting the pH, but they must be used according to the manufacturer's instructions.

Figure 6.8 The pH of the water in the aquarium must be kept in the ideal range for the fish.

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ACTIVITY 6.8

Marine science careers

A career in marine science could involve research and conservation of ocean and coastal environments for government agencies, or work in aquaculture, ecotourism or maritime archaeology. Marine scientists are also a vital part of running large aquariums such as the Sydney Aquarium, Oceanworld (Manly, NSW), SeaWorld on the Gold Coast and Reef HQ in Townsville.

1 Write down 10 questions you would ask a marine scientist.

2 **Investigate** the career of a marine scientist. Complete a plus delta chart to record what you think are the strengths and weaknesses of this career.

Extension

If possible, interview a marine scientist by asking the questions that you have developed.

WORKSPACE
Marine science careers

ACTIVITY SHEET
Studying Marine Science in Australia

Acids and bases in our bodies

Our blood should have a slightly basic pH of 7.4. Acidosis and alkalosis occur if the pH is too low or too high. Eating fruits and vegetables keeps the blood slightly basic.

Dr Amy Joy Lanou from the University of North Carolina at Asheville, USA, found a link between the pH of our blood and the brittleness of our bones. If we eat too much protein, which contains amino acids, then our blood becomes slightly acidic. To neutralise this excess acid in the bloodstream, basic compounds such as calcium carbonate are required. If we do not have enough calcium in our diet, it will be drawn out of our bones. This leaves our bones brittle and more likely to be fractured due to osteoporosis.

So eating lots of fruit and vegetables actually helps us to have strong bones.

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Figure 6.9 Eating lots of fruit and vegetables helps keep our blood at the right pH.

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Enzymes are important chemicals that control the rate at which chemical reactions such as respiration and digestion occur in our bodies. Enzymes are proteins and they are composed of amino acids, so this is another example of the role of acids in our bodies.

Other acids and bases also play a key role in the digestion of food. The saliva in our mouth contains bicarbonate, which maintains a stable chemical environment with a pH of 6.5–7.5. Our stomach contains hydrochloric acid, which has a pH of 2. This acid is used to kill bacteria and to change pepsinogen into pepsin, which helps to digest proteins. Pancreatic juice contains sodium bicarbonate, which neutralises the acidic material as it comes out of the stomach and into the small intestine.

WORKSPACE
Neutralising an acid

EXPERIMENT 6.5

Neutralising an acid

Possible risks	Safety precautions
Hydrochloric acid can be harmful if it comes in contact with skin or eyes.	Wear safety glasses while performing this activity. Wash your hands thoroughly at the end of the experiment.

Materials

- 20 mL of 2 mol/L hydrochloric acid
- 5 g of bicarbonate of soda (sodium hydrogen carbonate, $NaHCO_3$)
- universal indicator
- 150 mL beaker
- 25 mL measuring cylinder
- spatula
- electronic balance

Method

1. Place 20 mL of 2 mol/L hydrochloric acid into a small beaker.
2. Add a few drops of universal indicator.
3. Weigh out about 5 g of bicarbonate of soda.
4. Slowly add some bicarbonate of soda until the acid is neutralised.

Results

1. Record your observations.

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EXPERIMENT 6.5

Discussion

2 **Explain** how you know when the acid has been neutralised.

3 Determine how much bicarbonate of soda you used to neutralise the acid.

INTERACTIVE
pH: changing pH

Antacids are used to settle an upset stomach. Sometimes the acid from the stomach moves up into the oesophagus, a condition called acid reflux. Antacids neutralise this acid. Bicarbonate of soda (also called sodium bicarbonate or sodium hydrogen carbonate, $NaHCO_3$) is one of the chemicals that can be used in antacids. Magnesium hydroxide and aluminium hydroxide are other bases that are used.

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Figure 6.10
Antacid tablets can help settle an upset stomach.

EXPERIMENT 6.6

Student investigation: Testing a manufacturer's claim – antacids

WORKSPACE
Student investigation: Testing a manufacturer's claim – antacids

Antacids are available at pharmacies and supermarkets. The manufacturers claim that these substances can be taken to settle an upset stomach. But which one to buy?

As a team of scientists, use your knowledge of acids and bases and the scientific method to **compare** two brands of antacids.

- Determine which of the two is the more economical choice for neutralising stomach acid.
- **Define** 'economical'.
- **Design** your test and remember to control your variables.

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ACTIVITY 6.9

Types of chemical reactions

Go back to your mind map on the types of chemical reactions from Chapter 5.

1 Determine the type of chemical reaction to which the neutralisation reaction belongs.

2 Add information about neutralisation reactions to your mind map.

3 Create a new blabber to **summarise** what you have just learnt. Upload the URL to your blog or link to this on the class wiki.

WORKSPACE
What have you learnt? 6.2

QUESTIONS 6.2

What have you learnt?

Remembering

1 **Define** neutralisation.

2 **Define** salt.

Understanding

3 **Explain** how you would neutralise:
  a an acid
  b a base.

4 **Explain** what happens in the following reactions:
  a acid + hydroxide
  b acid + carbonate.

Applying

5 A bee sting is acidic. Would you apply sodium bicarbonate (baking soda) or vinegar to the site of the sting? **Explain** your choice.

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6.3 Acid and metal reactions

Acids also react with metals to cause the metals to corrode and form a salt and hydrogen gas. The general equation for this reaction is:

Acid + metal → salt + hydrogen gas (H_2)

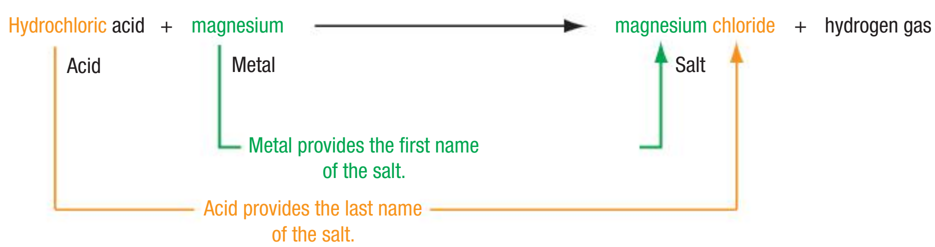

Figure 6.11 Naming salts of metals

WORKSPACE
Investigating the reaction between acids and metals

EXPERIMENT 6.7

Investigating the reaction between acids and metals

Aim

To **investigate** the reaction between acids and metals

Possible risks	Safety precautions
Hydrochloric acid can be harmful if it comes in contact with skin or eyes.	Wear safety glasses while performing this activity. Wash your hands thoroughly at the end of the experiment.

Materials

- 2 mol/L hydrochloric acid
- 3 test tubes
- strip of magnesium metal
- strip of zinc metal
- steel wool

Method

1. Pour 2 mol/L hydrochloric acid into three separate test tubes, to a depth of about 2 cm.
2. Add a 3 cm strip of magnesium to one test tube, a strip of zinc to another and a piece of steel wool to the third.
3. Feel the base of the test tubes with the back of your hand.

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EXPERIMENT 6.7

Results

1 Record all observations.

Discussion

2 **Identify** the observations that indicated that a chemical reaction occurred.

3 Write word equations for each of the reactions that have occurred.

4 **Explain** why you used the back of your hand to feel the test tube rather than your fingers or the palm of your hand.

WORKSPACE
Testing for hydrogen gas

EXPERIMENT 6.8

Testing for hydrogen gas

This activity is to be done as a teacher demonstration.

Possible risks	Safety precautions
Hydrochloric acid can be harmful if it comes in contact with skin or eyes.	This activity is to be done as a teacher demonstration only. The teacher and all students must wear safety glasses while performing this activity. Make sure you wash your hands thoroughly at the end of the activity.
This reaction is very vigorous.	This activity is best done outside on a still day. Stand well back from where the experiment is being performed.
The hydrochloric acid and zinc mixture is flammable.	Move the flask well away from where the experiment is being demonstrated.

Materials

- safety glasses
- 150 mL of 6 mol/L hydrochloric acid
- granulated zinc
- 250 mL conical flask
- balloon
- candle
- two 1 m rulers

Method

1 Pour about 75 mL of 6 mol/L hydrochloric acid into a 250 mL conical flask.

2 Pour about 12 pieces of granulated zinc into the flask.

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EXPERIMENT 6.8

3 Place the neck of a balloon over the mouth of the conical flask to collect the hydrogen gas.

4 When the balloon has inflated to about 10 cm diameter, tie it off.

5 Move the flask well away from where the experiment is being demonstrated.

6 Attach the balloon to a metre ruler.

7 Attach the candle to the other metre ruler.

8 Light the candle and, holding each of the metre rulers in your hands, bring the lighted candle close to the balloon.

Results

1 Your teacher will move around with the conical flask. Use the back of your hand (opposite side to the palm) to feel it.

2 Record all of your observations.

Discussion

3 **Describe** what happened when the gas in the balloon was lit. **Explain** this.

4 **Describe** what you felt when you touched the flask. **Explain** this.

5 **Explain** why the flask was moved away before the gas that was collected in the balloon was tested.

6 **Recall** the chemical reactions you learnt about in Chapter 5. **Classify** the type of chemical reaction to which the acids and metals reaction belongs.

ACTIVITY SHEET
Acids and metals

QUESTIONS 6.3

What have you learnt?

Remembering

1 **Identify** the products of a reaction between an acid and a metal.

2 **Describe** the test to **identify** the gas produced when an acid reacts with a metal.

Understanding

3 **Explain** why a balloon was used to collect one of the products of the reaction between hydrochloric acid and zinc.

Applying

4 **Identify** the salt formed when hydrochloric acid reacts with iron.

5 **Identify** the acid used to react with magnesium to produce magnesium sulfate.

WORKSPACE
What have you learnt? 6.3

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6.4 Combustion

combustion
a chemical reaction in which a fuel reacts with oxygen and produces heat as one of the products

Combustion is a chemical reaction that occurs when a substance reacts with oxygen. All elements present in the original substance form oxides. Heat is always produced in this type of reaction.

Burning is a combustion reaction. Combustion reactions are used to provide energy for many of our daily activities. Coal is burnt to produce energy to drive the turbines of our power stations (Figure 6.12). Petrol, diesel or LPG are burnt in the combustion chamber of car engines to produce the energy to drive the car.

Shutterstock.com/fotohunter

Figure 6.12 Burning coal produces energy at power stations.

a Shutterstock.com/ggw1962

b Alamy/© Joe Fox

Figure 6.13 **a** A Bunsen burner uses the combustion of methane gas. **b** LPG is a mixture of hydrocarbons, but is mostly propane, and is supplied in a cylinder.

For example, when you light a Bunsen burner with the air-hole open, the methane gas (CH_4) reacts with oxygen to form carbon dioxide (CO_2) and water (H_2O). Carbon dioxide is one of the oxides of carbon and water is the oxide of hydrogen.

The word equation for this reaction is:

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

This same reaction occurs when you use a hot plate on a gas stove at home.

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Hydrocarbons are compounds that contain only carbon and hydrogen. Many people, when they barbecue, use gas. This gas is LPG, liquefied petroleum gas, which is a mixture of hydrocarbons, but is mostly propane (C_3H_8), and is supplied in a cylinder (Figure 6.13b).

Not all fuels used in the science laboratory are gases, some are liquids. We use a special piece of equipment, called a spirit burner, to combust these fuels. The liquid fuel is placed in the spirit burner (Figure 6.14), then soaks into the wick. The wick is then lit to burn the fuel. The flame is extinguished by smothering it by placing the lid on the spirit burner.

All combustion reactions produce energy. In Experiment 6.9, the energy from the combustion of the fuel is used to heat water. The energy is transformed from chemical energy to heat energy.

Shutterstock.com/Tom Mc Nemar

Figure 6.14 A spirit burner

hydrocarbon
a chemical compound that only contains carbon and hydrogen

WORKSPACE
Student investigation: combustion of fuels

EXPERIMENT 6.9

Student investigation: Combustion of fuels

Aim

To determine whether we would use the same amount of each type of fuel to heat 100 mL of water by 20°C

Method and materials

1 State the hypothesis for your investigation.

2 **Identify** the independent variable.

3 **Identify** the dependent variable.

4 **Identify** the variable(s) that need to be kept constant (controlled).

5 **List** the equipment that you will use, including three different fuels.

6 **List** any safety precautions that you will need to take to ensure that the investigation is carried out safely.

7 **Describe** the method.

Results

8 **Construct** an organised way to record and present your results to make it easy to **compare** your data.

9 Record your results.

10 Provide one or two summary statements.

Discussion and conclusion

11 Write a discussion that **compares** your results for various fuels. Support your statement by referring to the data from your results. **Explain** your results as best you can.

Write a conclusion that refers back to your aim.

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EXPERIMENT 6.9

Extension

12 Using the results from your investigation and the information in the table, determine which fuel is the most economical to use

Fuel	Cost for 500 mL	Density (g/mL)
Ethanol	$16.02	0.79
Propan-1-ol	$23.42	0.81
Butan-1-ol	$24.65	0.81

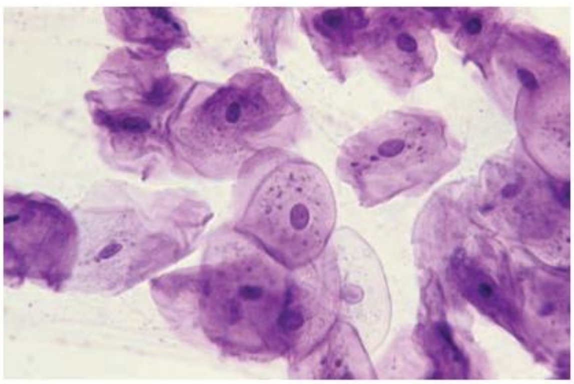
Cellular respiration – a combustion reaction in our cells

Respiration is a chemical reaction that occurs within our cells. During respiration, chemicals such as glucose are broken down to release the energy stored within them.

In our bodies, the energy in the foods we eat is released during respiration. This energy is transformed into kinetic energy and heat energy. This allows us to perform all of the activities that we need to live and enjoy ourselves. The energy enables us to think, talk and run. Some of the energy is used to keep our body at a constant temperature. Some food is in more useable forms than others for the energy to be released. Carbohydrates are foods that are high in useable energy. They contain carbon, hydrogen and oxygen.

Respiration in our body cells is a much slower chemical reaction than the combustion of fuels in industry because it occurs at a much lower temperature. Barbeques and car engines get very hot, the reaction occurs very quickly and releases energy in a short period of time. Respiration occurs at the much lower temperature of our body, 37°C, hence the reaction takes much longer and releases energy over a longer period of time. We don't need all of our energy at a single instant in time. We need a little energy continuously to allow us to do all the things that we do each day.

The rate of a reaction is a measure of how fast or slow a reaction is. Combustion reactions in industry are fast whereas respiration in our bodies is slow. We will learn more about the rate of chemical reactions in Year 10.



Corbis/© Dr. Robert Calentine/Visuals Unlimited

Figure 6.15 Respiration is a chemical process that occurs within every living cell, such as in these cheek cells.

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WORKSPACE
Why is breakfast so important?

EXPERIMENT 6.10

Why is breakfast so important?

Aim

To determine if cereal releases energy

Note: If you want to determine the amount of energy released by the cereal, then read the extension activity to ensure that you collect all of the data you need for the calculation.

Materials

- one piece of a breakfast cereal, such as Kellogg's® Nutri-Grain
- pin
- cork
- test tube half-filled with water (about 5–7 mL)
- test-tube holder
- thermometer or temperature probe
- matches

Method

1 Stick the pin through the piece of Nutri-Grain and attach it to the cork. (The cork and pin form the stand for the Nutri-Grain.)

2 Place the Nutri-Grain under the test tube of water.

3 Measure the temperature of the water. Record this in your results table.

4 Use the matches to light the piece of Nutri-Grain.

5 Measure the final temperature of the water.

Results

1 Devise a table to record your observations.

Discussion

2 State your result. **Compare** the temperature of the water from the start of the experiment to the end of the experiment.

3 **Account** for the change in temperature found in your results. **Relate** heat to energy to **explain** your findings.

4 Did you need to hold the match over the cereal continuously? Why?

5 **Identify** improvements that you could make to this experiment to obtain more accurate results.

6 **Justify** or refute the statement: 'All cereals will produce the same results as the Nutri-Grain tested.'

7 Devise a fishbone diagram to study the causes and effects of not eating breakfast.

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EXPERIMENT 6.10

Extension

8 **Calculate** the energy released by the cereal. You can **compare** the energy released by different cereals by determining the energy released by 1 g of each cereal. You will determine the energy released by the cereal indirectly, by measuring the energy absorbed by the water. The law of conservation of energy says that energy cannot be created or destroyed; it can only be changed from one form to another. So, if the temperature of the water increases, the water is absorbing heat (energy). This energy has been released by the combustion of the cereal.

Collect the following data:

- mass (g) of water
- initial temperature (°C) of the water
- final temperature (°C) of the water
- mass (g) of cereal.

specific heat capacity
the ability of a substance to hold heat

Each substance has an ability to hold heat. This is called its **specific heat capacity**. The specific heat capacity (C_g) of water is 4.2 J g^{-1}°C^{-1}. This means that 4.2 J of heat is required to raise the temperature of 1 g of water by 1°C.

So, to raise the temperature of 100 g of water by 1°C, you'd need 100 times more heat; that is:

$100 \times 4.2 = 420$ J

Energy absorbed by water = mass of water × specific heat of water × change in temperature of the water

Energy released by cereal = energy absorbed by water

$$\text{Energy released by 1 g of cereal} = \frac{\text{energy released by cereal}}{\text{mass of cereal}}$$

Fairfax/Craig Golding

Figure 6.16 These Kellogg's® Nutri-Grain Ironman athletes require sustained energy.

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QUESTIONS 6.4

What have you learnt?

Remembering

1 **Define** combustion.

2 **Identify** where respiration occurs in our body.

3 **Identify** three things that our body does with the energy released during respiration.

Understanding

4 **Explain** why respiration is classified as a combustion reaction.

Applying

5 **Explain** why respiration is a very important chemical reaction.

WORKSPACE
What have you learnt? 6.4

6.5 Energy and chemical reactions

Many chemical and physical processes involve either absorbing or releasing energy. Processes that absorb energy are called **endothermic** processes. During the process, energy is absorbed, so the products have more energy than the reactants (Figure 6.17a). Melting ice is an example of an endothermic process. The ice (water solid) absorbs heat energy from your hand to form water liquid. Another endothermic process is the decomposition of food scraps. In a compost bin, energy is absorbed to break the food down into elements that are used as nutrients for soil.

Processes that release energy are called **exothermic** processes. During the process, energy is released, so the products have less energy than the reactants (Figure 6.17b). Freezing water to form ice is an example of an exothermic reaction, the water must release

endothermic
a chemical reaction that takes in heat energy

exothermic
a chemical reaction that releases heat energy

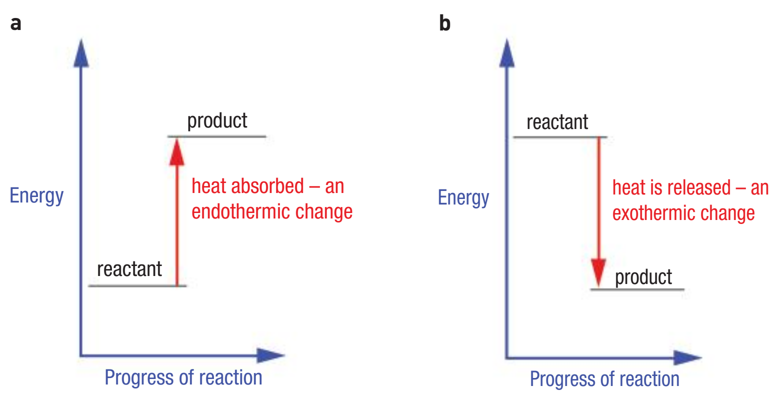

Figure 6.17
a Energy pathway for an endothermic reaction
b Energy pathway for an exothermic reaction

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energy to form ice. Using explosives to demolish buildings is another example of an exothermic reaction. During the explosion, large amounts of energy are released. This energy is used to bring down the building.

- Melting ice is an example of a physical process that is endothermic.
- Decomposition of food scraps is an example of a chemical process that is endothermic.
- Freezing water is an example of a physical process that is exothermic.
- Using explosives to demolish a building is an example of a chemical process that is exothermic.

Respiration – an example of an exothermic reaction

The respiration process involves the combustion of glucose, which is the useable form of carbohydrates in our body cells. During this process, the energy that we need to live is released, hence, respiration is an exothermic reaction. The other two products are carbon dioxide and water. All living things respire all the time, and for many the process is the same. The process described here is the common respiration process for most living things. Some bacteria have a slightly different process; however, it still releases energy to allow them to survive and thrive.

Photosynthesis – an example of an endothermic reaction

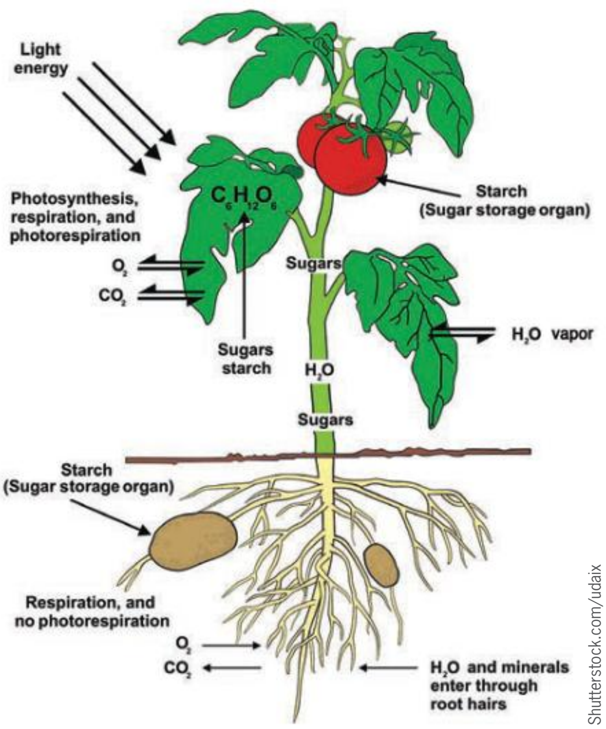

Figure 6.18 Photosynthesis

Plants are organisms that photosynthesise as well as respire. Plants do not eat food, like animals do. Instead they take in carbon dioxide and sunlight through their leaves and absorb water through their roots. The water is then transported to the cells in the leaves via the xylem system. These cells also have a special chemical called chlorophyll, which gives the leaves their green colour. The chlorophyll traps the light energy from the Sun. This energy is used to power the photosynthetic reaction. Photosynthesis takes in energy, so it is an endothermic reaction. Through the process of photosynthesis, the plant breaks down carbon dioxide and water and produces glucose and oxygen. This glucose is a store of chemical energy that can then be used by the plant for respiration.

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ACTIVITY 6.10

Respiration and photosynthesis

1 Write the word equation for the respiration process.

2 Write the word equation for the photosynthesis process.

3 Draw energy chain diagrams for the energy transformations involved in:

  a respiration

  b photosynthesis.

4 Using a Venn diagram, **compare** the processes of respiration and photosynthesis in terms of reactants, products and energy.

WORKSPACE
Respiration and photosynthesis

ACTIVITY 6.11

Endothermic and exothermic reactions

Watch the videos on endothermic and exothermic reactions.

Summarise your understanding of these two types of reactions by comparing their similarities and differences using a Venn diagram or a graphic organiser of your choice.

Include at least three examples of each.

VIDEO
Endothermic reactions

VIDEO
Exothermic reactions

QUESTIONS 6.5

What have you learnt?

Remembering

1 In an endothermic reaction, is the energy absorbed or released?

2 In an exothermic reaction, is the energy absorbed or released?

3 **Define** 'specific heat capacity'. What is the specific heat capacity of water?

Understanding

4 Write the word equations for respiration and photosynthesis.

5 **Explain** why respiration is classified as a combustion reaction.

WORKSPACE
What have you learnt? 6.5

ISBN 9780170231503

QUESTIONS 6.5

Applying

6 **Explain** why respiration and photosynthesis are two very important chemical reactions.

7 **Classify** each of the following reactions as endothermic or exothermic:

a acid + carbonate
b photosynthesis
c respiration
d combustion.

6.6 Industrial reactions

It is not only compounds that contain carbon and hydrogen that undergo combustion reactions. However, carbon and hydrogen are the common elements found in the fossil fuels coal, petrol and diesel. We use many of these for our daily activities. These fossil fuels also have some small quantities of other elements present as impurities. Sulfur is a common impurity in these fossil fuels. Sulfur undergoes combustion to form sulfur dioxide. Another source of sulfur dioxide is the extraction of metals from their ores. For example, chalcopyrite ($CuFeS_2$) is a common ore of copper. The extraction of copper occurs at high temperatures in air. Hence, the sulfur reacts with the oxygen in air to form sulfur dioxide. This is an air pollutant.

Air is about 79% nitrogen and 20% oxygen with 1% being a mixture of other gases, including carbon dioxide. In the combustion chamber of car engines, it is not only the petrol, diesel or LPG that undergoes combustion. Some of the nitrogen in the air also undergoes combustion to form oxides of nitrogen, such as nitrous oxide (NO) and nitrogen dioxide (NO_2). These are also air pollutants.

In chemistry, reactions can be classified in a variety of ways. In Chapters 5 and 6 we have classified them as synthesis, decomposition, single-displacement reactions, double-displacement reactions and combustion reactions. However, reactions can be grouped in other ways. Combustion and corrosion (we saw these in Chapter 5) reactions are forms of **oxidation reactions**. The simplest definition of an oxidation reaction is one in which a chemical reacts with oxygen.

oxidation reaction
a reaction of a substance with oxygen

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Figure 6.19 Car exhausts release polluting gases into the atmosphere.

WOW! Powering the space shuttle

The space shuttle had three different propulsion systems – these were used at different stages of the shuttle's journey. One of these was the **cryogenic** system in which liquid hydrogen and liquid oxygen were ignited by a 'spark plug' and combusted to form water vapour exhaust. As this was forced out of the shuttle, the shuttle was propelled forward. This mixture was also used in the shuttle's fuel cells to provide electricity for the equipment on the shuttle.

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cryogenic
at very low temperature

ACTIVITY 6.12

Oxidation reactions

1 **Identify** the conditions that are needed for iron to rust.

2 **Compare** the conditions required for combustion reactions and corrosion reactions.

3 Create a blabber of what you have learnt. Upload this to your blog.

WORKSPACE
Oxidation reactions

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Impacts on the environment – acid rain

Industry and vehicles are sources of a number of non-metallic oxides. These form acidic oxides when they dissolve in water.

acid rain
rain that has sulfur dioxide, carbon dioxide and nitrogen oxides

This reaction occurs in the atmosphere. Earlier in this chapter, we looked at how the oxides of carbon, nitrogen and sulfur were formed during combustion and were released into the atmosphere. These oxides dissolve in water in the atmosphere to form **acid rain**.

Getty Images/Science Photo Library

Figure 6.20 A statue affected by acid rain

WEBLINK
Coal combustion and acid rain

WORKSPACE
Non-metallic oxides

EXPERIMENT 6.11

Non-metallic oxides

This activity could be performed as a teacher demonstration.

Possible risks	Safety precautions
Universal indicator may be harmful if ingested.	Do not ingest any universal indicator by sucking it up through the straw. Only blow through the straw.
Universal indicator is harmful to eyes.	Wear safety glasses while performing this activity. Don't blow too hard through the straw or the solution will splash up into your face.

Materials

- safety glasses
- universal indicator in a dropper bottle
- 150 mL beaker
- 50 mL of water
- straw

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Method

1 Place five drops of universal indicator into a 150 mL beaker containing 50 mL of water.

2 Place a straw into the solution.

3 Gently, blow through the straw for 2 minutes and record your observations.

Discussion

1 **Identify** the gas you are blowing into the solution.

2 State the colour of the universal indicator at the beginning.

3 State the colour of the universal indicator at the end.

4 Determine the pH of the gas dissolved in the water.

5 **Identify** whether this is acidic, basic or neutral.

ACTIVITY 6.13

Formation of acid rain

Complete the following word equations:

________	+	water	→	carbonic acid (H_2CO_3)
________	+	water	→	sulfurous acid (H_2SO_3)
________	+	water	→	nitrous acid (HNO_2)

Draw a flowchart of the water cycle, clearly indicating where acid rain is formed. This flowchart could be drawn by hand or by using a free web-based program such as Gliffy.

WORKSPACE
Formation of acid rain

QUESTIONS 6.6

What have you learnt?

Remembering

1 **Identify** the products when a hydrocarbon undergoes combustion.

2 **Identify** two combustion reactions that occur in industry.

3 **Identify** two gases that contribute to acid rain.

4 **Identify** some effects of acid rain.

Understanding

5 Write a word equation for the combustion of LPG.

WORKSPACE
What have you learnt? 6.6

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QUESTIONS 6.6

Applying

6 In commercial cold packs, two liquids are mixed and a chemical reaction occurs. This is an endothermic reaction that dramatically reduces the temperature of the pack. This can then be applied to sore muscles.

Identify two other household uses of either endothermic or exothermic reactions.

7 **Compare** combustion and oxidation reactions.

Evaluating

8 'Acid rain has minimal effects on the environment.' **Discuss** this statement.

Creating

9 Create a pie chart to **show** the quantities of the gases that make up air. Upload your graph to your blog.

Reflecting

10 'Today's society would not be possible without combustion reactions.' **Discuss** this statement using specific examples.

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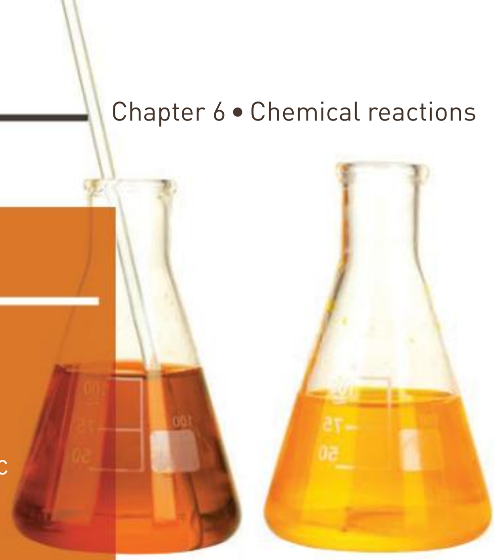

Chapter review

Remembering

1 **Identify** the gas that must be present for combustion to occur.

2 **Classify** the chemical reactions of photosynthesis and respiration as endothermic or exothermic.

Understanding

3 Determine if the following statements are true or false.

For the statements that are false, correct and rewrite them so that they are true.

- a Electrical conductivity is a chemical characteristic.
- b Oxides, hydroxides and carbonates are bases.
- c The definition of an acid put forward by Lavoisier has remained the same for hundreds of years because all of the evidence supports this definition.
- d Phenolphthalein is an example of a base.
- e Using universal indicator is a more accurate method for measuring pH than using a pH meter.
- f During an exothermic reaction heat is released.
- g In an acid–base reaction, the salt formed gets the first part of its name from the acid and the second part of its name from the base.
- h Respiration is an endothermic reaction.
- i Our mouth, stomach and small intestine all have different chemical environments as they each have a different pH.
- j To test for hydrogen gas, a lighted taper is placed over the gas and it goes 'pop'.

4 Complete the generalised word equations.

- a acid + hydroxide →
- b acid + carbonate →
- c acid + metal →

5 A piece of magnesium was placed in a test tube of hydrochloric acid. Bubbles were produced. **Identify** the gas that produced the bubbles.

Applying

6 **Justify** whether the following statement is true or false. 'A substance with a pH of 9 is an acid.'

7 One substance has a pH of 8 and another has a pH of 10. State which of the substances is more acidic. **Justify** your answer.

8 Substance X has a pH of 4 and substance Y has a pH of 6. Deduce how much more acidic substance X is than substance Y.

9 Determine whether you would use universal indicator or a pH meter to prepare a solution of pH 8.3. **Justify** your answer.

10 Bicarbonate of soda is often added to cake mixtures. It reacts with other ingredients to produce bubbles of carbon dioxide. **Describe** the effect this has on the cooked cake.

WORKSPACE
Chapter 6 review

ACTIVITY SHEET
Chapter 6 checklist

REVIEW QUIZ
Chapter 6

ISBN 9780170231503

Analysing

11 You have performed many experiments throughout this chapter. **Explain** why it is very important that you follow all of the safety advice given. Give examples to support your answer.

12 Many modern diets are high in fizzy drinks and fruit juices. These drinks are high in acid. The pH of the mouth is about 7.4, yet many of these drinks have a pH about 3.4. **Describe** the effect you think overconsumption of these drinks will have on teeth, the stomach and the rest of the digestive system.

Evaluating

13 **Evaluate** this statement: Acids and bases do not affect me.

Creating

14 From your knowledge of energy in foods, create a pamphlet or poster to alert people to the problems associated with overeating carbohydrates. Make sure your pamphlet contains scientific evidence to back up your claims.

Reflecting

15 Using what you have learnt in this chapter, **summarise** three ways in which you could change your behaviour to improve your lifestyle.

16 Acid rain and its effect on our planet is a significant environmental issue. **Discuss** actions that could be taken to minimise the effects of acid rain.

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7

Waves

How do waves transfer energy?

There are sound waves, light waves and microwaves, to name a few. All waves carry energy and they can transfer that energy to another material. Ocean waves carry energy with them too. When you hear waves crashing on rocky shores, you are hearing some of the energy being transferred and transformed. Surfers need to capture energy from the surface of a wave in order to move towards the shore. Small waves with close to 200 kJ of energy can get you surfing, but big waves over 6 m can get you in trouble. A big-wave rider can surf waves as tall as a seven-storey building. Underneath the rider there can be as much as 5000 kJ of energy. If a surfer is dumped from a wave such as this, they will be battered by some of that energy.

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Physical world – Stage 5

Key knowledge

- Waves carry energy and transfer energy.
- Waves of sunlight or ocean waves can transfer energy to anything they contact.
- The wave model includes the quantities of a wave: wavelength, frequency, speed, amplitude, period, crests and troughs.
- Sound waves can transfer energy through different media as the particles of the wave bump into each other and transmit sound; the closer the particles, the faster the speed of sound.
- Everyday materials can help absorb sound to keep rooms quieter, or reflect light to keep rooms cooler. Waves can also be refracted in everyday situations.
- High-energy waves, such as X-rays, from the electromagnetic spectrum are used in medicine and lower-energy waves, such as radio waves, can be used in communication.
- The particle model can be used to explain the processes of heat energy conduction and convection.

ACTIVITY SHEET
CAT with rubric: Hello? Can you hear me?

CULMINATING ASSESSMENT TASK

Hello? Can you hear me?

Have you ever tried to make a mobile phone call only to find that you have no reception? Mobile phone reception relies on energy transfer by waves.

Good reception requires that the signal quality be maintained from its source to the final destination, your mobile phone. Loss in quality of the signal will occur if some of the energy is re-directed or lost (either reflected or absorbed) as non-useful energy.

In this task you will **investigate** how good reception is achieved in a number of communications technologies. You will then **compare** the technologies that our modern society has come to rely upon.

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What do you already know about energy?

Identify the different types of energy involved in Figure 7.1. Discuss.

a

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b

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c

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d

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e

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f

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Figure 7.1
Energy is involved in each of these examples.

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7.1 Communicating messages

communication

conveying a message from a sender to a receiver

Humans have always needed to convey messages to one another. Talking is the most common form of **communication** between humans. However, talking only allows you to communicate with people in your immediate area.

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Figure 7.2 Talking is the most common form of communication.

WORKSPACE
Stages for communication

ICT

You could use Gliffy to create your diagram, concept map or flowchart.

ACTIVITY 7.1

Stages for communication

Imagine you need to get a message to your best friend who lives in the next suburb without using technology. Create a diagram, concept map or flowchart that **shows** some possible methods (types) and the stages (sequence of events) for that communication to successfully occur.

Over human history, a variety of methods have been used to communicate messages over long distances. In ancient Greece the first marathon runner, Pheidippides, travelled from the town of Marathon to Athens. He delivered a message that the Persians had been defeated in the Battle of Marathon (490 BCE). The distance that Pheidippides ran to deliver his famous message has been estimated to be 42.2 km, the distance of the modern marathon.

Today, there are many different methods by which we can communicate. These include carrying the message and giving it to the recipient, or transferring an electronic signal along a wire or by radio (wireless) from the sender to the recipient.

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A message such as a phone call may be communicated direct and in real time. This enables a conversation with another person. Communication could also be a one-way recorded message, such as a letter. The message could be recorded by writing on paper or typing on a keyboard to a screen, or it could be an audio or video (and audio) recording.

Successful communication requires there to be a sender, a message and an intended recipient of that message who is able to interpret the message. If a person sent you a written message in a language you could not understand, then we could not say that communication had occurred.

Observatory Hill in Sydney was the first place from which astronomical observations were made in the early settlement. The timeball tower on top of the observatory (Figure 7.3) was used to communicate with ships anchored in the harbour. The large ball was dropped at exactly 1 pm each day to allow ships' captains to set their chronometers.


Alamy/© david sanger photography

Figure 7.3
The timeball tower on the Sydney Observatory

ACTIVITY SHEET
A new pigeon carrier system


Australian War Memorial

Figure 7.4
A carrier pigeon transferred a message from the sender to the recipient.

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Carrier pigeons were used in World War I to transfer information between command and the front lines. Messages were written onto waxed paper that was tied to a pigeon's leg or inserted into a small cylinder attached to the pigeon's leg.

WORKSPACE
Communication systems

ACTIVITY 7.2

Communication systems

Part A

Choose one of the following methods of communication.

- Semaphore
- Pony express
- Cobb and Co.
- Telegram
- Morse code

For your chosen method conduct some research and find out:

- when it was popular
- how it worked
- whether it is still used
- the stages in the communication process
- what energy was needed to make this type of communication work.

Devise three more questions to answer as part of your research.

Part B

Upload the following table to the class wiki. As a class, complete the table by adding the above forms of communication.

Table 7.1
Means of communication

Means of communication	Method	Energy required	Estimated speed	Possible problems to delay or stop communication
Carrier pigeon	Message written on waxed paper and tied to pigeon's leg	Chemical energy in the form of seed Kinetic energy	Can fly at speeds of up to 90 km/h	Pigeon could be killed by a hawk

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QUESTIONS 7.1

What have you learnt?

WORKSPACE
What have you learnt? 7.1

Remembering

1 **Describe** what is meant by the term 'communication'.

2 **List** five different methods of communication that have been used over human history.

3 **List** the three stages on which successful communication relies.

Applying

4 **Describe** the role that energy plays in communication. **List** two examples.

5 You are on the battlefield and have been asked to write an urgent request for reinforcements. This message has to be carried by carrier pigeon. **Propose** what you would write.

Creating

6 Devise a new form of communication that your grandchildren might use. **Describe** how it might work.

7.2 Communication using waves

All the forms of communication we have explored so far have used **energy**. Writing a letter, running a marathon, riding a horse and a pigeon carrying a message all used chemical energy. This chemical energy was in the form of food to provide the energy to move the muscles in the letter writer, marathon runner, horse or bird. Dropping the timeball on Observatory Hill used potential energy – the timeball had energy due to its high position.

Modern communication systems rely on the fast transfer of energy from one place to another. This energy travels as waves.

energy

a fundamental quantity that can only be identified in terms of transfers from place to place or transformations from form to form

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Waves – energy that travels

medium

the substance through which a wave moves

wave

a disturbance that moves through time and space, carrying energy

When you drop a pebble into water, ripples spread out from the centre. These ripples are disturbances in the surface of the water. In this case, water is called the **medium**, the substance through which the waves travel. A **wave** is a disturbance in a medium that carries energy. A similar disturbance can occur in air, only we cannot see it.

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Figure 7.5 A wave is a disturbance in a medium such as water.

ANIMATION
Anatomy of a wave

crest

the point at which a wave is at its maximum upwards value

trough

the point at which a wave is at its maximum downwards value

wavelength (λ)

the distance from a point on the wave until it repeats on the next wave, e.g. crest to crest

Anatomy of a wave

Although you may not have seen the similarity, ocean waves, microwaves and sound waves have a lot in common. They can all be described by the seven quantities that define every wave: wavelength, frequency, crest, trough, amplitude, period and wave speed.

Crests and troughs

The **crest** of a wave is the point at which the wave has its maximum upwards value. A **trough** is the opposite of a crest. It is the point at which a wave has its minimum downwards value.

Wavelength

The length of a wave can range from very small, measured in nanometres, or billionths of a metre, to large, measured in kilometres. The **wavelength (λ, lambda)** is measured from the

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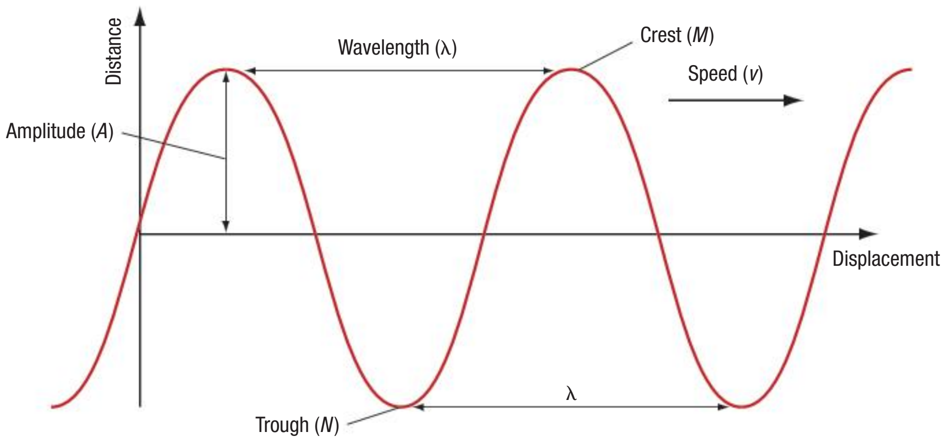

Figure 7.6 The seven quantities of a wave

crest of one wave to the crest of the next wave or from trough to trough. The length of the wave indicates its energy level. A wave with a short wavelength has high energy. A wave with a long wavelength has low energy.

Frequency

The **frequency (*f*)** of a wave indicates the number of waves per second. It is measured in **hertz (Hz)**. One wave (or cycle) per second is equal to 1 Hz. A high-pitched sound such as a scream will have a large number of waves per second and is said to have a high frequency.

Amplitude

The **amplitude (*A*)** of a wave is the height of the wave from its rest position. A sound wave of higher amplitude is higher in volume and, a sound wave of lower amplitude is lower in volume.

Period

The **period (*T*)** of a wave is the time (in seconds, minutes or hours) for one complete wave to move past a fixed point (for example, from crest to crest).

frequency (*f*)
the number of waves per second

hertz (Hz)
the unit of frequency; 1 Hz is one whole wave per second

amplitude (*A*)
the maximum height of a wave from its rest position

period (*T*)
the time for a particle to move through one complete wave cycle

ACTIVITY 7.3

Visualising frequency and amplitude

Vibrations cause the particles in solids to move and hence produce waves that carry energy. Frequency of vibration can be observed when a ruler is allowed to overhang the end of the desktop and made to vibrate when sprung.

WORKSPACE
Visualising frequency

vibration
a rapid continuous back and forth or up and down movement

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WORKSPACE
Oobleck dance

ACTIVITY 7.4

Oobleck dance

Materials

- oobleck (mixture of cornflour and water) (or styrofoam balls for a less messy option)
- large speaker inside a plastic bag
- digital video camera

Method

1 Connect the speaker to an amplified sound source or signal generator.

2 Pour the oobleck (or styrofoam balls) onto the speaker cone and turn on the sound source. Play some music and change the volume. What do you notice about the oobleck 'dance' as the volume changes?

Results

1 Record your observations with the video camera.

2 **Explain** your observations using the terms 'vibration', 'amplitude' and 'frequency'. Create a movie or slide show of your findings and publish it on your class wiki.

Speed

propagate
to continue through

The speed of a wave refers to how fast the wave moves or **propagates** through a medium. For example, if you stand 170 m from a cliff face and shout, it would take 1 second for the echo to return to you. The speed of the wave would be 340 m/s through the air.

The speed of a wave can be found by multiplying the frequency by the wavelength: speed = frequency × wavelength.

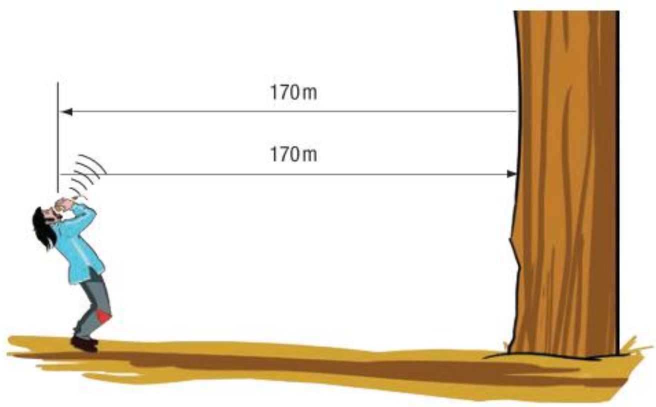

Figure 7.7 It would take 1 second for the echo to return, so the speed of the wave would be 340 m/s.

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ACTIVITY 7.5

Wavy lines

Create a series of wave diagrams to **compare** the appearance of a wave as one of its quantities is altered. Refer to the standard diagram of a wave on page 235, Figure 7.6. Redraw this wave for yourself as a reference wave.

Changing amplitude

1 Redraw the reference wave to **show** a whisper.

2 Redraw the reference wave to **show** a scream.

3 **Summarise** the change: As the loudness decreases, the amplitude ___________; as the loudness increases, the amplitude ___________.

Changing frequency

1 **Contrast** how the wave appearance of the reference wave changes at high and low frequency. Draw a low frequency and a high frequency wave.

2 **Summarise** the change: As the frequency decreases, ___________.

Changing wavelength

a Draw a wave with low energy and one with high energy. **Summarise** what you notice.

b Label the seven quantities on your waves.

WORKSPACE
Wavy lines

WEBLINK
Collaroy Narrabeen Beach Erosion Time Lapse

Waves in the ocean

Wind-generated ocean waves usually have periods of 5–20 seconds and wavelengths of 100–200 m. A tsunami can have a period in the range of 10 minutes to 2 hours and wavelengths of 20–500 km.

Alamy/© Kenna Love

Figure 7.8 The wavelength of this ocean wave is only a few metres.

WOW!

Harnessing wave energy

There are many projects underway worldwide that involve trying to transform the powerful ocean wave energy into electrical energy for human use. In the UK, for example, the 'Wave Hub' off Cornwall will act like a giant electrical 'socket' on the ocean floor. Ocean wave energy will first be converted to electrical energy, then it will be transmitted through cables to potentially power up to 7500 homes!

ISBN 9780170231503

ACTIVITY 7.6

Observing wavelength

Aim

To find out if it is possible to see a wavelength

Materials

- microwave-safe plate
- pack of marshmallows (cheese slices work just as well)
- access to a microwave oven
- digital camera

Method

1 Arrange the marshmallows side by side on a microwave-safe plate so that they cover the whole plate.

2 Remove the turntable from the microwave oven and place the plate with marshmallows into the microwave oven.

3 Turn on the microwave oven to high power for about 30 seconds. Open the door and check that melted spots have appeared. If not, close the door and heat again in short bursts. Not all the marshmallows will melt. Only those at the maximum and minimum amplitudes of the wave will melt. The spots of melted marshmallows will be separated by half a wavelength.

Results

1 Take a digital image of your marshmallows and label the wavelength. Upload your image to your blog.

2 The frequency is listed on the back of the oven or inside the door. Multiply the frequency by the wavelength to **calculate** the speed of the microwaves.

WORKSPACE
What have you learnt? 7.2

QUESTIONS 7.2

What have you learnt?

Remembering

1 **Describe** what a wave is.

2 **List** the seven quantities that define a wave.

Understanding

3 **Describe** what would happen to the speed of a wave if its frequency increased and its wavelength remained constant.

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QUESTIONS 7.2

4 **Explain** how the wavelength of an ocean wave could be found.

5 **List** three different mediums through which waves can travel.

Applying

6 **Describe** the difference between the amplitude of an ocean wave and the height of the wave between the trough and the crest.

7 **Explain** why echoes are often heard several seconds after the initial sound.

Analysing

8 **Compare** and **contrast** the terms 'period' and 'frequency' of a wave.

Creating

9 Using Quizlet, create a set of flashcards to help you remember what you have learnt so far. Share your quizlet with a friend and then write about your friend's quizlet on your blog.

WEBLINK
Quizlet

7.3 Sound waves

Air has matter, so it can also act as a medium to carry a wave. This can happen when a bell rings, a drum is banged or someone talks. Particles of air around the energy source vibrate and transfer the energy to the next particle and so on. This is called sound energy. The energy travels as a sound wave.

VIDEO
What is sound?

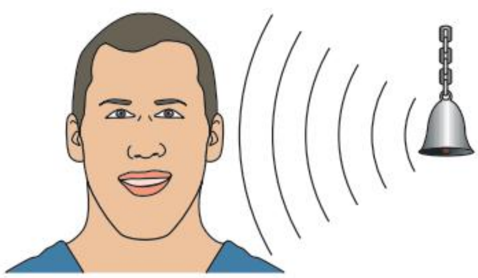

Figure 7.9 Particles of air vibrate and this vibration moves from the sound source as a wave.

Mechanical transfer of energy

You will remember that all materials are made up of particles. When one particle in a material 'bumps' the next particle, energy is transferred mechanically. This continues and the energy is transferred to the next particle in the line, rather like a long line of dominoes falling over. Some waves are mechanical waves, and require a medium for the wave to travel in or to propagate. Water waves and sound waves are the most commonly experienced mechanical waves.

INTERACTIVE
Seeing with sound

ISBN 9780170231503

Getty Images/AFP

Figure 7.10 Mechanical transfer of energy is like a Mexican wave.

Vibrations cause the particles in solids, liquids and air to move and hence produce sound waves. The speed of sound waves differs in different mediums. As the density of air is less than that of a solid, sound vibrations travel more slowly through air than through solid objects. Different air conditions can also cause changes to the speed of sound. Sound travels faster in hot air than in cold air because the air particles are moving faster and the vibrations are transmitted faster. In calm conditions the sound of a ship's foghorn can travel long distances. This creates the illusion that the ship is closer than it is. When sound travels from hot air to cold air it bends (refracts) due to the change in speed. This is called **refraction**.

refraction
the bending of waves when they change speed

WORKSPACE
Sound waves

ACTIVITY 7.7

Sound waves

1 Place your ear on the table or desktop and tap the surface. Listen for the vibration. Lift your ear from the surface and repeat the tapping. **Describe** what you observe.

2 **Explain** your observations.

3 Whales can communicate across long distances. Earthquakes can be 'heard' (or felt) at long distances as the energy travels quickly through the particles in solid rock. **Explain** these phenomena.

4 **Explain** how sound waves travel in solids and liquids.

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WOW!

Faster than a speeding bullet

The speed of sound depends on the density of particles in the medium through which it is travelling. At room temperature, sound travels at about 343 m/s, but outside at freezing temperatures, sound waves are slower at 331 m/s. In freshwater, sound can travel at 1482 m/s! Through steel, the speed of sound is 5960 m/s – 17 times faster than in air.

ACTIVITY 7.8

Air cannon

Aim

To **construct** an air cannon

Materials

- balloon
- large plastic cup with the end cut off
- thick sticky tape
- candle
- matches

Method and Results

1 Stretch the balloon over the large end of the cup. Secure it in place with the sticky tape.

2 Stretch the balloon and quickly release it. **Describe** what you observe.

3 Determine how far the air wave can travel by directing it towards a lit candle. How far from the air cannon can you place the candle away so that it is still blown out?

Discussion

1 **Predict** how you could change the air canon to increase the distance the air will travel.

2 Would an air cannon work in space? **Explain** your answer.

WORKSPACE
Air cannon

Slinky waves

A toy slinky can be used to demonstrate two different types of waves. These waves can be either **transverse** (across) or **longitudinal** (along) waves. The motion of a wave and the motion of the medium that carries that wave may be different.

transverse
at right angles to where the energy was propagated

longitudinal
along the length of an object (i.e. in the same direction as the wave)

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Longitudinal and transverse waves

A transverse wave shows movement at right angles to the direction of energy flow. A water wave is a transverse wave. An object in the water moves up and down as the wave passes, the energy passes through and the object remains stationary. When you float in the ocean you will notice that you move up and down as the wave passes under you.

A longitudinal wave moves to and fro in the direction of energy flow. A longitudinal wave is sometimes called a pressure wave. A sound vibration is a longitudinal wave of pressure changes.

WEBLINK
Longitudinal and transverse waves

ACTIVITY SHEET
Slinky waves

VIDEO
Types of waves

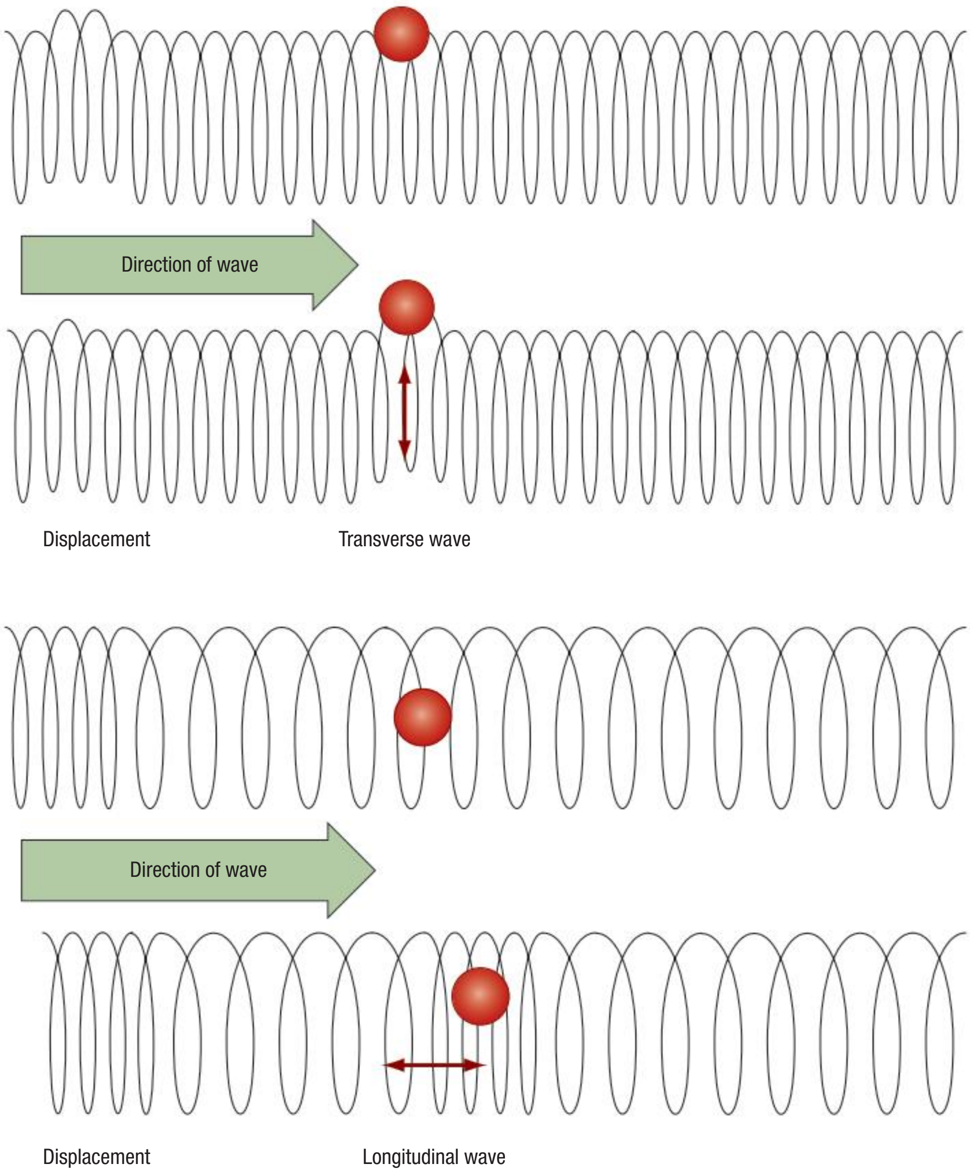

Figure 7.11 Slinky with transverse and longitudinal travelling wave

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EXPERIMENT 7.1

Student investigation: Making a soundproof box

WORKSPACE
Student investigation: Making a soundproof box

This is a small group task that can be done as a class competition.

Aim

To create a soundproof shoe box that best absorbs the sound from a mobile phone on low volume ring

Suggested materials

A shoe box, glue, tape, styrofoam, high-density foam, egg cartons, cotton wool, corkboard, newspaper, cool gel packs, ziploc bags with shaving foam inside, mobile phone or other with adjustable alarm or ring. (You will need to **list** what you use.)

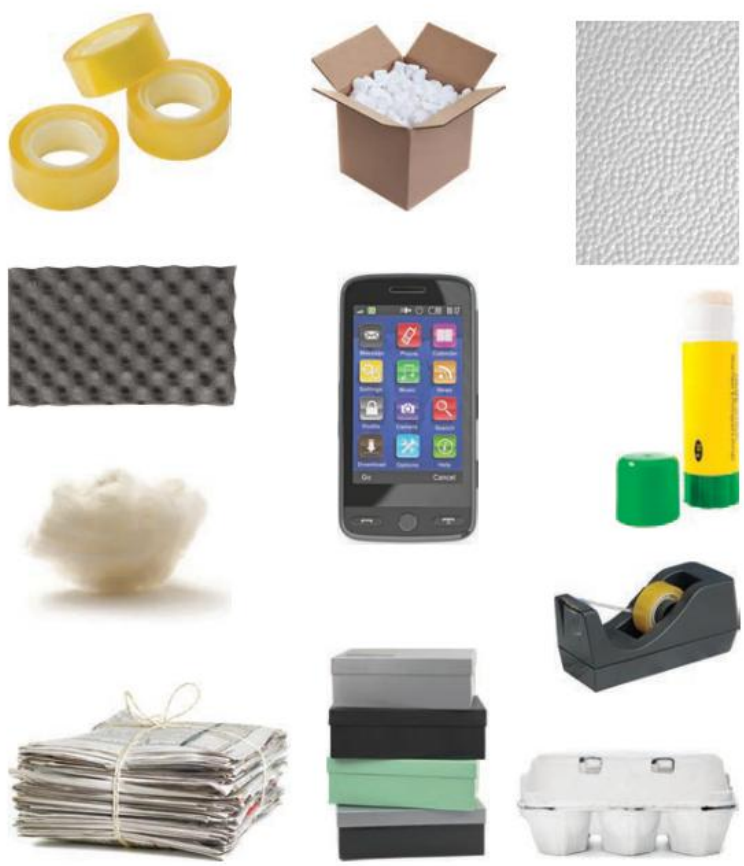

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Figure 7.12 Materials you can use for your soundproof box

Method

In a team of three to four, and using only the materials supplied, design the most soundproof box you can in 30 minutes. (You will need to describe your final design.)

Test your design with a mobile phone set to ring three clicks up from the lowest volume.

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EXPERIMENT 7.1

Your teacher will judge all final boxes. By walking slowly towards the box and listening, your teacher will measure the distance when they can first hear the phone. The team with the shortest distance wins.

Results

Record the distance for your team's box. **Compare** this result with the distances for the other teams and state how the distance relates to how soundproof a box is.

Discussion

Write a discussion that relates the materials used to the level of soundproofing your team achieved. Be sure to outline how each medium you used would have affected the sound waves emitted by the phone, and suggest the types of media you could use to improve your design. Research where soundproofing is used and relate your findings to real world applications, to enhance your discussion.

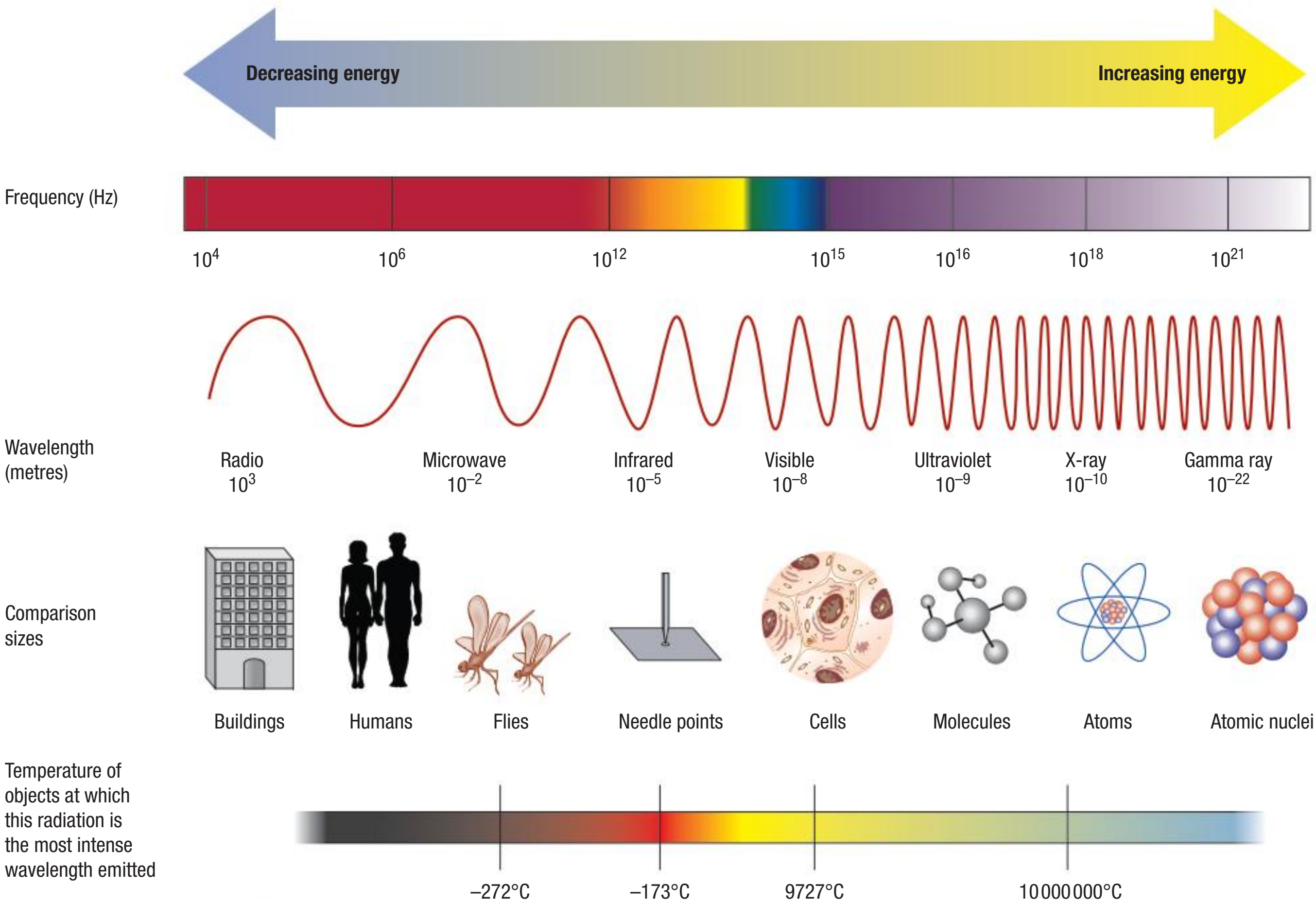

Figure 7.13 The electromagnetic spectrum

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Electromagnetic radiation

Electromagnetic radiation (EMR) is a form of energy that moves as waves as it travels through space. It ranges from long-wave radiation (low energy) to short-wave radiation (high energy).

The spectrum of radiation is known as the **electromagnetic spectrum** (Figure 7.13). The waves are classified according to their frequency and wavelength. You can see that radio waves and microwaves have a low frequency and a long wavelength whereas gamma rays have a high frequency and a short wavelength.

Electromagnetic radiation spreads out from its source in straight lines in all directions. Light, for example, travels in straight lines from its source.

electromagnetic radiation (EMR)
energy that travels as waves and moves at the speed of light

electromagnetic spectrum
the range of electromagnetic radiation classified according to frequency and wavelength

Uses of electromagnetic radiation

X-rays

X-ray radiation is short-wavelength radiation of high energy. X-rays travel through different materials differently. This property of X-rays makes them useful for medical analysis. X-rays pass through body tissue but not through dense objects such as bone. Hence, they can be used to take images of bones to diagnose for breaks, dislocations and other injuries.

Microwaves

Microwave radiation has a longer wavelength and lower energy than X-rays, making microwaves more like radio waves. Microwaves can penetrate food, where their energy is absorbed by the fats, sugars and water and conducted through the rest of the food as heat. This property of microwave radiation makes it ideal for cooking and reheating food.

VIDEO
Biomedical beamline at the Australian Synchrotron

Shutterstock.com/John Keith

Figure 7.14
X-rays are used to diagnose breaks such as this broken finger.

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WEBLINK
Blabberize

ACTIVITY 7.9

Careers with waves

1 Brainstorm a **list** of careers that involve wave energy in some form. *Hint:* Consider communications or engineering.

2 Select one of the careers. Create a blabber and record information about this career as if you were in this field of work. **Discuss** your education, places you work, hazards involved in your type of work and safety precautions you take. Upload the link to your blabber in your blog.

Microwave radiation is used in radar by air traffic controllers to detect remote objects, such as planes, and by forecasters at the weather bureau to detect rain.

Shutterstock.com/Doug Baines

Figure 7.15 Microwaves are used in speed detection radars.

Radio waves

Radio waves have the longest wavelengths (they can be longer than a football oval) and lowest energy. They travel at the speed of light (3×10^8 m/s or 300 000 km/s), as does all electromagnetic radiation. Their existence was first proposed by James Clerk Maxwell in 1865. In 1887 Heinrich Hertz demonstrated that they actually existed, and seven years later they were first used for communication.

VIDEO
Microwaves and radio waves

ACTIVITY SHEET
Science careers – optometrist or ophthalmologist

ACTIVITY SHEET
The function of the lens

Visible light

Electromagnetic radiation with wavelengths in the visible light range can be detected by the human eye. Light waves can be absorbed or reflected by objects. It is these reflected light waves that are detected by our eyes. For example, in Figure 7.16 the light waves in the red part of the spectrum are reflected off the car, and all the other visible light waves are absorbed. Hence we see the car as red. Later, we will discuss how heat energy is absorbed or reflected.

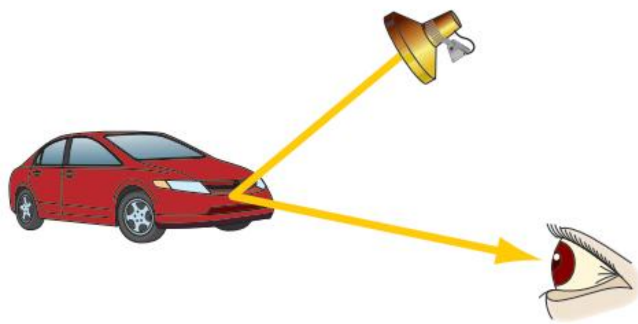

Figure 7.16 Our eyes detect light waves that have been reflected off an object.

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WOW! Do you see what I see?

There is more to the world than meets the eye – the human eye, that is. Just as we can't hear all sound frequencies, we cannot see beyond the 'visible' region of the electromagnetic spectrum, about 390–700 nm. Most insects and birds can see beyond this, into the part of the spectrum containing ultraviolet wavelengths, where patterns unseen by the human eye (e.g. on flowers and feathers) can be detected. Butterflies have a much wider range than most other insects. They can see down into the ultraviolet wavelengths as well as up into the infrared wavelengths, where there is a world of butterfly markings invisible to us!

Below is a flower as seen by the human eye (left) and a simulated view of the same flower showing how it is seen beyond the human spectrum (right).

Science Photo Library/Bjorn Rorslett

Science Photo Library/Bjorn Rorslett

QUESTIONS 7.3

What have you learnt?

Remembering

1 **Describe** what 'electromagnetic radiation' is.

2 Place these examples in order of decreasing wavelengths (i.e. start with long waves): red light, ultraviolet radiation, radio waves, X-ray, microwaves, blue light, green light.

Understanding

3 **Describe** how electromagnetic radiation is classified using the electromagnetic spectrum.

4 **Explain** how wavelength is related to the energy of an electromagnetic wave.

5 **List** ways in which we use the different properties of radiation in the electromagnetic spectrum, especially for communication.

WORKSPACE
What have you learnt? 7.3

ISBN 9780170231503

QUESTIONS 7.3

Applying

6 Draw a transverse wave that has a:
   a short wavelength and low amplitude
   b long wavelength and high amplitude
   c long wavelength and low amplitude.

7 The speed of sound is 340 m/s.
   a **Explain** why during a thunderstorm you see the lightning before you hear the thunder.
   b If the thunder is heard 7 seconds after the lightning is seen, **calculate** the distance to the lightning strike.
   c **Calculate** how many times faster light is than sound.

Analysing

8 Use a double bubble map to **compare** and **contrast** period and wavelength.

Creating

9 Using Quizlet, create a set of flashcards to help you remember what you have learnt so far. Share your quizlet with a friend and then write about your friend's quizlet on your blog.

10 Go back to your mind map and add your understanding of waves, electromagnetic radiation and the electromagnetic spectrum to it.

WEBLINK
Quizlet

7.4 Modern communication using waves

In our modern world, it is essential that we have fast and reliable forms of communication. We can no longer rely on carrier pigeons or marathon runners to carry messages from one person to the next. We expect instant messaging and communication technologies. We have a vast array to choose from, and the technology we use will depend on the message we want to send and the recipient of the message.

Shutterstock.com/Monkey Business Images

Figure 7.17 SMS allows instant communication.

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ACTIVITY 7.10

Modern communication technologies

WORKSPACE
Modern communication technologies

1 Rearrange the following modes of communication in order from fastest to slowest.
- Telephone (fixed line)
- Twitter
- Facebook
- Mobile phone
- Fax
- Email
- SMS
- Satellite phone
- Post-it note

2 **Identify** some of the hardware requirements for each of these methods of communication.

3 **Outline** the assumptions that are made about each method when getting a message from the sender to the recipient.

4 **Describe** the problems that could occur with each method of communication.

5 Complete the following table to **show** the method of communication (from the list in Question **1**) you would use if you wanted to get a message to someone in the location listed.

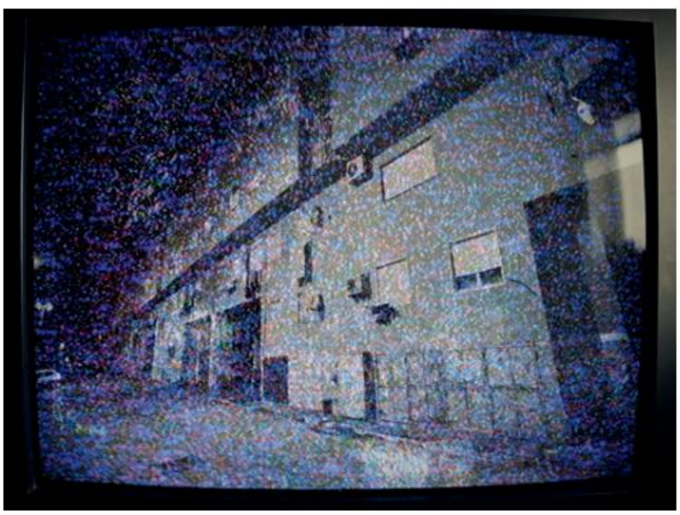
The next room	The next suburb	The next city	The next state	Another country

Communication and energy

Modern communication systems use different wavelengths of the electromagnetic spectrum to transfer messages. Each system uses an electronic process of coding the signal to construct a message. Messages can be sent by either a continuous signal (**analogue**) or discrete packages of data (**digital**).

analogue
continuous signal

digital
discrete packages of data



istockphotos.com/peeterv

Figure 7.18
Confetti on an analogue television

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Analogue signals

Communication relied on analogue signals until 2009, when analogue signals were phased out and replaced by digital signals.

One of the consequences of analogue television was the confetti (or fuzzy) distortion displayed on the screen. Confetti is the random signals displayed as coloured dots anywhere on the screen and not part of the message. Bad weather, sunspots, passing aircraft and trucks, even someone walking across the room, could all contribute to a poor analogue picture in weak signal areas. We could usually detect the program signal through the confetti and still make sense of the picture.

base station

an antenna at the centre of a mobile phone network

Mobile phones

Mobile phones were first introduced for general use in about 1973 when a Motorola executive made the first mobile phone call using a prototype model. Early models were big and bulky, weighing more than half a kilogram. They were dubbed 'bricks', offered voice-only services and cost more than $4000 each. Analogue mobile phones used electromagnetic radiation in the radio wave range.

A 1G (first generation) mobile phone network was launched in Japan in 1979, and 23 **base stations** were built to provide the entire population of Tokyo with coverage. The 1G networks quickly spread to other countries such as the United Kingdom, Canada and the United States.

Figure 7.19 An analogue mobile phone from around 1983 and a modern smart phone

Digital signals

During the 1990s, 2G (second generation) networks emerged that used digital transmission instead of analogue.

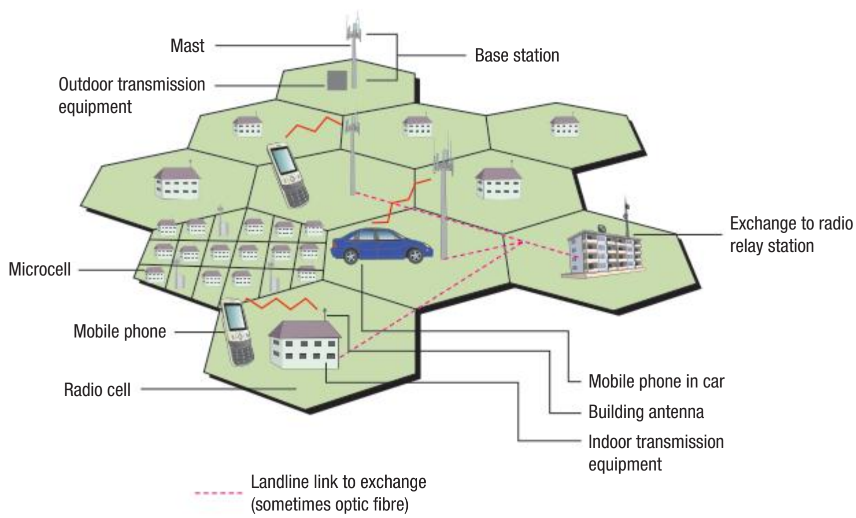

Figure 7.20 A cellular network

ACTIVITY SHEET
From old to new

cell

a separate area of land serviced by a base station

Digital networks are microwave networks that cover an area of land called a **cell**. Cells are smaller in cities than in rural areas. Each cell has a base station that receives and transmits large numbers of messages at a time. As you move away from one cell, you connect to the

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base station in the next cell. This maintains continuous coverage. However, loss of signal can occur if the signal is blocked by hills or buildings that microwaves cannot penetrate or if it is a long way to the base station. These areas are called **dead zones**. Each cell is connected to other cells by fibre optic cable landlines.

dead zone

an area where microwave radiation cannot penetrate so no mobile phone reception is available

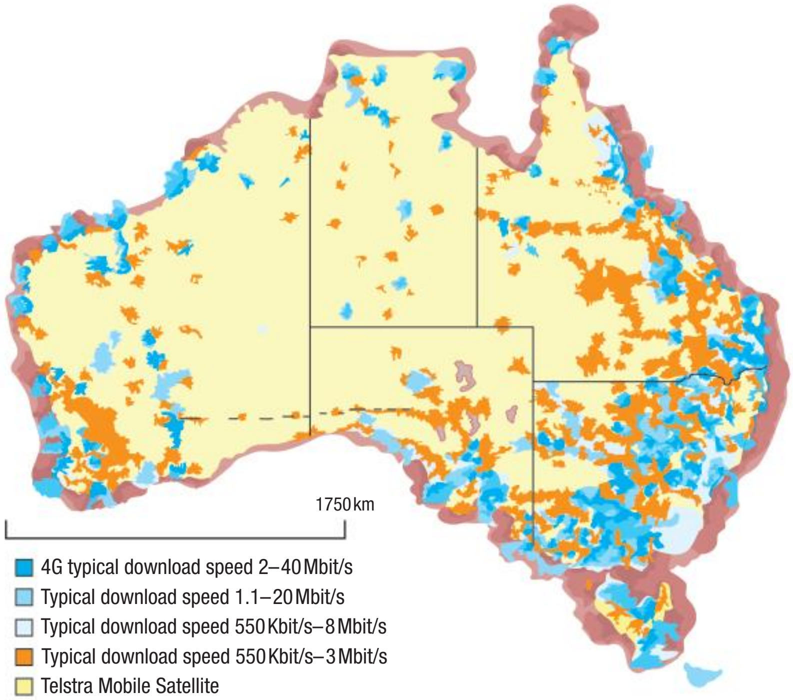

Figure 7.21 Mobile phone coverage across Australia. Coverage and performance depend on where you are and the device you are using, and can be improved by adding an external antenna.

ACTIVITY 7.11

Mobile phone coverage

WORKSPACE
Mobile phone coverage

Signal strength on your mobile phone can be seen as a set of five bars usually in the top right- or left-hand corner of the screen (Figure 7.22). More coloured bars means greater signal strength.
Each mobile phone system calculates the bars differently. The signals cannot be compared easily.

Method

Part A: The location

1 Choose a location in which you want to test signal strength. This could be where you live or where your school is situated.

2 Download a Google satellite map for your chosen area or take a screen image. On this map locate the mobile phone towers.

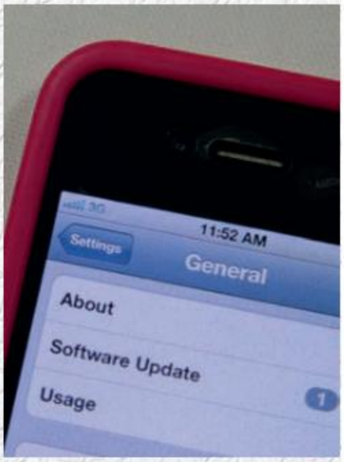

Figure 7.22 Signal strength on your mobile phone is indicated by a set of five bars.

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WEBLINK
Key facts

ACTIVITY SHEET
Investigation: Decoding the TV controller

ACTIVITY 7.11

3 **Identify** any local geographic features, such as hills, that would affect the mobile phone coverage.

Part B: The coverage

4 Record the signal strength observed on your mobile phone in your chosen location. Record the signal strengths as you move around your location. **Show** this on your map.

5 Are there any dead spots (also known as 'not-spots') in your area?

6 Use the weblink to find five interesting key facts about Australians' use of information and communications technology (ICT).

Radio communication

Commercial AM radio was first transmitted in Sydney in 1923 and the simple AM signal was quickly adopted across all major Australian population centres. The FM signal was first broadcast in 1980 and digital radio was introduced in 2009 in Sydney, Melbourne, Adelaide, Perth and Brisbane. Currently, only the major cities are provided with digital radio due to the high costs of re-equipping both broadcasters and listeners with new digital equipment. The digital radio signal is of high quality but has a short range as it travels in direct straight lines from the transmitter. A digital radio signal does not vary in quality with changes in distance or weather conditions.

AM radio has the greatest range but suffers the most from interference from other radio sources. Any electrical spark will create a radio signal, which will interfere with the quality of the message and introduce noise.

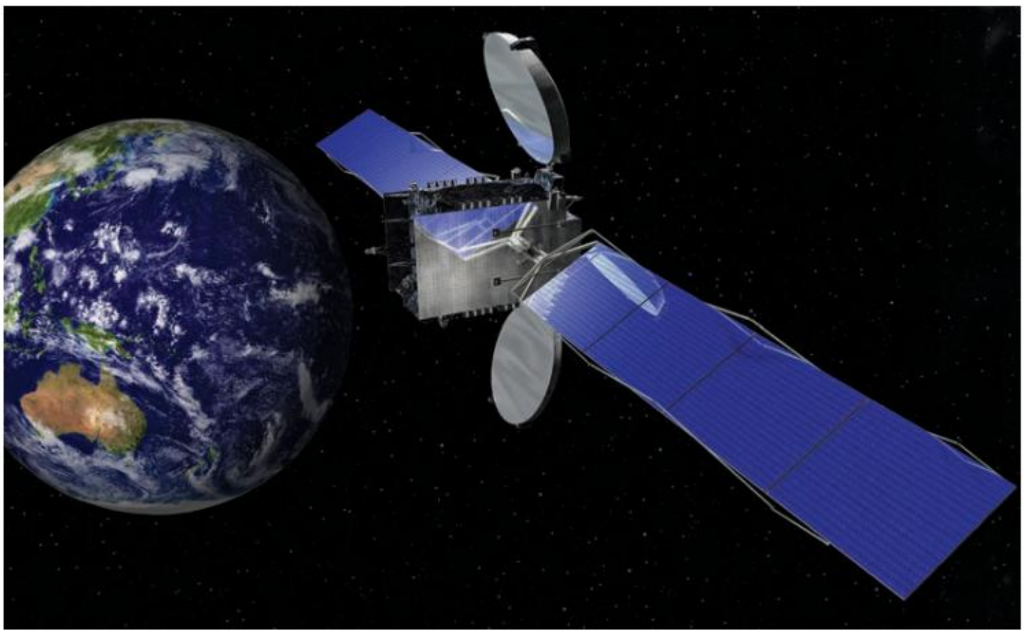

Image courtesy of Optus

Figure 7.23 AUSSAT satellites provide television signals to remote locations in Australia.

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Regional television

There are several major television broadcasters common to the major capital cities in Australia. However, away from the capital cities, regional stations have been allocated a restricted area to provide a television signal. The AUSSAT satellites are used to provide signals to many remote locations. A special satellite dish is required to receive the AUSSAT signal (Figure 7.23).

ACTIVITY 7.12

Digital radio reception

Find out if there is a correlation (relationship) between the quality of digital radio reception and the geography of the landscape.

1 Go to the weblink and find the satellite map for your capital city.
2 **Identify** the conditions that affect the digital radio coverage in your capital city.
3 Determine the location of the transmitter.
4 **Explain** why there is such a small area in green.
5 What is significant about the green area?
6 Switch to the 'terrain' view.
7 **Explain** how the signal coverage correlates with terrain coverage.

WORKSPACE
Digital radio reception

WEBLINK
Coverage maps

ACTIVITY 7.13

Regional TV coverage

1 Go to the weblink.
2 **Describe** the TV coverage map.
3 Click on the area where you live.
4 **Identify** who delivers the TV signal in the area where you live.
5 What happens to the signal in Western Australia?

WORKSPACE
Regional TV coverage

WEBLINK
Regional TV coverage

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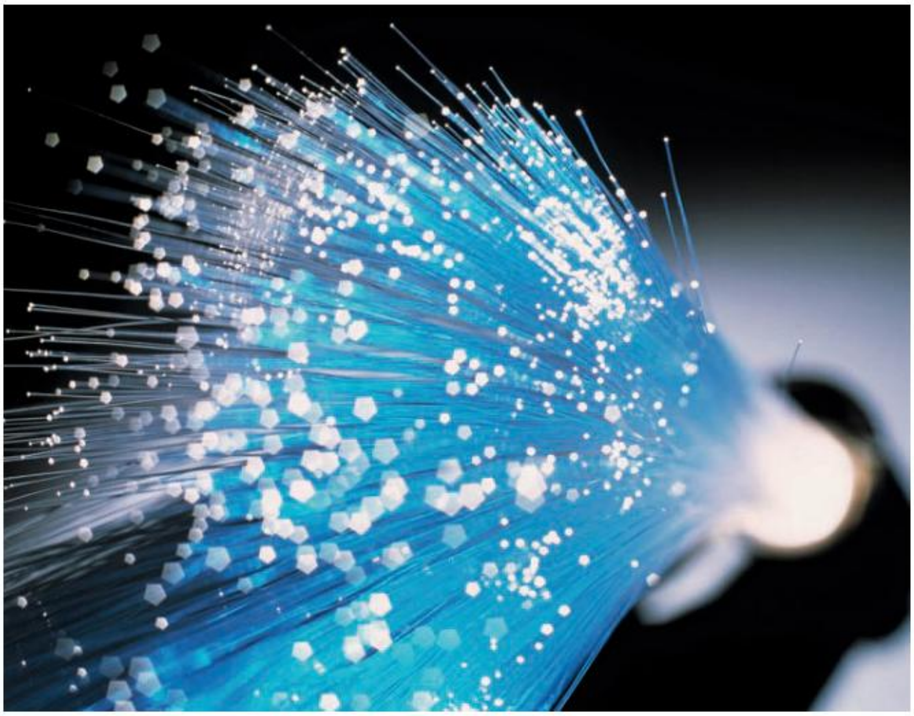
National Broadband Network

The National Broadband Network (NBN) is a major construction project that aims to connect every major population centre (93% of the population) directly to an optical fibre network. The optical fibre can transfer huge amounts of digital data. Optical fibre is made from a type of glass and the signal is a laser light that is switched on and off very rapidly. The signal travels at the speed of light, and does not need as many repeater signal boosts as the copper electricity cable that it will replace. The NBN with optical fibre will be able to consistently offer high speed data access to all connected users anywhere and at any time of day.

The limitations of the current copper network restrict high-speed connections to a distance of up to 2 km from the nearest switching exchange. The copper network suffers from overloading during peak times, when too many users are connected at the same time.



Getty Images/Science Photo Library

Figure 7.24 Optical fibres can transfer huge amounts of data.

WORKSPACE
Your NBN opinion

ACTIVITY 7.14

Your NBN opinion

Write a persuasive factual essay to sway the public to your opinion on whether or not to implement and fund the NBN in Australia.

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ACTIVITY 7.15

NBN coverage

1 Go to the weblink.

2 Give reasons for the locations of the areas of coverage.

3 Click on the dot closest to where you live.

4 When is the NBN due to be rolled out in your area?

WORKSPACE
NBN coverage

WEBLINK
Coverage and timing of rollout across Australia

QUESTIONS 7.4

What have you learnt?

WORKSPACE
What have you learnt? 7.4

Understanding

1 **Compare** and **contrast** the speed and distance a signal can travel in optical fibre and copper wire.

2 **Explain** why a digital signal is able to deliver a better quality signal than an analogue signal.

3 **Explain** how a cellular network is set up.

Applying

4 Look at the map of mobile phone coverage (Figure 7.21, page 251). **Identify** any obvious causes for the variation in coverage in each of the Australian states/territories.

5 **Outline** how waves transfer energy in:
   a sound waves
   b radio waves
   c mobile phone communication.

Evaluating

6 Brainstorm a **list** of reasons why countries might take a long time to adopt digital technologies.

7 A number of communication technologies have been described. State which one you think is the greatest achievement. **Justify** your choice.

Creating

8 Go to your chapter summary or flashcards and add in your new understandings of modern communication technologies.

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VIDEO
How the ear hears sounds

WEBLINK
How the ear works

7.5 Transfer of sound energy through the ear

Many of the communication methods discussed so far depend on the receiver being able to see (light waves) or hear (sound waves) in order to understand the message. As we have already discussed, sound waves pass through the air as mechanical waves. Particles of air move from the sound source as a wave. They pass energy on to surrounding particles until the wave reaches and enters our ears.

Shutterstock.com/Jason and Bonnie Grower

Figure 7.25 Particles of air are made to vibrate and travel towards your ears, which sometimes need protection from loud noises.

Structure of the ear

The ear is ideally structured to receive, transfer and transform sound waves. Table 7.2 summarises the main structures in the ear.

Sound waves enter the ear as moving air particles. Because they are moving, they have mechanical energy. This energy is transferred to the eardrum, which starts to vibrate. As the eardrum vibrates, the small bone or malleus (or hammer) on the other side of the eardrum receives the mechanical energy and starts to move. The sound energy has been transformed into kinetic energy. This causes the attached incus (or anvil) to move, which in turn causes the stapes (or stirrup) to move. The pressure of the stirrup pushing on the oval window transfers the kinetic energy to the fluid in the cochlea. This causes the fluid to flow, moving the hair cells. It is here that the kinetic energy is transformed into electrical energy as the hair cells start firing. This electrical energy travels along the auditory nerve to the brain, where it is interpreted as sound.

Along this entire pathway, the sound wave passes from air to solid eardrum and ossicles (ear bones) to fluid in the cochlea before being transformed into electrical energy.

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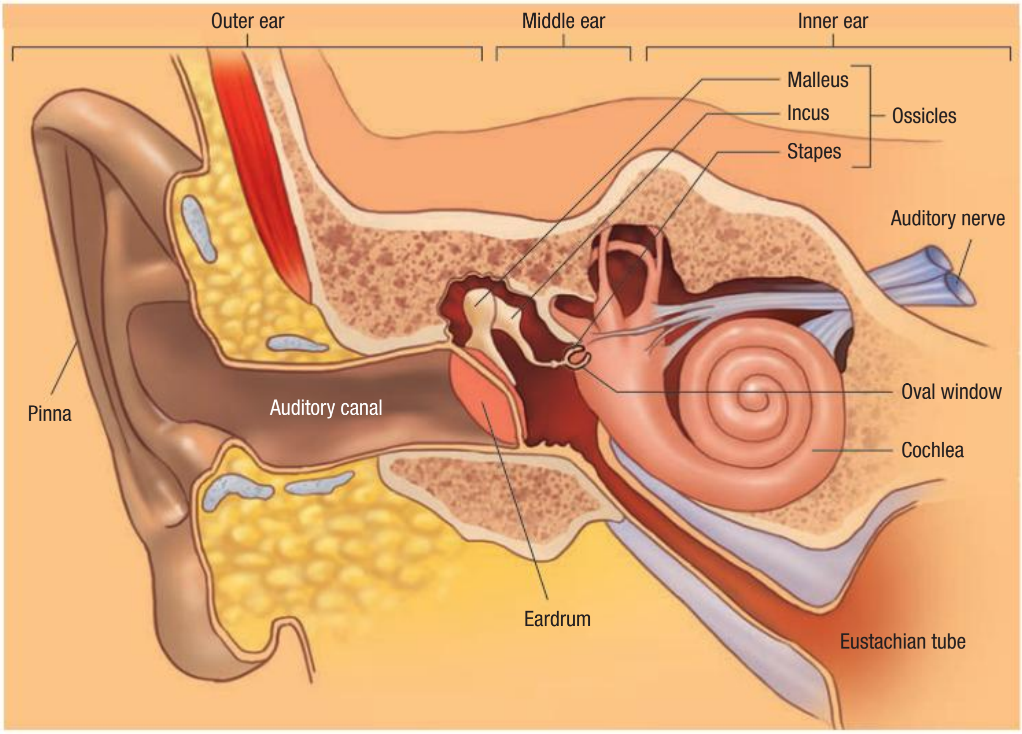

Figure 7.26 The structure of the human ear

Table 7.2 The main parts of the ear

Part of the ear		Description
Outer ear	Pinna	Acts like a funnel to direct sound waves into the auditory canal
	Auditory canal	A canal that leads sound waves to the eardrum
Middle ear	Eardrum	A thin membrane that vibrates when struck by sound waves
	Ossicles	Three small connected bones that amplify and transfer the vibration from the eardrum to the fluid in the cochlea
	Eustachian tube	A tube connected to the throat that helps equalise the pressure in the middle ear to the outside
Inner ear	Oval window	A small oval section of the cochlea where the ossicles connect to the cochlea
	Cochlea	A fluid-filled snail-shell-like structure. The ossicles transfer the vibration to the fluid, which begins to flow and moves hair cells. The hair cells start firing and send electrical signals to the auditory nerve.
	Auditory nerve	The nerve that transfers the electrical signals from the hair cells to the brain for decoding

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Hearing loss

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Figure 7.27 It is important to protect against hearing loss when working in noisy environments.

Deafness occurs when part or all of the ability to hear is lost. The most common cause of deafness is exposure to continuous loud noises, which damages the hair cells in the cochlea. This means the vibration of sound cannot be transferred from the cochlear to the auditory nerve. Deafness acquired through work has been a large problem in the industrialised era. Many people now suffer the effects of having working alongside loud machinery. In 1995, 22% of all workplace injuries were related to complete or partial deafness. Up to 85% of all deaf people lost their hearing as a result of work-related conditions. Work-related hearing loss continues to be a critical workplace safety and health issue, but its incidence is decreasing.

It is only in recent years that a damaged cochlea can be replaced by a cochlear implant. This is an electronic device that does the work of damaged parts of the inner ear (cochlea) to provide sound signals to the brain.

WEBLINK
Cochlear implant

ACTIVITY SHEET
Workplace regulations

WOW!

What did that dolphin say?

Humans can hear sounds in the frequency range of 20 to 20 000 Hz. Dolphins have a much bigger range and can hear frequencies from 0.5 to 200 000 Hz.

EXPERIMENT 7.2

How noisy is your school?

Aim

To determine the average noise level at your school

Materials

Sound level meter (decibel meter)

Method

1 With a partner, measure the sound level, in decibels, of six to ten common places or situations. Examples include talking to one person, listening to a group of friends, in the Science classroom, the library, the PE class outside, or in the hallway at class change.

2 Take three separate readings over one minute and record the average.

Results

1 Record your results in Table 7.3. Classify whether the level is safe or unsafe – anything over 85 dB is considered to be 'unsafe'. Normal conversation level is about 60 dB.

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EXPERIMENT 7.2

Table 7.3
Noise levels around school

Place or situation	Sound level (dB)	Safe or unsafe?	Minutes/day

2 Estimate how many minutes or hours you spend under each of the conditions you measured. Calculate the amount of school time during which you are exposed to unsafe noise levels.

Discussion

3 Identify the difficulties encountered in conducting this experiment. Propose three ways in which you could improve it.

4 Your library is likely to be a quieter place than your locker area. Compare the design of these areas and discuss how you think the materials, shapes and spaces might amplify or absorb sound waves.

5 Propose five ways to decrease noise levels around the school.

ACTIVITY 7.16

Hearing loss in teens

1 Go to the weblink and read the article.

2 **Describe** why teenagers are at risk of deafness.

3 **Outline** what tinnitus is and **identify** how many 18–24 year olds suffer from it.

4 **Describe** the precautions you can take now to protect your hearing.

5 Determine the percentage of Australians who have their headphones or headsets turned up too loud.

6 Determine whether damaged hearing can recover without intervention.

WORKSPACE
Hearing loss in teens

WEBLINK
Hearing loss in teens

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WORKSPACE
What have you learnt? 7.5

QUESTIONS 7.5

What have you learnt?

Remembering

1 **Describe** how sound energy moves from the sound source to our ears.

2 **Label** the diagram of the human ear in your workspace.

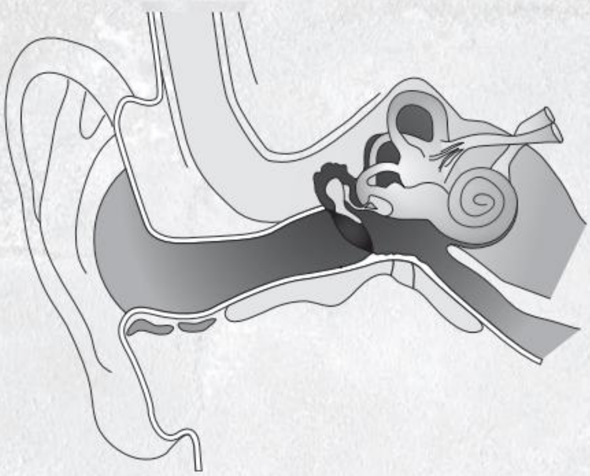

Figure 7.28 The human ear

Understanding

3 **Identify** the most common cause of deafness in Australia.

Applying

4 During an accident your malleus was broken and no longer functioned. **Outline** the consequences for the functioning of your ear.

Creating

5 Draw a flowchart to **summarise** how mechanical energy is passed through the structures of the ear.

6 Go back to your chapter summary or flashcards and add in your understandings of how the ear is involved in communication and the energy transfers involved.

7.6 Energy and heat transfer

When particles vibrate they pass on energy to the next particle. When microwave radiation meets a solid material, the transferred energy causes the particles to vibrate more rapidly. This causes the solid material to increase in temperature. Mobile phones use microwave energy. If you hold the antenna of an active mobile telephone to your head for several hours, there will be localised heating of the particles in your head as they vibrate more quickly. The medical evidence for biological interference with cell development is as yet inconclusive. The effect, if any, is so small that very few

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people out of millions are immediately affected. However, young adults and children are advised to minimise their time on a mobile handset, and all users should use a hands-free cable, choose a device that does not rest against the head, or keep the antenna at least 2 cm from the head.

The particle model of matter

The particle model of matter describes the three states of matter. The particles in the solid state are tightly packed and are only able to vibrate. The particles in the liquid state are less closely packed and are able to move freely over each other. The particles in the gas state are far apart and can move freely.

The idea of heat energy is incorporated into this particle model as the amount of vibration or movement of the particles. If heat energy is supplied to a substance, then the

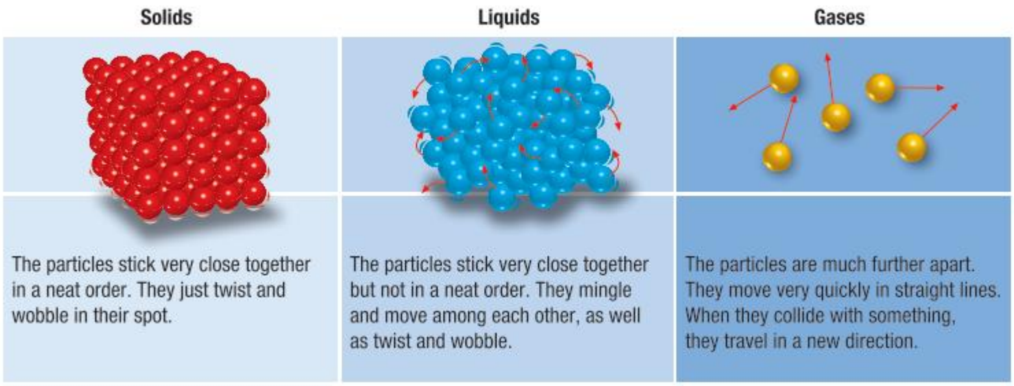

Figure 7.29 The three states of matter – solid, liquid and gas

ACTIVITY 7.17

What can you remember?

Working in groups, develop a role-play or create an animation that **demonstrates** your understanding of how particles change state. Upload your creation to the class wiki.

particles in the substance move or vibrate faster and more vigorously. This also explains the change from one state to another. Increased vibration breaks the bonds and overcomes the attraction between the particles so they move further apart. This allows a solid to change into a liquid (melting) and a liquid to change into a gas (evaporation). If energy is removed from the substance, the particles move more slowly and they move closer together. The gas will change into a liquid (condense) and the liquid will change into a solid (freeze).

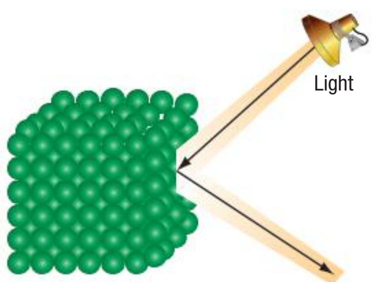

Figure 7.30 When light hits a particle, radiation can be reflected away.

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If electromagnetic radiation comes into contact with a particle, the radiation can be reflected away or absorbed and transformed into heat energy. When light from a lamp meets a particle, the radiation can be reflected, and the substance looks shiny, or the radiation can be absorbed and the temperature of the substance increases.

conduction
the transfer of energy through a solid object

conductor
a substance through which heat travels easily

insulator
a substance through which heat travels poorly

Conduction

When a solid is exposed to electromagnetic radiation, the solid's surface gains energy as the temperature increases and the particles vibrate faster. Each particle in turn 'bumps' or transfers energy to its nearest particle neighbour. These nearby particles increase their vibration, and this is detected as an increase in temperature. This is known as **conduction**.

When heat energy travels quickly through a substance, the substance is described as a good **conductor** of heat energy. When energy travels slowly through a substance, it is described as a poor conductor of heat energy or an **insulator**.

a

Shutterstock.com/TDHster

b

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Figure 7.31 **a** Metal is a good conductor of heat. **b** Wool is a good insulator.

convection
transfer of energy through a gas or fluid

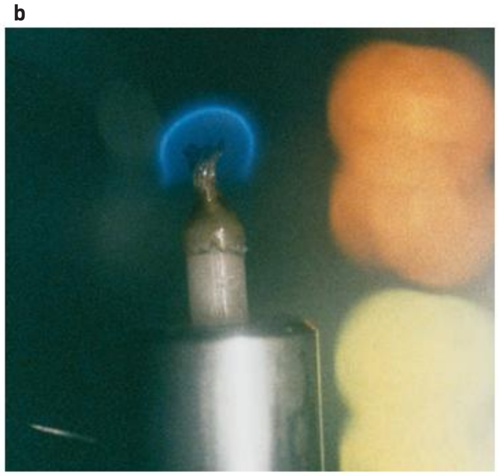
Convection

Heat energy can also be transferred by **convection**. Heated fluid (liquid or gas) expands and becomes less dense. The more dense material is pulled down by gravity and forces the hot fluid upwards. A candle in space is a good example. On Earth, the flame rises into its familiar shape because the hot gases are lighter than the surrounding cool air (Figure 7.32a). But in space, where the effects of gravity are minimal, the hot gas does not rise above the cool air and so the flame is a small sphere (Figure 7.32b).

a

Shutterstock.com/LeventeGyori

b



Getty Images

Figure 7.32 **a** A candle on Earth **b** A candle on the International Space Station

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Heat exchangers

Heat exchangers are an important part of every mechanical system (Figure 7.33). They either transfer excess heat energy away from the system or distribute heat energy more evenly within a system.

ACTIVITY SHEET
Heat exchangers

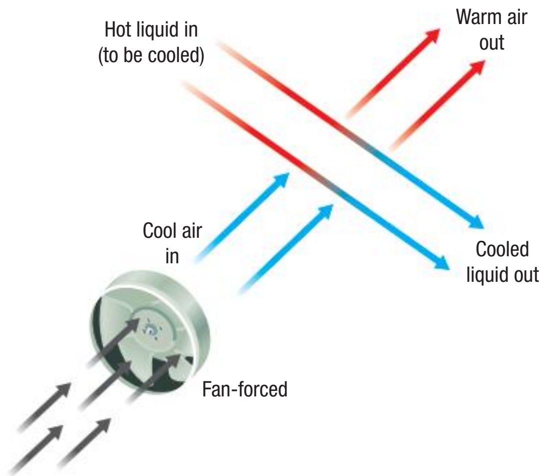

Figure 7.33 How a heat exchanger works

Heat exchangers are found in:

- the back of refrigerators
- car radiators
- reverse-cycle air conditioners
- evaporative air conditioners
- cooling gaps above LCDs and plasma TVs
- the black metal grills around wood fire burners
- heat sinks in notebook computers, usually near the base of the computer
- heat vents behind a microwave oven
- exhaust fan outlets of vacuum cleaners
- cooling towers.

Vertical systems use convection to remove the hot air. Horizontal systems use a fan to force cool air into the heat exchanger.

Alamy/DWImages

Figure 7.34 A car radiator is a type of heat exchanger.

QUESTIONS 7.6

What have you learnt?

Remembering

1 State two examples of a heat exchanger.

Understanding

2 **Explain** why radiation can travel through space but convection and conduction cannot occur.

WORKSPACE
What have you learnt? 7.6

ISBN 9780170231503

QUESTIONS 7.6

3 **Explain** why we place a lid on a saucepan being heated on the stovetop.

4 Write three possible questions for each of the following answers.
   a Convection
   b Conduction
   c Radiation

Applying

5 **Explain** why candle flames have a pointy shape on Earth.

6 **Apply** the particle model to explain why wool does not conduct heat as well as a metal rod.

Analysing

7 Use either a double bubble map or a Venn diagram to **compare** and **contrast** convection and conduction.

8 Complete a five whys analysis for this question: 'Why do we need to understand convection, conduction and radiation?'

Evaluating

9 **Describe** how you would demonstrate energy transfer in solids, liquids and gases to a Year 7 student.

10 Space satellites are sometimes covered in a very thin, and very expensive, gold foil. Gold is a very good conductor of heat.
   a **Explain** why there is a problem with heat and cold when space satellites are in orbit.
   b **Describe** the purpose of the gold foil.

Creating

11 Go back to your chapter summary or flashcards and add your new understanding of energy used in communication.

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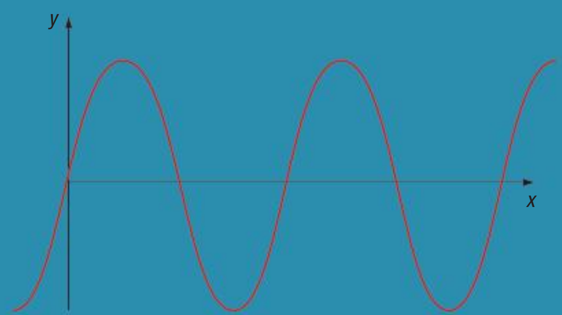
Chapter review

Remembering

1 Label the following wave diagram in your workspace with amplitude, wavelength, crest, trough and direction of motion.



2 **Recount** the pathway of sound waves through the human ear by **listing**, in order, the structures through which they pass.

3 **Identify** the transformation of sound energy as it moves through the ear.

4 **Identify** the parts of the human ear that can be damaged by continuous loud sounds.

Understanding

5 **Explain** how a microwave oven heats food.

6 **Explain** why your nose gets sunburnt when you wear sunglasses.

7 **Describe** how the structure of your ears relates to the function of communicating.

Applying

8 The standard treatment for a burn is to place the burnt area under cold running water for 20 minutes. **Explain** why such a long time is recommended and why cold water should be used. Would ice do the same thing? Research to find why ice introduces new problems if it is held on skin for 20 minutes.

9 **Explain** why microwave ovens have a rotating turntable. Use the words *wave, energy* and *transfer* in your answer.

10 **Explain** why very dry food is unsuitable for re-heating in a microwave oven and why a little water is added to rice before it is re-heated.

11 When a person is rescued, they are often wrapped in a foil-covered blanket. **Explain** why this is done.

Figure 7.35 Wave diagram

WORKSPACE
Chapter 7 review

ACTIVITY SHEET
Chapter 7 checklist

REVIEW QUIZ
Chapter 7

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Analysing

12 **Describe** the flow of heat energy that occurs when you grab the hot metal handle of a pot on the stovetop. **Describe** the flow of heat energy as you treat the burnt area.

13 Infrared cameras are used by fire fighters looking for bushfire hotspots, and by emergency rescue workers looking for lost bushwalkers or skiers. **Describe** how these cameras work. **Explain** why these cameras work best in winter and at night when looking for lost people.

14 **Explain** how noise-cancelling earphones work. You may need to conduct research to answer this. **Explain** how this is different from sound-proofing in a classroom or theatre.

15 **Describe** how you can cool off quickly in summer. **Explain** the science behind your choice.

16 Using Figure 7.13 as a guide, **identify** the parts of the electromagnetic spectrum that are used for communication purposes, and **describe** the type of communication they are used for.

Evaluating

17 **Evaluate** the importance of using the electromagnetic spectrum for communication in our society today.

18 MP3 players (including iPods and iPads) are sold with health warnings in many European countries. In Australia, the volume control limit is automatically off. **Discuss** whether you think that Australia should have hearing protection rules for MP3 players.

Creating

19 **Construct** a safety message for teenagers who use bud-style earphones.

20 Create an electronic crossword for which the parts of the eye and ear are the answers and the functions are the clues. Upload your crossword to the class wiki so someone else can complete it.

Reflecting

21 **Identify** the three most interesting things that you have learnt from this chapter. **Describe** how they will influence the way you live your life or view the world.

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8

Global patterns

How has Earth changed?

The ground under our feet feels solid, but our planet is constantly changing. Over the last 4.6 billion years, mountain ranges, valleys, continents and islands have all been formed and changed. Glaciers melt, volcanoes erupt and earthquakes open up the ground. How do these dramatic events affect the face of Earth and our life on it?

ACTIVITY SHEET
CAT with rubric:
Continental drift research

Earth and space – Stage 5

Key knowledge

- Earth is constantly changing due to forces and actions above and below the crust.
- The internal structure of Earth influences life on Earth.
- The age of the Earth is much greater than time scales humans normally experience.
- The theory of plate tectonics explains global events.
- Advances in scientific understanding have confirmed much of the evidence for the theory of plate tectonics.
- Natural disasters are mostly caused by the dynamic nature of Earth.
- Technology is being used to warn people of potential natural disasters.

CULMINATING ASSESSMENT TASK

Continental drift research

Your task is to **investigate** and **summarise** evidence for the theory of continental drift. Include the following pieces of evidence:

- The continental jigsaw
- Fossils of plants and animals
- Evidence of past glaciers in what are now very hot environments
- Coal in Antarctica
- Magnetic striping

Evaluate how and why each piece of evidence supports the theory of continental drift. **Explain** the evidence clearly.

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What do you already know about our changing planet?

In a large group or as a class, play the One Minute Game.

Rules

One student at a time stands up and tries to speak for one minute about one of the topics in the list below. They cannot say 'um' or 'uh' or repeat themselves. If they do, another student calls 'Out', and then this student has a turn with the same topic until the end of the minute. New topics can be drawn out of a hat or picked by the student or teacher.

Mountains	Volcanoes
Earthquakes	Earth's structure
Fossils	Continents moving
Atmosphere	Glaciers

Hints

Try to say everything you know and have ever heard about the topic. For example, **describe** how that feature forms or what it does, or name some examples or **describe** the effects of that feature. As you speak, more memories and random facts will come to you. Have fun!

8.1 The dynamic Earth

Earth is truly a **dynamic** place with changing weather patterns, mountain ranges being pushed higher and eroded, and tidal forces moving vast bodies of water. The very ground we stand on is sliding, buckling, shaking and disappearing only to be recycled and appear again in volcanic eruptions. This is called the **rock cycle**.

dynamic
constantly changing, energetic in nature

rock cycle
the continual recycling of rocks through weathering, erosion, burial, compacting, melting and uplifting

Earth is both beneath us and above us. We know a lot about the atmosphere, as it is very easy to observe and measure. But to understand the events that are constantly changing our planet, we must understand its structure. Two-thirds of the planet is covered in water and the average radius is 6371 km, so digging a hole to the centre of Earth is not a viable option (Figure 8.1).

Shutterstock.com/Alex Staroseltsev

Figure 8.1 Two-thirds of Earth is covered in water.

To get a complete picture of our changing planet, we will start from space and work our way to its core.

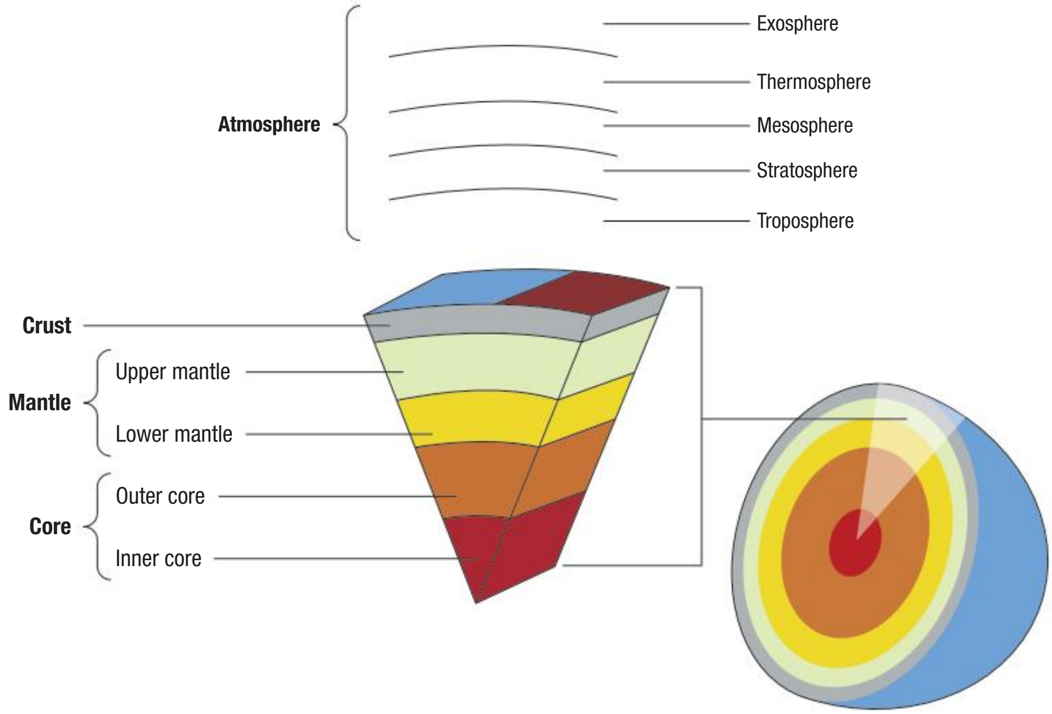

Figure 8.2 The layers of Earth consist of the atmosphere, crust, mantle and core.

WORKSPACE
Earth measurements

ACTIVITY 8.1

Earth measurements

Here are some measurements that scientists have calculated for Earth:

- Earth's atmosphere ends between 550 km and 600 km above sea level.
- Earth's radius is approximately 6371 km.
- The mass of Earth is 5.97×10^{24} kg or 6×10^{21} tonnes; nearly one-third is core and two-thirds is mantle. The rest is crust, ocean, atmosphere and ice caps.

What to do

Research the answers to the following questions.

- How do scientists calculate the measurements of Earth?
- How is the radius measured?
- Who first calculated the radius of Earth?
- How often is the radius measured?

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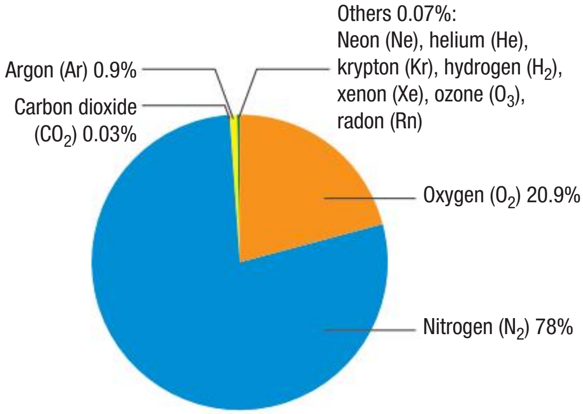
The atmosphere

The atmosphere is the layers of gases surrounding planet Earth. Much of the atmosphere is held close to Earth's surface by **gravity**. Its temperature, density and composition change the higher you go.

The main gases in the atmosphere are nitrogen (78%), oxygen (20.9%), argon (0.9%) and carbon dioxide (0.03%). There are also small amounts of other gases.



gravity
the attractive force between two masses

Figure 8.3 The gases that make up Earth's atmosphere.

As you travel further above Earth's surface, the gravitational pull of Earth decreases. The air becomes less dense and at about 550 km there is little remaining atmosphere. This is where Earth finishes and space begins.

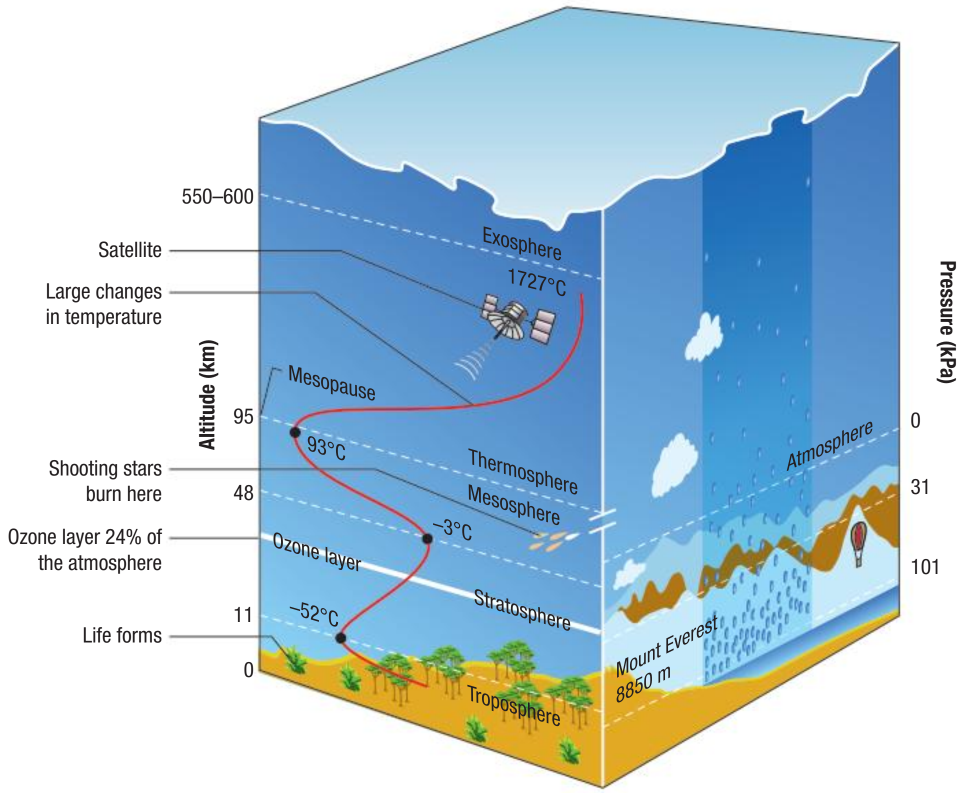


Figure 8.4 Earth's atmospheric layers

ACTIVITY 8.2

Balloon ride through the atmosphere

Use the information shown in Figure 8.4 to create a short story about what you would experience if you took a balloon ride from the ground to the orbiting satellite. Try to refer to layers, temperature and altitude as you travel.

WORKSPACE
Balloon ride through the atmosphere

ISBN 9780170231503

WORKSPACE
How does the atmosphere change our planet?

WEBLINK
The rock cycle

ICT

You could use Gliffy to create your concept map.

ACTIVITY 8.3

How does the atmosphere change our planet?

Using your knowledge of the rock cycle, especially weathering and erosion, create a concept map with a central idea of 'Weather and our changing planet'. **Identify** factors and processes in the atmosphere that directly or indirectly affect the Earth. You can use information from the weblink in your concept map.

WOW!

That's high!

The highest point on Earth is the summit of Mount Everest. Its official height is under dispute since India, China and the United States all measure it differently. It is approximately 8840 m above sea level.

Shutterstock.com/my-summit

Australian-raised Tim Macartney-Snape climbed Everest starting from sea level up to the summit from Nepal in 1990. He would have experienced the effects of the increasing altitude, including the thinning out of oxygen in the air. Amazingly, Tim climbed without additional oxygen.

The crust

The crust is the outermost **terrestrial** layer (the layer we live on). It is made up of a variety of landscapes, such as hills, mountains, valleys, plains and deserts. The crust is not the same thickness all over. The seabed is, on average, 8 km thick and the continents are, on average, 40 km thick.

terrestrial
relating to the Earth, the ground

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Earth's crust is made from two types of rock. Seabed crust rock consists of denser basalt and continental rock (making up the continents) is a lighter granite. The rocks consist of minerals, which are composed of elements. Almost 99% of Earth's crust consists of just eight elements. These are:

- oxygen O (46.6%)
- silicon Si (27.7%)
- aluminium Al (8.1%)
- iron Fe (5%)
- calcium Ca (3.6%)
- sodium Na (2.8%)
- potassium K (2.6%)
- magnesium Mg (2.1%).

ACTIVITY 8.4

Checking out the crust

Complete the following.

1 Select a common street name (such as Main Street or King Street). Choose these streets in four different Australian states.
2 Enter the street name and state into Google Maps and go to street view.
3 **Describe** the landscape in each of the four locations.
4 Take a screen capture of different views and save these as jpegs. Use Animoto to create a 30-second movie that **shows** the four different locations. Add a brief description of each landscape.
5 Create your own blog. Either embed the code or put a link to your movie on your blog.

WORKSPACE
Checking out the crust

WEBLINK
Google Maps

WEBLINK
Animoto

Most of Earth's surface is covered with water. Have you thought about what the seafloor looks like? Modern oceanography began in 1872, when the British Royal Navy sent HMS *Challenger* on a 4 year expedition to survey a variety of oceanic features, including the **geology** of the seafloor. To convert HMS *Challenger* from a naval ship to a scientific research ship, all its guns were removed and fully fitted scientific laboratories, cabins and dredging equipment were installed. Scientists on the expedition determined the depth of the ocean, found new species, collected many samples and made many other measurements.

geology
the scientific study of the origin, history, structure and composition of Earth


Getty Images/Time & Life Pictures

Figure 8.5
The scientific crew of HMS *Challenger*, October 1874

WEBLINK
Take a tour of the Mariana Trench

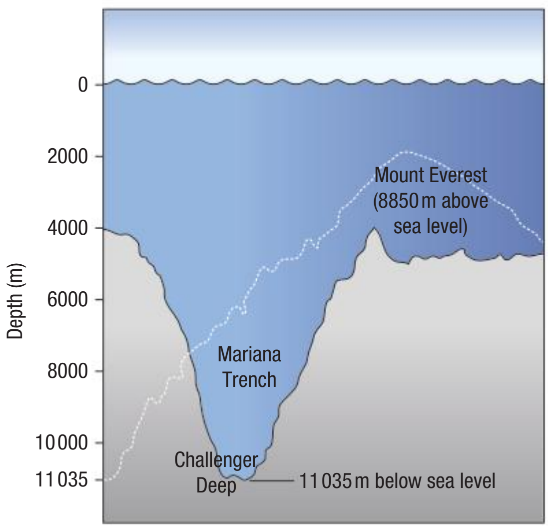

Figure 8.6 How deep is deep? At 11 035 m, the Mariana Trench is the deepest place on Earth. Mount Everest would fit into the Challenger Deep with about 2 km of water still above it.

HMS *Challenger* discovered the Mariana Trench below the surface of the western Pacific Ocean near Guam, where the seafloor is 8.2 km deep. The deepest part of the trench, and also the deepest place on Earth, is called Challenger Deep – it is 11.04 km deep.

Modern scanning of the ocean floor uses some very interesting techniques. One such technique is echo sounding. This involves sending pulses of sound and recording the length of time it takes the sound to return. In water sound travels at 1.5 km per second, which means that the ocean depth can be mapped relatively quickly. Echo sounding is also used by fishing boats to find schools of fish.

Another useful device is a magnetometer. It is a device that measures changes in the strength of magnetic fields. This is how scientists were able to find magnetic striping patterns around mid-oceanic ridges. This was further evidence for the theory of plate tectonics.

The mantle

The layer directly below the crust is the mantle. The mantle has not been seen or sampled directly. Scientists have based their ideas on secondary or indirect measurements, usually seismic data (earthquakes) and laboratory experiments on rocks and minerals.

The mantle is thought to be 2900 km thick and has upper and lower layers (Figure 8.7). The temperature increases with depth, so the upper layer is cooler (1000°C) and its rocks are hardest. The lower and hotter (3700°C) layer contains soft, but not molten, rocks.

A **discontinuity** is where one thing stops and another starts. There are discontinuities where the layers of the Earth start and stop. Between the crust and the mantle is the Mohorovicic discontinuity, commonly referred to as the 'Moho'. It is named after the Croatian seismologist Andrija Mohorovicic.

discontinuity
a change in regions within the Earth

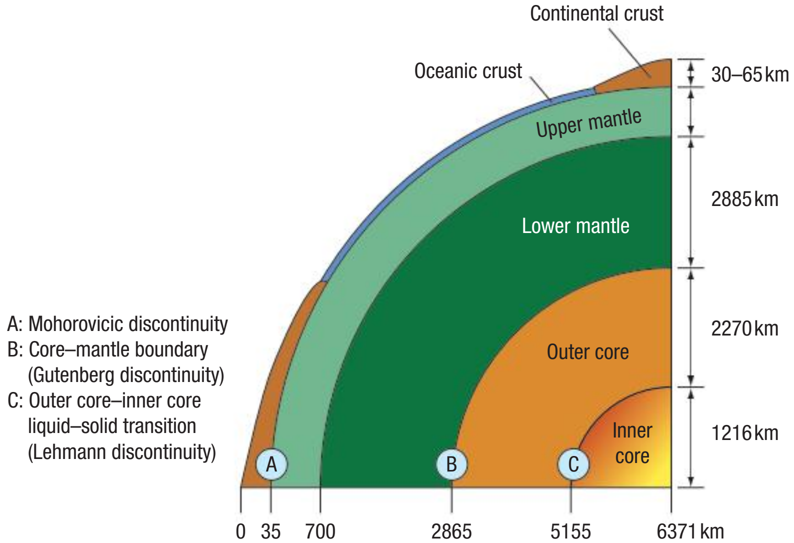

Figure 8.7 Discontinuities in Earth's layers

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ACTIVITY 8.5

Layers

1 Research and upload a definition for each of the following terms to your blog.

- Lithosphere
- Mesosphere
- Asthenosphere

2 **Describe** some of the properties that a machine designed to sample the Earth's mantle would have. Consider the challenges it would have to overcome. Draw, either digitally or by hand, such a machine, or just **outline** its specific features.

WORKSPACE
Layers

The core

Astronomers think that Earth and the solar system did not form directly after the big bang – the enormous explosion that started the expansion of the universe. Rather, Earth formed after a first-generation star went **supernova** – that is, it exploded. Some of the heavier elements from this supernova are found on Earth, including iron (Fe), nickel (Ni) and sulfur (S). As the growing planet gathered mass, lighter and lighter elements were pulled in by the increasing gravitational field. This evolutionary process, along with data from seismic and magnetic events, strongly suggests that the core mainly consists of an iron–nickel alloy.

supernova
an explosion of a star after it has used up its hydrogen fuel

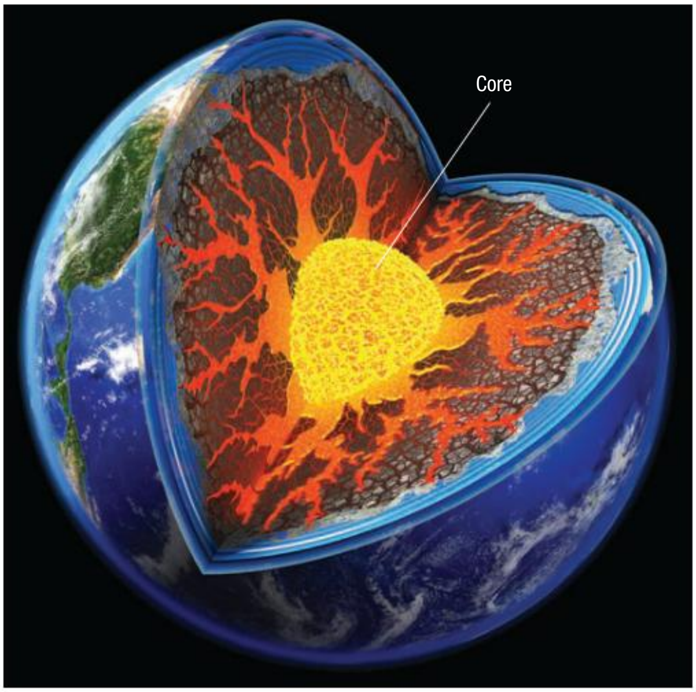

Figure 8.8
Earth's core

The core, like the mantle, has two layers, an outer and inner core. The outer core is molten and very hot (4000–5000°C). This outer layer of the core is moving and contributes to the Earth's magnetic field. The inner core is a lot smaller than the outer core. The pressure at the centre of the Earth is so great that the iron core doesn't melt even though the temperature is estimated to be 5000–7000°C.

ISBN 9780170231503

WORKSPACE
Discontinuities

ACTIVITY 8.6

Discontinuities

Similes

1 A discontinuity is like . . .

Create three of your own similes for discontinuity and upload them to your blog. Select your favourite and place it on the class wiki.

Quiz

2 Create an online quiz with no more than 10 questions.

Use the following as your answers:

inner core, outer core, lower mantle, upper mantle, oceanic crust, continental crust, Mohorovicic discontinuity, Gutenberg discontinuity, Lehmann discontinuity.

You could use Survey Monkey to create your quiz.

3 Send the link to your classmates to complete.

WEBLINK
Survey Monkey

WORKSPACE
What have you learnt? 8.1

ICT

You could use electronic mind-mapping software such as eDraw Mindmap.

WEBLINK
eDraw Mind-map

QUESTIONS 8.1

What have you learnt?

Remembering

1 The Earth has a number of layers, starting from its centre and ending at the edge of space. **List** them in order and state two facts about each layer.

2 **Recall** the two most abundant gases in the Earth's atmosphere.

Understanding

3 **Describe** why Earth is said to be dynamic.

4 **Outline** three problems involved in exploring the structure of Earth.

5 **Recount** why we believe that Earth's core is made up of a Fe–Ni alloy.

Applying

6 **Explain**, using particle theory, why Earth's core is not molten, even though the temperature is thought to be as high as 7000°C.

7 **Describe** why Earth's atmosphere doesn't drift off into space.

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QUESTIONS 8.1

Creating

8 Create a graph of the elements making up Earth (page 273). **Justify** the type of graph you created.

Reflecting

9 As you go through this chapter, **construct** either a mind map or a lotus diagram, showing a central image relating to Earth. Add information to **demonstrate** your understandings and connections. Save this summary to prepare for tests.

8.2 Force fields and heat

To understand how and why Earth's layers interact, we need to know what forces are acting on these layers and how the forces are being generated.

A force can change the shape of an object, it can change the direction in which an object is travelling, or it can speed up the object or slow it down (*Nelson iScience 7 for NSW*, Chapter 9).

Forces that act without touching act through **force fields**. Such forces include the forces of gravity and magnetism, which play an important role in maintaining and changing our planet.

force field

a region of space where a force can act upon an object

Earth's magnet

Physicists know that magnetic fields are produced when electric charges move. Earth's magnetic field is thought to be generated by the 'dynamo effect' of the liquid iron and nickel outer core spinning inside the planet.

Having a magnetic field surrounding the planet is essential for our existence. It protects us from some of the more harmful solar radiation. It also magnetises rocks as they are formed.

Charged particles from the Sun hit Earth's magnetic field and become trapped. They can then only move along the field lines that lead into the Earth. As these energetic particles move into the atmosphere, they collide with oxygen (O_2) and nitrogen (N_2) molecules. These molecules absorb this energy and become 'excited'. They eventually release this energy as visible light. You can see this in the night sky as an aurora. In the northern hemisphere this is called the aurora borealis and in the southern hemisphere this is called the aurora australis (Figure 8.10).

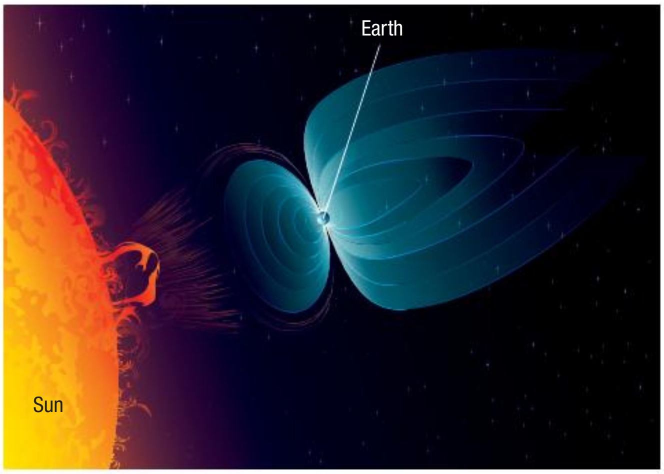

Figure 8.9 Solar winds and Earth's magnetic field

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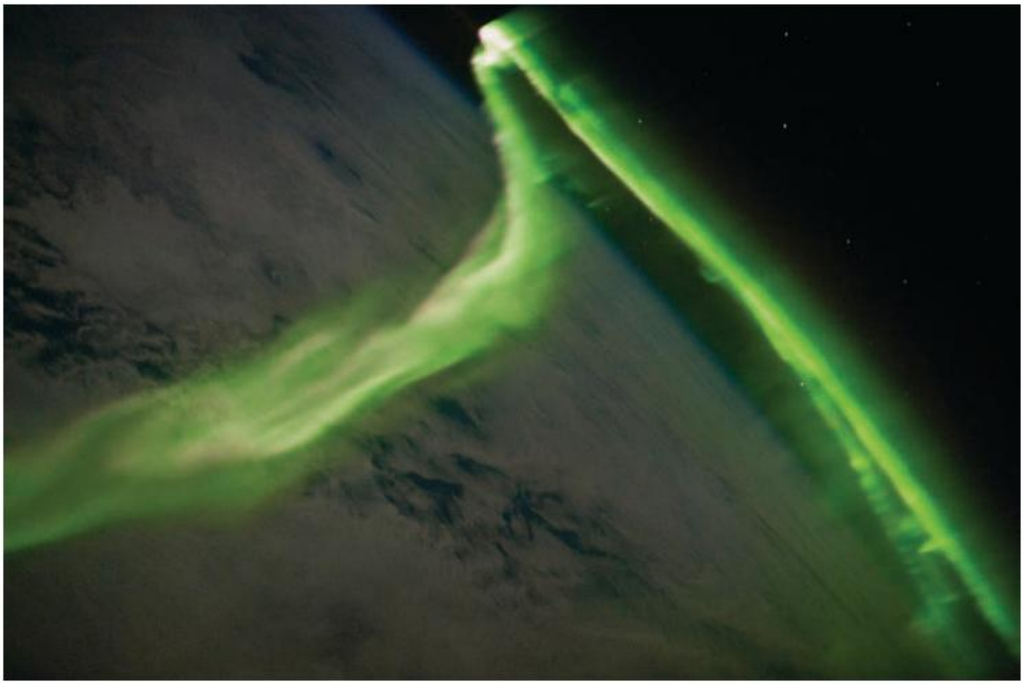

Figure 8.10 The aurora australis, or southern lights, is caused by the collision of high-energy particles with molecules in the atmosphere.

ACTIVITY SHEET
Northern and southern auroras

Rocks contain minerals and nearly all minerals are influenced by magnetic fields. When a rock is heated to very high temperatures and then allowed to cool, its magnetic components line up along the magnetic field lines that are present at that location. This information means that we can determine where rocks were formed and we can track past locations of tectonic plates.

Heat

The energy to drive the forces deep below Earth's surface comes from a natural process that generates heat. The deeper you go into the Earth, the greater the pressure generated by the weight of overlying rocks. Naturally occurring radioactive elements uranium (U), thorium (Th) and potassium (K) are found in granite. The radioactive decay of these elements over millions of years releases heat energy.

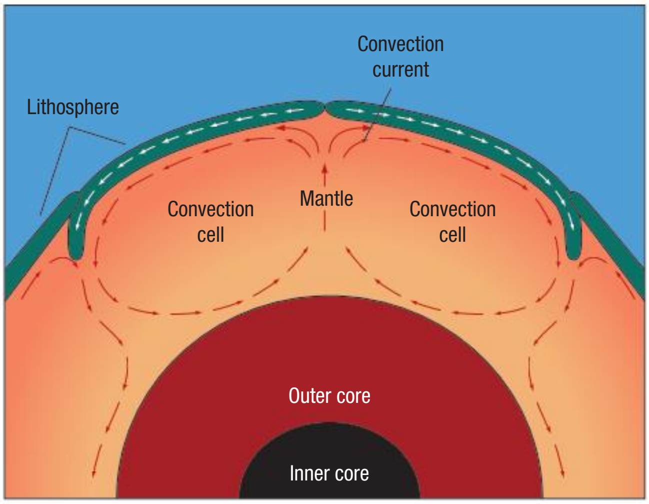

Figure 8.11 Convection currents move heat from the core towards the surface of the Earth.

Heat generated within the Earth moves towards the cooler surface. This movement sets up a **convection current** so that energy moves through the mantle towards the crust. Strong convection currents constantly move through the mantle, and therefore move heat towards the surface.

convection current
a movement of hot material upwards towards cooler regions where it cools and sinks again

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Scientific tools and evidence

Scientists often cannot examine things of interest to them directly. They have to investigate them in indirect ways. This applies to the Earth. We can't drill to its centre to see the core and mantle. We have to use other tools and gather data to find the answers to what is below the surface of Earth.

There are two key principles in geology – **uniformitarianism** and **superposition**.

Uniformitarianism is a scientific principle (a rule proved to be true and based on scientific law) that arose from the work of Scottish geologist James Hutton (1726–97). This principle suggests that landscapes develop over long periods of time through slow geologic processes. Often this principle is stated as: 'The past is the key to the present.'

The law of superposition says that where there are layers of rock, those lower down will be older than those near the top.

uniformitarianism
the theory that says that Earth's surface was shaped in the past by gradual processes

superposition
the law that says that lower layers of rocks are older than those near the top

ACTIVITY SHEET
Uniformitarianism

Seismology

Seismology is the study of earthquakes and **seismic waves** that move through and around the Earth.

Seismic waves are disturbances that travel through or around the Earth. These disturbances occur when energy is released due to rocks breaking suddenly within the Earth or if there is an explosion.

seismology
the scientific study of earthquakes and the internal structure of the Earth

seismic wave
energy travelling through the Earth in the form of a longitudinal or transverse wave

WORKSPACE
Science career – seismologist

ACTIVITY 8.7

Science career – seismologist

1 **Outline** the work of a seismologist.
2 **List** universities in your state that offer courses in seismology.
3 **Identify** the career opportunities for a seismologist in the Asia–Pacific region.
4 **Investigate** some examples of new technology used on the job that can affect people's lives.

Gravity map

The European Space Agency's Gravity field and steady-state Ocean Circulation Explorer Mission is a gravity-mapping satellite that has produced the amazing image of Earth, as shown in Figure 8.12. The map is called a 'geoid'. The different colours indicate regions below Earth's surface where there is more gravity or less gravity. It helps scientists better understand the interior of the Earth. It is a hypothetical, or mathematical, representation of the Earth's surface and is an approximation of sea level and hence gravity.

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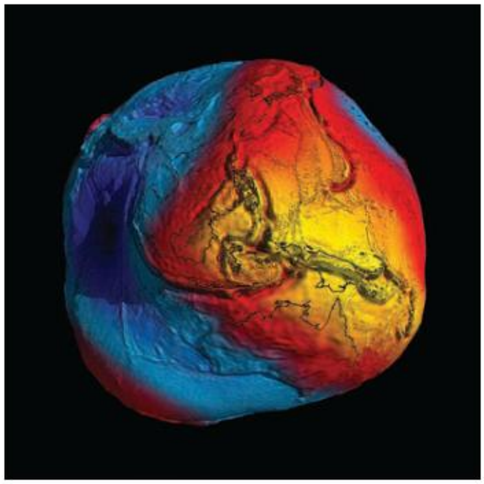
Gravity is a force that affects all matter, even the gases of the atmosphere. The strength of the force is proportional to the amount of matter. For example, a mountain will have a stronger gravitational field than a stone because the mountain has more matter.



European Space Agency/HPF/DLR

Figure 8.12 Geoid showing Earth's gravity distribution

WOW! Lake Eyre fossils

Fossils found in the Kallakoopah–Coopers Creek region suggest that Lake Eyre was a deep freshwater lake until about 100 000 years ago. Drier conditions resulted in the lake eventually drying up about 60 000 years ago.

Local fossils from this period include a diprotodon, a crocodile, a large freshwater turtle and *Megalania prisca*, a lizard the size of a Komodo dragon.

Getty Images/De Agostini

ACTIVITY SHEET
How to make a fossil

Fossils

Fossils are the mineralised remains of living organisms. The fossils, and especially the location where they are found, tell us a lot about the environment at the time the organism was alive. Similar fossils found in different locations would suggest the habitats would have been very similar. Fossils can tell us what the local climate was like at that time.

Fossils, or a lack of them, can indicate mass extinctions, such as the KT event, which occurred 66 million years ago. Something

fossil
any evidence of an organism from a former geological time

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Figure 8.13 Fossils such as these ammonites provide evidence about the environment at the time the organisms were alive.

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happened between the Cretaceous (K) and the Tertiary (T) periods to cause the disappearance of about 70% of all species. What changes to the planet's environment caused this mass extinction? Scientists believe an asteroid approximately 10 km wide hit Earth, causing dramatic changes to the climate, collapsing food chains worldwide and leading to the mass **extinctions**.

extinction
dying out, not existing any more

Volcanic activity

A more frequent event that changes the planet is volcanism. Worldwide there are on average 50–60 eruptions a year. Records of volcanic activity have only been kept in recent times, so trying to predict the next large eruption is difficult. In 2011, a volcanic eruption in Chile affected flights in Australia and New Zealand.

The nearest active volcanoes to Australia can be found in Taupo, New Zealand, and in Indonesia. These volcanoes could be capable of producing super-eruptions, which would produce 200–300 km^3 of ash. This amount of ash would change Earth's climate by reducing sunlight for years and producing acid rain. Luckily for us, this type of eruption is estimated to have a frequency of only once every 10 million years.

Shutterstock.com/Isabella Wertschnig

Figure 8.14 A volcano at Taupo, New Zealand

WOW!

Krakatoa

In 1883 the volcanic island of Krakatoa erupted. It is estimated that 30 km^3 of ash was produced and 40 000 people were killed by this eruption. There were reports of the sound of the explosion being heard nearly 5000 km away. It is said to have been the loudest sound in all of history.

Shutterstock.com/Byelikova Oksana

WORKSPACE
What have you learnt? 8.2

QUESTIONS 8.2

What have you learnt?

Understanding

1 **Outline** the forces involved in maintaining and changing our planet. **Explain** how each is generated.

2 **Recall** two effects Earth's magnetic field has on us.

3 **Describe** an example of one law and one principle in science.

4 **Outline** how heat is generated deep within the Earth.

5 **Explain** how convection currents move heat towards the surface.

Applying

6 Heat energy generated below Earth's surface drives convection currents. **Describe** where in your home you would find convection currents.

7 Halfway down a cliff face are some seashells and near the bottom are fossils of plants that only grew on land. **Extrapolate** what this observation means.

Analysing

8 **Calculate** how long a 200 km^3 layer of volcanic ash would it be if you could spread it out so that it was 1 m thick and 1 km wide.

Creating

9 Locate Krakatoa, Mount St Helens, Eyjafjallajökull, Pinatubo and Tambora on a Google Map. These are all volcanoes that have erupted in recent times. Take a screen capture and upload it to your blog. Summarise details for each eruption.

Reflecting

10 **Describe** the effects that one event from Question **9** had on people living near them and on the planet.

8.3 Geological time scale

stromatolite
a solid structure produced by cyanobacteria over many years by trapping sediment on their sticky surface

cyanobacteria
blue-green algae or bacteria

Time can be a difficult concept to explain. How old is the universe? How old is our planet? Scientists have only recently been able to suggest answers to these questions.

The age of the universe has been calculated to be about 13.7 billion years. (A billion is 1000 millions.) The Earth is about 4.6 billion years old, with the earliest fossils dating back 3.4–3.7 billion years. The oldest fossils include **stromatolites** (Figure 8.15) and **cyanobacteria** (blue-green algae) discovered in the north-west of Western Australia. Cyanobacteria thrive in the extremely salty water, where other organisms cannot survive.

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Figure 8.15 Stromatolites in Hamelin Pool, Western Australia

Relativity of scales

When using any measuring device, it is important that you choose the appropriate scale for what you intend to measure and its **magnitude**. If you wanted to measure the length of your fingernails as they grow, would you use a ruler with a scale of millimetres or centimetres? We would use different scales to measure the distances between galaxies, the length of a leaf, and the diameter of an atom.

magnitude
size, how big something is

WEBLINK
Orders of magnitude

Time scales

One way to represent time is as a straight line of unrolled toilet paper where one piece of paper represents 20 million years. You would need 230 squares of toilet paper or approximately one whole roll to show all of time. Humans would appear right near the very end of the very last piece of paper. The human species is very new to this planet.

Size scales

We use kilometres to measure a planet's dimensions. For smaller objects we use centimetres (cm), millimetres (mm) and even smaller units.

$$1\,\text{km} = 1000\,\text{m}$$
$$1\,\text{m} = 1000\,\text{mm}$$
$$1\,\text{mm} = 1000\,\mu\text{m (micrometre)}$$
$$1\,\mu\text{m} = 1000\,\text{nm (nanometre)}$$

ACTIVITY SHEET
Scientific notation

Periods of time

If you want to talk about when something happened, but you aren't exactly sure when it happened, you usually refer to a period of time, such as last week or two years ago.

Scientists who study events that took place over geologic timespans name the major divisions of time so they can talk about them. Some names refer to where fossils and rocks were first discovered – for example, the Mississippian period is named after Mississippi in the United States. Other names link the period to the characteristic of the time – for example, Proterozoic comes from the Greek term for 'earlier life'.

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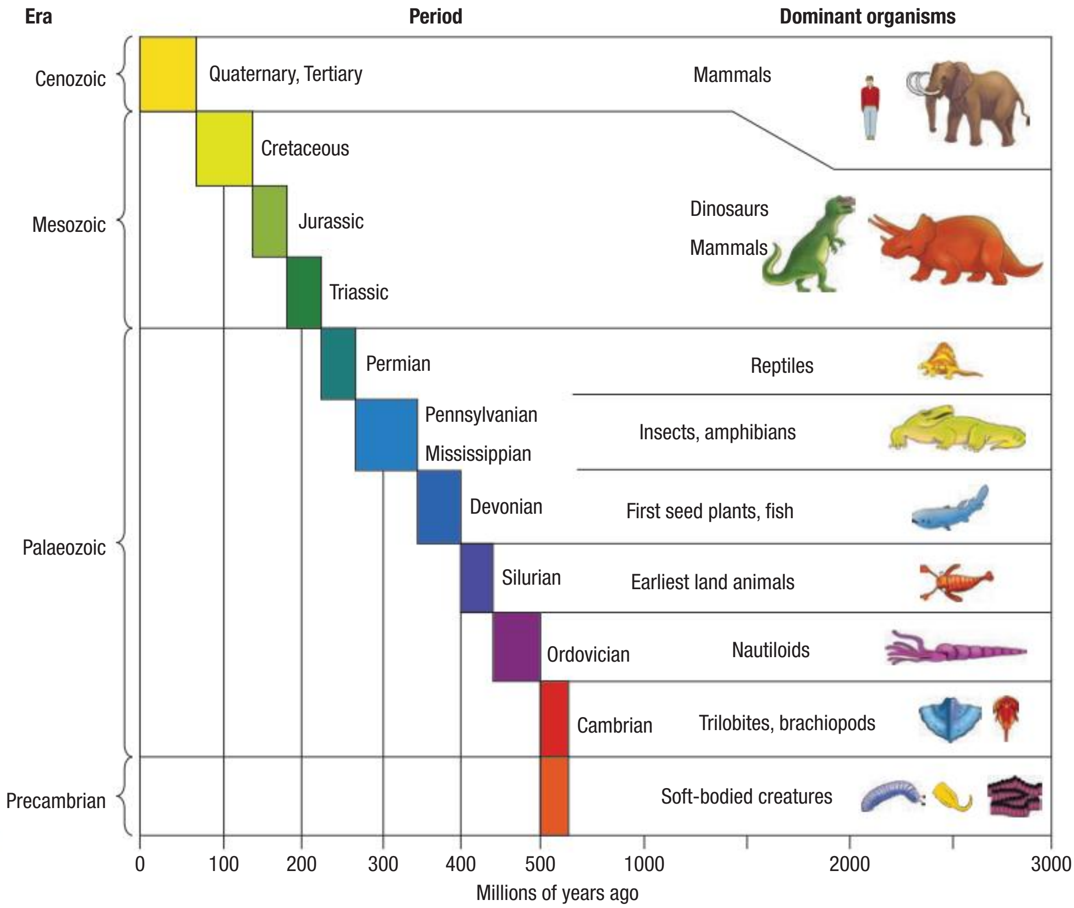

Figure 8.16 Earth's time periods

WORKSPACE
What have you learnt? 8.3

QUESTIONS 8.3

What have you learnt?

Understanding

1 The Earth is approximately 4.6 billion years old. **Recall** when human ancestors first appear on Earth.

2 **Describe** how cyanobacteria get their name.

3 **Recall** when life first appeared on Earth.

Applying

4 **Calculate** the number of seconds in a year, giving your answer in scientific notation (index form).

5 Choose a period of time from Figure 8.16 and **describe** its characteristics.

6 If you moved at a rate of 1 mm per year, **calculate** how many years it would take you to travel from:

a your home to school

b Australia to the United Kingdom (approximately 12 000 km).

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QUESTIONS 8.3

Creating

7 Create a mnemonic to help you remember the time periods shown in Figure 8.16. Upload your mnemonic to the class wiki.

Reflecting

8 **Explain** why humans need to have an understanding of past extinction events.

8.4 Plate tectonics – theory and evidence

If you look at a world map or globe, you might notice that the continents fit together much like a jigsaw puzzle. This is exactly what German scientist Alfred Wegener (1880–1930) noticed. In 1912 he proposed that the continents had been one big landmass, which he called Pangaea from the Greek for 'entire Earth'.

In science there is a process called peer review, in which scientists put their theories and evidence up for review by other scientists (their peers). Alfred Wegener didn't have sufficient evidence to explain to other scientists how such a large landmass could break up and move apart to form the continents that we see today. It was not until the early 1960s when other scientists had more evidence to support Wegener's theory on continental drift that his Pangaea theory was accepted.

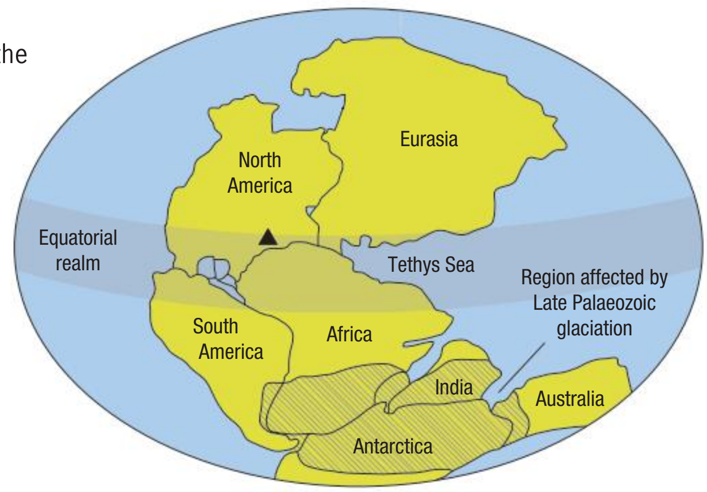

Figure 8.17 Pangaea – the supercontinent proposed by Alfred Wegener

Science Photo Library

Figure 8.18 Alfred Wegener

WEBLINK
Plate tectonics

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ACTIVITY SHEET
Layers jigsaw

ACTIVITY 8.8

Layers jigsaw

Complete the following.

1 Cut out the continents in activity sheet 'Layers jigsaw' and glue them on another piece of paper so that they fit together like the pieces of a jigsaw puzzle.

2 Use the question matrix provided in the workspace to develop your own questions about the Earth's structure and the *how* and *why* of its changes. How did the continents get from being close together to being where they are today? Why did scientists think they had moved? How did they figure out that they did move? If your class has a Padlet, post some of your questions there.

WEBLINK
Padlet

plate tectonics
the theory that explains how Earth's crust is broken into plates and how they move

The theory of **plate tectonics** describes Earth's surface as being covered by a series of plates, which make up Earth's crust. Plate tectonics has a variety of different pieces of evidence that support it. Scientists have put together these pieces to help complete the theory. We will discuss the evidence next.

Density and convection

As discussed earlier, convection results from the movement of heat energy through the mantle. As the fluid rock heats, the particles move further apart and the density decreases. As it becomes less dense, it rises. Near the crust, the rock is pushed sideways and some of its heat energy is transferred to its surroundings. As the temperature of the rocks falls, the particles move closer together, and so the density increases. The rock starts to sink and the cycle starts over again.

It is thought that this cycle is the force that moves the tectonic plates. The large energy generated by the heat from the centre of Earth is able to move these giant plates, if only a few centimetres each year. Over millions of years these small movements have resulted in the plates shifting large distances.

WEBLINK
Buoyancy and floating continents

Crustal densities

Objects float because of density. A substance will float in a liquid of higher density. The density of the continents is, on average, less than that of the mantle, so the continents float.

Magnetic stripes

solidify
to harden, to change a liquid into a solid

Molten rock cools and **solidifies**. The magnetic elements that make up the rock align (line up) themselves with the local magnetic field. This is similar to watching the needle of a compass move, and when it points to magnetic north the needle is frozen so it can't move anymore. The rock's magnetic particles will point north and stay that way after they have cooled and solidified.

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As more and more **magma** is pushed up through the crack in the crust, the seafloor is pushed sideways. As the magma cools, more tiny magnetic particles are fixed so that they point towards magnetic north.

If the Earth's **magnetic fields** remained constant, then all the magnetic particles in rocks would point north. But, over tens of thousands of years, Earth's magnetic north and south poles have swapped. These reversals mean that in rocks created at different times the magnetic particles point in opposite directions. This is seen as striping on the seafloor on either side of mid-ocean ridges (Figure 8.19).

The analysis of magnetic striping patterns indicates new seabed rock is being formed along the mid-ocean ridges. New seafloor is spreading out from this ridge.

magma

molten rock material located beneath the Earth's surface

magnetic field

the region of space where a magnetic force acts on charged particles and other magnets

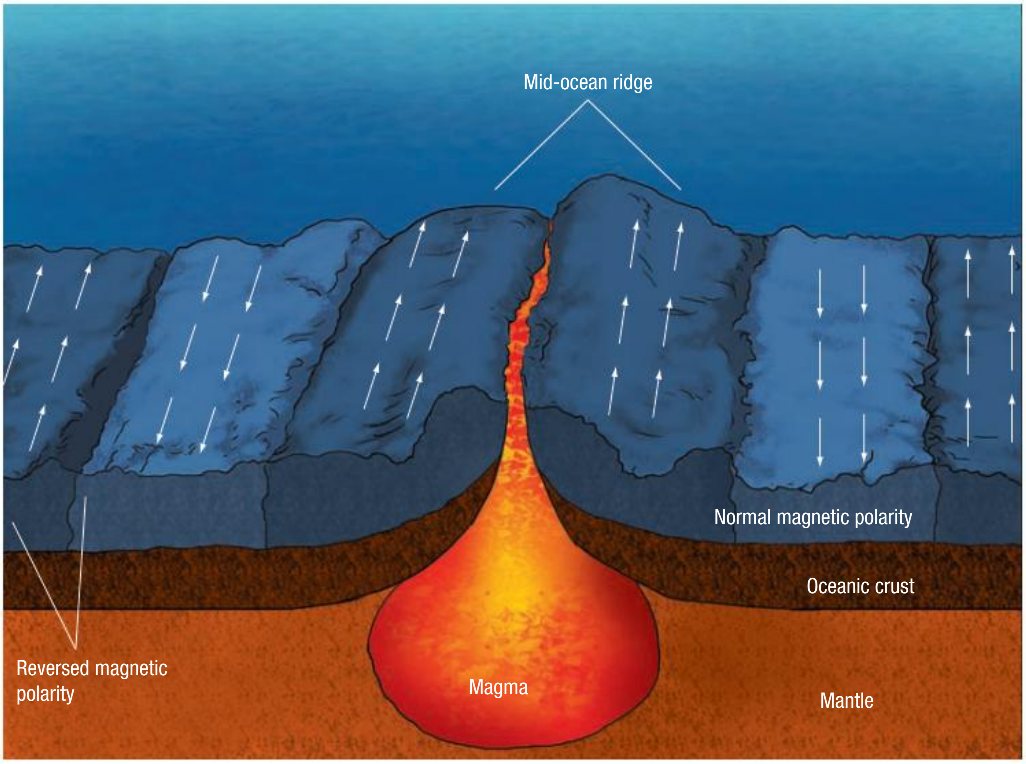

Figure 8.19 The Mid-Atlantic ridge shows magnetic striping. The stripes indicate areas where the Earth's polarity has been reversed.

Subduction zones

HMS *Challenger* expedition in 1872 surveyed the seafloor and found the Mariana Trench (see page 273). Scientists now understand why these trenches exist. These trenches are the boundaries where one heavier crustal plate is pushed under another lighter crustal plate in a process called **subduction**. As the subducted plate is pushed further below the other plate, it generates a huge amount of heat. This energy turns the rock into molten magma.

The new seafloor being created at the mid-ocean ridges is eventually recycled back into the mantle. The ridge that separates the diverging plates is referred to as a **divergent** plate boundary.

subduction

the process in which two converging tectonic plates collide and one plate slides beneath the other

divergent

moving away from

ANIMATION
Subduction

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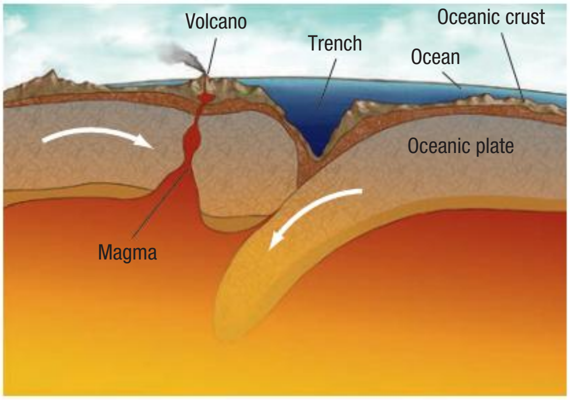

Figure 8.20 Enormous forces push a colliding plate down into the mantle, generating extreme temperatures.

Volcanic activity usually occurs where there are subduction zones, such as in Hawaii, or Indonesia. The volcanoes are particularly dangerous as they have an abundant supply of magma from the subducting crust below them. The border between colliding tectonic plates is known as a **convergent** plate boundary. The areas of volcanic activity, or hot spots, are caused by **plumes** of hot magma making its way to the surface through the Earth's crust.

convergent
moving towards, coming closer

plume
a column of super-hot magma rising up under the crust

WEBLINK
Hawaiian volcano

WEBLINK
Seafloor spreading

Fossil evidence

Scientists have found fossils of the freshwater reptile *Mesosaurus* in both southern South America and the southern tip of Africa. These points of the globe are thousands of kilometres apart. The *Mesosaurus* was not a good swimmer and could not have possibly have swum such a large distance. Fossils of the fern *Glossopteris* have been found spread across South America, Africa, India, Antarctica and Australia, which shows that these continents were once joined.

The distribution of these fossil species can be explained by the theories of plate tectonics and continental drift. According to these theories, the continents were originally one big

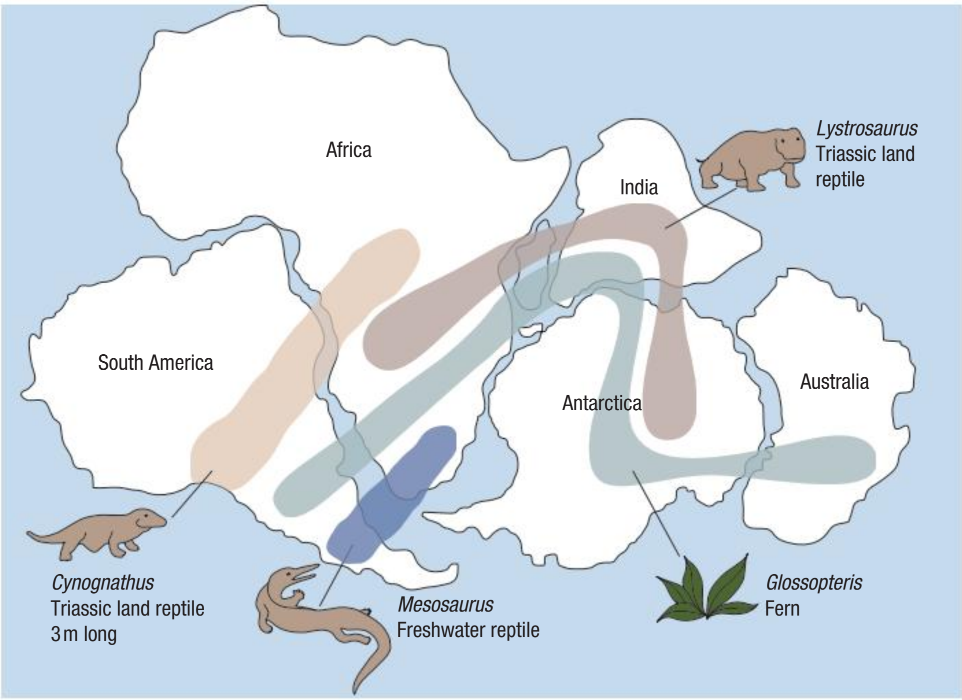

Figure 8.21 Fossil distribution can be explained by plate tectonics and continental drift. The coloured areas show where fossil remains have been found.

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landmass called Pangaea. This landmass broke apart to form smaller continents and islands. The fossilised remains of animals and plants that inhabited one region of Pangaea were separated on the smaller continents. Fossils travelled over millions of years on the smaller landmasses to new locations on the planet. So finding almost identical fossils in very disparate (widely spread out) continents can be explained if the continents were once joined. The fossil distribution further supports the theory of plate tectonics.

Climate change

A **glacier** is a river of ice and snow. Evidence of past glacial activity exists in the form of U-shaped valleys (Figure 8.22) and the deposits that are left behind when the glacier has retreated or melted.

Figure 8.23 shows the distribution or 'reach' of glaciers on the continent of Pangaea and on the continents today. It explains why evidence of glaciers can occur in desert regions. If the continents were arranged as one large continent located near the South Pole, then it provides a more logical picture of why glacial evidence exists where it does today.

glacier
a river of ice and snow

Figure 8.22 Glacial valleys such as this one are evidence of past glacial activity.

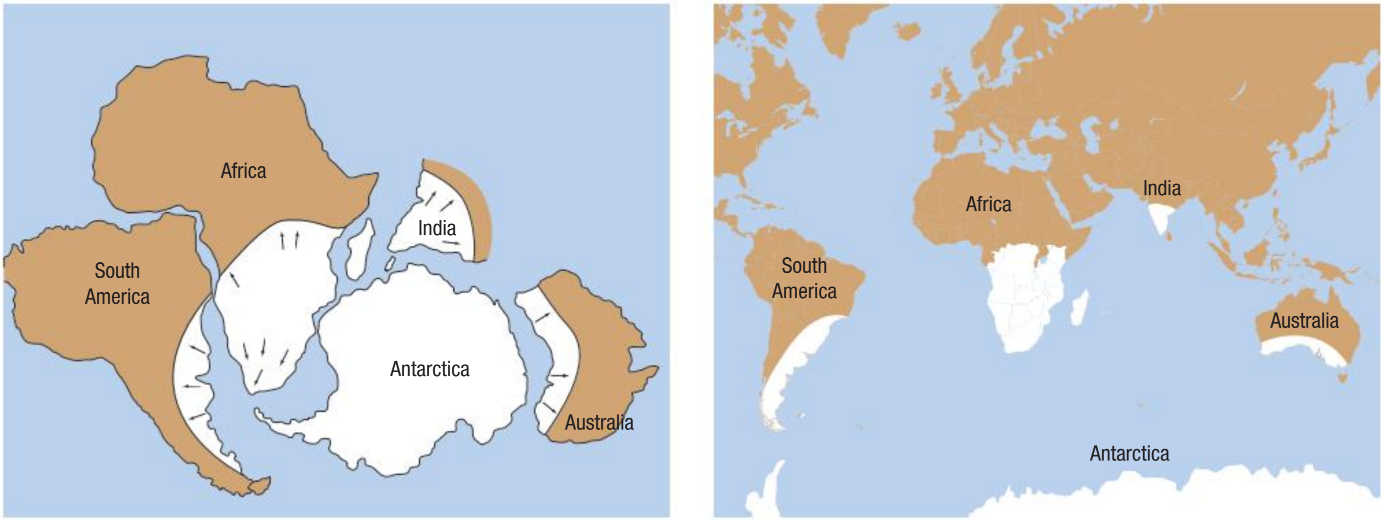

Figure 8.23 Glacial distribution then and now. The arrows show the direction of glacial movement.

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ACTIVITY 8.9

What if...?

What if the theory of plate tectonics had not yet been suggested? **Propose** some ideas for how the lack of this theory might have an impact on other ideas, or change our lives in some way.

WORKSPACE
What have you learnt? 8.4

QUESTIONS 8.4

What have you learnt?

Understanding

1 **Explain** how the theory of plate tectonics helps explain continental drift.

2 Density can be defined as how much of something fits into a certain volume. Provide two examples of objects with different densities and **explain** why they have different densities.

3 Can mountains float? **Explain** your answer.

4 **Compare** plate tectonics and continental drift.

Applying

4 **Describe** what evidence you would use to convince someone that the Earth's magnetic poles swap with each other.

5 **Propose** why deep trenches form at the bottom of oceans.

Analysing

6 **Outline** how you could **explain**:

a almost identical fossils in very disparate continents
b evidence of glacial activity in countries near the equator.

Reflecting

7 How do you think the theory of plate tectonics changed people's ideas about the structure of the Earth? **Discuss** your thoughts.

8.5 Causes of geological events

plate boundary
the border between two tectonic plates

We know Earth has internal layers and that the crust has a series of tectonic plates that ride on a molten mantle. We also know that the seafloor is spreading out (diverging) from mid-ocean ridges and then subducting at **plate boundaries**. It is at these zones of subduction that the extreme, rapid changes to the planet's surface occur.

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Moving plates

There are four types of plate boundaries:

- **divergent boundaries** – where new crust is generated as the plates pull away from each other
- **convergent boundaries** – where crust is destroyed as one plate dives under another
- **transform boundaries** – where crust is neither produced nor destroyed as the plates slide horizontally past each other
- plate boundary zones – broad belts in which boundaries are not well defined and the effects of plate interaction are unclear.

Types of **fault** lines include:

- thrust (or reverse) – the two blocks move towards each other so one is thrust higher
- strike–slip – the two blocks slide in opposite directions (horizontally), resulting in sideways movement of roads and rail lines
- normal – the two blocks are initially pulled away from each other, allowing one block to slip down and the other to slip upwards.

Tectonic plates become stressed by the pressure of colliding neighbouring plates or by movement of the mantle below them. Energy is released by this sudden and very violent movement of the crust. This energy is then released via an earthquake, which can have a variety of effects on the landscape.

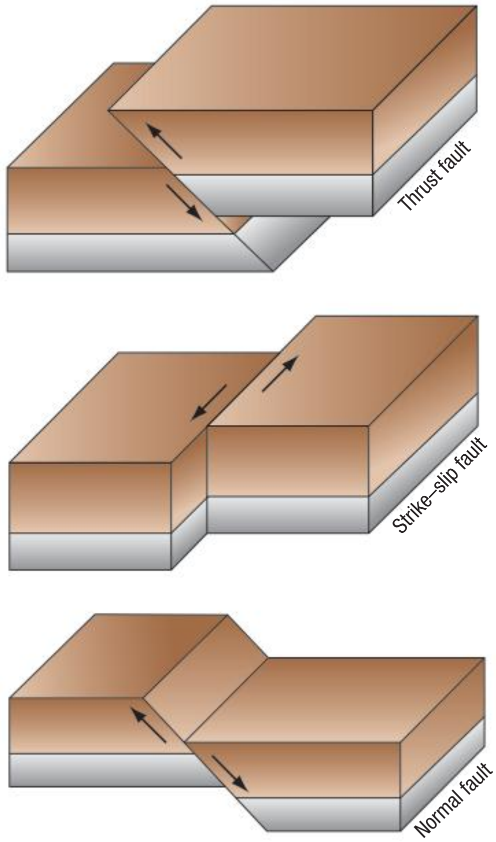

Figure 8.24 Types of faults

divergent boundary
the border at which new crust is being formed as the plates pull away from each other

convergent boundary
the border at which crust is destroyed as one plate moves beneath the other

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

fault
a fracture or line of weakness in the Earth's crust

Earthquakes

The energies required to slide a crustal plate below another are immense. We see what a little bit of this energy can do when built-up energy is released as earthquakes. These disturbances occur when energy is generated by rocks breaking suddenly or if there is an explosion. This energy travels as seismic waves either through the ground (body waves) or across the surface. Body waves are either transverse (**S wave**) or longitudinal (**P wave**). Other S waves you might be familiar with are sea waves. Sound or vibrations are examples of P waves. The S and P waves travel through the Earth at different speeds. P waves travel faster than S waves and are usually the first waves to be recorded by a seismograph.

Earthquakes are caused when the energy is released at a point (focal point) between two crustal regions moving against, past or over one another (fault lines). Energy released in an earthquake travels as seismic waves, which cause the ground to move as they pass through it. The point directly above the focal point on the surface of the Earth is called the **epicentre**.

S wave
a transverse earthquake wave that travels through the interior of the Earth

P wave
a longitudinal earthquake wave that travels through the interior of the Earth

epicentre
the location on the surface directly above the site of an earthquake

ISBN 9780170231503

WEBLINK
Continental drift and plate tectonics

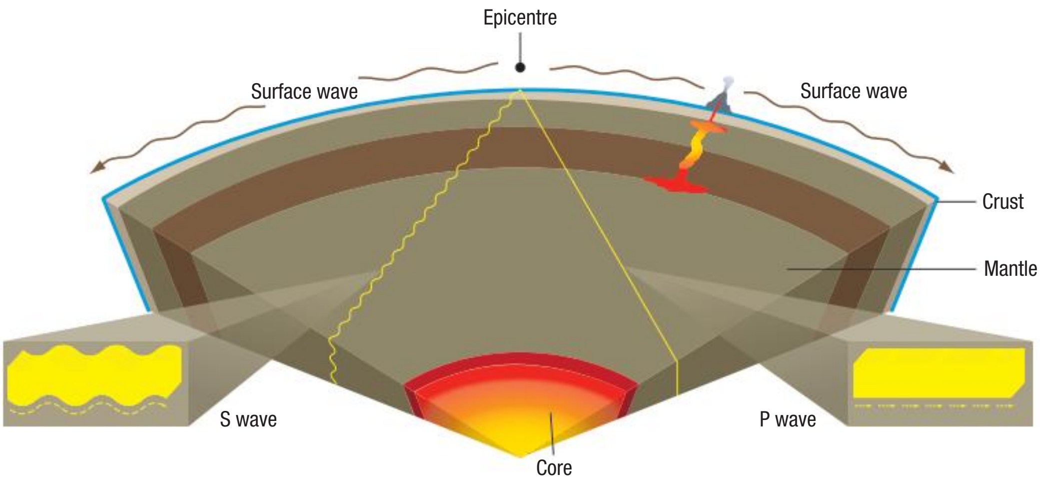

Figure 8.25 Seismic P and S waves

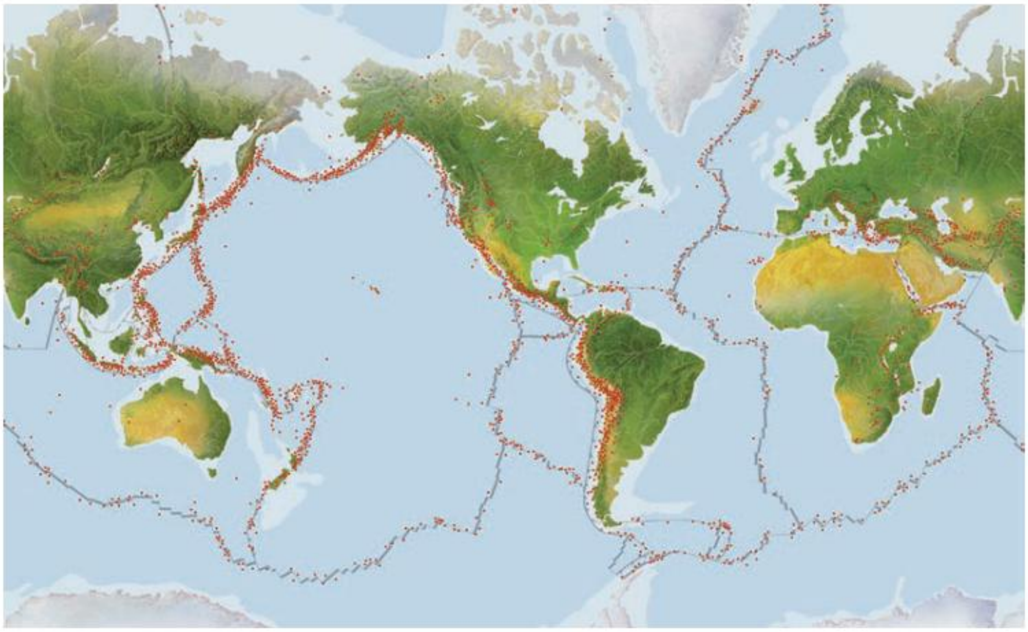

Figure 8.26 Seismic activity around the world. Each of the coloured dots represents points of volcanic and earthquake activity.

ACTIVITY SHEET
P and S waves with a slinky

ACTIVITY SHEET
Build a seismograph

WEBLINK
Submarine arc volcanism

Figure 8.26 shows earthquake activity (seismicity) around the Pacific Rim and along other plate boundaries. Circling the Pacific Ocean is a huge ring of volcanic and subduction zones called the Pacific Ring of Fire. 'Fire' refers to the volcanic activity that is prevalent on the surface, as well as below the sea.

Plate boundaries have more seismic activity than regions located in the middle of tectonic plates. Earthquakes do occur in the middle of tectonic plates in these regions, but they are usually very small and often go unnoticed.

There is a high degree of seismic activity in the Asia–Pacific region in Figure 8.26. Australia lies in the middle of the Indian–Australian tectonic plate, well away from the plate boundaries. This location provides a very stable region. Compare this to New Zealand, Japan and Indonesia, all of which lie on or are very close to plate boundaries (see Figure 8.27). These countries experience regular seismic and volcanic activity.

Volcanic activity can also produce earthquakes. These are usually less violent than those generated when fault lines rupture, but cataclysmic eruptions can generate destructive seismic activity.

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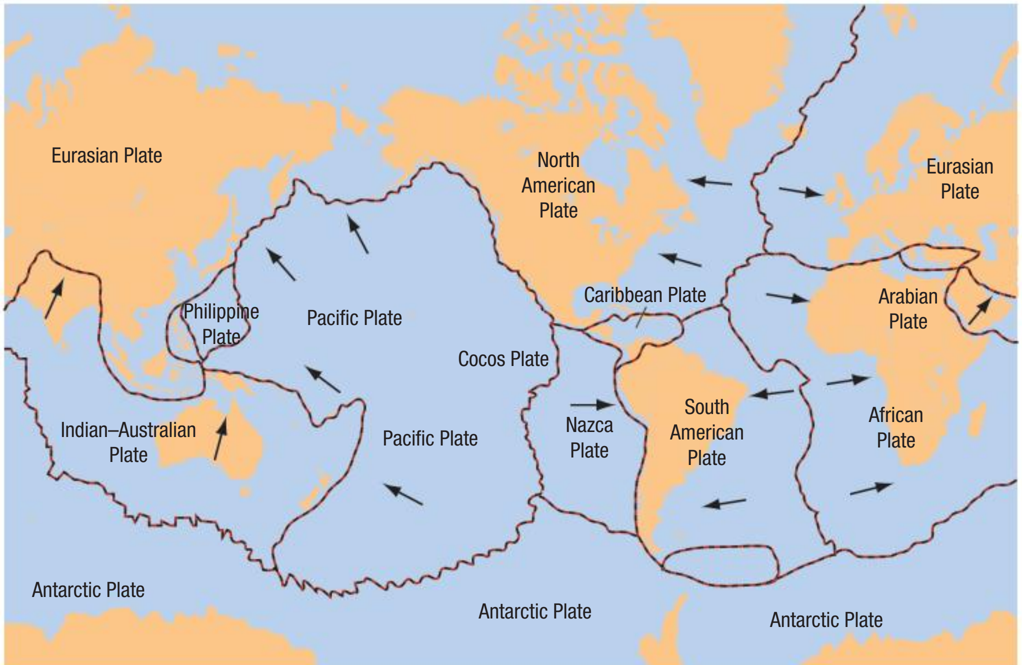

Figure 8.27 Tectonic plate movements. Australia lies in the middle of the Indian–Australian Plate.

VIDEO
Earthquake in Pakistan

VIDEO
Farming in the Philippines

WEBLINK
Seismic array Australia

WORKSPACE
Eruption!

ACTIVITY 8.10

Eruption!

Suppose a cataclysmic eruption happened today where you live. Assume you survive. Complete a W chart to **describe** what it would look, sound, feel, smell and taste like.

WEBLINK
Visualising Christchurch, NZ, earthquakes

On 4 September 2010, Christchurch in New Zealand experienced a 7.1 magnitude earthquake, followed by numerous smaller quakes. On 22 February 2011, there was a 6.3 magnitude earthquake followed by another 6.3 quake on 13 June 2011.

On 23 December 2011, an initial 5.8 magnitude earthquake was followed by a series of 5 and 6 magnitude quakes.

The violent shaking in these earthquakes caused **liquefaction**, which resulted in an increase in water pressure in the ground and soil particles moving. The ground literally turned into liquid mud and lost the ability to support heavy objects. Building foundations could no longer support the weight of the building. Many damaged buildings toppled over, and others have had to be demolished.

liquefaction
the release of water within the soil, turning the ground into liquid mud

Corbis/NZPA/Xinhua Press

Figure 8.28 The violent shaking of the earthquake in Christchurch, New Zealand, in 2011 caused water to be released from the soil. This liquefaction turned the soil into mud, which was unable to support the weight of this car.

ISBN 9780170231503

WORKSPACE
Earthquakes

ACTIVITY 8.11

Earthquakes

1 **Investigate** the scales used to measure earthquakes.

2 Research what life is like after an earthquake. Choose a recent earthquake and **describe** how long it took for the area to recover. **Define** what you mean by 'recover'. **Outline** the effects earthquakes have other than the physical damage. You might like to visit some of the social media that occurred at the time.

Tsunamis

tsunami
a series of 'waves' caused by an undersea earthquake or volcanic eruption

Tsunamis are waves usually generated by the sudden movement of the seafloor or, on rare occasions, by huge landslides or meteorite impacts into the ocean. The Japanese word 'tsunami' derives from *tsu*, meaning 'harbour', and *nami*, meaning 'waves'.

Tsunamis, like all waves, have a crest, a trough, a wavelength (distance between successive crests), an amplitude, a frequency and a velocity (see Chapter 7). These properties are not like those of a usual wind-generated wave. The wavelength of a tsunami is extremely long. Normal ocean waves are measured in metres. The wavelength of a tsunami is measured in kilometres. The speed of a tsunami can be up to 950 km/h compared with ocean waves of 90 km/h.

WEBLINK
Tsunami: How does it go so fast?

VIDEO
What caused the earthquake?

As a tsunami reaches the coast, ocean depth decreases, the wave slows down and its height increases.

On 11 March 2011, a tsunami hit Japan. The land along the coast of Japan near the epicentre of the earthquake dropped down. This had the effect of lowering the sea walls that were designed to protect the coastal populations from any tsunamis. A combination of a lowering of the land due to the earthquake and the close proximity to the epicentre resulted in a large loss of life and destruction. The magnitude 9 earthquake on 11 March 2011 that struck Japan shortened the Earth's day by 1.8 microseconds and increased the planet's wobble.

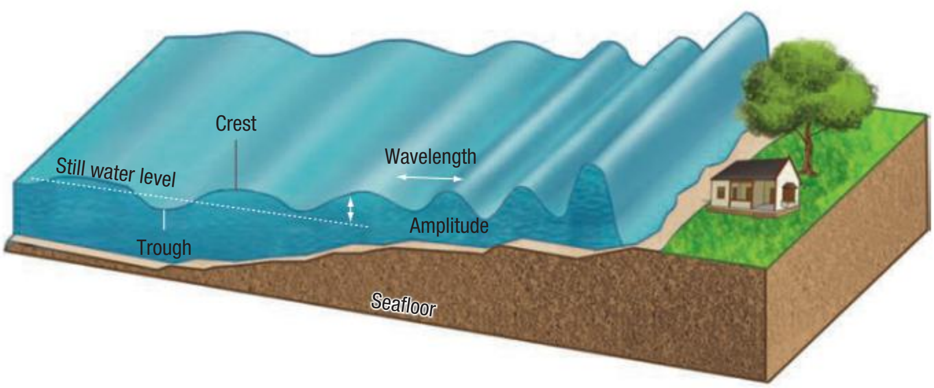

Figure 8.29 As a tsunami reaches the coast, where water depth decreases, the wave slows down and its height increases.

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WOW! Boxing Day tsunami

On 26 December 2004, a tsunami off Sumatra, Indonesia, killed an estimated 275 000 people. It became known as the Boxing Day tsunami. It was triggered by an underwater earthquake of 8.9 magnitude after a 1200 km section of the Earth's crust shifted under the Indian Ocean. The energy released was greater than the energy of 23 000 atomic bombs.

WEBLINK
Japan earthquake and tsunami

Volcanoes

Volcanoes are breaks or ruptures in the Earth's crust, which allow magma to escape its confines deep within the upper mantle. Magma is extremely hot rock that contains gases. As the magma reaches the surface and the pressure decreases, the gases are released. As the magma reaches the surface, it becomes **lava**.

lava
extremely hot rock that has come up to the surface of the Earth

If we want to understand the geology deep below a volcano, we could analyse the lava that comes out of it. Lava is classified into four types (Table 8.1, page 296) depending on its composition, mainly by how much silicon dioxide, SiO_2 (silica), it contains. Silicon is the second most abundant element on the planet.

Shutterstock.com/Manamana

Figure 8.30
A volcano in Indonesia

Volcanic activity creates land by extending islands, such as Iceland and the Hawaiian islands. Sometimes volcanoes blow themselves up, as Mount St Helens did, in Washington State, USA, in 1980. Volcanoes have, and will, affect the planet's climate through eruptions that change CO_2 levels and reduce sunlight reaching the planet's surface.

The Volcanic Explosivity Index (Figure 8.31) provides a relative measure of the explosiveness of volcanic eruptions. The index ranges from 0 (non-explosive) to 8 (very large explosion). The eruption of Mount St Helens in 1980 was a 5 on this scale. Eruptions of this size occur about once every 10 years. Krakatoa (1883) and Pinatubo (1991) rated 6 and Tambora (1815) rated 7. Eruptions of these size occur on average once every 100 and 1000 years respectively.

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Table 8.1
Classification of lava

Amount of silica	Name	Description
More than 63%	Felsic	Very viscous, the lava is thick and flows slowly. This type of lava is dangerous as it traps gases, which suddenly burst from the lava, showering the surrounding volcanic cone with hot lava.
Approximately 53%	Andesitic	Found in volcanoes along convergent boundaries where a tectonic plate is being subducted; for example, Mount Merapi in Indonesia.
45–52%	Mafic	Contains more magnesium (Mg) and iron (Fe). Mafic lava is less viscous than felsic lava so it flows more easily and is less explosive as gases are released more gently.
Less than 45%	Ultramafic	Rare, was flowing during the Proterozoic eon 2500 to 542 million years ago.

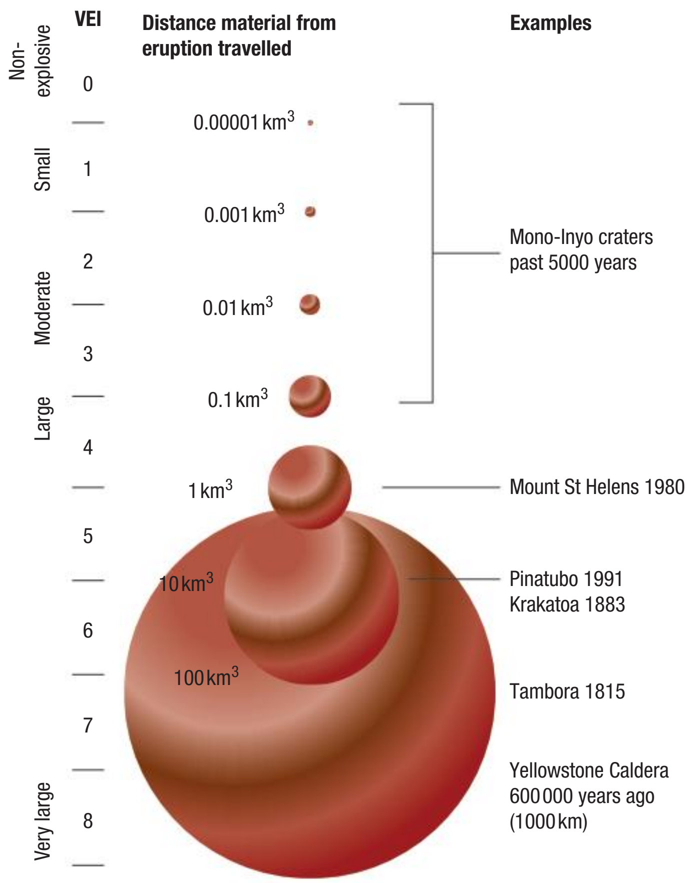

Figure 8.31
The Volcanic Explosivity Index (VEI): 0 is non-explosive and 8 is a very large explosion.

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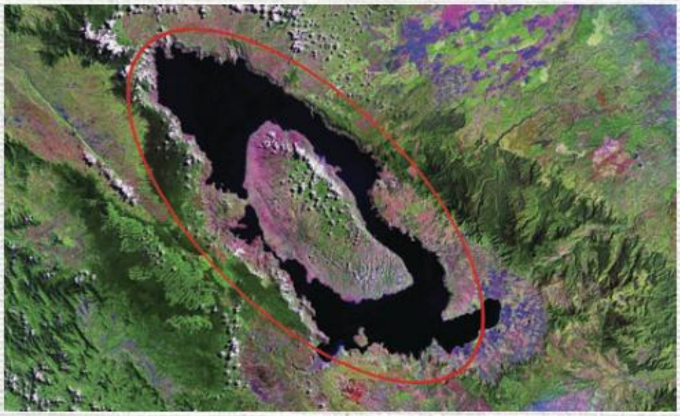
WOW! Super volcanoes

The last super volcano to erupt was Toba (circled in red) in Sumatra, Indonesia, 74 000 years ago. It was 10 000 times bigger than Mount St Helens in the USA.



Getty Images/Science Photo Library

WEBLINK
Mt St Helen eruption

QUESTIONS 8.5

What have you learnt?

Understanding

1 **Identify** the source of energy that moves crustal plates.

2 **Outline** why there are many more volcanoes situated near subduction zones than elsewhere on crustal plates.

3 **Discuss** why Australia has very few earthquakes compared to New Zealand.

4 **Identify** the direction and **recall** the speed of movement of the Indian–Australian plate.

Applying

5 There is a quick way to determine the distance from a location to the origin of a seismic wave less than 200 km away. Take the difference between the arrival times of the P wave and the S wave in seconds and multiply this by 8 km/s. **Outline** how you would **distinguish** a P wave from an S wave.

6 **Evaluate** the type of land you would build on in an earthquake-prone location.

Analysing

7 **Explain** the effect that one natural disaster has had on the crust and on human society.

8 **Analyse** the difficulties that occur when a massive meteor strikes a major city. In your analysis include how individuals, emergency services and governments might react.

WORKSPACE
What have you learnt? 8.5

ISBN 9780170231503

QUESTIONS 8.5

Evaluating

9 **Evaluate** the effect that a tsunami the size of the one that struck Japan in 2011 would have on the area where you live. Include the effect on people, buildings and the local environment.

Creating

10 Create a flowchart to **show** how one group of people should react in the event of a major disaster.

11 Create a poster for an area such as Christchurch in New Zealand, warning of a potential disaster.

Reflecting

12 A large amount of money is being spent on disaster warning systems. **Describe** how one system works and **justify** the expense.

8.6 Technology for survival

It is estimated that earthquakes and volcanic eruptions have been responsible for 1 million deaths in the last 100 years. If we could have predicted and prepared for their occurrence, then the death rate would have been reduced considerably. Building with safer building materials and methods will further save lives.

The Japanese earthquake and the subsequent tsunamis on 11 March 2011 would have killed more than the estimated 20 000 people if it had not been that Japan was the most prepared country in the world for such events. In Japanese communities there are both fire and earthquake drills. Sea walls have been built to hold back tsunamis. Strict building codes are enforced to minimise earthquake damage and extensive monitoring of seismic activity gives authorities time to predict earthquakes and evacuate people if needed.

Mapping continental movement

Scientists know the tectonic plates are moving, but how fast and in what direction? Scientists can measure precisely points on the planet's surface, separated by very large distances. If the points move, the separation distance can be measured.

Scientists use the global positioning system (GPS) of 30 satellites to take repeated measurements between multiple points along fault lines and so determine if the plates are moving. The satellites continuously send radio signals back to ground receivers. These receivers have computers that calculate the position of each point on the fault line. The receiver needs a minimum of three satellite signals, but if it has four it can determine a point on the fault line's height (altitude). If there is movement along a monitored fault line, the GPS system will record it. The plate boundary observations are precise to within 1 to 2 mm.

Ground-based measurements using laser equipment are also used, but the size of the areas being measured makes the GPS method more suitable.

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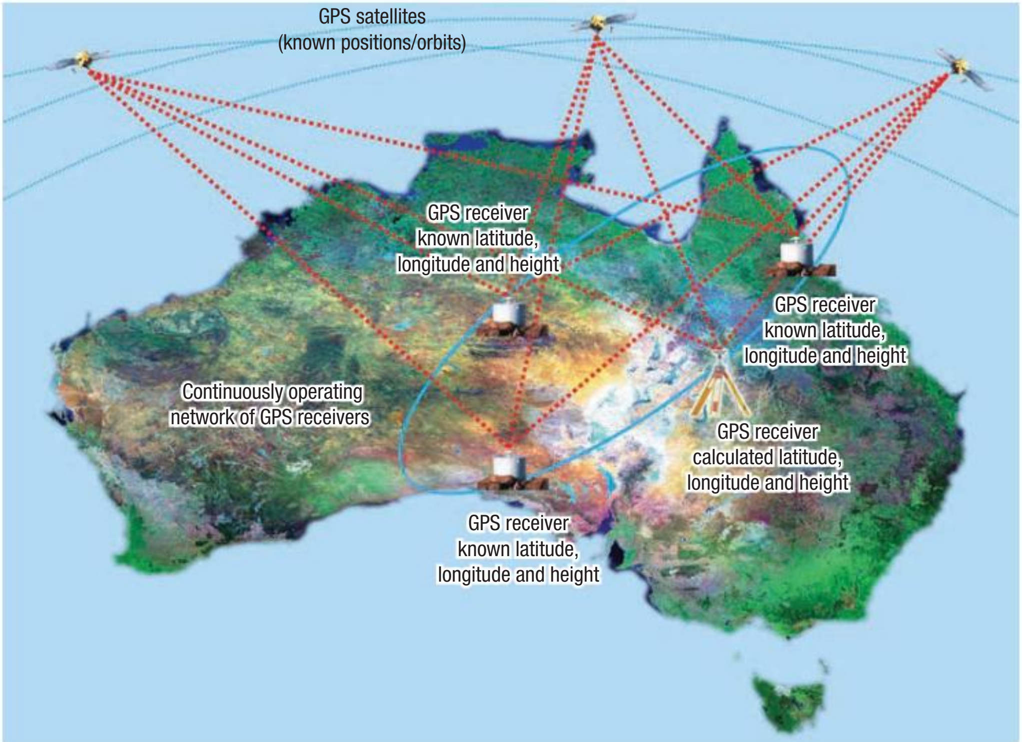

Figure 8.32
The global positioning system is used to monitor tectonic plate movements.

Australia is on the Indian–Australian tectonic plate (see Figure 8.27, page 293). This plate is moving north-east at a rate of 73 mm each year. Australia has little seismic activity due to its central position on the plate. New Zealand lies across the converging boundaries of the Indian–Australian and Pacific plates (Figure 8.33). This collision of the continental plates through central New Zealand has resulted in a combination of strike–slip and uplift motion with horizontal motions of 40–55 mm per year along the plate boundary. This situation means New Zealand experiences large earthquakes, volcanic activity and rock and landslides.

Figure 8.33
New Zealand's position across a plate boundary

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Building better structures

Investigations into new materials and building methods and explanations about disasters are highlighted in the news media after devastating natural disasters such as the Japanese and New Zealand earthquakes.

Local advances in building safer structures can be unique and the news media can help spread this information.

The Taipei 101 building in Taiwan has a unique way of reducing the effects of strong winds. It has a mass damper – a 660 tonne steel ball suspended from the 93rd to the 88th floors – that moves to offset the swaying of the building.

Shutterstock.com/punksid

Figure 8.34 The Taipei 101 building is built to withstand typhoons and earthquakes.

WORKSPACE
Web search

ACTIVITY 8.12

Web search

Conduct a web search using 'news media reports scientific advances in earthquake building' as your search words. **Summarise** and **analyse** the results that you get for the first 20 hits. Were they relevant to the search? Create a table to display your results.

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ACTIVITY 8.13

Sea wall defence

Japan's sea wall defence against tsunamis failed and scientists are evaluating why. Use the weblink to answer the following questions.

1 **Propose** reasons why Japan's sea wall failed.

2 **Explain** why a sea wall could minimise the impact of a tsunami on the shoreline.

WORKSPACE
Sea wall defence

WEBLINK
World's deepest breakwater failed to stop tsunami

ACTIVITY 8.14

Building for the Big One

1 Visit the weblink and use the online earthquake simulator to **design** a building to survive an earthquake. **Outline** the factors you determined were important.

2 Based on all of the information that you have read, **describe** where you think the safest place in the world would be to **construct** a building. Imagine that you are a property developer in this area. Create an advertising campaign to highlight the area's safety and **outline** why it is an ideal place to live.

WORKSPACE
Building for the Big One

WEBLINK
Quake simulator

QUESTIONS 8.6

What have you learnt?

Remembering

1 **Explain** why people are developing disaster-warning systems.

Understanding

2 **Describe** how one possible disaster warning system works.

3 **Outline** reasons why the GPS system has been useful in understanding the movement of tectonic plates.

Applying

4 **Describe** how a sea wall defence system works. **Critically analyse** whether this would be useful for a city such as Sydney.

WORKSPACE
What have you learnt? 8.6

ISBN 9780170231503

QUESTIONS 8.6

5 **Evaluate** the type of disaster warning systems that would be most suitable for Australia.

Analysing

6 **Outline** how Japan prepared for the tsunami in 2011. **Explain** what other countries can do to be as prepared. Add your ideas to the class wiki.

Evaluating

7 Which has more power to change the planet – earthquakes or volcanoes? **Justify** your opinion.

Creating

8 Imagine you are at the beach and a friend asks what they would see if a tsunami was about to arrive. **Describe** what your friend might see.

9 Create a model that **compares** the effect that an earthquake would have on a rigid building with the effect it would have on a building designed to withstand movement. Present your model to the class.

Reflecting

10 **Describe** your thoughts about the information that you have learnt in this unit. What are three things that have surprised you?

11 **Critically analyse** whether the city of Christchurch New Zealand could have better prepared for an earthquake. In your answer **describe** whether things such as building codes could have been changed.

12 **Analyse** how a disaster such as the San Francisco earthquake of 1906 was affected by the structure of the city.

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Chapter review

Remembering

1 **Identify** reasons why the Earth is said to be 'dynamic'.

2 **List** the different layers of the Earth.

3 **Describe** some pieces of evidence for the theory of plate tectonics.

4 **List** some of the natural disasters that have affected the planet in the last 10 years. **Outline** how each has affected people and the environment and the ecosystem.

Understanding

5 **Describe** the forces of nature acting to change the surface of the planet.

6 Deep within the Earth, heat energy is generated by a process called nuclear fission. **Compare** and **contrast** how this process is different from nuclear fusion.

7 **Clarify** why objects as large as continents float.

8 There are three types of boundaries where tectonic plates collide. **Recall** and **describe** each one.

Applying

9 Tectonic plates are being subducted along the boundaries of other plates. **Explain** why you would find volcanoes along this type of boundary.

10 The edge of the Pacific Ocean is often referred to as the 'Pacific Ring of Fire'. **Justify** the use of this term.

Analysing

11 Imagine that the Earth's magnetic field disappeared. **Explain** how this might occur and **extrapolate** the potential consequences.

12 On a trip to the mountains, you find large deposits of limestone (from the remains of seashells). **Explain** how this type of rock could have been deposited so high up above sea level.

13 **Analyse** why building codes in Australia might be different from those in Japan.

14 **Describe** why an earthquake such as the one in Newcastle in 1989 caused so much destruction.

WORKSPACE
Chapter 8 review

ACTIVITY SHEET
Chapter 8 checklist

REVIEW QUIZ
Chapter 8

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Evaluating

15 Complete the paragraph.

'For millions of people, living on the Pacific Ring of Fire means . . .'

16 The media often sensationalises large disasters and reflects on whether the effects of these disasters can be reduced. **Outline** whether natural disaster can be totally avoided.

17 **Compare** and **contrast** the types of disasters that mostly affect Australia with those in a country in the northern hemisphere. **Describe** why the disasters in Australia might differ from those in the northern hemisphere.

18 Seismic activity is an indication of a number of events. **Describe** the destruction you might see in your city or town if there were a magnitude 9 earthquake.

19 Population growth has meant that people are living closer to volcanoes. **Predict** the impact on humans if a volcano in Indonesia were to erupt and send out 100 km^3 of ash into the atmosphere. **Discuss** the rescue limitations.

Creating

20 Create a checklist that a country such as Japan could make available to its citizens to assess the possibility of a tsunami.

21 **Synthesise** your knowledge to **outline** the building materials and systems you might use to **construct** earthquake proof homes in Christchurch, New Zealand.

Reflecting

22 Can humans ever control the movement of the Earth's crustal plates to prevent the mass destruction of towns and cities and the death of tens of thousands of people? **Explain** your answer.

23 Do you expect there will be more earthquakes and volcanic eruptions in the future or will the number of these events decrease or remain about the same? **Justify** your answer.

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Appendices

How to write a scientific report

The main purpose of writing a scientific report is to communicate the results of your experiment. There is a standard format for scientific reports. Each of your reports should include: Title, Introduction, Aim, Hypothesis, Materials, Method, Results, Discussion, Conclusion, References and Appendices if required.

All scientific reports are to be written in past tense and in the third person. For example, it should be 'It was found that the iron nail rusted the fastest', not 'We found that the iron nail rusted the fastest', or, 'Sanja and I found that the iron nail rusted fastest'.

Your school or science teacher may ask you to write your reports in a different style (for example, often the Introduction is not required, except for Student investigations).

The features of a scientific report

At the top of your scientific report, include the date, your name, and the name(s) of your partner(s).

Title

The title should be less than 10 words long and be descriptive of the aim of the experiment. For example, 'Comparing the rate of corrosion of different metals', rather than 'Rusting metal!'.

Abstract

(This may be optional in your school at Year 9.)
This is a summary of your investigation – sort of the who, what, when, where, how and why. It includes about one sentence per feature – Aim, Hypothesis, Materials, Method, Results, Discussion and Conclusion. The abstract always comes first, but is written last. In a scientific journal, it provides a summary so researchers can decide if it is what they are interested in reading.

Introduction

This section may be optional at your school, but is important for student investigations. This is where you supply background information to the reader and define any scientific terms in your report, such as 'elasticity'. It also provides some detail of previous related work or a reason for the experiment. You must supply references for the sources of your information provided here.

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Aim

State the purpose of the experiment; what is being investigated. It should reflect the title.

Hypothesis

State your predicted outcome for what you are testing. Write it in the format 'If …, then …'. For example, 'If the water temperature is increased, then the rate of corrosion will increase'.

Materials

This section provides a list of the quantity and type of material that you used to conduct the experiment. Remember that you are not suggesting any possible choice here because others must be able to repeat your experiment exactly and get the same results. Therefore, you cannot list options, such as 'a few pieces of stretchy material'.

Method

This is the numbered step-by-step instructions detailing how to repeat your experiment. Remember that you are not suggesting any possible choice here because others must be able to repeat your experiment exactly and get the same results. In some cases you may find it appropriate to include a labelled diagram of the set-up.

Results

In this section, present all observations (qualitative) and measurements (quantitative) here. Present your results in written, full sentences as well as in summary tables and graphs where possible. Do not double up by presenting the same data in two different ways. Be sure to clearly label all tables and graphs with titles and label axes and units on graphs. Raw data can be saved for an Appendix. There should be writing in this section; not just data. You may state observations and summarise any trends. Remember, do not interpret any of your results here or draw conclusions. For example, you may state that iron rusted the fastest and gold rusted the slowest, but don't try to explain why.

Discussion

This is where you discuss your results, so refer back to the data and trends and then try to explain them. Interpret your results here. Relate any unexpected results perhaps to errors during the experiment or other explanations. Discuss any problems with the experiment and how to improve it for future research. You can tie in any background information here that you presented in your Introduction. For example, you may have found the same results as previous researchers, or your results may be different. Besides interpreting your results, one of the most important aspects of your discussion is to describe how your experimental findings can be applied in the real world. What are the applications of your findings? What should future researchers explore?

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Conclusion

This is brief and refers back to your aim; in the end, what did you find?

Bibliography/References

Acknowledge resources if applicable.

Appendix

If required, raw data or series of photographs can be included here.

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An example of a scientific report

Growing tomato plants with fertiliser

What are the risks in doing this investigation?	How are you going to manage these risks to stay safe?
Potting mix contains fungal spores that could be harmful to health.	Wear gardening gloves when using potting mix, and only use potting mix in well-ventilated areas.

Aim

To investigate the effect of fertiliser on the rate of growth of tomato plants

Hypothesis

If a tomato plant has fertiliser added to the soil, then it will grow more quickly.

Materials

- 6 tomato seedlings
- 6 small rectangular pots, each measuring 4 cm × 4 cm × 6 cm
- potting mix
- 100 mL measuring cylinder
- water
- fertiliser (Aquasol)
- electronic balance
- 30 cm ruler (showing millimetres)

Method

1. Fill each pot with the same type and amount of potting mix.
2. Plant one tomato seedling into each pot.
3. Measure and record the height of each seedling to the nearest centimetre. (These are the heights on day 0.)
4. Sprinkle 10 g of fertiliser onto the soil of three of the pots. Label these pots clearly.
5. Water each pot with 20 mL of water each day.
6. Measure the height of the seedlings (in centimetres) every second day.
7. Repeat step 6 for 2 weeks.

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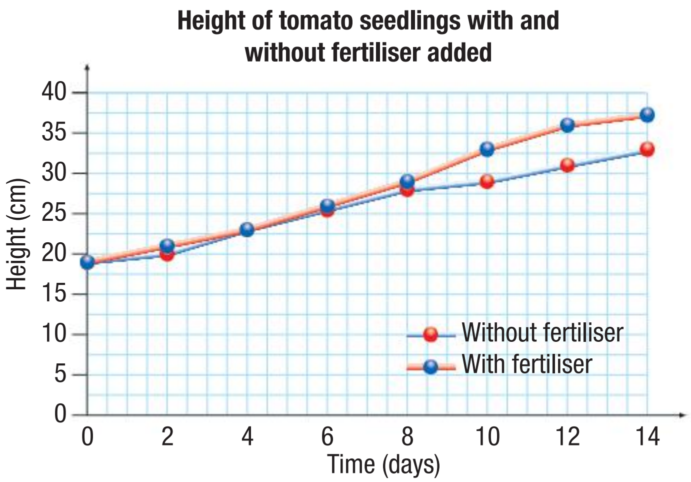
Results



Height of tomato seedlings with and without fertiliser added

Discussion

Six tomato seedlings were grown under identical conditions, except that 10 g of Aquasol fertiliser was added to the soil of three plants. Results showed that the tomato plants that received the fertiliser grew 4 cm taller than the ones that did not. At weekends, neither plants received any water. As this affected all plants equally, the final results would not have been affected. Any future investigations of this type should include more plants under each condition. This would provide more data and also prevent problems arising if any of the plants died during the experiment.

Conclusion

Results from this experiment support the hypothesis that tomato plants with fertiliser added to their soil grow more quickly.

Appendix

Time (days)	Average height of tomato plants (cm)	
	Without fertiliser	**With fertiliser**
0	19	19
2	20	21
4	23	23
6	26	26
8	28	29
10	29	33
12	31	36
14	34	38
Total increase in height (cm)	15	19

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How to write a bibliography

Whenever we do research it is very important that we acknowledge where we get our information from. We can do this by including information about the source in a bibliography at the end of our report or assignment.

In a bibliography we list each source in alphabetical order by the author's surname. If there is no author, the title is used instead, ignoring the words 'A' and 'The'.

The information below shows the information needed, and the order in which it is listed, for different types of resources.

Books

Author's surname followed by their initials
Year of publication in brackets
Title in italics or underlined
Edition (if relevant)
Publisher and the place of publication
(If the author is unknown, put the book title first.)
For example:

Denning, A. (1994) *The craft of woodcarving*, Sandstone: London.

Encyclopaedia (printed)

Title of article in single quotation marks
Year of publication in brackets
Title of encyclopaedia in italics or underlined
Volume number
Publisher and place of publication
Page number(s)
For example:

'Minerals in Australia' (1996) *The World Book Encyclopedia,* Vol. 6, World Book: Sydney, p. 308.

Encyclopaedia (online)

Title of article in single quotation marks
Year of publication
Title of encyclopaedia in italics or underlined
[Online]
<URL address>
[Date accessed in square brackets]
For example:

'Jupiter' (2006) *Encyclopaedia Britannica Online School Edition* [Online] <www.school.eb.com.au/all/comptons/article-9345009> [accessed 10/11/2006].

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Journals, magazine or periodicals (printed)

Author's surname followed by their initials
Year of publication in brackets
Title of article in single quotation marks
Title of magazine or journal in italics or underlined
Volume number if relevant
Issue number if relevant
Page number(s)
For example:

Choi, C. (2003) 'Cleaner living', *Scientific American,* Vol. 289, No. 5, p. 32.

Journals, magazines or periodicals (online)

Author's surname followed by their initials
Year of publication in brackets
Title of article in single quotation marks
Title of magazine or journal in italics or underlined
Volume number if relevant
Issue number if relevant
Page number(s)
[Online]
<URL address>
[Date accessed in square brackets]
For example:

Coghlan, A. (2003) 'GM crops can be worse for environment', *New Scientist.com* [Online] <www.newscientist.com/hottopics/gm/gm.jsp?id=ns99994283> [accessed 9/1/2013].

Newspaper

Author's surname followed by their initials
Year of publication in brackets
Title of article in single quotation marks
Title of newspaper in italics or underlined
Date
Page number
For example:

Shaw, P. (1996) 'Mining shares drop', *The Age,* 31 August, p. 1.

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Internet

Author's surname followed by their initials (if identified)
Last update (if identified) in brackets
Title of article in italics or underlined
Sponsor name
[Online]
<URL address>
[Date accessed in square brackets]
For example:

Ward, C. (2004) *Australian bush fires burn on*, Disaster Relief, [Online] <http://disasterrelief.org/Disasters/020104Austfires4> [accessed 10/1/2013].

Audiovisual materials

Title in italics or underlined
Year of publication in brackets
[Type of media in square brackets]
Publisher and place of publication
For example:

Diet and Health (1997) [videocassette] Classroom videos: Melbourne.

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Glossary

abiotic a non-living part of the environment or ecosystem

abundance how many organisms there are

acid a substance that produces hydrogen ions in solution; acids neutralise bases

acid rain rain that has sulfur dioxide, carbon dioxide and nitrogen oxides

action potential a 'wave' of electrical charge passing along a neuron

all-or-nothing response a response that either happens or it doesn't

alpha particle the helium nucleus emitted when an unstable larger nucleus decays

amplitude (*A*) the maximum height of a wave from its rest position

anaerobic without oxygen

analogue continuous signal

antibiotic extract from fungus that is capable of killing disease-causing bacteria

antibody a specialised protein found in the plasma that binds to an antigen

antidiuretic hormone (ADH) a hormone responsible for the reabsorption of water from the nephron into the bloodstream

antigen a substance that is foreign to the body and causes an immune response

apnoea a suspension of breathing

aquatic living in water

arteriole a small artery

artery a thick, elastic blood vessel that branches out from the heart, carrying blood at high pressure and volume to major organs and appendages (legs and arms)

atom the fundamental particle of matter, made up of protons, neutrons and electrons

atomic number (*Z*) a number that is equal to the number of protons in the nucleus (and is the same for every atom of that element)

atomic weight the mass of protons, neutrons and electrons that make up an atom

axon the neuron extension that conducts impulses away from the cell body

bacteria single celled organisms, some of which cause disease

base a substance that forms hydroxide ions, oxide ions or carbonate ions in solution; bases neutralise acids

base station an antenna at the centre of a mobile phone network

beta particle an electron or positron (which has the same mass as an electron but the opposite charge) emitted when an unstable nucleus decays

biomass the total mass of living things

biome a collection of ecosystems with similar biotic and abiotic factors

biosphere the land, water and gas around Earth that is habitable by living organisms

biotic a living part of the environment or ecosystem

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Bowman's capsule the part of the kidney that contains the glomerulus and filters small molecules out of the blood

bradycardia an abnormal slowing of the heart rate, seen in diving marine mammals

capillary a minute blood vessel that extends throughout tissues, from which materials can be exchanged with cells by diffusion

capture–mark–recapture method a method for estimating populations of mobile organisms like animals

carnivore an organism that feeds solely on animals

cell a separate area of land serviced by a base station

cell body the enlarged part of a neuron that contains the nucleus

cellular respiration a series of chemical reactions that release chemical energy (and water and carbon dioxide) from nutrients for use by an organism

central nervous system (CNS) the brain and spinal cord

chain reaction a reaction that is self-sustaining as a result of one step starting another step

chemical reaction a reaction in which a new chemical is formed

chlorophyll the green photosynthetic pigment in chloroplasts of plants

cilia hair-like projections from the surfaces of some cells that by beating together cause cell movement or push external fluids

combustion a chemical reaction in which a fuel reacts with oxygen and produces heat as one of the products

commensalism a close physical relationship between species in which only one benefits and the other is not harmed

communication conveying a message from a sender to a receiver

community a collection of organisms (different species) in one place

competitors organisms that require the same resources from the same habitat

conduction the transfer of energy through a solid object

conductor a substance through which heat travels easily

consumer an organism that must consume other organisms to gain chemical energy; also known as a heterotroph

convection transfer of energy through a gas or fluid

convection current a movement of hot material upwards towards cooler regions where it cools and sinks again

convergent boundary the border at which crust is destroyed as one plate moves beneath the other

convergent moving towards, coming closer

cortex the dark outer part of the kidney that is rich in glomeruli

crest the point at which a wave is at its maximum upwards value

cryogenic at very low temperature

cyanobacteria blue-green algae or bacteria

dead zone an area where microwave radiation cannot penetrate so no mobile phone reception is available

deciduous forest a forest in which a majority of the trees lose their foliage at the end of the typical growing season

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decomposer a micro-organism, such as a fungus or bacterium, that breaks down dead matter

decomposition a chemical reaction in which a more complex substance (compound) is broken down into simpler substances

dendrite the branching neuron extension that brings impulses towards the cell body

denitrifying bacteria bacteria that break down nitrogen compounds, producing nitrogen gas

density mass of a substance in a specific volume, measured in kg/m^3

desert a landscape that receives less than 250 mm precipitation or rain annually

deuterium an isotope of hydrogen with one proton and one neutron

diffusion passive movement of molecules from regions of higher concentration to regions of lower concentration

digital discrete packages of data

discontinuity a change in regions within the Earth

disease any condition that interrupts the normal organ or body function

distribution where organisms live

divergent moving away from

divergent boundary the border at which new crust is being formed as the plates pull away from each other

double displacement reaction a reaction in which two compounds react to form two new compounds

dynamic constantly changing, energetic in nature

ecosystem a community of organisms and the non-living environment in which they live

effector a structure or organ that brings about a response, e.g. muscles and glands

electromagnetic radiation (EMR) energy that travels as waves and moves at the speed of light

electromagnetic spectrum the range of electromagnetic radiation classified according to frequency and wavelength

electron a negatively charged particle in the atom, which moves in space around the nucleus

endemic occurring only in a specific region

endocrine gland a gland without ducts that releases hormones straight into the circulatory system

endotherm an animal that generates heat to maintain its body at a constant warm temperature; also called warm-blooded

endothermic a chemical reaction that takes in heat energy

energy a fundamental quantity that can only be identified in terms of transfers from place to place or transformations from form to form

enzyme a biological catalyst; a protein that speeds reactions without being used up

ephemeral temporary, lasting only a short time

epicentre the location on the surface directly above the site of an earthquake

epicormic bud an area under tree bark that can sprout new growth if the tree is damaged

epidemic a disease outbreak that occurs suddenly in a region or group and affects more people than expected

epidermis a layer of tissue (usually one cell thick) on the surface of organisms

eutrophication an increase in the nutrient levels of waterways

excretory system a system that removes waste gases, heat and solutes from the body

exothermic a chemical reaction that releases heat energy

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extinct having no living members

extinction dying out, not existing any more

fault a fracture or line of weakness in the Earth's crust

feedback a system in which the response to a stimulus modifies the stimulus

feral having returned to the wild from being domesticated

fire-stick farming the Aboriginal practice of using fire to burn vegetation regularly in order to change the composition of plant and animal species in the area

fomite an inanimate object that is capable of passing on disease-causing organisms

food chain a single linear diagram that shows the way energy is transferred from producer to consumer

food web a group of food chains interlinked to show how energy is transferred through an ecosystem

force field a region of space where a force can act upon an object

fossil any evidence of an organism from a former geological time

frequency (*f*) the number of waves per second

geology the scientific study of the origin, history, structure and composition of Earth

glacier a river of ice and snow

glomerulus a network of capillaries inside the Bowman's capsule

glucagon a hormone that acts to increase blood sugar levels

grassland wide, open ecosystems dominated by low vegetation, particularly grasses

gravity the attractive force between two masses

greenhouse gas any gas that traps heat in the atmosphere

habitat the place in an environment where species are found in an ecosystem (such as soil, leaf litter, tree tops)

haemocyanin a transport protein in which oxygen is temporarily and reversibly held by copper 'haems', giving these organisms a bluish colour

haemoglobin a transport protein in which oxygen is temporarily and reversibly held by iron 'haems' giving these organisms a reddish colour

half-life the time it takes for half of an isotope to decay

herbivore an organism that feeds solely on plants

hertz (Hz) the unit of frequency; 1 Hz is one whole wave per second

homeostasis the process for maintaining the internal 'steady state' in an organism

hormone a chemical produced by a gland or organ that produces an effect on another part of the body

hydrocarbon a chemical compound that only contains carbon and hydrogen

hyperventilation an increase in depth or rate of breathing

immunity having biological defences against a specific disease

indicator a substance that changes colour under different acidic or basic conditions

infectious disease a disease caused by a pathogen and able to be passed on from one organism to another

inflammation a response of a tissue to injury characterised by increased blood flow to the damaged tissue

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insulator a substance through which heat travels poorly

insulin a hormone that acts to decrease blood sugar levels

interspecific competition competition between members of different species

intraspecific competition competition between members of the same species

invertebrate an animal that does not possess a backbone

irritant an agent (can be chemical, biological or mechanical) that causes a painful response

isotopes atoms with the same number of protons but a different number of neutrons

lava extremely hot rock that has come up to the surface of the Earth

lichen a composite organism that is made from a fungus and an alga

lignotuber a swollen root that helps some plants regrow after being burnt

liquefaction the release of water within the soil, turning the ground into liquid mud

loam soil with a mixture of sand, clay and organic matter

longitudinal along the length of an object (i.e. in the same direction as the wave)

loop of Henle a U-shaped part of the nephron that reabsorbs water from the glomerular filtrate

lymphocyte a type of white blood cell involved in adaptive immunity

lysozyme an enzyme found in mucus, urine, tears, saliva and other body secretions that kills harmful bacteria by rupturing their cell walls

macrophage a type of white blood cell that destroys invading particles by engulfing them

magma molten rock material located beneath the Earth's surface

magnetic field the region of space where a magnetic force acts on charged particles and other magnets

magnitude size, how big something is

malleable relating to metals, having the property that it can be hammered until it is a very thin sheet without breaking

mass number the total number of protons and neutrons in an atom; also known as atomic mass

medium the substance through which a wave moves

medulla the central or middle part of an animal organ such as the kidney

monomer a single unit, or molecule, that can bind together with similar units to form a polymer

mutualism a close physical relationship between species in which both benefit

mycorrhizae fungi that live symbiotically on plant roots, helping the absorption of nutrients

myelin sheath a fatty covering around the axon that insulates it; produced by Schwann cells

nanometre one-billionth of a metre

nanotechnology an emerging science that deals with developing materials or devices in the size range 1–100 nanometres (nm)

natural radioactivity the result of spontaneous disintegration of naturally occurring radioactive elements

negative feedback a process in which the response cancels or lowers the original stimulus

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nephron the functional unit of the kidney

nerve a bundle of nerve fibres (neurons)

neuron a single nerve cell

neurotransmitter a chemical that diffuses across synapses to transmit a message

neutralise to cancel out the effect of an acid by adding a base, or cancel out the effect of a base by adding an acid

neutron a particle found in the nucleus of an atom and does not have an electrical charge

neutrophil the most abundant type of white blood cell in mammals

niche the very particular place within the habitat, and the role in the environment in which an organism lives

nitrogen fixation the process of incorporating nitrogen gas from the atmosphere into compounds such as nitrates that can be absorbed by plants

nitrogen-fixing bacteria bacteria that incorporate nitrogen gas to form compounds such as nitrates that can be absorbed by plants

non-infectious disease a disease that cannot be transmitted directly from one organism to another

nuclear fission the splitting of a nucleus into two smaller pieces

nuclear medicine the branch of medicine that uses radioactive isotopes to diagnose, manage and treat diseases

osmosis the diffusion of water through a semi-permeable membrane

oxidation reaction a reaction of a substance with oxygen

P wave a longitudinal earthquake wave that travels through the interior of the Earth

pandemic when a severe disease outbreak is widespread, perhaps over continents or the world, or the incident rate increases greatly in a region

parasite any organism that lives on or in the body of another organism, the host, and gets its nutrition from the host without the host benefitting

parasitism a close physical relationship between species in which only one benefits and the other is harmed

pathogen a disease-causing organism, such as a bacterium or virus

period (*T*) the time for a particle to move through one complete wave cycle

peripheral nervous system all parts of the nervous system except the brain and spinal cord

pH a number that indicates how acidic or basic a substance is

phagocytosis the process in which a large cell extends its cytoplasm around a foreign object and draws it inside, later destroying it with enzymes

photoreceptor a specialised receptor that is sensitive to light; in vertebrate animals, the photoreceptors are the rods and cones in the retina of the eye

photosynthesis a series of chemical reactions in plants that convert light energy into usable chemical energy and produce glucose

pituitary gland an endocrine gland located in the centre of the brain

plate boundary the border between two tectonic plates

plate tectonics the theory that explains how Earth's crust is broken into plates and how they move

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plume a column of super-hot magma rising up under the crust

pollinator an organism that assists in the transfer of pollen from the male part (anther) of a flower to the female part (stigma) of a flower

polymer a large molecule made up of repeating units

population a number of individuals of one species living together

postsynaptic membrane the membrane that receives neurotransmitters

predator an organism that kills and eats other animals

presynaptic membrane the membrane that releases neurotransmitters

prey an organism that is used as food

prion an infectious agent that is composed entirely of protein

producer an organism that creates its own chemical energy store from simple substances such as carbon dioxide and water through photosynthesis; also known as an autotroph

product a chemical that comes out of (is produced in) a chemical reaction

propagate to continue through

protium an isotope of hydrogen with one proton and no neutrons

pyramid of numbers a diagram that shows the number of organisms that exist at each successive level of a food chain

quadrat equal-sized areas that cover a representative sample of the area being studied

qualitative test a chemical test that identifies whether a substance is present or not

quantitative test a chemical test that identifies how much of a substance is present

quarantine the strict isolation of people or countries to reduce the risk of unwanted pests and diseases entering a specific place

radiation a stream of particles and/or energy from a radioactive source

radioactivity the spontaneous disintegration of certain atomic nuclei accompanied by the emission of alpha particles, beta particles or gamma radiation

radiotherapy the treatment of cancer by radiation

rainforest a dense evergreen forest with a very high annual rainfall

reactant part of a cell or organ that responds to a specific signal such as light, heat or a particular chemical

red blood cell a smooth, flattened, elastic, biconcave disc-shaped blood cell that is packed with haemoglobin

reflex arc the nerve pathway that regulates a simple, automatic response (reflex action)

refraction the bending of waves when they change speed

renal pelvis the funnel-shaped part of the kidney that collects urine

respiration a series of chemical reactions that release chemical energy (and water and carbon dioxide) for use by an organism

rock cycle the continual recycling of rocks through weathering, erosion, burial, compacting, melting and uplifting

S wave a transverse earthquake wave that travels through the interior of the Earth

salt an ionic compound

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savannah grassland with small, widely spaced trees

scavenger an animal that eats meat that has been abandoned by predators, rather than hunting for itself

Schwann cell a specialised cell that rolls its membrane around axons to form the myelin sheath

seismic wave energy travelling through the Earth in the form of a longitudinal or transverse wave

seismology the scientific study of earthquakes and the internal structure of the Earth

semi-permeable allowing some substances to pass through but not others

sensor a structure or organ that detects changes in the internal or external environment

serial dilution a stepwise dilution of a substance in solution, usually keeping the dilution factor the same

set point the narrow range within which organisms function at their best

single displacement reaction a reaction in which one element takes the place of another element in a compound; more commonly referred to as a substitution reaction

solidify to harden, to change a liquid into a solid

solute a dissolved substance in a solution

specific heat capacity the ability of a substance to hold heat

spontaneous a reaction that occurs at room temperature; it does not require any extra energy to get it started

stimulus anything that activates a sensory cell in the nervous system or a response in the endocrine system

stromatolite a solid structure produced by cyanobacteria over many years by trapping sediment on their sticky surface

subatomic particle a particle found inside an atom, such as a proton, a neutron and an electron

subduction the process in which two converging tectonic plates collide and one plate slides beneath the other

supernova an explosion of a star after it has used up its hydrogen fuel

superposition the law that says that lower layers of rocks are older than those near the top

symbiosis interaction between two organisms that live in close proximity, benefitting at least one of them

synapse a tiny gap separating two neurons

synthesis reaction a chemical reaction in which a more complex chemical is produced from simpler chemicals

taiga a large terrestrial biome characterised by coniferous forests

terrestrial organism an organism that lives on land

terrestrial relating to the Earth, the ground

thermoreceptor a receptor that responds to heat and cold

transect a strip of land used for estimating population and distribution

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

transverse at right angles to where the energy was propagated

tritium an isotope of hydrogen with one proton and two neutrons

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trophic level an organism's position in a food chain

trough the point at which a wave is at its maximum downwards value

tsunami a series of 'waves' caused by an undersea earthquake or volcanic eruption

tumour a clump of cells that are dividing uncontrollably

tundra a treeless biome north of taiga, with only low vegetation and permafrost

turbidity cloudiness of a solution

uniformitarianism the theory that says that Earth's surface was shaped in the past by gradual processes

urea the main end product of nitrogen (in protein) metabolism; produced in the liver from ammonia

vaccination the administration of live or dead antibodies to stimulate an immune response to that disease

vertebrate an animal that has a backbone

vibration a rapid continuous back and forth or up and down movement

virus a small infectious pathogen that can only reproduce inside living cells

wave a disturbance that moves through time and space, carrying energy

wavelength (λ) the distance from a point on the wave until it repeats on the next wave, e.g. crest to crest

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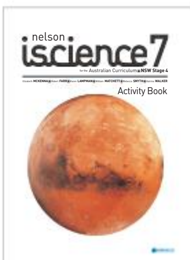

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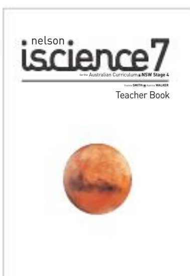

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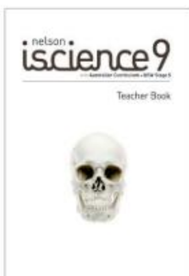

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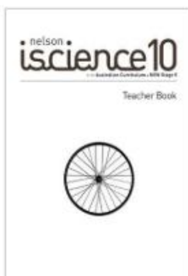

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