

A close-up photograph of a bird of prey, likely a hawk or falcon, focusing on its head and eye. The bird has brown and white feathers, a sharp beak, and a dark, intense eye. The background is blurred.

OXFORD

INSIGHT SCIENCE

AUSTRALIAN CURRICULUM FOR NSW

STAGE 4

8

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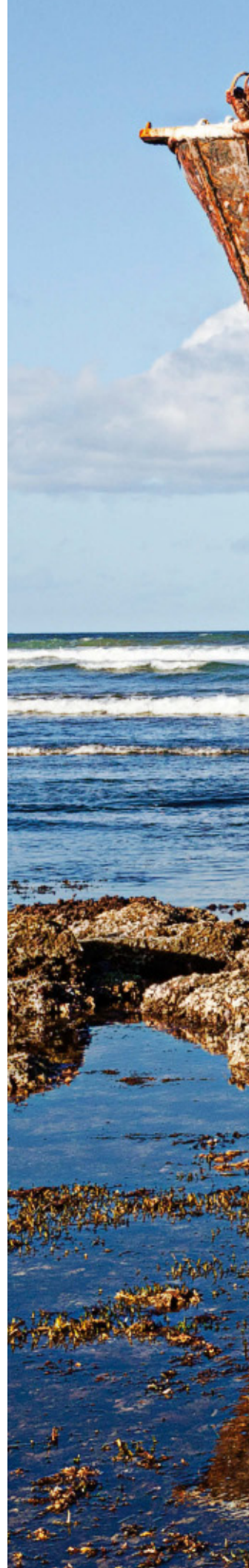
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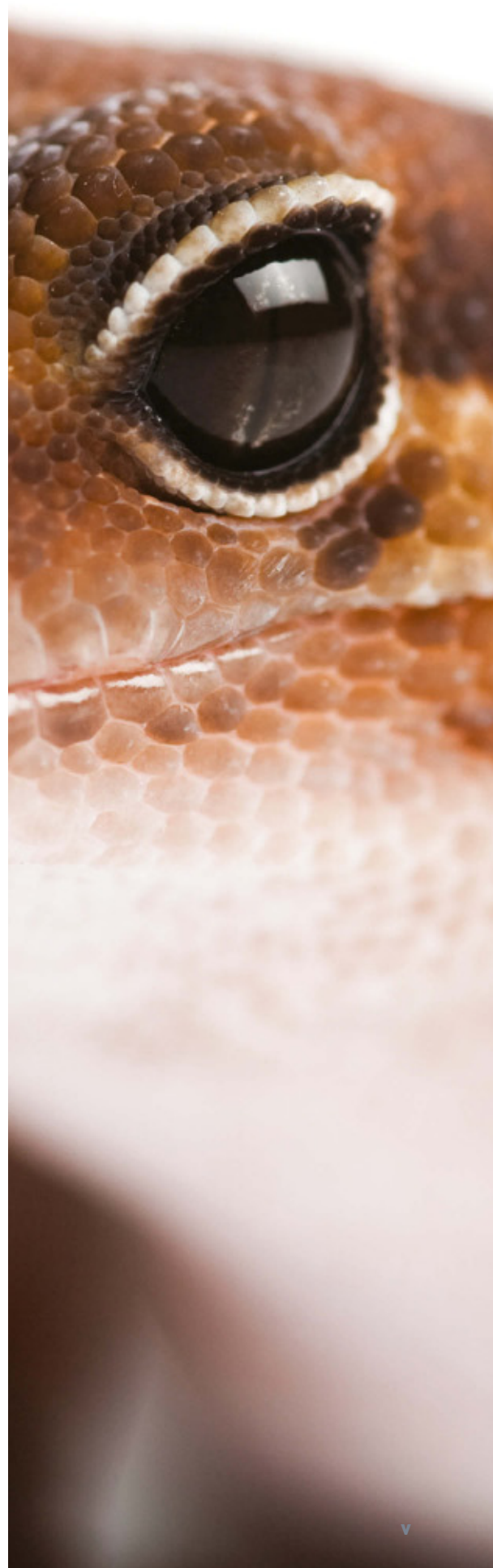
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CORRELATION TO THE NSW SYLLABUS FOR THE AUSTRALIAN CURRICULUM: SCIENCE STAGE 4

			Insight Science 7								Insight Science 8					
Stage 4 outcomes			1 Curiosity, Wonder and Questioning	2 Classification	3 Cells	4 Nature of Matter	5 Mixtures	6 Earth, Sun and Moon	7 Earth's Resources	8 Forces	1 Ecosystems	2 Functioning Organisms	3 Energy	4 Elements and Compounds	5 Chemical Change	6 The Changing Earth
A student:																
Working Scientifically Skills	SC4-4WS	identifies questions and problems that can be tested or researched and makes predictions based on scientific knowledge	●		●	●	●	●	●	●	●	●	●	●	●	●
	SC4-5WS	collaboratively and individually produces a plan to investigate questions and problems	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	SC4-6WS	follows a sequence of instructions to safely undertake a range of investigation types, collaboratively and individually	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	SC4-7WS	processes and analyses data from a first-hand investigation and secondary sources to identify trends, patterns and relationships, and draw conclusions	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	SC4-8WS	selects and uses appropriate strategies, understanding and skills to produce creative and plausible solutions to identified problems		●	●	●	●	●	●	●	●	●	●	●	●	●
	SC4-9WS	presents science ideas, findings and information to a given audience using appropriate scientific language, text types and representations	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Physical World	SC4-10PW	describes the action of unbalanced forces in everyday situations								●						
	SC4-11PW	discusses how scientific and technological developments have contributed to solving problems involving energy transfers and transformations											●			
	PW1	<i>Change to an object's motion is caused by unbalanced forces acting on the object. (ACSSU117)</i>								●						
	PW2	<i>The action of forces that act at a distance may be observed and related to everyday situations.</i>								●						
	PW3	<i>Energy appears in different forms including movement (kinetic energy), heat and potential energy, and causes change within systems. (ACSSU155)</i>											●			
	PW4	<i>Science and technology contribute to finding solutions to a range of contemporary issues. (ACSHE120, ACSHE135)</i>											●			

			Insight Science 7								Insight Science 8					
A student:			1	2	3	4	5	6	7	8	1	2	3	4	5	6
Earth and Space	SC4-12ES	describes the dynamic nature of models, theories and laws in developing scientific understanding of the Earth and solar system						●								●
	SC4-13ES	explains how advances in scientific understanding of processes influence the choices people make about resource use and management							●							●
	ES1	<i>Sedimentary, igneous and metamorphic rocks contain minerals and are formed by processes that occur within Earth over a variety of timescales. (ACSSU153)</i>														●
	ES2	<i>Scientific knowledge changes as new evidence becomes available, changing people's understanding of the solar system.</i>						●								
	ES3	<i>Scientific knowledge influences the choices people make in regard to the use and management of the Earth's resources.</i>							●							
	ES4	<i>Science understanding influences the development of practices in areas of human activity. (ACSHE121, ACSHE136)</i>							●							
Living World	SC4-14LW	relates the structure and function of living things to their classification, survival and reproduction		●	●						●	●				
	SC4-15LW	explains how new biological evidence changes people's understanding of the world		●	●						●	●				
	LW1	<i>There are differences within and between groups of organisms; classification helps organise this diversity. (ACSSU111)</i>		●												
	LW2	<i>Cells are the basic units of living things and have specialised structures and functions. (ACSSU149)</i>			●											
	LW3	<i>Multicellular organisms contain systems of organs that carry out specialised functions that enable them to survive and reproduce. (ACSSU150)</i>										●				
	LW4	<i>Scientific knowledge changes as new evidence becomes available, changing people's understanding of the world. (ACSHE119, ACSHE134)</i>										●				
	LW5	<i>Science and technology contribute to finding solutions to conserving and managing sustainable ecosystems.</i>									●					
Chemical World	SC4-16CW	describes the observed properties and behaviour of matter, using scientific models and theories about the motion and arrangement of particles				●	●							●	●	
	SC4-17CW	explains how scientific understanding of, and discoveries about the properties of elements, compounds and mixtures relate to their uses in everyday life					●							●	●	
	CW1	<i>The properties of the different states of matter can be explained in terms of the motion and arrangement of particles. (ACSSU151)</i>				●										
	CW2	<i>Scientific knowledge and developments in technology have changed our understanding of the structure and properties of matter.</i>												●		
	CW3	<i>Mixtures, including solutions, contain a combination of pure substances that can be separated using a range of techniques. (ACSSU113)</i>					●									
	CW4	<i>In a chemical change, new substances are formed, which may have specific properties related to their uses in everyday life.</i>													●	



WHAT IS INSIGHT SCIENCE?

Oxford Insight Science is a comprehensive and flexible suite of resources designed specifically to address the NSW Syllabus for the Australian Curriculum: Science. Engaging content and activities for a range of abilities enable students to develop deep understanding of science concepts and transferable scientific skills, which promote scientifically literate citizenship.

FOUR STRANDS OF SCIENCE

Knowledge and Understanding of Science has been classified into four main strands of content and ideas. Within each strand, core concepts build on the previous year as students progress through the stages.

Physical World

Forces, motion, energy transfers and transformations, and the contribution of scientific and technological development to solving problems

Earth and Space

The Earth and its place in the solar system, the development of models and theories, resource use and management, and geological activity

Living World

Structure and function of living things, classification, interactions between living things and their environment, and the advancement of biological understanding through technological development

Chemical World

Properties of matter and arrangement of particles, relating properties to uses, chemical reactions produce new substances, and the refinement of models, theories and laws with new scientific evidence

WORKING SCIENTIFICALLY

Knowledge and understanding of scientific ideas is gained through the application of scientific skills. The development of these key skills enables students to transfer them to new situations and, through inquiry, discover new ideas for themselves. The use of scientific skills promotes deeper understanding of and greater engagement with content.

The Working Scientifically skills of the NSW Syllabus are scaffolded and integrated throughout all experiments and activities within the *Oxford Insight Science* series:

Questioning and predicting

Identifying problems, and developing predictions and testable hypotheses

Planning investigations

Collaboratively and individually develop plans to investigate questions, problems and hypotheses

Conducting investigations

Collaboratively and individually follow instructions to safely conduct investigations and collect valid and reliable data

Processing and analysing data and information

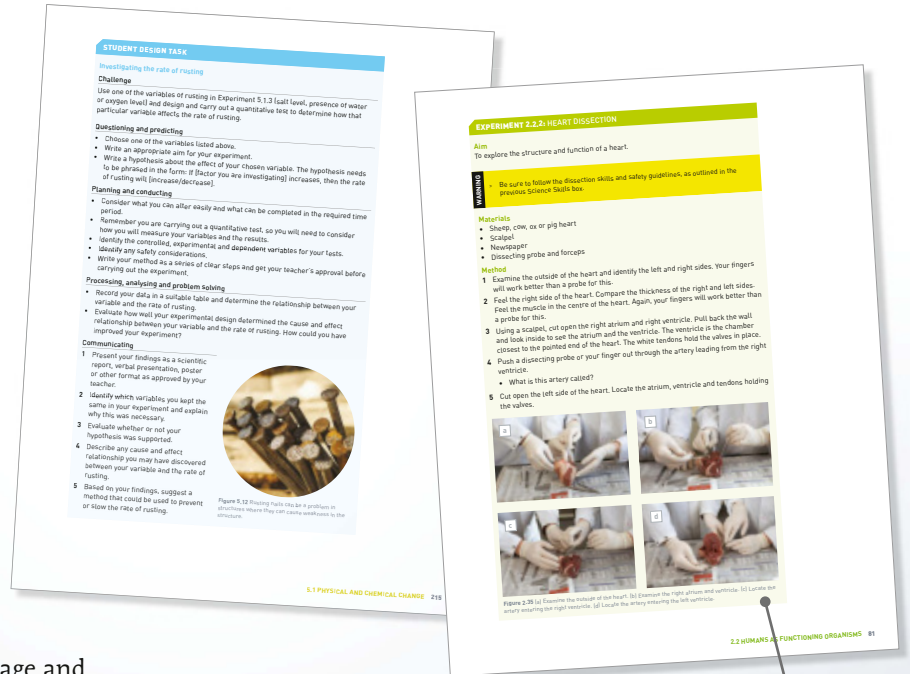
Process and analyse first- and second-hand data to identify trends and relationships and to draw conclusions based on evidence

Problem solving

Develop and use appropriate strategies to produce plausible solutions for problems

Communicating

Present science ideas in a manner, language and presentation type appropriate for a specific purpose or audience

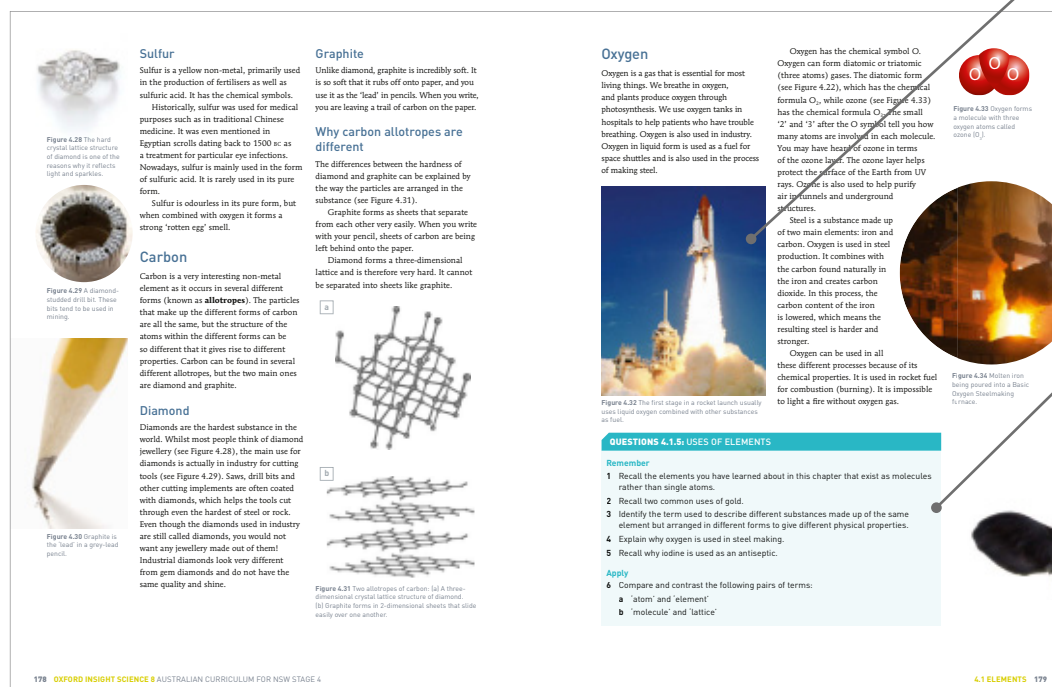


Step-by-step instructional photography models correct scientific skills and techniques in experiments

ENGAGING LEARNING

Each Student Book chapter is designed to visually and creatively engage students with beautiful artwork, photographs, case studies, source material and in-depth coverage of each topic being studied. Supported by numerous experiments and activities suitable for classrooms and different learning styles, all students have the opportunity to engage with science and their own learning.

Spectacular and current photography bring science to life.



Question blocks throughout the text for constant review of knowledge and concepts.



INTEGRATED TEACHING AND LEARNING SUPPORT

obook + assess

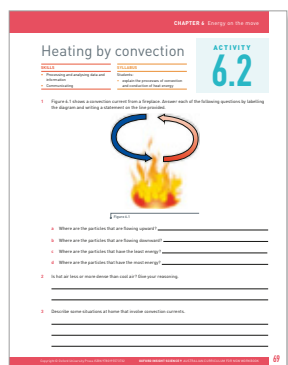
Access to Oxford's electronic book format — the **obook** — is included with this Student Book and offers online and offline access to the complete Student Book in an easy-to-read format for any screen size, with multimedia links, interactive learning objects, videos, note-taking tools and dynamic question blocks. Oxford's **obook** is compatible with laptops, iPads, tablets and IWBs. **assess** provides 24/7 online assessment designed to support individual student progression and learning.



Flexible navigation options take you where you want to go, when you want to go there.



Content is screen friendly.



Workbook

Oxford Insight Science is supported by a Workbook for each of the years 7–10. The Workbooks provide extra practice of key skills and encourage an inquiry-based approach to learning — perfect for use in class or for homework. All workbook activities are also available digitally on the **obook**.

obook + assess teacher

obook and **assess teacher** includes all content from the Student Book with a huge range of teaching support for mixed ability classes:

- Comprehensive syllabus mapping and customisable teaching programs.
- Hundreds of teaching strategies, additional activities and lesson planning tips.
- Checkpoint worksheet, differentiated to suit different abilities and learning styles.
- Advice on addressing common misconceptions.
- Support for Student Book experiments, student-designed investigations and activities, including risk assessment templates.
- Suggested answers to all Student Book and Workbook questions.
- Ability to assign reading and extras to students or classes.
- Access to a testbank (of unseen questions), auto-marking assessments and class progress and results.

ANSWERING SCIENCE QUESTIONS

In the senior sciences, questions asked in examinations are often phrased as statements, which begin with a verb such as 'identify' or 'justify'. While not all questions are structured in this way, it is important to learn how to respond to these types of questions. In this book, many of the questions start with these verbs. The table below gives a quick guideline to the level of response and the types of information required for **some** of the verbs that you are likely to come across.



← Increasing in complexity	Verb	Explanation
	Recall	Usually based on a simple fact or theory. Requires you to remember ideas or facts and present them.
	Identify	Can be completed in a sentence or two. Recognise the content and name certain features.
	Define	Identify the main qualities and/or state the meaning.
	Outline	Give the main features of something in general terms.
	Calculate	Use calculations to determine information from facts or figures.
	Deduce	Make conclusions based on information given.
	Account	Give reasons for the statement/s made.
	Predict	Suggest what may happen. This usually needs to be done based on the information available.
	Describe	Give features and characteristics.
	Distinguish	Note how things are different.
	Compare	Show how things are different and similar.
	Contrast	Show how things are different. Contrast is often used with compare in order to look at both similarities and differences.
	Interpret	Usually refers to figures, diagrams or graphs. Find meaning of the trends, or draw meaning from the diagrams.
	Propose	Usually used in conjunction with other verbs, 'propose' typically requires you to put forward an action.
	Explain	Give reasons for the statement/s made relating cause and effect. Generally, you will need to link ideas and statements by looking at the relationship between them.
	Analyse	Identify the key components of the context and explain the relationship/s between them. Relate cause and effect and relate this to implications.
	Justify	Support a statement, argument or conclusion based with your understanding and/or scientific knowledge. This usually requires you to explain your reasoning in order to justify a statement.
	Discuss	Provide points for and against a particular issue. This usually requires you to use evidence from given information as well as your background understanding.
	Assess	Based on the information given, and through thorough discussion, make a judgement regarding the content. A question beginning with the verb 'assess' is typically an extended response requiring a high level of succinctness and depth in the answer. Ensure you include a judgement statement based on the evidence you provide.
	Evaluate	Similar to an assess question, evaluate questions require you to make a judgement. The key difference is that evaluations require a judgement based on a given criteria and require you to make a statement regarding the value of the context.



ECOSYSTEMS

All organisms, from the tiniest bacterium to the cattle that we farm, make up the living part (biosphere) of our planet. These organisms and their interactions with each other and their physical environment make up the huge variety of ecosystems on the Earth. The air we breathe, the food we eat and the water we drink are all produced in ecosystems. Each living thing in an ecosystem is linked to another so that the survival of everything, including us, is connected.

INTERACTIONS BETWEEN ORGANISMS IN ECOSYSTEMS

1.1

Energy can be thought of as the 'money' used in ecosystems. For all organisms on the Earth, the ultimate source of energy is the light from the Sun. However, this energy must be transformed before it can be transferred between organisms. For most organisms, this transferrable energy is in the form of food, which flows through ecosystems in the form of food chains and food webs.

Students:

- » construct and interpret food chains and food webs
- » describe the interactions within food chains and food webs
- » predict the effect of human activities on food chains and food webs

MICROORGANISMS IN ECOSYSTEMS

1.2

Microorganisms are all around us and make up a vital component of ecosystems. Microorganisms help us to produce food, assist in digestion and help fight infection. Not all microorganisms are helpful though. Many cause diseases in humans, animals and plants. Microorganisms can be producers, consumers or decomposers, and can feature in every level of a food web.

Students:

- » describe some beneficial and harmful effects of microorganisms in ecosystems

MANAGING ECOSYSTEMS

1.3

Human activities alter natural ecosystems, sometimes for the better, sometimes for the worse. We require lots of space to live and grow food, and the land we use is taken away from natural ecosystems. However, through ecological and environmental science research, sustainable management practices can help us reduce our impact on ecosystems and help us manage natural events such as bushfires.

Students:

- » explain the development of strategies for managing natural events in Australian ecosystems
- » describe the contribution of scientific developments in agricultural practices
- » research Australian contributions to the study of ecology and human impacts on the environment (additional)

1.1

INTERACTIONS BETWEEN ORGANISMS IN ECOSYSTEMS

Living organisms can be found almost everywhere on the Earth, but they do not live in isolation. Organisms interact with others of their species and with other species, including humans. Though extremely diverse and well adapted to suit their particular ecosystems, all organisms have one thing in common – the need for energy. Where does this energy come from, and how does it move through ecosystems?

THE BIOSPHERE AND ECOSYSTEMS

The **biosphere** describes the living component of the Earth. The biosphere is made up of all the living organisms found within the kingdoms of life – bacteria, protozoa, fungi, plants and animals of all shapes and sizes. It extends into the atmosphere, where some birds and insects can be found, as well as deep underground and to the bottom of the ocean where bacteria and other unusual forms of life can

be found. The biosphere extends to any place on the Earth where life exists.

The biosphere can be thought of as a link between the atmosphere (air), the hydrosphere (water) and the lithosphere (land). It is large and all encompassing, and its relationships and interactions can be very complex, so we tend to study smaller components of the biosphere, called **ecosystems**.



Figure 1.1 The biosphere links the atmosphere, hydrosphere and lithosphere because living organisms can be found everywhere on the Earth.

ACTIVITY 1.1.1: MAKING A BIOSPHERE

What you need: large glass jar with a lid, pond water, aquatic plants, macro-invertebrates (e.g. water fleas, pond snails), mud or sand from pond, electronic balance.

For this activity, work in pairs and take turns with making observations and recording them.

WARNING

- > Avoid contact with pond water. Wear gloves while collecting pond items and wash your hands well afterwards.

- 1 Take a large glass jar, partly fill it with a thin layer of mud or sand from the bottom of a pond, and then top it up with pond water. Make sure there are some small macro-invertebrates in your pond water.
- 2 Add some small pieces of aquatic plants to the jar.
- 3 Seal the jar with an airtight lid and then weigh the jar and contents.
- 4 Place the jar near a well-lit window (but not in the direct sunlight or it may warm up too much).
- 5 Check your biosphere every few days and record your observations.
- 6 Reweigh your jar and contents when you have finished the activity.
- 7 Present your observations in a table, with the date of each observation clearly marked. You could also include photographs or sketches.
- 8 Return the contents of the jar to their original source.



Figure 1.2 Your biosphere, or jar aquarium, may look something like this.

Questions

- 1 Identify the components in your jar that make it a biosphere.
- 2 How did the weight of your jar and contents change over time? Explain what might have caused this change, or suggest a reason why it remained the same.
- 3 Animals consume sugar and oxygen to produce carbon dioxide. What is this process called?
- 4 Research other homemade biospheres on the Internet and suggest some improvements you could make to the design of your experiment.
- 5 Research the difference between a terrarium and an aquarium. Suggest what the ultimate homemade biosphere should contain.
- 6 *Biosphere 2* is a massive artificial biosphere in the Arizona desert in the United States of America. Research why this artificial biosphere was built.



Figure 1.3 *Biosphere 2* in the desert of Arizona in the United States.



Figure 1.4 The wetlands of Kakadu National Park are an example of an ecosystem.

Ecosystems

An ecosystem is made up of all the living organisms (**biotic** factors) and the physical, non-living conditions (**abiotic** factors) in a particular area and the interactions within and between the two. So a wetlands ecosystem is not made up of just the plants and animals that live there, but includes which animal eats what, where the different organisms live, the climate, water and nutrient availability, and how the organisms have adapted to the conditions.

Ecosystems are made up of habitats. A **habitat** is a particular area where a group of different organisms live, and the area has similar abiotic conditions throughout (e.g. temperature, water availability, wind speed). Habitats vary in size depending on the amount of food, water and shelter they provide.

All the individuals of a particular species living in the same habitat are called a **population**. All the populations of all the different organisms in that habitat are called the **community**. The biotic community interacts with the abiotic conditions of the habitat to form the ecosystem.

A habitat must supply all the needs of a population, such as food, water, shelter, suitable temperature and pH (acid level), and mineral availability. If that population's needs are not met, individuals or the entire population may move to a different habitat or die out.

Benefits of ecosystems

Humans are a part of ecosystems too, and we rely on ecosystems as much as any other organism for our survival.

Water, oxygen, carbon dioxide and other chemicals cycle through ecosystems with the help of the biosphere. Plants and animals continuously cycle oxygen and carbon dioxide between themselves and with the soil, water and air. Plants take in carbon



Figure 1.5 Dolphins come to the surface of the water to breathe in oxygen and breathe out carbon dioxide through their blowhole.

dioxide from the air (or from the water if they are aquatic plants) and release oxygen in the process known as **photosynthesis**. Plants and animals, including humans, use that oxygen in a process called **respiration**, and release carbon dioxide back into the air.

Plants and animals contribute to the filtering and cleaning of water in ecosystems as well. Root systems act like filters and slow down the flow of water, trapping sediment and some pollution. Some aquatic animals such as clams and anemones filter microscopic particles from the water to feed on, and in doing so they help clean the water they live in.



Figure 1.6 This anemone filter feeds by removing small food particles from the water, which helps clean the water it lives in.

One example of plants and animals interacting is when animals are searching for food. Some plants attract insects, birds and even bats with brightly coloured or strong-smelling flowers. The animals eat the sweet sugar-rich liquid called nectar produced by the flower and get dusted with a fine powder called pollen. As the animal moves to the next plant, it transfers the pollen to the new flower and the pollen helps fertilise that plant, which is then able to make seeds. Pollination is important not only for wild flowers but for crop plants too. Insects, birds and other animals pollinate over 70% of plant species worldwide, including the fruits and vegetables commonly eaten by people.



Figure 1.7 Bees are important pollinators of plants.

QUESTIONS 1.1.1: THE BIOSPHERE AND ECOSYSTEMS

Remember

- 1 Identify the four spheres of the Earth and main component that each represents.
- 2 Define the following terms and provide an example of each:
 - a ecosystem
 - b habitat
 - c abiotic factor
- 3 Recall the scientific term for all the living organisms in a habitat.
- 4 Complete the following sentences by deleting one word from each pair:
 - a The biosphere/ecosystem is made up of all living things on the Earth.
 - b An ecosystem is made up of a living population/community interacting with its habitat.
 - c The ways in which an animal finds a mate is an example of a(n) biotic/abiotic factor.

Apply

- 5 Demonstrate how the biosphere is important in the water cycle. You may like to draw a diagram.

Analyse

- 6 Describe why humans rely on ecosystems for their survival.
- 7 Propose what would happen to humans if all the pollinators disappeared.

FOOD CHAINS AND FOOD WEBS



Figure 1.8 Plants undergo photosynthesis to convert the energy from sunlight into glucose.

The characteristics that identify something as a living thing are the abilities to move, to respond to their environment, to grow and to reproduce. These activities all require energy, which means all organisms require a source of energy for their continued survival. All animals, including humans, get their energy from the food they eat. But what is the ultimate source of this energy?

The Sun – the source of energy on the Earth

On the Earth, the primary source of energy for most organisms is sunlight. While sunlight is readily available to almost all organisms, it is a difficult energy source for most organisms to use, and it cannot be stored to use later.

All plants, some bacteria and some protozoa use photosynthesis to convert the energy in sunlight into a sugar that is easily transferred and stored. The Sun's energy is used to join carbon dioxide and water molecules to form oxygen and a sugar called **glucose**. The energy is stored in the chemical bonds between the atoms in glucose.

The energy stored in the bonds of glucose can be released slowly through the process of respiration in individual cells. While not all cells can photosynthesise, all living cells respire, which means that glucose is a vital source of energy for the entire ecosystem.

The processes of photosynthesis and respiration are examined in chapter 2.

Glucose – transferable energy

Plants use the glucose they produce during photosynthesis for their own growth, repair, reproduction and other cellular functions, and they store any excess glucose for use in the future. Photosynthesis provides all the energy they require and therefore plants are **autotrophic** ('auto' meaning 'self' and 'troph' meaning 'nutrition').

The glucose in plants, and all the energy the glucose contains, is passed on to any organism that eats the plant. Organisms that cannot make their own glucose and must eat something to obtain their required energy are **heterotrophic** ('hetero' meaning 'other/different').

Autotrophs are also called **producers** because they make (produce) glucose using the chemical reaction of photosynthesis. Heterotrophs are also called **consumers** because they must eat (consume) food to gain the glucose and the energy they require.

Energy, in the form of glucose, moves through ecosystems as different organisms eat each other. The paths the energy can take from producers to consumers can be represented by food chains. A **food chain** shows a list of organisms in the order of what eats what with an arrow between each organism to indicate the direction of the flow of energy.



Figure 1.9 Cows are heterotrophs (consumers) because they must eat grass to obtain the energy they require.



Figure 1.10 These decomposers eat dead and decaying matter.

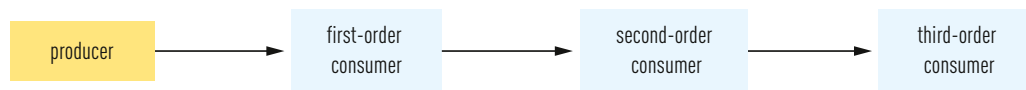


Figure 1.11 A food chain starts with producers such as plants and moves through several orders of consumers.

Food chains

All food chains must start with a producer, because producers make the glucose for all other organisms to consume. The type of producer will vary depending on the ecosystem. The producer could be grass, a massive tree, seaweed or microscopic phytoplankton. In food chains, an arrow pointing from one organism to another means that the first organism is eaten by the second.

Consumers are then ordered according to what they eat. The first consumer in the food chain is referred to as a first-order consumer. Each step away from the producer is represented in the name: second-order consumer; third-order consumer, and so on.

Consumers are also named according to what they eat. First-order consumers only eat plants or other producers, and are

called **herbivores**. Organisms that only eat other consumers are called **carnivores**. Consumers that eat both plants and other animals, like most humans do, are called **omnivores**. The highest carnivore in a food chain is referred to as the top predator.

Another vital component of food chains are **detritivores** and **decomposers**. Detritivores are usually small invertebrate animals such as maggots, worms and insects, which eat dead and decaying **matter**. Decomposers are organisms such as bacteria and fungi, which break down the dead matter into basic chemicals and return them to the soil, air and water. These chemicals can then be absorbed by plants through their roots and recycled back into the start of a new food chain. You will learn more about microorganisms and their impact on ecosystems later in this chapter.

A possible food chain is shown in Figure 1.12.

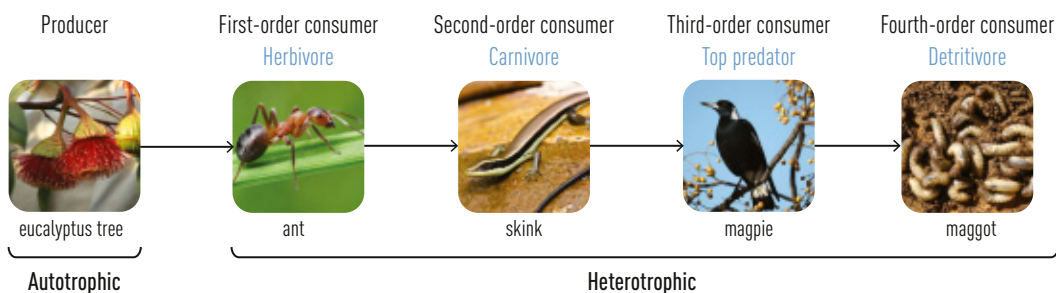


Figure 1.12 Organisms in a food chain can be classified and named according to their position in the chain and what they eat. Decomposers and detritivores actually appear at every level of a food chain, eating all decaying matter, not just the top predator.

ACTIVITY 1.1.2: DETRITIVORES AND DECOMPOSERS

Leaf litter is the dead and rotting leaves that lie on the ground under trees and in gardens. Leaf litter helps protect soil and is home to many invertebrates, bacteria and fungi that work together to help break down the decaying matter and keep the soil in good condition.

What you need: old newspaper, gloves, plastic test tubes or specimen tubes with lids, wet paintbrush, hand lens, pen and paper

WARNING

- > Before you start, ask your teacher about any bull ants, poisonous spiders or centipedes that are found in your area. There may be some animals that could bite you. If in doubt, leave the animals alone and ask your teacher.
- > Wear gloves at all times and wash your hands thoroughly after this activity.

- 1 Find an undisturbed area of leaf litter about 50 cm long by 50 cm wide. Work only in this area.
 - 2 Lift up the leaves slowly. Use your brush to pick up any tiny animals and make sure not to crush them.
 - 3 Make a list of the animals you find. Include as a separate list any eggs, cocoons, larvae or types of fungi that you find.
 - 4 Return the animals to the place where you found them.
 - 5 Wash your hands.
- Why is it important to know something about the animals you are likely to find before looking for them?
 - Why should you return animals to the place where you found them?
 - A leaf litter community doesn't contain any producer organisms such as healthy green plants. What is the energy source for this community?
 - What food chain classification could you apply to the organisms you found? Why are they an important part of food chains?
 - How does this leaf litter community help the soil?



Figure 1.13 Leaf litter is a habitat, which is home for a diverse community of detritivores and decomposers.



Figure 1.14 Particular species of decomposer fungi 'eat' the softer parts of leaves, leaving the tougher veins behind to create these beautiful leaf skeletons.

Food webs

Like humans, most organisms will eat more than just one type of food. Eating more than one type of food ensures that if one food source becomes scarce, the organism can eat something else. This means a species may be part of many food chains at the same time. These multiple food chains can be linked together in a **food web** to represent the feeding relationships between the different organisms in an ecosystem. Some consumers will have several labels to describe their **trophic level** (position) in the food web depending on which food chain within the web you are examining.

Figure 1.15 shows a food web with three different producers. The skink could be a second-order or a third-order consumer, depending on the food chain that is followed, while the ant is only a first-order consumer.

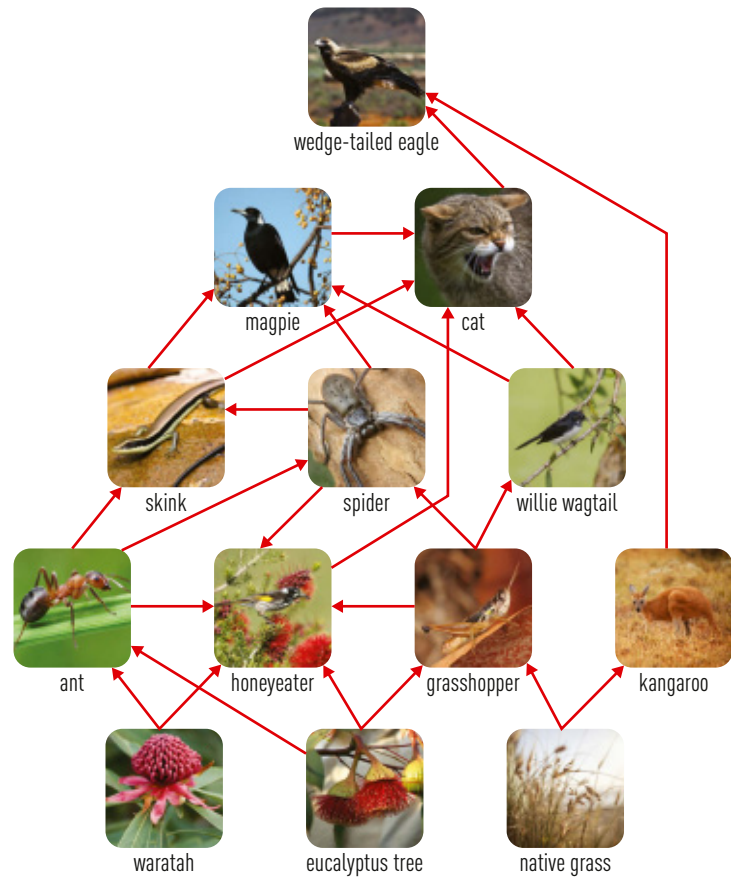


Figure 1.15 A food web shows the diverse feeding relationships between organisms in an ecosystem.

ACTIVITY 1.1.3: UNDERSTANDING FOOD WEBS

What you need: whiteboard, whiteboard marker, small index cards, Blu-Tack

This is a whole-class activity.

- 1 Your teacher will set up a whiteboard display with the title 'Food webs for humans', with a circle representing the Sun drawn at the bottom in the centre.
- 2 Your teacher will hand out index cards with the following names on them:

grass	hay	water plants	carrot
kangaroo	grasshopper	twigs	mosquito
human	cow	rabbit	worm
corn	trout	berries	pig
chicken	shark	dingo	long-necked turtle
duck	seal	Murray cod	sheep
- 3 One student is to call out the following statements. For each statement, students with the corresponding index cards will attach them to the whiteboard using Blu-Tack, and draw arrows to the correct locations.
 - 'Plants obtain their energy from the sun. Draw your arrows as squiggly ones.'
 - 'Your organism eats plants.'
 - 'Your organism eats any of those already displayed'.
- 4 Repeat the third point in step 3 until all cards are used.
- 5 As a class, discuss the food chain sequences in the completed food web.



Sustainable food chains

Ecosystems are sustainable if there is enough energy available to pass through the food webs to maintain all the organisms in the community. Sustainable ecosystems have a consistent flow of energy and **nutrients** through the system so that all life can be supported. Unsustainable ecosystems use up energy or nutrients faster than they can be produced; therefore, some or all of the organisms in it will die.

Not all the energy from one trophic level of a food chain is passed to the next level.

Some of the energy is used by the organisms for their own movement, growth, repair and cellular functions. Most of the energy is lost from the food chain in the form of heat. Only around 10% of the original energy at any level is passed up the food chain. The decreasing amount of energy available at each trophic level of the food chain is what limits the number of organisms at each level and explains why there are usually more herbivores than carnivores. Imagine visiting the African savannah and watching hundreds of lions hunting a herd of only a few zebras. The lions would very quickly run out of food!

ACTIVITY 1.1.4: STUDYING FOOD WEBS

What you need: metre-long sticks (or 1 m rulers)

WARNING

- > Before you start, ask your teacher about any poisonous or dangerous organisms in your area.
- > Wash your hands thoroughly after this activity.

- 1 Think about what you know about food webs in your area. Compile a list of 20 components within these food webs. Do some areas support more life than others?
- 2 Measure out two 1 m × 1 m squares in your backyard, schoolyard or neighbourhood to study. The study areas should be near each other but in two different habitats (e.g. on a footpath and on some grass, or just inside a forest and in a clearing). Mark out these squares using the metre-long sticks or rulers. A quadrat could be used (see Figure 1.16).
- 3 Observe and record in a notebook all organisms inside your marked squares and the area directly above them (i.e. look up into any overhanging trees above the squares).
 - Which organisms are producers?
 - Which organisms are consumers?
 - Which organisms are decomposers?
 - How do the numbers (of individuals and species) of producers, consumers and decomposers compare?
- 4 Devise a system for estimating the number of something too great to count, such as the number of grass blades in your study area. Hint: You could divide the study areas into smaller squares as shown in Figure 1.16.
- 5 Make predictions about which study area is producing more food and which one is using the most food. Is enough food produced within each study area to support that area? Do the consumers need to get food from somewhere else, or do other animals come into that area just to eat?
- 6 Devise methods to test your predictions. You might like to group organisms into 'visitors' and 'residents'.
 - Are the 'visitors' bringing food energy into the study area or taking it away?
 - How will you measure the flow of energy from decomposed matter?
- 7 After you have collected data, analyse your findings and summarise what you have learned.

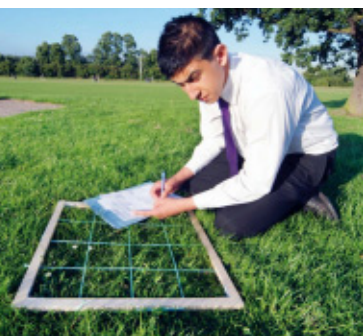


Figure 1.16 This student is using a quadrat to divide the survey area into equal smaller sections.

Changing food webs

The addition or removal of a species from a food web will affect all other species within that web. Consider the food web in Figure 1.15 on page 11. The cat is an introduced species to the native food web. It competes with the magpies for skinks and is a major predator of the other birds.

Without cats, the populations of skinks, wagtails, honeyeaters and magpies would all increase.

When considering changes in food webs, it is important to consider all trophic levels. How will competitor species on the same level be affected? What about prey species on lower levels? What about predator species on higher levels?

QUESTIONS 1.1.2: FOOD CHAINS AND FOOD WEBS

Remember

- 1 Recall the name of the sugar that is used to transfer energy between organisms.
- 2 Define the term 'trophic level'.
- 3 Identify what the arrows in a food chain represent.
- 4 Identify the process used by autotrophs to use energy from sunlight.

Apply

- 5 Classify the following organisms as herbivores, carnivores, omnivores or detritivores:

worm	dung beetle	crab	brown snake
kangaroo	wedge-tailed eagle	bear	bee
human	shark	honeyeater	koala

- 6 Draw a food chain with four trophic levels.
- 7 Examine the food chain in Figure 1.12 on page 9. Identify the trophic level to which the magpie belongs.
- 8 Examine the food web in Figure 1.15 on page 11. Identify all the predators and all the prey of the spider.

Analyse

- 9 Analyse the meaning of the term 'photosynthesis'. Break the term into parts and identify what each part means.
- 10 It could be said that all organisms on the Earth ultimately get their energy from the sun. Evaluate whether this statement is true or not. Justify your opinion.
- 11 Examine the food chain in Figure 1.17. Identify the mistakes and redraw it correctly.

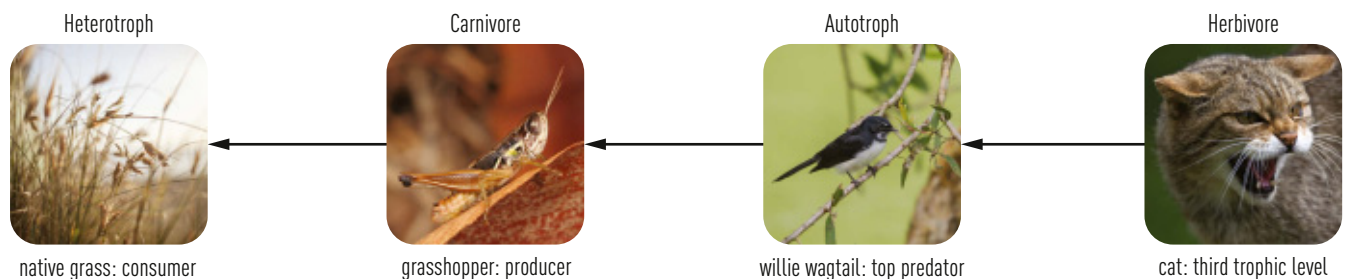


Figure 1.17 Can you identify the problems with this food chain?

THE EFFECT OF HUMAN ACTIVITIES ON FOOD WEBS



Figure 1.18 Urban sprawl around some of Australia's largest cities, such as Sydney, continues to grow.

Food webs can show the delicate balance between producers and consumers. For example, if more grass grows, then animals that eat grass will have more energy and nutrients and so will have a greater chance of survival and greater chance to reproduce. More herbivores means more food for carnivores, but greater numbers of herbivores will increase the grazing on the grass and control its growth, balancing the ecosystem.

Food webs and the ecosystems they are a part of can be surprisingly fragile. Food webs can become unbalanced when organisms are removed or introduced to the ecosystem. Even the smallest change can have surprisingly large effects later on and can seriously disrupt the flow of energy and food.

Altering habitats

Organisms are constantly changing their environments. They use resources and provide resources for other organisms.

Humans are certainly no exception. The impact of humans on environments is considerable due to our population numbers and our ability to manipulate our surroundings to suit our needs. We are all able to make both positive and negative changes to our environment.

Urbanisation and deforestation

Humans require a lot of space to live. Urban sprawl is the spread of urban areas into rural and coastal areas. Urban sprawl increases the distance between the city centre and its outer edge.

Huge areas of natural ecosystems have been cleared for human cities, roads and farmland as a part of urban sprawl. Today, Australians are clearing land at the massive rate of over half a million hectares a year.

That is the equivalent of about one million cricket grounds each year! Much of that land is used for our homes, to grow our food or to manufacture products. Clearing land of large producers, such as trees, significantly alters the habitat and food webs of the area.

Human changes to the producers in natural ecosystems will affect the number of types of herbivores, which in turn will affect the number and types of carnivores in the ecosystem. In areas that are being used for agriculture, the main types of producers tend to be grasses rather than large trees. Many different animal species are forced to compete fiercely for the food and shelter the few remaining trees provide. However, organisms that feed on grasses have plenty of food and their populations often significantly increase.

Eastern grey kangaroos are an example of a species to benefit from the clearing of woodlands. Grass is the eastern grey kangaroo's main source of food – with the increased amount of grassland available their populations have significantly increased. However, eastern grey kangaroos compete with the livestock for which the land was cleared in the first place. Kangaroo culling is now common in New South Wales and many other parts of Australia.

Land degradation

Human activities have led to a degradation (a decrease in health and quality) of the physical environment. Soil erosion is a major problem caused by the clearing of land for agriculture. In ecosystems with many trees, a dense mat of plant roots stabilises the soil. A layer of leaf litter covers the surface, which protects the soil from wind and water erosion. Water from rainfall is quickly absorbed through the top layers of soil.

Plants filter water as it soaks into the soil. The stems and leaves of grasses catch large particles of pollutants, and the plants



Figure 1.19 Kangaroos and other native grazers benefit from human activities that provide more grass for them to eat, like this golf course!

themselves often remove toxins from the water that is absorbed into their roots. When these plants are cleared for human habitation or agriculture, these pollutants and toxins can get into the groundwater and can contaminate natural waterways.

Soil is compacted by the grazing of animals with hard hooves, such as cattle. This slows the absorption of water into the soil, increasing the water run-off and erosion. Wind erosion is also increased with less vegetation.

Other forms of land degradation include overuse of ecosystems, where humans take more resources from an ecosystem than the system can replenish. Examples of this type of degradation include overcropping (taking too many of a particular type of organism for food or materials), over-stocking of farmland (too many cattle in one area) and overfishing of oceans, rivers and lakes. Pollution of soil and water with chemical wastes, animal dung or excess fertilisers can also cause lasting damage to ecosystems.



Figure 1.20 Root systems of plants hold the soil together and act as a natural filtering system for water.

EXPERIMENT 1.1.1: NATURAL FILTERING OF WATER

Aim

To find out how effective natural systems can be at filtering water.

Materials

- 3 medium-sized plastic plant pots with holes in the bottom
- 1 plastic bucket
- 3 medium-sized jugs
- Stopwatch
- Gravel
- Sand
- Soil
- Plants (native grasses)
- Mixture of castor oil, dirt, small pieces of paper, water, salt
- Water
- Camera (optional)

Method

- 1 A few weeks in advance, prepare three plastic pots: one with just gravel, and two with gravel, then a layer of sand and finally a layer of soil on top. Each layer should be around 3–4 cm deep.
- 2 Plant some native grasses in one of the pots with the layers of gravel, sand and soil. You will need to wait until the grasses have established themselves in the pot before proceeding with this experiment. (Hint: You should be able to see the roots of the plant in the bottom of the pot.)
- 3 Mix the castor oil, dirt, finely shredded paper, salt and any other materials you wish to include into a bucket of water. The mixture should be very cloudy. Ensure the contents of the bucket are mixed well. Pour even volumes of the mixture into the three separate jugs and keep a small sample for later comparison with the filtrates. Rinse the bucket.
- 4 Slowly pour the mixture from a jug into one of the three pots, using the bucket to collect the solution that filters out of the base of the pot. Time and record the flow of solution out of the base of the pot. Measure the volume of liquid collected and compare it to the volume poured into the pot. Keep a small sample of the filtrate.
- 5 Repeat step 4 for the other pots, making sure to empty and rinse the bucket between filtrations.

Results

Create a table to record the volume of the mixture poured into each pot, the volume of liquid that flows out of the pot and the time taken for each solution to flow out of the base of its pot. Include a description and/or photograph of the appearance of each solution before and after filtration has been completed.

Discussion

- 1 Did the solution flow out of each pot at a different rate? Was there a difference in the volume of solution that flowed out the bottom of the three pots? Suggest a reason for any differences observed.
- 2 Compare the cloudiness of the final solutions. Suggest a reason for the differences observed.

Conclusion

How effective are natural systems at filtering water? Write a sentence that addresses the aim of this experiment.

Introduced organisms

Humans have introduced a large number of species into natural ecosystems. An **introduced species** is any organism not native or natural to that ecosystem. Introduced species can upset the balance of an ecosystem because they can alter the existing food web. Introduced species may outcompete native species for a limited resource, or they may not have a predator to keep their numbers in check. Many introduced species are considered to be a pest or, in the case of plants, a weed.

Humans often introduce pest species accidentally. It is thought the northern Pacific seastar was carried into Australian waters by ships from its native ecosystem in northern Pacific Ocean areas.

The northern Pacific seastar is a huge pest in Australian waters – it is an efficient predator that feeds on a large variety of marine organisms, including fish eggs, oysters and mussels. It outcompetes the native seastars and has become the dominant predator in some areas. With very few natural predators and a large amount of food available to them, the population of northern Pacific seastars has increased dramatically and is also spreading out.

Some plant and animal species were deliberately introduced into Australia. Cows, sheep, horses, rabbits, foxes, cats and dogs are among the commonly known introduced mammals. Prickly pear, an introduced cactus species from South America, was brought to Australia to be used in the production of dye. However, it flourished in



Figure 1.21 This pretty northern Pacific seastar is an introduced species devastating marine ecosystems in southern Australia.



Figure 1.22 Prickly pear was deliberately introduced, but quickly spread out of control without any native herbivores that would eat it.

the dry conditions and spread out of control through agricultural areas. None of the Australian native herbivores were able to eat such a large cactus, and even cattle couldn't eat it quickly enough. By around 1912, more than 10 million acres had been infected in New South Wales and Queensland.

In 1929, after much research and laboratory experiments into the prickly pear problem, a new species, a moth called *Cactoblastis cactorum*, was introduced to Australia. This cactus moth was also from South America and was the main consumer of the prickly pear in its original habitat. The *C. cactorum* moths lay their eggs in the prickly pear, which then hatch caterpillars that eat the plant. Once the caterpillars turn into moths, native Australian insectivores eat them. The caterpillars don't eat any Australian plants so they did not become a pest themselves. Ecological knowledge of the prickly pear's native food chain identified *C. cactorum* as a natural way to control the spread of the plant in Australia. Using existing food web relationships to control a species is called **biological control**.

Unfortunately, not all stories of biological control in Australia have such a good ending. Cane toads were introduced into Australia from Hawaii in an attempt to control the cane beetle, a native beetle species that was eating cane sugar and damaging crops in northern Queensland. Over 100 cane toads bred in a laboratory were released in August of 1935 around Cairns and Innisfail. However, there was very little research or experimentation conducted before the introduction of the cane toad.

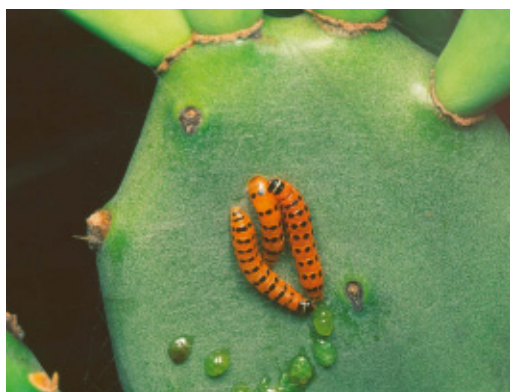


Figure 1.23 *Cactoblastis cactorum* caterpillars eating prickly pear.

Adult cane beetles infest the upper leaves of the sugar cane and the toads cannot climb that high. The beetle grubs live in the root system of the sugar cane and the toads are unable to find them. So the toads were not performing the role that they were expected to. Natural food webs involving cane toads were not investigated and so the impact of the toads on Australian food webs could not be accurately predicted. Cane toads are poisonous and very few native Australian animals have immunity to this poison and so almost all die when they eat the toads. This has a devastating effect on the populations of many native species. The endangered status of some species can be linked directly to the introduction of cane toads.

Without predators to control their numbers, the cane toad populations increased significantly. There are well over 200 million toads throughout Queensland and the Northern Territory, and they are now spreading into Western Australia and New South Wales.

While populations of native predators such as the northern quoll have been severely affected by cane toads, some predators are showing signs of behavioural adaptations by either avoiding the toads or handling them appropriately. The Torresian crow has learnt to flip toads onto their backs



Figure 1.24 Adult cane beetles eat the leaves of sugar cane, while their grubs eat the roots.



Figure 1.25 The introduced cane toad secretes a milky white poison from glands on its back.

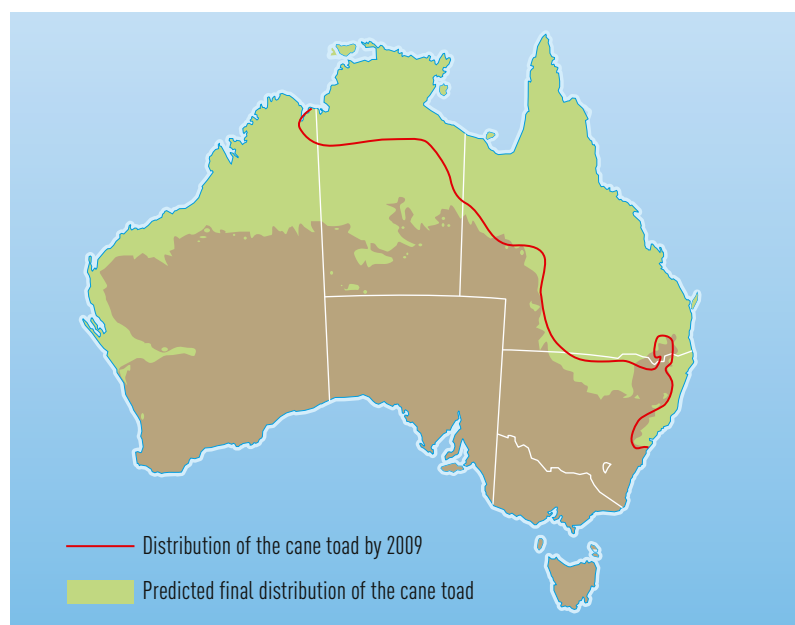


Figure 1.26 The distribution of cane toads in Australia in 2009 and their predicted final distribution.

and only eat their soft underside to avoid the poison on the toads' backs. Captive populations of northern quolls in Kakadu National Park are being taught to avoid eating the toads. These 'educated' animals are then released into the wild to hopefully 'teach' other quolls not to eat toads.

Biological control can be a very effective way to manage a pest species, but food webs must be thoroughly researched. Ecologists do just that, and must prepare forecasts and predictions about the introduced species and their impact on natural ecosystems. Any introduced species must fit into the food web and maintain that balance or risk affecting other species.

Loss of biodiversity

Biodiversity is a measure of the number of different species in a particular ecosystem. A rainforest ecosystem with hundreds of different producers, consumers and

decomposers has much higher biodiversity than a wheat field ecosystem.

High biodiversity increases the chances of the ecosystem surviving environmental change. The different species within the community will all have slightly different adaptations and requirements that can be met by the habitat. If those conditions change, for example due to a new disease in the area, not all the species in the community will be able to survive the change. But the more different species there are in that ecosystem, the more likely it is that some will survive the change.

In an ecosystem with low biodiversity, if the conditions change so that the main species is affected, then the ecosystem can collapse because the majority of the individuals move away or die.

Biodiversity of an ecosystem can be reduced by the active removal of species or by introducing a new species that unbalances the food web.

Figure 1.27 (a) A rainforest ecosystem has many different species and high biodiversity; (b) a field with a massive population of one species of wheat has low biodiversity.



LITERACY BUILDER

Scientific research

Not all scientific research involves conducting experiments. Background research is also really important. The trick is finding the right information.

The Internet is a powerful tool for finding information. However, it is important to remember to think critically when you read the information you find. How accurate is the information? Is it

reliable? If you go to a different source, does it tell you the same thing?

Printed material such as books and scientific magazines have gone through an editing and checking process, so they tend to be more reliable than some Internet sources. However, some books may not be current and up-to-date. It is important to note the date of publication when acknowledging either print or online sources.

Some things to remember when searching the Internet:

- 1 Anyone can write a blog; they don't have to be an expert. Blog sites (often .net) are often unreliable sources of information.
- 2 Anyone can add to online encyclopedias such as Wikipedia; they don't have to be an expert. While they might be a good place to start, all information from online encyclopedias must be verified.
- 3 Education sites (universities or .edu sites) and government (.gov) websites tend to be good reliable sources.
- 4 Check the date of last update of the web page. This can be tricky to find on some pages, but it is usually there and will let you know how current the information is.
- 5 Verify the information you find by looking for at least one other site that says the same thing.
- 6 Every time you find new information, write down the reference straight away before you forget.
- 7 Google is a search engine, not a reference. You must list the URL of the specific page, not the Google search page.

How to write a bibliography

The way you acknowledge the source of information depends on whether it is from a book or from an online source. Collect all your references together and then list them in alphabetical order by the author's surname. Most of the information needed to acknowledge books can be found on the imprint page, usually at the front or back of the book.

How to cite a book

Author's surname, first initial, year of publication, title of book underlined, place of publication, name of publishing company
e.g. Smith, J 2013, Ecology for secondary students, Sydney, NSW Publishing House

How to cite a website

Owner or author of site if there is one available (look in the 'contact' section), 'title of page in quotation marks', year published or last updated, title of website, date you viewed the page, full URL
e.g. ScienceDaily, 'Microorganism', 2010, ScienceDaily, 4 Jan 2014, <http://www.sciencedaily.com/articles/m/microorganism.htm>

QUESTIONS 1.1.3: THE EFFECT OF HUMAN ACTIVITIES ON FOOD WEBS

Remember

- 1 Recall a species that benefits from the clearing of ecosystems by humans for agriculture, and explain why they benefit.
- 2 Define the term 'biodiversity'.
- 3 Recall how it is thought that the northern Pacific seastar was introduced into Australian waters.
- 4 Explain why introduced species can upset the balance of an ecosystem.

Apply

- 5 Predict whether a woodland ecosystem or a grassed paddock would filter water entering underground water supplies more effectively. Justify your decision.
- 6 Using specific examples, describe how two different human activities have changed natural ecosystems.

Analyse

- 7 Explain why the introduction of *Cactoblastis cactorum* was so successful with reference to food webs.



1.1

CHECKPOINT

INTERACTIONS BETWEEN ORGANISMS IN ECOSYSTEMS

Remember

- 1 Identify the three main groups of organisms that are present in all food chains. Provide at least two specific examples for each group. [3 marks]
- 2 Describe the difference between a food chain and food web. [1 mark]
- 3 Define the term 'biodiversity'. [1 mark]
- 4 Complete the following statements by selecting the correct term from each pair:
 - a Biological control is the use of (natural predators and diseases)/(chemicals and culling) to control pest populations. [1 mark]
 - b Urban sprawl is a threat to natural ecosystems due to (introduced species)/(habitat loss). [1 mark]
 - c Low biodiversity increases the chance of the collapse of an ecosystem due to (small populations not breeding well)/(little variation within the community and low resistance to change). [1 mark]
- 5 Describe the role of detritivores and decomposers in ecosystems. [2 marks]
- 6 Recall the trophic level of a second-order consumer. [1 mark]

Apply

- 7 Explain how knowledge of food webs can allow the successful introduction of a new species and the sustainable management of ecosystems. [2 marks]
- 8 Cats are an introduced species into Australia and are excellent predators. There are many pet and feral (wild) cats throughout the country. Explain how the introduction of cats into Australia would have affected each of the species in the original food chain shown in Figure 1.28. [4 marks]
- 9 Food chains are usually represented as a line. Propose why food chains could be thought of as a cycle. Hint: Think about how decomposers and producers may be linked. [1 mark]
- 10 Draw a food web to represent the following information: [5 marks]
 - Native grass and wattle trees are the main producers in an ecosystem.

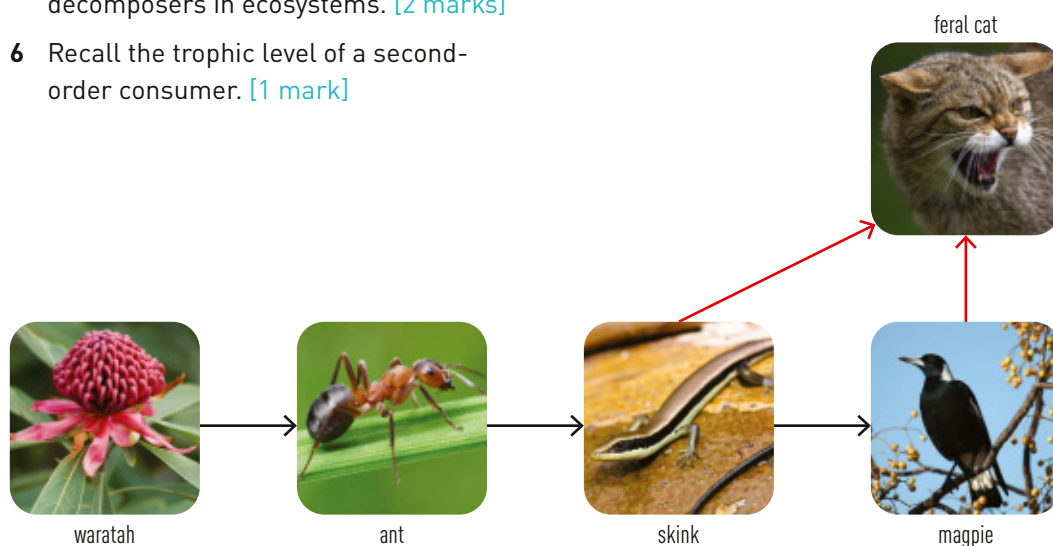


Figure 1.28 In what ways does the feral cat affect the natural food chain?

- Finches eat the seeds of the native grass, honeyeaters eat the nectar of the wattle and beetles eat both types of plant.
 - Honeyeaters will also eat the beetles.
 - Crows will eat the beetles and the eggs and the young of the finches and honeyeaters.
- 11** Predict the effects of the removal of the honeyeaters from the food web you drew in question 10. [3 marks]
- 12** Figure 1.29 shows part of a food web typical for the oceans around Antarctica.
- Identify the producer of this food web. [1 mark]
 - Identify all the prey of Emperor penguins. [2 marks]
 - List all the predators of crabeater seals. [2 marks]
 - Draw a food chain that has the south polar skua as a tertiary consumer. [3 marks]
 - Phytoplankton are microscopic organisms that can photosynthesise. Explain how these small organisms can support such a diverse food web. [2 marks]

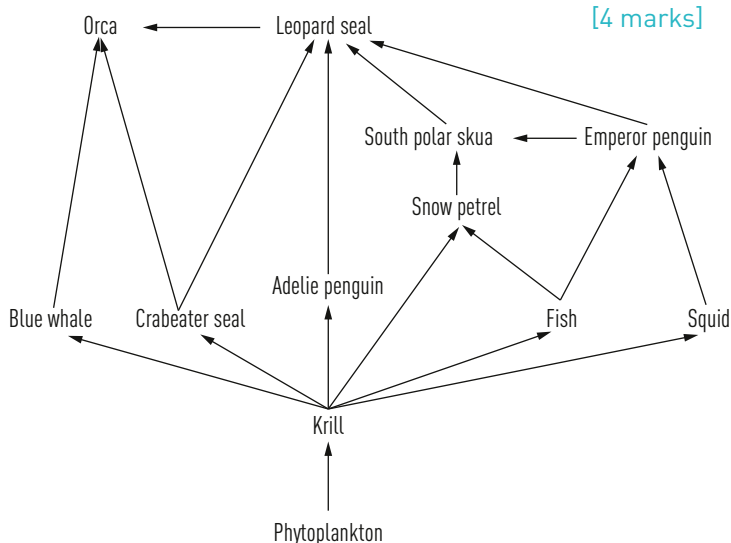


Figure 1.29 An Antarctic food web.

Analyse

- 13** The Earth's spheres are all connected through the biosphere. Suggest how changes in the lithosphere, hydrosphere or atmosphere could affect the biosphere and food chains. [2 marks]
- 14** Predict whether it would be more harmful to an ecosystem to lose a producer or a consumer. Justify your opinion. [2 marks]
- 15** Propose why food chains rarely have more than five trophic levels. [1 mark]

Research

- 16** Investigate the local ecosystems around your school or home. Research the different species and create a food web with as much detail as possible. [3 marks]
- 17** Many people are afraid of spiders and try to remove them from around their home. Research why spiders are an important part of ecosystems. [2 marks]
- 18** Urbanisation has a major impact on natural habitats, but it is not always negative. Investigate some Australian native species that benefit from urbanisation. For one of the species, identify where they can be commonly found and suggest at least two reasons why they thrive in urban areas. [4 marks]



TOTAL MARKS
[/50]

1.2

MICROORGANISMS IN ECOSYSTEMS

Microorganisms are living things that can only be seen with a microscope. They are usually bacteria or protozoa, but some species of fungi are also microorganisms. Microorganisms can be found on our skin, inside our bodies, deep under the oceans and even in the boiling mud pools near volcanoes. Some microorganisms interfere with the way our body works and can make us sick. Others supply us with vitamins and help digest the substances our bodies cannot use. We even use some microorganisms to make food to eat and to produce alternative fuels for our vehicles.

MICROORGANISMS AROUND US

Microorganisms were one of the first forms of life on the Earth. Some of the oldest fossils discovered, which date back 3.5 billion years, were found to contain microorganisms that could photosynthesise. These microorganisms called blue-green algae, or cyanobacteria, lived in colonies in the ocean and used photosynthesis to produce usable energy, just as modern plants do today.

The cyanobacteria colonies trapped sediment in the water, which over time create limestone structures called stromatolites (see Figure 1.30). The live cyanobacteria colonies are spread out in a thin layer on the surface of these stromatolites, with the next layer of limestone slowly forming beneath them. It can take up to 100 years for a stromatolite to grow five centimetres!



Figure 1.30 The stromatolites of Hamelin Pool in Western Australia are made by photosynthesising cyanobacteria.

ACTIVITY 1.2.1: MICROORGANISMS IN THE ENVIRONMENT

WARNING

- > Most human pathogenic bacteria and fungi (those that are potentially harmful to humans) grow optimally at 37°C. Do not reopen any of the plates once they have been sealed. Samples should be sealed with paraffin wax or tape before incubation and safely disposed of as instructed by your teacher immediately after analysis.
- > Do not swab surfaces that may have human pathogens, such as bathrooms or toilets.
- > Wash your hands thoroughly before and after the experiment, and after examining the plates.

What you need: 3 Petri dishes (containing nutrient agar), 2 sterilised swabs, paraffin wax strips, 2 incubators, masking tape, marker pens

- 1 Use two agar plates for growing microbes and the third as the control plate. Do not open the control plate at any stage of the activity. Label it 'control', seal it and incubate it alongside the sample plates.
- 2 Decide on a site around the school to be tested for microorganisms. Examples include tap handles, laboratory benches, light switches and rubbish bin lids.
- 3 Keep the swabs sealed and sterile (germ-free) until you reach the site.
- 4 Rub the swab over the site and then very gently rub it backwards and forwards across the surface of the agar. Take care not to damage the surface of the agar.

- 5 Quickly place the lid on the plate, seal it with wax or tape and label it with the test site name and '22°C'.
- 6 Repeat steps 2–5 for the second plate, taking the swab from the same location, but labelling this plate with '30°C' as well as the site name.
- 7 Incubate each plate at its labelled temperature for 2 or 3 days.
- 8 Observe and identify any bacterial and fungal growth. Some charts showing common types of bacteria and fungi may assist your identification. Record your observations and any identifications made. A labelled drawing of your plates may be useful.
- 9 At the end of the activity, dispose of the agar plates appropriately, following instructions from your teacher.
 - Describe the growth on your sample plates after the incubation period. Did you observe the growth of both bacteria and fungi? If so, what were some of the differences between them?
 - If either of your sample plates showed evidence of growth, do you think that more than one type of microorganism was present? Justify your response.
 - Suggest why the agar plates were incubated at 22°C and 30°C for 2 or 3 days.
 - Describe how the growth on the two sample plates differed. How do you think the temperature influenced this growth?
 - Suggest why there may be some differences between the growth on your plates and those of other students.
 - Explain why it is important that both the swab and plate are sterile and only exposed to the environment for a short period while collecting the sample.
 - If the control plate was sterilised appropriately before the activity and then incubated alongside the sample plate, it should have showed no bacterial or fungal growth. Explain the purpose of the control plate.
 - What do your results suggest about microorganisms in your local environment?

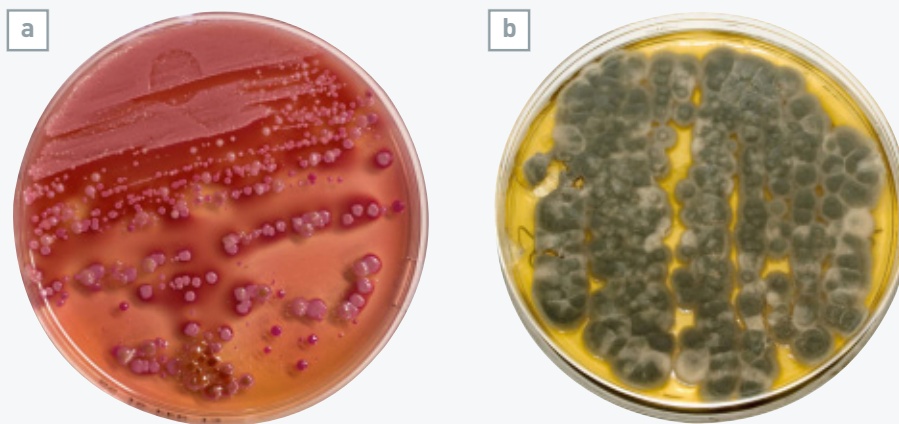


Figure 1.31 (a) Bacterial colonies growing on an agar plate. (b) Fungi tend to have a dusty or fuzzy appearance.



Increasing the reliability of your data

When planning or conducting an experiment, you should always think critically about the reliability of the data in your results.

Reliability of data is a measure of how accurate and consistent the results are. A reliable experiment will produce similar results every time the experiment is conducted using the same method and conditions. Unreliable data is when different results are gathered every time the experiment is carried out.

To ensure your results are reliable, you should always repeat your experiment and average the results. Conducting the same experiment multiple times in a row can be very time consuming, so scientists commonly do three things to ensure reliability:

- Run a controlled experiment and think carefully about what variables should be controlled, tested (independent variable) and measured (dependent variable).
- Compare the results to others doing the same experiment. This means you can use the data gathered by other students in your class.
- Complete multiple trials at the same time. Instead of growing one plant under particular conditions, you would grow 10, 20 or even 100 plants under those conditions at the same time.

Once you have collected multiple pieces of data for the same condition, you should

then find the average of those results and use the average to make your inferences and draw conclusions.

For example

A microbiologist was investigating the environmental conditions that best promote fungal growth. She compared three different sets of conditions by growing fungal colonies in agar plates. Rather than putting one plate (one trial) in each condition, she used 10 different plates (10 trials) for each condition. Her results were as follows:

To find the average number of colonies grown under condition A, add all the results for that condition together, then divide by the number of results, in this case, 10.

$$\begin{aligned}
 \text{average} &= \frac{\text{sum of data}}{\text{number of data}} \\
 &= \frac{5 + 6 + 4 + 7 + 4 + 5 + 6 + 4 + 5 + 4}{10} \\
 &= \frac{50}{10} \\
 &= 5
 \end{aligned}$$

So an average of five colonies grew in condition A, per plate.

Your turn

Calculate the average number of colonies that grew in conditions B and C. Compare the averages and decide which condition is best for growing this species of fungi.

Condition	Number of fungal colonies after 5 days (per plate)									
	Plate 1	Plate 2	Plate 3	Plate 4	Plate 5	Plate 6	Plate 7	Plate 8	Plate 9	Plate 10
A	5	6	4	7	4	5	6	4	5	4
B	9	8	9	9	11	12	11	12	10	9
C	1	0	2	0	1	0	0	2	1	3

Types of microorganisms

Microorganisms are too small to be seen by the human eye. Instead, a microscope is needed to study them. Microorganisms vary in size from one-tenth of a millimetre to one-thousandth of a millimetre. Some microorganisms, such as bacteria and protozoa, are unicellular (single-celled). Others, such as some fungi, are multicellular. Microorganisms exist within and around us all the time.

Bacteria

Bacteria are from the kingdom Monera and are prokaryotic. While they have DNA, prokaryotic cells do not have a true nucleus or membrane-bound organelles. Bacteria come in many different shapes and sizes, and the shape of an individual bacterium can help identify the bacteria species.

Bacteria cells can be identified by the following characteristics:

- very small size
- presence of a cell wall (although it is made from a different chemical from those in plants)
- absence of a membrane-bound nucleus and organelles.

Some bacteria may have cilia (short hair-like structures) and/or flagella (long tail-like structures) on the surface of the cells. Cilia and flagella both help with movement.

Extremophiles are a relatively newly discovered group of microorganisms that can survive in extreme conditions such as the frozen poles of the Earth (cryophiles), the hottest deserts (thermophiles), environments with high acid concentrations (acidophiles), environments with high salt concentrations (halophiles), or environments with no oxygen (anaerobic extremophiles). Once considered part of the bacteria family, extremophiles are now in their own domain called Archaea.

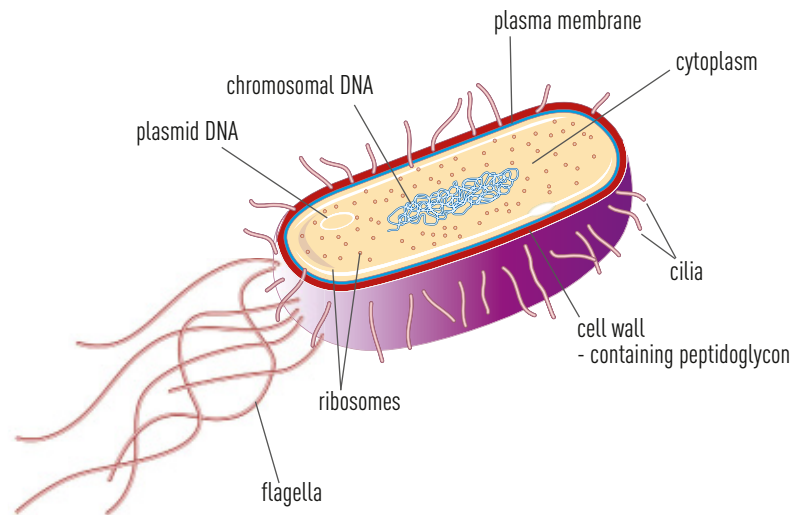


Figure 1.32 A bacterial cell.

Protozoa

Protozoa are from the kingdom Protista and tend to be much larger than bacteria, up to one millimetre in length. They are eukaryotic organisms and as such have membrane-bound organelles and a true nucleus. Rather than a cell wall, they have an outer membrane called a pellicle that is more rigid than the inner cell membrane, which helps to give them additional structure and support. However, like bacteria, they may have cilia and/or flagella on their cell surface to help with movement.

The shape and internal structure of protozoa vary greatly between species depending on their requirements. Protozoa can appear in food webs as producers, consumers, parasites and decomposers.

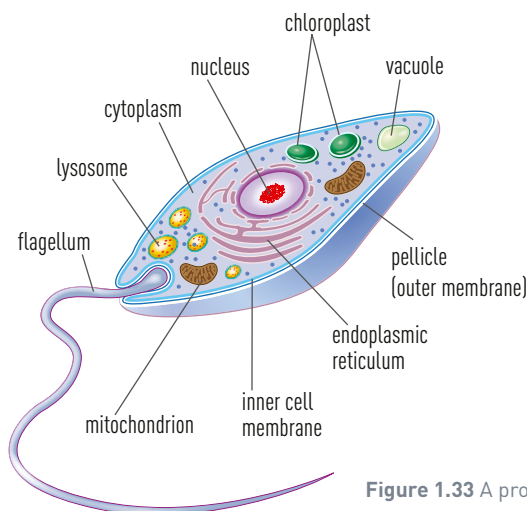


Figure 1.33 A protozoan cell.

Fungi

When we think of organisms from the kingdom Fungi, we often think of mushrooms. But this group of microorganisms is much broader and includes organisms such as yeasts and moulds. Yeast is a unicellular fungi commonly used to make bread. The yeast organisms break down the sugar in the dough and form carbon dioxide gas as a by-product. It is this gas that causes the bread to rise.

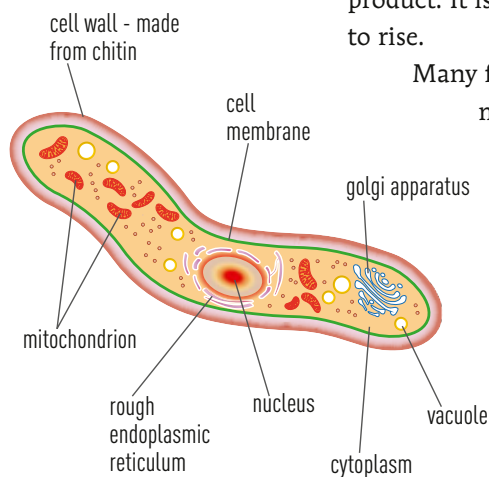


Figure 1.34 A fungal cell.

Many fungi species, such as food moulds, grow as a mass of small threads called hyphae. These long thin cells are connected end-to-end. We cannot see this jungle of hyphae without a microscope. Instead, we often see a furry mass (the hyphae) with tiny black spots, which are the reproductive cells of the fungi.

Fungi are eukaryotic (like protozoa), and so have a membrane-bound nucleus and organelles. However, fungi are unable to photosynthesise so they never contain chloroplasts. Fungi are heterotrophic, like animals. They are surrounded by a cell wall made from a chemical called chitin.

Fungi must grow on a surface, so do not require cilia or flagella for movement.

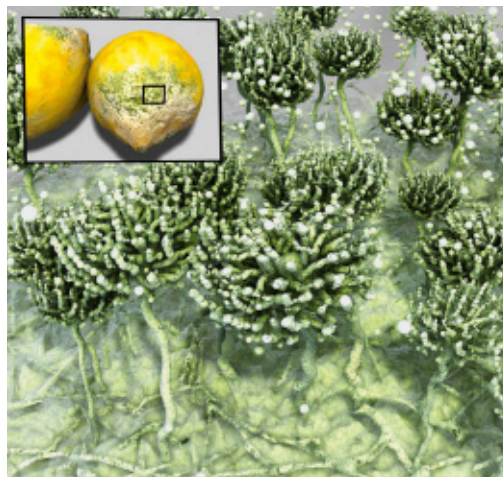


Figure 1.35 A microscopic view of the food mould growing on this lemon.

ACTIVITY 1.2.2: EVERYDAY MICROBES

Working in small groups, research ways that microorganisms (microbes) are a part of our everyday lives.

- Which microbes improve our lives? Describe how they do this.
- Which microbes cause harm? Describe how they do this.
- Are there any microbes that can both improve our lives and cause harm?
- Share the results of your group's research with the rest of the class.

QUESTIONS 1.2.1: MICROORGANISMS AROUND US

Remember

- 1 Define the term 'microorganism'.
- 2 Recall the three kingdoms that contain microorganisms.
- 3 Identify which microorganisms form stromatolites.
- 4 Recall the function of cilia and flagella.

Apply

- 5 Propose a reason why some of the earliest forms of life on the Earth needed to be able to photosynthesise.
- 6 Identify the likely position cyanobacteria would occupy in a food chain.
- 7 Use a Venn diagram or other graphic organiser to display the similarities and differences between the three main groups of microorganisms.

BENEFICIAL MICROORGANISMS

Microorganisms are present in every ecosystem on the planet and appear in every trophic level of food webs. When we think of microorganisms, we tend to think of them in terms of things that give us disease and make us ill. However, only a small percentage of microorganism species cause disease. Most of the microorganisms that live on our skin or inside us are actually helping to keep us alive and healthy.

Microorganisms as producers

All plants need nitrogen to make important molecules for their cells. Many soils do not contain enough nitrogen in the soil alone to keep a plant growing. Instead, some plants work with the **nitrogen-fixing bacteria** in the soil. The plants provide protection for the bacteria, which live in their roots, and the bacteria take the nitrogen out of the air and soil and change it to a form the plant can use. When the plant dies, the excess nitrogen and the nitrogen-fixing bacteria return to the soil for other plants to use.

Phytoplankton is a group made up of a huge variety of microorganisms that live in the ocean and photosynthesise. Phytoplankton is a vital food source

for many marine organisms and the producer in many marine ecosystems.

Phytoplankton reproduces very quickly, but is eaten almost as fast and so their numbers remain fairly consistent and relatively low compared with the number of consumers they support. However, their rapid reproduction allows them to maintain a balanced food web and to provide around 40% of the Earth's oxygen through photosynthesis.

Microorganisms as consumers

Yoghurt is a result of bacteria being deliberately being added to milk. The milk is heated, and then a bacteria such as *Lactobacillus delbrueckii* is added. These microorganisms consume and break down the lactose in the milk to produce lactic acid, which thickens the milk and forms yoghurt.

Other microorganisms are used to make soft cheeses. Yeast is used to help make bread rise and also to form alcohol. All the microorganisms used in food production are simply consuming nutrients and converting them into different chemicals. What are considered as wastes for the microorganisms are vital ingredients for some of our food products.



Figure 1.36 These foods are all made using bacteria or yeast.

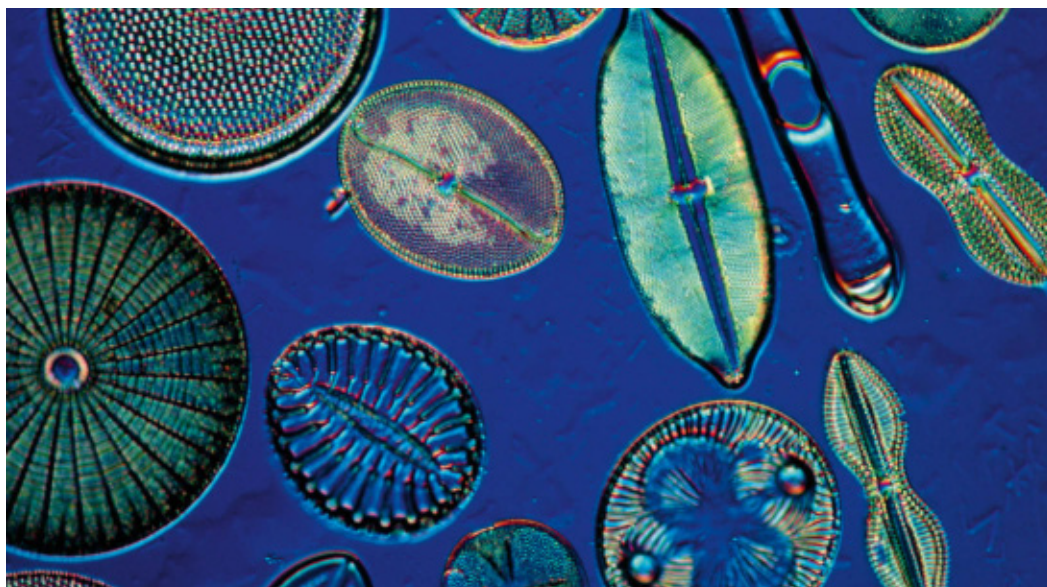


Figure 1.37 Phytoplankton is composed of a huge variety of photosynthetic microorganisms.

The microorganisms we use to help produce food were originally found in natural ecosystems. Discovering that different microorganisms could be used to make food for us was often accidental.

Microorganisms also live inside the digestive systems of animals to help them digest the food they eat. Herbivores eat only plants. Although there is a lot of energy in plant tissue, it is difficult to digest. Animals such as cows can digest the cellulose in grass with the help of archaea (ancient group of

bacteria) that live in their four-chambered stomachs. Cows repeatedly regurgitate the food in their stomach, which is covered in digestive chemicals and bacteria, back into their mouths to be re-chewed and mixed further. This 'chewing of cud' explains why you often see cows that seem to be chewing without eating anything new. Without the bacteria, even this long chewing process would not be enough to obtain the nutrients from the grass.

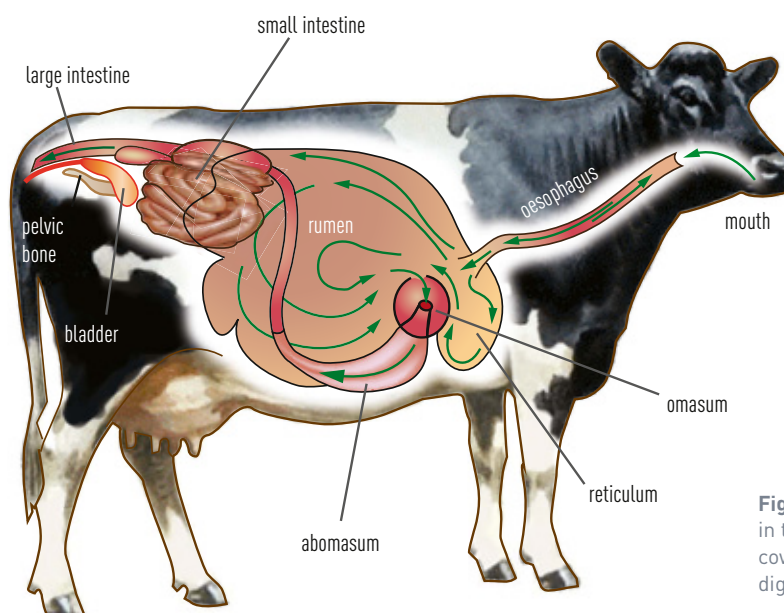


Figure 1.38 It is the bacteria in the four chambers of the cow's stomach that help it digest cellulose in grass.

ACTIVITY 1.2.3: MAKING YOGHURT

WARNING

- > Never consume food or drink in a science laboratory.



Figure 1.39 Why should you use sterilised containers for making yoghurt?

What you need: 2 cups powdered milk, 4 cups warm water (~40°C), 1/3 cup plain yoghurt with active culture and no additives, sterilised plastic cups or jars, insulated container

- 1 Mix the milk powder and the warm water thoroughly until all clumps are dissolved.
- 2 Add the yoghurt and mix quickly to prevent the milk from cooling.
- 3 Pour the mixture into the sterilised plastic cups or jars, then place into an insulated container.
- 4 Fill a few plastic cups or jars with hot water and place them into the insulated container to help keep it warm. Leave undisturbed for 6–8 hours.
 - What happened to the milk mixture?
 - Why did you need to add some yoghurt to the milk?
 - If you have time, design an experiment to test the optimum temperature for the bacteria to work.

Biofuels

We are very dependent on fossil fuels for many things, such as energy production and transport. Bacteria discovered in the hot springs of Yellowstone National Park in the United States of America are starting to help us run our cars on plants instead of petrol. The bacteria consume and break down a plant called switchgrass to produce a fuel called ethanol. This ethanol is called a biofuel because living organisms make it. Although the ethanol is currently only being used to fuel the rangers' trucks within the park, scientists are hopeful that they can develop ways of using the bacteria to produce enough ethanol to run much larger numbers of cars ... potentially for the whole country!

Oil spills

When 800 million litres of oil was spilled in the Gulf of Mexico in 2010, scientists were surprised to find that the oil did not spread as far as expected. After taking samples of the sea water in the area, scientists found the numbers of a particular bacteria species were larger than expected. These bacteria live naturally in the ocean, consuming petrochemicals (such as oil) that seep from the ground. The large oil spill caused

the bacteria to grow and divide rapidly, 'eating' the petrochemicals within a few months and changing them into a less toxic substance. Scientists are now trying to determine what helps these bacteria to grow so we can use them to clean up oil spills in the future.

Microorganisms as decomposers

Imagine if dead things did not go soft and mouldy, and did not eventually decompose back into the soil. We would have to wade through dead plants and animals every time we left the house! Bacteria and fungi are responsible for the breakdown of once-living tissue. This allows the molecules that made up the tissue to be used over and over again. We also use microorganisms in the treatment of our sewage. Once we flush our waste down the toilet, it flows to a sewerage plant, where it is treated. One part of this treatment uses bacteria to digest the chemicals within the sewage into less toxic forms.

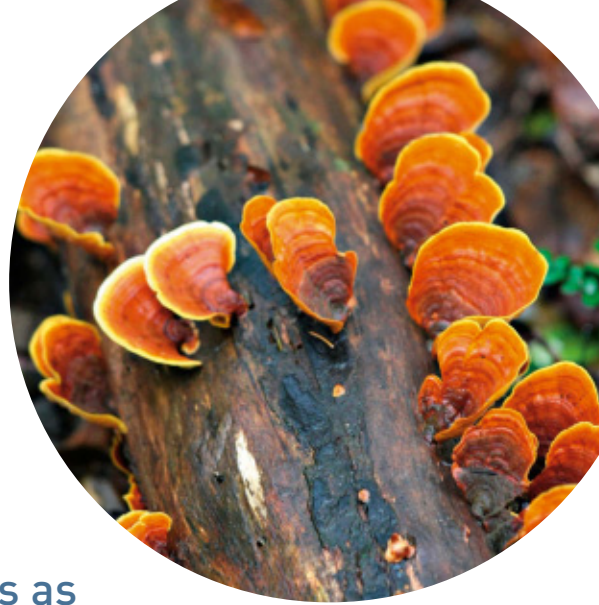


Figure 1.42 Microorganisms such as fungi help break down living tissue and return the compounds to the soil for plants to reuse.

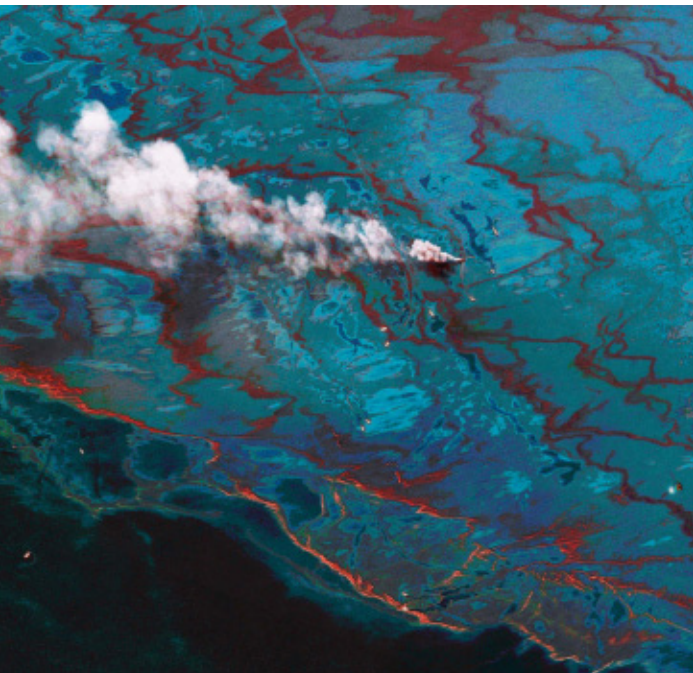


Figure 1.40 Bacteria helped to contain the oil spill in the Gulf of Mexico in 2010.



Figure 1.41 This once-living tree is slowly decomposing.

Microorganisms inside us

Some of the microorganisms we most depend on are the natural flora that live on our skin and inside our intestines. The microorganisms on our skin protect us from other microorganisms that might be harmful. The bacteria in our intestines also prevent other 'bad' bacteria from growing there.

The average adult human has 1 kilogram of microorganisms inside their large

intestine alone. This kilogram is made up of thousands of different species of microorganisms. Without the microbes in our gut, we would not be able to digest food properly, get rid of wastes or make essential vitamins. You might be familiar with the bacteria *Escherichia coli* (*E. coli*) from reading about cases of food poisoning. However, there are also harmless, beneficial forms of this bacteria that live in our intestines and make vitamin K. We need vitamin K to help keep our body healthy.



Figure 1.43 Some bacteria that make up our natural flora include (a) *Staphylococcus epidermis* on our skin; (b) *Staphylococcus aureus* on our skin and in our nose and other airways; and (c) *Escherichia coli* in our large intestine.

QUESTIONS 1.2.2: BENEFICIAL MICROORGANISMS

Remember

- 1 List at least three foods that require microorganisms in their production.
- 2 Identify the difference between a fossil fuel and a biofuel.

Apply

- 3 Identify two professions that would use microorganisms every day.
- 4 Identify at least three ways in which bacteria are helping your personal health and survival.
- 5 Explain, using examples, how microorganisms appear in every trophic level of food webs.
- 6 Describe an example of a beneficial effect of microorganisms on the environment.

Research

- 7 Investigate an ecosystem where phytoplankton is the main producer. Draw a food web to represent this ecosystem.
- 8 Mammals such as cows that have multichambered stomachs are called ruminants. Research at least two other ruminants and two herbivores that are not ruminants. Research how non-ruminants digest plant material.



Figure 1.44 Are elephants ruminants?

HARMFUL MICROORGANISMS

Not all microorganisms are beneficial to us or to the environment. Too many 'good' microorganisms can also be bad for us or bad for the ecosystem in which they live.

Too much of a good thing

Eutrophication of an aquatic ecosystem occurs when excess nutrients are available. Eutrophication can happen naturally but is most often caused by fertiliser runoff reaching freshwater lakes or oceans. In eutrophication, protozoan algae and cyanobacteria in the water thrive on the extra nutrients and reproduce rapidly, and form what is known as an algal bloom.

These photosynthetic algae form a layer on the surface of the water, preventing the sunlight from reaching other aquatic plants or photosynthetic organisms below the surface. Without access to sunlight, these organisms die.

The huge numbers of algae also cause massive changes in the amount of oxygen available in the water. During the day, the algae photosynthesise faster than they respire, and therefore produce much more oxygen than they use. However, during the night when they cannot photosynthesise, the algae use up the dissolved oxygen during the process of respiration, which then limits the amount of oxygen available to other organisms. When the plants killed by the lack of light and oxygen decay, the process of

decay caused by other bacteria will also use up dissolved oxygen from the water body, further limiting the amount of oxygen to other organisms.

In some cases, anaerobic bacteria (which do not require oxygen to respire) flourish. These bacteria release toxins that are deadly to birds and mammals, harming anything that may live in or drink the water.

Microorganisms that cause disease

We have all been sick at some stage in our lives. Wild animals and plants in natural ecosystems can also become sick and die, and if many animals or plants are affected, it can affect the overall balance of an ecosystem. Some diseases are caused by pathogens.

A **pathogen** is a foreign body that can potentially cause a disease. Not all pathogens are microorganisms. Viruses and prions (rings of faulty proteins) can also cause diseases, but they are not living organisms.

It is important to remember that not all microorganisms are pathogens. In fact, most microorganisms are either harmless or beneficial to our health. Microorganisms that are **pathogenic** (cause disease) include bacteria, fungi and protists. If these 'bad' microorganisms make it through your skin and your body's other defences, they will make you sick.



Figure 1.45 Some microorganisms make us sick.



Figure 1.46 Fish and other aquatic organisms are often killed as a result of algal blooms that remove oxygen from the water.

Figure 1.47

(a) *Trichophyton mentagrophytes* – a fungus that causes tinea and ringworm; (b) a red blood cell infected with *Plasmodium* – a protozoan that causes malaria; (c) *Mycobacterium* – a bacteria that causes tuberculosis.



Pathogenic fungi

Fungi can be harmful to both plants and animals. Fungi can be passed between people through clothing, towels and face cloths. A fungal infection often shows up as a small or rough patch of irritated red skin. Fungal infections such as tinea and ringworm are often itchy and uncomfortable.

Fungi and mould can grow on damp clothing, leaving small black spots and eventually decomposing the material. These microorganisms can also grow in damp houses. The fruiting bodies of the mould can be released into the air and inhaled by people living there. This can cause severe asthma-like reactions or potentially life-threatening chest infections.

Fungi are the most common pathogens that infect plants. The names of the plant diseases usually relate to the description of the symptoms rather than the pathogen that causes the disease because plant diseases were first noticed in crop plants, many years before the invention of the microscope. Fungal plant diseases include rusts, rots, blights, wilts, cankers and galls.

Pathogenic protozoa

Most pathogenic protozoa are considered to be parasitic because they take nutrients directly from their host, the organism in which they live. For example, *Giardia lamblia* infects the small intestines of mammals, absorbing digested nutrients and

causing weight loss, diarrhoea, vomiting and stomach pain in the host.

Another common group of pathogenic protists are those in the genus *Plasmodium*. These pathogens cause malaria, one of the most common diseases in the world. *Plasmodium* cells are transferred to humans via the saliva of an infected mosquito. Once inside the body, they travel to the liver and infect red blood cells, absorbing nutrients. The symptoms and signs of malaria are similar to a bad flu; headaches, fever, nausea, vomiting and muscle aches. In some severe cases, malaria can lead to coma or death.



Figure 1.48 *Plasmodium* is spread between hosts by mosquitoes.



Figure 1.49 Ringworm is actually caused by a fungus, often appearing like a worm curled up under the skin.

Pathogenic bacteria

Clostridium tetani is a bacteria species that lives in the soil and on rusty objects. When we get a cut or scratch, these bacteria can enter our body. They grow well in the anaerobic (oxygen-free) environment under the skin and start to reproduce. They produce a toxin that causes our muscles to seize, including the jaw muscles. For this reason, the infection is sometimes called lockjaw, as well as tetanus.

Salmonella is another genus of bacteria that produces a toxin. It causes nausea,

vomiting, stomach cramps and bloody diarrhoea. It can often be found in raw chicken or fish. Although cooking can kill the bacteria, the toxin it produces is not affected. This is why it is important to refrigerate food, because few bacteria can grow below 4°C (the temperature of a fridge).

Only around 100 species of bacteria infect plants. These bacteria invade the plant cells and produce chemicals that are toxic, destroy cell walls, or block the plant's transport system.



Figure 1.50 Tetanus is a common bacterial infection that is easily avoided by having regular vaccinations.

Viruses and prions

Viruses and prions are considered by most scientists to be non-living pathogens. Viruses cannot survive and reproduce outside a host cell, and prions are just an infectious form of a naturally occurring protein molecule.

Viruses are responsible for most of the common colds we experience and cannot be controlled by antibiotics because, unlike

bacteria, they hide inside our own cells. The treatment for viruses like the common flu is to rest, eat nutritious food and drink plenty of water. This will help our body get rid of the virus by itself.



DEEPER
UNDERSTANDING

QUESTIONS 1.2.3: HARMFUL MICROORGANISMS

Remember

- 1 Not all microorganisms are harmful. Identify the term used to describe microorganisms that cause disease.
- 2 Define the term 'natural flora'. Recall whether or not natural flora is harmful to our bodies.
- 3 Recall the reason why disease-causing viruses and prions are not considered to be microorganisms.

Apply

- 4 Propose why it is important to wash a skin cut if you injure yourself while gardening.
- 5 Outline why it is important to refrigerate food.
- 6 Explain why populations of blue-green algae as a result of eutrophication are harmful to their ecosystem.

Research

- 7 Choose a human infectious disease caused by a microorganism. You may choose one mentioned in this chapter or a different one. Investigate your microorganism and the disease(s) it causes. Prepare an informative pamphlet that outlines the type of microorganism, how it is passed between people, how common the disease is, the symptoms of the disease and the common treatment.

1.2

CHECKPOINT

MICROORGANISMS IN ECOSYSTEMS

Remember

- 1 Recall what a stromatolite is. [1 mark]
- 2 Identify a reason why having natural flora on our skin is beneficial. [1 mark]
- 3 Define the term 'pathogen'. [1 mark]
- 4 Identify the five main groups of pathogens. [5 marks]
- 5 Recall the main producers in aquatic ecosystems. [1 mark]
- 6 Identify the main difference between eukaryotic and prokaryotic organisms. [1 mark]

Apply

- 7 An unknown microorganism is viewed under a microscope. Each cell can be seen to have a cell wall and a cell membrane, to contain a nucleus and mitochondria, and to have flagella on the surface of the cell. Identify the likely group of microorganism these cells comes from. Justify your choice. [3 marks]
- 8 Explain why most herbivores benefit from having bacteria in their digestive systems. [1 mark]
- 9 Phytoplankton produce around 40% of the breathable oxygen on the Earth. Explain how these microorganisms can be harmful to the environment. [3 marks]
- 10 Identify one example of a microorganism as a producer, one as a consumer and one as a decomposer. [3 marks]
- 11 Complete the following table to compare types of microorganisms. [10 marks]

	Bacteria	Protists	Fungi
Outer membrane/cell wall	cell wall containing peptidoglycon	outer membrane – pellicle	
Chromosomal DNA			present
Plasmid DNA	present	absent	
Nucleus		present	present
Flagella or cilia	either		
Chloroplasts		some	absent
Mitochondria	absent		

Analyse

- 12 Antibiotics are chemicals that kill bacteria. One side effect of taking antibiotics is an increased chance of a fungal infection. Using your knowledge of microorganisms to explain how this could happen. [3 marks]
- 13 'Bacteria are bad for us.' Evaluate this statement and write a response to support or disagree with it. [2 marks]

Research

- 14 Research ethanol as a biofuel and the role of microorganisms in its production. Present your information as a poster, an audio-visual presentation or an informative pamphlet. [5 marks]



TOTAL MARKS
[/40]

MANAGING ECOSYSTEMS

1.3

Australia has a vast range of ecosystems and unique species. Maintaining this biodiversity is important for the health and functioning of Australian ecosystems. The interactions between organisms in an ecosystem are complex, and losing a key species could have a devastating effect on an ecosystem. It is up to us as a society to manage and preserve our ecosystems effectively.

ECOLOGY IN AUSTRALIA

Ecosystems in Australia are affected by human activities, such as deforestation and the use of fossil fuels, as well as natural events such as floods, droughts and bushfires. Such changes can affect individual or multiple species, often reducing biodiversity and potentially causing food webs and ecosystems to collapse.

Around 85% of Australia's flowering plants, 84% of mammals, 45% of birds and 89% of inland fish species are native only to Australia and nowhere else in the world. If

these species become extinct in Australia, they will be lost from the biosphere forever.

Ecology is the study of ecosystems and changes to ecosystems. **Ecologists** and environmental scientists work to reduce the impact of natural events and human activities on ecosystems to develop **sustainable** management strategies for those ecosystems.



Figure 1.51 The platypus is one of many species that are unique to Australia.

Australian ecologists and environmental scientists

Dr Joe Benshemesh

The Australian marsupial mole is an interesting animal that has no eyes, no external ears, sharp shovel-like paws for digging and a hard pad to protect its nose. They are extremely difficult to find, are rarely seen or photographed, and as a result have been listed as a critically endangered species. However, Dr Joe Benshemesh of La Trobe University has uncovered evidence that the marsupial mole may be a lot more common than previously thought.

Using a geophone, a device that detects vibrations underground, Dr Benshemesh detected the sounds of the moles 'swimming' through the loose sand of the dunes in Uluru-Kata Tjuta National Park in the Northern Territory. By digging a series of short, shallow trenches,

Dr Benshemesh and his team of ecologists discovered 90 km of tunnels in a 10 000 m² area.

Further research about this marsupial and its ecosystem is required to ensure that additional habitats can be located, and the animal and its ecosystem are protected.



Figure 1.52 Ecologist Dr Joe Benshemesh is researching the marsupial mole and its ecosystem. This mole is eating a gecko.

LITERACY
BUILDER

Professor Peter Newman

Peter Newman is Professor of Sustainability at Curtin University in Perth. His most well-known research as an environmental scientist is about sustainable cities and reducing the impact of human activities on the environment.

He investigated the relationship between increasing urban sprawl and 'car dependence', a concept that must now be considered when planning new cities or suburbs. Professor Newman helped redesign Perth's railway system to encourage people to use public transport and reduce the number of cars on the roads.

Professor Newman has written a book about redeveloping urban areas to increase local biodiversity and sustainability. Some of the main ideas include collecting rainwater, growing gardens on the roofs of large buildings, having biodiversity gardens and parks designed specifically for endangered species, using community gardens to grow food locally, and creating pedestrian-friendly spaces to encourage walking or cycling instead of driving.

Questions

- 1 Why does Dr Joe Benshemesh believe the marsupial mole is not critically endangered?
- 2 What scientific technology did Dr Benshemesh use to locate marsupial moles?
- 3 Why do you think it is important to research a species like the marsupial mole?
- 4 What research is Dr Peter Newman best known for?
- 5 What was the purpose of redesigning the railways in Perth?
- 6 Suggest some long-term benefits of rooftop gardens.
- 7 What do ecologists and environmental scientists have in common?

Figure 1.53 Rooftop gardens increase biodiversity and help reduce greenhouse gases in the atmosphere. They can be used to grow food, to provide a vital habitat or simply be beautiful places to visit.



Figure 1.54 Rising salinity makes soil toxic for many plant species.

Lifestyle and biodiversity

Not everyone in the world has the same lifestyle as we do in Australia. Our basic standard of living in most of Australia is far higher than that of most other people in the world.

On average, Australians now own more goods, use more energy, eat more processed food and have larger houses than ever before. All this consumption, on top of a growing population, can create problems for biodiversity. Land is cleared to grow our food, to make room for industries and to build houses, which results in removing habitats for other living things. Clearing land can cause increasing salinity (salt

concentrations) of some Australian soils. A severe salinity increase makes the soil unsuitable for many of the plants that usually grow on the land. Without the producers, consumers have nothing to eat and the balance of the ecosystem can fail.

The environmental effect of consumption is not confined to a local area. For example, using fossil fuels such as coal

for energy in Australia affects global carbon dioxide levels and most scientists believe this contributes to the enhanced greenhouse effect. Many of the products consumed by Australians are made from materials sourced overseas. Australian consumption from a global perspective leaves a very large 'ecological footprint' on the environment.

NUMERACY BUILDER

Calculating your ecological footprint

Ecological footprint calculators are online surveys that help you and your family compare the impact of different activities or decisions you make.

- 1 Search online for an ecological footprint calculator or follow the link in your obook. Calculate the ecological footprint for your home or school.
- 2 Calculate your greenhouse gas emissions and the impact of your car, if your family owns one.

- What things can you do at home to live more sustainably?
- What changes would you have to make to your home to live more sustainably?
- What changes would you and your family have to make to your lifestyles to live more sustainably?
- Will these changes eventually save you and your family money?

Why conserve biodiversity?

Worldwide, many species are rapidly becoming extinct. It is likely that 20% of all known species will become extinct within the next 30 years, largely due to human activities that result in habitat loss. Orangutans (see Figure 1.55) are currently listed as endangered and are under threat from habitat loss and hunting. But why does it matter if we lose some species? There are several reasons why we should conserve biodiversity.

The biosphere connects the planet

The biosphere links all the abiotic spheres – the hydrosphere, atmosphere and lithosphere. A decrease in biodiversity in the biosphere will eventually result in large-scale changes to the other spheres. Healthy ecosystems are necessary to maintain our atmosphere, climate, clean water and productive soils.

Biological resources

Biological resources include the whole or part of an organism, the genetic material found in the cells of organisms and the chemicals produced by its cells. These chemicals might be used for food, clothing, medicine or even transport.

Bioprospecting is the search among living things for new biological resources with potential medical or commercial use. Of the world's 25 top-selling pharmaceuticals, ten were originally sourced from animals, plants or microorganisms. A quick look in your bathroom cabinet will reveal many medicines that rely on biodiversity. Aspirin, a common painkiller, is based on a chemical from willow trees. Penicillin, a very common antibiotic, is naturally produced by a particular species of fungi.

Australia has a huge potential for bioprospecting because it is one of the world's most biodiverse nations.



Figure 1.55 Orangutans are currently an endangered species due to hunting and destruction of their habitat.



Figure 1.56 (a) Sea sponges are simple marine animals that can be farmed for use as household sponges by cosmetic and cleaning companies. (b) Cotton is a type of plant, and can be refined and woven into cloth to make clothing.



Figure 1.57 The Australian bush is full of varied and beautiful places for locals and tourists to visit.



Social and cultural values

There are many cultural reasons for maintaining biodiversity. Native plants, animals and ecosystems are part of our cultural identity. People value such areas for relaxation and enjoyment, outdoor activities such as bushwalking and bird watching. The Australian natural landscape has featured in many films, literature and photographs. Our natural environment is a major international tourist attraction.

Indigenous Australians are well known for describing themselves as custodians rather than owners of Australian land, placing such immense value on the country.

Conserving biodiversity raises important ethical questions. Do other species have as much right to the Earth as humans do? What responsibilities do we have for the environment?

We are only one of many species on the Earth. Viewing the planet as a shared one is very important to conserving biodiversity.

Figure 1.58 Humans are just one species on a living planet.

Conservation in Australia

At one time, conservation was thought to be the responsibility of politicians and scientists. Today, individuals and local communities also work to help conserve biodiversity.

If you have access to a piece of land, no matter how large or small, then you have the power to conserve a part of our biodiversity. This includes land such as your backyard, school grounds, community garden or local reserve. The secret is learning how to share our living space with the plants and animals around us.

Corridors of green

Many cities have set aside a permanent 'green belt' as part of their future planning. Green wedges are the non-urban areas of metropolitan areas such as parks and large gardens. These areas protect a city's open spaces and natural areas from overdevelopment. In some places, green wedges are important habitats for animals. They are also important for tourism and recreation. Some green wedges include areas with high heritage values for local Indigenous Australians.



Figure 1.59 Sydney's Royal Botanic Gardens serve as an important green wedge.

Green corridors are consistent stretches of native habitat that allow animals to move from one location to another, through farmland or developed areas. Young animals can use green corridors to move out of an area and form their own territories. Areas of bush with a range of vegetation linked by green corridors provide a safe and suitable area for native birds and animals to live in and travel through. These areas also benefit farmers as they provide windbreaks and shelter. Pest problems are significantly reduced because of the increased number of predatory birds and insects that thrive in these native habitats.

Figure 1.60 The remnants of natural ecosystems along roadsides act as green corridors, and are a vital habitat for many species.



Waterwatch Australia

We have a strong dependency on water, whether it is for crops, drinking or recreation. Unfortunately, many of our river systems have degraded over time. Increasing salinity, sediments, nutrients and algal blooms in our waterways are all symptoms of poor management in our water catchments. Both rural and urban communities can reduce their impact on river systems to maintain or improve the biodiversity.

Waterwatch Australia is a community program that connects local communities, such as schools, with river health and sustainable water management issues. Waterwatch supports and encourages communities to become actively involved in monitoring their local waterways and in taking action. Thousands of Australians volunteer countless hours monitoring, planting and caring for their local creeks, wetlands, groundwater, rivers and estuaries.



Figure 1.61 Waterwatch volunteers monitoring the health of a creek.

QUESTIONS 1.3.1: ECOLOGY IN AUSTRALIA

Remember

- 1 Recall the definition of the term 'bioprospecting'.
- 2 Explain why Australian ecosystems are so important to international biodiversity.
- 3 Recall the difference between a green wedge and a green corridor.

Apply

- 4 Explain why it is more than just the government's responsibility to help protect the natural environment.
- 5 Explain how our standard of living in Australia can have a negative effect on biodiversity.
- 6 Define the term 'ecological footprint' and suggest four things you can do to reduce your ecological footprint.
- 7 Suggest at least one other reason why we should conserve biodiversity that is not already mentioned in this chapter.

Research

- 8 The use of natural sponges is very common. Investigate the advantages and disadvantages of farming sponges in tropical waters off the Australian coast.
- 9 Research a conservation organisation that works in your local area. Identify their main activities that help conserve ecosystems.

MANAGING THE IMPACTS OF NATURAL EVENTS

Change is inevitable in all ecosystems, whether they are natural changes or as a result of human activities. Natural changes can be long-term, such as climatic changes. These long-term changes take such a long time to happen that they are usually beyond the control of humans.

Natural short-term changes are either regular and cyclical, or they are irregular events that can sometimes be considered as natural disasters. Regular and cyclical changes include the changes in abiotic conditions between day and night, between high tide and low tide, and between the different seasons. Examples of irregular **natural events** include bushfires, floods and droughts. Irregular changes are unpredictable in terms of when the event occurs, how long it lasts, and the intensity or severity of the event.

Research into irregular natural events can help ecologists understand and predict the effect on ecosystems and the species

within the ecosystems. If the frequency and intensity of natural events are too great, an ecosystem may experience a significant loss of biodiversity. In this situation, knowledge from ecological research is critical in the development of sustainable management strategies to help conserve ecosystems and reduce the impact of the change on organisms.

Bushfires

Bushfire is a common natural event that ecosystems all over Australia experience at some stage. Many plant species have adapted to survive irregular burning with particularly thick or heat-reflective bark and special epicormic buds that re-sprout from the trunk after burning, and some species even require fire to germinate their seeds.

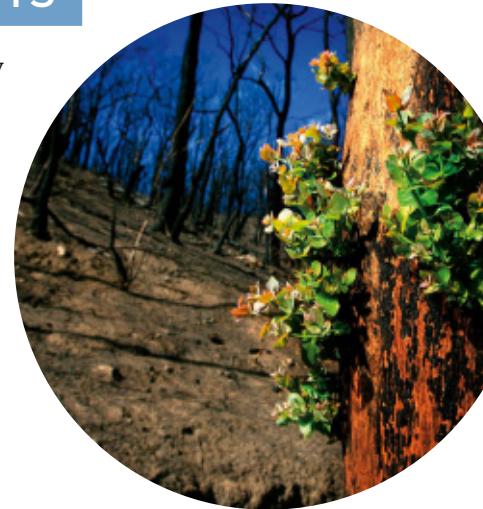


Figure 1.62 Some Australian trees recover from bushfire by re-sprouting leaves from epicormic buds under their bark.

Table 1.1 Managing the impact of some major natural events.

Natural event	Some common impacts	Ways of managing these impacts
Bushfire	- loss of habitat, farmland and homes - human injury and death	implement fire regimes and back burning to reduce impact of unplanned fires and promote growth of natural habitat
Flood	- significant soil erosion - water contamination - damage to property and habitat - risk of death for non-aquatic organisms that cannot escape the floodwater	- use weather stations to predict extreme rainfall - geologists can analyse flood plain structure to predict floodwater flow - construct levies, dams and weirs to control flow of flood water - re-establish natural wetlands to reduce likelihood and intensity of flooding - use modelling systems to simulate water flow during floods and predict levels of damage
Drought	- low farmland productivity - food shortages - risk of death of plants and animals	- construct dams and reservoirs to store water - develop infrastructure to transport water to where it is needed - implement water restrictions for industry, agriculture and homes - develop desalination plants to convert seawater into drinking water
Earthquake	- damage to property - significant changes to soil structure - human injury and death	- use computer models to predict the likelihood and impact of earthquakes around Australia - use seismic (ground) monitoring to help detect early warning signs of earthquakes and help aid early recovery
Cyclone	- significant soil erosion - damage to property - water contamination - human injury and death	- use computer models to predict the likelihood and impact of cyclones around Australia - use weather stations to track progress and intensity of cyclone - implement early warning systems to improve evacuation procedures

Fire intensity is a measure of the damage a bushfire does to an ecosystem. The plant life of the ecosystem provides the fuel for the fire and some plants are better fuel than others. The more or better the fuel, the more intense the fire is likely to be.

Short, sparse or spread-out undergrowth burns quickly and forms fast-moving 'cool' fires. These low-intensity fires will only damage the undergrowth, leaving scorch marks on the trunks and lower branches of trees. Tall trees may not even lose any of their leaves. The ash of the burnt plants provides nutrients for the soil, and the spaces that remain after the plants are gone are prime locations for new seedlings to grow.

Tall, dense grasses can provide lots of fuel for an intense bushfire. The fire takes time to burn all the fuel and can result in very hot fires. Slow-moving and hot fires tend to do the most damage. The fire has time to climb trunks and burn the upper branches and tops of the trees, removing all leaves. Without leaves, the trees cannot photosynthesise. To survive, the trees must quickly regrow new leaves from epicormic buds. Very hot fires can burn through bark and damage the epicormic buds, and can also burn through the soil and kill the seeds, which prevents them from sprouting. Sap within the trees can even evaporate into a highly flammable gas and gives the fire even more fuel.

Natural fires of this intensity are usually started by lightning strikes in long-unburnt areas with lots of dry undergrowth for fuel. It can take years for an ecosystem to recover from the devastating effects of an intense

fire. Unfortunately, many bushfires are also started by people. Accidental fires can be started by discarded cigarette butts and poorly managed campfires. Occasionally people deliberately light bushfires. Intentionally lighting fires to cause bushfires is illegal and extremely dangerous as it can result in massive fires that may destroy homes and cause injury or death.

Effects of bushfires on ecosystems

Long-term ecological research shows that areas that were badly burnt one year are protected from major fires in the following years. The loss of undergrowth from the previous fire means less fuel for any fire that may come through that same area again. Recovering burnt patches act as natural firebreaks and can even stop the progression of a moving fire.

Ecologists who specialise in bushfire management have put **fire regimes** into practice. Positive fire regimes are intentionally lit fires that are carefully managed, with the controlled burns conducted in rotation through specific areas within an ecosystem to create a mosaic of habitats as the end result. Recently burnt patches of land protect long-unburnt patches from natural bushfires, and also reduce the intensity of natural bushfires. You may have heard of this process referred to as 'back burning'.

The frequency of burning a particular patch of land can also influence the biodiversity of that patch. If left too long, a dominant species in the ecosystem may

Figure 1.63 Crown fires (fires that burn all the way to the tops of the trees) are very intense, killing the trees and even killing the seeds of the trees in the soil.



overgrow most other species and reduce the overall biodiversity of plant species in the area. Too frequent burning may not give enough time for the plants to recover and produce seeds. If there are no seeds or seedlings left, those species could become extinct in that particular habitat.

With the loss of adult plants as well as the seedlings and seeds of the plants,

the open spaces often become vulnerable to introduced plant species. Fast-growing introduced grasses compete with the slower-growing native species and can take up all the available space. Introduced grasses have not adapted to bushfires in the same way native grasses have. They tend to be denser, be taller and make much better fuel for future bushfires.

Learning from experience

On 28 December 1989, an earthquake struck Newcastle, NSW. It registered 5.6 on the Richter scale, which is a measure of the amount of energy released by an earthquake. An earthquake of a magnitude between 5.0 and 5.9 is only considered to be a moderate earthquake. However, 13 people were killed from the earthquake and more than 150 were injured. Over 50 000 buildings were destroyed outright during the earthquake and a further 300 had to be demolished a short time afterwards because they were damaged.

It is suggested that the high level of damage from this moderate earthquake was the result of a number of different factors:

- The epicentre (the origin of the earthquake) was only 15 kilometres south-west of the centre of the CBD and estimated to have only been 11 kilometres from the surface.
- The soil that Newcastle is built on is relatively soft due to the sediments of the Hunter River, which made the shaking much worse.

- Many of the buildings were very old and not built with modern reinforcement.

While Australia is less prone to earthquakes than New Zealand, Japan, Indonesia and Papua New Guinea, the Newcastle earthquake resulted in the development of Australian national standards that considers earthquake resistance in the design of new buildings. However, many people around Australia are still living and working in old, un-reinforced buildings.

Engineers and geologists are still working together to improve both building design and the testing of substrate (the ground the buildings are built on) with the aim to reduce the impact of earthquakes. Building design and construction is a vital part of reducing the impact of earthquakes because it is not usually the earthquake itself, but the collapsing buildings and falling rubble that injures and kills people.



Figure 1.64 Thousands of buildings were destroyed in the 1989 Newcastle earthquake.

QUESTIONS 1.3.2: MANAGING THE IMPACTS OF NATURAL EVENTS

Remember

- 1 Recall three common natural events in Australia.
- 2 Recall how epicormic buds help trees recover from burning.

Apply

- 3 Propose why controlled burns are usually done during the winter months.
- 4 Explain why burning introduced grasses tends to result in more intense fires than burning native grasses.
- 5 Explain how poorly planned controlled burns could damage an ecosystem.
- 6 Explain how positive fire regimes maintain or increase the biodiversity of an ecosystem.

AGRICULTURAL PRACTICES

Clearing land for agricultural use is one of the main reasons for the deforestation of natural ecosystems. Land for grazing livestock and planting crops is vital to support the growing human population in Australia. The knowledge gained through ecological research can be applied to agriculture, improving the productivity and sustainability of existing cleared land and reducing the need for further land to be cleared.



Figure 1.65 Soil organic carbon is contained within decomposing plant material.

Soil organic carbon

Producers like plants convert energy from the Sun and chemicals from the soil into a form that animals and other organisms can use. Carbon stored in soil is a vital nutrient for producers and for microorganisms that live in the soil. Carbon stored within soil is called **soil organic carbon (SOC)** and is made up of decaying plant and animal material. Dead plants and animals on the surface of the ground are not a part of soil organic carbon, and when they decompose, the carbon is often released as carbon dioxide into the atmosphere.

Ecological and agricultural research shows that deliberately increasing SOC raises the health and yield (amount of food produced) of crops and improves pastureland for grazing livestock. Decomposition of plant and animal material in the soil also releases other nutrients such as nitrogen and phosphates, which are vital for plant growth.

The presence of SOC also changes the overall soil composition. It increases the amount of water that can be absorbed and stored, improves gas exchange, and breaks up the soil, making it easier for root systems to grow and spread. SOC provides an excellent food source for many microorganisms, many of which continue to improve soil quality.

Many Australian farmers are looking for ways to increase the carbon in their soils. There are a number of different agricultural practices that help improve SOC.



Figure 1.67 Ploughing fields removes stubble and exposes the soil to air, releasing carbon into the atmosphere.



Figure 1.66 High-yield crops need healthy soil to grow.

Conservative farming

Traditionally, after a crop has been harvested, the stubble (remaining roots and bases of plants) is removed. This is often done by using ploughs that tear up the soil or by burning the fields. Both of these methods release carbon dioxide into the atmosphere. Removing the stubble means there is less material to decay and turn into SOC.

Conservative farming does not plough the field after harvesting and leaves the stubble behind to decay and generate SOC.

Organic fertilisers

Compost and manure are common organic fertilisers made from partially decomposing plant and animal materials. Organic fertilisers instantly increase SOC when added to soil. Organic fertilisers are more sustainable than chemical fertilisers because their effect is longer lasting and they are less likely to pollute waterways and cause eutrophication.

STUDENT DESIGN TASK

Investigating the crop yield benefits of SOC

Soil organic carbon is said to improve the yield of crops. Your task is to determine how true this is qualitatively and quantitatively. Design and carry out an experiment to test the effectiveness of SOC on small vegetable plants such as peas or tomatoes.

Questioning and predicting

- Determine your dependent variable – what will you be testing?
- Identify your independent variable(s) – what will you be changing?
- Write an appropriate aim and hypothesis for your experiment.

Planning and conducting

- Design your experiment to appropriately test your aim.
- What will your control condition be? What will your experimental conditions be?
- What are the safety issues in this experiment and how will you minimise them?
- What information will you collect and how will you collect it?
- How can you make sure your results are reliable?
- Check your method with your teacher. Once they have approved it, carry out your experiment and record your results.

Processing and analysing data

- How will you summarise and present your results?
- What do your results tell you about SOC?
- What problems did you encounter during your experiment?

Problem solving

- Did your results show a cause-and-effect relationship between SOC and crop yield? If so, explain the relationship and suggest the implication it may have for farmers.
- How could you improve your experimental design? What could you have done better? What follow-up experiment could you conduct to investigate this issue further?

Communicating

- Present your findings as an experimental report or other appropriate format as discussed with your teacher.

Dung beetles reduce impact of cattle

Cattle for beef and dairy are large industries in Australia, but cows are not native to Australia. In the early 1950s, entomologist (insect specialist) and ecologist Dr George Bornemissza noticed that cow pats lay around in paddocks for extended periods of time, suffocating and killing the plant life under them. In Europe, this was not a problem because dung beetles were removing the cow pats quickly. Dung beetles

are detritivores that eat dung and other decaying material. They also lay their eggs in dung so their larvae can eat the dung.

Native Australian dung beetles have adapted to dealing with native Australian dung from grazing marsupials like kangaroos and wombats. Dung from these animals is usually small and fairly dry. The introduced cattle produce huge quantities of dung and the native beetles can not break it all down quickly enough.

Hawaiian dung beetles were released between 1968 and 1984 as an introduced



Figure 1.68 Some species of dung beetle collect the dung into a ball and roll it back to their burrows to eat.

species to help control the level of cow dung. These Hawaiian dung beetles were bred in sterile captivity to ensure no new diseases were accidentally introduced along with the beetles.

Cow dung is now under better control. Soil quality in areas with beetle activity is greatly improved and excessive fly populations, which also breed in cow pats, are less common.

Ecological research into dung beetle species is ongoing, and European dung beetles were introduced into Western Australia as recently as 2011.

Selective breeding

There are many examples of animals and plants being bred to keep, lose or enhance characteristics by humans carefully choosing their 'partners'. This is known as **selective breeding**. For example, a cow that is known to produce lots of milk would be chosen to breed with a bull that is known to produce healthy, strong offspring. This would mean a greater chance of any female offspring being good milk producers and any male offspring being good meat producers.



Figure 1.69 Labradors are known to have hip problems as the result of many years of inbreeding.

The same applies to plants. A type of wheat known to survive frost or disease can be cross-pollinated with a type of wheat that produces high-quality grains to hopefully produce a combination of both features.

Selective breeding can also be used to reduce disease. Inbreeding results from animals reproducing with animals to which they are related. When this happens, rare diseases are more likely to occur. Inbreeding has been quite a problem with dog breeds, especially when people do not properly check the animal's ancestry. Selective breeding and genetic testing can be used to make sure the animals are not closely related and reduce the chances of these rare diseases occurring.

QUESTIONS 1.3.3: AGRICULTURAL PRACTICES

Remember

- 1 Recall a benefit of applying ecological understanding to agriculture.
- 2 Identify the meaning of the acronym SOC.
- 3 Recall three soil quality benefits of SOC content.
- 4 Explain why dung beetles were introduced into Australia when there are native dung beetles already here.
- 5 Explain selective breeding.

Apply

- 6 Propose two benefits of increasing SOC rather than increasing atmospheric carbon dioxide.

Analyse

- 7 Describe how knowledge of ecosystems and food webs has influenced agricultural practices.

Research

- 8 Research into dung beetles is ongoing. Investigate the Australian Dung Beetle Project. Identify the current aims of the project and evaluate the success of the introductions so far.

MANAGING ECOSYSTEMS

1.3

CHECKPOINT

Remember

- 1 Identify whether the following statements are true or false. Rewrite the false statements to make them true.
 - a School ovals are nature strips known as green corridors. [1 mark]
 - b A frog pond in your backyard or school ground could help protect the diversity of frogs and other species in your local area. [1 mark]
 - c The world's human population is decreasing. [1 mark]
- 2 Define the term 'biodiversity'. [1 mark]
- 3 Explain why even your backyard or school ground is important for the conservation of biodiversity. [2 marks]
- 4 Identify the components of soil organic carbon. [1 mark]
- 5 Recall which type of fire does more damage to the ecosystem: fast 'cool' fires or slow hot fires. [1 mark]
- 6 Cattle are an introduced species to Australia. Explain why Australian dung beetles are not able to process cattle dung effectively. [2 marks]

Apply

- 7 Explain how the types of plants in the undergrowth can determine the intensity of a fire. [2 marks]
- 8 Describe three ways in which humans change the environment. [3 marks]
- 9 Identify two examples of how ecological research has improved agricultural practices. [2 marks]
- 10 Explain why it is important for trees to regrow their leaves quickly after a fire. [1 mark]

- 11 Explain why the control of introduced species is an important part of fire ecology. [2 marks]
- 12 Explain why farmers should use conservative farming practices. [2 marks]
- 13 Draw a food chain involving dung beetles. Label each organism with its appropriate trophic level and whether it is a consumer, decomposer or producer. [3 marks]
- 14 Summarise the reasons why we should conserve biodiversity in the table below. [4 marks]

Reason	Explanation
Biosphere links all other spheres	
Biological resources	
Social and values	
Ethical values	

- 15 Lake Eyre is a massive lake in South Australia. Most of the time it is completely dry, with a crust of salt up to half a metre thick. When it is dry there are few animals present. However, during floods, when the lake fills up, native freshwater fish can live in it and huge flocks of birds are attracted to the new feeding grounds to breed.
 - a Propose how freshwater fish get into the lake. [2 marks]
 - b Define the term 'sustainable'. [1 mark]
 - c Discuss whether or not the Lake Eyre ecosystem could be described as sustainable. [2 marks]

Analyse

- 16 Investigate the amount of A4 copy paper your school uses each year and the percentage of recycled content in the standard paper your school uses. Research roughly how many sheets of A4 paper are produced from a single tree. Using that number, calculate how many trees would be cut down to supply your school with paper for a year. Present your findings as a report and suggest ways in which your school can use paper more sustainably. [4 marks]
- 17 A simple change to your everyday habits, such as reusing and recycling paper at school, can make a big difference to ecosystems. Using this example or a different one, explain how the actions of one person can impact on biodiversity. [2 marks]
- 18 Evaluate the contribution of scientific developments to agriculture by listing at least one advantage and one disadvantage for each solution in the table below. [6 marks]

Issue	Solution	Advantages of solution	Disadvantages of solution
Poor soil quality	Increase SOC through conservative farming		
	Increase SOC through organic fertilisers		
Cow pats 'burning' grass	Introduce dung beetles		



Figure 1.70 A frog pond in your school could become vital habitat and increase local biodiversity.

Ethical understanding

- 19 A number of different methods have been tried to reduce the population of introduced rabbits in Australia, including the release of viruses that can cause a slow and painful death. Discuss whether this is an ethical method of 'biological control'. [4 marks]

Critical and creative thinking

- 20 Determine the best location for a frog pond in your school grounds. As a class or in small groups, brainstorm how to implement the building of a frog pond, including how to raise funds for its construction. [5 marks]

1

CHAPTER REVIEW

1 Fill in the gaps using the words in the Word Bank below:

Ecosystems are a delicate balance between the _____ of living things and the _____ conditions of their habitat. The living things in the community interact through feeding relationships. These relationships can be displayed as _____.

There are three main roles within food webs: _____ photosynthesise to convert energy into a usable form for other organisms; _____ eat organisms to gain their energy; and _____ break down dead matter to return the nutrients to the ecosystem.

Microorganisms can feature at any level in a food web and are _____ to humans as part of our _____, by helping us to fight disease and to digest food. However, some _____ can also cause disease.

Human activities can alter food webs; for example, the introduction of plant or animal species into an ecosystem or _____ and urbanisation, which results in _____.

Ecological research has enabled humans to alter ecosystems for the better through the management of irregular _____ and improving _____ practices.

WORD BANK

abiotic	consumers	food webs	natural events
agricultural	decomposers	habitat loss	natural flora
beneficial	deforestation	microorganisms	producers
community			

Construct and interpret food chains and food webs

- Examine the food web in Figure 1.15 on page 11. Identify and draw a food chain from within that food web with five trophic levels. [2 marks]
- Explain why a food web is a more accurate representation of the feeding relationships within an ecosystem than a food chain is. [2 marks]
- Determine which would be more resistant to change: an ecosystem with high biodiversity or an ecosystem with low biodiversity. Justify your choice. [2 marks]

Describe the interactions within food chains and food webs

- Examine the food web in Figure 1.15 on page 11.
 - Identify an organism that is both a secondary and a tertiary consumer. [1 mark]
 - Identify the trophic level(s) of a skink. [2 marks]
 - Classify the honeyeater (pictured) using one of the following terms: producer, herbivore, carnivore, omnivore, detritivore. [1 mark]



- 6 Examine the food web in Figure 1.15 on page 11.
 - a Predict what would happen to three other organisms in the food web if bushfire destroyed all the native grasses. [3 marks]
 - b Predict what would happen to three other organisms if all the feral cats were removed from the ecosystem. [3 marks]
- 7 Explain why every food chain must start with a producer. [1 mark]

Describe some beneficial and harmful effects of microorganisms in ecosystems

- 8 Identify the three main groups of microorganisms. [3 marks]
- 9 The surface of our skin is home to a large variety of microorganisms. Recall the term used to collectively describe these microorganisms. [1 mark]
- 10 Provide two different examples of when microorganisms are a vital component of food webs. [2 marks]
- 11 Explain a situation where microorganisms are harmful to other living things. [2 marks]

Predict the effect of human activities on food chains and food webs

- 12 Explain why some introduced plants and animals can become pests in Australia. [2 marks]
- 13 Create a table with two columns headed 'Problems' and 'Solutions'. In the Problems column, list three things people do that affect ecosystems and food chains (e.g. cutting down trees). In the Solutions column, provide some possible solutions to each problem. [3 marks]

- 14 Explain the role of green corridors in preserving biodiversity. [2 marks]
- 15 Evaluate biological control as a method of controlling introduced pest species. [2 marks]

Explain the development of strategies for managing natural events in Australian ecosystems

- 16 Identify the term that describes the location and frequency of controlled burns to reduce the impact of bushfires in an ecosystem. [1 mark]



- 17 Identify one factor that influences the intensity of a fire. [1 mark]
- 18 Research some management strategies for flood or drought in NSW. Identify the benefits of these strategies and the scientific knowledge or technological developments that enable this practice to be implemented. Present your research as a multimedia presentation. [5 marks]
- 19 Imagine someone asked you 'Why are ecosystems so important?' Draft a reply, taking into account the key concepts covered in this chapter. [4 marks]

KEY WORDS

abiotic
autotrophic
biodiversity
biological control
biological resource
biosphere
biotic
carnivore
community
consumer
decomposer
detritivore
ecologist
ecology
ecosystem
eutrophication
fire regime
food chain
food web
glucose
habitat
herbivore
heterotrophic
introduced species
microorganism
natural event
nitrogen-fixing
bacteria
omnivore
pathogen
photosynthesis
population
producer
respiration
selective breeding
soil organic carbon
sustainable
trophic level

Describe the contribution of scientific developments in agricultural practices

- 20 Explain why introduced dung beetle species have not become a pest species in Australia. [2 marks]
- 21 Explain how research into the benefits of soil organic carbon has improved crop yield. [2 marks]
- 22 Other than ecology and environmental science, suggest some specific branches of science that contribute to researching improved agricultural practices. [3 marks]

Research Australian contributions to the study of ecology and human impacts on the environment (additional content)

- 23 Population sizes of organisms and biodiversity of ecosystems can decrease for a number of different reasons, including habitat loss, climate change and direct removal by humans. Describe how each reason listed here can reduce biodiversity. [3 marks]
- 24 Research an Australian environmental scientist or ecologist. Identify their name and profession and summarise the findings of their most important research. [5 marks]

RESEARCH

Mars biosphere

The Earth is particularly special because, as far as we know, it is the only planet that sustains life – our biosphere. The biosphere concept has been looked at as a means of long-distance space travel and as a way to colonise planets such as Mars. As a class project, decide how to set up a biosphere on Mars that would support organisms from the Earth.

Water-sensitive urban design

Australians are regularly encouraged to be water wise when planting their gardens. What does it mean to be water wise? How

is this linked to ecosystem benefits? Do all areas of Australia need to be reducing their garden's water requirements?

Sewage treatment

Find out more detail about how your city treats its sewage. What is the difference between sewage and sewerage? How has sewage treatment in your city changed? Many countries drink water that was once sewage but has been treated. Do you think this is a good idea? How do your actions affect sewage and water quality? Show your research as a multimedia presentation to the class.

REFLECT

Me

- What new science skills have you learned in this chapter?
- What was the most surprising thing you found out about Australian ecosystems?
- What were the most difficult aspects of this topic?

My world

- Why is it important to understand ecosystems?

- What is being done to prevent loss of biodiversity in Australia and throughout the world?

My future

- What can you do now to help preserve living habitats in the area around your home?
- What aspects of your current lifestyle are *not* contributing to a sustainable future for your local ecosystems?

1

MAKING CONNECTIONS

Easter Island – an ecological lesson from the past?

Easter Island is over 3000 kilometres from the nearest population centres (Tahiti and Chile), making it one of the most isolated places on the Earth. A triangle of volcanic rock in the South Pacific, it is best known for the giant stone statues, known as *moai*, that dot the coastline.

About 1200 years ago, Polynesian seafarers in double-hulled canoes landed upon its distant shores. Their canoes were filled with seeds for crops such as bananas and sugarcane, chickens, drinking water and rats that stowed away on their canoes.

Fossil evidence indicates the first islanders were greeted with a lush tropical paradise when they arrived at Easter Island, including three species of tree that grew up to around 15 metres tall and at least six species of land birds. *Paschalococos dispersa* was endemic to Easter Island and thought to be the tallest palm tree in the world.

The people called themselves the Rapa Nui. Over the centuries that followed, a complex, well-populated society developed in isolation on Easter Island. The island's

volcanic environment was rich enough to support their crops as well as the native palm forest ecosystems. In these prosperous years, the people began carving giant statues out of volcanic rock. These *moai* are some of the most incredible ancient relics ever discovered.

Scientists believe that, at its peak, the population of the island was 10 000–15 000 people, with a sophisticated culture that included a written language, music and stone carving.

Organising the carving, transport and erection of the *moai* is evidence of the complexity of the society and the resources available. The *moai* were carved in a volcanic quarry, and then transported across the island to various ceremonial platforms. It is believed the massive *moai* were rolled along the island's roads on two large logs that were placed on other logs perpendicular to them. The logs were likely to have been lubricated with palm oil. To transport a *moai* probably took about five days and 70 men.

In times of plenty, the Rapa Nui flourished and their population dramatically increased. But, as the number of consumers began to outweigh the producers on the island, the ecosystem became unbalanced. The Rapa Nui had to clear more of the forest to grow more crops and build more houses, until there were no more trees left. They hunted sea birds that nested on the island and the rocky outcrops, and ate the sea birds' eggs. Competition for food and other resources between tribes increased and wars became common.

The Dutch navigator Jacob Roggeveen, sailing on-board the ship *Arena*, was the first European to visit the island. Early explorers called the island *te pito o te henua* (navel of the world), but Roggeveen named it Easter Island when he spotted the land on Easter Sunday in 1722.



Figure 1.71 There are 887 giant carved *moai* dotted around Easter Island. The largest is almost 10 metres tall.

Roggeveen found a society in a fairly primitive state with only about 3000 people remaining. The few trees left on the island were less than 3 metres tall and were not large enough to make sea-going canoes. This meant the people were marooned on the island, unable to travel to sea to fish or find other food and resources.

Nowadays, there are none of the original trees on Easter Island. All six land bird species and 21 plant species have become extinct on the island. The once rich volcanic soil is depleted of nutrients and erosion is wide spread. This collapse of the natural ecosystem can largely be contributed to deforestation, overharvesting of natural food sources and crops, and the introduction of rats.

In 1862, slave traders arrived on the island and took many people away to be sold as slaves. Missionaries came in the mid-19th century and evacuated much of the remaining population to Tahiti and other islands, and brought European diseases to those who stayed behind. By 1877, only 111 people still lived on Easter Island. With so few people remaining, most of the Rapa Nui culture and tradition was lost forever. Today, there are only a few people who can trace their ancestry back to the original inhabitants of Easter Island.

Questions

- 1 Identify the main producers and consumers in the Easter Island ecosystem after the Rapa Nui settled there.
- 2 Explain, in terms of energy, why the Easter Island ecosystem collapsed when there were more consumers than producers.
- 3 Figure 1.72 shows a desolate, treeless landscape. Yet when the Rapa Nui first encountered the island, it was covered in a lush forest of giant palms. What types of living things and abiotic conditions would have been available on Easter Island to support such a complex ecosystem?



Figure 1.72 Lush palm forest used to cover this treeless landscape of Easter Island.

- 4 Identify how the Rapa Nui would have used the island's natural ecosystem and resources to survive an increase in population.
- 5 In what way did the loss of trees affect the Rapa Nui's ability to survive?
- 6 On an island as small as Easter Island, a person could stand on the highest point and see every part of the island. The person who cut down the last tree would have seen that this was the last tree. But they still cut it down. How do you think this person would have felt? Do you think they would have understood what they were doing?
- 7 We like to think that, in our culture, we would never put ourselves in the same position as the person on Easter Island who cut down the last tree. What similarities do you see happening in our culture to what happened on Easter Island?
- 8 Fossil evidence and radiocarbon dating has been used to estimate when the Rapa Nui first arrived on Easter Island, and when each stage of the ecological collapse occurred. Investigate what radiocarbon dating is and how it was used to determine these dates.

2



FUNCTIONING ORGANISMS

We cannot understand how living organisms function without also understanding their structure. It may seem that plants are nothing like multicellular animals, but both plants and animals have to achieve the characteristics of living things. All living organisms move, reproduce, need nutrition, grow, respond to stimuli, exchange gases, produce wastes and require water. There are many ways that living organisms achieve these functions and many structures that enable this to happen.

FLOWERING PLANTS AS FUNCTIONING ORGANISMS

2.1

Flowering plants rely on their roots, stems and leaves to work together to meet their needs for survival, growth and reproduction. Flowers are just one of the ways that plants reproduce, but these have become a key feature of the way some plants can disperse and colonise new areas.

Students:

- » describe the role of the flower, root, stem and leaf in flowering plants
- » explain that plant systems work together to provide all cell requirements
 - » identify the requirements for photosynthesis and respiration
- » outline the role of cell division in growth, repair and reproduction in plants

HUMANS AS FUNCTIONING ORGANISMS

2.2

As multicellular animals, humans rely on a complex set of organ systems to deliver requirements to each cell and remove wastes. Humans rely on cell division for the vital functions of growth, repair and reproduction.

Students:

- » describe the role of the digestive, circulatory, excretory, skeletal/muscular and respiratory systems in humans
- » explain that human body systems work together to provide all cell requirements
 - » outline the role of cell division in growth, repair and reproduction in humans
 - » outline the role of the reproductive system in humans

SCIENCE FOR BETTER HEALTH

2.3

Human life expectancy has more than doubled in the last 100 years. Not only are we living longer but our quality of life has improved, particularly for those who have experienced injuries or illness. Science and technology has played a major role in improving our understanding and our ability to prevent, diagnose and treat a wide range of health problems.

Students:

- » recount how scientific evidence has contributed to solving real-world problems
- » research how scientific developments have contributed to finding solutions to health problems
 - » describe how technological developments have helped solve medical issues
- » give examples to show that people may weight criteria differently in making decisions about the use of biotechnology
 - » debate why society should support biological research (additional content)

2.1

FLOWERING PLANTS AS FUNCTIONING ORGANISMS

Flowering plants are found throughout the world. They include all our cereal crops and grasses, palms and many trees, shrubs, vines and some water plants. The reason for their success is not only their ability to obtain nutrition and water, grow and respond, exchange gases, remove wastes and meet the needs of all their cells, but the competitive advantages of flowers as a means of reproduction.

OBTAINING WATER AND NUTRITION

Flowering plants have two organ systems in addition to their flowers: the shoot system and the root system. These systems contain a range of cell types and tissues that have structures well suited to their various functions. The shoot system consists of the stem, leaves, buds, flowers and fruits. The root system consists of either a branching or a fibrous system of roots.

Figure 2.1 shows the root and shoot system of a typical flowering plant, but in reality there is great variation in the size and shape of plants. For example, trees and shrubs contain woody tissues, whereas herbs and grasses do not. Plants also grow in many different ways. Some plants grow vertically, some have horizontal branches that droop downwards, while others spread

out across the ground. Some plants grow over many years (perennial), whereas others complete their life cycle within a year (annual) or even a single season. Some flowering plants are evergreen while others shed all their leaves in one season to regrow them in another (deciduous).

The root system

The function of the root system is to anchor the plant to a surface and to absorb and transport water and minerals. The root system may also store substances or allow a special type of reproduction called vegetative propagation that results in new plants the same as the parent plant. Vegetative propagation will be explained in more detail later in the chapter.

The shoot system

The stem supports the leaves, flowers and fruit in positions where they can function effectively. Stems contain tube-like vascular bundles through which water and mineral nutrients travel up from the soil to the leaves and glucose solutions travel to the cells throughout the plant. Some stems also can carry out **photosynthesis**, the food-making process in plants.

The leaves are the main site of photosynthesis, water evaporation and gaseous exchange. Gaseous exchange

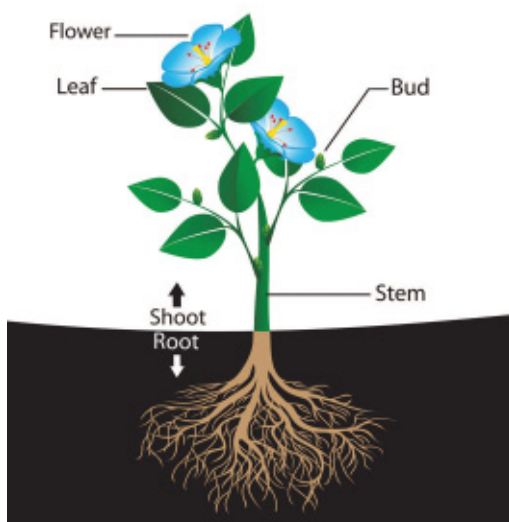


Figure 2.1 The main structures of a flowering plant.

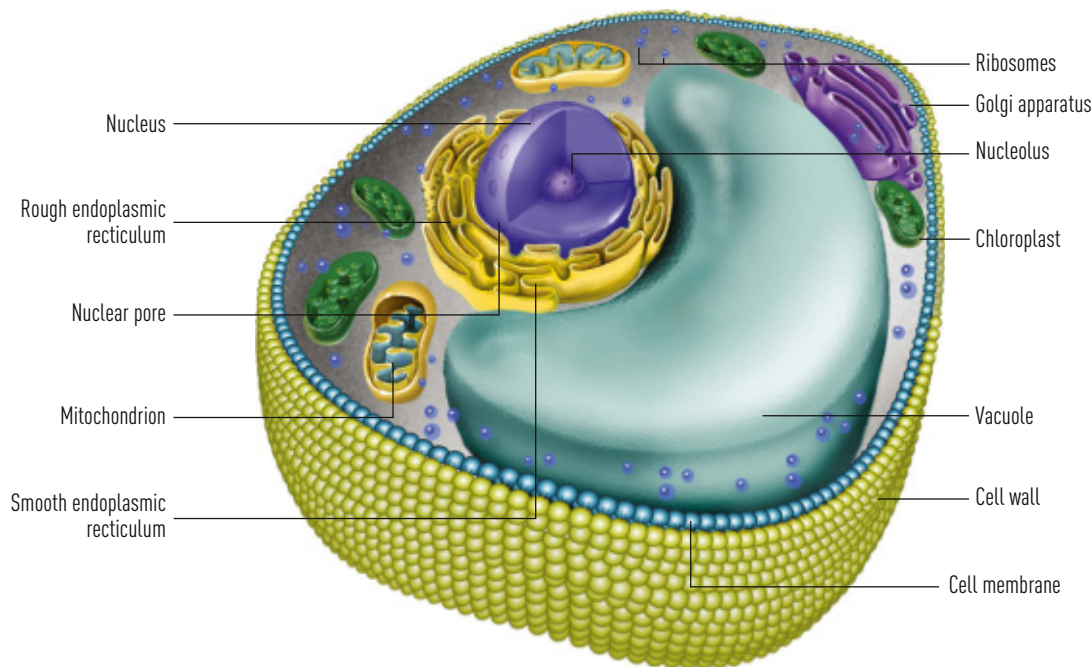


Figure 2.2 Artist's impression of a typical plant cell.

involves both carbon dioxide and oxygen. Carbon dioxide is absorbed for photosynthesis and the oxygen released. All cells in plants carry out **respiration**. During respiration, oxygen is absorbed and carbon dioxide is released through pores in leaves and stems.

The flowers and fruit are responsible for **sexual reproduction** in plants. Sexual reproduction is important as it produces offspring with different characteristics from the parent plants, which gives a species a better chance to survive a changing environment. In order for sexual reproduction to occur, flowers must be pollinated and, when mature, form the fruit that releases seeds or attracts animals that will disperse the seeds for the plant.

The organ systems and their functions relate back to the needs of individual plant cells. Key features of plant cells (see Figure 2.2) are the possession of a rigid cell wall external to the cell membrane and membrane-bound organelles, which include chloroplasts in the shoot system. The cell wall provides support so there is no need for a skeleton, while the chloroplasts give plants the ability to carry out photosynthesis so there is no need to capture and eat food. Vacuoles may make up 90% of the volume of plant cells and store the cell sap.



Figure 2.3 The branching root system of this bean plant absorb water and mineral nutrients from the soil and transport them up to the plant shoot systems.

How do flowering plants obtain water and minerals?

When you learnt about the states of matter in chapter 4 of *Oxford Insight Science 7*, you learnt about a special process that occurs in gases and liquids called diffusion. Remember that diffusion is a mixing process in which a substance moves from a place where it is highly concentrated until it is evenly spread out.

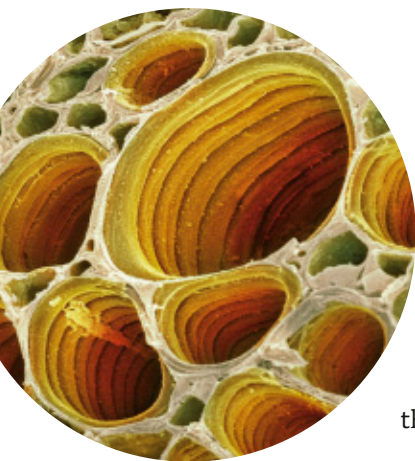


Figure 2.4 This electron microscope image shows xylem cells. These cells are no longer alive. The xylem cells transport water using the passive transport system of osmosis.

In nature, the cell membrane acts as a selective barrier for diffusion. Some substances, such as water, can easily diffuse through the cell membrane. Other particles, such as dissolved salts and sugars, cannot pass directly through the cell membrane. **Osmosis** is the movement of water through a semipermeable membrane, which includes the cell membrane.

During osmosis, water will always move from an area with higher water concentration (less dissolved substances) through the cell membrane to an area of

lower water concentration (greater dissolved substances). The cytoplasm in **root hair cells** contains lots of dissolved substances, so the water in the soil moves into the plant by osmosis. Root hairs are elongated so that they have a high surface area to increase the rate of osmosis.

Water and some dissolved minerals move through a part of the vascular bundle called **xylem tissue**, which is made up of long tube-like cells that are not living. The main force that moves water from the roots up to the leaves is pressure resulting from **transpiration** (see Figure 2.4).

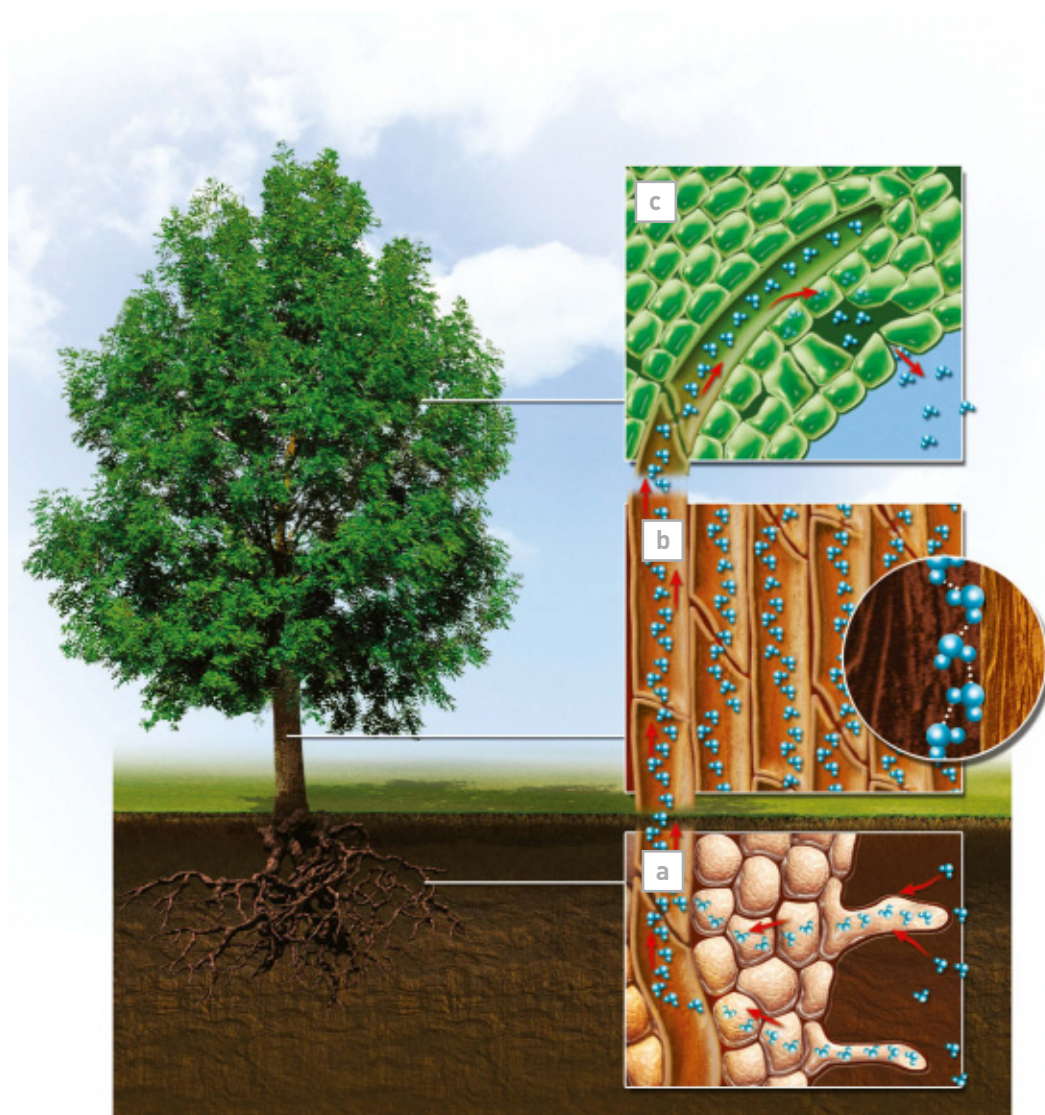


Figure 2.5 The transpiration stream. (a) Water molecules enter the root hair cells by osmosis. (b) They then travel through the xylem tissue in the transpiration stream up to the leaves. (c) Unused water leaves the plant by evaporating through small pores in the leaves (transpiration).

The transpiration stream

Less than 1% of the water that moves in the transpiration stream of plants is used for photosynthesis or growth. Most of the water is lost through transpiration, the process by which water evaporates from the surface of the leaves. Transpiration is useful for cooling plant leaves, and also for helping to pull the transpiration stream up to the uppermost leaves. Other forces that help to draw water up through plants include the pressure from osmosis as water enters the cytoplasm of the root hairs.

EXPERIMENT 2.1.1: OBSERVING OSMOSIS IN SULTANAS

Aim

To investigate osmosis in dehydrated foods such as sultanas. (Other dehydrated items such as currants, raisins or dried apricots may be used.)

- 250 mL beaker
- 100 mL measuring cylinder
- 10 sultanas
- Stereo microscope
- Electronic balance
- Paper towel

Method

- 1 Measure and record the total mass of all the sultanas.
- 2 Calculate the mean mass of a sultana by dividing the total mass by 10.
- 3 Observe a sultana by using the stereo microscope and draw a diagram to record its appearance.
- 4 Place all the sultanas in a beaker and add 100 mL of tap water.
- 5 Leave the sultanas for at least one day at room temperature.
- 6 Remove the sultanas and pat them dry with paper towel.
- 7 Observe a soaked sultana by using the stereo microscope and draw another diagram to highlight the changes.
- 8 Measure the total mass of all the soaked sultanas, and calculate the mean mass and the change in mass.

Results

Copy and complete the following table.

	Total mass of sultanas	Mean mass of sultanas	Appearance (diagram)
Before soaking			
After soaking			

Discussion

- 1 Predict the concentration of the sugary solution in a sultana and a soaked sultana.
- 2 A sultana is really a dehydrated grape. Would a grape or a sultana be sweeter? Explain your answer, using knowledge of osmosis and concentrations.
- 3 If the membrane around the sultana had been fully permeable (allowed both the water and the sugar particles to pass through), what would have happened to the water in the beaker?

Conclusion

Write a short paragraph about what you know about the movement of water into a sultana. Ensure you address the aim.

STUDENT DESIGN TASK

Investigating osmosis

Osmosis is the movement of water through a semipermeable cell membrane. Design and carry out an experiment that investigates an aspect of osmosis.

Questioning and predicting

- With help from your teacher, construct a list of testable questions about the process of osmosis. Some examples include:
 - Does osmosis happen faster in warm water or cold water?
 - Does osmosis happen faster in smaller objects than in larger objects? (e.g. currants versus raisins)
 - What happens if a sultana is placed in a sugary solution rather than in tap water?
 - Working in groups, select a question and write an appropriate aim and hypothesis to test.

Planning and conducting

- Design a step-by-step procedure to test your aim. Remember to consider a control group and all the variables you will need to control.
- Identify any risks – ensure you take steps to minimise them and fill out a risk assessment.
- Have your teacher check your procedure before proceeding.
- Carry out your experiment and record your results.

Processing and analysing

- Organise your results as a graph or table as appropriate.
- Interpret your results and decide whether or not your hypothesis was supported.
- Were there any unexpected results? What might have caused them?
- How reliable were your results?

Problem solving

- Identify any issues your group encountered during the experiment.
- Suggest ways of improving or extending your experiment for further investigation.

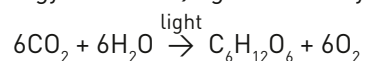
Communicating

- Write up your experiment as an experimental record. Make sure you include the aim, method, results, discussion (including an evaluation of your procedure) and the conclusion.

Photosynthesis

Photosynthesis is the reaction used by plants to transform light energy into chemical energy. Photosynthesis needs the help of a chemical called **chlorophyll**, the green pigment in the chloroplasts of plant cells. Chloroplasts are found in cells in the shoot system, particularly in tissues near the surface of the leaves. The shape and arrangement of the leaves in many flowering plants maximises their ability to absorb sunlight and carry out photosynthesis. Photosynthesis can be summarised by the following word and symbol equations:

carbon dioxide + light energy + water → glucose + oxygen



Although photosynthesis is summarised as a single equation, it is actually a complex series of reactions. First, the chlorophyll traps the light energy, and then the sugars are made.

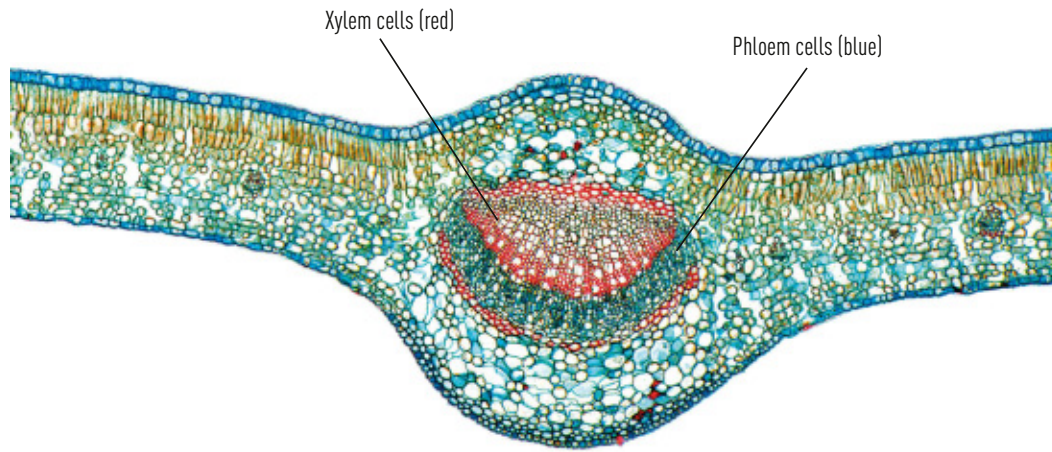


Figure 2.6 A stained light microscope image of a leaf cross-section. The brown cells near the top surface contain chloroplasts and are the main site of photosynthesis.

How does the plant obtain its requirements for photosynthesis?

Photosynthesis requires carbon dioxide, light energy and water. The light energy is obtained from the sun. Water enters the plant through the roots and is transported to the leaves by the xylem tissue. Carbon dioxide moves into the leaf through microscopic pores called **stomata** (singular: stoma, Figure 2.7).

The stomata are also involved in releasing the oxygen produced by photosynthesis back into the atmosphere. Guard cells open and close the stomata to regulate the exchange of gases and water loss.

Sometimes plants experience conflicting demands, especially in periods of water shortage. The stomata may be forced to close to prevent damage from wilting and dehydration. This will restrict the availability of carbon dioxide, so photosynthesis may be interrupted.

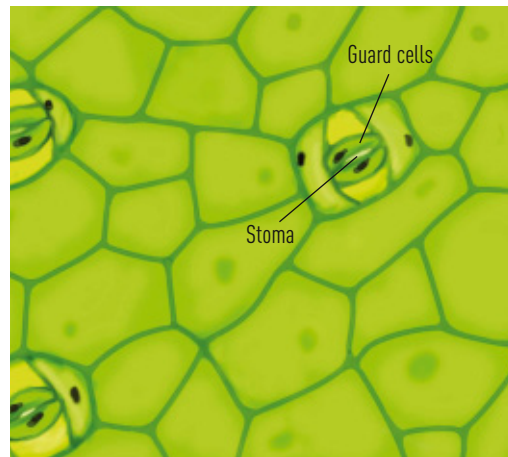
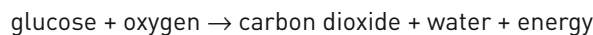


Figure 2.7 Guard cells open and close the stomata of a plant.

What happens to the glucose that the plant produces?

Green plants make millions of glucose molecules during daylight hours. Plants require a constant supply of glucose for respiration.

Respiration can be summarised in the following word equation:



In many ways, respiration is the opposite process to photosynthesis. During the day, the oxygen released into the leaf tissues through photosynthesis will be available for respiration and the carbon dioxide released from respiration will be available for photosynthesis.

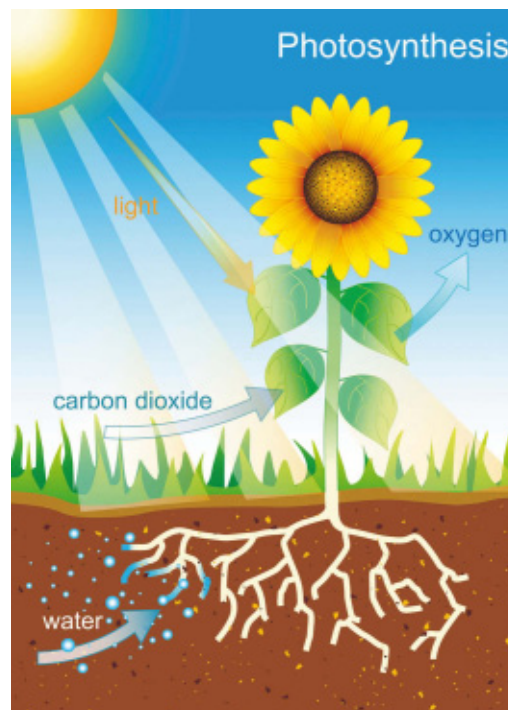


Figure 2.8 A summary of photosynthesis.



Figure 2.9 Excess glucose is converted into starch and stored in tubers and roots.

Respiration releases energy to run all the metabolic processes within a plant.

These processes include transporting substances around the plant and making leaves, flowers, fruit and seeds. This means the glucose has to be moved from the leaves to all the cells in the plant.

Phloem cells in the vascular bundles are responsible for the absorption of excess glucose and its transport in solution around the plant. Some glucose is converted into cellulose, the material used in plant cell walls. Other glucose molecules are converted

into components of the plant's membranes.

Photosynthesis produces more glucose than can be used directly by plants. Excess glucose is stored in the form of a carbohydrate called starch and other carbohydrates in the roots, stems or the leaves. Starch is stored in underground storage organs such as roots and tubers. Potatoes, carrots and parsnips all store starch in this way.

Systems working together

The plant root and shoot systems work together to ensure plant survival, growth and reproduction. These functions are described further in Table 2.1.

Table 2.1 How plants systems work together.

Plant system	Function
Root system	- holds the plant in the ground - absorbs water and minerals for photosynthesis and building of new cells - may be involved in glucose storage and vegetative reproduction (see page 63) - contains xylem and phloem tissue for transport
Shoot system	- positions leaves for photosynthesis - positions the flowers where they can be pollinated and the fruits where the seeds can be dispersed - may be involved in glucose storage and vegetative reproduction (see page 63) - contains xylem and phloem tissue for transport

QUESTIONS 2.1.1: OBTAINING WATER AND NUTRITION

Remember

- 1 Identify the process by which water enters the plant through the root system.
- 2 Describe the two main organ systems in plants.
- 3 Outline the process of photosynthesis, including the inputs and outputs.

Apply

- 4 Not all of the oxygen produced in photosynthesis is released through the stomata. Describe a way that the oxygen may be used.
- 5 Compare the roles of the root system and the shoot system in a flowering plant.

Analyse

- 6 Propose a reason why the leaves of undergrowth rainforest plants are much darker than the leaves of plants in open forests.
- 7 Some plants grow on the upper branches of other trees in dense forests. Explain how their root and shoot systems would vary from other plants in the same forest.

Create

- 8 Imagine you are the guard cells of the stomata that live in the leaves of a spinifex plant in the Australian desert. Write a diary entry about your typical day and night. Ensure you explain in detail why you would do certain actions. Remember that when a guard cell swells up, the stoma opens.

GROWTH, REPAIR AND RESPONDING

Most flowering plants are very resilient. Leaves are grazed and trampled upon, termites eat their wood, sap is sucked and trunks are burnt by bushfires. Flowering plants also suffer excesses and shortages of water. Despite these conditions, flowering plants remain the dominant plants on the Earth. Their ability to regenerate, grow and reproduce is dependent on the process of cell division.



Figure 2.10 Eucalypts respond to bushfire by regrowth from epicormic buds in the trunk and lignotubers in the roots.

Cell division

Cell division is the process by which a cell divides into two or more cells. Cells that have the ability to divide and become specialised cells are called **stem cells**. But not all cells can divide. Some cells develop specialised structures so they can carry out particular functions but, in the process, they lose the ability to divide.

Mitosis

In chapter 3 of *Oxford Insight Science 7* you learnt about **mitosis**. Mitosis is a type of cell division where one parent cell divides to produce two daughter cells with the same identical genetic instructions carried in their DNA (see Figure 2.11). DNA is the genetic material that includes the instructions to make every part of a cell. DNA is made up of enormous molecules found in the nucleus of cells. These molecules have the incredible ability to replicate or copy themselves. When the cell divides, these

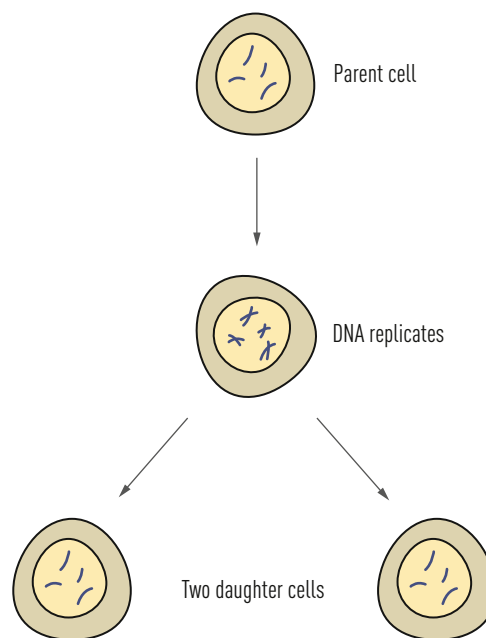


Figure 2.11 The process of mitosis.

molecules condense into structures called **chromosomes**, which are visible under the light microscope (see Figure 2.12).

Asexual reproduction

Asexual reproduction results from mitosis, and the offspring are essentially the same as the parents. Asexual reproduction occurs in many unicellular organisms as well as many plants and a few simple animals. In plants, asexual reproduction is generally referred to as **vegetative reproduction**.

Vegetative reproduction is the process where new plants arise without the production of seeds. It occurs in the specialised cells and tissues of roots, stems and leaves of some flowering plants. Vegetative reproduction often involves part of the plant breaking off and surviving as a new organism that is genetically the same as the original 'parent' plant. Vegetative reproduction can occur naturally or be induced by humans (such as during plant cloning: see Deeper Understanding on page 65). Often we carefully manage vegetative reproduction to maximise the production of desirable plants.

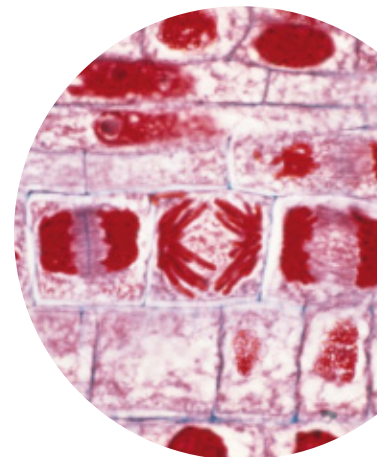


Figure 2.12 Onion cells undergoing mitosis. The darkly stained sections are the chromosomes.

Vegetative structures in plants

- Plantlets – tiny plants that grow on either side of the parent stem or leaf, or on roots



- Suckers – roots that specifically head towards the ground's surface and produce shoots



- Rhizomes – underground stems



- Stolons (also known as runners) – stems that run along the ground



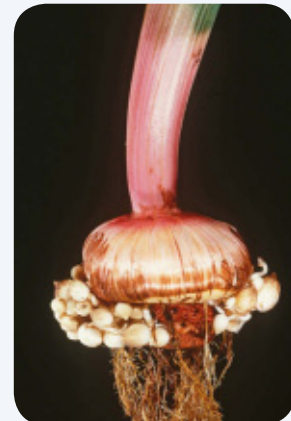
- Bulbs – develop into segments as they grow, with each segment eventually capable of living separately



- Tubers – grow on underground stems or shoots with buds or eyes that can sprout new plants



- Corms – can be broken into pieces, each of which is capable of producing a new plant



Cloning plants

Plants are very important to humans, both directly as a food source and for feeding livestock. Plants provide timber, shelter and shade, paper and many other useful materials and medicines. Often we want to produce new plants identical to the useful parent plant. In these cases, we use vegetative propagation.

Perhaps you have heard of Dolly the sheep, the first mammal to be cloned. Cloning of animals is a controversial topic. However, humans have been cloning plants for hundreds of years and it is the basis of our horticultural industry. We have developed an understanding of the natural ways that plants vegetatively reproduce and have been able to manipulate and enhance these processes to produce many of the plants we use in agriculture and horticulture.

Plant cloning techniques include:

- **Budding:** a single bud of the desired plant is inserted into a slit in the bark of a compatible root stock. Disease-resistant root stocks can be used to improve plant health in the new plant.
- **Grafting:** similar to budding but a number of buds, shoots or twigs can be placed on the stock. This technique can be used to produce one tree, such as a peach tree, but with branches of different varieties of peach that ripen at different times and have different desirable qualities.
- **Cuttings:** segments of a plant, usually the stem, are cut and inserted into water or a growth medium. New roots will grow and the plant is eventually transplanted.
- **Layering:** exposing part of the stem to soil or moisture-holding materials such as sphagnum moss to achieve the best root development. Once the root system is sufficiently established, the offspring can be severed from the parent.



Figure 2.13 This species of blackberry self-propagates by runners. Removing the runner from the parent plant and replanting it elsewhere will enable a new plant to grow.

Another way of cultivating new plants is by maximising the plants' natural vegetative reproduction. Plantlets or offsets can be removed from the parent plant and replanted. This method can be used for plants such as cactuses and succulents. Corms, tubers and bulbs may be separated and replanted. Tissue culture uses sterile conditions and sophisticated growth media to grow many offspring from dividing plant material.

Questions

- 1 Choose one of the methods of vegetative propagation and research it in detail. Report your findings to the class, perhaps with a demonstration of the technique.
- 2 Consider and discuss any disadvantages for plants that rely mainly on vegetative reproduction.



Figure 2.14 New vascular bundles beneath the bark of woody plants can be seen as growth rings.

Role of cell division

Cell division is essential for growth. Cell division is also a response by plants to changes in the environment. For example, increasing day length (such as in spring) may stimulate cell division and result in the production of new leaves or flower buds. Cell division is stimulated by the production of plant hormones.

Cell division for growth occurs at the tips of roots and stems, and in special buds called axils in flowering plants. The cluster of actively dividing cells at the tips of roots and shoots, are called the apical meristems. Some plants, such as woody plants, produce new vascular bundles by cell division in the outer layers beneath the bark. This can be seen as growth rings.

Sometimes, plant cells develop abnormal growths. Parasites, fungi, bacteria or insects may cause these growths. For example,



Figure 2.15 This azalea plant has grown a gall in response to a fungal infection.

wasps lay their eggs in plant tissues, which can stimulate the surrounding plant cells to divide. This cell division results in the production of structures such as galls, which serve to isolate the infected area.

EXPERIMENT 2.1.2: EXAMINING GROWTH IN ROOT TIPS

Aim

Read the instructions for this experiment carefully and write an appropriate aim. Remember that an aim should always begin with 'To ...'.

Materials

- Light microscope
- Prepared slides of a stained onion plant root tip (showing DNA in resting cells and chromosomes in dividing cells)

Method

- 1 Place the slide under the light microscope and observe the root tip of the onion, using the low power lens.
- 2 Identify the root cap, the zone where cells are dividing, the zone where cells are elongating (growing longer) and the zone where the cells have matured and become specialised. Use Figure 2.16 to help with identification.

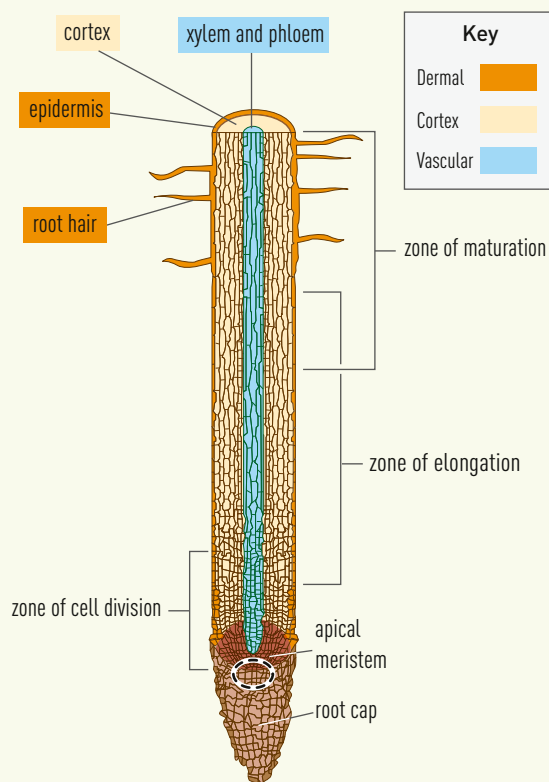


Figure 2.16 The growing tip of an onion root has four main zones, each with its own specific function: the root cap, zone of cell division, zone of elongation and zone of maturation.

Results

Draw a series of diagrams that show samples of the cells from each zone of the root tip as mentioned in the method. Label your diagrams with as many key structures as you can identify.

Discussion

- 1 Suggest the role of the outer layer of cells (epidermis) and the root cap.
- 2 How does the structure of the root cap cells relate to its function?
- 3 Describe how you can distinguish cells that are dividing from those that are not.
- 4 Describe the differences in the appearance of the cells within the zone of cell division. Suggest reasons for these differences.
- 5 Suggest the functions that the cells in the zone of maturation have become specialised to perform. Relate their structure to their specific function.

Conclusion

Write a brief statement explaining the differences in the appearance of onion root tip cells in the four zones identified in Figure 2.16, and try to relate these differences to the function of each region.

QUESTIONS 2.1.2: GROWTH, REPAIR AND RESPONDING

Remember

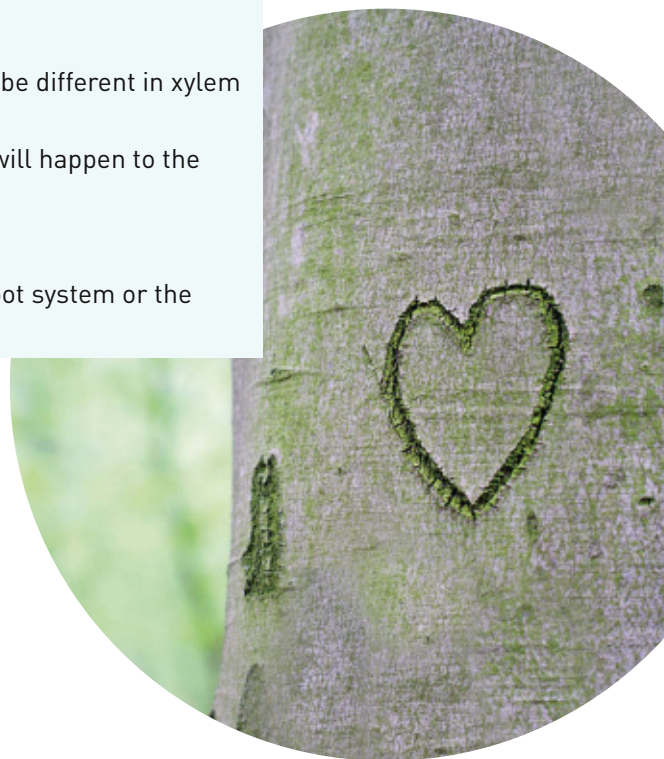
- 1 Identify the type of cell division that results in the production of two identical daughter cells from the one parent cell.
- 2 Describe the role of the type of cell division you named in question 1, in the growth of flowering plants.
- 3 Explain what causes growth rings in some plants.
- 4 Recall the name of the cells that can divide and differentiate into different specialised cells
- 5 Recall what is meant by vegetative reproduction and give an example.

Apply

- 6 Suggest how the process of a cell becoming specialised might be different in xylem cells compared with phloem cells.
- 7 A vandal carves a heart in a eucalypt tree trunk. Explain what will happen to the position and size of the carving as the tree grows.

Analyse

- 8 What do you think is more important in flowering plants, the root system or the shoot system? Justify your opinion.



THE ROLE OF FLOWERS

Asexual or vegetative reproduction is more common in plants than in animals, yet sexual reproduction in plants remains very important. Sexual reproduction involves the production of special sex cells that combine in the process of fertilisation to result in a new organism.

In the case of flowering plants, **pollination** needs to occur before fertilisation. Pollination is the transfer of pollen (the male sex cell) to the female reproductive organ.

Diversity of flower structure, arrangement and mechanisms to achieve pollination has contributed to the success of flowering plants.

Meiosis

Sexual reproduction results in increased genetic diversity because it allows the

genetic material from two different parents to combine. Sexual reproduction is dependent on the production of sex cells or **gametes** in a special type of cell division called **meiosis**. In this division, the daughter cells contain only one member from each of the pairs of chromosomes of the original parent cell.

Meiosis (see Figure 2.17) has two divisions to enable this halving of genetic material. The first division separates the pairs of chromosomes; the second division is similar to mitosis. The final product is four daughter cells that have only half the number of chromosomes of the original cell.

A new organism is the result of the union or **fertilisation** of two gametes, usually one male gamete and one female gamete, which restores the full complement of chromosomes to the cells of the first cell of the new organism, called the **zygote**.

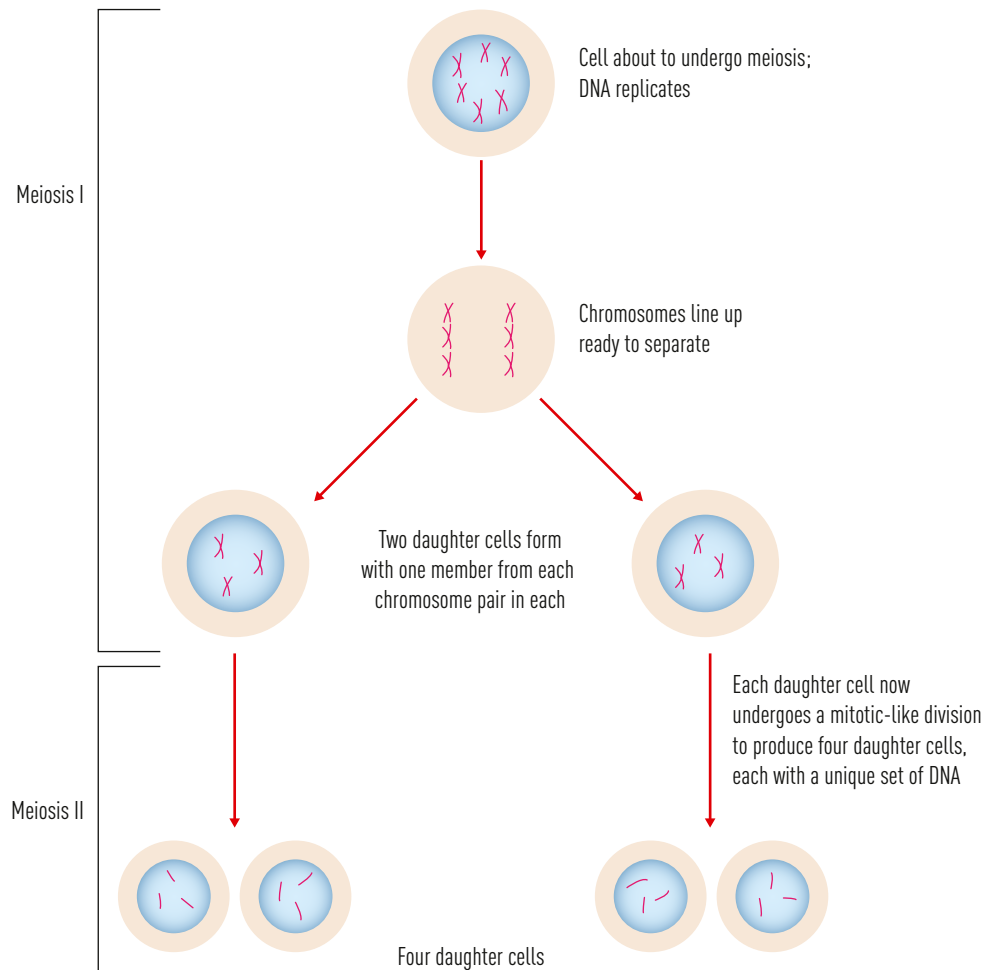


Figure 2.17 The process of meiosis.

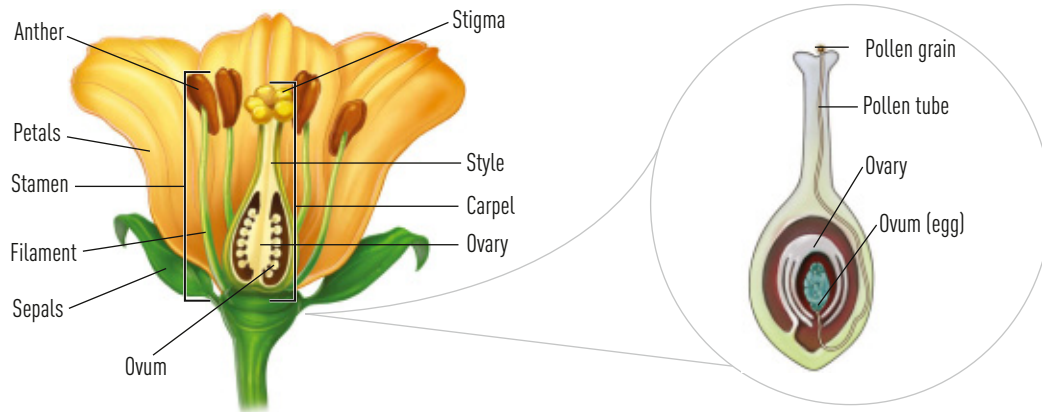


Figure 2.18 The parts of a flower showing the key structures involved in fertilisation.

Flowers: sexual reproduction

Sexual reproduction in plants results in increased genetic diversity because it allows new combinations of genetic material or DNA from two different parents. Sexual reproduction helps plants spread over large areas by releasing seeds or fruit that are spread by agents. These agents include wind, running water and animals.

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

Meiosis occurs in the **anther** (male) and **ovary** (female) organs, resulting in the production of pollen and **ova** (singular: ovum).

The anther is supported by a stalk-like filament, and together these structures form the stamen. The ovary sits below a stalk-like style that is topped by the sticky stigma, and together they form the **carpel**. For fertilisation to occur, the pollen needs to find the ovum. This requires pollination – the pollen is transferred to the stigma where it grows a pollen tube down the style to the ovary.

Many flowers need assistance from agents for pollination to occur. **Self-pollination** involves pollen from a flower landing on its own stigma or that of another flower on the same plant (see Figure 2.19). **Cross-pollination** occurs when pollen from one flower lands on the stigma of a flower on a

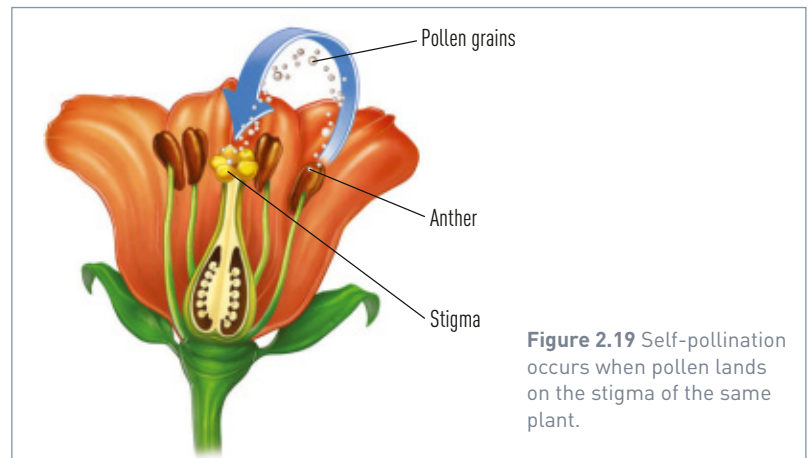


Figure 2.19 Self-pollination occurs when pollen lands on the stigma of the same plant.

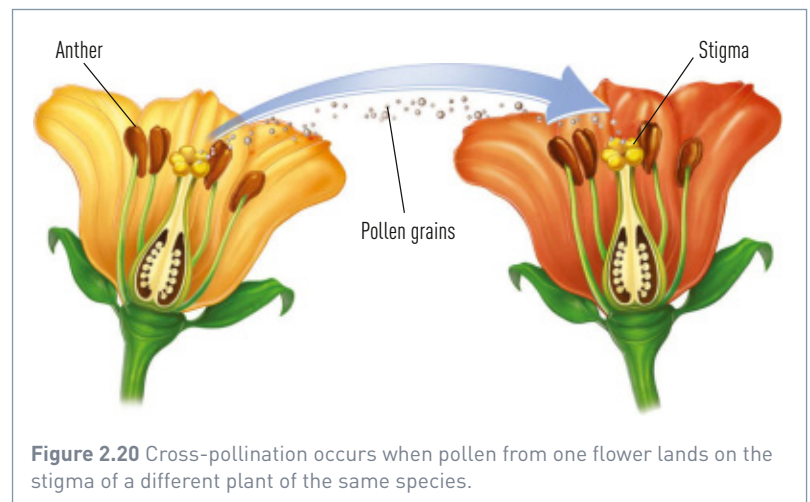


Figure 2.20 Cross-pollination occurs when pollen from one flower lands on the stigma of a different plant of the same species.

different plant, producing greater variation (see Figure 2.20). Just like animals, the pollen from one flower can only fertilise flowers from the same or very similar species.

After fertilisation, the ovary takes on a role similar to a bird's egg. It swells to become a fruit, which provides nutrition and protection for the zygotes to grow into embryos in the enclosed seeds. The ovary structure is reflected in the structure of the seed-bearing area of the fruit (see Figure 2.21).



Figure 2.21 After pollination and fertilisation of pea plants, the ova develop into the peas and the ovary develops into the pea pod.

EXPERIMENT 2.1.3: FLOWER DISSECTION

Aim

To examine the main structures of a flower.

Materials

- A flower (you can dissect any type of flower available; hibiscuses, lilies and fuchsias are a good choice)
- Scalpel blade or sharp knife
- Newspaper
- Hand lens

WARNING

- > Scalpel blades are very sharp; be extremely careful when using them.

Method

- 1 Place the newspaper on the bench.
- 2 Cut the flower off the stalk.
- 3 Observe the flower. Identify the main parts of the flower using Figure 2.18 on page 69.
- 4 Gently remove the sepals and petals.
- 5 Look for the stamen with anthers at the top. The anthers hold the pollen. You should be able to dust some pollen onto your finger.
- 6 Cut off the male parts at the bottom of the filaments.
- 7 Observe the female part of the flower. It has the stigma at the top and the ovary at the bottom.
- 8 Cut the ovary lengthwise. In it you will see tiny white scales, which are the ovules. When the ova inside the ovules are fertilised by the pollen, they will grow to become seeds and the ovary will grow to become the fruit.
- 9 Clean up your bench by wrapping the flower in the newspaper. Wash your hands.

Results

Draw labelled diagrams of the male and female parts of the flower.

Discussion

- 1 How easy was it to clean the pollen from your fingers? Is this good for the flower?
- 2 How were the male and female parts arranged to encourage pollination? Explain your answer.
- 3 How long is the filament (the stem of the stamen)? Why do you think this is?
- 4 Some flowers have anthers that ripen at a different time to the ovary maturing, to ensure cross-pollination. Do you think this is the case for the flowers you have studied? Give evidence for your opinion.

Conclusion

Write a statement to explain how the structure of a flower enables fertilisation of the ova.

Not all flowers are the same

If a flower smells, it is usually to attract a pollinator – but not all smells are sweet. *Rafflesia* is a flower native to Borneo that smells like rotting flesh to attract flies for pollination.

The colour of a flower is also important for attracting pollinators. Birds tend to pollinate red flowers, whereas insects are attracted to a range of colours including some white flowers that actually reflect ultraviolet light that the insect detects. Nocturnal nectar-feeding mammals and moths rely on odour to locate food.

Some flowers have modified structures to suit particular pollinators. Bird-pollinated flowers tend to have strong stems and large quantities of nectar. Some bird-pollinated flowers are curved at a similar angle to that of the beak of the visiting honeyeaters. Insects can be small and need to be forced to brush against the anther, followed by the stigma, so the flower may be full of obstacles or simply a tight fit.

Many of the flowers we see in the bush appear nothing like the diagram of the flower structure in Figure 2.18 on page 69. This is because what we call 'flowers',



Figure 2.22 Banksia flowers don't have typical petals.

including eucalyptus and wattle blossoms, waratahs, bottlebrushes and banksias, are really clusters of many tiny individual flowers. Having clusters of tiny flowers increases the efficiency of each pollinator visit and the potential food rewards for the pollinator.

Questions

- 1 Identify the reason for different colours in flowers.
- 2 A particular night-blooming flower has white petals that form a narrow tube. The flower produces only a small amount of nectar, but a very strong perfume. Suggest a possible pollinator for this flower. Justify your answer.



Figure 2.23 *Rafflesia* flowers can grow to over 100 cm in diameter.

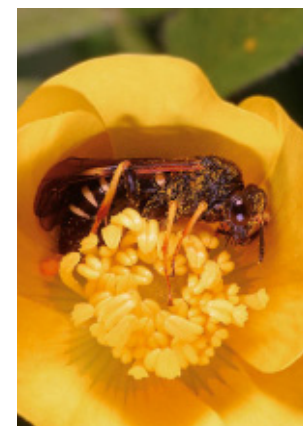


Figure 2.24 The tight fit of this daffodil ensures the insect gets covered in pollen.

QUESTIONS 2.1.3: THE ROLE OF FLOWERS

Remember

- 1 Recall the name of the structure that contains a plant's sexual reproductive system.
- 2 Explain the difference between self-pollination and cross-pollination.
- 3 Identify and describe the components of the carpel in a flower.
- 4 Outline the roles of the anthers and filaments in flowers.
- 5 Describe the function of a fruit.

Apply

- 6 Draw a circular flow diagram using the following terms: flower, pollen, seed, fruit, pollination, fertilisation, ovum, pollen, ovary, zygote, anther.

Analyse

- 7 Compare and contrast mitosis with meiosis.

Research

- 8 The Bureau of Meteorology website has a section that outlines Indigenous Weather Knowledge of a number of Indigenous language groups. Research the D'harawal people and find out their names for the seasons and how they used their knowledge and observations of native Australian plants to find food and materials.

2.1

CHECKPOINT

FLOWERING PLANTS AS FUNCTIONING ORGANISMS

Remember and understand

- 1 Describe the role of the root system in flowering plants. [1 mark]
- 2 Define the term 'vegetative reproduction'. [1 mark]
- 3 Identify the advantages of sexual reproduction in flowers. [1 mark]
- 4 Recall the relationship between diffusion and osmosis. [1 mark]
- 5 Describe one technique used in vegetative propagation. [1 mark]
- 6 Identify all the requirements of the cells of a flowering plant for photosynthesis. [2 marks]

Apply

- 7 Explain how the root system of a flowering plant is dependent on the shoot system. [2 marks]
- 8 Explain why the stem is important in flowering plants. [1 mark]
- 9 Explain how the structure of a root hair is related to its function. [1 mark]
- 10 Compare the role of phloem with the role of xylem in flowering plants. [2 mark]
- 11 Many plants that have become adapted to desert conditions have needle-like leaves. What effect will this have on the growth rate of the plant? Explain your answer. [2 marks]

Analyse and evaluate

- 12 The cells that carry out photosynthesis are usually located on the upper surface of leaves while the stomata are mostly located on the lower surface of leaves. Propose an explanation for the locations of these cells and structures. [2 marks]

- 13 Propose reasons why there is so much diversity of flowers. [2 marks]

Ethical behaviour

- 14 Flowering plant reproduction contributes to their dispersal, especially for invasive plants we often call weeds. Use your understanding of plant reproduction and ethics to present arguments about the introduction of plant species near national parks. [5 marks]

Critical and creative thinking

- 15 Construct a flow chart that shows the path of a carbon dioxide molecule after it is absorbed by a flowering plant and the processes it is involved in before it is released. [2 marks]
- 16 Which do you think is the least important to the survival of a flowering plant: the flower, the root, the stem or the leaf? Justify your choice. [2 marks]

Making connections

- 17 Propose why there is a relationship between the life cycles of some native Australian plants and the seasonal activities of traditional Indigenous communities. [2 marks]



TOTAL MARKS
[/30]

HUMANS AS FUNCTIONING ORGANISMS

2.2

Compared with flowering plants, humans are very active, so the requirements of our cells for energy and oxygen and the removal of toxic wastes are much greater than those of plants. As multicellular organisms, our bodies are composed of cells that must work together in order to ensure their own survival and the survival of the organism. Cells are specialised to take on specific roles. Cells with similar structures and functions group together to form tissues, different tissues work together to form organs, and different organs work together in organ systems to carry out vital functions that keep us alive.

THE DIGESTIVE SYSTEM

Digestion is the process by which foods (and drinks) are broken down and absorbed into your blood for transport to your cells. Food provides us with the materials for energy, growth and repair. The food we eat is broken down into smaller chemicals, called nutrients, by our digestive system.

Nutrients provide nutrition to the body. They are mostly soluble substances that are absorbed by the blood and circulated around the body. Different types of foods provide us with different nutrients. The function of the digestive system is to break down food into substances that can be transported around the body.

The **digestive tract** (also known as the gastrointestinal tract) is made up of a group of organs that form a tube travelling from the mouth to the anus. Along the way, food is broken down and absorbed into the blood. The internal walls of the intestines are highly folded into projections called villi to increase their surface area for absorption into the blood (see Figure 2.25). Food that is not digested by the body remains in the digestive tract where it is broken down further by bacteria and forms solid faeces. When it reaches the end of the digestive tract, the faeces is released into the toilet. Figure 2.27 on page 74 shows what happens as food moves down through the digestive tract.

The mouth

Breakdown of food begins in the mouth. The human mouth has three main types of teeth: incisors (the front ones), canines (the pointy teeth next to the incisors) and molars (the flatter ones toward the back). The tongue is a large muscular organ in the mouth that can push upwards, sideways and backwards to help move food onto

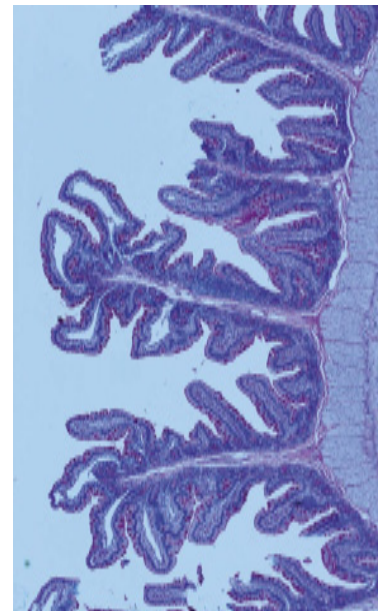
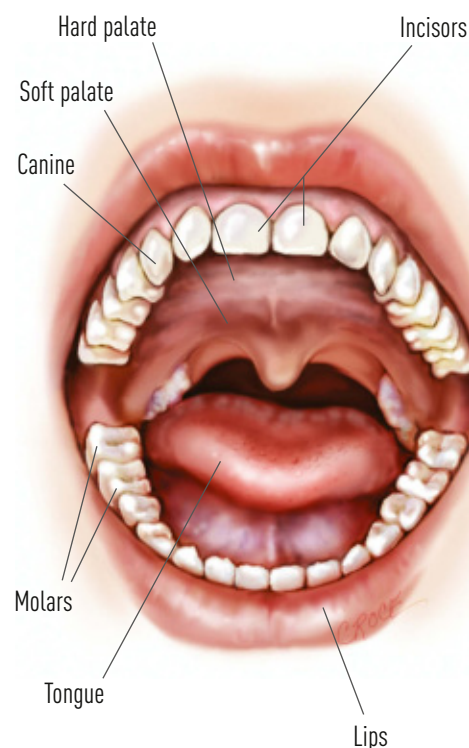


Figure 2.25 The highly folded villi of the intestines help absorb nutrients into the blood.

Figure 2.26 The teeth and mouth physically break down food.

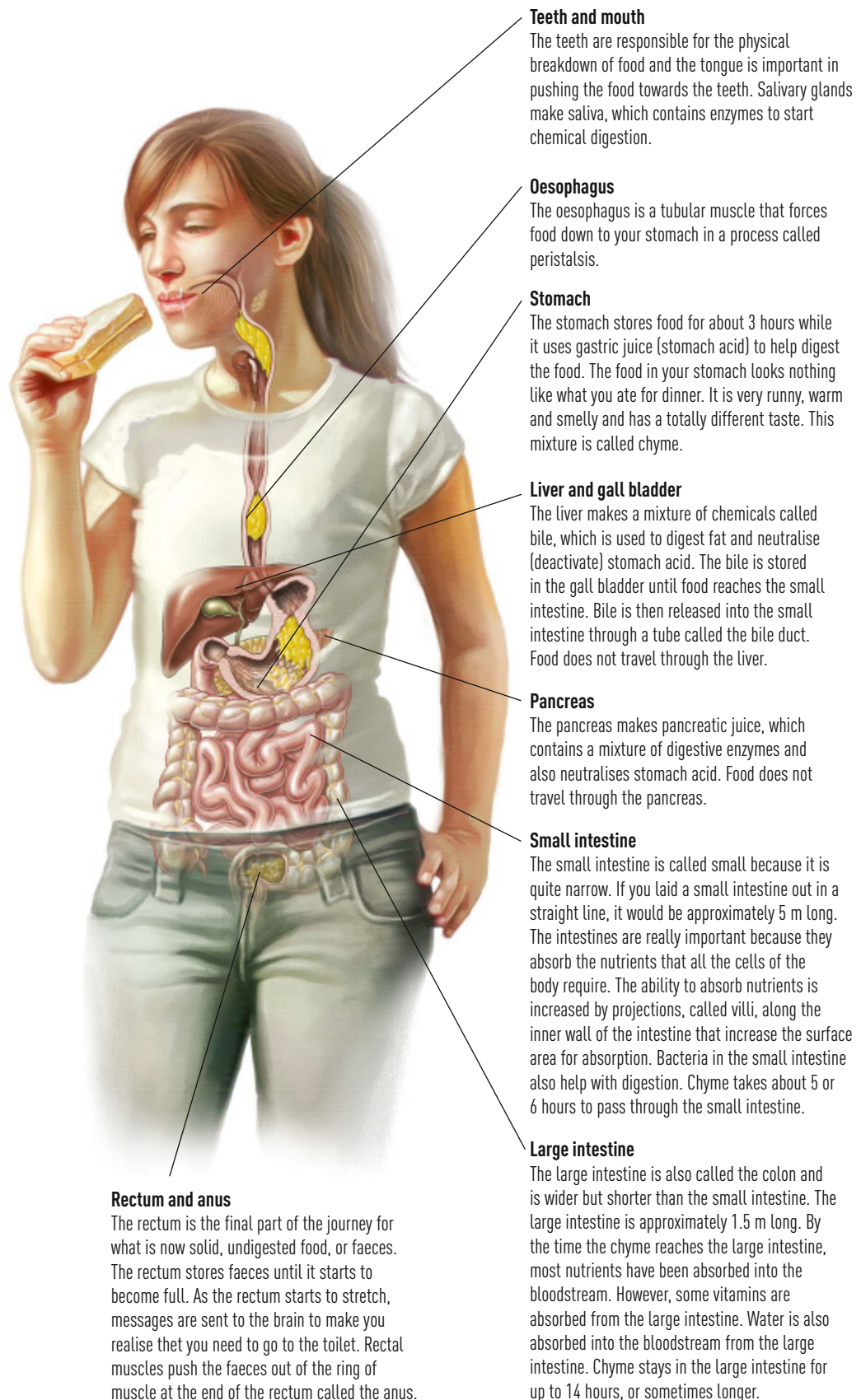


Figure 2.27 The key structures and functions of the digestive system.

the teeth to be chewed. Saliva is the liquid found in the mouth. It is mostly water, but also contains **enzymes**. Enzymes are special chemical molecules that help chemical reactions happen.

The stomach

The human stomach is J-shaped and spends its time churning its contents round and round, with muscular walls pulling in all directions. The stomach is filled with gastric juices made of hydrochloric acid and enzymes. The cells lining the inside of the stomach produce mucus to stop the acid burning the stomach walls.

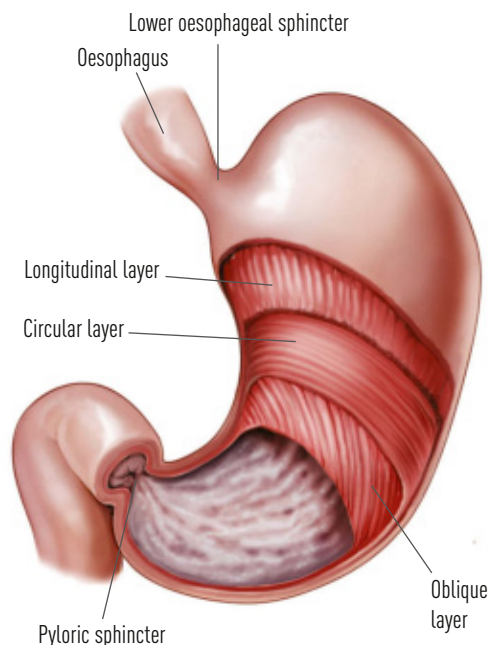


Figure 2.28 The stomach is a bag of layers of muscle that squeeze in different directions.

EXPERIMENT 2.2.1: DIGESTING PROTEIN

Aim

To investigate the function of pepsin, an enzyme found in the stomach, and to establish the conditions under which pepsin functions best. Egg white is used as the source of protein in this experiment.

Materials

- 1% pepsin solution
- Dilute hydrochloric acid (1 M HCl)
- Dilute sodium hydroxide solution (0.1 M NaOH)
- Hard-boiled egg white
- 1 mL pipette
- 10 mL measuring cylinder
- Water
- Incubator (37°C)
- 4 test tubes
- Test tube holder
- Permanent marker
- Rubber band

WARNING

- > Dangerous chemicals are involved – pour carefully, wear safety goggles, clean up all spills immediately and rinse your hands if you come into contact with any chemicals.
- > Bring the materials to the test tubes, rather than risking them being dropped when carrying them around the room.

Method

- 1 Label four test tubes A, B, C and D with the permanent marker.
- 2 Collect some hard-boiled egg white. Cut four cubes of approximately 1 cm³, ensuring the cubes are the same size.
- 3 Put a cube of egg white in each tube.
- 4 Add 10 mL pepsin to tubes A, C and D.
- 5 Add 10 mL water to tube B.
- 6 Add 10 drops of HCl to tubes A and B.
- 7 Add 10 drops of 0.1 M NaOH to tube D.
- 8 Add 10 drops of water to tube C.

9 Bind the four tubes with a rubber band and label the bunch with your initials.

10 Incubate for at least 24 hours at 37°C.

Results

Record the ingredients for each tube with a tick or cross. Provide very brief statements to describe your observations of the results.

Tube	Egg white	Pepsin solution	HCl	NaOH	Water	Observations
A						
B						
C						
D						

Discussion

- 1 A 'control' is different from a controlled variable. While controlled variables must be maintained through the practical, a control test is one where we know that nothing will happen (negative control), or something will happen for certain (positive control). Identify the negative control for this experiment and justify your answer.
- 2 How can combining the class's data improve the accuracy of the interpretations?
- 3 Construct a sentence to explain how the comparison of tubes relates to the human stomach for A and B, A and C, and A and D.
- 4 In which test tube(s) has the protein been completely digested? How do you know?
- 5 Has the pepsin digested the protein? If so, how can you be sure?
- 6 Does hydrochloric acid digest the protein by itself? How do you know?
- 7 Complete the following word equations to show what has happened in this experiment.

Tube A: protein + _____ + _____ → amino acids

Tube B: water + _____ + _____ → _____

Tube C: pepsin + _____ + _____ → _____

Tube D: pepsin + _____ + _____ → _____

- 8 Why does the body digest protein? What would happen to the protein after it has been digested?

Conclusion

What do you know about the function of pepsin and the conditions under which pepsin functions best? Write a summary that also reflects the aim of the experiment.

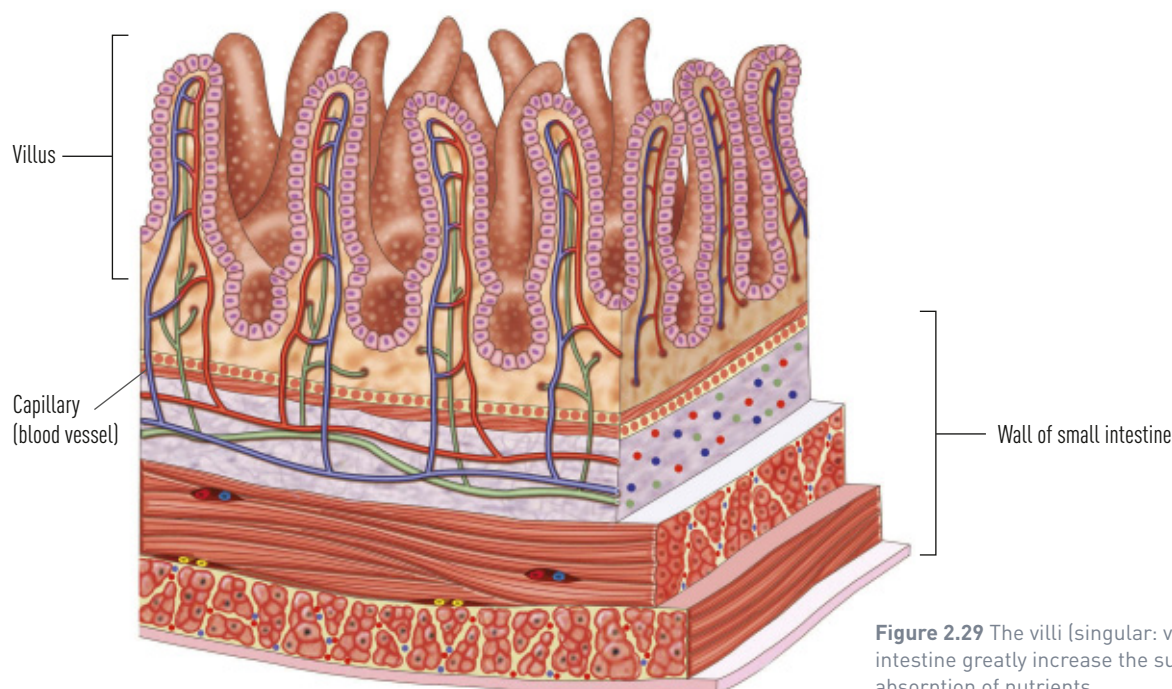


Figure 2.29 The villi (singular: villus) in the small intestine greatly increase the surface area for absorption of nutrients.

The intestines

In the small intestine, digestion via enzyme action and the absorption of nutrients continues. Although the stomach absorbs water and some other simple substances, including alcohol and some medications (which is why they have a rapid effect), most nutrients are absorbed in the small intestine. Figure 2.29 shows the villi that allow absorption of nutrients.

The junction of the small intestine and

large intestine contains the appendix, which is not believed to be functional in humans. Infection and swelling of the appendix is known as appendicitis. The large intestine contains lots of bacteria to help with the absorption of some vitamins, minerals and water from undigested fibre. Wastes (faeces) collect and are stored in the rectum before being passed out through the anus. Passing faeces is not considered part of excretion since it is not a waste product from within the body's cells.

QUESTIONS 2.2.1: THE DIGESTIVE SYSTEM

Remember

- 1 Recall the organs of the digestive system, listing them in the order that food moves through from the mouth to the anus.
- 2 Distinguish between physical and chemical digestion. Identify which of these occurs in the stomach and justify your answer.
- 3 Distinguish between the digestive system and the digestive tract.
- 4 Identify the organs that are involved in digestion but do not have food pass through them.

Apply

- 5 Teeth would look very nice if they were all the same size and shape. Explain the advantage of having different types of teeth in your mouth.
- 6 Predict how the length of the intestines contributes to the function of villi.

Analyse

- 7 Propose why digestive systems differ between many types of animals.

THE CIRCULATORY SYSTEM

The circulatory system is the body's transport system and is responsible for moving blood around your body. The heart pumps the blood through the system of blood vessels including the main arteries and veins (Figure 2.30). Many different substances, including nutrients and wastes, are transported in the blood, picked up from and dropped off at different locations.

Blood

Blood is a combination of cells, cell fragments, liquid and dissolved substances.

- Oxygen is carried by a chemical called haemoglobin in red blood cells from the lungs to all the cells of the body. You will learn more about red blood cells later in this chapter. Carbon dioxide is also carried in the red blood cells. However, it generally moves from the cells of the body to the lungs.
- Nutrients and wastes are dissolved in the plasma for transport to and from cells.
- White blood cells are involved in fighting foreign cells, including disease-causing pathogens, and travel in the blood to places where they are needed.
- Platelets are cell fragments that travel in the blood to places where cuts need to be blocked – they fill the hole.

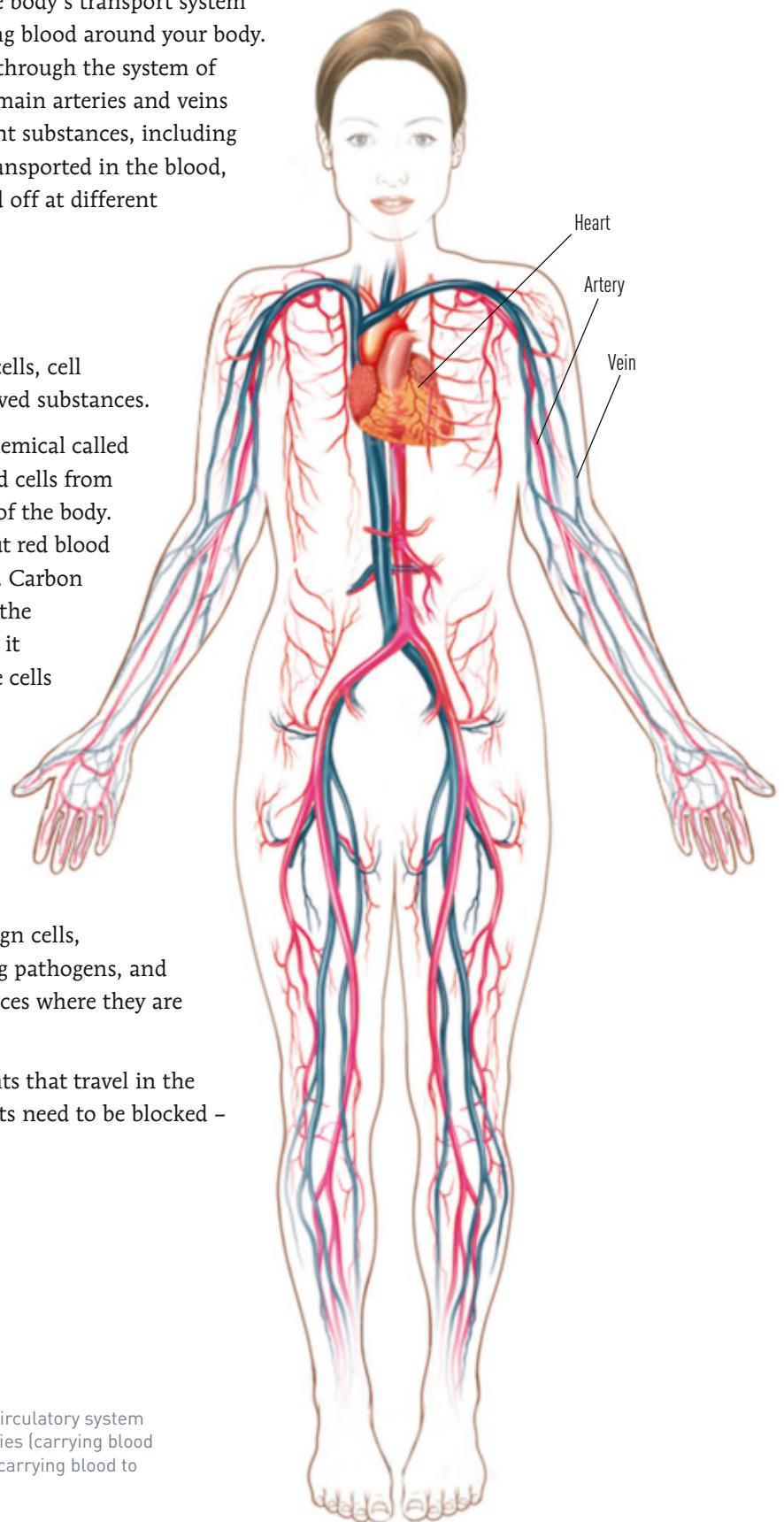
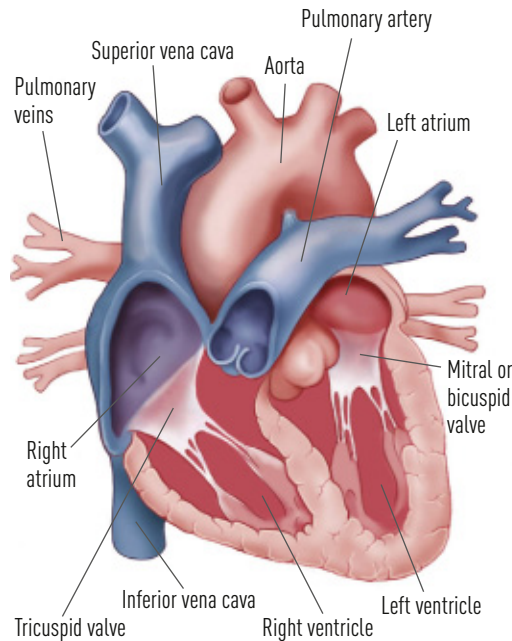


Figure 2.30 The structure of the circulatory system showing the heart, the main arteries (carrying blood from the heart) in red, and veins (carrying blood to the heart) in blue.

The heart

The heart is a large pump about the size of your fist. It is made of four chambers: two atria (singular: atrium) at the top and two ventricles at the bottom. The right side of the heart pumps blood to the lungs to 'drop off' carbon dioxide and 'pick up' oxygen, whereas the left side pumps blood around the rest of your body. Valves keep the blood moving in the right direction. The aorta extends from the top of the heart and is the largest blood vessel in the body.

Figure 2.31 This diagram shows your heart, as well as some of the major blood vessels travelling to and from the heart. The diagram uses a convention that shows the arteries in red and the veins in blue.



Blood vessels

Blood travels through tubes called blood vessels. Blood vessels have different sizes and structures depending on the amount of blood they need to carry as well as the speed of the blood and whether it is picking up or dropping off substances.

Arteries (see Figure 2.32) have thick, muscular walls to cope with high pressure and to squeeze the blood along. Arteries travel away from the heart – the blood is at a higher pressure here because it has just been pumped. Arteries branch into arterioles (smaller arteries).

Veins carry blood back to the heart to be pumped elsewhere. These vessels are similar in size to the arteries, but they only have a small amount of muscle in their walls. To avoid any blood going backwards due to a lack of pressure, veins have one-way valves in them.

Capillaries (see Figure 2.33) are the thinnest of the blood vessels: their walls are only one cell thick to allow substances to easily pass in and out of the blood. Capillaries are the vessels connecting the arteries and veins.

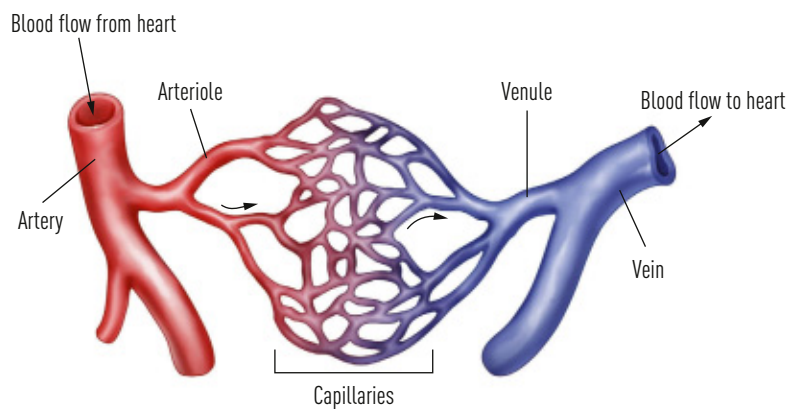


Figure 2.32 The relationship between arteries, veins and capillaries.

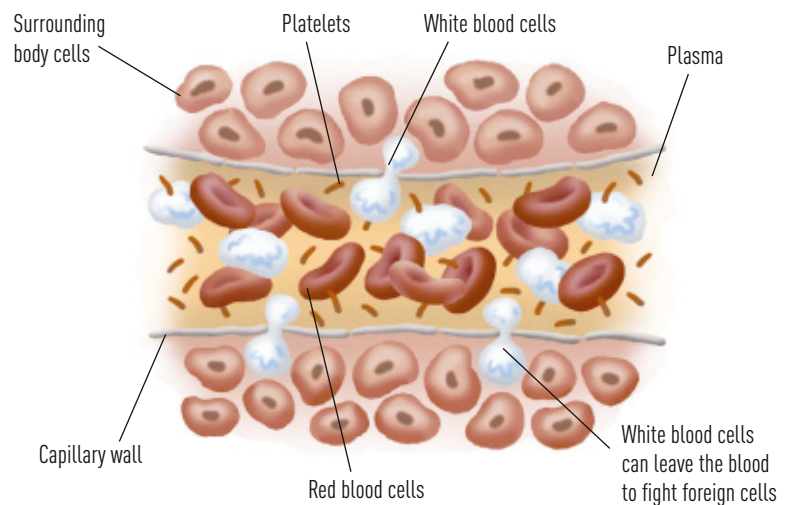
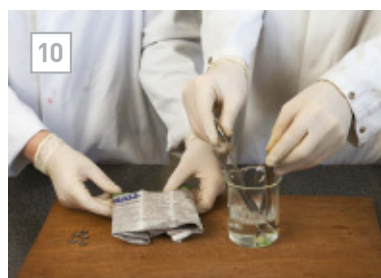
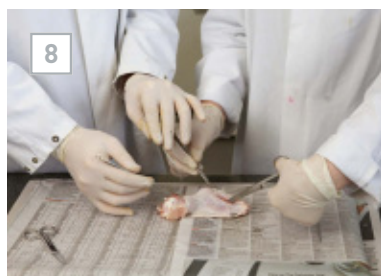
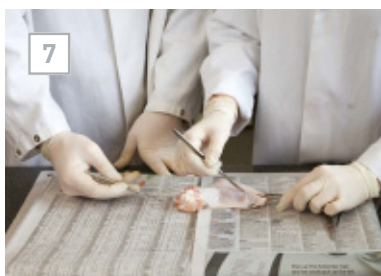
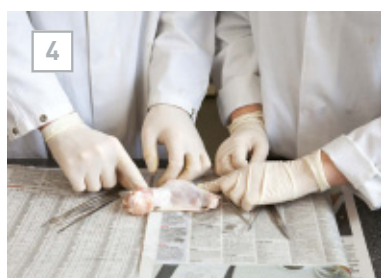
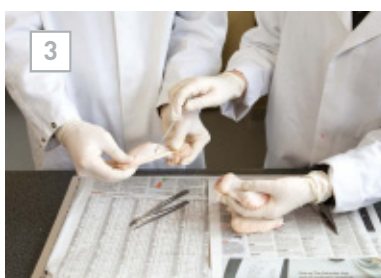
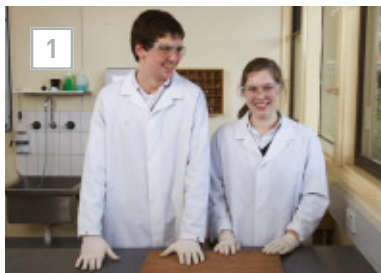


Figure 2.33 A cross-section of a capillary.

Dissections

A few simple guidelines are all that are required to keep you safe and germ free while successfully dissecting a specimen.



- 1 Make sure you are wearing appropriate safety gear: gloves, lab coat and safety glasses.
- 2 Set up your workspace, covering surfaces with newspaper that can be disposed of easily and collecting any dissection tools you may need.
- 3 Collect your specimen for dissection. Identify all external structures.
- 4 Pin the specimen to the dissection board to keep it from moving.
- 5 Use probes to look inside any folds.
- 6 Use forceps to hold and pull tissue.
- 7 Use scalpels to cut carefully. Run the scalpel gently over the tissue several times to cut through. Do not dig the scalpel into the specimen or expect to cut through in one movement.
- 8 Use scissors to cut when you can see what is under the structure you are cutting. Scissors with rounded ends are less likely to cause unnecessary damage than those with pointed ends.
- 9 Fingers are always the safest way to 'look around' your specimen.
- 10 When finished, your specimen should be wrapped in newspaper for disposal. Your instruments should be rinsed, cleaned and disinfected, and your hands should be washed thoroughly.
- 11 Dissection instruments and workspaces should be cleaned while you are still wearing your safety gear. Your lab coat and gloves should be on before you start your dissection and they shouldn't come off until the dissection is completely finished – this includes disposal and cleaning! The last things you should do are: remove your gloves and throw them in the bin; wash your hands thoroughly; and take off your lab coat and hang it up.

EXPERIMENT 2.2.2: HEART DISSECTION

Aim

To explore the structure and function of a heart.

WARNING

- > Be sure to follow the dissection skills and safety guidelines, as outlined in the Science Skills box on page 80.

Materials

- Sheep, cow, ox or pig heart
- Scalpel
- Newspaper
- Dissecting probe and forceps

Method

- 1 Examine the outside of the heart and identify the left and right sides. Your fingers will work better than a probe for this.
- 2 Feel the right side of the heart. Compare the thickness of the right and left sides. Feel the muscle in the centre of the heart. Again, your fingers will work better than a probe for this.
- 3 Using a scalpel, cut open the right atrium and right ventricle. Pull back the wall and look inside to see the atrium and the ventricle. The ventricle is the chamber closest to the pointed end of the heart. The white tendons hold the valves in place.
- 4 Push a dissecting probe or your finger out through the artery leading from the right ventricle.
 - What is this artery called?
- 5 Cut open the left side of the heart. Locate the atrium, ventricle and tendons holding the valves.

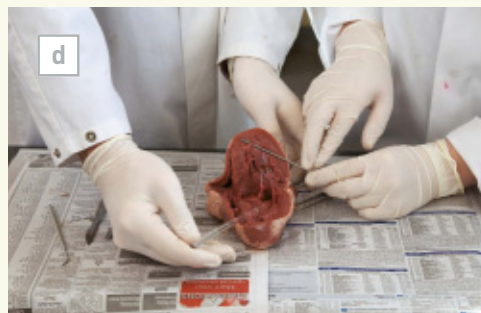
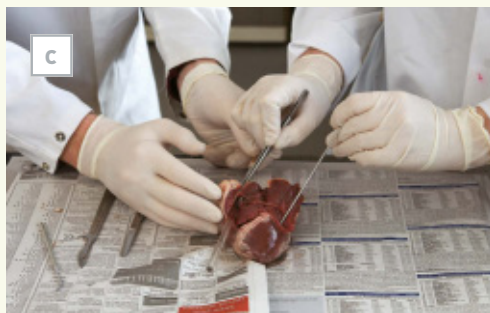
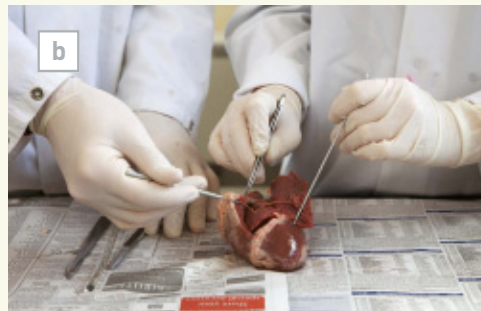
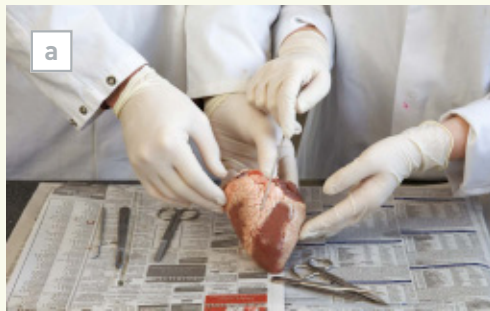


Figure 2.34 (a) Examine the outside of the heart. (b) Examine the right atrium and ventricle. (c) Locate the artery entering the right ventricle. (d) Locate the artery entering the left ventricle.

- 6 Push a dissecting probe or your finger out through the artery leading from the left ventricle.
 - What is this artery called?
 - How does the thickness of this artery wall compare with the thickness of a vein wall?
 - How does the thickness of ventricle walls compare with that of atrial walls?
 - How can you explain the difference between the left and right ventricle walls?

Results

Include labelled diagrams and observations here.

Discussion

- 1 Include responses to the questions above.
- 2 Discuss any other observations you made.
- 3 The heart you dissected was once a functioning organ inside a living animal. Discuss some ethical considerations involved with this dissection experiment.

Conclusion

What do you know about the structure and function of the heart?

QUESTIONS 2.2.2: THE CIRCULATORY SYSTEM

Remember

- 1 Outline how the three blood vessel types differ in their structure, function and location. Use diagrams in your answer.
- 2 Identify all the chambers in the human heart.
- 3 Recall the path of blood through the chambers of the heart. Include the names of the veins and arteries involved. Refer back to Figure 2.31 on page 79 to help you.
- 4 Identify the body system from which the circulatory system absorbs nutrients.

Apply

- 5 Explain why your muscles need your heart to pump faster during exercise.
- 6 If a person is dehydrated, their blood becomes thicker. Explain the effect this could have on the heart.

Analyse

- 7 Instead of the blood travelling directly from the lungs to the rest of the body, the blood returns to the heart first. Explain the advantage of this process.
- 8 Compare the circulatory system with a suburban rail network.

THE RESPIRATORY SYSTEM

The respiratory system (see Figure 2.35) is responsible for **gas exchange** through breathing. The key processes involved in gaseous exchange occur in the lungs. Oxygen enters the blood from the air we inhale and carbon dioxide leaves the blood and is exhaled.

We breathe air in through our nose and mouth, cleaning it with hairs and wet surfaces as it travels to our throat or pharynx. At the bottom of the pharynx is a trapdoor called the epiglottis, which controls the path of food and air. Food goes down the oesophagus to the stomach while air goes down the trachea to the lungs.

For gas exchange to occur, the circulatory system is involved. The blood vessels need

to be able to get really close to the air in the lungs. We will now look at how the structure of the lungs allows this to happen.

The lungs

There are two lungs in our chest, which change in size every time we take a breath and they fill with air. The trachea branches into two to carry air into each lung. These branches are called bronchi. The lungs feel spongy to touch because they are home to millions of tiny air sacs called **alveoli** (see Figure 2.36 on page 84). If these air sacs were unravelled and flattened, they would have a surface area of approximately half the size of a tennis court. Each tiny alveolus

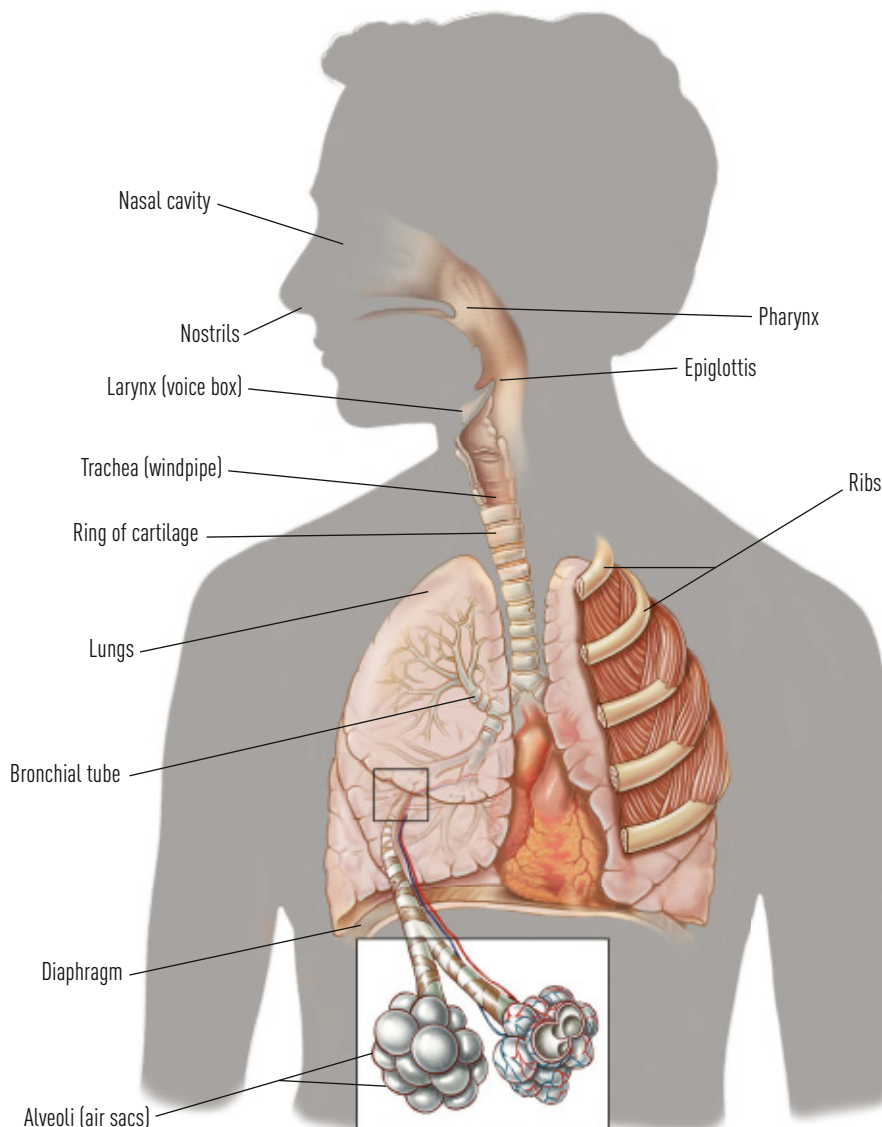


Figure 2.35 Key structures of the respiratory system.

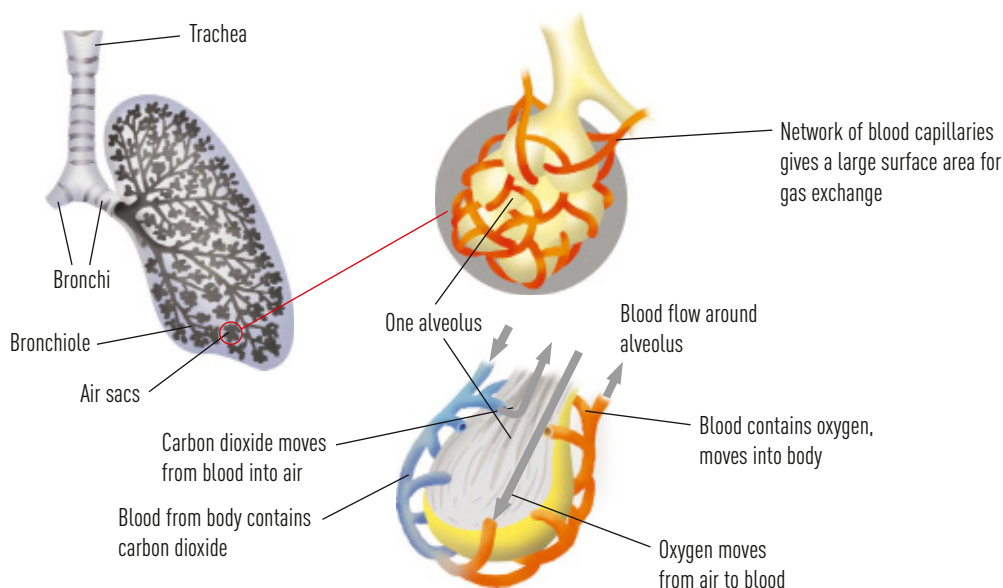


Figure 2.36 Gas exchange in the alveoli.

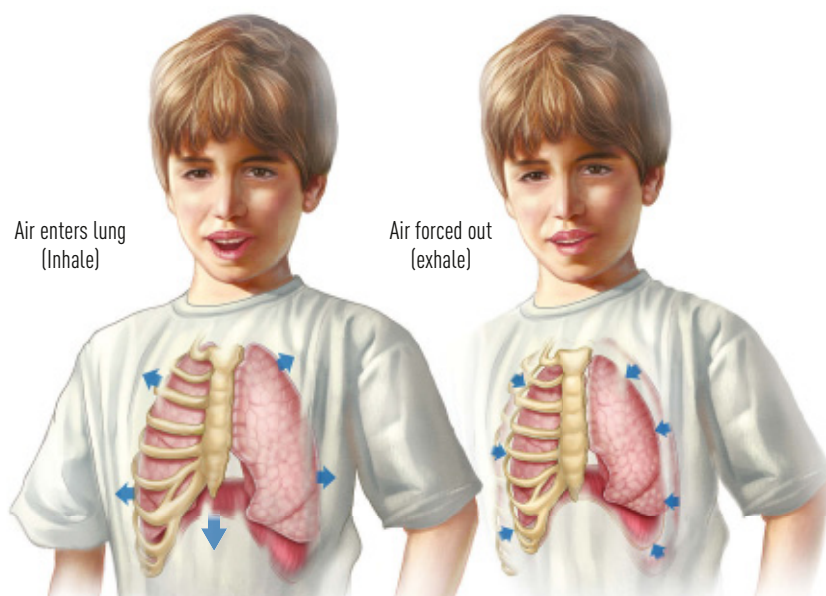


Figure 2.37 Inhalation and exhalation. The arrows show the movement of muscles

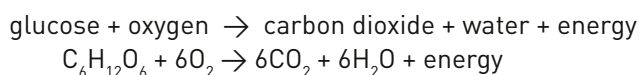
is covered by a mesh of capillaries. The lungs are structured to have as many air sacs as close to as many blood vessels as possible to aid gas exchange.

The diaphragm

The diaphragm is a dome-shaped muscle that is attached to your ribs and moves up and down beneath your lungs. The muscle contracts down and relaxes up. The diaphragm also separates the heart and lungs from the stomach and digestive system. The lungs have no muscle tissue, so they can't move on their own. Muscles between the ribs lift the rib cage up and out to increase the 'suction' of air into the lungs.

Comparing respiration with breathing

The reaction that occurs in human body cells to produce energy is the same reaction we saw in plant cells: respiration. Oxygen taken in by the lungs reacts with glucose, which the digestive system releases from the food we eat.



The energy produced by respiration is then used for all the jobs the cell needs to perform, from making and breaking down substances to making new cells. You can see why people get confused about the difference between breathing and respiration – respiration is the actual process that happens in cells and breathing is the inhalation of oxygen and exhalation of carbon dioxide by your lungs and other organs in the respiratory system.

When things go wrong in the respiratory system

Asthma is quite common in our population, affecting more than one in ten Australians with symptoms such as wheezing, coughing, tightness of the chest and shortness of breath. A severe asthma attack can be fatal if untreated.

Asthma is usually triggered by something in the environment, which causes the bronchi and bronchioles to swell, making it harder for air to pass through them. Triggers that cause an attack include allergic reactions, exercise and sudden exposure to cold air. The likelihood of developing asthma can be inherited, but certain respiratory infections in children may also prompt its development. The symptoms of asthma attacks can be lessened by drugs, such as Ventolin, which are taken through an inhaler and relax the airways.

Smoking involves breathing toxic chemicals and tar into your lungs. The tar is thick like honey, covering the inside of the alveoli and stopping air from being exchanged. The toxic chemicals in the smoke kill the cells, destroying the alveoli, and travel through the blood to cause trouble all over your body. Emphysema is a disease that results from alveolar damage that reduces the surface area over which gases can exchange. It is just one of many diseases that can be caused by smoking.



Figure 2.38 (a) Healthy lungs. (b) Smoker's lungs.

QUESTIONS 2.2.3: THE RESPIRATORY SYSTEM

Remember

- 1 Explain the term 'gas exchange'.
- 2 Explain the difference between respiration and breathing.
- 3 Recall the sequence of steps in breathing in and breathing out.
- 4 Recall the role of the epiglottis.
- 5 Explain how the structure of the lungs provides a large surface area.

Apply

- 6 Describe a health risk people take with their lungs and what the consequences are. Explain what can be done to avoid this risk.

Analyse

- 7 We breathe without making a conscious effort. Propose what changes in the blood might be the triggers to make the body subconsciously start to breathe faster or deeper.
- 8 Physically fit people often have a high lung capacity. Propose why this may be the case.

THE EXCRETORY SYSTEM

Our cells and our bodies create a number of waste products. To keep functioning correctly, these wastes need to be removed. The process of removing wastes is called **excretion**. The organs of excretion are the kidneys, liver, lungs and skin. These organs make up the excretory system.

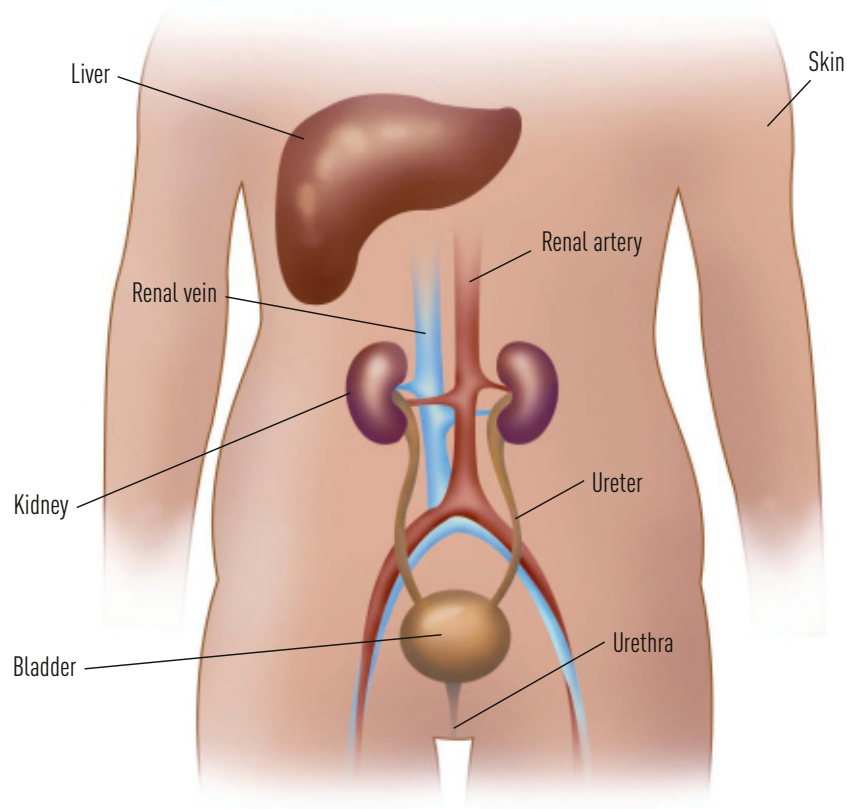


Figure 2.39 The key organs of the excretory system.

The kidneys

You have two kidneys, one on each side of your lower back. They are approximately 10 centimetres long. Blood carrying waste products enters your kidneys to be filtered by tiny structures in the kidney called **nephrons**. At the end of this filtering process there are two main outputs: clean blood in the renal vein and urine in the ureter.

The kidneys are also responsible for regulating the levels of water and salts in the blood. This can affect blood volume and pressure. If you drink large quantities of water, you will produce a larger volume of pale-coloured urine than if you do not drink much water. Urine is stored in the bladder before it passes down the urethra to be expelled from the body.

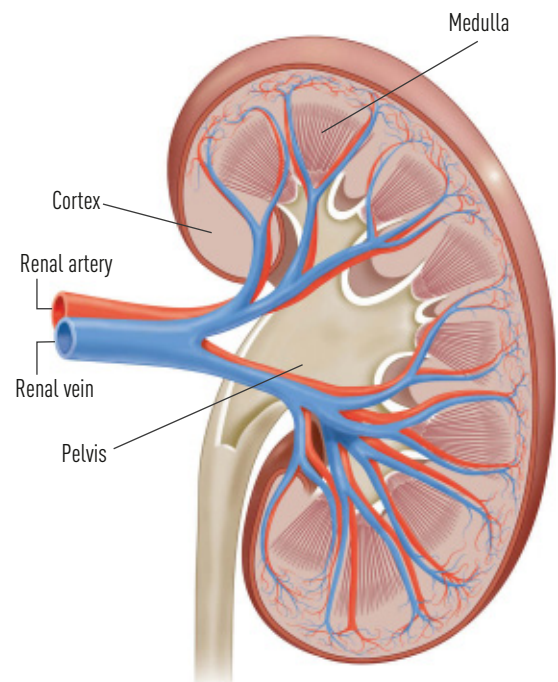


Figure 2.40 The basic structure of the kidneys.

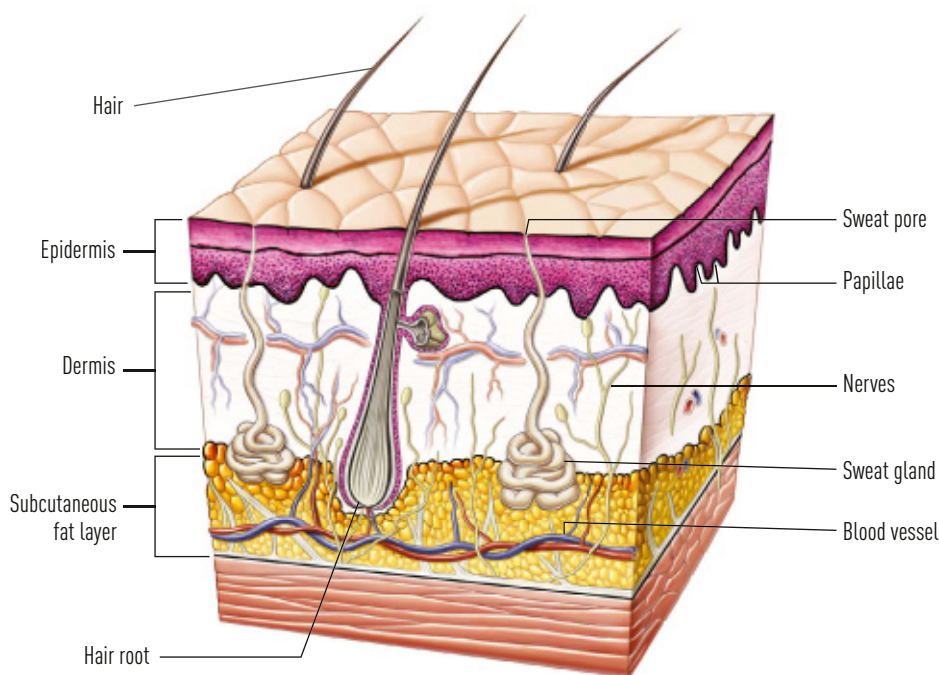


Figure 2.41 Cross-section of human skin.

The skin

In chapter 3 of *Oxford Insight Science 7* you looked at the structure of the skin. The skin plays a very important role in releasing waste heat by evaporation of sweat from wet skin. If you have ever licked your upper lip after exercise, you will know that your sweat is also very salty. This is because some salt is also excreted through the skin.

The liver

All our food has to be metabolised, or processed. **Metabolism** is the name given to the chemical reactions that occur in the body. These reactions can break down substances or build new substances. The liver is responsible for the metabolism of many substances, especially waste substances. Waste substances that can be dangerous to the body are often changed into less dangerous forms by the liver before their removal from the body.

What is waste?

Our bodies produce a number of substances that need to be removed to avoid damage to our bodies. The human body, like all organisms, relies on a careful balance of inputs and outputs to work properly. Some substances are just taking up precious space,

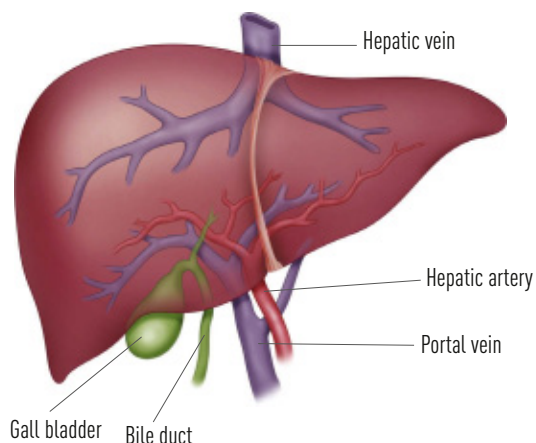


Figure 2.42 The key structures of the liver.

whereas others can actually harm us. Water is important in controlling wastes because it can dilute harmful substances, reducing the damage they can cause at the same time. Water also helps move substances quickly and is essential for keeping our body temperature just right.

When your body digests proteins, it breaks them down into smaller molecules called amino acids. Your liver converts these amino acids into glucose for energy. During this process, a very toxic substance called ammonia is produced. The liver then uses energy to change the ammonia into a safer substance called urea, which is then filtered by the kidneys for removal. When you have not drunk much water, you will have noticed that your urine is darker and smells more strongly. When you have drunk enough water your urine is lighter and has



Figure 2.43 These foods are all rich in protein. Protein digestion produces toxic ammonia.

no smell. The amount of water in your urine can dilute the colour and smell of urea.

Storage of the faeces in the rectum and their expulsion through the anus is not considered part of the excretory processes. The contents of the gastrointestinal tract are not really considered to be within the body until the digested food is absorbed into the blood in the intestines.

EXPERIMENT 2.2.3: KIDNEY DISSECTION

Aim

To investigate the structure of a mammalian kidney and explore the various functions of the different parts.

Materials

- Sheep's kidney
- Dissecting kit
- Dissecting board

Method

- 1 Place the whole kidney on the board and identify as many parts as possible.
- 2 Draw a labelled diagram.
- 3 Cut the kidney in half longitudinally (lengthways).
- 4 Draw a labelled diagram.

Results

Include your labelled diagrams here.

Discussion

- 1 What did you notice about the colour of the kidney on the outside compared with the inside?
- 2 The colour of the kidney gives an indication of the amount of waste products it contains. How does this support your observations?
- 3 Could you actually see any nephrons? What does this tell you about their size and the size of the substances they filter?
- 4 The medulla, the middle section of the kidney, has a striped appearance. This is due to the collecting ducts heading in the same direction. Where are they heading?

Conclusion

What do you know about the form and function of a mammalian kidney?

QUESTIONS 2.2.4: THE EXCRETORY SYSTEM

Remember

- 1 Define the term 'excretion'.
- 2 Recall the organs involved in excretion.

Apply

- 3 Explain why we tend to drink a lot of water after a salty meal.
- 4 Propose what effect running a marathon would have on the quantity and concentration of the urine.

Analyse

- 5 Explain why passing blood in the urine is a likely sign of infection.

THE SKELETAL/MUSCULAR SYSTEM

The skeletal/muscular system allows for voluntary movement in humans. Muscle cells have the special ability of being able to contract. Skeletal muscles occur in pairs, each one attached to a different side of a bone. **Bones** are the levers that bring about the movement of the body. Contraction of one member of a muscle pair, such as the biceps, allows movement of the arm in one direction, or the arm flexes. When it relaxes and the opposite member (the triceps) of the pair contracts, the arm will return to the original straight position.

The skeletal system

The skeletal system or skeleton in the adult human consists of 206 bones of varying shapes and sizes. It includes the bones that make up the skull and spine and the bones of the limbs, shoulders and pelvis. It also consists of the three tiny bones that transfer vibrations in the ear to allow us to hear. The skeletal system includes the long bones found in our limbs that are levers for movement. The vertebrae provide support and flexibility, and the skull and ribs protect vital organs.

Bones are living tissues, which means they can repair themselves when damaged. They contain cells surrounded by calcium phosphate, the substance that makes the bone hard, and collagen, which provides elasticity. Blood vessels supply the bone with the nutrients it needs. The marrow inside bone is also very important because it is the site of production of blood cells.

Bones meet other bones at joints, which are the pivot points of the bone levers. Some joints are highly moveable because they are capsules containing membranes that secrete a type of lubricating liquid. Many bones are tipped by a tissue called **cartilage**, which cushions impacts with the joining bone and reduces friction.

Ligaments hold adjoining bones together in the joint. The shoulder and hip joints are ball-and-socket joints, which allow movement in many directions. The elbow

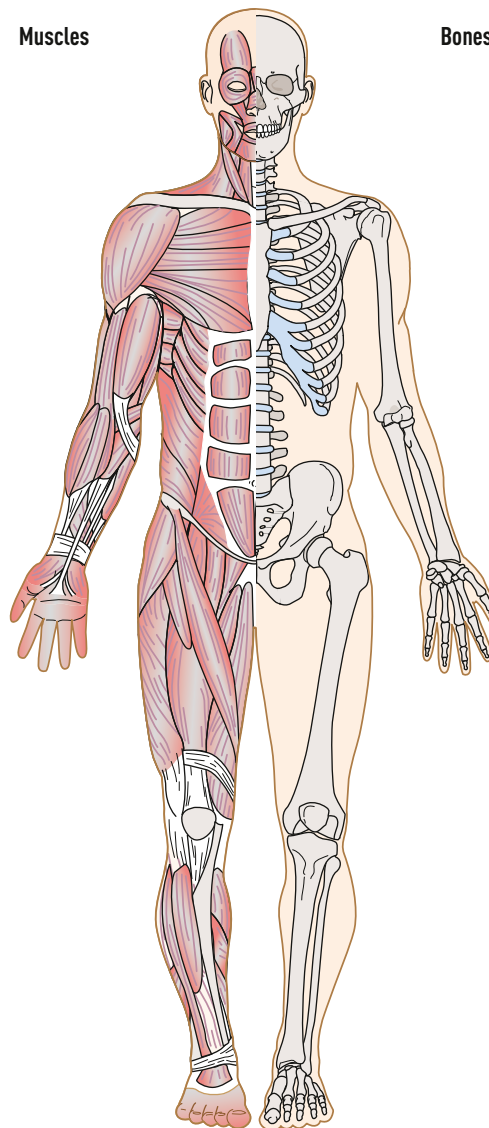


Figure 2.44 The skeletal/muscular system – the skeletal muscles (shown on the left) attach to the bones (shown on the right).

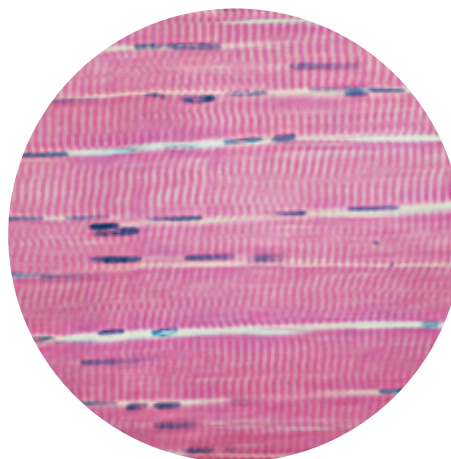


Figure 2.45 Skeletal muscles have a striated (striped) appearance under the microscope.

and knee are hinge joints, and they only move in one direction. Other types of freely moveable joints include pivot joints, which allow the head to turn on the spine, and gliding and saddle joints that allow movement in the wrist and ankle.

The muscular system

The muscular system consists of about 640 skeletal muscles that are responsible for movement and posture, smooth muscles and cardiac muscle.

A muscle is made up of muscle fibres containing protein molecules that slide over one another to bring about muscle shortening or contraction. Muscle fibres are bundled together and the end of the muscle, the connective tissue from the bundles, combines to form tendons that attach to the **skeleton**. Skeletal muscles attach to bones of the skeleton to bring about voluntary movement.

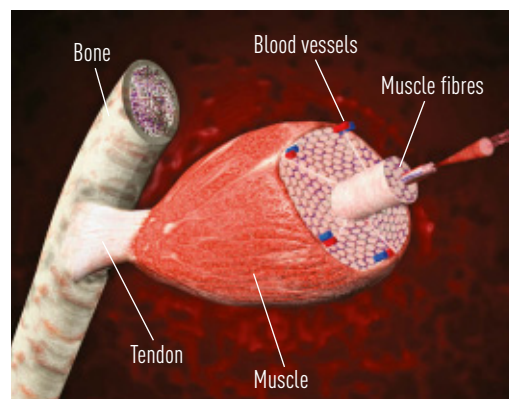


Figure 2.46 A cross-section of a skeletal muscle attached to a bone.

In addition to **skeletal muscles** (also called voluntary muscles), the muscular system contains **smooth muscles** that contract automatically in internal organs such as the digestive tract and the uterus (womb) in females. A third muscle type, cardiac muscle in the heart, contracts in a highly coordinated way to bring about a heartbeat.

DEEPER UNDERSTANDING

When things go wrong in the muscular/skeletal system

Arthritis is a joint disorder involving painful, inflamed and swollen joints. There are many different types of arthritis. Osteoarthritis is the most common type and results in joints become stiff and less mobile. Osteoarthritis results from accidents, age or infection. Rheumatoid arthritis often results in highly disfigured joints in the hands and elsewhere. Rheumatoid arthritis is an autoimmune disease, which means the immune system actually attacks the body's own tissues, including the joint lining and cartilage.



Figure 2.47 In this 76-year-old patient, the knee shown on the left is swollen due to osteoarthritis.

QUESTIONS 2.2.5: THE SKELETAL/MUSCULAR SYSTEM

Remember

- 1 Recall the special ability of muscle cells.
- 2 Define the term 'voluntary muscle'.

Apply

- 3 Explain why joints are important in the skeletal system.
- 4 Distinguish tendons from ligaments.

Analyse

- 5 Explain why skeletal muscles occur in pairs but smooth muscles do not.

THE ROLE OF MITOSIS IN GROWTH AND REPAIR

In section 2.1, you learnt about the role of two types of cell division in flowering plants: mitosis and meiosis. Vegetative reproduction is not an option in humans, but mitotic cell divisions are essential to the functioning of humans to allow growth, cell replacement and repair of body tissues.

When the first cell (zygote) of a new human forms, all the subsequent cell divisions are by mitosis. These mitotic cell divisions result in the growth and development of the embryo into a **foetus**, an infant, a teenager and eventually an adult. Eventually, humans end up with about 10 trillion cells of over 200 different specialised types.

To achieve the growth of various tissues, organs and organ systems, the cells develop specialised structures through a process called differentiation. The first cell or zygote has the ability to differentiate into all types of cells. As humans mature, some of the cells become so specialised that they can no longer carry out mitosis. In these cases, specific cell groups called stem cells retain the ability to divide and differentiate. Stem cells are important in the repair, growth and normal functioning of humans.

Repair and maintenance of the human body are complex processes. Mitotic cell divisions are essential for the production of new cells but cell differentiation must also occur so that cells can carry out their specialised roles. Some organs consist of a variety of cells and tissues, so it is not a simple process to repair them when something goes wrong.

Mitosis and red blood cells

Red blood cells are tiny but they are present in our bodies in huge numbers, making up one quarter of our total number of cells. Red blood cells are highly specialised to carry oxygen on haemoglobin molecules throughout the body.

Red blood cells have no nucleus or organelles, which gives them their distinctive biconcave shape. This shape is beneficial as it allows more room for oxygen and provides the flexibility for a red blood cell to squeeze through even the smallest capillary. The disadvantage of not having a nucleus is that red blood cells only have a life span of 100–120 days and cannot divide by mitosis. Our bodies are constantly making red blood cells, at the rate of about 2 million per second. This occurs in the bone marrow of the long bones in adults and in the liver of embryos.

People who lose a lot of blood may not be able to make enough red blood cells to survive. Blood transfusions can be given, but the donated blood must be a compatible blood type to that of the recipient or a fatal rejection may occur.

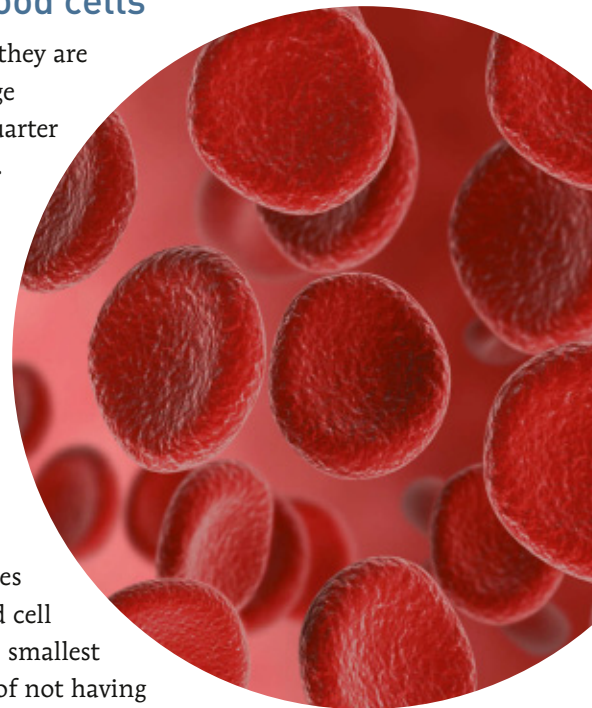


Figure 2.48 Red blood cells are one of the most common cells in our bodies.

QUESTIONS 2.2.6: THE ROLE OF MITOSIS IN GROWTH AND REPAIR

Remember

- 1 Describe the type of cell division responsible for the growth of a zygote into an embryo.
- 2 Identify where mitosis occurs that results in the production of red blood cells.
- 3 Explain how muscles grow.
- 4 Outline cell differentiation.

Apply

- 5 Construct a concept map showing the role of mitosis in the human body.

REPRODUCTION IN HUMANS

All living things reproduce, leaving new organisms to carry on when others die. We are constantly seeking ways to live longer, to monitor the health and development of our babies even before they are born, and to help those who are unable to have babies naturally.

ACTIVITY 2.2.1: HUMAN REPRODUCTION

Working in small groups, write down everything you already know about the role of human reproductive systems. Use diagrams and words as appropriate.

You might like to consider the following to get you started:

- What do you know about pregnancy and childbirth?
- Do you have anything in common with your parents (appearance, abilities etc.)?
- What are some causes of human infertility?
- What technologies assist human reproduction?

Share your thoughts with the class, discussing any inconsistencies of understanding.



Sexual reproduction

Sexual reproduction produces variations in a population. The offspring (babies) are all different from their parents, having new combinations of features. This variation is important for the survival of the entire species. Imagine what life would be like if all humans looked and behaved exactly the same!

The structure and function of the human reproduction system enables people all around the world to have babies – approximately four births occur every second! As of 2014, the world population was just over 7 billion people.

The vast majority of animals reproduce sexually. Many are also sexually dimorphic, which means that the males look physically different from the females. This is true for humans, who have external and internal differences between the genders. Just like in flowering plants, meiosis is a key process in the formation of male and female gametes in humans.



Figure 2.49 Pregnancy is a vital part of human reproduction.

Female reproductive system

The reproductive system in females is mostly internal. The external opening of the vagina leads up to the uterus, which has two fallopian tubes branching off that connect to the ovaries. The female gametes or ova (singular: **ovum**) are produced in the ovaries through meiosis. Once released during ovulation, the ova move slowly down the fallopian tube towards the uterus. Fertilisation with the male's sperm usually happens in the fallopian tube.

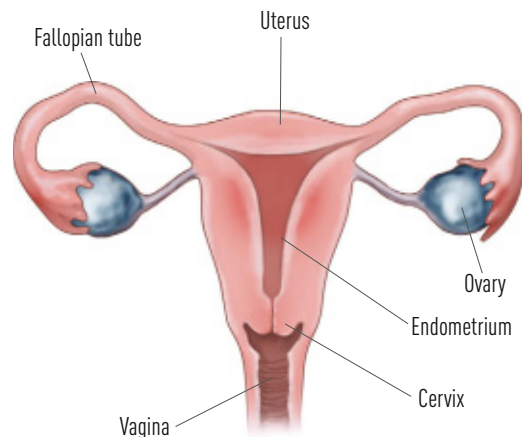


Figure 2.50 The female reproductive system.

ACTIVITY 2.2.2: STRUCTURES FOR REPRODUCTION

The female reproductive system varies between vertebrates depending on the reproductive habits of the species. For example, humans have a uterus that is large enough to hold one or two developing fetuses until they are fully formed. Rats and rabbits have a uterus large enough for multiple fetuses. Amphibians have almost no uterus at all because they lay eggs that are fertilised by the male outside their bodies.

Find a diagram of the female reproductive system of each of the vertebrate classes, as well as each of the different mammal groups, labelling the features of the system that suit the organism's needs.

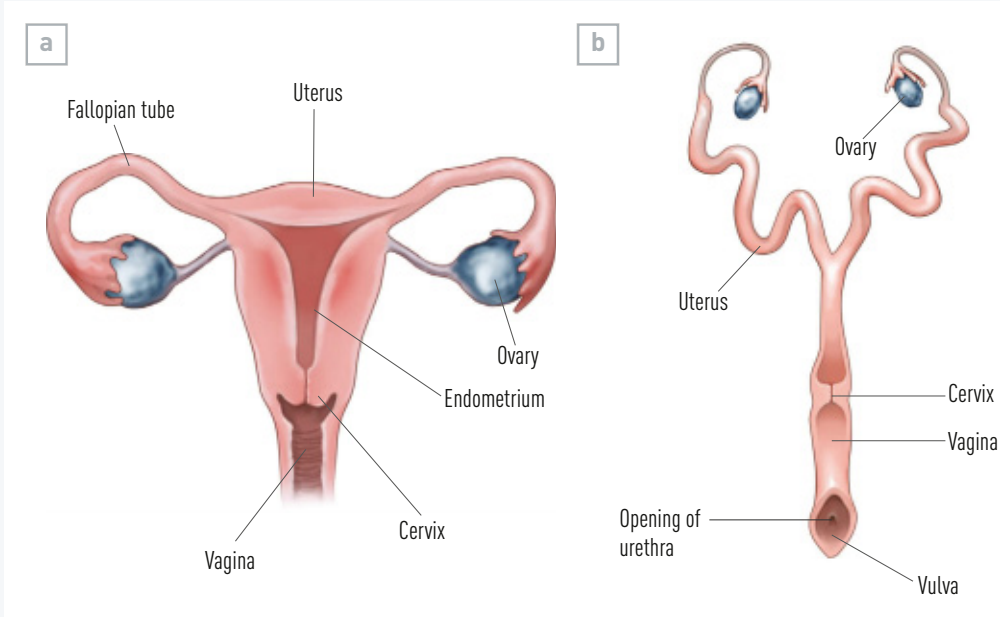


Figure 2.51 (a) Humans have a uterus that is suited to growing usually one foetus at a time. (b) Rabbits have two really long and stretchy uteruses; each can hold up to 10 foetuses.

Male reproductive system

The male reproductive system is much more obvious from the outside of the body. Both the penis and testes are external. The **testes** are where sperm are produced through meiosis. The testes are contained in the scrotum, which is able to regulate the temperature $1-2^{\circ}$ below normal body temperature of 37°C . To get outside of the body, the sperm move up through the vas deferens, has seminal fluid added from the seminal vesicles, and then moves into the urethra and out through the glans penis.

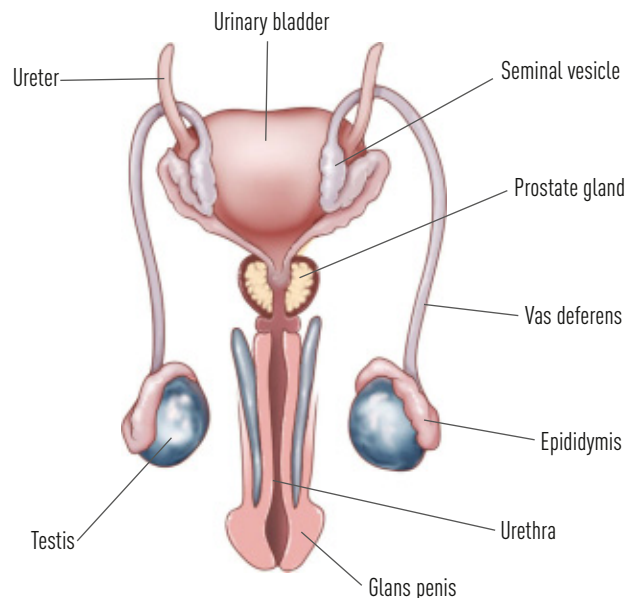


Figure 2.52 The male reproductive system.

Puberty

While the specific reproductive systems are already in place before birth, both the male and female reproductive systems do not mature until puberty. Puberty is the phase of physical development when sexual maturity takes place. It is a time of significant change and is experienced by everyone differently. Puberty is triggered and controlled by hormones that affect both the internal system and the external secondary sexual characteristics, such as facial hair in males and breasts in females.

Before puberty, boys and girls have a very similar basic body shape. After puberty, the differences are very obvious.

In females, puberty triggers the onset of the **menstrual cycle**. The menstrual cycle continues until menopause, with the exception of during pregnancy. The menstrual cycle is controlled by chemicals called hormones and is essentially the preparation of the female body for a potential pregnancy. During the menstrual cycle, the lining of the uterus grows thicker and develops an increased blood supply. If the ovum released during the menstrual cycle is not fertilised, menstruation will occur. Menstruation is the loss of the uterus lining, which is passed out of the body. The menstrual cycle takes approximately 28 days.

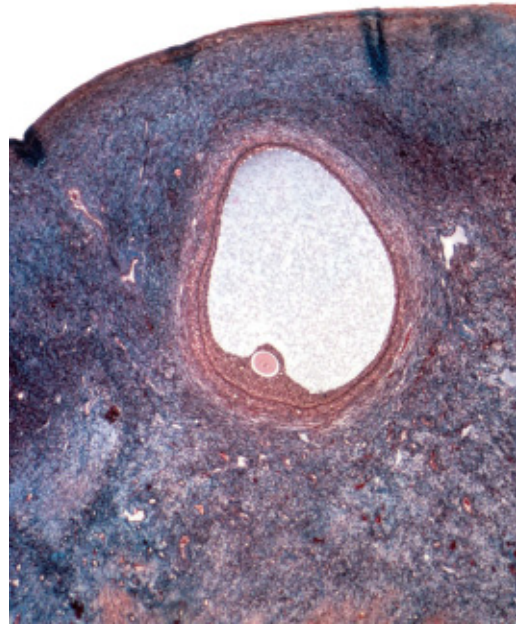


Figure 2.54 An ovarian follicle in the late stage of development of the ovum.

The role of meiosis in reproduction

The production of haploid gametes that fuse together to form new individuals means a continual blending of genetic material (DNA) across the generations. Children receive half of their chromosomes from their mother and the other half from their father. The chromosomes will be similar, in that they will have the information for the same features, such as eye colour, but

ACTIVITY 2.2.4: NATURE OR NURTURE?

Your DNA does not control how you cut your hair or what you eat, and the same goes for other organisms. The contribution of DNA to some features, such as personality and intelligence, may not be so clear-cut. Scientists often talk about 'nature versus nurture' – whether DNA is responsible for certain features or whether the features are the result of environmental factors. Your DNA controls your genetic features, whereas the environment (lifestyle, education etc.) controls everything else and can change regularly.

As a class, brainstorm the features that are genetically controlled compared with those that are influenced by the environment.



Figure 2.53 Identical twins have identical DNA, but the individuals are not exactly the same because of different environmental conditions and experiences.

the specific instructions can be different. For example, your father could have blue eyes while your mother has brown eyes. You could end up with blue, brown or maybe even hazel eyes.

Meiosis in the human female

Meiosis is a prolonged process in human females. The ova develop in structures called follicles. Many follicles fail to complete their development to release ova, but after puberty, once every 28 days, a single follicle will release its ovum into a fallopian tube. This cycle of releasing an ovum every 28 days is the basis of the menstrual cycle. It is controlled by hormones but also produces hormones that are involved in the complex process of preparing a female for pregnancy.

Meiosis in the human male

Meiosis occurs in the testes of the male from the onset of puberty at about 11 or 12 years. It then occurs continuously with gradual decline only in old age. Meiosis division and differentiation into a sperm takes about 72 days.

The sperm itself has three parts: the head contains the nucleus, the mid-piece contains mitochondria to provide energy, and the hind part is a tail or flagellum that allows it to move.

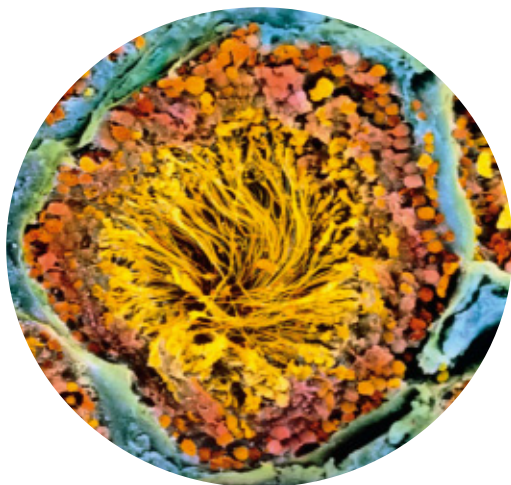


Figure 2.56 Artificially-coloured SEM image of sperm developing in the testes by meiosis. The orange filaments are the tails of developing sperm.

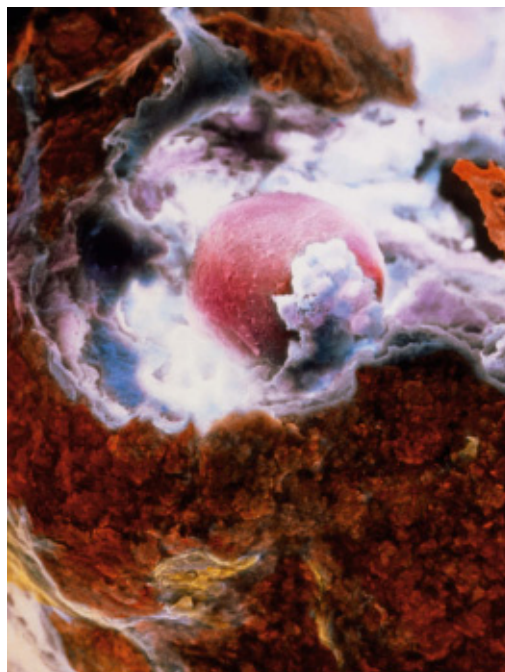


Figure 2.55 Artificially-coloured SEM image of an egg being released from the follicle during ovulation. The egg (pink at centre) has ruptured the external surface of the ovary (brown), and has started its journey through the fallopian tube towards the uterus.

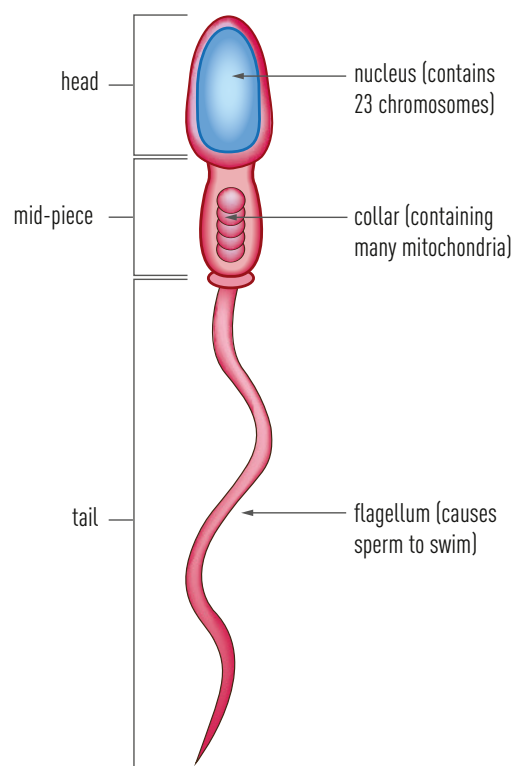


Figure 2.57 The basic structure of a human sperm cell.

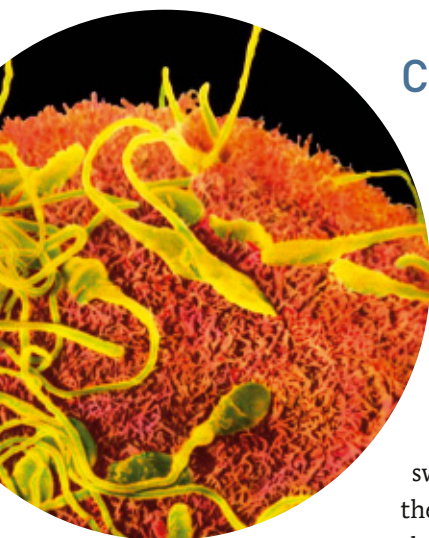


Figure 2.58 Many sperm (yellow) will reach the egg (orange), but only one will penetrate its surface and fertilise it.

Copulation

For fertilisation to occur, sperm and ovum must meet. Fertilisation in humans is internal.

Copulation is the process where the male inserts his penis into the vagina of the female. Ejaculation during copulation ensures that the sperm is deposited inside the female reproductive tract. The sperm then swim up through the uterus and into the fallopian tubes. If an ovum is present, then the sperm fertilise it to form a zygote. Even though it only takes one sperm to fertilise the ovum, millions of sperm will enter the fallopian tubes. Changes in levels of hormones occur if fertilisation and implantation of an embryo do not occur, and the female will menstruate.

Pregnancy and birth

If fertilisation does occur, the zygote (the first diploid cell that results from the fusion of sperm and ova) grows by the production of new cells from mitosis to become a blastocyst. The blastocyst implants in the lining of the wall of the uterus, then becomes an embryo with an attachment through the umbilical cord to a structure called the placenta. The embryo develops organs and limbs through cell differentiation and by 8 weeks has become

Eight Months

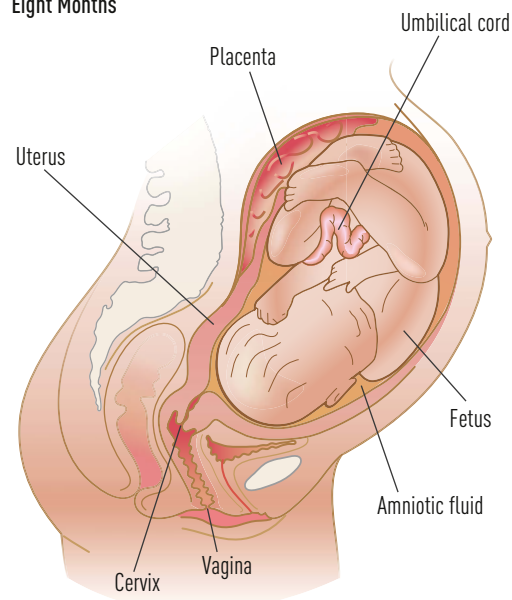


Figure 2.59 Foetus in the late stage of development.

a foetus. The placental connection to the mother enables the transfer of oxygen and other nutrients through a capillary network directly into the bloodstream of the foetus. The nutrients for the foetus are provided by the mother's body systems, and most of the wastes produced by the foetus are collected and removed by the mother's body systems.

After around 9 months of pregnancy, the foetus has developed enough to survive outside the mother's body. During birth, the uterus involuntarily contracts and, along with a lot of active pushing from the mother, the baby is pushed out of the uterus through the vagina.

QUESTIONS 2.2.7: REPRODUCTION IN HUMANS

Remember and understand

- 1 Identify the scientific term for 'making new organisms'.
- 2 Define the term 'gamete'.
- 3 Explain where meiosis occurs in human females.
- 4 Name and compare the two types of human gametes.
- 5 Identify the difference between a foetus and a baby.

Apply

- 6 Use your understanding of sexual dimorphism to describe three features that differ between a male and a female in humans.
- 7 Compare meiosis in human females with meiosis in males.

Analyse

- 8 Explain why ova are much larger than sperm and produced in fewer numbers.

HUMANS AS FUNCTIONING ORGANISMS

2.2

CHECKPOINT

Remember and understand

- 1 Identify the process that occurs in the walls of the small intestine. [1 mark]
- 2 Describe what urea is. [1 mark]
- 3 Recall the structure that attaches muscles to bones. [1 mark]
- 4 Recall where red blood cells are made. [1 mark]
- 5 Identify the type of cell division that results in the formation of sperm and ova. [1 mark]
- 6 Name the structure in which exchange of gases occurs in human lungs. [1 mark]
- 7 Recall the two main roles of the liver. [2 marks]
- 8 Identify the type of cell division that occurs in the embryo. [1 mark]
- 9 Recall the special property of muscle cells. [1 mark]
- 10 Outline a safety rule when conducting a dissection. [1 mark]

Apply

- 11 Compare physical digestion with chemical digestion. [2 marks]
- 12 Describe the relationship between the respiratory system and respiration in humans. [2 marks]
- 13 Suggest a reason why patients who suffer from emphysema need to breathe oxygen-enriched air. [1 mark]
- 14 Identify at least two differences between the production of sperm and the production of ova in humans. [2 marks]

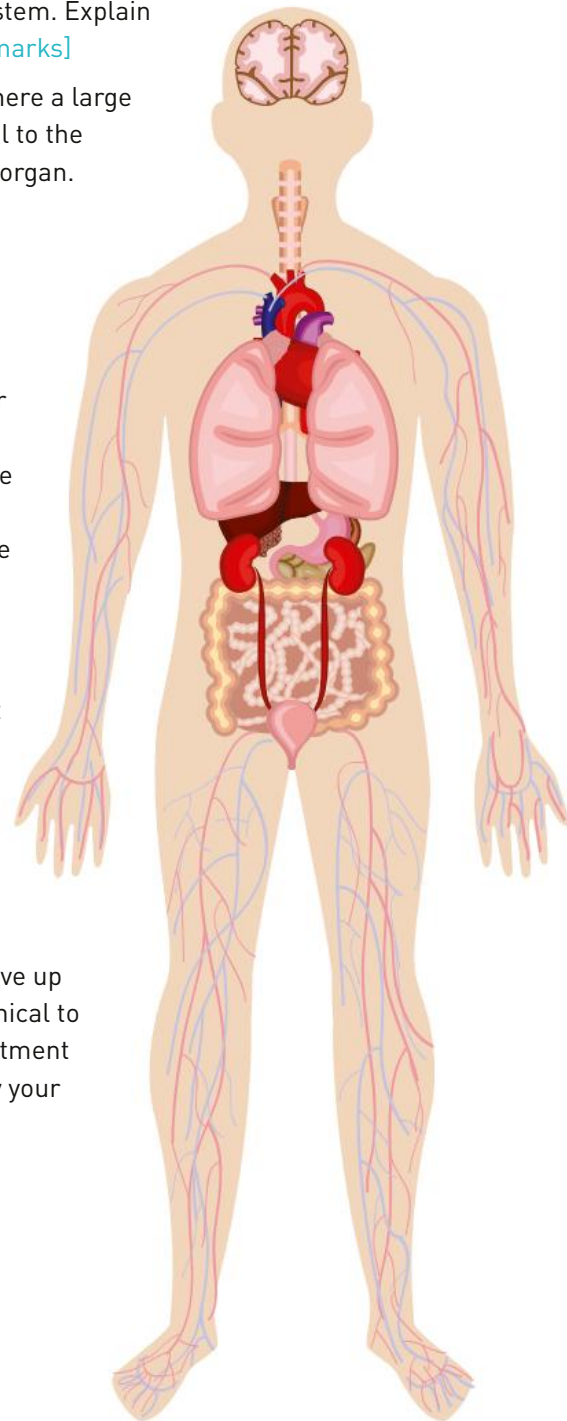
- 15 Compare the role of the ribs with the role of the thigh bone. [2 marks]
- 16 Some people argue that the lungs are part of the excretory system. Explain why this is justified. [2 marks]
- 17 Explain one example where a large surface area is essential to the functioning of a human organ. [1 mark]

Analyse and evaluate

- 16 The human circulatory system is called a closed system. Use your understanding of the relationship between the arteries, capillaries and veins to propose why the system is called closed. [2 marks]
- 17 From the body systems you have studied, select the organ you consider to be the most important and justify your choice. [2 marks]

Ethical behaviour

- 18 If a person refused to give up smoking, would it be ethical to deny them medical treatment for emphysema? Justify your answer. [3 marks]



TOTAL MARKS
[/30]

2.3 SCIENCE FOR BETTER HEALTH

The increased quality and length of our lives today is a direct result of new scientific understanding and the development of technologies for the diagnosis and treatment of disease. Science and technology has also influenced wider aspects of agriculture and biotechnology that allow our growing population to be sustained. However, not all advances are without controversy. There are ethical implications for use of some new medical treatments and biotechnology.

SOLVING REAL-WORLD PROBLEMS

Scientific research in many different fields has led to discoveries that have solved important real-world problems relating to human health. The discovery of bacteria and other pathogens that cause infectious disease has led to ways of preventing these diseases, and ways to treat our food and waste to keep us healthy.

Table 2.2 summarises how some real-world problems have been solved or at least improved with the use of scientific discoveries.

Table 2.2 Some examples of how science has contributed to solving human health problems.

Problem	Contributions of science
Rabies - a fatal disease that humans can contract from bites by infected dogs, wolves, cats, ferrets and foxes - has been recorded for 4000 years in human history - currently 55 000 people a year die of rabies (mostly in Asia and Africa), and it is the 10th highest cause of death by infectious disease - symptoms of the disease do not appear until 2–3 months after a bite by an infected mammal – once symptoms appear it is too late for treatment 	- Louis Pasteur and assistant Emile Roux started to research a cure for rabies in 1881. - In 1885, a boy was brought to Pasteur after being bitten by a rabid dog. Pasteur and Roux injected him with substances they had developed that helped the boy fight the infectious agents. This was called a vaccine and it saved his life. - Later research showed that <i>Lyssavirus</i>, which is carried in the saliva of an infected mammal, is the cause of rabies. The virus travels to the brain of the animal where it causes changes in behaviour including increased aggression, fear of water and foaming at the mouth. - It is difficult to vaccinate wild populations of dogs, foxes and wolves. Recent research has led to the development of an oral vaccination, which is used to vaccinate wildlife. - Quarantine has restricted the entry of rabies into Australia.
Potato blight - a fungus that infects potatoes - during the Great Irish Famine of the mid-1800s, the lack of genetic diversity of potatoes meant that all potato crops were infected by potato blight and wiped out, resulting in about 1 million people dying of starvation 	- Scientists determined the environmental conditions that promote the growth of the fungus, and then developed chemicals to kill or slow the growth of fungi. - Researchers investigated wild varieties of potato that were resistant to the disease and used these varieties in breeding experiments. - Finally, scientists discovered the DNA that is responsible for resistance to the disease, which has been used to develop resistant plants.

Problem		Contributions of science
Hygiene - good practices such as ensuring water supplies are not contaminated, washing hands and covering mouth when coughing can prevent disease, but this was not always known - historically, although people knew about the existence of microorganisms, they did not know there was a link between microorganisms and disease		- In 1876, Robert Koch used scientific procedures to prove that some microbes cause disease. Koch demonstrated that different types of bacteria were the causes of diseases such as anthrax, cholera and tuberculosis. - Koch's discoveries and the methods he used helped to establish the germ theory (that infectious diseases are caused by microorganisms).
Food preservation - supermarkets, people in remote communities and some other consumers like the convenience of being able to store 'fresh' milk and juices for longer periods of time - foods exposed to microorganisms can become contaminated and cause serious illness if eaten		- In 1862, Pasteur heated a broth and prevented the entry of air-borne organisms. From this experiment, he realised it was the presence of small organisms that resulted in decay and contamination of organic matter. Pasteur then developed the preservation of beer and wine by pasteurisation. - Current modern pasteurisation involves food being heated to 72°C for at least 15 seconds. In the case of milk, this gives it a refrigeration life of between two and three weeks. - Ultra-heat treatment (UHT) technologies heat to higher temperatures and slightly change the taste, but allow long-life non-refrigeration of milk and juices.
Sewage treatment - sewage waste must be treated to stop the spread of disease, remove nutrients and add oxygen so the water is clean and will not harm waterways - water discharged into waterways after sewage treatment may have high levels of phosphorus, which can contribute to eutrophication or high levels of heavy metal toxins		- About 60 years ago, it was discovered that incorporating some algae into sewage treatment stages provided a number of benefits. - The algae released oxygen during photosynthesis, helping to add oxygen to the sewage waste. - The algae removed nutrients such as phosphates and nitrates, which could then be extracted and used as fertiliser. - The algae were also capable of removing certain toxic metals. - The algae used for sewage treatment include <i>Chlorella</i>, <i>Euglena</i>, <i>Chlamydomonas</i> and <i>Scenedesmus</i>.

QUESTIONS 2.3.1: SOLVING REAL-WORLD PROBLEMS

Remember

- Recall the plant disease that resulted in the death of one million Irish people in the mid-1800s and outline why this happened.
- Describe two practices based on good hygiene.
- Explain why the discovery of the link between microorganisms and specific infectious diseases was important for human health.
- Explain why sewage treatment is important.
- Explain how food preservation contributes to good health.

Create

- Create a poster highlighting the benefits of scientific research to a real-world problem.

TECHNOLOGY FOR BETTER HEALTH

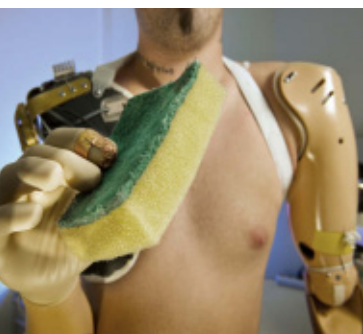


Figure 2.60 A thought-controlled robotic arm uses sensors to transmit information to this man's brain via electrodes implanted on his left shoulder. Other electrodes implanted on his chest allow the arm to be moved.



Figure 2.61 Ultrasounds allow the developing foetus to be seen without invasive procedures.

Technology refers to the creation of instruments, machines and devices that can improve our lives and aid science investigations. **Biotechnology** is the application of science to living organisms. Traditional biotechnology is involved in making cheese and bread by using microorganisms as discussed in chapter 1. Modern biotechnology is used to develop living things that meet our requirements based on our understanding of genetics and inheritance.

The development of artificial limbs is just one way that technology has helped humans that are suffering from disease or injury.

Artificial limbs and joints

Artificial limbs, or prosthetics, are devices used to replace a missing body part (usually an amputated arm or leg) in patients that have suffered a major injury, have an illness such as cancer or were born with particular defects. Artificial joints are used to treat patients with severe cases of arthritis or joint damage.

Improvements in prosthetics are a result of developments in material sciences and electronics. Materials must be strong, lightweight and free of pathogens. Artificial limbs are made out of titanium and carbon fibre. Artificial limbs are now individually shaped and dyed to match existing limb shapes and appearances.

Electronic advances even allow robotic artificial limbs to respond to nerve messages from the patient. The nerves that would have controlled the limb before it was amputated are surgically re-directed. Electrodes are then placed at the re-directed site and transferred to electrodes in the artificial limb.

Influencing reproduction

There are many situations in which we wish to encourage reproduction. When a human couple wants to have a baby and encounter troubles, technology can assist. If a species of plant or animal is threatened with extinction, technology can also help. When certain features or characteristics are favoured in a plant or an animal, humans may use techniques such as selective breeding (see chapter 1) and biotechnology to influence the outcome.

Technology and human reproduction

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

Unborn babies can also be screened for health problems. The amniotic fluid that protects the growing foetus can be tested, as can the cells of the placenta. The problem with these tests is that they involve inserting a needle into the uterus, which can result in an infection or may interfere with the pregnancy. Thankfully, many issues can be spotted in an ultrasound – a moving picture of what is going on inside, complete with the baby's heartbeat.

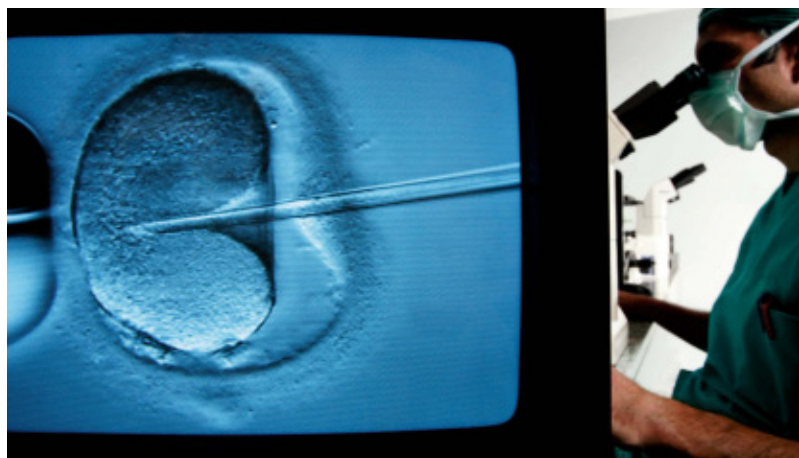


Figure 2.62 During IVF, eggs are injected with sperm for fertilisation.

Biotechnology

Recently, technologies have been developed so that characteristics can be transferred from one species to another by gene technology. The desirable characteristics of plants and animals that can be transferred include resistance to disease, higher concentrations of nutrients (such as vitamin A in rice), and resistance to insects. The use of biotechnology has led to cows that produce milk with built-in medicines,

and bacteria that can produce human insulin for diabetics.

There are concerns about some of these experiments and the impacts of genetically modified organisms (GMO) on the environment, including how they are owned and controlled. As well as ethical concerns, there are worries about producing resistant species or the genes escaping into other organisms. Research into these potential impacts is ongoing.

QUESTIONS 2.3.2: TECHNOLOGY FOR BETTER HEALTH

Remember

- 1 Define the term 'technology'.
- 2 Describe an example of technology applied to reproduction.
- 3 Identify the technologies that support farming.

Apply

- 4 Compare selective breeding with gene technology.

Analyse

- 5 Explain the relationship between science and technology in keeping humans healthy.
- 6 Is material science a science or a technology? Explain your answer.

Figure 2.63 Biotechnology has produced BT cotton, which has an inserted gene that destroys certain insects that eat it or suck its sap.



DIFFERENT APPROACHES TO TREATING DISEASE

Science and technology have greatly increased our options of avoiding certain diseases or treatment if we become diseased or injured. This section will look at case studies involving kidney disease, heart disease and diabetes, and consider the different options available for their treatment.

Kidney disease

We cannot survive without kidney function. When the nephrons in the kidneys become damaged, the kidneys can no longer function efficiently and remove toxins such as urea from the blood. While we can survive with kidneys functioning at only 20% capacity, kidney failure requires ongoing dialysis treatment or a kidney transplant. Technological advances have increased the range of options for people with kidney failure. There is now a range of dialysis treatments, some of which can be carried out in the home and with minimal equipment. These treatments rely on osmosis and the diffusion of toxins into a solution that can be removed.

Option A: Prevention. Healthy diet and lifestyle, drinking water and avoiding salty foods, not smoking and minimal alcohol consumption, management of blood glucose (if diabetic) and management of blood pressure all help to prevent kidney disease for those at risk.

Option B: Dialysis. When option A is no longer a possibility and the kidneys begin to fail, dialysis is necessary. Haemodialysis involves the use of a machine in a clinic or hospital for 3–5 hours three times a week to filter the blood and remove toxins, and then return the filtered blood back to the body. Another form of dialysis can occur more conveniently in the home and requires less equipment, but it must be carried out for longer periods.

Option C: Compatible organ transplant. A kidney may be transplanted from a compatible donor based on blood type. The donor may be alive or deceased. This treatment is medically preferable, as patients tend to live on average 15 years longer than those on dialysis, although the need for drugs to suppress the immune system may be a complicating factor for some people. Not all patients are able to receive a donated kidney for medical reasons. Also, it may take a long time for a compatible donor kidney to become available. Australia has a very low rate of organ donation. Kidney donors can live successfully with only one healthy kidney.

Option D: Non-compatible organ transplant. A kidney may be transplanted from a non-compatible donor. Additional medical treatment is required to help prevent the immune system from rejecting the transplanted organ.

Many factors impact on the decision about the type of treatment for kidney disease. Some of these include the effectiveness of the different treatments, cost and availability. Some religious groups also do not believe in receiving blood transfusions or organ transplants.



Figure 2.64 Kidney dialysis is a procedure that cleans waste products out of the blood using a dialysis machine (shown on the right).

Heart disease

A heart attack is usually caused by heart disease, which is basically fatty deposits called cholesterol blocking important blood vessels in the heart (see Figure 2.66). The 'attack' occurs when the vessels become completely blocked or when a bit of the fatty deposit breaks off and travels into the heart. Heart muscle cells may be killed in the process.

In 1967, history was made in South Africa when Dr Christian Barnard transplanted a human heart from a woman who had died in a car accident into a patient. The patient survived for 18 days. Since then, much has been learnt about tissue rejection. New drugs have been developed so that heart transplantation is a viable option for some people at risk of dying from heart disease. Shortages of heart donations have resulted in efforts to develop artificial hearts. Xenotransplantation, the transplantation of an organ from a different animal, such as a pig, has even been trialled. Issues with rejection of transplanted hearts are still reducing the long-term benefits. There is more research to be done and many ethical issues to be debated.

Other new technologies include artificial heart valves, pacemakers, replacement of blocked arteries with bypass surgery, widening blocked arteries or the placement of devices called stents inside arteries. Many of these surgical techniques depend

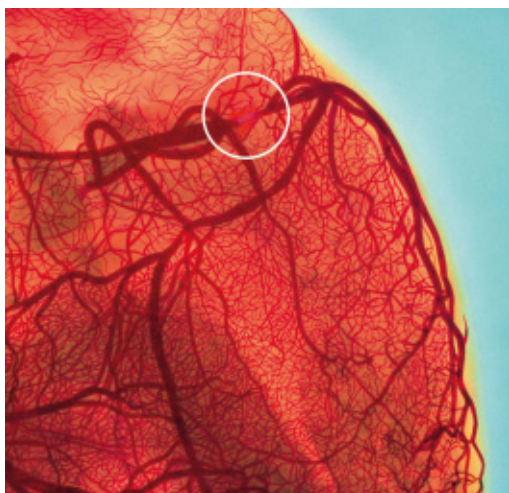


Figure 2.66 The artery supplying the heart with blood (in dark red) is blocked by fatty plaque. Depending on the severity of the blockage (circled in white), this may result in death of the heart muscle and a heart attack.

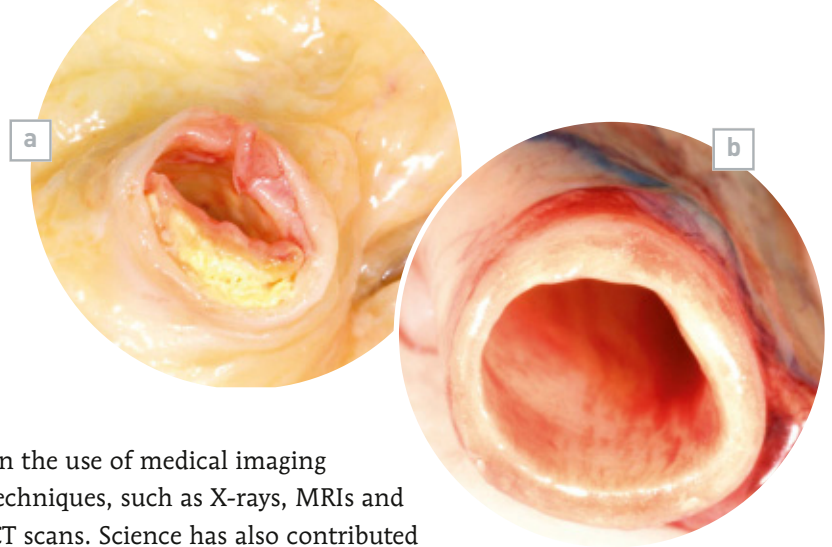


Figure 2.65 (a) An artery blocked with fatty material. (b) An unblocked artery.

on the use of medical imaging techniques, such as X-rays, MRIs and CT scans. Science has also contributed to the treatment of heart disease with the discovery of risk factors linked to the incidence of heart disease.

Option A: Prevention. The likelihood of heart disease can be significantly reduced by addressing the risk factors such as obesity, high blood pressure and high levels of cholesterol in the blood, and by living a healthy lifestyle with regular exercise, keeping a balanced diet and not smoking. Diets high in foods such as salmon, sardines, cod, walnuts and flax seeds also reportedly reduce the risk of heart disease.

Option B: Use of preventative medications. Some people take aspirin as a blood thinner, and there are prescription drugs available such as cholesterol-lowering drugs, but the effectiveness of these is still being investigated.

Option C: Surgical repair. Heart valves may be repaired or sometimes replaced. Replacement heart parts can be obtained from other organs of the patient, a deceased human donor, pigs or cows, or be mechanical. A device called a pacemaker may need to be inserted to restore the heartbeat rhythm. Diseased heart arteries can be replaced during bypass surgery, or stents can be inserted to repair the blocked artery (see Figure 2.67 on page 104).

Option D: Compatible organ transplant. A heart may be transplanted from a compatible donor based on blood type.

Option E: Rehabilitation. There are a number of rehabilitation therapies to help survivors of heart attacks and strokes recover and regain movement and other abilities.

Many factors affect whether people and groups in society adopt preventative measures against heart disease. If heart disease does occur, the decisions involve the treatment options available and what is considered acceptable. Death rates from heart disease have been declining, but some risk factors have been increasing.

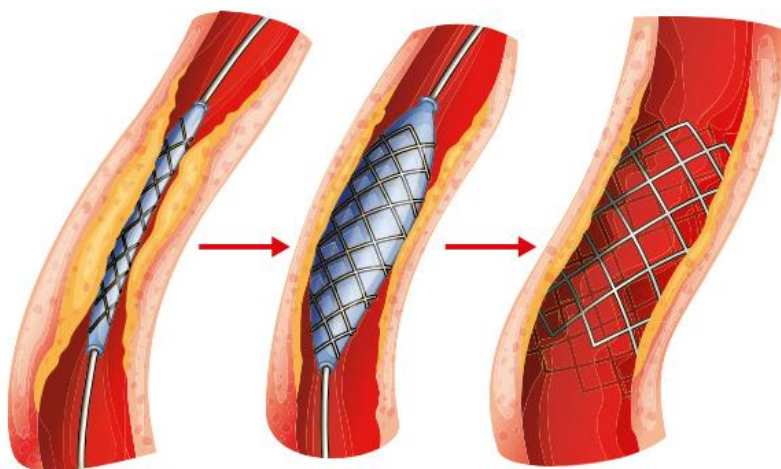


Figure 2.67 A stent is a mesh tube that is inserted into a blocked artery to restore blood flow.

Diabetes

Diabetes is a disease where the body cannot control the level of glucose in the blood. A person with diabetes will have high blood glucose levels either because their pancreas is unable to produce insulin (which controls the blood glucose level), or because their body cannot respond properly to the insulin that is released.

There are a variety of types of diabetes and factors associated with the onset of the disease. Type 2 diabetes has been linked to obesity and a variety of lifestyle factors, and its incidence is increasing. Diabetes can also develop during pregnancy.

Currently, 1.8 million Australians suffer from some form of diabetes. Type 2 diabetes does not always show symptoms and may go undetected until serious complications arise.

Diabetes was once a fatal condition, and even now it shortens life expectancy and can cause a wide range of complications. These include heart disease, kidney

disease, poor circulation and ulcers on the hands and feet, and eye problems causing blindness. Modern treatments can be a change of diet and lifestyle in mild cases, and the monitoring of blood glucose levels and injection of insulin in more severe cases. Insulin is now available as a result of genetic engineering so that bacteria actually manufacture human insulin. Previously, animal insulin was used and dose levels were much harder to manage.

Option A: Prevention. Prevention is especially important for type 2 diabetes. If there is a family history of type 2 diabetes, an active lifestyle and well-managed diet may help prevent the disease. Blood tests may detect diabetes that has not been diagnosed or is not showing any symptoms. Some high-risk people have surgical procedures to assist weight loss.

Option B: Insulin. Insulin injections, in addition to controlling diet and lifestyle, will maintain a relatively stable concentration of sugar in the blood.

Options are limited in the treatment of diabetes. Even with the use of insulin, modification to diet and lifestyle are the key to long-term survival.



Figure 2.68 People with diabetes must inject themselves with insulin to ensure the correct level of glucose is in their blood.

Ethical animal research

Medical research, both historical and current, often uses animals at some stage. Dissection of deceased animals (and humans) has increased our knowledge and understanding of the structure and function of body systems. Many experimental procedures and medications are tested on animals before being trialled on humans. The reason animals are used in medical research is to gather information that cannot be found by any other means, and to test whether new treatments are safe for trialling in humans.

The National Health and Medical Research Council (NHMRC) is an Australian Government body responsible for maintaining ethical practice during research on and with animals. The NHMRC published the eighth edition of the *Australian code for the care and use of animals for scientific purposes* in 2013.

The Code provides rules and regulations that must be followed by people who want to use animals in their medical research. The Code has 32 governing principles, which include:

- respect for the animal
- justification for the use of animals in that research
- maintenance of the wellbeing of the animal by providing care that is appropriate for that species
- avoidance or minimisation of harm, pain and distress to the animal
- an experimental design that follows good scientific principles
- methods that reduce the numbers of animals to be used
- the researcher being responsible for ensuring that all principles are followed.

While the Code is in place to ensure the best possible quality of life for the animals used in research, some people believe that animals should not be used in research at all. They argue that if it is not ethical to perform the tests on humans, then the tests should not be performed on animals either.

We would not have the current level of scientific or medical knowledge without the use of animals in medical research, but their use always raises ethical issues and a range of opinions.

Questions

- 1 Identify why animals are used in medical research.
- 2 Recall the name of the code of ethics that refers to the use of animals in research.
- 3 In your own words, describe what the ethical treatment of animals in research would be.
- 4 Explain why some people object to the use of animals in research.
- 5 Locate a copy of the Code on the Internet and read the governing principles. Evaluate whether the Code does enough to protect the rights of animals.
- 6 Research some diseases that can be controlled or cured with today's medicines due to research or testing on animals. In a table, list the disease, the control, cure or medicine, as well as the animal that was used in developing it.
- 7 Do you believe that the use of animals in medical research is ethical? Justify your decision.



Figure 2.69 Without the use of pigs in medical research, the amounts of insulin required for people with diabetes would never have been produced.

ACTIVITY 2.3.1: INVESTIGATING THE BENEFITS OF SCIENTIFIC RESEARCH

Review how improvements in science understanding and new technologies have contributed to solving real-world problems and to finding solutions to health issues. Use the information provided in this chapter and your own Internet research. Working in a group, construct a table of arguments for why society should support biological research. Prepare to contribute your arguments in a class discussion.

QUESTIONS 2.3.3: DIFFERENT APPROACHES TO TREATING DISEASE

Remember

- 1 Identify two diseases that might be avoided by an active lifestyle, non-smoking and a well-balanced diet.
- 2 Recall the substance that a person with diabetes is testing for in a blood test (see Figure 2.70).
- 3 Identify the key substance removed from the blood by the kidneys.
- 4 List some risk factors related to the development of diabetes.
- 5 Explain an example of the use of biotechnology.

Apply

- 6 Suggest why people in remote communities might have greater health risks than those in large urban centres.
- 7 Propose how education can influence the management of common diseases in society.
- 8 Some people have a disease such as type 2 diabetes without showing any symptoms. Describe a problem that may result from having a disease without showing symptoms.



Figure 2.70 People with diabetes use a glucometer to test their blood.

Analyse

- 9 Heart transplant surgery was first trialled on baboons. Describe some of the ethical issues involved in such experiments.

Create

- 10 Investigate the activities of a biological research organisation such as the Children's Medical Research Institute or CSIRO. Prepare a pamphlet explaining to the public why the research is important and should continue to be funded.

SCIENCE FOR BETTER HEALTH

2.3

CHECKPOINT

Remember and understand

- 1 Identify two major advances in scientific understanding that have assisted in the detection of infectious disease. [2 marks]
- 2 Outline a technology that has helped couples who are otherwise unable to have children to conceive a baby. [2 marks]
- 3 Explain how material science has supported the development of artificial limbs and replacement joints (see Figure 2.71). [2 marks]
- 4 Suggest a reason why effective sewage treatment is important for human health. [1 mark]
- 5 Recall a disease that can be transferred from dogs to humans. [1 mark]
- 6 Identify an application of biotechnology that has been used to improve human health and briefly describe its benefits. [2 marks]
- 7 Distinguish disease prevention from disease treatment. [1 mark]
- 8 Recall three benefits of food preservation. [3 marks]
- 9 Describe how biotechnology is used to produce human insulin for injection into people with diabetes. [1 mark]
- 10 Explain why kidney disease may go undetected for some time. [1 mark]

Apply

- 11 Use an example to explain why plant diseases can affect human health. [2 marks]
- 12 Describe the ethical issues that may arise with some heart valve transplants. [2 marks]
- 13 Explain how living in a remote community would restrict options for treatment of kidney failure. [2 mark]

Analyse and evaluate

- 14 Describe the advantages and disadvantages of vaccination in the prevention of disease. [2 marks]
- 15 The development of improved electronics has led to artificial limbs that can be robotically controlled by the wearer. Explain two advantages of having artificial limbs that can be manipulated this way. [2 marks]

Ethical behaviour

- 16 Research and summarise some of the ethical issues associated with companies being able to patent (copyright) particular medicines or genes. [3 marks]
- 17 Outline one of the arguments for and one against the use of animals for trialling surgery such as organ transplants. [3 marks]
- 18 Illegal trade in kidneys has become a problem in some third-world countries. Propose some ethical issues in paying for an organ donation. [3 marks]



Figure 2.71 Advances in artificial limbs have enabled their wearers to enjoy a wide range of sports and activities.

TOTAL MARKS
[/35]

2

CHAPTER REVIEW

1 Fill in the gaps using the words in the Word Bank below:

Multicellular _____ comprise many different types of specialised cells. Each of these cells, whether in the tallest tree or the largest whale, needs to have a supply of energy, _____, oxygen and water and its _____ removed. Cells and tissues are arranged into organs and _____ to meet these needs. All cells carry out _____, which requires glucose and _____ and releases energy in a form the cell can use, carbon dioxide and water. Some plant cells carry out _____. These cells use sunlight energy that is absorbed by a pigment called _____, and then combines water and _____ to produce glucose and oxygen.

Multicellular organisms also need to be able to produce new individuals in a process called _____. Sexual reproduction results in _____ in the offspring partly because of the cell division called _____. Some organisms, especially plants, also use mitotic cell divisions and _____ reproduction to produce natural clones of themselves. Mitosis is also important for growth and _____ in multicellular organisms.

Humans use science and _____ to diagnose, prevent and treat a range of health problems and injuries. Different groups in society may have different attitudes to the use of some technologies such as organ transplantation.

WORD BANK

asexual	meiosis	oxygen	respiration
carbon dioxide	nutrients	photosynthesis	technology
chlorophyll	organisms	repair	wastes
diversity	organ systems	reproduction	

Identify the requirements for photosynthesis and respiration

- Describe the role of the chloroplast in photosynthesis. [1 mark]
- Recall the word equation that summarises photosynthesis. [1 mark]
- Recall the word equation that summarises respiration. [1 mark]

Explain that plant systems work together to provide all cell requirements

- Outline the role of the root system in flowering plants. [2 marks]
- Describe how transport of water, minerals, nutrients and sugars occurs in plants. [2 marks]
- Explain the importance of stomata in plant leaves. [2 marks]

Explain that human body systems work together to provide all cell requirements

- Identify a gaseous waste and explain how it is produced and removed from the human body. [2 marks]
- Identify a soluble nitrogenous waste and explain how it is produced and removed from the human body. [2 marks]

Outline the role of cell division in growth, repair and reproduction in plants

- Identify the type of cell division essential for growth, repair and asexual reproduction in flowering plants. [1 mark]



- 11** Recall where meiosis occurs in flowers and explain why it is important.

[2 marks]

Outline the role of cell division in growth, repair and reproduction in humans

- 12** Recall what stem cells are and explain why they are important for growth and repair in humans. [2 marks]
- 13** Outline the role of meiosis in sexual reproduction in humans. [2 marks]

Describe the role of the flower, root, stem and leaf in flowering plants

- 14** Outline how the stem and leaf structures contribute to the ability of the plant to compete and carry out photosynthesis. [4 marks]
- 15** Identify the flower structures that contribute to successful pollination. [2 marks]

- 16** Describe how root hair cells support the process of osmosis. [2 marks]

Describe the role of the digestive, circulatory, excretory, skeletal/muscular and respiratory systems in humans

- 17** Explain why the stomach and intestines are important in humans. [2 marks]
- 18** Describe how transport of materials occurs in the human body. [3 marks]
- 19** Outline how the muscular and skeletal systems help humans to function. [4 marks]
- 20** Describe the ways that human bodies get rid of wastes. [4 marks]

Outline the role of the reproductive system in humans

- 21** Outline the role of the ovary and testes in humans. [2 marks]

Figure 2.72 Why is your skeletal/muscular system important?



- 22 Explain how the structure of the uterus relates to its function. [2 marks]

Recount how scientific evidence has contributed to solving real-world problems

- 23 Explain how understanding kidney function has led to new options for the treatment of kidney failure. [2 marks]
- 24 Explain how food preservation can help prevent illnesses. [2 marks]

Research how scientific developments have contributed to finding solutions to health problems

- 25 Identify two diseases that you are less likely to develop if you lead an active lifestyle and eat a balanced diet. [2 marks]
- 26 Outline how discoveries about microorganisms have affected human health. [2 marks]

Describe how technological developments have helped solve medical issues

- 27 Identify two options for treatment of a patient with kidney failure and explain how technology has supported these options. [4 marks]

- 28 Outline the types of technology that have supported the development of artificial limbs. [2 marks]

Give examples to show that people may weight criteria differently in making decisions about the use of biotechnology

- 29 Identify two different opinions groups of people might hold about the use of animals in medical research. [2 marks]
- 30 Outline some of the benefits and risks of using genetically modified organisms. [2 marks]

Debate why society should support biological research (additional content)

- 31 Explain three benefits of biological research. [3 marks]
- 32 Explain two benefits that have resulted from biological research. [4 marks]

TOTAL MARKS
[/70]

RESEARCH

Choose one of the following topics for a research project. A few guiding questions have been provided to get you started. Use a format that presents your findings in an informative and attractive way.

Whooping cough

Whooping cough is an infectious disease of the respiratory system that has increasing incidence in Australia in recent years. What are the causes and symptoms? What are ways of treating or preventing this disease? Why is this disease such a risk for babies?

Medical ethics

Research the term 'medical ethics'. What does the term 'ethics' mean? What practices have been found to be unethical and why? Find an example of a controversial medical treatment and outline the ethical issues involved.

Liver damage

You may have heard that drinking too much alcohol can damage a person's liver. Why is this? How much alcohol is too much alcohol? What happens when the liver cannot do its job anymore?

Me

- 1 What were the three most surprising things you learned about the function of multicellular organisms?
- 2 What new laboratory skills did you learn?
- 3 What aspects of human health would you like to investigate further?
- 4 What questions do you still have about how multicellular organisms work?

My world

- 5 How do you think health conditions around the world compare to those in Australia?
- 6 How do you think health conditions where you live compare to those of people living in isolated parts of Australia?

My future

- 7 What can you do now to keep your body healthy for many years to come?

KEY WORDS

alveoli
 anther
 artery
 blood
 biotechnology
 bone
 capillary
 carpel
 cartilage
 chlorophyll
 chromosome
 cross-pollination
 diabetes
 digestion
 digestive tract
 enzyme
 excretion
 fertilisation
 foetus
 gamete
 gas exchange
in vitro fertilisation (IVF)
 meiosis
 menstrual cycle
 metabolism

mitosis
 nephron
 ovary
 ovum
 osmosis
 phloem cell
 photosynthesis
 pollination
 respiration
 root hair cell
 self-pollination
 sexual reproduction
 skeletal muscle
 skeleton
 smooth muscle
 stem cell
 stomata
 technology
 testes
 transpiration
 vegetative reproduction
 vein
 xylem tissue
 zygote

2

MAKING CONNECTIONS

Spray-on skin

In October of 2002, three terrorist bombs exploded in Bali, killing 202 people, including 88 Australians. Another 240 people were injured, many of them with horrific burns to their bodies. Serious burns victims, some with burns covering up to 92% of their body, were flown to Perth for treatment by Dr Fiona Wood.

Following her work done for these victims, Dr Wood's unique solution for burns victims has attracted worldwide acclaim. Currently Director of the West Australian Burns Service, she developed a technique known as 'spray-on skin', which helped to substantially reduce the impact of the Bali bombings. Dr Wood's method allows for the rapid administration of skin cells that have been grown in the

laboratory (cultured), speeding up the healing process and significantly

reducing scarring. Where previous techniques of skin culturing required 21 days to produce enough cells to cover major burns, her innovative technique has cut this time to 5 days.

Research has shown that scar formation is significantly reduced if the wound heals quickly. A burn wound that takes 21 days or more to heal has a greater than 70% risk of developing a significant scar, compared to a burn wound that heals in less than 10 days, which has only a 4% risk of developing a scar. It is important to treat burns as soon as possible in order to reduce scarring and improve the patient's ability to move.

The development of skin cell transplant technology began in 1990, when Dr Wood was treating patients for serious burn injuries. Treating large burn injuries traditionally involves applying cultured skin in the form of sheets to the wound. The skin sheets are grown from skin cells taken



Figure 2.73 Dr Fiona Wood.

from the patient but usually take 14–21 days to produce. Dr Wood discovered that scarring could decrease if the wound could be treated within 10 days. She found that although skin sheets produced in 10 days often had holes in them, these areas healed faster than those treated with complete sheets, and with less obvious scarring. And thus, a new technique was born.

The next step was to apply cells in a suspension even as early as 5 days before they formed a sheet. In tests, spraying the cells directly onto the burnt area was found to give the best results. Cells are harvested from the epidermis of a patient, and grown in culture. The healthy, living cells are cultured in a highly specialised laboratory by natural cell division, and then transplanted into the patient. As the original cells are taken from the actual patient instead of a donor, the body accepts these cells as its own, the tissue continues growing, and the healing process is improved. The burn acts as an ideal culture medium, and sprayed-on cells grow more quickly on the patient than in the laboratory. The advantage is that wounds or burns heal rapidly and leave less scarring if a skin graft is applied soon after an injury.

Commercialisation of these techniques and technology is handled by the Australian commercial biotechnology company, Clinical Cell Culture or 'C3'. Royalties from licensing will be put back into a research fund, called the McComb Foundation.



Figure 2.74 Skin grafts heal but take time and leave scars.



Figure 2.75 Two-year old Zed, who suffered major scalds from a hot cup of tea, recieved spray-on skin treatment.

The commercial rights for the new technique are protected by trademark law (patents) and by the details of the exact process being kept confidential within the company.

Adapted from article on: *From Moulds to Colds* website; www.biotechnology-innovation.com.au

Questions

- 1 Discuss arguments about the commercialisation of biological research such as the patenting of genes and the development of 'spray-on skin'.
- 2 Use 'spray-on skin' to discuss how the role of science is connected with the role of technology in developing better health care.
- 3 Use *From Moulds to Colds* or another website to find out information about another Australian biotechnological innovation. Identify the medical problem and explain how the technological development has contributed to a solution.
- 4 The skin is the largest organ in the body. Damage to the skin by a burn

causes excruciating pain, and can also result in dehydration, infection and problems in the regulation of body temperature. Using the information provided and from your own research, describe how nerve tissue, epidermal tissue and connective tissue work together to make the skin an important organ.

- 5 Today, research workers such as Dr Wood need to make commercial, legal, ethical decisions about their research as well as present their findings to gain public approval. Write a job advertisement for an assistant to join the team at Clinical Cell Culture.



Figure 2.76 Artificial human skin can be grown in a laboratory. It may be used as skin grafts in burns victims who don't have enough of their own skin to produce a graft.

3



ENERGY

How do you feel when you say you have a lot of energy? How do you feel when you say you don't have any energy? Energy is hard to define. Even scientists struggle to define energy because it is such an important concept and relates to so many different areas of science. Energy appears in different forms and makes things happen. Without energy, nothing would move, nothing would change and the world would be a very dull place! Energy cannot be created, nor can it be destroyed. However, it can transform (change) from one form into another.

EVERYDAY ENERGY 3.1

We experience energy every day in many different forms. Heat, light, sound, motion and electricity are only a few of the forms you will have encountered today. All types of energy can be transformed into a different type, and some of that energy is almost always transformed into heat energy. Heat energy can also be transferred between objects or between substances.

Students:

- » identify objects that have either kinetic or potential energy
- » investigate everyday energy transformations involving heat, light, sound and motion
- » describe the process of conduction, convection and radiation using examples

ELECTRICAL ENERGY 3.2

Electrical energy is one of the most versatile forms of energy. It can be transformed into almost every other type of energy, it is easily transported and it can be stored for long periods of time. Electricity has driven huge technological developments since we learned to produce and use it.

Students:

- » relate electricity to the transfer of energy
- » construct circuits and draw circuit diagrams with various components
- » investigate everyday energy transformations involving electrical energy
- » trace the history of the development of an electrical device (additional content)

INCREASING ENERGY EFFICIENCY 3.3

Energy efficiency measures how well a device transforms energy. All energy transformations produce waste energy in forms we do not need. The more efficient the device, the less waste energy is produced. Scientific research is continuing to improve the efficiency of devices to reduce wasted energy. This is increasingly important as non-renewable sources of energy begin to run out.

Students:

- » identify that most energy transformations are inefficient and produce heat energy
- » research how scientific knowledge and technological developments have improved energy efficiency
- » discuss the implications for society and the environment of increasing energy efficiency

3.1

EVERYDAY ENERGY

Energy is all around us. We use electrical energy to wash our clothes, to keep our food cool and to watch television. We use thermal energy (heat) to cook our food and to heat our homes and water. Light energy helps us see when it is dark, and sound energy brings our favourite music to our ears. These are just a few examples of different types of energy. We experience the effects of energy every time something happens – for something to happen, energy is required. However, what happens depends on the type and amount of energy involved.

COMMON TYPES OF ENERGY

Think about where you see **energy** – you are probably thinking of something related to electricity, but there are other forms of

energy you may not be aware of. Any time an object moves or something changes, energy is involved to make that change happen.

ACTIVITY 3.1.1: DIFFERENT FORMS OF ENERGY

With a partner or in a small group, brainstorm as many different types of energy as you can think of. Spend some time carefully examining Figure 3.1, which shows some different types of energy and how we use them in our everyday lives.

- 1 Make a list of all the energy types you can think of.
- 2 For each energy type, think of an example of where or when it could be used. For the energy types in Figure 3.1, try to come up with a different example from what is already shown.



Figure 3.1 Some examples of energy use in the modern world.

- 3 X, Y and Z in Figure 3.1 do not have labels. Identify what type of energy is being used.
- 4 Create your own energy illustration showing either the energy you use every day or the energy used by another imaginary person.

Light energy

Light energy is essential to our lives and comes from sources such as the Sun, light globes, fires and some animals. The humble electric light globe revolutionised the world. Oil and gas lamps were popular in the past and a torch helps us see at night when we go camping. But the best source of light is, of course, the Sun.



Figure 3.3 The heat of a 'burn-out' creates great clouds of smoke.



Figure 3.2 Kerosene lamps were used for many years before the invention of electricity.

Heat energy

Heat is one of the best known of our energy types. We crave it in winter and it can overwhelm us in summer. Heat energy is more scientifically known as **thermal energy**. Thermal energy can be generated by friction, such as rubbing your hands together or the rubbing of the tyres on the road. It is also commonly generated by chemical reactions or by electrical devices.

Electrical energy

Electrical energy comes from generators, power stations, solar cells, batteries and lightning. It can be used to power any sort of electrical device, such as computers, light globes, mobile phones, microwave ovens and stereo systems. You will learn more about electrical energy in section 3.2.



Figure 3.4 Batteries store electrical energy and release it when needed.





a



b

Figure 3.5 Some items release elastic potential energy to provide motion such as (a) jumping stilts and (b) wind-up toys.

Potential energy

At some stage of your life you have probably been told that you have ‘shown potential’, perhaps while playing a sport or a musical instrument. This means you have demonstrated you still have room for improvement – that you have got more in you to improve your performance. **Potential energy** is a similar concept. Potential energy is the energy stored in objects that is waiting to be used. This stored energy can be the result of a change of shape (stretching or squashing), an object’s height above the ground, or chemical reactions that change the chemical bonds within a substance.

Elastic potential energy

A trampoline has the ability to ‘store’ or hold energy for later use. The springs and

the mat of the trampoline stretch under our weight and hold this as stored energy. The more the springs stretch, the more energy they hold. The energy is returned to our bodies when the springs and mat return to normal and we are thrown into the air. Energy stored through the stretching or squashing of the physical shape of an object is called **elastic potential energy (EPE)**.

A bow and arrow is another example of energy being stored in this way. When the bowstring is stretched, it holds elastic potential energy. When the string is released, the energy pushes the arrow forward. Wind-up toys also work in a similar way. You wind up the spring inside the toy and when you let go, it releases its stored energy. Springs can be both compressed (squashed) and stretched, which means they can work in two opposite directions.

ACTIVITY 3.1.2: RUBBER BAND BOATS

What you need: waxed cardboard (milk cartons work well), water bath or swimming pool, scissors, butterfly pins (also known as split pins), rubber band

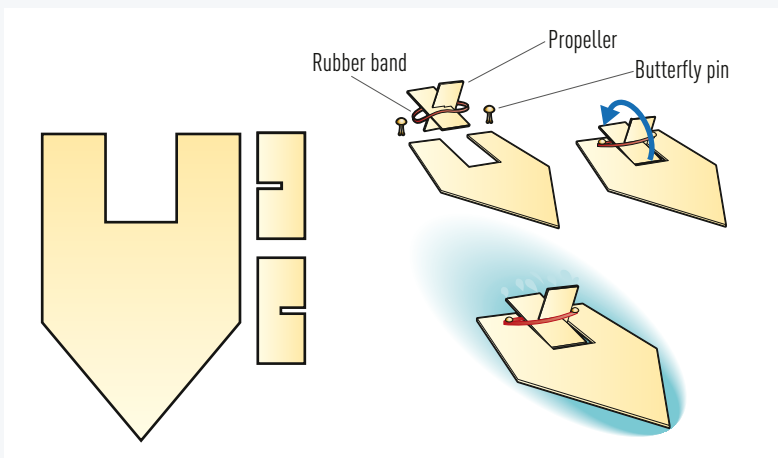


Figure 3.6 The parts and method of assembly for a rubber band boat.

- 1 Cut out the waxed cardboard to match the diagram in Figure 3.6.
- 2 Connect the propeller blades using the slots.
- 3 Loop the rubber band over the propeller.
- 4 Attach the propeller to the boat using butterfly pins.
- 5 Wind the propeller towards the back of the boat a number of times, place the boat gently on the surface of the water and release the propeller.
 - What happened to the boat when the propeller was released?
 - What types of energy are involved in this activity? Explain your answer.
 - How could you make the boat travel further? How are you changing the energy when you do this?

Gravitational potential energy

If we lift an object up, it gains **gravitational potential energy (GPE)**. Any object in the air has the potential to fall due to the force of gravity. The larger the mass and the larger the height, the more GPE the object gains.

Have you ever noticed that falling a greater distance produces a greater ‘thud’ and can hurt more? This is because of the amount of GPE. As an object falls under the influence of gravity, the object’s GPE can be transformed into other forms of energy. This happens when a child plays on a slide at the playground. As the child climbs up the ladder, their GPE increases. As the child comes down the slide, their GPE decreases but they go faster. The child may also feel the friction of the slide as heat energy.



Figure 3.7 This television has increased gravitational potential energy when raised above the ground.

Chemical potential energy

After we have done a lot of exercise, we often crave foods that we believe will restore our energy levels. These foods, usually sweet, release stored chemical energy very quickly to satisfy our cravings. All foods have some energy stored in them, but the difference is how quickly the energy can be released.

The energy stored within a chemical substance is called **chemical potential energy (CPE)**. Using chemical reactions to break the bonds holding the atoms together releases the energy. The chemical substance our body uses for energy is glucose. The chemical reaction of respiration within our cells breaks the bonds between atoms of glucose and releases energy.

Fuels such as natural gas and petrol also contain chemical energy. A Bunsen burner uses the burning of natural gas to provide heat in the laboratory so you can perform your experiments. Petrol and natural gas have chemical energy stored in them, as do explosives and batteries.

Biomass energy

Biomass energy is potential energy stored in plants and animals. It is a type of chemical potential energy (CPE). The most

common way of releasing biomass energy, and many other types of CPE, is by burning the material, such as burning wood to produce heat. Another common use of biomass energy is to ferment the sugar of various plants to produce ethanol (pure alcohol). The ethanol can be used as a biofuel – a biomass energy source that is burned to power machines. In Australia, we sell petrol for cars that contains 10% ethanol. Petrol of this sort is known as E10 (see Figure 3.9). Most modern cars can run on E10 just as well as they run on normal unleaded fuel.



Figure 3.8 The chemical potential energy in dynamite can be released when the fuse is lit.



Figure 3.9 Ethanol is a biofuel that is already available as a part of E10 fuels in Australia.

EXPERIMENT 3.1.1: BIO-POWER!

Aim

To discover the energy content of a Cheezel.

- Cheezels
- Cork
- Needle or short metal wire
- Heatproof mat
- 150 mL beaker
- Water
- Tripod and gauze mat
- Boss head and clamp
- Thermometer
- Long matches or oven lighter
- Stopwatch or clock
- Safety glasses

WARNING

- > Do not eat the Cheezels. NO food or drink should be consumed in a science laboratory.
- > Be careful of naked flames. Ensure you follow appropriate laboratory procedures and wear safety glasses and a lab coat.

Method

- 1 Push the eye of the needle into one end of the cork.
- 2 Carefully push a Cheezel onto the sharp end of the needle.
- 3 Place the boss head and clamp over the heatproof mat, and then attach the cork to the clamp.
- 4 Pour 20 mL of water into the beaker and record the temperature. This is at time 0 seconds.
- 5 Place the beaker of water on the gauze mat and tripod, and adjust the clamp so the beaker is immediately above the Cheezel but not touching it.
- 6 Light the Cheezel using a long match or oven lighter. (It may take a while to catch alight.) Start the stopwatch when the Cheezel starts to burn.
- 7 Allow the Cheezel to burn for 5 minutes or until it has gone out. During this time, record the temperature of the water every 30 seconds.

Results

Copy and complete the following table for your results, using the formula below for calculating energy.

The amount of energy generated by burning the Cheezel is:

$$\text{Energy (joules)} = \text{volume of water (mL)} \times 4.2 \times \text{change in temperature (}^{\circ}\text{C)}$$

Table 3.1 Water temperature and energy generated.

Time (s)	Temperature ($^{\circ}\text{C}$)	Volume of water (mL)	Energy generated (J)
0		20	
30		20	
60		20	
90		20	

Discussion

- 1 How does this experiment demonstrate how biofuels can be used to create energy?
- 2 What does this experiment suggest about Cheezels as an energy source for humans?
- 3 What type of energy does this experiment investigate?
- 4 How could you improve this experiment?

Conclusion

Write a statement about the energy content of a Cheezel, using your results as evidence.



Figure 3.10 In this experiment you will attempt to discover the energy content of a Cheezel.

Nuclear energy

Although nuclear energy is used throughout the world, it is not used in Australia at the moment. **Nuclear energy** involves the splitting or joining of the centre (nuclei) of atoms. When atoms react in chemical reactions, they usually release only small amounts of energy. However, if the nuclei of atoms can be made to react, the amount of energy released is much, much larger. The amount of energy released is so huge that it can power whole cities or cause massive amounts of destruction. The Australian Government is concerned about the risks associated with nuclear energy and is unlikely to use it in the near future.

Nuclear power can also be used in explosive weapons and some countries in the world possess such weapons (but not Australia). Thankfully, they are not used very often because their destructive power is huge.



Figure 3.11 The potential energy released from a nuclear explosion is much, much greater than from other types of explosions.

Kinetic energy

The scientific term for the energy of movement is **kinetic energy (KE)**. You use kinetic energy every day of your life. Whenever objects or people move, they are using kinetic energy. The heavier an object is and the faster it is moving, the more kinetic energy it has. A fully loaded truck travelling

at 60 kilometres per hour has much more kinetic energy than a small motorbike travelling at the same speed.

Cars are designed with safety features to absorb the kinetic energy of a collision. For example, a car's brakes are designed to absorb kinetic energy and slow the car down safely. An object stopping suddenly when hitting an obstacle will receive more damage than an object slowing down before gently coming to a stop. The kinetic energy of a sudden stop is what causes damage to the car and the people inside it.



Figure 3.12 Airbags in cars are designed to slow you down before you stop in a crash, reducing the kinetic energy and hopefully preventing injury.

Sound energy

Have you ever been at a very loud concert and stood near the huge **speakers**? If so, you will remember that you not only heard the deep bass sound, but also felt it in your body. This is **sound energy**. You can feel the same vibrations in the car if you put your hand on the dashboard when the radio is on full blast. Sound is made when things vibrate. Every time you make a sound – whether it is playing a musical instrument, speaking, singing or even whispering – you



Figure 3.13 The kinetic energy a drummer uses to hit the drum skins is transformed into sound energy.

are making vibrations. Vibrations are simply tiny movements back and forth. Vibrations can occur in gases, liquids and even in solids. If you put your ear to the desk in front of you and a friend taps at the other end of the desk, you will hear the vibrations.

Energy is needed to make sound. For example, a drummer uses energy to hit the drums, which vibrates the drum skin to make a sound. The more energy the drummer uses to hit the drum, the bigger the vibrations and the louder the sound will be (see Figure 3.13). The sound travels to your ears through the air. The particles in the air also vibrate as the sound passes through.

ACTIVITY 3.1.3: SOUND ENERGY

What you need: tuning fork, wooden table or wooden box, acoustic guitar, electric guitar

- 1 Hit a tuning fork on the sole of your shoe and then listen to the sound it makes.
- 2 Repeat step 1, but hold the tuning fork so it is standing on a wooden table or wooden box. What difference did the table make to the loudness of the sound?
- 3 Repeat step 2, but see if you can feel the table or box vibrating this time. Why do you think this may have happened?
- 4 Compare the sound of an unplugged electric guitar to the sound of an acoustic guitar. Which is louder? Why do you think this is so?
- 5 Now place your hand on the body of the acoustic guitar as it is played. Can you feel the vibrations? What about with the electric guitar? Does this help explain why the acoustic guitar may be louder?
 - How do you change the way you play a recorder so it gives out more sound energy?
 - How does a pianist manage to play some notes softly and others very loudly?
 - When you want to yell or speak louder, how do you make the sound coming from your mouth louder?
 - How do drummers make their drums sound louder?



Figure 3.14 What energy does a tuning fork use and produce?

QUESTIONS 3.1.1: COMMON TYPES OF ENERGY

Remember

- 1 List four examples of devices or situations that involve potential energy.
- 2 Describe four devices, other than those mentioned already, that possess elastic potential energy.
- 3 Recall the scientific term for 'movement energy'.
- 4 Complete the following statement: When a person plays a musical instrument, _____ energy is transformed into _____ energy.

Apply

- 5 Identify three situations where you used kinetic energy today.
- 6 Identify an advantage of using 10% ethanol as a fuel source instead of normal petrol.
- 7 In terms of the energy involved, list one benefit and one problem with using nuclear power.
- 8 Identify the features of a car that would absorb the:
 - a car's kinetic energy to avoid a collision
 - b driver's and passengers' kinetic energy in a collision.



Figure 3.15 Crash test dummies are used to test the safety features of cars.

Research

- 9 Compare the amount of energy released from the burning of brown coal with the equivalent amount of uranium-235 in a nuclear reactor.
- 10 Investigate the vibrations of sound further. If the size of the vibrations determines the volume of the sound, identify the feature of the vibrations that determines the note or the pitch of the sound.



Figure 3.16 Headphones convert electrical energy into sound energy.

TRANSFORMING ENERGY

We use a huge range of devices and equipment every day. Some electrical devices, such as headphones, produce sound. Some devices produce light or use light to analyse something, such as a barcode scanner at the supermarket. Others produce heat to dry and style our hair or to provide us with hot water for our showers. A gas stove produces heat to cook our food, and solar panels transfer sunlight into electricity. All these devices and pieces of equipment are energy transformers because they convert one type of energy into another.

ACTIVITY 3.1.4: ENERGY CONVERTERS

Consider each device in Table 3.2, the energy it uses to work (the energy input) and the useful energy it produces (the energy output).

- 1 Work in groups to fill in the gaps in Table 3.2.

Table 3.2 Energy input and output of some devices.

Device	Energy input	Energy output
Drum		Sound
	Electrical	Sound
Light bulb		Light
Battery	CPE	
Car engine		Kinetic
	Elastic potential	Kinetic
Gas heater		Heat
Solar panel	Light	
Phone charger		Electrical

- 2 Discuss any patterns you see in the table. For example, are there any energy types that are more commonly 'inputs' rather than 'outputs'?
- 3 What is significant about the energy transformation performed by a phone charger?
- 4 Extend the list with five more devices your group comes up with.

Representing energy transformations

Flow diagrams can be used to represent **energy transformations**. The arrow in the flow diagram is used to represent a number of things.

- 1 The arrow points in the direction of the transformation.
- 2 The energy input is written at the beginning of the arrow.
- 3 The useful energy output is written at the tip (or point) of the arrow.

For example, the battery in a mobile phone transforms chemical energy into electrical energy. The previous sentence describes this energy transformation, but using a flow diagram it would simply be:

Chemical energy → Electrical energy

Sometimes, there is more than one energy output, so we try to concentrate on the main one. Minor energy outputs are known as by-products. Think how you would write the energy transformation in a light bulb. What is the energy input? What is the main energy output? Is there a by-product (wasted energy)?

In some devices, there are several energy transformations in a row, resulting in an energy chain. For example, listening to music from a smartphone would be as described in the following paragraph.

The chemical energy stored in the battery of the smartphone is transformed into electrical energy. The electrical energy flows through the wires to the headphones, where it is transformed into kinetic energy as the tiny speakers in the headphones vibrate. This is then transformed into sound energy, which our ears detect.

As a flow diagram, this energy chain is shown in Figure 3.17.

Chemical energy → Electrical energy → Kinetic energy → Sound energy



Figure 3.17 The energy chain involved in listening to music from a smartphone.

Transformations for heat

The most important energy transformations in our lives are those that keep us comfortable, reduce our stress and entertain our brains! Energy transformations involved in our comfort usually mean using heat for things like drying our hair, cooking our food and keeping us warm.

A hairdryer has two basic components: a fan and a heating element. When plugged in and switched on, the fan motor spins and the heating element heats up. So, a hairdryer converts electrical energy into heat energy and kinetic energy. The air blown by the fan is directed over the heating element, generating warm air, which flows out of the hairdryer.

Gas ovens and stoves use the chemical energy of the gas to produce heat by burning the gas. All these devices are very common – our homes would not be much use to us without energy converters.

No doubt your house has some sort of heating or cooling system, depending on where you live. Electricity can be used to heat your home or water supply, but burning natural gas is another option. All these heating and cooling devices are energy converters. If you wave a piece of cardboard in front of your face to cool yourself down, you are converting energy. The chemical energy inside your muscles is converted into kinetic energy (the movement of your hand) to assist the transfer of thermal energy from your face into the surrounding air.



Figure 3.18 An electric stove converts electricity into thermal energy. Some electrical energy is also transformed into the by-product light energy, which is why the element looks red.

EXPERIMENT 3.1.2: MAKING AN ELECTRIC JUG

Aim

To model the energy transformation of an electric jug.

- Power supply
- Pencil
- Thermometer
- 250 mL beaker
- Heatproof mat
- Two connecting wires
- Alligator clips
- Blu-Tack
- Approximately 70 cm of nichrome wire

WARNING

- > Do not allow the two alligator clips to touch while the power is on.
- > Be careful handling the hot water produced, and be especially careful not to touch the wire once it is hot.
- > Ensure you allow the wire to cool properly before packing up the experiment.

Method

- 1 Coil the nichrome wire around the pencil, leaving a 10 cm straight section of wire at each end. Remove the pencil from the coil and make sure both straight ends of the wire are pointing in the same direction. Check that the coil will fit into the beaker.
- 2 Stand the beaker on the heatproof mat and add 50 mL of water to the beaker, ensuring the nichrome coil remains below the water level.
- 3 Connect the straight sections of the nichrome wire to a power supply with alligator clips and connecting wires. Set the power supply on 12 V DC and switch on the power. Use the Blu-Tack to hold the setup in place on the top edges of the beaker if necessary.
- 4 Put the thermometer near the base of the beaker and check the temperature. Check the temperature again after 2, 4, 6, 8 and 10 minutes.

Results

Record your results in a table, then convert this data to a temperature–time line graph. Refer to the Science Skills on page 133 to see how to draw different types of scientific graphs.

Discussion

- 1 What advantage do you think a coiled heating element has over a straight one?
- 2 Why must the two alligator clips not be allowed to touch while the power is on?
- 3 Approximately how long did it take for the water to get warm?
- 4 How could the speed of heating the water be improved?

Conclusion

Write two or three sentences to explain how electrical energy can be used to heat water.

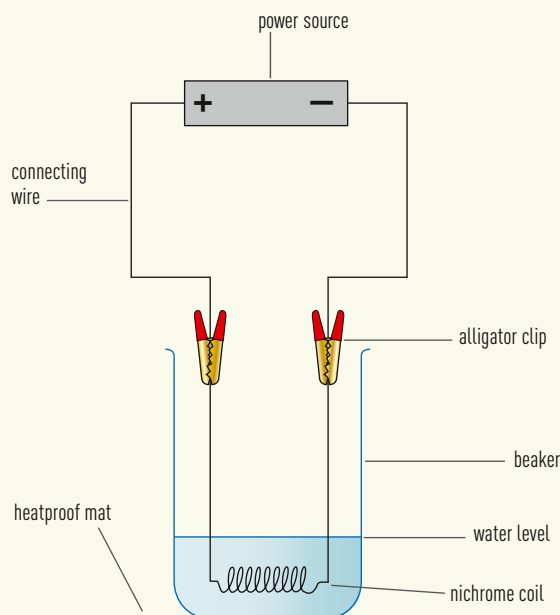


Figure 3.19 Experimental setup for an electrical jug.

Transformations for motion

Transport is a vital part of our everyday lives. Which form of transport did you use to get around today? Each form uses an energy conversion. Even walking uses energy. We know this because, when we walk a long way, we get very tired. Humans have invested a lot of resources into improving transportation to reduce the energy we expend. Getting from one place to another is much easier with a car. Trucks and trains mean we can transport large quantities of goods in a short period of time.

When we ride a bicycle, the chemical energy stored in our bodies from the food we have eaten is transformed into kinetic energy and heat energy. A car engine also uses

chemical energy that is stored in the petrol, converting it mainly into kinetic energy but with the by-products of sound, heat and electrical energy.

Electric cars are being designed to run on the chemical energy stored in batteries, rather than petrol, to power an electric motor that makes the wheels turn. This will make electric cars less polluting and more energy efficient. Hybrid cars have been on our roads for many years. These cars have both a petrol engine and an electric motor with large banks of batteries, usually under the floor. The Toyota Prius (Figure 3.21) and the Hybrid Camry were two of the first hybrid cars on our roads, but many more are being designed.

Public transport uses energy too. Metropolitan trains (and trams in some cities) convert electricity from overhead wires into kinetic energy to make them move.

Trains that travel to country areas or interstate usually run on diesel fuel and do not need overhead electrical wires. The engines in these trains burn diesel fuel, transforming its chemical potential energy into kinetic energy. Ships and planes use a similar process in their engines.



Figure 3.20 Cycling requires fuel from food and by-products of heat and sound are produced by the rider.



Figure 3.21 Hybrid cars use both a petrol engine and an electric motor to send power to the wheels.



Figure 3.22 Power lines provide electrical energy for public transport.

Figure 3.23 Power lines are not practical in rural areas, so diesel fuel is used to provide energy for transport.



Figure 3.24 Aircraft use higher-quality fuels than road transport vehicles to minimise weight and waste.

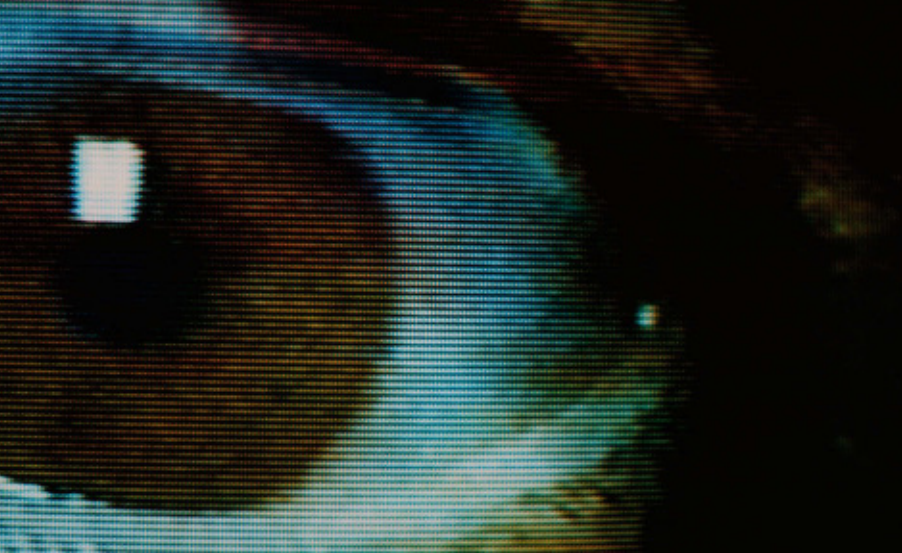


Figure 3.25 The picture you see on the television screen is made up of thousands of coloured dots called pixels.

Transformations for light

Humans are one of the few animals that are known to do things just for fun. Massive amounts of time, energy and money are dedicated to entertaining ourselves.

These days, light is used extensively for entertainment. Television and other screens display pictures that are made up of thousands of dots of red, green and blue light. The dots are known as pixels (see Figure 3.25). When an electrical signal reaches a pixel, it glows. Making different combinations of pixels glow with different combinations of brightness can produce any colour. To produce yellow, both the red and green pixels glow. To make white, all three of the pixel colours glow. Our eyes merge the coloured light from the pixels to make the colour we see. All the coloured pixels over the entire screen merge to form the picture of the television program or DVD we are watching.

CD and DVD players use light energy from a laser to read the information stored on the CD or DVD. Tiny microscopic pits on the surface of the disc make up the digital code. The laser, which is a very pure type of light, reads the code. The code is then transformed into sound, information or pictures.

A television remote control uses light energy to communicate with the television set. Most remote controls use infrared light, which is an invisible type of light usually associated with heat. The remote control sends a pulse of infrared light that represents a particular command, such as to change



Figure 3.26 A television remote control uses an infrared LED to operate the television.

the channel or to increase the volume (see Figure 3.26). An infrared light detector on the television receives the light signal and transforms it back into electrical energy, which then carries out the command.

Transformations for sound

Speakers come in a range of sizes, from the tiny earphones that come with smart phones or MP3 players to the huge speaker systems used at concerts. Earphones are simply a pair of tiny speakers that connect to an audio source. The music files stored on an MP3 player (see Figure 3.28) are transformed into electrical energy using chemical energy from the battery. The wires carry the electrical energy and the tiny speakers vibrate to transform the electrical energy into sound energy.

A mobile phone also uses a speaker to produce the sound of a person's voice or the various ringtones and beeps that the phone makes. Home phones use a speaker too, as do televisions, CD systems, radios and many other devices. They all transform electrical energy into sound energy.

The microphone in a mobile phone transforms the sound energy from our voice into electrical energy, which can then be sent as a radio wave signal to another phone. Nowadays, smartphones have a lot of different parts inside them because of the number of jobs we now expect them to do.



Figure 3.27 Earphones transform electrical energy into sound energy.



Figure 3.28 The internal components of an iPod.

ACTIVITY 3.1.5: INVESTIGATING ENERGY TRANSFORMATIONS

What you need: model dynamo/generator, model steam engine, radiometer



Figure 3.29 Some devices that transform energy.

- 1 Carefully identify the different parts of each of the devices provided. In what ways are they similar? How do they differ?
- 2 Rotate the handle of the dynamo to make the lamp work.
- 3 Watch the model steam engine as it runs.
- 4 Shine a bright light on the vanes of the radiometer.
 - What energy transformations are involved in each of the devices investigated?
 - Which of the devices is/are producing electrical energy? How do you know?
 - Suggest an application in the real world for each device.

QUESTIONS 3.1.2: TRANSFORMING ENERGY

Remember

- 1 Recall the features that make hybrid cars different from regular petrol-driven cars.
- 2 Recall why country trains mostly use diesel instead of overhead electrical wires.
- 3 Describe the importance of energy and energy transformation in transportation.
- 4 Describe how electrical energy is transformed into thermal energy in a toaster or hairdryer.

Apply

- 5 Suggest three examples, other than those provided, of how light energy can be used.
- 6 Identify the by-products of energy transformations of a car.
- 7 Choose three energy-converting devices mentioned in this section and draw flow diagrams to identify the energy transformations they perform.
- 8 Draw an energy chain for how we get the energy to run a race from eating an apple. (Hint: Start with the sun.)
- 9 Propose some of the advantages and disadvantages of an electric car over a petrol car.
- 10 Many devices use remote controls. List as many as you can think of and explain how they send their signals.

TRANSFERRING HEAT ENERGY

Most energy transformations result in at least some of the energy being converted into heat. Heat energy is more properly called thermal energy. As you discovered in year 7, all substances, such as water and air, are made of particles called atoms. Atoms move around at different speeds, depending on the temperature. The atoms in hot air or water move faster than the atoms in cold air or water.

When substances are heated, they expand to occupy more space because heating gives the atoms more kinetic energy to move further and faster, spreading the substance out. The molecules do not get bigger, but the spaces between the atoms do. Heat energy travels through materials in three different ways: conduction, convection and radiation.

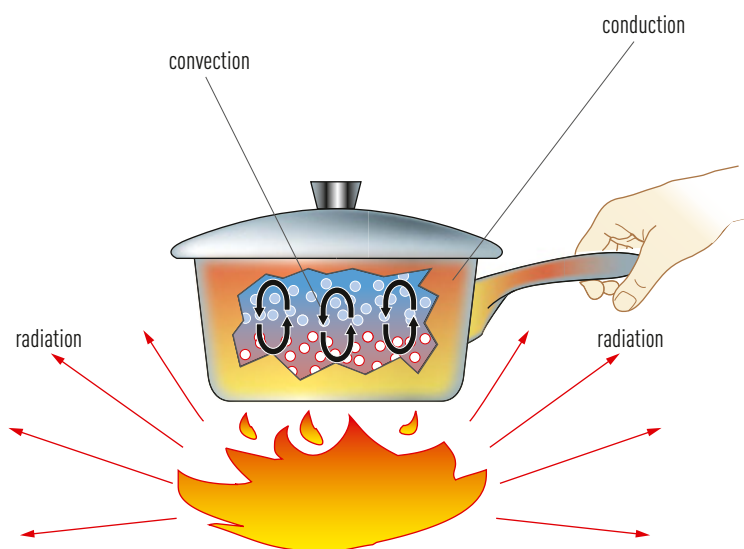


Figure 3.30 Thermal energy can be transferred in three main ways: conduction, convection and radiation.

Conduction and convection

Thermal energy always moves from a hotter substance to a cooler substance. This energy transfer can occur by conduction or convection. Radiation is a different type of energy transfer that will be discussed later in this section.

Heating by conduction

Heat transfer by **conduction** is the transfer of thermal energy between two objects in direct contact with each other. Heat transfers from the hotter object to the cooler object.

Consider what happens when a saucepan of water is heated on a gas burner:

- When the gas burns, chemical potential energy is transformed into thermal energy.
- The hot atoms in the gas flame move quickly and occasionally bump into atoms of the relatively cold metal of the saucepan.
- Energy passes to the slowly vibrating atoms in the bottom of the saucepan so that they vibrate faster.
- These quickly vibrating atoms in the saucepan then bump into other nearby metal atoms, transferring energy to them. This heats the saucepan.
- When the saucepan heats up, thermal energy is transferred to the water inside the saucepan that is touching the metal.

Although the energy is transferred through the metal of the saucepan and into the water, the atoms in the metal do not change their positions.



Figure 3.31 Only the bottom of this saucepan is being heated, but conduction will transfer the heat through the metal to the water inside.

Conductors and insulators

A thermal conductor is any material that allows thermal energy to flow easily through it. All metals are conductors, although some are better conductors than others. Thermal insulators are materials that slow down the transfer of thermal energy because the arrangement of their atoms do not allow the energy to flow very easily. Insulators such as socks, jumpers and blankets keep us warm in cold weather. They make it difficult for our 'body heat' to escape, insulating us against the cold. Insulation in the roof and walls of a house prevents heat gain and loss during summer and winter. Insulation can hold heat in or keep it out.

Heating by convection

In liquids and gases, thermal energy can also move by **convection**. Tiny circular currents, called convection currents, carry the thermal energy. A convection current is movement within a liquid or gas that is driven by differences in the thermal energy of the molecules.

Think again about what is happening when a saucepan of water is heated on a gas flame:

- Energy transfers by conduction from the hot saucepan to the water molecules that are touching the metal.

- The water molecules in contact with the metal have more energy and are moving faster than the molecules in the cooler water above. Because they are moving faster, they take up more space and so are less dense than the cooler water.
- The hotter, less dense molecules rise and the cooler, more dense molecules sink.
- The cooler water molecules are now heated by the saucepan and the process continues.

Convection can occur in air as well as in liquids. The sun heats the ground, and the warmed ground then heats the air touching it by conduction. The warmed air is less dense than the cooler air above it, so it will rise, taking the energy with it. This distributes the energy through a much deeper layer of air than could occur just by conduction from the ground. This process of convection in the air is what drives the weather on the Earth.



Figure 3.32 Convection currents are created in a saucepan of water when it is heated. The heated water molecules rise (shown in red) while the cooler ones sink (shown in blue).

Living in Iceland

Iceland is just south of the Arctic Circle, in the North Atlantic Ocean. Maximum temperatures in the capital, Reykjavik, range from about -3°C in winter to about 13°C in summer. For much-needed heating throughout the year, Icelanders rely on a renewable source of heat energy: geothermal energy. Iceland is a highly volcanic and geologically active island. The abundant energy from the hot water and steam just below the ground is used to generate electricity, and used directly as heating. Geothermal heating has been

used since the times of the Roman Empire to heat buildings and water. This energy is so inexpensive that some footpaths in Reykjavik are heated in winter.

Questions

- 1 How could the steam from below the ground be used to generate electricity?
- 2 Suggest why almost 90% of Iceland's households use geothermal energy for heating and hot water.
- 3 What other sources of energy are used to heat homes throughout the world?

DEEPER UNDERSTANDING



Figure 3.33 The Blue Lagoon is a geothermal spa near Reykjavik, Iceland.

EXPERIMENT 3.1.3: INVESTIGATING CONVECTION

Aim

Carefully read the experiment and write an appropriate aim. The title of the experiment may be a hint. Remember that an aim should start with 'To ...'.

Materials

- Bunsen burner
- Heatproof mat
- Tripod
- Gauze mat
- Matches
- Stopwatch
- 500 mL beaker
- Retort stand
- 2 boss head and clamp sets
- 2 thermometers
- Safety glasses
- Tongs

WARNING

- > Be careful when heating liquids and near naked flames; do not leave them unattended. Handle hot glassware with tongs.
- > Wear safety glasses.

Method

- 1 Add approximately 300 mL of water to the beaker.
- 2 Assemble the apparatus as shown in Figure 3.34. Ensure the lower thermometer is not touching the bottom of the beaker and that the bulb of the top thermometer is about 2 cm under the surface of the water.
- 3 Read the temperature of the water with both thermometers and record both values in the results table as time 0.
- 4 Light the Bunsen burner and turn it to the blue flame.

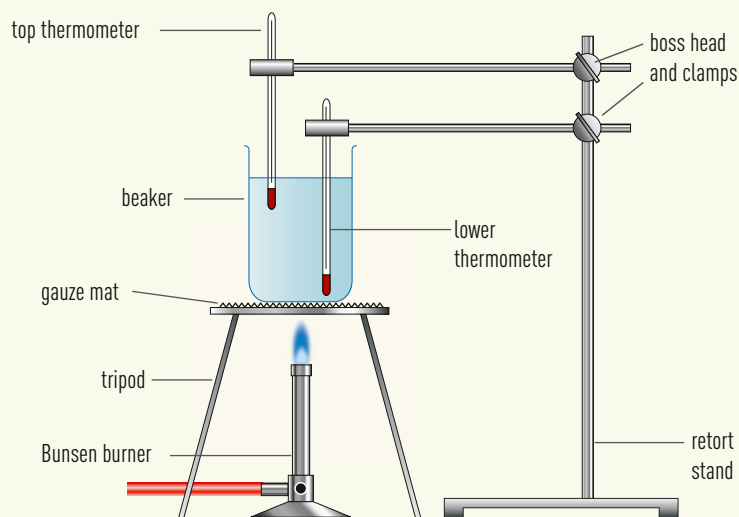


Figure 3.34 Experimental setup.

- 5 Record the temperature of the water with both thermometers every 30 seconds for 3 minutes.
- 6 Use your table of results to draw a line graph that shows the change of temperature versus time at the two locations. See the Science Skills box on page 133 for instructions on how to draw a scientific graph. Draw both lines on the same set of axes.

Results

Time (s)	Temperature (°C)	
	Lower thermometer	Upper thermometer
0		
30		
60		
90		
120		
150		
180		

Discussion

- 1 Describe any differences in temperature between the water at the bottom of the beaker and the water at the top of the beaker at time 0. Explain why this might be.
- 2 Describe any differences between the temperatures of the water at the bottom of the beaker compared with the water at the top of the beaker over the 3 minutes.
- 3 If you continued this experiment until the water was boiling, would you expect any differences in water temperature between the bottom and top of the beaker? Explain your answer.
- 4 Describe how the water was heated in the beakers using your knowledge of thermal energy, conduction and convection and using your results as evidence.

Conclusion

Write two or three sentences to address your aim and explain what you know about the process of convection.

Drawing scientific graphs

SCIENCE SKILLS

Many scientific experiments collect lots of data. The easiest way to summarise this data and to see any patterns is to draw a graph. The most common types of graph used in science are line graphs, sector graphs (pie charts) and column graphs. The type of graph you draw depends on the type of data you have collected.

Column graphs

Column or bar graphs are used when data falls into discrete groupings. For example,

Table 3.3 Table showing the colours of cars seen over one day.

Car colour	Number
Red	12
Blue	15
Silver	20
Green	2
Black	5
White	12

if you were recording the colours of cars you saw passing your window over a day, you could produce a table as shown in Table 3.3.

In a column graph, the discrete grouping is usually displayed on the horizontal axis, and the numbers are displayed on the vertical axis, as shown in Figure 3.35.

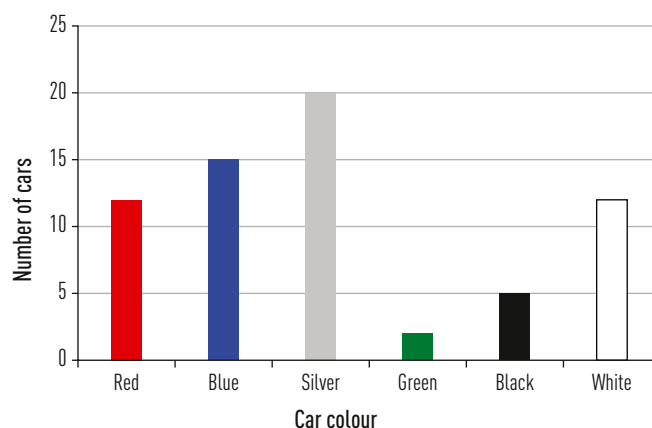


Figure 3.35 Column graph showing the colours of cars seen over one day.

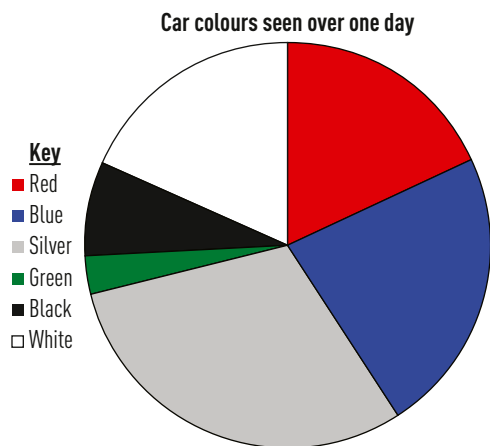


Figure 3.36 Sector graph showing the colours of cars seen over one day.

Sector graphs

Sector graphs, also known as pie charts, are also used to display data that has discrete groupings. In contrast to a column graph, a sector graph displays the data as proportions of a circle. For the data in Table 3.3, the whole circle represents the total number of cars seen.

$$\begin{aligned}\text{Total number of cars seen} &= 12 + 15 + 20 + 2 + 5 + 12 \\ &= 66\end{aligned}$$

To determine how big each sector of the graph should be, each value must be divided by the total and multiplied by 100 to get a percentage value (rounding is often required). For example, to determine the size of the sector representing red cars:

$$\begin{aligned}\text{Percentage of red cars} &= \frac{\text{Number of red cars}}{\text{Total number of cars}} \times 100 \\ &= \frac{12}{66} \times 100 \\ &= 18\%\end{aligned}$$

To draw the sector graph you need to calculate how many degrees each sector will represent. A full circle has 360° , which can be used to calculate each sector (again, rounding is often required). For example, to determine the degrees of the sector representing red cars:

$$\begin{aligned}\text{Degrees of red car sector} &= \frac{\text{Number of red cars}}{\text{Total number of cars}} \times 360 \\ &= \frac{12}{66} \times 360 \\ &= 65^\circ\end{aligned}$$

Once these calculations have been done for each car colour, the sector graph can be created. Draw a circle, and then use a protractor to measure out the sectors that represent each car colour. Figure 3.6 shows a sector graph for the data in Table 3.3. Sector graphs must include a key to show what each sector represents.

Line graphs

Continuous data is data that can take any value, for example, the time taken to run 100 metres. Line graphs are used to show how one continuous variable changes in relation to another variable. The independent variable (the variable you change or control) is always on the horizontal axis. The experimental or dependent variable (the variable you measure for your results) is placed on the vertical axis.

Steps for drawing a scientific line graph

- 1** Take a blank sheet of graph paper. Give your graph a title that briefly explains what the graph is showing. Both the variables should be a part of the title. For example, 'The change in plant height over time'. In this example, time will be the independent variable and the height of the plant will be the dependent variable.
- 2** The length of your axes and the spacing of units will depend on your data. Identify the highest values for each variable and base your axes on those, adding a few extra unit lengths in case you need to extend (extrapolate) your results to predict what would have happened if you had continued your experiment.

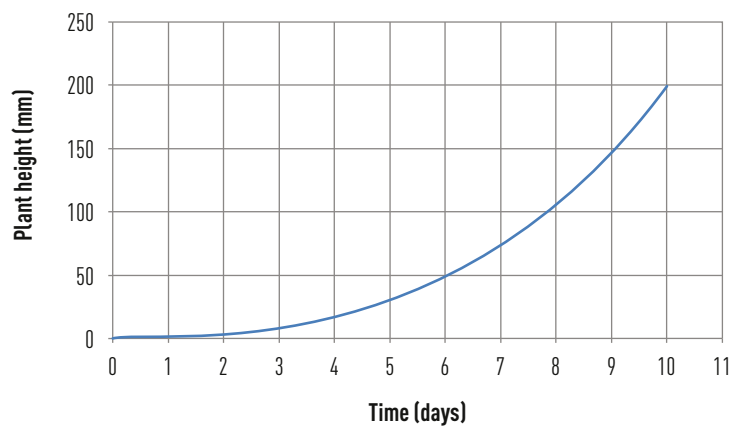
Table 3.4 Plant height measurements over 10 days.

Time (days)	Plant height (mm)
0	0
1	0
2	1
3	4
4	15
5	28
6	49
7	73
8	102
9	148
10	195

- Label each axis with the variable and the units you have used to measure it. Using a pencil, plot each point of data from the table.
- Join the points with a line of best fit. This does not necessarily mean you rule a straight line through the first and last point. You may have to hand-draw a curve in some cases. The line may not pass through every single point, but should be a smooth line that passes near as many points as possible. This line of best fit shows you if there is any trend (pattern) in your data to indicate a relationship between the two variables. It also identifies any outliers, which are data points a long way from the line of best fit that may indicate a mistake in your data recording or method.

Table 3.5 The efficiency of three brands of kettle.

	Time (s) taken to boil following volumes (mL) of water					
	250	500	750	1000	1500	2000
Kettle A	50	100	150	200	300	400
Kettle B	62	110	134	169	278	367
Kettle C	48	92	151	223	341	443

Change in plant height over time**Figure 3.37** Line graph showing the change in plant height over time.

- You can draw more than one set of data on the same graph axes if they are using the same variables. For example, you might want to compare the electrical efficiency of three different brands of kettle. When you place multiple lines on the same graph you must label each line, or draw them in different colours and provide a key.

Your turn

You carried out an experiment to compare the efficiency of three different brands of kettle when boiling different amounts of water. The results are shown in Table 3.5. Draw an appropriate graph to display this data.

Heating by radiation

When you go outside on a warm day, you are being heated by **radiation**.

Unlike convection and conduction, when something radiates energy, the medium (substance) through which it travels is not affected. Radiation is a type of energy that includes visible light, ultraviolet light, radio waves, microwaves and infrared radiation. Radiation is not necessarily absorbed when

it meets a substance – it may be reflected or transmitted. For example, radiation from the sun is transmitted through the atmosphere – some of the radiation is reflected from the tops of clouds, some is absorbed by the ground and some is reflected by the ground.

Radiated energy that is absorbed gives the atoms of the substance more energy to vibrate, increasing the substance's thermal energy.

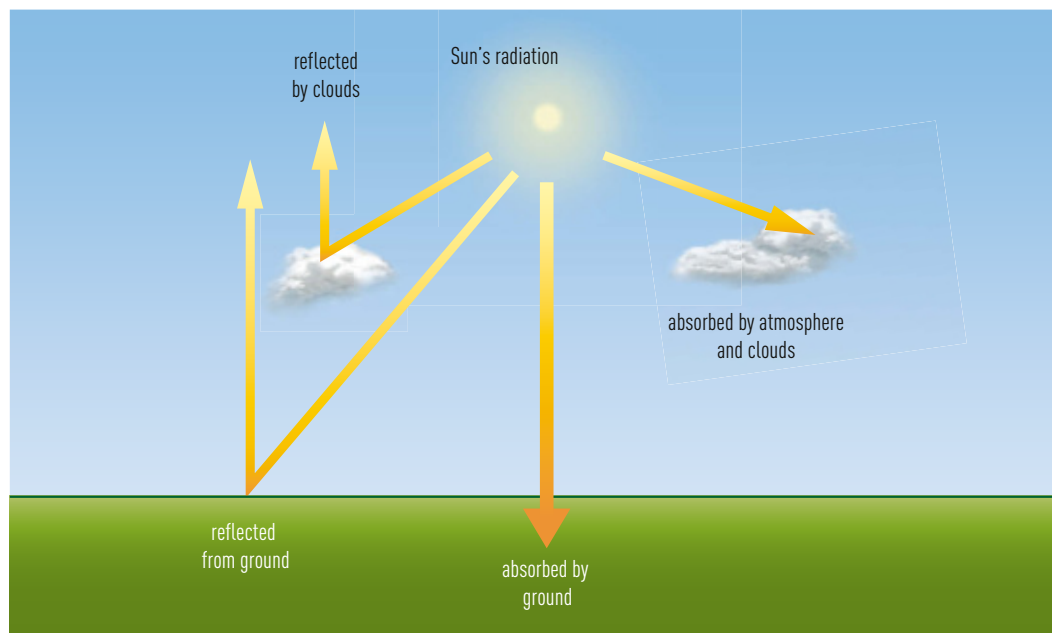


Figure 3.38 Radiation from the sun does several things, depending on weather conditions.

ACTIVITY 3.1.6: INVESTIGATING HEATING BY RADIATION

What you need: 3 cm square of black paper, 3 cm square of white paper, 3 cm square of aluminium foil, 3 thermometers, sunlight (alternatively, use an incandescent lamp or heat lamp), stopwatch

- 1 Work in groups of three.
- 2 Place the bulbs of the thermometers under the different materials and then place them in sunlight (or under a lamp, making sure that they are all 6 cm from the lamp).
- 3 Use a table to record the temperature of each thermometer every minute for 10 minutes.
- 4 Draw graphs of the change in temperature for the different materials.
 - Which surface was the best at absorbing radiation?
 - Which surface was the best at reflecting radiation?

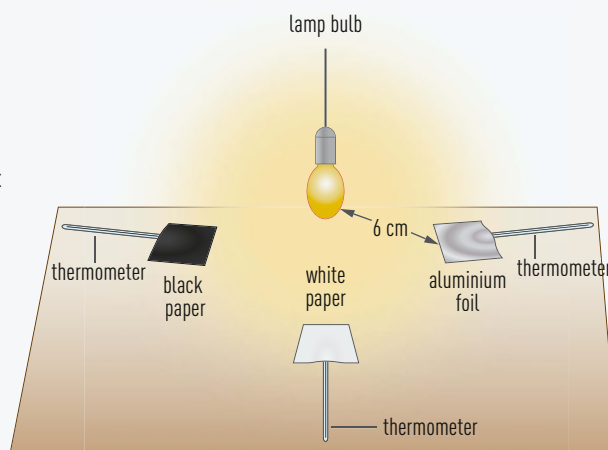


Figure 3.39 Experimental set-up.

Solar snakes

Snakes and other reptiles rely on thermal energy from the sun. Reptiles are poikilothermic (pronounced poy-kilo-thermic): they take on the temperature of their surroundings. 'Cold-blooded' isn't a very scientific description because their blood is very rarely cold. Reptiles regulate their body temperature by moving from sunny to cooler areas.

Snakes and lizards lie at right angles to the direction of the sunlight to maximise the amount of solar radiation falling on their skin. They increase the surface area exposed to the sun by expanding their ribcages. Many reptiles can also darken their skin to absorb more heat from solar radiation.

Snakes and lizards are also often seen lying on hot roads or rocks that have absorbed thermal energy from the sun. In this case, they are using conduction from the hot rocks to transfer heat.

When a reptile is too hot, it will lie parallel to the sun's rays, move into the shade, lighten the colour of its skin, open its mouth wide, or burrow under cool soil. Reptiles are much more active in warmer temperatures and hibernate (a sleep-like state) in colder seasons.

Questions

- 1 Why does increasing the surface area of the reptile's skin allow more energy to be absorbed into its body?
- 2 Does the body of a reptile store thermal energy? Explain your answer.
- 3 Why would opening its mouth allow the reptile to cool down?



Figure 3.40 Bearded dragons darken their skin and spread out their bodies to help absorb solar radiation.

QUESTIONS 3.1.3: TRANSFERRING HEAT ENERGY

Remember

- 1 Identify an everyday situation where thermal energy is transferred by:
 - a conduction
 - b convection
 - c radiation.
- 2 Recall the possible pathways of solar radiation from the sun, depending on the weather conditions.
- 3 List some examples of common devices that work by the use of light, infrared radiation, microwaves or radio waves.
- 4 Identify what happens when a substance absorbs radiation.

Apply

- 5 Explain why you think scientists are happy to refer to thermal energy transfer as heating, even though in every case something is being cooled.
- 6 Modern saucepans have a copper bottom, steel sides, a plastic handle and a glass lid. Identify why each of these materials is used for a particular part of the saucepan.
- 7 Identify a key difference in the way thermal energy is transferred using radiation compared with conduction and convection.
- 8 Explain why we tend to heat substances from the bottom, rather than from above or from the side.
- 9 From your everyday experience, list some examples of where good thermal insulators and conductors are needed. Identify the materials used in each case.

3.1

CHECKPOINT

EVERYDAY ENERGY

Remember and understand

- 1 Match these terms with their correct meanings: [6 marks]

Nuclear energy	Another name for stored energy
Biomass energy	The energy of an object when lifted up
Elastic energy	Energy from atoms
Kinetic energy	The energy stored in a compressed spring
Gravitational energy	Possessed by all moving objects
Potential energy	Energy stored in plants and animals

- 2 Identify whether the following statements are true or false. Rewrite the false statements to make them correct.
- a Springs only hold stored energy when they are stretched. [1 mark]
 - b Nuclear energy provides much more energy than chemical reactions do. [1 mark]
 - c When an object is thrown up in the air, it gains gravitational potential energy. [1 mark]
 - d Sound energy is a type of potential energy. [1 mark]
 - e Petrol contains nuclear energy. [1 mark]

- 3 Identify the main form of energy in each of these situations:
- a water flowing over a waterfall [1 mark]
 - b a boy riding his skateboard [1 mark]
 - c a stretched rubber band [1 mark]
 - d a mobile phone battery [1 mark]
 - e a racing car travelling around the race track [1 mark]
 - f a clap of thunder [1 mark]
 - g a rollercoaster at the highest point of the ride [1 mark]
- 4 Name a device that transforms:
- a elastic energy into kinetic energy [1 mark]
 - b gravitational energy into electrical energy [1 mark]
 - c kinetic energy into electrical energy [1 mark]
 - d light energy into electrical energy [1 mark]
 - e electrical energy into sound energy. [1 mark]
- 5 Identify the type of heat transfer that happens when you touch something hot. [1 mark]

Figure 3.41 What are all the energy transformations that happen in a moving car?





Figure 3.42 An earthquake in Japan in 2011 damaged the cooling system in the Fukushima nuclear power plant.

- 6 Recall what E10 is. [1 mark]
- 7 Explain how sound travels. [2 marks]

Apply

- 8 A gas flame used in cooking emits some radiant energy. Explain how you would be aware of this heat transfer. [1 mark]
- 9 Draw labelled diagrams of the three methods of transferring energy by heating. [3 marks]
- 10 Identify the input energy source for a car, the main useful source of energy it produces, and some of the by-product forms of energy it produces. [3 marks]
- 11 Have you ever swum in the sea and noticed that the water is warmer near the surface at the end of a hot day? Explain why convection currents don't work very well to heat water when the heat source is above. [3 marks]
- 12 How many different energy forms have you possessed, used or witnessed today? Identify the most commonly used form of energy and suggest a reason why this might be the case. [3 marks]
- 13 Using an example, explain how biomass energy usually harnessed. [2 marks]
- 14 Explain why substances expand when they are heated. [2 marks]

Critical and creative thinking

- 15 Energy types rarely exist alone. Different types of energy often work together to make something happen. Think about some of the things energy is responsible for. Choose one thing and identify the type or types of energy involved. If more than one type of energy is involved, link the different types with arrows. Compare your scenario with a friend's and see who can come up with a scenario that involves the most forms of energy. [3 marks]
- 16 Create a story that analyses the energy transformations in a device. There needs to be at least four steps in the story. Convert your story into an energy chain, written in the correct format. [4 marks]

Research

- 17 The massive earthquake and tsunami in Japan in March 2011 caused extensive damage to the Fukushima nuclear power plant, north of Tokyo and created an emergency situation (see Figure 3.42). Research this disaster and present a two-minute news report to the class that highlights the issues surrounding the use of nuclear energy. [4 marks]

TOTAL MARKS
[/55]

their nuclei gets changed (or transformed) into some other form, such as light and heat energy in a light bulb.

The flow of electrical energy from one place to another along a pathway made from a conductive material is called an electrical current.

Electric circuits

The pathway travelled by electrical energy is called an **electric circuit**. As negatively charged electrons move around an electric circuit, they carry electrical energy from the energy source, such as a battery, to the device that uses the energy, such as

the bulb in a torch. Devices have ‘gaps’ in the pathway called switches to control the flow of electricity in a circuit. If the switch is open, the pathway is broken and no electricity flows.

The essential requirements for an electric circuit are a power source, the wires or pathway, and a **load** or a component such as a light bulb or resistor. Electrons need a component to transfer their energy to, otherwise they transfer energy to the wires, which transform the energy into heat. Without a load on the circuit, the wires can get hot enough to melt or even catch fire. Many house fires can start as a result of electrical faults.

ACTIVITY 3.2.1: LEMON BATTERIES

What you need: copper metal (foil or uninsulated wire), galvanised nails, 4 lemons per group, small knife, felt-tip marker, 6 alligator clip leads (short), LED (light-emitting diode), multimeter (optional)

WARNING

> Wear safety glasses – juice from the lemons can sting your eyes.

- 1 Roll the lemons and squeeze them gently to soften the skin and make sure they are juicy on the inside.
- 2 Make a slit in the lemons and insert a strip of copper foil. Use a marker to indicate positive (+) on each lemon near the copper foil. At the opposite end of each lemon, push in a galvanised nail and mark it as negative (–).
- 3 Connect the lemons in a line with alligator leads from the + copper terminals to the – galvanised nail terminals.
- 4 Connect the alligator leads to the last copper terminal and galvanised nail. Connect the lead from the copper to the positive side of the LED (the long leg of the LED). Connect the galvanised nail lead to the negative side of the LED (the short leg of the LED). The LED will not glow if it is connected the wrong way round.
- 5 Darken the room and look carefully at the LED. It should have a faint glow.
- 6 If you have time, repeat the activity using potatoes instead of lemons.
 - How do you think the lemons are able to act like a battery?
 - How is the electrical energy in the lemons getting to the LED?
 - What energy transformations are happening for the LED to light up?

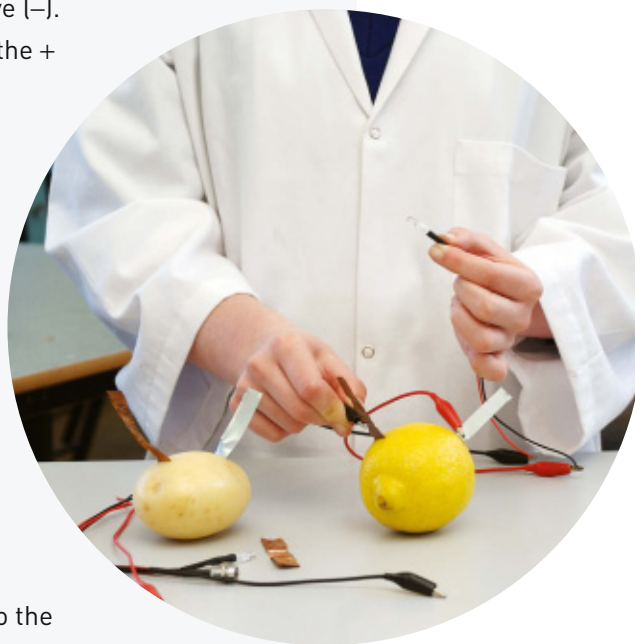
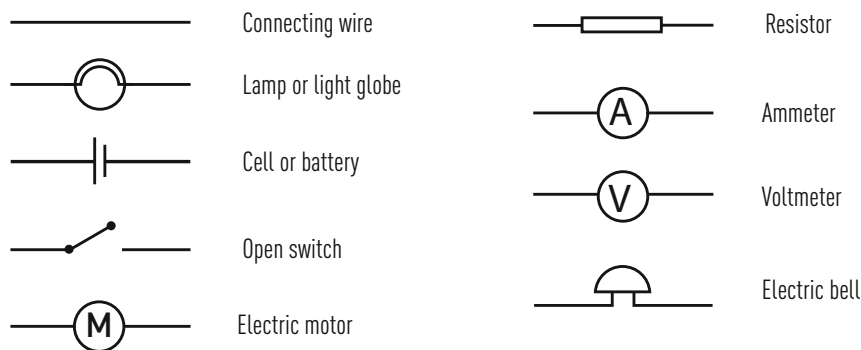


Figure 3.44 Fruits and vegetables can be used as a source of electrical energy.

Figure 3.45 Some common symbols used in circuit diagrams.



Circuit diagrams

Circuits and their components are represented using **circuit diagrams**. Rather than drawing a picture of the different devices, each component of a circuit is represented by a symbol (Figure 3.45). Straight lines are used to represent the wires that connect the components together and form the circuit. The connecting wires are usually drawn using a ruler and right angles are used to show corners rather than curves.

A cell is a power source. It could be a battery cell, a power pack or a plug point in the wall.

An ammeter is a device that measures the current or flow of electrons through the circuit. The ammeter counts the electrons in packets called coulombs. The number of electrons that pass through the circuit is measured as coulombs per second, or amperes (A) – commonly called amps. To use an ammeter, it must be connected as part of the circuit so all the electrons flowing around the circuit also flow through the ammeter.

A voltmeter is a device that measures the voltage, which is the amount of energy the electrons are transferring to the components. Voltage is measured in volts (V). To use a voltmeter, it must be connected around a component so it can measure the difference in the energy of the electrons from just in front of the component to just after it.

When the components are connected in a line or row, it is called a **series circuit**. When the circuit has more than one pathway for the electrons to travel, it is called a **parallel circuit**. Electrons transfer their energy differently in series and parallel circuits.

Figure 3.46 (a) A simple circuit. (b) A circuit diagram of the same circuit.

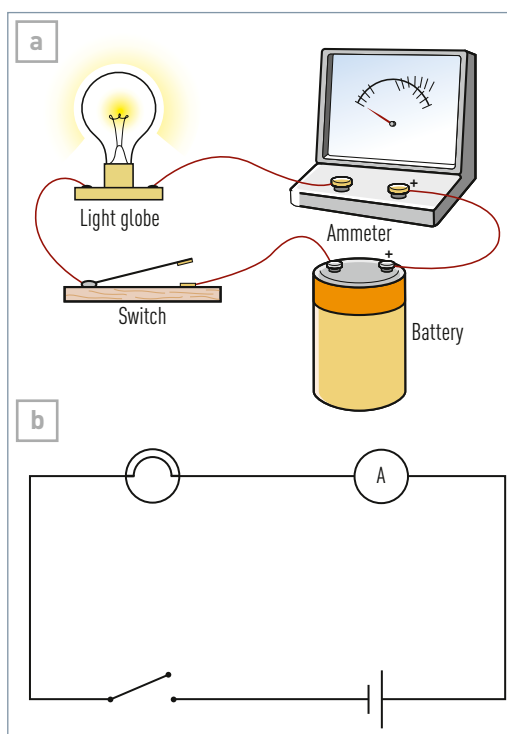
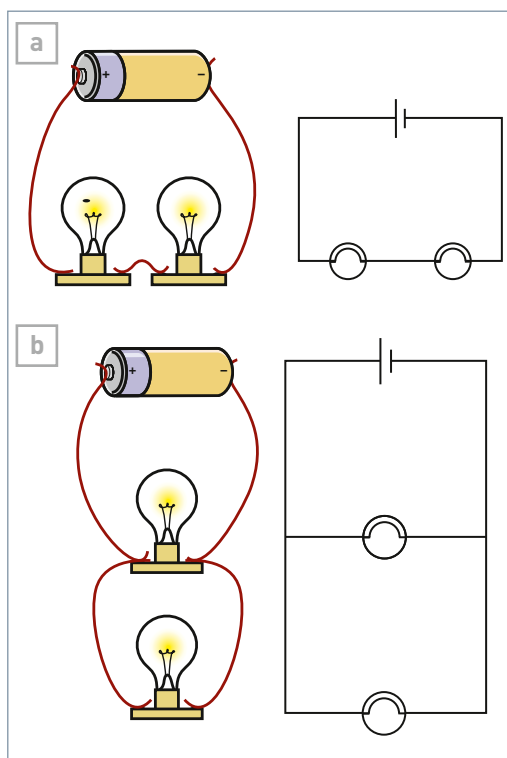


Figure 3.47 (a) A series circuit. (b) A parallel circuit.



ACTIVITY 3.2.2: DRAWING AND CONNECTING CIRCUITS

What you need: power supply, 2 light bulbs, 7 electrical leads, 2 resistors, a switch, ammeter, voltmeter

1 Draw a circuit diagram for each of the following circuits and check it with your teacher.

Circuit 1: One light bulb connected to a power supply. This is a simple circuit.

Circuit 2: Two light bulbs in a row connected to a power supply. This is a series circuit.

Circuit 3: Two circuits connected to a power supply at once – one light bulb placed on each loop of this double circuit. This is a parallel circuit.

Circuit 4: A switch inserted into circuit 3 so that it can switch off one of the light bulbs independently of the power supply switch. (Keep this circuit connected to answer some of the questions that follow.)

2 For each circuit, connect the components together to match your circuit diagram.

3 Turn on your circuit and check that it operates as desired.

4 Turn off the electricity before you move onto the next circuit.

- Which circuit arrangement made the light bulbs brighter: circuit 2 or circuit 3?
- Why does the switch in circuit 4 only affect one of the light bulbs?
- Use a voltmeter to measure the voltage across each light bulb in circuit 4. What does this tell you about the transfer of energy in this type of circuit?
- Add an ammeter to each loop in circuit 4 to measure the current coming from the power supply. What does this tell you about the flow of electrons in this type of circuit?

Transistors and integrated circuits

The invention of a component called the transistor in 1947 heralded the dawn of the electronic age. The team who invented it received the 1956 Nobel Prize.

A transistor is made from a material called silicon, which is a semiconducting

material. The three legs of a transistor (see Figure 3.49 on page 144) are known as the collector, base and emitter. A transistor has two main functions. Firstly, it can act as a switch, although it has no moving parts. In this role it can control the functioning of many electronic circuits, including computers. Secondly, a transistor can act as an amplifier. When a small current flows



Figure 3.48 A 1950s transistor radio.

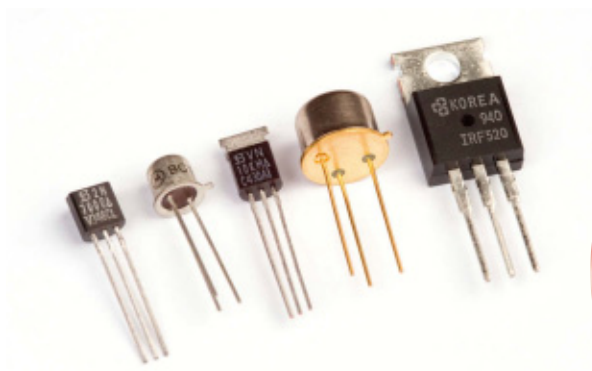


Figure 3.49 Transistors come in different shapes and sizes. The miniaturisation of transistors has revolutionised electronics and computing.

into a transistor, the transistor amplifies it to produce a larger current. The transistor replaced larger devices called vacuum tubes or valves that were used to amplify radio signals. This made the new 'transistor radio' much more portable.

A semiconductor is a material that carries or conducts electricity better than an electrical insulator (which does not conduct electricity at all) but not as well as a pure conductor. Electrical conductors and insulators behave the same as thermal ones. Electrical conductors carry or pass electricity easily and electrical insulators block electricity.



Figure 3.50 When it was introduced in March 1998, this operational amplifier, containing 50 transistors, was the world's smallest integrated circuit. Even smaller integrated circuits are now used in phones, games and many other electronic devices.

These days, many millions of semiconductor devices can be printed onto wafers of silicon, called silicon chips. The finished device is called an **integrated circuit** (IC) or microchip. An IC is a miniaturised electronic circuit. It may contain many thousands of components yet it is only 5 millimetres square and 1 millimetre thick.

QUESTIONS 3.2.1: ELECTRICAL CIRCUITS

Remember

- 1 Recall how energy is transferred in a simple circuit.
- 2 Identify the essential components of an electrical circuit.
- 3 Describe the similarities and differences between series and parallel circuits.
- 4 Identify the role of a switch in a circuit.
- 5 Recall the two roles of a transistor.

Apply

- 6 Draw a series circuit containing a cell, a switch, a light bulb and an electric bell. Is it possible to turn the bell on while the light bulb is off? Explain your answer.
- 7 Draw a parallel circuit with a single light bulb and a resistor on one pathway, and an electric motor on the other.
- 8 Redraw the parallel circuit in question 7 but this time insert a switch that will turn the light bulb on and off without affecting the motor.
- 9 Explain what is significant about the name 'transistor radio'.
- 10 Identify the major contributing factor to the small size of today's computers.

ELECTRICAL ENERGY TRANSFORMATIONS

Electrical energy is very versatile as it can be transformed into most other forms of energy. We rely on electrical energy for heating and cooling, for making dark places light, and for recording and producing sound. Many of the energy transformations already discussed in this chapter involve electrical energy at some stage.

Electric lighting

Humans have been using light energy for thousands of years in both simple and complex gadgets, but the most obvious use of light is for illumination. You may be using light for this purpose right now. What types of light bulbs are installed in the room you are in?

Fluorescent tubes are common in schools. These are long glass tubes filled with mercury gas. This type of light bulb doesn't generate much heat, so it is more efficient than the older-style incandescent (or filament) light bulbs and uses less electrical energy to produce the same amount of light. The Australian Government started to phase out the sale of incandescent light bulbs from November 2009, replacing them with **compact fluorescent lights (CFLs)** as an energy-saving alternative. Most CFLs are designed to replace existing filament bulbs and fit in the same sockets. The CFLs use less energy than the filament bulbs and last much longer.

Light-emitting diodes (LEDs) are tiny light bulbs (Figure 3.53). When they

are grouped together, they can produce extremely bright light with very little energy. LEDs come in a large range of colours and are used extensively for illumination in torches, traffic lights and garden lighting. They tend to last a long time before they 'blow', which makes them a good alternative to incandescent bulbs in traffic lights and other signs.

Solar cells turn light from the sun directly into electricity. Solar cells are used to power many devices such as calculators, streetlights and even cars. Many houses use solar cells in panels to produce their own electricity from the Sun.

Everyday electrical energy

Most people living in Australia have access to electricity and have come to depend on it. As well as for our lighting, we use electrical energy around the house every day. Electricity is generated in different types of power stations. Whether these power stations are fuelled by coal, geothermal energy, wind, wave or nuclear energy, they all have one thing in common – a **generator**. A simple generator moves a strong magnet inside a dense coil of wire. The movement of the magnetic field within a coil of wire attracts the negatively charged electrons and starts them moving in the wire. Moving electrons are what make up an electric current, which provides electrical energy.

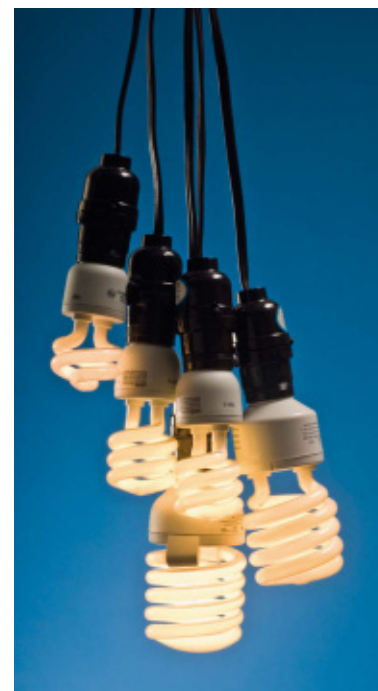


Figure 3.51 Compact fluorescent lights (CFLs) are an energy-saving form of lighting.



Figure 3.52 Solar-powered signs are becoming common all across our country. These signs transform solar radiation into light energy.



Figure 3.53 (a) Light-emitting diodes (LEDs) are tiny bulbs that use very little energy. (b) LEDs are commonly used in torches.

ACTIVITY 3.2.3: ELECTRICAL ENERGY TRANSFORMATIONS

Imagine you are walking around your house and your neighbourhood. Try to think of all the devices that either plug into the wall or run off batteries. With a partner, or in a small group, try to complete the examples of energy transformations in Table 3.6. See if you can come up with some different energy transformations involving electrical energy.

Table 3.6 Examples of energy transformations.

Input energy	Output energy	Example 1	Example 2
Electrical	Kinetic		
Electrical	Chemical potential		
Chemical potential	Electrical		
Electrical	Light		
Light	Electrical		
Electrical	Sound		
Electrical	Thermal		

Transporting electrical energy

Besides being able to undergo a large range of transformations, electrical energy has other advantages over other types of energy. Electrical energy can be transferred from one place to another without having to change form. Overhead transmission lines transport electricity from a power station to our houses, schools and businesses.

The voltage or the electrical energy carried in the transmission lines between towns is extremely high, usually between 130 000 and 500 000 V. Before it reaches your suburb, the voltage is dropped to around 11 000 V, but this is still enough energy to power almost the whole of your suburb!

Devices called **transformers** reduce the amount of energy in the power lines to make it safer to use. The electricity in your house is only 240 V. If the voltage of the electricity in your house were higher than this, devices using the electricity could not transform that much energy fast enough and would end up producing heat instead. This can cause sparks and fires.

Your laptop, mobile phone and MP3 player do not need 240 V of energy, and therefore have step-down transformers as a part of their charger cables. The block on the plug or on the cable itself contains the transformer. As the step-down transformer reduces the amount of energy in the electricity, some of that energy is transformed into heat. You can often feel this heat when your device has been on for a long time.

Storing electrical energy

Most forms of energy cannot be stored for use at a later time. You cannot collect sunlight in a box to read by at night! But electrical energy is so easily transformed into chemical energy and back again, it is as though we are storing electricity. Batteries of all shapes and sizes store electrical energy in the form of chemical potential energy.

Batteries can either be single use or rechargeable. Single-use batteries are thrown away once they are 'dead'. The chemical reactions that take place inside them to release electrical energy cannot be reversed, so once the ingredients of the reaction have



Figure 3.54 Batteries come in all different shapes and sizes, such as (a) everyday batteries and (b) car batteries, but they all transform chemical potential energy into electrical energy.

run out, no more electricity can be released.

Rechargeable batteries use different chemicals and their reactions are reversible. When you put electrical energy back into the rechargeable battery, the chemical products are broken back down into the ingredients again.

These reversible chemical reactions are not perfect though. After a while the

ingredients break down or are turned into something else. So even rechargeable batteries fail after a while.

There are many different types of rechargeable batteries. The most recent ones are lithium ion batteries. A car battery is a rechargeable lead-acid battery. It constantly discharges and recharges when the car engine is running.

QUESTIONS 3.2.2: ELECTRICAL ENERGY TRANSFORMATIONS

Remember

- 1 Recall the three common types of light bulbs.
- 2 Identify the function of step-down transformers.
- 3 Recall at least two places where you would find step-down transformers.

Apply

- 4 Draw a labelled flow chart to explain the voltage conversions of electrical energy from the transmission lines to the power line in your street, and then to the electricity that comes into your house.
- 5 Identify an advantage of CFLs over incandescent light bulbs.
- 6 Explain how a battery is different from a generator in the way it produces electrical energy.
- 7 Solar-powered lights use light energy to produce light energy. Explain whether or not any energy transformations have occurred.
- 8 Propose why the Australian Government has phased out incandescent light bulbs.

3.2

CHECKPOINT

ELECTRICAL ENERGY

Remember

- Recall three advantages of LEDs over incandescent bulbs. [3 marks]
- Complete the following sentences:
 - Electrical energy is carried by _____ around a circuit. [1 mark]
 - Electrical energy is measured in _____. [1 mark]
 - The flow of electrons moving in a circuit is measured in _____. [1 mark]
 - Every electrical circuit needs a _____, connecting wires and a load. [1 mark]
- Recall the function of a voltmeter. [1 mark]
- Explain how a switch works in an electrical circuit. [2 marks]

Apply

- Examine Figure 3.55 carefully and answer the following questions.
 - Identify whether the circuit is a series or parallel circuit. [1 mark]
 - Identify all the components within the circuit. [4 marks]
 - If the component labelled A were to break, explain whether components B and C would still work or not. [3 marks]

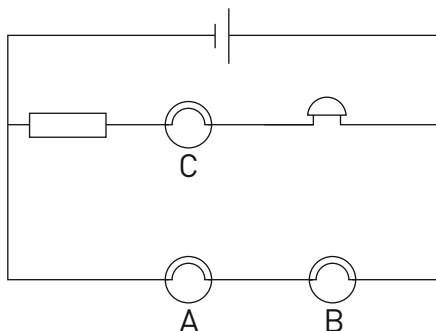


Figure 3.55 An electrical circuit.

- List the different types of light bulbs in order from the one that produces the most waste energy to the one that produces the least. Explain why they are so different. [4 marks]
- Explain why electrical energy can be used to produce sound, light, heat and motion. [1 mark]
- Describe the steps you would take to determine the exact amount of electrical energy being used by a light bulb in a circuit. [3 marks]
- Explain why step-down transformers are required before electricity reaches your house. [1 mark]

Research

- Many types of light energy exist. Research the electromagnetic spectrum and the different types of radiation it contains. List them, and state a use for each type. [4 marks]
- Car batteries are a vital component in a car. Investigate what they are used for and how they are recharged. Present your information as an annotated poster or a short presentation. [4 marks]
- Investigate the development of the light bulb throughout history. Who invented the first light bulb? What other types of bulbs have been invented? What do the most modern light bulbs look like? What is their advantage over older versions? Present your findings on an annotated timeline, including diagrams. [5 marks]



Figure 3.56 Illumination technology has changed a lot over the years.

TOTAL MARKS
[/40]

INCREASING ENERGY EFFICIENCY

3.3

Energy efficiency is a phrase being used more and more often. It is also often paired with the term 'sustainability'. But what is energy efficiency? How do we become more energy efficient? In what ways have scientific knowledge and technological developments helped to increase the efficiency of energy use and transformations? What are the benefits of energy efficiency to society and to the environment?

ENERGY EFFICIENCY

Energy efficiency is a measure of how much energy is transformed into the desired energy type, compared with the amount that might be a by-product and lost as heat, sound or other types of energy. Most energy conversions are inefficient and lead to the production of wasted energy. A light bulb is designed to transform electrical energy into light energy, so if heat energy is also produced, it takes energy away from the original purpose – to produce light.

The most common form of by-product energy is heat, or thermal energy. Thermal energy is difficult to use, it cannot be stored, and often damages the device itself if too much is produced.

Reducing the amount of by-product energy transformed by a device is the ultimate goal of many scientists, which promotes the search for better energy efficiency. Many appliances now come with efficiency star ratings (Figure 3.57).

A trampoline transforms elastic potential energy into gravitational potential energy so you can bounce. If a device such as a trampoline transforms most of its input energy into the useful output energy, then it is considered to be a very energy-efficient device. All energy transformations produce by-product energy forms. In the case of the trampoline, by-product energy forms include heat and the sound of the springs squeaking. Both these by-product energy forms reduce the amount of 'bounce' energy and are said to be 'wasted' energy. The less wasted energy, the more energy efficient the device. Energy efficiency is calculated as the percentage of useful energy transformed out of all the available input energy. The scientific unit of energy is joules (J).

To calculate efficiency as a percentage, the electrical energy output is divided by the energy input before being multiplied by 100:

$$\text{Efficiency} = \frac{\text{Energy output}}{\text{Energy input}} \times 100$$

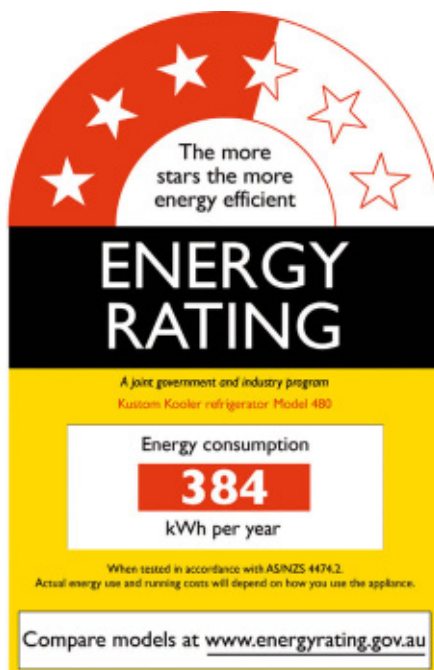
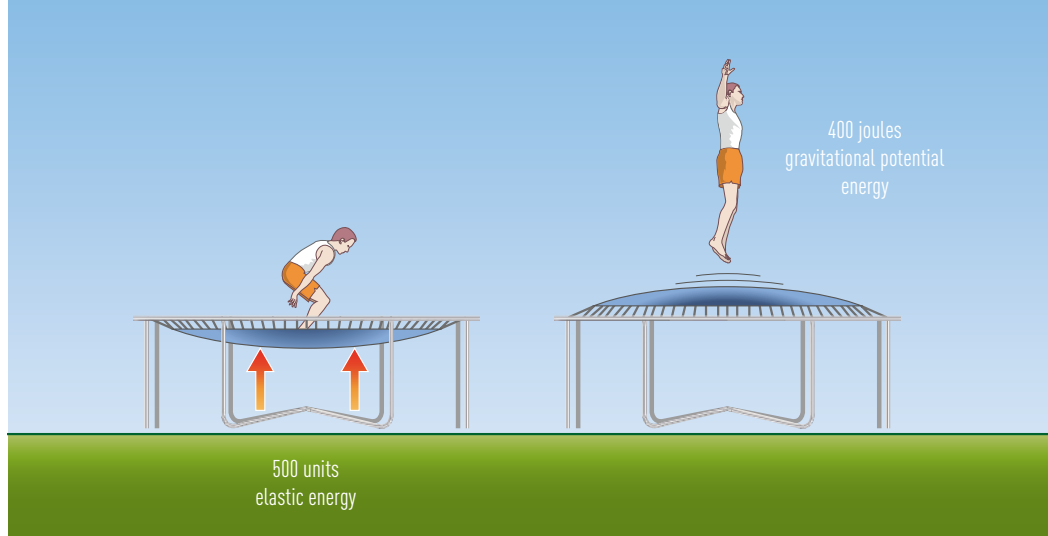


Figure 3.57 More stars mean an appliance is more energy efficient.

Figure 3.58 500 joules of energy are stored in the springs of the trampoline. At the highest point, the jumper has 400 joules of gravitational potential energy. Where have the 'missing' 100 joules gone?



Consider the efficiency of the trampoline in Figure 3.58. The input energy was 500 joules and the useful output energy was 400 joules. This means that the trampoline is $400 \div 500 = 0.8$ efficient, or 80% efficient, which is not too bad. Most energy transformations for everyday appliances do not get this high.

Scientists are constantly trying to design the best appliances possible with the highest efficiency ratings. This would make the

devices better for the environment and cost less to power. Do you and your family always buy the most efficient appliances? More stars mean that the appliance is more energy efficient. When you are using an appliance with a high-star rating you know that less energy is being wasted. This means you pay less on your electricity and gas bills, as you are only paying for the energy being used rather than lots of energy being 'wasted'.

ACTIVITY 3.3.1: ENERGY EFFICIENCY RATINGS

Many people leave their energy efficiency rating stickers on their appliances, but if yours have been removed, a quick Internet search of the appliance brand and model number will determine the rating of your appliances. Most appliances have their model number printed on them somewhere, often on a metal plate on the back or inside of the appliance.

Investigate the energy efficiency rating of your major household appliances, such as the refrigerator, washing machine, clothes dryer and dishwasher.

- Is the number of stars related to the energy consumption?
- Identify the full name of the unit kWh.
- Compare your results with those of some classmates. Are particular appliances typically more or less efficient than others?

QUESTIONS 3.3.1: ENERGY EFFICIENCY

Remember

- 1 Define the term 'energy efficiency'.
- 2 Explain why by-product energy transformations are considered 'wasted' energy.

Apply

- 3 Explain why it is better to buy energy-efficient appliances.
- 4 Propose a reason why 6-star energy-rated appliances are rare.
- 5 A friend of yours is considering buying a 2-star energy-rated device because it is slightly cheaper than a 4-star device. Outline the advice you would give your friend.

EFFICIENT ENERGY GENERATION AND USE

It is becoming more common to read and hear about how we need to be more energy efficient in our lives. In these cases, people are usually referring to switching off lights at home when we are not using them, or changing our light bulbs at home to more economical ones. There are other ways though to improve our energy efficiency.

ACTIVITY 3.3.2: WHICH IS THE MORE ENERGY EFFICIENT?

What you need: 2 different electric kettles of the same power rating (e.g. 2000 W), 500 mL measuring cylinder, thermometer, stopwatch

- 1 Empty both kettles and fill each of them with exactly 500 mL of cold tap water.
- 2 Check that the temperature of the water in both kettles is the same.
- 3 Plug both kettles in and turn them on at the same time. Use the stopwatch to time how long each one takes to boil the water.
- 4 Double-check at the end that the temperature of the water in both kettles is 100°C.
- 5 When both kettles have cooled down, tip the water out and repeat the experiment.
 - How do you know which kettle is the most energy efficient?
 - Why was it important to keep the conditions exactly the same for both kettles?
 - Was it really necessary to check the water temperature at the end of the test? Why?
 - Why was the experiment repeated?



Efficient lighting

We learnt about the different types of light bulbs in section 3.2, but how efficient is each type and how much does each type cost to run?

Cost comparison

NUMERACY
BUILDER

To calculate the cost of buying and running each of the three types of light bulb listed in Table 3.7, we need to compare them over the same length of time, for example, 50 000 hours. In this time, only one LED bulb would be needed as they last the longest. It would require five CFL bulbs as they last about 10 000 hours. However, 50 of the older incandescent bulbs would be needed as they only last about 1000 hours each.

Example

Incandescent bulbs

The number of incandescent bulbs needed for 50 000 hours of use is 50, at \$1.50 each. So the total base cost of buying the bulbs is:

$$50 \times \$1.50 = \$75$$

Table 3.7 A comparison of light bulbs.

Bulb	Wattage (w)	Life (h)	Cost (\$)	No. bulbs for 50 000h	Cost for 50 000 h (\$)
Incandescent	60	1 000	1.50	50	375
CFL	14	10 000	3.50	5	?
LED	10	50 000	20.00	1	?

Now look at electricity running costs. Incandescent bulbs use 60 watts or 0.06 kilowatts ($60 \div 1000$) of electrical energy.

The number of kilowatt hours (the unit we use to pay for electricity) is:

$$0.06 \text{ kW} \times 50\,000 \text{ hours} = 3000 \text{ kWh}$$

At an average cost of 10 cents per kWh (or \$0.10), that would cost:

$$3000 \text{ kWh} \times \$0.10 = \$300$$

So the total cost of buying and running enough incandescent bulbs for 50 000 hours is:

$$75 + 300 = \$375$$

Your turn

Perform similar calculations for the CFL bulb and the LED bulb to complete the table and see which is the most cost-effective alternative.

Some things to consider

- Estimated figures are given in the table. At the time of writing this textbook, LED bulbs were expensive at approximately \$20 each. You might like to research more current prices.
- An estimated cost of electricity as \$0.10 per kWh was used for the example. You might also like to research more current costs.



Figure 3.59 Solar panels can be used to heat water for your house.

Efficient electrical energy generation

Just as the efficiency of electrical energy usage can be measured, so too can the efficiency of electricity generation. Many different energy transformations can take place to result in electrical energy, but not all of them are efficient.

Solar panels

When it is sunny outside, your school or home could benefit from solar panels on the roof to transform the sunlight into usable electricity. This electricity could power the lights, computers, cooling or heating system. Anything connected to a power point could run off the solar panels.

A solar panel system at home could pay for itself after 4–7 years and may last approximately 25 years. Another benefit of using solar panels is that you do not have to pay for the electricity the panels generate. You may even get a refund from the electricity company if the panels generate more electricity than the home or the school uses.

Scientists and engineers are still researching and investigating solar panel design to improve their efficiency. The first

solar panel was only around 7% efficient. That is, for every 100 W of sunlight that hit the panel, only 7 W of electricity was produced.

In May 2013, researchers at the University of New South Wales discovered that hydrogen atoms could be used to improve the efficiency of the silicon-based solar cell to around 23%. That may not seem like much of an improvement, but every little bit counts. Because there is so much energy in sunlight, even a 1% improvement makes a dramatic difference to the amount of electrical energy that can be transformed.



Figure 3.60 Installing solar panels on your roof could make a big difference to your electricity bills. It is something your household should consider?



Figure 3.61 A wind farm in South Australia.

Wind turbines

Wind power is increasing in popularity as a non-polluting, renewable energy source. Worldwide, its use is increasing at a rate of approximately 35% every year. Some countries, such as the United States, the Netherlands, Germany, the United Kingdom and Denmark, rely heavily on wind power. Denmark currently uses the wind to supply 20% of its electricity, with plans to increase this to 35% by 2015. In Australia, wind farms account for only 1% of our electricity production. However, South Australia has embraced wind power technology with about 15% of its energy produced by wind farms (Figure 3.61), and there are plans for more wind farms in the future.

In the production of wind power, there are no chemical or heat energy steps. The kinetic energy of the wind spins the rotor blades, which spins the generator and produces electricity.

Future wind turbines may take the form of blimps that float 100–300 metres high in the air. The Magenn Air Rotor System (MARS) is one such proposal (Figure 3.62). Originally designed for generating electricity in remote areas, the blimp is tethered to the ground and the whole structure spins as the wind blows over and around it. Inflated with a low density gas such as helium, the MARS

is relatively easy to install and deploy.

The most notable features of a wind turbine are the tall towers and huge rotor blades that spin at anything from 5 to 20 revolutions per minute (rpm). The actual generator component is tiny in comparison.

Wind power is increasing in popularity as an energy source for two main reasons. Advances in wind power science are increasing the cost-effectiveness of wind power. Wind turbine design has come a long way and wind power now rivals coal and oil in terms of cost, as well as offering many other advantages. The second main reason for its popularity is that wind power is non-polluting when operating.

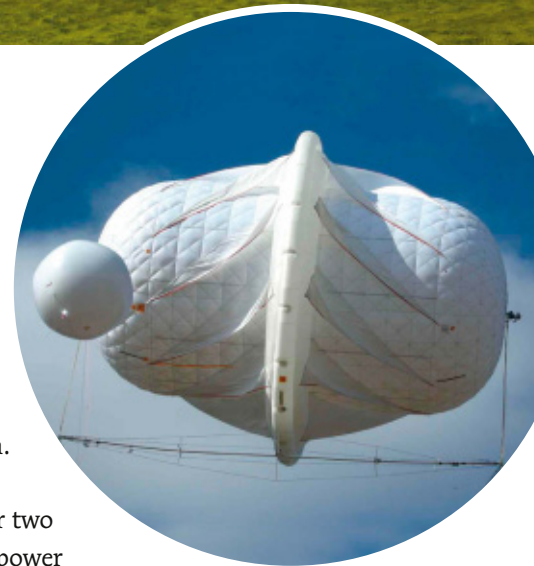


Figure 3.62 A Magenn Air Rotor System (MARS) wind turbine.

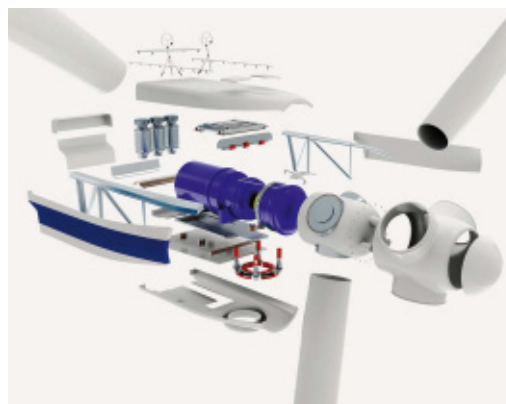


Figure 3.63 The generator inside a wind turbine.

Energy efficiency and the environment

If a new washing machine is more energy efficient than an old one, it means the new appliance will use less energy to do the same job.

The term 'energy efficiency' is often used to represent any type of energy-saving technique, although this is not technically correct. The term 'energy conservation' is even better. It means reducing the energy used in the first place. For example, walking to school rather than being driven means

the energy expended by the car is not used at all. Some people fall into the trap of using their new, more energy-efficient device for longer than they used their old one, or not worrying about switching off the lights when they aren't being used because they are energy-saving light bulbs. It is important to remember that energy-saving devices do not save energy if you use them significantly more than the older version.

To reduce carbon emissions and help save the environment, energy efficiency is just one side of the issue. Improving energy efficiency does not necessarily mean a reduction in CO₂ emissions. If the energy is supplied from fossil fuels, such as petrol in a car or electricity generated by a coal-fired plant, then improved efficiency will cut emissions. However, if the energy is supplied by another source, such as wind or solar power, then improving efficiency may have little or no impact on CO₂ emissions.

Improving energy efficiency is always a good idea. When practised along with energy conservation and higher use of renewable energy, the environment and the consumer can both benefit.



Figure 3.64 Instead of being driven to school, walking or riding your bike conserves the energy that would have been expended by the car.

QUESTIONS 3.3.2: EFFICIENT ENERGY GENERATION AND USE

Remember

- 1 Recall at least two methods of improving electrical efficiency around your home and school.
- 2 Recall how a generator transforms energy into electrical energy.
- 3 Identify the unit of energy used by electricity companies to determine the amount of electrical energy you have used.
- 4 Identify some devices in your home that need a supply of electrical energy. Do any of them have non-electric options? (For example, a whisk or wooden spoon could be used instead of an electric mixer in the kitchen.)

Apply

- 5 Propose some problems with using solar panels as a main source of electrical energy.
- 6 Outline some advantages of the MARS wind turbine over the wind turbines currently in use.
- 7 A large group of wind turbines in the same location is called a wind farm. Propose a possible location for a wind farm. List as many features of a suitable location as you can.
- 8 Explain what it means if a device is said to be 'cost-effective'.
- 9 Explain what it means if a new energy system 'pays for itself'.

INCREASING ENERGY EFFICIENCY

3.3

CHECKPOINT

Remember and understand

- 1 Recall the features that help to determine what type of light bulb is the most cost-effective. [2 marks]
- 2 Describe the energy transformation that occurs in a solar panel. [3 marks]
- 9 Prepare and carry out an audit of your home lighting. How many of each type of light globe do you have? Could the lighting in your home be improved? Research lighting costs and efficiency on the Internet, at a hardware store or a lighting store. Use the information gathered to produce a cost analysis for improving the lighting at your home. Are there alternatives that would cost less? Prepare a report with a summary of your findings and recommendations for improvement. [6 marks]

Apply

- 3 Explain why most wind turbines are mounted on towers 40–100 metres high. [1 mark]
- 4 Coal-fired power stations in New South Wales run 24 hours a day, 7 days a week. Determine whether wind power or coal-fired power could be considered more reliable. Explain your answer. [2 marks]
- 5 Explain the term 'energy efficiency'. [2 marks]

Analyse and evaluate

- 6 Calculate the percentage efficiency of a device if it transforms:
 - a 20 joules of input energy into 12 joules of useful output energy [1 mark]
 - b 600 joules of input energy into 500 joules of useful output energy. [1 mark]
- 7 Describe where the missing joules of energy went in question 6. [1 mark]
- 10 Solar panels and wind turbines may one day replace coal-fired power stations. Which form of energy would you prefer to supply your power and why? [3 marks]
- 11 Propose some problems associated with expecting people to change their current lighting systems or energy usage at home. [3 marks]

Critical and creative thinking

- 8 Research and identify where the major wind farms in New South Wales are located. Create an annotated poster that identifies their locations, their electrical energy production capabilities, how they compare to other wind farms around the country and what plans are in place to build more wind farms in the state. [6 marks]

Ethical understanding

- 10 Solar panels and wind turbines may one day replace coal-fired power stations. Which form of energy would you prefer to supply your power and why? [3 marks]
- 11 Propose some problems associated with expecting people to change their current lighting systems or energy usage at home. [3 marks]

Research

- 12 Investigate the star rating system for indicating the energy efficiency of appliances. Identify how the star rating for an appliance is determined. Present your information as an annotated poster or a short presentation. [4 marks]



TOTAL MARKS
[/35]

3

CHAPTER REVIEW

- 1 Fill in the gaps using the words in the Word Bank below:

Energy comes in many different forms, such as thermal, light, sound, _____, electrical and potential energy. It cannot be created or _____, but it can be transferred or _____ into a different type.

Thermal energy can be _____ in three different ways: conduction, _____ and radiation. Electrical energy is transferred in electrical _____ and then transformed into almost any other form of energy by the _____ in the circuit.

Most energy transformations also produce by-product energy, most commonly _____, which reduces the _____ of the device. Scientific knowledge and technological developments have led to the improvement of energy efficiency, such as the invention of CFLs and _____. Increased energy efficiency means less energy is _____, which is _____ for individuals and better for the environment as fewer resources are consumed.

WORD BANK

circuits	efficiency	more economical
components	heat	transferred
convection	kinetic	transformed
destroyed	LEDs	wasted

Identify objects that have either kinetic or potential energy

- 2 Define the following terms and provide an example for each:

- a gravitational potential energy [2 marks]
- b biofuel [2 marks]
- c kinetic energy. [2 marks]

- 3 Explain all the ways that energy can be stored. [2 marks]

- 4 Identify whether a spring or a string has more advantages for storing elastic potential energy. Explain your answer. [2 marks]

Investigate everyday energy transformations involving heat, light, sound, electricity and motion

- 5 Compare an electric- to a petrol-driven car to answer the following questions:

- a Identify the main energy transformations that occur in a petrol-powered car. [2 marks]

- b Identify the main energy transformations that occur for an electric car. [2 marks]

- c Identify the advantages and disadvantages of each type of car. [2 marks]

- d Explain how hybrid cars are different from both petrol and electric cars. [2 marks]

- 6 Explain the difference between an energy flow diagram and an energy chain. [1 mark]

- 7 Identify a device that performs the following energy transformations and draw an energy flow diagram or energy chain as appropriate:

- a light energy to sound energy [2 marks]
- b kinetic energy to heat energy [2 marks]
- c electrical energy to sound energy [2 marks]
- d chemical potential energy to light energy. [2 marks]

Describe the process of conduction, convection and radiation using examples

- 8 Compare and contrast conduction, convection and radiation. [3 marks]
- 9 When a hot brick is placed into a bucket of water, the water gets hotter as thermal energy spreads from the brick into the water. Identify if this process is called conduction, convection or radiation. Explain your choice and why it is not the other options. [2 marks]
- 10 An electric kettle uses a heating element to heat water. This process involves both conduction and convection. Explain where each process occurs to heat the whole jug of water. [2 marks]

Relate electricity to the transfer of energy

- 11 Define the term 'electrical energy'. [2 marks]
- 12 Describe why circuits are needed to transport electrical energy to components and devices. [1 mark]
- 13 Compare conduction of thermal energy with the transfer of electrical energy. [2 marks]

Construct circuits and draw circuit diagrams with various components

- 14 Explain why circuits are drawn as diagrams rather than as detailed pictures. [1 mark]
- 15 Draw a circuit diagram for a circuit that contains a power supply and three light globes in a parallel circuit, with a switch in series with one of the light globes. [2 marks]
- 16 Explain the difference between how two light bulbs in a series circuit and two bulbs in a parallel circuit are arranged. [2 marks]

Trace the history of the development of an electrical device (additional content)

- 17 Briefly describe the development of the light bulb and explain why these improvements have been made. [3 marks]
- 18 Explain why scientists and engineers continue to research the design of solar panels. [2 marks]

Investigate everyday energy transformations involving electrical energy

- 19 Draw an energy flow diagram for the following activities:
 - a hearing a loudspeaker [1 mark]
 - b using a hairdryer [1 mark]
 - c listening to an iPod [1 mark]
 - d using a microphone. [1 mark]
- 20 Explain how electrical energy is transformed and transported. [2 marks]

Identify that most energy transformations are inefficient and produce heat energy

- 21 Define the term 'by-product'. [1 mark]
- 22 List four different energy transformations that produce heat as a by-product. [4 marks]
- 23 Calculate the percentage energy efficiency of a device that turns 200 J of input energy into 150 J of useful output energy. [2 marks]
- 24 What is the percentage efficiency for a device that transforms 40 J of energy into 30 J of useful sound energy and 10 J of wasted heat? [2 marks]



Figure 3.65 Electric kettles use both conduction and convection to boil the water.

Research how scientific knowledge and technological developments have improved energy efficiency

- 25** Explain why LEDs are becoming more commonly used than incandescent bulbs. [2 marks]
- 26** Compare LEDs, CFLs and incandescent bulbs in terms of their energy efficiency. [3 marks]

Discuss the implications for society and the environment of increasing energy efficiency

- 27** 'Solar panels for my house are too expensive and will cost me too much money in the long term'. Evaluate this statement and write a response to support or disagree with it. [2 marks]

- 28** Calculate the cost of running a 15-watt CFL light globe for 100 000 hours if it costs \$4.00 for each bulb, the bulbs last 10 000 hours each and electricity costs \$0.15 per kWh. [3 marks]
- 29** Is there an endless supply of energy on the Earth or do you think it will run out one day? Justify your answer. [4 marks]
- 30** What are two major benefits wind power offers over conventional coal-fired power stations? [2 marks]

TOTAL MARKS
[/80]

RESEARCH

Choose one of the following topics to conduct further research. A few guiding questions have been provided for you but you should add more questions that you want to investigate. Present your findings in a format that best fits the information you have found and the understandings you have formed.

Energy-efficient housing

In the past, energy efficiency was important because people had limited access to the types of energy supplies and their

applications that we have today. Research how civilisations in hot and humid climates designed their homes to keep them cool and damp free. What different types of energy-efficient practices have humans used throughout the ages?

Perpetual motion machine

What is a perpetual motion machine? Is it possible to build one? Who has tried to do it and what were their designs? How efficient were the machines? Is anyone working on one of these machines nowadays?

Figure 3.66 The unique design of Queenslander houses provides natural cooling in the tropical climates.



Me

- 1 What new science laboratory skills have you learned in this chapter?
- 2 What was the most surprising thing you found out about energy?
- 3 What were the most difficult aspects of this topic?

My world

- 4 Why is it important to understand energy?
- 5 How important is it for scientists to understand energy transformations?

My future

- 6 How might energy resources change in the future?
- 7 Do humans need to change the way they use energy?

KEY WORDS

biomass energy
chemical potential energy (CPE)
circuit diagram
compact fluorescent light (CFL)
conduction
convection
elastic potential energy (EPE)
electric circuit
electrical energy
energy
energy efficiency
energy transformation
generator
gravitational potential energy (GPE)
integrated circuit (IC)

kinetic energy (KE)
light-emitting diode (LED)
light energy
load
nuclear energy
parallel circuit
potential energy (PE)
radiation
series circuit
solar cell
sound energy
speaker
thermal energy
transformer

3

MAKING CONNECTIONS

Design your own mousetrap car

Many devices transform energy from one form to another. The humble mousetrap works on this principle. It uses the elastic potential energy stored in a spring as its input and converts that to kinetic energy as the trap springs shut. In this activity, you will use the elastic potential energy of a 'loaded' mousetrap to build a model car that can run on its own mousetrap 'engine'.

When engineers design new machines, they produce very detailed plans called blueprints. Engineers also consider the concept of energy efficiency. For this challenge, you will need to work like an engineer. Follow the engineering process (see Figure 3.68) and use your understanding of energy transformations and energy efficiency to produce the best working model of a mousetrap car.

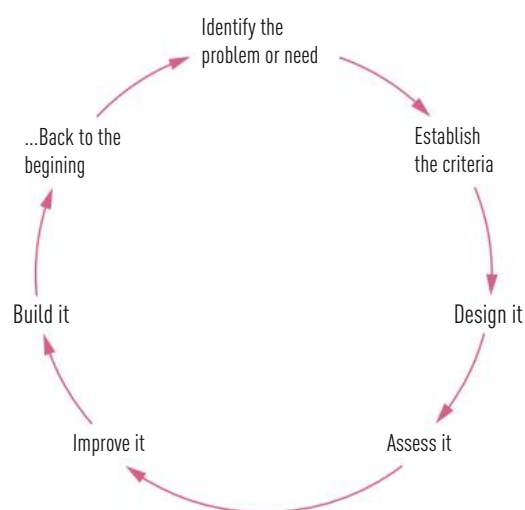


Figure 3.68 The development process.

Challenge

Identify the problem: to build a vehicle powered by a household mousetrap.

Questioning and predicting

Establish the criteria. Some questions to consider are:

- How you will get the movement from the mousetrap to the wheels?
- How heavy or light will your machine be?
- What materials will you use to make the machine?
- How are you going to construct it?

Planning and conducting Design

- Produce a detailed plan of your car design that shows how the elastic energy stored in the spring will be transferred to the wheels. List the materials you will use for each component. Remember, there may be some Lego parts that you can incorporate into your car design, and your school may be able to supply some of the equipment for you.

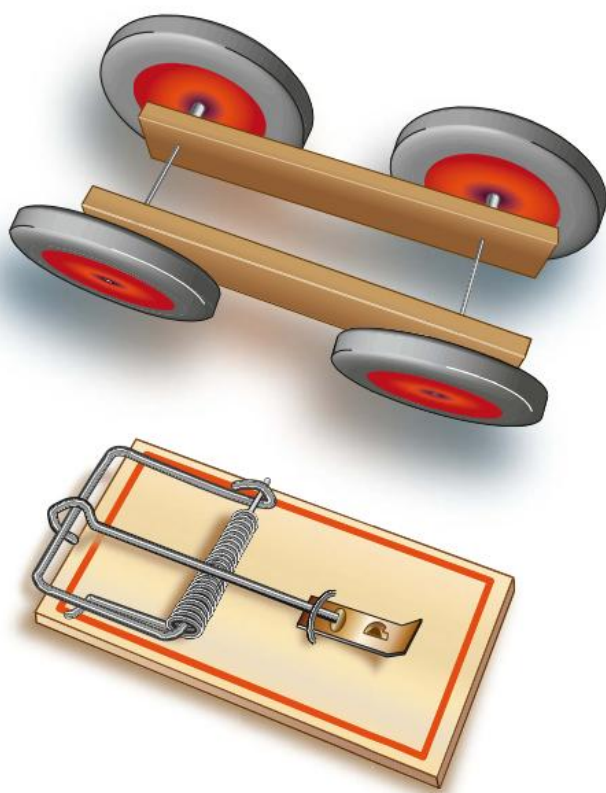


Figure 3.67 How will you use the elastic potential energy stored in the spring of the mousetrap to power the car?

- Make sure you consider safety in your design, complete a risk assessment and have your plan checked by your teacher before you proceed.

Assess and improve

- Reassess your design and incorporate any modifications it needs to improve its performance.

Build

- Build your prototype.

Processing, analysing and evaluating

- 1 How energy efficient is your model? If parts of your car rub too much on each other, they will create friction and the car will not travel very far. For example, if the wheels or axles are too tight, they will create drag and slow your car down.

Consider how to loosen or lubricate parts so this does not happen. Real cars use oil and grease for lubrication to prevent this happening.

- 2 How far did your car run?
- 3 What advantages did it have over other students' designs?
- 4 Did anything go wrong with your car?
- 5 How could your design be improved?
- 6 What types of energy were involved in your mousetrap vehicle?

Communicating

Imagine you had to explain to someone how you followed the engineering process so that they could build on your work. You want them to learn from your mistakes and understand why you made certain choices along the way. Present your thinking, processes, data and evaluation in a clear, interesting and appropriate way.



Figure 3.69 Engineers must consider energy efficiency when they are designing racing cars.

4



ELEMENTS, COMPOUNDS AND MIXTURES

We use elements, compounds and mixtures every day – from the pens we use to the cars we drive, everything is made up of elements, compounds and mixtures. Some materials, such as carbon, exist in different forms. Diamonds and the 'lead' in pencils are both made of carbon. Every element, compound or mixture we use has been selected for that particular job because of the properties it has. Developments in technology and increased scientific knowledge have changed how we use certain materials.

ELEMENTS 4.1

All substances are made up of particles. The way the particles interact and the nature of the particles themselves determine the properties of substances.

Students:

- » explain why element symbols are used in science
- » identify that our understanding of the structure and properties of elements has changed due to technological advances
- » describe the properties and uses of some metal and non-metal elements
- » investigate the nature of mineral crystals (additional)

COMPOUNDS AND MIXTURES 4.2

Elements are the basic components of chemistry. All substances are made of elements. There are 98 naturally occurring elements, but the number of different materials we have access to is much larger. How do we have so many different types of substances?

Students:

- » describe the differences between elements, compounds and mixtures
- » identify some common compounds
- » investigate how the chemical properties of a substance will affect its use (additional)

THE IMPACT OF ELEMENTS AND COMPOUNDS ON SOCIETY 4.3

Physical and chemical properties of materials are very important since they determine what the material can be used for. You would not want to wear clothes made of iron, and you certainly would not want buildings made from cotton! Human culture and society has evolved and developed because of our understanding of elements and compounds and their properties.

Students:

- » investigate how people in different cultures in the past have used certain substances to their advantage



4.1

ELEMENTS

All matter is made up of particles called atoms. An element is a pure substance – it is made up of only one type of atom. Different elements have different properties due to the atoms they are made of. These different properties help determine the uses of each element.

PARTICLE AND KINETIC THEORIES OF MATTER

In chapter 4 of *Oxford Insight Science 7*, you examined the particle model of matter. This section is a quick revision of this concept, as it is very important for our understanding of how elements and compounds behave.

The particle model of matter

For all substances, we can visualise the **particles** they are made of as being tiny balls. By imagining what these tiny balls would do, we are building a model that helps explain why substances behave as they do. These tiny balls are called atoms, and the model we use to visualise them is called the particle model of matter. The key concepts of the particle model are:

- All matter consists of tiny particles called atoms that are too small to be seen, but have mass.
- Atoms cannot be created or destroyed, and atoms are indivisible.
- Particles are always moving. When it is hotter, particles move faster; when it is cooler, particles move slower.

- All atoms of the same **element** are identical, but are different from atoms of other elements.
- Atoms can join together to form larger particles called molecules. When they combine, their masses add together.
- Different atoms can combine to form **compounds**.
- Forces hold molecules and compounds together to stop them from separating.
- Atoms follow these rules in all substances.

The kinetic theory of matter

The particle model of matter is always true. Every observation and every chemistry experiment can be explained with this model. Because it is always true and has huge amounts of scientific evidence to support it, the model is now called a theory. Its full name is the kinetic molecular theory of matter, but it is also known simply as the **kinetic theory** of matter.

In the particle model of matter, the particles are always moving. The word 'kinetic' refers to anything that is moving. '**Molecular**' refers to molecules, which are particles made of atoms. You will learn more about molecules later in this chapter.

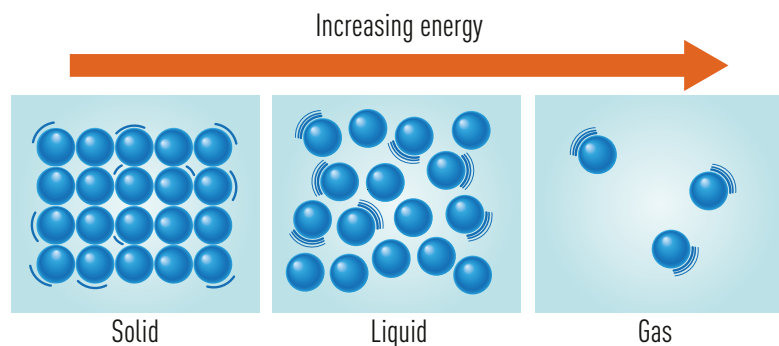


Figure 4.1 The movement of particles, as well as how much energy they contain, determines the state of the particles.

ACTIVITY 4.1.1: MODELLING ATOMIC BEHAVIOUR

From your work in year 7, as well as the revision provided on the previous pages, you will need to model some aspect of atomic behaviour. Think about the best models you should be using. What will you use to represent atoms? How you will show molecules? Choose three points in the particle model of matter that you can show with your model. Take photos of your model and present them to your classmates. How do your models compare to those of your classmates?

QUESTIONS 4.1.1: PARTICLE AND KINETIC THEORIES OF MATTER

Remember

- 1 Define the term 'atom'.
- 2 Explain the main concepts behind the particle model of matter.
- 3 Explain what the term 'kinetic' refers to in the kinetic theory of matter.

Apply

- 4 The images in Figure 4.2 are models of some aspects of the particle and kinetic theory of matter. Explain what each model is demonstrating.

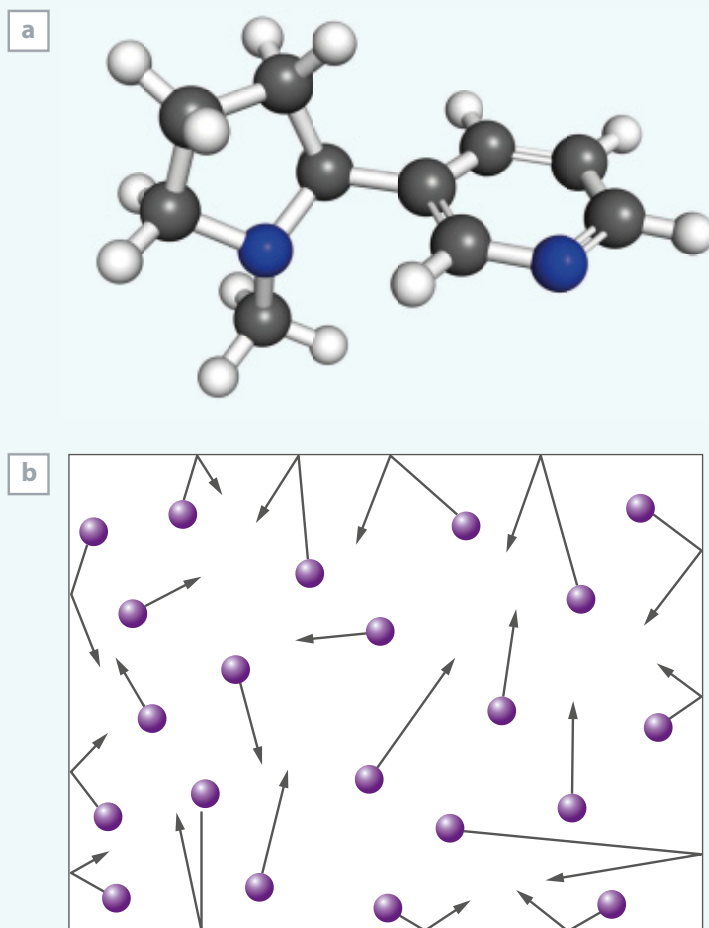


Figure 4.2

ELEMENTS

Elements are substances made up of only one type of atom, and are often referred to as pure substances. If we were to examine every single particle within an element, we would find that each one has the same structure. There are 98 different elements found naturally on the Earth. The smallest atom in terms of mass is the hydrogen atom. The next smallest is helium. Some of the heaviest atoms include those of lead and uranium. Another 20 or so atoms have been made artificially, but these are highly radioactive and are too large to be stable, and therefore they decay (break apart) almost as soon as they are made.

Elements cannot be broken down into other substances because they are already the simplest substances. If it was possible to break a lump of gold down to individual atoms, each atom would still be gold.

The differences in the atoms of the different elements explain why different elements have different properties.

Gold looks yellow because it is made up of gold particles. Platinum looks like a dull silver colour because it is made up of platinum particles. The different atoms also determine properties such as what certain chemicals will react with.

Everything that is unique about an element is due to the behaviour and nature of its atoms.

elements and to group elements with similar properties. Other scientists built on his work to produce the modern periodic table that we use today.

The periodic table groups together elements with similar properties. Horizontal rows in the table are called **periods**, and vertical columns are called **groups**. Elements in a group often have similar properties, such as the way they look or how they behave.

The main types of elements are **metals**, **metalloids** and **non-metals**. Metals are found on the left-hand side of the periodic table, non-metals are on the right and a thin band of metalloids are between the two. Metalloids are a small set of elements that show properties of both metals and non-metals.

Elements are also classified on the basis of their chemical properties. These include how they react with other substances, such as acids and the oxygen in the air. You will learn more about the chemical reactions of elements in chapter 5.

On the periodic table, elements are represented by their symbols. These symbols consist of one or two letters, often the first one or two letters of the element name. Some chemical symbols are related to the element's name, such as helium (He), hydrogen (H) and carbon (C). However, some symbols seem unrelated to their name, such as gold (Au), tungsten (W) and lead (Pb). This naming difference relates to when each element was discovered.

Most elements on the periodic table have been discovered in the last 200 years or so. These elements have usually been English-based names, so their chemical symbols make sense. However, some elements have been around since ancient times and their chemical symbols are based on the old Latin or Greek names, such as aurum (gold) and plumbum (lead).

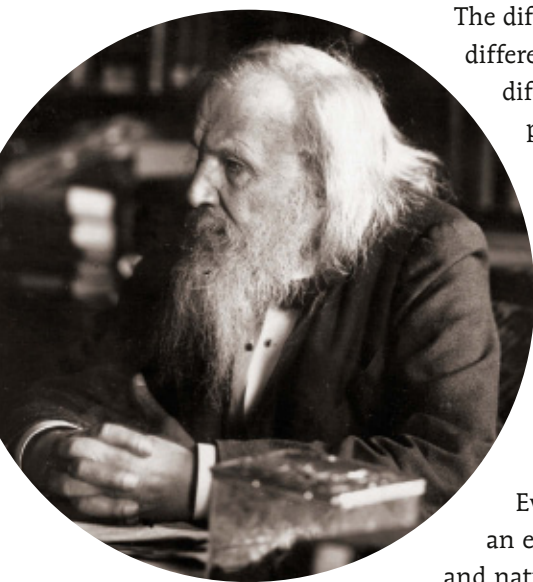


Figure 4.3 Dmitri Mendeleev is hailed as the creator of the periodic table.

Organising elements

The periodic table, as shown in Figure 4.4, arranges all the elements in order of their atomic number (the number of protons in their nucleus). The first modern periodic table was created by Russian scientist Dmitri Mendeleev to help organise the

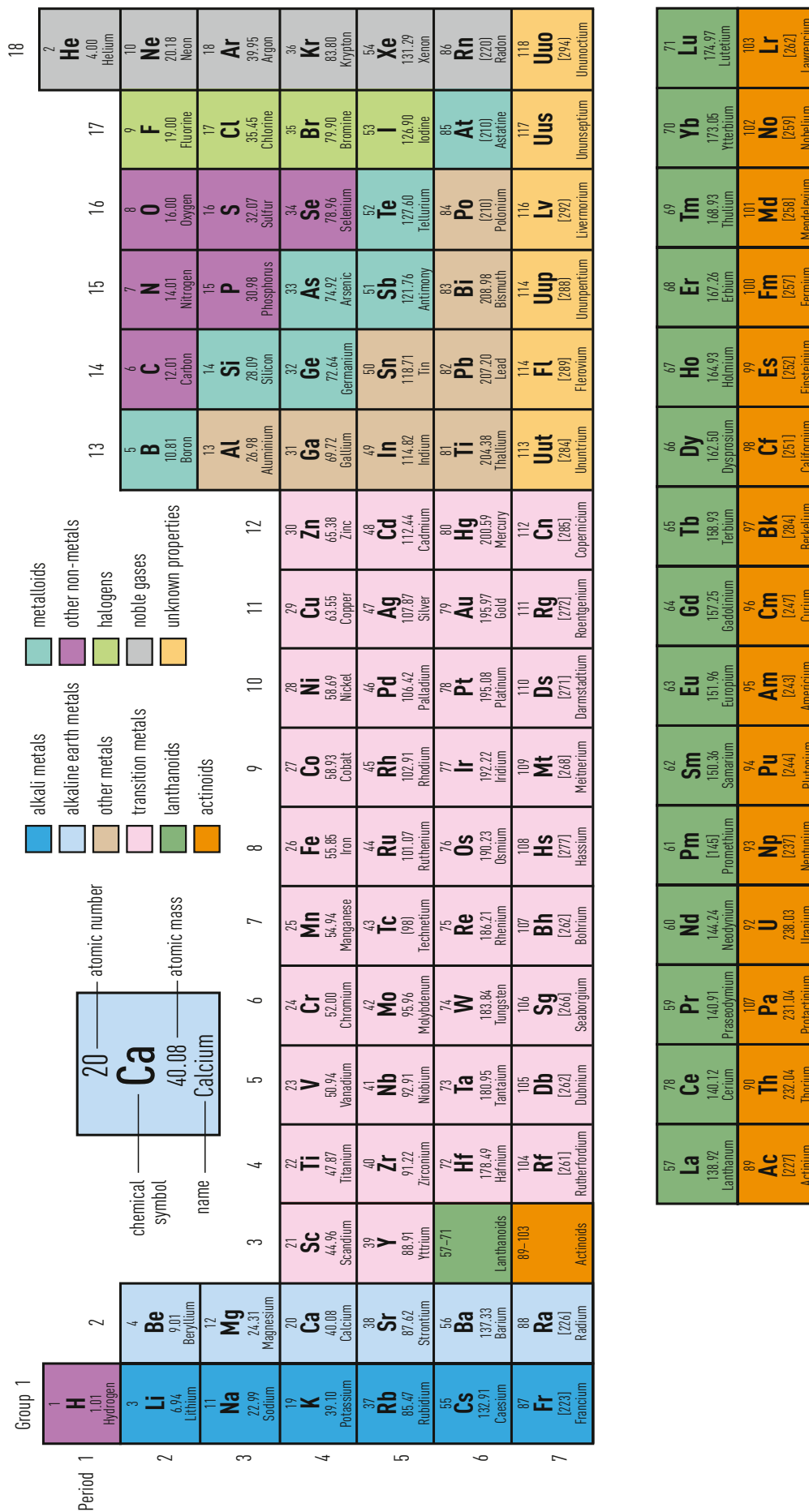


Figure 4.4 The periodic table of elements.

ACTIVITY 4.1.1: CLASSIFYING ELEMENTS

What you need: cardboard, felt-tip pens, scissors

- 1 Make up some cards like the ones shown in Figure 4.5 to represent the different elements.
- 2 Sort the cards into those with a one-letter symbol and those with a two-letter symbol.
 - How many elements have a one-letter symbol?
 - How many have a two-letter symbol?
 - Why is classifying elements according to their symbol a bad idea?
 - Sort the cards according to the colour of the element.
 - How many elements are coloured silver?
 - How many elements are another colour?
 - Why is classifying elements according to their colour a bad idea?
 - Sort the cards according to whether they are solids, liquids or gases.
 - How many elements are solids, liquids or gases?
 - Why is classifying elements according to their state a bad idea?

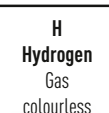
Cu Copper Solid brown, shiny 	Al Aluminium Solid silver, shiny 	Mg Magnesium Solid silver, shiny 	Cl Chlorine Gas yellowish-green 	C Carbon Solid black, dull 	S Sulfur Solid yellow, dull 
Fe Iron Solid grey, shiny 	P Phosphorus Solid red, dull 	Pb Lead Solid grey, shiny 	K Potassium Solid silver, shiny 	Hg Mercury Liquid silver, shiny 	O Oxygen Gas colourless 
H Hydrogen Gas colourless 	I Iodine Solid grey, sparkly 	Ca Calcium Solid grey, shiny 	Sn Tin Solid silver, shiny 	Br Bromine Liquid red-brown 	Zn Zinc Solid silver, shiny 

Figure 4.5 Some element information cards.

The periodic table is used by scientists worldwide. All scientists use the same symbol for an element, even though they may know the elements by a different name. Table 4.1 shows the different names used for the element helium in several different countries.

Table 4.1 The name for helium in different languages.

Language	Name
English	Helium
Chinese	氦
Spanish	Helio
Arabic	الهليوم
Korean	헬륨
Japanese	ヘリウム
Italian	Elio
Polish	Hel

Imagine the difficulties scientists would have if they were talking about the same element with a scientist in another country and they were both using just the names from their own language. With a common set of symbols, scientists are able to research and discover new information about a substance without repeating each other's research. Collaboration across the scientific community is also easier with a common set of symbols.

Questions

Choose an element from the periodic table and research:

- what the element is known by in other languages
- where the chemical symbol for it comes from.

ACTIVITY 4.1.2: WHAT'S IN A NAME?

Have you heard of Marie Curie, Albert Einstein, Glenn Seaborg and Niels Bohr? These are all scientists who made great discoveries about the structure and behaviour of atoms. But they also have another thing in common: they all have elements named after them.

- Find out the actual names of the elements named after these scientists. Find out about the work of these people. What did they discover? Why has their work been so important?
- Look through some names of other elements. Identify as many elements as you can that have been named after people or places. Make a table listing these elements and the origin of their name.



Figure 4.6 Marie Curie.

QUESTIONS 4.1.2: ELEMENTS

Remember

- Recall another term used to describe an element.
- Recall the name of a vertical column on the periodic table.
- Identify the main differences between metals and non-metals.
- Identify a typical non-metal and a typical metal and suggest possible uses for them.

Apply

- Suggest a reason why only some of the element symbols come from their Latin names.
- Some common elements are gold, silver, calcium, sodium, nitrogen and carbon. Locate each of these elements on the periodic table in Figure 4.4 and identify the element symbol for each.
- Explain why chemical symbols are used rather than the full names of elements.

CHEMICAL AND PHYSICAL PROPERTIES

All the properties of elements, compounds and mixtures can be classified into two different types: chemical properties and physical properties.

Physical properties

Physical properties of matter are properties that can be measured by physical means.

Physical properties include:

- whether something is a solid, liquid or gas at room temperature
- boiling and melting point
- whether it conducts electricity
- density
- strength
- ductility (ability to be stretched into wires)
- malleability (ability to be hammered or bent into shape)
- appearance (such as its colour and whether it is shiny or dull).

You will already be familiar with the physical properties of appearance, compressibility, density, strength, hardness, particle pressure, melting point, boiling point, heat conductivity and heat capacity from chapter 4 of *Oxford Insight Science 7*. Viscosity and electrical conductivity are two other important physical properties of matter.

Viscosity

Viscosity is the thickness or 'gooiness' of a liquid. It is a measure of how easily a liquid flows or pours. Viscous liquids such as honey are hard to pour.

Viscosity of an element or a compound is usually measured at 25°C because viscosity usually decreases when a substance is heated. Usually, all measurements to do with properties of various chemicals and substances are taken at 25°C. This value is considered to be a standard temperature as

it is easy to achieve in laboratory conditions.

Water has a relatively low viscosity. Cooking oil is more viscous than water, and honey is even more viscous than oil (see Figure 4.7). Engine oils used in different engines have different viscosities depending on their use. Chemically, the viscosity of a liquid is due to the size of particles and the attraction between the particles. Water is made up of very small particles, and even though the particles are strongly attracted to each other it is quite easy to separate them. Honey is made up of very large particles that are very attracted to each other. Imagine you had very fine magnetic filings versus large magnets. The fine magnetic filings would 'flow' more easily.

Although oil and honey are both made up of large particles, the particles of oil are less attracted to each other compared with the particles of honey. Imagine very large magnets and very large ball bearings. The ball bearings would 'flow' more easily even though they are the same size as the magnets.

Electrical conductivity

Conductivity is how easily something moves through a substance. Electrical conductivity refers to how easily electricity flows through a substance. Metal elements have a high conductivity, which means they conduct electricity readily. This is why substances with high conductivity are commonly called conductors.

Materials such as rubber and plastic do not conduct electricity. Elements and compounds that do not conduct electricity are called insulators.



Figure 4.8 Electrical cables contain copper wiring with high electrical conductivity, surrounded by layers of insulating plastic with low electrical conductivity.



Figure 4.7 Honey is more viscous than cooking oil.

Chemical properties

Chemical properties of matter are only obvious when we react the element or compound with another substance. Chemical properties are a measure of the **reactivity** of the substance with other substances and include things such as:

- how easily a substance ignites (**flammability**)
- how easily a substance reacts with other substances (reactivity)
- how dangerous it is to organisms (**toxicity**).

Overall, chemical properties relate to how stable or reactive matter is in any given environment. Just looking at a substance or measuring it on its own cannot determine its chemical properties. The substance in question must be combined with different substances and any reactions observed to determine its chemical properties.

Corrosion

You may have heard of iron ‘rusting’. Chemically, this means the substance is reacting with both oxygen and water and corroding. Gold is highly resistant to **corrosion**. Some chemicals corrode more easily than others. For example, iron corrodes faster than copper. When copper corrodes, it forms a green layer known as a ‘patina’ rather than rust. Corrosion is a big problem for iron structures, especially ships that are exposed to salt water all the time. Some metals such as gold and platinum do not corrode at all. Other metals such as zinc and magnesium will corrode over much longer periods of time than iron. So why is iron still used? Iron is commonly available and very cheap, which means it is very widely used.

Most metals tend to form flakes of corrosion, which fall off and expose the metal beneath for further corrosion. However, the corrosion of some other metals forms a hard layer on the surface of the metal. This layer of corrosion, which is called a passive film, bonds tightly to the



Figure 4.9 The iron of this ship has almost completely corroded.

metal beneath and actually protects the metal from further corrosion. Aluminium, stainless steel, titanium and silicon all form passive films.

Flammability

Flammability is how easily a substance will burn or catch fire (ignite). Substances that are easy to ignite have a high flammability. Substances that are hard to ignite have a low flammability. If a substance cannot burn or catch fire, it is called non-flammable.

Substances that have a high flammability are often referred to as ‘fuels’. These include things such as petrol, ethanol, methanol, paper, wood, phosphorus and acetone. Some chemicals, such as water, are non-flammable.

The storage of flammable substances is very important. If they are stored incorrectly, they can cause fires or even explosions. Highly flammable solids tend to be stored under oil so they cannot react with the gases found in the air (because most substances require oxygen to burn). Flammable liquids need to be stored in airtight containers.



Figure 4.10 Crude oil is highly flammable.

Toxicity

Toxicity measures how much damage a substance can cause to a living organism. Toxicity is highly dependent on the dosage (amount) an organism is exposed to. Even water, the least toxic of all known substances, can become toxic in extremely high doses. In contrast, substances such as snake venom are extremely toxic in very small doses.

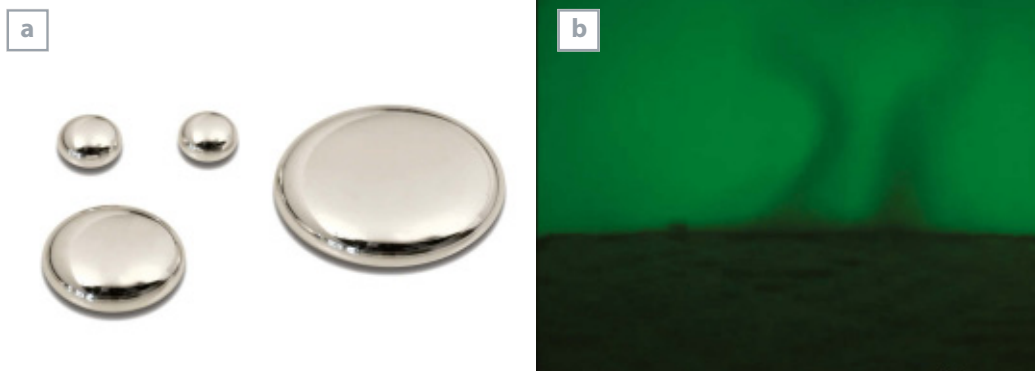


Figure 4.11 (a) Mercury is a toxic substance. (b) The dangerous fumes mercury gives off are easily seen using UV light but cannot be seen at all under normal lighting.

The most toxic natural substance is produced by a species of bacteria known as *Clostridium botulinum*. The toxin causes a disease known as botulism, which causes symptoms such as paralysis of the muscles. Death can often occur due to paralysis of the diaphragm – the muscle that controls breathing.

Other toxic substances include mercury, lead and chlorine. Mercury is a bioaccumulant, which means it cannot be used up by the body or excreted. When an organism absorbs mercury, the mercury remains in that organism until a predator eats it or until it dies. Mercury fumes are particularly dangerous, as you cannot see them under a normal light (see Figure 4.11).

Subatomic particles and element properties

The atoms that make up each element can explain the properties of that element. Atoms are not the smallest units that make up matter after all. Atoms themselves are made up of three main subatomic particles: **electrons**, **protons** and **neutrons**. You will learn more about subatomic particles in *Oxford Insight Science 9*; however, to understand some properties of substances you will need a basic understanding of them.

Protons and neutrons are about the same size as each other. They are both found in the centre of an atom, which is called the **nucleus**. Electrons are very small particles that orbit the nucleus. Protons are positive in charge, neutrons are neutral, and electrons are negative in charge.

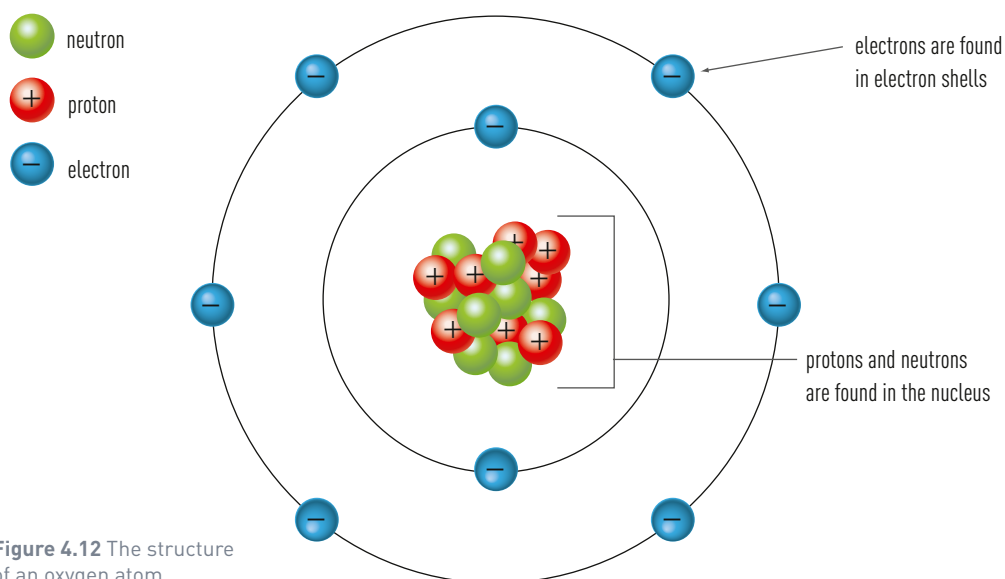


Figure 4.12 The structure of an oxygen atom.

Subatomic particles such as protons, neutrons and electrons are extremely small. So how did we discover them and how do we know what the structure of an atom is like? Originally, scientists thought that atoms were the smallest possible particles and could not be divided any further. However, in 1897 a scientist called Joseph John Thomson discovered electrons within an atom by using a piece of technology called a cathode ray tube. This meant that atoms themselves were actually made up of even smaller particles.

The nucleus of the atom was discovered in 1909 by a team of scientists (Ernest Rutherford, Hans Geiger and Ernest Marsden) who were experimenting with very thin sheets of gold called gold foil. They were using radioactive particles to shoot through the gold foil when Rutherford realised that an atom was mostly empty space. Experiments such as these and the technology used in them have increased our understanding of what

the structure of an atom is like. You will learn about the gold foil experiment in more detail in year 9.

Today, scientists are still looking at improving our understanding of the atom. Technologies such as the Large Hadron Collider (LHC) are currently being used to help scientists probe even deeper into the atom. The LHC is a powerful particle accelerator situated underground beneath the Swiss–French border near Geneva, Switzerland. It has been hailed as one of the most complex experimental facilities ever built, requiring collaboration between 10 000 scientists and engineers from over 100 countries. The LHC lies in a circular tunnel with a circumference of 27 kilometres. So far, the LHC has detected the existence of three new particles found within an atom. Scientists are still analysing the results to further understand the nature of these particles.

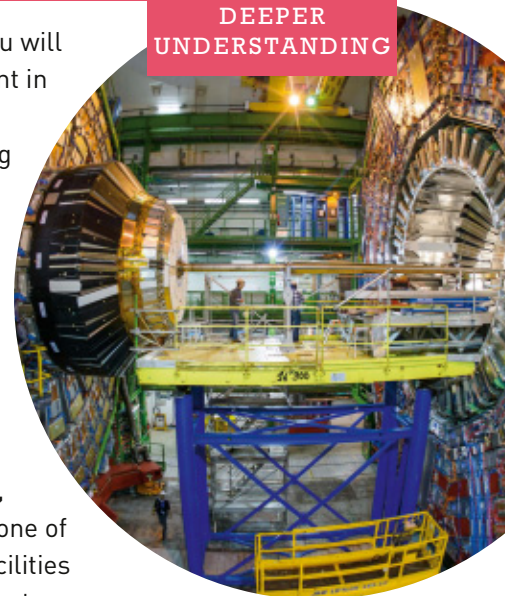


Figure 4.13 A section of the Large Hadron Collider.

QUESTIONS 4.1.3: CHEMICAL AND PHYSICAL PROPERTIES

Remember

- 1 Recall the difference between a physical and a chemical property of a substance.
- 2 If copper is used for electrical wiring in a house, recall which physical property of copper we are trying to take advantage of.
- 3 Fill in the following table with information about the subatomic particles found within an atom.

Name	Location	Size	Charge

Apply

- 4 Iron is the most commonly used element in the world. Identify whether each of the following are chemical or physical properties of iron:
 - a it is a grey, silvery solid at room temperature
 - b it will melt at temperatures of 3000°C
 - c it can conduct electricity
 - d it will rust
 - e it is needed by humans to combine with and carry oxygen in the blood
- 5 Outline the difference between rust and corrosion.

METALS AND NON-METALS

One of the first steps to categorise elements is to determine whether they are a metal or a non-metal. Elements are grouped into one of these categories based on the properties they have in common.

EXPERIMENT 4.1.1: METALS AND NON-METALS

Aim

To determine the difference between metals and non-metals.

Materials

- 5 different types of elements (such as sulfur, copper, aluminium, carbon, magnesium)
- Power supply
- Light bulb
- Connection wires (and alligator clips)
- Hammer

Method

- 1 Observe and describe each element. Record your results in an appropriate table in the results section.
- 2 Test each element for ductility and malleability by hitting it with a hammer. Ensure you use the hammer outside on concrete. If a substance cracks or breaks when hit, it is non-ductile and non-malleable.
- 3 Test each element for electrical conductivity by connecting an appropriate circuit (refer to Figure 4.14).
- 4 Record the electrical conductivity of each element in the same table in your results.

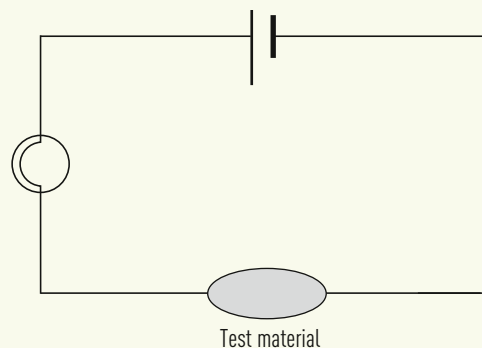


Figure 4.14 Substances that conduct electricity will allow the globe to light up.

Results

Design and draw an appropriate results table.

Discussion

- 1 Your teacher will let you know which elements are metals and which are non-metals. Describe the trend you see with metals.
- 2 Describe the trend you see with non-metals.
- 3 Are there any exceptions to the trends you discussed in questions 1 and 2? Describe any exceptions noted.
- 4 Locate the metals and non-metals you tested on a periodic table. What do you observe?

Conclusion

Write an appropriate conclusion that reflects what you found and addresses the aim.

Table 4.2 summarises the general properties of metals and non-metals, some of which you should have noticed in Experiment 4.1.1. Note that not all metals and non-metals necessarily have all of these features, but most do.

Table 4.2 A comparison of the general properties of metals and non-metals.

Property	Metals	Non-metals
State at room temperature	solid	gas or liquid
Lustre (shine)	shiny surface	variable appearance
Colour	silver/grey in colour	various colours, or colourless as gases
Ability to conduct electricity and heat	able to conduct electricity and heat	not able to conduct electricity and heat
Malleability (ability to be flattened)	malleable	not malleable
Ductility (ability to be drawn into a wire)	ductile	not ductile

There is also another group of elements called metalloids or semi-metals. As their name suggests, they have some properties like metals and some like non-metals. Examples of metalloids include silicon, arsenic and germanium.

Metals

In the solid state, the atoms of a metal are arranged in a shape called a **lattice**. A lattice is a three-dimensional shape and it is most commonly seen in metallic elements. The positive nucleus and some electrons are attracted to each other, but metals also have some free electrons that are able to move around the substance. For this reason, we say the structure of metals is a lattice of positive particles surrounded by a sea of free electrons.

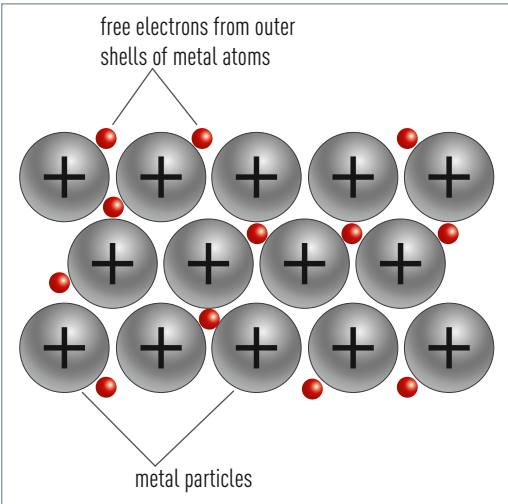


Figure 4.15 The subatomic structure of a solid metal substance.

The best way to imagine this structure is to consider a box of tightly packed oranges. The oranges represent the positive particles of the metal. If you dropped marbles into the box, they would represent the electrons. The electrons can move around the substance independently of the positive particles, just like the marbles are able to move through the box of oranges independently of the oranges.

Metals can conduct electricity because the electrons are able to flow through the solid, carrying the electrical charge with them. Free electrons also account for the lustre of a metal. When light hits the metal, the electrons pick up a little bit of that energy and reflect the light back.

With the electrons loosely held, the metal atoms become positive particles as they lose some of their negative charges. These positive metal particles can slide quite easily over each other. This means metals are malleable and ductile, as their positive particles will easily separate.

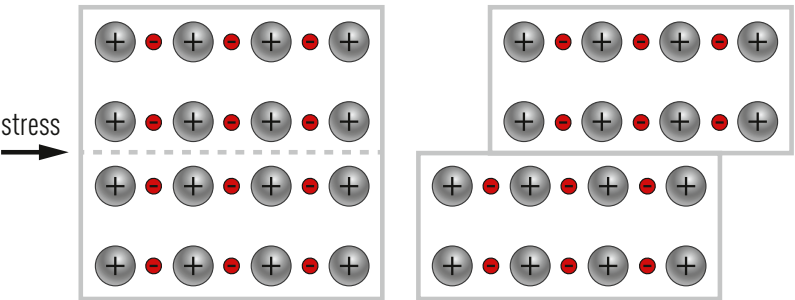


Figure 4.16 The positive particles in metals can slide over each other relatively easily. This allows for the metal to be malleable and ductile.



Figure 4.17 Most metals have a shiny lustre.



Figure 4.18 Most metals are ductile and can be drawn into a wire.



Figure 4.19 Most metals are malleable and can be flattened into a sheet.



Figure 4.20 A tightly packed box of oranges is similar to how positive metal particles are packed into a solid.

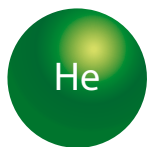


Figure 4.21 Helium is a monatomic gas.

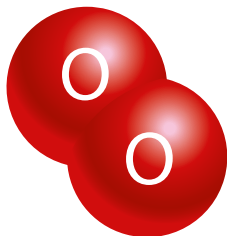


Figure 4.22 A molecule of oxygen. Oxygen is diatomic – its molecules consist of two oxygen atoms joined together.

Non-metals

Non-metals vary greatly in their properties. Their electrons tend to be connected, either to other atoms or to each other, which is a key difference to metals. This means non-metals cannot conduct electricity as their electrons are all used in connections rather than being free to wander.

Most non-metals are gases at normal temperatures. Some gases, such as helium, neon and argon, are **monatomic** (see Figure 4.21). This means each gas particle is a single atom (mono means one). However, the atoms in other gases such as oxygen, hydrogen and nitrogen are **diatomic** (see

Figure 4.22). The atoms of these elements join together in pairs (di means two). Other non-metals exist as solids and gases. Some, such as sulfur are **polyatomic** (Figure 4.23). Many of their atoms are joined together (poly means many). Sulfur exists as a solid at room temperature.

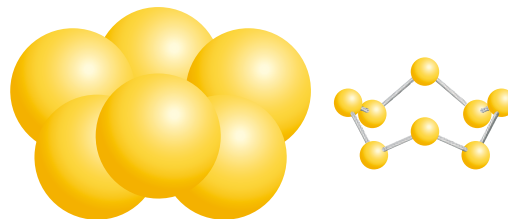


Figure 4.23 Two different representations of a sulfur molecule.

QUESTIONS 4.1.4: METALS AND NON-METALS

Remember

- 1 Select four metals or non-metals and describe the appearance of each.
- 2 Explain how metals are able to conduct electricity

Apply

- 3 From the periodic table, identify three metallic and three non-metallic elements.
- 4 Construct a table to compare and contrast a metal and a non-metal you have examined. In the table, make sure the name and chemical symbol of the substances are included.
- 5 A new substance was discovered with the structure as shown in Figure 4.24.
 - a Do you think it is likely to conduct electricity? Justify your answer.
 - b The substance was found to be relatively soft. Explain why this may be the case (consider many of these ball structures together).
- 6 Graphite, a non-metal, is able to conduct electricity. Predict what its structure would be like. Explain your answer.
- 7 Explain why we are still discovering new things about the structure of the atom.
- 8 Contrast the structures of a typical metal and non-metal and outline some key differences that result in different properties between metals and non-metals.

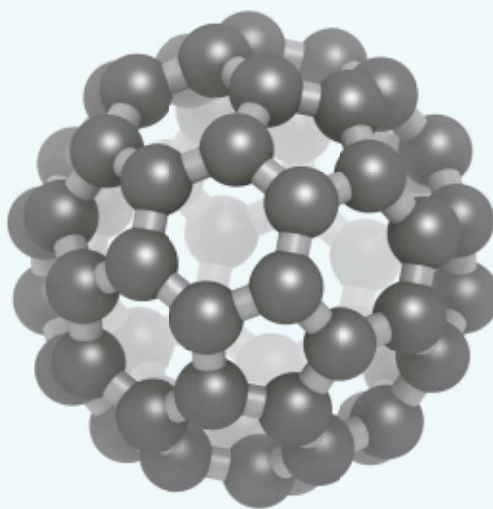


Figure 4.24 What can the structure of a substance tell you about its properties?

Research

- 9 Research a semi-metal and explain its use in relationship to its properties.

USES OF ELEMENTS

The uses of elements are as different and varied as the elements themselves. Not all of the 98 naturally occurring elements can be found in their pure form. Many react with other elements and form compounds, which you will learn more about in section 4.2. But all substances can be purified into their base elements, even if they do not occur in their pure form.

Gold

Gold is a metal typically used for jewellery and ornaments. It has the chemical symbol Au, which stands for *aurum*, the Latin word for gold. In ancient times, gold was used as the currency in many countries. Its bright yellow colour and lustre (shine) made it irresistible to many cultures. Gold is also very unreactive. As a result, lumps of pure gold can be mined directly out of the ground.

You can quite easily determine if an element is a metal or a non-metal simply by examining its position on the periodic table of elements.

Things that were made from gold thousands of years ago still have the same lustre – they have not tarnished or reacted with the air and moisture around them. Jewellery needs to be unreactive to reduce the chances of it reacting with your skin and possibly causing an allergic reaction.

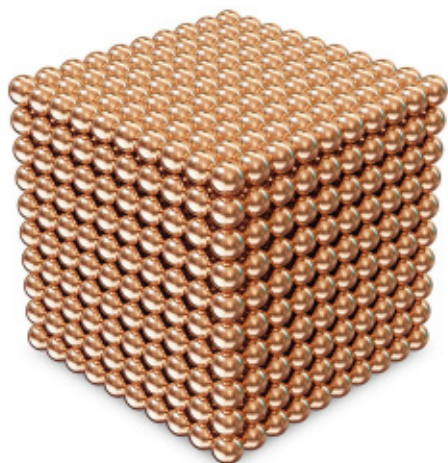


Figure 4.25 A small part of the lattice structure of gold. The electrons are not shown in this diagram.

Gold is also used in some electronic components. Transmission of electricity is easily interrupted by corrosion (see page 171), so components using low voltages or currents often contain gold because it does not tarnish or corrode easily. Devices that use gold components include mobile phones, GPS devices and computers.

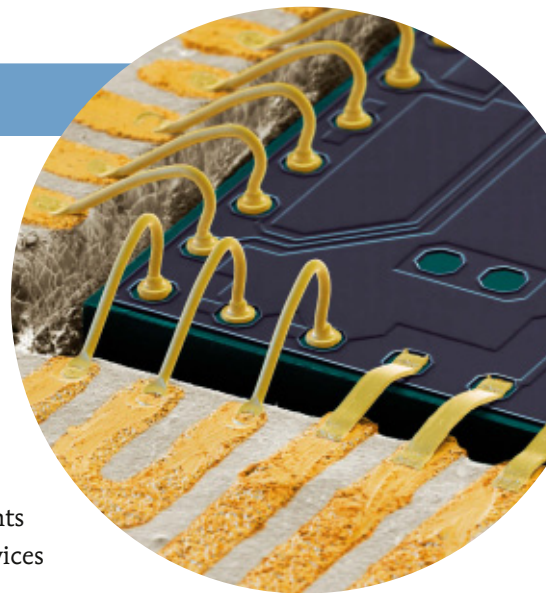


Figure 4.27 A coloured SEM image of the gold micro-wires connecting a microchip to a circuit board.

Iodine

Iodine is a grey sparkly non-metal that dissolves slightly in water. Iodine has antibacterial properties and is used largely as a disinfectant. When used as an antiseptic, it is often diluted so that the solution is approximately 5–7% iodine.



Figure 4.26 Iodine being used as an antiseptic.

Helium

Helium is a gas that is often used in balloons. It is less dense than air, which is why helium balloons float. Helium is non-reactive and will not burn, making it safer to use in airships than hydrogen, which is highly flammable. Helium is an element that only occurs in an atom form – it will not react with other elements to form compounds. It has the chemical symbol He.



Figure 4.28 The hard crystal lattice structure of diamond is one of the reasons why it reflects light and sparkles.



Figure 4.29 A diamond-studded drill bit. These bits tend to be used in mining.



Figure 4.30 Graphite is the 'lead' in a grey-lead pencil.

Sulfur

Sulfur is a yellow non-metal, primarily used in the production of fertilisers as well as sulfuric acid. It has the chemical symbol S.

Historically, sulfur was used for medical purposes such as in traditional Chinese medicine. It was even mentioned in Egyptian scrolls dating back to 1500 BC as a treatment for particular eye infections. Nowadays, sulfur is mainly used in the form of sulfuric acid. It is rarely used in its pure form.

Sulfur is odourless in its pure form, but when combined with oxygen it forms a strong 'rotten egg' smell.

Carbon

Carbon is a very interesting non-metal element as it occurs in several different forms (known as **allotropes**). The particles that make up the different forms of carbon are all the same, but the structure of the atoms within the different forms can be so different that it gives rise to different properties. Carbon can be found in several different allotropes, but the two main ones are diamond and graphite.

Diamond

Diamonds are the hardest substance in the world. Whilst most people think of diamond jewellery (see Figure 4.28), the main use for diamonds is actually in industry for cutting tools (see Figure 4.29). Saws, drill bits and other cutting implements are often coated with diamonds, which helps the tools cut through even the hardest of steel or rock. Even though the diamonds used in industry are still called diamonds, you would not want any jewellery made out of them! Industrial diamonds look very different from gem diamonds and do not have the same quality and shine.

Graphite

Unlike diamond, graphite is incredibly soft. It is so soft that it rubs off onto paper, and you use it as the 'lead' in pencils. When you write, you are leaving a trail of carbon on the paper.

Why carbon allotropes are different

The differences between the hardness of diamond and graphite can be explained by the way the particles are arranged in the substance (see Figure 4.31).

Graphite forms as sheets that separate from each other very easily. When you write with your pencil, sheets of carbon are being left behind onto the paper.

Diamond forms a three-dimensional lattice and is therefore very hard. It cannot be separated into sheets like graphite.

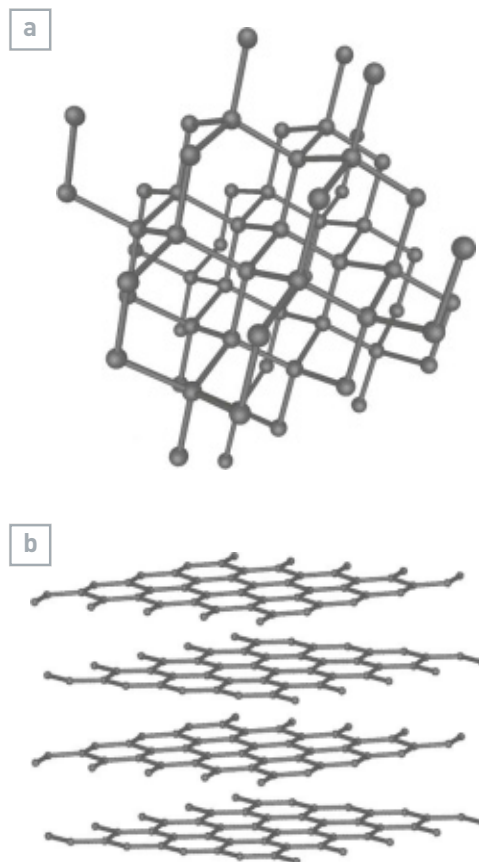


Figure 4.31 Two allotropes of carbon: (a) A three-dimensional crystal lattice structure of diamond. (b) Graphite forms in 2-dimensional sheets that slide easily over one another.

Oxygen

Oxygen is a gas that is essential for most living things. We breathe in oxygen, and plants produce oxygen through photosynthesis. We use oxygen tanks in hospitals to help patients who have trouble breathing. Oxygen is also used in industry. Oxygen in liquid form is used as a fuel for space shuttles and is also used in the process of making steel.



Figure 4.32 The first stage in a rocket launch usually uses liquid oxygen combined with other substances as fuel.

Oxygen has the chemical symbol O. Oxygen can form diatomic or triatomic (three atoms) gases. The diatomic form (see Figure 4.22), which has the chemical formula O_2 , while ozone (see Figure 4.33) has the chemical formula O_3 . The small '2' and '3' after the O symbol tell you how many atoms are involved in each molecule. You may have heard of ozone in terms of the ozone layer. The ozone layer helps protect the surface of the Earth from UV rays. Ozone is also used to help purify air in tunnels and underground structures.

Steel is a substance made up of two main elements: iron and carbon. Oxygen is used in steel production. It combines with the carbon found naturally in the iron and creates carbon dioxide. In this process, the carbon content of the iron is lowered, which means the resulting steel is harder and stronger.

Oxygen can be used in all these different processes because of its chemical properties. It is used in rocket fuel for combustion (burning). It is impossible to light a fire without oxygen gas.

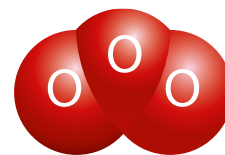


Figure 4.33 Oxygen forms a molecule with three oxygen atoms called ozone (O_3).



Figure 4.34 Molten iron being poured into a Basic Oxygen Steelmaking furnace.

QUESTIONS 4.1.5: USES OF ELEMENTS

Remember

- 1 Recall the elements you have learned about in this chapter that exist as molecules rather than single atoms.
- 2 Recall two common uses of gold.
- 3 Identify the term used to describe different substances made up of the same element but arranged in different forms to give different physical properties.
- 4 Explain why oxygen is used in steel making.
- 5 Recall why iodine is used as an antiseptic.

Apply

- 6 Compare and contrast the following pairs of terms:
 - a 'atom' and 'element'
 - b 'molecule' and 'lattice'

4.1

CHECKPOINT

ELEMENTS

Remember and understand

- 1 Recall the three subatomic particles and where they are found in the atom. [3 marks]
- 2 Recall the chemical formula for a common element and describe its usage. [2 marks]
- 3 H, Ne and Cu are all common elements. Use the periodic table to identify their names. [3 marks]
- 4 Identify each of the following substances as a metal or non-metal: [5 marks]
 - a sodium
 - b iron
 - c sulfur
 - d nitrogen
 - e chlorine
- 5 Recall the use of some non-metals. In your answer, relate their properties to their uses. [3 marks]
- 6 Recall the use of some metals. In your answer, relate their properties to their uses. [3 marks]

Apply

- 7 Account for the use of iron in society by the properties that it has. [2 marks]
- 8 Explain the difference between monatomic and diatomic particles. [2 marks]
- 9 Explain why metals are malleable. Use a diagram in your answer. [2 marks]
- 10 Explain why non-metals do not conduct electricity. [1 mark]
- 11 Explain why some chemical symbols for elements are based on their Latin or Greek names yet most are based on their English names. [2 marks]
- 12 Explain why gold cannot be used as electrical wiring, even though it conducts electricity very well. [2 marks]

Analyse and evaluate

- 13 Compare and contrast chemical and physical properties. [3 marks]
- 14 Suggest a reason why we have discovered more metals in the last 200 years than we have in our entire human history. [2 marks]
- 15 Explain why the periodic table is arranged the way it is. Is this the best arrangement for it? Justify your answer. [3 marks]
- 16 Metalloids have features of both metals and non-metals. However carbon, in the form of graphite, also has features of a metal (it conducts electricity and is often shiny). Justify why carbon is classified as a non-metal and not a metalloid. [2 marks]

Ethical behaviour

- 17 A lot of important elements we use are present in finite (limited) amounts or are expensive to obtain. Explain why recycling is a necessary process. [3 marks]

Critical and creative thinking

- 18 Explain why we use models in science, giving at least one example where models have been used. [3 marks]
- 19 A new element has been found that is shiny and green, malleable, strong, non-reactive, ductile (but not very) and conducts electricity (but not well). Suggest two uses for this element and explain your reasoning. [4 marks]



TOTAL MARKS
[/50]

COMPOUNDS AND MIXTURES

4.2

Compounds are substances that form when elements are chemically joined (bonded) together, whereas mixtures are substances made up of compounds and/or elements that are not chemically bonded. The possibilities for the formation of materials from mixtures and compounds are endless. What are some uses for them? What properties do compounds and mixtures have that make them useful?

COMPOUNDS

You have seen that elements contain only one type of atom. However, there are far more substances than just the 98 naturally occurring elements. Many of the vast range of substances we see around us are formed when the atoms of different elements join together to form compounds.

A compound is any substance made up of more than one type of atom or element that are chemically bonded or joined together. Compounds can be broken down into smaller and lighter substances until the base elements are separated. This process is a type of chemical reaction called **decomposition** and involves breaking

chemical bonds. Keep in mind that a specific element will not necessarily join with another specific element to form a compound.

Most of the substances we use are compounds. By altering the ratio of atoms of the different elements, chemists can alter the properties of these substances. Compounds are used because of their specific properties. Important compounds are made in factories or obtained from natural products. Artificially made compounds are commonly used in medicines, fertilisers, plastics and food materials.

EXPERIMENT 4.2.1: DECOMPOSING A COMPOUND

Aim

To decompose copper carbonate.

Materials

- | | | |
|----------------------|-----------------|----------------|
| • Copper carbonate | • Spatula | • Wooden tongs |
| • Electronic balance | • Bunsen burner | • Tripod stand |
| • Plastic beaker | • Heatproof mat | • Paper towel |
| • Test tube | • Matches | |

WARNING

- > Wear safety glasses and a lab coat, and tie long hair back when using a Bunsen burner.
- > Hold the test tube or crucible securely with the tongs and always point it away from yourself and others.
- > Never place hot objects on a balance.

Method

- 1 Place the plastic beaker on the electronic balance and tare the balance so it reads zero.
- 2 Add an empty test tube to the beaker and record its mass.
- 3 Using a spatula, add approximately 3 g of copper carbonate into the test tube. Record the combined mass of the copper carbonate and the test tube in grams.

Observe the copper carbonate and record your observations.

- 4 Set up the Bunsen burner on the heatproof mat. Light the flame, ensuring the hole is open and an orange (safety) flame is burning. Turn your Bunsen burner to the heating flame.
- 5 Using the wooden tongs to hold the top of the test tube, gently wave the base of the test tube over the flame twice. Record any changes. Continue to do this for 2 minutes, recording any changes. Be very careful to point the open end of the test tube away from others and yourself. Make and record appropriate observations.
- 6 Allow the test tube and copper carbonate to cool. Wipe off any powder from the outside of the tube with paper towel.
- 7 Tare the plastic beaker and place the test tube into it to record the new combined mass of the test tube and the substance.
- 8 Collate the class results to obtain averages for the mass of copper carbonate before heating, mass of substance after heating, and average change in mass.

Results

- Record your observations of copper carbonate before heating.
- Record your observations of the substance after heating.
- Record your class results in the following table:

	Mass of original copper carbonate + test tube (g)	Mass of substance after heating + test tube (g)	Mass difference (g)
Your result			
Class average			

Discussion

- 1 What happened to the copper carbonate? Consider the colour and any changes in mass.
- 2 What evidence is there that copper carbonate is a compound and not an element?
- 3 Identify any sources of error with this experiment.
- 4 Explain why you used the class average rather than just your results.

Conclusion

Write an appropriate conclusion that addresses the aim.

STUDENT DESIGN TASK

Chemical and physical properties of elements and compounds

Challenge

Your task is to design a series of experiments to determine the differences between the chemical and physical properties of an element (copper) and its compound (copper sulfate).

Planning and conducting

- How do you test for electrical conductivity of a metal?
- Does copper sulfate conduct electricity in its solid form? What happens if you dissolve it in water?
- How do you test for chemical reactivity? How does copper react with a chemical called silver nitrate? What about when you place copper into water? How about copper sulfate – does it show the same reactions with silver nitrate and water?

- How can you find out physical properties such as the melting point of copper and copper sulfate? It is not feasible to heat and measure it.
- Make sure you satisfy any safety issues in the experiment and include steps to minimise them.

When you have designed an experiment, show it to your teacher, who will check your method and allow you to proceed.

Processing and analysing

- 1 What were some differences between the physical and chemical properties of copper and copper sulfate? What were some similarities?
- 2 Research what copper is used for. How are its physical properties related to its use? How are its chemical properties related to its use?
- 3 Research what copper sulfate is used for. How are its physical properties related to its use? How are its chemical properties related to its use?
- 4 Does the compound of an element have the same properties as the element? Use evidence from your experiment to answer this question.

Communicating

Write your experiment as a proper experimental report. Ensure you include the aim, materials, method, an appropriate discussion and a conclusion.

Types of compounds

When models are used in science, atoms are generally represented by individual spheres. Spheres of the same size and colour represent the same element. Molecules are represented in models by two or more spheres joined together. They may be of the same atom (for a molecular element) or of different atoms (for a molecular compound).

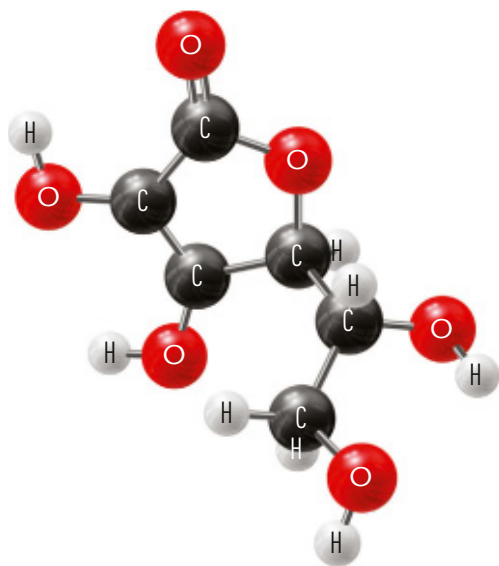


Figure 4.35 Vitamin C is also a molecular compound, although more complex than water. How many different atoms does it have?

Examples of molecular compounds include water and carbon dioxide.

Molecular compounds form discrete units that are made up of a set number of atoms. For example, water (H_2O) is made up of two hydrogen atoms joined together with one oxygen atom. Every water molecule has this same structure.

Some compounds are called **polymers**. The molecules in polymers are made of groups of atoms in a pattern that repeats over and over like the beads of a necklace. Plastics are polymers. Other polymers include chemicals found in plants and animals, such as starch and proteins.

Other compounds do not contain molecules but exist in a lattice arrangement, with atoms held together in three-dimensional networks. Lattices often form when metallic and non-metallic elements bond together.

Compounds do not necessarily have any of the properties of the elements that make them. For example, sodium chloride (see Figure 4.39) is the scientific name for common table salt. It is made up of sodium, a highly reactive metal, and chlorine, a

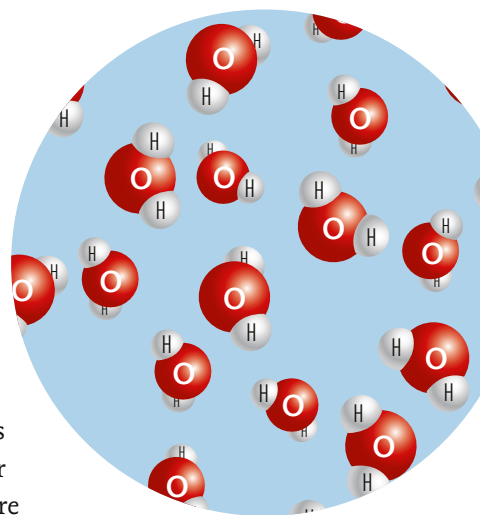


Figure 4.36 Water is a molecular compound. How many different atoms does it have? How many atoms does it have in each molecule?

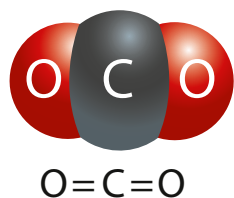


Figure 4.37 A molecule of carbon dioxide drawn two different ways.

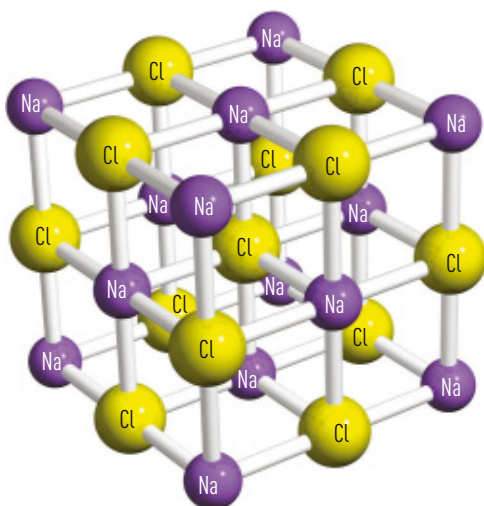


Figure 4.38 Sodium chloride (NaCl), common table salt, is an example of a compound that has a lattice structure. Notice the repeating three-dimensional pattern.

poisonous greenish-yellow gas. Yet sodium chloride (the compound made up of sodium and chlorine) is colourless, a solid, and is so safe that we regularly eat it.

Elements and compounds are both pure substances. The particles within a pure substance, whether they are atoms or molecules, must all be the same. Figure 4.39 shows the different types of elements and compounds.

Common compounds

Many compounds form in nature, but many are manufactured artificially to have desired properties.

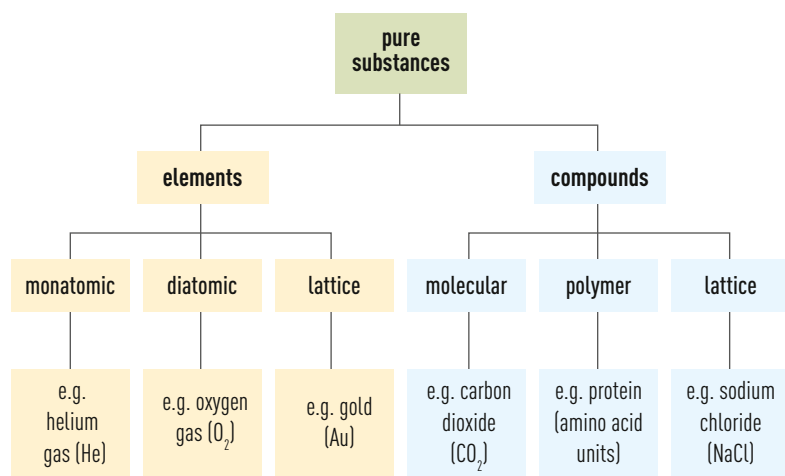


Figure 4.39 Elements and compounds are both pure substances because each particle in the substance is the same, but both elements and compounds come in different forms.

Water

Water (H₂O) is one of the most common substances in the world, and we depend heavily on it. Water is a versatile compound vital for all life on the Earth. It is also sometimes called the universal solvent because so many other substances will dissolve in it.

Carbon dioxide

Carbon dioxide (CO₂) is breathed out during respiration, and plants use carbon dioxide to photosynthesise. Carbon dioxide in the atmosphere helps to trap heat against the surface of the planet – without it the Earth would be frozen solid! It is also commonly used in fire extinguishers because fire cannot burn in carbon dioxide. Carbon dioxide has the chemical formula CO₂, which means it has 1 carbon atom and 2 oxygen atoms.



Figure 4.40 A carbon dioxide fire extinguisher.

Carbon dioxide has many uses, the most familiar being to provide the 'fizz' in carbonated drinks. It is used in this manner because carbon dioxide is cheap to obtain and does no harm when consumed. Carbon dioxide also produces a slightly sour taste as it makes carbonic acid when placed in water, which contributes to the flavour of many soft drinks.

Carbon dioxide is also used in types of fire extinguishers as it can 'smother' the oxygen required for fires.

Iron oxide

Iron is a metal element that conducts electricity well. While it is rarely used in its pure form, iron is commonly used in lots of different **alloys** (mixtures of metals) and compounds used largely in construction. Iron has the chemical symbol Fe, based on its historical Latin name of *ferrum*. Pure iron forms a lattice like all metallic elements.

There are several different forms of iron oxide (FeO), but they are commonly known as rust. Iron oxide forms when iron reacts chemically with oxygen, usually from the air. Rust does not conduct electricity, nor is it a gas. The reaction to form iron oxide will be covered further in chapter 5.

Iron oxide forms a lattice structure. One form of iron oxide has the chemical formula FeO. Lattice structures can be any size, so the actual number of atoms involved cannot be accurately listed in the formula. Instead, the formula states the ratio that the different elements appear in the lattice. In this case, there is an oxygen atom for every iron atom in the lattice.

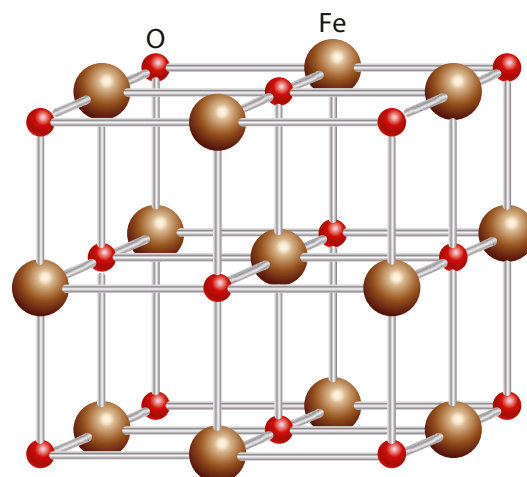


Figure 4.41 The lattice structure of iron oxide.

QUESTIONS 4.2.1: COMPOUNDS

Remember

- 1 Define the term 'decomposition'.
- 2 Compare and contrast the following pairs of terms:
 - a 'element' and 'compound'
 - b 'compound' and 'molecule'
 - c 'molecule' and 'lattice'
- 3 Recall which compound features in both respiration and photosynthesis.
- 4 Compare and contrast iron, oxygen and iron oxide.
- 5 Recall the chemical formula for:
 - a water
 - b carbon dioxide
 - c iron oxide

Apply

- 6 Explain, using appropriate examples, the difference between a polymer and a molecule.
- 7 Classify the substances in Figure 4.42 as elements or compounds. Justify your classification.
- 8 For all the common compounds given in this section, construct a table that provides their scientific name, their chemical formula, the different elements, the number atoms of each element and one common use.

Analyse

- 9 From the table constructed in question 8, identify the relationship between the number of capital letters in a formula and the number of elements involved in the compound.
- 10 A scientist discovered a new substance, but found she could not decompose it into simpler substances. Is this new substance an element or a compound? Use your understanding of elements and compounds to justify your answer.

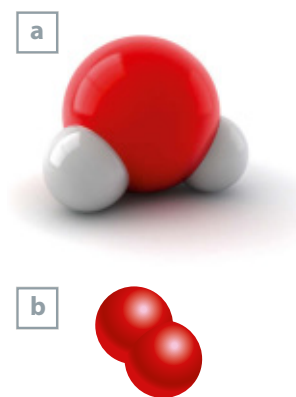


Figure 4.42 Identify these models as elements or compounds.

MIXTURES

You were introduced to mixtures in chapter 5 of *Oxford Insight Science 7*, and you will now compare mixtures with elements and compounds. You will also learn about the two main types of mixture.

Mixtures are not pure substances. They are substances made up of two or more different pure substances, elements and/or compounds that are not chemically bonded together. Remember that compounds are different elements chemically bonded or joined together. Mixtures are different from compounds.

Table 4.3 highlights some of the main differences between compounds and mixtures.

Table 4.3 Some key differences between compounds and mixtures.

	Compound	Mixture
Components	contains two or more elements	contains two or more elements or compounds
Bonding between particles	the elements are chemically bonded together	the elements/compounds are not chemically bonded together
Ratio of different particles	elements occur in a strict ratio to each other, e.g. water is always H_2O (not H_3O or H_4O)	substances within the mixture can occur in different ratios



Figure 4.43 Chocolate cake is a homogeneous mixture.



Figure 4.44 Medicine is another homogeneous mixture.

Varying the composition of a mixture will not change the name or type of the mixture. For example, your grandmother's chocolate cake may be different from your chocolate cake (different amounts of chocolate, different amounts of butter), but it is still chocolate cake. The properties will change slightly as the proportions of each component of the mixture changes. Your grandmother's cake might taste better than yours but not significantly different, as opposed to when the ratio of elements is altered in a compound. O_2 is an odourless gas that is vital for our survival, while ozone O_3 is toxic if breathed in and has a distinct metallic smell.

Just as elements and compounds can be classified by their structure, so too can mixtures.

Homogeneous mixtures

A **homogeneous** mixture looks the same throughout the substance. Each type of particle in the mixture is distributed evenly throughout the substance. Common homogeneous mixtures include air, milk, seawater and most medications. Chocolate cake is also a homogeneous mixture.

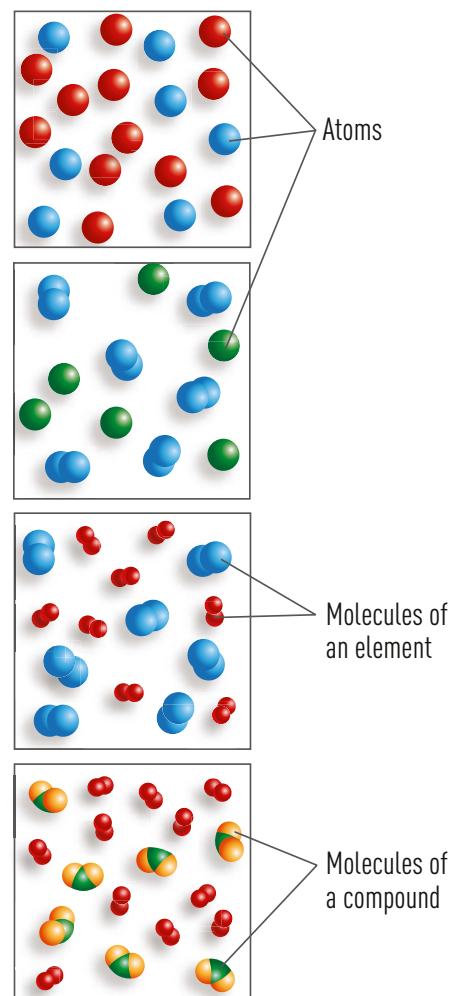


Figure 4.45 Mixtures can contain different elements, different compounds or a combination of elements and compounds. The key is that the different particles are not bonded together.



Figure 4.46 Plain cookie dough is a homogeneous mixture but chocolate chip cookie dough is heterogeneous, as you will get different amounts of chocolate chips throughout the dough.



Figure 4.47 Sand often looks like it's uniform, but if you inspect it up close it is actually made up of many different types of substances.



Figure 4.48 This type of sedimentary rock is called conglomerate rock. Each different part of the rock contains different substances with visibly different make up. Is this a homogeneous mixture or a heterogeneous mixture?

Heterogeneous mixtures

A **heterogeneous** mixture does not look the same throughout the substance. Sand is an example of a heterogeneous mixture – the composition of sand varies from beach to beach, and often between different spots on the one beach. Other heterogeneous mixtures include rocks and chocolate chip cookie dough. The amount of chocolate chips in the cookie dough will change depending on which spoonful you take.

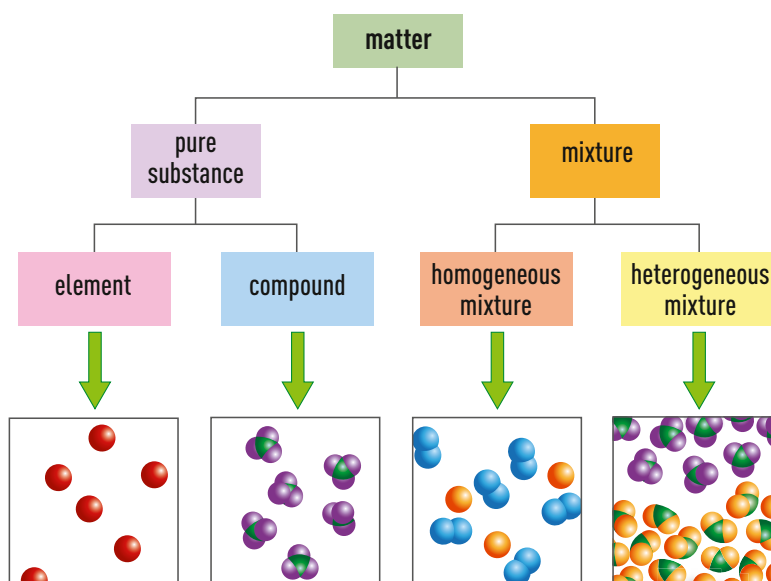


Figure 4.49 The key differences between elements, compounds and mixtures.

ACTIVITY 4.2.1: MODELLING ELEMENTS, COMPOUNDS AND MIXTURES

What you need: items for modelling (such as polystyrene balls, molecular kits, marbles, stones), camera

- 1 Use the equipment provided to model the following elements, compounds and mixtures:
 - an monatomic element
 - a diatomic element
 - a compound made up of two elements
 - a compound made up of four elements
 - a mixture containing at least two different substances.
- 2 Take a photo of each of your models.
- 3 Using your models, explain the different particle arrangements in elements, compounds and mixtures.
- 4 Explain why the use of models is important in science.

Sandy mixtures



Figure 4.50 Black sand beaches of New Zealand.

We see sand on beaches and in sandstone buildings all the time, but what exactly is sand? 'Sand' is a general term given to any granular substance (a substance containing grains) between 0.0625 mm and 2 mm in size. As a heterogeneous mixture, the composition of sand varies – not only between parts of a beach, but also between locations. The most common substance

found in sand is quartz, which is also known as silicon dioxide (SiO_2), but it is the other substances that make up sand that often give it a unique colour.

White sand

White sand often occurs in tropical locations where there is a high percentage of seashells, corals and a single-celled organism known as a foraminifera. The whiteness of the sand comes from a compound called calcium carbonate (CaCO_3), which these organisms produce to build their hard exoskeletons and shells.

Red sand

Australia is famous for the red sand that occurs in Central Australia, often called the Red Centre. The red of the sand is due to iron oxide (FeO).



Figure 4.51 Red sands of the Australian outback.



Figure 4.52 (a) White sand is often seen in tropical regions where foraminifera are common. (b) Foraminifera are microscopic single-celled organisms.

Black sand

Black sand is usually found on beaches that are close to active volcanoes. Maui in Hawaii has black sand beaches, as do some beaches in New Zealand. The black colour comes from a mineral called magnetite, which can be found in high concentrations in volcanic rocks such as basalt and obsidian.

Yellow sand

The most common type of sand seen on the beaches of Australia is yellow sand. The yellow in the sand is due to a combination of impurities in the quartz, which causes a yellow colour, as well as the high number of shell fragments found in the sand.



Figure 4.53 The yellow sand of Bondi Beach is a similar mixture to the sand on most beaches of Australia.

QUESTIONS 4.2.2: MIXTURES

Remember

- 1 Recall the difference between a mixture and a compound.
- 2 Compare and contrast a heterogeneous mixture with a homogeneous mixture.
- 3 Identify two common components of sand.

Apply

- 4 Identify whether fruitcake is a heterogeneous mixture or a homogeneous mixture. Explain your answer.
- 5 In Figure 4.54, identify which diagram models a mixture and which models a compound. Justify your answer.

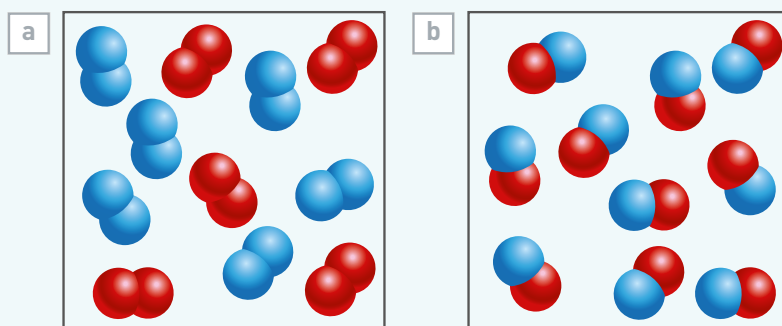


Figure 4.54 Can you explain which diagram is showing a compound and which is showing a mixture?

4.2

CHECKPOINT

COMPOUNDS AND MIXTURES

Remember and understand

- 1 Recall the difference between an atom and a molecule. [1 mark]
- 2 Explain the difference between an element and a compound. [1 mark]
- 3 Identify the term used to describe when a compound has been broken down into simpler components. [1 mark]
- 4 Recall the chemical formula for a common compound and describe its usage. [2 marks]
- 5 Relate the usage of a common compound to its properties. [1 mark]
- 6 Describe the difference between a homogeneous mixture and a heterogeneous mixture. [2 marks]
- 7 Identify an example of a homogeneous mixture. [1 mark]

Apply

- 8 Examine Figure 4.57 and identify each diagram as showing an element, a compound or a mixture. Explain your reasoning. [4 marks]
- 9 Methane is a gas produced by cows. It's highly flammable and has the chemical formula CH_4 .
 - a Is methane an element or a compound? Justify your answer. [2 marks]
 - b Explain what the chemical formula tells you about the number of different types of atoms methane contains. [2 marks]
 - c Explain what the chemical formula tells you about the number of atoms methane contains. [2 marks]

Analyse and evaluate

- 10 'If it is possible to separate two things from a chemical, it means it is a mixture.' Analyse this statement and explain where it is correct and where it is not. [3 marks]

Critical and creative thinking

- 11 Draw a series of your own diagrams to depict the differences between an atom of an element, a molecule of an element, a molecule of a compound, a homogeneous mixture and a heterogeneous mixture. [5 marks]
- 12 When atoms and elements were shown in this section, usually solid balls were used to represent individual atoms. Can you think of a better model? If yes, explain why your model is better. If not, explain why the model used is good. [3 marks]

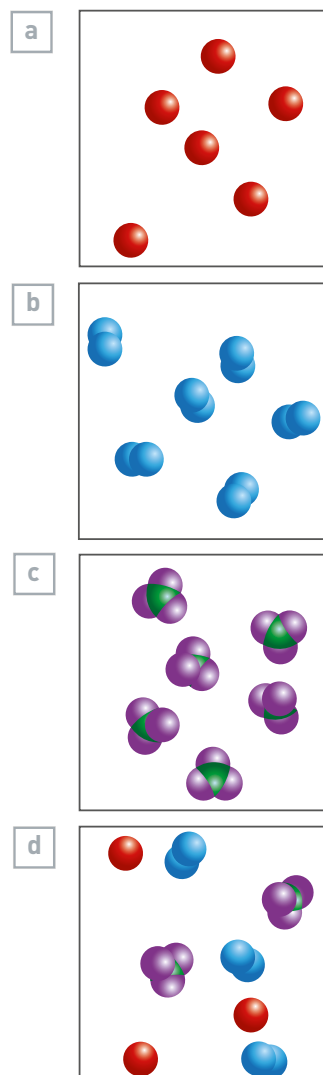


Figure 4.55 Can you explain what each of these diagrams is showing?

TOTAL MARKS
[/30]

THE IMPACT OF ELEMENTS AND COMPOUNDS ON SOCIETY

4.3

Humans have long had a close relationship with elements and compounds found naturally. These elements and compounds have given huge advantages to the societies that had access to them and who knew how to use them, and have helped shape human history. New developments enabling us to use elements and compounds that were previously inaccessible, and the creation of completely new materials, are continuing to shape our society.

TRADITIONAL USES OF ELEMENTS AND COMPOUNDS

The development of human society throughout history has been linked with our understanding of the uses of elements and compounds. Metals, in particular, have significantly changed the way humans have lived, both in ancient and modern times.

Archaeology is the study of human activity in the past. Its study is usually a combination of history and science. Humans have left artefacts throughout

history, from the very large such as the Pyramids in Egypt and Stonehenge in England, to the very small such as shells and jewellery.

The materials used in particular places and times have been important to archaeologists as this helps them to understand how human society and culture have evolved. The three basic ages of prehistoric human development are the Stone Age, the Bronze Age and the Iron Age.

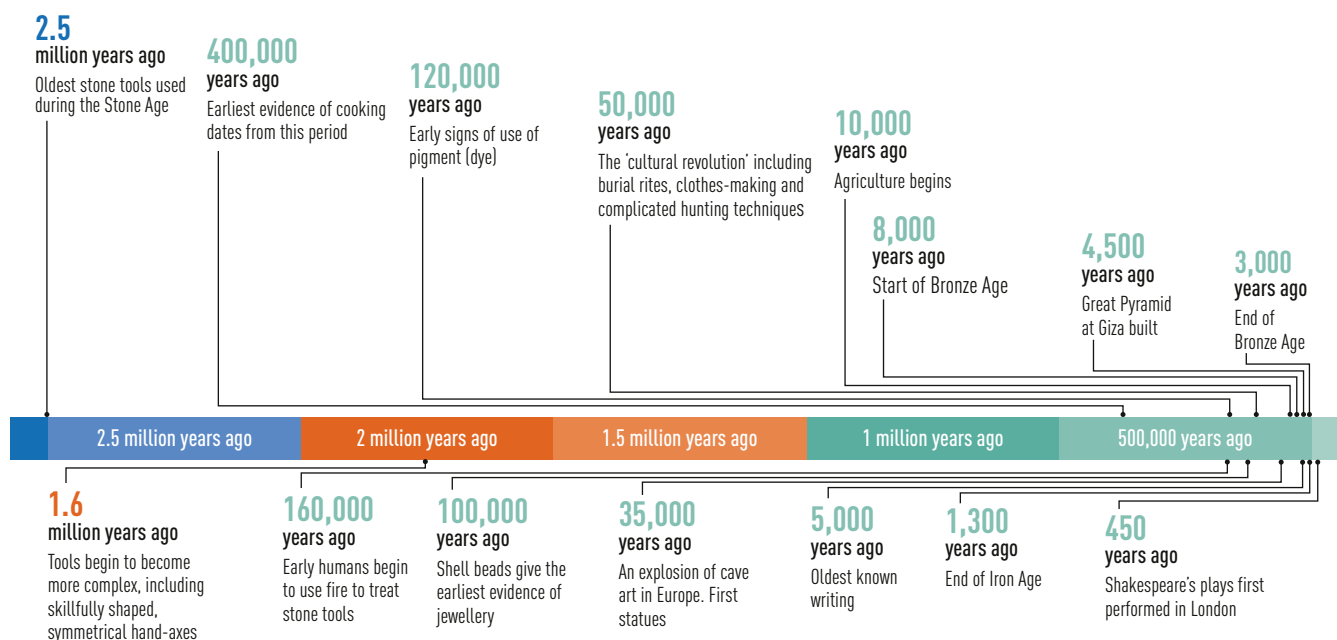


Figure 4.56 The development of human society is closely linked to resources and technological development.

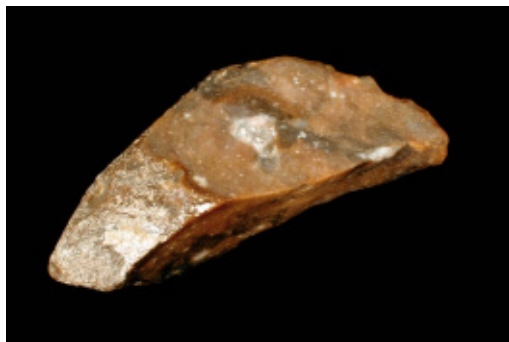


Figure 4.57 A stone axe made from flint. The glassy shine to the rock comes from the high content of quartz in the rock.

The Stone Age

The Stone Age is one of the earliest ages. Its start is always being revised as new discoveries are made. It is likely to have lasted around 3.4 million years and ended around 6000 to 2000 BC.

The Stone Age was characterised by the use of stone tools; however, bone tools were also made and used in this time. The stones used are a type of compound. Typically, flint and chert (quartz, SiO_2) were used as cutting tools and weapons. They could be sharpened to a point, allowing them to be used as cutting devices.

Basalt (volcanic rock) and sandstone were used to grind and shape stone tools. Basalt and sandstone are hard, and they themselves cannot be sharpened.

Additionally, wood, bone and shell were used in the Stone Age for utensils and weapons. Wooden handles of stone axes are not preserved very well, but they are occasionally found.

The Bronze Age

The start of the Bronze Age can be identified through the beginnings of **metallurgy** – the extraction and processing of metals. At the beginning of the Bronze Age, a transitional period often called the Copper Age was occurring. Metals were superior to stone as it was less time consuming to work them yet they held their shape just as well as stone. Additionally, damaged metal implements could easily be melted down and re-worked into new implements. Stone did not have that advantage.



Figure 4.58 A bone tool. A tool like this was likely to be used as some sort of piercing weapon.

The Copper Age

In places where copper was found naturally, melting copper to create different shapes would have been very easy. To make pins and other small objects, copper is soft enough to be ‘cold-hammered’ – it can be hit with a hammer into the desired shape. For larger objects, all copper requires is very high temperatures for it to be melted and a mould for it to be poured into. However, copper is very soft and cannot keep a sharp edge. This limited its effectiveness for tools and weapons. The supply of native copper (naturally formed lumps or nuggets, as seen in Figure 4.59) also decreased as the demand for it increased.

As a relatively abundant metal in the Earth’s crust, copper appears in many different types of metal ores. Ores are minerals that contain metal elements.

It is not yet known exactly how or why copper ores were first used to extract copper. Temperatures above 1000°C are required to extract copper from its ores. This process of extraction is known as **smelting**. Copper ores such as malachite and azurite were used in powdered form to decorate vases in times that predate the start of the Bronze Age.



Figure 4.59 Native copper was one of the first metal elements to be mined and refined.

However, when the first smelting occurred, the consequences of it were enormous. For the first time, large stable cities were built around sites where copper ores were found. Trading routes were established through settlements that started to specialise in what they produced. Los Millares, a Copper Age city in modern Spain, may have supported around 1000 people at its peak (see Figure 4.60).

It was found, towards the end of the Copper Age, that copper smelted with tin made a much stronger metal alloy – a homogeneous mixture of metals called bronze.

Bronze

Bronze is classified as an alloy. An alloy is a mixture of two or more substances that produces a new substance with metallic properties. Copper on its own is very soft, but with the addition of tin the physical properties of the substance change. Items made from bronze are harder and more durable than stone and copper items.

The ores that give rise to copper and tin are rarely ever found together. When bronze was first used widely, proper trade had to occur between settlements and cultures. For example, a lot of tin was mined in Cornwall in England. Trade routes were established and it was found that some of the Cornwall tin was traded as far as Syria and Israel.

The Bronze Age was also when written language became more widespread. Scientists and archaeologists believe the written language was likely to have developed further due to the need to communicate between traders.

It is unknown exactly why bronze gave way to iron in the Iron Age. Iron in its natural form is softer than bronze and harder to work with. Bronze was still commonly used during the Iron Age – bronze swords were given to officers in the Roman army, although regular soldiers received steel swords. The current theory for the transition to iron is that there were decreasing supplies and increasing prices of tin.



Figure 4.60 A model of Los Millares based on current excavations.



Figure 4.61 Bronze Age spearheads. The bronze spearheads remain, while the wooden shafts rotted away over time.



Figure 4.62 A bronze vessel from 1600 to 1046 bc, China. The Chinese used bronze largely as a ritual material – these vessels were designed to be used by the spirit of the dead.

EXPERIMENT 4.3.1: EXTRACTING COPPER FROM COPPER ORE

You have already heated copper carbonate and observed the reactions in Experiment 4.2.1 (page 181), but is it possible to obtain solid copper from this reaction?

Aim

Read the method of this experiment and write a suitable aim that starts with 'To ...'

Materials

- Heatproof mat
- Bunsen burner
- Tripod
- Gauze mat
- Crucible
- Beaker
- Spatula
- Powdered copper(II) carbonate
- Powdered charcoal

WARNING

> Copper carbonate is a respiratory irritant. In some parts of this practical, heating a powder may give off sparks or heated powders. Wear safety glasses and ensure that all care is taken and flammable material is moved away from the experimental space.

Method

- 1 Set up equipment as shown in Figure 4.63.
- 2 Place 1 spatula of copper(II) carbonate into a crucible.
- 3 Heat the crucible and contents, being very careful of the hot powder.
- 4 When there is no further change in appearance of the mixture, allow the crucible and contents to cool.
- 5 Add 2 spatulas of powdered charcoal to the crucible.
- 6 Mix well while holding the crucible.
- 7 Add a thin layer of powdered charcoal to cover the surface of the mixture.
- 8 Heat the apparatus for a few minutes. Be careful of any hot powder or sparks.
- 9 Allow mixture to cool.
- 10 Tip the powder from the crucible into a beaker half-filled with water.
- 11 Swirl the contents of the beaker around. Any copper you have made will fall to the bottom of the beaker.
- 12 Pour off the water and charcoal mix, add fresh water and swirl the mixture again.

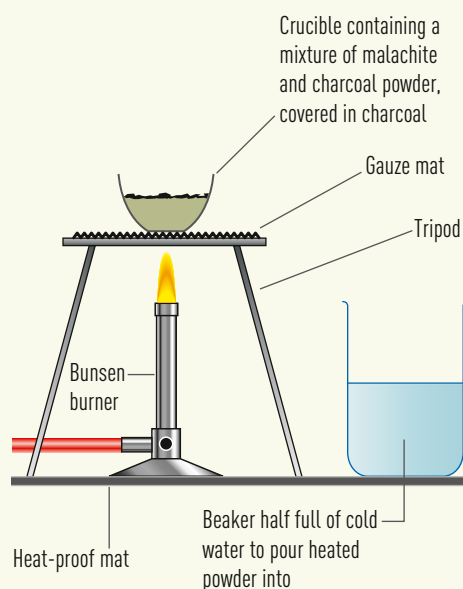


Figure 4.63 Experimental setup.

Discussion

- 1 How successful were you at making copper?
- 2 Compare the amount of copper you have made to how much copper carbonate you used.
- 3 Explain why technology had to be more advanced to extract copper from its ores compared with using native copper.

Conclusion

Write a suitable conclusion for your experiment that addresses your aim.

The Iron Age

Similarly with the Bronze Age, scientists and archaeologists do not know how iron started to be made. Iron is more easily obtained than bronze, but it is softer than bronze and cannot hold a sharp edge. This makes iron unsuitable for weapons and sharp tools.

However, sometime during the Iron Age, the process of alloying iron with carbon was discovered. This produced an alloy called steel, which was much stronger than bronze. The best steel was produced with approximately 0.3% to 1.2% carbon. However, the best steel weapons often fetched a very high price as the method of producing steel was difficult. Wrought iron (fairly pure iron) was often used, as it was cheaper. Steel could not be cold hammered – it had to be forged. Forging is a process of heating the steel until it is red hot before hammering it into the desired shape. It is likely that the saying ‘to strike while the iron is hot’ came from forging.

The Iron Age also led to better agriculture. The use of iron ploughs increased the speed at which a field could be ploughed and allowed for soils to be turned over more regularly. This increased the nutrient levels in the soils and allowed crops to be planted year-round rather than needing to rotate through plots of farmland.

It has also been suggested that civilisations with access to steel were able to dominate over civilisations that still used bronze in times of war. The Hittites, an empire of people from the Hattusa region (now part of Turkey, Syria and Lebanon) had dominated much of current-day Europe through their ability to forge and create iron weapons.

Eventually, the Iron Age gave way to the Middle Ages, or the medieval times.



Figure 4.64 Forging of steel.



Figure 4.65 Pure iron is too soft to make effective weapons, but steel is strong and can be honed to form sharp edges. These Iron Age weapons and chains are made from steel.

STUDENT DESIGN TASK

Comparing properties of iron and steel

Aim

To compare the physical and chemical properties of iron and steel.

Planning and conducting

- Some chemical properties and physical properties cannot be tested easily (e.g. melting point). You will need to consider where or how you can obtain reliable information for these chemical and physical properties.
- Some physical properties you can measure (e.g. electrical conductivity). How are you going to measure these? What is the best way to examine this?
- How do you make your experiment a fair test?
- Once you have written your method, have your teacher check and approve it before beginning. Ensure you identify any safety issues and take steps to minimise them.

Processing and analysing

- Consider how you are going to summarise your findings.
- Consider how you can check the reliability of your data.
- What inferences can you make about the differences in properties between iron and steel?

Communicating

- How are you going to present your findings? You may choose a report format, a poster or other suitable way.
- How will you cite your research resources?

QUESTIONS 4.3.1: TRADITIONAL USES OF ELEMENTS AND COMPOUNDS

Remember

- 1 Define the term 'alloy'.
- 2 Name two alloys and identify the components involved in each alloy.
- 3 Explain why bronze was used instead of copper during the Bronze Age.

Apply

- 4 Suggest a reason why wooden handles for axes and spears are not usually well preserved.
- 5 Copy and complete the following table to summarise the types of stones used in the Stone Age, their usages and the reason for their usage.

Stone type	Usage	Reason

Analyse

- 6 Each 'Age' in prehistory used a defining element or compound in many of the tools of the day. What do you think you would call our age now? Explain how and why you came up with your answer.

MODERN USES OF ELEMENTS AND COMPOUNDS

Our current dependency on elements and compounds is incredibly high. Every material object we use or touch comes from raw materials somewhere in the production line. We still use the materials we had in prehistoric times, though in a slightly different way.

Copper

Copper is a very good electrical conductor and is used as wiring in most electrical circuits. While gold is a better electrical conductor,

copper is much cheaper. Copper is also commonly used to make water pipes.

Due to our reliance on copper, copper ores with a high percentage of copper are decreasing. As a result, we no longer extract copper in the same way that prehistoric people did – we now use electricity to extract copper in a process called electrolysis. However, because there is less copper available to make new products, it is becoming more and more expensive.

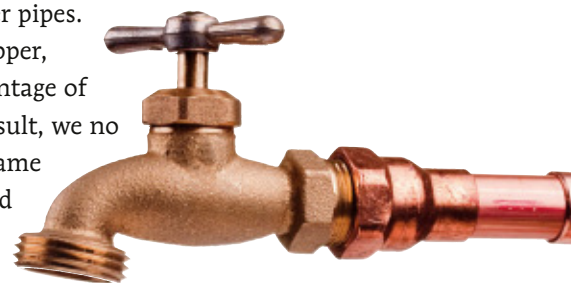


Figure 4.66 Copper is commonly used to make electrical wiring and water pipes.

EXPERIMENT 4.3.2: ELECTRICAL EXTRACTION (ELECTROLYSIS) OF COPPER

Aim

To extract copper from a copper sulfate solution using electricity.

Materials

- Power pack
- Electrical leads
- 0.5 M copper(II) sulfate solution
- 2 carbon electrodes

Method

- 1 Set up the equipment as shown in Figure 4.67.
- 2 Set the power pack to 6 V DC and switch it on.
- 3 Leave the reaction for 20 minutes, ensuring that you make and record observations every 2–3 minutes.
- 4 Switch off the power supply and record any observations for a further 2 minutes.

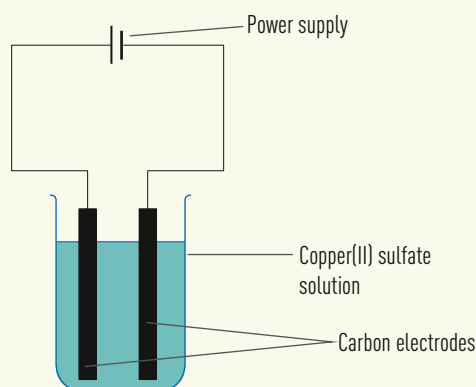


Figure 4.67 Electrolysis set-up.

Results

Record your observations in an appropriate way.

Discussion

- 1 One of the electrodes should become covered with a thin layer of copper. Was this electrode attached to the positive or negative terminal of the power supply?
- 2 Where does the solid copper come from? Justify your answer.
- 3 Electroplating is an application of this process. Research what electroplating is and how we can use this equipment to do it. If time permits, you may be able to electroplate some of your own items.
- 4 This reaction will also work if copper electrodes are used in place of carbon. Suggest a way to measure whether this reaction has taken place if copper electrodes were used.

Conclusion

Write a suitable conclusion that summarises your results and addresses the aim.



Figure 4.68 The chassis and frame of cars are usually made from steel.

Iron

Nowadays, iron is largely used in the form of steel. Steel is a versatile material used in many items, most notably in building construction and car manufacturing. Steel is a relatively cheap material, very durable, strong, and can be formed into many different shapes.

One problem with steel is that it corrodes (rusts) very easily. The iron in the alloy reacts with water and oxygen in the air in a process known as oxidation. You will learn more about corrosion and rusting in chapter 5.

Aluminium

Aluminium is the second-most widely used metal in the world (iron is the first). It is a highly reactive metal and is very difficult to extract from its ore. Electrolysis is used to extract the metal. Aluminium is extremely lightweight and malleable. Because it is so reactive, aluminium is almost always alloyed with other substances.



Figure 4.69 Bauxite, the ore of aluminium.

Household aluminium foil and aluminium drink cans usually contain only 92–99% aluminium.

The combination of strength and lightness means aluminium is often used in the manufacturing of cars, aeroplanes and trains. It is also used in window and door frames in many households.

Sulfuric acid

Sulfuric acid is one of the most important chemicals in the chemical industry. Its use is only second to water.

Approximately 60% of the sulfuric acid used in the chemical industry goes into making fertilisers. While some of the sulfur from sulfuric acid is required for plant growth, sulfuric acid is largely used to help increase the amount of fertiliser produced. It has been estimated that 50% of the world's population consumes food grown with the aid of fertilisers. Because of this high reliance on fertilisers, the volume of sulfuric acid used in fertiliser production is also very high.

Of the sulfuric acid used in industry, 20% goes towards the production of medicines, detergents, resins, water treatment and aluminium production. Another 6% is used to produce pigments including paints, printing inks and fabrics. The remainder goes into the production of cellophane plastic, cleaning metals, batteries and explosives.

Mainly, it is the chemical properties of sulfuric acid that dictate its use, rather than its physical properties.

Bronze

Bronze is not used in modern times as an industrial alloy. Stainless steel is used instead because it is far cheaper to produce, easier to obtain and has relatively the same properties. Owing largely to the increasing price of copper, bronze is only used as a decorative metal. Many sculptures and musical instruments, such as cymbals, are made of bronze.

Stone

Stone is still used in many buildings and surfaces that are required to be weather resistant. Many buildings in the Sydney city region are made of sandstone. Granite and marble are also used for decorative purposes and for kitchen bench tops as they are resistant to water and heat.

ACTIVITY 4.3.1: OUR LIMITED RESOURCES

It is important to recognise some of the problems we face as a society. Our current resources of natural substances, such as minerals from which we extract compounds and elements, are running out due to increased consumption of them. We cannot produce any more.

Research a piece of technology you use regularly (such as a mobile phone, game console or computer), and identify some of the elements or compounds that go into making it. Find out approximately when these elements are expected to run out and compare this with our current demand for them. Once completed, suggest some ways that may be required to conserve our use of these elements. You may wish to present your findings as a verbal report or a written report.

QUESTIONS 4.3.2: MODERN USES OF ELEMENTS AND COMPOUNDS

Remember

- 1 Identify two reasons why bronze is not often used in today's society.
- 2 Compare and contrast the use of metals and stones in today's society with that of ancient society. Suggest reasons for any differences.

Apply

- 3 Suggest a reason why extraction of aluminium did not occur until the mid 1800s compared with the prehistoric uses of copper and iron.

Analyse

- 4 Draw a pie chart to show the various uses of sulfuric acid.
- 5 Choose one element or compound and explain how its chemical and/or physical properties relate to its use.

4.3

CHECKPOINT

THE IMPACT OF ELEMENTS AND COMPOUNDS ON SOCIETY

Remember and understand

- 1 Recall the three main periods in archaeological history. [1 mark]
- 2 Select a chemical element and identify one chemical property and one physical property. [2 marks]
- 3 Explain why stone such as chert and flint used in tools needed to be hard. [2 marks]
- 4 Explain why trading was necessary in prehistoric times. [2 marks]
- 5 Explain what an alloy is and identify two different alloys and their uses in modern society. [3 marks]
- 9 'We should use gold instead of copper in our homes for electrical wiring as gold is a better conductor of electricity than copper.' Evaluate this statement based on what you know about gold and copper. [3 marks]
- 10 Investigate some common solders used. What are solders? What properties do they have? Explain how their properties relate to their uses. [4 marks]

Apply

- 6 Suggest a reason why the Copper Age was relatively short compared to the Bronze Age. Justify your answer. [2 marks]
- 7 Steel bridges, such as the Sydney Harbour Bridge, must be frequently painted to ensure the metal is not exposed to salt water, moisture and oxygen so it does not rust. Propose a reason why bridges are still made out of steel, even though it needs this amount of care. [2 marks]

Analyse and evaluate

- 8 In ancient times, metals such as gold and silver were only used by the very rich. Stones such as turquoise and lapis lazuli were also highly prized. Suggest two reasons why these substances were particularly sought after. [2 marks]

Research

- 11 Bronze was used for many purposes by our ancestors, such as for weapons, tools and fittings on ships, but bronze is rarely used for these purposes today. Suggest reasons why we no longer use bronze for these purposes. [2 marks]



TOTAL MARKS
[/25]

4

CHAPTER REVIEW

- 1 Fill in the gaps, using the words in the Word Bank below:

The _____ model of matter states that all substances are made up of small components. The ways these particles behave determine the _____ of the substance. We can separate all substances into elements, _____ and mixtures.

We use substances in different ways because of their different _____ properties and _____ properties. For example, _____ is used in electrical wiring because it is ductile and can _____ electricity. It also doesn't react with _____, which means we can also use it to make pipes.

Historically, humans have used substances to their advantage. The first age was the _____ Age, followed by the _____ Age and the _____ Age. As we have developed as a culture, our uses of substances have become more _____.

WORD BANK

Bronze	copper	properties
chemical	Iron	sophisticated
compounds	particle	Stone
conduct	physical	water

Explain why element symbols are used in science

- Recall the chemical symbol for:
 - hydrogen [1 mark]
 - carbon [1 mark]
 - copper [1 mark]
- We often use symbols and chemical formulas to describe substances in science. Explain why this is the case. [2 marks]
- The chemical symbols used in science are often derived from ancient names. For example, gold has the symbol Au, which comes from *aurum*, the Latin word for gold. Explain why less reactive elements are more likely to have their Latin names. Hint: How does the reactivity of an element relate to how easily it could be discovered? [3 marks]

Identify that our understanding of the structure and properties of elements has changed due to technological advances

- Our understanding of the structure of elements has changed due to technological advances. Explain how a specific technological advancement has changed our understanding of the structure of an element. [2 marks]
- Explain how a specific technological advancement has changed our understanding of the properties of an element. [2 marks]
- The Large Hadron Collider (LHC) was very expensive and complicated to construct. Suggest a reason why scientists persisted with building the LHC, and recall the outcomes of the research so far. [2 marks]



Describe the properties and uses of some metal and non-metal elements

- 7 Identify some physical differences between a metal and a non-metal. [2 marks]
- 8 Describe the properties and uses of copper. [2 marks]
- 9 Describe the properties and uses of oxygen. [2 marks]
- 10 Compare and contrast the properties of a metal and a non-metal element. [2 marks]
- 11 Carbon is often found as an allotrope. Explain what this term means and outline why carbon is classified as a non-metal. [4 marks]
- 12 Explain how the property of an element relates to its use, using an example. [2 marks]

Investigate the nature of mineral crystals (additional)

- 13 Identify the general crystal shape that table salt (sodium chloride) forms. [1 mark]
- 14 Compare the main differences between a crystal of sodium chloride and a crystal of diamond. [2 marks]

Describe the differences between elements, compounds and mixtures

- 15 Recall the definitions of an element, a compound and a mixture. [2 marks]
- 16 Describe how particles are arranged in an element. [1 mark]
- 17 Compare and contrast the particle arrangements in a compound and a mixture. [2 marks]

Identify some common compounds

- 18 Recall two common compounds you have come across in this chapter. Identify their uses and their chemical formulas. [2 marks]
- 19 Sodium bicarbonate (NaHCO_3) is a common compound also known as baking soda. Identify the elements baking soda contains, including the element names and their symbols. [2 marks]

Investigate how the chemical properties of a substance will determine its use (additional)

- 20 Gold is not chemically reactive, while nickel is. Explain why gold is more ideal to use in jewellery instead of nickel. [2 marks]
- 21 Water pipes used to be made from lead before copper became the preferred material. Plastics are now commonly used to make water pipes. Investigate these three substances and suggest reasons why lead was replaced by copper, and then why plastic replaced copper. [5 marks]

Investigate how people in different cultures in the past have used certain substances to their advantage

- 22 The development of human society has been closely linked to the availability of metals and materials. Using your understanding of one material used in prehistoric times, explain why this material was used, what it was used for and what we use to perform that function today. [3 marks]
- 23 Explain how our understanding of elements and their properties has helped to shape history. [2 marks]
- 24 Explain how technology affected the development of a particular culture. [3 marks]

TOTAL MARKS
[/55]

RESEARCH

Choose one of the following topics for a research project. Your job is to discover a little more about how materials are used in society, both historically as well as in present day.

Historical uses of toxic elements

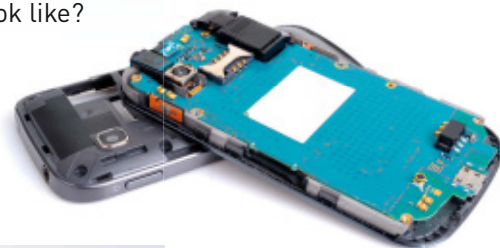
The term 'mad as a hatter' was used to describe hat makers in England who used mercury in their jobs and suffered the symptoms of mercury poisoning. There are some theories that lead poisoning sent emperors crazy, which caused the fall of Rome. Research toxic chemicals such as mercury and lead, and find out how they were used in the past. What are some problems with their usage and when was it realised that these chemicals were causing damage?

Beaker people

The Beaker People were a movement during archaeological history that came after the Iron Age. The Beaker People are known for using a particular kind of vessel to carry liquids. Investigate the Beaker People culture including why and how they moved through Europe and took over from the Iron Age.

Emerging technologies

There are many new technologies available for use in touch technology and smart phones. Investigate some of the compounds and elements used in these technologies. How do we obtain these elements and compounds? What does the demand and supply of them look like? Are there any estimates as to when these materials may run out?



REFLECT

Me

- 1 How has my understanding of elements, compounds and properties of substances changed?
- 2 What did I find difficult in this topic?

My world

- 3 What elements and compounds do we typically use in everyday life?

- 4 Why do we use certain materials in technology? What is it about those materials that make them suitable?

My future

- 5 Are we running out of some materials?
- 6 How will we tackle problems of limited supply of certain materials?

KEY WORDS

allotrope	flammability	metallurgy	period
alloy	group	mixture	polymer
compound	heterogeneous	molecular	pressure
corrosion	homogeneous	monatomic	proton
decomposition	kinetic theory	neutron	reactivity
diatomic	lattice	non-metal	refractive index
electron	metal	nucleus	smelting
element	metalloids	particle	toxicity

4

MAKING CONNECTIONS

Use of elements and compounds by Indigenous Australians

Australia is one of the oldest and flattest countries in the world. There are no active volcanoes on the mainland, and it has been a long time since the extinct volcanoes were active. There are a few interesting geological features because of this.

Australia has low nutrient soils

Nutrients come from the recycling of organic matter such as decaying trees or animals, but also from new rocks made by volcanoes. Over many thousands of years, the nutrients found in new rocks are leached further down into the soil. Australia, being a very 'old' country, means there are very few new rocks – Australia has the oldest rocks in the world! However, this also leads to very poor soil quality.

Australia has very little volcanic rock

Another result of Australia's location and long-extinct volcanoes is that harder volcanic rocks were weathered and eroded away long before the arrival of Indigenous Australians. Australia lacked the flint and chert that other continents had access to during the Stone Age.

Influences of geology

The geology of the region meant the tools that Indigenous Australians used were very different from others around the world. So, the lifestyles of Indigenous Australians tended to be quite different from European or Asian civilisations at the same time.

Indigenous Australian tools

As Australia is such a vast country, the materials available to make tools and implements varied greatly depending on location. Different groups produced their tools and implements differently depending on the purpose of the tool and the location of the group. Knives, spears, digging implements and vessels for eating and drinking were common among all communities. Coastal communities would use fish bones as spears, whereas communities with no access to the ocean would use stones or fire-hardened wood for this same purpose.



Figure 4.70 Blades made by chipping away at the edges of stones. These kinds of blades were often used for ceremonial purposes, but also for cutting up meat and other food.

Weapons

A lot of tools such as boomerangs, clubs and spears were made of materials that decay easily, such as wood and fibre. Very few ancient examples remain. Spears tended to be made from light wood that grew tall and straight. This meant little work was required to shape the spear. Lighter wood also meant that spears took less energy to throw.

Boomerangs tended to be made of heavier wood, as more force was required to hunt larger prey such as kangaroos. Lighter boomerangs existed, but they were still made out of wood that was heavier than the wood used for spears.



Carriers

Nets, baskets and bags were used for hunting and fishing as well as for carrying multiple objects. The weaves in some baskets were so tight that they were capable of carrying honey! Bags were usually made from a plant called cordyline, as well as grass stalks and bush string. Twined bark fibres, swamp reeds, flax and seagrasses were also used to weave baskets. Basket weaving is closely linked with Indigenous culture. Often stories are passed on from generations during sessions of basket weaving.

Canoes

Canoes were relatively fragile. They were often made from bark and left to rot after a few uses. Canoes were typically used when hunting bird eggs and fish. Rivers were used to travel quickly through regions. There are often trees around riverbeds that still show 'canoe scarring' – a region of bark that has been peeled from the tree to make a canoe.



Figure 4.71 An assortment of Indigenous tools: coolamon (wooden carrying bowl), stone axe, wooden shield, dilly bag (carrier), grinding stone, fire sticks and woomera (spear-throwing device).

Research tasks

- 1 Research some other tools used by traditional Indigenous Australians. You may wish to look at items such as digging sticks, seed-grinding stones, spear throwers, shelters and message sticks. Examine the materials these tools and implements were made from, and suggest a reason why these materials were selected.



Figure 4.72 A tree showing a typical canoe scar.

- 2 Research some key cultural ceremonies of Indigenous Australians. Ceremonial wear, body paint and rock painting were all common. What were used for these special purposes? How were the materials used different from those used for everyday items?
- 3 Indigenous Australians established trading routes to exchange items available in one region but not another. Ochre, grinding stones, shields and weapons were all traded. Research some of these trade routes. How did traditional Indigenous Australians communicate with each other when languages between communities were so different?
- 4 Consider the following statement: 'Cultural development was largely influenced by the geology of a groups' surroundings.' For example, in Australia, traditional Indigenous Australians lived a largely nomadic life due to the poor soil quality and the lack of easy access to metals such as copper.' Research the geology of Australia and the lifestyle of traditional Indigenous Australians compared with places like Europe, and evaluate the statement. Present your information as an annotated poster, multimedia presentation or another format of your choosing. You must supply a bibliography of your sources.

5



CHEMICAL CHANGE

Chemistry is the study of how substances react with one another and how the properties of substances can be used in everyday life. In particular, chemical reactions can be used to produce new substances and new materials. Industrial chemists look at processes that allow us to make new substances, while material scientists design and determine uses for these new substances.

PHYSICAL AND CHEMICAL CHANGE

5.1

Matter can undergo a number of different types of changes. Physical changes are where matter undergoes a change in state, such as from solid to liquid, or a change in shape, such as breaking glass. Chemical changes occur when there is a change in the chemical makeup of the substances involved and a new substance is formed.

Students:

- » compare chemical and physical changes based on particle arrangement and reversibility
- » identify that the signs of chemical changes include a change in temperature, the original substance disappearing or a new substance appearing
- » demonstrate that chemical change involves reactions between substances to form new substances

COMMON CHEMICAL REACTIONS

5.2

Chemistry is all around us, whether we notice it or not. Chemical reactions occur when plants photosynthesise, when organisms respire and when rocks are weathered by chemicals within rainwater.

Students:

- » investigate everyday chemical reactions like photosynthesis, respiration and chemical weathering

CHEMISTRY IN INDUSTRY

5.3

Have you ever considered the materials that surround you, such as the clothes you wear, medicines, gadgets, glues and dyes? Chemistry is used in industry to create these and countless more products that we use every day.

Students:

- » propose reasons why the development of polymers and pharmaceuticals is important to society
- » describe how collaboration across different fields of science has enabled us to obtain new materials from the Earth's spheres

5.1

PHYSICAL AND CHEMICAL CHANGE

We are surrounded by substances continually undergoing change. When a substance just changes in shape or appearance, this is a physical change. When the change involves one substance changing into a different substance, it is called a chemical change. Some of these changes are spectacular, such as fireworks or special effects used in movies. Some changes are not so dramatic, but can also affect our lives in important ways, such as photosynthesis in plants or the digestion of food in our bodies. These changes can happen quickly or they may be very slow.

PHYSICAL CHANGE

You have already learned that everything around us is made up of matter. Anything that takes up space and has mass is matter. How different types of matter interact determines some of their properties. In chapter 4 you examined some common atoms and elements as well as some compounds. This chapter will look at how matter changes.

EXPERIMENT 5.1.1: EXPLORING PHYSICAL CHANGES

Aim

To explore some different physical changes.

Materials

- Aluminium drink can
- Elastic band
- Rock salt
- Ice
- Sugar cube
- Vitamin C tablet
- Slice of bread
- Piece of cloth

Method

- 1 For each of the materials provided, find ways to change their appearance. There may be more than one way for each substance, so be creative.
- 2 Record your method(s) used and observations of the results for each substance in an appropriate table in your results section.

Results

Include your methods and observations in an appropriate table.

Discussion

- 1 Identify three different ways a physical change can take place.
- 2 Explain what each change had in common.

Conclusion

Write a statement that summarises your results and addresses the aim.



Characteristics of physical changes

In a **physical change**, the substance still consists of the same particles but the substance looks different before and after the change. A cut diamond is made of the same material as an uncut diamond. Chocolate that has melted (see Figure 5.1) is the same substance as the original block of chocolate. A change in appearance, size or shape is called a physical change.

Physical changes can happen when a force is applied, when substances break down into smaller pieces or are mixed together, and when substances change state between solid, liquid and gas. You learned about changes of state and mixtures in chapters 4 and 5 of *Oxford Insight Science 7*.

Arrangement of particles

When physical changes occur, the particles within substances rearrange themselves and atoms often gain or lose energy, however, the chemical bonds between the atoms are not changed. Freezing water is a good example. In liquid water, the water molecules have enough energy to roll over each other. When we freeze water, the molecules lose that energy and become relatively still. The water molecules themselves remain the same; they are not broken up into hydrogen and oxygen atoms.

Reversibility

Physical changes are usually much easier to reverse than chemical changes. For example, if salt is dissolved in water, the change can

be easily reversed by separating the salt from the water by evaporation. However, it is incorrect to say that physical changes can always be easily reversed. Breaking a piece of glass is a physical change, but the glass is not easily changed back into its original size and shape. You would have to melt the pieces of glass (a state change), and then reshape the glass to reverse the change.

Conservation of mass

In any **reaction**, mass is always conserved, meaning it is the same before and after the reaction. You will always have the same number of atoms or molecules before and after a physical change.



Figure 5.2 Ice melting to water is an example of a physical change.

Energy changes

There may be some energy changes that occur when physical changes happen. For example, ice absorbs energy from the environment to become liquid water. However, this energy change is a lot smaller than the energy changes that occur in chemical changes.



Figure 5.1 Melting chocolate is a physical change.



Figure 5.3 Breaking a glass is a physical change that is not easily reversed.

QUESTIONS 5.1.1: PHYSICAL CHANGE

Remember

- 1 Define the term 'physical change'.
- 2 Identify some physical changes that are easy to reverse.

Apply

- 3 An analogy is a comparison of two things that have similar features but are otherwise different. Use an analogy to describe the way particles interact when physical changes occur.

CHEMICAL CHANGE

A **chemical change** occurs when new substances are formed as a result of the change. Chemical change creates new products that have different properties from the substances present before the chemical change.

Characteristics of chemical changes

There are several key characteristics of chemical changes.

Arrangement of particles

In a chemical change, chemical bonds are broken in the original substance and re-formed in a different way in the new substance. This is called a **chemical reaction**. Chemical changes alter the nature of the substance that was originally present (see Figure 5.4). This is the most important difference between chemical and physical changes. Chemical changes produce a new substance, while physical changes do not.

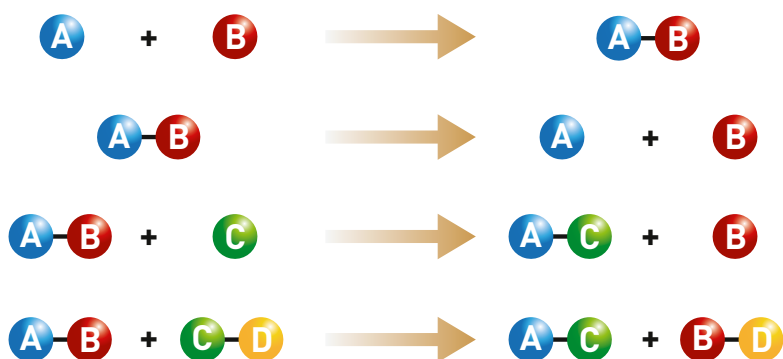


Figure 5.4 A model showing four different types of chemical reactions. In each case, new products are formed although all the substances are present in the reaction originally.

Reversibility

Chemical changes, which can sometimes be reversed, are often more difficult to reverse than physical changes. Burning wood (see Figure 5.5) is a chemical change that cannot be reversed.



Figure 5.5 Burning wood is an example of a chemical change. The wood cannot go back to its original form.

Conservation of mass

As with physical reactions, mass is conserved in chemical reactions. A chemical change does not create or destroy atoms; it just changes the chemical bonds that hold those atoms together. The total mass of the **reactants** (the substances or chemicals used) equals the total mass of the **products** (the substances or chemicals that are produced).

Energy changes

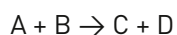
The energy changes involved in chemical reactions are usually far greater than the energy changes in physical reactions. To break chemical bonds, a lot of energy is required. However, the making of chemical bonds will release energy. An **exothermic reaction** is a reaction that will release energy into the environment. An **endothermic reaction** is a reaction that will take energy from the environment.

Chemical equations

A chemical change can also be described as a chemical reaction. In chemical changes or reactions, chemical substances change to become new substances.

The substances you start with are called reactants. They react to produce new substances. The substances you finish with are called the products. There may be more than one reactant and product for each chemical change.

You may see chemical reactions written in the basic form of the equation below.

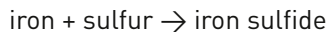


This means that the reactants A and B chemically react to form the products C and D. This is known as the general form of a chemical reaction. The arrow indicates that a reaction has taken place.

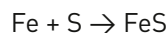
Chemical equations can be written as a **word equation** or a **symbol equation**. Symbol equations use the chemical symbols from the periodic table (see page 167) instead of the names of the chemicals.

For example, the chemical equation for the reaction between iron and sulfur can be written as:

Word equation:



Symbol equation:

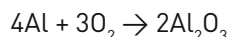


You may also find large numbers in front of the chemical substance in an equation. For example:

Word equation:



Symbol equation:



The large numbers in front of each chemical symbol indicate how many of those atoms or molecules are required. You will learn more about these large numbers and how to use them in year 10.

QUESTIONS 5.1.2: CHEMICAL CHANGE

Remember

- 1 Define the term 'chemical reaction'.
- 2 Recall some characteristics of a chemical reaction.

Apply

- 3 Use an analogy to describe how chemical changes occur.
- 4 A year 8 student said: 'A chemical change just involves changing the position of the chemicals in a reaction.' Is the student correct? Justify your answer.

SIGNS OF CHEMICAL CHANGE

Although some chemical reactions involve gas reactants and products that we cannot see, we can generally determine whether chemical reactions have taken place through a few key signs:

- a gas is produced, which is seen as either bubbles or fizz, or can be smelled
- energy in the form of light is produced
- energy in the form of heat is absorbed or produced
- a permanent colour change occurs
- a **precipitate** (insoluble solid substance) forms in the solution and does not disappear.



Figure 5.6 Mixing bicarb soda (sodium bicarbonate) and vinegar (acetic acid) produces bubbles (carbon dioxide).

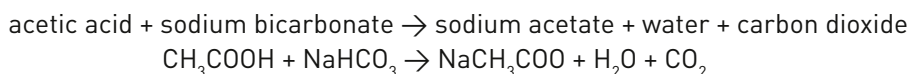


Figure 5.7 We can tell a chemical reaction is occurring when a firework explodes because light and heat are produced.

Production of gas

If a reaction releases a gas, this indicates the production of a new substance and thus a chemical change. Gases can be easily detected if the reaction takes place in an aqueous environment (in a solution).

A good example of a chemical reaction producing a gas is the reaction between sodium bicarbonate and acetic acid, as shown in Figure 5.6. The carbon dioxide gas created in this reaction is easily seen as bubbles.



DEEPER UNDERSTANDING

Chemical reactions in cars: Airbags

An airbag in a car provides extra protection to the driver or occupant in the event of a collision. Airbags are designed to work in conjunction with seat belts. Airbags fill rapidly with gas and then deflate (go down) relatively slowly after they have absorbed the force of the person.

In an accident, an airbag is activated by a sensor. The sensor detects the very sudden stopping of the car, such as a high-speed collision. This generates an electric current, which detonates (explodes or ignites) a small amount of a compound called sodium azide.

A driver's side airbag contains approximately 50 grams of sodium azide. When heated, this reacts to produce 60 litres of nitrogen gas. The nitrogen gas fills the airbag within 40 milliseconds. By the time the driver's body impacts the airbag, the bag has filled and is deflating. This means that the airbag is soft when the driver's body hits it. After about 2 seconds the air bag is fully deflated.

The nitrogen gas is made by the decomposition of sodium azide. The sodium also produced in this reaction may be a health hazard, but it reacts with other

chemicals in the airbag to produce an inert (unreactive) powder. This powder remains sealed inside the core of the airbag. Even if the airbag were cut apart, the powder would not harm you.

The passenger's side airbag is much larger than the driver's side airbag, so it has more sodium azide because more gas is needed to fill it.

Some newer airbags contain reactants other than sodium azide. These bags produce different products from the reaction but they still produce nitrogen gas at the same rate.

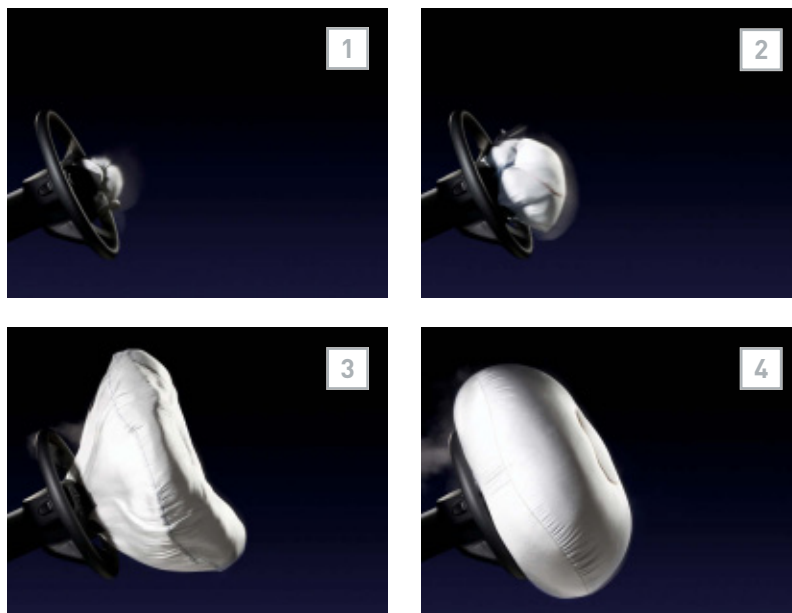


Figure 5.8 Airbags in cars fill rapidly with gas to protect the driver and passengers in a car crash.

Permanent colour change

A colour change needs to be permanent to show that a chemical reaction has taken place. A colour change usually indicates that a different substance is formed, but not all colour changes indicate that a chemical reaction has taken place. Heating an iron nail will cause it to become red hot. Although this is a colour change, it is not permanent and the nail will return to its normal colour when as it cools again.

Rusting, on the other hand, is a chemical reaction. In this reaction, iron metal reacts with oxygen in the air and water to produce the orange-brown compound iron(III) oxide (Fe_2O_3), which is more commonly known as rust. If you try to scrape rust off an iron object, you will find that it leaves a hole in the metal. The chemical equation for rusting is:

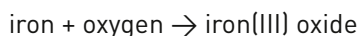


Figure 5.9 Rust will 'eat away' iron metal and cause the formation of holes. When iron reacts with the air and the moisture, it forms a completely new substance that can be washed or scraped away.



Figure 5.10 Rust is a big problem for ships and cars. If not looked after and exposed to the elements, iron will rust very easily.

EXPERIMENT 5.1.2: RUSTY NAILS

Aim

To determine the variables that affect the speed of nails rusting.

Materials

- 6 medium test tubes
- 6 iron nails (with no galvanising)
- Salt
- Oil
- Kettle
- Rubber test tube stoppers
- Petri dish

WARNING

- > Boiling water is used in this practical. Take care not to splash it.
- > Gently slide the nails into the test tubes. Do not drop them in.

Method

- 1 Carefully observe the nails before you start and record your observations.
- 2 Set up the equipment as shown in Figure 5.11.
- 3 Leave the equipment setup and make as many observations as possible over the next two weeks.
- 4 After the two weeks, make one last observation of the nails by pouring the contents out into a Petri dish and examining them closely.

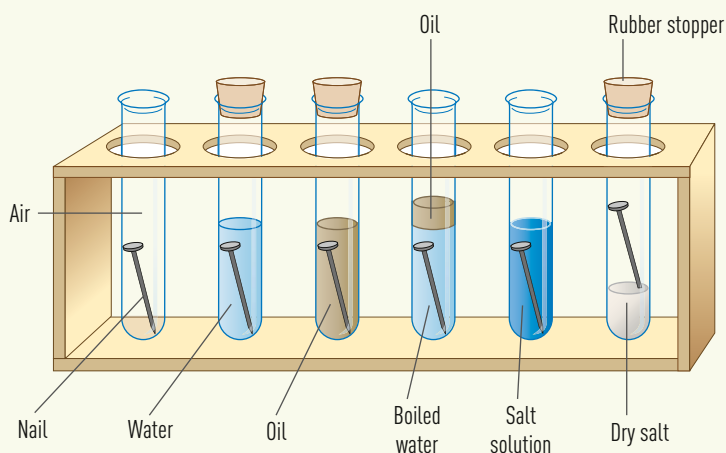


Figure 5.11 Rusty nail experimental setup.

Results

Record your results in an appropriate format.

Discussion

The following table lists some of the reasons why certain chemicals may have been used in the test tubes for the setup.

- 1 Explain why each of the test tubes were set up the way they were and what they were designed to show.
- 2 Compare the different test tubes and the amount of rust found on each nail.
- 3 Deduce the main causes of rusting.

Substance	Reasoning
Boiled water	Lower oxygen
Oil	No water, lower oxygen
Water	Moisture
Salt	Increased salt content

Conclusion

Write an appropriate statement that summarises your results and reflects the aim.

STUDENT DESIGN TASK

Investigating the rate of rusting

Challenge

Use one of the variables of rusting in Experiment 5.1.2 (salt level, presence of water or oxygen level) and design and carry out a quantitative test to determine how that particular variable affects the rate of rusting.

Questioning and predicting

- Choose one of the variables listed above.
- Write an appropriate aim for your experiment.
- Write a hypothesis about the effect of your chosen variable. The hypothesis needs to be phrased in the form: If [factor you are investigating] increases, then the rate of rusting will [increase/decrease].

Planning and conducting

- Consider what you can alter easily and what can be completed in the required time period.
- Remember you are carrying out a quantitative test, so you will need to consider how you will measure your variables and the results.
- Identify the controlled, experimental and dependent variables for your tests.
- Identify any safety considerations.
- Write your method as a series of clear steps and get your teacher's approval before carrying out the experiment.

Processing, analysing and problem solving

- Record your data in a suitable table and determine the relationship between your variable and the rate of rusting.
- Evaluate how well your experimental design determined the cause and effect relationship between your variable and the rate of rusting. How could you have improved your experiment?

Communicating

- 1 Present your findings as a scientific report, verbal presentation, poster or other format as approved by your teacher.
- 2 Identify which variables you kept the same in your experiment and explain why this was necessary.
- 3 Evaluate whether or not your hypothesis was supported.
- 4 Describe any cause and effect relationship you may have discovered between your variable and the rate of rusting.
- 5 Based on your findings, suggest a method that could be used to prevent or slow the rate of rusting.



Figure 5.12 Rusting nails can be a problem in structures where they can cause weakness in the structure.



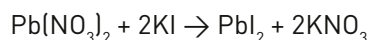
Figure 5.13 The formation of the yellow lead iodide precipitate is a very vivid reaction between two clear solutions.

Precipitation

A **precipitate** is a solid that forms from in a solution. The formation of a precipitate is one of the more common signs that a chemical reaction has taken place. A precipitate is different from a solid that does not dissolve. For example, sand is not a precipitate.

A precipitate forms in a reaction when the reactants are dissolved in solution, but after the reaction one of the new substances formed is no longer soluble and suddenly appears in the solution. A precipitation reaction will form a precipitate (the solid) and the solution (the aqueous substance). An example of a precipitation reaction is the reaction of lead(II) nitrate and potassium iodide, producing lead iodide as a yellow precipitate:

lead nitrate + potassium iodide → lead iodide + potassium nitrate



Energy changes

If you place a thermometer into a beaker or flask where a chemical reaction is occurring, you often notice a temperature change. This change is due to the nature of a chemical reaction itself. Energy in the form of heat is absorbed by the reactant in order to break the bonds that hold the atoms together. As new chemical bonds are formed, energy is released.

In most chemical reactions, the temperature is likely to increase and the energy is released into the surrounding environment.

In any chemical reaction, bonds may be both broken and formed. Chemical reactions that have an overall increase in temperature are called exothermic reactions.

Where there is an overall decrease in temperature, they are called endothermic reactions.

Many chemical reactions require some energy to get them started, but once started they often release energy themselves. This little ‘push’ of energy is called the **activation energy** of a reaction. The activation energy is given to the reactants and starts off a chemical reaction by allowing the energy to break chemical bonds. Activation energy can be thought of as a barrier. If the bonds between the chemicals in the reactants are weak, little energy is required to break them. However, if the bonds are very strong, a much greater amount of energy is required. If the activation energy is not supplied, the reaction cannot start.



Figure 5.14 A sparkler is made up of powdered magnesium. When lit, an exothermic chemical reaction takes place that releases energy in the form of heat and light.

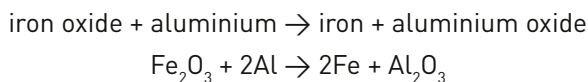
ACTIVITY 5.1.1: MODELLING CHEMICAL AND PHYSICAL REACTIONS

What you will need: Polystyrene balls or jellybeans, toothpicks

- 1 Design a model of a chemical substance using the materials you have.
- 2 Alter the model to show the chemical substance undergoing a physical reaction. Draw or take photographs of your model.
- 3 Now show the same chemical substance undergoing a chemical reaction. Draw or take photographs of your model.
 - What are the key differences between chemical change and physical change that you have modelled?
 - Is this model a good model of chemical and physical reactions? Why or why not?
 - How can you improve this model?

The legacy of Hans Goldschmidt and Alfred Nobel

The thermite reaction was discovered in 1839 by Hans Goldschmidt. Hans Goldschmidt, a German chemist, was a student of Robert Bunsen (the inventor of the Bunsen burner). Thermite is usually a mixture of aluminium powder and iron(III) oxide that, when ignited by heat, undergoes a highly exothermic reaction. The equation for the reaction is:



The thermite reaction requires a very large input of energy – only temperatures achieved by burning magnesium can allow it to be set alight. Once alight, this reaction reaches temperatures of over 2500°C and can melt iron.

When the thermite reaction was discovered, Goldschmidt immediately recognised the value of such a process in industrial welding. Even today, underwater welding occurs through the use of thermite, as it does not require oxygen to burn metal.

Nitroglycerin is known as a contact explosive and is a substance that will react violently when a small amount of friction or shock is applied. Although not invented by Alfred Nobel, he was the chief person involved in finding a use for nitroglycerin. By combining nitroglycerin with an absorbent non-reactive material, Nobel packaged the chemical into sticks called



Figure 5.15 Hans Goldschmidt discovered the thermite reaction.

dynamite. Initially, dynamite was used for road building and other construction tasks.

Due to the sensitive nature of nitroglycerin, many lives were lost simply through the production and transportation of the material. Nobel's own younger brother, Emil, was killed in a nitroglycerin explosion that occurred at a manufacturing plant.



Figure 5.16 Alfred Nobel used nitroglycerin to make sticks of dynamite.

LITERACY
BUILDER

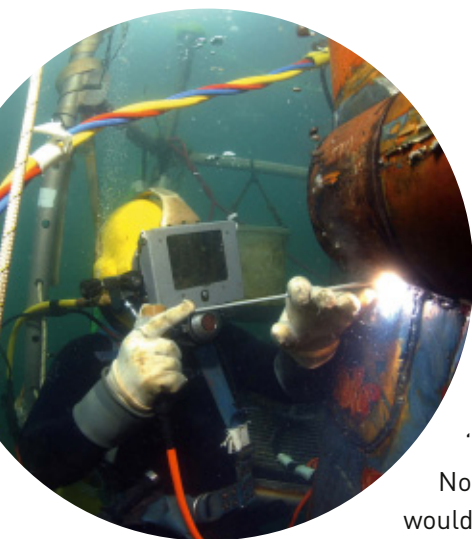


Figure 5.17 Underwater welding requires a process that does not involve free oxygen, so the thermite reaction is used.

Nobel spent much of his life trying to stabilise nitroglycerin and, in the process, became very rich through the various patents that he generated.

When one of Nobel's brothers died, a French newspaper accidentally published Alfred's obituary, claiming him to be the 'Merchant of Death'. This prompted Nobel to consider the legacy that he would leave when he passed away. As a result, he included in his last will and testament that he wanted the vast majority of his fortune to be used to recognise significant achievements and contributions to science or culture. In 1895 the Nobel prizes were established and now include six categories with prizes awarded each year for the most significant scientific or cultural advances in each category.

Questions

- 1 Identify which of the chemicals mentioned in this Literacy Builder has a low activation energy, and which one has a high activation energy. Justify your answer.
- 2 Identify the uses of the thermite reaction.
- 3 Recall two different uses of nitroglycerin.
- 4 Research the Nobel prizes. What are the six categories? Are there any Australians who have won the prize? If so, what did they win them for?
- 5 Choose one recipient of a Nobel prize and create a biography for this person including their contributions to science that prompted their award.



Figure 5.18 Instant ice packs are used to help reduce swelling from injuries. They use an endothermic reaction to cool the injured area.

Uses of endothermic and exothermic reactions

There are many uses of endothermic and exothermic reactions. An instant ice pack is a good example of an endothermic reaction. Instant ice packs are commonly found in first aid kits because they can be activated anywhere. The ice pack is made up of two sealed bags, one inside the other. The outer bag contains ammonium nitrate crystals and the inner bag contains water. Squeezing the outer bag until the inner bag bursts allows the water to mix with the ammonium nitrate. As the ammonium nitrate dissolves, the weak bonds holding the molecules together break. While this is not a chemical reaction, since dissolving is a physical process, the overall reaction is endothermic and feels cold to touch.

Glow sticks are an example of an exothermic reaction. The chemical reaction inside them gives off energy, but not in the form of heat. When you bend the glow stick, you hear a 'snap' sound. This is a smaller internal vial breaking within the main glow stick. As the two chemicals react, they release energy in the form of light.

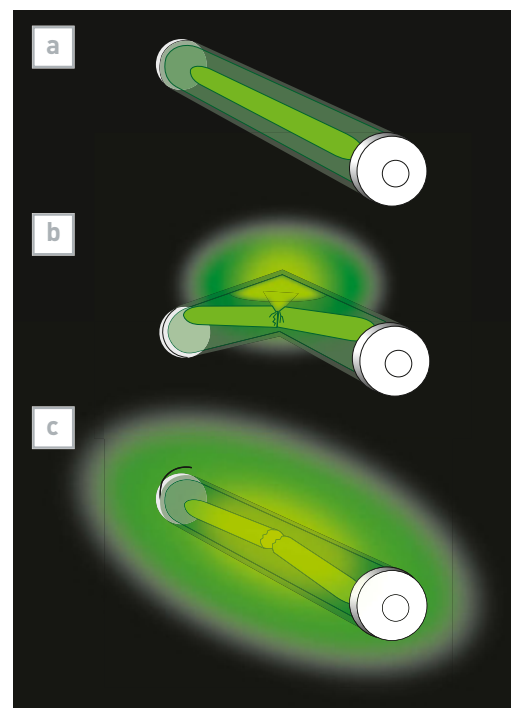


Figure 5.19 How a glow stick works. (a) The green glass vial inside the glow stick separates the two reactants. (b) As you break the glow stick, the two reactants come into contact with each other. (c) The glow stick fully glows when the two reactants are mixed well.

EXPERIMENT 5.1.3: ENERGY IN REACTIONS

Aim

To observe changes in temperature in chemical reactions.

Materials

- 3% hydrogen peroxide
- Measuring cylinder
- 3 teaspoons yeast
- Beakers
- Thermometer
- Stopwatch
- Vinegar
- 3 teaspoons baking soda

Method

- 1 Add 30 mL of hydrogen peroxide into a beaker. Measure and record the temperature.
- 2 Add 1 teaspoon of yeast to the beaker and gently swirl the beaker.
- 3 Measure and record the temperature every 10 seconds until it becomes constant.
- 4 Repeat steps 1–3 two more times to increase reliability.
- 5 Calculate the average temperature at each time interval.
- 6 In a new beaker, add 30 mL of vinegar. Measure and record the temperature.
- 7 Add 1 teaspoon of baking soda into the beaker and gently swirl the beaker.
- 8 Measure and record the temperature every 3 seconds until it becomes constant.
- 9 Repeat steps 6–8 two more times to increase reliability.
- 10 Calculate the average temperature at each time interval.

Results

Record your results in an appropriate table. Draw a line graph to represent your results for the hydrogen peroxide reaction (temperature on the vertical axis and time on the horizontal axis), and a separate line graph on the same set of axes for the vinegar reaction. Ensure you label each line or provide a key.

Discussion

- 1 For each reaction, identify when the temperature changed the most.
- 2 Identify if each reaction is an example of an endothermic or an exothermic reaction. Explain your answer.
- 3 Hydrogen peroxide in the reaction breaks down into water and oxygen gas. Write a word equation to show this reaction.
- 4 Sodium bicarbonate (baking soda) and acetic acid (vinegar) reacts to form carbon dioxide, water and sodium acetate. Write a word equation to show this reaction.

Conclusion

Write a suitable conclusion that addresses the aim.

QUESTIONS 5.1.3: SIGNS OF CHEMICAL CHANGE

Remember

- 1 Identify the four main signs that a chemical reaction has taken place.
- 2 Identify the easiest way to determine whether a gas has formed.
- 3 Define the term 'precipitate'.
- 4 'A colour change generally indicates that a new substance has been formed.' Justify this statement with your understanding of chemical reactions.
- 5 Recall why energy is required to start a chemical reaction.
- 6 Define the term 'endothermic reaction' and give an example of an endothermic reaction.
- 7 Describe how airbags work in cars.

Apply

- 8 Explain how you would determine that a new gas is being formed when all the reactants in a reaction are gaseous.
- 9 Compare and contrast a precipitate with a solid substance.
- 10 A student said: 'If a reaction is absorbing heat, it will feel cold'. Is the student correct? Justify your answer.
- 11 When you open a bottle of soft drink, you will see bubbling. Is this a sign of a physical or chemical reaction? Justify your answer.

Research

- 12 Find out more about endothermic and exothermic reactions. Find an example of each type of reaction not already mentioned in this chapter. Present your information as a poster and include any relevant diagram and images. Remember to properly site all your resources, including any images.



PHYSICAL AND CHEMICAL CHANGE

5.1

CHECKPOINT

Remember and understand

- 1 Identify some physical changes that are hard to reverse. [2 marks]
- 2 Identify some physical changes that can occur to a piece of paper. [2 marks]
- 3 Identify some chemical changes that can occur to a piece of paper. [2 marks]
- 4 Recall the meaning of the term 'exothermic'. [1 mark]
- 5 Recall two examples of chemical reactions. [2 marks]
- 6 Recall the signs that indicate a chemical change has occurred. [3 marks]
- 7 Identify the difference between a chemical change and a physical change. [2 marks]
- 8 Recall some uses of exothermic reactions. [2 marks]

Apply

- 9 In your own words, define an exothermic reaction and an endothermic reaction. [2 marks]
- 10 When an egg is instantly frozen with liquid nitrogen, the egg resembles a cooked egg. Is this a physical or chemical change? Explain your answer. [2 marks]



Figure 5.20 An egg can be frozen using liquid nitrogen.

- 11 Chemical reactions often release energy.
 - a Recall the types of energy that may be released when a chemical reaction occurs. [3 marks]
 - b Give examples of each of these types of energy. [3 marks]
 - c Give an example of the use of each of these types of reactions. [3 marks]
- 12 Two chemicals have been added to a beaker. When you touch the beaker, it feels very cold. Is this a result of an exothermic or endothermic reaction? Justify your answer. [2 marks]
- 13 In terms of the changes that are occurring, explain the differences between melting butter and baking a cake. [3 marks]

Analyse and evaluate

- 14 The following are descriptions of interactions that occur around us in our daily lives. Describe what the products of these interactions might be and explain whether they are a chemical or physical change.
 - a A bike is left out in the rain and the parts of the bike made of steel are in contact with water for a few hours. [2 marks]
 - b A barbecue fuelled by propane gas is turned on. [2 marks]
 - c A hairdresser adds bleach to someone's hair. [2 marks]

TOTAL MARKS
[/40]

5.2

COMMON CHEMICAL REACTIONS

Chemical reactions do not just occur in science laboratories – they happen everywhere, from within nature to within your own house, even within you. Our bodies use chemical reactions every second of every day. We digest food, convert oxygen into carbon dioxide during respiration, and build proteins from simple compounds called amino acids. These chemical reactions are occurring all the time. Some use energy and some release energy. There are also chemical reactions we can use and control in our daily lives.

CHEMISTRY OF COOKING

The process of cooking involves a lot of chemistry. Cooking causes the chemical reactions within the things we are cooking. As we burn toast, we are altering the structure of the chemicals within the toast.

Preparing and cooking food involves many physical and chemical changes to the food. There are other similarities between chemistry and cooking – some of the techniques used in cooking, such as heating, mixing and filtering, are similar to the tasks of a chemist.

There are many chemical reactions in the kitchen. Baking meat and vegetables turns them brown as the sugars are caramelised. Usually the sugar comes from the breakdown of the starch granules into starch molecules, followed by a chemical change into a sugar. Other chemical changes involve the breakdown of proteins in meat. A few vitamins may be destroyed by some cooking methods.

Chemicals may be added to our food to help keep the food stable, improve its appearance and increase its shelf life. These chemicals include emulsifiers, flavourings, colourings, antioxidants and preservatives. Processed foods usually have a list of these additives on the packet.

Baking soda

Baking soda, or bicarb soda, is also known chemically as sodium hydrogen carbonate or sodium bicarbonate. In cooking, baking soda is mainly used to allow cakes to rise. It belongs to a class of chemicals that are bitter to the taste known as bases. To counter the taste of baking soda, often salt or sugar (depending on the recipe) will need to be added.

Baking soda works by the reaction:

sodium hydrogen carbonate $\rightarrow$ carbon dioxide + sodium oxide + water



Figure 5.21 Sodium bicarbonate is a white powder that can be added to water. It has many different uses in the household.

This reaction is also known as a **decomposition reaction** – a reaction where a compound is broken up into simpler substances. The carbon dioxide produced by this decomposition is responsible for the ‘rising’ of cakes. This reaction only occurs at high temperatures or in water.

EXPERIMENT 5.2.1: HEATING BAKING SODA

Aim

To observe the effects on baking soda when it is heated.

Materials

- 1 spoonful baking soda
- Bunsen burner
- Heating mat
- Test tube
- Test tube holder
- Test tube rack

WARNING

- > Warm the baking soda in the Bunsen burner flame gently, with the test tube facing away from yourself and other students.
- > Wear safety glasses and a lab coat.

Method

- 1 Place the baking soda in the test tube to a depth of 1 cm.
- 2 Heat the test tube for a few seconds and then check the contents. Record all observations.
- 3 Reheat the test tube gently for another 10–30 seconds. Record any further observations.

Results

Draw an appropriate table to record your observations.

Discussion

- 1 Explain what has happened to the baking soda.
- 2 Is the change a physical change or a chemical change? Justify your answer with appropriate evidence from your results.

Conclusion

Write an appropriate conclusion for this experiment. Your conclusion should address the aim.

Fermentation

In chapter 2 you were introduced to the process of fermentation. **Fermentation** is used in many food processes such as making bread, yoghurt, cheeses and alcohol. Recall that the process of fermentation to make bread and alcohol uses a microorganism called yeast. Yeast gains energy to survive by using sugar to produce carbon dioxide and a little bit of alcohol called ethanol. This reaction is a form of metabolism that does not use any oxygen, so we often refer to fermentation as an **anaerobic** reaction.

The following chemical reaction gives a summary of the process of fermentation:

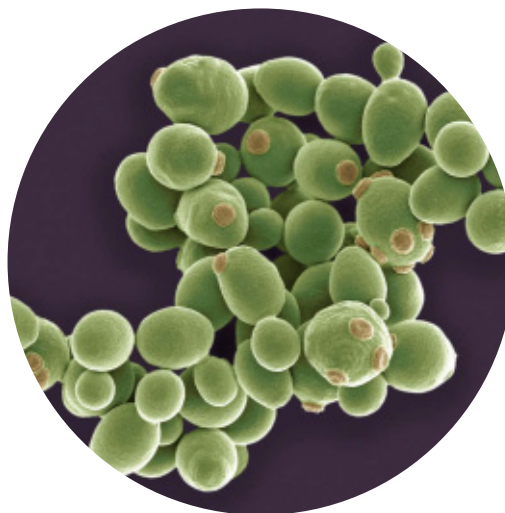
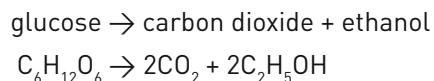


Figure 5.22 A microscopic image of the yeast *Saccharomyces cerevisiae*, also known as baker's yeast.



Figure 5.23 Yeast in action in a bowl. Notice the bubbles that are formed in the process of fermentation.

In most cooking processes, the ethanol is burnt off, but the air holes caused by the carbon dioxide remain. Bread is fluffy due to all the air holes created during the fermentation process.



Figure 5.24 (a) Fermentation is a critical process in cheese production. (b) Fermentation gives bread its air bubbles, causing the bread to rise.

EXPERIMENT 5.2.2: ROLE OF YEAST

Aim

To compare bread made using yeast and bread made without yeast.

Hypothesis

Construct an 'If ... then ...' statement that predicts the effect of yeast on bread.

Materials

- 380 mL warm water
- 1/2 sachet dried yeast
- 600 g plain flour
- 1/2 teaspoon caster sugar
- 1 teaspoon salt
- 60 mL olive oil

WARNING

- > No food should be consumed in a science laboratory. The tasting part of this experiment should be completed at home or in a food technology room.

Method

- 1 Combine 190 mL of warm water, 1/2 teaspoon of caster sugar and yeast. Set aside for 5 minutes until the mixture is foamy. Meanwhile, continue with the method.
- 2 Combine 190 mL of warm water and 300 g of flour slowly to form a dough.
- 3 Add 30 mL of oil and 1/2 teaspoon of salt. Combine well by kneading the dough for 2 minutes. Label this dough 'without yeast'.
- 4 Leave the dough aside in a container.
- 5 Combine 300 g of flour, 30 mL of oil and 1/2 teaspoon of salt. Make a well in the centre of the mixture and pour in the foamy yeast mixture you prepared in step 1.

- 6 Combine well by kneading the dough for 2 minutes and label this dough 'with yeast'.
- 7 Leave both balls of dough in a warm place and observe the difference after 30 minutes.
- 8 (Optional) Flatten both dough balls to a thickness of 1 cm and bake them in an oven of 220°C for around 8 minutes.
- 9 Remove the bread balls from the oven and measure the height of each. Break open the bread and observe any other differences. Record your observations and measurements.
- 10 When cooled, taste the different breads and record any differences.

Results

Draw an appropriate table to record your results.

Discussion

- 1 Identify the independent and the dependent variables in this experiment.
- 2 Identify at least two controlled variables in this experiment.
- 3 How could you have improved the experiment to make the results more quantitative?
- 4 Relate the differences you have observed between the dough made with yeast and the dough made without yeast to the experimental variable.

Conclusion

Write an appropriate conclusion for the experiment that addresses the aim and summarises the role of yeast in baking bread.



Graphing with computer technology

The use of graphs in science is very important. Therefore it is also very important to learn to draw graphs using computer technologies and software programs such as spreadsheets.

The following data was gathered from an experiment examining how the amount of yeast affects the height that a sample of bread rises.

Amount of yeast added (g)	Height of bread made (cm)
0.0	2
0.5	2.4
1.0	3.1
1.5	3.3
2.0	3.8
2.5	4.2

- 1 Enter the data into a spreadsheet.
- 2 Select your data and use the chart function of your spreadsheet program to create a scattergraph.
- 3 Using the program, insert a trendline (line of best fit).
- 4 Identify how thick the bread is without any yeast.
- 5 Predict how much yeast is required to make the bread rise 4 cm.
- 6 Use your graph to identify the relationship between the amount of yeast added and the height of the bread.

NUMERACY
BUILDER

QUESTIONS 5.2.1: CHEMISTRY OF COOKING

Remember

- 1 Identify the chemical name for bicarb soda.
- 2 Identify some foods that are made using the process of fermentation.
- 3 Recall the gas released when sodium bicarbonate is broken down. Compare this to the gas released when fermentation takes place.

Apply

- 4 Explain why yeast is often used instead of sodium bicarbonate in cooking.
- 5 Draw a table to compare the processes of fermentation and the reaction that sodium bicarbonate undergoes. The table headings may include reactants and products.

Create

- 6 Design a poster to show the process and uses of either fermentation or the reaction of sodium bicarbonate.

Research

- 7 Yoghurt and cheese production does not use yeast to help with the fermentation process. Research the type of organism used to make one of these foods and explain how their fermentation differs from that of yeast.



CHEMISTRY IN NATURE

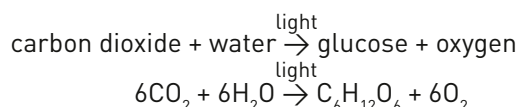
Chemical reactions are found throughout nature. Chemical processes are even occurring within you. Whenever your body moves, many chemical reactions take place in order for your muscles to have the energy they require.

Photosynthesis

Photosynthesis is a **metabolic process** – a process that organisms use to gain energy. Organisms that photosynthesise are known as autotrophs, as they create their own nutrition (auto means self). While there are a few different ways organisms undergo photosynthesis, photosynthesis mostly occurs within the cell inside **chloroplasts**.

Chloroplasts are organelles, which are membrane-bound small ‘organs’ found within cells. Chloroplasts are green due to the presence of the pigment **chlorophyll**. Chlorophyll reduces the activation energy of the reaction so that photosynthesis can

proceed. Chlorophyll works by absorbing most colours of visible light except for green. The green light is reflected back, which is why leaves usually appear green. Light and chlorophyll are both necessary for the reaction to progress, but they are not reactants in the reaction itself. Many different chemical reactions occur during photosynthesis. However, the following word and symbol equations show the overall process:



Glucose is a sugar, which is part of a group of substances known as simple carbohydrates. You may have heard of carbohydrates in terms of wheat products such as bread, noodles and rice. When plants produce glucose during photosynthesis, that sugar is converted to more complex carbohydrates, such as starch, for storage and later use.

Starch is one of the first carbohydrates converted from simple sugars. If we want to test whether a plant is undertaking photosynthesis, we can test for the presence of starch. If starch is present, then we can infer that photosynthesis has occurred.



Figure 5.25 Plants need sunlight to undergo photosynthesis.

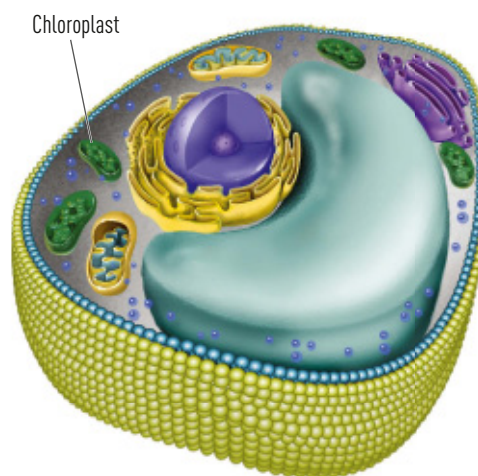


Figure 5.26 A simplified diagram of a plant cell.

EXPERIMENT 5.2.3: ROLE OF SUNLIGHT IN PHOTOSYNTHESIS

Part A

Aim

To test leaves under different conditions for starch and use this as an indicator for photosynthesis.

Materials

- 2 green leafy plants with many leaves, one of which has been kept in the dark for two days
- Beaker
- Water
- Test tube
- Tongs
- Bunsen burner
- Tripod
- Gauze mat
- Iodine solution
- Ethanol
- Petri dish
- Paper towel
- Aluminium foil
- Paper clips

WARNING

- > Ethanol is highly flammable. Do not heat ethanol directly; always use a water bath and keep away from open flame.

Method

- 1 Half fill a beaker with water and boil the water.
- 2 Remove a single leaf from the green leafy plant, draw it, and place the leaf in boiling water for 1–2 minutes. This stops any chemical reactions occurring within the leaf. Remove leaf from the boiling water with tongs.
- 3 Place the leaf into a test tube and add enough ethanol to cover the entire leaf.
- 4 Place the test tube into the beaker of boiling water.
- 5 Remove the flame when the ethanol boils.
- 6 Re-introduce the flame when the ethanol stops boiling. Repeat until the leaf is decolourised (the leaf turns white or very pale green in colour).
- 7 Carefully remove the leaf from the ethanol using tongs and dip it into cold water. Pat the leaf dry with paper towel.
- 8 Place the leaf into a petri dish and add dilute iodine solution to the leaf surface to cover the leaf.

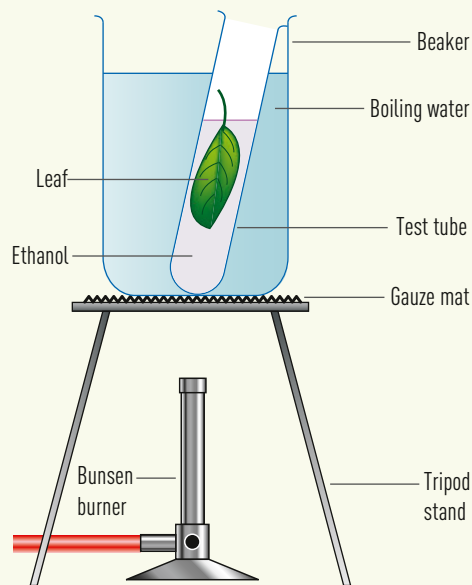


Figure 5.27 Testing a leaf for starch.

Results

Draw a diagram of your leaf before and after the experiment, and write down any observations you have made.

Discussion

- 1 What colour did the leaf turn when the iodine was added?
- 2 Starch will cause iodine to turn black whereas iodine in no starch remains a brown/yellow colour. What does this mean for your results? Justify your answer.
- 3 When the leaf was in the ethanol, what did you observe about the colour of the ethanol? Explain your observation.

Part B

Aim

Read the part B method carefully and write an aim appropriate to this part of the experiment. Ensure you write your aim beginning with 'To ...'.

Method

- 1 Fold the aluminium foil into a small strip. Place the foil over one part of a leaf on the leafy green plant that was kept in the dark. Ensure the plant is well watered (see Figure 5.28).
- 2 Draw a diagram of the leaf showing the covered and the uncovered parts.
- 3 Leave the experimental setup overnight under a lamp or in good sunlight (at least 4 hours of sunlight is required).
- 4 Remove the aluminium foil and test the leaf for starch as in part A of the experiment.
- 5 Draw a diagram of your results, labelling where starch is present and where starch is absent.

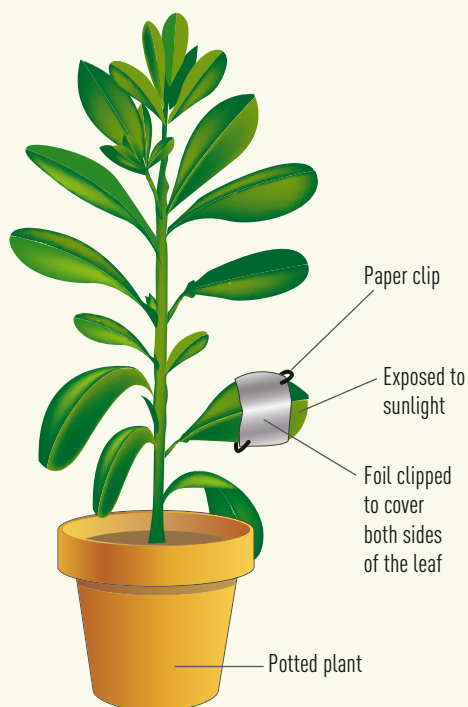


Figure 5.28 Investigating whether light is necessary for photosynthesis.

Results

Draw a labelled diagram of your results.

Discussion

- 1 Identify the purpose of placing the aluminium foil over one part of the leaf.
- 2 Identify the relationship between sunlight and the presence of starch.
- 3 Recall how the presence of starch can determine where photosynthesis is occurring.
- 4 Using your answers from questions 1 to 3, deduce the relationship between sunlight and photosynthesis.

Conclusion

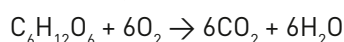
Write a statement that summarises the results of both parts of the experiment and addresses the aim.

Respiration

Respiration is often described as the opposite reaction to photosynthesis, but it is actually more complicated than this. While the chemical reaction that describes the overall process of respiration may look like the reverse of photosynthesis, respiration is really a series of complex biochemical reactions (as is photosynthesis).

The overall chemical reaction of respiration can be expressed as:

glucose + oxygen $\rightarrow$ carbon dioxide + water



The process of respiration allows an organism to gain energy. Respiration occurs in cell organelles called **mitochondria** (singular: mitochondrion). Mitochondria are found in every living cell since every living cell requires energy. Even cells that contain chloroplasts for photosynthesis also have mitochondria.

Respiration is often confused with breathing. Breathing is the process that allows oxygen to be taken into the body. As the body takes up the oxygen, red blood cells carry the oxygen to all the body cells, which then use the oxygen and the glucose that is also carried in the blood to respire.



Figure 5.29 When you are more active, you breathe faster as your body needs more oxygen for your cells to undergo respiration and produce more energy.

The process of breathing out pushes the waste products of respiration out of the body. This is why when you breathe out against a pane of glass you see moisture being formed. We can test the presence of carbon dioxide through a simple test (see Experiment 5.2.4).

EXPERIMENT 5.2.4: THE PRODUCTS OF RESPIRATION

Aim

To examine whether carbon dioxide is produced when you breathe out.

Hypothesis

Use your knowledge of respiration and decomposition to predict what will happen to the limewater in Parts A and B of this experiment.

WARNING

- > Part A involves burning using a Bunsen burner. Ensure that standard laboratory safety procedures, including wearing lab coats and safety glasses, are followed. Ensure that your hair is tied up and your tie is tucked away.
- > Part B involves blowing into chemicals. Ensure you only blow through the straw and do not suck.

Part A

Materials

- Calcium carbonate
- Bunsen burner
- Test tube with stopper and delivery tube
- Test tube rack
- Test tube with a little limewater

Method

- 1 Set up the equipment as shown in Figure 5.30.
- 2 Make observations of the chemical before the reaction.
- 3 Light the Bunsen burner and observe any changes.
- 4 Once you have finished your observations, turn off the Bunsen burner and remove the test tube with limewater from the delivery tube.

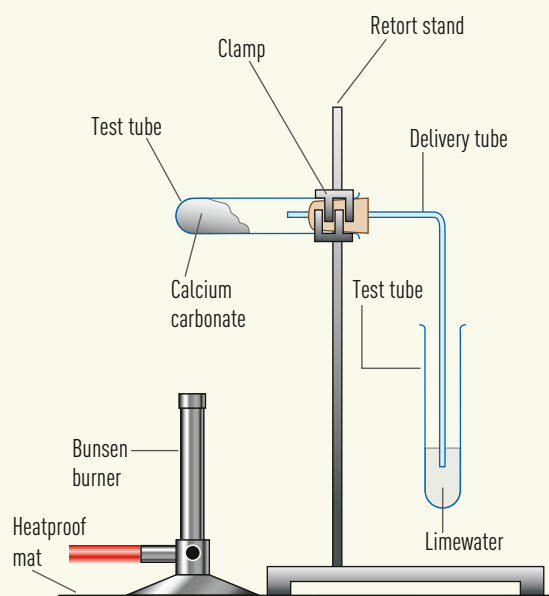


Figure 5.30 Experiment setup for investigating the reaction between limewater and carbon dioxide.

Part B

Materials

- Drinking straw
- Small beaker containing water and a few drops of universal indicator
- Small beaker containing limewater

Method

- 1 Make observations about the appearance of the two small beakers and the solutions they contain.
- 2 Using the straw, blow bubbles into the small beaker with universal indicator for 2 minutes. Record any changes in appearance of the solution.
- 3 Repeat step 2 using the beaker with limewater.

Results

Record your results for both parts in an appropriate way.

Discussion

- 1 Knowing that calcium carbonate decomposes (see page 222), suggest what the decomposition reaction produces.
- 2 Explain why part A of this experiment was necessary.
- 3 What can you conclude about the gases that you breathe out? Justify your answer.

Conclusion

Write an appropriate statement that summarises your findings for both parts of the experiment and addresses the aim.

Chemical weathering

In *Oxford Insight Science 7 Student Book* you examined some useful minerals and ores, and later in this book you will look at the rock cycle in detail. One of the key steps that help rocks and minerals be recycled in nature is the process of weathering.

Weathering breaks down larger rocks into smaller particles. It is a slow but continuous process that affects any substance exposed to the atmosphere. There are two main types of weathering: chemical and mechanical.

Mechanical weathering is physical change. It causes the parent rock to break into smaller components without changing the chemistry of that rock. **Chemical weathering** will change the chemical components of the rock through chemical reactions.

Water causes the most chemical weathering. Water can dissolve many minerals found in rocks. As minerals often hold rocks together, the action of dissolving by water can often break the rocks apart. This process of water dissolving and splitting rocks is actually a physical change. However, rocks become more susceptible to chemical weathering during this process.

True chemical weathering of rocks comes in two forms: oxidation and the actions of acidic substances.

Oxidation

Oxidation occurs when oxygen chemically combines with another substance. Oxidation can affect many different minerals within rocks. Two of the most important metals that undergo oxidation are iron and copper. When the iron or copper minerals within rocks become oxidised, the new compounds in the rock may not hold together as strongly. This can cause the rock to crumble and become weathered. The colour of the rock often changes too. For example, when dolerite rock weathers, it forms iron oxide, a red substance similar to rust.

The equation for the oxidation of iron is:

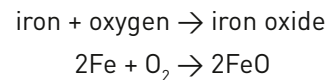


Figure 5.31 The different layers of the rocks of the Bungle Bungles in Western Australia are susceptible to different types of weathering. Most of the Bungle Bungles were likely formed due to the physical weathering actions of water and wind.



Figure 5.32 An iron ore mine. The earth is stained red by the iron oxide.

Acidic substances

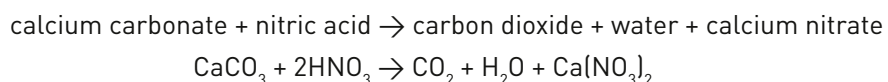
An **acid** is a substance that tastes sour and has a pH of less than 7 when dissolved in water. You may have heard of many common acids such as citric acid (found in citrus fruits such as oranges and lemons), acetic acid (found in vinegar) and hydrochloric acid (produced by your stomach for digestion).

Acids can sometimes be formed naturally. When carbon dioxide is dissolved in water, the result is an acid known as carbonic acid. This means that rainwater is normally slightly acidic.

Other acids found in the environment are due to pollution. The burning of fossil fuels such as coal can release sulfur dioxide and nitrogen oxides into the atmosphere. As they combine with the moisture in the atmosphere, they can create acids such as sulfuric acid and nitric acid. When these acids fall with natural rain, it is called acid rain.

Acid rain can corrode substances and wear away at rocks, metals and other materials. Acid rain particularly affects limestone and marble, two similar rocks made up of the same compound: calcium carbonate. Acid rain has caused damage to many ancient stonework and statues made of marble.

Chemically, the following reaction occurs when an acid such as nitric acid reacts with calcium carbonate:



Calcium carbonate normally does not dissolve in water. However, when calcium carbonate reacts with nitric acid, calcium nitrate is the product formed. Calcium nitrate is extremely soluble in water.

In the natural world, acid rain causes many problems including destroying nutrients in soils and killing plants or causing them to lose their leaves.



Figure 5.33 Citric acid can be found in citrus fruits such as oranges, lemons and limes.



Figure 5.34 Acid rain has worn away the features of this statue.



Figure 5.35 A forest affected by acid rain.

EXPERIMENT 5.2.6: EFFECT OF ACID ON LIMESTONE AND MARBLE

Aim

To determine the effects of acid on rocks such as limestone and marble.

Hypothesis

Construct an 'If ... then ...' statement that predicts the effect of the acids on limestone and marble.

Materials

- 1M hydrochloric acid in a dropper bottle
- Rock samples: limestone, marble, granite, basalt, sandstone, gneiss
- 1M nitric acid
- Beaker
- Electronic balance
- Watch glass
- Hand lens

WARNING

- > Hydrochloric and nitric acid are corrosive. Handle with extreme care. If you get any on you, wash under running water straight away. Wear safety goggles and a lab coat.

Method

Part A

- 1 Obtain a rock sample and record its name. Write a general description of the sample.
- 2 Place the rock sample on a watch glass. Drop several drops of hydrochloric acid onto the sample and record any observations.

Part B

Your teacher will perform the rest of the experiment as a demonstration.

- 1 Weigh a small beaker filled with 1M nitric acid. Leave the beaker on the electronic balance.
- 2 Very carefully, place a small sample of limestone or marble into the beaker.
- 3 Record the immediate mass when the rock sample has been placed into the water.
- 4 Leave the beaker for 20 minutes. Make observations and record the mass.

Results

Display your results in an appropriate manner. You may wish to use a table.

Discussion

- 1 Identify the rock samples that reacted with hydrochloric acid.
- 2 Your teacher used a different acid in the demonstration. Does the type of acid make a difference to how the rock sample is affected? Justify your answer.
- 3 You may have noticed some bubbling in your observations. What does this mean? Explain your answer fully and identify the substance produced.
- 4 What did you notice about the mass of the rock sample in the demonstration? What does this tell you about what is happening? Explain your answer fully.
- 5 If a rock contained components of limestone and sand, describe the effect of acid rain upon that rock.

Conclusion

Write an appropriate statement that summarises your results and addresses the aim.

QUESTIONS 5.2.2: CHEMISTRY IN NATURE

Remember

- 1 Compare and contrast respiration and photosynthesis.
- 2 Identify where respiration takes place in cells.
- 3 Recall the word equation for photosynthesis.

Apply

- 4 Explain why testing for starch can be seen as testing for photosynthesis.
- 5 Recall how rocks containing iron can be chemically weathered.
- 6 Would you expect acid rain to be a bigger problem in developed industrial areas or in natural areas? Justify your answer.

Analyse

- 7 The pH scale can be used to determine how acidic or basic something is. The more acidic a substance, the lower the number. Water, which is neither acidic nor basic but neutral, is 7.0 on the pH scale.
 - a Would you expect acid rain to have a pH lower or higher than 7.0? Justify your answer.
 - b Would you expect sodium bicarbonate to have a pH lower or higher than 7.0? Justify your answer.

Research

- 8 What are some consequences of acid rain on the natural and human environment? Use reliable sources from the Internet as well as reference books such as encyclopedias and textbooks to help research this question. Present your research in the form of a report appropriate to classmates and others in your school. Remember to record all your sources in a bibliography.



5.2

CHECKPOINT

COMMON CHEMICAL REACTIONS

Remember and understand

- 1 Identify the gas given off when baking soda decomposes. [1 mark]
- 2 Recall what is required for baking soda to decompose. [1 mark]
- 3 Define the term 'decomposition'. [1 mark]
- 4 Recall the term for a class of chemicals that taste bitter. [1 mark]
- 5 Recall one of the products of fermentation. [1 mark]
- 6 Identify the organism responsible for fermentation during the making of bread. [1 mark]
- 7 Recall where photosynthesis takes place in cells. [1 mark]
- 8 Recall the word equation for respiration. [2 marks]

Apply

- 9 Compare and contrast chemical weathering with physical weathering. [2 marks]
- 10 In your own words, explain why the action of water on rocks can be seen as chemical weathering and physical weathering. [3 marks]
- 11 Using your understanding of energy in chemical reactions, identify whether the decomposition of sodium bicarbonate has a high or low activation energy. Justify your answer [3 marks]
- 12 Compare and contrast breathing and respiration. [3 marks]

Ethical understanding

- 13 Do we have a responsibility to preserve historical artefacts such as marble statues and buildings and protect them from acid rain? Explain your answer. [5 marks]
- 14 'We must label different foods with the chemicals they contain.' Evaluate this statement. [4 marks]

Critical and creative thinking

- 15 Produce a pamphlet, video or web page that aims to persuade people to stop burning fossil fuels, such as coal, to prevent acid rain. [6 marks]



TOTAL MARKS
[/35]

CHEMISTRY IN INDUSTRY

5.3

Many substances and materials that we rely on in our everyday lives are processed or manufactured before they are used. Substances such as medicines, electronic components, polymers and new materials such as carbon fibre in aeroplanes, only exist because of the work of chemists. Chemical engineers are also important because they help design the processes that ensure that the chemical reactions used produce high-quality products with as little energy, pollution and waste as possible.



Figure 5.36 Many everyday items are the result of the use of chemistry in industry.

PETROCHEMICALS AND POLYMERS

Oil, coal and natural gas are all called fossil fuels as they are made from the ancient fossilised remains of organisms. The remains that form fossil fuels are often from marine creatures and ancient forests that were rapidly buried before being subjected to millions of years of pressure and heat to form oil, coal or natural gas.

Currently, Australia's main source of energy is fossil fuels. The biggest problem is that fossil fuels are a non-renewable resource – they are not easily replaced. Our use of fossil fuels is constantly increasing, and it is highly likely that fossil fuels may eventually run out. Chemically, fossil fuels are simply

carbon and hydrogen, in different ratios and molecules of different lengths.

As well as being used as energy sources, fossil fuels are also used to produce **petrochemicals**, which are products or chemicals produced from crude oil. Crude oil is sometimes called petroleum.

Obtaining oil and gas

Extraction of fossil fuels depends on the fossil fuel itself. Oil and gas are obtained through a process of extraction from the lithosphere. Natural gas tends to be extracted from offshore rigs, such as those



Figure 5.37 Offshore rigs are used to extract natural gas.

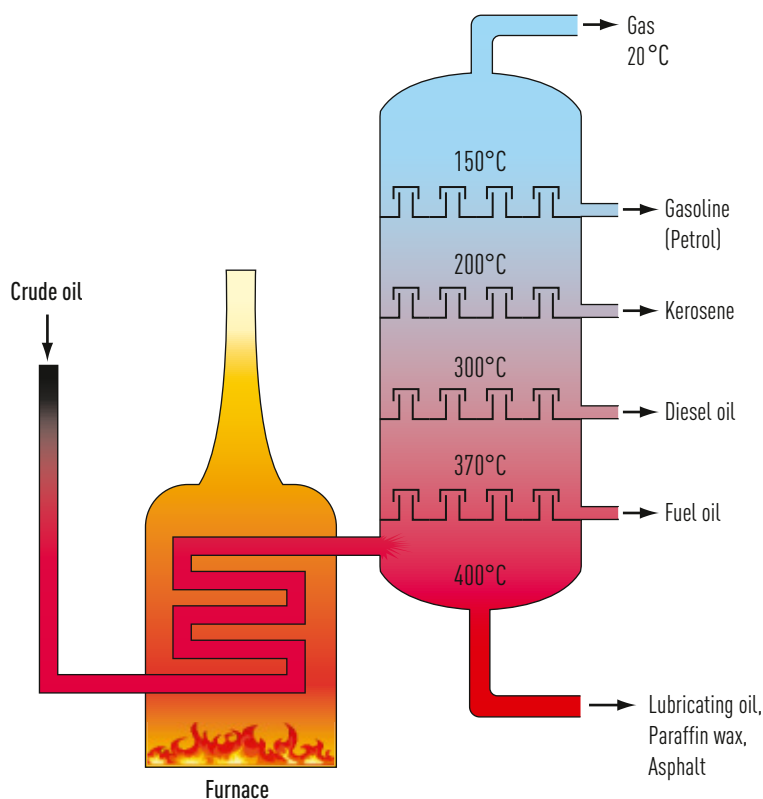


Figure 5.38 Crude oil is pumped from the ground.

found off the coast of Western Australia. Crude oil is pumped from the ground from numerous Australian sites including inland Queensland, outback South Australia, and offshore sites in Bass Strait and the Timor Sea.

Industrial chemists work closely with mining engineers and structural engineers to ensure that the products produced by mines and rigs are of the appropriate quality. Once crude oil has been extracted from the ground, it is separated into components that we can use by the process of fractional distillation, which you encountered in chapter 5 of *Oxford Insight Science 7*.

Petroleum is used in cars, trucks and planes for transport. The petrol you use to fuel your car is a component of petroleum. Trucks use diesel and planes use a higher-grade fuel, but all of these fuels are found in petroleum.



Polymers – plastics

Oil is useful in our everyday lives for more than just transport and energy. You rely on oil more than you may realise. A small component of crude oil is used to make **polymers**.

The term 'polymer' means many repeating structures. You may have heard them being called 'plastics'. However, the term 'plastic' is a property of these specific polymers, meaning they are malleable and able to change and take on different shapes easily without breaking. While all plastic materials are polymers, not all polymers are plastic materials.

There are many different types of polymers. Think of the types of plastic you come in contact with on a daily basis.

Figure 5.39 The process of fractional distillation used to separate crude oil. Different 'fractions' are separated due to the difference in boiling points.



Figure 5.40 Some of the different types of polymers or plastics that you will probably have seen throughout the day.

ACTIVITY 5.3.1: POLYMERS AND THEIR PROPERTIES

What you will need: A3 paper or butcher's paper, felt-tip markers

- 1 Brainstorm a list of polymers you come in contact with on a day-to-day basis.
- 2 What properties are required for each of these polymers to be used in their capacities?
- 3 If you were making a new polymer, what types of properties would you try and include? Justify your answer.

EXPERIMENT 5.3.1: MAKING PLASTIC FROM POTATOES

Aim

To make plastic from potatoes.

Note: An alternative, quicker way to complete this experiment is to buy commercially available potato starch or to use instant mashed potato instead of completing Part A.

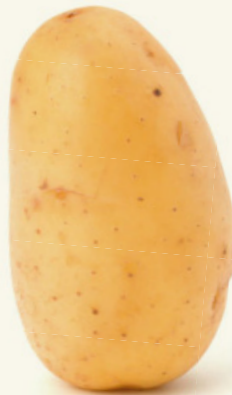
Part A: Extracting the starch

Materials

- Potatoes
- Grater
- 2 x 400 mL beaker
- Large pestle and mortar
- 250 mL beaker
- Distilled water
- Tea strainer

Method

- 1 Grate 100 g of potato into the mortar.
- 2 Add 100 mL of distilled water and use the pestle to grind into a paste-like consistency.
- 3 Pour the liquid through the tea strainer into a beaker and leave the potato behind in the mortar.
- 4 Repeat steps 2 and 3 two more times.
- 5 Leave the solution to settle in the beaker for around 5 minutes.
- 6 Decant (carefully pour out) the water from the beaker, making sure to leave the white starch at the bottom.
- 7 Clean off the starch by pouring in 100 mL of distilled water, stir gently, and then leave to settle again.
- 8 Decant off the water and leave the starch behind. You will use the potato starch in Part B.



Part B: Making plastic

Materials

- 5 g potato starch or instant mashed potato
- 2 beakers
- 2 Petri dishes or white tiles
- Universal indicator paper
- Plastic droppers
- 25 mL measuring cylinder
- 10 mL hydrochloric acid (0.1M)
- 10 mL sodium hydroxide (0.1M)
- Distilled water
- Food colouring
- 2 mL glycerol
- 2 large watch glasses
- 2 Bunsen burners
- 2 heat-resistant mats
- 2 tripods
- Gauze
- 2 glass stirring rods

WARNING

- > While using a Bunsen burner and heating liquids, ensure that standard laboratory safety procedures are followed – this includes wearing a lab coat and safety glasses. Ensure hair is tied back and your tie is tucked away.

Method

- 1 Add 25 mL of distilled water into a beaker, then add around 2.5 g of the potato starch, along with 3 mL of hydrochloric acid and 2 mL of glycerol.
- 2 Set up another set of apparatus at the same time, except leave out the glycerol.
- 3 Put a watch glass onto each beaker and gently heat the mixtures using Bunsen burners. Bring to a gentle boil and allow to boil for around 15 minutes. Do NOT let them dry.
- 4 Dip a glass rod into each mixture and drop it onto indicator paper to measure the pH. Adjust the pH to neutral (7) using sodium hydroxide. You will probably need to use about the same amount of acid that you did at the beginning (3 mL).
- 5 Add a drop of food colouring to each mixture and mix thoroughly.
- 6 Pour each mixture onto separate Petri dishes and spread each with a glass rod so there is an even covering.
- 7 Label each Petri dish appropriately.
- 8 Leave both Petri dishes to dry (about 2 days).

Results

Examine and compare the two plastics you have made.

Discussion

- 1 Does the addition of glycerol into the solution make a difference to your plastic? Explain your answer.
- 2 Plastics come from petroleum, a resource that is non-renewable. Is the plastic you have made from a renewable or non-renewable resource? Justify your answer.
- 3 Is it likely that Australia will increase its use of biodegradable plastics? Explain your answer.

Conclusion

Write a statement that summarises what you have observed and addresses the aim.

In addition to the plastics that we use, oil is also used for the plastics that we wear. The main type of polymer used in fabrics is **polyester**. Made from a petrochemical, polyester is the same chemical as used in PET plastic drink bottles (polyethylene terephthalate).

durability and it keeps its colour well. To improve the feel of polyester, it is often woven into natural fibres to produce a blend that has properties of both the natural fibre and the polyester itself.

Rayon is another popular material used in fabrics. Unlike polyester, rayon is made from cellulose, a natural polymer produced by plants. Because rayon comes from a natural resource, it is often seen to be a semi-synthetic material. There are different types of rayon, including viscose and modal.

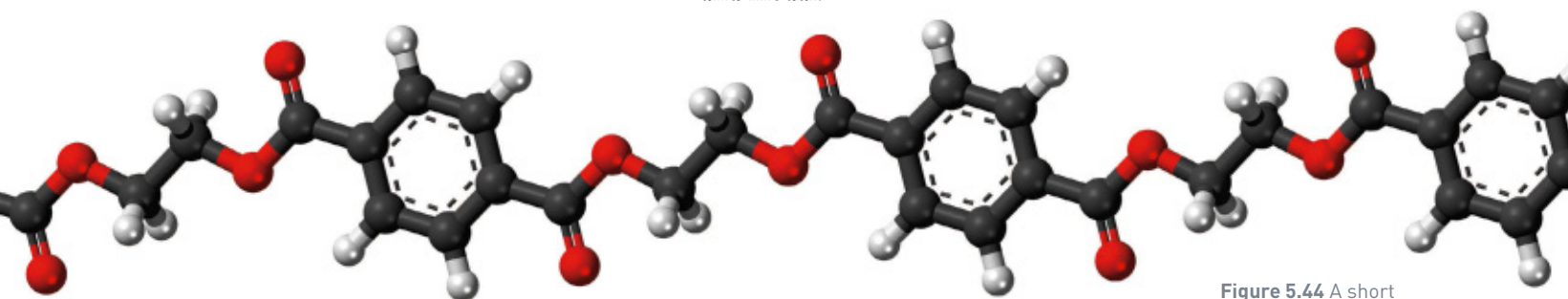


Figure 5.44 A short section of polyester with repeating structures. Polyester is usually made up of thousands of the same repeating structures.



Figure 5.41 Most clothing labels indicate the blend of the material. Adding 10–20% polyester to cotton allows shirts to remain wrinkle resistant.



Figure 5.43 Polar fleece is made from 100% polyester. It has the ability to retain heat, which makes it ideal for winter wear.

Figure 5.42 Viscose is often used in scarves.





Figure 5.45 What kind of properties would the snow jacket and pants of this snowboarder need to have?

Sportswear

Sportswear is designed for specific uses and needs to have specific purposes. Most sportswear these days is designed to be light and to move with the body. Sports materials also tend to draw away moisture, stay warm when it is cold and keep cool when it is warm.

Polyester and other synthetic materials are used with special weaves to satisfy specific purposes. Sporting brands have sports scientists and material scientists who work with sportspeople to research and develop new materials and blends.

Figure 5.46 Close-up view of a pair of nylon sports shorts. Notice the weave of the fabric, which would allow for increased air ventilation.



Figure 5.47 What kind of properties would a football jersey need to have?

QUESTIONS 5.3.1: PETROCHEMICALS AND POLYMERS

Remember

- 1 Recall why fossil fuels are named as such.
- 2 Define the term 'non-renewable resource'.
- 3 Recall the difference between petrol and petroleum.
- 4 Compare and contrast the terms 'plastic' and 'polymer'.
- 5 Recall three different fabrics that are synthetic or semi-synthetic.

Apply

- 6 Explain why cotton or wool may not be the best material to make sportswear.
- 7 Explain why research into new polymers is required.

Research

- 8 As a non-renewable resource, petroleum and objects we make from petroleum, such as polymers, will eventually run out. Research current developments in bioplastics such as polylactic acid (PLA) and evaluate the importance of the research and development of these plastics.

Create

- 9 Plastics tend to melt when placed in fire. Design an experiment to test the flammability of some synthetic fabrics compared with natural fabrics. Remember to include any safety considerations.

PHARMACEUTICALS

When a person is feeling sick, they may take medicine. These include painkillers such as paracetamol, and antibiotics if it is a bacterial infection. How did the first medicines come about?

Pharmacies are where medicines are prepared and dispensed. A pharmacist (sometimes called a chemist) has studied chemistry, but has specialised in the study of medicines and their effect on the body (pharmacology). The development of pharmaceuticals or medicines involve the study of three main branches of science:

- biology – how microorganisms affect humans, how human immune systems work and how our systems work together to keep us functioning normally
- pathology – how diseases affect our bodies
- chemistry – how to develop new pharmaceuticals through chemical reactions, and how medicines react with the human body.

Traditional medicines

In the past, the discovery of traditional medicines tended to rely on luck. Traditional medicines come from natural products such as plants or animals. Some chemistry research nowadays looks at the effectiveness of traditional medicines by looking for **active ingredients** – chemicals that have known activity to biological systems. The research has been surprising; many traditional medicines contain materials that are active. You may have already used some traditional medicines, such as eucalyptus drops when you have a sore throat or aspirin for a headache. Aspirin originally came from the bark of willow trees.



Figure 5.48 Pharmacists are chemists who specialise in medicine and medications.

Indigenous medicines

From witchetty grubs to kangaroo apples, native medicines were used to cure ills. The 10 most common bush medicines are:

1 Tea-tree oil

Bundjalung Aboriginal people from the coast of New South Wales crushed tea-tree (or paper bark) leaves and applied the paste to wounds as well as brewing it into a kind of tea for throat ailments. In the 1920s, scientific experiments proved that tea-tree oil prevented the growth of microorganisms far better than the commonly used antiseptic of the time. Tea-tree oil has since been used to treat everything from fungal infections of toenails to acne (pimples).

2 Eucalyptus oil

Eucalyptus leaves were soaked to extract the oil and used for body pains and fevers and chills. Today the oil is used commercially in mouthwash, throat lozenges and cough medicines.

3 Billy goat plum/Kakadu plum

The world's richest source of vitamin C is found in this native fruit from the woodlands of the Northern Territory and Western Australia. The plum has 50 times the vitamin C of oranges, and was a major source of food for communities in the areas where it grows.

4 Desert mushrooms

Some traditional Indigenous Australian societies suck on the bright orange desert mushroom to cure a sore mouth or lips.

5 Emu bush leaves

Concoctions of emu bush leaves were used by Northern Territory Aboriginal tribes to wash sores and cuts; occasionally it was gargled. In the last decade, leaves from the plant were found to have the same strength as some established antibiotics. South Australian scientists are looking at using the leaves for sterilising implants, such as artificial hips.

DEEPER UNDERSTANDING





Figure 5.49 Witchetty grubs, well known for being a traditional bush food, also have medicinal properties and were used to treat skin burns.

6 Witchetty grub

Witchetty grubs, also a good source of bush tucker, were crushed into a paste, placed on burns and covered with a bandage to seal and soothe the skin by some groups in Central Australia.

7 Snake vine

Communities in Central Australia used to crush sections of the snake vine to treat headaches, rheumatoid arthritis and other inflammatory-related ailments. The sap and leaves were sometimes used to treat sores and wounds.

8 Sandpaper fig and stinking passion flower

The combination of the two plants was used in northern coastal communities to relieve itching. The rough leaves of the sandpaper fig were crushed and soaked in water, then rubbed on the itch. The pulped fruit of the stinking passion flower was then smeared onto the affected area. Sandpaper fig leaves have also been used to treat fungal skin infections such as ringworm, sometimes in combination with the milky sap.

9 Kangaroo apple

The fruit was used on swollen joints. The plant contains a steroid that speeds up the healing process.

10 Goat's foot

For pain relief from sting ray and stone fish stings, the leaves of goat's foot were crushed and heated, then applied directly to the skin. Goat's foot is common near sandy shorelines across Australia.

Source: Adapted from Top 10 Aboriginal bush medicines, Marina Kameney, 8 February 2011

Discovery of penicillin

The antibiotic penicillin, one of the most widely used medicines, was discovered by accident. Alexander Fleming, a British scientist, was known as a brilliant scientist, though very messy. In 1928, Fleming returned to his laboratory after a holiday and realised he had not cleaned up his bacterial culture plates. He found that on one of the bacterial plates some fungus had grown, and there were no bacteria where the fungus was growing.

Fleming identified the mould as from the family *Penicillium* and called the substance penicillin. While Fleming could show that penicillin could stop the growth of many bacteria, he could not isolate the chemical compound from the mould. It took another two scientists, Australian Howard Florey

and Briton Ernst Boris Chain, to isolate and refine penicillin to the point where it could be mass-produced. Penicillin was first mass-produced in 1943 during World War II. Florey, Chain and Fleming all went on to win the Nobel Prize in Medicine or Physiology in 1945.

New medicine development

New drugs for medicines are always required. Pathogens such as microorganisms and viruses are becoming more resistant to certain drugs (see Activity 5.3.2). Additionally, with newer technology and research techniques, we are finding new pathogens all the time that cause diseases.

For example, it was only in the 1980s that two Australian scientists, Dr Barry Marshall and Dr Robin Warren, discovered that stomach ulcers were caused by bacteria, and not by stress. As a result, a new drug was required to treat these newly discovered bacteria, known as *Helicobacter pylori*.

New drug developments these days are less dependent on luck. Research scientists generally discover new drugs through several different processes such as:

- New understanding of a disease. This allows scientists to design drugs that can help treat a specific effect of a disease.
- Unexpected effects of existing treatments. Some drugs will have side effects that may be beneficial in the treatment of other diseases. For example, aspirin is used as a multi-purpose painkiller but when given in higher doses it has an additional effect of thinning the blood. This makes aspirin very useful in treating heart attacks and strokes.
- Development of new technologies. Technologies that manipulate genetic material or provide new ways to target medical products to specific sites within the body can enable drug treatments that were previously impossible. Gene therapy is one such new technology, which is being used to treat diseases such as leukaemia.

Chemists find appropriate chemicals that have biological activity through one of two main processes: **random screening** or **combinatorial chemistry**.

Random screening involves creating thousands of new chemicals through various chemical reactions. These chemicals are then screened one by one to see how they affect pathogens such as bacterial and fungal cells and viruses. The chemicals that show signs of being able to prevent pathogens from growing are then tested further. Similarly, for non-infectious diseases such as cancer, random screening is used to see whether the chemicals will affect cancer cells while leaving normal cells undamaged.

Combinatorial chemistry is a less intensive process and involves adding a 'tag' to new chemicals. These tags allow scientists to track chemicals as they move through biological systems such as bacteria, viruses or abnormal cells. If biological systems take up these chemicals and the tag can be easily detected, it means that the chemical will probably be effective against pathogens or diseased cells.

Another way of developing new drugs is through looking at natural medicine. Diseases do not just affect humans – by looking at how other organisms, both plants and animals, prevent disease, we can often find chemicals to help us. As previously mentioned, antibiotics started with the accidental discovery of penicillin. Australian red bull ants contain substances in their saliva that have been shown to have antibacterial properties.



Figure 5.50 The red bull ant, *Myrmecia gulosa*, secretes a substance that has antibacterial properties. This bull ant can be found around the eastern coast of Australia.



Figure 5.51 Research scientists often test lots of potential drugs in the hope of finding one that works as required.

ACTIVITY 5.3.2: ANTIBIOTIC-RESISTANT INFECTIONS

The search for new medicines never ends. As we develop new medicines, pathogens such as bacteria and viruses develop resistance to these medicines. Methicillin-resistant *Staphylococcus aureus* (MRSA), is a potentially deadly strain of a bacteria that is resistant to most antibiotics. Without the use of antibiotics, we must rely on our own immune system to combat MRSA infections.

- 1 Research MRSA infections. How many people have been affected by it? When and where was the last outbreak?
- 2 Examine how antibiotics have changed the way we deal with diseases. How many people died from bacterial diseases in World War I?
- 3 Where do you think we may find the next new medicine? Explain your answer.

Blue-blooded horseshoe crabs

Horseshoe crabs are very old organisms that have remained relatively unchanged over 450 million years. Horseshoe crabs can be found during mating season along the eastern coastline of the United States of America as well as through the seas of China and Japan. Originally used for eating and as fishing bait, horseshoe crabs are now being used in a very interesting way.

Horseshoe crabs have blue blood. Rather than the iron-based blood that mammals have, horseshoe crabs have blood that is copper-based. In the 1950s, scientists found that a clotting agent in the blood reacts to fungi and some toxins,

and binds to them, causing the blood to clot. This coagulation allows us to detect contamination or impurities in drugs. If you have ever been vaccinated for a disease, horseshoe crab blood would have been used to test that batch of drugs.

We can extract the blood from horseshoe crabs without killing them. There are companies that have been licensed to collect horseshoe crab blood humanely, without killing the organisms. Some studies completed by these licensed companies have shown that approximately 3% of crabs are killed during the blood harvesting process, however, more recent studies have shown that this rate is likely to be closer to 10–15%.

On top of this mortality rate, due to the value of the blood (currently priced at around \$15 000 per litre), horseshoe crabs are also subjected to poaching.

Questions

- 1 Explain why the blood of horseshoe crabs is used in the pharmaceutical industry.
- 2 Evaluate whether you agree with the use of organisms such as horseshoe crabs to help manufacture vaccines.

Figure 5.52 The blue copper-based blood of horseshoe crabs contains proteins that help us to test drugs.



QUESTIONS 5.3.2: PHARMACEUTICALS

Remember

- 1 Recall another name for a pharmacist and explain why they are also called this.
- 2 Identify three branches of science that are commonly involved in developing pharmaceuticals.

Apply

- 3 Explain why medicines in the past were often discovered by chance.
- 4 Explain how modern medicines are discovered today.

Analyse

- 5 Evaluate the importance of research into new pharmaceutical products. Incorporate as many new pharmaceutical products mentioned in this section as possible.

OBTAINING NEW MATERIALS

In the past, humans have had to rely on what was available from the Earth's spheres: atmosphere (the gas and air around us), lithosphere (the rocks and minerals that make up the Earth's crust), hydrosphere (the water-based regions on the Earth) and the biosphere (all the living organisms on the Earth).

You have already learned about how humans have used living substances from plants and animals (the biosphere) for medicine, but what about products from the other spheres? We can extract some metals in their pure form, but what additional processes can we do to make other metals useful? How can we enhance materials so that they have the properties that we need?

Extracting metal

Many substances that are mined are found as compounds, rather than elements. You have already learned in chapter 4 about how some metals such as iron and copper are extracted using heat. However, we need to use electricity to extract other substances from their compounds. Aluminium is an incredibly reactive metal that forms a layer of aluminium oxide between itself and the air, which does not chemically react with many compounds. This means that although pure aluminium is very reactive, aluminium



Figure 5.53 Aluminium is used in vast quantities in aeroplanes as it is incredibly lightweight yet strong.

oxide protects the metal and makes it very unreactive. The aluminium oxide layer also means that pure aluminium is very difficult to extract and so electricity must be used to extract it. This extraction process is known as electrolysis (see Figure 5.54). Because electricity is expensive, the process of extracting aluminium is very expensive. We need pure aluminium, rather than a mixture of aluminium ores, to make important aluminium alloys. Aluminium alloys are used in a wide variety of machines and structures because they are so lightweight yet strong.

The extraction of aluminium requires industrial chemists to determine the quality and purity of the aluminium. Material scientists and engineers then use that aluminium to make alloys.

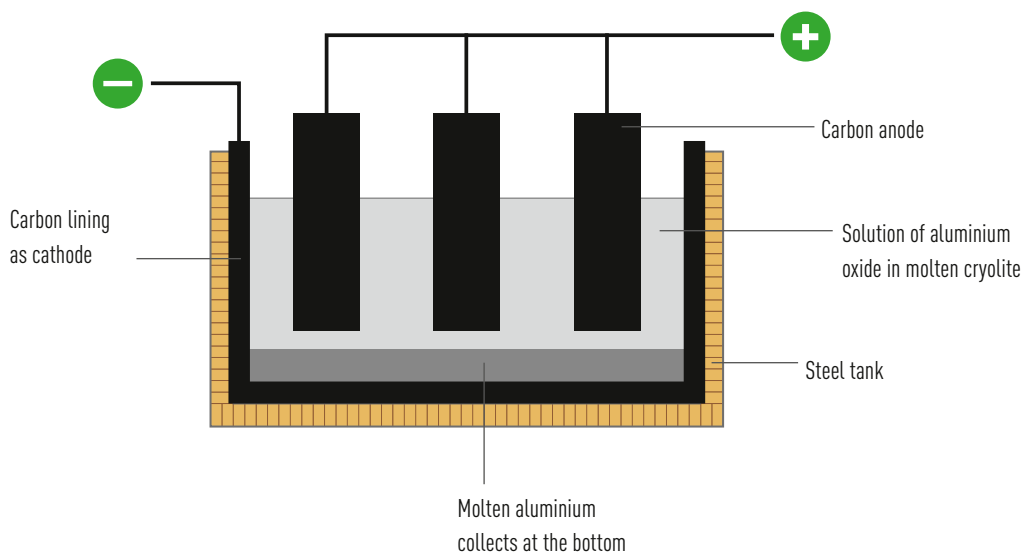


Figure 5.54 A simplified diagram of one of the final steps in the aluminium extraction process. Cryolite is a compound used to dissolve the aluminium oxide to help with the electrolysis.

ACTIVITY 5.3.3: EXTRACTION OF ALUMINIUM

While at school, you may work by yourself in some aspects of some subjects or you may work with others. This is the same situation when it comes to science in industry. Scientists will work on small parts of a project themselves, but in most situations, they will collaborate with other experts. The flow chart in Figure 5.55 shows the steps in the production and recycling of aluminium.

Working in groups, complete the following tasks.

- 1 For each step in the production and recycling of aluminium, brainstorm the input that scientists working in different branches of science may have had to understand the process.
- 2 Propose which scientists are required to keep the processes at each step occurring.
- 3 Compare your group's answers with the rest of the class.

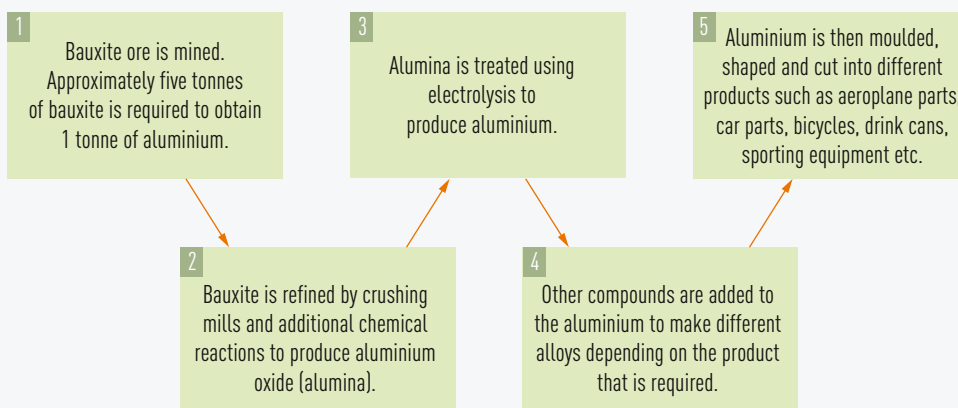


Figure 5.55 The production and recycling of aluminium.

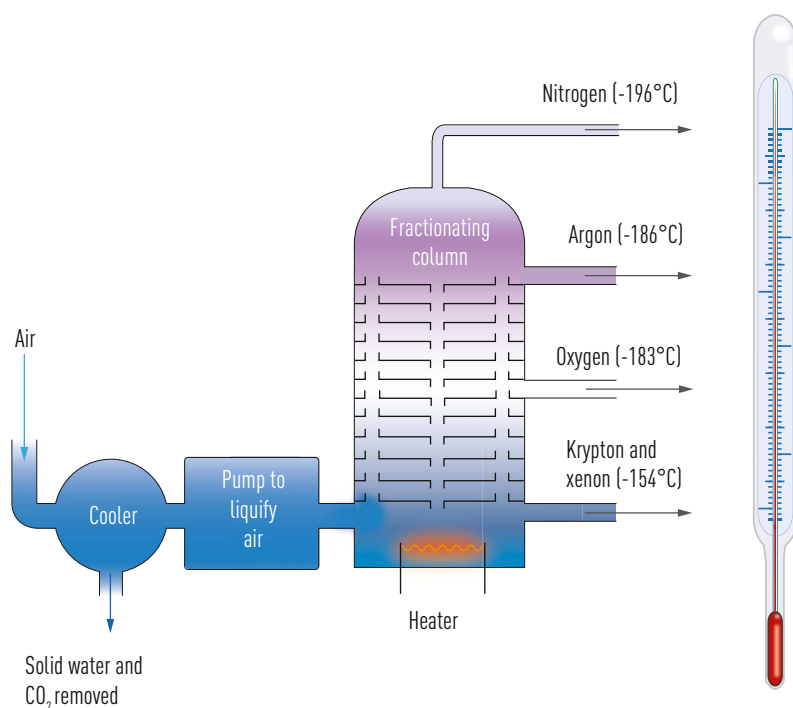


Figure 5.56 The process used to extract oxygen from the air.

Extracting oxygen

Oxygen is the vital gas that keeps us all living. Oxygen in tanks is used in hospitals for patients who are having trouble breathing. It is also used in industry in the production of polymers and melting iron to make steel. How do we obtain this relatively pure oxygen? Chemists working in the late 1700s were the first to extract pure oxygen. While oxygen's ability to combust was known since the 2nd century, as a gas, it was difficult to isolate. Three chemists have been credited with the discovery of oxygen: Carl Wilhelm Steele, Joseph Priestly and Antoine Lavoisier.

The air we breathe is made up of approximately 20% oxygen. Scientists and engineers use high pressures to make the air into a liquid. Once in a liquid form it is fractionally distilled, meaning various components of the air can be extracted based on their boiling points.

Oxygen is usually extracted as a liquid, then placed into tanks.

Shrilk

Scientists often have to work outside of their specialties and collaborate with each other to develop new materials for production. Shrilk is a relatively new plastic created completely from biological sources. It is made from two main components: chitin and silk.

Chitin is a polymer found in many places throughout the natural world, including in the shells of shrimp (Figure 5.59), in the cell wall of fungi, in the beaks of squid and octopuses, and forming the cuticle (outer covering) of insects. Biologists have been studying what makes chitin structures so lightweight but also strong.

You may know of silk as a type of material produced by the silkworm, however, many other insects also produce silk. Silk is made primarily of fibroin, an incredibly strong polymer (see Figure 5.57). Biochemists have used their understanding of chemistry to determine the chemical structure of fibroin.

In 2011, material scientists working at Harvard University developed the new material Shrilk, which combines chitin and fibroin. Shrilk is made from discarded shrimp shells and fibroin extracted from silk. Materials engineers who study the properties of materials have found that Shrilk is ten times stronger than either silk or chitin.

There are many different uses for Shrilk. It is produced as a thin film such as cling wrap and can then be layered or moulded. Because it is as strong as aluminium but only half its weight, Shrilk can be used to make packaging and nappies. Additionally, because it is biologically compatible, there are plans for medical researchers to test Shrilk for use in surgical procedures such as stitching. Shrilk is a pioneering new material as it is the first biologically inspired material designed using molecular science methods.

The development and use of Shrilk has involved many different fields of scientists and many different aspects of engineering and design. Without biologists to study chitin, biochemists to understand the structure of fibroin, materials engineers to study its properties and medical researchers to test the material, Shrilk and its many uses would not have been developed.

Questions

- 1 Recall the two substances that Shrilk is made from.
- 2 Identify some fields of science involved in developing Shrilk.
- 3 Is Shrilk a material that is made from the biosphere, hydrosphere, atmosphere or lithosphere? Explain your answer.
- 4 Identify the material that Shrilk is looking to replace.
- 5 Explain why scientists often collaborate to find new discoveries.
- 6 Suggest some other uses for Shrilk with reference to its properties.
- 7 Do you think Shrilk is biodegradable? Why or why not? Justify your answer.
- 8 Would Shrilk be considered to be a renewable resource or a non-renewable resource? Justify your answer.



Figure 5.58 Shrilk is a tough, low-cost plastic made completely from biological sources.



Figure 5.57 Silk pupae from a silk worm. Fibroin is extracted from silk threads and used in the manufacture of Shrilk.



Figure 5.59 The chitin used to make Shrilk can be extracted from the usually unused and discarded shrimp shells.

Dyes

Before the use of dyes, all clothes were only the colour that natural fibres (raw cotton, silk and wool) could produce. This was usually off-white, brown or black.

The first evidence of humans using dyes on textiles (materials) dates back to the Neolithic period (around 10 200 BC to 4500 BC) when traces of red dyes likely to be from a natural pigment called ochre have been found. Textiles with dyes from plants, bark and insects have been found from China dated to around 5000 years ago. Also from around 5000 years ago, a vegetable dye on a piece of cotton has been found in Pakistan.

Dyes were traditionally a heavily traded commodity with some dyes more precious than others. A purple dye, known as Tyrian purple, was made from murex whelk shells, a type of sea snail. It took 9000 shells to make enough dye for one Roman emperor's toga! Only the emperor could afford such a luxury, which is why the colour purple has always been associated with royalty. So scarce and in demand was the dye that the murex whelk almost became extinct as a result of being hunted for its dye.



Figure 5.60 The murex whelk gave rise to the dye Tyrian purple.

William Perkin, a chemist, developed the first synthetic dye in 1856. Derived from coal tar, it was named mauveine, though we know it as mauve. The development of the dye opened up a whole new field of chemistry. By the 1870s natural dyes were disappearing to be replaced by synthetic ones.

Nowadays, computer printers use dyes when they print photographs. Technology and science are constantly improving the quality and brightness of dyes and inks used in printing so that pictures last longer and look more vibrant.



Figure 5.61 There are many synthetic dyes now available in a wide range of colours.

QUESTIONS 5.3.3: OBTAINING NEW MATERIALS

Remember

- 1 Recall the name of the process used to obtain aluminium.
- 2 Identify some uses of oxygen.
- 3 How is oxygen extracted from the air? Explain this process.
- 4 Recall the first example of the use of dyes.

Apply

- 5 Identify some professions that use dyes.
- 6 Explain how scientists work together to develop or create new materials.
- 7 Describe some uses for aluminium. Explain how its physical properties are related to these uses.
- 8 Explain why natural dyes are used less now than during the 1800s.
- 9 Explain why research into dyes is still important.

Create

- 10 There are many different dyes used for different purposes such as dying cotton, synthetic fibres or hair. Develop a scientific experiment that will allow you to compare the effectiveness of the different dyes on one particular fabric (choose either cotton or polyester for ease). Ensure you include any safety issues in your method and steps to minimise them.

Research

- 11 Glues and adhesives play a vital part in our lives. Research the development of glues from around 5200 years ago to now. What type of adhesives are we currently using? What have previously been used? What is superglue and what are its uses?



5.3

CHECKPOINT

CHEMISTRY IN INDUSTRY

Remember

- 1 Recall the generalised term given to fuel sources such as gas, coal and oil. [1 mark]
- 2 Compare and contrast renewable fuels such as biofuels with non-renewable fuels. [3 marks]
- 3 Identify at least two polymers that you use every day. [2 marks]
- 4 Identify at least two fabrics that are made of plastics [2 marks]
- 5 Recall a bush medicine and explain its use. [3 marks]
- 6 Recall the method used to separate components of crude oil. [1 mark]
- 7 Outline the differences between petroleum (crude oil) and petrol. [2 marks]

Apply

- 8 Explain the advantages of synthetic fibres over natural fibres. [2 marks]
- 9 Explain why research into new clothing materials is necessary. [2 marks]

- 10 These days, a lot of toys are made up of plastic. Metal was often used before plastic.
 - a Propose why plastic may be preferred over metal. [2 marks]
 - b Propose why metal may be preferred over plastic. [2 marks]
 - c Incorporating your answers from parts a and b, evaluate the use of plastic over metal in toys. [2 marks]
- 11 Explain why traditional medicines were usually made up of plant or animal products. [2 marks]

Analyse and evaluate

- 12 Based on what you have learned in this section, evaluate the importance of continued scientific research to society. [4 marks]
- 13 Explain why collaboration between scientists is necessary to produce many of the substances we use in today's society. In your answer, give an example of a substance that was created due to collaboration between scientists. [5 marks]



Figure 5.62 These days, many toys are made of plastic rather than metal.

TOTAL MARKS
[/35]

5

CHAPTER REVIEW

- 1 Fill in the gaps, using the words in the Word Bank below:

Chemical reactions are an essential part of _____ life. Creating new materials requires an understanding of the difference between _____ changes and _____ reactions. Physical changes are changes in the physical state of substances, such as from _____ to gas, from solid to liquid, or _____. Chemical reactions involve changes to the _____ in a substance. Chemical _____ are used to produce new pharmaceuticals, _____ to use in technology, as well as in dyes and the mining industry.

Scientists who work in these fields often need teamwork and to _____ on many projects, as one single person cannot have all the understanding required for many of the tasks. For example, scientists researching the best way to produce a dye would need people who understand _____ (to extract dyes from natural sources), _____ (to create a synthetic version of natural dyes) and materials (to test out dyes).

WORD BANK

biology	collaborate	materials
chemical	dissolving	physical
chemical bonds	everyday	reactions
chemistry	liquid	

Identify that the signs of chemical changes include a change in temperature, the original substance disappears or a new substance appears

- 2 Explain why bubbling can be used to show that a chemical reaction has occurred. [1 mark]
- 3 Define the term precipitate. [1 mark]

Compare chemical and physical change based on particle arrangement and reversibility

- 4 In the following reaction, identify the products and the reactants:
magnesium + oxygen $\rightarrow$ magnesium oxide
[2 marks]
- 5 Compare physical and chemical changes in terms of changes in arrangement of particles. [2 marks]
- 6 Compare chemical reactions and physical changes in terms of reversibility. [2 marks]

Demonstrate that chemical change involves reactions between substances to form new substances

- 7 The reaction for respiration is as follows: $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$
Explain how this reaction is a chemical reaction in terms of reactants and products. [2 marks]
- 8 Using the symbols 'A', 'B' and 'C', write a general equation which shows a chemical reaction between:
- a substances A and B [1 mark]
 - b substances B and C [1 mark]
 - c all three substances to form one product [1 mark]

Investigate everyday chemical reactions like photosynthesis, respiration and chemical weathering

- 9 Recall the:
- a reactants of photosynthesis [1 mark]
 - b products of photosynthesis [1 mark]
- 10 Explain why respiration is often described as the opposite of photosynthesis. [2 marks]
- 11 Describe an example of chemical weathering. [2 marks]

Propose reasons why the development of polymers and pharmaceuticals is important to society

- 12 Explain why scientific research into the development of new drugs for medicine is important. [2 marks]

- 13 Scientific research often relies on chance: when researching one thing, scientists often discover another. This is known as serendipity. Research and describe two more discoveries that have involved serendipity. [4 marks]

Describe how collaboration across different fields of science has enabled us to obtain new materials from the Earth's spheres

- 14 Identify the branches of science you have examined in this chapter that are commonly involved in industry. [2 marks]
- 15 Explain why collaboration is required in scientific industry. [1 mark]
- 16 Describe one example of different types of scientists collaborating in the development of a product for industry. [2 marks]

TOTAL MARKS
[/30]

RESEARCH

Choose one of the following topics for a research project. Your job is to examine in depth how scientific research and chemistry affects your life.

NASA

NASA is the US space agency that is responsible for the launches of space shuttles and probes for space exploration. NASA receives a large amount of funding from the US government. Research how much funding it receives compared to other government departments. Examine some of the developments that NASA has produced and how they have improved people's lives all over the world. Justify whether you think NASA should continue to receive the same level of funding from the government.

Traditional medicines

There are many different types of traditional medicine, including traditional Chinese and Middle Eastern medicine. Research some of the items used in these medicines and what scientific evidence there is for their effectiveness.

New materials

Smart technology such as phones and touch pads are everywhere. One new piece of technology is flexible displays. Research how these flexible displays work and what kind of chemistry is required to make them.



Figure 5.63 Flexible displays may eventually become the standard in consumer electronic devices.

Me

- 1 What have you learnt about chemical and physical reactions?
- 2 How does chemistry affect you and your life?
- 3 How does scientific research in chemistry affect you?

My world

- 4 What are some things you rely on that were developed using chemistry?
- 5 How does scientific research improve your life?

My future

- 6 How important is it that scientific research continues to be funded?
- 7 How do you think scientific research will change the future?

5 CHAPTER REVIEW**KEY WORDS**

acid	decomposition reaction	polyester
activation energy	ethanol	polymer
active ingredients	endothermic reaction	precipitate
anaerobic	exothermic reaction	product
aqueous solution	fermentation	random screening
chemical change	mechanical weathering	reactant
chemical equation	metabolic process	reaction
chemical reaction	mitochondrion	respiration
chemical weathering	oxidation	symbol equation
chlorophyll	petrochemicals	weathering
chloroplast	photosynthesis	word equation
combinatorial chemistry	physical change	

5

MAKING CONNECTIONS

Acid sulfate soils

Acid sulfate soils are found around Australia's coastline, where most of the population lives. These soils were formed underwater a long time ago when the sea level was much higher. When the seas receded, the acid sulfate soils remained. These types of soils are found in muddy and sandy low-lying coastal areas, such as coastal plains, wetlands and mangroves. Under the right conditions, they can still form today, caused by the interactions between chemicals and living bacteria.

How are acid sulfate soils formed?

Acid sulfate soils contain compounds called iron sulfides (pyrite). They form when sea water (or water that contains a lot of chemicals called sulfates) mixes with waterlogged soils and sands that contain iron and some organic matter. This process occurs where there is not much oxygen present, such as in mangrove swamps. Some bacteria flourish under anaerobic conditions – conditions without oxygen. These bacteria carry out chemical reactions that help form the pyrite.

The following are needed for pyrite to form:

- sulfur – usually from sea water
- anaerobic conditions (a lack of oxygen)
- anaerobic bacteria
- rotting material (e.g. mangrove leaves) to supply energy for the bacteria
- a source of iron – usually from mud or sand
- temperatures above 10°C.

In an undisturbed and waterlogged state, acid sulfate soils cause minimal problems. However, when these soils are exposed to air (usually due to drainage or excavation works), a chemical reaction occurs and acids are produced in the soils, which can cause major environmental problems.

The effect of acid sulfate soils

Acid sulfate soils can produce sulfuric acid when exposed to the air and become strongly acidic. The sulfuric acid and toxins released end up in estuaries and waterways. It has been estimated that 72 000 tonnes of acid have been washed into Trinity Inlet in Cairns after 700 hectares of land

Figure 5.64 Acid sulfate soils are commonly found around mangrove swamps and estuaries.



containing acid sulfate soils was drained in the 1970s. This decreased the quality of the water, killing fish and damaging sensitive ecosystems. Acid sulfate soils have had huge effects on our fisheries. Acid run-off also affects human constructions, such as drains, pipes, bridges and foundations.

Changing colours

The presence of sulfuric acid causes toxic quantities of heavy metals to be released into the environment. The acid run-off from acid sulfate soils reacts with iron in surrounding rocks and soils, causing it to dissolve. This results in the water containing more iron compounds than normal. Jarosite is an iron compound. It is yellow in colour, which can make the soil yellow too.

As the sulfuric acid moves through the soil, it can also interact with clay containing aluminium. This causes soluble forms of aluminium to be released into the waterways. High levels of aluminium in the water causes suspended particles in the murky water to clump together and drop to the bottom. This makes the water go clear and turn a blue-green colour.

Questions

- 1 How do you know that the formation of pyrite is a chemical reaction?
- 2 How are bacteria involved in changing the nature of the soil?
- 3 Why do you think that a temperature above 10°C is required for the interactions between the chemicals and the bacteria to cause a change?
- 4 Why are acid sulfate soils a particular problem where major building or landscaping work has been carried out?
- 5 What substances interact to form actual acid sulfate soils?
- 6 How would the water in an estuary be changed if sulfuric acid and toxins were washed into the estuary?
- 7 What changes do you think would occur to pipes and bridges if the metal in the bridges interacted with the acid from the actual acid sulfate soils?
- 8 How could knowledge of chemistry be used to reduce the effect of acid sulfate soils?
- 9 How can soil colour be used to identify acid sulfate soils?
- 10 What interactions cause the level of iron dissolved in water to increase?
- 11 Describe the changes caused by the interactions between aluminium compounds and solid particles suspended in the water.
- 12 Apart from affecting the colour of water, increased levels of aluminium in the water can be a risk to health. Find out why aluminium in water is dangerous to living things.



Figure 5.65 This concrete bridge pylon is being destroyed by sulfuric acid from acid sulfate soils, which reacts with the carbonate in the concrete.

A large, bold white number '6' is positioned on the left side of the image. The background is a solid blue sky. To the right of the number, a large, rounded, reddish-brown rock formation, known as a Devil's Marble, sits on a flat, textured rock surface. The rock has a mottled appearance with various shades of orange and red.

6

THE CHANGING EARTH

The Devils Marbles rocks are an extraordinary landform located in the Northern Territory. Once part of a solid layer of granite and sandstone rock, the processes of erosion and weathering led to the formation of these spectacular granite boulders, which vary in size and are an iconic feature of the Australian outback landscape. The Devils Marbles are an example of how our planet is constantly being reshaped and changed through the rock cycle.



UNDERSTANDING THE EARTH

6.1

The Earth is a rocky planet that formed approximately 4.5 billion years ago. The outer layer of the Earth, the crust, is composed of a thin layer of rock. The ancient rocks that first formed the Earth's crust have eroded and been replaced in an ongoing process called the rock cycle.

Students:

- » describe the structure of the Earth in terms of core, mantle, crust and lithosphere
- » outline the origins of and relationships between sedimentary, igneous and metamorphic rocks
- » relate the formation of landforms to physical and chemical weathering, erosion and deposition
- » explain the role of forces and energy in the formation of different types of rocks (additional)

PROPERTIES OF ROCKS AND MINERALS

6.2

Minerals are the building blocks of rocks. Rocks and minerals can be classified according to their properties, such as how hard or soft they are, if they are shiny or dull, or whether they have a distinctive colour. Australia is rich in mineral resources and many people are employed in industries associated with them.

Students:

- » identify that sedimentary, igneous and metamorphic rocks contain minerals
- » classify a variety of common rocks and minerals into groups according to their properties
- » describe examples to show how skills from across the disciplines of science are used in the exploration, mining or processing of minerals

THE EARTH'S GEOLOGICAL PAST

6.3

Geologists are able to determine the history of planet Earth by studying its rocks. Fossils that form in sediments, which later become rock, give scientists important clues about the age of rocks.

Students:

- » describe the conditions under which fossils form
- » outline how geological history can be interpreted in a sequence of sedimentary layers
- » describe some methods used by scientists to determine the age of rock layers (additional)

6.1

UNDERSTANDING THE EARTH

The surface of the Earth, both under the sea and on land, is composed of rocks. Scientists classify rocks according to how they were formed. The three main groups of rocks are sedimentary, igneous and metamorphic. Over time, the surface of the Earth changes as rocks break down, erode and cycle from one form of rock to another. Scientists who study the structure of the Earth, rocks and minerals are called **geologists**.

THE EARTH'S STRUCTURE

Although the Earth is now a solid planet, it began as a ball of molten materials. Scientists believe the Earth and other planets are a result of a massive explosion billions of years ago. According to this theory, planet Earth began as a molten fragment from this explosion called the Big Bang. As the fragment hurtled through space, the outside layers cooled, forming a ball of solid rock and ice. Most of the ice eventually melted and formed the oceans and rivers.

The Earth's surface has continued to slowly change and is still changing – many

rocks have worn down to form soil and sand, mountains and valleys have formed, and the land and oceans have changed shape. Some of this change is due to molten rocks moving from deeper down, which in places push their way up to the surface and also move sections of the Earth's crust.

If you could make a journey deep inside the Earth, you would find it is made of several layers.

The core

The **core** is the centre of the Earth. It consists of the outer core and the inner core. The outer core is approximately 2200 km thick. The inner core is about 2500 km thick.

The outer core is made mainly of metals (not rock), and the main metal is iron, possibly with some nickel. The outer core is very hot and liquid, with temperatures ranging from 4000°C to 6000°C. The heat comes from nuclear reactions and some of the heat is left over from when the Earth was formed. The outer core gives the Earth its north and south poles and magnetic field.

The inner core has a temperature of almost 10 000°C. The inner core does not melt or boil because of the weight of the rest of the Earth pushing down on it. Of course, no geologist has ever seen the core. Even our deepest mines only penetrate a few kilometres of the Earth's crust.

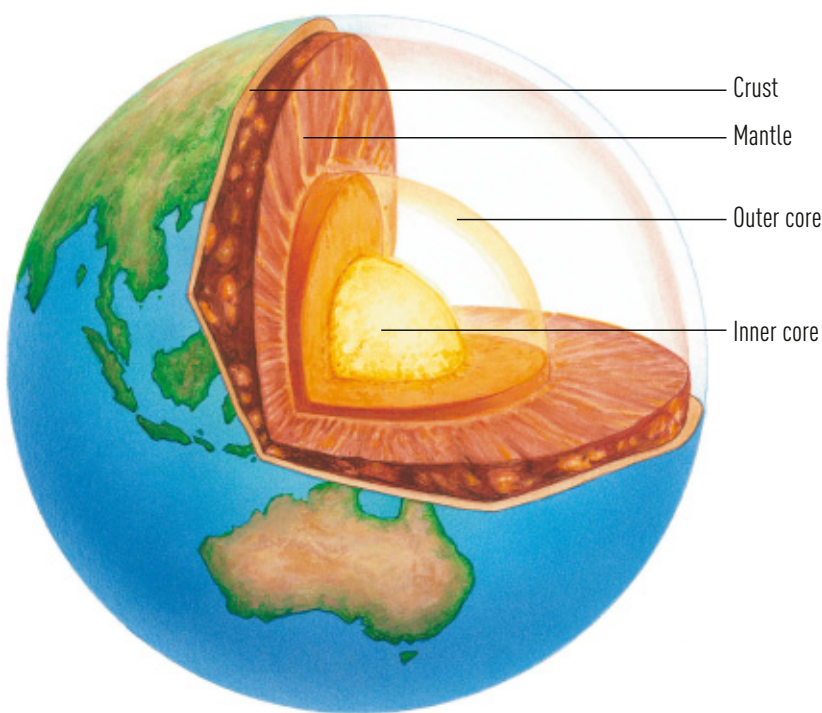


Figure 6.1 Layers of the Earth.

The mantle

The **mantle** is about 2800 km thick. Temperatures at the top of the mantle near the crust are 500°C and at the bottom of the mantle reach 3000°C. The bottom of the mantle is solid, but nearer to the top the rock slowly moves due to convection currents. Convection currents (see chapter 3) are one type of movement of heat – you have probably heard that ‘heat rises’. When heated regions rise, cooler regions move into the spaces left behind. As the hotter regions cool, they move down until they are heated and rise again, forming the cycle of a convection current. The top part of the mantle is more like modelling clay than solid rock. It is the source of volcanoes and earthquakes.

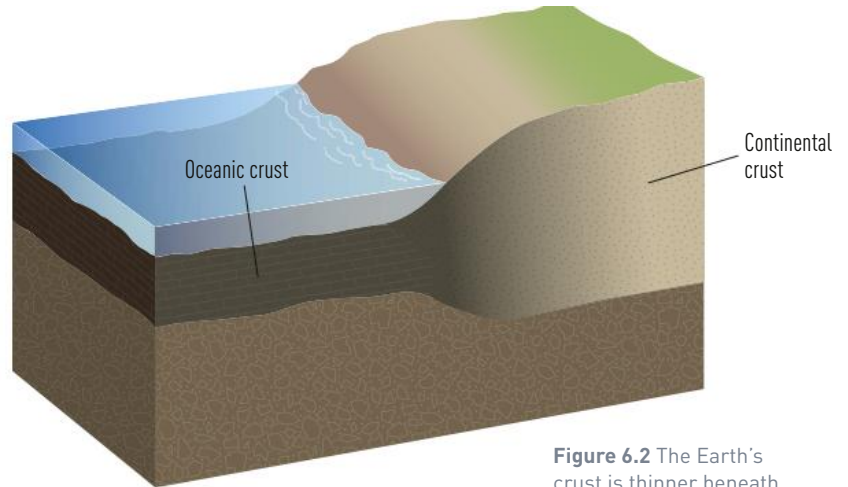


Figure 6.2 The Earth's crust is thinner beneath the oceans than it is beneath the continents.

thickest under the continents and thinnest under the oceans. Compared with the rest of the layers of the Earth, the crust is very thin and brittle.

The crust

The **crust** is the thin outer layer of the Earth on which we live. The crust ranges in thickness from 7 km to 50 km. It is made up of rocks and minerals, and much of the crust is covered by water. Do not think of the crust as just the landmasses; the oceans cover 70% of the crust. The Earth's surface is not smooth. It has hills, mountains, valleys, oceans and deserts. The crust is

The lithosphere

The **lithosphere** is the term used by scientists to describe the solid outer shell of a planet. The Earth's lithosphere consists of the crust and the upper part of the mantle, and is approximately 100 km thick. The lithosphere is broken into large sections, which are constantly moving. The speed of movement is similar to fingernail growth: between 1 cm and 10 cm per year.

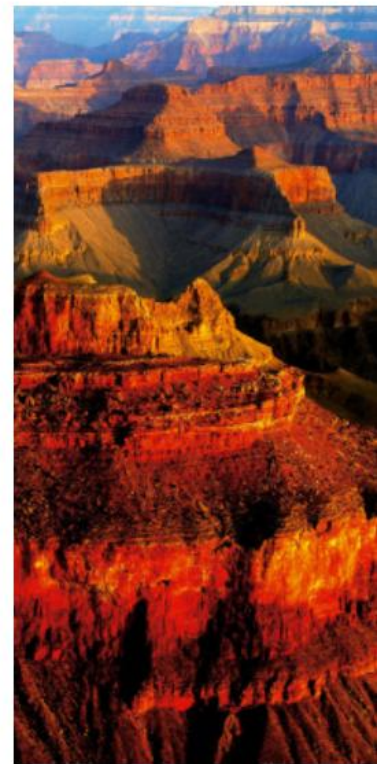


Figure 6.3 The Grand Canyon is part of the lithosphere.

QUESTIONS 6.1.1: THE EARTH'S STRUCTURE

Remember

- 1 Describe the core of the Earth.
- 2 Identify where the Earth's crust is thickest.
- 3 Identify where the Earth's crust is thinnest.
- 4 Identify the layer of the Earth that is the source of volcanoes and earthquakes.
- 5 Define the term 'lithosphere'.

Apply

- 6 '70% of Earth's crust is made of ocean and 30% is made of rock.' Is this statement true or false? Justify your answer.
- 7 Contrast the core of the Earth and the crust of the Earth. Identify three differences.
- 8 Propose why no geologist has seen the core of the Earth.

Analyse

- 9 Propose what feature of the Earth would lead scientists to think that the Earth's core might be made of iron. Hint: You might need to think back to year 7.

HOW ROCKS ARE FORMED

There are hundreds of different rocks on the Earth. Scientists classify rocks into three main groups according to how they

are formed. The three main types of rocks – igneous, sedimentary and metamorphic – all form in different ways.

ACTIVITY 6.1.1: MAKING ROCKS

Do you know how rocks are made? In small groups, discuss the following questions.

- 1 Where are rocks found?
- 2 How do rocks differ from one location to the next?
- 3 What conditions might be necessary to make a rock?
- 4 Could you provide those conditions in a science laboratory?

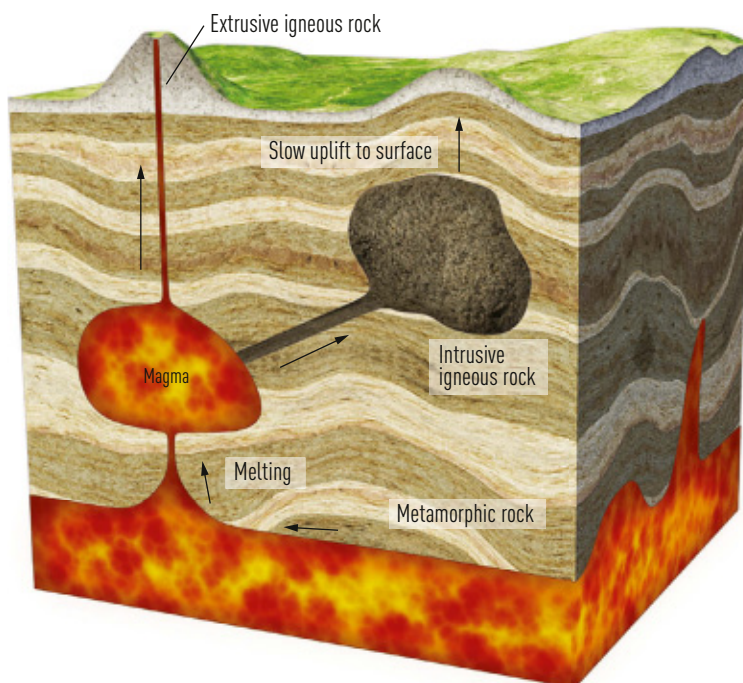


Figure 6.4 Igneous rocks are formed from volcanic magma.

Igneous rocks

In a volcanic eruption, red-hot molten rock called **magma** rushes out onto the surface of the Earth. Once magma is on the Earth's surface, it is known as **lava**. Magma from inside the Earth and lava from volcanic eruptions cool and solidify to form **igneous rocks**. The term 'igneous' comes from the Latin word *ignis*, which means 'fire'. The lower temperatures on the Earth's surface help the lava to solidify quickly. Igneous rocks that form from magma under the ground look quite different from those formed on the Earth's surface because they cool much more slowly.

Intrusive igneous rocks

Intrusive igneous rocks form slowly beneath the surface of the Earth when magma becomes trapped in small pockets.

These pockets of magma cool slowly underground (sometimes for millions of years) to form igneous rocks. Although formed underground, intrusive igneous rocks reach the Earth's surface when they are either pushed up by forces in the Earth's crust or uncovered by erosion. Granite is an example of an intrusive igneous rock (see Figure 6.5).

Extrusive igneous rocks

Lava cools much more quickly on the Earth's surface to form **extrusive igneous rock** such as pumice (see Figure 6.6). Pumice forms when hot, gas-filled lava cools very quickly. Pumice has many tiny holes that are formed by volcanic gases escaping from the cooling lava. Because there are so many holes, pumice is extremely light and can float on water. Pumice stones are used to scrub hard skin from our feet and powdered pumice is found in some abrasive cleaning products.



Figure 6.6 Pumice is an extrusive rock that is so light that it floats on water.

Crystals in igneous rocks

It is hard to understand how the same magma can solidify into both extrusive and intrusive igneous rocks and why the two types of igneous rocks behave quite differently. The answer is in how igneous rocks form and what they are made of. All rocks are made of **minerals** that are found in shapes called **crystals**. The longer it takes for lava to cool, the bigger the rock crystals that grow. Intrusive igneous rocks (such as granite) have large crystals. Lava cools much more quickly on the surface of the Earth, so extrusive igneous rocks have small crystals. Sometimes the lava cools so quickly that no crystals are formed.

Basalt is the most common type of rock in the Earth's crust. Most of the crystals in basalt are microscopic or non-existent because the magma cools so quickly that large crystals are unable to form. We commonly think of basalt as the building product bluestone. However, basalt can look different depending on the type of volcanic eruption it came from and how quickly it cooled. Scoria is a type of basalt full of bubble holes. The lava was filled with gases when it began to cool and the holes in the scoria are where the gas bubbles once were. Scoria is a light rock often used for garden paths and as fill in drainage trenches.

Obsidian is a smooth, black rock that looks like glass. It is formed when lava cools almost instantly and forms no crystals. Obsidian is used to make blades for surgery scalpels; the resulting blades are much sharper than those made from steel.

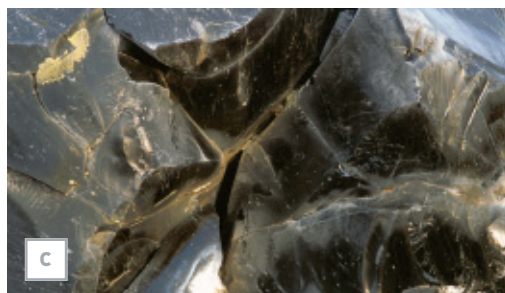


Figure 6.7 Basalt comes in different forms: (a) bluestone, (b) scoria and (c) obsidian.



Figure 6.5 Granite is an intrusive igneous rock.

EXPERIMENT 6.1.1: FACTORS THAT AFFECT CRYSTAL SIZE

Aim

To grow crystals and determine what affects their size.

Materials

- Bunsen burner
- Matches
- Heatproof mat
- Tripod
- Gauze mat
- Alum powder
- 2 Petri dishes
- Evaporating dish
- Safety glasses
- 250 mL beaker
- Tablespoon

WARNING

- > Wear safety glasses while heating the alum solution.

Method

- 1 Prepare a solution of alum by mixing 2 1/2 tablespoons of alum with 1/2 cup of hot water. Stir until dissolved.
- 2 Pour roughly equal amounts of alum solution into the evaporating dish and the two Petri dishes.
- 3 Put one of the Petri dishes in the refrigerator.
- 4 Put the other Petri dish on a windowsill.
- 5 Place the evaporating dish on the gauze mat.
- 6 While wearing safety glasses, gently heat the evaporating dish containing the alum solution over an orange (safety) flame. The orange flame is cooler and will allow for gentle boiling.
- 7 Continue heating the solution until nearly all the water has evaporated.
- 8 Observe the size of the crystals formed in the evaporating dish.
- 9 After two days, observe the size of the crystals formed in the two Petri dishes.
- 10 Observe the crystals formed in the refrigerator again after four or five days.

Results

Draw a labelled diagram of the crystals formed in the evaporating dish and in the two Petri dishes. Your diagram should show the different sizes of the crystals in the different dishes.

Discussion

Each of the crystals grew over a different time span. How does the time allowed for the crystal to form affect the size of the crystals?

Conclusion

What do you know about the factors affecting crystal size?



Figure 6.8 Crystals form in different shapes, colours and sizes.

Sedimentary rocks

Sedimentary rocks are formed when sediments (loose particles) are pressed together over a long period of time. Sediments are rock particles, such as mud, sand or pebbles, that are usually washed into rivers and eventually deposited on the riverbed or in the sea. Sediments can also come from the remains of living things, such as plants and animals.

Over thousands or even millions of years, these sediments form thick layers on the riverbed or sea floor. Pressure from the sediments and water above squeezes out the air and gaps in the bottom layer. Over time, the compacted sediments become sedimentary rocks. Chemicals that are dissolved in the water can soak into the sediments. The chemicals help cement the grains together once the water has evaporated.



Figure 6.12 Sandstone is a popular building material. The Art Gallery of NSW in Sydney is one of many sandstone buildings in the CBD (central business district).



Figure 6.9 Coal is formed from dead plant material.

The names of some sedimentary rocks give clues to the sediments that formed them. Sandstone, mudstone, siltstone and conglomerate are all types of sedimentary rock. Sandstone, for example, is made up of sand deposited in environments such as deserts and beaches. Conglomerate (as the name suggests) is a mixture of all sizes of rocks that have become cemented together.

Sedimentary rocks are not always formed from the sediments of minerals or other rocks. Living things also break down and their remains are deposited as sediments. Shells and hard parts of sea organisms break down and are deposited in layers on the ocean floor. Eventually they cement together under pressure to form limestone.

The compaction of dead plant material can also help form sedimentary rocks. For example, **coal** is formed from dead plants that were buried before they had decayed completely. Pressure from the layers above may change the plant material into coal or oil.

Chemical sedimentary rocks form when water evaporates, leaving behind a solid substance. For example, when seabeds or salt lakes (such as Lake Eyre) dry up, they leave a solid layer of salt behind. If the layer of salt is compressed under the pressure of other sediments, it may eventually form rock salt.

Figure 6.14 Lake Eyre is a very large inland salt lake in South Australia that is rarely filled with water. It is usually a large salt pan.

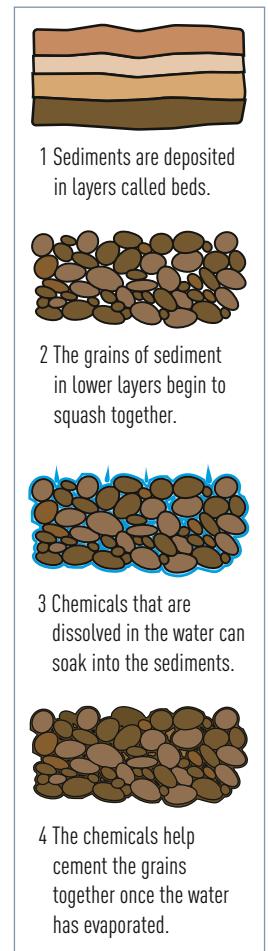


Figure 6.10 The formation of sedimentary rocks.



Figure 6.11 Conglomerate rocks have grains of different sizes. The sediments for these rocks were deposited in fast-flowing rivers during flooding or by glaciers.



Figure 6.13 Shale (or mudstone) is the most common sedimentary rock. Shale is a fine-grained sedimentary rock made up of clay minerals or mud.

EXPERIMENT 6.1.2: MAKING SEDIMENTARY ROCKS

Aim

To make small samples of sedimentary rocks and compare them with real samples.

- Dry clay
- Mortar and pestle
- Dry sand
- Small, smooth pebbles
- Plaster of Paris
- Teaspoon
- 4 empty matchboxes (or similar small cardboard boxes)
- White tile
- Photos of sandstone, shale and conglomerate

Method

- 1 Grind a lump of dry clay with a mortar and pestle until it is fine and powdery.
- 2 Using the teaspoon, mix the dry ingredients for each rock sample on a white tile according to the recipes below, but do not add the water just yet. You will need to prepare two shale samples so they can be used later in Experiment 6.1.3.

Rock	Dry clay	Sand	Plaster of Paris	Pebbles	Water
Sandstone	1/2	4	1/2	0	2
Shale	5	1/2	0	0	2
Conglomerate	1/2	1	1/2	4	2

(All measurements are in teaspoons)

- 3 Pile your ingredients into a little hill and make a small dip in the centre for the water.
- 4 Slowly add the water and stir until the ingredients are uniformly mixed. Be careful not to make the mixture too wet.
- 5 Press your mixture into an empty matchbox, label it with the rock type and your name, and leave it to dry for two days.
- 6 When your 'rock' is dry, peel off the matchbox and examine your sample. Take digital photos of your samples and photos of the 'real' rocks for comparison. Keep your two shale samples for Experiment 6.1.3.

Results

Include images of your rocks, along with any statements about the process or products.

Discussion

- 1 How do your sedimentary rock samples compare with the real samples?
- 2 What were the differences between your samples and the real rocks?

Conclusion

What have you discovered about sedimentary rocks?

Metamorphic rocks

Metamorphic rocks are formed when other types of rocks are changed by extreme heat and pressure inside the Earth. When igneous, sedimentary or even metamorphic rocks are heated to extreme temperatures by magma, or when they are placed under extreme pressure from the layers of rocks above them, they can change into a different type of rock. For example, basalt can be changed into hornfels, granite can be changed into gneiss, shale can be changed into slate (see Figure 6.15) and limestone can become marble (see Figure 6.16).



Figure 6.16 The Taj Mahal in India is made of marble, the metamorphosed form of limestone. Marble is also a popular material for sculptures and kitchen bench tops.

Metamorphic rocks are stronger than the original rocks they came from because the particles have been fused together under great pressure or heat.

Bands can sometimes be seen in metamorphic rocks. The bands tell us that the crystals inside the rock were squeezed together under immense pressure. For example, when granite is squeezed under high pressure, the crystals change and the rock gneiss is formed (see Figure 6.17).



Figure 6.15 Slate is the metamorphosed form of shale. It is a useful material for floor and roof tiles and as the base for billiard tables.



Figure 6.17 When granite (a) is subjected to high heat or pressure, it can change into the metamorphic rock known as gneiss (b). The bands on the gneiss show that the crystals have been squeezed together under immense pressure.

EXPERIMENT 6.1.3: MAKING A METAMORPHIC ROCK

Aim

To make a sample of a metamorphic rock.

Materials

- 2 shale rock samples from Experiment 6.1.2
- Bunsen burner
- Tripod
- Pipe clay triangle
- Gauze mat
- Evaporating dish
- Tongs
- 2 × 250 mL beakers

WARNING

- > Never leave a Bunsen burner unattended during an experiment.
- > Wear safety glasses and a lab coat.
- > The apparatus will be very hot at the end of this experiment. Leave it to cool before packing it away.

Method

- 1 Allow your shale samples made in Experiment 6.1.2 to dry for approximately one week.
- 2 Place one of the shale samples on a pipe clay triangle on top of a gauze mat and heat it strongly over a blue Bunsen burner flame for about half an hour. If an evaporating dish is placed upside down over the shale, more heat will be retained.
- 3 After about half an hour of heating, carefully pick up the shale sample using the tongs and drop it into a beaker of water.
- 4 Drop the second, unheated shale sample into another beaker of water and observe what happens to the two rock samples.

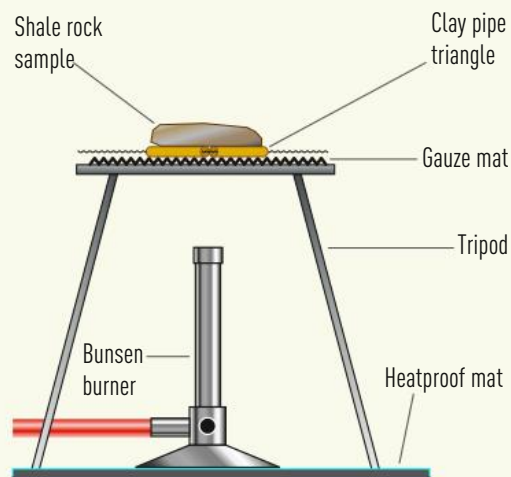


Figure 6.18 Experimental setup.

Results

Record your observations in a table.

Discussion

- 1 What differences do you notice about the two rock samples when they are dropped into the water?
- 2 Can strong heat change the properties of rocks over time?
- 3 How different was your new metamorphic rock sample from the original shale sample? Was the method successful?

Conclusion

What do you know about the formation of metamorphic rocks?

QUESTIONS 6.1.2: HOW ROCKS ARE FORMED

Remember

- 1 Identify the sediments that the following sedimentary rocks are made from:
 - a sandstone
 - b conglomerate.
- 2 Recall why pumice floats on water.
- 3 Explain how metamorphic rocks form.
- 4 Explain how sedimentary rocks form.
- 5 Explain how igneous rocks form.

Apply

- 6 Explain what plants have to do with coal.

Analyse

- 7 The ancient civilisations that discovered obsidian had a competitive advantage over those who did not know about obsidian. Propose why this might have been the case.

FORMATION OF LANDFORMS

The Earth's crust is not flat – it is covered in landforms such as cliffs, valleys, canyons, caves and plateaus. Rocks are gradually broken down and sculpted through both physical and chemical processes. The gradual breaking down of rocks is a process called **weathering**.

Weathering

Rocks look indestructible and permanent. They are used to make roads, important buildings and monuments. Large rocks can be used to hold back the surf and ocean waves. Rocks seem to last forever, but they don't. They are slowly worn down into smaller pieces by weathering. The causes of weathering are either physical or chemical.

Physical weathering

Physical weathering refers to the breakdown of rocks by non-living things. It includes the effects of heat and cold on rocks, the formation of ice, and the effects of wind and water.

In desert areas, the processes of **onion-skin weathering** and **frost shattering** are common. The days are very hot and the nights are freezing cold in the desert. This daily heating and cooling affects only the outside of the rock because rocks do not transmit heat very well. Sometimes the outside of the rock can peel off, just like onion skin. The round rocks produced in this way are called tors.

Frost shattering involves an unusual characteristic of water: when water freezes, it takes up more space. When water freezes in a crack of a rock to form ice, it expands and pushes hard against the rock around it. This can make the crack larger. The next day, the ice melts and water fills the crack again. That night, ice forms again and makes the crack even larger. This process is repeated many times until part of the rock is split off.

Living things also help to break down rocks. Tree roots can grow within small cracks in rocks and exert forces that can eventually break the rocks apart. This is called biological weathering.

Figure 6.19 A frost-shattered rock.



Figure 6.20 The Devils Marbles in the Northern Territory's hot desert have been formed by onion-skin weathering.

ACTIVITY 6.1.2: BIOLOGICAL WEATHERING

Figure 6.21 shows trees growing in the cracks in the rocks of Mount Remarkable National Park in South Australia. Using only this image, and your knowledge of physical weathering, prepare a three-stage diagram to show how trees such as those pictured might cause biological weathering in rocks. Try to imagine what will happen as the trees grow. Add labels and captions to your diagram to explain what is happening.



Figure 6.21 Mt Remarkable National Park, South Australia

Chemical weathering

Sometimes chemicals in the environment cause the weathering of rocks. This is called chemical weathering. The chemicals in air and water can react with the chemicals in rocks. The most common chemicals involved in weathering are water, oxygen and acids.

There are many natural acids. Natural acids come from the decay of dead plants and animals, and also from chemicals dissolved in rainwater that form naturally by the effect of lightning. These acids

are not as strong as the acids in a science laboratory but can dissolve some rocks slowly. Limestone is commonly dissolved by rainwater and acids. Amazing features, called stalagmites and stalactites, are formed in this way when a solution containing limestone drips from the roof of caves and evaporates (see Figure 6.23).

In areas of the world where air pollution is very bad, acid rain is a problem. You learnt about the chemical reaction of acid rain in chapter 5 on page 233. Acid rain can form when raindrops dissolve pollution in the air and carry it to the ground. If the pollution is acidic, then the rain will be too. Winds can also carry acid to other regions.

Acid rain destroys forests and makes lakes and rivers so acidic that fish and plant life die. Acid rain is also a problem because it can dissolve the limestone and marble often used in statues and buildings (see Figure 6.22).



Figure 6.22 Acid rain is a form of chemical weathering that has worn away the features of this statue.

Limestone caves

The amazing long strands of rock found on cave floors and ceilings are composed of calcium carbonate from the limestone ceiling of the cave. A stalagmite grows from the floor towards the ceiling (they 'might' reach the ceiling one day) and a stalactite grows down from the ceiling (they hold on 'tight'). If these formations meet in the middle, a column is formed.

Stalagmites and stalactites form when acids in water dissolve the limestone rocks above the cave. The acid and dissolved limestone makes a solution that drips through the ceiling of the cave and is deposited on the stalagmites and stalactites, gradually increasing their width and length. When touring inside limestone caves with stalactites and stalagmites, do not touch these rock formations because they are generally still forming. Oil from our skin can interfere with their formation.



Figure 6.23 Striking limestone formations at the Jenolan Caves in New South Wales.

EXPERIMENT 6.1.4: THE EFFECTS OF CHEMICAL WEATHERING

Aim

To investigate the action of acids on limestone.

Materials

- 4 small lumps of limestone
- Dilute sulfuric acid
- Soda water
- White vinegar
- Tap water
- 4 test tubes

WARNING

> Safety glasses and lab coats should be worn when handling acids.

Method

- 1 Carefully place a piece of limestone into each of the four test tubes.
- 2 Pour some sulfuric acid into one test tube, soda water into another, vinegar into the third and ordinary tap water into the fourth. The fourth test tube, with tap water, is the control.
- 3 Carefully observe what happens to each piece of rock.

Results

Draw a labelled diagram of the four test tubes.

Discussion

- 1 Are bubbles produced in each test tube?
- 2 What do you think is causing any bubbles that are present?
- 3 Are all the pieces of limestone reacting? If not, why not?
- 4 Why was tap water used as the control in this experiment?

Conclusion

What can you conclude about the action of acids on limestone?



Figure 6.24 The Twelve Apostles rock formation near the Great Ocean Road in Victoria were formed by water erosion. The soft limestone stacks are prone to further erosion by the ocean waves.

Erosion and deposition

Once rocks have weathered and been broken down into smaller pieces, they are moved and carried away by wind or water. This process is called **erosion**. The weathered rock moved by erosion is deposited on the land, in rivers, and on the floors of lakes and oceans to form sediments. The key agents of erosion are wind, ice and water.

Wind erosion occurs when the wind blows grains of sand and dust. Ice erosion occurs when ice in glaciers (frozen rivers) carries away earth and rock. Water erosion occurs when moving water washes away stones, sand and mud.

Surf and ocean waves remove sand from beaches and wash it along the coast or out to sea. Rivers carry sand, gravel and smaller particles. As rivers slow, these particles are deposited in a process called **deposition**.

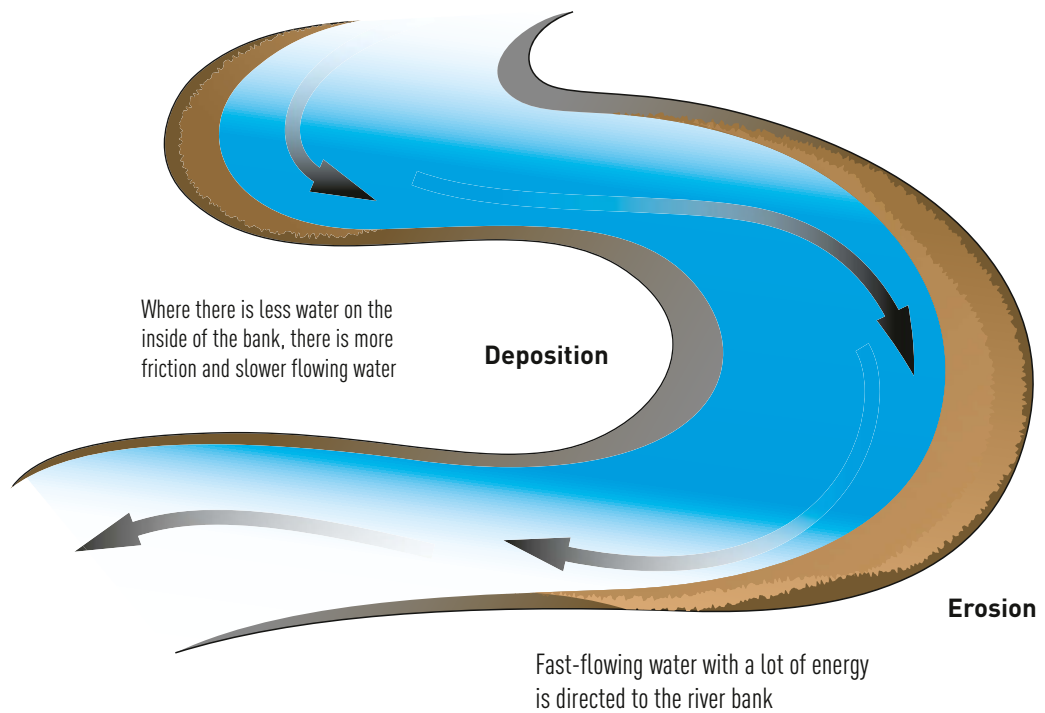


Figure 6.25 The process of water erosion by a river.

QUESTIONS 6.1.3: FORMATION OF LANDFORMS

- 1 Identify the two types of weathering.
- 2 Describe the process of onion-skin weathering.
- 3 Identify the most common chemicals involved in the process of chemical weathering.
- 4 Explain where natural acids come from.
- 5 Explain how stalagmites and stalactites are formed.
- 6 Identify three different types of erosion.

Apply

- 7 Compare the process of weathering with the process of erosion. What is the key difference?

THE ROCK CYCLE

The **rock cycle** is a model used by scientists to describe the formation and destruction of sedimentary, igneous and metamorphic rocks. It also describes the relationships between the different types of rocks, as geological processes act to recycle one type of rock into another. Erosion and forces within the crust are the main drivers involved in the rock cycle.

The rock cycle: step-by-step

1. Magma and lava cool and solidify to form igneous rocks. These rocks are brought to the Earth's surface through volcanic activity, through the uplifting forces acting on land when tectonic plates collide, or through erosion.
2. On the surface of the Earth, rocks are weathered by water, ice, wind, chemicals and biological forces.
3. The weathered particles are then removed by erosion, transported and eventually deposited.
4. As the deposited sediments become covered with additional eroded sediments, layers form and are cemented

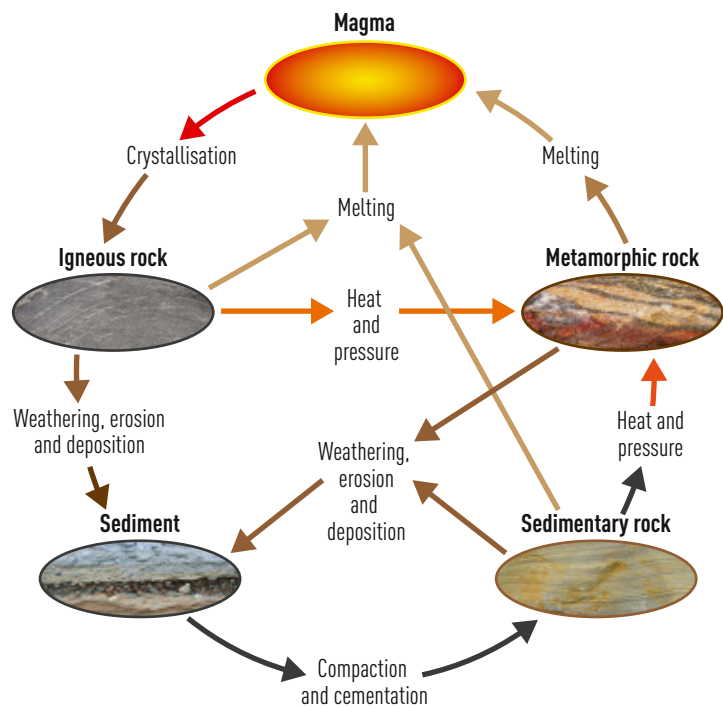


Figure 6.26 The rock cycle.

together under pressure to form sedimentary rocks. Forces within the Earth or additional heat and pressure can transform igneous and sedimentary rocks into very hard metamorphic rocks. If too much heat or pressure is applied to rocks, they melt and form magma, and the cycle continues.

QUESTIONS 6.1.4: THE ROCK CYCLE

Remember

- 1 Summarise the different stages in the rock cycle as short bullet points. Use Figure 6.26 to assist you.

Apply

- 2 Analyse the importance of sedimentary rocks in the rock cycle.

Create

- 3 In a similar way to humans, rocks change with time. However, unlike humans, rocks don't always head in the same direction – they may move through the rock cycle, covering the same phase many times in many different ways. Rocks are never truly 'born'. Write a creative story about the 'life of a rock'.

6.1

CHECKPOINT

UNDERSTANDING THE EARTH

Remember and understand

- 1 Match each word with its meaning. [4 marks]

mantle	central part of the Earth
lithosphere	layer of hot, semi-molten rock below the crust
core	outer layer of the Earth on which we live
crust	solid outer shell of the Earth comprising the crust and the upper part of the mantle

- 2 Identify the rocks formed when:
- loose particles are pressed together by the weight of sediments above them [1 mark]
 - other types of rocks are changed by heat and pressure inside the Earth [1 mark]
 - magma and lava cool and solidify. [1 mark]
- 3 Explain the difference between magma and lava. [2 marks]
- 4 Define the term 'sediment'. [1 mark]
- 5 Identify the type of rock that can be dissolved to make caves. [1 mark]
- 6 Identify the three chemicals in the environment that help weathering. For each chemical, explain where it can be found. [3 marks]
- 7 Identify the model used to describe the relationships between sedimentary, igneous and metamorphic rocks. [1 mark]
- 8 Identify the features of pumice that make it useful for removing dead skin. [1 mark]

Apply

- 9 Compare intrusive and extrusive igneous rocks. [2 marks]
- 10 Explain why sedimentary rocks form at the Earth's surface. [2 marks]

- 11 Cave systems in limestone rocks follow the course of underground rivers. Explain why water is necessary to make caves. [2 marks]

Analyse and evaluate

- 12 Predict where you would expect to find a black sedimentary rock that is formed from carbon. Explain your answer. [2 marks]
- 13 Propose why old buildings and monuments are weathering faster than ever before. [3 marks]

Critical and creative thinking

- 14 Figure 6.27 shows the Three Sisters in the Blue Mountains in New South Wales. Use this image to propose how these rocks were formed. Prepare a poster to show how the rocks were formed and how they would have changed over time. [5 marks]



Figure 6.27 The Three Sisters at Katoomba in the Blue Mountains, New South Wales.

- 15 Explain the role that forces play in the formation of sedimentary, igneous and metamorphic rocks. [3 marks]

Making connections

- 16 It can be said that the Earth's history is written in our rocks. Explain how learning about the rock cycle can help us to understand the history of our planet. [5 marks]

TOTAL MARKS
[/40]

PROPERTIES OF ROCKS AND MINERALS

6.2

Scientists classify rocks into three major groups according to how they are formed – sedimentary, igneous or metamorphic. But within these three major groups there are many different rocks, each with their own name. Each rock has characteristics that give clues to its identity, such as its **colour** or **hardness**. These characteristics are referred to as **properties**. Rocks display properties that make them useful to humans, such as their hardness, shininess or ability to be shaped without breaking. By making careful observations of a rock's properties, geologists can tell where a rock came from and what has happened to it.

ACTIVITY 6.2.1: ROCKS IN YOUR HEAD!

How do you tell one rock type from another? There are probably certain properties you look for to identify objects around you. What properties would you use to identify rocks? Do you know any particular types of rocks already? What do you know about them? Are there certain words you would use for rocks that wouldn't be used for anything else?

- 1 Working in small groups, suggest properties that could be used to group rocks.
- 2 Find some rocks out in the schoolyard and group them using the features you discussed.
- 3 Share your results. Did the class end up with the same ideas? If not, how did the properties differ?
- 4 Would you consider the properties identified by your group as 'scientific'?



IDENTIFYING AND SELECTING ROCKS

Humans select rocks for particular purposes because of their properties. Granite, for example, is selected for kitchen benchtops because it is a hard building stone, it is not porous (it doesn't let liquid through), it does not change with temperature and it is resistant to damage from chemicals.

Rocks can first be identified by how they look. Coal, for example, is black or dark brown. The surfaces of pumice and scoria are full of holes. Conglomerates are rocks made up of individual stones that have become cemented together.

Geologists also use a range of other properties to help identify rocks, including:

- hardness
- **lustre** (shininess)
- transparency
- density
- composition (including the minerals that make up the rock)
- size of the grains in the rock.



Figure 6.28 shows some different rocks and how they can be identified by their type of rock, grain size, hardness and colour.



Quartzite
Metamorphic
Coarse grain
Hard
Light colour



Obsidian
Igneous
Fine grain
Soft
Dark colour



Conglomerate
Sedimentary
Mixed grain
Hard or soft
Colour varies



Coal
Sedimentary
Fine grain
Soft
Dark colour



Limestone
Sedimentary
Fine grain
Soft
Light colour



Slate
Sedimentary
Fine grain
Soft
Dark colour



Granite
Igneous
Coarse grain
Hard
Light colour



Scoria
Igneous
Fine grain
Soft
Dark colour



Pumice
Igneous
Fine grain
Medium hardness
Light colour



Basalt
Igneous
Fine or mixed grain
Hard
Dark colour



Shale
Sedimentary
Fine grain
Soft
Colour varies



Marble
Metamorphic
Coarse grain
Soft
Light colour



Sandstone
Sedimentary
Coarse grain
Hard
Light colour



Gneiss
Metamorphic
Coarse grain
Hard
Alternating light and dark bands



Schist
Metamorphic
Medium to coarse grain
Medium hardness
Colour varies



Rhyolite
Igneous
Fine grain
Hard
Light colour

Figure 6.28 Different types of rocks.

EXPERIMENT 6.2.1: IDENTIFYING ROCKS

Aim

To identify a range of common rocks.

Materials

- Rock samples (unnamed, labelled A, B, C, D etc.)
- Hand lens
- Table 6.2 (on page 280), as well as a rock key from the Internet or your rock kit

Method

- 1 Examine each rock sample with the hand lens.
- 2 Use the key to identify each of your rocks. Be aware of the following:
 - Crystals in rocks have straight edges and flat, shiny surfaces.
 - Grains are not shiny – they are jagged or rounded, and more like grains of sand.
 - Coarse grains are about the size of a grain of rice. Medium grains are smaller but still visible to the naked eye. Small grains are only visible with a hand lens or magnifier.

Results

Display your results in a table that identifies the rock sample (e.g. sample A), lists its main properties and gives its name.

Discussion

- 1 How hard was it to identify your rock samples?
- 2 Were there any samples you could not identify?
- 3 Compare your results with those of another group. Were there any differences between your results?
- 4 Ask your teacher for the names of your rock samples and see which ones you got right (hopefully all of them!).

Conclusion

Write a comment on the use of a key to identify common rock samples.



Figure 6.29 Rock identification keys are used to identify unknown rock samples. Often a hand lens is needed to see the finer details of the rock.

QUESTIONS 6.2.1: IDENTIFYING AND SELECTING ROCKS

Remember

- 1 Identify five properties that geologists use to identify rocks.
- 2 Use Figure 6.28 to identify three rocks that share the following properties: fine grain, soft and dark in colour.

Apply

- 3 Explain why the properties of granite make it useful as kitchen benchtops.

Analyse

- 4 Using the properties listed for sandstone, basalt and limestone, construct a dichotomous key to differentiate between them.
- 5 Identify each type of rock from the following descriptions:
 - a dark with holes in the surface
 - b hard with alternating light and dark bands of colour
 - c light in colour with coarse grains; used for sculptures



Figure 6.30 Geologists use tools and instruments to examine and identify rocks.

MINERALS

All rocks are made up of one or more minerals. A mineral is a naturally occurring solid substance with its own chemical composition, structure and properties. The minerals that make up a rock determine the properties of the rock. There are more

than 4000 minerals known, but only approximately 150 of these are common. Quartz is the most common mineral and it is found in nearly every rock type. Quartz is made up of the two most common elements on the Earth: oxygen (O) and silicon (Si).

DEEPER UNDERSTANDING

Quartz in watches

Quartz watches use quartz crystals to keep time. One property of quartz crystal is that it generates an electric charge when mechanical pressure is applied to it. Depending on the type of quartz crystal, a quartz timepiece can accurately keep time to within 1 second every 10 years.



Figure 6.31 A quartz watch.



Figure 6.32 Under a microscope, the minerals that make up the rock olivine basalt can be seen as individual crystals.

Mineral crystals

Minerals are found in shapes called crystals (see Figure 6.32). The structure of the crystal greatly influences a mineral's properties. For example, both diamond and graphite have the same chemical composition – they are both pure carbon. Graphite (used as the lead in a pencil) is very soft, whereas diamond is the hardest of all minerals. As you learnt in chapter 4, this difference arises because the carbon atoms in graphite crystals are arranged into sheets that can slide past each other, whereas the carbon atoms in diamond crystals form a strong, interlocking unit (see Figure 6.33).

Identifying minerals

To identify minerals correctly, geologists carefully examine their properties. The main colour of the mineral is not a reliable property to identify them by because many minerals are impure. For example, pure quartz is colourless, but impurities can cause it to be many colours, such as purple (amethyst), pink (rose quartz) or yellow (citrine). Even in one sample, the colour

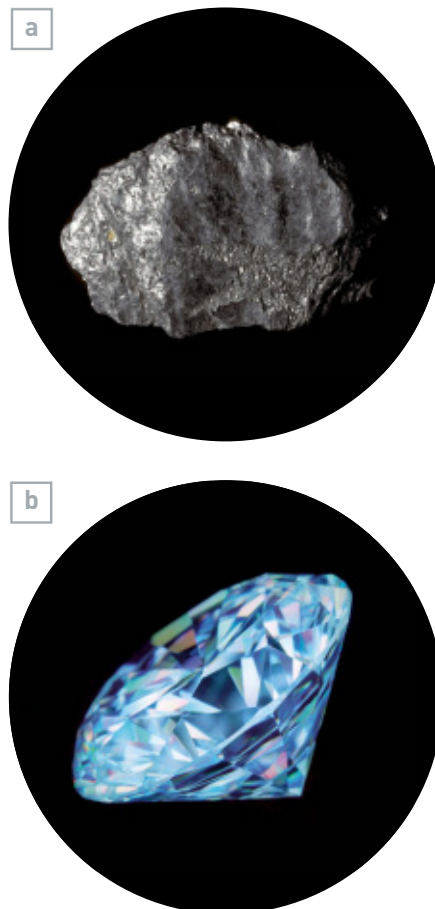


Figure 6.33 (a) Graphite is soft because the carbon atoms are arranged in sheets. (b) Diamond is hard because the carbon atoms are interlocked.

may change. The colour of a mineral is a guide to identifying it, but colour cannot be relied on for correct identification. Properties such as lustre, streak, hardness and cleavage are used instead.

Lustre is the shininess of the surface of the mineral (see Figure 6.34). Some types of lustre are:

- metallic – looks like a shiny new coin
- brilliant – very shiny, like a mirror
- pearly – a bit shiny, like a pearl or fingernail
- dull – not shiny at all
- earthy – like a lump of dirt.

Streak is the colour of the powdered or crushed mineral. This colour can be seen by drawing with the mineral on a footpath. The colour of the line that the mineral leaves behind is its streak. Often the streak is different from the main colour of the mineral.

Hardness is how easily a mineral can be scratched. Some minerals are so soft that they can be scratched with a fingernail. Other minerals are so hard that they can scratch glass. A hard mineral can scratch a soft mineral and not get scratched itself. Austrian geologist Friedrich Mohs devised a scale on which the hardness of a mineral is described by a number. Mohs gave a hardness number to 10 common minerals, as shown in Table 6.1. Talc is the softest mineral and has a hardness of 1; diamond is the hardest mineral and has a hardness of 10. These minerals can be used to find the hardness of any other mineral. A piece



Figure 6.34 The lustre of a mineral describes its shininess.

of copper (hardness 3.5) will be scratched by fluorite (hardness 4), but not by calcite (hardness 3). Copper will scratch calcite because copper has a higher hardness number than calcite. The hardness of some common objects are:

- 2.5 – fingernail
- 3.5 – copper metal
- 6.5 – iron nail
- 6.5 – glass in a microscope slide.

Table 6.1 The Mohs scale of mineral hardness.

Hardness	Example
1	Talc
2	Gypsum
3	Calcite
4	Fluorite
5	Apatite
6	Orthoclase feldspar
7	Quartz
8	Topaz
9	Corundum
10	Diamond

ACTIVITY 6.2.2: TESTING THE HARDNESS OF COMMON SUBSTANCES

What you need: iron nail, glass microscope slide, plastic disposable Petri dish, piece of copper sheet, half a stick of chalk.

- 1 Scratch the samples against each other and rank them in order of hardness from softest to hardest. When testing the hardness, scratch only a small part of the mineral or object. You only need a scratch that is about 5 cm long.
 - Which sample is the hardest?
 - Which sample is the softest?
- 2 Collect some samples of different minerals and arrange them in order of hardness. Use Table 6.1 to help you.



Figure 6.35 Calcite is a transparent mineral that has three cleavages.

Cleavage is the number of smooth planes that minerals break along. Mica breaks into flat layers, like the pages in a stack of papers. Calcite has three cleavages because it breaks with three smooth surfaces: left and right; front and back; top and bottom.



Figure 6.36 Mica has one cleavage. Minerals that demonstrate cleavage look like thin slabs stuck together.

Several minerals have unusual properties. For example, some minerals shine in ultraviolet (UV) light – these minerals absorb UV light, which we cannot see, and emit it as visible light, which we can see. Calcite is a transparent mineral. When you look through it, you see a double image.

Minerals are usually identified by using a key that outlines the properties of known minerals. A tabular key to identifying minerals is given in Table 6.2.

Table 6.2 Key for the identification of minerals.

Lustre	Colour	Hardness	Description	Mineral
Non-metallic lustre	White or pale	Scratched by a fingernail	- White to pale green - Greasy feel - Often flaky	Talc
			- Often transparent, vitreous lustre - Breaks along cleavage planes to give smooth faces	Gypsum
			- Transparent, shiny lustre - Breaks along one cleavage plane to give flat sheets that are flexible	Muscovite mica
	Increasing hardness	Hardness similar to that of a fingernail	- Vitreous lustre - Cleaves into tiny cubes - Salty taste	Halite (rock salt)
		Scratched by a knife blade, scratches a fingernail	- White or pale yellow coloured, often transparent - Three good cleavages, not at right angles - Forms tiny blocks	Calcite
		Scratches a knife blade, may just scratch a microscope slide	- White or grey coloured - Sometimes shows two cleavages at 90°	Plagioclase feldspar
			- Pink or flesh coloured - Sometimes shows two cleavages at 90°	Orthoclase feldspar
		Easily scratches a microscope slide	- Transparent or milky, vitreous lustre - No cleavage - Forms six-sided crystals - Conchoidal fracture (cleavage that does not follow any natural planes) sometimes seen	Quartz

Lustre	Colour	Hardness	Description	Mineral
Non-metallic lustre	Coloured minerals	Scratched by a fingernail	- Black coloured, shiny lustre - Breaks along cleavage plane to give thin flexible sheets	Biotite mica
			Orange-red coloured, earthy lustre, orange or red-brown streak	Bauxite
	Increasing hardness	Scratched by a knife blade	- Orange-brown coloured, earthy lustre, yellow-brown streak - Bright green coloured, green streak	Limonite Malachite
			Bright blue coloured, blue streak	Azurite
		Scratches a fingernail	- Bluish purple coloured, white streak, vitreous lustre - Four cleavages to give pyramid shape in good specimens	Fluorite
			- Greenish coloured, white streak, greasy looking - Poor cleavages	Apatite
		Hardness similar to that of a knife blade	- Black coloured, vitreous lustre - Sometimes two cleavages - Short, thick crystals, eight-sided	Augite
		Scratches a steel blade, but does not scratch a microscope slide	Glassy green grains, partly transparent	Olivine
			- Pink or flesh coloured - Sometimes shows two cleavages	Orthoclase feldspar
			- Colour variable, vitreous lustre - Amethyst = purple - Rose quartz = pink - Smoky quartz = grey - Conchoidal fracture	Quartz varieties
Lustre is partly metallic, partly earthy	Black or coloured	Does not scratch a steel blade	- Black to brown coloured, brown streak, vitreous lustre, sometimes metallic - Often shows cleavage	Sphalerite
			- Yellow-brown coloured, yellow to brown streak - Dull lustre	Limonite
		Approximately the same hardness as a steel blade	Red or grey coloured, red streak, red rubs off onto fingers	Haematite
		Scratches a steel blade	- Black magnetic - May be too hard for streak plate	Magnetite
Metallic lustre	Gold colour	Scratched by a steel blade	Dark brass coloured, tarnishes to purple colour	Chalcopyrite
		Scratches a steel blade	- Pale brass coloured - Crystals may be seen	Pyrite
	Silver colour	Scratched by a copper coin, but not by a fingernail	- Very dense (heavy), grey streak - Three good cleavages to give tiny cubes	Galena



Haematite



Bauxite



Galena



Rutile



Pitchblende



Molybdenite



Cinnabar



Malachite



Pentlandite



Sphalerite



Chalcopyrite



Cassiterite

Figure 6.37 Different types of minerals.

QUESTIONS 6.2.2: MINERALS

Remember

- Define the following terms:

a mineral	c streak
b lustre	d cleavage
- Identify the most common mineral on the Earth.
- Identify the term used to describe the shapes that minerals form.
- Identify an unusual property of calcite.
- Recall the properties of quartz that make it useful in timepieces.

Apply

- If a mineral has a hardness of 6, identify if the following minerals will scratch it:

a fluorite	c topaz
b talc	d feldspar

Analyse

- Explain why the main colour of a mineral is not a reliable property to use for correct identification.

MINERAL RESOURCES

Minerals are important as a source of metals and other materials needed by our society. Some minerals, such as iron ore, have to be treated before they can be used. An **ore** is a mineral with a large amount of a useful metal in it. Some important ores and the metals they contain are listed in Table 6.3.

Table 6.3 Important ores and the metals they contain.

Ore	Metal
Haematite, limonite	Iron
Bauxite	Aluminium
Galena	Lead
Rutile	Titanium
Pitchblende	Uranium
Molybdenite	Molybdenum
Cinnabar	Mercury
Malachite, azurite	Copper
Sphalerite	Zinc
Chalcopyrite	Copper
Pentlandite	Nickel
Cassiterite	Tin

Australia is rich in mineral resources. It is among the world's leading producers of aluminium, gold, iron ore, manganese, rutile, lead and zinc. Australia is also a significant producer of nickel, silver, coal, diamonds and copper. Demand for mineral resources worldwide is high, particularly due to increased demand from countries such as China as they become more industrialised.

Australia's mineral resources have always been in big demand. During the 1850s, after gold was initially discovered in Bathurst, New South Wales, hundreds of thousands of people migrated to Australia to take part in the Gold Rush in Victoria and New South Wales. The Australian economy boomed during this time. Because gold is chemically stable, it is almost always found as pure gold. This means it can be collected without having to be processed. In addition to jewellery, gold has many uses such as in

fine wires in electronics and fillings for teeth. Because of its reflective properties, gold can also be used to protect satellites and spacecraft from solar radiation.

Australia is an old continent rich in mineral sands. Mineral sands are old beach sands with significant concentrations of heavy minerals, such as rutile, zircon and ilmenite. Rutile is a rich source of titanium dioxide, which is used as a pigment in paints, plastics and paper. You may have seen little glass jars of mineral sands being sold as souvenirs.

Copper was the first metal to be used by humans. In Australia, copper is found as the mineral chalcopyrite in rocks that are over 250 million years old. Copper is a good conductor of electricity and is used in electrical generators and motors, for electrical wiring, and in electronic goods such as televisions. Copper is also used for water pipes because it does not corrode easily.

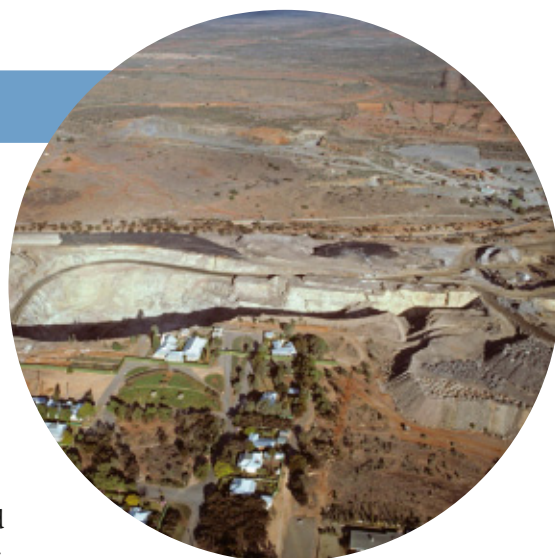


Figure 6.38 The Broken Hill Ore Deposit is the world's richest zinc and silver mine.



Figure 6.39 Gold panning is one of the oldest and simplest ways of extracting gold.



Figure 6.40 Coloured sands reflect the concentrations and types of minerals they contain.

However, mineral resources are finite. One way to overcome this limitation is to recycle materials. For example, aluminium can be recycled over and over again. A lot of energy is used to produce aluminium from bauxite, but once the metal has been made, it can be recycled indefinitely. In fact, recycling aluminium uses only 5% of the energy needed to produce new aluminium. Recycling aluminium saves having to use coal to produce energy in power stations, which reduces the emission of greenhouse gases into our atmosphere. For a sustainable future, the world's mineral resources need to be used wisely.

Locating minerals

Ore deposits are located by mining companies in several different ways. Some of the most common ways are magnetic, gravity, seismic and geochemical surveys.

Magnetic surveys are done from an aircraft carrying a device called a magnetometer. The magnetometer detects changes in the Earth's magnetic field caused by metallic minerals.

Gravity surveys are similar to magnetic surveys as they use a gravimeter attached to an aircraft. The gravimeter detects changes in the Earth's gravitational field caused by large ore deposits.

Seismic surveys are done on the ground and involve sending soundwaves down into the rock and recording the waves that are reflected. Analysis of these waves can detect dense bodies such as ore deposits.

Other methods used on the ground include geochemical surveys where rock samples are drilled out from way below the surface and then analysed to find out what minerals they contain.

All these survey methods allow mining companies to form a picture of what is below the ground to help them decide where to mine. Satellite technology has recently started to play a key role in locating new deposits.

Mining minerals

The type of mining used to extract a particular mineral depends on the location and type of deposit being extracted. Open-cut mines are the simplest type of mines and are used for ore deposits that are near the surface. They involve drilling and blasting away rock on the surface to create a deep pit, allowing rock to be shovelled up and transported away for processing.



Figure 6.41 Moreton Island, off Brisbane, is rich in mineral sands.



Figure 6.42 An open-cut mine in Kalgoorlie, Western Australia.

Underground mines are used when the ore deposit is positioned deep underground. Underground mines use tunnels dug down into the Earth to get to the deposits. Rock containing the mineral is then dug away and transported to the surface in lifts, or driven out by vehicles.

Leach mining is another method used to extract minerals from deep underground. Holes are drilled down to the deposit and a solution called a leach solution is pumped into the holes to dissolve the minerals. The solution is then pumped back to the surface and the minerals are extracted.

Mineral jobs

Many Australians are employed in jobs related to the exploration, mining and processing of minerals. These jobs require understanding and skills from across many different areas of science. Some of these occupations are described in Table 6.4.



Figure 6.43 Geologists play an important role in Australia's mineral industry.

Table 6.4 Jobs that relate to the exploration, mining and processing of minerals.

Job and description of role	Areas of science	A day in the life
Underground mine geologist Controls the quality of the ore mined and decides which areas of an ore body should be mined at a particular time. Spends a lot of time mapping and collecting samples underground.	Earth science Chemistry	'Mine geology is a practical application of geology in the field, and will be rewarding to people who love getting outdoors and working as part of a team.' Tim Berryman, Senior Mine Geologist, Kalgoorlie Consolidated Gold Mines
Exploration geologist Completes surveys and fieldwork to determine the geological structure, distribution and age of rocks.	Earth science Chemistry	'I have worked in places that people pay to go on their holidays.' David Bushell, Senior Exploration Geologist, Iluka Resources Ltd
Metallurgist Controls and improves the processes that separate, concentrate and recover minerals and their valuable metals from the natural ores.	Chemistry Physics Mineralogy	'At completion of first year university I landed my first vacation job with Newcrest at Cadia (copper/gold flotation) in NSW. Each year afterwards I completed vacation work with a different company in a different commodity.' Adam Lonergan, Metallurgical Engineer, Rio Tinto

Job and description of role	Areas of science	A day in the life
Geotechnical engineer Identifies and tries to solve problems involving soil, rock and groundwater, and designs structures on and below the ground.	Earth science Engineering	'[I enjoy] Being exposed to different conditions and problems every day – the job/profession is never the same on any two consecutive days.' Steve Webber, Geotechnical Engineer, Consolidated Minerals
Mining engineer Plans and directs the various engineering aspects of extracting minerals from the Earth.	Earth science Physics Chemistry Maths	'I have worked all around Australia and in mines in South America, America and South Africa.' Kate Sommerville, Principal Mining Engineer–Iron Ore, BHP Billiton
Human resources Provides employment and personnel administration services within the mining industry.	Earth science Psychology	'I studied Geology in my final year of high school and went into University studying a Bachelor of Science with a double major in geology and psychology.' Karin Baxter, Resourcing, BHP Billiton
Environmental engineer Assesses and manages the effects of human activity on the natural and built environment.	Environmental science Engineering Biology Chemistry	'Up until year 12 I wasn't sure what I wanted to study. I loved mathematics, science and geography and had a deep love for the outdoors and the environment.' Laura McIlwaine, Senior Environmental Engineer, BHP Billiton

QUESTIONS 6.2.3: MINERAL RESOURCES

Remember

- 1 Define the term 'ore'.
- 2 Recall the metal that comes from each of the following ores:
 - a bauxite
 - b galena
 - c sphalerite.
- 3 Explain the difference between a mineral and an ore.
- 4 Identify five of Australia's most important minerals.
- 5 Explain the role of a metallurgist.

Apply

- 6 There are many different types of geologists. Predict what you think a petroleum geologist would do and what they would learn from studying rocks.
- 7 Propose what a mineralogist would study.

Create

- 8 Research a career related to the exploration, mining or processing of minerals that is not mentioned in Table 6.4. Describe the job in detail and the areas of science it covers. Make a set of PowerPoint slides about your chosen job. Merge the slides from your whole class to create a mineral resources job directory.

PROPERTIES OF ROCKS AND MINERALS

6.2

CHECKPOINT

Remember and understand

- 1 Copy and complete the following statements.
 - a Rocks are selected for particular purposes because of their _____. [1 mark]
 - b Rocks are made up of one or more _____. [1 mark]
 - c An _____ is a mineral with a large amount of useful metal in it. [1 mark]
 - d Australia is rich in _____ deposits. [1 mark]

- 2 Match each term to its definition. [4 marks]

lustre	how easily a mineral can be scratched
streak	the number of smooth planes that minerals break along
hardness	the shininess of the surface of the mineral
cleavage	the colour of the powdered or crushed mineral

- 3 Explain how geologists identify minerals. [1 mark]
- 4 Explain how a magnetic survey works. [1 mark]

Apply

- 5 Contrast rocks and minerals and explain how they are different. [2 marks]
- 6 Identify the lustre of:
 - a a shiny new nail [1 mark]
 - b a rusty nail [1 mark]
 - c a newly polished car [1 mark]
 - d a mirror [1 mark]
 - e bricks used for building a wall. [1 mark]

Analyse and evaluate

- 7 A kitchen scourer can be used to clean stainless steel cutlery, but this type of scourer should not be used to clean silver-plated cutlery. Explain why this is so. [2 marks]
- 8 Identify the properties of gold that made it so valuable to early civilisations. [2 marks]
- 9 Research mineral recycling and explain why we need to recycle minerals. What minerals can be recycled? In what forms can minerals be used in once they have been recycled? [3 marks]

Ethical understanding

- 10 Australia mines many minerals and exports (sells) them to other countries. List three positive and three negative impacts of mining and exporting minerals. [3 marks]

Critical and creative thinking

- 11 Some famous works of art around the world are made of marble.
 - a Identify the properties of marble that make it ideal for sculpture. [2 marks]
 - b Identify some of the properties of marble that may make it unsuitable for all works of art. [2 marks]
- 12 Make a set of flip cards with the definition of 20 rock terms you have learnt so far. [5 marks]
- 13 Imagine you are a geologist who is going to discover minerals in a remote part of Australia. You will need to take a test kit to help you identify the minerals you find. Identify the items that should go into your test kit to allow you to test for streak, hardness and other common properties of minerals. [4 marks]



Figure 6.44 The marble Abraham Lincoln statue sits as part of the Lincoln Memorial in Washington D.C.

TOTAL MARKS
[/40]

6.3

THE EARTH'S GEOLOGICAL PAST

Planet Earth is 4.5 billion years old. The events of the Earth's history are recorded in our rocks. From about 570 million years ago, the ancestors of the plants and animals that now populate the Earth came into being. The remains of some of these life forms are captured in the rocks as **fossils**. Fossils allow specialist geologists, known as **palaeontologists**, to build a picture of the Earth's long history.

ACTIVITY 6.3.1: FOSSIL FEATURES

There's no time like the present to jump right in and be a palaeontologist!

What you need: A selection of fossils

For each fossil, write down as many observations as you can about the organism that it holds. Your observations will most likely be of physical features.

- What inferences can you make about the organism's lifestyle?
- Is there any evidence to suggest that this organism lived alone or in groups?
- Is there any evidence to suggest how this organism reproduced?
- Is there any evidence to suggest what this organism ate?
- What other information would you need to support your inferences?



Figure 6.45 Palaeontologists compare MRI scans of a fossilised dinosaur skull with the real thing.

LEARNING ABOUT THE PAST THROUGH FOSSILS

What are fossils?

Fossils are the remains (or imprints) of animals or plants preserved in rock. A fossil is evidence of life in the past. Fossilised evidence may be found in many forms, but it is usually the hard parts of animals that remain after decay – bones, teeth and shells. Sometimes softer

parts of an organism are preserved, and even footprints or impressions of organisms are considered fossils. Palaeontologists study these remains to gain clues about ancient life.

Through a process known as **petrification**, wood, bones, teeth and shells can be replaced chemically by minerals dissolved in water. Minerals slowly replace the original material as it decays, leaving a stone replica in the same shape as the original.



Figure 6.46 Broome, Western Australia, is the site of many trace fossils. Can you spot the footprints?



Figure 6.47 This petrified tree trunk looks like a real tree, but its wood has been replaced by minerals to make it as hard as stone.

Sometimes the whole organism may be preserved as a fossil. Animals and plants trapped under frozen ground have been uncovered with flesh, hair and even stomach contents intact. Ancient insects have been found trapped in the sap of ancient trees (amber). Even animal droppings can be petrified – these are called coprolites. The remains of animals or plants sometimes leave an imprint in the rock. Remains can also be broken down by minerals in water, leaving a mould in the exact shape of the organism. **Trace fossils**, such as footprints, can also leave an impression in rocks.

How do fossils form?

Fossils are usually only found in sedimentary rocks. These rocks are formed by the deposition of layers of sediments, such as mud, silt or sand. Any organism caught up in the mud and silt can eventually become part of the rock through the process of fossilisation. The fossils can be uncovered when the rocks are broken apart or weathered away. This process can take millions of years.



Figure 6.48 If the conditions are just right, soft body parts can be fossilised.

Fish fossils

One of the richest and most extensive fossil fish deposits in the world can be found at Canowindra, west of Sydney, near Orange. Some of the fossils date back 360 million years ago from the Devonian **period**. The Wellington Caves in central-western NSW contain famous megafauna fossils – skeletal remains of giant kangaroos, marsupial lions, and even a diprotodon (a three-tonne wombat) have been found at this location. It is one of the world's most significant fossil sites with fossils dating back 30 000 to 4 million years ago.



DEEPER UNDERSTANDING

Figure 6.49 One of the fish fossils at the Age of Fishes Museum at Canowindra.

Steps in fossil formation

After the death of an animal, other animals would usually eat its body. Its bones would be crushed or weathered, leaving no evidence of the remains. However, for fossils to form, parts of the animal must be left behind. This process of fossil formation occurs as follows:

Step 1 When an animal dies in or near water (see Figure 6.50a), such as a river or a swamp, its remains can be quickly covered in sediment (see Figure 6.50b) and thus protected from being eaten. The soft parts of the body eventually decay, leaving behind the bones and teeth.

Step 2 Over millions of years, more and more layers of sediment are deposited. The sediment surrounding the buried remains transforms

gradually into sedimentary rock. The bones and teeth may be replaced by minerals dissolved in water, which seeps into the remains. The shape of the animal remains the same, although it is generally flattened by the pressure of the sediments above (see Figure 6.50c).

Step 3 The layers of rock containing the fossilised remains may be pushed upwards and fractured, bent and moved by forces beneath the Earth's surface. Weathering and erosion eventually wear away some of the rock to expose one or more of the bones or teeth (see Figure 6.50d). Fossils can also be uncovered when digging mines or cuttings for roads. If fossilised remains are discovered, palaeontologists may start looking for other remains in the same area.

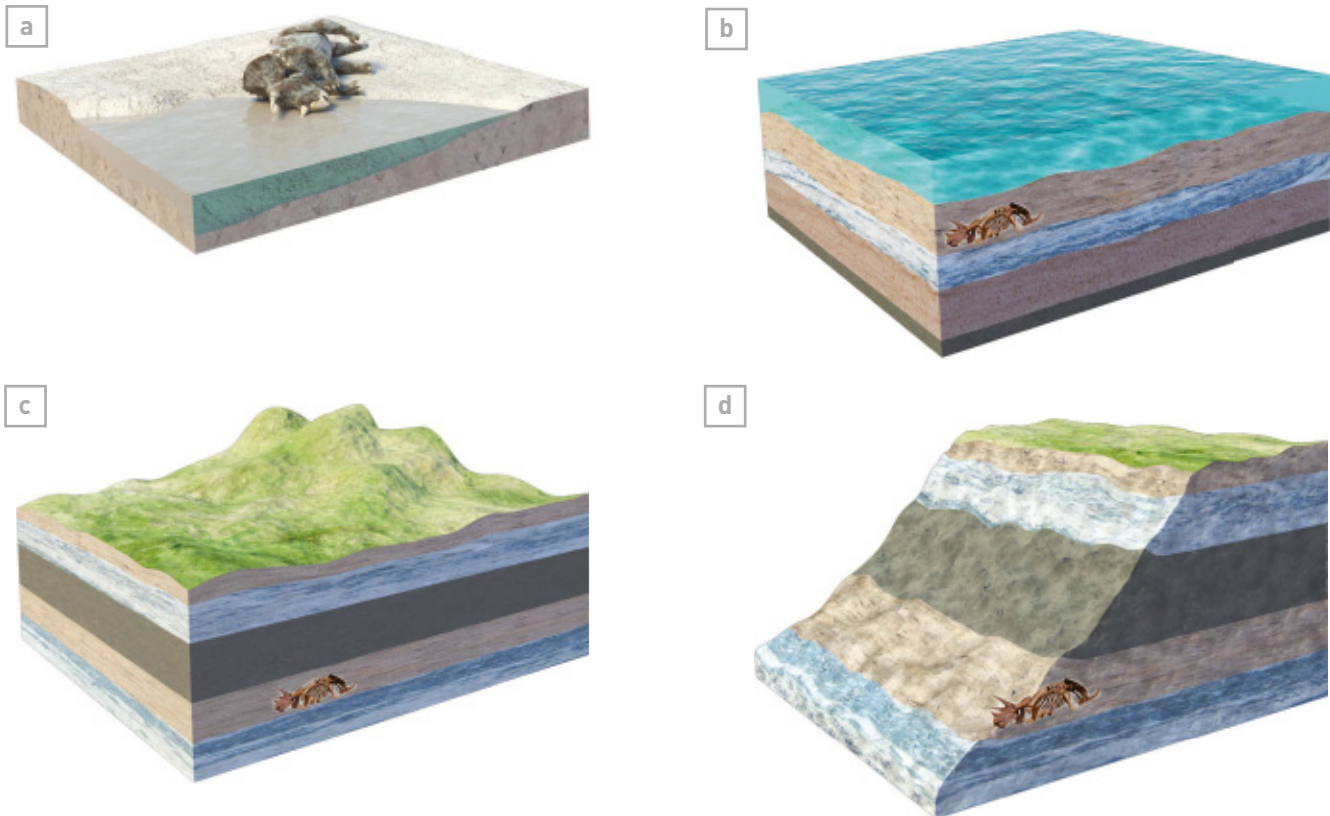


Figure 6.50 Formation of a fossil. (a) If an organism dies near water, it has a greater chance of being covered by sediment. (b) The sediment protects the body from predators and weathering. (c) Over millions of years, more sediment is deposited and the remains are transformed gradually into sedimentary rock. (d) Years of geological movement, weathering and erosion may eventually expose the fossil.

Building animals from bones

In most instances, fossils are the only evidence of life forms that are now extinct. Palaeontologists are skilled in cleaning and preserving fossils, piecing parts of them together and reconstructing them into a lifelike shape (see Figure 6.52). Usually only a few fossilised bones are found, rather than a complete skeleton.

Very detailed observations need to be made of these bones so that they can be compared with other finds. If the bones are a good match, palaeontologists may decide that the bones have come from a similar organism, but further evidence will be required to confirm that theory. A palaeontologist's skills cover the areas of zoology, botany, anatomy, ecology and drawing.



Figure 6.52 A palaeontologist applies the final touches to the skull of a dinosaur from southern Africa.



Figure 6.51 This fossilised pterodactyl was in the middle of laying an egg when she was killed. This fossil provides valuable information about pterodactyl reproduction.

STUDENT DESIGN TASK

Fossil impressions

Challenge

Sometimes when an organism is buried in sediments and the hard parts of it dissolve over time, only an imprint or impression of it remains. This type of fossil evidence is known as a mould. Moulds reveal the size, shape and pattern of the organism.

Your task is to use plaster of Paris and a leaf with a prominent shape or vein structure to create an impression. Imagine your leaf has settled to the floor of a lake or seabed (a white tile can be used for this surface). Over time, it becomes covered with sediment (plaster of Paris can represent this stage). As the leaf itself decays, only the imprint is left.

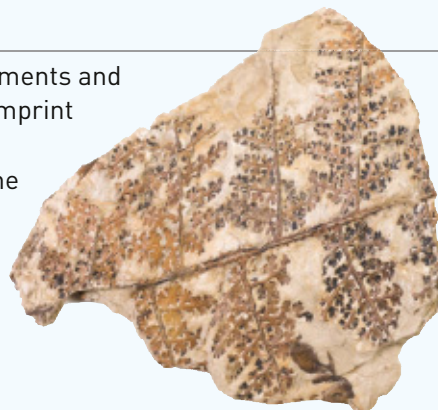


Figure 6.53 A plant fossil found in a rock.

Questioning and predicting

- What consistency of plaster will work best?
- How will you contain the plaster on top of your leaf so it doesn't spread everywhere?
- How will you prevent your leaf from sticking to the plaster?

Planning

Plan your experiment by drafting an aim, materials list, method and diagram of your setup. Have your plan approved by your teacher before starting work.

Conducting

Carry out your experiment, making any necessary changes to your method as you go.

Processing, analysing and evaluating

Take some digital photos of the different stages of the investigation.

Communicating

Write a full experimental report at the conclusion of your experiment, including a discussion of the following ideas:

- Evaluate the success of the investigation.
- What improvements would you make to your experimental design?
- How does your leaf impression compare with a real fossil impression?

QUESTIONS 6.3.1: LEARNING ABOUT THE PAST THROUGH FOSSILS

Remember

- 1 Recall the type of geologist who investigates fossils.
- 2 Define the term 'fossil'.
- 3 Explain how trace fossils are formed.

Apply

- 4 Draw a flow chart to outline a series of events or conditions that need to occur, over a period of geological time, for a fossil to be preserved.
- 5 Explain why fossils are not found in igneous rock.
- 6 Explain why it is important to take accurate and detailed records of all fossils, even if they can already be identified.

Analyse

- 7 Describe what fossils can show us or tell us about the Earth's history.



FINDING THE AGE OF ROCKS AND FOSSILS

Extremely old rocks have fossils of simple animals in them, whereas rocks that are slightly younger have fossils of animals with shells. Rocks that are younger still have fossils of fish. Only the newest rocks have fossils of mammals. The variety and complexity of life has increased as the Earth has become older.

Comparative dating

Geologists can place rocks and fossils into a date order. They work this out from the different layers of sediment in rocks. When layers of sand or mud are deposited, the oldest sediments are at the bottom. Newer or younger sediments are deposited on top (see Figure 6.54). This is known as the law of superposition. Working out the age of rocks as being younger or older than existing rocks is called **comparative dating** or relative dating. It is comparative because we are comparing the old with the new.

Different rocks that are the same age have the same type of fossils in them. These fossils are called **index fossils**. They are used to find rocks of the same age.

Radioactive dating

The actual age of a rock, measured in millions of years, is found by looking at the amount of radioactivity left in rocks. For example, uranium (U) is a radioactive substance found in many rocks. It decays to lead (Pb) at a known rate. The age of rocks can be calculated by comparing the amounts of uranium and lead they contain. This is called **radioactive dating**.

The oldest rocks found on the Earth have been dated at 4500 million years. This method has been checked using different radioactive atoms. This age is the same as that of meteorites that crash to the Earth, as well as that of Moon rocks brought back to the Earth by astronauts.

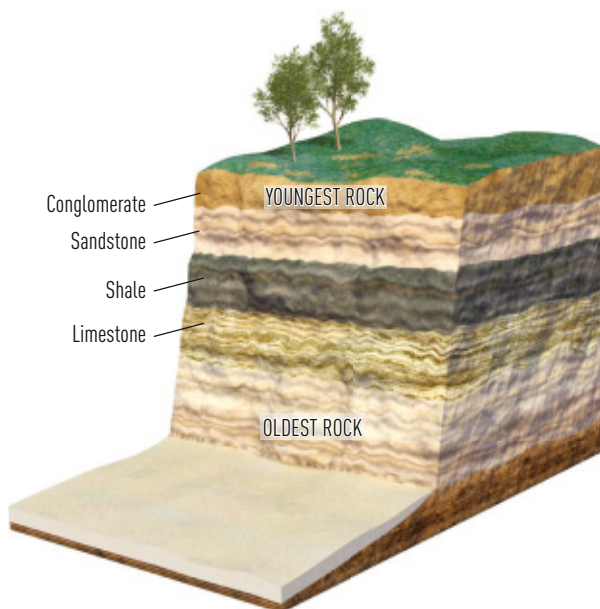


Figure 6.54 Comparative dating is used to work out the age of rocks and fossils.

Geological time scale

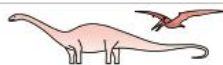
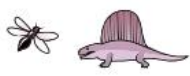
Geologists and palaeontologists use a similar time scale. Because they are dealing with such huge periods of time, they divide time into eras and periods. The time scale used is millions of years. The eras and periods are based on major events such as ice ages, widespread volcanic activity or the mass extinctions of species.

Each period has particular fossils associated with it. For example, the fossils in the Cambrian period include the first shells and trilobites (see Figure 6.55). These are different from the fossils found in the Triassic period, which include the first dinosaurs. The end of most periods is marked by a large number of extinctions. The most famous of these is the extinction of many plants and animals, including dinosaurs, at the end of the Cretaceous period. All the periods have been dated in millions of years using radioactive dating. The names and order of the periods, as well as their period in millions of years, are shown in the geological time scale in Table 6.5 on page 294.



Figure 6.55 This trilobite fossil has been dated to 500 million years ago. The fossils of some trilobites are the size of beetles, whereas others are the size of dinner plates.

Table 6.5 Geological time scale (not to scale).

Era	Period (millions of years ago)	Plant life	Animal life
CENOZOIC (recent life)	Quaternary 2	Modern plants. 	Development of humans. 
	Tertiary 65	Forests of angiosperms. 	Mammals dominant over the Earth. 
MESOZOIC (middle life)	Cretaceous 142	Angiosperms take over from gymnosperms. 	Dinosaurs become extinct. Mammals develop, birds appear. 
	Jurassic 206	Gymnosperms abundant, first angiosperms appear. 	Age of reptiles, some flying reptiles. 
	Triassic 248	Age of gymnosperms. 	First mammals. Reptiles dominate land. Amphibians decline. 
PALEOZOIC (ancient life)	Permian 290	Early seed plants develop. 	Many land vertebrates. Familiar insects develop. Some invertebrate sea life becomes extinct. 
	Carboniferous 354	First large forests. Rise of gymnosperms. 	Insects become more common. First reptiles appear. 
	Devonian 417	Well-developed land plants. Ferns common. 	Fish and coral reefs common. 
	Silurian 443	First land plants. Many algae. 	Many coral reefs, shells. First animals on the land – amphibians and invertebrates. 
	Ordovician 493	Types of large algae found as fossils. 	Many invertebrates. First vertebrates, fish, found. 
	Cambrian 545	More types of algae. 	Animals with bodies protected by shells. 
PRECAMBRIAN	Ediacaran 600	Algae—the simplest plants, lived in the water. 	Soft-bodied animals. Very few fossils found, except in special locations. Their bodies were jelly-like. 
	2500	Multicellular life develops in the shallow warm seas. Fossils are rarely found because of the great age of the rocks and the soft fragile bodies of these organisms.	
	Archaean 3800	Bacteria are abundant. Some lived in extreme environments; stromatolites were photosynthetic. Fossilised and living mounds are still found on the Earth today. Oldest known sedimentary rocks, and oldest 'fossil' remains. They are chemical traces of living things.	
	Hadean 4500	Solidification of the Earth from a ball of molten rock.	

QUESTIONS 6.3.2: FINDING THE AGE OF ROCKS AND FOSSILS

Remember

- 1 Describe the process of comparative dating.
- 2 Define the term 'index fossils'.

Apply

- 3 On page 289 you read about Canowindra, where some of the fossils date back 360 million years ago from the Devonian period. Outline the Devonian period by writing a description or creating a labelled drawing. Use Table 6.5 to help you. Explain how palaeontologists would have known that the Canowindra fish fossils were from the Devonian period.

THE EARTH'S GEOLOGICAL PAST

6.3

CHECKPOINT

Remember and understand

- 1 Recall how old planet Earth is. [1 mark]
- 2 Refer to the geological timescale in Table 6.5 and identify the period in which the following events occurred.
 - a Dinosaurs became extinct. [1 mark]
 - b The first land plants appeared on the Earth. [1 mark]
 - c Insects became common. [1 mark]
 - d Humans appeared. [1 mark]
- 3 Explain how index fossils help to identify rocks of the same age. [2 marks]
- 4 Explain why only simple fossils are found in the oldest types of rocks, whereas younger rocks have fossils of mammals. [2 marks]
- 9 Explain why most organisms do not form fossils when they die. [2 marks]
- 10 Explain why it is usually quite hard to find fossils. [2 marks]
- 11 Petrified wood is stone in the shape of a piece of wood.
 - a Is it classed as a fossil or not? Explain your answer. [2 marks]
 - b Propose how a piece of petrified wood could have formed. [2 marks]
- 12 A palaeontologist found a dinosaur skull but was not able to find any other bones in the area. Explain why this was the case. [2 marks]
- 13 Imagine you are a palaeontologist searching for fossils. Explain the types of rocks you would look for. [2 marks]

Apply

- 5 Construct a flow chart showing the steps in fossil formation. [4 marks]
- 6 The fossil records show that some ancient organisms survived on the Earth for only very short periods of time, while others were very long-lived. Propose two possible reasons for this. [4 marks]
- 7 A geologist finds a rock sample with a fossilised trilobite in it.
 - a Identify the approximate age of the rock sample. [1 mark]
 - b Recall the term used to describe a trilobite fossil when it is used to date a rock. [1 mark]

Analyse and evaluate

- 8 Identify which process gives the more accurate age of a rock: comparative or radioactive dating. Explain your answer. [2 marks]



Critical and creative thinking

- 14** Construct a series of diagrams demonstrating the different ways that fossils can be formed and the types of fossils that are formed in each way. [4 marks]
- 15** The only evidence found worldwide of a dinosaur stampede is near Winton in Queensland (see Figure 6.56). A large theropod, which had steps of up to 2 metres in length and walked at 9 kilometres per hour, approached from the north. After six steps, the animal slowed down and, at the tenth step, it turned right. The smaller tracks show that there was then a stampede by 150 smaller ornithopods and coelurosaurs.
- a** Explain how palaeontologists would know the species of the dinosaurs involved in the stampede. [1 mark]
 - b** Propose what information would help palaeontologists work out the weight of the dinosaurs. [1 mark]
 - c** Explain how the palaeontologists could work out how fast the dinosaurs were travelling. [1 mark]
 - d** Explain how the palaeontologists could tell that the theropod slowed down. [1 mark]
 - e** Why do you think there was a stampede? Explain your answer. [2 marks]

Making connections

- 16** Imagine you are living 10 million years into the future. Predict what you might find in the fossil record for the year 2014 in the area where you live. [4 marks]



Figure 6.56 These footprints from near Winton, in Queensland, show a dinosaur stampede.

- 17** Table 6.5 on page 294 shows the geological history of the Earth over 4500 years. If this time scale could be compressed into one calendar year, each day on this new scale would represent approximately 12.3 million years. Since humans and modern plants developed in the Quaternary period, propose which day(s) of the year that would be on this new scale. Identify what other life forms developed around this time and propose where they would fit into the new scale. [3 marks]

6

CHAPTER REVIEW

- 1 Fill in the gaps using the words in the Word Bank below:

The Earth is made of three layers: the _____ and the _____. The rocky outer shell of the Earth, which is divided up into tectonic plates, is known as the _____.

Magma and lava cool to form _____ rocks. Sedimentary rocks are formed when _____ are compacted together over a long period of time. _____ rocks are formed when other types of rocks are changed by incredible heat and _____ inside the Earth. _____ and movement of tectonic plates are the main forces that drive the rock _____. Sedimentary, igneous and metamorphic rocks are made of _____. Minerals can be classified according to their _____, which include lustre, hardness and _____.

_____ are the remains of animals or plants preserved in rock. Fossils can only form under specific _____. Geologists can date rocks by studying _____ of sediment in rocks.

WORD BANK

conditions	erosion	mantle	properties
core	fossils	metamorphic	sediments
crust	igneous	minerals	streak
cycle	layers	pressure	

Describe the structure of the Earth in terms of core, mantle, crust and lithosphere

- 2 Describe the Earth's crust. [1 mark]
- 3 Recall the layers of the Earth in order from the centre outwards. [1 mark]
- 4 Describe the characteristics and features of the lithosphere. [2 marks]

Relate the formation of landforms to physical and chemical weathering, erosion and deposition

- 5 The Great Sphinx of Giza (see Figure 6.57) was carved in a limestone quarry in Egypt that was formed at the bottom of the sea 50 million years ago. Shells can be found around the embankment and there was once a sandbar and a coral reef here.
 - a Identify the process you think would have formed the limestone. [1 mark]
 - b Explain what has happened to the Great Sphinx of Giza over time. [1 mark]

- 6 Describe how the processes of weathering, erosion and deposition are linked. [3 marks]
- 7 Apply your knowledge of weathering, erosion and deposition to describe how Uluru might have formed. [3 marks]

Outline the origins of and relationships between sedimentary, igneous and metamorphic rocks

- 8 Explain why sedimentary rocks form at the Earth's surface. [1 mark]
- 9 Recall the processes that can cause metamorphic rocks to change. [1 mark]
- 10 Identify if intrusive igneous rocks:
 - a are rapidly cooled or slowly cooled [1 mark]
 - b contain large crystals or small crystals [1 mark]
 - c form on the Earth's surface or beneath the Earth's surface [1 mark]



Figure 6.57 The Great Sphinx of Giza in Egypt has been badly damaged by wind erosion.

Explain the role of forces and energy in the formation of different types of rocks (additional)

- 11 Intrusive igneous rocks are formed deep underground. Explain how they reach the Earth's surface. [1 mark]
- 12 Recall which two rock types are formed by force and pressure. [1 mark]

Identify that sedimentary, igneous and metamorphic rocks contain minerals

- 13 Identify what rocks are made of. [1 mark]
- 14 Recall the shape in which minerals are found. [1 mark]

Classify a variety of common rocks and minerals into groups according to their observable properties

- 15 Recall the name of a sedimentary rock formed from smaller rocks that have been cemented together. [1 mark]
- 16 Identify the hardness value of a substance that is scratched by feldspar (hardness of 6) but not by quartz (hardness of 7). [1 mark]

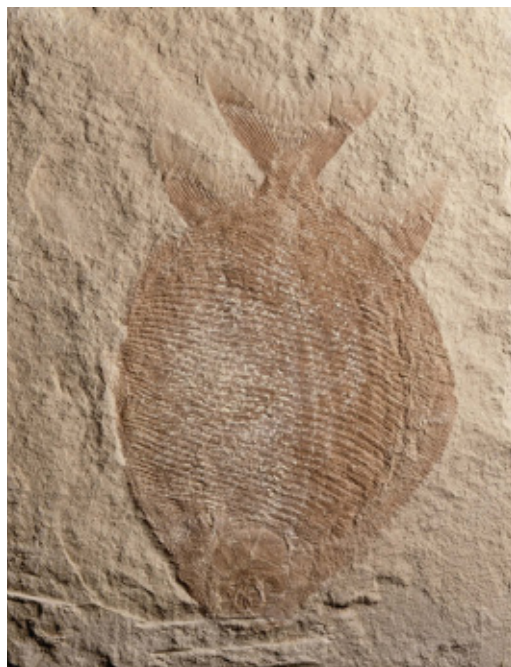


Figure 6.58 A fish fossil found in Australia.

Describe the conditions under which fossils form

- 17 Explain what is meant by the term 'fossil'. [1 mark]
- 18 Explain why marine plants and animals are more commonly found as fossils than those that lived on land. [1 mark]
- 19 A fossil has been dated as 360 million years old. Outline a chain of events that may have led to this fossil being formed, discovered and dated. [3 marks]

Outline how geological history can be interpreted in a sequence of sedimentary layers

- 20 Recall where the oldest sediments are found when layers of sand or mud are deposited. [1 mark]
- 21 One rock has a fossil of a trilobite and another rock has a fossil of an early mammal. Based on this information alone, identify which rock is older. [1 mark]

Describe some methods used by scientists to determine the age of rock layers (additional)

- 22 Explain the process of radioactive dating. [2 marks]
- 23 Explain the process of comparative (or relative) dating. [2 marks]

Describe examples to show how skills from across the disciplines of science are used in the exploration, mining or processing of minerals

- 24 There are many branches of geology. Recall the names of three specialist geologists that you have read about in this chapter. [3 marks]
- 25 Identify two areas of science that a geotechnical engineer would have studied. [2 marks]
- 26 Identify the type of scientist that would assess and manage the effects of human activity on the natural and built environment. [1 mark]

TOTAL MARKS
[/40]

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

Formation of oil

Oil is formed from the compression and heating of dead marine plant material in mud over millions of years. Oil is made up of hydrocarbons, which are lighter than rock and water, so it often migrates up porous rock towards the Earth's surface. Research on the Internet to find out the following:



- What is an oil reservoir?
- What conditions are needed for an oil reservoir to form?
- How is an oil field formed?
- In what other forms is oil found?

Gemstones

Find out what types of gemstones are found in Australia. Which gemstones do people sometimes dig up? What do the gemstones look like?

Extraction of metals

Metals are extracted from their ores by a variety of methods. Some are heated, some are purified using electrical energy and some are extracted using chemical processes. Why are different metals extracted by different chemical or electrical processes? Find out how some metals are extracted, such as copper and aluminium, and design a poster that shows the process of extraction.

New discoveries

Fossils are being found all over the world all the time.

- Where are the most recent finds?
- What animals or plants do they represent?
- What do the fossils reveal about these animals or plants?
- How important are these finds?

Me

- 1 What new science laboratory skills have you learned in this chapter?
- 2 What was the most surprising thing you found out about studying rocks?
- 3 What were the most difficult aspects of this topic?

My world

- 4 Why is it important to understand how the Earth has changed?
- 5 Why is it important to understand how life on the Earth has changed?

My future

- 6 What can you do now to make sure that humans do not become extinct like the dinosaurs?

KEY WORDS

cleavage
coal
colour
comparative dating
core
crust
crystal
deposition
erosion
extrusive
igneous rock
fossil
frost shattering
geologist
hardness
igneous rock
index fossil
intrusive
igneous rock
lava
lithosphere
lustre
magma
mantle
metamorphic rock
mineral
onion-skin
weathering
ore
palaeontologist
period
petrification
property
radioactive dating
rock cycle
sedimentary rock
streak
trace fossil
weathering

6

MAKING CONNECTIONS

Evidence from Antarctica

The Earth's landmasses have not always been in the same position. About 200–500 million years ago, Antarctica, South America, Africa, Madagascar, Australia, New Guinea, New Zealand, Arabia and the Indian subcontinent all made up a southern supercontinent called Gondwana. This huge landmass extended from near the South Pole to near the Equator, and mostly had a mild climate. Gondwana broke up over time, and the Antarctica we know today was formed about 25 million years ago. The changing climate and latitude greatly influenced the rocks formed on Antarctica.

Although nearly the entire continent of Antarctica is covered with a thick layer of ice, making studying the rocks difficult, new techniques have been used to determine the types of rocks and minerals found in Antarctica. The Antarctic Peninsula was formed by the uplift of metamorphic rock from seabed sediments. Volcanic activity occurred and intrusive igneous rock also formed.

In East Antarctica, some of the rocks formed more than 3 billion years ago. This area is largely made up

of a platform of metamorphic and igneous rocks, which form the base for more modern rocks such as limestone, sandstone, coal and shale. Faulting has also occurred in some coastal areas.

Figure 6.59 The Antarctic Peninsula.

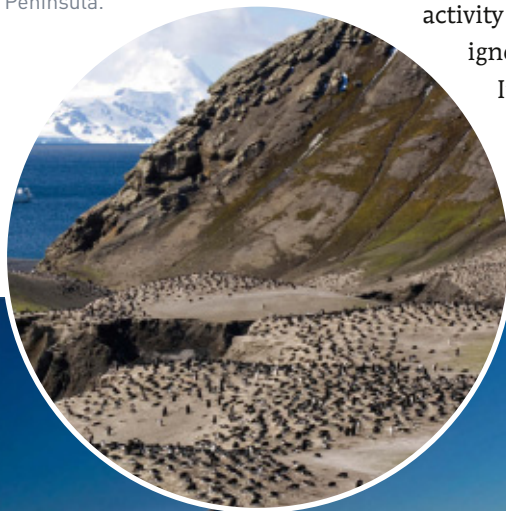


Figure 6.60 Ash from an Antarctic volcano.



Figure 6.61 The Transantarctic Mountains contain a wealth of valuable minerals.

About 500 million years ago, West Antarctica was partially in the Northern Hemisphere and had a mild climate. During this time, the rocks formed were largely sandstone, limestone and shale. Over the next 100 million years, as Gondwana moved south and the climate cooled down, sand and silt were deposited in mountain areas.

About 360 million years ago, glaciers formed, thus weathering the rock formations. In areas where fern-like plants grew in swamps, deposits of coal formed. Coal can be found near the Beardmore Glacier and as a low-grade form across many parts of the Transantarctic Mountains. Iron ore has also been found in significant deposits in the Prince Charles Mountains. However, the Protocol on Environmental Protection to the Antarctic Treaty has banned all exploitation of mineral resources by signatory states until 2048.

Although plant life is limited on Antarctica to mostly mosses and liverworts because of the extreme climate, fossils provide evidence of a rich plant life in the past. Fossils of leaves and wood are abundant and indicate the existence of extensive forests in warmer times when Antarctica was part of Gondwana, and even in colder times when it was closer to the South Pole.

Fossils of dinosaurs and marsupial mammals have also been found in Antarctica, indicating that they once

roamed across its surface. Marine fossils of invertebrates, including shells with their original mother-of-pearl shell still intact, giant penguins and marine reptiles have also been found. Dinosaur fossil evidence from Antarctica reveals that the extinction of dinosaurs was not as great as it was in a lot of other places around the world, but it still took 300 000 years for shallow marine communities of organisms to reappear. This sort of information has enabled scientists to understand how long it takes for communities of organisms to recover after mass extinction events.

Questions

- 1 Explain what types of rock formation processes have occurred in Antarctica.
- 2 Explain what types of weathering processes have dominated in Antarctica.
- 3 What can you deduce about the past climate if sedimentary rocks such as sandstone, limestone and shale are found?
- 4 Identify the sort of climate that would have existed on Antarctica for forests of trees and ferns to have grown there.
- 5 Mass extinction events, such as the extinction of the dinosaurs, were not as great on Antarctica as in other places in the world. Explain why you think this may be.

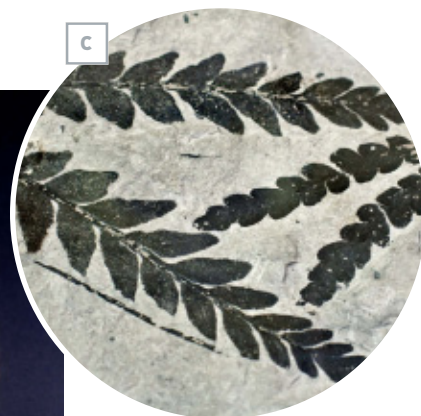
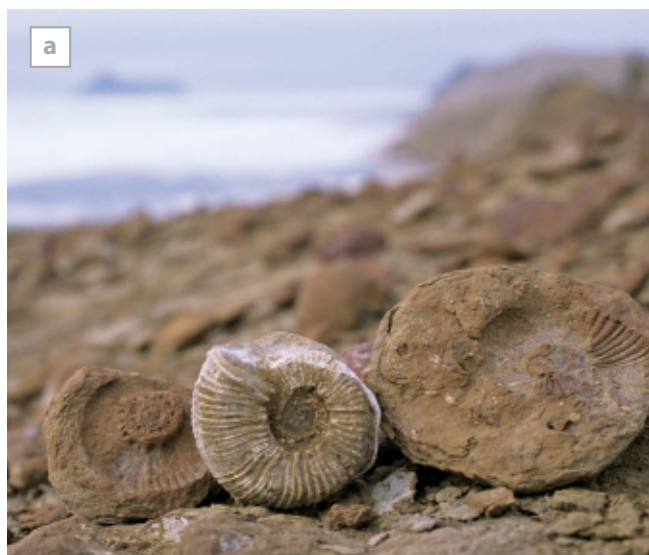


Figure 6.62 (a) An Antarctic ammonite fossil, (b) a petrified conifer tree from Antarctica, (c) a 260-million-year-old fossil leaf from Antarctica.

GLOSSARY

A

- ABIOTIC** non-living factors that affect an ecosystem
- ACID** chemical compound that tastes sour and can turn blue litmus red
- ACTIVATION ENERGY** amount of energy required to start a chemical reaction
- ACTIVE INGREDIENTS** often referring to pharmaceuticals, the ingredients that will act on a living organism
- ALLOTROPE** different form of the same chemical (e.g. graphite and diamond)
- ALLOY** mixture of two or more substances that forms a substance with metal characteristics
- ALVEOLI** tiny air sacs in the lungs where gas exchange occurs
- ANAEROBIC RESPIRATION** metabolic reaction that does not require oxygen
- ANTHER** part of the stamen that produces the pollen in a flower
- AQUEOUS SOLUTION** salt (solute) that has been dissolved in water
- ARTERY** thick, muscular-walled blood vessel that carries blood away from the heart under pressure
- AUTOTROPH** organism that makes its own food, e.g. plants

B

- BIODIVERSITY** variety of all life on the Earth
- BIOLOGICAL CONTROL** use of natural predators or pathogens to control a pest population
- BIOMASS ENERGY** energy derived from plants and animals
- BIOSPHERE** all the living organisms from the upper areas of the atmosphere to deep under the ground or ocean
- BIOTECHNOLOGY** application of science to living organisms
- BIOTIC** living organisms that are contained in an ecosystem
- BLOOD** liquid that circulates in the blood vessels and contains a combination of cells, cell fragments, liquid and dissolved substances
- BONE** strong structure that makes up the skeleton consisting of a dense matrix supporting calcium salts

C

- CAPILLARY** blood vessel with a wall only one cell thick, allowing substances to easily pass into and out of the blood
- CARNIVORE** organism that obtains its energy by eating animals
- CARPEL** female reproductive part of a flower consisting of the ovary, style and stigma
- CARTILAGE** flexible tissue found at the joints that enhances bone movement
- CHEMICAL CHANGE** results in a new chemical substance being formed and rearrangement of atoms
- CHEMICAL EQUATION** shorthand way of showing what happens to the reactants and products in a chemical reaction
- CHEMICAL POTENTIAL ENERGY (CPE)** energy stored in chemicals (e.g. in food, fuel or explosives); also known simply as chemical energy
- CHEMICAL REACTION** procedure that produces new chemicals; same as a chemical change
- CHEMICAL WEATHERING** weathering of rocks and minerals through chemical means
- CHLOROPHYLL** green pigment found inside chloroplasts that absorbs solar energy and uses it in photosynthesis
- CHLOROPLAST** organelle found in plant cells that transforms solar energy into chemical energy
- CHROMOSOME** packet of genetic material that carries several sets of instructions for cells
- CIRCUIT DIAGRAM** representation of an electrical circuit; drawn with symbols to represent the components and straight lines to represent the wires
- CLEAVAGE** number of smooth planes that minerals break along
- COAL** type of sedimentary rock formed from dead plants that became buried before completely decaying
- COLOUR** (in geology) guide to identifying a mineral; cannot be relied on as many minerals are impure
- COMBINATORIAL CHEMISTRY** procedure used by research scientists to find the best combination to create new chemicals
- COMMUNITY** populations of different species that interact with each other

COMPACT FLUORESCENT LIGHT (CFL) small fluorescent tube, designed to replace incandescent light globes; also known as an energy-saving light globe

COMPARATIVE DATING process of working out the age of rocks as being younger or older than existing rocks; also known as relative dating

COMPOUND two or more different elements that are chemically joined

CONDUCTION process of heat transfer through direct contact and without the movement of any part of the material itself

CONSUMER organism that obtains energy by eating other organisms

CONVECTION process of heat transfer that involves the movement of a fluid, i.e. a liquid or a gas

CORE centre of the Earth

CORROSION chemical reaction with oxygen, usually referring to iron, that creates rust

CROSS-POLLINATION involves pollen from a flower landing on the stigma of a flower on a different plant, producing greater variation than self-pollination

CRUST thin outer layer of the Earth on which we live

CRYSTAL shape formed by minerals; the structure of the crystal greatly influences a mineral's properties

D

DECOMPOSER organism that feeds on dead things

DECOMPOSITION REACTION reaction that breaks a complex chemical substance into simpler substances

DECOMPOSITION chemical reaction where a complex substance is broken up into simpler substances

DEPOSITION when particles that have been carried along by erosion are deposited

DETRITIVORE organism that feeds on dead and decaying matter

DIABETES disease resulting in the inability of the body to control the levels of glucose in the blood; symptoms may be tiredness, frequent urination and thirst

DIATOMIC molecular element made up of two atoms (e.g. hydrogen gas)

DIGESTION process by which food is broken down and absorbed into the blood for transport to the cells

DIGESTIVE TRACT group of organs that form a tube travelling from the mouth to the anus

E

ECOLOGIST scientist who studies the interactions of living things with their environment

ECOLOGY study of interactions of living things with their abiotic environment

ECOSYSTEM group of living and non-living things that interact with each other and their abiotic environment in a self-sustaining way

ELASTIC POTENTIAL ENERGY (EPE) energy stored through stretching or squashing (e.g. in a stretched spring or rubber band)

ELECTRIC CIRCUIT pathway travelled by electrical energy

ELECTRICAL ENERGY energy associated with electric charge, either stationary (static) or moving (current)

ELECTRON negatively charged subatomic particles found orbiting around the nucleus

ELEMENT pure substance made up of only one type of atom (e.g. oxygen, carbon)

ENDOTHERMIC chemical reaction that requires heat from the external environment

ENERGY capacity for doing work; many different forms (e.g. kinetic, gravitational potential, chemical, nuclear); measured in joules

ENERGY EFFICIENCY measure of the amount of useful energy transformed in an energy transformation process; usually expressed as a percentage of the input energy

ENERGY TRANSFORMATION conversion of energy from one type into another (e.g. in a toaster, the main energy transformation is from electrical to heat)

ENZYME biological substance that increases the rate of reaction by decreasing the activation energy

ENZYME chemical that helps make chemical reactions happen

EROSION process where the products of weathering are moved and carried away to somewhere else

ETHANOL pure alcohol, added to petrol to improve the performance of the engine or used as a fuel in its own right, particularly popular in Brazil

EUTROPHICATION extreme increase in nutrients of aquatic environments

EXCRETION process of removing wastes from the body

EXOTHERMIC chemical reaction that produces heat

EXTRUSIVE IGNEOUS ROCK rock formed quickly on the Earth's surface from cooling lava; has small crystals or sometimes the lava cools so quickly that no crystals are formed at all

F

FERMENTATION metabolic process that produces ethanol from sugar

FERTILISATION stage of sexual reproduction involving the joining of a sperm and egg

FIRE REGIME practice of deliberately setting planned fires to reduce the risk of bushfire damage

FLAMMABILITY whether a substance will easily catch alight

FOETUS stage in the development of a human baby from when the baby acquires human features (normally after 8 weeks of development)

FOOD CHAIN chain of organisms arranged to show the flow of energy in an ecosystem: producers to herbivores to carnivores

FOOD WEB diagram showing the interactions between several food chains

FOSSIL remains or imprints of animals or plants preserved in rock

FROST SHATTERING type of weathering where water repeatedly freezes and expands inside cracks in rock

G

GAMETE sex cell; in humans, the sperm and egg cells

GAS EXCHANGE transfer of gases in and out of an organism; in humans, oxygen is exchanged from the lungs into the blood and carbon dioxide is exchanged from the blood into the lungs

GENERATOR machine that produces electrical energy from kinetic energy; a simple generator consists of a wire-wrapped coil rotating between the poles of a magnet

GEOLOGIST scientist who studies the structure of the Earth, rocks and minerals

GLUCOSE sugar molecule used in respiration to provide cellular energy

GRAVITATIONAL POTENTIAL ENERGY (GPE) energy stored through the raising of a mass to a height above the Earth's surface; any raised object has GPE

GROUP vertical column in the periodic table

H

HABITAT place where a population of organisms lives

HARDNESS ability of a substance to scratch another substance

HERBIVORE organism that obtains its energy by eating plants

HETEROGENEOUS mixture that is not the same throughout

HETEROTROPH organism that relies on other living things for food (e.g. an animal)

HOMOGENEOUS mixture that is the same throughout

I

IGNEOUS ROCK rock formed when magma and lava from volcanic eruptions cools and solidifies

IN VITRO FERTILISATION (IVF) type of assisted reproductive technology where an egg is fertilised by a sperm *in vitro* or 'in glass', meaning in a test tube; hence the term 'test tube baby'

INDEX FOSSIL fossil that indicates the age of rocks; also known as a guide fossil; different rocks that are the same age have the same type of fossils in them

INTEGRATED CIRCUIT (IC) also known as a silicon chip or microchip; a miniaturised electric circuit produced on a single crystal, or chip, of semiconductor material, usually silicon

INTRODUCED SPECIES species of organisms that is not native, or natural, to the ecosystem

INTRUSIVE IGNEOUS ROCK rock formed slowly beneath the surface of the Earth when magma becomes trapped in small pockets; has large crystals interlocked together

K

KINETIC ENERGY (KE) energy of movement; any moving object has kinetic energy

KINETIC THEORY theory that encompasses particle theory and explains why substances behave the way they do

L

LATTICE three-dimensional arrangement of particles in a regular pattern

LAVA molten rock that erupts from a volcano onto the surface of the Earth

LIGHT-EMITTING DIODE (LED) made from a semiconductor material that glows when electricity is passed through it

LITHOSPHERE solid outer shell of a planet; on the Earth comprises of the crust and upper part of the mantle

LOAD component of an electric circuit that converts electrical energy into another form (e.g. light bulb, resistor bell)

LUSTRE shininess of the surface of a mineral; there are various types including metallic, brilliant, pearly, dull and earthy

M

MAGMA hot, molten rock inside the Earth from which igneous rocks are formed

MANTLE layer of the Earth between the crust and the core, which is both solid and liquid

MATTER anything that has mass and volume

MECHANICAL WEATHERING weathering of rocks and minerals by mechanical means such as general wear and tear, wind and ice

MEIOSIS process of cell division that produces the reproductive cells, gametes and in which only half the DNA is transmitted to the resulting cells

MENSTRUAL CYCLE cycle of changes that occurs in females after puberty in which the ovary and uterus prepare for conception and implantation of the embryo; if this does not occur the uterus lining and blood (menstruation) are released

METABOLIC PROCESS how an organism produces energy

METALLOID substance (element) that has some metallic properties and some non-metallic properties

METALLURGY process of metal production and purification

METAL substance (element) that has metallic properties such as ability to conduct electricity, malleability, ductility and shininess

METAMORPHIC ROCK rock formed when other types of rocks are changed by incredible heat and pressure inside the Earth

MICROORGANISM tiny organisms only visible with a microscope; includes bacteria, protists and some fungi

MINERAL naturally occurring solid substance with its own chemical composition, structure and properties

MITOCHONDRION powerhouse organelle of a cell; the site of energy production (plural: mitochondria)

MITOSIS process of cell division to provide growth or repair

MIXTURE something made up of two or more pure substances mixed together

MOLECULAR discrete chemical substance

MONATOMIC molecular element made up of only one atom (e.g. neon)

MUSCLE CELL cell that can contract to cause movement

N

NATURAL EVENT sudden and dramatic change in environmental conditions e.g. fire, flood, drought, earthquake)

NEPHRON tiny structure in the kidneys that filters the blood

NEUTRON unchanged, sub-atomic particle that is found in the nucleus of atoms

NITROGEN-FIXING BACTERIA bacteria that live in the roots of some plants and provide them with usable forms of nitrogen

NON-METAL substance (element) that has non-metallic properties such as no ability to conduct electricity, not malleable, not ductile and not shiny

NUCLEAR ENERGY energy stored in the nucleus of an atom and released in nuclear reactors or explosions of nuclear weapons; much larger than the chemical energy released in chemical reactions

NUCLEUS centre of an atom where neutrons and protons can be found

NUTRIENT soluble substance that an organism needs to live and grow; usually taken in from the environment

O

OMNIVORE organism that obtains its energy by eating plants and animals

ONION-SKIN WEATHERING type of weathering where heating and cooling of rock causes the outer layer of the rock to peel off like an onion skin

ORE mineral with a large amount of a useful metal in it

OSMOSIS special case of diffusion that, in living things, is usually associated with the movement of water from a weak to a stronger solution across a cell membrane that is selectively permeable

OVARY organ in females that produces the gametes or ova and hormones

OVUM female gamete or egg cell (plural: ova)

OXIDATION reaction with oxygen

P

PALAEONTOLOGIST scientist who studies fossils

PARALLEL CIRCUIT type of electrical circuit in which there is more than one path or branch for the electricity to flow

PARTICLE building block of matter with mass and volume, usually represented as dots; this is a general term and may refer to atoms, molecules or subatomic particles

PATHOGEN microorganism that can potentially cause a disease

PATHOGENIC ability to cause disease

PERIOD (in geology) division of geological time, less than an era, that has special fossils associated with it; the end of most periods is marked by a large number of extinctions

PERIOD (in chemistry) row in periodic table

PETRIFICATION chemical replacement of wood, bones, teeth and shells by minerals dissolved in water

PETROCHEMICAL chemical substance that is derived from petroleum

PHLOEM TISSUE living transport cells in the vascular bundle in plant stems that are responsible for transport of glucose around the plant

PHOTOSYNTHESIS process where the energy of the Sun is used to convert carbon dioxide and water into oxygen and sugars

PHYSICAL CHANGE change in the appearance of a substance; the substance still consists of the same particles, but it looks different; no new chemical substances are produced (e.g. melting and boiling)

POLLINATION process that occurs in flowering plants when a pollen cell lands on the stigma

POLYESTER polymer that is used largely in the textiles industry

POLYMER long-chain molecule made up of many simpler repeating units

POPULATION group of the same kind of organisms that live in the same place at the same time

POTENTIAL ENERGY energy stored in objects, waiting to be used (e.g. gravitational potential energy)

PRECIPITATE insoluble solid substance

PRESSURE force per unit area; particles exert pressure

PRODUCER plant or plant-like organism found at the start of a food chain; see *autotroph*

PRODUCT substance obtained at the end of a chemical reaction; written on the right of a chemical equation

PROPERTY (in chemistry) characteristic or behaviours of something that is always the same (e.g. the density of gold)

PROTON positively charged sub-atomic particle found in the nucleus of an atom

R

RADIATION process of heat transfer where there is no movement of the substance itself; rather the heat is carried by infrared waves that cause heating when absorbed

RADIOACTIVE DATING process of working out the actual age of a fossil by looking at the amount of radioactivity left in rocks

RANDOM SCREENING method that pharmaceutical companies use to determine the usefulness of a chemical as a possible drug

REACTANT substance used at the beginning of a chemical reaction; written on the left of a chemical equation

REACTION any process where there has been change

REACTIVITY how reactive a substance is to other chemicals

REFRACTIVE INDEX how much light will bend when it passes through the substance

RESPIRATION breakdown of glucose and oxygen into water, carbon dioxide and energy; usually occurs in the mitochondria of a cell

ROCK CYCLE illustration explaining how the three rock types (igneous, metamorphic and sedimentary) are related to each other and how they change from one type to another over time

ROOT HAIR CELL elongated cell in the root of a plant through which osmosis occurs

S

SEDIMENTARY ROCK rock formed when loose particles are pressed together by the weight of the overlying sediments

SELECTIVE BREEDING reproductive technique where animals and plants are bred to keep, lose or enhance a certain characteristic or to be immune to disease

SELF-POLLINATION involves pollen from a flower landing on its own stigma or that of another flower on the same plant

SERIES CIRCUIT type of electrical circuit in which there is only one path or branch for the electricity to flow

SEXUAL REPRODUCTION type of reproduction involving the fusing of gametes

SKELETAL MUSCLE muscles that attach to bones of the skeleton and are identified under the microscope by their striped appearance, they occur in pairs and are responsible for conscious movement

SKELETON system of bones in the body that supports, protects, stores minerals and produces blood cells

SMELTING extracting metal from its ore through a process of melting and heating

SMOOTH MUSCLE muscles that are associated with internal organs such as the uterus and digestive tract, they contract to bring about some body functions that are not under conscious control

SOIL ORGANIC CARBON carbon-based compounds (decaying plant and animal material) found within the soil

SOLAR CELL also known as a photovoltaic or P-V cell; semiconductor material, usually silicon, that generates electricity when illuminated by sunlight

SOUND ENERGY type of kinetic energy made when things vibrate

SPEAKER device that converts electrical energy into sound energy

STEM CELL cell in a multicellular organism that hasn't been specialised yet

STOMATA openings in plant leaves (and stems) that are enclosed by guard cells through which transpiration and gas exchange occur

STREAK colour of a powdered or crushed mineral seen as the colour of the line left behind when the mineral is drawn along a surface

SUSTAINABLE ability to maintain or keep conditions relatively constant over time

SYMBOL EQUATION chemical equation in which symbols and formulas are used instead of the names of the reactants and products

T

TESTES organs in the male reproductive system that produce the gametes or sperm and hormones

THERMAL ENERGY scientific term for heat energy

TOXICITY degree to which a substance will harm an organism

TRACE FOSSIL impression of a once living organism left in rock, such as footprints

TRANSFORMER device that converts one AC voltage into another AC voltage value via the process of electromagnetic induction

TRANSPIRATION STREAM flow of water and dissolved minerals through the xylem of a plant

TRANSPIRATION process of evaporation of water from plant leaves

TROPHIC LEVEL position an organism holds within a food chain

V

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

VEIN thin blood vessel that carries blood back to the heart

W

WEATHERING process in which rocks and minerals are broken down

WORD EQUATION chemical equation where the names of the reactants and products are written in words

X

XYLEM TISSUE non-living tube-like structures in plant stems through which water and minerals are transported

Z

ZYGOTE scientific term used for a fertilised egg

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