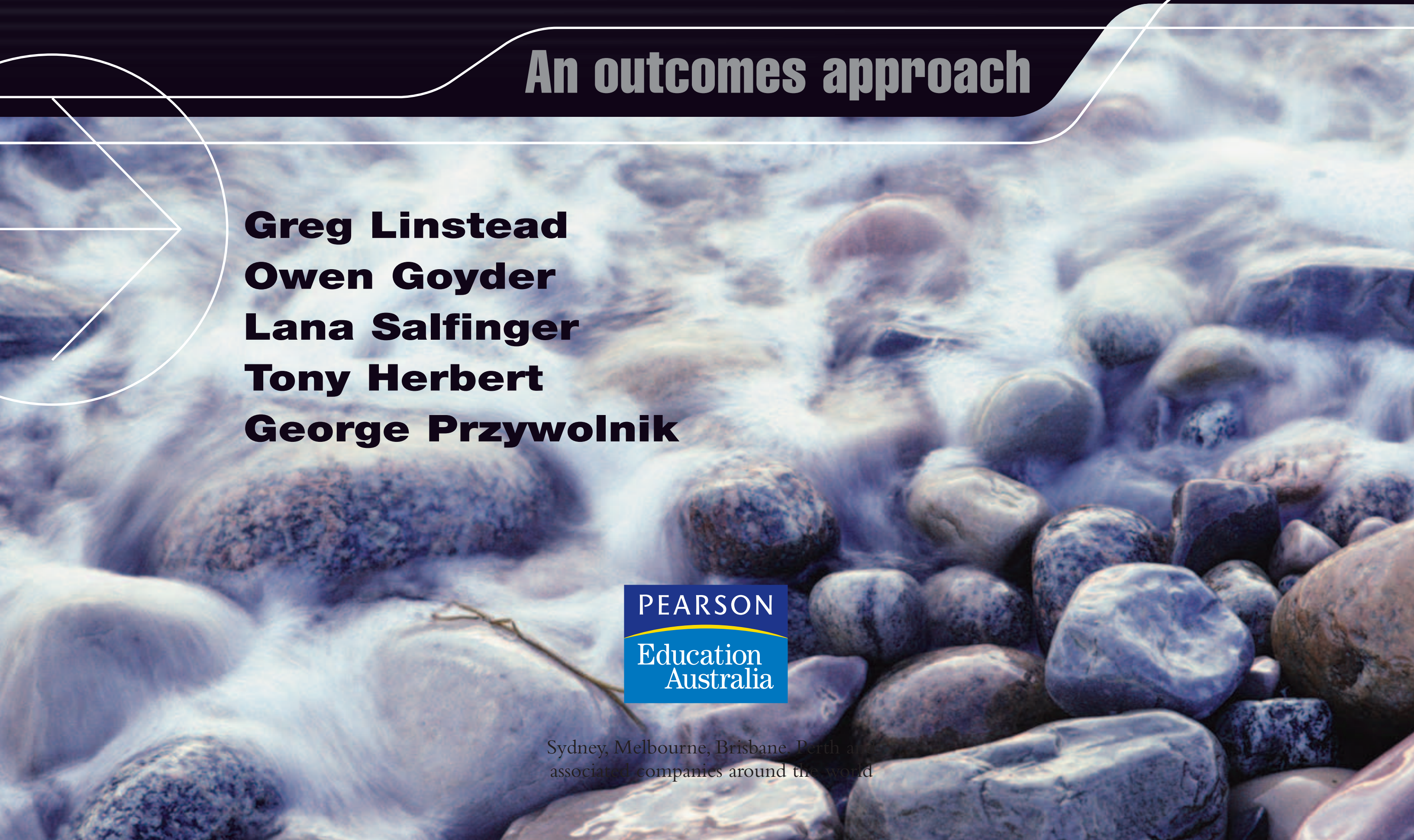
Science Aspects 3

An outcomes approach



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Contents

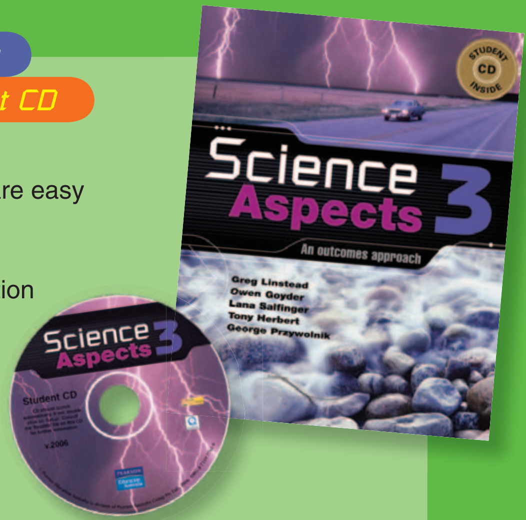
Science Aspects 3
An Outcomes Approach

The complete science package!

Science Aspects 3: *An Outcomes Approach* has been designed to meet the requirements of the latest curriculum initiatives in Western Australia. It integrates an outcomes approach, drawing on the:

- Curriculum Framework
- Curriculum Framework Curriculum Guide
- Progress Maps.

Science Aspects 3: *An Outcomes Approach*
Coursebook *Includes Student CD*



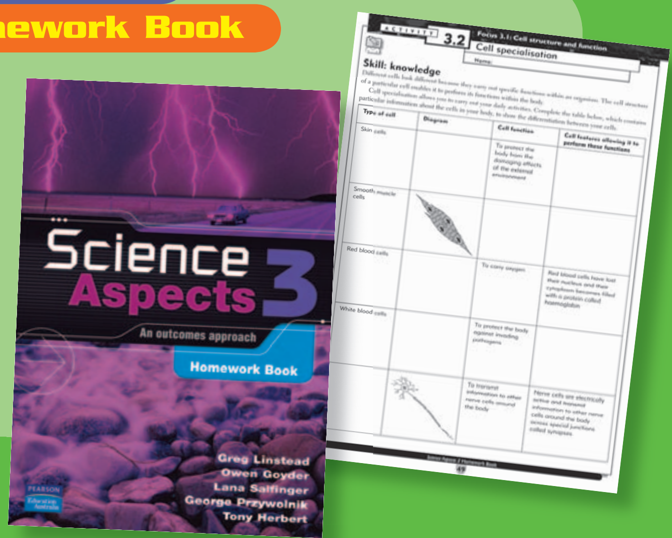
The **coursebook** consists of chapters with the following features:

- the most up-to-date science content presented in foci (units) that are easy to read and follow
- graded Review Questions to allow all students to achieve success
- investigating questions to encourage further research and exploration
- section reviews to consolidate and apply learning
- practical activities.

Each **coursebook** includes an interactive Student CD containing:

- an electronic version of the coursebook
- the Companion Website on CD
- a link to the live Companion Website.

Science Aspects 3: *An Outcomes Approach*
Homework Book



The **homework book** provides a structured homework program to complement the coursebook. These homework activities:

- cover various skills required in science
- offer consolidation and interesting extension activities
- provide revision activities, including the construction of a glossary
- cater for multiple intelligences through varied activity types.

Science Aspects 3: ***An Outcomes Approach***
Teacher's Resource

The **Teacher's Resource pack** consists of a CD with printout. All documents are available as editable MS Word documents, enabling teachers to modify and adapt any resources to meet their needs.

The Teacher's Resource pack provides a wealth of teacher support material including:

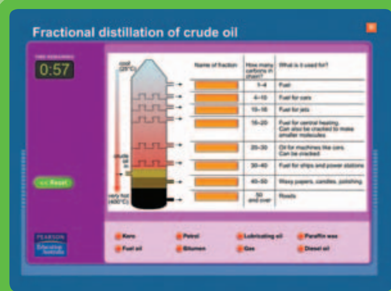
- coursebook answers
- homework book answers
- teacher assessments and levelling guides
- levelling guides for section review questions of the coursebook
- laboratory notes for practical activities.

Science Aspects 3: ***An Outcomes Approach***
Companion Website

www.pearsoned.com.au/schools/secondary

The **Companion Website** is available live, and on the Student CD. It contains a wealth of support material for students and teachers, written to enhance teaching and learning:

- **Review Questions**: auto-correcting multiple-choice, labelling, matching and fill-in-the-blanks questions
- **Web Destinations**: a list of reviewed websites that support research and exploration
- **Interactive Animations** to engage students in exploring ideas
- **Drag and Drop Interactives** to revise key terms and key diagrams
- **QuickTime videos** to explore chemical concepts in a visually stimulating way
- **Interactive Crosswords** to revise basic concepts and key terms for each section
- **3D molecules gallery** for viewing and manipulating molecular structures
- **Teacher's Resource Centre**: password-protected part of the site containing the teacher resources found in the Teacher's Resource pack.



For more information on the *Science Aspects: An Outcomes Approach* series, visit www.pearsoned.com.au/schools/secondary

How to use this book

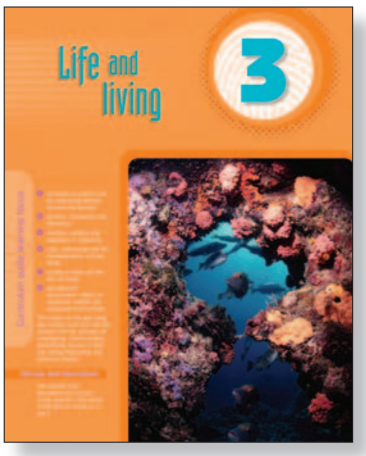
Science Aspects 3: *An Outcomes Approach* has been designed to meet the requirements of the latest curriculum initiatives in Western Australia. It integrates an Outcomes approach with the latest science content to intrigue and motivate students. The content is presented through varied contexts to engage students in seeing the relationship between science and their everyday lives.

The structure of the coursebook draws on information in the following documents to produce a cohesive resource that will allow teachers to meet the demands of teaching, learning and assessment using an Outcomes-based approach:

- Curriculum Framework
- Curriculum Framework Curriculum Guide
- Progress Maps.

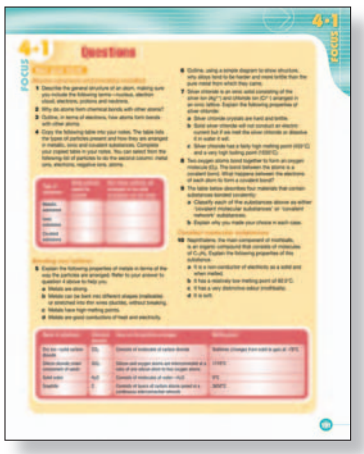
Each coursebook consists of sections with the following features:

- **section opening pages**, which include:
  - Curriculum Guide Learning Focus relevant to the section content
  - Outcome Level Descriptions
  - photograph to stimulate interest.



- **foci** (units) that open with a 'context' to encourage students to make meaning of science in terms of their everyday experiences. The foci also reinforce contextual learning by presenting theory, photos, illustrations and 'science snippet' boxes in a format that is easy to read and follow.

- **focus review sections**, divided into straightforward 'use your book' questions that build confidence and allow all students to achieve success, followed by 'use your head' questions requiring application and higher level problem-solving. There are also 'investigating questions' for further research and exploration, and to reinforce skills. These also include design-your-own investigations.



- **practical activities**, which are placed at the end of each focus to allow teachers to choose when and how to best incorporate the practical work. Icons for practical activities are included in the focus theory to signal suggested points for practical work.

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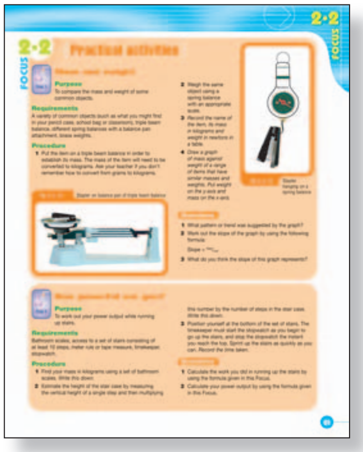
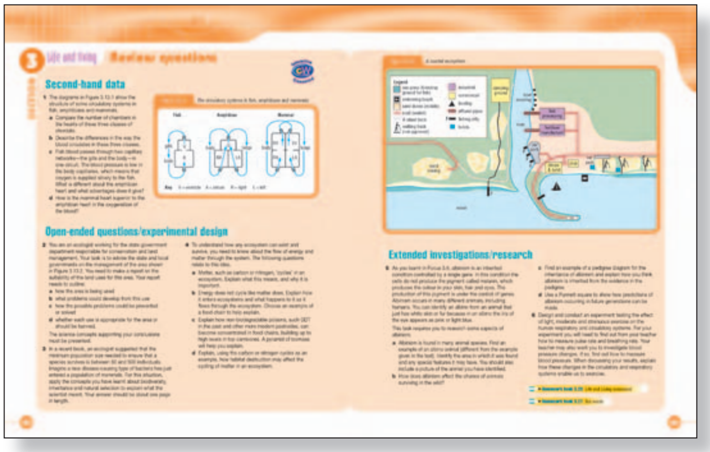


- **skills**, which are integrated throughout the coursebook. Each section and each focus has activities that will develop students' science skills, allowing progressive development in this area.
- **section review activities**, following the last focus in each section. These activities are divided into three types:
  - second-hand data
  - open-ended question/experimental design
  - extended investigation/research.

  These activities integrate outcomes from all foci for each section of the coursebook, and provide opportunities for all students to consolidate new knowledge and skills. These activities are structured tasks that can be used as levelling assessment tasks. Levelling grids for these activities are supplied in the Teacher's Resource pack. They can also be used as practice assessment tasks before an assessment activity from the *Science Aspects 3: An Outcomes Approach Teacher's Resource Pack* is used.



Other icons used in the *Science Aspects 3: An Outcomes Approach* coursebook are listed below:

Homework book 2.11 Sci-words

The Homework Book icon indicates an activity that is available in the *Science Aspects 3: An Outcomes Approach Homework Book.*

DYO

The DYO icon indicates where a 'Design Your Own' investigation is suggested.

Interactive CW Animation

The CW icon indicates when an activity is available for students on the *Science Aspects 3: An Outcomes Approach* Companion Website. The text written around the icon indicates the type of activity that is available. In the electronic version of the coursebook on CD these icons are directly linked to the actual activity for convenience.

Science Aspects 3: An Outcomes Approach package

Do not forget the other ***Science Aspects 3: An Outcomes Approach*** components that will help engage and excite students in science:

- *Science Aspects 3: An Outcomes Approach Homework Book*
- *Science Aspects 3: An Outcomes Approach Companion Website*
- *Science Aspects 3: An Outcomes Approach Teacher's Resource Pack*, including the *Teacher's Resource CD.*

Science Aspects 3: *An Outcomes Approach*

Curriculum correlation

Science Aspects 3: An Outcomes Approach is designed using the **Curriculum Framework**, the **Curriculum Framework Curriculum Guide** and **Progress Maps**. The following grid outlines how each focus of the coursebook matches the contents of these documents to produce a cohesive resource, allowing teachers to meet the demands of teaching, learning and assessment using an outcomes-based approach.

The **Investigating** learning area outcome is integrated into all sections to ensure that it is covered progressively throughout the course.

	Progress Maps Aspect/Organiser	Curriculum Guide—scope and sequence Learning focus/Content
SECTION 1 Earth and beyond		
1.1 Our place in the Universe	EB 4, 5 Relationship between Earth, Solar System and the Universe	Solar systems, nebulas, galaxies, black holes, quasars, light years
1.2 Conditions for life	EB 3, 4, 5 Sustainability of life and wise resource use Earth forces and materials	Conditions for life, search for life on other planets
1.3 Cycles in nature	EB 4, 5 Sustainability of life and wise resource use	Water cycle, carbon and nitrogen cycles
1.4 The Earth's crust	EB 4, 5 Earth forces and materials	Rock cycle, rock types due to conditions of origin, rock-forming minerals—chemical and physical properties
1.5 Plate tectonics	EB 4, 5 Earth forces and materials	Causes, types of movement, volcanic activity and plate margins
1.6 Fossils and dating	EB 4, 5 Earth forces and materials	Types of fossils, geological time and dating methods, stratigraphy and index fossils, fossil evidence for tectonics
1.7 Movement of the Earth and the atmosphere	EB 3, 4, 5 Relationship between Earth, Solar System and the Universe	Faulting, folding, earthquakes and volcanoes, cyclones, lightning
1.8 Mining methods	EB 3, 4, 5 Earth forces and materials Sustainability of life and wise resource use	Open cast, underground, oil wells, repairing/replacing the ecosystem

	Progress Maps Aspect/Organiser	Curriculum Guide—scope and sequence Learning focus/Content
SECTION 2 Energy and change		
2.1 Sources, stores and carriers of energy	EC 4, 5 Energy sources, patterns and uses	Energy definition and storage, kinetic and potential energy, sources—e.g. chemical, electrical, heat, nuclear
2.2 Force, work and power	EC 4, 5 Energy sources, patterns and uses Transfer and transformation	Measuring force, contact and non-contact forces, calculating work and power
2.3 Transferring energy	EC 4, 5 Transfer and transformation	Source, carrier and receiver, mechanical transfer—collisions, heat, electricity, sound waves, electromagnetic waves—light
2.4 Energy transfer by simple machines	EC 4, 5 Transfer and transformation	Definition of simple machine, levers, mechanical advantage, classes of lever
2.5 More simple machines	EC 3, 4 Energy sources, patterns and use Transfer and transformation	Wheel and axle, belts and chains, gears, pulleys, inclined plane
2.6 Energy transformations	EC 4, 5 Energy sources, patterns and uses Transfer and transformation	Source, converter and receiver, efficiency
2.7 Organisms as energy converters	EC 4, 5 Energy sources, patterns and uses Transfer and transformation	Eyes, ears, skeletal muscles, respiration, photosynthesis
2.8 Sustainable energy use	EC 4, 5 Energy sources, patterns and uses Transfer and transformation	Power consumption, changing energy use, declining energy reserves, enhanced greenhouse pollution, alternatives—energy sources, efficient design, recycling, pollution controls

	Progress Maps Aspect/Organiser	Curriculum Guide—scope and sequence Learning focus/Content
SECTION 3 Life and living		
3.1 Cell structure and function	LL 4, 5 Structure and function	Life processes, cell organelles, cell division, adaptation to function
3.2 Body systems—organisation and interactions	LL 4, 5 Structure and function	Major human systems—structure and function
3.3 Body systems and regulation	LL 4, 5 Structure and function	Homeostasis, control mechanisms
3.4 Protecting the body	LL 4, 5 Structure and function	Health and disease, specific defences and the immune response, infectious and non-infectious disease
3.5 Reproduction and survival	LL 4, 5 Structure and function Reproduction and change	DNA, sexual and asexual reproduction, parental care and survival
3.6 Variation and inheritance	LL 5, 6 Reproduction and change	Variation, predicting genotypes, sex linkage, effect of the environment on a species
3.7 Evolution	LL 5, 6 Reproduction and change	Evolution and natural selection, evidence—fossils, DNA
3.8 Environments and ecosystems	LL 4, 5 Interdependence	Definition of environment, living and non-living factors, definition of ecosystem
3.9 Interdependence of organisms	LL 4, 5 Interdependence	Definition of interdependence, relationships between organisms, recycling, stability of communities
3.10 Damaging the environment	LL 4, 5 Interdependence	Ways of damaging the environment—overpopulation, habitat destruction, introduced species, chemical pesticides and pollution, overcropping
3.11 Conservation	LL 4, 5 Interdependence	Reasons for conservation, strategies for conservation
3.12 Environmental management	LL 4, 5 Interdependence	Biological control, other alternative control methods, examples of environmental management

		Progress Maps Aspect/Organiser	Curriculum Guide—scope and sequence Learning focus/Content
SECTION 4 Natural and processed materials			
4.1	Chemical bonding and uses	NPM 5 Structures, properties and uses Interactions and changes	Types of chemical bond, relating properties to bonds
4.2	Solubility	NPM 5 Structures, properties and uses Interactions and changes	Types of solution, concentration, factors affecting solubility, solubility rules
4.3	Separating substances	NPM 4, 5 Structures, properties and uses Interactions and changes	Dissolving and the kinetic theory, methods of separating
4.4	Structure and uses of polymers	NPM 5 Structures, properties and uses Interactions and changes	Polymers—relating properties and uses to structure
4.5	Organic chemistry	NPM 5 Structures, properties and uses Interactions and changes	Types of organic compounds—relating properties and uses to structure, uses as soaps, detergents, solvents, foods
4.6	Chemistry and sustainability	NPM 5, 6 Interactions and changes	Need for sustainable chemistry, principles of green chemistry

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Science Aspects 3

Earth and beyond

1

Curriculum guide learning focus

- how resource use can affect the environment and sustainability
- how physical changes can affect living things eg carbon cycle, water cycle
- changes such as tectonic movements and the rock cycle, and their effects
- the properties and structure of materials making up the Earth
- features of the Universe and processes of change
- technologies for exploration and mining

This section on Earth and Beyond also contains work that will help students with the outcomes of Investigating, Communicating Scientifically, Science in Daily Life, Acting Responsibly and Science in Society.

Outcome level descriptions

The outcome level descriptions for Earth and Beyond covered in this section of the book are mainly EB 4 and 5.

FOCUS 1.1 Our place in the Universe

Context

The last hundred years or so have seen a revolution in astronomy. New instruments and new ways of thinking about information have changed the way we see the night sky completely. We know a lot about the Universe beyond our own Solar System, and it seems the more we find out, the stranger it all becomes.

Solar systems

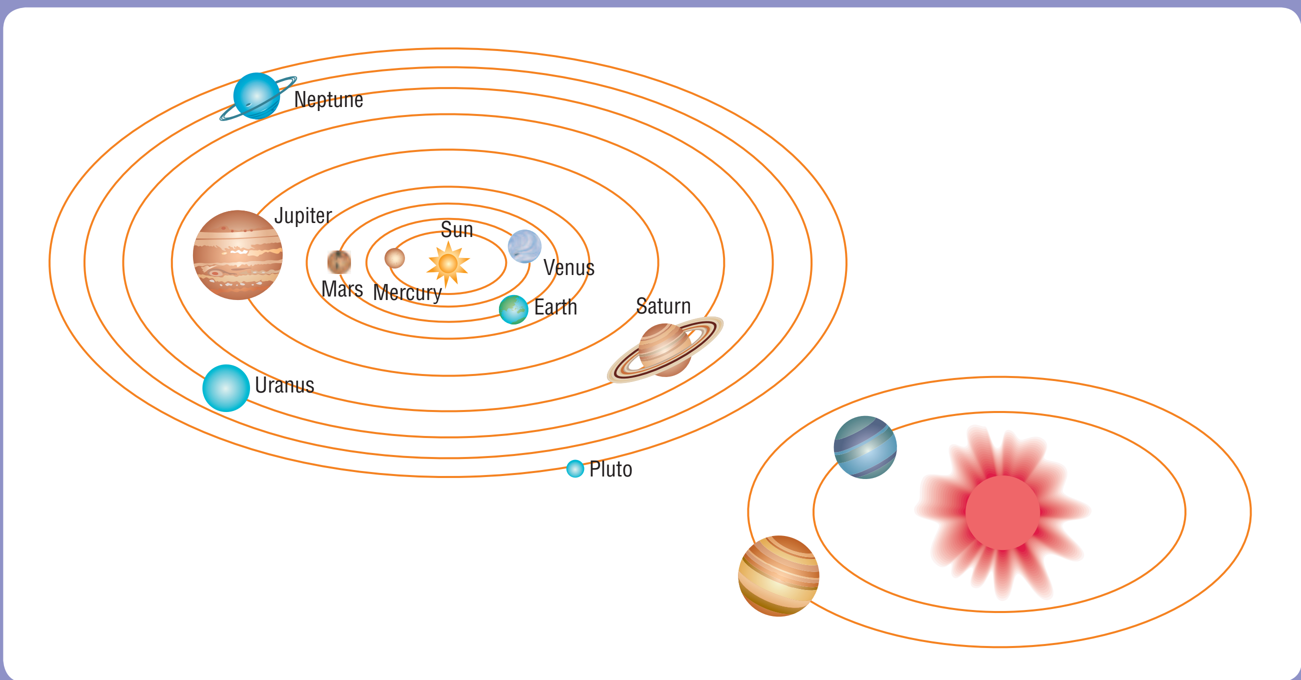
For many years, astronomers believed either that our Solar System was unique, or that it was an example of a common pattern. There was no proof either way, because there was no way to detect planets orbiting other stars. Recently, new ways of measuring the movement of stars have given us a whole new view of the heavens. It seems that our Solar System is not unique, or even rare. There are many solar systems out there, but in an important way, most are not like ours.

A star that has planets in orbit around it wobbles as a result of the gravitational pull of its planets on the star. If the star is close enough to us, and the planet is big enough, Earth astronomers can see the wobble. Most of the stars that have such wobbles seem to have gas giant planets in very close orbits. This is a very different arrangement from that of our own Solar System, in which small rocky planets are in close orbit, and gas giants far out.

The methods used to detect planets work best for systems in which large planets are close to the central star. Thus, it is not surprising to find that astronomers have found many such systems, but not systems like ours. Whether this is because of the measurement method or a real effect remains to be seen.

In our own Solar System, the gas giants, especially Jupiter, have protected the Earth from many impacts with comets and asteroids. If a comet or asteroid has an orbit that takes it in towards Earth, a close encounter with a gas giant can swing the smaller body into a different orbit in another direction.

Fig 1.1.1 Our Solar System (on the left) compared with an extrasolar system



An even closer encounter can lead to a collision with the gas giant. Either way, the comet or asteroid no longer poses a threat to the Earth. This could not happen if the gas giants were closer to the star than the Earth-like planets. Life would be much less certain if we lived on a planet in a different Solar System.

Nebulas

Nebulas are clouds of dust and gas. The words 'dust' and 'gas' might be a little misleading. Compared with the vacuum normally found between stars, a nebula has many atoms and molecules in every cubic centimetre. However, the best vacuum we can get on Earth still contains more atoms and molecules in each cubic centimetre than there are in any nebula.

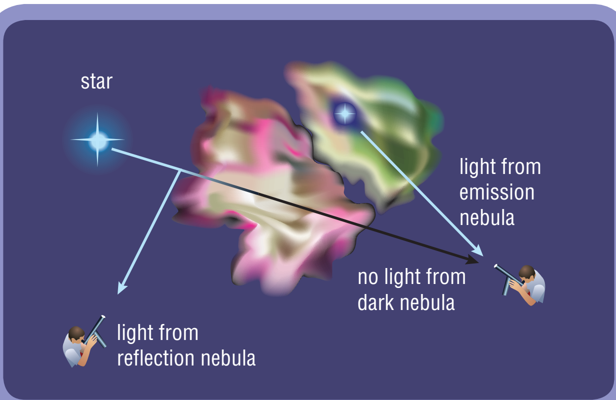


Fig 1.1.2 We see emission, reflection and dark nebulas in different ways.

A reflection nebula is visible to us because it reflects light from nearby bright stars. An emission nebula glows because ultraviolet light from hot stars embedded in it heats the atoms in the nebula. At very high temperatures, atoms can form ions by losing electrons. These ions give out energy as light. We see dark nebulas because they block the light from stars behind them, causing dark patches in the sky. Dark nebulas are too far away from bright stars to reflect much light. The dust and gas in a typical nebula come from the remains of stars near the end of their life cycles, which eject matter into the space around them.

Nebulas are important because they are the places where new stars develop. The stars inside emission nebulas are mostly young stars whose life cycles have just begun. Our own Sun, and the rest of the Solar

Fig 1.1.3 This nebula in the constellation of Carina shows both emission and dark nebulosity. The colours in this image give a clue to temperature—blue is hotter, red is cooler.

System, began in just such a cloud of dust and gas, left over from the death of an older star. Thus most of the atoms that make up the Earth, and us, were created billions of years ago inside a long-dead star. As the astronomer Carl Sagan put it, 'we are made of star stuff'.

Galaxies

Millions of stars, their planets and moons, and clouds of dust and gas make up a galaxy. All the objects in a galaxy are bound together by gravity. In our own Milky Way galaxy, there are probably about 400 billion stars, distributed across a bulging central hub and flat 'arms' that curve out from the hub, as in Figure 1.1.4. Our Solar System is in one of the arms. When you look at the Milky Way, you are looking towards the centre of the galaxy.

Dust and gas obscure the galactic centre from our direct vision. Some types of electromagnetic radiation such as radio waves can pass through the dust and gas to us. Radio astronomers have used these to map the hidden parts of the galaxy.

Fig 1.1.4 Our own Milky Way galaxy is a spiral shape, much like this one.

Whichever way you look, there are other galaxies, but most are too distant and faint to be visible to the unaided human eye. In some, catastrophic events are occurring, such as the collision in Figure 1.1.5.

Millions, perhaps billions of galaxies exist, all them far away from our own. Most of them are incredibly distant. There are several ways to measure the distance to a galaxy, depending on how far away it is.

Some stars vary in brightness in a predictable way and their brightness can be used as a kind of measuring stick. These are called **variable stars**. Using powerful telescopes, astronomers can see such stars in relatively close galaxies. For more distant galaxies, the brightness of the whole galaxy is used to estimate the distance. This is less accurate, because some galaxies emit more light than others. Our own Milky Way galaxy, for example, is unusually large and would look brighter than average to alien astronomers viewing it from another galaxy. A map showing the location of every known galaxy has revealed previously unknown structures, including a 'wall' of galaxies (see Figure 1.1.6).

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Some galaxies would be exciting places in which to live. This image shows two galaxies in the process of colliding. *Fig 1.1.5*

Science Snippet

The comet hunter's legacy

Through a telescope, comets look like fuzzy patches of light. Finding comets was once an important part of an astronomer's work. Charles Messier became annoyed when he kept finding fuzzy patches that were not comets. In 1781, he made a catalogue of 109 prominent fuzzy patches, all of which are now referred to by their Messier number. For example, M31 is a large spiral galaxy in the constellation Andromeda; M42 is a nebula in Orion; and M13 is a globular cluster in Hercules. Many other astronomical catalogues have been compiled since then. The New General Catalogue, in which the numbers begin with NGC, is widely used.

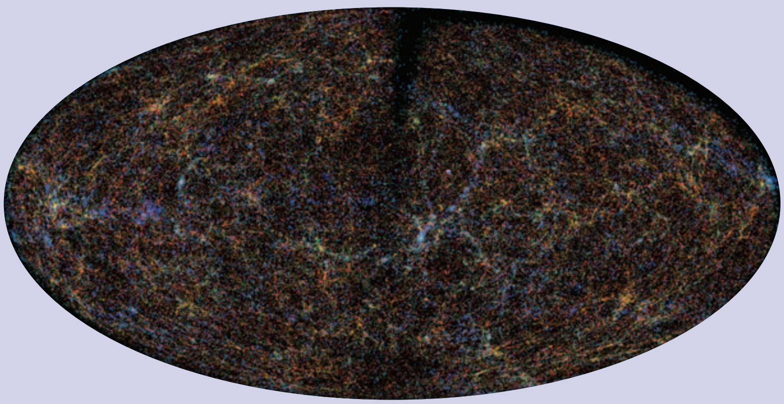


Fig 1.1.6 This is a map showing the location of every known galaxy. Each dot represents a galaxy whose location has been measured.

Fig 1.1.7 Omega Centauri globular cluster. This contains thousands of stars very close together, like a very small galaxy.

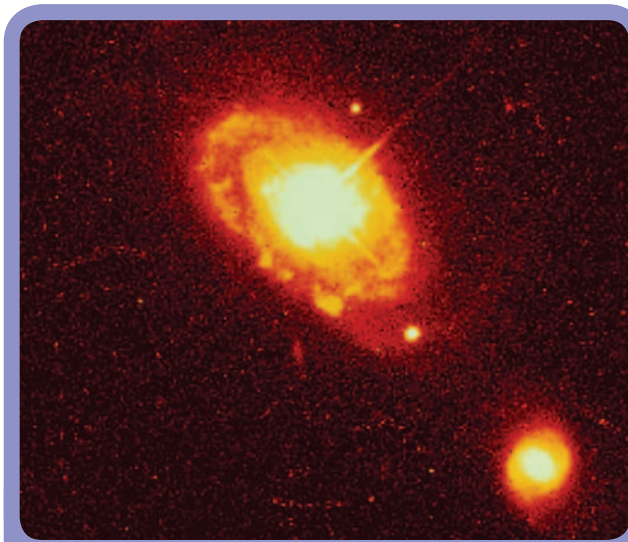


Fig 1.1.8 The spiral galaxy surrounding this quasar is clearly visible.

Homework book 1.1 Nebulas and galaxies

Black holes

When you throw a ball upwards, it slows down, stops, then falls back to Earth. If you throw it harder, it rises higher before falling back. If you were able to give the ball enough speed, it would never come down. This speed, called the escape velocity, is about 40 000 kilometres per hour for the Earth. The escape velocity depends on how strong the gravity is. A black hole is a place where the gravity is so strong that the escape velocity is greater than the speed of light, so not even light can leave it.

A black hole is called black because light cannot escape from inside it. Its enormously strong gravitational pull attracts any material around it. As this material falls into the black hole, it releases energy as light and X-rays. Scientists have detected 'X-ray bursters' that seem to be black holes behaving this way. Most galaxies, including our own, apparently have black holes at their centres. This makes the average galactic centre a very energetic place, full of dangerous radiation.

Quasars

Quasars look like stars, but are incredibly distant. The word quasar means 'quasi stellar object'; that is, an object that looks like a star, but is not a star. No star we know of could be bright enough to be visible at such distances. Quasars emit energy at truly enormous rates.

Every quasar we know of is billions of light years away. Because light travels at a finite speed, 'two billion light years away' also means 'happened two billion years ago'. The closest quasar is over two billion light years away. Thus, quasars seem to be a feature of the early Universe. We cannot see any quasars close by, so it seems that the conditions that created them no longer apply.

The energy source that could allow quasars to shine so brightly used to puzzle astronomers. We now know that a quasar is a distant galaxy with a very active black hole at its core. Active in this sense means able to draw in lots of material from around it, and so produce lots of radiation as matter falls into the black hole. No one knows what makes a black hole 'turn on' as an energy source for a quasar, nor what might turn it off. Was our own galaxy a quasar in the distant past?

Homework book 1.2 Black holes

Science Snippet

The expanding Universe

When astronomers could measure how quickly, and in what direction, each galaxy is travelling, they found that the more distant the galaxy is, the faster it moves, and that just about every galaxy is moving away from us. Does this mean we are at the centre of the Universe? Surprisingly, the answer is no. You would see the same result, no matter where in the Universe you measured from. Other galaxies are not rushing away from us; instead, the whole Universe is expanding. It has been expanding since the Big Bang, the moment at which the Universe came into existence.

Drag and Drop CW Interactive

1·1 Questions

Use your book

Solar systems

1 The information we have about planets orbiting other stars may be biased. Astronomers may be detecting only those solar systems in which gas giant planets are close to the star. Why would the location of gas giants have more effect on a star's wobble than the location of Earth-like planets?

2 All the solar systems discovered so far have been around stars relatively close to us. Does this mean that there are no solar systems further away? Explain your reasoning.

Nebulas

3 Draw a diagram showing how a cloud of dust and gas may be a reflection nebula when seen from one direction, but a dark nebula when seen from another direction.

4 If you could travel in some way to the centre of a nebula to make observations, how might the sky appear if you were in:

a an emission nebula?

b a dark nebula?

Galaxies

5 How would the measured distance to a far-off galaxy be affected if this galaxy gave out more light than the average?

6 The distance to a nearby galaxy is best measured using variable stars. You watch each individual variable star and measure how its brightness changes. Give your ideas about why this method would not work for more distant galaxies.

Black holes

7 The acceleration due to gravity on the Moon is about one-sixth of the value at the Earth's surface. Would you expect the escape velocity for the Moon to be greater, about the same, or less than that for the Earth? Explain your reasoning.

8 You cannot see a black hole, but the space around it may be brightly lit up. Explain.

Quasars

9 What evidence is there that quasars were active only in the early part of the history of the Universe?

Use your head

10 Direct observation of planets orbiting other stars is almost impossible with our present-day technology. What factors make such direct observation difficult?

11 If a quasar suddenly turned on in the centre of our galaxy, how might this affect us?

12 The table below shows the distances to a number of galaxies, and the speed at which each galaxy is moving away (receding) from us.

Galaxy	Distance (billions of light years)	Recession velocity (thousand kilometres per second)
A	4.50	114
B	1.80	46
C	2.40	61
D	1.10	28
E	0.85	22
F	3.30	84

a Draw a graph showing the relationship between distance and recession velocity. Is there a simple mathematical relationship between these variables?

b Use your graph to predict the likely recession velocity of galaxy G, which is 2.8 billion light years away from us.

c Use your graph to predict the likely distance of galaxy H, which is moving away from us at 13 000 kilometres per second.

Investigating questions

13 You can illustrate the way the Universe is expanding by taking a balloon and partly inflating it. Use a permanent marker to make six or seven dots on the balloon. Measure how far apart any four pairs of dots are. Then inflate the balloon some more and measure again. If each dot represents a galaxy, in what ways is your balloon model like the expanding Universe model? In what ways is the balloon model different from the expanding Universe model?

14 Our own Solar System formed inside a nebula. The dust and gas that formed the nebula are no longer anywhere near us. What might have happened to them?

FOCUS 1·1

[Practical activity]

Prac 1 Focus 1.1

DYO

Classifying galaxies

Purpose

To investigate ways to group similar galaxies together.

Requirements

Access to a suitable astronomy reference book or the Internet; access to images of a range of galaxies.

Procedure

1 In groups, find out the various ways in which galaxies have been grouped by astronomers. *Collate the names and essential features of the various classifications in a suitable table.* One has been done for you (see Figure 1.1.9 and the following table).

Classification	Essential features	Example
Barred spiral	Spiral shape; dark bar across the middle	NGC 1365

2 Using your table, discuss each of the galaxies whose images you have, and work out the classification of each. Make sure that everyone in your group agrees with the reasons for the group's choice. In each case, *write down your classification.*

3 Some galaxies may not fit easily into a particular category. Find out how other groups have dealt with these galaxies. *Add to your table if it helps you to classify all the galaxies you are working on.*

4 Report your results to the rest of the class, for example as a poster or an electronic presentation, or on a whiteboard. Did all the groups classify every galaxy in the same way?

Fig 1.1.9 This is the galaxy NGC 1365.

Questions

1 What difficulties might an astronomer have when faced with classifying a newly discovered galaxy?

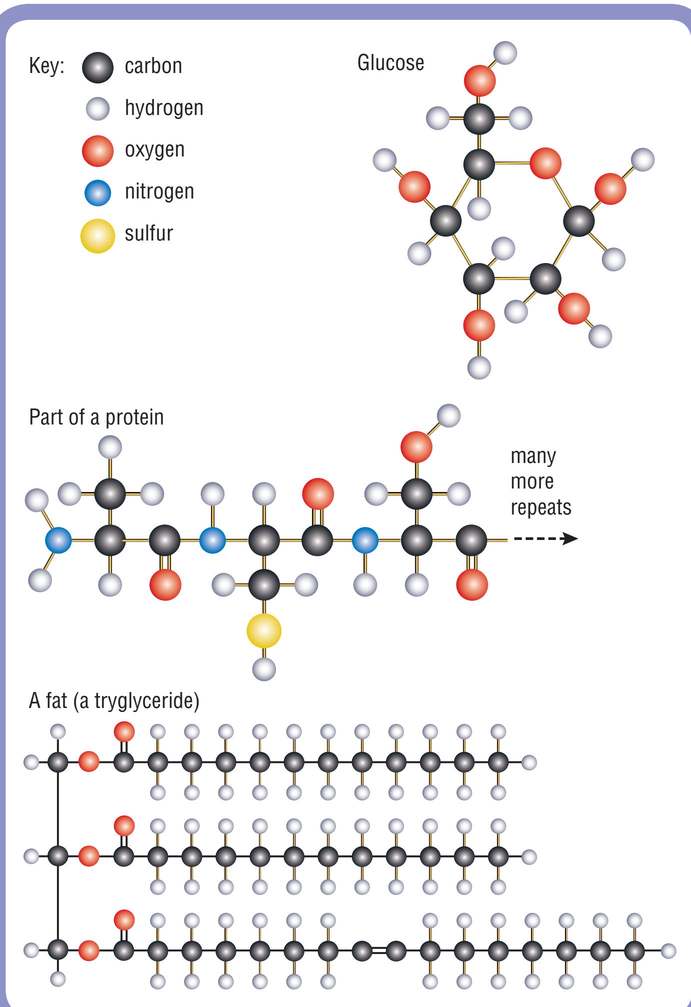
2 Were any of the identification features easier to use than others? What made them easier to use?

3 What question could you develop for further research, based on what you have found out about galaxies in this exercise?

FOCUS 1·2 Conditions for life

Context

What conditions are needed for life to exist? In this Focus we will look at this fascinating subject and reflect on what it tells us about the chances of finding life on some other planet. Imagine that—discovery of an alien life form. It would probably be the greatest discovery of all time. But this act of identifying what is necessary for life here is very important for another reason. It helps us focus our minds on just how fragile Earth is, and how easy it would be to wipe out life on the only planet we know of that supports life.



These diagrams show some examples of the chemicals of life. **Fig 1.2.1**

What is life?

This may seem an obvious question, but it is not easy to answer without some knowledge of science. In *Science Aspects 1* you learnt that living things are called organisms, and that there are about seven different life processes that we can identify. At least these are the ones that we know occur with organisms from Earth. See if you can remember them before reading on.

The life processes identified in *Science Aspects 1* were respiration, movement, excretion, nutrition, reproduction, growth and response. Organisms are made from units called **cells**. There is good reason to believe that any alien life forms will show similar processes, and will probably be composed of units like cells. We think they will probably have cells because of the basic ways in which materials can move from place to place. A process called diffusion allows materials to move, but there is a limit to how fast materials can diffuse. So one big cell does not function well. Many smaller cells tend to occur partly as a way of supplying materials fast enough for cells to use as they are needed.

Organisms on Earth are built from a group of chemicals called **organic** compounds. These are based on the element **carbon**, which forms the backbone of the main compounds of life. These compounds are DNA, proteins, lipids (fats and oils), carbohydrates and vitamins.

You can see from the diagrams in Figure 1.2.1 that organisms need a supply of carbon, nitrogen, hydrogen, oxygen and other elements that are used to build these molecules. Any other life forms discovered are likely to also be based on carbon compounds. NASA is searching for any objects or places in space where organic compounds exist. Some have been found in gas and dust, some in comets, some in meteors. A large number of different compounds have been found, and scientists are beginning to speculate that these materials may be widespread in the Universe.

Why life on Earth?

There are some things that we know were important in nurturing life on Earth:

- The Sun has been a fairly steady source of light and heat for an extremely long time.
- The Earth has a nearly circular orbit around the Sun.
- There was a rich mixture of organic chemicals, and also chemicals that helped to make organic materials.
- There has been a large amount of liquid water for a very long time.

Water

The most important material needed for life is liquid water. It is so vital that NASA is going to look for life on planets or moons only where they are fairly sure liquid water exists or could exist. For example, the two most likely places for life in our Solar System are two moons of Jupiter called Europa and Callisto. They have a surface of frozen water. But beneath the surface there may be enough heat to keep the water liquid. The heat may be generated by Jupiter's gravitational pull on the moons causing rocks to move and heat up.

The reason that liquid water is essential for life is due to its role in cell chemistry. Cells are really packets of reacting chemicals.

Science Snippet

The icefish

The icefish is an amazing fish which has a type of alcohol in its blood. This alcohol is similar to ethylene glycol, which is used to stop car radiators freezing in icy winters. This antifreeze chemical enables the icefish to live in waters that normally would freeze its cells. The icefish also has no red blood cells.

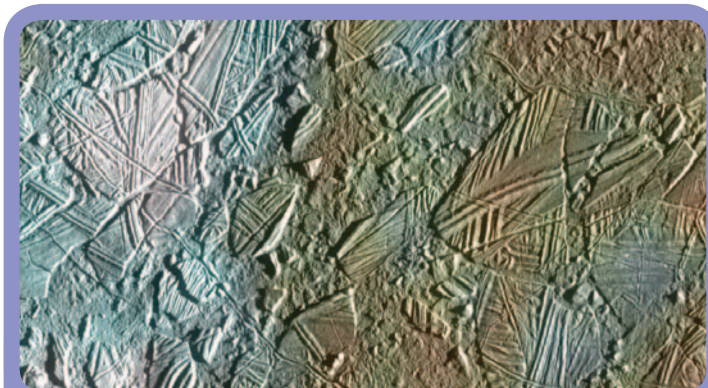


Fig 1.2.2 Photo of the surface of Europa showing an area of 70 kilometres by 30 kilometres. You can see broken ice sections like rafts, similar to those in the polar regions of Earth.

The reactions can work only if they are in a solution, and water is the **solvent** for this. If the water freezes, the chemical reactions stop because the particles cannot move around enough and with enough energy to react. Ice crystals in cells also usually destroy the structure of cells. Their cell membranes are punctured and their contents can leak out.

Homework book 1.3 Antarctic icefish

Temperature

Many forms of life can live in temperatures in the range 10°C to about 30°C. Some organisms, such as bacteria, can even live in temperatures well above this. Some bacteria live in almost boiling water around volcanic areas on Earth. They are called **thermophiles**. If life exists elsewhere in the Universe, we can expect that similar organisms could exist in temperatures near 80°C.

Fig 1.2.3 Some types of bacteria live in this very hot volcanic pool.

Temperature is important in living organisms. Temperatures above the freezing point of water are needed to prevent water freezing. But another reason why warmer temperatures are necessary for life is that the temperature affects how fast chemical reactions occur. To react, particles need to be moving fairly fast to give them the energy to break chemical bonds. This results in chemical change.

If temperatures become too high, the proteins in cells begin to break down. The most important group of proteins affected by high temperatures are **enzymes**, which control the rate of chemical reaction. If they are destroyed then the cell chemistry will be too slow to sustain life.

So a good guide to the likelihood of the existence of life is how warm the planet or moon is.

Prac 1 p. 13
Prac 2 p. 14

Carbon dioxide

Carbon dioxide has been important in the development of life on Earth. Carbon dioxide gas in the atmosphere acts as a 'blanket' around the Earth, keeping it warm. This process is called the **greenhouse effect**. It is a major reason why liquid water exists on Earth.

You probably know about the greenhouse effect from last year's work, and it has been explained in *Science Aspects 1* and *2*. The effect occurs because the Sun's rays easily penetrate through the atmosphere and warm the ground. The ground begins to emit infra-red electromagnetic radiation. These rays are a longer wavelength than the light. The carbon dioxide molecules are the right size to absorb some of the radiation. The particles begin to vibrate faster and this is sensed as heat. Even the small percentage of carbon dioxide in the air (0.035%) is enough to warm the atmosphere. This percentage means that for every 100 000 particles of air, only 35 would be carbon dioxide. Other gases such as water and methane also absorb the infra-red radiation and warm up. So do pollutants such as fluorocarbons and nitrous oxide.

Planets or moons that have an atmosphere can trap heat in this way. This may keep the planet warm enough for liquid water to be present. Too much carbon dioxide can raise the temperature to a level that is a threat to life. For us on Earth, even small rises in temperature may cause a problem. If the polar ice caps melt, the sea level will rise and drown many islands and low-lying places. It will also cause severe problems in the polar regions for life that is adapted to the low temperatures. Many species could become extinct.

Fig 1.2.4 If the polar ice caps melt, the sea level will rise.

Oxygen

On Earth, most organisms use oxygen to enable them to obtain energy from food. The chemical process in cells that releases this energy from food is called **respiration**. You breathe oxygen to supply respiration in your cells.

However, there is another form of respiration that does not use oxygen. This is called **anaerobic respiration**. Many bacteria use this method to obtain energy. An example is the bacteria which cause tetanus. These infect human tissues if they contain little oxygen. Some types of bacteria have been found living deep in the soil and even in solid rock hundreds of metres below the Earth's surface. It is possible that similar bacteria live on planets or moons that lack oxygen.

Oxygen is also important as a protective shield for the Earth. Ultraviolet rays from the Sun penetrate the atmosphere, but a form of oxygen called ozone, O_3, shields out some of these rays. Ultraviolet rays can cause skin cancers, sunburn and eye cataracts. High levels are lethal to many organisms. Damage to the ozone layer on Earth is an issue of very real concern to scientists at present because of this protective role of ozone.

Pressure

High pressures can kill many organisms. On Earth, organisms that live on land are used to pressures of 1 atmosphere. This is equal to 101.3 kilopascals. In the ocean, 2000 metres below the surface, the pressure can increase to 700 times this. Some microorganisms can withstand such pressures. They are called **barophiles**. Scientists are studying why they can survive such high pressures.

For many land animals, if the pressure dropped well below 1 atmosphere, they would die. This would happen in space. The pressure in space is zero. Gas in the blood vessels would come out of solution and the vessels would fill with gas bubbles, stopping blood circulation. The lungs would swell up and explode as the gas in them expanded. This is the reason that astronauts need to wear special suits that keep them under pressure. Any organism in space would have to withstand this zero pressure environment.

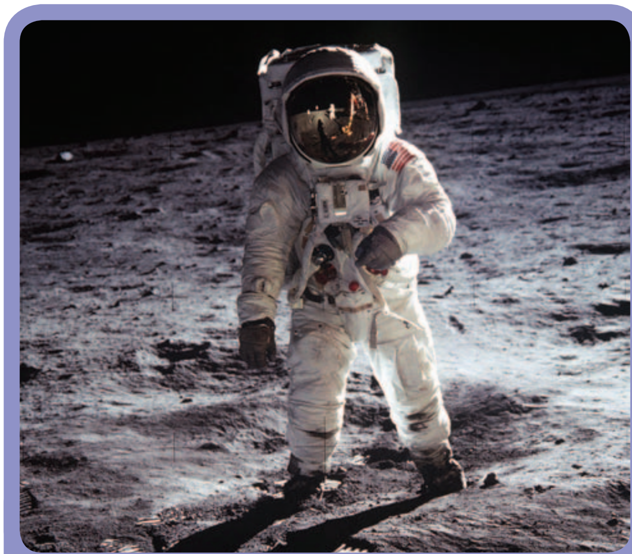


Fig 1.2.5 Astronauts need pressurised space suits to stop their blood boiling and their lungs bursting.

Gravity

Gravity can affect the health of an organism. Humans who have lived in low-gravity environments for a long time develop problems such as bone and muscle weakening. A condition called osteoporosis develops, whereby bones lose their calcium and become brittle and weak. This seems to be related to a lack of stress on the bones. Muscles also seem to decrease in size and lose their power—they are not used enough to maintain the correct structure and therefore strength. This shows that an organism which evolves in a particular gravity will probably be suited only to a gravity of similar size.

Astronauts exercise in space to keep their bones and muscles healthy. *Fig 1.2.6*

Gravity also has an effect on the heart. Organisms with a heart and circulatory system, such as humans, would find it difficult to pump blood in a higher gravity environment. This could lead to heart failure. These factors obviously affect space travel.

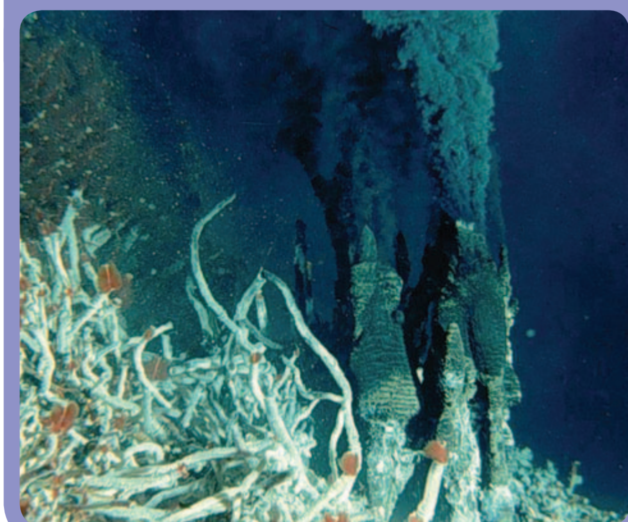
Light

Light is very important to life on Earth. Most organisms depend on light in some way for their energy supply. Plants require light for photosynthesis to produce their organic foods. Nearly all the common animals that you know feed on plants or on animals that eat plants. The plants are called producers because they produce the food for the food web. If other planets have life based on a similar process, they must have the necessary light.

There are some producers that do not use photosynthesis to make organic food materials, such as some of the thermophile bacteria already discussed in the section on temperature on page 10. These organisms are called **chemosynthetic**. Unlike photosynthetic organisms, they obtain their energy through chemicals such as sulfur or iron, rather than sunlight. One very unusual example of these is the bacteria found at the bottom of the ocean where the tectonic plates of the Earth separate. Regions commonly called 'black smokers' have thriving communities of bacteria, worms, crabs and other animals. There are no green plants because there is no light. This has helped scientists realise that there may be life forms like this on other planets.

Drag and Drop CW Interactive

Fig 1.2.7 Some life in the ocean depths does not depend on photosynthesis.



FOCUS 1·2

[Questions]

Use your book

What is life?

1. What do we mean by life?
2. Explain what we mean by organic compounds and give some examples.
3. Use Figure 1.2.1 to answer these questions:
   - **a** What elements are in glucose?
   - **b** What elements are in proteins?
   - **c** What elements are in fats?
   - **d** In a protein chain what elements seem to form the ‘backbone’ of the chain?
   - **e** Which two elements would you predict are the most common in organic compounds?
4. Why is NASA looking for organic compounds in space?

Water

5. Why is NASA looking for liquid water on other planets?
6. Why is liquid water essential to life?

Temperature

7. What temperature range is suitable for life, and why?

Carbon dioxide

8. Why is carbon dioxide important to life on Earth?

Oxygen

9. Name some organisms that do not need oxygen, and describe their method of respiration.
10. How does oxygen gas in the atmosphere protect us from the damaging ultraviolet rays from the Sun?

Pressure

11. What happens to humans in the zero pressure environment of space without a pressure suit?

Gravity

12. Explain how humans are affected in the low-gravity environment of space.

Light

13. Explain how light is important to life on Earth.
14. Some organisms are photosynthetic, and some are chemosynthetic. What is the difference?

Use your head

15. Read the section in this Focus titled ‘Why life on Earth?’. Try to explain why a nearly circular orbit of a planet around a star such as the Sun may be important to the development and nurturing of life.
16. Can life exist without light? Explain your answer.
17. NASA is looking for life on other planets or moons in our Solar System. They think that if it exists it may be more like the bacteria found in hot springs, or in underground rocks or at the bottom of the ocean. Why would they think that?

Investigating questions

18. What could be the benefits to science and industry of research into the chemistry of organisms that can live in high temperatures?
19. Look up the term ‘extremophile’ on the Internet and find out some benefits that could result from studies of these strange organisms.
20. The periodic table shows that silicon is a possible candidate for building molecules similar to carbon. It is in the same group as carbon. Find out if other scientists think it is possible or likely that a life form based on silicon could exist somewhere in the universe.
21. How can scientists detect the presence of particular chemical compounds in space when they have not sent space ships out to collect these chemicals?

FOCUS 1·2

[Practical activities]

Prac 1
Focus 1.2

Freezing

Purpose

To investigate the effect of freezing on cells.

Requirements

Lettuce leaf, slides and cover slips, Pasteur pipette, pond water, forceps, spirogyra, protozoa such as paramecium, monocular microscope, microscope lamp.

Procedure

1. Obtain a small piece of lettuce leaf about 10 cm by 10 cm square. Tear it in half and place one piece in the fridge freezer and the other half in the fridge cabinet.
2. On a clean blank slide place one drop of the pond water.
3. Using the tweezers place a few strands of spirogyra in the drop and cover with a cover slip.

>>

4 On another slide place a few drops of the protozoa.
5 Use a monocular microscope to obtain a high power view of the cells of spirogyra. Remember your microscope procedure. You will have to obtain a focus on low power first before switching to high power.
6 Describe and *draw a few cells of the spirogyra.* The cells are in lines, attached end to end. Be particularly careful about drawing the shape of the spiral chloroplasts inside the cells.
7 Observe and *draw the protozoa.*
8 Place your slides in the fridge freezer for about 15 minutes.
9 Remove the slides and let them thaw out. Wipe the bottom of the slides and again use the microscope to obtain a view of the cells. If you cannot see any real change either replace the slide in the freezer or make another slide and put it in the freezer for longer, even overnight.
10 Remove the piece of lettuce from the freezer and from the fridge cabinet. Let the freezer piece thaw out.
11 Observe and describe the difference between the two pieces of lettuce. If there was no real difference, leave the lettuce in the fridge and freezer overnight.
12 Observe the slides of spirogyra and of protozoa again after having left them for much longer or overnight in the freezer.
13 *Draw and describe the cells again.*
14 Observe and describe the two pieces of lettuce.

Questions

1 Describe the changes in the spirogyra cell after freezing.
2 Describe the changes in the protozoa after freezing.
3 Describe the changes in the lettuce leaf after freezing.
4 What problems do you think the freezing may cause for the spirogyra, the protozoa or the lettuce?

Prac 2
Focus 1.2

Yeast respiration and temperature

Purpose

In this experiment you will investigate the effect of temperature on the respiration rate of a microscopic fungus called yeast.

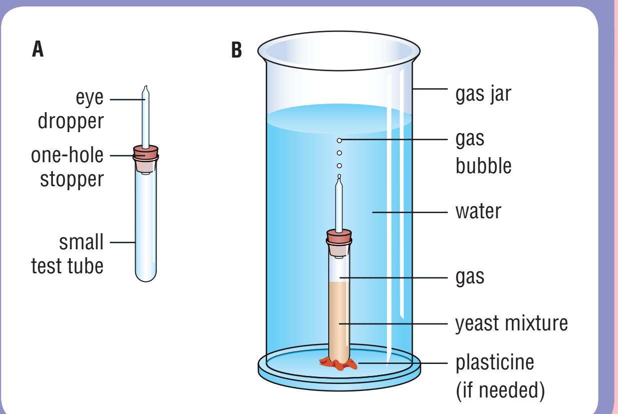
Requirements

Four test tubes short enough to fit into gas jars or graduated cylinders, one-hole stoppers to fit test tubes, eye dropper, test tube rack, 5 g yeast, 10 g sucrose or glucose, water (both ice water and water at room temperature), 100 mL beaker, four gas jars or graduated cylinders, plasticine, stopwatch.

Procedure

1 You need four people in your group for this experiment. Set up the four test tubes, stoppers and eye dropper as in Figure 1.2.8A. Place them in a test tube rack.

How to set up your equipment *Fig 1.2.8*



2 Mix up about 5 g yeast, 10 gram of sucrose and about 50 mL of water at room temperature in a beaker.
3 Remove the stoppers from each test tube and pour 5 cm of yeast mixture into each test tube. Replace the stopper and eye dropper assembly. Make sure the bottom of the eye dropper is not in the yeast mixture.
4 Fill one gas jar with ice water, one with water at 20°C, one with water at 30°C and one with water at 60°C.
5 Place one test tube with yeast mixture and its stopper assembly into each of the gas jars. If it floats, stick a piece of plasticine on the bottom so it sinks to the bottom.
6 Let the set-ups stand for about two minutes. You should see bubbles of gas coming out of the top of the dropper.
7 *Draw up a table to record your results.*
8 Count the number of bubbles emitted by each test tube at 30-second intervals for the next five minutes. You will need to count for 30 seconds, then stop counting for 30 seconds, then count again, and so on. *Write the number of bubbles in your table in the breaks between counting.*
9 *Draw a graph of these results on the same set of axes.*

Questions

1 What gas is in the bubbles and where did it come from?
2 Describe the differences in the four graphs.
3 Using a science idea, explain why there was a difference in the number of bubbles in each set-up.
4 From your results, and from what you know, what may have happened if you froze one of the gas jars?
5 On a planet with no liquid water, would yeast survive?

FOCUS 1.3 Cycles in nature

Context

The carbon, oxygen, hydrogen and nitrogen atoms that living things are made of are in limited supply on the Earth's surface. Every atom in every molecule in your body has been used many times in many different ways.

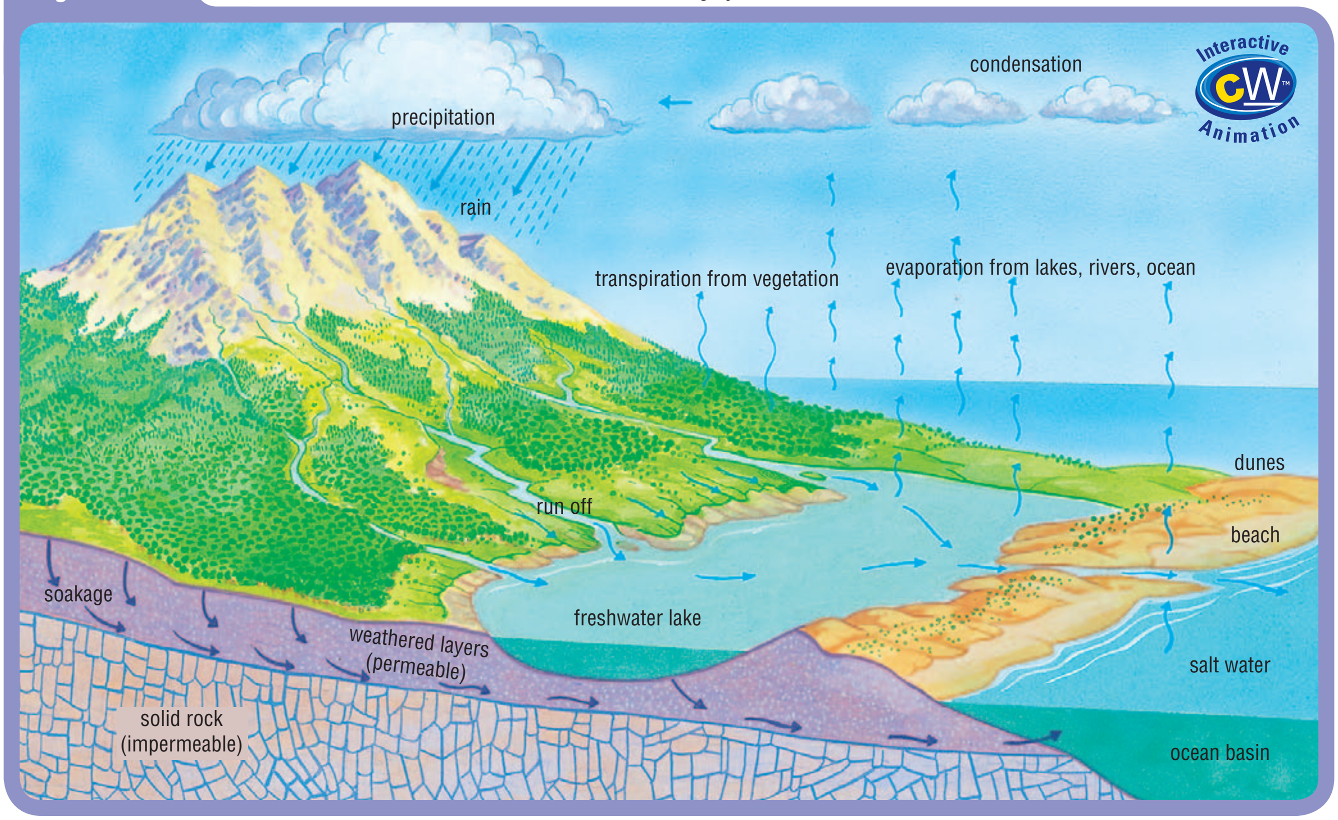
Your atoms are very old; most are older than the Earth itself. They have been a part of the Earth's crust, its oceans and its atmosphere. They have also been in countless other organisms, perhaps algae, bacteria, dinosaurs and clams, before getting into you. They will continue to pass from one organism to another, and in and out of rocks, for millions of years to come. The Earth's surface is one huge recycling system.

Water cycle

As populations increase and demand for resources grows, clean, fresh water has become harder to find. To understand why water is fast becoming a scarce resource, we need to understand where it comes from and where it goes. Water moves around the Earth's surface in a continuing cycle. The Sun provides the energy that drives this cycle.

Oceans cover about 70 per cent of the Earth's surface, and so receive about 70 per cent of the sunlight. The oceans absorb some energy and reflect the rest back into space. The absorbed energy warms the surface of the ocean. This provides the energy to evaporate water molecules from the ocean surface. Evaporation moves water vapour into the air from any body of water, whether it's a puddle or an ocean.

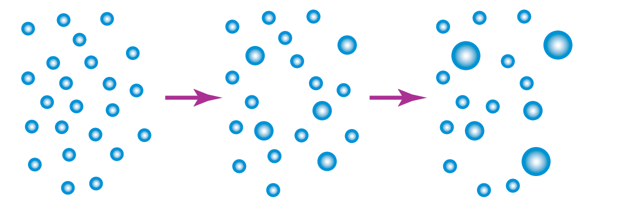
Fig 1.3.1 Water moves around the Earth's surface in a continuing cycle.



Vascular plants transpire large quantities of water into the atmosphere through openings in the undersides of the leaves.

Fig 1.3.2

Vascular plants, such as grasses, trees, shrubs and ferns, contain water-conducting tissues called xylem. Such plants absorb water through their roots. They then transport this water, and the minerals it contains, up through the xylem to the leaves. The price that plants pay for this water transport is that they must continuously lose water from stomata, which are tiny holes in the leaves. This process is called **transpiration**. Transpiration moves a lot of water from the soil into the atmosphere. One large tree is able to transpire a swimming pool full of water every year.



Water drops in a cloud tend to grow by collision. *Fig 1.3.3*

You can only see water in the atmosphere if it has condensed into liquid or solid, since water vapour is invisible. Pressure and temperature changes can cause water molecules in the air to collect together as drops of liquid water. If the temperature is very low, water molecules can come together as ice crystals. If the drops of water or ice crystals are small enough, winds can keep them airborne. A collection of airborne water drops or ice crystals is a **cloud**. Water drops in a cloud may collide and join together, making ever larger drops. Eventually, the drops get too heavy for the wind to hold them up, and they fall out of the sky as **precipitation** such as rain. Cumulonimbus clouds bring thunderstorms, and sometimes hail.

Fig 1.3.4 Hail stones form in cumulonimbus clouds.

Most precipitation occurs over the oceans, returning water directly into the sea. The precipitation that occurs over land creates fresh water rivers, lakes and groundwater, thus keeping all terrestrial organisms alive. Gravity pulls this water downwards, through rivers or groundwater, back into the oceans. Every time fresh water flows over rocks and soil, it dissolves some minerals, mostly salt. These dissolved minerals end up in the oceans, making them increasingly saline over time.

Human activity, such as agriculture and manufacturing, can result in the addition of unwanted chemical compounds to previously fresh water. Once added to fresh water, these pollutants stay in the water. Polluted lakes and rivers can end up full of water that is unsuitable for human consumption. When the pollutants reach the oceans, they slowly build up there, too.

Nitrogen cycle

Nitrogen is an essential element for all living things. Proteins, the basic building block chemicals of living things, contain nitrogen. Despite making up about 80 per cent of the atmosphere, nitrogen is not reactive enough to be available for most organisms. Thus, most organisms ‘breathe in’ nitrogen, but don’t remove any from the air and so they breathe it all out again.

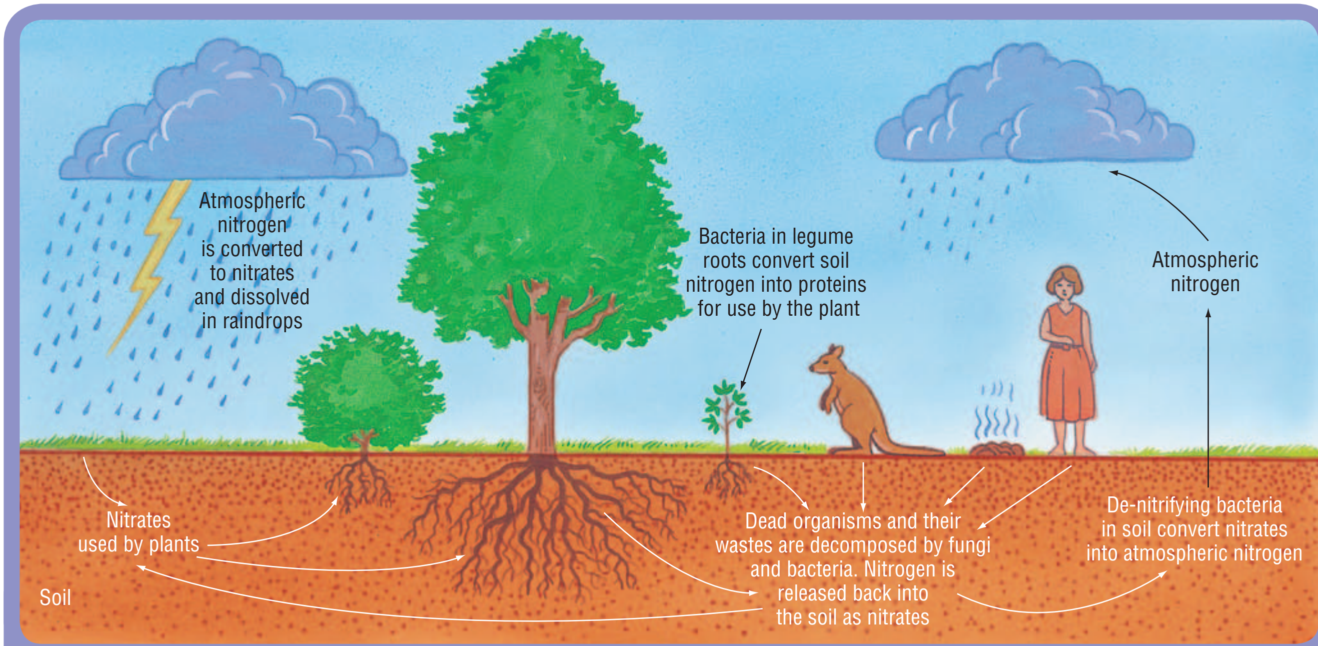
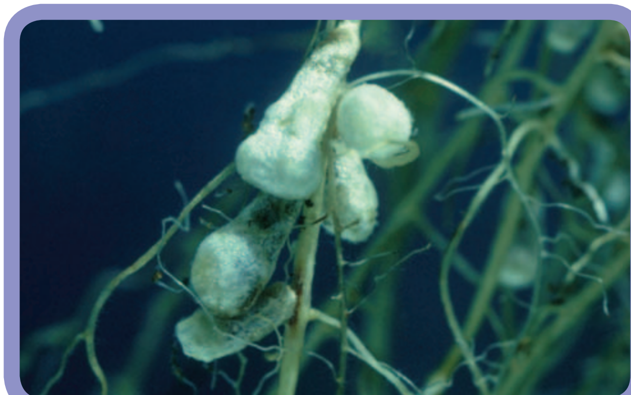


Fig 1.3.5 The nitrogen cycle

A few natural processes, such as lightning, can cause a reaction between atmospheric nitrogen and oxygen. Some unnatural processes, such as burning fossil fuels, can do the same. The amount of nitrogen that becomes available in this way is much too small to sustain life on Earth.

The main source of nitrogen for living things is a group of microorganisms called **nitrifying bacteria**. These bacteria are able to absorb nitrogen, and react with it to make water-soluble substances such as nitrates and ammonium compounds. These are then available for plants to absorb through their roots. Some nitrifying bacteria live in the soil, while others are symbiotic with certain plants, such as **legumes**. The bacteria in legumes live in nodules on the roots. Legumes include clovers, lupins, peas and wattles. If you pull up a clover plant you can see the little lumps on the roots.



Legumes are hosts for symbiotic nitrogen-fixing bacteria. *Fig 1.3.6*

Other bacteria and fungi in the soil convert organic nitrogen compounds into plant-usable nitrates and ammonium compounds. Examples of nitrogen-containing organic compounds include urea, found in manure, and proteins, from the bodies of dead organisms.

Various processes operate to put nitrogen back into the atmosphere. **Denitrifying bacteria** that live in the soil convert nitrates into nitrogen gas. Others convert urea, found in manure, into ammonia gas, which can escape into the atmosphere. Rainfall and movement of the water table can dissolve nitrates and ammonium compounds and leach them into deep soil layers that are beyond the reach of most plants.

Lakes and estuaries can change if too much soluble nitrogen enters, through rivers or run-off. Soluble nitrogen is a fertiliser, so nitrogen build-up increases algal growth, creating an algal bloom. The problem is that 'many living organisms' also means 'many dead or dying organisms'. A bloom may result in the rotting algal remains making the water smell and taste foul. This is called eutrophication.

What we call the nitrogen cycle is a summary of this complex web of interactions. Plants and animals can survive as long as the rate at which nitrogen is fixed, or made available, is equal to the rate at which fixed nitrogen is lost.

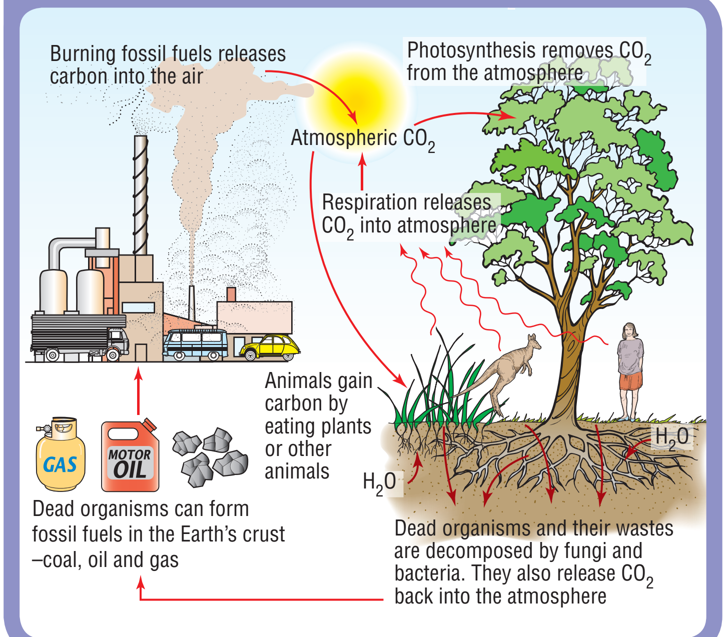
Homework book 1.4 Nitrogen cycle

Carbon cycle

All living things respire, and almost all form carbon dioxide as a waste product of respiration. Plants, animals, bacteria and fungi exhale huge quantities of carbon dioxide every day. Despite this, the amount of carbon dioxide in the atmosphere remains remarkably constant. This is because photosynthetic organisms, or **autotrophs**, take in more carbon dioxide than they excrete. A tree, for example, shows a net removal of carbon dioxide from the air over its life. This is where the carbon in its body comes from. When sunlight is available as an energy source, autotrophs combine carbon, hydrogen and oxygen to make sugars by photosynthesis.

Drag and Drop CW Interactive

Fig 1.3.7 The carbon cycle



Heterotrophic organisms such as animals have to eat other organisms to get their carbon (and hydrogen, and nitrogen) atoms in forms that they can use. You saw this when you looked at the food pyramid. Thus, carbon occurs in the cells of all living things, and carbon dioxide is excreted by all living things as they respire.

The first organisms on Earth were probably anaerobic bacteria. Oxygen initially entered the atmosphere as a pollutant, a waste product. Some bacteria evolved that could metabolise oxygen. They competed with the anaerobes, and won. The atmosphere became a hostile place for anaerobes. They now live in airless places, such as waterlogged soil, or badly sterilised preserved food. They are very useful in your septic tanks if your house is not on deep sewerage.

Carbon also occurs naturally in fossil fuels such as coal, natural gas and petroleum. Volcanoes emit carbon dioxide during eruptions, and burning fossil fuels creates carbon dioxide as well. Carbon dioxide exists both in the atmosphere and dissolved in sea water. Insoluble carbonate rocks, such as limestone, also contain carbon. Some rare rocks contain tiny amounts of carbon as graphite or diamond.

Prac 1 p. 20

Science Snippet

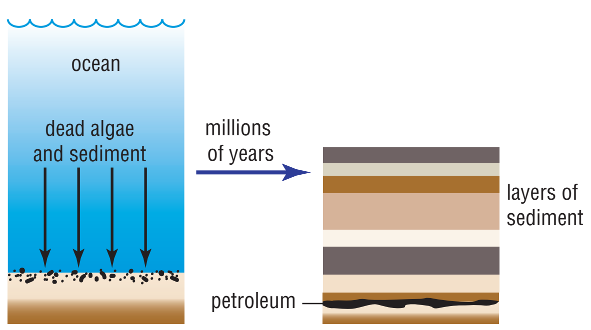
Anaerobic respiration

Aerobic organisms get energy by metabolising oxygen. A waste product of aerobic respiration is water, H_2O. Anaerobic bacteria metabolise sulfur. Their waste product is hydrogen sulfide, H_2S. Hydrogen sulfide smells like rotten eggs and is poisonous to aerobic organisms. Conversely, the oxygen we need is poisonous to anaerobes.

Fossil fuels

Fossil fuels include natural gas, petroleum and coal. They are probably biogenic in origin. This means that they originally came from living things. Coal is mostly carbon, with varying amounts of other materials, such as water and hydrocarbons. The popular explanation for how coal forms involves chemical changes to buried plant material over extremely long periods. Fossil pollen, leaves and stems occur in coal deposits. This supports the biogenic origin hypothesis.

Natural gas and petroleum are hydrocarbons that probably formed from the bodies of aquatic microorganisms such as algae. This hypothesis is supported by the ratios of two isotopes of carbon found in petroleum. As plants carry out photosynthesis, they change the ratio of these



Most petroleum is probably biogenic in origin. *Fig 1.3.8* isotopes. Petroleum tends to have the isotopes present in the same type of ratio as in living plants. The evidence also suggests that fossil fuels have formed at various times, rather than all at the same time. There is a real chance that some gas, petroleum or coal may be in the process of forming now.

Homework book 1.5 Fossil fuels

Science Snippet

Where does petroleum come from?

Most petroleum geologists support the biogenic origin hypothesis. This states that petroleum probably started millions of years ago as the buried, rotting bodies of dead algae. Over many millions of years, the remains of these microscopic organisms changed from a gooey mess into fossil fuels. How exactly this happened is still unclear. A minority of petroleum geologists believe that petroleum comes from abiogenic or inorganic sources. For example, methane may come from huge reservoirs deep in the Earth's mantle. If the biogenic hypothesis is true, it will take tens of millions of years to replace the petroleum we are using. If petroleum is abiogenic in origin, however, there is much, much more oil down there.

Detailed studies of the isotope ratios in natural gas samples suggest that some gas could be abiogenic. However, most petroleum geologists remain unconvinced.

1·3 FOCUS [Questions]

Use your book

Water cycle

1 Plants absorb minerals and salts in the water they take in through their roots. Do plants transpire these minerals and salts through their leaves? Explain.

2 Was the water in the Earth's original oceans, billions of years ago, salty or fresh? Explain your reasoning.

Nitrogen cycle

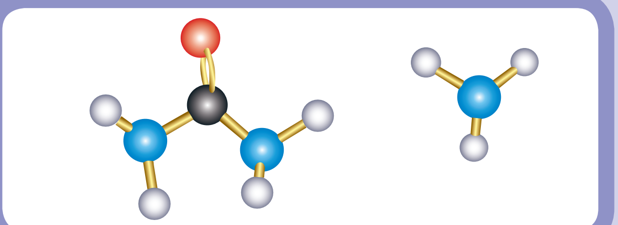
3 Ammonium compounds contain the ion NH_4^+. Nitrate compounds contain the ion NO_3^-. The sulfate ion is written as SO_4^{2-} and the potassium ion is K^+. Write down the formulas of:

a ammonium nitrate **b** ammonium sulfate

c potassium nitrate.

4 The urea molecule is made of carbon, hydrogen, oxygen and nitrogen. The ammonia molecule consists of nitrogen and hydrogen atoms. The structures of the two molecules are shown in Figure 1.3.9. What do denitrifying bacteria do to the bonds between the atoms when they convert urea into ammonia?

Fig 1.3.9 Urea (left) and ammonia (right)



5 Draw a labelled diagram to show how eutrophication might occur when too much fertiliser is applied to a farm or a park near a river.

Carbon cycle

6 Things that supply, or feed, carbon into the carbon cycle are called carbon sources. Things that absorb carbon and remove it from the cycle are called carbon sinks. Make up a table showing at least three carbon sources and at least three carbon sinks.

7 What do you think might happen if:

a heterotrophs stopped excreting carbon dioxide?

b autotrophs stopped taking in carbon dioxide?

Fossil fuels

8 Why are they called 'fossil' fuels?

9 Hydrocarbons have been found in cracks in igneous rock. Explain how the hydrocarbons might have got there if the origin of the hydrocarbons was:

a biogenic **b** abiogenic.

Use your head

10 Cutting down a forest, such as the rain forest in the Amazon basin, can change the climate in the area. How might this happen?

11 The table below shows the ratio of the naturally occurring isotopes of carbon, carbon-12 and carbon-13, as found in the atmosphere, in algae, and in three different natural gas fields.

Source	Ratio of C-13 to C-12 (parts per thousand)
Atmosphere	1.6
Algae	3.5
Gas Field 1	1.4
Gas Field 2	2.9
Gas Field 3	4.2

a Do plants increase the concentration of C-13, or do they decrease it? Explain your reasoning.

b Which of the natural gas fields might contain biogenic gas?

c Which of the natural gas fields might contain abiogenic gas?

12 Farmers who do not use fertilisers, either by choice or by necessity, often plant clover, lupins or some other leguminous plant in a recently used field. >>

After the plants grow, the farmer digs them in and then plants the next crop. How could this procedure replace artificial fertilisers such as ammonium nitrate?

Investigating questions

13 Hailstones are often quite small, but they can be several centimetres in diameter. What conditions could possibly lead to pieces of ice as big as golf balls falling out of the sky?

14 Geologists use the ratio of carbon-12 to carbon-13 to investigate petroleum. There is another isotope of carbon, carbon-14. Why do geologists not worry about this isotope when they do their measuring?

FOCUS 1·3 [Practical activity]

Prac 1 Focus 1.3

DYO

Making limestone

Purpose

To investigate the formation of insoluble carbonate compounds.

Requirements

Test tubes, test tube rack, magnesium sulfate solution, calcium chloride solution, marble chips, stopper with delivery tube, solution of hydrochloric acid (2M).

Procedure

1 Pour about 2 cm depth of calcium chloride into a test tube, label it and stand it in the test tube rack. Repeat this for the magnesium sulfate solution.

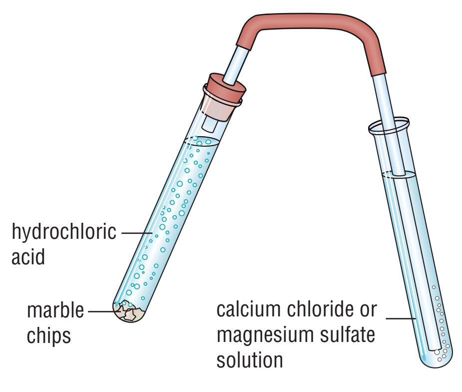


Fig 1.3.10 Making carbonate minerals by precipitation

2 Put a few marble chips in a test tube. Make sure that the stopper fits tightly and the delivery tube reaches down below the surface of the solutions in the test tubes in the rack.

3 Add about 5 cm of hydrochloric acid to the test tube with the marble chips. Stopper the test tube, and quickly put the end of the delivery tube under the surface of the calcium chloride solution. Bubbles should start to come out of the tube. Let it bubble until you see a definite change in the solution, then remove the delivery tube. Stop the reaction by pouring water into the test tube. *Write down your observations in a table.*

4 Rinse the calcium chloride solution off the end of the delivery tube, then bubble some gas through the magnesium sulfate solution. *Write down your observations in the table.*

Questions

1 What was the gas produced when you added acid to marble chips? Write a balanced chemical equation to describe the chemical reaction that occurred.

2 What was the substance produced when the gas bubbled through calcium chloride solution? Write a balanced chemical equation to describe the chemical reaction that occurred.

3 What was the substance produced when the gas bubbled through magnesium sulfate solution? Write a balanced chemical equation to describe the chemical reaction that occurred.

4 Calcium carbonate occurs as limestone, and magnesium carbonate occurs as dolomite. Explain one way in which limestone and dolomite might form.

5 Scientists have said that the world's coral reefs could be in danger if atmospheric carbon dioxide levels keep rising. The suggestion is that:

- coral is made of calcium carbonate
- calcium carbonate dissolves in acids
- carbon dioxide dissolves in water, making an acidic solution.

Discuss with your lab partners how you could investigate this effect to see if it really happens. Check your experimental design with your teacher, and if time allows, carry out your experiment. Be prepared to explain your results to others in the class.

DYO

FOCUS 1.4 The Earth's crust

Context The Earth's crust is a complex mixture of rocks, with a thin layer of soil over most of the land surface. Almost all rocks are made of a mixture of minerals, which have a bewildering range of colours, crystal shapes and other properties. Thus, the rocks have a wide range of properties too; and the soils that rocks create … well, they vary a great deal as well.

Origin of rocks and soils

Most of the Earth's crust is made of **igneous** rock. These rocks form when melted rock cools down and solidifies. **Extrusive** igneous rocks form when lava comes out of a volcano and freezes. Such volcanic rocks form quickly and have small crystals. Sometimes the crystals are so small you need a microscope to see them. **Intrusive** igneous rocks form when magma, which is still underground, cools down enough to freeze. Because they grow more slowly than extrusive rocks, the crystals in intrusive rocks are bigger.

Fig 1.4.1 The dark rock is basalt, the light rock is granite. Which of these igneous rocks is extrusive and how can you tell?

As magma forces its way upwards into cracks in existing rocks, it heats up the rock around it. This intense heating can change rocks chemically even if they do not completely melt. Rocks that have changed this way are called **metamorphic** rocks. Metamorphic rocks look different from the parent rock from which they formed, and often contain different minerals. The high pressures caused by kilometres

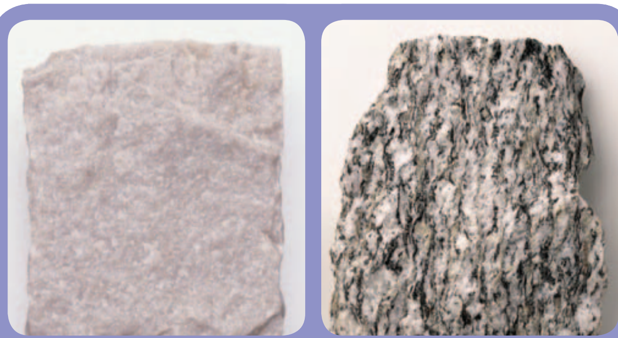


Fig 1.4.2 Quartzite (left) is metamorphosed sandstone. Gneiss (right) is metamorphosed granite. Compare these with the original rock types in Figures 1.4.3 and 1.4.1 respectively.

of overlying rock can also contribute to the way that heat changes a rock. Thus, metamorphic rocks from deep underground may be different from those formed closer to the surface.

Weathering is the process by which air, water and temperature changes break down rocks on the surface of the Earth. The small pieces that break off a rock as it weathers may collect in valleys, stream beds or at the bottom of a lake or the ocean. Layers of small rock fragments are called sediments. Over time, the grains in a sediment may be cemented together, thus creating a **sedimentary** rock. Because sedimentary rocks form at low temperatures, they may contain fossils, as well as minerals quite different from those found in igneous and metamorphic rocks.

The limestone (left) is made of the mineral calcite, and contains fossil shells. The sandstone (right) is made of quartz grains. *Fig 1.4.3*

Science Snippet

Soil biota

A single cubic centimetre of garden soil may contain several billion bacteria. Soil biota also includes fungi, algae and animals such as worms and insects. Many soil bacteria and fungi break down organic matter such as dead leaves and animal droppings. Some soil bacteria and fungi can harm plants and animals. Others produce antibiotics. Yet others do important jobs such as 'fixing' nitrogen so that plants can absorb it to make proteins. Termites break down dead plants, releasing the nutrients in the wood for other organisms to use. In some parts of the world, soil biota also includes larger animals such as moles.

When rock fragments collect on the land surface they usually become soils. However, a soil is not just a collection of rock fragments. In almost all soils, each grain is coated by a thin film of water, which can be absorbed through the roots of plants. This soil water contains dissolved salts. Some of these salts may be useful to plants, while others may be harmful.

Soils also contain organic matter, such as the remains of dead plants and animals, and biota—that is, living organisms. The organic part of the soil is enormously important to us. The fertility of a soil can depend strongly on the amount and type of organic matter it contains.

The parent rock has a big influence on the type of soil that its fragments form. Some minerals, such as pyroxene and feldspar, change chemically as they weather, while others, such as quartz, strongly resist chemical change.

Parent rocks rich in quartz, such as sandstones or granite, tend to create sandy soils. Basalt, a rock rich in the minerals pyroxene and feldspar, tends to create soils that contain lots of clay.

The rock cycle

In the beginning, about four and a half billion years ago, all rocks on the Earth's surface formed from cooling magma. These rocks were almost entirely igneous, with some metamorphic rocks forming around the hotter, slower cooling magma chambers. As time went by, weathering resulted in the breakdown of these original rocks, and the first sediments formed. The oldest sedimentary rocks found date back to almost four billion years ago.

This process of rock solidification, rock alteration and rock breakdown has continued ever since the beginning. All types of rock can be altered by heating to make metamorphic rocks; be weathered to form sediments; or be dragged by subduction to depths where the rock melts into magma. This interrelationship is called the rock cycle.

Most of the rocks at the Earth's surface have been recycled continuously ever since they first formed.

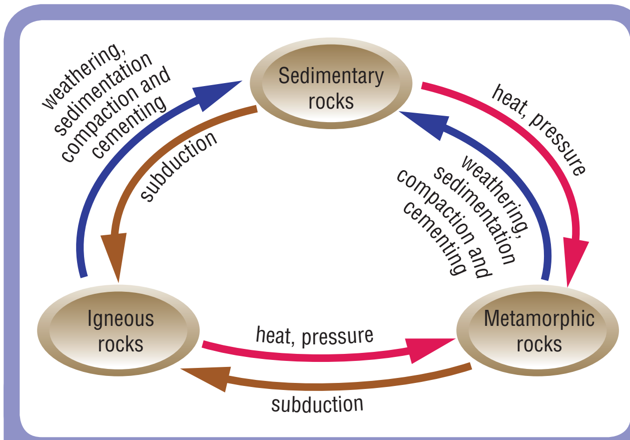


Fig 1.4.4 The rock cycle explains how one type of rock may form the basis for another type, as weathering and plate tectonics recycle rocks in different ways.

Drag and Drop CW Interactive

Although the processes are slow by human standards, over billions of years there has been complete change. No one has ever found rocks old enough to be part of the original crust, that is, 4.54 billion years old. All the rocks around us are younger, most of them much younger. The oldest rocks in Western Australia date back to about 3.7 billion years. By contrast, the limestones along the south-west coast are mostly only a few tens of millions of years old.

Homework book 1.6 Rock cycle

Science Snippet

The strange case of the old crystals

All sedimentary rocks are made of grains that are older than the rocks themselves. In some cases, the grains are much, much older. Some old sedimentary rocks from northern Western Australia have been found to contain some amazing ingredients. The mineral zircon is both very hard and very resistant to chemical change. This makes zircon a survivor. Using radioactive dating techniques, researchers have found that some individual zircon crystals are 4.4 billion years old. They are only a hundred million years or so younger than the Earth itself. Because zircon forms in the crust rather than the mantle, it seems that even at that early stage the Earth already had a solid crust.

Fig 1.4.5 The yellow part of this rock is a large zircon crystal.

Physical properties of rocks and soils

Rocks differ in many ways. For example, they can have different colour, grain size, density and hardness. The properties of rocks depend mostly on their minerals. Hard minerals, such as quartz, tend to form hard rocks, while softer minerals, such as calcite, tend to form softer rocks. High-density minerals lead to high-density rocks, dark-coloured minerals to dark rocks and so on.

In a similar way, the properties of soils depend on the minerals they contain, the grain size and the organic content. The proportions of small grains (clay) to larger ones (sand) decide most of the physical properties of a soil. For example, clay soils tend to form solid clumps, while sandy soils are generally free-flowing.

Prac 1 p. 25

Fig 1.4.6 The sand grains in this view have been magnified about 100 times.

Chemical properties of rocks and soils

A rock is a mixture of minerals, and each mineral in a rock has its own chemical properties. This means that if you check the chemical properties of a rock, you are really checking the properties of several minerals simultaneously.

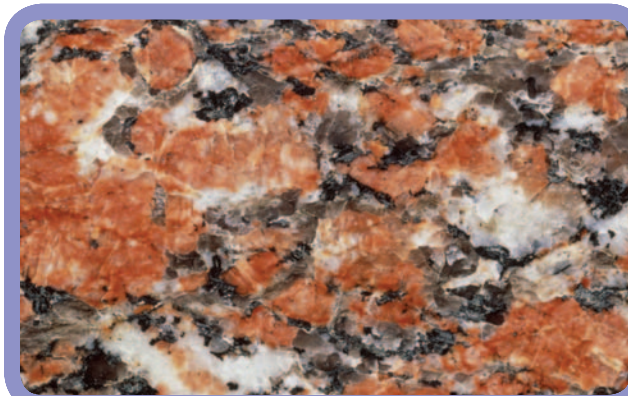


Fig 1.4.7 This view of a sample of granite shows the major minerals quartz (grey), feldspar (white and pink) and biotite (black).

Calcite is a mineral that is common in sedimentary rocks, but not in igneous rocks. Adding acid to calcite causes a fizzing reaction in which the gas carbon dioxide is given off as the calcite dissolves. Marble, limestone and sea shells are almost pure calcite. Many sedimentary rocks contain calcite as fossils, and as a kind of glue or cement that enables the grains to stick together. The equation for the reaction between hydrochloric acid and calcite is:

$$CaCO_3\ (s) + 2HCl\ (aq) \rightarrow CaCl_2\ (aq) + H_2O\ (l) + CO_2\ (g)$$

This reaction is typical of the response of minerals that contain carbonate ions. Dolomite ($MgCO_3$) is another example of a carbonate mineral.

The clay in some soils collects other chemicals on its surface through a process called adsorption. This is important when adding fertiliser to such soils because the clay may adsorb and hold some of the fertiliser from the water in the soil. In this case, plants may not easily take it up through their roots.

Prac 2 p. 25

Fig 1.4.8 The mineral calcite forms distinctive crystals with parallel sides.

1·4 FOCUS [Questions]

Use your book

Origin of rocks and soils

1 How are intrusive igneous rocks different from extrusive igneous rocks?

2 Heating up a rock may create a new metamorphic rock, or a new igneous rock. Explain how each of these could happen.

>>

3 Why is it that sedimentary rocks may contain fossils, but metamorphic and igneous rocks never do?

4 Draw a flow chart or a series of small labelled diagrams to show the sequence of events that takes place as a rock becomes soil.

The rock cycle

5 If anyone ever finds a sample of the Earth's original crust, will it be an igneous, a metamorphic or a sedimentary rock? Explain your reasoning.

6 The rock cycle describes how rocks of one type can become rocks of a different type.

- **a** Describe briefly how granite can become sandstone.
- **b** Suggest how sandstone might turn into quartzite (a metamorphic rock).
- **c** Is it possible for quartzite to become sandstone? Why, or why not?

Physical properties of rocks and soils

7 Both limestone and marble are made of calcite. A sample of limestone had a significantly different density from a sample of marble. Close inspection showed the limestone had air spaces between its grains while the marble had no air spaces. Which rock was denser, and why?

8 The soil in most of the Perth region is free-flowing when you dig it. What does this suggest about the grains that the soil is made of?

9 You can test the make-up of a soil by adding lots of water, shaking it and letting it settle. The biggest grains settle first (at the bottom of the container) while the smallest particles settle more slowly and collect at the top. Much of the organic matter may float. Draw a labelled diagram of a soil that has been tested this way—about three-quarters of the soil is sand-sized grains and one-quarter is clay-sized grains, with a small amount of organic matter.

Chemical properties of rocks and soils

10 If you put a piece of dolomite into hydrochloric acid a reaction occurs.

- **a** Predict the names of the products of this reaction.
- **b** Write a word equation or a chemical equation for this reaction.

11 Max had two soil samples, one from a farm, and one from a city garden. What should Max observe or measure to describe how these soils are similar and how they are different?

Use your head

12 Obsidian, also called volcanic glass, is an igneous rock. It contains almost no crystals because when it was formed it froze too quickly for crystals to have time to grow. Is obsidian likely to be an intrusive or an extrusive igneous rock? What evidence supports your answer?

13 The mineral calcite never occurs in igneous rocks. What does this suggest about the properties of calcite?

14 Where in the world might you find soils that do not have a thin layer of water around each grain?

15 Max treated samples of four different rocks with hydrochloric acid, and recorded the results as shown in the table below. One of the rocks was marble (a metamorphic rock that is almost pure calcite), one was a quartz sandstone cemented by calcite, one was a limestone with some quartz sand in it, and one was an igneous rock that contained no calcite at all.

Rock	Mass before treatment with acid	Mass after treatment with acid
A	3.56 g	3.41 g
B	4.97 g	0.25 g
C	8.83 g	8.82 g
D	6.22 g	5.89 g

- **a** Which sample probably contains calcite as a cement? How do you know?
- **b** Which sample was probably marble? How do you know?

16 If you weighed some beach sand, treated it with hydrochloric acid, then weighed it again, what would you expect to find? Explain your answer.

Investigating questions

17 Using several rock samples and various common items such as a knife blade, glass, ceramic and so on, develop a scale of hardness by seeing which scratches the other. Compare your results to other groups' scales. Are all the scales the same? What factors might make hardness of a rock difficult to report in a repeatable way?

18 Soil is not just the stuff that plants grow in. Over time, people have found many different uses for soil. For example, scientists have discovered soil organisms that produce antibiotics. Brainstorm as many other uses for soils as you can think of. Choose one of your ideas and find out when and where people have made use of soil in this way. Present your findings as a model, as a poster or in electronic form.

1·4 FOCUS [Practical activities]

Physical properties of rocks

Prac 1 Focus 1.4

DYO

Purpose

To investigate the colours and densities of some rocks.

Requirements

Rocks samples, hand lens, access to standard laboratory equipment, calculators.

Procedure

Colour

1. What colour is your rock sample overall? Are different parts of it different colours? Does a fresh surface look different from one that has been exposed to the air? *Write down your observations.*
2. Observe separate grains (eg with a hand lens or a microscope). What colours are the separate grains? *Write down your observations.*
3. Repeat this with other rock samples. Compare your results with those from other groups. *Record your observations for each rock type.*

Density

1. What is the formula for working out the density of a substance? *Write down the formula you have found out.*
2. What two properties of your rock sample will you have to measure in order to work out its density? *Write down the two properties you will investigate.*
3. As a group, discuss what you will have to do to measure the properties. *Write down the procedure you will follow, including the equipment required.*
4. Choose one sample of rock, identify its type and measure the above properties. *Record your measured values.*
5. Using your calculators, work out the density of your sample and *write down your results.* Compare your value to those that other groups obtained for the same rock type.

Questions

1. What is the 'official' colour of the rock that you worked with? Is your observed colour close to this? What might explain any differences?
2. What range of colours did the class find overall?
3. What is the 'official' value for the density of the rock that you worked with? Is your measured value close to this? What might explain any differences?
4. What range of densities did the class find overall?

Chemical properties of rocks

Prac 2 Focus 1.4

Purpose

To investigate the effect of acid on rocks.

Requirements

Small samples (chips) of an igneous rock and a limestone, access to an oven, access to a balance, 200 mL dilute hydrochloric acid, two 500 mL beakers, two large watch-glasses, water, heat proof gloves.

Procedure

1. Heat a chip of igneous rock and a chip of limestone in the oven at about 80°C for a day, then weigh each and *record the masses.*
2. Put each chip into dilute (2M) hydrochloric acid solution, in separate beakers. Cover each beaker with a large watch-glass. *Record any observations.*
3. Leave the chips in the acid overnight. *Record any observations.*
4. Use water to rinse the remains of the rocks, dry them in the oven, weigh them and *record the masses.*
5. Did all groups observe the same pattern of results?

Questions

1. Why did you have to heat the rocks in an oven before weighing them?
2. Did the igneous rock react with acid? What evidence do you have?
3. Did the limestone react with acid? What evidence do you have?
4. Write down equations for any chemical reactions you have observed.

FOCUS 1·5 Plate tectonics

Context

A quick look at a globe or an atlas will show you that the coastlines of Africa and South America seem to fit together remarkably well. For many years, this was explained as a coincidence. We know now that Africa and South America were once part of the same continent, which split open and drifted apart millions of years ago. The energy needed to split a continent, then push the pieces apart, is enormous.

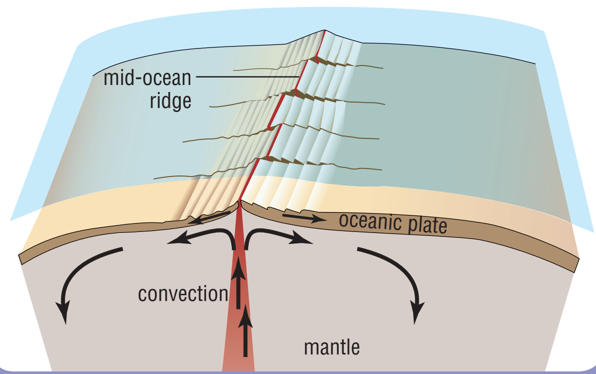
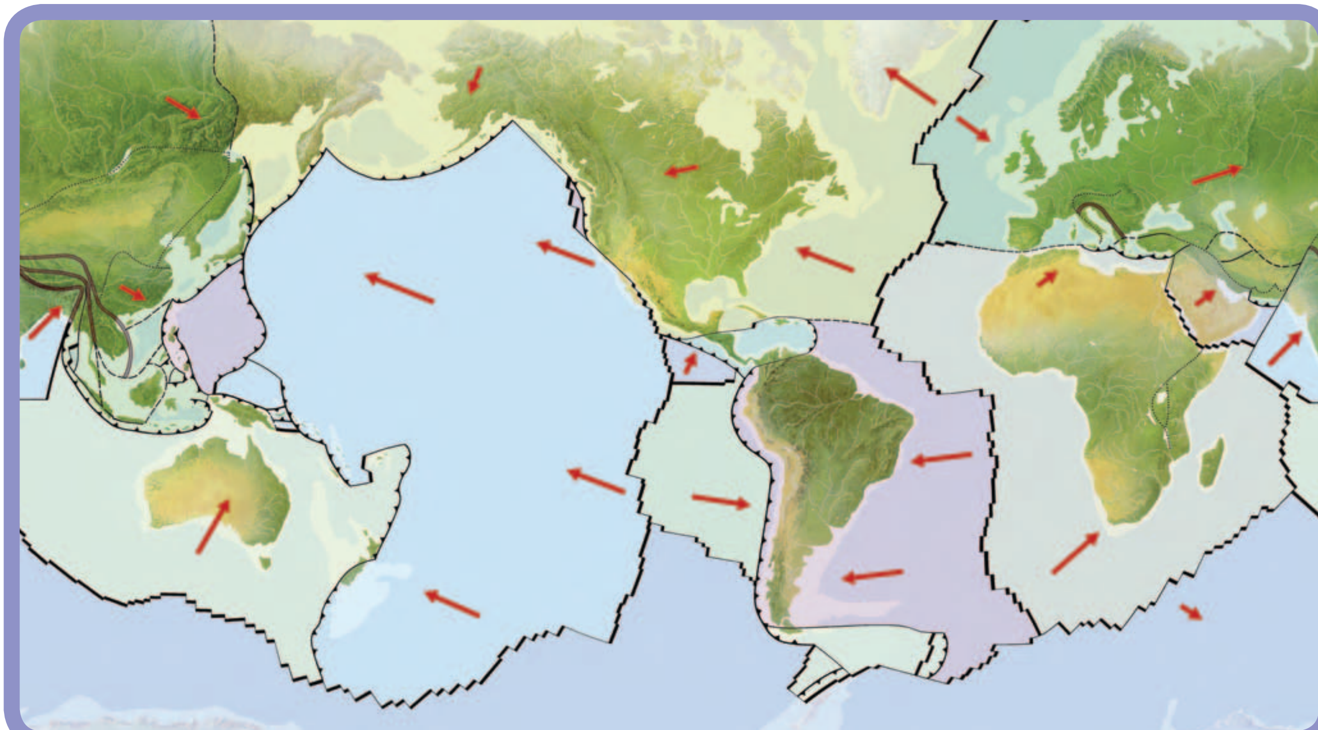


Fig 1.5.1 Convection currents in the mantle may move the crust.

What is plate tectonics?

We live on the Earth's rocky outer surface, which we call the crust. Far below us, the solid rock changes into a semi-solid layer, the mantle, which behaves like a very thick, sticky liquid. Slow convection currents in the mantle move the rock material around, bringing thermal energy from the core and lower mantle up towards the surface. The energy that heats the core and mantle comes partly from the energy trapped in the core when the Earth formed, and partly from nuclear reactions in radioactive atoms in the rock.

The Earth's crust is made of pieces, or plates, of different sizes. We know that these crustal plates move around, but we do not yet know what drives this movement. One popular theory is that the convection



The Earth's surface is made up of interlocking crustal plates. *Fig 1.5.2* currents in the sticky mantle drag the crust along by friction. Evidence supporting this idea came with measurements of the heat flow on the ocean floor. Heat flow is highest at the mid-ocean ridges. The heat carried up by convection could be coming out of the crust along these ridges, where new rock forms continuously.

An alternative to the convection theory is that gravity pulling on denser rock may provide the driving force that moves the plates around. Oceanic crust is hottest when it is new. As it moves away from the mid-ocean ridge, it cools and contracts. The decrease in volume increases its density. Thus, the older, cooler, denser parts of the plates could pull the newer, hotter, less dense sections apart, allowing new crust to form.

Fig 1.5.3 Oceanic plates are thinner than the continental plates.

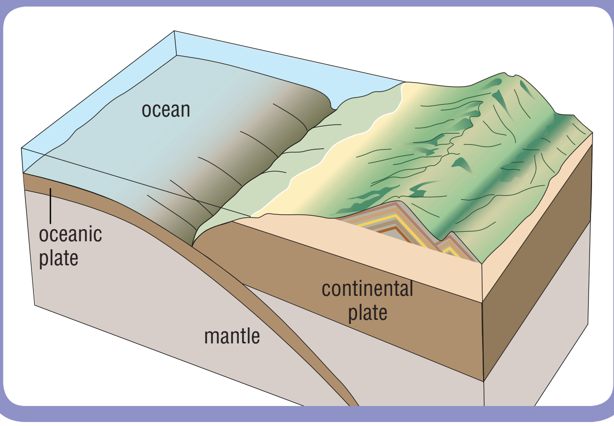


Fig 1.5.4 The present-day continents once fitted together to make a super continent.

Types of plate margins

When plates move, they can move apart, slide past each other, or come together. The types of plate movement decide what happens at the boundaries, where plates meet. An area where two plates move apart is called a diverging or spreading boundary. Two colliding plates form a converging boundary. Plates scraping past one another create a transform fault boundary. Some plate interactions are not easily classified. Plate boundary zones are large areas where the movements of the plates, and the effects of those movements, are not at all clear.

Most of the changes caused by plate movement happen around the edges, where plates come in contact. The plates that make up the ocean floors are made of dense, dark-coloured rock, while the continental plates are made of less dense, lighter-coloured rock. These density differences determine which plate, if any, will be pushed under the other when plates collide.

Diverging boundaries

At a **diverging** boundary, the plates move away from each other, and magma rises into the opening. New rock continually forms in the oceans, along the lines where the plates spread apart. The emerging basaltic rock forms ridges, sometimes called mid-ocean ridges because the first ridge to be discovered runs down the middle of the Atlantic Ocean. A typical mid-ocean ridge has a central rift valley with higher ridges on

Science Snippet

Palaeomagnetism

The Earth's magnetic field flips, apparently quite rapidly, at odd intervals. Thus, a compass that points north today will one day, after such a flip, point south. Geophysicists can work out the direction of the Earth's magnetic field when magma cooled by looking at magnetic crystals in the rock. These crystals have their own magnetic fields, which originally lined up with the Earth's field when the crystals cooled down. Studies of such palaeomagnetism in rocks around the mid-ocean ridges show a striping effect, with parallel strips of rock having opposite magnetic fields. This is evidence that rock forms at a mid-ocean ridge and then moves away from it.

Science Snippet

Super continents

According to the theory of plate tectonics, continents have moved around for billions of years. Over this time, tectonic plates have merged, then split apart again, forming continents of all shapes and sizes. The last time that most of the continental plates were together, they formed a super continent known as Pangaea. Over time, a process of rifting, which is separation of landmasses and subsidence, split this super continent into Laurasia (in the north) and Gondwana (in the south). Being able to trace the paths of the continents this way has changed mineral exploration enormously, because it is now possible to connect known deposits with as yet undiscovered ones.

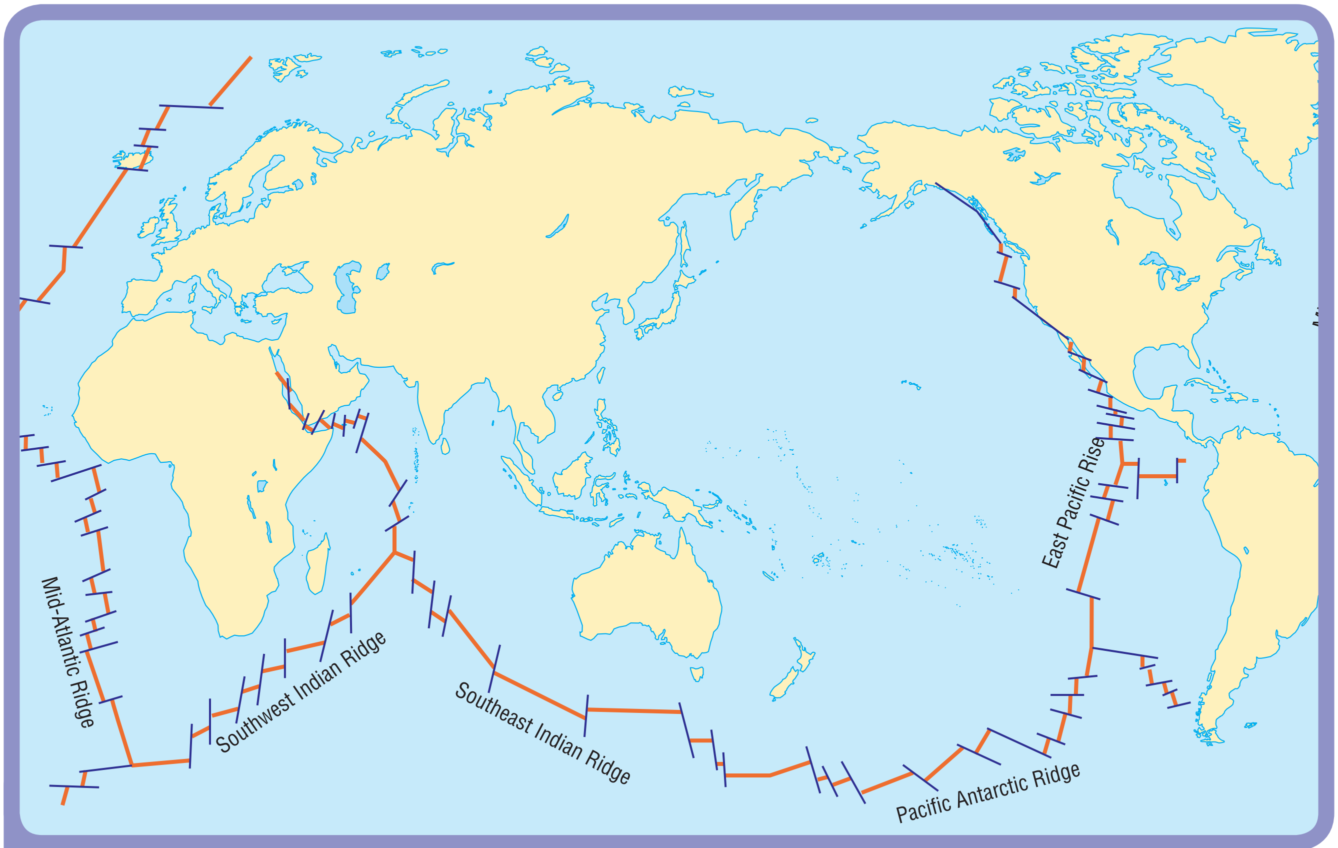


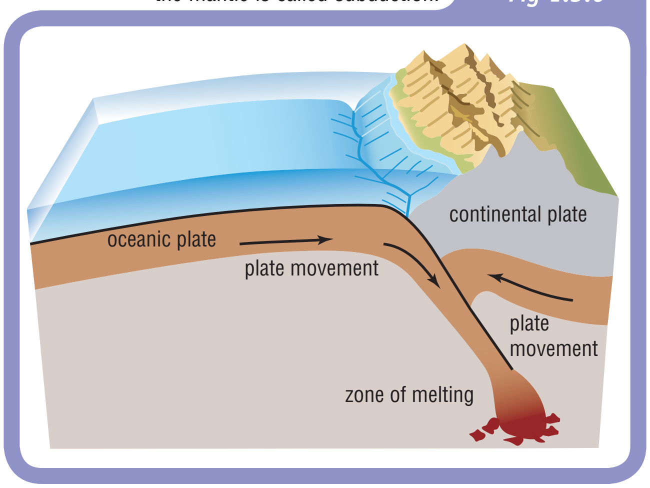
Fig 1.5.5 Locations of the mid-ocean ridges in the major oceans

Drag and Drop cW Interactive

either side, and may stand two or three kilometres above the ocean floor. A diverging boundary is therefore a place where new material is continually added to an oceanic plate.

Converging boundaries

Fig 1.5.6 The movement of a plate downwards into the mantle is called subduction.



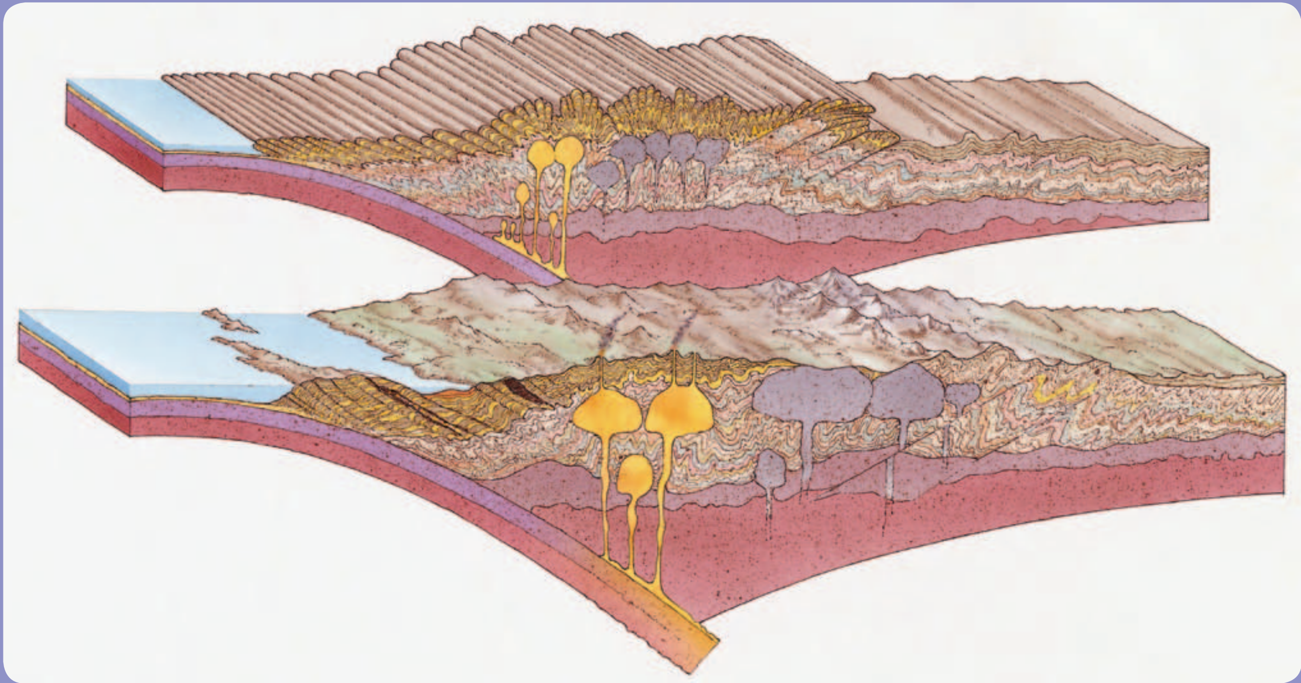
When two plates collide, the result is a **converging** boundary. The forces involved in the collision are huge, and they buckle and crack the rocks of both plates.

If two oceanic plates collide, one is always subducted while the other rides over the top of it. A deep ocean trench forms along the line where the subducting plate descends into the Earth. The descending plate melts as it goes deeper into the mantle. Thus, a converging boundary that involves an oceanic plate is a place where oceanic crust is continually being destroyed.

If a continental plate collides with an oceanic plate, the less dense continental plate rides up over the denser oceanic plate. As the continental plate rises and deforms, it creates a belt of fold mountains. The descending oceanic plate creates a deep trench in the ocean, roughly parallel to the mountain range.

If two continental plates collide, neither is dense enough to be subducted. Instead, both plates are deformed, rather like two pieces of plasticine being pushed together. This process lifts up mountains as the upper surface is pushed upwards. At the same time, the lower parts of the colliding plates

Fig 1.5.7 Fold mountains form where colliding plates force one or both plates upwards.



push downwards, creating deep 'roots' under the mountains. A striking example of such a fold mountain belt is the Himalayas, created as the Indian Plate ploughs into the Eurasian Plate.

Homework book 1.7 Plate tectonics

Transform boundaries

The term '**transform boundary**' refers to the situation where two plates move in parallel but opposite directions. When this happens, the plates move in a series of sudden movements along splits in the rock called fault lines. A common feature of transform faults is the sideways displacement of once-continuous rock strata. Material is neither added nor destroyed at a transform boundary.

Each sudden shift of the plates creates shock waves that spread outwards, through the rock. On the surface, these shock waves move the ground chaotically, both up and down and from side to side. This is an earthquake. Probably the most famous transform boundary is the San Andreas Fault, located on the western coast of North America. A long, narrow feature, the San Andreas Fault is the origin of many earthquakes.

Homework book 1.8 Where do quakes happen?

Fig 1.5.8 The San Andreas Fault lies along a transform boundary.

Volcanic activity

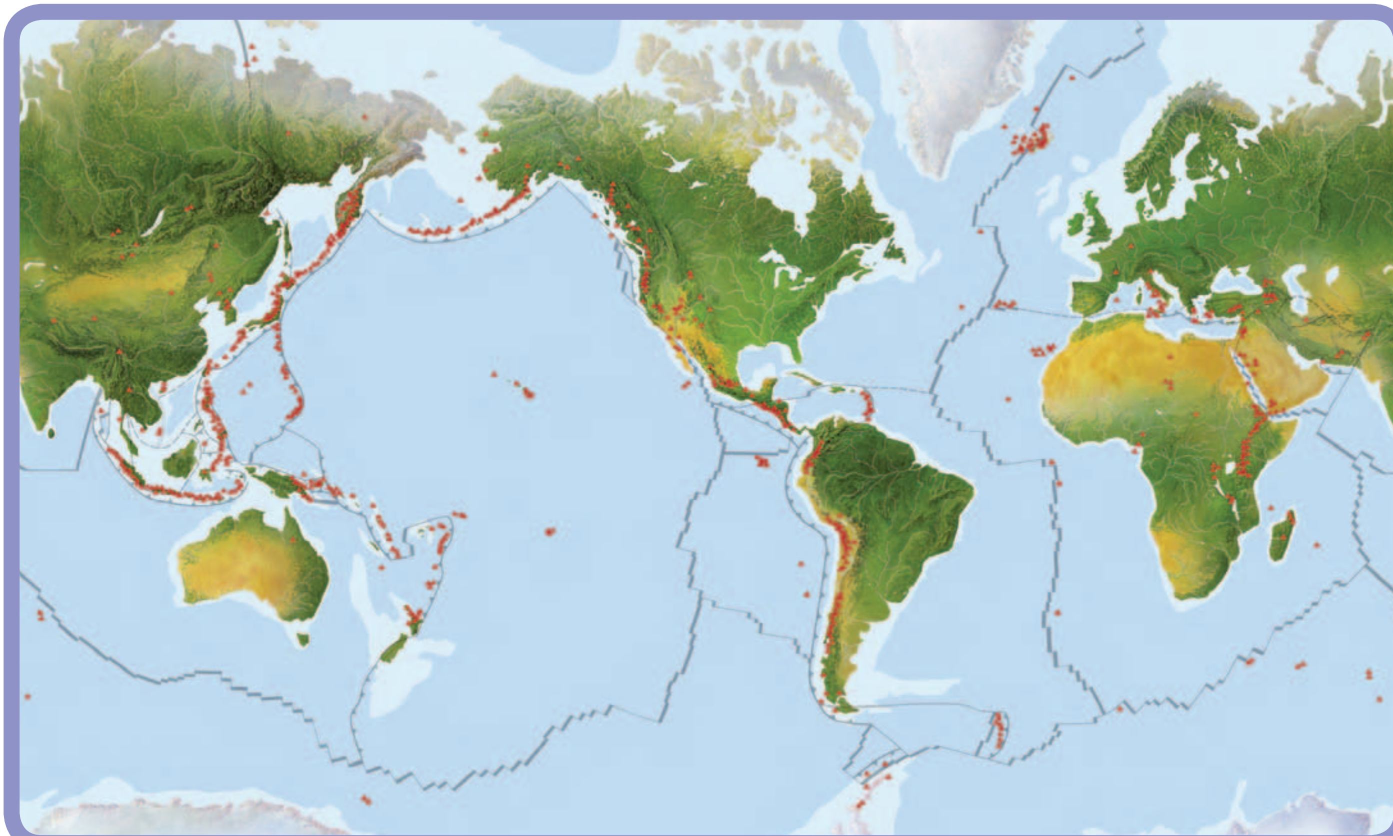


Fig 1.5.9 The Pacific Plate is surrounded by hundreds of active volcanoes. This is called the Pacific 'Ring of Fire'.

Science Snippet

Black smokers

No plants live on the deep ocean floor, and without a base for the energy pyramid, there is little to sustain animal life. And yet, there are tiny pockets where animals live in large numbers. These are places where plumes of very hot sea water containing dissolved minerals emerge from the ocean floor. They are called 'black smokers' because of the clouds of black sulfide minerals that precipitate as the hot water cools rapidly. The giant worms, blind crustaceans and other animals living around black smokers feed on bacteria that live in very hot water. It is possible that life on Earth originated in just such a place billions of years ago.

Most volcanoes form near plate boundaries. The lava, ash and gas that come out of most erupting volcanoes have their origins in the melting edge of a subducting plate. As the plate descends into the mantle, the magma it creates as it melts tends to move up towards the surface through fissures, or cracks in the rock. Usually it collects far underground, in a magma chamber. Eventually, this magma either escapes to the surface through a volcanic vent, or cools, crystallises and forms igneous rock.

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Some volcanoes, such as those that make up the Hawaiian island arc, form far from any plate boundaries. The islands that make up Hawaii are probably the world's tallest volcanoes, because they rise so high from the deep sea floor. The volcanic activity that built the islands is the result of a magma plume or 'hot spot' under the middle of the Pacific Plate. The rising magma periodically breaks through the crust and creates a volcano, which eventually becomes extinct as the plate's motion carries it away from the magma plume. Thus, all the Hawaiian islands are volcanic, but only the most recently formed volcanoes are active at any one time.

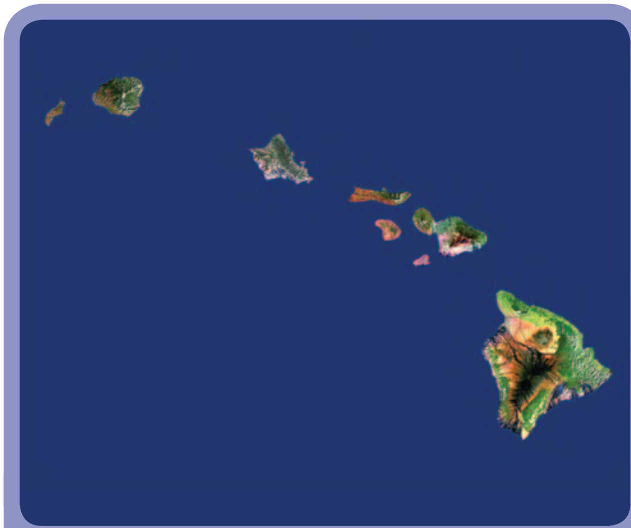

Fig 1.5.10 The Hawaiian island arc has formed over a single 'hot spot' that is a long way from any plate margins.

Interactive CW Animation

Some hot spots occur under continental plates. Yellowstone National Park in mid-western USA lies over a hot spot. The magma chamber under Yellowstone is huge, and its heat causes geothermal activity such as hot springs and geysers. Such long-lasting magma plumes suggest that convection cells in the mantle are not as simple as once thought. Geologists estimate that fifty or so hot spots may be active at any one time.

Drag and Drop CW Interactive

Homework book 1.9 Volcanoes—where are they?

1·5 FOCUS [Questions]

Use your book

What is plate tectonics?

1 Draw a labelled diagram showing how a convection current in the Earth's mantle could make a crustal plate move.

2 Why is the high heat flow at mid-ocean ridges considered to be evidence that convection is responsible for plate movement?

3 Draw a labelled diagram showing how density differences in crustal plates could make the plates move.

Types of plate margins

4 Draw up a table showing the major types of plate boundary, including a description of what happens at each type of boundary.

5 How does a plate boundary zone differ from other types of plate boundary?

Diverging boundaries

6 Iceland, an island in the Atlantic Ocean, sits right on top of a diverging plate boundary. Would you expect Iceland to be made of volcanic rocks, old continental crust, or uplifted oceanic crust? Explain your reasoning.

7 Explain why palaeomagnetic striping parallel to mid-ocean ridges is considered to be evidence that these ridges are sites where new sea floor is being created.

Converging boundaries

8 Converging plate boundaries can vary enormously.
- **a** What factors decide what happens when two plates collide?
- **b** Why does subduction happen in some cases but not in others?

9 If you wanted to find places in Australia where continental plates might have collided in the past, what would you look for?

Transform boundaries

10 Draw a labelled diagram showing the likely pattern of rocks on either side of a transform boundary.

11 The movement of plates at a transform boundary is jerky rather than smooth. Explain why plates tend to move suddenly instead of sliding evenly past each other.

Volcanic activity

12 Draw a labelled diagram showing the relationship between convection currents in the mantle, and the formation of an island arc a long way from any plate boundaries.

Use your head

13 New ocean floor is continually created at diverging plate boundaries. Does this mean that the Earth must be getting bigger? Justify your answer.

14 Fold mountains all over the world have rock strata containing fossils of marine organisms. Some of these occur high above sea level. How can the remains of deep-sea creatures end up at the top of a high mountain?

15 Earthquakes often occur because of the jerky motion of plates at a transform boundary.
- **a** What factors might affect how strongly an earthquake is felt at a particular location?
- **b** There have been proposals to reduce the severity of earthquakes around the San Andreas Fault by pumping water into the rock near the fault. How might this make earthquakes less severe?

>>

16 Is it more accurate to say that ocean crust is *created* at a mid-ocean ridge, or that it is *recycled*? Explain your answer.

Investigating questions

17 The Earth's magnetic field affects compass needles. It has other, less obvious effects, which range from deflecting some types of radiation coming in from space, to guiding some migratory birds as they migrate between their summer and winter homes.

- **a** Research these and other possible effects of the Earth's magnetic field.
- **b** Suggest and discuss some changes that might result if the Earth's magnetic field 'flipped' tomorrow.

18 What is the accepted geological age of the iron ore deposits in north-western Australia? Where do other iron ore deposits of similar age exist elsewhere in the world? Is there evidence that these deposits were once linked tectonically?

19 The magma that causes volcanic activity near plate margins is very different from the magma that creates volcanoes far from plate boundaries.

- **a** How are these magmas different?
- **b** What effect does the difference in magmas have on the type of volcano found in these locations?

FOCUS 1·5

[Practical activity]

Modelling the effects of plate tectonics

Prac 1 Focus 1.5

DYO

Purpose

To create models of the various effects at plate boundaries.

Requirements

Plasticine of at least two colours, greaseproof paper or other material to protect the work surface, and access to a video camera or a digital camera.

Procedure

1. Discuss how you can use the plasticine to make models of tectonic plates. *Write down the method your group will use.*
2. Discuss how you can use the plasticine models to simulate collisions between tectonic plates. Your method should allow you to simulate converging boundaries between two continental plates, between a continental and an oceanic plate, and between two oceanic plates. *Write down the methods your group will use.*
3. Try one of the simulations. If your method worked to your satisfaction, record the effects with the camera, and by *writing down your observations in a table.*
4. If your method did not work properly, discuss how you could improve it. *Write down the problem you identified, and the method you devise to overcome the problem.*
5. Once you have the simulation working, try each of the other types of collision. *Record your observations.*
6. Create a report about your simulations. *Use a poster, an electronic presentation or a booklet to inform your audience about your findings.*

Questions

1. In what important ways did your simulation represent actual plate collisions?
2. In what important ways did your simulation misrepresent actual plate collisions?
3. In what ways, if at all, did your simulation illustrate aspects of plate boundaries such as subduction, mountain formation, folding, faulting, volcanism, or earthquakes? Explain.

FOCUS 1·6 Fossils and dating

Context

How old is the Earth and what organisms have lived here in the past? These questions have fascinated humans throughout history. However, it is really only in the last 100 years that we have been able to give some accurate answers to these questions. This is the subject of Focus 1.6.

Science Snippet

Amazing fossils

Some amazing fossils have been found. Many early humans have been found, such as the Lake Turkana Boy. This is a fairly complete skeleton of a young boy about 9 to 12 years old, based on his teeth. He lived about 1.6 million years ago. You can see some great images of him on several websites. His official fossil number is KNM WT 1500.

Fossils

Fossils are the preserved evidence of organisms which were alive long ago. They can tell us what kind of organisms lived in the past.

Most fossils form when the dead organism is covered by sediment. This would happen at the bottom of an ocean, lake or river. It has to happen quickly before scavenger organisms can eat the dead body. The small particles of rock in the water sink to the bottom and cover the dead organism there. The sediment slowly builds up and the pressure of overlying sediment eventually turns it into rock. When the rocks are exposed at the surface of the Earth by erosion the fossils can be discovered. So fossils are found in sedimentary rock.

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Some types of fossils are:

- original fossils—a part of the organism is preserved, such as a skeleton
- replacement fossil—a part of the organism is changed into another chemical compound, such as calcium carbonate shells turning into silicon dioxide (sand)
- mould—an imprint of the outside of the body is made in rock
- cast—an organism in rock decomposes and the space in the rock fills with soil and turns to rock
- carbon trace—the body partly decomposes to carbon and leaves an outline
- indirect—a trace of activities, such as a row of footprints, dung or burrows.

Fig 1.6.1 Some fossils. A dinosaur (an oviraptor) and one of its eggs, an amphibian and a human skull of the extinct species called Neanderthal

Drag and Drop CW Interactive

Relative dating of fossils

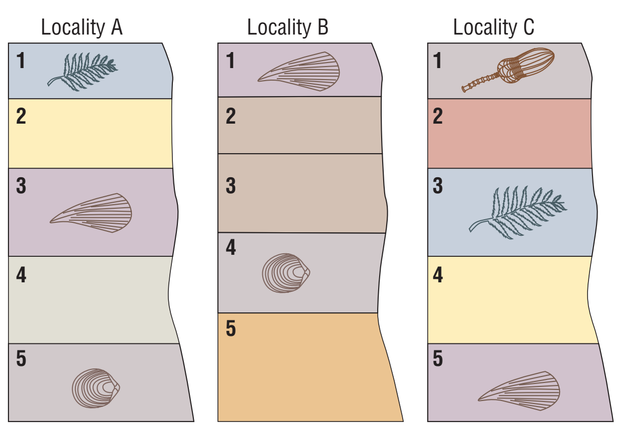
Because sedimentary rock forms in layers from the bottom, the bottom layers of rock are the oldest. So in one location it is easy to work out which organisms lived earliest. The only times this is not true is if the layers have become folded over and turned upside down by earth movements, or if something has been buried.

In the history of life it appears that each species has only lived for a short time. The fossils show this. Each fossil species is found in only a narrow layer in rock strata in any location. For example, certain species of dinosaurs are found together, but only in a particular layer at a particular depth in the sequence of rock strata in the one location. In other locations the same species of dinosaurs seem to occur as well, but again only in a particular narrow layer.

This gives us a way of comparing the age of rocks in different localities. We know the fossil species must have only lived at a particular time in the past, so rocks containing the fossils must be the same age. This type of dating is called **relative dating**. We can only say how old something is compared with another, but not the actual age for each.

For example, compare the rock layers in Figure 1.6.2. We can say that layers A3, B1 and C5 are the same age because they had the same fossil species in them. Layers A5 and B4 are the same. So are A1 and C3. So we can say that the oldest layer in the three localities is B5. The youngest is C1.

Fig 1.6.2 Rock layers can be compared in different localities to work out when different species lived in the past.



Fossils of organisms that lived for a very short time in the past and occur in many different localities are very useful to date different rock layers like this. These fossils are known as **index fossils**. Comparing rock layers like this to determine their relative age is called **stratigraphy**.

Absolute dating

Comparing layers to see which one is older still does not tell us how long ago the layer was formed. Methods that give us an actual age of rocks and fossils are called **absolute dating** methods. There are many methods of absolute dating, and more are being discovered all the time. The best known is radioactive dating.

Radioactive dating uses the breakdown rate of radioactive **isotopes**. These are atoms of an element that have extra neutrons. For example, carbon 12 and carbon 14 exist. Carbon 14 is radioactive. Potassium 39 is not radioactive, but potassium 40 is. Elements such as these break down at a steady fixed rate and release particles or rays called radiation, which can be detected. If we know the rate at which these elements disintegrate, then we can work out how long ago the rock was laid down. Many elements can be used, depending on the type of fossil and the type of rock. As an example, radioactive potassium 40 is found mainly in rocks that contain ash from a volcano.

A history of life

Using absolute dating methods scientists have worked out a sequence in which life seems to have developed. A series of time periods that shared some major important events have been constructed and named. The resulting time scale of life and geology in the past is called **geological time**.

These dating methods have given scientists a way to show which species lived first. We can write a history of life. For example, there was a time when there were no vertebrates. We know that fish appear in the fossil record before amphibians, and these came before reptiles. From these observations scientists have developed a theory that life **evolved**, meaning that it changed from simple organisms to very complex ones. The fossils show that simple organisms came first.

Homework book 1.10 Tiktaalik and the tetrapods

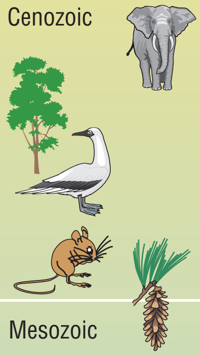
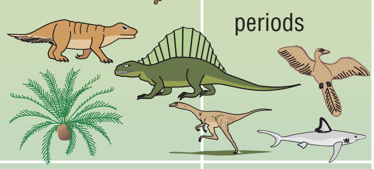
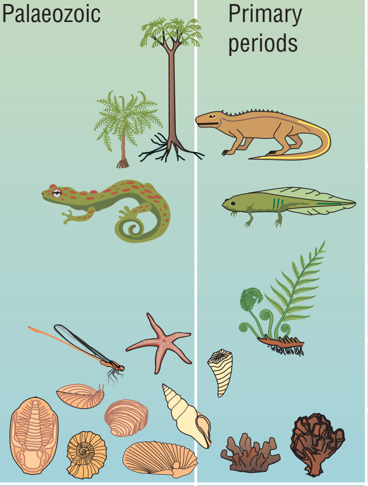
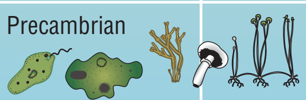
Geological era		Geological period in era	Important events and evolution history	Time in millions of years
Cenozoic 	Quaternary periods	Holocene (recent)	Some mammals disappear. Modern man. Warmer climate.	0.015
		Pleistocene	Ice ages. Large mammals. Primitive man.	2
	Tertiary periods	Pliocene Miocene Oligocene Eocene Paleocene	Life as we know it develops—birds and mammals increase. Huge reptiles disappear. Flowering trees and shrubs replace giant ferns and mosses.	5 23 36 53 65
Mesozoic 	Secondary periods	Cretaceous	Flowering plants.	145
		Jurassic	Reptiles dominate—dinosaurs. First birds and mammals. Widespread lowlands.	200
		Triassic	Vertebrates replace invertebrates. Reptiles increase in number.	251
Palaeozoic 	Primary periods	Permian	Many plants and ferns. Dinosaurs evolve.	299
		Carboniferous	Tropical coal swamps formed. Giant insects dominate. First reptiles.	359
		Devonian	Fish dominate—variety. Development of amphibians. Land supports large tree plants.	416
		Silurian	Flat land, primitive animal life. First land plants.	443
		Ordovician	Sea invertebrates (starfish, coral). Primitive fish. First insects.	488
		Cambrian	First abundant fossils—trilobites, molluscs, sponges.	542
Precambrian 		Proterozoic	Earliest fossil life, algae,fungi.	2500
		Archaen	Earliest known life. Mountain building.	3600
		Hadean	Formation of Earth's crust. No life.	6000

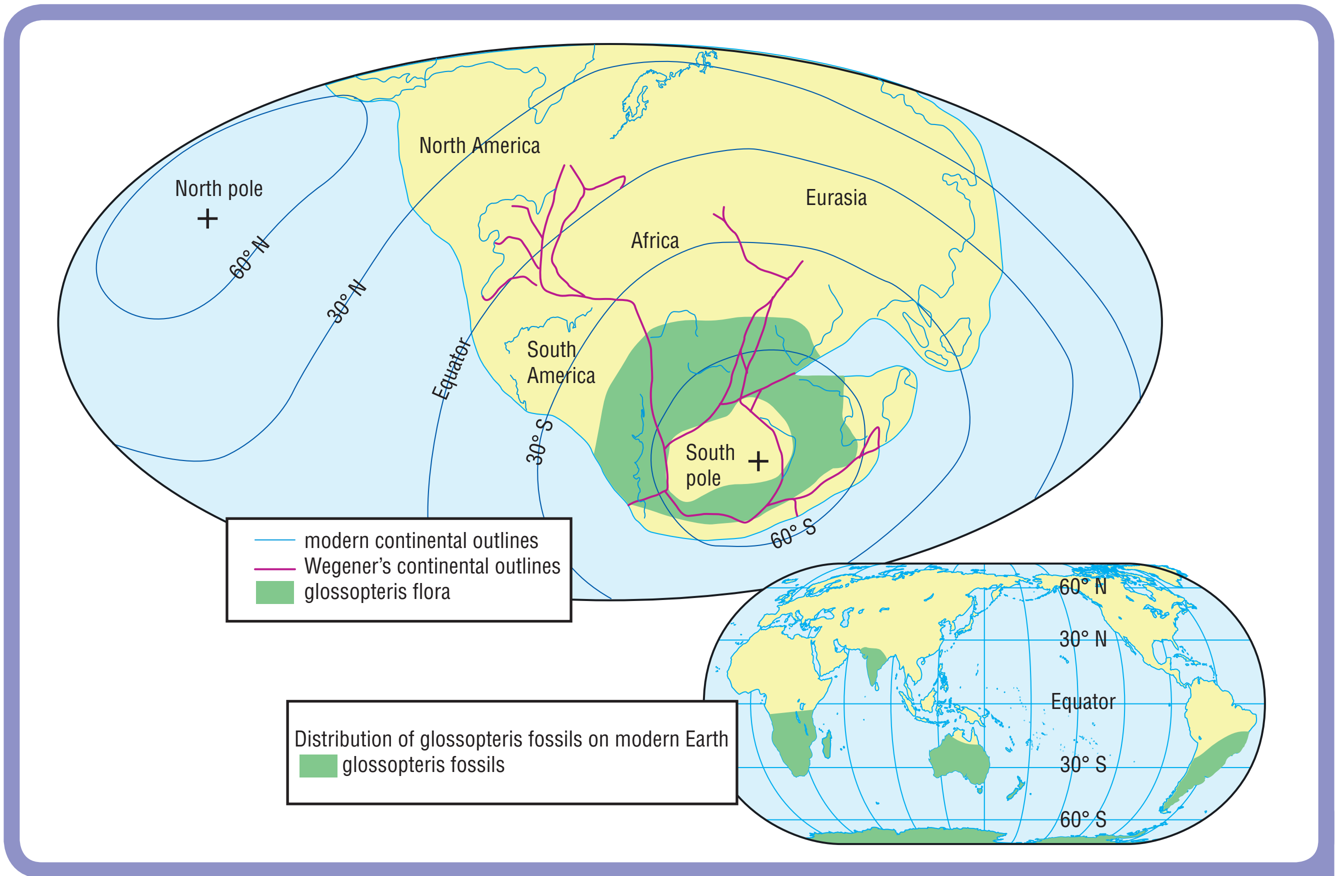
Fig 1.6.3 A geological time scale

Drag and Drop CW Interactive

Fossil evidence for tectonics

Well before the theory of plate tectonics was put forward, it had been noticed that fossils of similar species occurred in different countries separated by ocean. Scientists were puzzled about how the species managed to spread to the different places. As an example, an extinct plant called glossopteris has been found in the places shown in Figure 1.6.5. This shows the continents as they are now. But 200 million years ago these landmasses were connected in the great

A glossopteris fossil *Fig 1.6.4*



Gondwana and the present-day distribution of glossopteris

Fig 1.6.5

southern landmass called Gondwana. Australia was part of this. So the fossils are found in these places not because the species managed to cross oceans, but because the landmasses were connected. This has provided strong evidence to support the theory of plate tectonics.

FOCUS 1·6 [Questions]

Use your book

Fossils

1 What are fossils and where and how do they form?

Relative dating of fossils

2 Why are fossils in the lower layers of rock older than those in the upper layers?

3 What is meant by relative dating of fossils?

4 What are index fossils?

5 What is stratigraphy?

Absolute dating

6 What is meant by absolute dating?

7 What are isotopes and how can they give us an age for a rock?

A history of life

8 What can dating tell us about life in the past?

Fossil evidence for tectonics

9 How have fossils helped give us evidence for plate tectonics?

Use your head

10 If you found some worm burrows preserved in ancient rocks, could you call this a fossil? Explain.

11 Explain how the fossil in Figure 1.6.4 probably formed.

12 Explain how you could use fossils to date two rock layers from different countries.

13 How is it possible for fossil sea shells to be found on the highest mountain on Earth, Mount Everest?

14 How does the construction of a geological time scale suggest that evolution has occurred in the history of life?

Investigating questions

15 Why do scientists think that the history of the vertebrates began with fish, then amphibians developed, then reptiles developed and, from reptiles, birds and mammals evolved?

16 Look up Ediacara Formation on a website. What is so unusual about the fossils from here?

17 **a** What is the fossil emblem of Western Australia?
b Where are these fossils found?
c What were they like in life?

18 How are fossil pollens used to help scientists search for oil and gas?

19 Glossopteris have been found in Western Australia. Find out where, and what this tells us about the climate in that period.

20 Use the Internet to find out about 'Otzi the Iceman'. Could you call him a fossil? What has he shown us about life back then?

1·6 FOCUS

[Practical activity]

Prac 1 Focus 1.5

DYO

Making fossils

Purpose

To work out a way of modelling the formation of some different types of fossils using plaster of Paris.

Requirements

Plasticine, plaster of Paris, plastic container for mixing, stirring rod, variety of objects (such as shells, leaves, bones, nuts), petroleum jelly, newspaper for keeping the desk clean.

Procedure

1 You are going to model the process of forming some fossils. You have to think of a way of achieving this using only the materials you have been given. Each fossil has to be made in the plaster.
2 The fossils that you have to make in the plaster are:
   - a mould of the outside of one side of a leaf
   - a cast of the outside of half a shell (a bivalve such as a scallop)
   - a cast of the outside of a complete shell (such as a gastropod)
   - a mould of the outside of a shell
   - a cast of the outside of a eucalypt fruit (gumnut).

Questions

1 Explain the difference between a cast and a mould.
2 Describe how you made each model fossil.
3 What information does a cast give you that a mould cannot give you?
4 What real-life material are you simulating with the plaster?

FOCUS 1•7 Movement of the Earth and the atmosphere

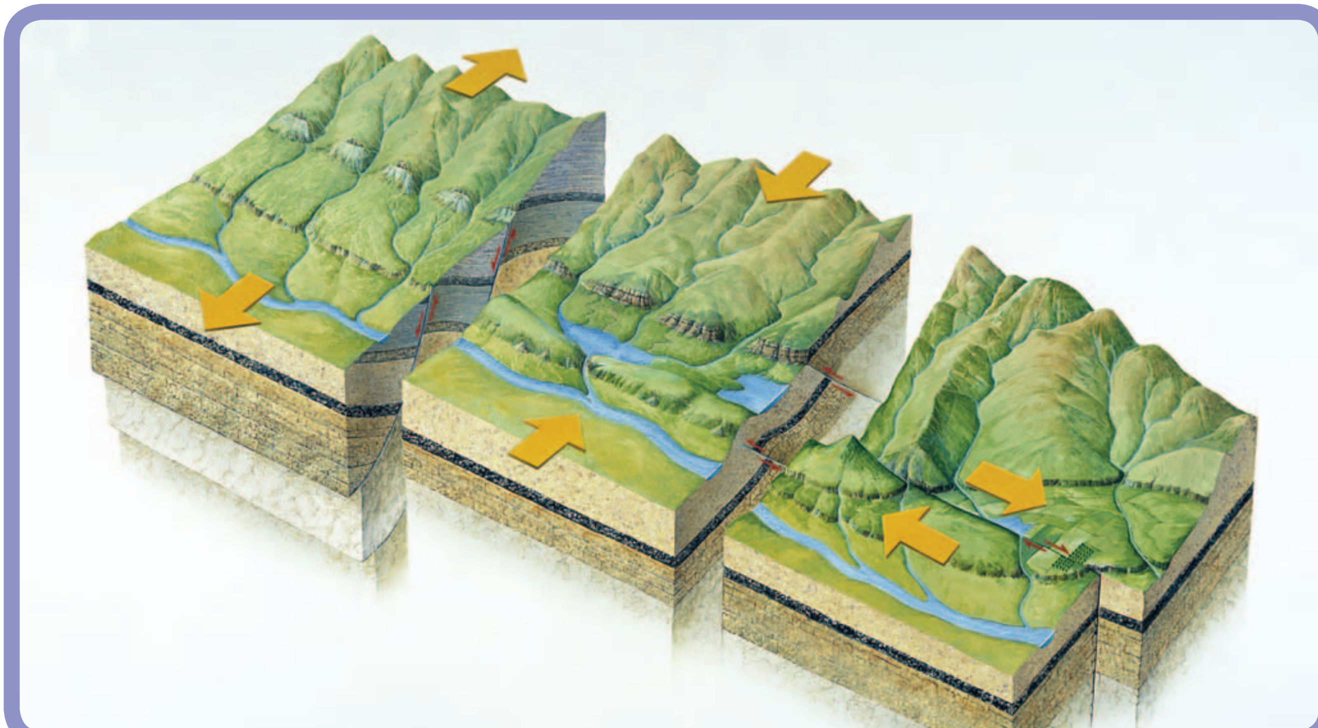
Context

You have seen that the Earth's surface continually moves. These movements of the crust can bend, break and shake the rocks. They also affect humans, both by shaping the environment, and through the destructive power of earthquakes. The atmosphere is also in continuous motion, again with some profound effects. Cyclones devastate large areas, while lightning is much more localised but no less destructive.

Fig 1.7.1 Faults can affect your daily life.

Faulting

The Earth's surface consists of moving tectonic plates that exert large forces on one another. Some types of rock tend to crack under stress. These cracks are called **faults**. Faults come in all lengths, from a few centimetres to hundreds of kilometres.



A normal fault (left), a reverse fault (middle) and a strike-slip fault (right) *Fig 1.7.2*

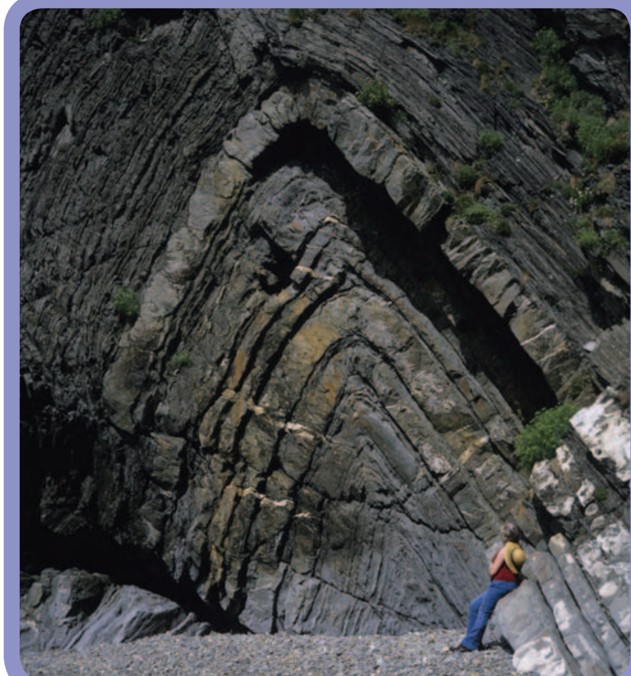
The movement of the rock in a fault may be vertical, horizontal, or a combination.

Normal faults occur when rocks are under tension—that is, when the rock is pulled apart. In a normal fault, one block of rock usually slides down the fault face, leaving the other block at a higher elevation. **Reverse faults** occur when the rock is under compression—that is, when the rock is pushed from opposite directions. Typically, one block slides up the fault face, leaving the other block lower down. A **strike-slip fault** occurs when two pieces of crust slip sideways past each other. Sudden movements may occur, which can cause devastating earthquakes.

Folding

Rocks that resist faulting when stressed tend to change shape. The buckled layers that form in these rocks are called **folds**. Folds can be of any scale. The simplest type of fold is called a **monocline**. Other types of fold result from more complicated movements of the Earth.

An anticline *Fig 1.7.3*



Where rock layers form a series of folds, some parts of the folded strata get pushed downwards, while other parts hump upwards. The downwardly deformed part of a fold is called a **syncline**. The upwardly deformed part of a fold is called an **anticline**. Figure 1.7.3 shows a striking example of an anticline. Figure 1.7.4 shows a range of fold types.

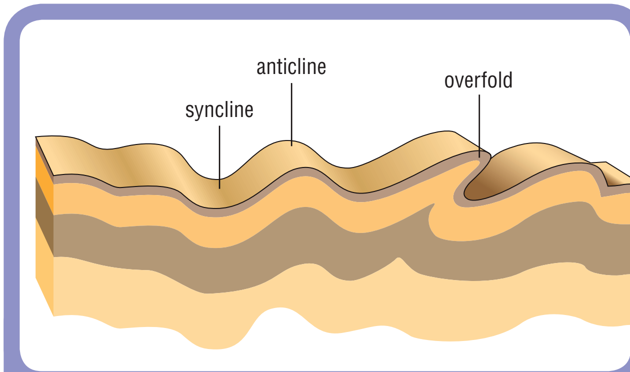


Fig 1.7.4 Folds come in many forms.

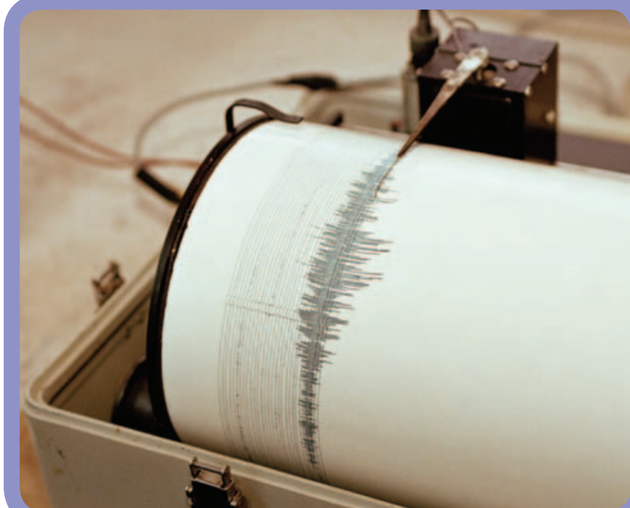
Prac 1
p. 42

Earthquake intensity

Seismologists study earthquakes and other movements of the ground. They use an instrument called a **seismograph** to record the size and timing of earthquake waves as they arrive at the observatory. The size of a wave is called its **amplitude**. The **Richter scale** measures the intensity or strength of an earthquake according to the amplitude of the waves it creates in the rock.

The Richter scale seems unusual because it is logarithmic, not linear. A step of one whole number in the Richter scale represents an amplitude change of ten times. This means that a quake that measures 3 has ten times the amplitude of a quake of magnitude 2. A quake of magnitude 4 has 100 times the amplitude of a magnitude 2 quake, and a magnitude 5 quake has 1000 times the amplitude of a magnitude 2 quake.

A record of an earthquake produced on a seismograph. The amplitude of the quake is shown by the height of the spikes on the trace. *Fig 1.7.5*



Science Snippet

Pinpointing the epicentre

The epicentre of an earthquake is the place where an earthquake actually happens. An earthquake produces various types of wave in the rock. At an observatory, a seismograph records their arrival times. Earthquake waves have known speeds, so the arrival times allow seismologists to calculate how far each observatory is from the epicentre. If three observatories pick up the quake, the one location inside the Earth where all three distances match is the epicentre. The calculations are complicated because the wave speed depends on the rock type and the wave type, and the waves refract as they pass from one rock type to another.

The Richter scale is open-ended—that is, there is no smallest or largest value that an earthquake can have. The amplitude of a magnitude 2 quake is too small to be felt by most observers, and can only be detected by a seismograph. The strongest earthquake ever recorded occurred off the Chilean coast and measured 9.5. Its amplitude was tens of millions of times that of a magnitude 2 quake. The disastrous tsunami that devastated coastal parts of Indonesia and several other South-East Asian nations on 26 December 2004 was caused by a magnitude 9.0 undersea quake.

The energy released by an earthquake is connected to the amplitude of the wave, but again the connection is not linear. The energy change associated with a whole number step in the scale is about 31 times. Thus, a magnitude 3 quake releases about 31 times as much energy as a magnitude 2 quake.

Cyclones

Willy-willies, **tornadoes** and tropical **cyclones** are all intense low-pressure weather systems involving strong winds that spiral in towards the low pressure at the centre. Tropical cyclones are usually several hundred kilometres across, unlike their smaller cousins, tornadoes and willy-willies. Cyclones, also called hurricanes or typhoons, produce torrential rain. The air in a southern hemisphere cyclone rotates clockwise as it spirals in. The direction of rotation is anticlockwise in the northern hemisphere.

Tropical cyclones get their energy when sunlight warms the surface of the ocean. The warm, moist air rises quickly, creating a low pressure area. Air from around the low rushes in towards its centre. If the Earth did not rotate, the path of the inrushing air would be straight. Because of the Earth's rotation the path of the incoming air is a curve.

Typically, a satellite image of a cyclone is a swirl of cloud, often with a hole at the very centre. This hole is the 'eye' of the cyclone, where the wind speed is low (see Figure 1.7.6). Wind speed and rainfall tend to be most severe in the eyewall, just outside the eye itself. Cyclone winds can exceed 300 kilometres per hour, and can cause massive destruction to trees and structures. Much of the damage caused by cyclones is from heavy objects such as trees or sheets of roofing material being blown about. Heavy rain tends to cause local flooding, adding to the damage and making the clean-up after the storm more difficult.

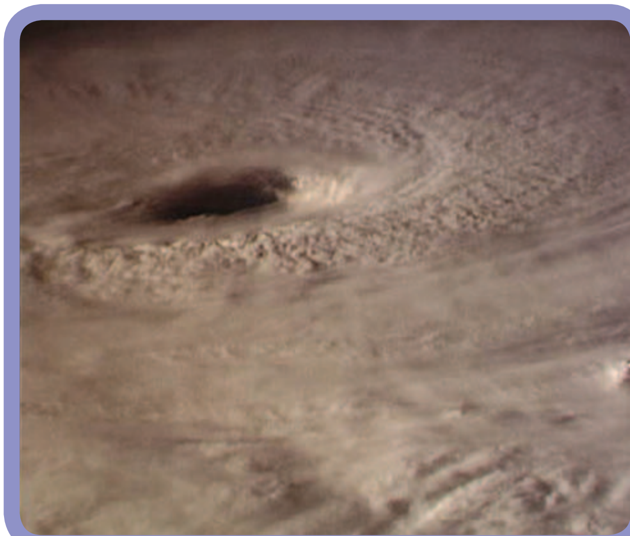


Fig 1.7.6 This view of a cyclone shows the eye clearly. Is this cyclone in the northern or the southern hemisphere?

Tropical cyclones tend to move around. Their paths are usually influenced by existing weather patterns such as prevailing winds. When cyclones travel over land they tend to weaken and become rain-bearing depressions. Sometimes, a weakened cyclone goes back out to sea and grows again in strength. Most global warming models predict that extreme weather events such as cyclones will become both more common and more intense.

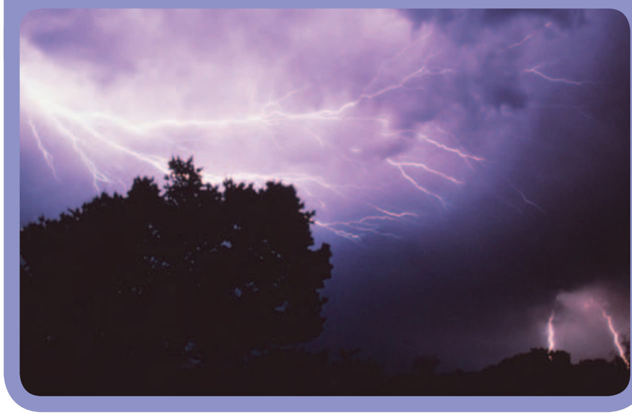
Cyclones are not just a feature of Earth's climate. Astronomers can see the upper clouds in the atmospheres of the gas giant planets, Jupiter, Saturn, Uranus and Neptune. Rounded, rotating features in these clouds have been interpreted as cyclones. With no land surface to disrupt and weaken them, storms on these gas giants can grow very large, and last for a long time. Jupiter's great red spot has been visible for hundreds of years, and is wide enough that the entire Earth could fit inside it.

Lightning

One way to build up a static charge on an object is through friction. Cumulonimbus clouds contain fiercely strong winds that carry ice crystals up and down through the cloud. This movement allows the crystals to accumulate large electric charges through friction with air and by collision with other crystals. This may create a large difference in electric potential between parts of the cloud, often millions of volts. Very high voltages are able to ionise air molecules, creating a conducting path for a very large current.

As the charge moves along the conducting path, it loses energy and heats up the air. The suddenly hot air expands quickly, creating a shock wave in the air that we hear as thunder. The hot ionised air glows, and we see this as a lightning bolt. So much energy released in a very short time means that the power of a lightning bolt is enormous.

Fig 1.7.7 You can see both cloud-to-cloud and cloud-to-ground lightning in this photograph.



Often there is more than one conducting path, creating multiple leaders. While some lightning bolts carry charge from a cloud to ground (or from ground to cloud), most lightning moves electric charge from one part of a cloud to another. Does lightning strike in the same place twice? Photographs of city skylines during thunderstorms often show that same buildings are hit again and again. Tall, pointed objects are more likely to be struck than short, flat ones.

Electric currents such as lightning bolts heat up the conductors they pass through. Do not shelter under a tree in a thunderstorm. Its height makes it a likely strike point. When lightning hits a tree, the huge current through the tree often boils the sap inside it. This can literally explode the bark off the tree. Even a near-miss can harm you, because lightning creates large electric currents in the ground or through water. If these flow through your body, the effects will be painful.

As is the case with cyclones, astronomers have observed lightning in the upper clouds of the gas giants. A lightning discharge bright enough to be photographed by Earth telescopes must be a spectacular event.

Science Snippet

Why aren't aeroplanes hit by lightning?

Actually aeroplanes *are* hit by lightning, quite often. Pilots avoid thunderstorms when they can, but this is not always possible. Aeroplanes are made of electrically conducting metal such as aluminium, giving lightning a low resistance path through the plane. However, hollow conductors (such as metal aeroplanes) protect the people inside, so passengers may never know that their plane was struck by lightning. A protective hollow conductor is called a Faraday cage, after its inventor, Michael Faraday. Thus, a closed vehicle such as a car or a truck is a relatively safe place if you are caught by a thunderstorm—'relatively' safe, because petrol catches fire easily.

Homework book 1.11 Movement of the atmosphere

Drag and Drop CW Interactive

1·7 FOCUS [Questions]

Use your book

Faulting

1 How is a normal fault different from a reverse fault?

2 Why do earthquakes often occur near fault zones?

Folding

3 When geologists look at rock strata, they often can only see a part of a structure such as a fold.

a What is the name of the structure exposed at A?

b What is the name of the structure exposed at B?

4 Is the top of a fold mountain likely to be a syncline or an anticline? Explain.

Fig 1.7.8 A partly exposed fold

Earthquake intensity

5 What factors might make one earthquake more or less intense than another?

6 A magnitude 7.0 earthquake is a serious event. How much:

a more energy does a magnitude 9.0 earthquake give out?

b less amplitude is a magnitude 5.0 earthquake?

Cyclones

7 Why do the clouds form curved patterns around a cyclone?

8 Suggest a reason why many cyclones have an 'eye' in which the wind speed drops dramatically.

Lightning

9 If you are swimming and a thunderstorm approaches, is it safe to stay in the water? Explain.

10 Hail falls from cumulonimbus, or thunderstorm, clouds. What is the reason that cumulonimbus clouds form hailstones while other cloud types usually do not?

12 Why do cyclones get more intense over the oceans but lose intensity quickly over land?

13 Some buildings are struck by lightning often while others are hardly ever hit. Suggest three reasons why one building might be more at risk than another.

14 Lightning bolts are very powerful phenomena—that is, they deliver a large amount of energy in a short amount of time.

a List some advantages and some disadvantages of using lightning to provide electric power for a community such as a country town.

b On balance, is lightning a promising power source?

15 Folds do not occur when a rock layer is put under tension by forces that pull the layer in opposite directions. Why not?

Use your head

11 Suggest a reason why an earthquake's intensity is measured according to its amplitude rather than the damage it causes.

Investigating questions

16 How do meteorologists classify the severity of a cyclone? How do they get the information they need to make a decision about a cyclone's strength?

17 A rock layer is subjected to forces that put it under compression. What decides whether this particular rock layer will undergo folding or faulting?

FOCUS 1·7 [Practical activity]

Folds and faults

Prac 1 Focus 1.7

DYO

Purpose

To model Earth structures including folds and faults.

Requirements

A large sheet of paper, access to plasticine and a digital camera.

Procedure

1 Select one type of structure, such as a normal fault or a monoclinal fold. Your group will make a model of this structure. *Write down the structure that your group will model.*

2 As a group, decide how you use the materials to which you have access. *Draw a sketch of the finished model.*

3 Using a large sheet of paper to keep the plasticine from sticking to the desk, make your model.

4 When all the models are ready, view all the models your classmates have made. *Sketch the structures they have modelled. You may want to take some digital images of these models.*

Questions

1 Which of the models showed the features best?

2 On each of the sketches you made, show the directions of any forces that could cause the structure to form.

3 Which of the structures that your class modelled might have created an earthquake as they formed? Explain.

FOCUS 1•8

Mining methods

Context

Western Australia's economy is strongly tied to exploration and mining. There are many ways to mine a resource. The choice of method depends on striking a favourable balance between cost and income. Cost includes setting up the mine, running it and rehabilitating the landscape. Income depends on world commodity prices, especially the price of the mineral being mined. Mining companies can stay in the game only if the income is greater than the costs—that is, if they can make a profit. In this Focus you will examine some of the factors that mining companies have to consider when planning operating and closing a mine.

Open-cut mining

Once geologists have located and mapped a mineral resource or ore body, planning the mining method is the next step. If the resource being mined is close to the surface, the simplest and cheapest way to mine is open cut. First, the miners remove the overburden (overlying soil and rock) and store it close by. They then dig up the ore and load it directly into trucks. These transport the ore either to a refinery or to a port, if it is destined for export.

Open-cut mines exist all around Western Australia, taking out many valuable minerals, including aluminium ore, iron ore, gold ore, diamonds and coal.

Fig 1.8.1 Open-cut mines can be vast in size.

This technique is useful at any scale. For example, a lone gold miner might scrape soil away from a small deposit with a bulldozer, making a pit a few metres across and perhaps one or two metres deep. At the other extreme, the Kalgoorlie 'Super Pit' gold mine will eventually measure about 3800 metres long, 1400 metres across and 500 metres deep.

Mineral sand deposits are ancient beaches. They contain sand-grain-sized pieces of minerals such as rutile, ilmenite and zircon, mixed with ordinary beach sand. The mining companies remove the sand in a number of ways.

In some cases, they just dig up the sand deposit, making an open-cut mine. Alternatively, they flood the deposit, creating an artificial pond, then dredge, or pump the sand out. In another variation, they blast the sand deposit with high-pressure water from a water cannon. Both the dredging and water cannon techniques create a slurry—basically, sandy mud.

Prac 1
p. 48

Underground mining

The open-cut mining method is not suitable for mining deep-seated ore deposits; eventually, the cost of removing, storing and finally returning the overburden

Science Snippet

Mine safety

Mining has always been a dangerous occupation. Some types of mines are especially risky. Coal mines are particularly hazardous. As well as all the other risks involved in being underground and using vehicles, machinery and explosives, coal mines can also catch fire. Some coal deposits have flammable gas associated with them, and all coal mines produce coal dust. While big pieces of coal are generally a challenge to light, coal dust tends to burn explosively. Once alight, a coal seam can burn for a long time, even years. The only choice then is to abandon the mine until the coal burns out. Flammable dust is also a problem in grain silos, sawmills and flour mills.

It is impossible to judge how large an underground mine is from the structures at the entrance.

Fig 1.8.2

becomes too high. There are a number of ways to efficiently remove the ore from an underground mine. These depend on factors such as the depth, the hardness and strength of the rock and the size, shape and quality of the ore body. For example, miners usually remove small, high-grade ore bodies completely. Large ore bodies may require some of the ore to be left in the mine to hold up the roof and prevent collapse. Where possible, mining engineers design the mine to use lower grade ore for the pillars. Otherwise, they may simply remove the pillars when the rest of the mine is played out, and there is no further need to hold up the roof.

Fig 1.8.3 Hard rock is blasted out in an underground mine. This miner is drilling a shot hole for the explosive.

An underground mine is not just a hole in the ground. People and machinery must be moved in, moved around inside and moved out again. Ore and waste rock must be taken to the surface. Adequate ventilation and an electricity supply are essential. Heating or air conditioning may also be necessary, and mines in which water seeps in continuously need drainage.

Very deep mines have extra problems. The pressure of air increases with depth, and so does the temperature. The temperature of the Earth's crust rises by an average of about 30°C for every kilometre of depth. Really deep mines are thus uncomfortably hot places to work.

Drilling for oil

Petroleum, often just called 'oil', and natural gas are mixtures, mostly of hydrocarbons. Hydrocarbons are compounds made of carbon and hydrogen. Examples include methane, CH_4, which is the main ingredient of natural gas; and octane, C_8H_{18}, which is an ingredient of petrol. Hydrocarbons are useful as fuels and lubricants, and as the starting materials for a huge variety of polymers, or plastics. Petroleum and natural gas are usually found in sedimentary rocks, filling up the tiny spaces between sand grains in sandstone, or in cracks in other types of rock.

Fig 1.8.4 Oil drilling rigs can operate on land or at sea.

Many drill bits are diamond-tipped, which increases the cutting ability and decreases the rate at which they wear out. Special mud, pumped down the hole and back to the surface, stops the sides of the drill hole from caving in. It also lubricates and cools the cutting edges of the drill bit and, finally, carries the chips of rock, cut from the hole, up to the surface. The first signs of hydrocarbons in test holes come from the mud and the chips that it contains.

Gas can be a particular problem. High-pressure natural gas escaping from the rock can dissolve in the drilling mud. At the surface, the gas bubbles out when the pressure drops, just like the gas in a warm bottle of fizzy drink. This can present a high risk of fire or explosion. There are special problems when drilling offshore. Just keeping the rig over the hole can be a challenge in rough seas.

Drilling mud passes over 'shakers', which remove rock chips before the mud is pumped down the well again.

Fig 1.8.5

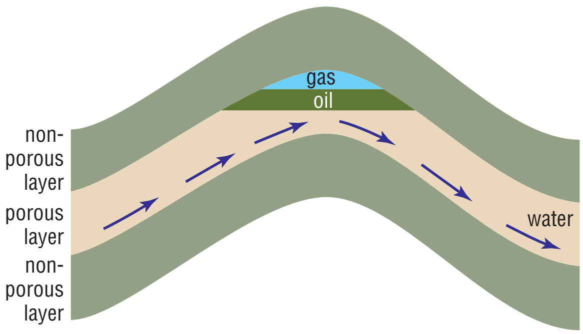


Fig 1.8.6 Oil can migrate for long distances through porous rocks until it reaches a natural trap.

Oil wells

Both petroleum and gas are fluids—that is, they are able to flow. Extracting them from under the ground usually requires only a hole connecting the surface to the place where the petroleum is trapped in the rock. Drillers can change the direction of each hole, so usually one rig makes many holes that spread out for kilometres around it.

In some wells, gas trapped above the petroleum exerts enough pressure to push it out of the well head, which is the top of the drill hole. Petroleum is often sticky, which makes extracting it that much harder. Often, when it stops flowing by itself, about three-quarters of the petroleum remains in the reservoir. In this case, a pump on the well head can help to get the fluid moving. Gas or water, pumped down into the reservoir, can increase the pressure on the petroleum, forcing even more to the surface. Steam, pumped down a well, can heat and help to move especially sticky oil.

The extracted petroleum moves into holding tanks, and ultimately into oil tankers for distribution to refineries. A pipeline carries natural gas to Perth residents from gas fields hundreds of kilometres north of the city. Exporting natural gas overseas is more difficult, and a fair proportion of the gas is lost.

Fig 1.8.7 An oil well showing the well head

Rehabilitating the ecosystem

To rehabilitate something is to restore it to its original condition. The days are long gone when mining companies stripped off the topsoil, mined a deposit and then left behind a big hole in the ground and an equally big pile of rubble. Modern mining methods always include ways to repair or minimise any damage to the environment.

Mining companies remove and store the topsoil. They store the waste rock from around the ore body separately. When the mining operation is finished, they refill the hole with rubble, and replace the topsoil. Then they seed the bare soil with suitable plants, preferably those that grew in the area before mining started.

Homework book 1.12 Mines

A working mine site, and a similar mine site after rehabilitation.

Fig 1.8.8

FOCUS 1.8 [Questions]

Use your book

Open-cut mining

1 What is the main advantage of an open-cut mine over an underground operation, if the ore body is close to the surface?

2 Suggest why a sand mining company may choose to extract the sand by using:

- **a** an open-cut mine.
- **b** a dredging technique.

3 The operators of the Super Pit mine at Kalgoorlie (see Figure 1.8.1) claim that their company extracts nearly 90 million tonnes of ore and waste from the mine each year. Assuming that one cubic metre of ore and waste has a mass of 2 tonnes:

- **a** How many cubic metres of material are extracted from the Super Pit in each year that it operates?
- **b** Assuming it will be a rectangular hole with vertical sides and a flat base, what volume of ore and waste must be removed to dig the Super Pit mine to its final size?
- **c** How many years of operation will be required to dig the Super Pit mine to its final size?
- **d** Your answers to questions (b) and (c) above are almost certainly overestimates. Examine Figure 1.8.1 closely, and suggest why the actual life of the mine will probably be less than your calculated value.

Underground mining

4 What are four factors that increase the cost of underground operations?

5 A new nickel mine in Canada will operate at about 3000 metres depth. The air-conditioning system for this mine will cost tens of millions of dollars. Explain why such an expensive system is considered necessary.

6 What are some of the reasons why ore bodies have to be mapped as completely as possible before any mining begins?

Drilling for oil

7 What are hydrocarbons, and why are they important in our society?

8 Why is it unlikely that petroleum would be found in an igneous rock such as granite?

>>

9 Drilling mud is recycled down the hole and back up many times. What would have to happen at the surface before pumping the mud down again?

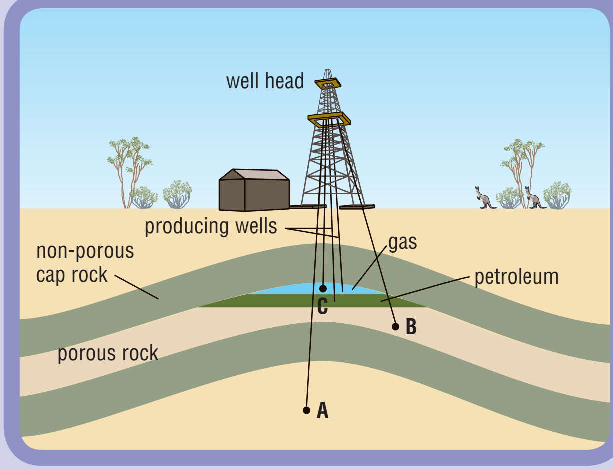
Oil wells

10 Briefly describe three ways to get oil out of a reservoir after the natural flow has stopped.

11 Petroleum no longer comes out of the producing well in Figure 1.8.9. Where would you recommend drilling some injector wells to inject high-pressure fluid into the reservoir, and push extra oil out through the well head—location A, B or C? Explain your reasoning.

This shows the location of a well head, a producing well and the reservoir it taps into.

Fig 1.8.9



Rehabilitating the ecosystem

12 What steps do mining companies take to repair any damage to the environment?

13 Will replanting a rehabilitated mine site with the original vegetation guarantee that the original ecosystem is restored? Explain.

Use your head

14 Methane, CH_4, and octane, C_8H_{18}, are hydrocarbons that belong to a 'family' called alkanes. All alkanes have a predictable number of carbon atoms and hydrogen atoms. Other examples of alkanes are butane, C_4H_{10}, and decane, $C_{10}H_{22}$.

a What is the connection between the number of carbon atoms in an alkane molecules, and the number of hydrogen atoms?

b Predict the number of hydrogen atoms in an alkane having 14 carbon atoms.

c Predict the number of carbon atoms in an alkane having 14 hydrogen atoms.

15 Sometimes it is not possible to rehabilitate the mined area with the original vegetation cover. Suggest why this might be so.

16 The table below shows the size and porosity of several layers of rock. The data were obtained from a test drill hole at a secret location. Porosity is an important factor in the formation of reservoirs for petroleum and natural gas. Because porosity is the fraction of the rock that is open spaces, a rock that has a porosity of 5 per cent would be 95 per cent solid material and 5 per cent open spaces.

Rock layer	Top of layer at depth (m)	Bottom of layer at depth (m)	Porosity (% spaces between grains)
Shale	500	512	0.4
Sandstone	512	548	11.5
Shale	548	566	0.8
Sandstone	566	567	6.5
Granite	568	1486	0.05

a Calculate the thickness (from top to bottom) of each layer.

b Which layer could be a petroleum or gas reservoir? How can you tell?

c What other information would you need to work out roughly how much oil or gas might be in the reservoir?

Investigating questions

17 Mining companies often concentrate ore after they mine it. Concentration removes as much waste material as possible from the ore before transporting it to a refinery where the metal in the ore is extracted. For example, aluminium ore, bauxite, is treated to convert it to alumina. Then the alumina is shipped off to refineries around the world for conversion into aluminium.

Research and prepare a report on three different ways that mining companies treat ore in order to concentrate it. In your report, explain why the mining companies would bother doing this.

18 What are some of the factors that affect the price of a mineral or a metal? For example, why is gold expensive while iron is cheap? Why does the price of gold change from day to day? How can mining companies know how much a metal will sell for months or years in the future?

FOCUS 1.8

[Practical activity]

Prac 1 Focus 1.8

DYO

Getting the most out of your ore

Purpose

To design and test a mineral separation system.

Requirements

Access to standard laboratory equipment and glassware, samples of mineral mixtures (50–50 mix of iron filings and quartz sand) for separation.

Procedure

1. In teams of three (or six), research the following separation techniques: froth flotation, magnetic separation, gravity separation. *Write down the information you have found out.*
2. In your group, decide which technique you will use, and how you will measure the percentage of mineral (iron filings) that you have separated. *Write down your initial plan of action, including the equipment required.*
3. Discuss your plan with your teacher, paying special attention to safe working practices. Order any special items of equipment you will need. *Write down your final plan of action, including the equipment required.*
4. Carry out your plan, using a preliminary trial to check if it works. *Record your results.*
5. As a class, discuss and decide which technique worked best. *Write down the details, and the reasons for choosing a particular method as best.*
6. Evaluate your plan and technique. In particular, can you identify what might have caused errors or losses in your separation? How would you change what you did to do it better next time? *Write down your evaluation.*

Questions

1. What percentage of mineral did your technique allow you to separate out?
2. Would your technique be practical in a mining operation? Why or why not?
3. Did any technique give consistently better results? Why do you think this was so?

Review questions

Interactive CW Crossword

Second-hand data

1 The information below shows the rock temperatures at various levels in three underground mines.

Mine A

Depth	surface	300 m	700 m	1.0 km
Temperature	15°C	28°C	49°C	62°C

Mine B

Depth	surface	600 m	1.5 km	3.5 km
Temperature	20°C	25°C	37°C	55°C

Mine C

Depth	surface	400 m	700 m	1.5 km
Temperature	10°C	21°C	30°C	56°C

a Draw graphs of temperature vs. depth for each mine. Use the graphs to work out:

i the depth at which the temperature will be 40°C in each mine

ii the temperature at a depth of 500 m in each mine.

b The rise in temperature of the Earth's crust with increasing depth is greater near diverging tectonic boundaries, up to 50°C per kilometre depth; and lower near subduction zones, down to about 10°C per kilometre. Why might this be so?

c Which of the mines might be near:

i a subduction zone? Explain your reasoning.

ii a diverging plate boundary? Explain your reasoning.

d All these mines would become increasingly expensive if they went significantly deeper. Suggest why this is so.

Open-ended questions/experimental design

2 One way for farmers to reduce their reliance on fertilisers is to grow legumes in each field and then plough the legumes in before planting the next crop of tomatoes, wheat or cauliflowers. Is it really necessary to plough the legumes in, or could a clever farmer make extra money by harvesting and selling the legumes as stock feed?

Design an experiment to help decide if ploughing-in is really necessary. Your experimental design should show clearly

- which variables you will control, which you will change, and which you will measure
- how you will ensure that the experiment is a fair test
- an approximate timeline for the experiment
- how you will decide whether ploughing-in is necessary.

3 Fresh pineapple contains an enzyme that breaks down proteins. If you put fresh pineapple pieces onto jelly, this enzyme can break down the protein that traps water to make jelly. This jelly turns into liquid – a solution. Cooked pineapple does not have this effect, presumably because high temperatures change the enzyme into an inactive form.

Design an experiment to find out the temperature at which the pineapple enzyme is altered to its inactive form. Your experimental design should show clearly:

- which variables you will control, which you will change, and which you will measure
- how you will ensure the experiment is a fair test
- an approximate timeline for the experiment
- whether you could use this experiment to find out the maximum temperature at which extremophile organisms can survive.

Extended investigation/research

4 Cyclones and lightning exist in the clouds of Jupiter, Saturn, Uranus and Neptune. They are very far from the Sun, their clouds contain little or no water or ice, and there is little chance of an ocean under the clouds. Research how cyclones and lightning might be created on these worlds.

5 Scientists can use radiocarbon dating to derive absolute dates for relatively recent objects such as charcoal from ancient campsites, but not for rocks that are millions or billions of years old.

a Why is carbon dating only useful for objects up to about 50 000 years old?

b What dating techniques can be used for older rocks?

c Scientists believe the Earth is about 4.54 billion years old. What evidence is there for this fairly exact date? How reliable is this evidence?

Homework book 1.13 Earth and Beyond crossword

Homework book 1.14 Sci-words

Energy and change

2

Curriculum guide learning focus

- the nature of energy
- the way energy interacts with different materials
- different forms and effects of energy
- using concepts and models to understand energy transfer
- efficiency of transfer
- the effect of forces
- the use of energy in systems such as simple machines
- simple machines such as levers, gears, inclined planes, wheel and axle
- energy sources, use and conservation

This section on Energy and Change also contains work that will help students with the outcomes of Investigating, Communicating Scientifically, Science in Daily Life, Acting Responsibly and Science in Society.

Outcome level descriptions

The outcome level descriptions for Energy and Change covered in this section of the book are mainly EC 4 and 5.

FOCUS 2.1

Sources, stores and carriers of energy

Context

What is the source of the light that is allowing you to read this book? Where does it come from? It probably comes from an electric light or from the Sun. Where was the energy stored before it got to you? How was it carried to you? These questions about the nature of energy bring together much of what you have learnt about energy so far. This Focus will help you to put the ideas together.

Fig 2.1.1 Walking is doing work. If work is being done then energy is being used up.

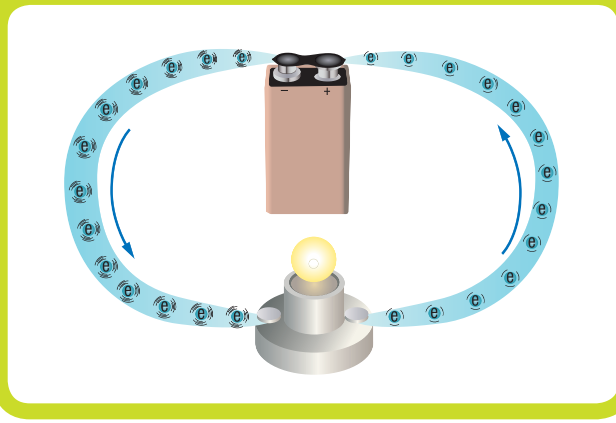
What is energy?

In *Science Aspects 1* and *2* you learnt that something has **energy** if it has the ability to do **work**. When you walk down to a corner shop you are doing work. Because you are doing work you must be using up some of your energy.

When electrons move around a circuit as an electric current they do work on the circuit. This could mean that the wires of the circuit are getting warmer, or a bulb could be giving off heat or light, or a bell could be ringing. Because these things are happening as a result of the flowing electrons, the electrons must be losing some of their energy.

The blades of a windmill or wind turbine rotate because the wind has done work on them. The wind has used up some of its energy in doing this. Remember that whenever work is done on something, whatever is doing the work must be losing energy.

Fig 2.1.2 Electrons use up some of their energy as they move through the filament of a light bulb.



The wind causing these turbines to rotate must be losing some of its energy. Fig 2.1.3

Sources of energy

Figures 2.1.4 to 2.1.9 show some common **sources** of energy. Examine each photo and explain to your partner where the energy is coming from. Check with your teacher or a friend if you have trouble understanding this.

Chemical reactions can provide a source of electrical energy.

Fig 2.1.4

Heat from under the ground is a source of energy that can be used to supply electricity to a town or city.

Fig 2.1.5

Fig 2.1.6

There are reasons for and against the use of nuclear reactors as an energy source today and in the future.

Interactive CW Animation

Fig 2.1.7

Damming water has provided people with an effective source of energy for hundreds of years.

Solar cells produce electrical energy using light energy from the Sun.

Fig 2.1.8

Fig 2.1.9

Power stations produce electricity by burning fossil fuels.

Storing energy

Dry cells can be used to operate portable radios, electric toothbrushes, computers and many other low-voltage electrical devices around the home. Wet cells, such as the battery under the bonnet of a car, also provide electrical energy. Most people know of batteries as a store of electrical energy. What are some other ways that energy can be stored? Food and fuel are energy stores because, like dry and wet cells, they both have stored chemical potential energy. This energy can be utilised when we consume food or when we burn the fuel. Most energy stores can be classified as ‘kinetic energy’ and/or ‘potential energy’.

Kinetic energy

When you catch a basketball you can hear the sound the ball makes as it makes contact with your hands and you can feel its pressure on your hands. These two observations indicate to you that the ball had energy stored in it as it moved through the air.

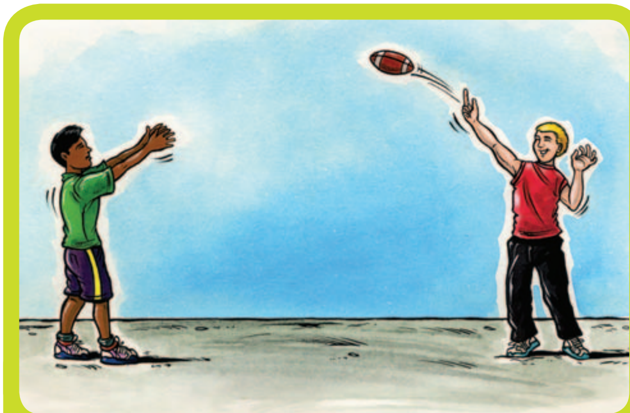


Fig 2.1.10 A moving football contains energy stored as kinetic energy.

Where did this energy come from? Your friend gave the basketball some energy when she threw it to you. The basketball stored this kinetic energy as it moved from your friend to you. When it made contact with you some of this energy was transferred to you. Energy stored in moving objects such as basketballs, people, cars, aircraft and even electrons is called **kinetic energy**. In order to be able to store kinetic energy something must have mass (m) and speed (v). To calculate the amount of kinetic energy you can apply the formula:

$$E_k = {}^1/_2\, m\, v^2$$

where:

- m is the mass of the object in kilograms (kg)
- v is the speed of the object in metres per second (ms^{-1})
- E_k is the kinetic energy in joules (J).

Sample problem

Find the kinetic energy of a family car that has a mass of 980 kg when travelling at a speed of 20 ms^{-1}.

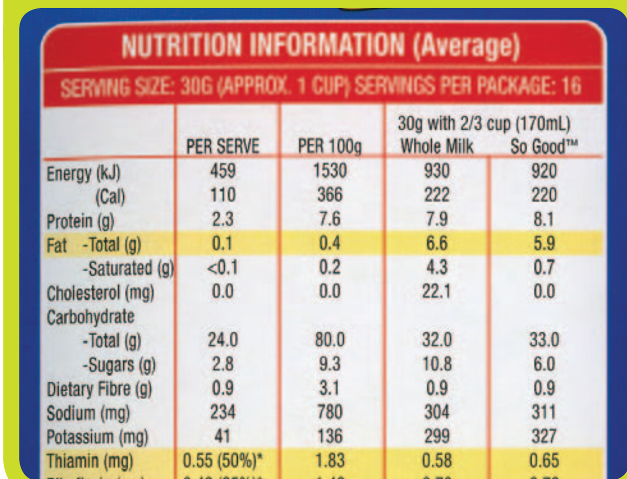
$$m = 980 \text{ kg}$$
$$v = 20 \text{ ms}^{-1}$$
$$E_k = ?$$

$$\begin{aligned} E_k &= {}^1/_2\, m\, v^2 \\ &= {}^1/_2\,(980)\,(20)^2 \\ &= {}^1/_2 \times 980 \times 400 \\ &= 196\,000 \text{ J} \end{aligned}$$

Potential energy

Many of the energy sources described in the first part of this Focus rely on stored **potential energy**. Potential energy is the energy that something possesses as a result of its state or position. One example is the chemical potential energy in fossil fuels, which provide heat energy when the fossil fuel is burnt. Another example is the chemical potential energy in food, which supplies energy to allow you to go about your day when your food is metabolised in your body.

Fig 2.1.11 The food that you consume contains energy stored as potential energy.



NUTRITION INFORMATION (Average)

SERVING SIZE: 30G (APPROX. 1 CUP) SERVINGS PER PACKAGE: 16

	PER SERVE	PER 100g	30g with 2/3 cup (170mL) Whole Milk	30g with 2/3 cup (170mL) So Good™
Energy (kJ)	459	1530	930	920
(Cal)	110	366	222	220
Protein (g)	2.3	7.6	7.9	8.1
Fat -Total (g)	0.1	0.4	6.6	5.9
-Saturated (g)	<0.1	0.2	4.3	0.7
Cholesterol (mg)	0.0	0.0	22.1	0.0
Carbohydrate				
-Total (g)	24.0	80.0	32.0	33.0
-Sugars (g)	2.8	9.3	10.8	6.0
Dietary Fibre (g)	0.9	3.1	0.9	0.9
Sodium (mg)	234	780	304	311
Potassium (mg)	41	136	299	327
Thiamin (mg)	0.55 (50%)*	1.83	0.58	0.65

A rubber band has elastic potential energy because when stretched it has the potential to do work on a model glider, as shown in Figure 2.1.12. The elastic potential energy in this case will be transferred to the plane as kinetic energy.

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The stored elastic potential energy of the rubber band can be transferred to the model plane. **Fig 2.1.12**

An object lifted above the ground has gravitational potential energy because when it is released it will fall. To calculate gravitational potential energy you can use the formula:

$$E_p = mg\Delta h$$

where:

- m is the mass of the object in kilograms (kg)
- g is acceleration due to gravity. Close to Earth this has a value of approximately 9.8 ms^{-2} (remember ms^{-2} represents acceleration in units of metres per second per second)
- Δh is the change in height of a body in metres (m)
- E_p is the potential energy in joules (J).

Sample problem

Find the potential energy of a ball with a mass of 0.5 kg when held at the top of a 6 metre ladder.

$m = 0.5$ kg
$g = 9.8\ ms^{-2}$
$\Delta h = 6$ m
$E_p = ?$

$$\begin{aligned} E_p &= mg\Delta h \\ &= (0.5)(9.8)(6) \\ &= 29.4\ J \end{aligned}$$

Energy carriers

Energy carriers explain how energy is transferred from place to place. Energy can be carried on objects like aircraft, cars and footballs. Even people are energy carriers. Energy can also be carried on very small particles such as electrons. Apart from objects or particles, do you think that there are other ways that energy can be carried from place to place? Think about how heat and light are able to be transferred from the Sun to the Earth through the vacuum of space. Remember, there are too few particles in space to act as carriers for all this energy. So how does all this energy get to us? The answer is that it is carried by a special type of wave.

Energy can be carried by waves. **Fig 2.1.13**

In much the same way that water waves are able to carry energy from offshore to the beach, different types of waves are able to carry energy through space. Water waves are called **mechanical waves** because they involve particles. Waves travelling through space are called **electromagnetic waves** because no particles are involved. They are changing electric and magnetic fields.

Drag and Drop CW Interactive

Homework book 2.1 Sources of energy

FOCUS 2•1 [Questions]

Use your book

What is energy?

1 What is energy?

2 Is energy being used up when an electric current flows through a circuit? How do you know?

3 What is the relationship between energy and work?

4 Where does the energy come from when an electric current flows around a circuit?

5 What loses energy when wind causes the blades of a wind turbine to rotate?

>>

Sources of energy

6 Where does the energy contained in a battery come from?

Storing energy

7 What are two ways that you could increase the kinetic energy of a shopping trolley?

8 State the difference between kinetic and potential energy.

9 Describe a situation that proves that a stretched elastic band has stored energy.

10 Calculate the potential energy of a 0.5 kg beach ball held 1.5 metres above the ground.

Use your head

11 Write down five things that you did today that involved energy. How was energy involved?

12 What kind of energy do you associate with:

- **a** a moving car?
- **b** a painter standing on a ladder?
- **c** gas from a gas stove?
- **d** a hamburger?

13 When a beach ball or a tennis ball is dropped on the ground it will bounce a few times and then stop. Why does a bouncing ball eventually stop bouncing?

Investigating question

14 Design an investigation to establish how many times a tennis ball will bounce as its height is increased. Ask your teacher if you can try your experiment.

DYO

2·1 FOCUS [Practical activity]

Prac 1 Focus 2.1

Elastic potential energy

Purpose

To investigate energy stored in a stretched rubber band.

Requirements

Rubber bands, chair, brass weights, empty ice-cream container with lid, metre rule or tape measure.

Procedure

1 Join four or five rubber bands together to make a rubber band chain.

2 Attach each end of the chain across the base of a chair or stool as shown in Figure 2.1.14.

3 Place a brass mass in the ice-cream container, close the lid and pull the container back a certain distance.

4 Let the container go and measure how far it travelled.

5 Now repeat the experiment a few times. Keep everything the same but change the mass of the ice-cream container by one brass mass each time.

6 *Record your results in a table.*

7 *Draw a graph to illustrate your results.*

Questions

1 What happened as you increased the total mass of the ice-cream container?

2 Why do you think this happened?

3 What energy was stored in the elastic band?

4 Where did this energy go after the elastic band was released?

Fig 2.1.14 How to set up your experiment

5 How could you improve this investigation if you were to do it again?

Further investigation

You can investigate Prac 1 further. Try either or both of the following experiments. Write a report on what you discover.

- **a** Keep the mass of the ice-cream container the same but change the number of elastic bands in the chain.
- **b** Keep the mass of the ice-cream container and the number of elastic bands in the chain constant but change the amount by which the elastic band chain is pulled back.

FOCUS 2.2 Force, work and power

Context

There are many ways in which you do work in the course of a typical day. Doing homework is often hard work. You might think that doing the dishes and cleaning your room is hard work. Some people your age may have part-time work. There are many different ways that you can use the word ‘work’ in everyday life. In science, however, work has a specific meaning and involves the concept of force.

A car collision is an example of a contact force. *Fig 2.2.2*

Force

Force is best described as a push or a pull. In *Science Aspects 1* you learnt that forces can be measured using a spring balance, as in Figure 2.2.1.

There is a coiled spring in the spring balance that stretches when a pulling force is applied. The spring balance measures force in units of newtons (N). In *Science Aspects 1* you learnt to classify forces as **contact** or **non-contact** forces.

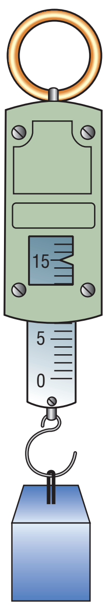

Fig 2.2.1 This spring balance shows that a 15 newton pulling force is being applied to the block.

Contact forces

When objects make contact with one another they exert a force on one another.

You can calculate the size of a force acting on a body if you know the mass of the body and its acceleration. To do the calculation you can use the formula:

$$\text{Force} = \text{mass} \times \text{acceleration}$$
$$F = m \times a$$

where:

- F is the force in newtons (N)
- m is the mass in kilograms (kg)
- a is the acceleration in metres per second, per second (ms^{-2}).

What is acceleration?

You are probably accustomed to thinking about the speed of a car in terms of kilometres per hour (km/h). The speed limit on many WA roads is 60 km/h. If a car is travelling at this speed then it travels 60 km each hour. In the science laboratory the unit metres per second (m/s or ms^{-1}) is often a more useful unit for measuring speed. When you step on the accelerator of a car, your speed will increase. For instance if your speed increases by 10 m/s each second then your acceleration is 10 metres per second, per second (m/s/s). The unit m/s/s can also be written as ms^{-2}.

Sample problems

1 Calculate the force acting if a 35 kg scooter is accelerated at 2 ms^{-2}.

$$F = ?$$
$$m = 35 \text{ kg}$$
$$a = 2 \text{ ms}^{-2}$$

$$\begin{aligned} F &= m \times a \\ &= 35 \times 2 \\ &= 70 \text{ newtons} \end{aligned}$$

2 What is the acceleration on an 85 kg rocket if propelled by a force of 3000 N?

$F = 3000$
$m = 85$ kg
$a = ?$

$F = ma$
$a = {}^{F}/_{m}$
$= {}^{3000}/_{85}$
$= 35.3\ \text{ms}^{-2}$

Non-contact forces

If you hold the north poles of two magnets close together, you will feel the two poles repelling one another. A force can be felt acting between the two magnets even though they are not actually in contact with one another.

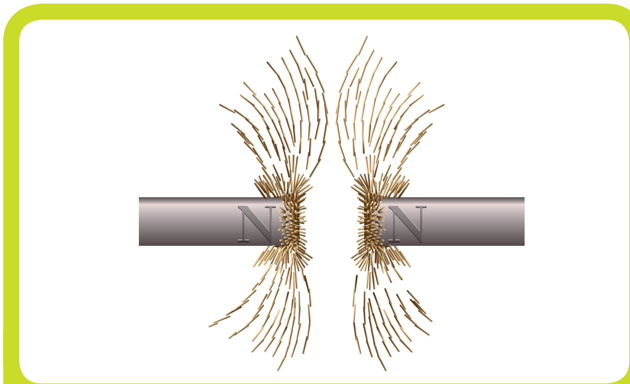

Fig 2.2.3 Even though the magnets are not touching there is a magnetic repelling force between them.

Science Snippet

Which hits the ground first?

When objects fall towards the Earth they fall with a constant acceleration. Close to the Earth free-falling bodies fall with an acceleration of about 9.8 ms^{-2}. This is called acceleration due to gravity and we use the symbol 'g' to represent this quantity. What would happen if you dropped your book and a heavy iron girder off the first storey of a building? They would both hit the ground at the same time! All objects when falling (no matter how heavy or light) accelerate downwards at 9.8 ms^{-2}. Remember, $g = 9.8\ \text{ms}^{-2}$.

When a ball is held up in the air and then released, it will fall under the influence of a gravitational force. The ball will fall even though there is no other object pulling or pushing on it. It is actually the gravitational field around the ball that pulls the ball downwards towards the Earth. The ball will accelerate downwards until it hits the ground. Gravity, magnetism and electricity are examples of how forces can act without objects actually touching each other. These types of forces are called forces that act through a distance, or simply non-contact forces.

Fig 2.2.4 The ball will accelerate downwards because of the gravitational force acting on it.

Weight

Your weight is the amount by which your mass is pulled downwards by gravity. It is a force and you can calculate your weight if you know your mass by using a variation of the formula F = ma. To do this, simply multiply your mass in kilograms by acceleration due to gravity (g).

$F = m \times a$
$Fwt = m \times g$
$Fwt = m \times 9.8$

Fig 2.2.5 A set of scales can register how much gravity pulls you down.

Science Snippet

Massing yourself!

When you are asked your weight you often give your answer in kilograms (for instance 70 kg). It is more scientifically correct to refer to your mass in kilograms. This is because your weight is a force and should be expressed in newtons. So you probably should say you are 'massing' yourself if the scales use kilograms.

Sample problem

Jamie has a mass of 55 kg. Calculate her weight.

Fwt = ?
m = 55 kg
g = 9.8 m/s/s

Fwt = (m)(g)
= 55 × 9.8
= 539 newtons

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Work

In science, work is done when a force moves a body in the direction of the force.

Fig 2.2.6 A force moving its point of application is doing work.

You can calculate the amount of work done on an object by using the formula:

$$W = F \times s$$

where:

- W is the work done in joules (J)
- F is the force applied in newtons (N)
- s is the displacement (distance moved in a straight line) in metres (m).

Sample problem

James pushes on a trolley with a constant force of 150 newtons. The trolley moves 55 metres in a straight line while this force is applied. Calculate the work done by James on the trolley.

W = ?
F = 150 N
s = 55 m

W = F × s
= 150 × 55
= 8250 J

Remember, if 8250 joules of work has been done on the trolley then James must have used up 8250 joules of his energy in doing this work.

What do you think is happening in Figure 2.2.7? James is now applying a force onto the brick wall, but the wall is not moving. In this situation James is doing work, but he is not doing work on the wall because the wall is not moving in the direction of James' pushing force. James' energy is being transferred into heat … so energy is still being expended, just not on the wall.

Is work being done on the wall? Fig 2.2.7

Work and potential energy

Walking up stairs can be very hard work in an everyday sense, but it is also work in a scientific sense. This is because in order to climb just one stair you must lift your own weight through the height of the stair.

Fig 2.2.8 You are doing work when you lift your own weight through a vertical distance.

Let's do a calculation to estimate how much work James does as he lifts his own weight through the height of just one step. James has a mass of 70 kg.

$$W = ?$$
$$m = 70 \text{ kg}$$
$$s = 0.25 \text{ m}$$

$$\begin{aligned} W &= F \times s \\ &= mg \times s \\ &= 70 \times 9.8 \times 0.25 \\ &= 171.5 \text{ J} \end{aligned}$$

If James were to walk up a flight of stairs consisting of 25 steps, what is the total amount of work he would have done?

$$\begin{aligned} W \text{ total} &= 171.5 \times 25 \\ &= 4287.5 \text{ J} \end{aligned}$$

Fig 2.2.9 Consuming a muesli bar means consuming energy.

Science Snippet

Muesli power

One tablespoon of pure sugar contains about 260 000 J of energy. A typical muesli bar may contain 350 kJ, which is 350 000 J of energy.

How many flights of stairs like the one in the calculation above would James have to climb in order to use up the total energy contained in a muesli bar?

$$\text{Number of flights of stairs} = \frac{\text{total energy needed to be used up}}{\text{energy used in single flight of stairs}}$$

$$= {}^{350\,000}/_{4287.5}$$

$$= 81.6 \text{ flights of stairs, or}$$

$$\text{Total number steps} = 81.6 \times 25$$

$$= 2041 \text{ steps}$$

Power

Imagine James racing up the flight of stairs at the same time as his best friend Jessie. Like James, Jessie has a mass of 70 kg.

Fig 2.2.10 Who will win the race?

James takes 6 seconds to get to the top, but Jessie takes 8 seconds. Have they both done the same amount of work in climbing the stairs? Of course they have, because they both have the same mass and they have climbed the same vertical distance. They therefore have also used up the same amount of energy in doing this work. But because James has done the work in a shorter time we say he has a greater power output than Jessie. Power relates to how quickly we can do work. We can calculate power by using the formula:

$$\text{Power} = \frac{\text{work done or energy used}}{\text{time}}$$

$$P = {}^{W}/_{t}$$

$$= {}^{E}/_{t}$$

where:

- P is the power in watts (W)
- W is the work done in joules (J)
- E is the energy used in joules (J)
- t is the time in seconds (s).

Let's compare James' and Jessie's power output.

James' power output

$$P = {}^{W}/_{t}$$

$$P = {}^{4287.5}/_{6}$$

$$= 714.6 \text{ W}$$

Jessie's power output

$$P = {}^{W}/_{t}$$

$$P = {}^{4287.5}/_{8}$$

$$= 535.9 \text{ W}$$

One watt is the power generated when one joule of energy is used in one second. A watt is actually a very small quantity. For this reason it is more common to talk about kilowatts (1000 watts) or megawatts (1 000 000 watts).

James has a greater power output than Jessie has. *Fig 2.2.11*

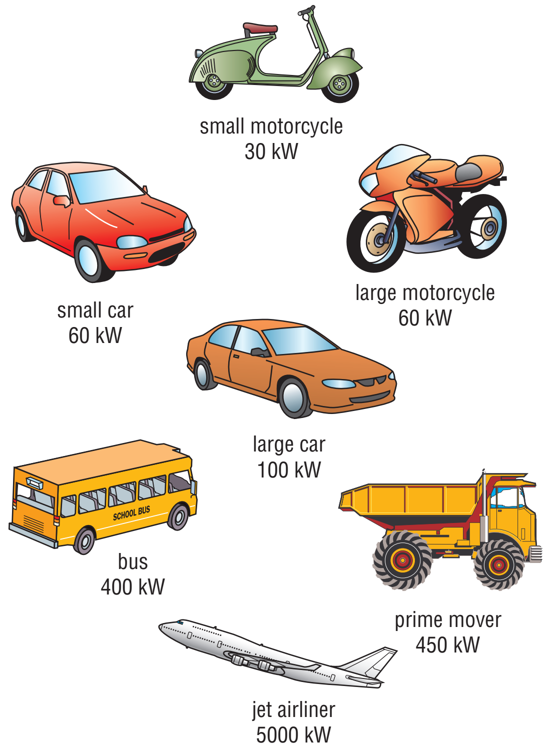


Fig 2.2.12 Power ratings for different vehicles

Homework book 2.2 Work and power

Drag and Drop CW Interactive

Prac 2 p. 61

FOCUS 2.2 [Questions]

Use your book

Force

1 Give an example of a pushing force and a pulling force.

2 Give an example of a contact force and a non-contact force.

3 What is meant by acceleration and what is the unit for acceleration?

4 Calculate the acceleration of a go-cart if the combined mass of the cart and driver is 80 kilograms when the cart is pushed with a force of 156 newtons.

5 Give an example of how a pushing force can also be a force that acts at a distance.

6 Give an example of a pulling force that acts at a distance.

7 What is the acceleration of a free-falling brick?

Weight

8 Calculate the weight of Tim if his mass is 75 kg.

Work

9 What work is done if the go-cart in question 4 is pushed 10 metres?

10 Where does the energy come from when the go-cart in question 4 is pushed?

11 How much energy is used in pushing the go-cart in question 4, 10 metres in a straight line?

12 Why is no work done on the wall, no matter how hard you push on the wall of your classroom?

Work and potential energy

13 When Jenny, with a mass of 60 kg, climbs a set of stairs that have a total height of 2.6 metres, how much energy would she use?

Power

14 What was Jenny's power output if she was able to climb the stairs in question 13 in a time of 5.5 seconds?

Use your head

15 In this Focus the point was made that all objects fall with a constant acceleration of 9.8 ms^{-2}. Would this be true for every object? Hint: think about whether your pen and a sheet of paper would hit the ground at the same time if dropped from the same height.

Investigating question

16 Design an investigation to show that objects of different masses fall from a certain height to the ground in the same time. Ask your teacher if you can carry out your investigation.

DYO

2·2 FOCUS [Practical activities]

Prac 1 Focus 2.2

Mass and weight

Purpose

To compare the mass and weight of some common objects.

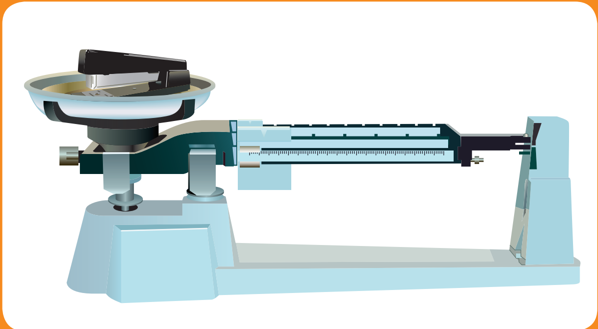
Requirements

A variety of common objects (such as what you might find in your pencil case, school bag or classroom), triple beam balance, different spring balances with a balance pan attachment, brass weights.

Procedure

1. Put the item on a triple beam balance in order to establish its mass. The mass of the item will need to be converted to kilograms. Ask your teacher if you don't remember how to convert from grams to kilograms.
2. Weigh the same object using a spring balance with an appropriate scale.
3. *Record the name of the item, its mass in kilograms and weight in newtons in a table.*
4. *Draw a graph of mass against weight of a range of items that have similar masses and weights. Put weight on the y-axis and mass on the x-axis.*

Fig 2.2.13 Stapler on balance pan of triple beam balance



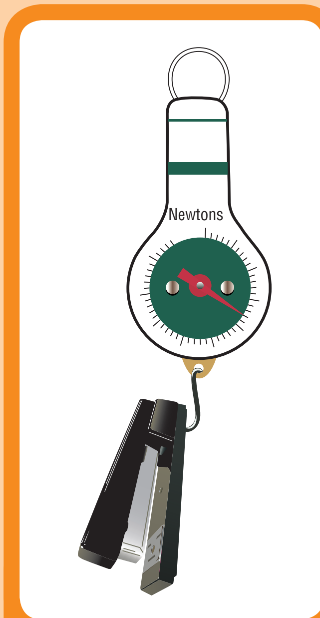


Fig 2.2.14 Stapler hanging on a spring balance

Questions

1. What pattern or trend was suggested by the graph?
2. Work out the slope of the graph by using the following formula:

   Slope = $^{rise}/_{run}$
3. What do you think the slope of this graph represents?

Prac 2 Focus 2.2

How powerful are you?

Purpose

To work out your power output while running up stairs.

Requirements

Bathroom scales, access to a set of stairs consisting of at least 10 steps, meter rule or tape measure, timekeeper, stopwatch.

Procedure

1. Find your mass in kilograms using a set of bathroom scales. *Write this down.*
2. Estimate the height of the stair case by measuring the vertical height of a single step and then multiplying this number by the number of steps in the stair case. *Write this down.*
3. Position yourself at the bottom of the set of stairs. The timekeeper must start the stopwatch as you begin to go up the stairs, and stop the stopwatch the instant you reach the top. Sprint up the stairs as quickly as you can. *Record the time taken.*

Questions

1. Calculate the work you did in running up the stairs by using the formula given in this Focus.
2. Calculate your power output by using the formula given in this Focus.

FOCUS 2.3 Transferring energy

Context Energy transfers occur around you all the time. When you walk outside during the day you can feel the warmth from the Sun. Heat energy from the Sun has to be transferred millions of kilometres through space to get to you. Turning on the TV, shouting at a football match and starting a car also involve energy transfers. So how is energy transferred? That is the subject of this Focus.

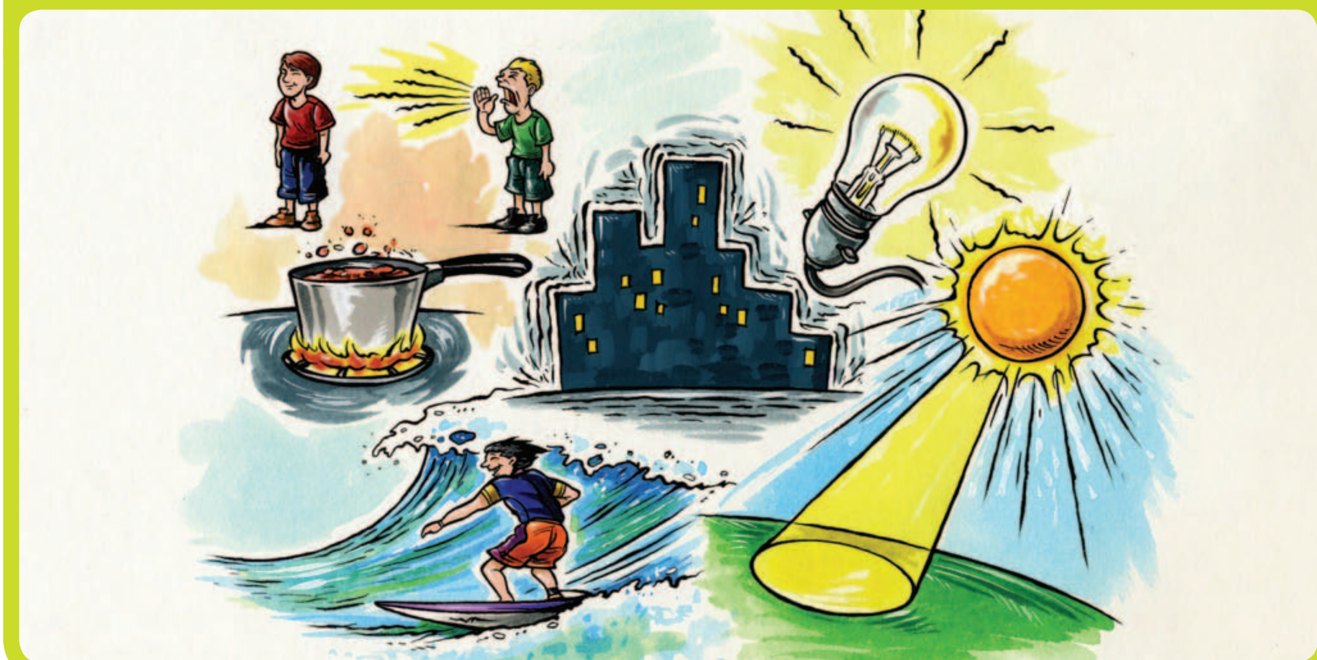
Fig 2.3.1 Many energy transfers occur during a typical sporting event.

Energy transfer systems

It is important to be aware of how energy is **transferred** from place to place. Think about a football being kicked by a player and then marked by another player. In this situation energy is transferred from one player to another. The **source** of the energy is the player who kicks the ball. The ball then **carries** this energy to the player who marks the ball. This player becomes the **receiver** of some of the energy **stored** in the football.

Figure 2.3.2 shows other situations of energy transfer. In each case you can identify the source, carrier and receiver. These are shown in the table opposite.

Fig 2.3.2 Common energy transfer situations



Description	Source	Carrier	Receiver
Heating water	Flame	Water	Saucepan
Solar energy	Sun	Electromagnetic waves	Earth
Sound	Vibrating vocal chords	Air	Ear
Surfing	Water currents	Water	Surfer
Earthquake	Underground disturbances	Ground	Buildings
Electricity	Batteries	Wires or conductors	Electrical appliances such as bulbs, bells, toasters etc

Mechanical transfer of energy

When energy is transferred from place to place by mechanical means, objects or matter are involved. Following are some examples.

Collisions

Figure 2.3.3 shows the effect of energy transfer when collisions between vehicles occur. The car on the right was travelling very fast and therefore carried much kinetic energy. When it collided with the second vehicle, most of this kinetic energy was transferred to the second vehicle, causing its body to buckle and bend.

Energy is transferred from one vehicle to the other during a collision. *Fig 2.3.3*

Machines

In Figure 2.3.4 the winch attached to the well is a simple machine. As the woman turns the handle of the winch, her energy is transferred to the bucket, which rises up the well. The energy that she is using is transferred to the increased potential energy of the bucket and its contents. In the next Focus you will learn more about how machines can transfer energy.

The winch is an example of a machine that transfers energy. *Fig 2.3.4*

Heat

Look at Figures 2.3.5 and 2.3.6. In Figure 2.3.5, the atoms of the base of the saucepan become hotter because they are in contact with the gas flame. As these atoms get hotter they vibrate faster and faster. The more they vibrate the more energy they pass to neighbouring atoms, which also start vibrating. This passing of energy from atom to atom, all the way up the handle of the saucepan, is called heat transfer by **conduction**.

Fig 2.3.5 Heat transfer by conduction

In Figure 2.3.6, the water molecules close to the base of the saucepan become hotter first. Because they are hotter and contain more energy they spread out. In this way the warmer water near the base of the saucepan becomes less dense than the cooler water close to the surface. The cooler, more dense water sinks, pushing the warmer, less dense water upwards. In this way heat can be transferred from one part of a liquid or a gas as a **convection** current.

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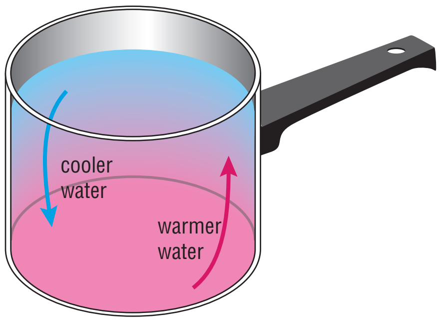
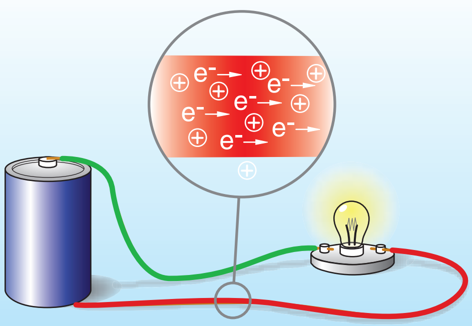
Fig 2.3.6 Heat transfer by convection



Electricity

If an electrical conductor such as a wire is connected to the terminals of a battery, an electric field is formed within the wire. When this happens the free, negatively charged electrons, which exist around the atoms that make up the wire, will start to move within the wire away from the negative terminal and towards the positive terminal of the battery.

Transferring energy in an electric circuit *Fig 2.3.7*



The electrons get much of their energy from the battery and as they move around the electric circuit they transfer energy from the battery to different components built into the circuit. In a simple electric circuit like the those you might build at school, these components could be bulbs or bells. In the circuits around your home the electricity could transfer energy to different points around your home to operate televisions, toasters, fans, ovens and sound systems.

Mechanical waves

The last time you were at the beach, did you notice the power that the waves have? When they crash on the shore, it is easy to imagine how much energy they have. Surfers are able to harness some of the energy of water waves. When a surfer catches a wave, some of the energy in the water is transferred to the surfer. The surfer then gains kinetic energy and moves faster and faster.

Fig 2.3.8 This surfer is harnessing the energy in a wave.

Energy transfer in waves is different from other ways in which mechanical energy is transferred. Although the wave transfers energy from place to place the water particles themselves are not transferred from one place to another, except when the wave hits the beach. You can see this clearly when you throw a beach ball way out beyond the surf. As the waves roll towards the shore, the beach ball will bob up and down many times without actually

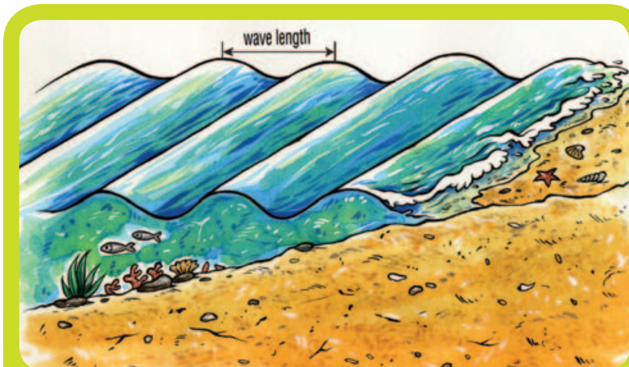
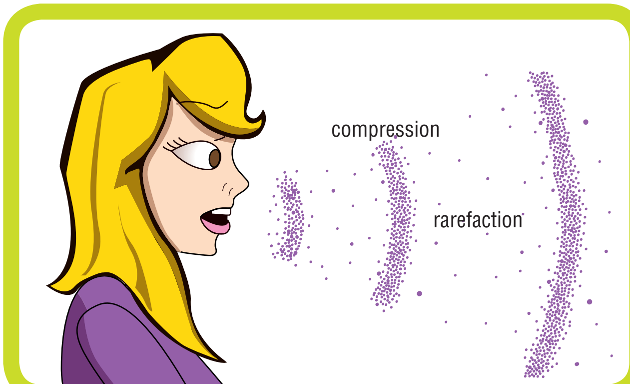


Fig 2.3.9 Water waves are transverse waves.

moving forward. The ball is actually bobbing up and down as waves of energy pass below it. At its highest position the ball is at the crest of the wave. At its lowest position the ball is in the trough of the wave. Because the particles of water move in a direction that is perpendicular to the direction of the wave, we call water waves '**transverse** waves'.

Sound waves

What is happening in the space between you and a friend, when you speak to your friend? Your friend can hear you because of sound waves travelling between you and them. All waves are caused by disturbances. When you speak, your vocal chords start to vibrate. These vibrations are the **disturbance** that produces sound waves.



Sound is transferred by the vibrations of particles. Fig 2.3.10

Sound waves are similar to water waves because the particles of the medium do not travel from the starting point to the finishing point. Sound waves are different from water waves though, in that the particles of air vibrate backwards and forwards, not sideways. Because particles move parallel to the direction of travel of a wave, we say that sound waves are '**longitudinal** waves'.

Drag and Drop CW Interactive

Science Snippet

Earthquakes

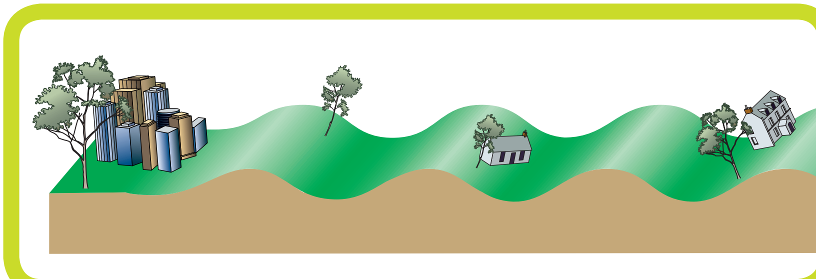
Often the greatest loss of life after an earthquake is due to the fires that start in cities and towns from gas leaks and damage to electricity cables.

Earthquakes

Earthquakes are the result of disturbances that occur deep underground. Often when underground rock movements occur we feel an earthquake. In an earthquake tremor waves move outwards from the source of the disturbance. The wave movement can be very complex.

Earthquakes can produce both transverse waves, called P waves (**pressure waves**), and longitudinal waves, called S waves (**shear waves**). Some earthquake waves are combinations of transverse and longitudinal waves, and are called L-waves.

Drag and Drop CW Interactive



Much energy is transferred during an earthquake. Fig 2.3.11

Transfer of energy by electromagnetic waves

The mechanical waves discussed above have one thing in common. They all transfer energy through a **medium**, such as water, air or the ground. But what happens when there is no medium to travel through? We know that energy gets to us through space from the Sun, even though space is nearly a vacuum. We can feel some of this energy as heat. The way this energy travels, without the need of a medium, is by **electromagnetic** waves.

Electromagnetic waves

In *Science Aspects 1* and *Science Aspects 2* you learnt that magnetic fields exist around the poles of a magnet and electric fields exist around electric charges. Scientists believe that electromagnetic waves are made up of electric and magnetic fields that exist together but lie perpendicular to one another.

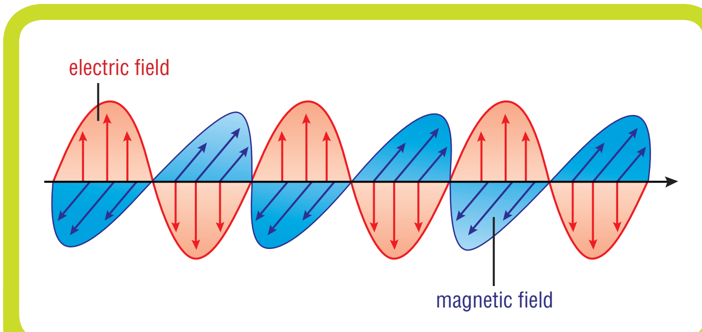
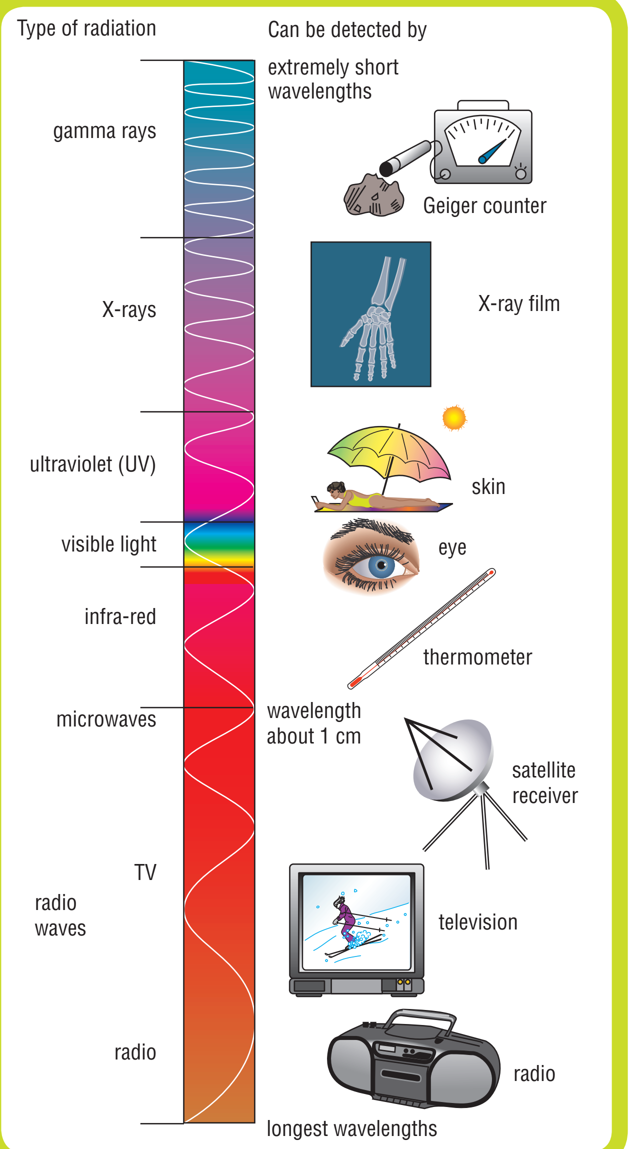


Fig 2.3.12 An electromagnetic wave

Electromagnetic waves with different wave lengths have different uses and effects.

Interactive CW Animation

Fig 2.3.13 The electromagnetic spectrum



Heat transfer by waves

Earlier in this Focus you learnt that heat could be transferred by conduction and convection. Both of these are referred to as 'mechanical energy transfer' because particles are necessary. You can see on the electromagnetic spectrum in Figure 2.3.13 that one part of the spectrum shows infra-red waves. Infrared radiation can also be called heat waves. It is infra-red radiation from the Sun that our skin feels as heat. When you stand in front of a burning fire or in front of an electric heater, most of the heat that reaches you is in the form of infra-red waves.

Fig 2.3.14 Heat transfer can occur as waves.

Homework book 2.3 Cooling it

Interactive CW Animation

Prac 2 p. 68

2.3 FOCUS [Questions]

Use your book

Energy transfer systems

1 Think of a simple activity that you did today that involved energy. Describe the activity in terms of the source of the energy, the energy carrier and the receiver of the energy.

2 What are the source, carrier and receiver of energy when a tennis ball makes contact with a tennis racket?

Mechanical transfer of energy

3 Describe a situation in which kinetic energy is transferred from one object to another.

4 Why are conduction and convection regarded as mechanical energy transfer?

5 Describe how convection might allow the air in a room being heated by an open fireplace to heat up quickly.

6 Why do electrons move away from the negative terminal of a battery and towards the positive terminal of the battery?

7 What do sound waves, water waves and earthquake waves have in common?

8 What three types of waves can flow outwards from the source of an earthquake?

>>

Transfer of energy by electromagnetic waves

9 Explain how energy can be transferred from the Sun to the Earth if there are no particles in space to carry the energy.

10 List three types of mechanical wave and three examples of electromagnetic wave.

Use your head

11 Tim was watching waves rolling towards the beach. He noticed that someone had thrown a beach ball out beyond where the waves were breaking. Instead of following the waves towards the beach, the ball simply seemed to bob up and down as the waves rolled under the ball. Why does the ball not follow the waves in towards the beach?

Investigating questions

12 Use the Internet or resources in your library to find out what information can be provided by a seismograph.

13 Investigate three design features that would minimise the heat gain in a house in summer.

14 Design an experimental investigation to find out how effective insulation batts are in preventing heat loss.

DYO

FOCUS 2·3 [Practical activities]

Prac 1 Focus 2.3

Conduction vs. convection

Purpose

To observe how quickly heating occurs by convection and conduction.

Requirements

Water, two 50 mL test tubes, three clamps, two retort stands, one-hole stopper with alcohol thermometer pushed into it up to about the 60°C mark, three boss heads, Bunsen burner, matches, timer, wooden test tube rack, marker for labelling test tubes.

Procedure

1 Place water in one test tube so that the water is about 4 cm below the top. This is test tube 1. Clamp this at the top of the tube to a retort stand so the test tube is about 15 cm above the desk. Clamp the stopper of the thermometer and stopper assembly to the same retort stand and position the thermometer bulb in test tube 1 as in Figure 2.3.15. The bulb of the thermometer should be just covered by the water.

2 Place water in the second test tube, test tube 2, so that the water is about 4 cm below the top. Clamp test tube 2 right at the bottom and attach it to a retort stand. Tilt the clamp so that the test tube is on about a 50–60 degree angle. Carefully place a thermometer in the tube. Make sure the water level is about 1 cm below the lip of the tube.

SAFETY NOTE: Never allow a flame to touch a thermometer, and never hold a thermometer directly over a flame.

3 *Draw up a table to record your results for test tubes 1 and 2. You need about 10 or 12 rows and three columns.* Carefully heat test tube 1 as shown in Figure 2.3.15, using a blue flame with the Bunsen hole about

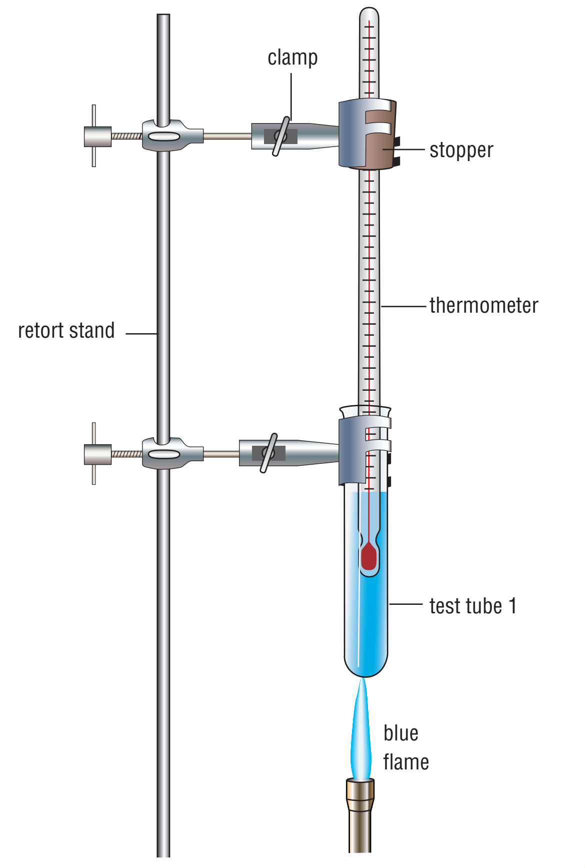


Fig 2.3.15 Set-up for test tube 1

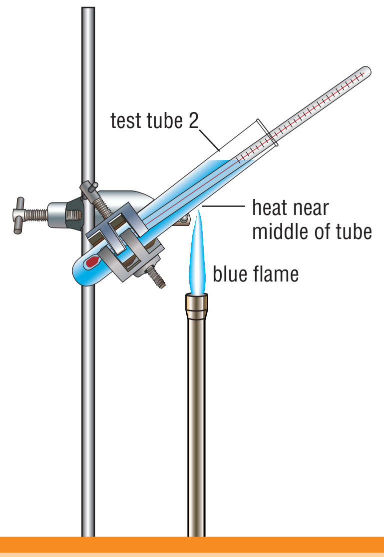
one-quarter open. The flame tip should be just touching the tube. *Record the temperature every 10 seconds until the temperature rises to 50°C or until two minutes have passed.* Leave the tube to cool when you have finished recording results.

4 Heat test tube 2 a bit above the middle of the tube, as shown in Figure 2.3.16. Use a blue flame as in step 3.

SAFETY NOTE: Do not point the open end of the test tube at anyone while heating it.

Do not allow the flame to go up near the thermometer or down near the clamp jaws. *Record the temperature every 10 seconds*, but stop heating if the water boils or if the water spits out of the end of the tube. Do not heat for longer than two minutes.

Fig 2.3.16 Set-up for test tube 2



Questions

1 Draw a line graph of the temperature change with time in both tubes. Do both lines on the one graph.

2 Account for the differences in the two graphs. Try to use the words 'conduction' and 'convection' in your explanation.

Prac 2
Focus 2.3

Radiant energy

Purpose

To observe the heating effect of radiant energy as distance from the heat source increases.

Requirements

Bunsen burner, matches, wire mat, large test tube painted black, water, graduated cylinder, thermometer, retort stand, boss head, clamp, timer.

Procedure

1 Set up the equipment as shown in Figures 2.3.17 and 2.3.18.

2 The Bunsen burner should have been on for at least two minutes so that the wire mat becomes a source of constant and uniform radiation.

3 Fill the test tube to within 1 cm of its rim with water. Measure this volume of water accurately with a graduated cylinder. Pour the water back into the test tube. Position a thermometer in the test tube and after one more minute *record the temperature of the water.*

4 Clamp the test tube to a retort stand 10 cm away from the wire mat. Immediately start your timer.

5 *Record the time taken for the water in the test tube to reach a temperature at least 10 degrees higher than its temperature when you started.* Your table might look like the one below, but will have more rows.

Distance of test tube from wire mat (cm)	Time taken for water to change temperature by 10°C
10	15

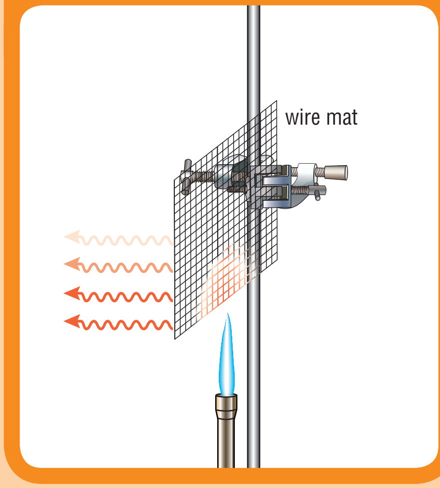
6 Without adjusting the Bunsen flame, pour out the water from the test tube, rinse the test tube a couple of times and then fill it with exactly the same amount of water as before. Wait for one minute, then *record the temperature of the water.*

7 Position the test tube 15 cm away from the wire mat this time and start your timer.

8 *Record the time taken for the water to reach the same temperature as before.*

>>

Fig 2.3.17 Set-up for Prac 2 (a)



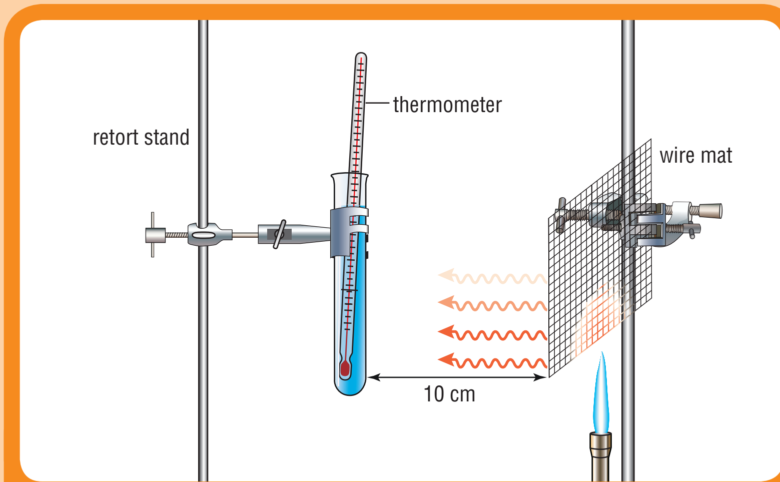


Fig 2.3.18 Set-up for Prac 2 (b)

9. You should repeat the above steps with distances of 20 and 25 cm from the wire mat.
10. *Draw a graph of your results, with distance on the x-axis and time on the y-axis.*

Questions

1. How would you describe the relationship between distance from source of heat and time to reach the desired temperature change? In other words, what happened to the time required to reach 10°C as you increased distance?
2. Why was it important for the test tube to have a black coating?
3. Why was it necessary to not alter the Bunsen flame during this investigation?
4. Which variables were controlled during this investigation?
5. What were the dependent and independent variables in this investigation?

FOCUS 2.4 Energy transfer by simple machines

Context In the last Focus you learnt that energy could be transferred from place to place mechanically and by electromagnetic waves. There are many examples of both ways of transferring energy in everyday life, but in this Focus you will be concentrating on transferring energy mechanically. Think of the last time you used a simple tool to do a job around the house. The tool might have been a screwdriver, a can opener, an electric drill, a chisel, a crowbar or a hammer. These tools are examples of devices that make work easier for us. Devices like these are called **simple machines**. In this Focus you will explore how simple machines can make work easier by transferring energy.

Simple machines

There are many examples of machines in the world around you. You probably see many different types of machines each day on your way to school. Cranes, bulldozers, cars and cement mixers are all examples of machines. Let's call them complex machines. So if these types of machines are complex, what is a simple machine? Most simple machines would not have parts that move independently. A car is a machine because it makes our work easier. It consists of many parts that move independently of one another and so it is not a simple machine. A wheelbarrow, however, is a simple machine because it does not consist of parts that move independently. The diagram of the wheelbarrow in Figure 2.4.1 introduces some terms that you will be using throughout the next two Foci.

This wheelbarrow shows where the effort (E) must be applied in order to lift the load (L).

Fig 2.4.1

In general terms, a simple machine:

a transfers energy from where the effort is applied to where the load needs to be moved

b can make the size of the force at the load bigger or smaller than the effort

c can change the direction in which the effort needs to be applied in order to move a load.

In this Focus you will explore how **levers** can do the above and why this makes them useful to us.

Levers

When was the last time you used a fishing pole, a can opener, a wheelbarrow or a screwdriver, or played on a see-saw? All these are examples of levers. The simplest application of a lever is shown in Figure 2.4.2.

Fig 2.4.2 This lever is being used to transfer energy from the man to the rock.

Examples of levers in common use Fig 2.4.3

In the diagram above you can see characteristics common to all levers. All levers have a point at which a force (or effort) is applied. In Figure 2.4.2 this point is called E. The lever applies a force to a load, labelled L. The point at which the lever turns is called a pivot or fulcrum (F). Figure 2.4.3 shows some different types of levers with their efforts, loads and fulcrums marked.

Types of lever

Levers are classified as types 1, 2 and 3, depending on the position of the effort, load and fulcrum.

Type 1 levers have the fulcrum positioned between the effort and the load. Type 2 levers have the load positioned between the effort and the fulcrum. Type 3 levers have the effort positioned between the load and the fulcrum. These are shown in Figures 2.4.4 to 2.4.6.

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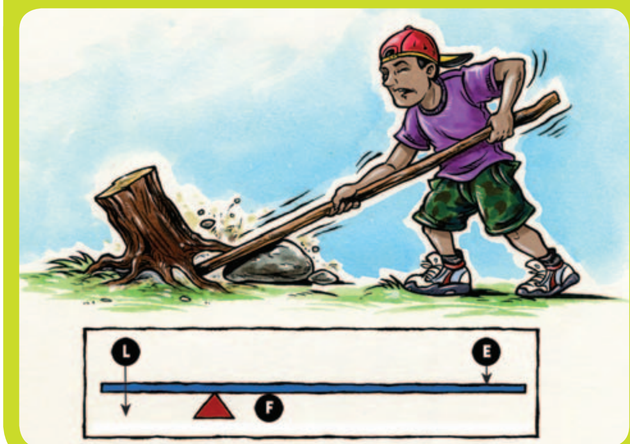
Fig 2.4.4 Type 1 lever



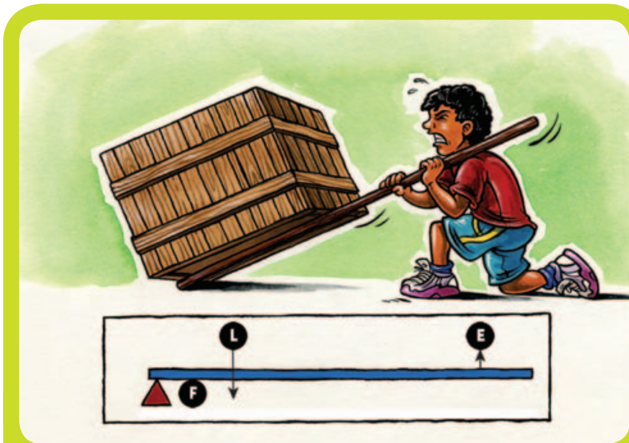
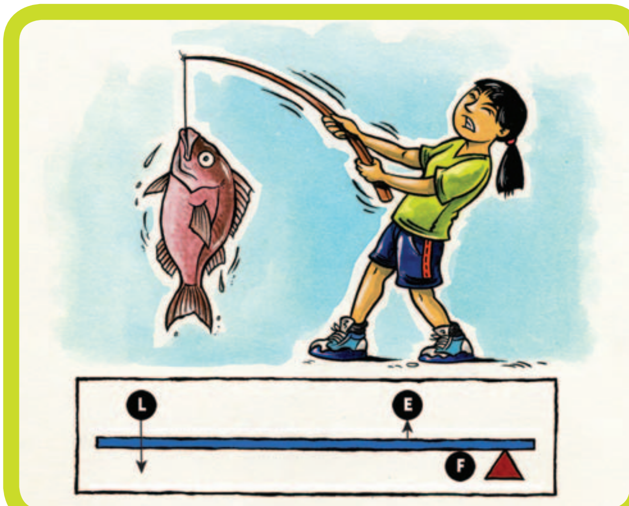


Fig 2.4.5 Type 2 lever



Type 3 lever Fig 2.4.6

Mechanical advantage

Why do people use levers? Imagine that you had to loosen the lid of a can. You have a range of screwdrivers you could use to do the job. Which would you use, a long-handled screwdriver or a short-handled screwdriver?

Why do you think that using the screwdriver with the long handle would make the job easier?

Fig 2.4.7

Generally we use levers to make work easier by producing a **force advantage**. A force advantage means that applying a smaller effort produces a bigger force on the load. A force advantage is one type of **mechanical advantage** (MA) that can be produced when we use a machine.

$$\text{MA} = \frac{\text{load force}}{\text{effort force}}$$

Science Snippet

Force advantage

A mechanical advantage of more than 1 means that a force advantage is produced. A mechanical advantage of less than 1 means that you have to use more force using the machine than you would without the machine. In the latter case we say a force disadvantage is produced.

Example calculation

Calculate the mechanical advantage in using the long-handled screwdriver shown in Figure 2.4.7 if an effort force of 10 N was applied to the handle of the screwdriver but this supplied a force of 150 N to the lid of the can.

$$\text{MA} = \frac{\text{load force}}{\text{effort force}}$$

$$\text{MA} = {}^{150}/_{10}$$

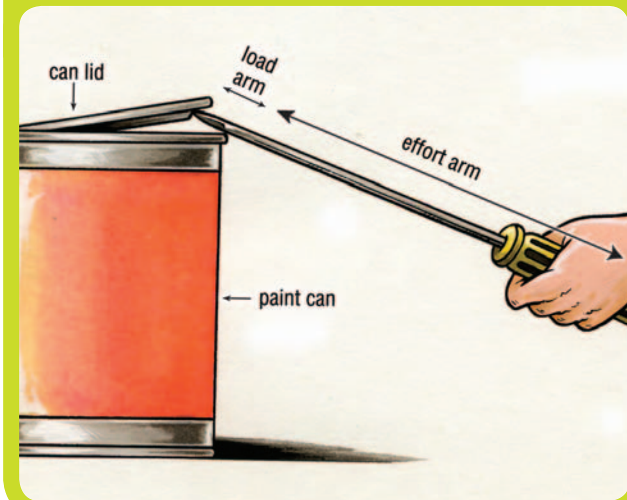
$$\text{MA} = 15$$

Notice that MA does not have units. The mechanical advantage of 15 simply indicates that using the screwdriver allowed you to use 15 times less force than you would have, had you not used the screwdriver.

Calculating the mechanical advantage of levers

A lever produces a force advantage when the length of the effort arm is bigger than the length of the load arm. In Figure 2.4.7, this would mean that the screwdriver with the long handle would provide the bigger force or mechanical advantage.

Fig 2.4.8 The parts of the lever for the long-handled screwdriver



The mechanical advantage of a lever (also called leverage) can be calculated using the formula:

$$\text{Mechanical advantage (MA)} = \frac{\text{length of effort arm}}{\text{length of load arm}}$$

Note that the length of both the effort and load arms are measured from the position of the effort or load to the fulcrum.

Sample problem 1

In Figure 2.4.9 Dave is using a crowbar to lift the lid on a heavy inspection hole in the road.

a Calculate the mechanical advantage in using this lever.

b Compare the distance that the effort moves and the distance that the load moves.

c If Dave were able to apply an effort of 150 newtons, what force would be applied at the inspection port cover?

Fig 2.4.9 Using a crowbar to lift the lid on a heavy inspection hole in the road

a Dimensions of the effort and load are marked: effort arm is 50 cm and load arm is 2.5 cm.

$$\text{Mechanical advantage (MA)} = \frac{\text{length of effort arm}}{\text{length of load arm}} = {}^{50}/_{2.5} = 20$$

b In this example a long distance moved by an effort moves the load through a smaller distance.

c Because this crowbar provides a MA of 20, the effort is multiplied by 20 at the load. This means that Dave's 150 N force at the effort would be transferred at the load as a 3000 N force.

Sample problem 2

As can be seen in Figure 2.4.10, a wheelbarrow has an effort arm with a length of 1.2 metres and a load arm that has a length of 0.8 metres. Calculate:

a the mechanical advantage that this wheelbarrow produced

b the force a gardener would have to exert on the wheelbarrow to lift a load of 350 N.

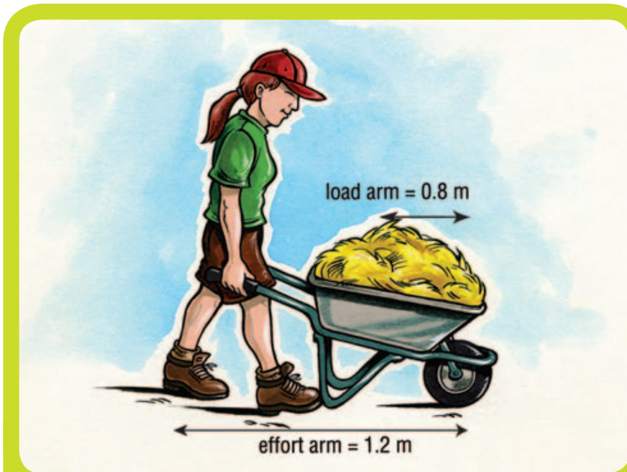


Fig 2.4.10 The wheelbarrow as a lever

a $$\text{Mechanical advantage (MA)} = \frac{\text{length of effort arm}}{\text{length of load arm}} = {}^{1.2}/_{0.8} = 1.5$$

b $$\text{Mechanical advantage (MA)} = \frac{\text{load}}{\text{effort}}$$

$$\text{Effort} = \frac{\text{load}}{\text{MA}} = {}^{350}/_{1.5} = 233.3\text{ N}$$

Homework book 2.4 Levers

Prac 1 p. 75

2·4 FOCUS [Questions]

Use your book

Simple machines

1 Why do we use simple machines?

2 What is the difference between a simple and a complex machine?

3 Name three characteristics common to all simple machines.

Levers

4 Give five examples of levers in common use.

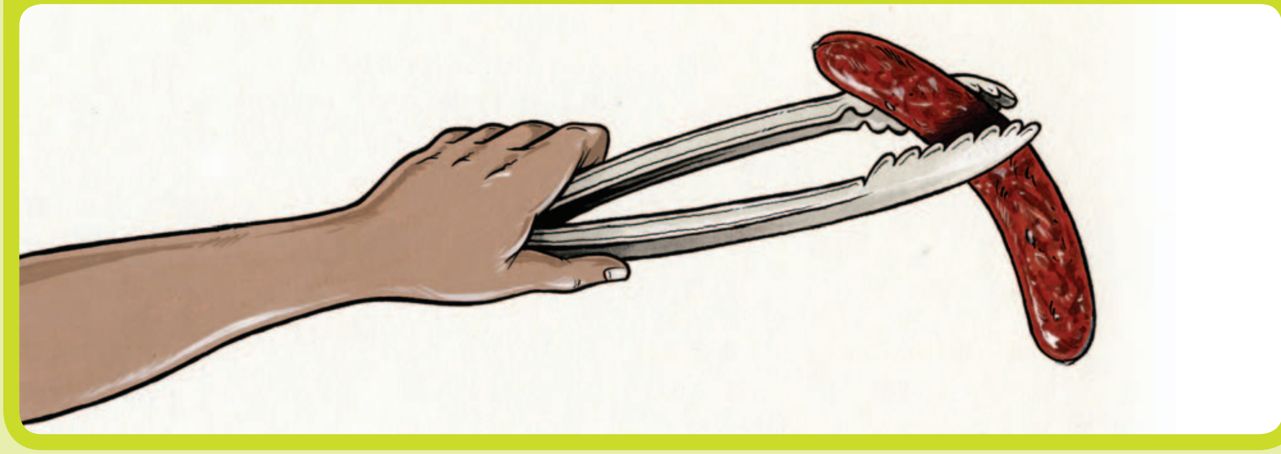
5 What is another word for the fulcrum of a lever?

6 Draw a rough sketch of the lever in Figure 2.4.11.

a On your sketch label the effort with an E, the load with an L and the fulcrum with an F.

b Identify on your sketch whether the lever is a type 1, 2 or 3 lever.

Fig 2.4.11 Barbecue tongs are a lever system.



Mechanical advantage

7. When does a lever produce a force advantage?
8. Calculate the mechanical advantage of the following lever in Figure 2.4.12. Does this lever produce a force advantage?

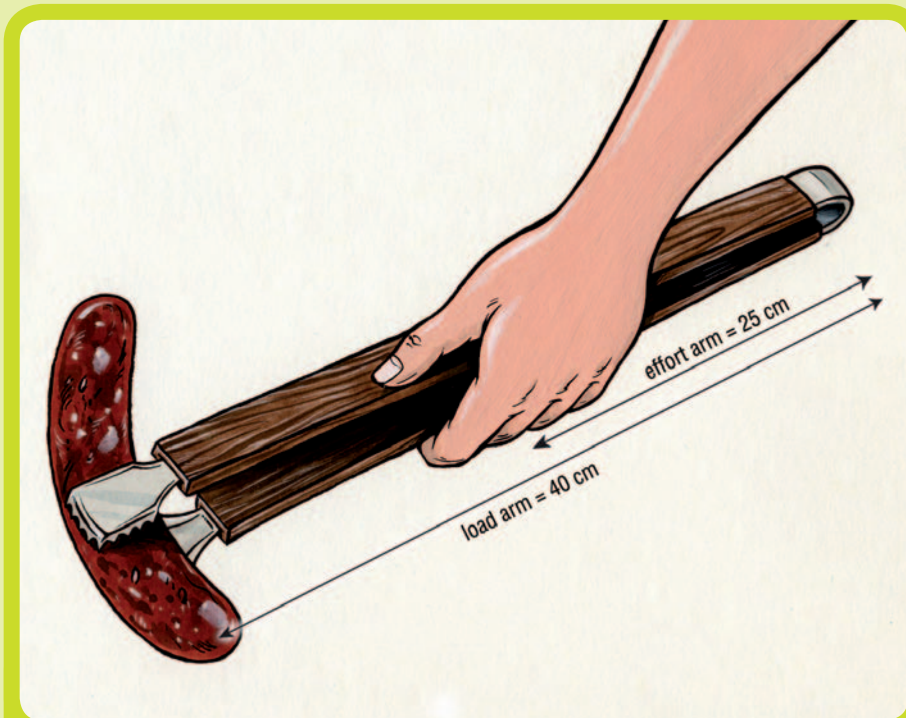


Fig 2.4.12 Do these tongs provide a mechanical advantage?

Use your head

9. Look at the claw hammer in Figure 2.4.13. If you haven't seen a claw hammer up close, or you don't know how it is used, ask your teacher to show you a claw hammer in use.
   - **a** Draw a sketch of the claw hammer like the one in Figure 2.4.13. Label E, L and F on your sketch.
   - **b** Estimate the MA of the claw hammer.
   - **c** Suppose you were trying to remove a nail by using this claw hammer but found the nail too hard to remove. What adjustment could you make to the position of the claw and the nail to increase the MA of the hammer?

Using a claw hammer **Fig 2.4.13**

11 Consider Figure 2.4.15. Which type of tap would you recommend for old people and why?

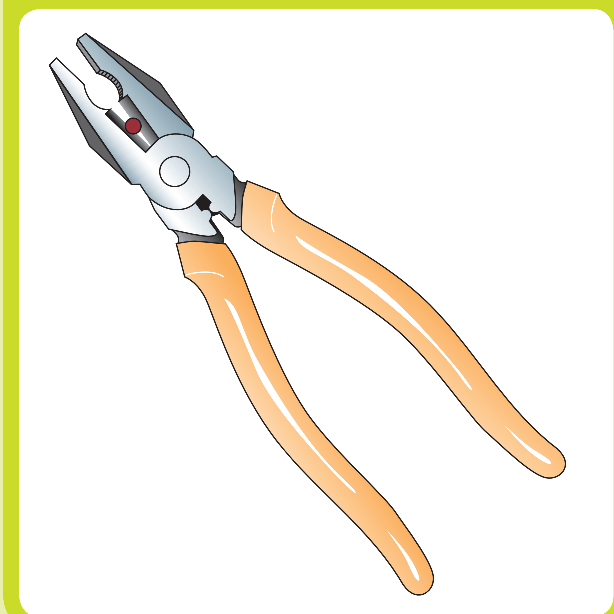
Fig 2.4.15 Which tap is better?

10 Examine a pair of pliers. Most pliers have a wire cutter close to the fulcrum of the pivot point of the pliers.

a Why are the wire cutting blades close to the pivot?

b Where would you position the wire to be cut if you wanted to exert the least force possible?

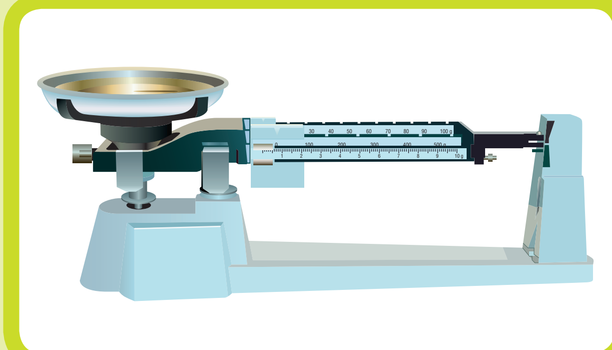
Fig 2.4.14 The blades on pliers



12 In the pliers in Figure 2.4.14, a force of 15 newtons is applied to the handles. What would be the size of the force produced at the wire?

13 Explain why the triple beam balance in Figure 2.4.16 is a lever.

A triple beam balance **Fig 2.4.16**



Investigating question

14 Design an investigation to test how far the effort arm of a lever moves as the MA of the lever is increased.

DYO

FOCUS 2.4

[Practical activity]

Prac 1 Focus 2.4

Levers

Purpose

To investigate how changing the effort affects the effort arm when lifting a load.

Requirements

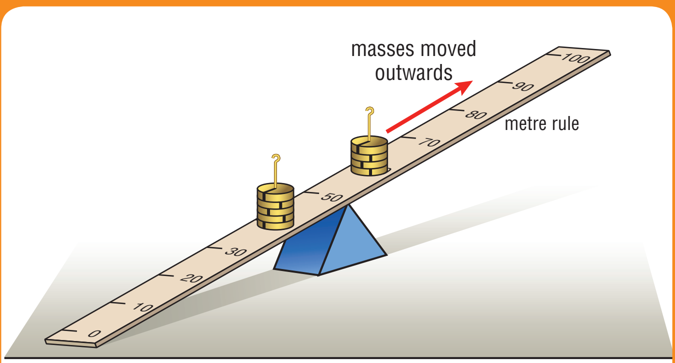
Metre rule, wedge to act as a fulcrum, plasticine, brass masses.

Procedure

1 Set up the metre rule so it is balancing on the wedge at the 50 cm mark. The ruler needs to be well balanced at this position so you might need to use small pieces of plasticine to get the rule balanced.

2 Place five 50 gram brass masses at the 40 cm mark. The centres of the masses need to be on the 40 cm mark. This is the load.

Fig 2.4.17 Set-up for Prac 1



3 Place four brass masses on the other side of the 50 cm mark. This is the effort. Slowly move these masses away from the centre of the rule until the rule balances. *Record the distance in cm from the centre of the rule to these four masses.*

4 Repeat step 3 with three, two and then one brass mass. Your data table might look like the one below.

Number of brass masses (effort)	Total mass of effort (g)	Distance from centre of rule to effort (effort arm) (cm)
4		
3		
2		
1		

5 *Draw a graph of mass and distance moved.*

Questions

1 Describe the shape of the trend or pattern suggested by your graph.

2 What conclusion have you arrived at in doing this investigation?

3 Why were the load and load arm fixed in this investigation?

4 Which variables were controlled in this investigation?

5 What were the dependent and independent variables in this investigation?

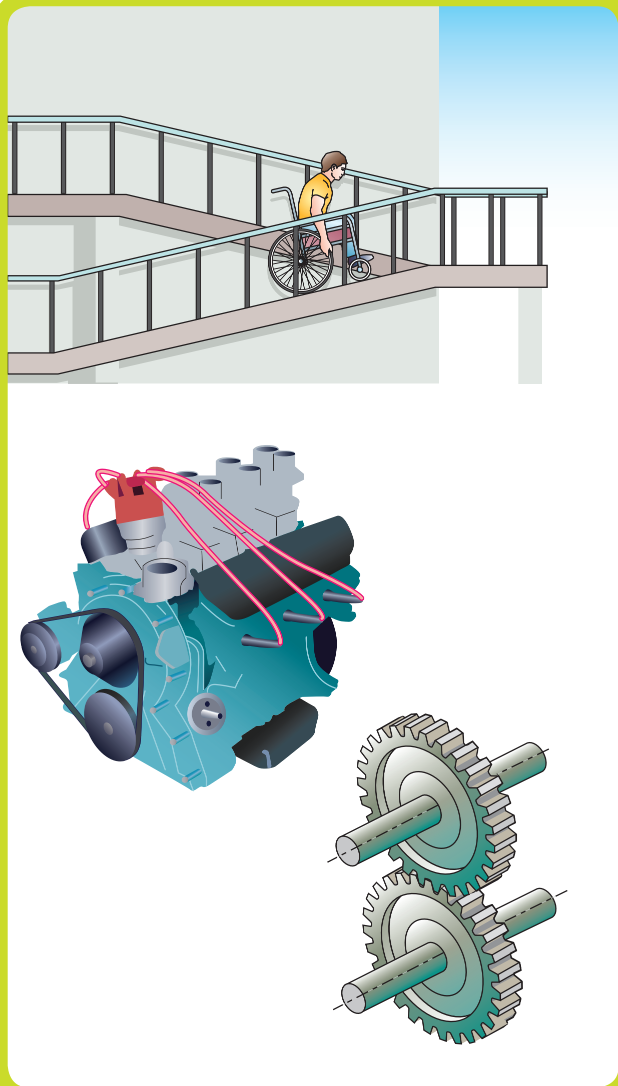
6 What type of lever (type 1, 2 or 3) did you use in this investigation?

FOCUS 2.5 More simple machines

Context

In the last Focus you learnt that machines help to make our work easier in some way. You learnt that machines can be classed as simple and complex. You explored several ways that levers can be used to make our work easier.

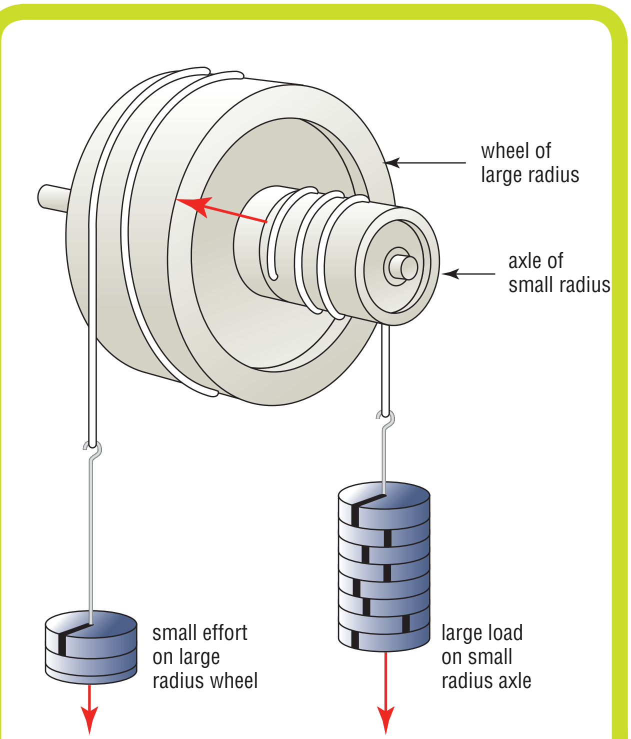
In this Focus you will be learning about four other types of simple machines. The pictures in Figure 2.5.1 show you some examples of these simple machines. See if you can guess the names of these machines.



Some simple machines *Fig 2.5.1*

The wheel and axle

The wheel and axle acts a little like a lever. With levers you learnt that by having a longer effort arm you could get a force advantage at the load. In Figure 2.5.2 the radius of the axle is like the turning load arm of a lever.



Wheel and axle being used to produce a force advantage *Fig 2.5.2*

The radius of the wheel is like the effort arm of a lever. If an effort is applied to the **wheel** (bigger diameter) then a force advantage is produced at the **axle** (smaller diameter). This is like having a lever with a longer effort than load arm to produce a force advantage.

A winch is an excellent example of a wheel and axle. In Figure 2.5.3 on page 78 you can see that the diameter of the circle traced out by the handle is wider than the diameter of the axle around which the rope is wound.

Fig 2.5.3 A winch is a good example of a wheel and axle.

In Figure 2.5.3, a force advantage is produced. This is because the handle is attached to an effort arm that is longer than the load arm. Using the wheel and axle in this way produces a force advantage, but there is a disadvantage in speed and distance. The wheel has to turn faster than the drum turns, and the handle has to turn further than the drum turns.

Fig 2.5.4 Common applications of the wheel and axle. Discuss with your partner or group members whether each picture shows a machine producing a force advantage or a speed advantage.

Belts and chains

Think of some machines with wheels that are turned by belts or chains. In Figure 2.5.5, a larger diameter front cog (attached to the pedals) turns a chain that then turns a smaller diameter rear cog (attached to the rear wheel of the bike). The rear cog turns more than once for every one complete turn of the pedal. The faster turning rear wheel means that this combination is producing a speed advantage.

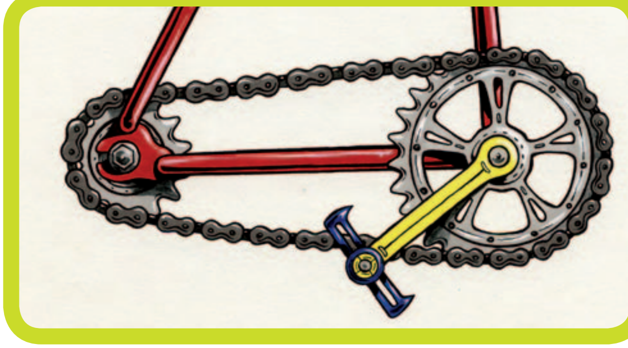


Fig 2.5.5 A chain connects the driving and driven cogs on a bicycle.

You would want this combination if speed was important. For instance, in a cross-country bike race on a flat straight road, cyclists would ensure that a small-diameter cog on the rear wheel was engaged, so that fewer pedal turns would allow more turns of the rear wheel and therefore a greater speed. Take note that this speed advantage would mean that the bike would be harder to pedal using this arrangement of gears. To make it easier to pedal you would engage the larger diameter rear cog.

In Figure 2.5.6 the motor has a smaller diameter driving wheel. It is turning a belt which then turns a larger diameter driven wheel. The motor is

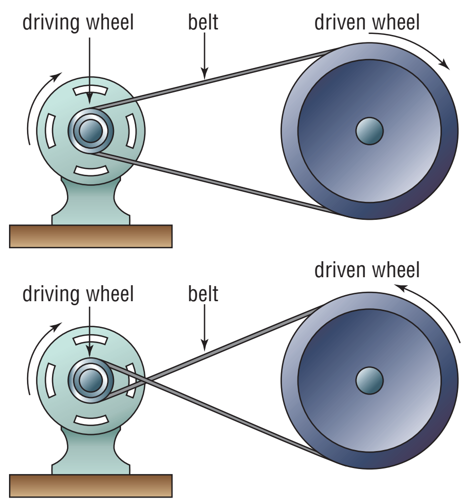


Fig 2.5.6 Belt-driven machines are frequently found in the workplace.

experiencing a force advantage but there is a speed disadvantage since the driven wheel is rotating more slowly than the driving wheel.

In the first illustration in Figure 2.5.6, both wheels turn in the same direction. In the second illustration, though, crossing the belt means that the wheels turn in opposing directions.

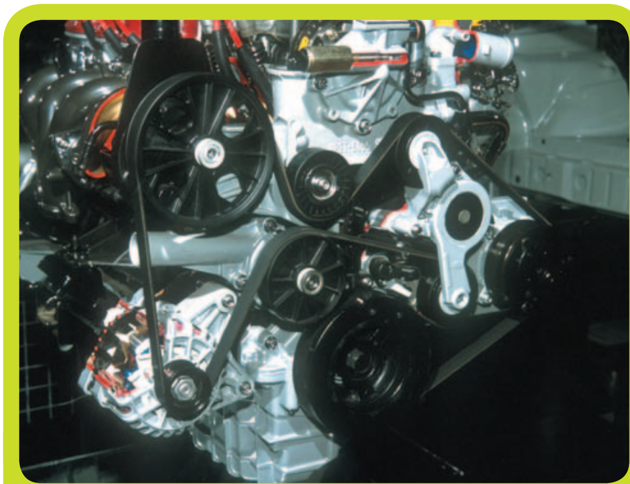
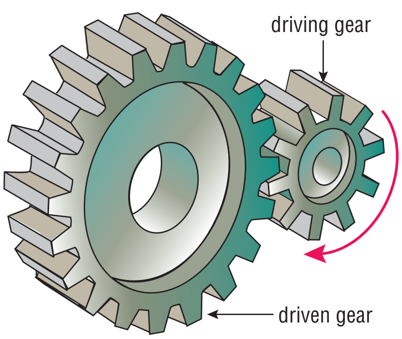


Fig 2.5.7 The fan belt of a car turns the wheel of the water pump and air conditioner.

Gears

Figure 2.5.8 shows how the gears are put together in a mechanical clock. Gears are wheels that have **teeth** (commonly called **cogs**) which mesh together so that when one gear wheel turns, the interlocking teeth cause another gear wheel to turn. In this way energy can be transferred from one place to another, but a mechanical advantage can also be produced, depending on the sizes of the driving and driven wheel.

Fig 2.5.8 Gear wheels with meshing cogs



In Figure 2.5.8, every time the smaller diameter driving wheel (on the right) turns once, its ten cogs cause the larger diameter driven wheel (with 20 cogs) to rotate through half a turn. This means that the driven wheel will rotate at half the speed of rotation of the driving wheel. This combination of gears produces a force advantage but a speed disadvantage. Note also that gears in contact will travel in the opposite direction to one another.

Interactive CW Animation

Drag and Drop CW Interactive

Homework book 2.5 Gear wheels

Pulleys

In Figure 2.5.9, pulleys are being used to lift a very heavy engine from the engine bay of a car. The way in which the pulleys are arranged can produce a force advantage as well as a directional advantage.

Fig 2.5.9 Pulleys arranged as a block and tackle to lift very heavy loads

In Figure 2.5.10 you can see that when a single pulley is used, there might be a directional advantage but there is no force advantage produced. This means that an effort of 10 N is required to lift a 10 N load. When the two-pulley combination is used, though, a force advantage is produced. In the latter case you can see that only half the effort is required to lift the load, meaning that a force advantage of 2 is produced. You can usually figure out the force advantage of a system of pulleys by counting the number of strings supporting the load. In the illustration the strings have been numbered. In the first illustration there is only one string supporting the load while in the second there are two.

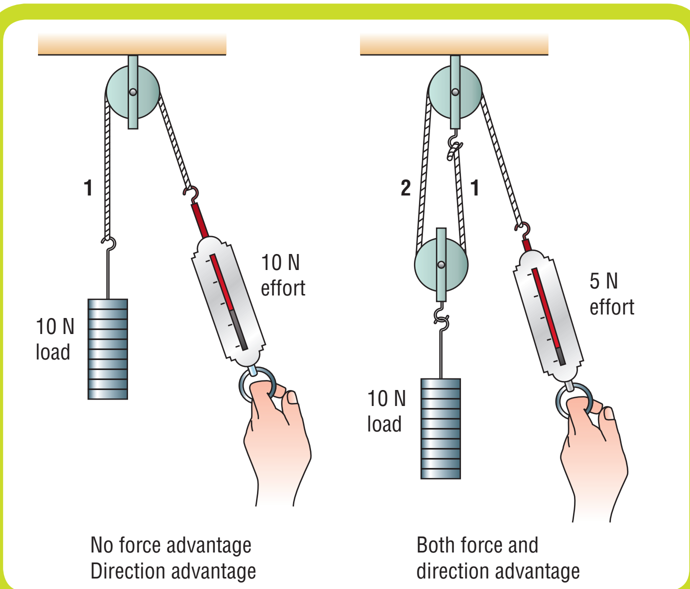


Fig 2.5.10 Pulleys can provide both force and directional advantages.

Homework book 2.6 Gear wheels

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The inclined plane

Imagine that you had to get to the top of a very steep hill. You have two options. The first is to drive straight up the hill. The second is to take the winding road up the hill to the top.

At first it might seem that the first option would be the better option, but believe it or not, going straight up the steep hill will require just as much work as taking the winding road. Remember that:

Work done = force applied × distance travelled.

Going straight up the hill would involve travelling a smaller distance but would require more force. Going up the gentle slope would involve a longer travel distance but would require less force. Because less force is required it is much easier to travel up a hill with a long gentle slope than it is to travel up a very steep hill to the same height. A sloping surface like those shown in both diagrams is called an **inclined plane**. Applying a smaller force over a larger distance is a main feature of inclined planes. Because inclined planes do this they produce a force advantage. A **ramp** is a commonly used name for an inclined plane. Figure 2.5.12 shows examples of inclined planes that you might be used to seeing.

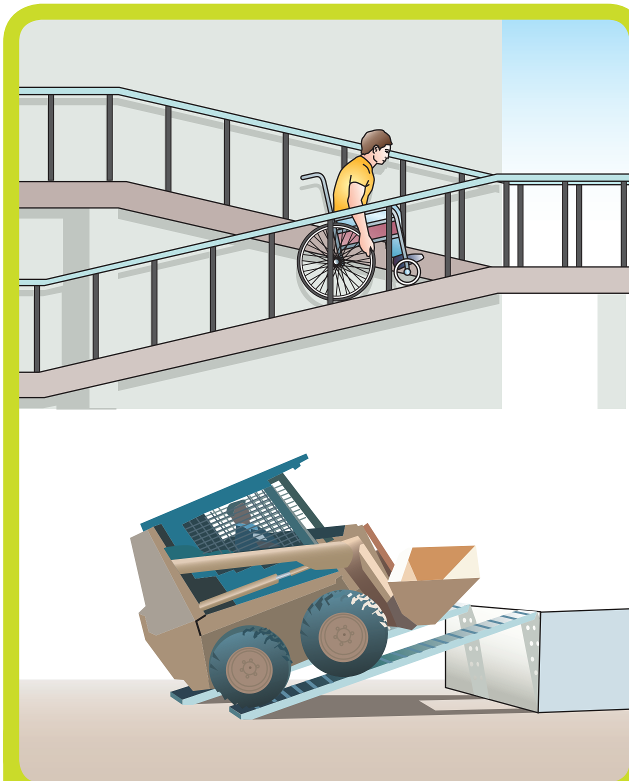
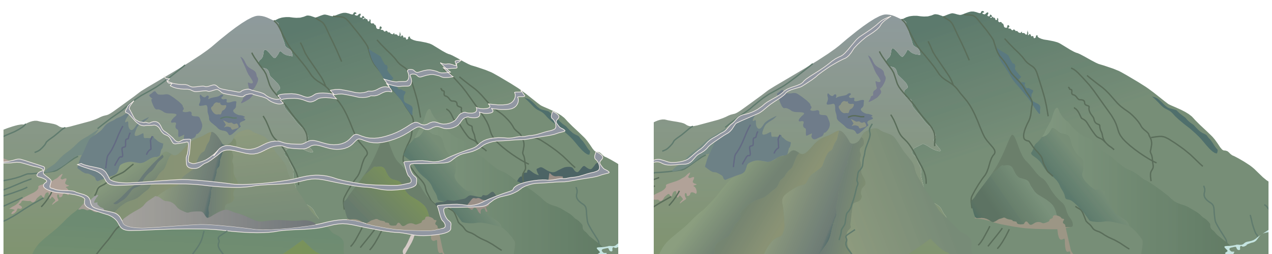


Fig 2.5.12 The longer the inclined plane, the smaller the force required to move upwards.

Fig 2.5.11 Which road would you prefer to travel on?



Science Snippet

The screw

The screw is an example of an inclined plane. The thread of a screw is really just an inclined plane wrapped into a three-dimensional shape. The top screw has a much gentler slope (called its pitch) than the bottom screw. Because it has a much more gradual pitch, there is more thread on the top screw. Consequently it is easier to screw this one into a piece of wood, but it would take more turns of the screw to do this. The screw on the bottom, having less thread, can be screwed into wood with fewer turns but would require more force.

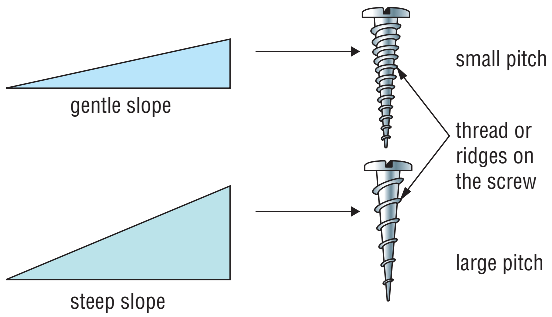


Fig 2.5.13 The screw is an example of another practical use for an inclined plane.

Drag and Drop CW Interactive

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2.5 FOCUS [Questions]

Use your book

The wheel and axle

1 Draw a sketch of a simple wheel and axle to show how a force advantage can be produced.

2 Explain why in Figure 2.5.5 there is a speed advantage.

Belts and chains

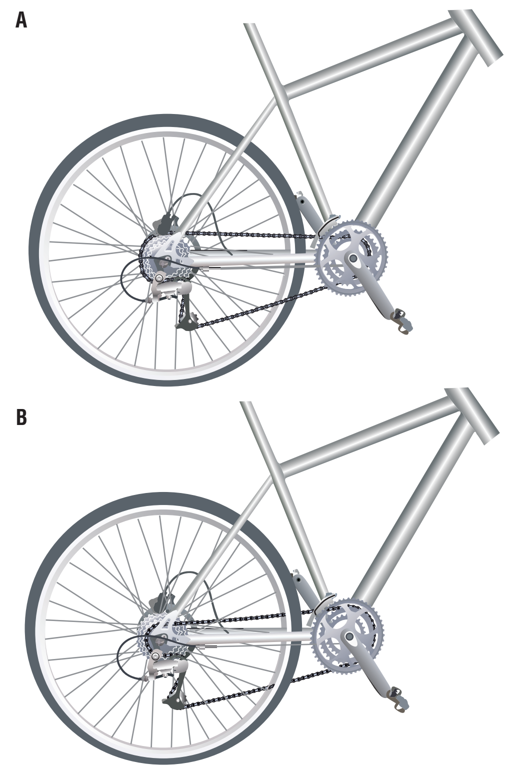
3 Draw a diagram to show how a belt and wheel combination using different-sized wheels can be used to produce a speed advantage. Label the driving and driven wheels.

4 For a two-wheel belt-driven system, what would have to be done to the belt in order to reverse the direction of the driven wheel?

Gears

5 Look at Figure 2.5.14 and select the better gear for riding uphill. Explain your selection.

Diagram for question 5 Fig 2.5.14



6 What is another word for the teeth of a gear wheel?

7 Will the driven gear in Figure 2.5.15 turn more slowly or faster than the driving wheel and by how much?

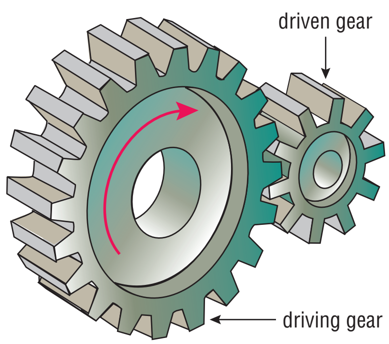


Fig 2.5.15 Diagram for question 7

>>

8 Figure 2.5.16 is a simplified system of gear wheels. The direction of rotation of the driving wheel is shown. Each gear has been numbered. Write down the direction of rotation (clockwise or anticlockwise) of each of the gear wheels 2–6.

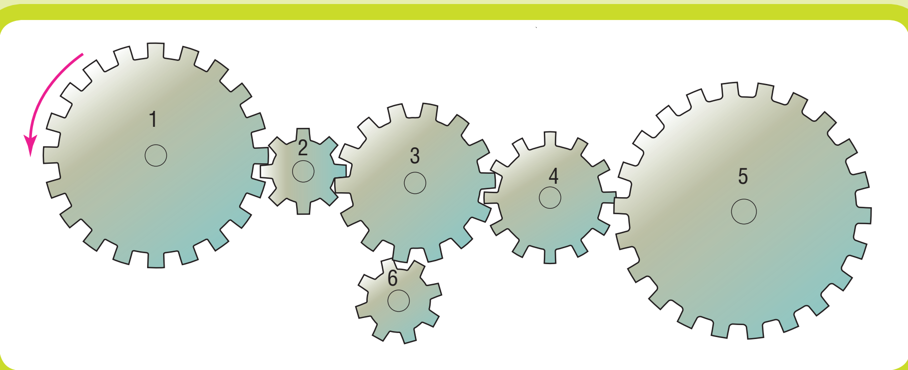


Fig 2.5.16 A system of gear wheels

Pulleys

9 How much force will be required to lift the 100 N mass using the pulley arrangement in Figure 2.5.17?

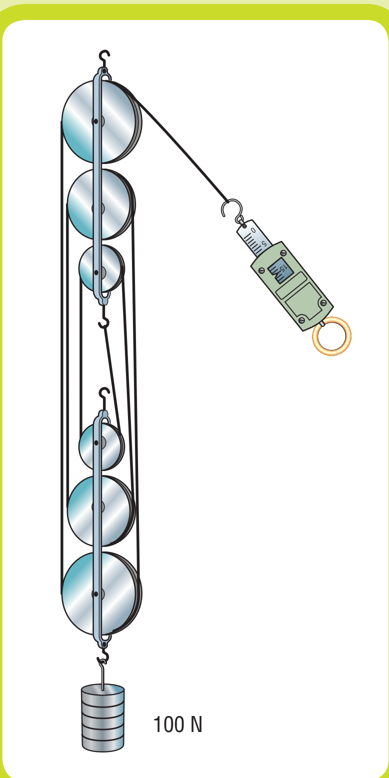


Fig 2.5.17 Diagram for question 9

The inclined plane

10 Look at Figure 2.5.18. In loading the lawnmower onto the back of his truck, the gardener could have lifted the lawnmower directly onto the back of the truck or he could have used the ramp shown in the diagram.

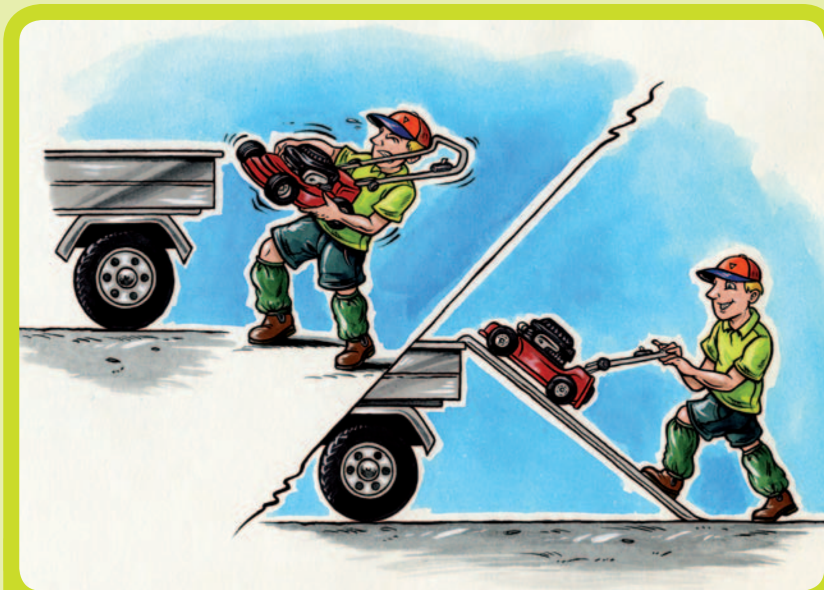


Fig 2.5.18 Diagram for question 10

a Is more work, less work or the same work done when using the ramp?

b Is more, less or the same force applied when using the ramp?

c Does the mower move through a bigger distance, smaller distance or about the same distance when using the ramp?

Use your head

11 Using Figure 2.5.16, choose the order of speed of the gears, from fastest to slowest.

For each of the gears marked 2, 3, 4, 5 and 6, indicate whether:

a the gear moves in the same direction as 1, or in the opposite direction

b the gear spins faster or more slowly than 1.

12 Figure 2.5.19 shows how a wedge can be used to split a rock. Name the type of simple machine shown by a wedge, and describe how it works.

Investigating question

13 Use your library or the Internet to find out why cars need gears. It might help you to understand if you first find out why gears are necessary on bicycles.

Fig 2.5.19 Diagram of a wedge for question 12

2·5 FOCUS [Practical activities]

Prac 1 Focus 2.5

Using pulleys

Purpose

To construct and test the force advantage produced by different pulley combinations.

Requirements

Brass masses, appropriate spring balances, two triple and two single pulleys (see Figure 2.5.20), string, retort stands, boss head, clamp, scissors.

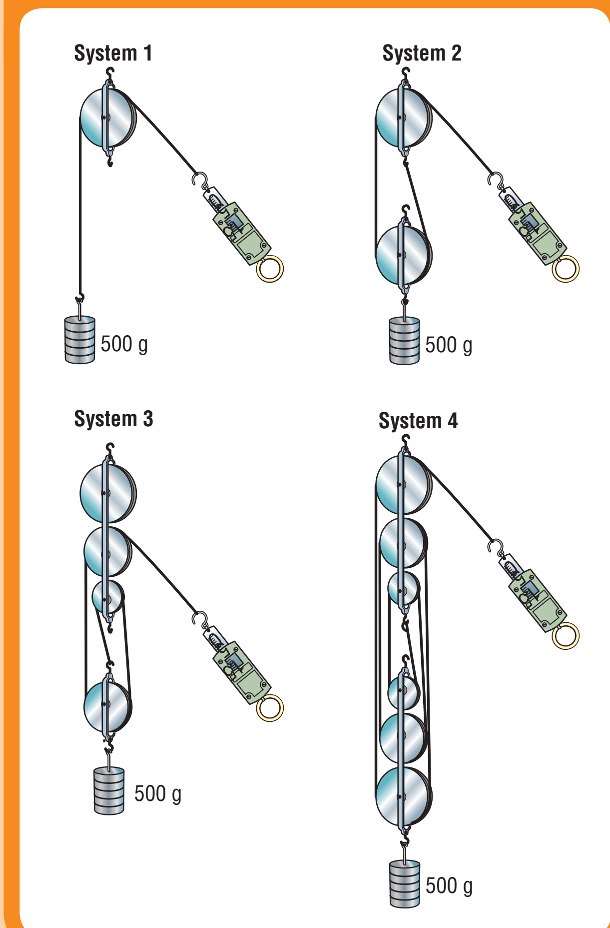
Procedure

1. Build each of the pulley systems shown in Figure 2.5.20.
2. Count the number of vertical sections of string between pulleys supporting the masses in each pulley system. Get your teacher to help you if you don't know how to do this.
3. *Draw up a suitable table to record the force required to lift the mass, against the number of strings supporting the masses for each of the pulley combinations.*
4. *Draw a graph of your results, with number of strings supporting the masses on the x-axis and force required to lift the masses on the y-axis.*

Questions

1. What happens to the force required to lift the masses when the number of strings supporting the masses increases?
2. Describe what happened to the distance you moved the spring balance while lifting the load with the different pulley systems.
3. What sort of advantage do several pulleys provide? Why?

Fig 2.5.20 Pulley systems to build



Prac 2
Focus 2.5

Investigating inclined planes

Purpose

To investigate how the force required to pull an object up an inclined plane changes as the slope of an inclined plane changes.

Requirements

Rollers with hooks (or a smooth wooden block with a hook), flat board between 30 and 35 cm long (a bench protector might do), books, protractor, spring balance, string, scissors.

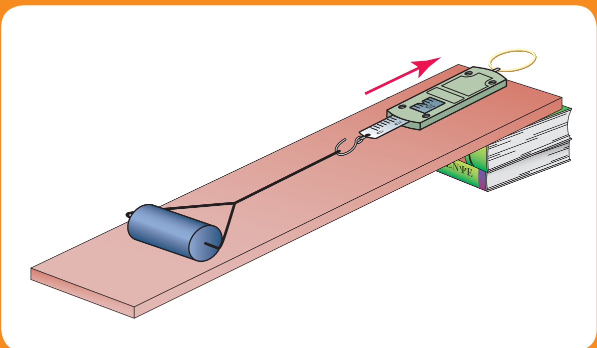
Procedure

1. Read through this activity first and *construct a suitable table to record your results.*
2. Measure the force required to drag the roller (or the wooden block) on the board while the board is horizontal. *Record your data in the table.*
3. Raise the end of the board by placing a book or books at one end. The board now becomes an inclined plane.
4. Use the protractor to measure the angle of the slope of the inclined plane. *Record this in the table.*
5. Use the spring balance and the roller to measure the force required to drag the roller up the plane. *Record this in the table.*
6. Repeat the process for other angles of the inclined plane and *record this in the table.*
7. Your last measurement should be the weight of the roller (or wooden block). You will need to hang the roller off the spring balance. What slope does this correspond to? *Record this in the table.*
8. *Draw a graph of your results.*

Questions

1. How does the angle of the inclined plane change the force required to move an object to a higher level?
2. What was the force required when the angles of the slope were 30° and 60°?
3. What advantage did the inclined plane give you in this experiment?
4. What were the independent and dependent variables in this experiment?
5. What are some of the variables you attempted to control in this investigation?
6. Did you experience any special difficulties in doing this investigation? What were some of these?
7. What modifications would you make to the way you did this experiment in order to improve your result?

Fig 2.5.21 Set-up for Prac 2



FOCUS 2.6

Energy transformations

Context

Think about all that is happening when you flick a switch to turn on an electric light. Electrical energy is flowing through a light bulb, causing it to become hot. The hot filament of the bulb causes it to give off light. Turning on an electric light now can be seen to involve electricity, heat and light—three very different ways that energy is transferred.

This is why a light bulb can be considered an energy-transforming device. Toasters, washing machines, televisions, power stations and the family car are all devices that transform the way in which energy is transferred. In this Focus you will investigate the devices that transform energy in different ways and the efficiency with which the transformations occur.

Science Snippet

Different forms of energy

It is often quite tempting to think about sound, light, heat or electricity as different forms of energy. In a scientific sense, though, this is not quite true because there are no different types of energy. Light, sound, heat, electricity and so on are simply different ways in which energy is transferred from place to place.

Energy converters

Figure 2.6.1 shows some examples of how devices can change the way in which energy is transferred.

Fig 2.6.1 Devices like these are able to transform the way in which energy is transferred.

In three of the examples in Figure 2.6.1 the **input energy** is electricity. The device then transforms the way in which energy is transferred as **output energy**. For instance, the output energy of a washing machine includes the kinetic energy of the moving drum that agitates and spins the water and clothes.

Useful and wasted energy

The spinning washing-machine drum possesses kinetic energy because of its movement. This kinetic energy is **useful energy** because it is necessary if our clothes are to be cleaned. Washing machines also produce quite a lot of heat and noise. Because most of this heat and noise are not directly necessary in order to clean clothes, we refer to them as **wasted energy**.

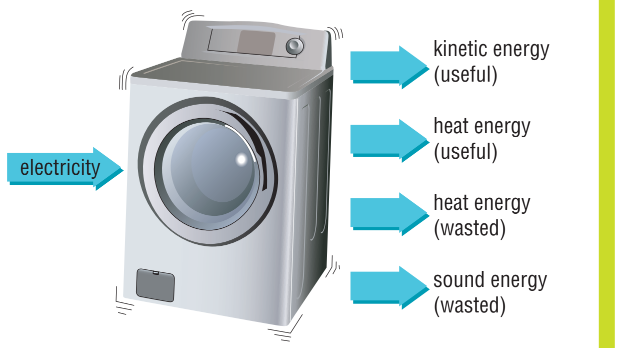
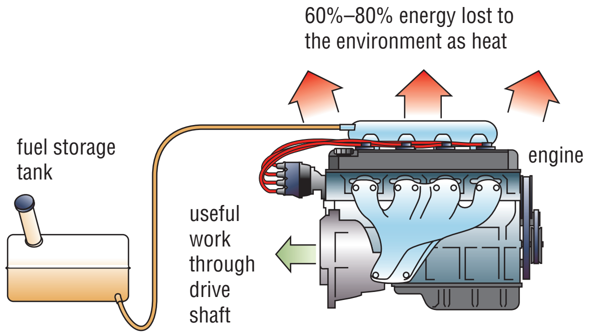


Fig 2.6.2 Most energy converters transform energy into useful and wasted energy.

Have you ever touched or put your hand close to an incandescent light bulb that has been turned on? If you have you probably know that light bulbs give off a lot of heat. Do you think that this heat energy is useful or wasted energy? Think about this. If you ask someone why we need light bulbs, they would no doubt say 'to produce light'. Therefore light is the useful energy produced when a bulb is turned on. The heat energy given off when a bulb is turned on is wasted energy.

The engine that drives your family's car is probably an internal combustion engine. This means that petrol is burnt inside the engine and the energy from the burning fuel eventually turns the wheels of the car. The internal combustion engine is a good example of an energy converter but, as Figure 2.6.4 shows, it is actually a very wasteful engine.

Fig 2.6.4 Only a small percentage of the input energy of the internal combustion engine is actually converted to useful output energy.



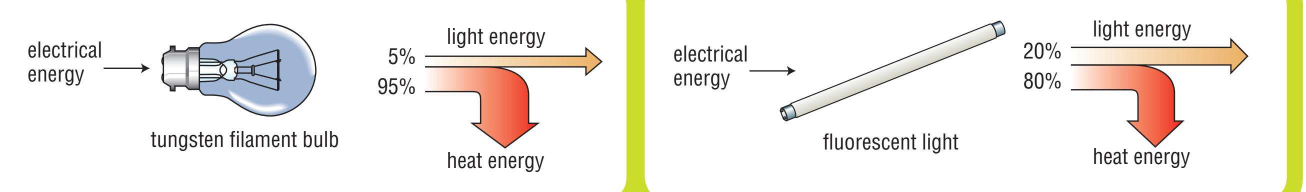
Efficiency:	petrol engine	25%
	diesel engine	35%
	jet turbine	30%
	steam engine	40%

Science Snippet

Friction and wasted energy

Most of the wasted energy produced by machines is the result of friction produced from moving parts. In the internal combustion engine discussed above, for instance, most of the input energy in the fuel is transformed into heat energy. Some of this heat is produced as the pistons move rapidly up and down within the engine. The friction between these and other moving parts produces a lot of heat, most of which is released to the air by the radiator of the car.

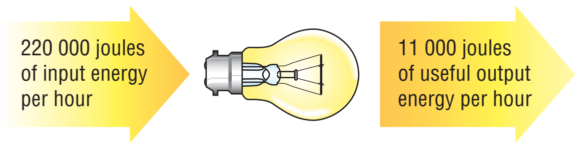
Fig 2.6.3 The fluorescent tube is more efficient than the incandescent bulb.



Efficiency

The efficiency of a machine is related to the amount of useful output energy produced from the input energy. Consider the examples of the electric light bulb and internal combustion engine again. Figure 2.6.5 shows details of approximately how many joules of energy are converted from a certain amount of input energy.

Only a certain amount of the input energy of a converter is transferred as useful energy. *Fig 2.6.5*



The formula for efficiency is:

$$\text{Efficiency} = \frac{\text{useful output energy in joules}}{\text{input energy in joules}} \times 100$$

Let's apply the formula to calculate the efficiency of the bulb.

Example

To calculate the efficiency of the bulb.

Useful output energy per hour = 11 000 J

Input energy per hour = 220 000 J

$$\text{Efficiency} = \frac{\text{useful output energy in joules}}{\text{input energy in joules}} \times 100$$

$$= {}^{11\,000\text{ J}}/_{220\,000\text{ J}} \times 100$$

$$= 5\%$$

From the example above you can see that the bulb is not a very efficient energy converter. Most of the input energy going into the bulb results in wasted heat energy. The table below gives you an idea of the efficiency of some common household appliances. Much the same can be said of the internal combustion engine of the family car. Most of the energy contained in the petrol is lost as heat energy. The table below provides some efficiency data for common energy converters.

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Appliance	Efficiency (%)
Petrol engine	25
Diesel engine	35
Man	15
Power station	30
Electric motor	80

Homework book 2.7 The Energy Allstars

2·6 FOCUS [Questions]

Use your book

Context

1 Why is a television considered an energy-transforming device?

2 Describe the different ways in which a light bulb allows energy to be transferred.

Energy converters

3 Draw an energy flow diagram to show the input and output energies when an electric drill is turned on.

4 Name an energy converter that enables the following energy conversions:

a chemical to electrical
b electrical to kinetic
c sound to electrical
d wave to kinetic.

Useful and wasted energy

5 What are the useful and wasted energies when an electric drill is turned on?

6 Why can we say that most of the input energy in your family car is wasted?

Efficiency

7 Calculate the efficiency of an electric toaster if only 300 J of the 2000 J of input energy required to make two slices of toast is useful energy.

Use your head

8 Describe the different ways that energy is transferred when a weightlifter does the exercise shown in Figure 2.6.6.

Fig 2.6.6 Diagram for question 8

Investigating questions

9 What is meant by the 'law of conservation of energy'? Use your understanding of the law to discuss how it applies to any of the energy converters mentioned in this focus.

10 Your challenge is to design and test a 'propeller' (turbine) that could be used for a wind-energy power station, or a steam-powered power station. You could use the metal from a cool-drink can, which can easily be cut with scissors. Be careful, because the metal will be very sharp. The propeller needs to be mounted so that it can turn when air (or steam) is blown on it. One possible arrangement is to push a test tube through the middle of the propeller and let it spin on a ballpoint pen. Use the Internet to research possible shapes for your propeller. Ask your teacher if you can try your design and test its efficiency. You will need to devise a way of testing the efficiency.

DYO

FOCUS 2·6 [Practical activity]

Prac 1 Focus 2.6

Make an energy converter

Purpose

To construct and use a device that transforms the way in which energy is transferred.

Requirements

Round-bottomed flask, rubber stopper with two holes, glass tubing, Bunsen burner, string, fishing swivel, retort stand and clamp, matches.

Procedure

1 Build the device shown in the diagram below.
2 Carefully heat the water in the round-bottomed flask.
3 *Record your observations in your notebook.*

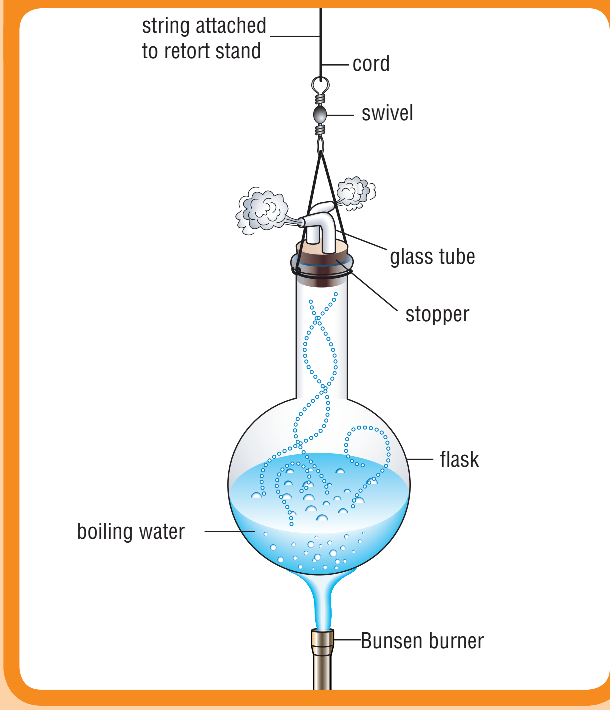
Questions

1 What transformations occurred in your model?
2 List the input and output energies involved in your model.
3 List the useful and wasted energies in your model.
4 What are some ways that you could redesign the steam engine to make it more powerful?

Ask your teacher if you can investigate the efficiency of your new design from question 4.

DYO

Fig 2.6.7 Steam turbine



FOCUS 2·7

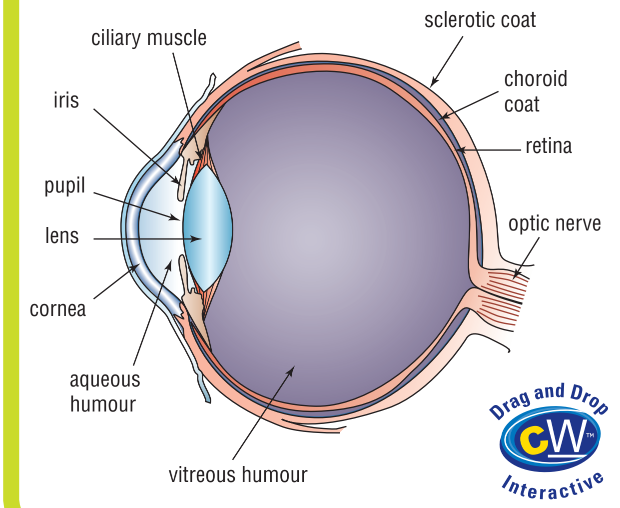
Organisms as energy converters

Context

You are an energy converter, just like all organisms. Your eyes, muscles, ears—in fact, all your cells—are converting energy from one form to another. In this Focus you will look at these conversions and the conversion that enables them all to occur—photosynthesis, probably the most important chemical process on Earth.

Eyes

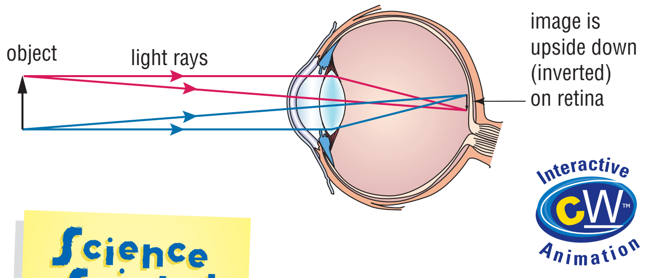
The human eye is one of the true marvels of nature. Its basic function is to change light into an electrical signal that can be sent by nerves to the brain. It is your brain that 'sees', not your eye. Your brain interprets the electrical signal and creates the image. The structure of the eye is shown in Figure 2.7.1, and the functions of the parts are shown in the table below.



The human eye *Fig 2.7.1*

Part	Structure	Function
Cornea	Transparent disc on the front of the eye	Allows light to enter the eye and to refract the light so that it can focus on the retina. Does most of the refracting of light
Iris	Circular sheet of muscle that can expand or contract	Regulates the amount of light entering the eye by expanding or contracting to change pupil size
Pupil	Circular hole in the centre of the iris	Allows light to pass to the retina
Lens	Transparent jelly-like biconvex disc	Does the fine focusing of light onto the retina
Retina	Layer of nerve tissue at the back of the eye	Converts light into an electrical signal and detects light of different frequencies to allow colour vision
Vitreous humour	Thick, transparent jelly-like contents of the back of the eye	Keeps the shape of the eye and allows light to reach the retina
Aqueous humour	Transparent watery liquid in the front of the eye	Supplies nutrients and oxygen to the lens and cornea (as they have no blood vessels) and allows light to reach the lens
Optic nerve	Thick nerve at the rear of the retina	Carries electrical message to the brain
Ciliary muscle	Ring of muscle around the lens	Changes the shape of the lens to allow focusing on near and far objects

Fig 2.7.2 The refraction of light to focus on the retina



Science Snippet

Seeing with your brain

An experiment conducted at a university involved a student wearing a special pair of glasses that turned everything upside down. The student had to wear the glasses for several days. After a few days the student started seeing everything the correct way up! Then the glasses were removed and they found that everything looked the wrong way up for a long time. Eventually their vision returned to normal.

Light travels in straight lines. It enters the eye and is refracted so that the rays meet on the retina at a point. You can see this process in Figure 2.7.2. On the retina, the image is in an upside-down position. So the brain interprets light falling on the top part of the retina as being from the bottom of the object. It is the brain that learns to 'see' this as upright.

Colour vision

We can see colours, but many animals cannot. The retina has three different types of **receptor** cells that can detect light. One type detects light that is a longer wave length, and the brain interprets it as the colour red. Another receptor senses shorter wave lengths, which the brain decodes as blue. The third type of receptor detects light of wave lengths between red and blue, which is seen as green. All other colours we see are various combinations of these three colours—so equal amounts of red and green are seen as yellow. Both red and green receptors detect the light and the brain interprets this as yellow.

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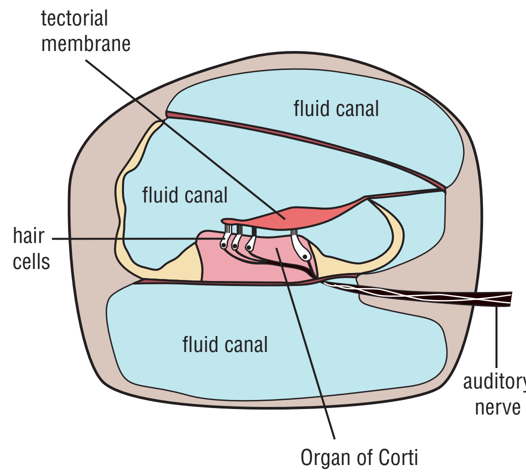
Homework book 2.8 Eyes in the night

Ears

The human **ear** is an incredibly sensitive organ. Its function is to change sound waves in the air into electrical signals that can be sent by nerves to the brain. It is the brain that 'hears' the sound, not your ears. The brain interprets the electrical signals as different sounds of differing pitch and loudness. You may have already learnt about the ear in *Science Aspects 1*. The key part of the ear responsible for creating the electrical messages is the Organ of Corti. This can be seen in Figure 2.7.3.



The Organ of Corti in the cochlea of the human ear Fig 2.7.3

The vibration from the moving **hammer, anvil and stirrup bones** sets up vibration in the fluid in the **cochlea**. This travels down the top part of the canal in the cochlea and pushes on the tectorial membrane. This causes it to move up and down and press on the hairs of the sensory cells. These then send an electrical message via nerves connected to them to the brain. So this is the part of the ear that converts the sound waves to electricity.

Science Snippet

Ear rings

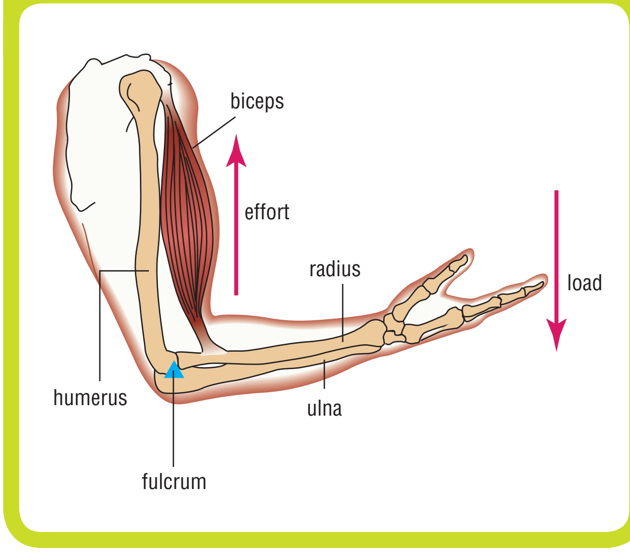
The **Organ of Corti** is easily damaged. Loud music, for example, can squash the hair cells flat and they may not recover, causing permanent deafness in particular frequency ranges. Protecting your ears is important around loud sounds. If your ears seem to 'ring' after a loud concert, you are listening to music that is too loud.

Skeletal muscles

In Focus 2.4 you learnt about levers, and the law of the lever. Human bones are levers, and the skeletal muscles that surround them provide the energy to work the levers. A muscle contains stored chemical energy. Respiration releases this energy and causes muscles to contract. So chemical energy is converted into kinetic energy. There is also some heat released. Look at Figure 2.7.4.

You can see that the fulcrum is at the elbow. The biceps provides the effort where it is attached to the radius only a few centimetres from the fulcrum. The effort arm is therefore very short. The load arm is from the hand to the elbow joint, a much longer distance than that of the effort arm. So this is a third-class

Fig 2.7.4 The human forearm is a lever.



lever, where the effort arm is shorter than the load arm. Before reading on see if you can identify the advantage and disadvantage of this lever system.

This type of lever means that the biceps muscle must exert more force on the load than would be required to lift the load without using the forearm. If the load has a weight of 10 newton, the biceps will have to exert a force of several times this to lift the load. This is a force disadvantage. What is the advantage you get from this lever? Moving the radius up a small distance moves the hand much further and faster. You gain a speed and distance advantage from this lever. So actions such as lifting and throwing can move an object very quickly.

There are other kinds of levers in the human body. Some can provide a force advantage, while others give a speed advantage.

Prac 2 p. 94

Respiration

All your cells convert chemical energy into heat. Many also convert chemical energy into kinetic energy. Respiration is the chemical process that uses oxygen to release energy. It converts carbohydrates such as glucose into carbon dioxide and water. So you are an energy converter. The heat helps your body to remain active even when the external temperature is very low. The kinetic energy is produced through movement of muscles.

$$\text{sugar (glucose)} + \text{oxygen} \rightarrow \text{carbon dioxide} + \text{water}$$

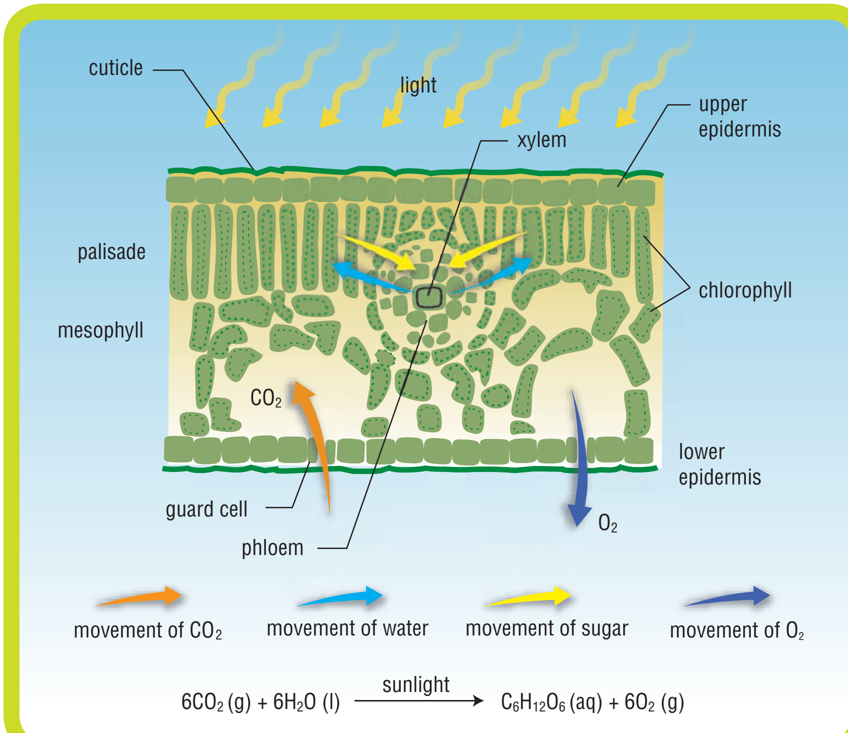
$$C_6H_{12}O_6\ (aq) + 6O_2\ (g) \rightarrow 6CO_2 + 6H_2O$$

Photosynthesis

You should already know quite a bit about photosynthesis. Where does it happen and what does it make? What does it need? See if you can answer these questions before reading on.

You should have remembered that it is a chemical process in green plants that enables them to make food. The major product is sugar. From sugar all the organic compounds such as vitamins and proteins can be made. Plants need a source of energy to power this process. The energy source is sunlight. The green-coloured chemical called chlorophyll traps the energy from sunlight. This is the energy needed to run the process. So the energy conversion is from light to chemical energy stored in the sugar. The energy converter is mainly the leaf. This is the organ in which the process occurs.

Interactive CW Animation



In a leaf, photosynthesis converts energy from sunlight into chemical energy in sugar. Fig 2.7.5

To summarise the process:

carbon dioxide + water → sugar (glucose) + oxygen

This is probably the most important process as it powers most of the life on Earth. The energy from sunlight is therefore able to pass eventually into food webs and give organisms the energy to perform all their life functions.

FOCUS 2·7 [Questions]

Use your book

Eyes

1 What is the function of the human eye?

2 What does the cornea do in the eye?

3 What part of the eye can change the amount of light entering it?

Colour vision

4 How many different types of colour receptors are there in the eye, and which colours do they detect?

Ears

5 What is the function of human ears?

6 What part of the human ear is damaged by loud sounds?

Skeletal muscles

7 What energy conversion occurs in a muscle?

8 What type of lever is the human forearm and what advantage does it give us?

Respiration

9 What energy conversion occurs in the process of respiration?

Photosynthesis

10 What is the energy conversion in photosynthesis?

11 What substance traps the energy from sunlight that powers the process of photosynthesis?

Use your head

12 Explain what you should see if a blue light is shone onto a red surface.

13 How do your eyes cope with the increased light when walking from a dark room out into sunlight?

14 When someone cries, their vision becomes blurry. Give a possible reason why this may happen.

15 Propose a theory about why we see only black and white at night and colour during the day.

16 Cataracts are lenses that have become clouded by opaque material laid down in the lens. How would this interfere with vision?

17 Cataracts can be removed. The lens is removed and the person can see again. Explain what you think this would do to someone's vision.

18 Read the Science Snippet 'Seeing with your brain' (page 90) again. What does this experiment tell you about how we see? Explain your answer.

19 Why are tall cricketers with long arms often able to bowl faster even though they move their elbow through at about the same speed as shorter bowlers?

Investigating questions

20 Find out why an echo occurs and explain how bats use this process.

Fig 2.7.6 How and why do bats use echolocation?

21 Submarines can determine where they are underwater using sonar. What is this process and how does it measure how far away something is?

22 Find out how a plasma television makes light and why it gradually dims after a few years.

23 A DVD player can send a signal to an amplifier either by an optical cable, or a coaxial cable. What is sent by these two different types of cable?

24 Some people have an inherited condition called red–green colour blindness. What is this condition and why is the vision of people with this condition different?

2·7 FOCUS [Practical activities]

The eye

Prac 1 Focus 2.7

Purpose

To use a light box to study the effect of lenses on light and to understand how colour vision occurs.

Requirements

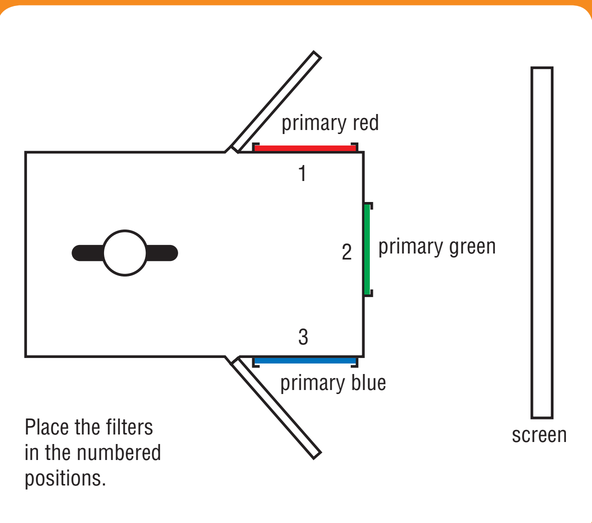
Light box with convex and concave lenses of different curvature; power pack; ruler; screen (white A4 sheet of paper); primary green, blue and red filters, ray-forming shield.

Procedure

Lenses

1. Connect the light box to the power pack on the DC terminals and set it on 12 volts. Do not turn on the power yet.
2. Place the light box on the benchtop. Place a ray-forming shield with three slits in the end further away from the light bulb.
3. Turn on the light box. Place the fatter convex lens into the light rays on the benchtop so that the thickest part of the lens is hit by the centre ray. The lens should be about 5 cm from the light box.
4. Measure the distance to where the three light rays cross. *Record this in a table.*
5. Replace the fat lens with a thinner lens in the same place. Again measure and *record the distance to the focus point.*
6. Try the concave lenses instead of the convex ones and *write down your observations.*

Fig 2.7.7 How to set up your colour experiment



Mixing colours

7. Set up the light box with coloured filters in the slots next to the mirrors and arrange it near your screen as shown in the diagram below.
8. By opening the mirrors different amounts, you can make different combinations of colours overlap on the screen. Try mixing pairs of colours and all three colours. *Record your observations in a table.*
9. Experiment with other filters to see what happens. Try cyan, magenta and yellow.

Transmission of colour

10. Remove the coloured filters. Close the mirrors, turn the light box around and place a primary blue filter in the end further from the light bulb. The blue colour should shine on the screen.
11. Now place a red filter between the light box and the screen. *Record the colour you see on the screen.*
12. Try different combinations of red green and blue filters like this and *record your observations.*

Questions

1. The cornea and the lens of your eye have convex surfaces. What did this activity show you about these parts of the eye?
2. If the cornea was curved differently how would this affect the light rays entering the eye?
3. If your lens in your eye became thinner what would happen to the light rays passing through it?
4. When green and blue colours were shone on the screen what did you observe?
5. What did you observe when red, green and blue colours were shone on the screen together?
6. Plasma television screens contain thousands of tiny units called pixels. These glow different colours as light strikes the surface, which is coated with a coloured chemical called a phosphor. These are the colours we see on the screen. How many colours would be the minimum you could use to see all the different colours we experience?
7. What would happen if you shone white light through a green filter followed by a red filter?
8. Why does a red object look red when white light is shone on it?

Prac 2 Focus 2.7

A foot long lever

Purpose

To study the action of a lever system in the human body.

Requirements

Meter rule or ruler, anatomy book, skeleton or diagram of skeleton (optional).

Procedure

1 Work in pairs. One person, the subject, removes a shoe and sock from one foot. It is best if this person is wearing a skirt or short pants, or can roll up their pants to the knee on the shoeless leg. The other person is the experimenter.

2 The subject must hold onto a desk or the wall. They use the shoeless foot to stand up onto their toes, allowing the other foot to lift off the ground. They must be careful to hold on. They do this a few times while the experimenter watches.

3 The experimenter must observe and decide where the muscle is that is supplying the energy for this lever. *Write a description of where this muscle is found.* If you can find an anatomy book, see if you can find the name of this muscle.

4 Decide where this muscle must be pulling on the foot. A skeleton or diagram of a skeleton may assist you. *Write down your decision.*

5 Identify the parts of this lever—the fulcrum, effort, load, effort arm and load arm. Discuss this in your group.

6 Measure the length of the load arm and effort arm.

7 *Draw a labelled diagram showing the parts of this lever, and your measurements.*

Questions

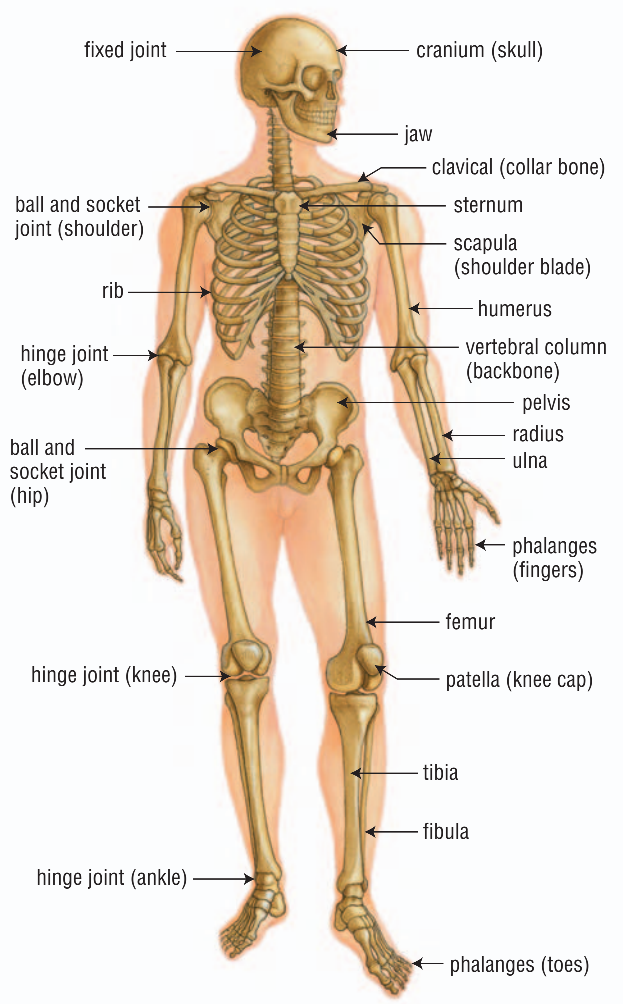
1 Where is the muscle that is powering this lever and where is it probably attached?

2 Which was longer in this lever, the load arm or the effort arm? Give your measurements.

3 Does this lever provide a force advantage? Explain how you decided this.

4 How does this lever system compare with the biceps and your forearm lever system?

Fig 2.7.8 The human skeleton



FOCUS 2·8

Sustainable energy use

Context

Each year humans use more and more energy. Most of this energy comes from resources that cannot be replaced when they are used up. Because the world's population is increasing, it is very important for us to understand the effect of diminishing energy resources on our lives and on the lives of future generations. We also need to appreciate how important alternative energy technologies and resources will be in the future.

Non-living energy consumers

Fig 2.8.1

Consuming energy

In the last Focus you learnt that living things need fuel of some sort in order to carry out the activities of life. For instance, in order to do all the things that you need to do during a typical day, you have to consume food. The food that you consume is the fuel that helps you to produce energy. Think about all the non-living things that you come across in a typical day that need energy in order to operate. All the electrical appliances in your home (dishwasher, toaster, TV, computer etc) need energy in the form of electricity in order to operate.

The cars, buses, trucks and other machines that you passed on the way to school need petrol or some other fuel in order to work. The energy for these appliances and machines generally comes from the burning of **fossil fuels**. These fuels include oil, natural gas and coal. For instance, the petrol or diesel that powers cars, buses, trucks and many other machines comes from the refining of crude oil. The electricity that you receive at

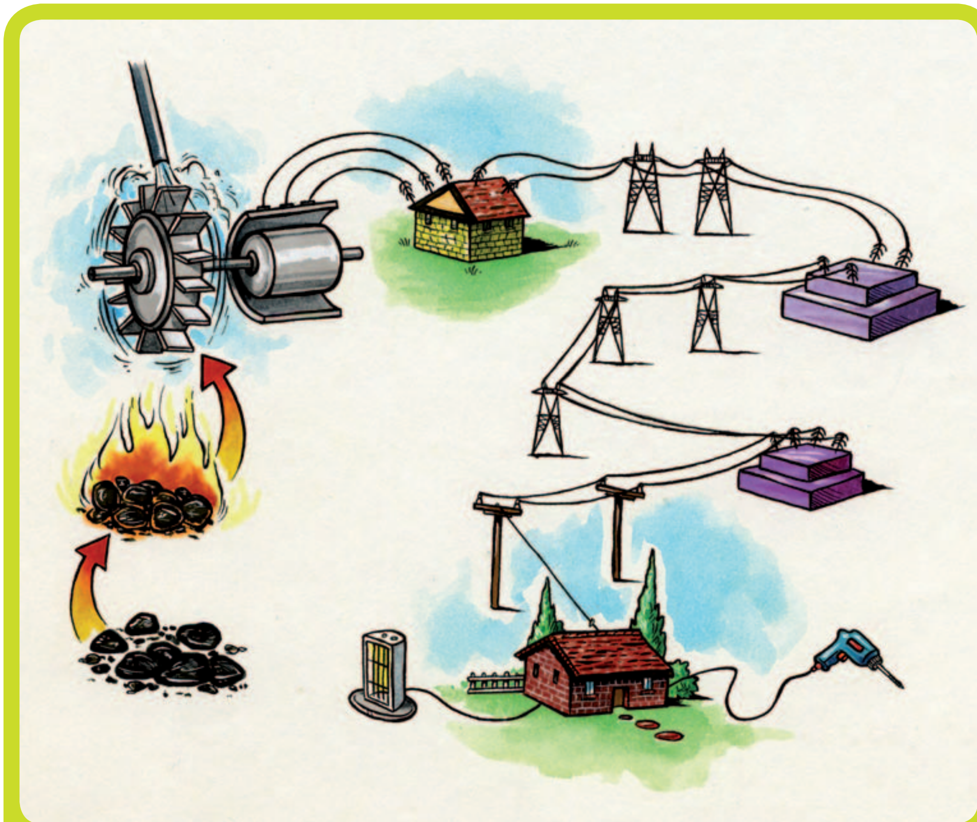


Fig 2.8.2 Power stations produce the electricity for homes and industry.

home probably comes from the burning of coal in a power plant. The burning coal produces heat, which is used to boil water. The boiling water produces steam under pressure, which is then used to turn a **turbine**. The turbine turns a **generator**, which produces electricity. This electricity is then transmitted to homes and industry.

Changing energy needs

We have been using energy at an ever-increasing rate over the last few hundred years, especially the last hundred years. The table in Figure 2.8.3 shows how the total daily energy requirements for humans have increased through the ages.

Fig 2.8.3 The total daily energy requirements of humans through the ages

Energy consumption activities	Primitive (before 10 000 BC)	Agricultural (around 1000 BC)	Industrial (1700–1800)	Technological (present day)
Food	8	8	11	13
Food for animals	1	8	19	29
Home and commerce		17	134	277
Industry and agriculture		17	101	382
Transport			59	265
Total	9	50	324	966

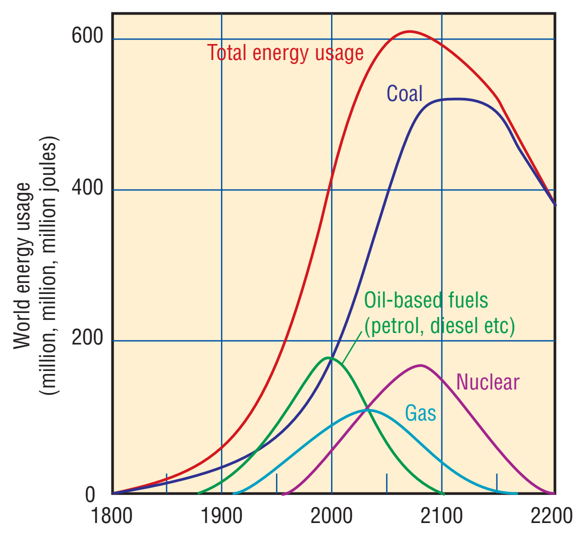
The problems of increased energy use

Diminishing resources

Most of our current energy needs are met by the burning of fossil fuels. Remember, fossil fuels are produced by the action of heat and pressure on the dead remains of plants and animals. The process takes millions of years, so once our current reserves of fossil fuels are used up we will have to explore alternative ways of producing energy to meet our needs.

The graph in Figure 2.8.4 shows that our use of petrol and natural gas will start to decline over the next hundred years. This is because of the scarcity of these resources in the future.

Fig 2.8.4 Fossil fuel usage over the next 100 years



Environmental concerns

Apart from our concerns about diminishing fossil fuel resources there is another pressing concern regarding the burning of fossil fuels to produce energy. All energy-consuming things (living and non-living) produce waste products. One of the biggest waste products of industry is the gas carbon dioxide. Carbon dioxide builds up in the Earth's atmosphere and, over time, causes its temperature to increase. This is called **global warming** or the **enhanced greenhouse effect**.

The greenhouse effect

Incoming solar radiation (sometimes called insolation) is the energy that comes to us from the Sun. This energy is absorbed by the Earth's surface and re-emitted into our atmosphere as heat radiation. It is this re-emitted heat that keeps our planet warm enough for us to survive. This is called the **greenhouse effect** and without it, our planet would not be warm enough for the survival of many species of animals and plants. You can see this in Figure 2.8.5—diagram 1 shows a balance of incoming and outgoing radiation from the Sun allowing the Earth to maintain temperature; diagram 2 shows how increased CO_2 concentration causes more radiation to be trapped in the Earth's atmosphere, causing increases in temperature.

Science Snippet

A cold, cold world

Without the greenhouse effect, our planet's temperature would average about –18°C, rather than the 15°C it is now.

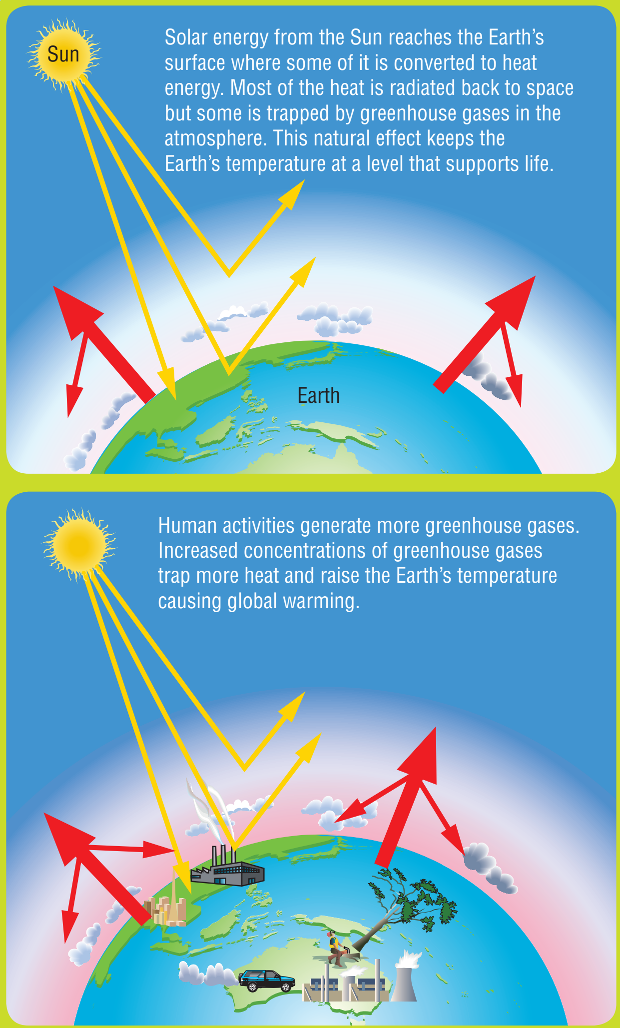


Fig 2.8.5 The greenhouse effect

The **enhanced greenhouse effect**, however, is another issue. Scientists believe that gaseous emissions from industry over the last 200 years or so have built up in the Earth's atmosphere, gradually causing it to become warmer. If the atmosphere warms up even by a few degrees it will increase sea level, mainly due to melting polar ice caps. It will also cause changes to the planet's weather patterns. Over a period of many decades, these changes would gradually affect conditions on Earth, which in turn could threaten the survival of many species, including ours.

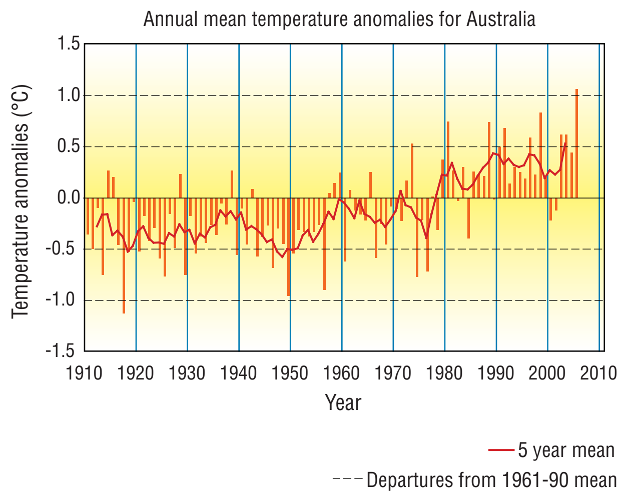
Science Snippet

Greenhouse and ozone

Many people confuse greenhouse and ozone issues. Ozone is a gas that consists of O_3 molecules. It is found mainly in the upper stratosphere and absorbs ultraviolet (UV) radiation from the Sun. Pollution by compounds called chlorofluorocarbons, or CFCs, has reduced the amount of ozone in certain areas (referred to as ozone holes). When ozone decreases, more UV radiation gets to the Earth from the Sun. This can cause increased skin cancers and cataracts in humans and can kill many organisms.

Figure 2.8.6 shows some evidence for temperature rise in Australia over the period 1910 to 2000. Each green column shows the difference between temperature in that year and an average temperature based on the years 1961 to 1990. Above the zero line means a temperature higher than average, while below the zero line means a temperature less than average. So, for example, the temperature in 1998 was 0.84°C above the reference period average. You can see from the graph that from the 1980s onwards, the green lines show temperatures above average, while they are mainly below average before this date.

Fig 2.8.6 Evidence that the average temperature is rising



Helping our planet

Since the burning of fossil fuels produces greenhouse gases—mainly carbon dioxide (CO_2), nitrogen dioxide (NO_2) and methane (CH_4)—it is important for all citizens and governments to do whatever they can to reduce the build-up of greenhouse gases in our atmosphere. Following are some actions that can be taken.

Agreements between countries

In recent years various countries have agreed to come together and discuss environmental issues such as the enhanced greenhouse effect. For instance, in 1997, 178 countries came together and signed the Kyoto Protocol, an agreement that required signature countries to reduce greenhouse gas levels by the year 2012 to the levels that existed in 1990.

In 1987 a similar agreement was reached when 46 countries signed the **Montreal Agreement**, which established a timetable for a global reduction of the production and use of ozone-depleting CFC gases.

Encouraging renewable energy

Fossil fuels are termed '**non-renewable resources**' because once a fossil fuel is consumed it cannot be replaced. Oil, gas and coal are non-renewable resources. **Renewable** resources, such as wind, solar and hydro, on the other hand, do not get used up in the production of energy. Many also have the benefit of producing few or no pollutants, including greenhouse gases.

Drag and Drop cW Interactive

Energy-efficient design

Figure 2.8.8 shows some of the features of an energy-efficient home. The following table indicates how some of these features might conserve energy.

Feature	How energy is conserved
North-facing aspect	Living areas are cooler in summer and warmer in winter
Floor insulation	Prevents heat loss in winter
Pool blanket	Keeps water warm so that heating is not required
Eaves over windows	Keeps windows in shade for longer, minimising excessive heating of living areas

Fig 2.8.7

Many electrical appliances carry energy efficiency labels.

Prac 1 p. 100

For many years environmental architects have been incorporating energy-efficient design principles into their houses and buildings.

Fig 2.8.8

Reducing pollution

Cars

A large proportion of the greenhouse gases causing the enhanced greenhouse effect result from transportation. Many gaseous wastes, such as carbon dioxide, sulfur dioxide and nitrogen dioxide, come from the exhausts of cars. Most new cars are equipped with catalytic converters, which ensure that these gaseous pollutants are kept to a minimum.

Recycling

Recycling is the reprocessing of already used materials that would otherwise become waste. If you do not recycle a bottle, for instance, it is sent to a landfill or incinerator and becomes waste. If you do recycle the bottle it does not become waste and therefore reduces the consumption of materials required to make another bottle. Recycling also requires less energy than producing similar products from their raw materials. Commonly recycled materials include glass, paper, aluminium, asphalt, steel and plastics. The recycling of aluminium, for example, saves 95 per cent of the CO_2 emissions that would otherwise be produced if new metal were to be refined.

Fig 2.8.9 Some symbols for recycling

Homework book 2.9 Energy in the community

2·8 FOCUS [Questions]

Use your book

Consuming energy

1 Is it correct to say that when you watch TV you contribute to a decrease in our fossil fuel reserves?

2 Looking at the table in Figure 2.8.3, which energy-consuming activity was responsible for the consumption of most energy:
  a during the industrial period?
  b during the technological period (present)?

3 What percentage of our total energy consumption today is due to transportation?

Diminishing resources

4 What types of natural resources are referred to as fossil fuels?

5 How are fossil fuels produced?

6 Referring to the graph in Figure 2.8.4, why is it important for us to explore alternative ways of producing energy?

7 According to the graph in Figure 2.8.4, which type or types of fossil fuel will we probably stop using first?

Environmental concern

8 What is the biggest gaseous waste produced by industry?

9 What is global warming and what is its cause?

10 What is the important difference in the impact of the greenhouse effect and the impact of the enhanced greenhouse effect on us?

11 What changes to our planet could we expect if estimates about the effects of the enhanced greenhouse effect come true?

12 What is ozone and how does it protect us?

13 Describe the aim of the Kyoto Protocol.

14 Identify one alternative energy production method discussed in this Focus and comment on why you think it might be beneficial to Australia's future.

Energy-efficient design

15 Why is it useful for manufacturers to label electrical appliances with energy efficiency labels?

16 Examine the energy-saving features of the home shown in Figure 2.8.8. Copy the table below into your workbook and then complete it for three energy-saving features of the home not already described in the table in this Focus.

>>

Feature	How energy is conserved.

17 Describe the difference between recycling and reusing. Give examples of each.

Use your head

18 Work with three or four other members of your class to prepare a poster or a chart on how people can reduce their home energy consumption by considering the following activities:

- **a** lighting
- **b** heating
- **c** cooling
- **d** water heating
- **e** and one other category you can think of.

19 What is meant by the term 'sustainable energy use'? Make a two- or three-sentence definition for your group and then compare your definition with those of other groups.

Investigating questions

20 This investigation will take a little time to set up. You will need to collect your family's electricity bills for a period of at least six months. The bills will need to be as consecutive as possible.

- **a** Find out what is meant by a unit of electricity, as described on the bills.
- **b** Summarise the data (number of units of electricity used) from the six months on a table and graph.
- **c** Explain the fluctuations (changes) in energy use over the period.

21 What are some of the hazards associated with nuclear power?

FOCUS 2·8

[Practical activity]

Prac 1
Focus 2.8

Double insulation

Purpose

To investigate the extent to which heat transfer is reduced through double-glazing.

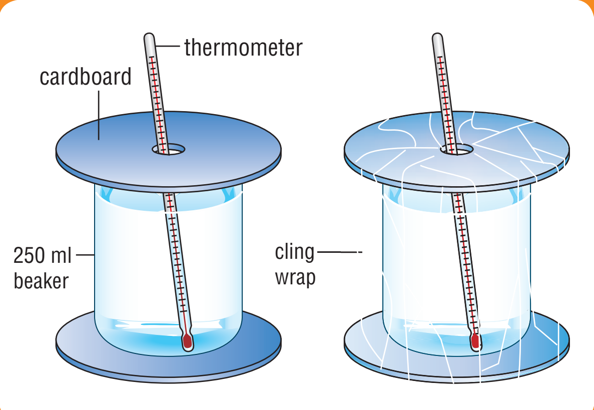
Requirements

Two 50 mL or 100 mL beakers, two thermometers, stopwatches or timers, cardboard, cling wrap, filter funnels, source of hot water, stopwatches or timers.

Procedure

1 Set up the apparatus as shown in Figure 2.8.10.

Fig 2.8.10 Set-up for Prac 1



2 Use the filter funnels to carefully transfer the same amount of hot water into each of the beakers. Each beaker should be filled to within a centimetre of the top.

3 Place the thermometers into the beakers at the same time. Wait 30 seconds and then start the stopwatches.

4 *Record the temperatures in each of the beakers every 30 seconds for at least 10 minutes.*

5 *Draw a graph to show how the temperature changed in each of the beakers throughout the time interval.* Note: Plot the temperatures for both beakers on the one graph.

Questions

1 Make a comment about your findings from this investigation.

2 Use some scientific ideas to explain the results.

3 What were some of the variables that needed to be controlled in this experiment?

4 Was your investigation a 'fair test'? Why or why not?

5 How could you improve this investigation if you were to repeat it?

6 Where could double glazing be used around your home and would it be desirable?

Review questions

[Second-hand data]

1 Josh's mum and dad had been talking about installing a particular brand of insulation foam in their home. Insulating foam is placed onto the ceiling in the roof space to stop heat transfer from the house to the roof cavity. In this way heating costs in winter and air-conditioning costs in summer can be reduced. Josh started thinking about how effective the foam is in comparison to other types of insulation materials in preventing heat transfer in the home. He designed an experiment to test the insulating properties of various materials. His experimental set-up is shown in Figure 2.9.1.

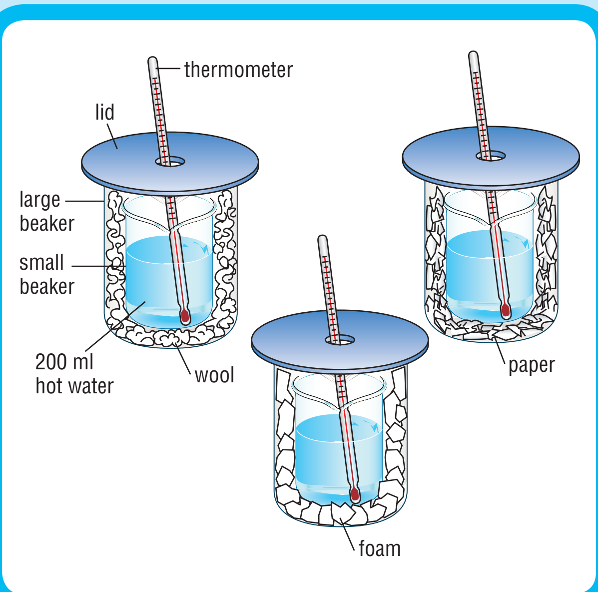


Fig 2.9.1 Josh's investigation for testing the heat insulation properties of different materials

Josh used small pieces of pillow foam, tightly crumpled paper pieces and cotton wool in the space between the three inside and outside beakers. He poured 200 mL of boiling water into each of the inside beakers. He then placed a thermometer/cover onto each of the beakers. After one minute he recorded the temperature in each of the beakers every one minute. The table at top right shows the results for three materials that they tested as part of this investigation.

Josh's hypothesis: that wool would prevent heat loss the best.

Draw a graph of the results shown in the table.

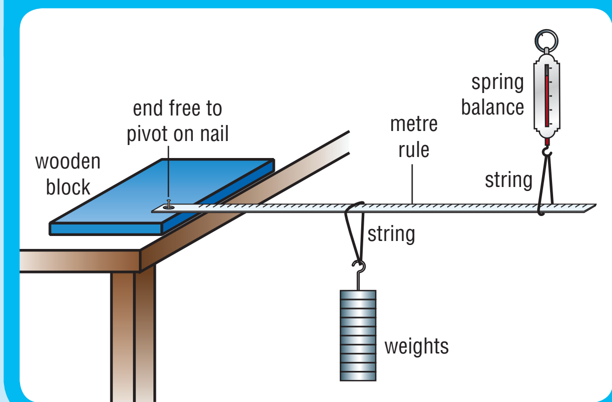
Time (minutes)	Temperature (°C)		
	Foam	Wool	Paper
0	97	96	98
1	80	77	74
2	72	63	56
3	66	53	48
4	59	48	43
5	55	45	38
6	51	40	38
7	50	39	34
8	49.5	38	32
9	49	38	31
10	49	38	30

Place time on the x-axis (horizontal) and temperature on the y-axis (vertical) and graph the data from all three materials on the one set of axes.

- **a** What did the results of this investigation show?
- **b** Did the results support the Josh's hypothesis?
- **c** Why do you think the substances tested acted as an insulator? Use some scientific ideas to explain why materials like these make good insulators.
- **d** List the dependent, independent and controlled variables in this investigation.
- **e** Was Josh's investigation fair? Why or why not?

2 As part of a school assessment Leah wanted to find out how the effort required to support a load on a lever changed as the length of the load arm increased. She set the apparatus up as shown in Figure 2.9.2.

Fig 2.9.2 Leah's apparatus to test how the effort on a lever changes as the length of the load arm is increased



Leah used a fixed mass of 200 g in her investigation. She started her investigation by placing the centre of the 200 g mass on the 20 cm mark of the metre rule. She then recorded the force registered on the spring balance. Leah then repeated these steps for the masses placed at the 40, 60 and 80 cm positions. The results she collected are represented in the table below.

Position of masses (cm)	Force on spring balance (N)
20	0.8
40	1.8
60	3.1
80	3.9

Draw a graph that shows the change in the force required to keep the ruler horizontal as the distance from the fulcrum increased.

a When Leah moved the 200 g masses from the 20 cm to the 80 cm mark, was she increasing or decreasing the length of the load arm?

b What conclusion should Leah have come up with in looking at the data she obtained from this investigation?

c What were the dependent and independent variables in this investigation?

d Which variables did Leah control in this investigation?

e Is the type of lever in this investigation a type 1, 2 or 3 lever?

f Give a real-world example of this type of lever and use your conclusion from this investigation to explain how your example of this type of lever is used to make work easier in some way.

Open-ended questions/experimental design

3 In these Energy and Change Foci you have studied the effects that an applied force has on objects. You have learnt that gravity is a force that causes objects to be attracted towards the Earth. This attraction is called weight. You know that weight can be measured by using a spring balance. The main component of a spring balance is a spring that stretches when a mass is hung from it, but returns to its original shape when the mass is removed. There are probably many examples of materials, such as springs, that stretch when a mass is hung from them. For instance, a piece of elastic material will stretch if a mass is allowed to hang from a length of the material. The same can be said of an elastic band or a length of rubber.

a Think of a material or substance whose elastic properties you would like to test. The material you select should have elastic properties; that is, it should stretch but return to its original shape.

b Design an investigation to explore how much the material stretches as you hang different masses from it.

c You should make a table of how the material stretched as greater masses were hung from its length.

d Draw a graph of your findings.

e Produce a report of your findings.

Ideas to keep in mind when producing your report.

i Is the purpose of your investigation clear in your report?

ii Have you included a prediction and hypothesis as part of your report?

iii Are the dependent, independent and controlled variables clear to someone reading your report?

iv The analysis of your results should include a statement on whether or not your chosen material stretched by an even amount every time the same amount of mass was added to it.

v Is your conclusion supported by the data you collected in the investigation?

vi Have you evaluated the method you used in doing the investigation? In other words, is it clear in your report what changes you would make to improve your investigation should you repeat the investigation?

Extended investigations/research

4 As our fossil fuel energy resources become rarer and more expensive, we will become more concerned with energy efficiency in our everyday lives. In the last Focus of this section you were introduced to some features of an energy-efficient home. Such a home would contain many energy 'smart' features that:

- make more efficient use of energy resources (such as positioning homes to minimise heat loss in winter and minimise heat gain in summer)
- rely more on renewable energy resources and less on non-renewable energy resources.

Investigate one feature of an energy-efficient home, such as:

- eave length
- home orientation
- ratio of glass area to total wall area of northern face
- insulation—roof and/or wall
- double-glazing
- type of building materials.

Produce a detailed report on how this feature is energy 'smart'. Your report should contain an analysis of how the feature conserves energy. As part of your report include a PMI chart. A PMI chart is a table that lists the (P) positives associated with the feature, the (M) minuses, or negatives, associated with the feature and the (I) interesting points relating to the feature. Your teacher will coordinate the groups within your class so that each group investigates a different feature.

5 Complete Task A (if your school has some Lego) OR Task B (if you do not have Lego available).

A Your challenge is to make a model out of Lego, or any other materials you wish, which contains at least two different types of simple machine. The two machines must interact to make the whole device work as a system. You can use a book of Lego models as a guide, or create your own. You must then write a report which explains the scientific principles by which each of the machines works, and how the machines interact to make the whole device work as a system. Your report is to be presented verbally to the class in a five-minute talk. You can do a PowerPoint presentation, if you wish, for the written report. Your assessment will be based on both the written report and how much you seem to know in your talk.

OR

B Dismantle a toy, an old electrical-mechanical device or a purely mechanical device which is no longer needed. You could use a toy car, electric drill, food mixer, electric knife, chain saw, etc.

Safety: Do not turn on any electrical device after you have dismantled it or you may receive an electric shock.

Identify at least two simple machines that help the device work. Your task is to write a report that explains the scientific principles by which each of the machines works, and how the machines interact to make the whole device work as a system. Your report is to be presented verbally to the class in a five-minute talk. You can do a PowerPoint presentation, if you wish, for the written report. Your assessment will be based on both the written report and how much you seem to know in your talk.

Homework book 2.10 Energy and Change crossword

Homework book 2.11 Sci-words

Life and living

3

Curriculum guide learning focus

- processes of systems and the relationship between structure and function
- genetics, reproduction and inheritance
- evolution, variation and adaptation of organisms
- roles, relationships and the interdependence of living things
- cycling of matter and the flow of energy
- damaging the environment—effects on organisms, habitats and sustainable environments

This section on Life and Living also contains work that will help students with the outcomes of Investigating, Communicating Scientifically, Science in Daily Life, Acting Responsibly and Science in Society.

Outcome level descriptions

The outcome level descriptions for Life and Living covered in this section of the book are mainly LL 4 and 5.

FOCUS 3·1 Cell structure and function

Context

As you are now aware, atoms are the building blocks of molecules. Cells built from atoms are the building blocks for the human body. An English scientist Robert Hooke first described cells in about 1665. Research over the next 342 years has given us great insights into cytology (the study of the structure and function of cells). For centuries scientists have been studying the way that animals move to try to find out how they work, and answer some of the many questions we have about living things and, more specifically, ourselves. Computer technologies and the use of Magnetic Resonance Imaging and other forms of imaging have made this study easier. For example, we can now look into the human body in great detail and study cellular physiology and homeostatic control in ways that have never before been possible.

Life processes

The **cell** is the basic unit of all living things. Simple **organisms** may consist of only one cell and more complex organisms are formed from many different types of cells grouped together. Some plants and animals consist of only one cell and are known as **unicellular**. You are an example of a more complex organism composed of many cells, which is known as **multicellular**. Your cells are grouped together to form tissues, the tissues are grouped to form organs and the organs interact to work as systems within your body.

Fig 3.1.1 Some organisms consist of only one cell such as bacteria, some small algae and yeasts.

Fig 3.1.2 Many organisms, including fish, humans, trees and mushrooms, consist of many specialised cells.

The world contains an enormous diversity of living organisms. Despite this diversity however, living things all perform the same basic functions. One function is that they **respond** to changes in their immediate environment. You will move your hand away from hot objects, fish swim away from sudden movement and daisies close their petals at night. Many also demonstrate **adaptability**, their responses vary over time as they adjust to their environment. At the beginning of summer you will get very burnt if you stay out in the Sun for an extended period of time, by the end of summer you can stay out in the sun without the same noticeably painful result. This is due to your skin producing pigments that absorb solar radiation, providing a small measure of protection. You should always wear sunscreen out in the Sun to provide greater protection though.

A second function is **growth**. Over your lifetime you and those around you will grow and also **develop**.

A third function is the ability to **reproduce**. Your body will become larger and will mature, allowing you to produce offspring.

A fourth function is that organisms are capable of **movement**. Movement may be internal, such as the transport of food, blood or other materials inside the body. It can also be external, such as the whole organism going from place to place through the environment.

Fig 3.1.3 All organisms share the features of growth and reproduction.

All these functions—responsiveness, growth, reproduction and movement—require **energy** for their performance. The energy must continually be available or the organism will not be able to function. This need for energy necessitates several other life process. So a fifth life process is **nutrition** (**absorption**). Organisms need nutrients—materials obtained from their environment which are required in their functioning. Organisms **absorb** materials from the environment. They use some of the absorbed substances for growth and repair, and the rest is broken down for energy.

A sixth life process is **respiration**. Respiration is a cellular process through which organisms obtain energy from the nutrients they consume. Many organisms require oxygen for this but some, such as many types of bacteria, do not need oxygen.

Fig 3.1.4 The frog shows the same life processes as humans. What are they?

A seventh life process is that of **excretion**. All living organisms produce useless or harmful wastes. These are produced through cellular processes, and must be removed from the cells in a process called excretion. The wastes are discharged into the environment.

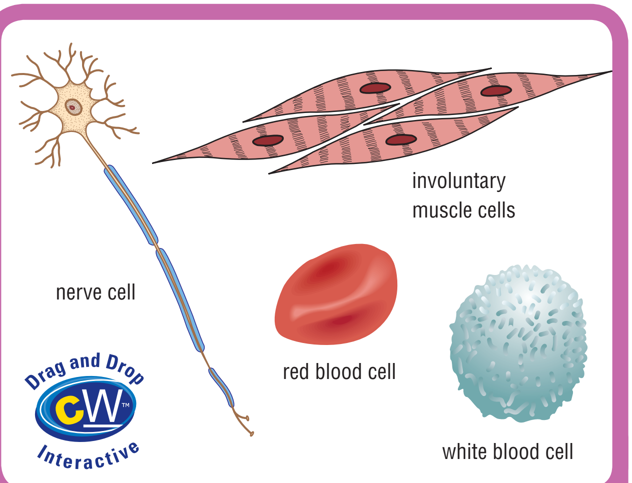
These are the seven basic life processes of living things. Other more complex functions can be identified in larger multicellular organisms.

Features of cells

Cells are the basic units of all plant and animal tissues. **Cell theory** is based on five main concepts:

1 Cells are the building blocks of all plants and animals.
2 Cells are produced through the division of pre-existing cells.
3 Cells are the smallest units that perform all vital physiological functions.
4 Each cell maintains homeostasis at the cellular level.
5 Homeostasis at the tissue, organ, system and organism levels involves the coordinated actions of many cells.

Cells have a variety of forms and functions. Some of the diversity of the cells in the human body can be seen in Figure 3.1.5. The human body contains trillions of cells. All of your daily activities, from running to eating, and even thinking, are a result of the coordinated actions of your cells.



The diversity of cells in the human body *Fig 3.1.5*

Science Snippet

The living transformer

Human embryonic stem cells hit the headlines in 1998 and have continued to be controversial ever since. Stem cells promise to be the basis of a powerful new technology that could revolutionise medicine. Most of the trillions of cells in the body have specialised functions. Blood, lung, brain, skin or liver cells are all specialised for the function they perform. Stem cells, on the other hand, do not have a specialised function. Stem cells are immature cells that still have the potential to develop into many different kinds of cells. Stem cells have infinite uses in research, medicine and biotechnology. How are stem cells being used today?

The study of the structure and function of cells is called **cytology**. The two most common methods used to study cells and the structure of tissues are **light microscopy** and **electron microscopy**. Light microscopy can magnify cellular structures about 1000× and show details as small as 0.25 μm. (This symbol μm stands for **micrometre**, often shortened to micron; 1 μm = 0.001 mm).

A light microscope allows you to identify cell types and see large intracellular structures. Because individual cells are fairly transparent, thin sections are taken and stained with dyes that stain the intracellular structures, making them easier to see. The finer details of the interior of cells remained a mystery until the electron microscope, invented in 1938, opened up this field of study. The electron microscope uses a focused beam of electrons, rather than a beam of light, to examine cellular structure.

The electron microscope can be used to show the fine structure of cell membranes and intracellular structures. The only problem is that the cell has to be killed in order to be observed it this way. So you cannot see a living cell. Using transmission electron microscopy you see great internal detail as the beam passes through the cell. You can gain a three-dimensional perspective of cell structure using scanning electron microscopy where the beam reflects off the surface of cells.

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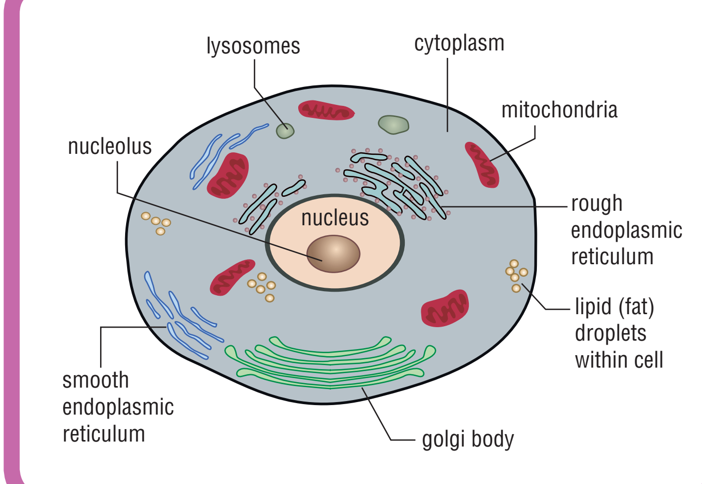


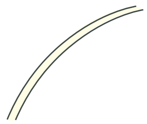
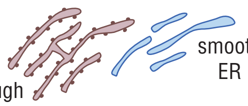
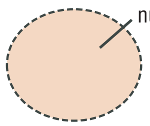
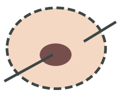
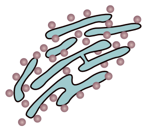
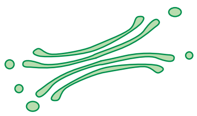
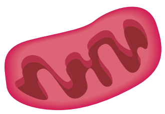
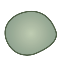
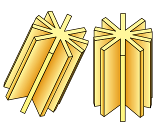
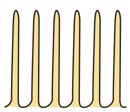
Cell diagram showing various cell structures *Fig 3.1.6*

As there are so many different types of cells, you will look at a model that will share features with most cells without being identical to any. Figure 3.1.6 shows such a cell and the table below summarises the structures and functions of its parts.

A cell survives because all these organelles work together in an integrated manner. Our cells float in a watery substance known as extracellular fluid. The cell membrane separates the cell contents, or cytoplasm, from the extracellular fluid.

Homework book 3.1 Cell diagrams

Cell organelles and their function **Fig 3.1.7**

Organelle	Structure	Function
Cell membrane		A selectively permeable membrane through which substances outside the cell may be absorbed and cell products may be released. Primary functions are protection and isolation from the environment
Endoplasmic reticulum		Greatly expanded surface area for biochemical reactions, which normally occur at or across membrane surfaces. Endoplasmic reticulum may be smooth (without ribosomes—structures that are involved in protein synthesis in the cytoplasm) or rough (with ribosomes scattered across its surface)
Nucleus (chromosomes)		Contains the DNA in chromosomes and therefore the information to regulate the metabolism and reproduction of the cell. The nuclear membrane provides a selective barrier between substances in the nucleus and cytoplasm. The nuclear pores control the movement of substances
Nucleolus		The nucleolus is involved in the construction of ribosomes
Ribosomes		Sites of protein synthesis (shown as dots lining the endoplasmic reticulum). They consist of two parts—a larger piece and a smaller piece. Both are made of a complex of ribosomal RNA and protein
Golgi apparatus		Site of production of cellular secretions—the 'packaging department' of the cell. Found associated with smooth endoplasmic reticulum
Mitochondria		The 'powerhouses' of the cell responsible for energy production. Cells with a large energy requirement (as in muscle cells) have a greater number of mitochondria. Contain their own DNA, different from the chromosomal DNA
Lysosomes		Lysosomes are the principal digestive organelles of the cell. They produce powerful digestive enzymes, which aid in disposal of intracellular bacteria and other foreign bodies, as well as unwanted organelles. They may cause destruction of the cell if ruptured
Centrioles		Centrioles form poles and spindles (extensions of the microtubules) for cell division, moving the chromosomes apart during mitosis and meiosis. Capable of self-replication
Cilia		Movement of materials over a surface
Microvilli		Absorption of extracellular materials

The cell life cycle

Between the stages of fertilisation and physical maturity your body will go from being a single cell to roughly 300 trillion cells. This amazing transformation occurs through a form of cellular reproduction called cell division. The division of a single cell produces a pair of **daughter cells**, each half the size of the original. These two new cells have replaced the original one.

Even after development has been completed, cell division continues to be essential for survival. Your cells can be damaged in any number of ways, such as exposure to toxins, temperature changes, environmental hazards and physical wear and tear. In addition to damage, cells are also subject to ageing. The life span of a cell varies from hours to decades, depending on the type of cell and the environmental stresses. Basically a cell does not live as long as a person does and so dead cells must be replaced by cell division.

Central to this process of cell reproduction is the accurate duplication of the cell's genetic material and its distribution into the two new daughter cells formed by division. This process is called mitosis. Mitosis occurs during the division of all cells in the body except reproductive cells. Production of reproductive cells requires a different process, called meiosis.

Your characteristics are determined by genetic units called **genes**, which are found on structures called **chromosomes**. Chromosomes are long, coiled, thread-like structures made from DNA (deoxyribonucleic acid) and protein. Chromosomes are found in the nuclei of your cells. Each chromosome has many thousands of genes along its length. It is the genes that are made of the chemical DNA. They can be thought of as the set of instructions or genetic program that makes you who you are, genetically speaking.

As your cells divide they duplicate their chromosomes. When each cell divides the resulting daughter cells receive a copy of the parent cell chromosomes. Figure 3.1.8 demonstrates the organised series of steps that ensures that each daughter cell is an exact copy of the parent cell.

Science Snippet

Cell division out of control!

Mitotic rates are usually well controlled and, in normal tissues, the rate of cell division balances cell destruction. When this balance breaks down, however, the tissue begins to enlarge. A tumour is a mass or swelling caused by abnormal cell growth through mitosis. In a benign tumour the cells remain within a capsule; these rarely threaten an individual's life. Surgery can usually remove the tumour if it is affecting the individual's ability to function or it is in a position that is not aesthetically pleasing. The cells of a malignant tumour do not respond to normal control mechanisms. These cells divide rapidly, spreading to the surrounding tissues, and may also spread to other tissues and organs. This spreading is called metastasis. Metastasis is dangerous and difficult to control because once in a new location the metastatic cells produce secondary tumours. The term 'cancer' is used to describe the illness characterised by malignant cells.

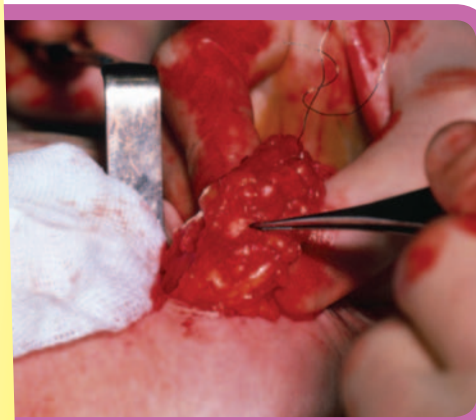
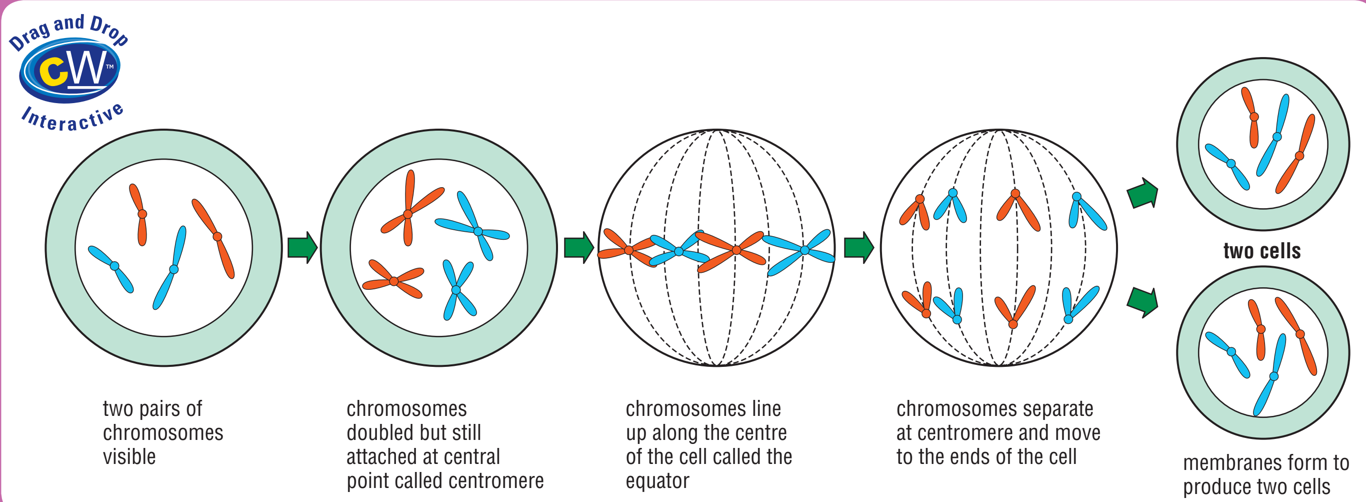


Fig 3.1.9 A cancerous tumour being removed by surgery

Fig 3.1.8 Mitosis



Adaptation to function

Many cells are specialised to perform a specific function. For example, blood is made up of several specific cell types, each of which is suited to its particular function. Red blood cells develop in the red bone marrow of bones such as the sternum and hip. During development, red blood cells lose their nucleus and their cytoplasm becomes filled with a protein called haemoglobin, which carries oxygen.

Another example of specialisation is the several different types of white blood cell. Granulocytes have granules in their cytoplasm. Another type of white blood cell, the agranulocyte, has no granules in its cytoplasm. Agranulocytes include lymphocytes and monocytes. Another type of defence cell, which travels through the blood but can also enter and move through the tissue outside the bloodstream, is the macrophage, a phagocytic or scavenger cell. Macrophages defend your body. They have the ability to engulf foreign material such as bacteria or other inorganic bodies and either destroy the bacteria or prevent the invaders getting to the rest of the body.

Other types of specialised cells include nerve cells (neurons), which are electrically active and transmit information to other nerve cells around the body across special junctions called synapses. Another type of electrically active cell is the muscle cell, which contracts in response to nervous or hormonal stimulus. Skin cells are also highly specific. They are continuously shed, because of their exposure to the damaging effects of the external environment, radiation, physical wear and tear, temperature extremes and humidity. To replace the shed cells, skin cells in the lower layers divide rapidly.

Cells in the body work together to maintain it at its most efficient at the tissue, organ and system levels. This is called **homeostasis**. Homeostasis is the maintenance of a relatively constant internal environment. The contact surface between the cell and its environment is the cell membrane. The cell membrane regulates the exchange between intracellular and extracellular fluids. This regulation is important because the environments are quite different and those differences must be maintained to preserve homeostasis.

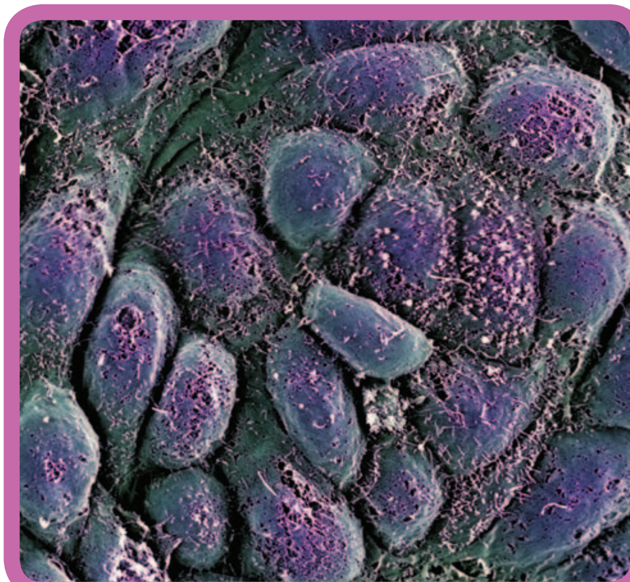


Fig 3.1.10 Most cells are used for specific functions. These stem cells have the ability to develop into many different types of cell.

Homework book 3.2 Cell specialisation

FOCUS 3·1 [Questions]

Use your book

Life processes

1. Explain the difference between a unicellular and a multicellular organism.
2. Describe three of the basic functions of living things.

Features of cells

3. What are the five basic concepts (assumptions) of the cell theory?
4. What is cytology?
5. Explain the structure and importance of the cell membrane.
6. Sketch and label a 'typical' cell as described in this Focus.

The cell life cycle

7. What is DNA and why is it important?

Adaptation to function

8. Give two examples of cells that have a specific function in the body.
9. What is special about stem cells?

>>

Use your head

10 Over the Christmas holidays Alex had a job gardening for neighbours. As a consequence she developed calluses on areas of her hands that were exposed to chronic pressure from the shovel and other gardening tools. Which of the functions of living things is this an example of and why?

11 Cells lining the small intestine have numerous finger-like projections on their surface. Do you remember their name from your studies over the last two years? What is their function?

12 Microscopic examination of a sperm cell shows a large number of mitochondria in the mid-piece. What does this observation imply about the sperm cell's energy requirements and does this make sense in view of the sperm's function?

Investigating questions

DYO

13 Design an experiment to test your body's response to a stimulus. You may choose to test how long it takes your body to catch a dropping object or respond to an increase in temperature within a room. Don't forget to identify and control your variables!

14 Through research in the library identify the reasons for and against stem cell research. Why is it so controversial? Form an argument for or against stem cell research giving evidence for your position. Present this in a format of your choice, such as a poster, PowerPoint presentation, debate, cartoon or mindmap.

3·1 FOCUS [Practical activity]

Prac 1 Focus 3.1

Preparing slides

Purpose

To use appropriate tissue preparation and staining techniques for microscopic examination.

Requirements

Compound microscope, microscope lamp, piece of onion, slides, distilled water, staining solutions—K/I solution, methylene blue, forceps, cover slips, lens tissue, mini grid, Pasteur pipette, cutting board, knife.

Procedure

PART A
Setting up the microscope

1 Place the microscope on a flat surface.

2 Check that your microscope has all of its pieces attached. If there is anything missing report this to your teacher.

3 Set up the microscope lamp in front of the microscope with the light shining onto the mirror. If your microscope has a built-in light source you will not need a lamp.

4 Remove your eyepiece and adjust your mirror so that the light is reflected up into the tube of the microscope. You may have to adjust the iris wheel or diaphragm.

5 Rotate the objective lenses until the low power lens (this is usually the shortest one with the lowest number on the side of it, e.g. 4×) clicks into position directly above the hole in the stage.

PART B
Preparing a wet mount of onion skin

6 Remove a small piece of the very thin skin on the inside of the onion section.

7 Place the sample in the centre of the slide using the forceps and carefully add a drop of water to prevent dehydration.

8 Carefully place a drop of K/I stain from the dropper bottle onto the sample on your slide.

9 Place a cover slip over the sample, lowering it from one side using forceps, as this will reduce the number of air bubbles. Ask your teacher to show you if you are not sure of how to do this.

10 While looking at the microscope from the side use the coarse focus knob to carefully lower the objective towards the slide.

11 Carefully blot next to your cover slip with tissue paper to remove any excess liquid.

12 Now to find the object in your view, look into the eyepiece and carefully wind the lenses back up using the coarse focus knob. When the object is in view though a little blurry, stop turning the focus knob. Never just wind up and down looking for your specimen—you may accidentally smash through the slide and this is how microscope and equipment is damaged! If you cannot find what you are looking for try repeating the steps. If you are still having trouble ask your teacher.

>>

13 Now that you have found your image, to bring this into sharper focus, use the fine focus knob. This moves the lenses only a small amount but it can make a big difference to the image you are trying to look at.

14 *Draw the sample you are looking at and label it. Also ensure that you note what the sample is, the magnification and the type of stain, if any was used.*

15 With your image still in focus and while watching from the side, turn the nosepiece until the 40× objective lens is clicked into place. Make sure the objective will not hit the slide.

16 Try to sharpen the image under higher magnification using ONLY the fine focus.

PART C
Calculating magnification and field of view

17 Calculate the magnification of your microscope by multiplying the eyepiece/ocular lens by the objective lens: *Eyepiece × objective = magnification.*

For example, a 10× eyepiece and a 40× objective give a magnifying power of 400×.

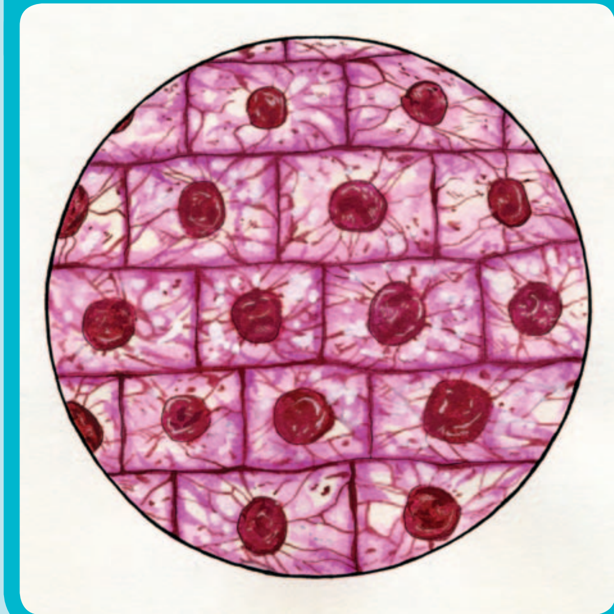
18 You can now work out the **field of view**. The field of view is the distance across the circle of light you see when you look though your microscope. Begin by placing a mini grid or plastic ruler under the microscope and focus your microscope on low power. *How many millimetre divisions can you see? Estimate to the closest 0.1 mm. Now calculate your field of view at low power.*

19 When you use a microscope, you will obviously be looking at things that are much smaller than 0.1 mm. Therefore we use the unit micrometre, which is one thousandth of a millimetre: 1 mm = 1000µ. *What is your field of view in micrometres?* You should notice that there is a mathematical relationship here between the magnification and the field of view. As the magnification increases the field of view decreases.

20 *Looking back at your tissue sample, can you estimate the fraction of the field of view that a cell takes up? Multiply the field diameter by this fraction to find the cell size*, as in the example that follows:

A cell from a particular flower takes up approximately one-quarter of the high power field of view.

Fig 3.1.11 Cells from a flower viewed under the microscope at high power



So the approximate size of the cell is = $^1/_4$ × high power field of view

= $^1/_4$ × 400

= 100 µm

= 0.100 mm

You can also use this method to estimate the size of objects at low power, but you must use the low power field diameter.

21 Prepare another onion skin and stain with methylene blue. Can you see any different structures that were not clearly visible before?

Questions

1 Why should care be taken to remove air bubbles from under the cover slip?

2 Why would you use different stains for microscopy?

3 Copy the following table into your notes and then complete it in your notes.

Ocular magnification	Objective magnification	Total magnification	Diameter of field of view (µm)

FOCUS 3.2 Body systems—organisation and interactions

Context

Your body consists of many systems—but which one is the largest? Do we need all them? All the food you eat and the air you breathe take a journey through your body. On this journey they interact with all the systems in your body. They provide your cells with the energy they need to undertake your daily activities, such as walking around the house.

This Focus discusses the major body systems, their structure, their interactions and the role they play in the body's daily functioning.

Body systems

Organs are combinations of different tissues that perform complex functions. Organs together form an organ system, whereby several organs work together in a coordinated fashion. We can learn a great deal about organs and their structure and function by dissecting them.

Some organs are very large and distinctive, such as the liver, which weighs in at about 1.6 kilograms. Some organs are much smaller, such as the ovary, which is only about as large as a walnut. Regardless of size, organs are composed of at least two of the four basic tissue types. The four basic tissue types are muscle tissue, connective tissue, nerve tissue and epithelium. The proportions of these change from organ to organ. For example, all these tissue types contribute extensively to the structure of the stomach. However, the heart is composed mainly of cardiac muscle tissue, and has very small amounts of epithelium, nerve and connective tissue. Figure 3.2.1 shows the amount of these tissues that make up the human body.

Despite structural and functional differences, all organ systems share the following characteristics:

1 They are specialised to perform a limited number of functions so there is a 'division of labour' between organ systems.

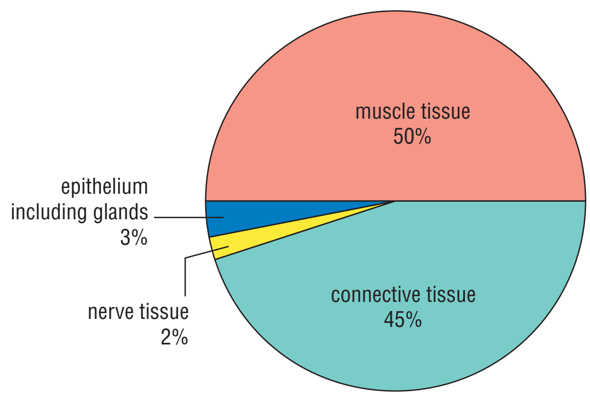


Fig 3.2.1 The four tissue types in the human body

2 They respond to particular stimuli only.

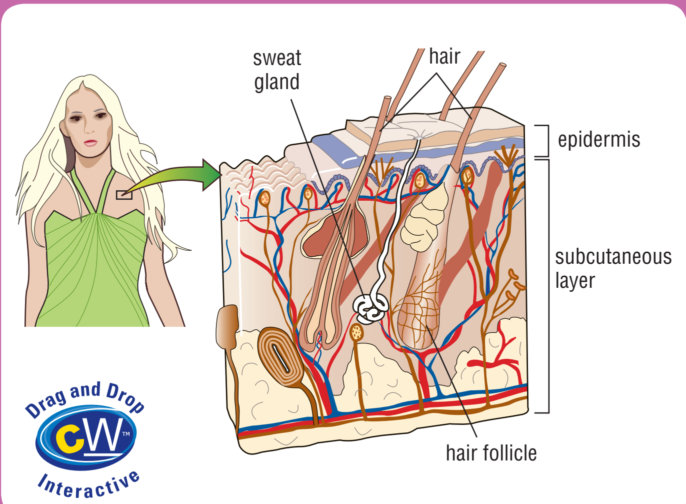
3 They depend on other organ systems for nutrient supply, oxygen and waste removal.

4 Activity is coordinated through nervous and hormonal mechanisms.

Throughout this Focus you will examine many organ systems and introduce the organs associated with them. Each organ is assigned a particular system on the basis of its primary function but it can also have important secondary functions. The pancreas is a good example of this, as most of it is concerned with digestion, so it is considered to be in the digestive system. However, a part of it also secretes hormones and so this part of it is considered to be in the endocrine system. A key issue to focus on is how the system depends on other systems.

Integumentary system

Fig 3.2.2 What makes up your skin?



Your integumentary system accounts for about 16 per cent of your total body weight and it is continually assaulted by sunlight, microorganisms, chemical substances and physical abuse. There is debate about whether 'skin' really is a system or an organ. We will consider it a system composed of 'skin' layers and other structures such as sweat glands, sensory cells, hair follicles, nails and others.

The basic components of the integumentary system and their functions are shown in the table at the top right of this page.

As a whole, the integumentary system provides protection from environmental hazards, assists in the control of body temperature, provides sensations to the nervous system through stimulation of receptors and assists in the excretion of water and solutes. Secondary functions include the synthesis of vitamin D and the storage of lipid reserves (also called fats).

Science Snippet

Sweaty armpits?

Each armpit has about 25 000 sweat glands which can in total produce about 1.5 mL of sweat every 10 minutes. Sweat is mostly salt water, with microscopic amounts of various chemicals. Each square centimetre of your armpit has about one million bacteria. The bacteria feed on the sweat to reproduce themselves, and they release waste products—some of which are the dreaded smells of body odour. Most antiperspirants use an aluminium chemical, which works by turning into an insoluble aluminium hydroxide gel inside the sweat glands. This gel physically blocks the sweat from getting out, and so stops the production of bacteria and body odour.

Organ	Primary functions
Epidermis	Protects underlying tissues
Dermis	Provides strength and nourishes the epidermis
Hair follicle	Produces hair
Hair	Provides some protection for the head
Sweat glands	Produce perspiration for evaporative cooling
Nails	Protect the tips of fingers
Sensory receptors	Provides sensations to pressure, temperature and touch
Subcutaneous layer	Stores lipids and attaches the skin to other structures

Homework book 3.3 The integumentary system

Skeletal system

The skeletal system forms the internal support framework for the body. The adult skeletal system includes approximately 206 bones, cartilage and ligaments. Surrounding tendons and muscle tissue also help to maintain proper alignment and orientation. The skeletal system supports all the other systems of the body and the body as a whole. Several bones together can provide protection for other organs and systems by creating a shield, such as the skull, which protects the brain, or a bony framework such as the ribcage.

The skeleton and skeletal muscles acting together produce movement. Individual bones store minerals received from the digestive system. In adults, red blood cells are formed in the bone marrow, a connective tissue that fills the spaces within many bones. So the circulatory system depends on the skeletal system for its red blood cells.

As you can see from Figure 3.2.3 the skeletal system can be divided into the axial skeleton and appendicular skeleton. The axial skeleton consists of the skull, the vertebral column, and the bones of the chest cavity. The axial skeleton protects the brain, the spinal cord and sense organs such as the eyes and nose. It also provides protection for the soft tissues of the chest cavity and supports the body's weight over the legs. The appendicular skeleton includes the bones of the arms and legs as well as the bones that connect them to the rest of the body. The appendicular skeleton provides the support for the arms and positions the legs to enable us to stand and walk.

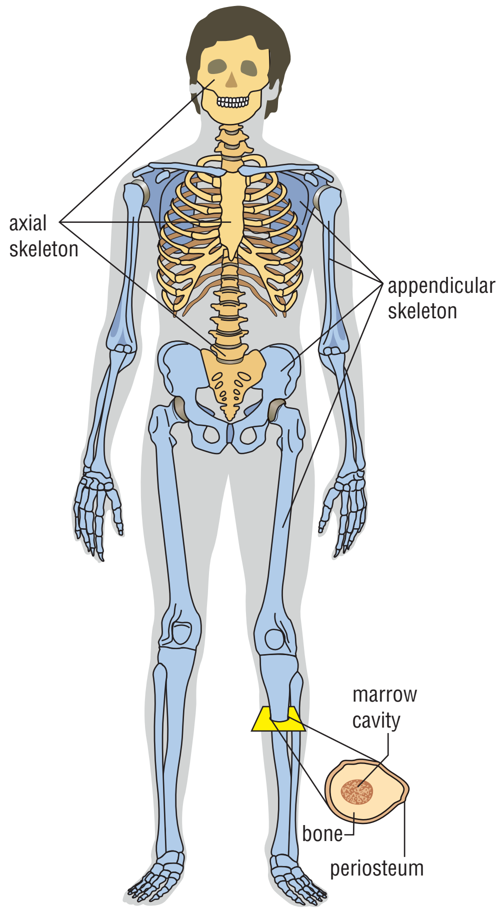


Fig 3.2.3 The human skeletal system

Homework book 3.4 The skeleton

Muscular system

The muscular system includes all muscles in the body that are under voluntary control, called skeletal muscles. Not all the skeletal muscles in the body are part of this system—there are approximately 700 skeletal muscles in the body and all but about ten are part of this system. These few are assigned to other systems in the body and work involuntarily, such as the muscles in your throat, which help you to swallow.

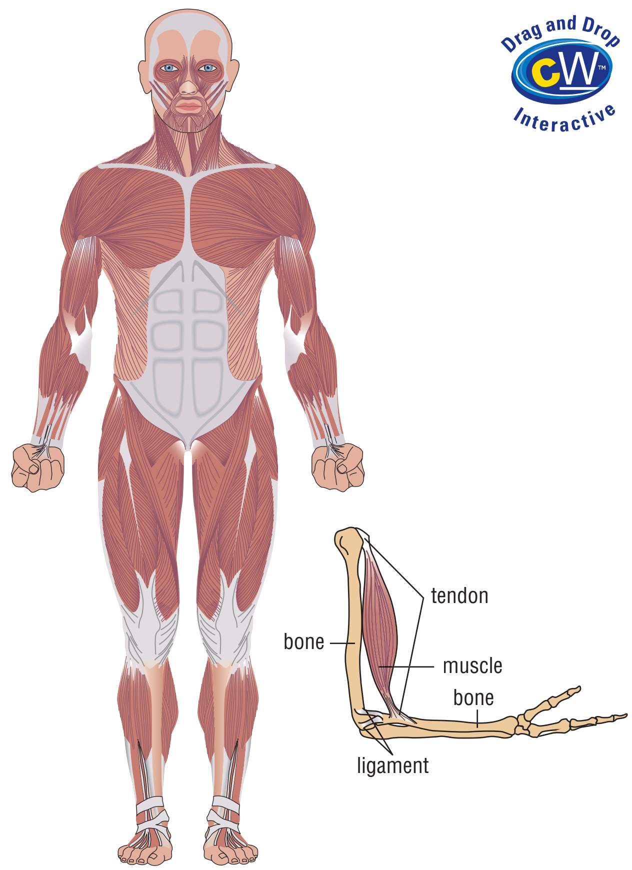
Science Snippet

Pairs of muscles

Most of your muscles work together in pairs. One muscle pulls while the other muscle relaxes. When you bend your arm the biceps muscle pulls and the triceps muscle relaxes. When you straighten your arm, the biceps muscle relaxes and the triceps muscle pulls. Even though you may not even be aware of it, all the actions you do use muscles. Did you know that you use 17 muscles when you smile and 43 muscles when you frown?

The skeletal muscles in your body are specialised for contraction. Skeletal muscles consist of muscle tissue and connective tissue called tendons, which anchor them to the bones. Muscles also contain blood vessels, which provide circulation, and nerve tissue, which controls and monitors its contraction. Because skeletal muscles are connected to the skeleton their contractions can make body parts move. Skeletal muscles also assist in the maintenance of posture and balance, support soft tissues, control the entrance and exit of the digestive tract and assist in returning blood in the veins to the heart. Heat produced in muscle contraction plays a vital role in the regulation of body temperature, which will be discussed in greater detail in Focus 3.3.

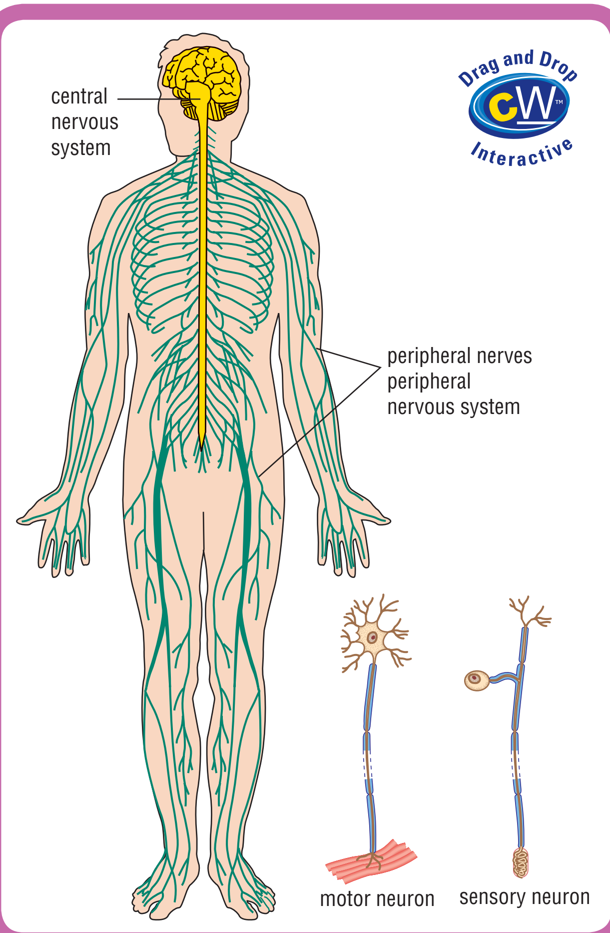
The muscular system Fig 3.2.4



Nervous system

The nervous system includes all the nervous tissue in the body, such as sensory neurons, which are sensitive to changes in the peripheral tissues such as those in your arms and legs, and motor neurons, which adjust the activities of tissues and organs throughout the body.

The components of the nervous system are the brain, the spinal cord, complex sense organs such as the eye and ear, and the nerves that connect these organs and the nervous system to the other systems of the body. The brain and spinal cord form the central nervous system. The **central nervous system** integrates sensory information and controls the activities of other systems. The sensory and motor neurons, which bring information to or from the central nervous system, are part of the **peripheral nervous system**. The **autonomic nervous system** includes both the central nervous system and peripheral nervous system in the automatic regulation of physical processes such as heart rate and digestion.



The nervous system *Fig 3.2.5*

Endocrine system

The endocrine system includes all the ductless glands that produce hormones. The secretions from endocrine glands are distributed by the circulatory system in the bloodstream, carrying specific instructions that

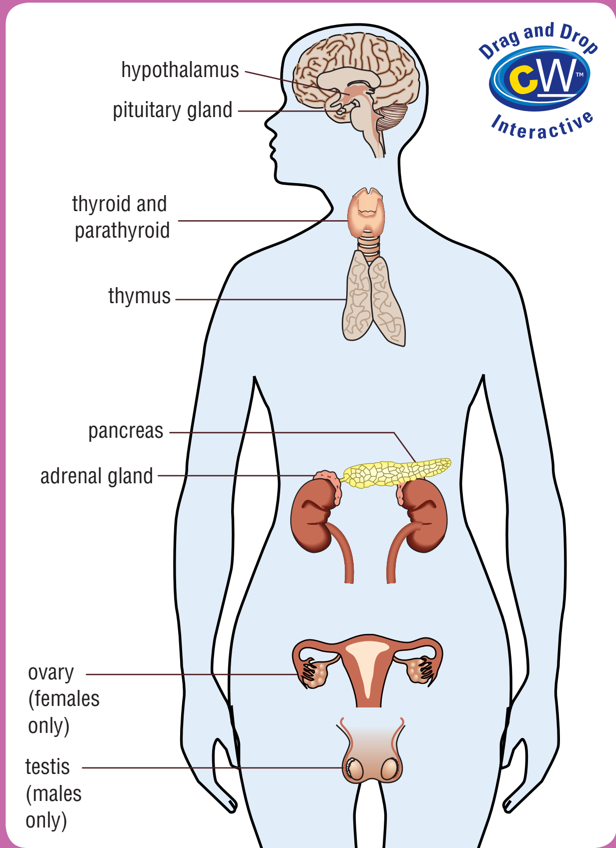


Fig 3.2.6 The endocrine system

Organ	Primary functions
Pituitary gland	Controls the secretions of other glands, integrates nervous and endocrine activities, regulates growth, secretes hormones involved in smooth muscle control and fluid balance
Thyroid gland	Controls metabolic rate and regulates blood calcium levels
Parathyroid gland	Regulates blood calcium levels with the thyroid gland
Thymus	Controls maturation and maintenance of lymphocytes (white blood cells)
Adrenal gland	Controls water balance and regulates metabolism of carbohydrates and lipids. Increases respiratory and cardiovascular activity in an emergency
Kidneys	Elevate blood pressure and control red blood cell production
Pancreas	Regulates blood glucose levels
Heart	Assists in regulating fluid balance
Digestive tract	Coordinates the activities of digestive glands
Testes	Support the production of sperm and male sexual characteristics
Ovaries	Support the production of ovum and female sexual characteristics. Also prepare uterus for embryo implantation and mammary glands for milk production.

coordinate cellular activities. Instructions may be quite general, affecting every cell in the body, or quite specific, targeting only a specific group of cells within an organ. Figure 3.2.6 and the accompanying table detail the primary functions of the organs involved in the endocrine system.

The nervous and endocrine systems represent different approaches to the regulation and coordination of internal activities. The nervous system specialises in providing an immediate short-term response, often within a second of the stimulus. Endocrine regulation usually occurs at a much slower pace, though a few responses, such as the breastfeeding mother's milk 'let down' response, occur within seconds. Most hormonal changes occur over minutes, hours, days or even years. Examples of endocrine regulation include the development of gametes and the control of blood glucose levels.

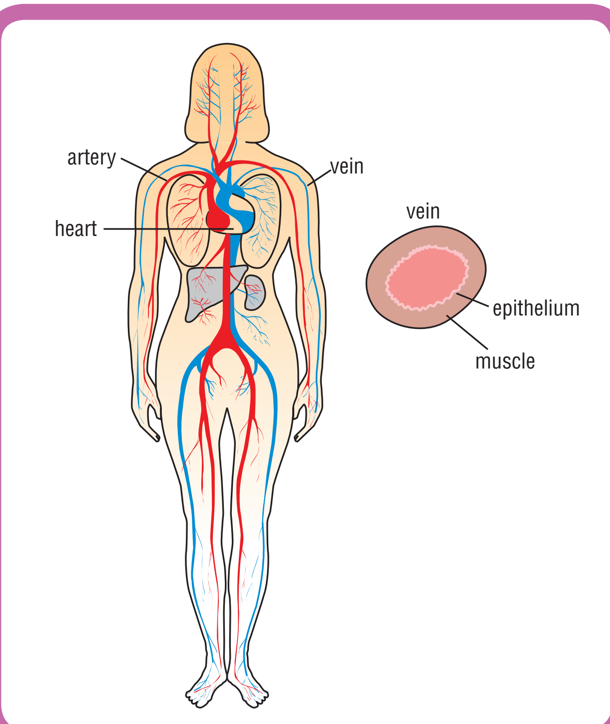
Cardiovascular system

The cardiovascular system consists of the heart, blood and blood vessels. This system depends on the skeletal system because bone marrow is where red blood cells are formed. The cardiovascular system transports nutrients, dissolved gases and hormones to the tissues throughout the body. Cellular waste products are transported throughout the body from tissues to sites of excretion, such as the kidney. Blood also carries heat from one location to another, participating in temperature control. White blood cells provide defence against disease and the formation of fibrin restricts the loss of blood through cuts and scrapes in the epithelium. So the circulatory system links all the systems of the body together.

Lymphatic system

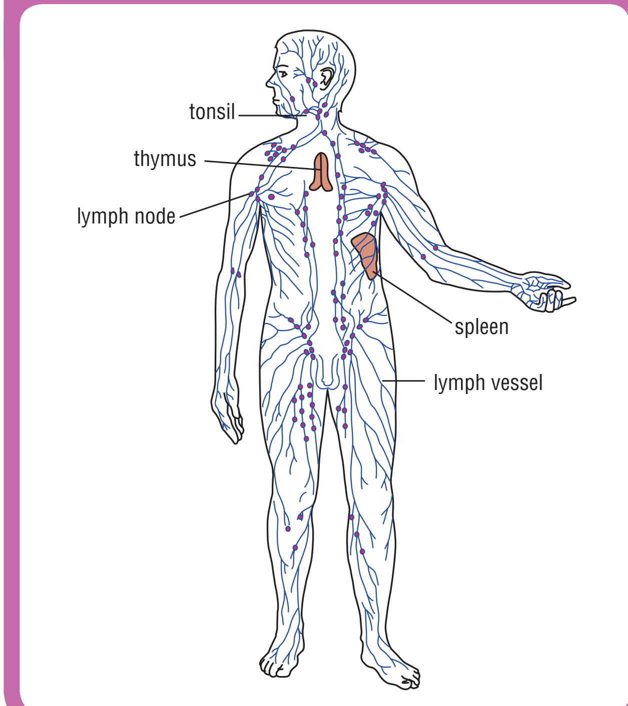
The lymphatic system is an extensive network of lymphatic vessels that deliver lymph to the circulatory system. In this process, molecules too large to pass through into capillaries, such as those in proteins and lipids, can enter the bloodstream. The lymphatic system also contains lymphatic organs, which produce or support a large population of lymphocytes, plasma cells and phagocytes—all discussed in Focus 4.3 of *Science Aspects 2*. Lymph nodes are small lymphatic organs that contain cells sensitive to the composition of the lymph fluid. Larger lymphatic organs in the body include the spleen, tonsils and thymus gland.

The lymphatic system defends the body against disease and toxic substances. Phagocytic cells throughout the body engulf foreign substances such as debris and pathogens. Lymphocytes also circulate through the body and when they encounter abnormal cells or pathogens they physically attack the intruders.



The circulatory system *Fig 3.2.7*

Fig 3.2.8 The lymphatic system



Other lymphocytes convert to plasma cells to produce antibodies, providing chemical defence.

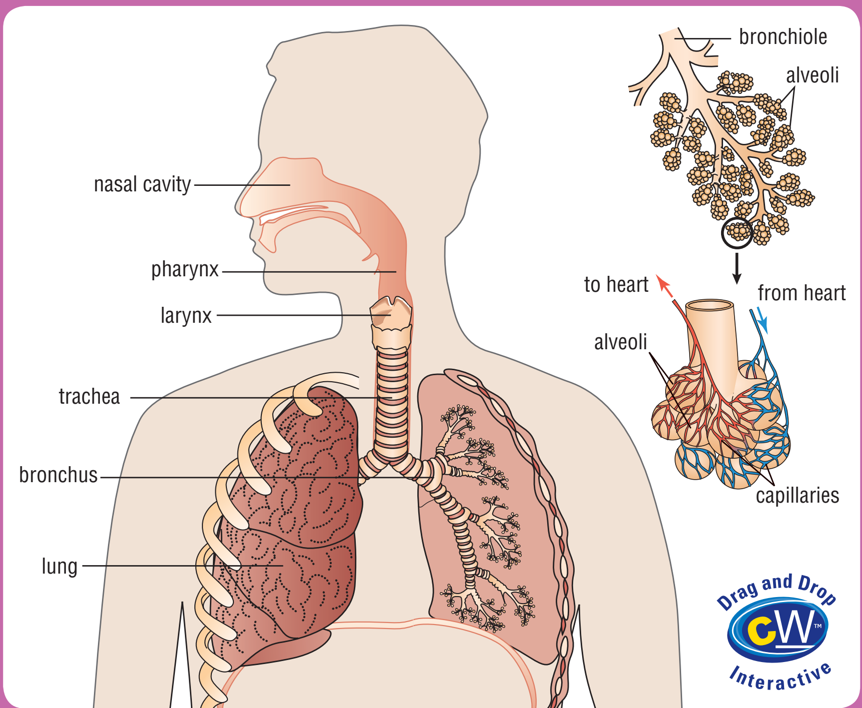
The basic components of the lymphatic system and their functions are shown in the table below.

Organ	Primary functions
Lymphatic vessels	Carry lymph from the peripheral tissues to the veins of the circulatory system
Lymph nodes	Contain sensitive cells that monitor the composition of the lymph, engulf pathogens and stimulate immune response
Spleen	Monitors circulating blood, engulfs pathogens and stimulates immune response
Thymus	Controls the development and maintenance of the lymphocytes

Respiratory system

The respiratory system includes the lungs and the passageways that carry air to them. These passageways start at the nasal cavity where air is filtered, warmed and humidified, and any smells are detected. From here the air passes to the pharynx and then to the larynx. The larynx, also called the voice box, is the opening to the trachea and contains two vocal cords.

Fig 3.2.9 The respiratory system



From the larynx, tiny hairs and mucus again filter air as it passes down the trachea. The trachea consists of cartilage rings, which keep the trachea open as air passes through the bronchi and into the lungs. In the lungs volume changes are responsible for air movement. Within the lungs the bronchi branch off into smaller and smaller air passages, the smallest of which are the alveoli. These are the site of gas exchange between the air and circulating blood.

The primary functions of the respiratory system are the delivery of oxygen and the removal of carbon dioxide. The respiratory system carries out these functions in cooperation with the circulatory system. The respiratory system also has a number of important secondary functions. By changing the concentration of carbon dioxide in the blood, the respiratory system helps to regulate the pH of body fluids. In addition, the evaporation of water in the lungs and along the respiratory passageways helps to cool the body. Air passing over the vocal cords also produces the sounds used in many forms of communication.

Homework book 3.5 Asthma

Digestive system

The long tube called the digestive tract, which starts at the mouth and ends at the anus, is the central component of the digestive system. The primary function of the digestive system is the breakdown of food into molecules small enough to be absorbed through the cell membranes of the intestines. These are then circulated in blood vessels and lymphatic vessels for use by the body. The digestive tract absorbs water and nutrients, including organic compounds, ions and vitamins. Ions and a few other metabolic wastes are moved into the digestive tract by the pancreas and liver. These wastes and any undigested food from previous meals are eliminated from the large intestine in the process of defecation. Figure 3.2.10 and the accompanying table detail the primary functions of the organs involved in the digestive tract.

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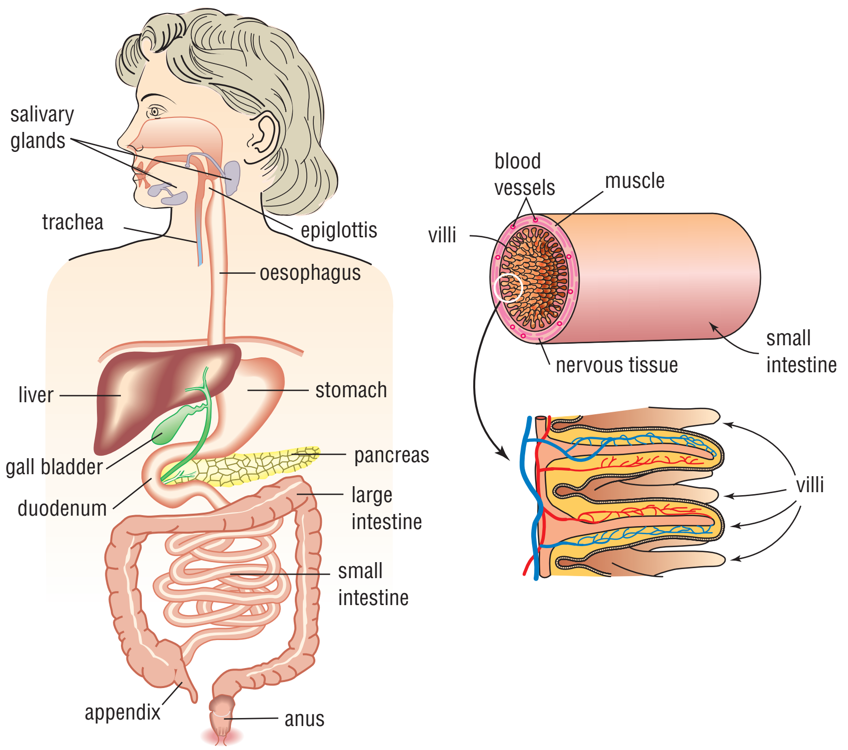


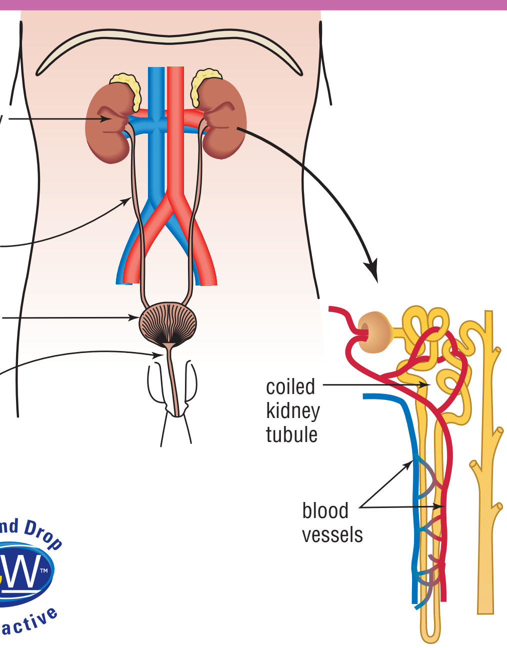
The digestive system **Fig 3.2.10**

Organ	Primary functions
Mouth	Mixes food with saliva, breaks up food and enables us to taste our food
Salivary gland	Lubricates food to swallow, small amount of carbohydrate digestion
Pharynx	Passage shared with the respiratory system, leads to the oesophagus
Oesophagus	Delivers food to the stomach
Stomach	Secretes acids and digestive enzymes that break down proteins
Small intestine	Absorbs nutrients and secretes enzymes for digestion
Liver	Secretes bile (required for lipid digestion), regulates the nutrient composition of the blood, stores lipid and carbohydrate reserves
Gall bladder	Stores bile for release into the small intestine
Pancreas	Secretes digestive enzymes into the small intestine
Large intestine	Removes water from faeces and stores waste before defecation, some mineral and vitamin absorption
Anus	Opening to the outside of the body for the discharge of faeces

Urinary system

The urinary system includes the kidneys, where urine production occurs; the ureters, which carry the urine to the urinary bladder for storage; and the urethra, which carries the urine from the bladder to the outside of the body. The primary function of the urinary system is the selective elimination of waste products, including acids that may otherwise affect pH of other body fluids. It also regulates fluid and electrolyte composition of the blood. Urine production begins at the kidneys, where filtration of the blood occurs across the walls of special capillaries into kidney tubules. As this fluid passes along the tubules its composition changes through osmosis and the transport activities of the epithelial cells. The urine that results is stored in the urinary bladder for a variable period before it is eliminated through the process of urination.

Fig 3.2.11 The urinary system



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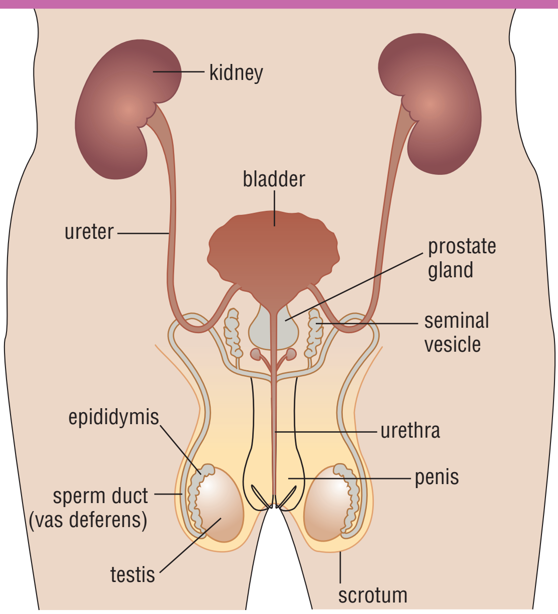
Reproductive system

The reproductive system is responsible for the production of offspring. It also produces hormones that affect development, growth and maintenance of many other systems. Sperm or eggs develop within reproductive organs known as gonads, the testes of a male and the ovaries of a female. Reproductive cells, or gametes, produced in the gonads travel towards the outside of the body in ducts that receive the secretions of accessory organs. The parts of the reproductive system that are visible from the outside of the body are called the external genitalia.

The male reproductive system *Fig 3.2.12*



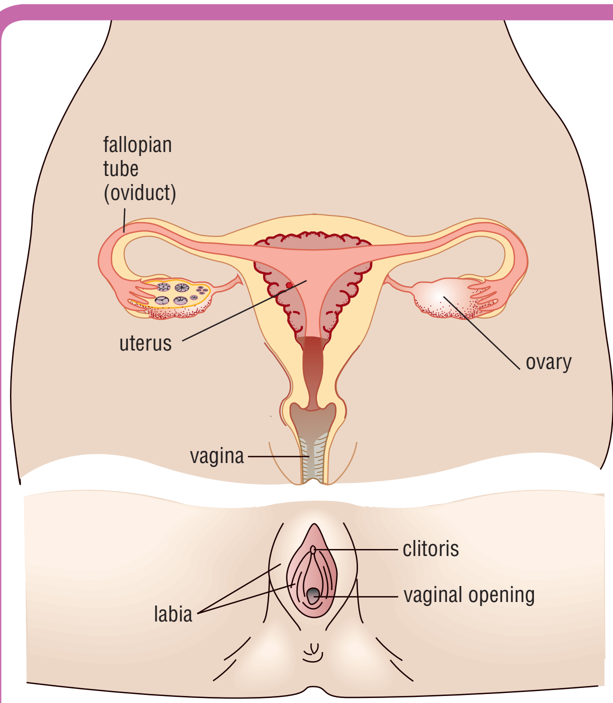


Fig 3.2.13 The female reproductive system

FOCUS 3.2 [Questions]

Use your book

Body systems

1 What are the four basic tissue types that form organs ?

2 What are the characteristics that all organ systems share despite structural and functional differences in the systems?

Integumentary system

3 What are the functions of the integumentary system?

Skeletal system

4 What are the functions of the skeletal system?

Muscular system

5 What are the functions of skeletal muscle?

6 Describe the interactions between the skeletal and muscular systems.

Nervous system

7 What part of the nervous system do we call the brain and the spinal cord?

8 What part of the nervous system includes the sensory and motor neurons that bring information to and from the central nervous system?

Endocrine system

9 How are the secretions from the endocrine glands distributed?

10 How do the nervous system and the endocrine system differ in the speed with which they respond?

Cardiovascular system

11 What does the cardiovascular system transport throughout the body?

12 What are the functions of the white blood cells in the blood?

>>

Lymphatic system

13 What is the primary function of the thymus?

Respiratory system

14 What are the primary functions of the respiratory system?

Digestive system

15 How are wastes and undigested food from previous meals eliminated from the body?

16 Copy the following table into your notebook and fill in the missing spaces:

Organ	Primary functions
Mouth	
	Produces enzymes that begin digestion
Pharynx	Passage shared with the respiratory system, leads to the oesophagus
Oesophagus	
Stomach	Secretes acids and digestive enzymes that break down proteins
	Absorbs nutrients
Liver	Secretes bile (required for lipid digestion), regulates the nutrient composition of the blood, stores lipid and carbohydrate reserves
	Stores bile for release into the small intestine
Pancreas	
	Removes water from faeces and stores waste before defecation
Anus	

Urinary system

17 Copy the following table into your notebook, matching the organ to its function by drawing arrows.

Organ	Function
The kidneys	carry the urine
The ureters	where urine production occurs
Urinary bladder	carries the urine from the bladder to the outside the body
Urethra	urine storage

Reproductive system

18 What is the function of the reproductive system?

Use your head

19 Deodorants are used to mask the effects of secretions from what type of skin gland?

20 How would severing the tendon that was attached to a muscle affect the ability of the muscle to move this body part?

21 Draw a flow diagram of the passage of air through the respiratory system and explain carefully how the circulatory and respiratory systems cooperate in the process of breathing.

22 All the systems of the body are integrated. For the muscular system to operate efficiently it must be supported by many other systems. The following four passages describe the responses of other systems to exercise. Name the system involved in each response.

a Dilation of blood vessels in the active muscles and the skin, and an increase in the heart rate. These adjustments increase oxygen delivery and carbon dioxide removal at the muscles and bring heat to the skin for removal.

b Increased respiratory rate and depth of respiration. Air moves in and out of the lungs more quickly, keeping pace with the increased rate of blood flow through the lungs.

c Dilation of blood vessels and increased sweat gland secretion. This combination helps to promote evaporation at the skin's surface and removes the excess heat generated by muscular activity.

d Direction of the responses of other systems by controlling heart rate, respiratory rate and sweat gland activity.

Investigating questions

23 How does ageing alter the integumentary system? How do these changes affect the physical condition of elderly people?

24 Why are malnourished people and those who are victims of chronic starvation more likely to have fractures than well-fed individuals?

25 Investigate how diabetes affects the systems of the body.

26 Design an experiment to test your reaction time to a stimulus.

27 Sometimes in movies you may see criminals sanding down their fingertips so they do not leave fingerprints. Would this permanently remove their fingerprints? Why?

FOCUS 3.2

[Practical activity]

Prac 1 Focus 3.2

Moving through tissues

Purpose

To investigate how glucose moves through the cell membranes lining the small intestine.

Requirements

Three 25 cm lengths of dialysis tubing, three 500 mL beakers, distilled water, starch solution, iodine solution, glucose solution, testape, Pasteur pipettes.

Procedure

1. *Copy the table below into your notebook.*
2. Soak the three lengths of tubing in a beaker of distilled water for a few minutes.
3. Tie one end of each tubing section in a knot.
4. Rub the other end of each tubing section to open it up.
5. Fill one tube with starch solution, tie the open end and rinse off with distilled water.
6. Place this tube filled with starch in a beaker containing 250 mL of distilled water and add 10 drops of iodine solution (beaker A).
7. Fill the second tube with distilled water, tie the open end and rinse off with distilled water.
8. Place this tube filled with water in a beaker containing 250 mL of distilled water and add 10 drops of iodine solution (beaker B).
9. Fill the third tube with glucose solution, tie the end and rinse with water.
10. Place this tube filled with glucose in a beaker containing 250 mL of distilled water (beaker C).
11. Test the water of the third beaker, beaker C, with testape.
12. Leave all three beakers for 20 minutes.
13. Do you notice any changes? Test beaker C with testape and *record your observations and results.*

Questions

1. How do you know if there is glucose or starch in the solution?
2. What does the dialysis tubing represent?
3. What was the purpose of the tubing in beaker B?
4. Draw a diagram of the dialysis tubing in the beakers and describe the direction of movement of the glucose and starch molecules. Why did this occur?
5. In what area of the body do you think this type of transport is important? Why?

Dialysis tubing containing	Beaker A (Distilled water and iodine)	Beaker B (Distilled water and iodine)	Beaker C (Distilled water only)
Starch	Before: After:		
Distilled water		Before: After:	
Glucose			Before: After:

FOCUS 3.3 Body systems and regulation

Context

Your body systems carry out millions of activities every day, many without you even being conscious of them. Information that is received from your surroundings often elicits a response from your body. The information may come in several different ways, such as through smell, sight, touch or hearing, and your body will respond appropriately—you will smell the flowers, move your hand away from a hot surface, walk towards the friends you have seen in the park, or turn as you hear somebody call you in the corridor. You are aware of and can control these responses to some extent, but your body also changes in ways that you cannot see—your pupil contracts when you walk into the Sun, or your heart beats faster during a scary part in a movie. This Focus uses a model to help you to understand how your body control systems regulate your internal environment.

A reverse-cycle air conditioner controls heating and cooling to keep the temperature at a comfortable level. *Fig 3.3.1*

Homeostasis

Your organ systems all act interdependently and are interconnected very closely in a relatively small space. All the cells, organs, tissues and systems in your body work in an environment that is shared. Your body's cells rely on the fluid, which surrounds them, to provide the oxygen and nutrients needed for survival. Blood or other fluids surround all the cells of your body. Any changes that occur to the fluid around your cells will affect the cells in some way. For example, temperature affects your body every day. A small change in the temperature of your blood changes the rate at which your heart beats. A variety of physical mechanisms also act to prevent potentially disruptive events for the body; if the outside temperature drops there will be decreased blood flow to the skin and shivering. These physical changes stabilise the internal conditions and ensure that the body maintains its optimum operating temperature.

Homeostasis is the maintenance of a stable and optimal internal environment. Maintenance of the correct amount of water, glucose and oxygen in cells is an example of homeostasis. The term **homeostatic regulation** refers to the physical changes the body makes to maintain homeostasis. Homeostatic regulation involves a **receptor** that is sensitive to a particular stimulus and an **effector** that has an effect on the same stimulus. A reverse-cycle air conditioner is an example of a homeostatic regulator.

If you set the air conditioner to 21°C, which is below the room temperature, the air conditioner will cool the room to that temperature and then turn off. If the temperature falls below the set 21°C the heater will be turned on. In each case the stimulus triggers the response that restores the room to the 'normal' or set temperature.

The goal of the air conditioner is to keep the temperature within acceptable limits. The air conditioner acts as the control centre; the receptor is the thermometer, which measures room temperature; and there are two effectors, one that operates the heater and one that operates the cooling on the air conditioner. This principle is simple: the heater turns on if the room is too cold and the cooling operation turns on if the room is too hot, as is shown in Figure 3.3.2 on page 124. Systems such as this keep the conditions within an acceptable range, not at a precise temperature. Although you may set the temperature at 21°C minor fluctuations in temperature occur.

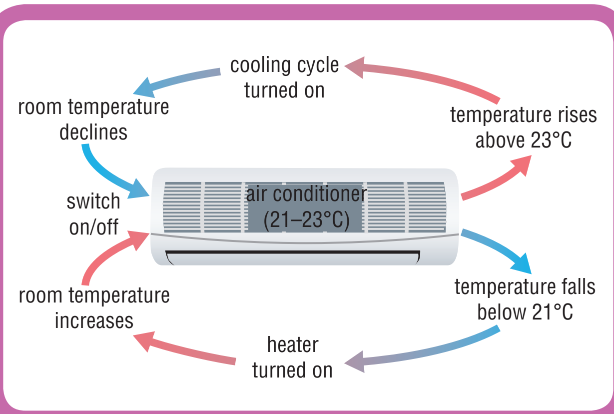


Fig 3.3.2 This flow diagram represents thermostatic regulation of room temperature. Here you can see the sequence of events that would occur as 'normal' is maintained.

Homework book 3.5 Temperature regulation

Control mechanisms

In the example above, regardless of whether the temperature rose or fell, a variation outside normal triggered an automatic response that corrected the situation. This is called **negative feedback** because the correction involves an action that directly opposes the variation in temperature. Most homeostatic responses involve negative feedback.

Your body's response to fluctuations in body temperature can be said to be comparable to that of a room with a reverse-cycle air conditioner. In this scientific model, part of your brain is the control centre that monitors the surrounding temperature. The centre will not trigger a response when the temperatures stay between 37.2°C and 36.1°C. If your body temperature rises above 37.2°C or falls below 36.1°C the temperature control centre will activate. It will change the balance between internal heat production and heat loss at the body's surface.

Science Snippet

Feeling cold?

Hypothermia occurs when the body's temperature falls below 35°C. You don't have to be in sub-zero temperatures to risk hypothermia though, as it often occurs in the temperature range 0°C–10°C. Hypothermia occurs in situations that cause the body to lose more heat than it can generate. This happens in prolonged exposure to cold conditions, immersion in cold water for a long time or spending excessive time in wet clothes. The first warning sign of hypothermia is uncontrollable shivering. The person stops shivering as they progress into severe hypothermia. Coma occurs when the body's temperature falls below 32°C.

For example, when your body temperature gets too high, the control centre causes increased blood flow to the skin and activates your sweat glands. The skin loses heat to the environment and the evaporation of sweat speeds this process. When the body temperature returns to normal the control centre switches off.

If the body temperature dips below normal, the control centre will again be activated. This time blood flow will be restricted to the skin, reducing heat loss to the outside world. At the same time muscle contractions may be triggered, which we call 'shivering'. Shivering generates heat and body temperature will again climb to normal levels. Once the acceptable range is reached the control centre closes down and the shivering stops.

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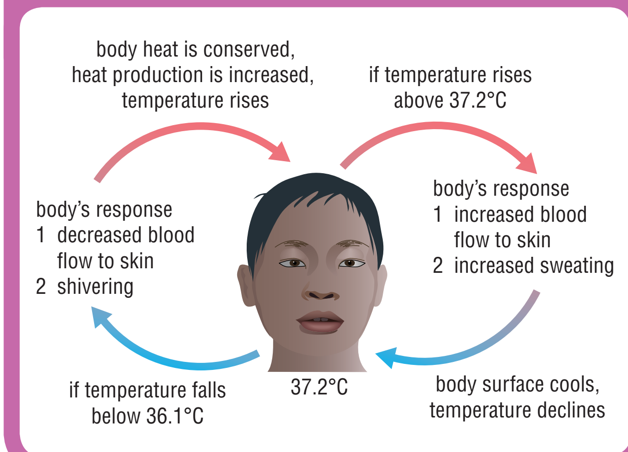
Fig 3.3.3 The control centre in the brain normally accepts a body temperature in the range 36.1°C to 37.2°C. A variation outside normal limits triggers an automatic response from the body, which corrects the situation.



Homeostatic processes occur all over the body from the level of the cell to the organ and system. **Autoregulation** is an automatic change in the activities of the cell, tissue, organ or system due to environmental variation.

Activities of the nervous or endocrine systems that can control or adjust many different systems simultaneously are called **extrinsic regulation**. Extrinsic regulation usually occurs when autoregulation fails to maintain homeostasis in some part of the body. It usually causes more extensive and potentially more effective adjustments in system activities. So the homeostatic control systems of the body are the nervous and endocrine systems.

Generally, the nervous system performs the ‘crisis management’ by allowing very specific responses. For example, when you accidentally set your hand down on a hot stove, the rising temperature produces a painful localised disturbance in homeostasis. The nervous system responds by ordering muscles to contract, pulling the hand away from the stove. This effect lasts only as long as the activity from the nerves, which could be just a matter of seconds.

In contrast, the endocrine system releases hormones that affect tissues and organs throughout the body. The responses may not be immediately apparent. However, when the effects appear they may be present for days, weeks or months. Despite their functional differences both systems usually operate by negative feedback.

In a few instances, homeostatic regulation involves **positive feedback** mechanisms. Positive feedback occurs when the initial stimulus produces a response that increases the stimulus. In a behavioural sense, your desire to eat a whole bar of chocolate after taking just one bite may be considered an example of positive feedback. In a physical sense the positive feedback occurs in cases where a particular process must proceed swiftly to completion. An example of positive feedback is shown in Figure 3.3.4. Blood clotting is a chain reaction that occurs when there has been damage to the circulatory system. Clotting temporarily repairs damage to the walls of the capillaries and limits the loss of blood. The damage to the blood vessels is the trigger that starts the clotting process. Once it begins to form, the growing clot releases chemicals that accelerate the clotting process. As a result, the walls of the blood vessels are patched.

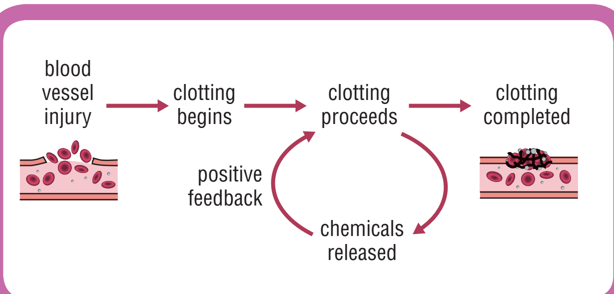


Fig 3.3.4 Positive feedback occurs when the stimulus produces a response that reinforces the original stimulus.

Homework book 3.6 Body regulation wordfind

Homeostasis and disease

The internal systems of your body do an amazing job of maintaining a stable internal environment, regardless of what you do. When homeostatic regulation fails, however, organ systems begin to fail and you may experience symptoms of illness or **disease**. An understanding of normal homeostatic mechanisms can help you to work out why you feel like you do.

For example, an increased body temperature may indicate that you are producing heat faster than it can be lost from the body’s surface, such as during exercise. Another possibility is that heat production may be normal but heat loss is prevented, such as when you have severe sunburn or when you are sitting in a sauna. Alternatively, your body’s normal temperature could be rising because of infection, where chemical messengers in the blood affect your temperature control centre and cause an elevated temperature we call a ‘fever’.

An understanding of homeostatic processes gives you a framework to help in the diagnosis of disease. This framework assists in the process of ‘critical thinking’. In this process, information is organised and analysed objectively so that conclusions can be made and those conclusions tested. Critical thinking is essential for an understanding of science. When you are trying to make sensible decisions about your life, you need to know how to organise information, evaluate evidence and make logical conclusions.

Drag and Drop CW Interactive

Homework book 3.7 Hypothermia

Fig 3.3.5 A fever is due to chemicals affecting the temperature control centre.

FOCUS 3.3

Questions

Use your book

Homeostasis

1 What is homeostasis?

2 What is homeostatic regulation and why is it necessary?

Control mechanisms

3 Name three substances in the body that are homeostatically controlled.

4 In humans, what does the homeostatic mechanism that controls temperature sense as ‘normal’?

5 What is the difference between positive and negative feedback mechanisms?

6 What term describes the automatic change that occurs in the activities of the cell, tissue, organ or system in the event of environmental variation?

7 What kind of feedback is associated with blood clotting in response to damaged blood vessels?

8 What are the two main systems in the body that allow homeostatic control?

Homeostasis and disease

9 What word is used to describe a malfunction of organs or organ systems resulting from failure of homeostatic regulation?

10 Give three reasons why you may experience an increase in your body temperature.

Use your head

11 Why is homeostatic regulation important to humans?

12 What happens to the body if homeostasis breaks down?

13 How is regulation of body temperature different from blood clotting?

Investigating questions

14 What do the nervous and endocrine systems have in common? How are their functions different?

15 Our bodies are amazing in the way that they stabilise internal conditions. However, what happens if our bodies are exposed to particularly harsh external conditions? If you fell from a boat into the ocean what changes would occur to your body? You may choose to present your information as a flow diagram, poster or short story.

16 When you are sick, you will sometimes have a fever. Research how a fever occurs and whether it is harmful or beneficial to your body.

FOCUS 3.3

Practical activity

Prac 1 Focus 3.3

Body temperature and exercise

Purpose

To investigate how exercise affects body temperature.

Requirements

Markers, willing participants, clinical thermometer, stopwatch, drinking water if needed, sterilising solution such as Dettol. You may also need a change of clothes and exercise equipment depending on the type of exercise you will be doing.

Procedure

1 Your group will first need to decide what type of exercise you will be doing and for what period of time. This is important, as the participants should be able to comfortably do the exercise consistently for a period of time. Running, step-ups or skipping are examples you may like to use.

2 Mark out the area in which you will be doing your exercise to ensure that it is safe for the person exercising.

3 *Draw a table like the example opposite in your notebook to record your results.* Ensure that you have everything you need to begin.

4 *Sterilise the thermometer using an antiseptic solution and record the body temperature of the person who will be exercising first.*

>>

5 Start your first trial and as the participants begin their exercise ensure the timer is started.

6 After the first session *record body temperature.* After a 2-minute break resume exercise. (Only continue if the person exercising is comfortable and happy to do so.)

7 *After each member of your group has completed their exercise and you have completed your table, average the results.*

Questions

1 Were there any differences in body temperature before and after exercise?

2 What physical changes did you notice during exercise? Why do you think these changes occurred?

3 How could you improve this experiment?

4 Design an experiment to test another type of homeostatic control in the body.

DYO

Student name	Trial 1—body temperature		Trial 2—body temperature		Trial 3—body temperature		Average
	Before exercise	After exercise	Before exercise	After exercise	Before exercise	After exercise	

Fig 3.3.6 Your body responds during exercise to keep your temperature stable.

FOCUS 3.4

Protecting the body

Context

Your body works to protect you from foreign pathogens and chemicals every day, often without you even being aware of it. Your body maintains a stable internal environment with narrow limits of tolerance in the changing external environment. You usually feel unwell if your body's protection systems fail, whether this is only a short-term problem such as having a cold, a long-term problem or life-threatening. This Focus is about the physical and behavioural mechanisms that protect the functioning of your body's systems.

Fig 3.4.1 There are many different types of exercise, from running on the beach to playing netball on the weekend.

Staying healthy

There are many factors that contribute to your overall health and well-being. There are, however, three main factors you need to be aware of to stay healthy. These are good nutrition, a healthy mind and exercise. If you do not pay attention to all three of these factors you may quickly become unhealthy.

There is an old saying 'healthy mind, healthy body', which implies that your mind strongly influences your physical health. Many alternative therapies heal by working with both mind and body. The way you feel and what you think have the ability to affect every system in your body. Depression, anorexia and bulimia are examples of mental illnesses. You may notice that when you feel stressed, such as before doing a test or when you are going on a date with a person you really like, you feel your heart rate increase, your palms may get sweaty and your respiratory rate increases. Your body is not under any real threat but your mind is causing these physical changes. Taking time out to relax, meditate or participate in activities you really enjoy can help you to reduce anxiety.

Exercise also helps you to feel better. In addition to the physical benefits, it helps to clear your mind and reduce stress. Exercise can range from playing football on the weekend to playing with your dog in the backyard after school. It is important to do activities that you enjoy, or you may become apathetic and not want to do much at all. Whatever your age or fitness level you should engage in some type of exercise at least three times a week to stay healthy.

Food provides energy for your body so that it can carry out the activities you need to survive. Your diet may be different from that of some of your friends, but as long as it is a varied diet it should provide all the nutrients you need. Fats, proteins, carbohydrates, vitamins and minerals are all used by the human body for cell metabolism. Your diet should consist of a variety of foods, including fresh fruit and vegetables, cereals, dairy, lean meat and water. You need more energy than your parents do, because you are still growing. If you are highly active you will also need higher levels of nutrients than somebody who leads a less active lifestyle.

The Healthy Living Pyramid, developed by Australian Nutrition Foundation (Nutrition Australia), depicts the basic food groups in sections according to their energy content and the nutrients they provide.

Fig 3.4.2

Homework book 3.8 The glycemic index and load

What is disease?

Even though you do your best to stay healthy, the environment you live in is not always kind to your body. When playing sport or during any of your daily activities you may accidentally, bump, bruise, cut, scrape or burn yourself, in addition to being exposed to varying temperatures. To make this worse you are also exposed to any number of bacteria, viruses, fungi and parasites, which live in the environment around you. Many of these organisms are capable of not only surviving but thriving in the environment inside your body and potentially causing you harm in the process.

The physical mechanisms inside your body do a remarkable job of maintaining a constant internal environment despite what your body is exposed to in daily activities. It is when homeostasis fails that organ systems begin to malfunction and you experience symptoms of illness or **disease**.

Science Snippet

Doctors of disease

Pathologists are doctors who specialise in the diagnosis of disease processes. They analyse observations of physical symptoms and any samples taken to determine the cause of the disease and how severe it is. Pathologists rarely deal with patients, concerning themselves with the diagnosis and treatment. When your doctor takes a sample of your blood, urine or tissue, it is probably sent to a pathologist for analysis.

Fig 3.4.3

When you have the flu how do you feel? When your systems are functioning abnormally due to the presence of disease you show **symptoms** of the disease.

Defence against disease

Staying healthy involves a massive, combined effort involving many different organs and systems. In this ongoing struggle your lymphatic system plays a vital role. **Lymphocytes** are the dominant cells of the **lymphatic system**. They respond to the presence of invading organisms such as bacteria and viruses. They also respond to abnormal body cells such as cells infected by viruses or cancer cells. Lastly, they respond to foreign proteins such as those released by some bacteria. Lymphocytes attempt to render these threats harmless or eliminate them with a combination of chemical and physical attack.

Fig 3.4.4 The primary function of the lymphatic system is to produce, maintain and distribute lymphocytes. The system includes a network of vessels that carry a fluid called lymph around the body.

Specific defences

Specific defences provide protection against specific threats. For example, a specific defence may protect against infection by one type of bacteria, but ignore other bacteria and viruses. Many specific defences develop after birth, as a result of accidental or deliberate exposure to environmental hazards. Specific defences are dependant upon the activities of the lymphocytes. They provide a state of protection called **specific immunity**. The goal of the **immune response** is the destruction or inactivation of pathogens, abnormal cells and foreign molecules such as toxins. Substances capable of inducing the production of **antibodies** are called **antigens**. An antigen activates specific defence and the response targets the specific antigen, not others.

Science Snippet

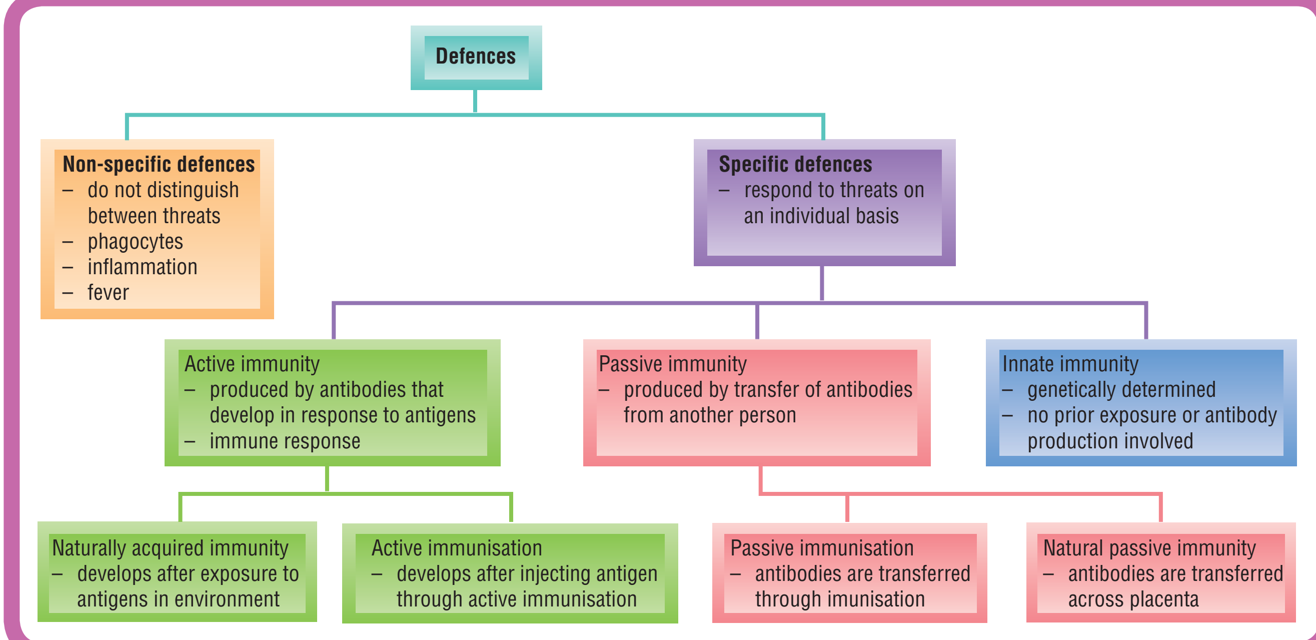
Losing your immunity

Your immune system, or immunity, can be switched off by specific types of drugs in a process called immunosuppression. Can you name why this may be necessary in the treatment of some conditions?

Non-specific defences

The body has other, less specialised defences also, called **non-specific immunity**. These less specialised defences protect against the approach of, entrance of, or spread of microorganisms or other environmental hazards. For example, the skin is an effective

Immunity is the resistance to injuries and diseases caused by foreign compounds, toxins and pathogens. This diagram represents the different types of immunity. *Fig 3.4.5*



physical barrier that both provides protection and prevents bacterial access to underlying tissues.

The exterior surface of the body has several layers of defence. The hair found in most areas provides some protection against scrapes and insects, especially in the scalp. The skin also secretes sweat and other fluids that contain destructive enzymes and antibodies which kill bacteria. Mucus covers most surfaces in the digestive tract and the stomach contains powerful acid that can destroy potential disease-causing organisms (also called **pathogens**). Mucus covers the respiratory tract, urine flushes the urinary tract and glandular secretions protect the reproductive tract. Special enzymes, antibodies and often acidic conditions add to the effectiveness of these secretions.

Phagocytes perform the police services in your body, removing cellular debris and responding to the invasion of foreign organisms and pathogens. Phagocytes are the body's 'first line' of cellular defence against pathogens. Phagocytes often attack and remove pathogenic microorganisms before the cells of the lymphatic system detect an invasion.

Inflammation occurs when a hazardous agent enters the tissue under the skin. Skin contains a mixture of cell types, including phagocytes. The presence of pathogens in body tissues triggers a complex process called the **inflammatory response**. Histamine is released, which increases blood flow to the area. This increase in circulation brings more cellular defenders to the site and carries away toxins and debris. Phagocytes attack bacteria and debris entering the bloodstream and this activity stimulates the lymphatic system and activates the body's specific defence mechanisms. The increased blood flow also raises the local temperature, increasing the rate of reactions within cells. You may feel this occurring if a mosquito bites you.

Fig 3.4.6 Have you been bitten by a mosquito lately?

A fever is the maintenance of a body temperature over 37.2°C. In Focus 3.3 we covered the regulation of temperature in the body. Within limits, a fever may be beneficial. A high body temperature may inhibit some bacteria and viruses, or it may speed up their reproductive rates so that the disease runs its course more rapidly. This increase in temperature also increases metabolic processes, since for every 1°C increase in body temperature there is about a 10 per cent increase in metabolic rate. This increase helps to mobilise tissue defences and speed up the repair process. A fever over 40°C, though, will have a negative effect on body systems, resulting in nausea, disorientation, hallucinations or convulsions.

Infectious disease

Many microorganisms are helpful to humans, for example as food sources, to decompose wastes, to aid in digestion or protection from other pathogens. Some microorganisms can be harmful; these pathogens include some varieties of bacteria, viruses, protozoa and fungi.

Bacteria can multiply very quickly under the right conditions. If your doctor prescribes antibiotics to fight bacterial infections, you should ensure that you take the whole course of antibiotics, even when you are feeling better, as some bacteria may still be in your system. If conditions are unfavourable for growth, some types of bacteria can form thick-walled spores that allow them to survive in heat, cold or prolonged dry conditions. There are other conditions caused by viruses for which your doctor will not give you antibiotics, for example varicella, commonly known as chickenpox. Antibiotics are not useful against viruses because viruses are not true cells, and are more like chemicals than living organisms. Viruses do not feed, grow, produce waste or move; to pass through your body they need to attach to something else. Your body needs to fight these pathogens without the help of antibiotics.

Science Snippet

How do you catch the flu?

Flu viruses spread through small respiratory droplets when you cough or sneeze. These small droplets are released into the atmosphere and others directly inhale them, or they land on surfaces and are picked up later by others. Viruses usually spread from person to person, though you can become infected by touching something with flu viruses on it and then touching your mouth or nose. You are able to infect others one day before symptoms develop and up to five days after becoming sick. That means that you can pass on the flu to someone else before you know you are sick, as well as while you are sick.

Fig 3.4.7 These bacteria, called salmonella, cause food poisoning.

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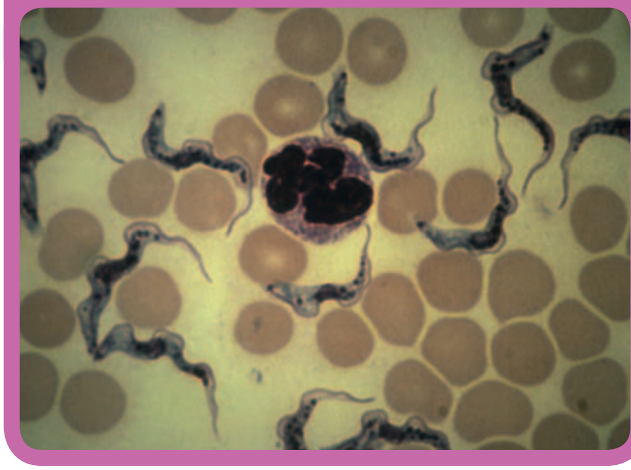
Fig 3.4.8 This protozoan causes 'sleeping sickness'.



Diseases caused by protozoa, or protists as they are often called, are commonly seen in tropical regions. Malaria and Giardia are both examples of protozoa found in water supplies that can cause serious illness. Few fungi cause disease and those that do often affect the hair, nails and skin. Fungi do not often cause infection, although if conditions are ideal or the immune system is not working properly the opportunistic fungi can cause infection. Tinea, thrush and ringworm are examples of fungi that cause infection in humans. Disease can also be caused by other opportunistic macroscopic parasites such as worms and flukes.

Homework book 3.9 Outbreak!

Drag and Drop Interactive

Tinea, sometimes known as 'athlete's foot' Fig 3.4.9

Non-infectious disease

There are many diseases that are not 'caught', meaning that they are not contagious or caused by pathogens. The causes of non-infectious diseases are varied and frequently unknown. Some are genetic disorders, such as Down syndrome, while others, like cancer, have been linked to environmental conditions. The cause of some is still unknown.

Diabetes is a non-infectious disease. Diabetics often have to do blood tests to check their blood sugar several times a day. Fig 3.4.10

Genetic disorders are caused by abnormalities in one or more genes; these problems may be caused by mutation in the genes and are often present from birth. Drugs, radiation, chemicals and some viruses can be responsible for mutations, and once a mutation has occurred it will be passed onto future generations. Some genetic disorders can be detected while the child is still in the womb.

Disease can also be caused by poor diet or malnutrition; people in developing countries are often susceptible to malnutrition because the quality and range of foods available are poor. Other problems associated with diet include obesity, eating disorders and diabetes. Smoking, a lack of regular exercise and poor diet can cause disease within the circulatory system, such as thrombosis, varicose veins, high blood pressure and heart disease.

Cancer is a disease that is on the increase across the world. Cancer occurs when cells divide uncontrollably. A tumour is any abnormal growth in the body caused by environmental conditions, such as smoking or excessive exposure to ultraviolet radiation, or genetic disposition, such as a family history of breast cancer. When a tumour is discovered, a biopsy is carried out. A small sample of tissue is taken and analysed under the microscope—to determine whether the tumour is malignant (growing uncontrollably) or benign (not growing uncontrollably). A common example of a benign tumour is a wart. Cancer can occur anywhere in the body, although the most common sites are the skin, breasts and prostate gland. The common treatments for cancer include surgery, radiotherapy and chemotherapy, all of which have side-effects. The best chance of beating cancer is to lead a healthy lifestyle and have regular check-ups so that problems can be detected early. Never ignore unexplained changes to your body—get your doctor to check them as soon as possible.

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3·4 FOCUS [Questions]

Use your book

Staying healthy

1 What are the three main factors you need to be aware of to stay healthy?

2 What should a balanced diet consist of?

What is disease?

3 What is 'disease'?

4 What is the role of a pathologist?

Defence against disease

5 What is your ideal body temperature?

6 What are the three main types of materials that lymphocytes attack?

7 What are the primary functions of the lymphatic system?

8 What is the difference between immunity and non-specific body defences?

9 At what temperature will a fever have a negative effect on the body?

Infectious disease

10 How are microorganisms helpful to humans?

11 List four different types of pathogens responsible for infectious disease.

12 Why are antibiotics useful for bacterial infections but not viral infections?

13 Why do bacteria cause more infections than fungus?

Non-infectious disease

14 What is a non-infectious disease?

15 What is a genetic disorder? Give one example.

16 Identify diseases associated with diet.

17 What is cancer?

18 What is the difference between a benign and a malignant tumour? Give an example of each.

Use your head

19 Explain why it is important to describe all of your symptoms to your doctor when you are sick.

20 Why may lymph nodes enlarge during some infections?

21 How can stress decrease the effectiveness of the immune response?

Investigating question

22 In Prac 1 you inoculated agar plates with bacteria from surfaces in your classroom. Design an experiment to test which of several disinfectants may be best to destroy these bacteria.

DYO

FOCUS 3.4

Practical activity

Prac 1 Focus 3.4

Microorganisms in the environment

Purpose

To grow a variety of microorganisms on nutrient agar.

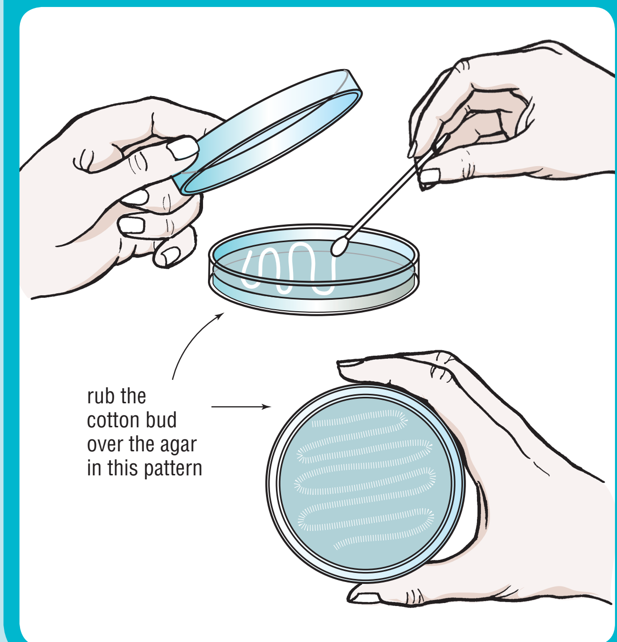
Requirements

Three petri dishes containing nutrient agar, masking tape, sterile cotton buds, disinfectant for used instruments and disposable gloves as directed by your teacher, marker pen.

Procedure

1. Collect three agar plates—DO NOT OPEN THEM.
2. Tape one plate closed and *label it with the name of your group and the date. Number the plate '1'.*
3. Take another plate, open it to expose the agar surface to the air. Close the plate and seal it with masking tape. *Number this plate '2' (don't forget to also include your name and the date).*
4. Take a sterile cotton bud and carefully open it without touching the end. Wipe the cotton bud surface onto a surface in the classroom—the surface doesn't have to look dirty. This **inoculates** the surface with bacteria. Brush the cotton bud lightly over the agar surface of the third plate. Close the plate and seal it with masking tape. *Number this plate '3' (don't forget to also include your name and the date).*
5. Place all the plates in a warm place (or an incubator at 32°C) for the next three days.
6. Do not remove the lids of the agar plates once they have been inoculated.
7. Examine your plates and *note the number and type of colonies that have grown on your agar plate.* Fungal colonies will look fuzzy and bacterial colonies will look glossy and smooth. Do not remove lids.
8. Return all plates to your teacher for safe disposal.

Fig 3.4.11 Specimen viewed under the microscope at high power



Questions

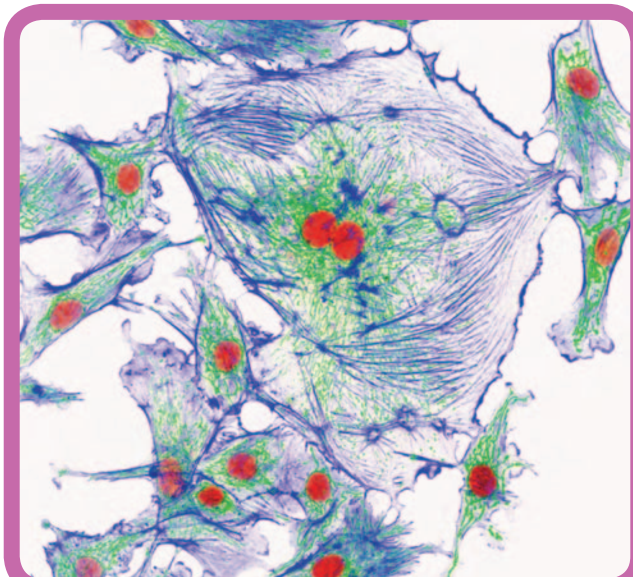
1. Explain which of the plates was the control.
2. Why did you expose one of the plates to the air?
3. Why didn't the surface you used to inoculate your plate have to be dirty?
4. Compare your results with other groups and explain any differences.
5. Draw your agar plate and try to label the colonies 'bacterial' or 'fungal'.

FOCUS 3.5 Reproduction and survival

Context For a species to survive, more of that species need to be constantly produced to replace those that die. All species have characteristics that enable them to survive successfully in their environment. Inheritance of these characteristics occurs through sexual or asexual reproduction. A key question is 'why are there different methods of reproduction?' Are there benefits and disadvantages of each method of reproduction? In this Focus you look at these processes and compare them at a cellular level.

Cells and cell division

When you look at your parents do you notice any similarities? In Focus 3.1 you learnt about cells and their structure. As all organisms consist of one or more cells and all cells show great variety in their size and shape, the diversity of cells in an organism allow them to function in different ways. However, the nucleus of each cell in an organism is identical. This is because every cell in the organism is a copy of the original cell that the organism developed from. The cell, from which all the cells in your body have developed, was formed when the sperm from your biological father and the ovum from your biological mother joined during fertilisation.



You can clearly see the red-stained nucleus in each of these cells.

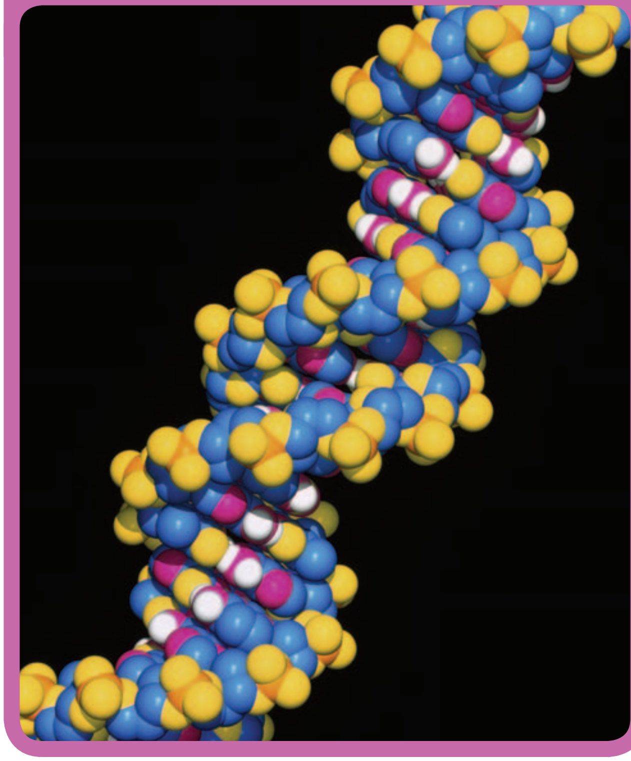
Fig 3.5.1

This fertilised cell contains a nucleus that holds the blueprint, a set of coded instructions, for how the cell functions and what it will do. The nucleus of a cell holds this blueprint in the thread-shaped structures called **chromosomes**. Chromosomes can only be seen when the cell begins to divide. In Prac 1 on page 140 you can isolate the chromosomes from a sample of kiwifruit using basic techniques. You will not see individual strands but a jelly-like blob that will form on the top of your sample. Each chromosome is made up of thousands of units called **genes**. These genes control what an organism looks like and how it will function. Your genes and those of all other organisms consist of a chemical substance called **deoxyribonucleic acid,** or **DNA** as it is more commonly known. DNA carries the information for the structure and function of the cell. In sexual reproduction the organism receives half of its DNA from one biological parent and half from the other.

The structure of DNA is a 'double helix' as shown in Figure 3.5.2. Obviously in Prac 1 the product you extract does not look like the diagram of DNA in Figure 3.5.2. The small sample you will use to do this experiment will contain not one or two cells but billions of cells. The various chemicals used allow you to separate the DNA from the cell. First of all the cell wall needs to break open. The soap extraction solution ruptures the outer part of the cell, and salt solution helps separate DNA from other cellular chemicals, such as carbohydrates. The process of cooling helps protect the DNA from enzymes that would destroy it if they came into contact with it in the normal cell. This does not normally happen in a cell because the DNA remains in the nucleus, separated from the rest of the cell by the nuclear membrane. The cold temperatures slow down these enzymes. Filtering removes most of the solid matter in the mixture. The last cooling helps the DNA solidify and precipitate.

Prac 1 p. 140

Fig 3.5.2 A model of the structure of the DNA double helix



Sexual or asexual?

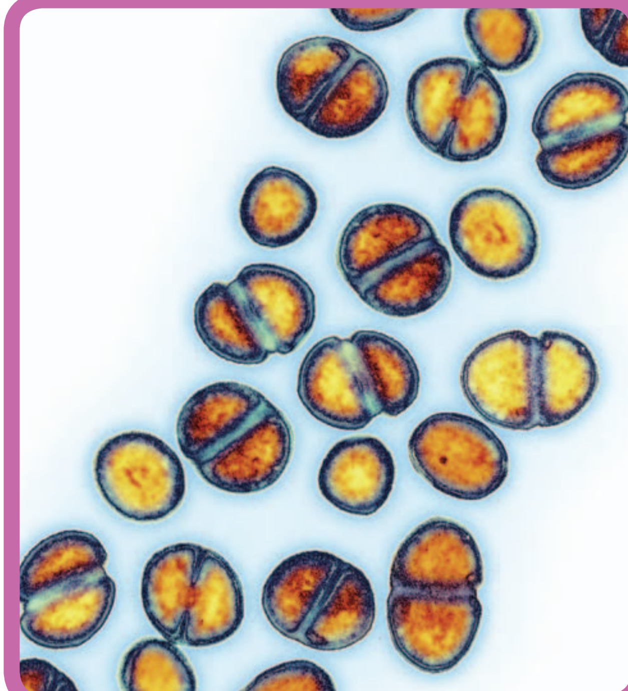
Humans reproduce by sexual means. Sexual reproduction requires two different sex cells, which must then combine. Asexual reproduction requires cells from only one individual to split. These organisms have the same genetic material as the individual they arose from and may sometimes be called clones. Organisms constantly reproduce all around us, from the bacteria in your environment to the animals and plants you would have passed on your way to school. Organisms may reproduce using sexual or asexual reproduction and some organisms have the ability to use either method.

Asexual reproduction

For asexual reproduction to occur and allow long-term survival of the species, the environment needs to be fairly constant, as the offspring will be the same as their 'parent'. This means that no members of the species may survive a dramatic change in the environment. This is because none of them are different enough to have genes that help them survive in the new environment. They are unable to become adapted to the new environment.

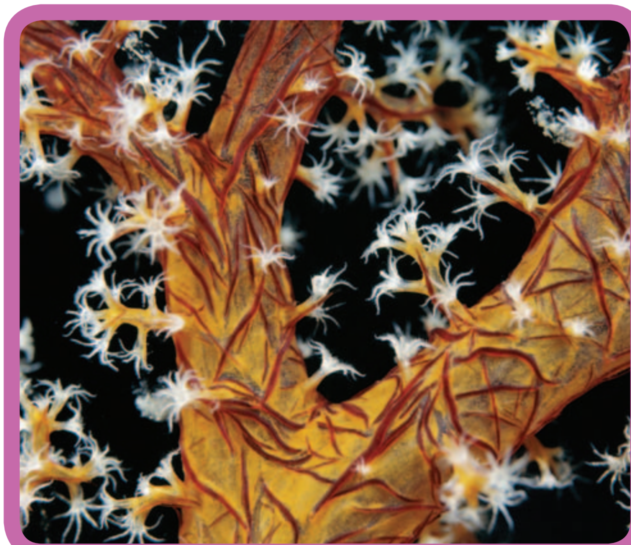
Asexual reproduction may be advantageous for organisms that do not have the ability to move around, or when finding a mate is difficult. Sometimes if a cell fails to make an exact copy of itself a change will occur in the characteristics of the offspring. This is called a **mutation**. Most mutations are lethal or do not provide the offspring with an advantage in the environment and soon die out. Occasionally a mutation provides the offspring with an advantage in the environment. This improves the organism's chances for survival and therefore its chances for reproductive success. An example is antibiotic-resistant bacteria. They can withstand antibiotics extracted from fungi and used in hospitals. These bacteria are able to thrive in the new environment as a result of their mutations, which give them resistance to the antibiotics.

Methicillin-resistant *staphylococcus aureus* has mutated to become resistant to many antibiotics. Fig 3.5.3



There are several types of asexual reproduction, including budding, fission, spores and fragmentation.

Budding involves the parent cell growing and producing a small offshoot or bud. The bud is an exact replica of the mother cell, only much smaller when it divides. Organisms such as yeasts and many cnidarians reproduce by budding.

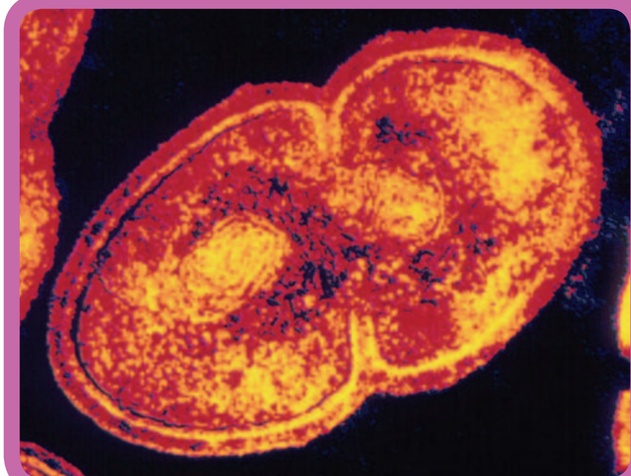


Many cnidarians reproduce by budding. *Fig 3.5.4*

Fig 3.5.6 This fern will release millions of spores into the air when conditions are right.

Fission produces cells that are identical to the parent cell. The parent cell simply grows and then divides across the middle, which causes it to split or fissure. This is how single-celled organisms such as bacteria and some fungi and algae reproduce. Fission allows reproduction to occur very quickly, as millions of new cells can be produced in hours.

Many bacteria reproduce very quickly by fission. *Fig 3.5.5*



Some organisms have reproductive structures called **spores**, encased in special structures called spore vessels. Spores are released periodically and are spread by water, wind or on animals as they come into contact with the plant. When the conditions are suitable the spores begin to grow.

Drag and Drop CW Interactive

Fragmentation occurs when pieces break off from an organism. Under the right conditions these pieces grow into new organisms. This can happen in some animals and many plants. Examples are earthworms and starfish, mushrooms and some angiosperms. Reproduction of plants by this method is known as **vegetative propagation**.

Prac 2 p. 140

Science Snippet

Serious spores

Dormant spores enable a fungus to live for years through conditions that are not conducive to survival. These might be periods of dryness, extreme heat or low temperatures. Dormant spores are usually produced at the same time as spores that do not have the ability to lie dormant, so a variety of germination conditions enable the fungus to colonise over a long time period. Overall, dormancy in spores provides a fungus with a greater chance of survival.

Fig 3.5.7 Vegetative propagation occurs when you take a cutting from a plant and grow it.

Sexual reproduction

For sexual reproduction to occur, two different sex cells are needed. These cells may both come from the same individual, such as happens in many plants, or from two individuals of the opposite sex. The two sex cells are called **gametes** and together they contain all the genetic material needed to form a new individual. In sexual reproduction the two gametes fuse together during the process of **fertilisation**, which may occur internally or externally. The new cell is now called a **zygote**. This new cell will now divide over and over again to form a new organism.

As discussed earlier in this Focus, asexual reproduction is well suited to environments that do not undergo great change. But where organisms of a species are all the same or very similar a small environmental change may have a devastating impact. If there is more variance within a species and an environmental change occurs it is more likely that some of them will survive. This is because some will have features that may make them more suited to that environment than their predecessors. The advantage of sexual reproduction is that the offspring may be very different from the parents. As there will be greater variance within the species, they will be suited to a wider range of environmental conditions. Biologists think that this is the reason that sexual reproduction became widespread.

The sex cells involved in this process, as has already stated, are called gametes. The male gametes are called sperm and move about using a whip-like tail called a flagellum. The female gametes are much larger and are called ova or eggs. Ova do not have the ability to move about on their own and have a store of food to nourish them. The release of the ova in a female is called ovulation.

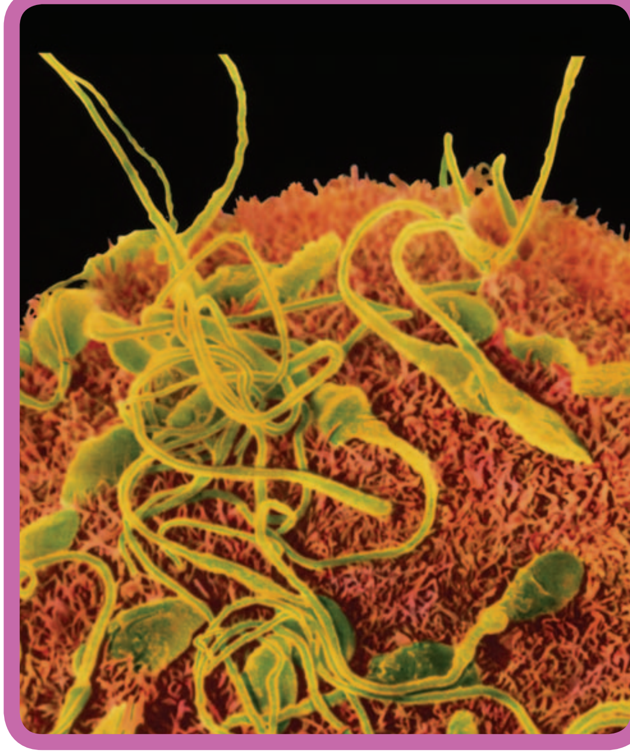
In plants, the ova are produced inside structures called **ovules**. The male gametes can be found inside **pollen** grains and are produced in the anthers. Plants rely on the wind and animals for fertilisation to occur. When pollen has been moved from the anthers to the stigma we say that pollination has occurred. Cross-pollination occurs when pollen is transferred from one flower to another flower on a different plant.

Science Snippet

Mixing the sexes

A plant or animal that has both male and female reproductive organs and produces both types of sex cells is called a hermaphrodite. This condition affects about one per cent of mammals. It is uncommon, however, for both sets of reproductive organs to be functional and often neither set is functional.

Sperm (yellow) and an ovum (orange) **Fig 3.5.8**



Embryo development

After fertilisation the first cell of the new individual is called a zygote. This continues to divide and is then called an **embryo**. Under the right conditions the embryo continues to grow and become a fully developed organism.

Parental care

Some organisms produce a large number of eggs at one time, increasing their changes that a few may survive into adulthood. Other organisms produce only one or two offspring at one time and provide **parental care** to the new offspring until they are ready to survive on their own. Generally, the less parental care provided by the organism the more eggs will be fertilised at once. Organisms providing more parental care may release only one egg at a time.

Fig 3.5.9 The young giraffe is provided with considerable parental care.

Drag and Drop CW Interactive

Homework book 3.10 Growth and reproduction wordfind

3·5 FOCUS [Questions]

Use your book

Cells and cell division

1 Where in the cell would you find chromosomes?

2 What is DNA?

Sexual or asexual?

3 What are the two types of reproduction and how are they different?

4 What process do humans use to reproduce?

Asexual reproduction

5 List the types of asexual reproduction.

6 When would asexual reproduction be advantageous?

7 Copy the following table into your notes then use arrows to match the type of reproduction to the organism.

Method of asexual reproduction	Organism reproducing this way
Fission	Hydra
Budding	Bacteria
Spores	Starfish
Fragmentation	Mushroom

Sexual reproduction

8 How many different types of sex cells are needed for sexual reproduction, and what are these cells called?

9 What are the benefits of sexual reproduction?

Embryo development

10 Name the new cell formed after fertilisation and describe what happens to it.

Parental care

11 Why do some organisms have a large number of offspring?

12 Select the correct word from the brackets: Often organisms providing (more/less) parental care may release only one egg at a time.

Use your head

13 In a tree plantation of one species of blue gum in Albany, some look quite different from the parent tree, and others look exactly the same as the parent tree. Explain why this is the case.

14 Do clones always look exactly the same as the parent organism?

15 Explain why being able to reproduce by both sexual and asexual means may be an advantage to one species.

16 Why may it be an advantage for koalas to have only one offspring at a time?

Investigating questions

17 Research how multiple births occur and why women who conceive through IVF programs often have multiple births. You may like to present your information as an informative poster or information pamphlet.

18 How has vegetative propagation assisted in the development of plants for residential use, such as the protea?

19 On a map of the world identify three different countries of various socio-economic status, and research the expected life span and the number of births and deaths for each. What trends do you notice in the data? You could expand on your research by collecting information about the numbers of children who die before their first, fifth, tenth and twentieth birthdays. Present your information as a graph.

FOCUS 3.5 [Practical activities]

Prac 1 Focus 3.5

Extraction of DNA from kiwifruit

Purpose

To isolate the DNA from a sample of kiwifruit.

Requirements

Half a kiwifruit, small plastic bag, 20 mL ‘extraction solution’, ice (to make an ice water bath), water, 250 mL beaker for water bath, small square of gauze, funnel, small 10 mL measuring cylinder, test tube, 2 mL 95% ethanol (collect this just before it is needed as it may evaporate before you use it), pipette, glass Pasteur pipette with loop to pick up DNA.

Procedure

1. Place kiwifruit in a plastic bag.
2. Add 20 mL of extraction solution.
3. Close the bag, carefully removing as much air as possible.
4. Squash and break up the kiwifruit while mixing it in the extraction solution for about five minutes.
5. Using the ice water bath, alternately cool the mixture for one minute and remove it for one minute. Repeat this three times.
6. Use the gauze square secured with a rubber band in a funnel to filter the mixture into a beaker. More than one group can filter through a funnel with the gauze in place.
7. Put 2 mL of the filtered mixture in a test tube.
8. Add 2 mL of cold ethanol using a pipette. DO NOT SHAKE THE TUBE.
9. DNA strands should form at the top of the tube and can be removed using a glass pipette with loop.

Questions

1. What did the sample you extracted look like? Is this what you expected?
2. What is the purpose of the extraction solution?
3. Write a few sentences to describe the function of this material in the kiwifruit.

Prac 2 Focus 3.5

Vegetative propagation

Purpose

To examine asexual reproduction in plants.

Requirements

Small pots, labels, rosemary cuttings, potting mix, water, watering can and scissors.

Procedure

1. *Label three pots with the name of your group, today’s date, and the name of the type of cutting you are using.*
2. Put potting mix in each of your pots and moisten with water.
3. Cut a small amount from the bottom of the cutting and place the bottom of the cutting 2–3 cm into the potting mix.
4. Water every couple of days depending on the weather conditions, ensure soil is moist and not waterlogged.
5. Watch for growth over the next few weeks.

Questions

1. Why was it important to cut the base off the cutting?
2. Will this new plant have the same genetic material as the one it was taken from?
3. Rosemary plants also have small white flowers. What is the purpose of these flowers?

FOCUS 3·6 Variation and inheritance

Context

One of the basic ideas in biology is that all life comes from organisms which lived before them. All individuals have a life span that eventually ends. Their characteristics, however, are carried in their offspring. Those genetic characteristics will therefore survive as they have done for many generations before them. Have you ever wondered why you have your mother's eyes or your father's ears? Although you are unique, you will still carry characteristics of those that have passed genetic material on before you were born, such as your parents, grandparents and even great-grandparents.

Variation

Sexual reproduction produces variation in offspring. This is why, unless they are identical twins, children from the same parents will look different from their brothers and sisters. Having difference or variation in a species is a survival 'insurance policy' against changes in the environment. If there is enough variation and a serious change to the environment occurs, some individuals of a species may survive. During long periods of drought in central Australia, although many of the organisms, both animals and plants will die, some, which are more able to cope with the lack of water, will survive. Some organisms will have the ability to live through the drought and others will leave spores or seeds to sprout when the next rains come along. This is why, although central Australia is a dry desolate place during the dry summer periods, during the wet season there is an abundance of life both animals and plants.

In humans, a similar process occurs. In the case of diseases caused by a pathogen, some individuals have a natural immunity to a disease that kills others. When you were little you may have played with other children who had diseases such as chicken pox. Some diseases are less severe if you have them when you are a child rather than as an adult. However, some children do not catch these diseases as children. If these children are infected as adults, especially in times of stress, they may catch the disease then. A famous example of this occurred in London 1665 when there was an outbreak of Bubonic Plague, called the 'Black Death'. Sixty per cent of the population died. Although almost everyone suffered from the disease, forty per cent of the population survived because they had a natural immunity to the disease and they were better able to fight off the invading microorganisms.

Prac 1
p. 146

Fig 3.6.1 A scene from the great plague. An official calls 'Bring out your dead', and the cart carries them away.

Inheritance

To study the process of inheritance we need to study what happens over several generations. The term **inheritance** is used to describe characteristics that are passed on from generation to generation. The passing on of those characteristics from generation to generation is called **heredity**. Much of the early work in the study of inheritance, also called **genetics**, was done by a monk, Gregor Mendel. We would call Gregor Mendel a **geneticist**, as he studied inheritance. Working in the monastery garden he noticed differences in his pea plants and wanted to know how the information was inherited. Mendel worked with a pea plant that was much like our common 'sweet pea'. He first crossed tall pea plants with short pea plants. Since plants are often fertilised by insects, to prevent this Mendel removed the stamens. He controlled the plants fertilisation by dusting the pistil with the pollen of another plant, thus cross-fertilising them. When he crossed the tall pea plants with short pea plants all the offspring (F1) were tall. The tall pea plants from the first generation were then mated, to produce a second lot of offspring (F2). The offspring produced three tall to every one short plant. Mendel repeated his experiments several times to ensure accuracy of his results.

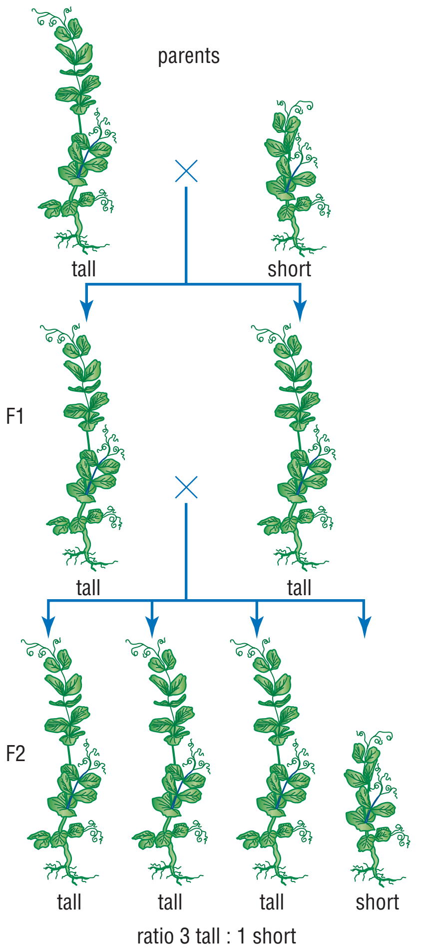


Fig 3.6.2 Mendel's breeding experiments with peas

Mendel invented a term for the original parents, which was **pure-bred**. In this example he meant that they could only pass on the tall characteristic, so tall plants crossed with tall plants produced tall offspring. He also suggested that characteristics were controlled by **factors**. He did not know what these were, but only that they seemed to be units of information passed from parent to offspring.

He suggested that there were two factors for every characteristic. So a tall factor and a short factor would combine in the offspring of a tall parent crossed with a short parent. Only one of these factors would show up in the offspring; the other factor seemed to be somehow hidden or lost. Because the first generation in his experiment crossing tall and short were all tall he said that this characteristic was **dominant**. As there were short plants in subsequent generations he called this characteristic **recessive**. He observed that the characteristic for tallness hid shortness for the first generation but that the characteristic for shortness did not disappear, as it reappeared in the second generation.

This diagram represents the genes for the pea plants in Mendel's experiment, crossing tall and short peas.

Fig 3.6.3

	t	t
T	Tt	Tt
T	Tt	Tt

First generation

→

	T	t
T	TT	Tt
t	Tt	tt

Second generation

This can be represented in a diagram called a **Punnett square**. In Figure 3.6.3 the symbol 'T' represents the factor for tallness and the symbol 't' represents the factor for shortness. We now know that Mendel's factors were dominant and recessive genes. Different forms of the same gene are called **alleles**. The original 'pure-bred' individuals in Mendel's experiment had 'TT' genes for tallness, or 'tt' genes for shortness. They all had the same two genes for a characteristic. When both alleles are the same we say the genotype is **homozygous**. The second generation, having one gene from each parent 'Tt', are called **hybrids**. When two alleles are different we say the genotype is **heterozygous**. Each plant will have two different genes for each characteristic. The gene type for an organism is known as its **genotype**. The characteristic that is observed in the organism is known as its **phenotype**. The pea plants had phenotypes of tallness or shortness.

Mendel also studied other characteristics of the pea plants, such as flower colour, size and colour of seed pods. All animals and plants have been found to have dominant and recessive characteristics. Some of these characteristics have been identified, while others have not.

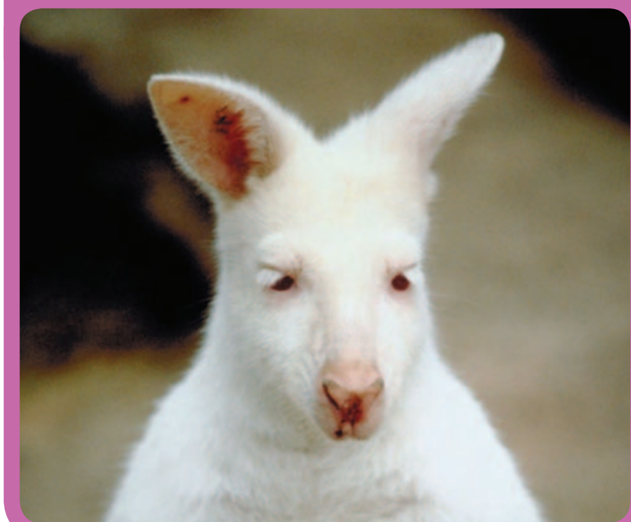
Interactive CW Animation

Homework book 3.11 Heterozygous or homozygous?

Genetics in humans

You have just read of an example of two genes controlling the one characteristic. Human genetics is not always as simple as this—usually many more than two genes control one characteristic, such as in height, weight, eye colour and intelligence. Usually characteristics controlled by a single gene pair are fairly trivial, such as whether you have attached ear lobes or can roll your tongue. There are, however, some characteristics controlled by a single gene that can affect your everyday life, such as right- or left-handedness and a condition known as albinism.

Fig 3.6.4 Albinism is a genetic disorder caused by a single recessive gene.



Sharply defined characteristics such as right- or left-handedness are described as showing **discontinuous variation**. The opposite is **continuous variation**, shown by characteristics such as height or eye colour, where a continuous range of characteristics may occur. For example, people do not simply have blue or brown eyes—there is a range of colours. This means that there have to be more than two genes in each person.

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Blood groupings are an example of co-dominance. There are three different alleles that determine blood groupings, identified as I^A, I^B and I^O. I^A and I^B are co-dominant and I^O is recessive to both I^A and I^B. The possible genotypes and phenotypes can be seen in the table below.

Genotype	$I^A I^A$	$I^A I^O$	$I^A I^B$	$I^B I^B$	$I^B I^O$	$I^O I^O$
Phenotype (blood group)	A	A	AB	B	B	O

Genotypes and phenotypes for the ABO blood grouping

Human inheritance is difficult to study because humans have only a few offspring, take a long time to reproduce and do not participate in breeding experiments. Mendel would have found his peas much easier to study. To overcome some of these problems we use pedigrees of families to record and analyse family data. A pedigree is a pictorial 'family tree' on which we can mark individuals who show a particular characteristic or disease. When drawing pedigrees we use the symbols shown in Figure 3.6.5.

Drag and Drop CW Interactive

Fig 3.6.5 Symbols used when drawing pedigrees

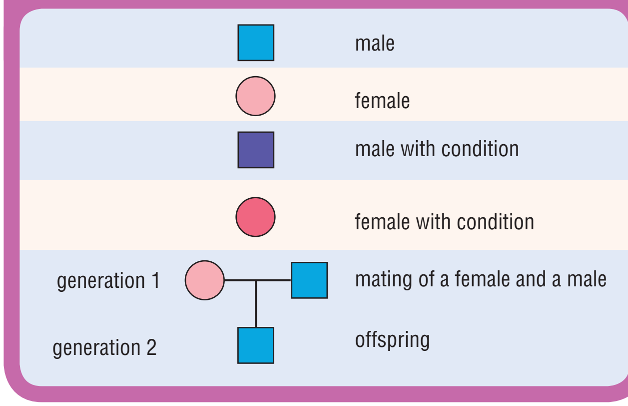


Figure 3.6.6 shows a pedigree for the disease haemophilia. People afflicted with this disease have a defective gene and as a result lack a chemical required for blood clotting. Without this chemical, even a simple wound can cause severe bleeding. Untreated, the disease is fatal. Looking at the pedigree you will notice that all those affected by the disease are male.

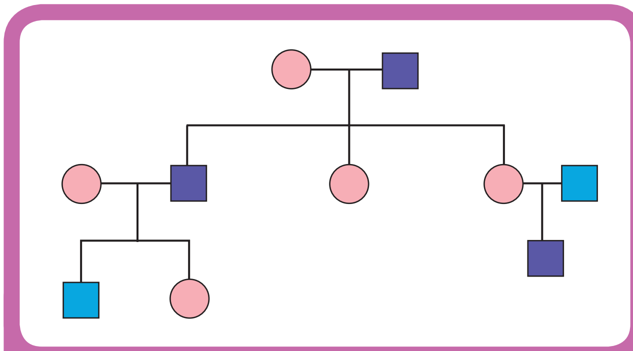


Fig 3.6.6 Pedigree showing the inheritance of haemophilia. Genetic diseases often affect many more males than females.

To understand why genetic diseases affect many more males than females you first need to look at what determines sex. Eggs and sperm must join to form a new individual. The answer lies in the gametes, as males and females have one different chromosome. All humans have twenty-three pairs of chromosomes. The sex chromosomes in human males are called 'XY' and the sex chromosomes in human females are called 'XX'. The sex of a human is therefore determined by the presence of the 'Y' chromosome. So twenty-two pairs of chromosomes are not related to sex at all. It is only the sex chromosomes that determine the sex of a child.

The sex chromosomes carry genes that control other features as well as sexual characteristics. For example, genes for colour vision are carried on the sex chromosomes. Defective genes carried on the sex chromosomes include those for haemophilia and muscular dystrophy. Characteristics that are carried by genes on the sex chromosomes are said to be **sex-linked**. It is the 'X' chromosome that carries these sex-linked genes, and so the conditions are also called 'X-linked'. The 'Y' chromosome does not seem to be involved with very many characteristics. Few 'Y-linked' features have been identified. Boys always inherit their 'X' chromosome from their mother.

The environment, heredity and natural selection

As you have read in this Focus, your genes control many human characteristics. Variation in a population of organisms occurs as a result of both genetic factors and environmental factors. Genetic factors that affect variation in a population include the types of genes, combination of genes and mutations. Environmental factors such as weather, temperature, pH and salinity strongly influence the growth of plants. The environmental factors that influence animals include nutrition, health and disease. Most diseases are not caused by genetic inheritance, however, but are due to environmental conditions. Genes can control the susceptibility to disease, which is why some people are more prone to illness than others.

Science Snippet

From mother to son

Muscular dystrophy is an X-linked recessive disease, so this disease is never passed from father to son. However, if the father has the disease his daughter will be a carrier. Muscular dystrophy is a disease in which the muscles of the body get weaker and weaker and slowly stop working. Muscles and membranes need many different kinds of proteins to stay healthy. Your genes tell your body how to make the proteins your muscles need. But in people with MD, these genes have wrong information or leave out important information, so the body can't make these proteins properly.

Fig 3.6.7 Drought is a major environmental factor in Western Australia. It affects not only native species but also food crops such as wheat.

The combination of inherited characteristics and environmental conditions affects the characteristics of a population. The genes of an organism determine its potential phenotype but the combination of environment and genes determines its actual phenotype.

Any group of a particular species living in a particular place at a particular time is called a **population**. Populations are in a constant state of change due to biotic (living) and abiotic (non-living) factors that exist in a particular environment. In any population there are more offspring produced than survive. Some individuals have features that enable them to cope better with the threats from the environment around them. Predators, disease and climatic change kill most of the young. Those that survive and breed are described as being 'selected'. This selection of individuals was originally called the 'survival of the fittest' by Charles Darwin. Darwin also invented the term **natural selection** for this process.

Differences in the rate of survival and reproduction mean that over time different genes become more common in the breeding population. Variation and natural selection are part of the theory of evolution. **Evolution** is the changes to and changes in populations and species. All species have a common ancestor.

Fig 3.6.8 The variety of dog breeds we have today can all be traced back to a common ancestor—the wolf (bottom).

Homework book 3.12 Variation and inheritance wordfind

3·6 FOCUS [Questions]

Use your book

Variation

1 Why is variation an advantage to a species?

2 Why do some people become ill when exposed to pathogens while others do not?

Inheritance

3 What is the difference between 'pure-bred' and hybrid plants in terms of their genes?

4 What is meant by the term 'dominance'?

5 Define the terms 'genotype' and 'phenotype'.

Genetics in humans

6 When two 'normal' parents give birth to a child with a recessive genetic characteristic being expressed, explain whether the parents have a heterozygous or homozygous genotype.

7 Outline the inheritance of blood groupings.

8 Can a man pass on haemophilia to his son? Why?

The environment, heredity and natural selection

9 What two factors influence the development of organisms?

10 What factors in the environment affect the survival of individuals in a population?

11 What is natural selection, and who invented the term?

Use your head

12 A scientist investigated the effect of insecticide on mosquitos. One hundred mosquitos were exposed to the insecticide. Only eight survived. Those eight mosquitos then reproduced and produced 80 offspring. The 80 mosquito offspring were then exposed to the same insecticide. Of these 76 survived and only 4 died. Explain the scientists' observations.

>>

13 In sweet peas the yellow pod is dominant and the green pod is recessive. Show all working for two generations of crosses and state the genotype and phenotype of the offspring.

14 If a mother's blood group is O and father's blood group is B, what are the possible genotypes and phenotypes of their offspring? Show all working.

Investigating question

15 Inherited diseases are a serious strain in any family. Children grow up knowing that their parents gave them a disease, and the parents have to live with this knowledge as well. Terrible diseases such as Huntington's disease, muscular dystrophy and cystic fibrosis cause enormous suffering to children and many die young. Your task is to research one of these genetic diseases and find out whether there are any ways this distress can be prevented, cured or reduced. Consider both how many cases there are and what can be done for individuals who already have the disease. Include in your answer a consideration of how children with the disease may feel about their disease and what can be done for them. Also comment on what the parents may feel about your research findings.

FOCUS 3.6 [Practical activities]

Variation within a population

Prac 1 Focus 3.6

Purpose

To analyse continuous variation in humans.

Requirements

People to survey, a measuring tape.

Procedure

1 *Draw a table for your results.*
2 Each student needs to measure their height and for homework measure the heights of their parents. Height should be measured in cm.
3 *Use a line graph to plot the height of the students in your class. On the same graph also plot the height of their parents.*

Questions

1 Based on your results, explain whether there appears to be any link between the heights of the students and their parents.
2 Do your results support the conclusion that height shows continuous variation in a population? Justify your answer.

Constructing your own pedigree

Prac 2 Focus 3.6

Purpose

To examine characteristics of your family and construct a pedigree.

Requirements

Willing participants!

Procedure

1 Choose an inherited characteristic, such as the length of your second toe, whether you can roll your tongue or whether your ear lobes are attached. Ask your teacher to describe these characteristics to you further.
2 Using family members, determine whether they have the chosen characteristic or not.
3 Construct a pedigree as shown on page 143 for the chosen characteristic.

Questions

1 Does your pedigree give you any indication as to how the characteristic was inherited?
2 Is it possible to predict if the characteristic is dominant or recessive?
3 Research how the characteristic is inherited. Do your findings support this?

FOCUS 3.7

Evolution

Context

How can we show that a species has changed over time? Can we show that all modern humans have a common ancestor? There is a powerful argument to support evolution. There are too many similarities that would not be expected to exist if each species originated independently. The order in which main groups of animals appear in the fossil record makes sense if they arose by evolution, but would be highly improbable otherwise. The existence of adaptations in living things has no non-evolutionary explanation.

Evolutionary genetics

Evolution

Evolution means change. **Biological evolution** is about change in the structure, function and behaviour of organisms between generations. The characteristics of organisms, from their DNA (deoxyribose nucleic acid) to their social behaviour and physical features, can be modified from their ancestors during evolution. Developmental change, such as a tadpole changing to a frog, is not evolution, as the definition of evolution is the change between generations. The molecule called DNA provides the physical mechanism of heredity in all living organisms. DNA carries the information used to build a new body, and to differentiate between the parts of the body. DNA exists inside almost every cell of your body, including reproductive cells.

Natural selection

Variation is a characteristic of all living things. It is only the inherited variations that are passed onto the next generation. This variation in a population originates through mutation of genes.

If the average pair in a population produces fewer than two offspring, the population will quickly become extinct. If they produce more than two offspring the population will rapidly grow. Over a small number of generations a female in a population may have more or fewer than two successful offspring, and the population will increase and decrease accordingly. As you have read in previous Foci, some organisms, for example snapper fish, have many more than two offspring. Since the sea does not become full of snapper, we can infer that if a female snapper has 5000 eggs in her life, about 4998 of those will die before reproducing.

Science Snippet

Too many offspring?

Which animal has the greatest number of offspring? Termite queens lay 30 000 eggs a day every day. Sponges could possibly produce the greatest number of offspring though, as they secrete millions of eggs and sperm into the water. Can you find out what animal produces the greatest number of offspring? Why hasn't this organism overrun the planet?

Fig 3.7.1 The termite produces a large number of offspring in mounds such as this every day.

A much larger number of individuals are produced than can possibly obtain enough food and other resources to survive and reproduce. So there is competition for resources, which results in a struggle to survive. There is also competition for mates, a struggle to avoid predators and many other environmental factors affecting survival and reproduction. These factors such as resources, predators, weather and disease are called the **selective agents**. They act on the population. The genetic variations help an organism to survive these selective agents. This was called **the survival of the fittest** by Charles Darwin. He meant fittest in the sense that they are better suited to their environment. These surviving individuals reproduce and pass on the characteristic or adaptation to their offspring. In this way successful characteristics are passed on from generation to generation.

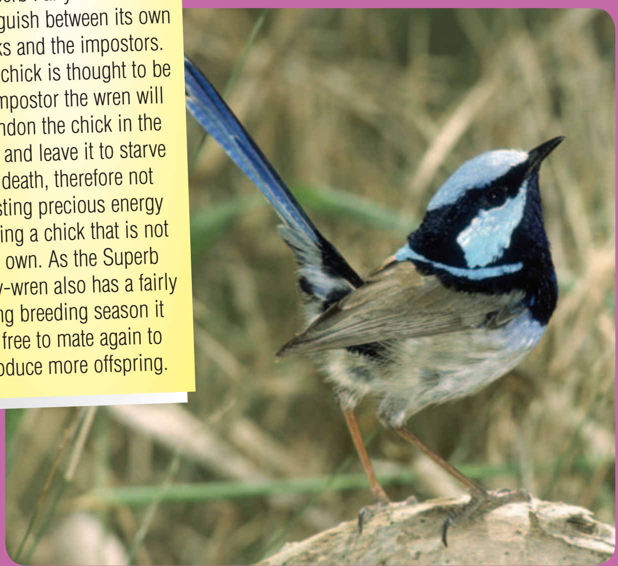
Darwin called this process natural selection. He defined natural selection as the process of some factor in the environment acting on a population and resulting in some individuals leaving more offspring than others.

Natural selection is a continual process and occurs over many generations until ultimately the **species** can look very different from its ancestors. The descendants may have even altered so much that they cannot produce fertile offspring with the original species. In this case, a new species is said to have been developed. We can observe this in organisms that have been isolated on islands or different continents for a period of time. This is said to be the theory of evolution by natural selection.

Science Snippet

The Australian fairy wren too clever for the cuckoo!

Some species of cuckoo bird lay their eggs in other birds' nests and then leave them be reared by the surrogate mother. This behaviour has evolved, allowing the cuckoo to be free of its parenting responsibilities so that it can mate again to produce more offspring. But the Superb Fairy-wren can distinguish between its own chicks and the impostors. If the chick is thought to be an impostor the wren will abandon the chick in the nest and leave it to starve to death, therefore not wasting precious energy rearing a chick that is not its own. As the Superb Fairy-wren also has a fairly long breeding season it is free to mate again to produce more offspring.



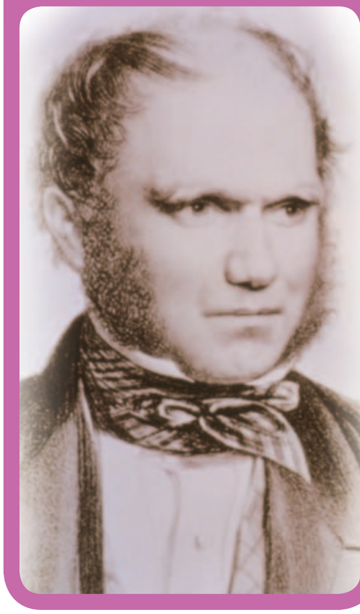
The Superb Fairy-wren, a clever little bird *Fig 3.7.2*

Theories of evolution

The Origin of Species, a famous book published by Charles Darwin in 1859, suggested that natural selection was the process by which species change over time and develop into new species. This process is now called evolution. Although Darwin was not the first to suggest that current organisms evolved from earlier types of organisms, he was the first to argue that this change was brought about by natural selection. His ideas created a lot of controversy because they conflicted with the biblical belief at that time that all organisms were created together.

When biologists construct a theory explaining how a species forms, they collect data on the species currently living and also any fossil evidence. Using this data biologists make inferences that are used to construct theories. The theory of evolution is a result of studies such as these. This theory is useful for explaining how different species have all come from the same ancestor.

Fig 3.7.3 Charles Darwin



Changes in most species occur over a very long period of time. Due to the long time periods involved in evolution, evidence is gathered by many people using many different techniques. As new discoveries are made, the theory of evolution is modified.

To gather evidence to support or disprove this theory, scientists need to observe natural selection in action. As human experiments are difficult, take long periods of time between generations and are expensive, it is much easier to study population change in insects, bacteria or other simple organisms.

Insect resistance to insecticides is a good example of evolution by natural selection. When an insect pest has become resistant to one insecticide, authorities often respond by spraying it with another insecticide. The pattern often repeats itself, on a shorter time scale. As more pests are sprayed with pesticides, more insects become resistant. This resistance is extremely important in farming and represents a major economic and health problem.

Evidence for evolution

Fossils

As you learnt in *Science Aspects 2*, direct evidence for evolution comes from the study of fossils, which is called **palaeontology**. This record provides evidence from all over the world of the continual changes in life forms over millions of years until the present. There are many different types of fossil evidence, which are clues to the past. Fossils can be body parts, such as bones, teeth and shells. There are fossil eggs, mummified bodies and also impressions, casts and moulds. The ages of the fossils and the rocks can be estimated using radio-isotope-dating techniques, as well as many other methods. Dating fossils and rocks enables scientists to produce a geological time scale of the history of the Earth.

The fossil record allows us to trace the evolutionary development of species, such as that of the modern-day horse (see Figure 3.7.4). This fossil evidence can now be used with DNA to produce a more accurate picture of the relationships between species and their ancestors. The fossil record is not a complete picture, because organisms must die where conditions are suitable for fossilisation. This means they must not easily decay and must be quickly covered by sediments. The soft tissues do not usually form fossils, though some have been found in places such as the Ediacara formation in South Australia and the Burgess shales of Canada. But these are rare, and so we usually can only make educated guesses as to what organisms looked like in history based on the fossils we have. These may give us a biased view of life in those times as so many of the organisms present were probably not fossilised.

DNA

DNA has revolutionised the way we make links between species and their ancestors. This is because we can now see how similar DNA is in different species. If the DNA is very similar, it means that the DNA has been passed down from a close recent ancestor. So they are closely related. Studies that make evolutionary links between organisms used to rely mainly on the comparative anatomy between them. Comparative anatomy looks at the similarities and differences between features of organisms, as could be seen in Figure 3.7.4. But just because features may look similar does not always mean that they have the same genes. You will practise this in Prac 1 for this Focus. Evidence from fossils is even more important in making connections between organisms and their ancestors as now DNA can be taken from fossil evidence, analysed and compared. The distribution of the organisms is also significant in making links in history.

Science Snippet

Cow of the sea

Where ever you go you leave a small part of yourself behind. DNA as evidence has revolutionised what we know about evolutionary history. Whereas determining the evolutionary origin of a species used to be based solely on physical appearance and the fossil record linking species, now molecular data or DNA is used. With this new evidence researchers have found that whales, dolphins and porpoises are more closely related to cows, camels and pigs than to horses, elephants and sea cows.

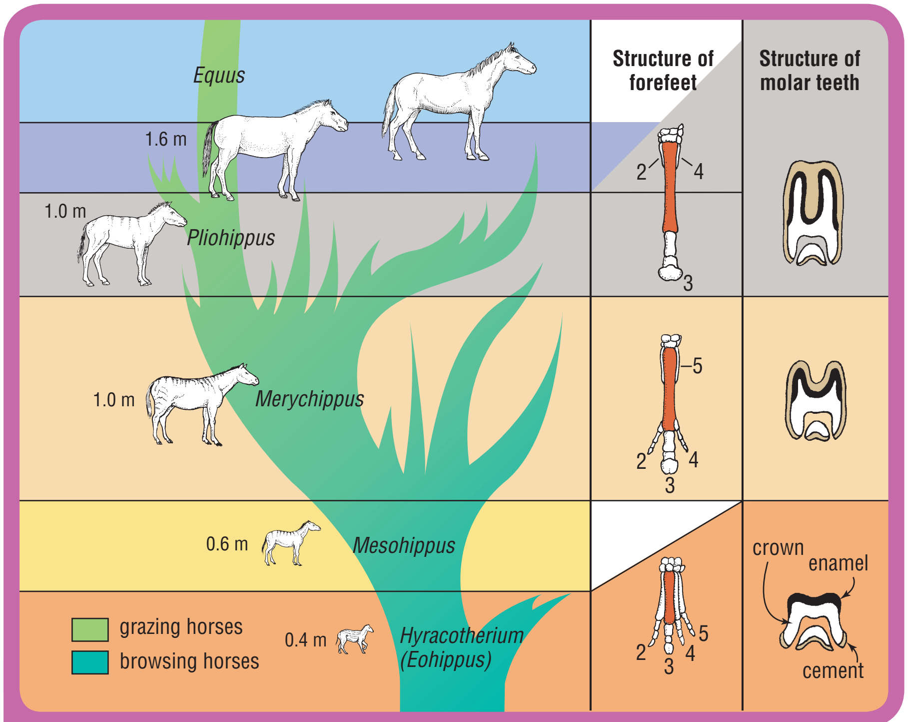


Fig 3.7.4 The evolutionary history of the horse has been re-created using fossil evidence. Here you can also see representations of what the ancient horse species may have looked like.

Fig 3.7.5 Fossilised horse remains can tell us a lot about their evolutionary history.

By looking at DNA, the fossil record and comparative anatomy we can see links between humans and primates.

Fig 3.7.6

Science Snippet

Fossil DNA

A comparative study of DNA from living and fossil horses suggests that horses were domesticated in many places, at many times. Evolutionary biologists have studied many pedigree horses, such as historical English and Swedish breeds, a breed derived from animals imported to Iceland by the Vikings and a Mongolian horse thought to be an ancestor of wild horses. They compared these samples with fossil DNA from leg bones of horses that had been preserved in the Alaskan ice for more than 12 000 years and with other samples from 1000- to 2000-year-old archaeological sites in Europe. This analysis of DNA showed that the modern horses had almost as much genetic variation as samples of fossil horses. This finding contrasted with similar studies done with DNA, showing that modern animals from cattle, sheep, water buffalo, and pig breeds are much less genetically diverse than their ancient ancestors. This suggests that the domesticated horse had ancestors in many places, implying that domestication occurred in many areas.

When comparing DNA, a species is different from another species in the number and types of genes it has. Evidence from the fossil record and other studies supports the theory that modern humans evolved from an ape-like ancestor. There is a great degree of similarity between the DNA of humans, apes and chimpanzees, suggesting that these animals may all have a common ancestor. This evidence is not agreed on by all scientists, however, and there is ongoing debate regarding the details of human evolutionary pathways, and even the mechanisms of evolution. The available evidence suggests that there have been many species of humans, all except one of which have become extinct. Only one has survived to evolve into the modern human.

Humans belong to the order primates. Hominoids are the most recently evolved group of primates. They include the lesser apes (gibbons), great apes (gorillas, chimpanzees and orang-utans) and humans. There is mounting evidence to suggest that the same ancestor produced all other hominoids. As the conditions needed to produce fossils are very specific in order to preserve the specimen without it decaying, there have been very few human fossils found, and the evolutionary process for humans is not definitely known. There is not enough evidence to produce an accurate record of the evolution of the modern human and the relationships linking the few existing fossil remains to modern humans are controversial. However, there is no doubt at all that many different human-like species lived in the past. What we are not sure of yet is which one we are descended from, and exactly how that occurred.

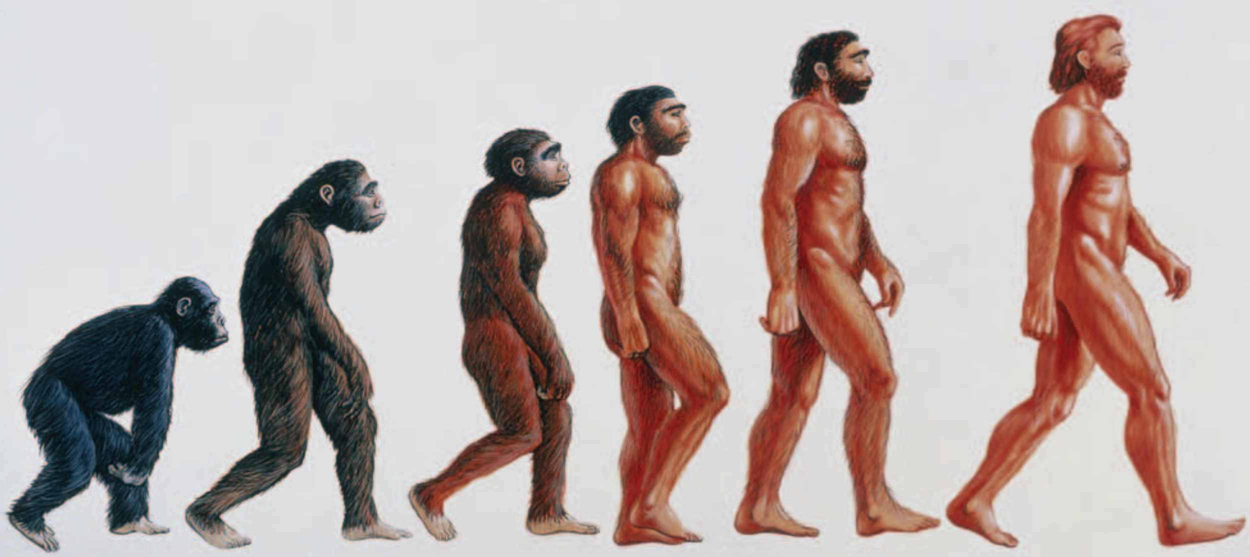
Prac 1 p. 152

Homework book 3.13 Human evolution

Homework book 3.14 Analysis of human evolution

Could Lucy be an ancestor of modern humans? Fig 3.7.7

Fig 3.7.8 This representation of human evolution has been developed using fossil records.



3·7 FOCUS

[Questions]

Use your book

Evolution

1 Define the terms 'evolution' and 'biological evolution'.

2 Why is the development of a tadpole into a frog not an example of evolution?

Natural selection

3 Explain what is meant by selective agents, and give some examples.

4 What did Darwin mean by 'survival of the fittest'?

5 What is natural selection?

Fossils

6 Why are fossils important evidence for evolution?

DNA

7 Suggest why comparing DNA is a more powerful tool than comparing the physical features of organisms.

8 Why do we believe that humans, chimpanzees and other apes may all have a common ancestor?

Use your head

9 Explain how natural selection could give rise to antibiotic-resistant bacteria.

10 Suggest why evolutionary changes to organisms that reproduce many times a year are more rapid than those in organisms that reproduce only once a year.

11 A scientist conducted an experiment with fruit flies. He put equal numbers of white- and red-eyed males in a container with fewer females. Then he let them breed over many generations and kept counting the number of red- and white-eyed males. The number of white-eyed males decreased to zero. When the scientist carefully observed the courtship rituals of the flies, the females seemed to reject the white-eyed males. Could this be considered to be natural selection? If so, what is the selective agent? Explain your answer.

>>

Investigating questions

12 Research the ancestors of one species and construct a poster to demonstrate how variation has resulted in increasing diversity. Include the causes and consequences of the changes to the genetic diversity of the organism.

13 How does the extinction of a species affect an ecosystem? Research the extinction of a species, including the events leading up to the organism's extinction and how the extinction of this organism has affected the biodiversity of the ecosystem.

14 Use your library or the Internet to find information on human evolution. Research five different fossil human-like species from the human family and comment on their possible relationship to us.

15 Use the Internet to research what fossils tell us about the fossil history of the classes of the phylum Chordata (only the vertebrates).

FOCUS 3·7 [Practical activity]

Variation and evolution in species

Prac 1
Focus 3.7

Purpose

To observe the comparative anatomy of the forelimb on several different animals.

Requirements

Skeletons of human, lizard, frog, bird, bat; photocopy of Figure 3.7.9; labelled diagram of the human forearm.

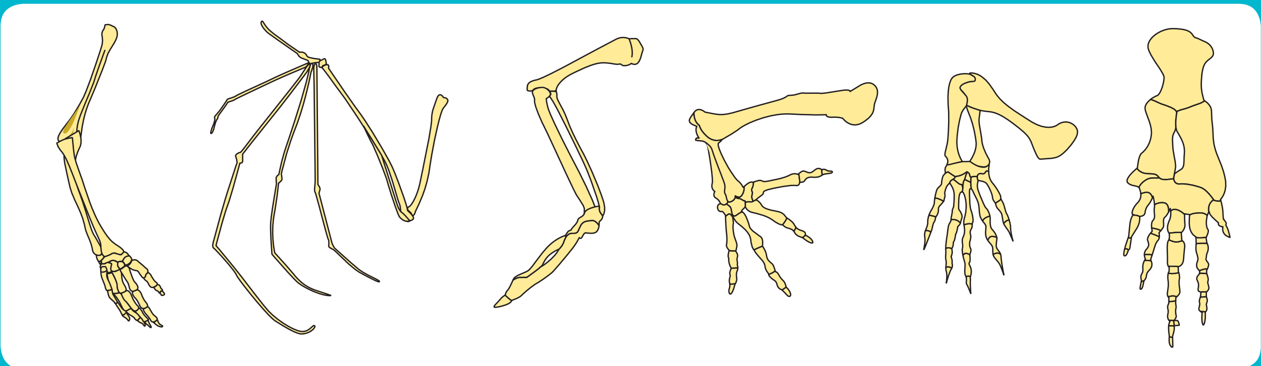
Procedure

1 Use the skeletons to observe the differences in the forearms of these animals.
2 On the photocopy of Figure 3.7.9, *write each animal's name next to its forearm.* The diagram shows a lizard, human, whale, bird, bat and frog.
3 Compare your answers with those of other groups.

Questions

1 Write a description of the similarities in the forelimbs.
2 Explain how the differences may assist in the functioning of the limb.
3 Try to label the forelimbs using the human arm as a reference. Each group should choose one forelimb and research the correct labels to compare.
4 Although all animals look very different on the outside you may have just figured out that they are remarkably similar on the inside. Today you have looked at forelimbs—are there any other parts of the vertebrate body that could be useful for comparison?

Forelimb bones of the lizard, human, whale, bird, bat and frog
Fig 3.7.9



FOCUS 3•8 Environments and ecosystems

Context

Ecology is the study of how organisms interact with each other and their surroundings. A knowledge of ecology is vital for the survival of life on Earth. In this Focus we will look at what we mean by an environment and how we study nature using the concept of ecosystems.

Environments

An **environment** consists of all the factors in an organism's surroundings that affect it. Every organism has its own unique environment so every species is affected by different factors.

Every environment consists of two kinds of factors that affect the organism. These factors are the living factors and the non-living factors.

The living factors

The living factors of the environment are also called **biotic** factors. Some living factors in the human environment include:

- predators, such as sharks, crocodiles and tigers
- parasites, such as tinea, tapeworms and head lice
- infectious organisms, such as bacteria and viruses that cause illnesses such as chickenpox
- competitors, such as other humans trying to obtain food that we also need
- collaborators, such as members of your family, who help you survive.

The non-living factors

The non-living factors are called **abiotic** factors or **physical** factors. These include water, air quality, the amount of light, temperature, wind, soil type, humidity of the air, tides, waves, lightning and fires.

These physical factors are not equally important in every creature's environment. For example, fires and soil type do not directly affect whales, but they are vital to kangaroos. The soil type affects growth of the plants that form the food for the kangaroo. Fires can kill kangaroos but also burn their food sources.

Even factors that affect both kangaroos and whales are still different in their environment. For example, temperature affects both but they live in different temperature ranges. Kangaroos can survive in temperature ranges from 40°C to below zero. Whales exist in a narrower range of temperatures, from perhaps 20°C to about zero. So even though temperature affects both, the environments are actually different.

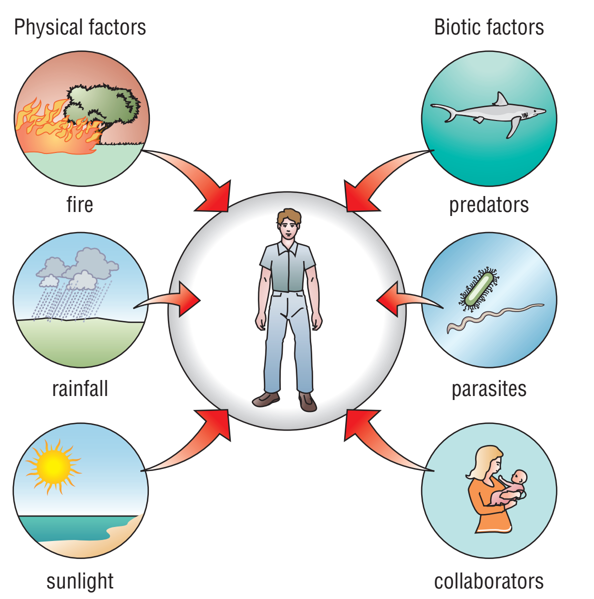


Fig 3.8.1 Living and non-living factors affect all organisms.

Drag and Drop CW Interactive

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Ecosystems

It is helpful to think about the ecology of an area as an **ecosystem**. An ecosystem is a place where the organisms and their physical surroundings form a balanced environment that is different from others nearby. In nature, ecosystems generally can exist on their own. They are fairly well balanced, with recycling of materials between the community and the physical surroundings. We can create artificial ecosystems, for example an aquarium, but they are not usually balanced.

Fig 3.8.2 A swamp or freshwater lake is an ecosystem.

Ecologists can identify boundaries between ecosystems, though they are rarely clearly seen. Ecosystems usually merge into each other. An example of a clearly seen boundary is the water's edge of an ocean. An ocean ecosystem is clearly separate from the coastal ecosystem on land. A boundary between a jarrah forest ecosystem and a wandoo woodland ecosystem is not as clear. An ecosystem is an area that scientists have selected for ease of practical study.

We identify ecosystems because they help to simplify the complexity in nature. To better understand the ecology of an area, we think of it as a **system**. A system is a collection of parts that affect each other. For example, one way to think of a swamp ecosystem is to group it into various parts. One grouping could be the community of living organisms and the physical surroundings. Using these groupings helps ecologists to examine how each part affects the others. A diagram, such as in Figure 3.8.3, can be drawn to represent the ecosystem. This is a simplified view of the ecosystem. A simplified view like this can help us to understand how an ecosystem works. Imagine how difficult it would be to understand if we tried to identify every organism and all their interactions with each other and with the physical factors of the environment.

This diagram of an ecosystem could help us to think about many factors and how important they are. For example, the recycling of materials such as carbon may be important. It could lead us to decide to measure how much recycling is occurring. Simplified diagrams of ecosystems like this are often used as a guide to help us decide what to study or measure. They also help summarise what factors have been found by research to be important in the ecosystem. We can compare ecosystems in different areas to see how they are different. This can help us decide if we are damaging the environment.

Science Snippet

Scientists love models!

A **scientific model** is a simplified diagram or description that can help explain how a system, such as an ecosystem, works. A model helps us understand by simplifying the interaction of all the factors. Scientists love using them.

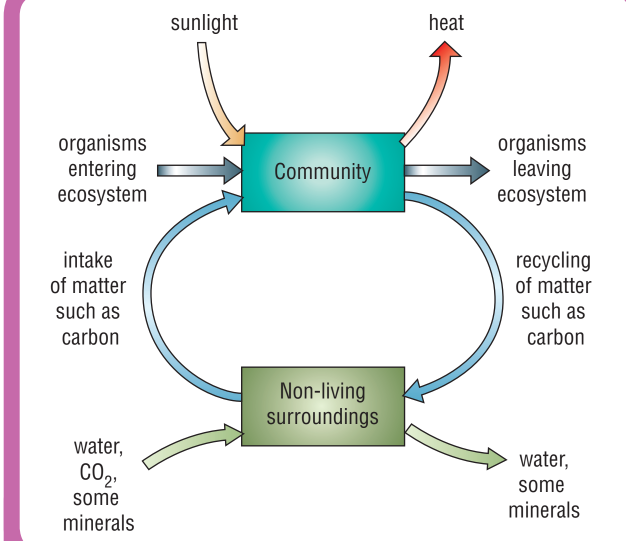


Fig 3.8.3 This diagram represents an ecosystem by showing its components and how they interact.

Effect of the environment on a species

The environment affects individuals every day of their lives. It also affects whole populations through the process of natural selection. Scientists have decided the characteristics of a species can change through a process called natural selection. These changes are called **evolution**.

Natural selection is the process where some environmental factor acts on a population and results in some individuals having more surviving offspring than others. The environmental factor that causes this is called the **selective agent**. The selective agent usually, but not always, acts by killing individuals that do not have features that are able to cope with it. Those that survive pass on their features to the next generation. So the next generation inherits those features that can cope with the selective agent. We say that those which survive have been **selected**.

Natural selection can only happen if there are **inherited differences** between individuals in the species. This difference is called **variation**. The differences among your friends, such as height, hair colour and length of legs, are variations.

The selective agent may be a biotic factor such as predation, bacterial or viral infections or competition. The selective agent could also be a physical factor such as temperature, the mineral content of the soil, wind speed or fire.

Fig 3.8.4 A selective agent

Natural selection clearly highlights the critical importance of the environment to organisms. The environment affects individuals and the whole species.

Homework book 3.15 Ecological pyramids

3·8 FOCUS [Questions]

Use your book

Context

1 What does the term 'ecology' mean?

Environments

2 Explain what the term 'environment' means. Make sure you name the two main components of environments.

Ecosystems

3 Explain the term 'ecosystem', and give three examples of ecosystems.

4 How are ecosystems helpful in understanding the ecology of an area?

5 Briefly describe the process by which the environment changes a species.

Use your head

6 List five physical factors and five biotic factors which affect the survival of a kangaroo.

7 List five physical factors that affect a eucalypt, and explain how each factor affects it.

8 Native Western Australian animals have lived with poisonous pea plants called Gastrolobium for perhaps millions of years. The poison the plants make is called fluoroacetate. Explain how natural selection would have caused the animal species that eat these pea plants to become resistant to the poison.

Fig 3.8.5 A poison pea plant called Champion Bay Poison

Fig 3.8.6 Native animals such as the tammar wallaby are resistant to fluoroacetate poison in poison pea plants.

9 If the poison pea plants had not been in the environment of the tammar wallaby, would it be resistant to the poison?

10 a Identify ten biotic factors and ten physical factors in your environment.

b Explain why these factors would not be the same as those for a gorilla.

>>

Fig 3.8.7 The Brush Bronzewing

Fig 3.8.8 Beach sand dunes are difficult places for plant growth.

11 The Brush Bronzewing is a native pigeon, which used to be eaten by the early settlers to WA. Settlers soon learnt not to give the bones to their dogs, because the dogs became ill and died. This was even though the people had eaten the meat from the bird's bones. The dogs suffered from fluoroacetate poisoning. What hypothesis can you offer to explain these observations?

Investigating questions

12 Sand dune ecosystems at the beach are difficult places for plants to survive.

- **a** Identify five major physical factors affecting most plants growing in this ecosystem shown in Figure 3.8.8.
- **b** Explain how they affect the plants.

13 Humans are greatly affected by the environment in which they grow up.

- **a** Identify six ways in which you may be different if you had grown up as an Australian, Iranian or Indian.
- **b** Would it be natural selection that made you turn out different in these different societies? Explain your answer.

14 Portuguese millipedes have invaded the hills areas of Perth. Many residents claim the millipedes enter their houses at night attracted by the lights. If you have access to any of these millipedes, design an experiment to test their response to light. If you don't have access to these millipedes, try mealworms or slaters.

DYO

FOCUS 3·8 [Practical activity]

Prac 1 Focus 3.8

Temperature and activity

Purpose

Design and conduct an experiment to test the hypothesis that temperature affects the activity of animals.

Requirements

Animals such as slaters, ants, mealworms or other insects, access to hot and cold water, ice, thermometer, at least four containers such as beakers and petri dishes, marking pens.

Procedure

1. As part of the planning process, decide which animals you will use in the activity. Remember you must not harm the animals. To design your experiment you must consider:
   - **a** what activity you will measure
   - **b** how to change the temperature
   - **c** what equipment you will need.
2. *Outline how you will carry out your experiment, how you will collect your data and a list of equipment you will need.* Show this to your teacher before you start experimenting.
3. Carry out your experiment and collect your data.
4. Present your data in a suitable way and answer the questions below.

Questions

1. Describe any pattern or patterns you found in the data.
2. What can you conclude about temperature and animal activity?
3. How can you explain the relationship between temperature and activity?

FOCUS 3.9

Interdependence of organisms

Context

All organisms are trying to survive in an environment where they are affected by many factors. They are affected by other organisms and by their physical surroundings. The community and its physical environment tend to be fairly stable for long periods of time and a delicate balance seems to occur. In this Focus we look at why ecosystems tend to remain fairly stable.

Interdependence

In ecology, **interdependence** means that all organisms affect the survival of each other, but it also means that organisms and their physical environment affect each other. We can talk of interdependence of organisms. But we also refer to interdependence of organisms and their physical environments.

Interdependence of organisms

An organism's survival is affected by all other organisms in its community. We say that its survival 'depends' on them—the word 'depends' meaning either helps or harms. As an example, the survival of a seal depends on its predator, the killer whale. The whale does help the seal that it kills.

As another example, in Figure 3.9.1 the tiger snake depends on the frogs for its food. The frog depends on grasshoppers for its food. So the snake really depends on the grasshoppers as well. Without the grasshoppers there would be no tiger snakes. The grasshoppers are affected by the tiger snakes because the snakes keep the numbers of frogs low. This means fewer frogs to eat grasshoppers, which means more grasshoppers survive. So tiger snakes, frogs and grasshoppers are interdependent for survival.

Interdependence of organisms and physical environments

Every organism is affected by its physical environment, so we can say an organism depends on its environment. This does not mean that the environment is always favourable. Changes in the physical environment can kill an organism. We can still say that its survival depends on the physical conditions.

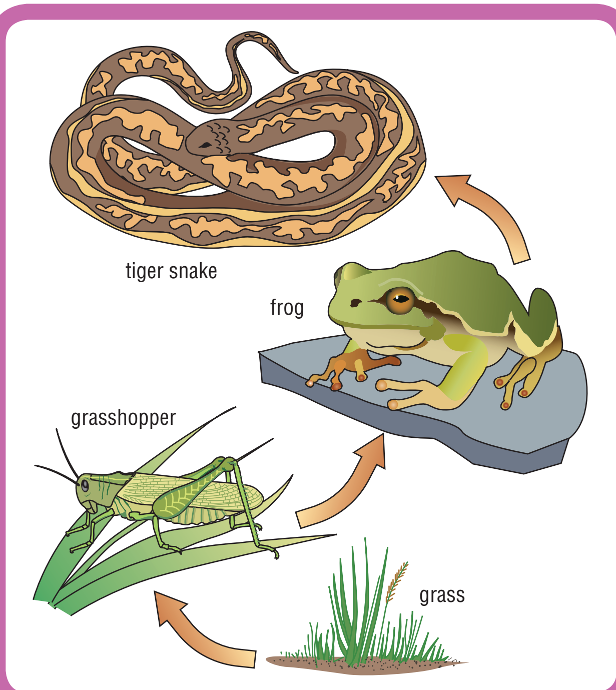


Fig 3.9.1 A food chain helps show the dependence of organisms on each other.

The physical environment also depends on organisms. As an example, the temperature of the soil is affected by plants growing in it and shading it. The amount of water vapour in the air is affected by the evaporation of water from the plant's leaves. Plants also drop leaves, which decay and change the amount of water the soil can hold. So the organisms and their physical environment are interdependent.

Interactive CW Animation

Relationships between organisms

A relationship in ecology is a description of the effect one organism has on another. There are many relationships in communities. Most of these relationships are concerned with nutrition. However, there are relationships that involve factors such as gases, shelter, defence and habitats. We will consider only the feeding relationships here.

Science Snippet

Volcano eaters

There are some producers that do not use photosynthesis to make food. These are bacteria that can use chemicals from volcanic activity. Some live at the bottom of the ocean where magma erupts into the sea. This feeds a community that lives in total darkness. Others live in hot water and mud pools around volcanic activity on land.

Producers are the most important organisms in a community because they are the only organisms that can make the **organic** compounds needed by all living organisms. These compounds are carbohydrates, lipids, proteins and vitamins. Most producers are green plants, which trap the energy of sunlight in sugar through the process of photosynthesis. The sugar can then be made into other carbohydrates, as well as proteins, lipids and vitamins.

Consumers are organisms that must eat other organisms, or the wastes of those organisms. Consumers cannot make their own organic compounds like producers can. They must have a ready-made source of these organic compounds. So consumers eat plants, animals that have fed on plants, or animals. Even the last animal in a food chain depends on the producer at the start of that food chain. Without that producer, the carnivores cannot exist. There would be no food materials to pass along the food chain to them.

Fig 3.9.2 This pygmy possum depends on this Eucalyptus plant to produce food for it.

When you think of organisms as producers or consumers, their dependence on each other and their role in the community can be identified.

Other relationships that you should already know about from *Science Aspects 2* are predation, parasitism, mutualism, commensalism and competition. All these relationships identify the nature and degree of dependence that organisms have on each other. For example, in mutualism, both organisms benefit from the relationship, as the fungus and the alga do in a lichen.

Fig 3.9.3 African bull elephants compete for dominance and access to females with trunk wrestling and pushing.

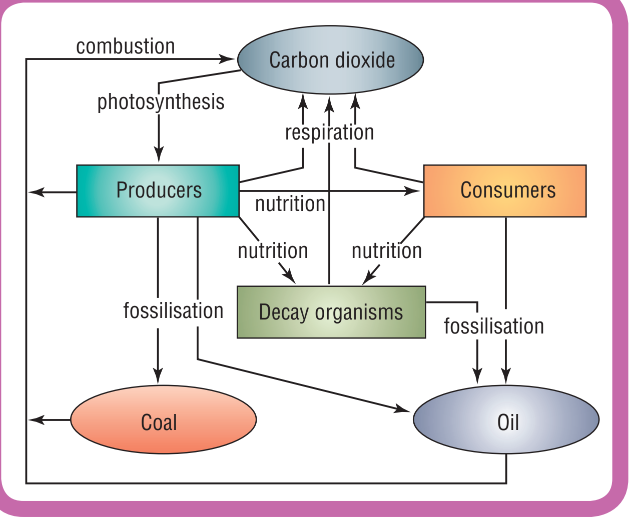
Recycling of nutrients

The recycling of materials in ecosystems is vital to life on this planet. Certain organisms, such as some bacteria, use the bodies of dead organisms and animal wastes for food. These **decay organisms** or **decomposers** are important to producers. This is because the dead bodies and animal wastes contain chemicals that producers can use to make their food. There is usually a limited supply of many of these chemicals in the soil and water. If they are added to the soil they improve plant growth. The bacteria return these important chemicals to the soil and water, allowing producers to use them.

The chemicals that were in the dead bodies originally came from the air, soil or water. They were passed along food chains as one organism ate another. Because they are returned to the place from which they came we say that they have been **recycled**.

Many substances cycle continuously through the environment. For example, carbon, nitrogen, phosphorus, potassium and other elements are continuously recycled.

Fig 3.9.4 The carbon cycle



Recycling of gases also occurs. Oxygen, one of the products of photosynthesis, is used by animals in respiration. Animals give out carbon dioxide when they respire. This carbon dioxide is then used by producers again in photosynthesis. So the carbon dioxide and oxygen are recycled.

Prac 1 p. 162

Recycling of substances by organisms is extremely important. If this did not occur there would need to be an endless supply of all the substances that organisms require. There are almost no resources on the Earth that are in endless supply. This is one reason why governments spend large sums of money to find ways of recycling materials that are thrown away as rubbish.

Science Snippet

Made to rot

Scientists are aware now that substances they produce should be **biodegradable**. This means that organisms can decay them and so recycle them. Some plastics cannot be broken down by organisms, so the chemicals in them may take thousands of years to break down. Some may never recycle.

The stability of communities

Natural communities tend to be fairly **stable** over a period of years. This means that the size of each population does not show a steady change in a particular direction. For example, the number of jarrah trees in an area of forest would not usually increase over a ten-year period. However, it is common for most species in any ecosystem to show fluctuations in numbers. They often show a cycle of increases and decreases in a repeating pattern as shown in Figure 3.9.5.

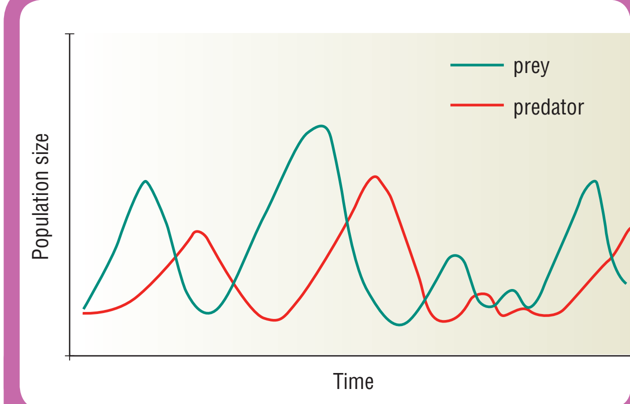


Fig 3.9.5 Changes in the number of prey and predators in an environment

There is debate among biologists about why these changes occur. One factor that does seem to have an effect is seasonal variation in physical conditions such as temperature. For example, the numbers of a herbivore may change as its food plants are affected by changes in water, temperature, light and other factors.

Occasionally these population changes can be large, such as in a mouse plague. These are generally temporary and the populations usually return to near

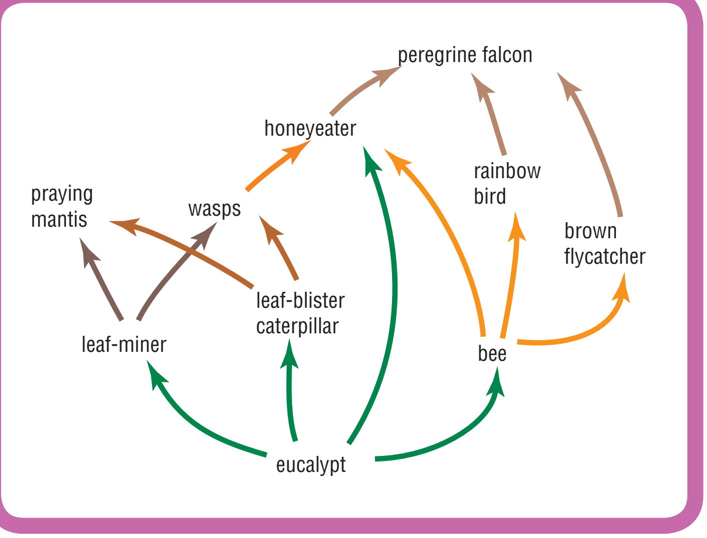
Fig 3.9.6 Locusts can lay millions of eggs. The offspring form swarms that destroy all vegetation in their path.

their original sizes when conditions return to normal. This stability of natural populations is often called the **balance of nature**. It is probably better called the stability of nature. This stability in communities is partly due to the recycling of materials, but also to the great complexity of food webs. To understand this, consider the food web in Figure 3.9.7.

If there is a change in the environment, such as an unusually heavy flowering of eucalypts, there may be an increase in the number of bees. This is because more food is available and so more bees can survive. If the number of bees increases, there is more food for honeyeaters, rainbow birds and brown flycatchers. Because of this more of these birds survive, and the bee population gradually decreases. As the bee numbers start dropping it is harder for the birds to find food. Consequently the bird numbers also decrease through death or migration out of the area.

So a population is kept in check by the organisms that prey upon it. A population increase will be followed by a return to the original level as the organism's predators increase. The numbers could cycle up and down for some time, but will probably return to somewhere near the previous levels.

Fig 3.9.7 Part of a food web



The peregrine falcon keeps the population of its prey in check. *Fig 3.9.8*

Homework book 3.16 Parasites

FOCUS 3•9 [Questions]

Use your book

Interdependence

1 What does the term 'interdependence' mean?

Relationships between organisms

2 Give an example of a nutritional relationship between two organisms.

3 Describe a relationship between two organisms that is not a nutritional relationship.

Recycling of nutrients

4 What is meant by the term 'recycling'?

5 Why are decomposers (decay organisms) important in an ecosystem?

The stability of communities

6 Explain why natural communities tend to be fairly stable or balanced.

7 Look at Figure 3.9.7 and name:

a three animals that compete for bees as a food source

b two animals that compete for leaf-miners as a food source.

Use your head

8 Explain how a eucalypt depends on both its living and physical environments. Use at least three examples for each.

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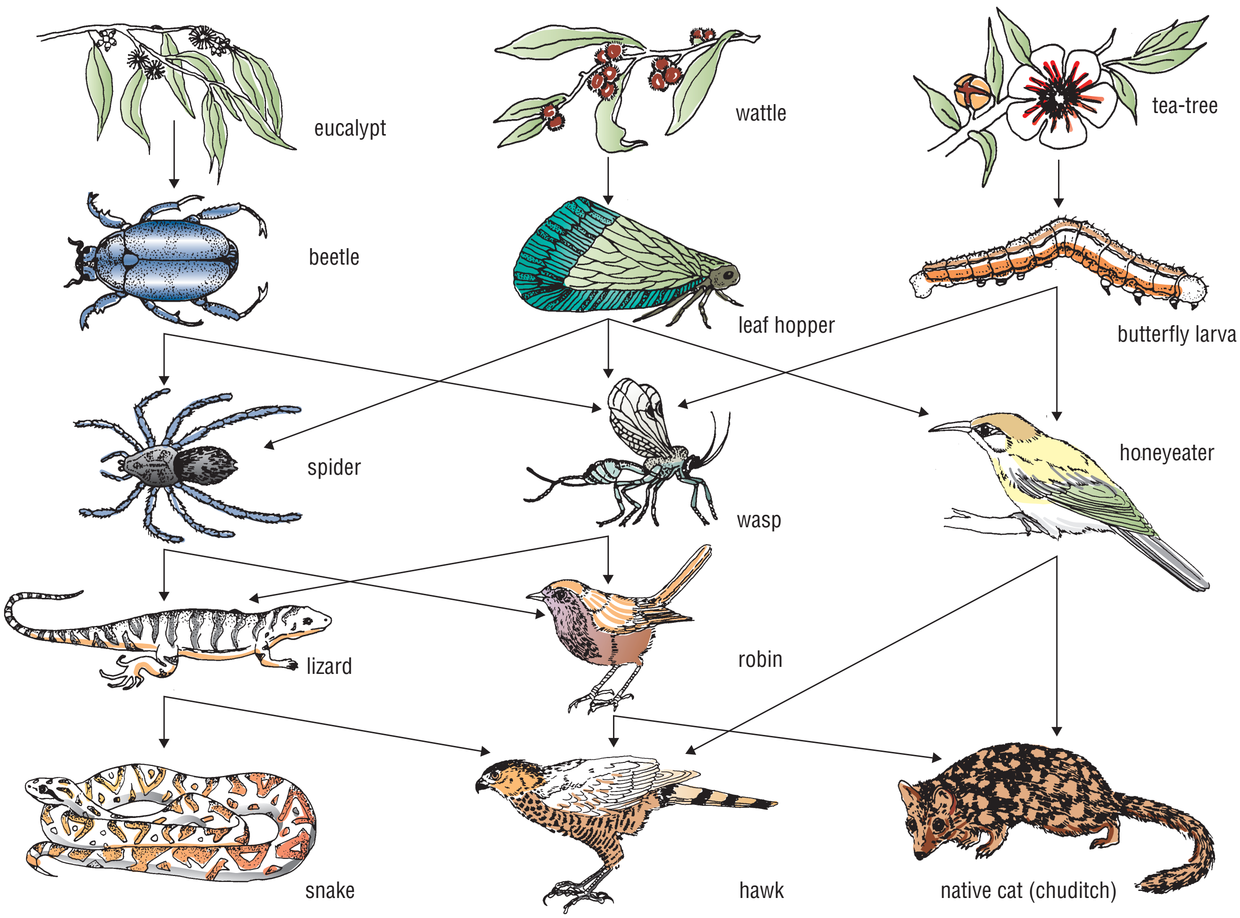


Fig 3.9.9 Part of a food web

9 Consider Figure 3.9.9 showing part of food web.
If the amount of wattle increased, explain what would happen to each of the following populations:
- **a** leaf hoppers
- **b** wasps
- **c** honeyeaters
- **d** beetles.

10 In Australia, termites are very important decomposers. How may termites be useful in an ecosystem?

11 Referring to the diagram of the recycling of carbon in Figure 3.9.4, describe two ways in which your body could contain carbon atoms that were once part of a dinosaur.

12 In what ways are bees and producers interdependent in ecosystems?

Investigating questions

13 Find a diagram of the nitrogen cycle in a library book or on the Internet.
- **a** Explain how the nitrogen is recycled to producers.
- **b** Explain why legumes are such an important crop species.
- **c** Explain why wattles and casuarinas are important in natural ecosystems.

14 Give a name for each of the following relationships, and explain why you chose that name.
- **a** a peregrine falcon and a pigeon
- **b** a tick and a kangaroo
- **c** tinea and a human
- **d** you and a pet
- **e** a kangaroo and a wallaby
- **f** a cow and the bacteria in its gut
- **g** rabbits and wedge-tailed eagles
- **h** a soldier ant and a worker ant in a colony.

FOCUS 3.9

Practical activity

Prac 1
Focus 3.9

Gas exchange

Purpose

To investigate how producers and consumers are interdependent for oxygen and carbon dioxide exchange.

Requirements

Carbon dioxide (CO_2) generator consisting of a test tube, stopper, delivery tube, marble chips or calcium carbonate ($CaCO_3$), 2 mol L^{-1} hydrochloric acid (HCl); bromothymol blue solution; four 250 mL conical flasks or large test tubes with stoppers; two snails; marking pen; two plants, such as shoots of land plants (eg soursob, wandering Jew, or geranium) or water plants (eg spirogyra); lamp.

Note: Fig 3.9.10 indicates how to set up this experiment with either water plants or land plants.

Procedure

1. Bubble some carbon dioxide gas through some bromothymol blue solution in a test tube. *Note the colour of the solution with and without carbon dioxide.*
2. *Number the conical flasks or test tubes 1 to 4* and set them up either with land plants or aquatic plants as shown in Figure 3.9.7 and with the required amount of bromothymol blue solution. Stopper the flasks.
3. In flask or test tube 2 add one snail, and stopper it.
4. In flask or test tube 3 place a plant shoot and stopper it.
5. In flask or test tube 4 place a plant shoot and a snail and stopper it.
6. Place the flasks under a lamp for the rest of the day. Check your flasks after about three hours and *record the colour of the bromothymol blue solution in a table.* At this time you should stop using flask 2 because the animal may die if left in much longer. Open the stopper and return the animal to your teacher. Turn the lamp off overnight.
7. Next morning before school check your flasks again and *record the colour of the bromothymol blue solution in the table.* If the animal looks healthy in tube 4, turn the lamp back on.
8. Later in the day or after school check the tubes again. *Record the colour of the bromothymol blue solution.* Stop the experiment at this time. Remove the animals from the tubes and return them to your teacher.

Questions

1. What is the purpose of flask or test tube 1?
2. Explain the colour changes in flask or test tube 2.
3. Explain the colour changes in flask or test tube 3.
4. Explain the colour changes in flask or test tube 4.
5. What does this experiment show about the interdependence of producers and consumers?

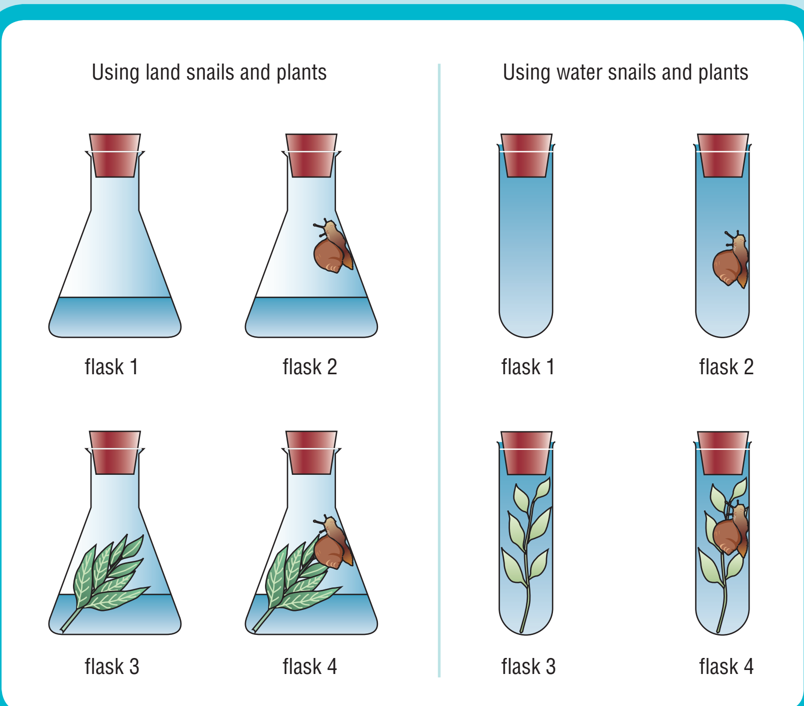


Fig 3.9.10 Two ways to set up this experiment

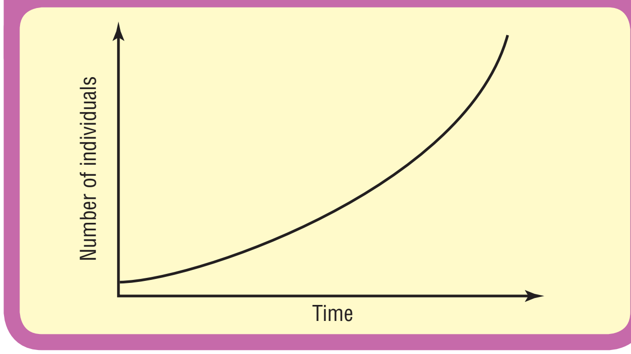
FOCUS 3.10 Damaging the environment

Context One of the main threats to life on Earth is overpopulation by humans. This brings with it many problems. These can be classified as habitat destruction, introduced species, chemical pesticides, chemical pollution and overcropping. This Focus is about these threats to the living environment.

Overpopulation

Populations of organisms grow in a way that is similar to the growth shown in the graph in Figure 3.10.1, unless growth is limited by some factor.

Fig 3.10.1 A population growing without limiting factors



The graph shows that a population can grow to huge numbers. However, this cannot continue indefinitely. Since the whole Earth is not filled by any one species, it is obvious something limits population growth.

The factors that limit population growth are predation, disease, shortage of food, accumulation of wastes and lack of resources. As a population increases, the population of its predators rises, which tends to reduce the population of the prey. Diseases spread more quickly as a population grows, as it is easier for the disease organisms to find another organism of the same type close by. A large population may consume its food source and be unable to find any more. Wastes, such as excretory wastes, may build up to toxic levels and kill some or all the population. The population may also run out of resources, such as nesting sites and shelter.

The human population has grown in a way that is very similar to the growth shown in Figure 3.10.1. It seems obvious that something must eventually limit its growth. Most biologists believe that it is necessary to halt the human population growth curve to ensure that life continues on this planet. It has been observed that as people become more affluent, they tend to have fewer children. In Australia the population growth rate has slowed in recent decades. However, in poorer countries such as Africa, India and South America the population growth rate has not declined. One possible solution may be to help poorer countries increase their wealth.

Habitat destruction

Habitat destruction is damage to the factors in the environment that an organism depends on for survival. Some examples are land clearing, logging, controlled burning and mining. Of course, these activities may not always permanently destroy habitats.

Agricultural development has caused the most habitat destruction in Australia. Huge areas of Australia have been cleared for agriculture to feed the human population. As a result, the populations of many native animals have decreased. Herbivores cannot survive without the native plants on which they feed. This has meant a decline also in the populations of carnivores that eat them. Animals such as the bilby, woylie, rat-

The woylie or brush-tailed bettong population declined partly due to habitat destruction, but also because of foxes. *Fig 3.10.2*

kangaroo, potoroo, noisy scrub bird and many others appear to have declined in numbers during the period of agricultural development. However, some appear to have increased in numbers because of the increased food supply, such as kangaroos, locusts and emus.

Introduced species

Many animals have been brought to Australia from other countries. Some of these are predators that kill native animals. Domestic cats and foxes are particularly bad in this regard. Domestic cats gone wild are called **feral** cats. They have had a devastating effect on wildlife. Feral cats can be found even in the deserts. They have reached such numbers in national parks that rangers often shoot them. The Department of Conservation and Land Management (CALM) is trying a baiting program to remove them. The problem is not helped by unwanted cats being abandoned and by pet cats hunting in gardens and nearby bush.

Fig 3.10.3 Feral cats are a great threat.

Animals such as rabbits, camels, donkeys, horses, goats, mice, rats and pigs have also been introduced. These can all be found running wild. They compete with native animals for food and shelter, and so fewer native animals survive.

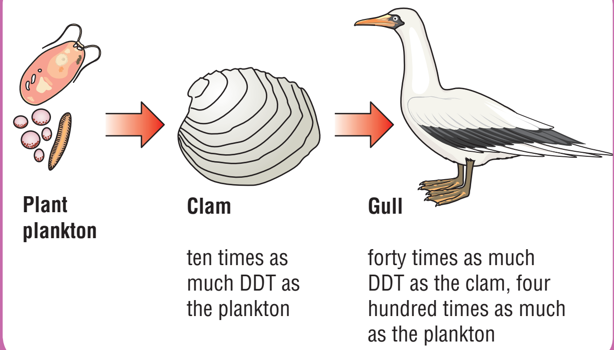
The situation is just as bad with introduced plants. Many of these become weeds and successfully compete with native plants for the limited resources available. Examples of these are watsonia, blackberry and veldt grass. These cover large areas of native bush.

Chemical pesticides

Studies by scientists have shown that insecticides such as DDT are present in all the organisms in a food chain of an estuary like the one shown in Figure 3.10.4.

The amount of DDT increases along the food chains. The reason more DDT is found in the clam than the plankton is because the clam consumes a great deal of plankton. The DDT in the plankton is nearly all stored in the clam's body. Little is lost. The gull eats many clams and stores most of the DDT in its body. So the gull contains a high concentration of DDT.

Fig 3.10.4 Food chain showing pesticide accumulation



DDT has had serious effects on birds. It causes birds to lay eggs with thin shells. These break when the adult sits down to incubate them. So fewer young are produced, and the population decreases as adults die and are not replaced by young.

The effects of DDT have been so serious in some countries that many predatory birds, such as eagles, hawks and ospreys, have become rare. DDT has also been found in human milk and in body organs. It is not clear how dangerous this substance is to humans. Certainly it is not as toxic as it is to insects. However, no one knows whether it has any long-term effects on humans. DDT use is now banned because of these problems.

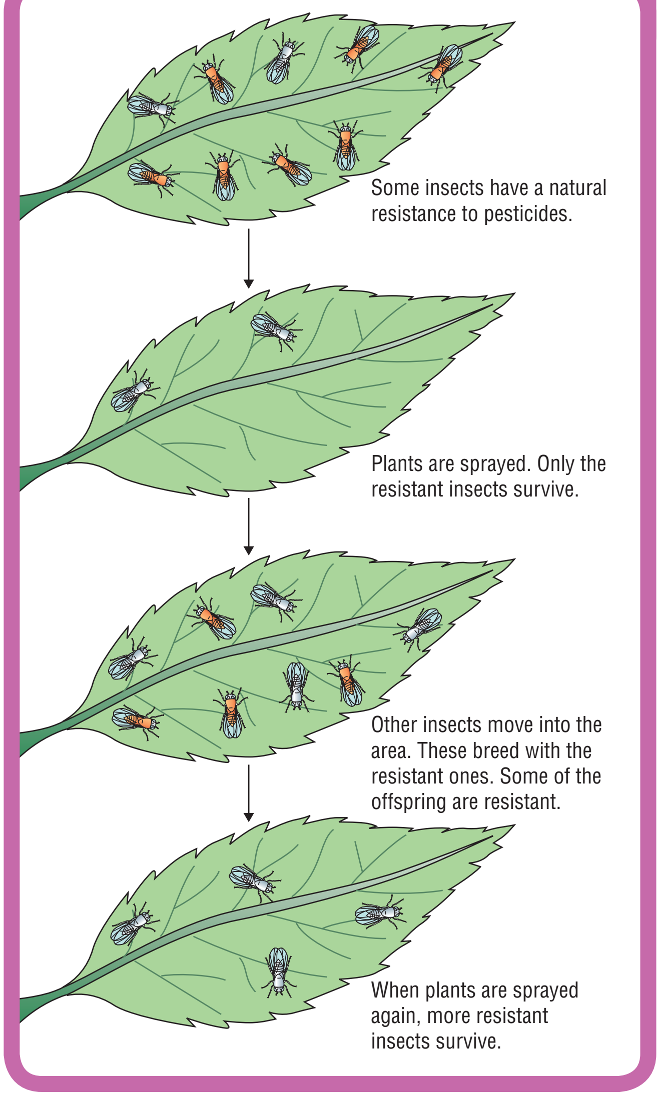
Fig 3.10.5 Spraying with insecticides

Not all pesticides accumulate in organisms like DDT does, but there are still problems associated with them. Many kill useful animals such as bees, which pollinate flowers, or predatory wasps, which kill insect pests.

Many scientists believe that the community should abandon or greatly reduce its use of chemicals to control pests. Apart from the disastrous effects on natural communities, the chemicals are becoming less effective. Larger and larger concentrations are needed to kill pests. Studies have shown that the insects of today can withstand much stronger sprays than when spraying began years ago. The insects have become resistant to the chemicals.

Insects become **resistant** to these chemicals by the process of natural selection, as shown in Figure 3.10.6.

Natural selection of resistant insects *Fig 3.10.6*



Chemical pollution

One of the most serious problems at present is the release of large quantities of carbon dioxide gas into the air. This comes from the burning of fossil fuels in home heating, car exhausts, industrial processes and electricity generation. The carbon dioxide is causing a warming of the Earth's atmosphere, a process called the enhanced **greenhouse effect**.

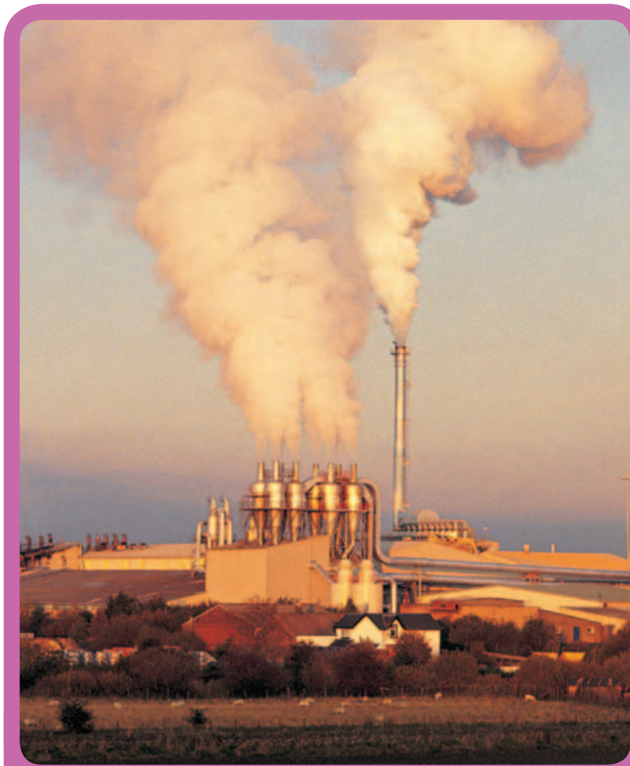


Fig 3.10.7 Burning reactions release carbon dioxide.

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Carbon dioxide absorbs heat radiated from the Earth, thus warming the atmosphere. The problem with raising the Earth's temperature is that the polar ice caps may melt, so raising sea levels. It is estimated that sea levels may rise by about 30 centimetres by the year 2030, and perhaps up to six metres higher if the polar ice caps melt at the rate predicted.

The warming of the atmosphere could also change wind and rainfall patterns of the Earth. These changes could have large-scale effects on agricultural production and even result in the extinction of many plant and animal species. Many governments have responded to this problem by trying to limit emissions of greenhouse gases.

Another problem is a 'hole' in the **ozone layer** above Antarctica. Ozone is a molecule consisting of three oxygen atoms. Ultraviolet radiation from the Sun forms the ozone high in the Earth's atmosphere. The ozone acts like a shield, reducing the amount of ultraviolet radiation reaching the ground.

This ozone layer is becoming thinner every Antarctic winter, allowing more ultraviolet radiation to reach the ground. The damage to the ozone layer is being done by chemicals called chlorofluorocarbons or CFCs. CFCs were used, and in some countries are still used, in air-conditioners, plastics, refrigeration, dry-cleaning and spray cans. If the thinning of the ozone layer occurs all around the Earth, there could be a large increase in the incidence of skin cancers and eye cataracts in every country. Many governments have acted to solve this problem by passing laws regarding CFC use.

Science Snippet

Minamata disease

One of the earliest cases of toxic chemicals harming health was in Japan. Over one hundred people living near Minamata Bay died or suffered nerve damage. The problem was caused by mercury wastes being released into the Bay by a chemical company. Certain mercury compounds were concentrated in the food chains in the surrounding sea. People eating the fish caught in the area absorbed large doses of these mercury compounds.

Overcropping

Overcropping of animal populations is the killing of more animals than the population can replace by its normal breeding cycle. This results in a decrease in the population. Many of the world's whale populations have declined dramatically as a result of overcropping. The population of the blue whale in the 1980s was only about 5 per cent of the population earlier in the century. Blue whales are now totally protected.

One of the important roles for ecologists is to find out how many animals can be removed from a population without endangering the survival of the species. Commercial fishing is a common area where this kind of research occurs. The western rock lobster or crayfish provides one of the best examples of population protection and management.

Fig 3.10.8 Overcropping of whales has caused a population decline.

Homework book 3.17 Dams and lungfish

Drag and Drop CW Interactive

FOCUS 3.10 [Questions]

Use your book

Overpopulation

1 List five factors that act to limit population growth.

Habitat destruction

2 How has the clearing of bush for farming affected natural communities?

3 What is habitat destruction? Give an example.

Introduced species

4 Why are introduced animals, such as rabbits, foxes, cats and wild pigs, a problem for native animals?

Chemical pesticides

5 Why do increasingly stronger and different insecticides have to be used to kill the same species of insect?

Chemical pollution

6 a What is the enhanced greenhouse effect?
  b What problems may it cause in future?

Overcropping

7 Why can overcropping lead to the extinction of a species?

Use your head

8 What factors may limit the growth of the human population of our planet in the future?

9 Are there any factors that may limit human population growth, but not the growth of other species? Explain your answer.

>>

10 Many scientists believe that limiting human population growth is necessary to control environmental damage. Explain why you agree or disagree with the statement.

11 Explain how a cumulative poison such as DDT, which is sprayed onto crops, could kill predatory birds, such as eagles.

12 An introduced water weed called salvinia has caused problems in freshwater lakes in Australia and other places in the world. This plant floats on the water surface. It spreads rapidly, covering the whole surface of a lake. The weed's roots take oxygen out of the water. Any oxygen produced by photosynthesis in the leaves is released into the air, not the water.
 a Explain how this weed would cause problems for other plants in the water.
 b Why would this weed be a problem for consumers that live in the water?

13 When a farmer is trying to control a particular species of insect pest, why may it be better to use different types of insecticide rather than constantly using the same type?

14 Should we all be concerned about the thinning of the ozone layer around Earth, or is it someone else's problem? Give reasons for your answer.

15 Many people see a forest only as a source of wood. What other uses are there for forests?

Investigating questions

16 Salinity of farmland in the wheat belt is one of our major environmental problems in Western Australia at present. Find out why farmland is turning salty, and what is being done to try to solve the problem.

17 What causes acid rain, and what effect does it have on ecosystems?

18 Large areas of the Amazon rainforest are being cut down. Explain the effect this might have on the Earth's atmosphere.

19 a Explain what is meant by eutrophication.
 b Explain the effect of eutrophication on ecosystems.

3·10 FOCUS [Practical activities]

Prac 1
Focus 3.10

Salt and germination

Purpose

To determine whether salt affects the germination of plant seeds.

Requirements

Cotton wool, three petri dishes, scissors, paper towelling, 0.2 mol L^{-1} sodium chloride (NaCl) solution, 0.4 mol L^{-1} sodium chloride (NaCl) solution, forceps, distilled water, fresh clover or wheat seeds, three rubber bands, incubator (if temperature is below 20°C).

Procedure

1 Place a layer of cotton wool about 0.5 cm deep in each petri dish.

2 Cut some paper towelling to fit each petri dish over the top of the cotton wool.

3 *Label the petri dishes as follows:*
 a Dish 1 (Control)
 b Dish 2 (0.2 mol L^{-1} NaCl)
 c Dish 3 (0.4 mol L^{-1} NaCl).

4 Add the correct solution to each dish. The water level must not cover the paper.

5 Place ten seeds in each dish, replace the lid and fix it in place with a rubber band.

6 Place the dishes in a dark place. If the temperature is below 20°C an incubator should be used.

7 Check the dishes the next day. If the paper is not wet, add more of the correct solution.

8 Check the seeds for the next five days, *recording in a table how many have germinated.*

9 Find out the results from all the other groups and *construct a table of class results.*

10 Calculate the average total number of seeds germinating in each dish.

Questions

1 Which dish had the highest average germination and which had the lowest?

2 Did salt affect the germination?

3 How could this experiment be changed to make it relevant to natural ecosystems and to agricultural ecosystems?

The effect of wastes on water communities

Prac 2
Focus 3.10

Purpose

To determine the effect of wastes on water communities.

Requirements

Dry yeast, teaspoon, 20 mL measuring cylinder, 20 mL warm water, 100 mL beaker, five 5 small test tubes, marking pen, 5 mL of each of 100%, 75%, 50% and 25% milk solutions, tap water, test tube rack, methylene blue indicator solution in dropper bottle, stirring rod, timer.

Procedure

1. Mix half a teaspoon of yeast and 20 mL of warm water in the beaker. Leave this to stand. Yeast is a microorganism that feeds on food materials in the milk. When it has food it uses oxygen to grow.
2. *Mark each test tube with a line 1 cm and 3 cm from the bottom. Number the test tubes 1 to 5.*
3. Pour the 100% milk solution into test tube 1 up to the 1 cm mark.
4. Repeat the process with the 75%, 50% and 25% milk solutions in test tubes 2, 3 and 4 respectively.
5. In test tube 5 place tap water up to the 1 cm mark.
6. Add eight drops of methylene blue to each tube and mix well. The tubes should appear blue because there is plenty of oxygen in the water. Methylene blue turns colourless when there is no oxygen.
7. Pour the yeast solution into each test tube up to the 3 cm mark and mix each test tube well. Make sure you try to do this as quickly as possible. Each tube should really be done at the same time. If this is not possible, *record the time when each tube was mixed.*
8. *In a suitable table, record how long each tube takes to lose its blue colour.*

Questions

1. What caused the change from blue to colourless?
2. What relationship is there between milk concentration and time taken to lose the blue colour in the test tube?
3. If wastes containing food materials entered bodies of water and the microorganisms in them reacted like the yeast here, explain what could happen to the water community.

FOCUS 3.11 Conservation

Context

Do you want to live in a world with fresh air to breathe, clean water to drink and healthy foods to eat? If so, you need to know about conservation. This involves a lifestyle that has the smallest possible impact on our environment and other ecosystems.

This Focus discusses four good reasons for conservation: compassion, cultural value, economics and survival.

Reasons for conservation

Conservation is the management and protection of ecosystems so they continue to exist. Following are four good reasons why humans are involved in conservation.

Compassion

Compassion is about feeling sympathy for other organisms. The argument for compassion is that all organisms have a right to live, and that humans have no right to exterminate any species. Many people feel that we should think of ourselves as fellow travellers with all the world's living creatures. They argue that we are the only organism on this planet that is capable of understanding the possible fate of all life. We therefore have a responsibility to make wise decisions.

Fig 3.11.1 A stranded whale and its human rescuers

Many people devote their lives to saving endangered species. An excellent example is June Butcher, who, with her husband, founded the Kanyana Wildlife Centre in Gooseberry Hill. The centre is a privately funded animal hospital that cares for sick native animals. An army of volunteers help out. Very little help comes from government. Most comes from donations from the public. These people do it because they love animals and have a deep respect for life.

June Butcher cares for injured wildlife and breeds endangered species. *Fig 3.11.2*

Cultural value

Many species have a value as part of our **culture**. They are part of our national view of ourselves. The Australian Coat of Arms features a kangaroo and an emu. How would you feel if we hunted them to extinction? These animals are a source of wonder, interest and enjoyment for many people. Australia's animals and plants have a reputation throughout the world for being unusual and interesting.

An example of an extinct species is the Tasmanian tiger. This animal was hunted because it had a reputation for killing sheep. It did kill some, but it probably did not threaten the farmers' survival as much the farmers claimed. A reward system was instituted for the killing of Tasmanian tigers and they ended up being hunted to extinction. Just before they became extinct, the Tasmanian Government tried to protect them. But it was too late. So the Earth lost a unique and amazing animal.

The Tasmanian Tiger is now extinct. *Fig 3.11.3*

Fig 3.11.4 The Australian coat of arms

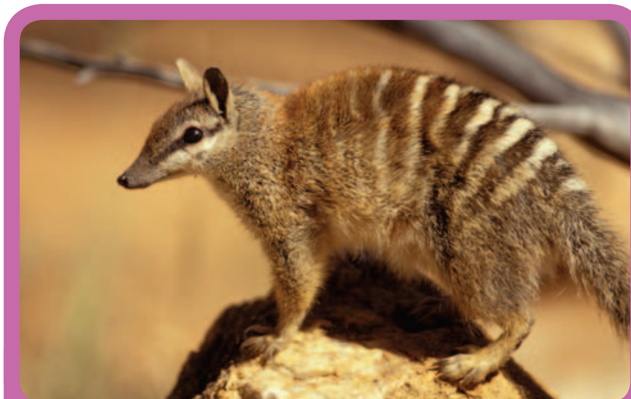


Fig 3.11.5 A numbat, one of the animal emblems of Western Australia

Economics

Economics is a social science greatly concerned with money. Native plants and animals have an **economic value**. This means they are worth money to us.

One source of income from native species is **tourism**. People are attracted to holidaying in Australia to see our spectacular wildflowers, forests and animals. Our plants and animals are world-famous. Our tourism industry creates many jobs.

Karri forests attract tourists. *Fig 3.11.6*

Another source of income from native species is from **farming** or **cropping**. Conserving commercial species, such as jarrah trees, the western rock lobster or kangaroos, while still cropping them, ensures that we will always be able to use them. Overcropping would destroy the populations of these species, and could even drive them to extinction.

Conserving species also enables us to use them in the future as new discoveries are made and new needs arise. Many **drugs** have been produced from plants that were previously not used by humans for anything. Also, certain animals could be possible **biological control agents** in the future.

Laws prevent people from catching western rock lobsters that are carrying eggs. *Fig 3.11.7*

Many animals and plants in the future may be used for **cross-breeding** experiments to improve the strains of commercial animals and plants. For example, Australian scientists have decided that eucalypts should be conserved because of the wide variety of conditions in which they grow. Recent salinity problems in Australia have made it important to find plants that tolerate high salt levels. Some species of eucalypt have been found that could be useful.

Fig 3.11.8 Salt-tolerant river red gums

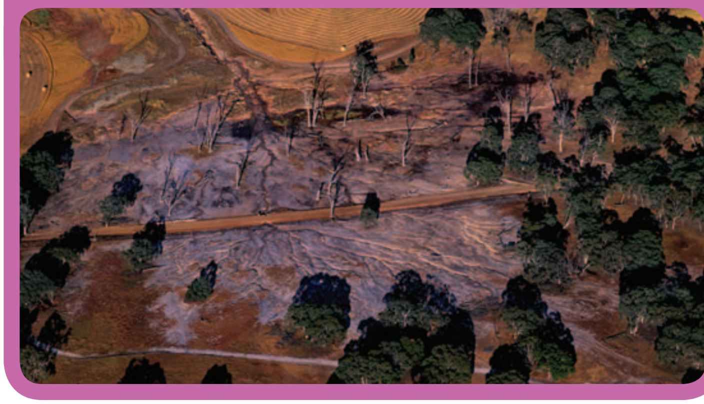
Survival

Many scientists believe that we risk destroying ourselves if we destroy other species. For example, clearing the world's forests for timber will reduce the amount of oxygen in the air.

Commercial fishing makes a significant contribution to the survival of humans because we rely on the food webs in the ocean, of which plant plankton is the base. If we disrupt these food webs by overfishing or chemical pollution, we could permanently destroy the fisheries and seriously reduce human food resources.

The soil on our farms is a precious resource. By clearing trees, we destroy our soils. One effect of clearing is to cause soil erosion by wind and water. This alters the soil and reduces the productivity. So less food can be produced.

Fig 3.11.9 Salt damage to soils is a major environmental problem in Western Australia.



Another effect of clearing bush is an increase in salinity in the environment. In Western Australia, huge areas of farmland have turned salty. This has occurred because the trees that keep the water table low have been removed. As a result the water table rises and salt deep in the soil is deposited in the upper layers where crops are planted. Crops cannot grow in this salty environment, so food production is reduced. Many farmers now realise this and plant trees in an attempt to lower the water table.

Classifying threats to species

The threats to native species can be classified as follows:

1. **Extinct**, which means that there is no reasonable doubt the last individual of the species is dead. An example of this is the Tasmanian tiger.
2. **Extinct in the wild**, which means that there may be some of the species in captivity but not in their natural habitat.

3 **Critically endangered**, which means that it is almost certain that the species will be extinct within a few years.
4 **Endangered**, which means that it is highly likely that the species will be extinct in perhaps five years.
5 **Vulnerable**, which means that the species faces a high risk of extinction in the medium term, perhaps between five and ten years.
6 **Threatened**, which includes the three categories above, 'critically endangered', 'endangered' and 'vulnerable'.

Fig 3.11.10 The elegant spider orchid is a threatened species.

National Conservation Strategy

The Australian Government produced a document called the 'National Conservation Strategy for Australia'. This document specified four conservation objectives. These are:

1 to maintain essential ecological processes and life support systems
2 to preserve genetic diversity
3 to ensure the sustainable utilisation of species and ecosystems
4 to maintain and enhance environmental qualities.

The **essential ecological processes** include cycling of materials such as water, phosphorus, oxygen, carbon and nitrogen. These are important as they are the life-supporting materials that sustain ecosystems.

Genetic diversity is also called biodiversity. **Biodiversity** refers to the range of genetic differences in a species. A species must have a large number of different genes to be able to cope with natural selection in the wild. If most individuals are alike, a selective agent in the environment could easily wipe out the species. This is because there would not be any or enough individuals with genes that can cope with the selective agent.

Biodiversity also refers to the range of different species in a community. Having many different species makes a community more stable and less likely to be affected by environmental changes. For example, it is much harder for weeds to invade a complex community with many species than one with only a few.

Sustainable utilisation refers to the use of organisms and ecosystems in a way that does not damage them so that their use can be sustained. This means they will always be there to be used.

The document clearly demonstrates that sustainable development can occur only if humans manage the environment and adopt a policy of conservation.

Some laws relating to conservation

Environmental Impact Statements (EIS)

The Australian Government has a large influence on projects that could affect the environment. State governments also have enacted legislation controlling development in each State. Any group wanting to undertake a project that may be large enough to cause environmental change must prepare an **Environmental Impact Statement**. This statement must include information on the following:

1 what the existing environment is like
2 the likely effects of the proposal on the environment
3 alternatives to the proposal and their effects
4 proposed safeguards and monitoring of the environment for damage.

Fig 3.11.11 This dredge mining operation for extracting heavy minerals from mineral sands required an Environmental Impact Statement.

There is usually some time allowed for members of the public to examine the proposal, and make objections to it if they so desire. One problem with these procedures is that the issues may not be communicated to the public clearly enough for people to be aware of the proposal, or people may not know that they have a right to comment. It is important that every member of the community feels strongly enough to comment in cases where there is potential for unacceptable environmental damage.

National parks and reserves

There are special areas set aside to conserve a range of important ecosystems. These areas are called **national parks** or **reserves**. There are strict rules about entry to these areas and the types of activities allowed there. Therefore, the habitats of these organisms that live in these protected areas are preserved.

Fig 3.11.12 Twin Swamps is a sanctuary for the western swamp tortoise.

Fig 3.11.13 The endangered western swamp tortoise

Fishing and hunting licences

State governments also control activities such as fishing and hunting. Laws control how many animals of each type may be caught, when they can be caught and what size or age they must be. For example, harvesting of the western rock lobster is allowed only between 15 November and 30 June each year, and females with eggs must not be taken. Boats are licensed to catch a certain number of lobsters and each lobster must be at least 76 millimetres long in the carapace. This is to ensure that enough breeding stock remains to keep the population at a particular level. Thus overcropping should not occur.

Homework book 3.18 Project Eden

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3·11 FOCUS [Questions]

Use your book

Reasons for conservation

1 What is conservation?

Cultural value

2 What is meant by the term 'cultural value'?

Economics

3 Briefly describe some ways in which conservation can be worth money.

Classifying threats to species

4 If a species is classified as threatened, what does this mean?

National conservation strategy

5 a What is biodiversity?
  b Why is it important to maintain this in a species?

Environmental Impact Statements

6 Describe four things which must be addressed in an Environmental Impact Statement.

Use your head

7 Which environmental problems does each of the following strategies attempt to solve, and how does it do it?
  a establishment of national parks and reserves
  b requirement for fishing licences
  c requirement for Environmental Impact Statements.

8 Why do you think an EIS is required to report on each of the four areas specified?

9 The Australian Navy protects those waters and intercepts any fishing vessels from overseas in Australian Territorial Waters (a 12-mile-wide strip of the seas around Australia). Explain why you think we do this. >>

10 When cropping native species, such as western rock lobsters, there are laws that control:

- how many animals of each type may be caught
- when they can be caught
- what size or age they must be.

How do you think each of these laws assist in the conservation of the rock lobster?

Investigating questions

11 Choose an Australian animal and in about ten lines write a convincing argument for its cultural importance.

12 Describe two environmental problems in Australia which show that conservation is necessary for human survival.

13 List the names of five species, including some plants and some animals, that are threatened at present. For each species:

a show on a map where it can be found, naming any national parks in the area

b include a picture of the species

c state the known population size

d say what is the main reason for its threatened status.

14 In a recent book, an ecologist suggested that the minimum population size needed to ensure a species survival was between 50 and 500 individuals. Imagine a new disease-causing type of bacteria has just entered a population of mammals. Apply the concepts of biodiversity and natural selection to this mammal to explain what the scientist meant.

3•11 FOCUS [Practical activity]

Prac 1 Focus 3.11

Recovery plans for threatened species

Purpose

To understand how recovery plans are involved in saving a species from extinction.

Requirements

None essential, although access to the Internet or printouts of relevant material may be useful. Weblinks to support this activity can be found in the Web Destinations on the *Science Aspects 3* Companion Website.

Procedure

1 This is a group discussion activity for groups of about four students. You will be discussing the following information:

The Western Australian Department of Conservation and Land Management (CALM) developed a management technique called a ‘Recovery Plan’ in 1992. This is a plan devised by a team, called a Recovery Team, to save a threatened species. Team membership can vary but consists of professional scientists, and often farmers, volunteers, shire councillors and sponsors. The first plan was for the western swamp tortoise.

There are about 172 animals and 356 plants that are officially classified under our laws as being specially protected due to being threatened. These numbers change as more is discovered.

2 In your group your task is to decide what you think should be included in any Recovery Plan. You need a list of about five to ten elements any recovery plan should have. For example, one element would be a description of where the species is found at present. *Each person in your group must write down the list.*

3 Each student in your group moves and forms a new group with about three students each from a different group. Take your list with you.

4 Each student in the new group reads and explains their list. If any ideas come up that you do not already have written down, *add them to your sheet.*

5 Report back to your first group and compare answers again to see if you can *add any more reasons to your sheet.*

6 Choose the best sheet from your group and stick it on the classroom wall.

Questions

1 Your teacher will read you what CALM decided would be needed in a Recovery Plan. How many of them did you have?

2 Do you think a Recovery Team could be formed for every threatened species?

3 What strategies do you think we could use to save all these threatened species?

FOCUS 3·12 Environmental management

Context

In the last Focus you learnt about Environmental Impact Statements, licensing for cropping of native species, the use of parks and reserves and the development of Recovery Plans. These were some of the ways in which we try to repair or prevent environmental damage. In this Focus we look at some more ways to protect our environment.

Biological control—alternative to pesticides

An alternative to the use of chemical pesticides is a method called **biological control**. Biological control is the use of a natural enemy of a pest to control the pest.

Aphids

The spotted alfalfa aphid has been controlled in Australia using biological control. This aphid entered Australia from overseas and spread rapidly, as it had no natural predators here. The aphid destroyed nearly all the lucerne crops in Queensland and other areas of Australia.

Australian scientists decided to look for a suitable biological control method. They discovered that the aphid had a natural enemy in the USA called the trioxys wasp. Before introducing this wasp to Australia scientists had to quarantine the wasps to make sure they were not carrying any diseases. They also had to check that the wasp would attack only the aphid. Then they had to find a way of producing large numbers of the wasp for field trials and ultimately for release.

The scientists found that the wasp lays its eggs in the aphids, one egg to each aphid. The egg hatches into a larva, which begins eating the inside of the aphid. It allows the aphid to stay alive for several days while it eats. Then the aphid dies, and the wasp changes to a pupa inside it. After several days, the adult wasp emerges from the pupa and breaks out of the body of the dead aphid. The wasp then mates and the cycle is repeated.

Fig 3.12.1 A trioxys wasp laying an egg in an aphid

The introduction of the trioxys wasp has been very successful, and the spotted alfalfa aphid is no longer a threat.

Dung beetles

Another very interesting example of biological control is the use of dung beetles to control bush flies. Many bush flies lay their eggs in the dung of animals. Dung beetles break up the dung and bury it, therefore removing the food of the bush fly larvae, so fewer bush flies are produced.

Dung beetles bury animal dung and lay their eggs in it. This reduces the number of places where bush flies can breed. *Fig 3.12.2*

Salvinia

Australia and New Guinea have had severe problems with a freshwater plant called salvinia, one of the worst waterweeds in the world. Salvinia is a floating fern, which can double the area it covers in a few days. It floats on the water surface and forms mats about a metre deep. This blocks all light from entering the water. The plants also remove oxygen from the water, causing water animals to die. Movement by boats through salvinia-infested water bodies is very difficult.

Lake Moondarra in Queensland became covered in the weed in 1980. Australia's famous scientific research organisation, the CSIRO, was called in to help. The CSIRO decided to try biological control. The scientists searched for a natural enemy for the weed, which they found in Brazil. It was a type of weevil, which fed on the plant. They collected some weevils and brought them to Australia and bred them. They were released onto the lake and in 14 months the weevils succeeded in rapidly reducing the weed to almost nothing.

Fig 3.12.3 The weevil that controlled the spread of salvinia

A similar problem occurred in New Guinea on the Sepik River. Again, the weevils were released and managed to clear the river of the weed.

These are two spectacular demonstrations of the use of biological control. They show that Australian scientists are leading the world in the control of waterweeds through biological control methods. They proved it again when they cleared Lake Victoria in Africa of the waterweed hyacinth.

Advantages of biological control

There are several advantages of the use of biological control over chemical pesticides. One advantage is that the pest does not become resistant to the biological control agent as it does to chemical pesticides.

A second advantage of biological control is that it targets only the pest. Chemical pesticides usually kill many other useful organisms, such as wasps, which are natural enemies of the pests. So pesticides may make the problem worse. They also kill useful organisms, such as bees, which may be helping to pollinate flowers. Usually the biological control agent kills the pest. It is very selective.

A third advantage of biological control is that it can become permanently established. It does not have to be regularly applied like pesticides. Once the control agent is released, it keeps on reproducing and so becomes a permanent part of the ecosystem.

A fourth advantage of biological control is that there is no use of chemicals and so there are no chemicals to accumulate in food webs. It is therefore preferable.

Fig 3.12.4 The Sepik river before and after the weevil was released to control salvinia

Disadvantages of biological control

The disadvantages of biological control are that many of the pests come from overseas, so their natural enemy has to be imported. However, such control agents may not be suited to the climate in Australia. When introducing a biological control agent the community must be sure it kills only the pest and not other organisms which are found naturally in the environment.

Other alternatives to pesticides

Pheromones are chemicals that an insect releases to affect the behaviour of others of its species. In the case of insect control, the main interest is in the chemical scents that female insects use to attract males for breeding.

Figure 3.12.5 shows how these can be used to reduce the mating of pests, which in turn reduces the number of the particular insects. The pheromone dispensers are twist-tie tubes with an artificially produced pheromone in them. This system is currently being used against the oriental fruit moth, a pest of peaches and nectarines. More research will result in its use for other pests.

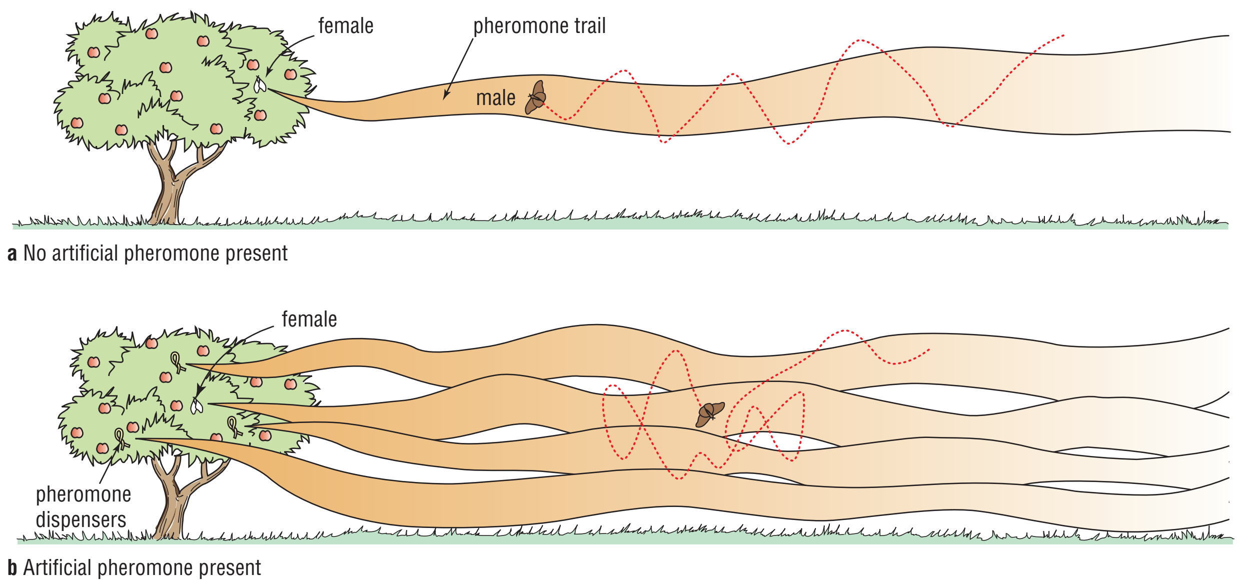
Breeding control involves interrupting the breeding cycle of the pest. For example, the breeding of flies can be controlled by covering rubbish, such as food scraps and lawn clippings. This prevents the flies finding a food supply in which to lay their eggs.

Removing feral animals—the Western Shield strategy

The fox and feral cat have contributed to the extinction of ten species of native mammal in Western Australia, and threatened many more. The Department of Conservation and Land Management (CALM) developed a strategy to poison these introduced predators. The clever solution was to use a naturally occurring poison in native plants, which native species are able to tolerate. The poison developed was called 1080. It was based on fluoroacetate, found in gastrolobiums or 'poison peas' (discussed in Focus 3.8). Foxes and cats are killed by this poison, but native mammals are not affected. The poison is distributed in sausages dropped from an aircraft.

Fig 3.12.6 The quenda, or southern brown bandicoot, was saved by the Western Shield program.

Fig 3.12.5 Releasing pheromones confuses male moths and reduces breeding.



The baiting began in 1993. It was soon discovered that cats would not usually eat these baits, but the foxes did. There has been a dramatic rise in the number of native animals since then. Near Collie, a check on woylie numbers by trapping, marking and releasing them found capture rates rose from less than one per 100 traps to nearly 70 per 100 traps after baiting for their feral predators. Chuditch numbers at Mundaring have increased nearly five-fold since fox control was begun.

The Western Shield program involves raising endangered animals in sanctuaries such as Kanyana and then releasing them in the areas where foxes and cats have been controlled. The numbat, noisy scrub-bird and ring-tailed possum are also beginning to increase. The woylie, quenda and tammar wallaby have been removed from the State's Threatened Fauna List as a result of successful conservation management under the Western Shield program.

The cooperation and support of local communities is vital as they help with fox-baiting by laying baits on their own land where it is next to conservation reserves and state forest. Publicly owned forest is baited four times a year at present.

Controlling pollution—the Cockburn Sound environmental strategy

Cockburn Sound is a fairly shallow body of water in the Indian Ocean near Rockingham in Western Australia. On the shore of the Sound are many industries, such as an iron and steel plant, power stations, a fertiliser manufacturer and a petroleum refinery.

Over a number of years people noticed an increase in foul smells and dead sea life. CALM became interested in the area, especially as the industrial area at Kwinana grew.

Studies showed that sea animals in the area had very high levels of **heavy metals** in them. Heavy metals, such as cadmium, lead, mercury, vanadium and zinc, were being absorbed by filter-feeding molluscs such as oysters and mussels. These metals were then being passed along the food chains. Seafood from the Sound thus had very high levels of poisonous heavy metals, which could cause severe illness and possibly death in humans. Clearly something had to be done to solve this problem.

CALM studied the area in an attempt to determine why the heavy metal contamination was so high. When studies of water circulation in the Sound were done, it was found that there was very poor mixing of water in the Sound with waters of the ocean beyond (as shown in Figure 3.12.7). Until the study was undertaken, it had been assumed that wastes dumped into the Sound would mix with the seawater and move out of the Sound. This was clearly not the case.

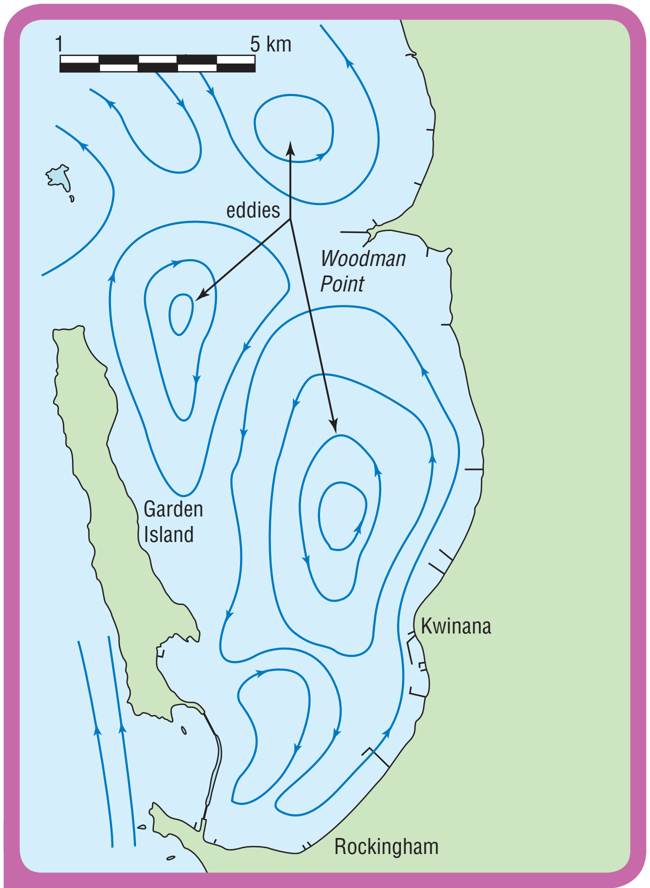


Fig 3.12.7 Water eddies in Cockburn Sound allowed pollution to build up.

The wastes were being trapped in the circulation patterns called eddies, and stayed in the Sound. So the heavy metal wastes were building up in the water of the Sound and reaching high concentrations. These were being absorbed by microscopic algae and then consumed by filter-feeding molluscs.

The obvious solution is to halt the disposal of high levels of heavy metal wastes into the Sound. It is proposed to pump the wastes into a pipeline that will transport them out beyond the Sound and into the Indian Ocean. However, there are people who consider this a less-than-satisfactory temporary solution, as the heavy metals are still being dumped into a natural ecosystem.

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Homework book 3.19 Managing rock lobsters

3·12 FOCUS [Questions]

Use your book

Biological control—alternative to pesticides

1 a How have bush flies been controlled in Australia?

b Briefly describe how the method works.

Advantages of biological control

2 Outline four reasons why biological control is superior to chemical pesticides in controlling the spread of pests.

3 Explain why a farmer who sprays insecticides on a crop is unlikely to kill all the insects of each pest species.

Other alternatives to pesticides

4 Explain how pheromones can be used instead of insecticides to reduce the numbers of insect pests.

Removing feral animals—the Western Shield strategy

5 a What is the aim of the Western Shield program?

b Describe the method of control that is used in the Western Shield program.

c Why are native animals not harmed by this strategy?

Controlling pollution—the Cockburn Sound environmental strategy

6 a Why did heavy metals reach high levels in Cockburn Sound?

b How could humans be poisoned by heavy metals entering the waters of Cockburn Sound?

c Why did the Department of Conservation and Environment recommend a pipeline to discharge the industrial waste into deeper water beyond Cockburn Sound?

Use your head

7 What reasons can you think of to explain why farmers still use pesticides, despite all the problems they cause?

8 In 1999, Lake Victoria in Africa was choked with water hyacinth, a floating weed. Dr Mic Julien, who had helped to find the solution to the salvinia problem in New Guinea, offered to assist. He had also succeeded in controlling the hyacinth in New Guinea by using a weevil (a different weevil from that used to control salvinia). He was again spectacularly successful in solving the crisis in Lake Victoria. Often biological control agents work well in some places, but not in others because the environments are different. Describe at least five environmental factors that could have been different in the Sepik River in Papua and New Guinea and Lake Victoria in Africa. Use an atlas to assist you.

Lake Victoria in Africa was cleared of water hyacinth weed using weevils. *Fig 3.12.8*

9 When the CSIRO scientists were searching for biological control agents for salvinia, they found it very difficult to find the place of origin of the weed. They had some idea it came from Brazil, so they searched there for a long time. Eventually they found small amounts of it in a small river system leading into the Amazon. Considering that it can cover large areas in a short time, why was it hard to find the weed in its natural environment?

10 The problem of heavy metal contamination in Cockburn Sound is planned to be solved by pumping the wastes further out to sea. On a global scale, can all governments adopt the same approach to using the ocean as a waste dump for the future? Explain your answer.

11 Prior to the implementation of the Western Shield program, fox-baiting research from Operation Foxglove produced the data shown in Figure 3.12.9. What conclusions can you make from this graph?

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Fig 3.12.9 Graph of chuditch numbers

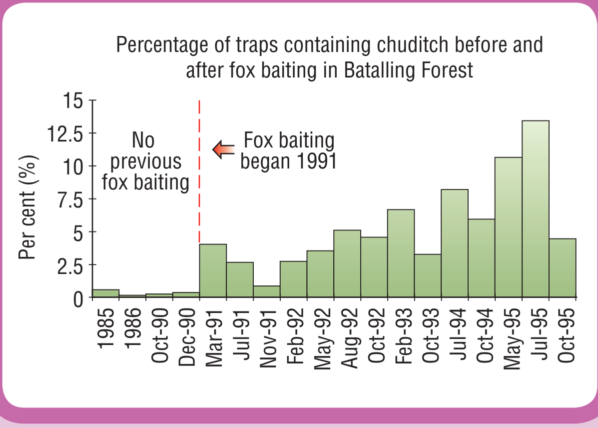


Fig 3.12.10 A chuditch

Cane toads were imported for biological control. Fig 3.12.11

Investigating questions

12 Search in your garden at home for aphid-infested plants. Roses and ivy are often attacked by them. Look for any evidence of natural predators such as wasps or ladybirds controlling the aphids. Observe for a few days. You may be able to observe a piece of the plant at school with a stereomicroscope.
- **a** How do you think the predators may have found the aphids?
- **b** What do you think will happen to the aphid population, and what could then happen to the predator population?

13 Use a library or the Internet to answer these questions about cane toads:
- **a** Why were they introduced into Australia?
- **b** What problems have occurred as a result of their introduction?
- **c** What lessons can be learnt from this experience?

14 Make a poster showing five threatened Australian species. Photographs from magazines and newspapers would be useful.
- **a** Show the habitat.
- **b** Give the population of each species.
- **c** List why each species is threatened.

15 Use the library or the Internet to find out about the aims of the following organisations: Greening Australia, the Australian Conservation Foundation, Greenpeace, and the World Wildlife Fund. Write a few lines on each.

16
- **a** List the names of five national parks or reserves in Western Australia.
- **b** Show where they are on a map of Western Australia.
- **c** Name the main organism or organisms that each park or reserve protects.
- **d** Describe the organisms and their importance.

17 Research one of the following activities and answer the questions below on the topic you chose to investigate.
- **i** fishing for rock lobster
- **ii** recreational fishing
- **iii** marroning
- **iv** harvesting wildflowers from the bush.
- **a** Find out which laws and regulations control the activity.
- **b** Explain why these laws and regulations are necessary.

19 Consider your own suburb.
- **a** What environmental damage do you see occurring?
- **b** Explain how you think it is happening.
- **c** What could be done to prevent it?

20 What research is being done into control of feral cats? Researching the CSIRO's Heirisson Prong program and CALM's baiting research under Western Shield will help you answer this question.

18 Research one of the following environmental issues and write about half a page outlining the problems that have occurred or may occur.

- **a** saline farmland
- **b** mining mineral sands
- **c** bauxite mining in the Darling Range
- **d** planting pine trees in native forests
- **e** doing regular small burns in forests to reduce leaf litter
- **f** allowing unlimited use of groundwater by private bores
- **g** using leaded petrol.

3·12 FOCUS [Practical activity]

Prac 1 Focus 3.12

Encouraging native animals in farming areas

Purpose

To explore ways of encouraging native animals in farming areas.

Requirements

A3 sheet of paper for each student.

Procedure

1 Form a group of about four students. You will be considering the following suggestions from a pamphlet designed to help farmers protect and encourage native animals:

- **a** Fence off from the stock any native vegetation remaining on the farm on land that cannot be used.
- **b** Plant a variety of trees and shrubs native to the area.
- **c** Leave old trees standing, especially those with hollows in them.
- **d** Form corridors of vegetation between bushland areas on the farm and neighbouring farms.

2 For each of the four suggestions above explore in your group all the reasons it will help native animals. *Each person in your group must write these down on their own A3 sheet of paper.*

3 Each student in your group moves and forms a new group with three students each from a different group. Take your A3 sheet with you.

4 Each student in the new group reads and explains the reasons they have written on the A3 sheet. If any ideas come up that you do not already have written down, *add them to your sheet.*

5 Report back to your first group and compare answers again to see if you can *add any more reasons to your sheet.*

6 Choose the best A3 sheet from your group and stick it up on the classroom wall.

Questions

1 What do you think is the most important reason for each of the suggestions on the pamphlet?

2 Do you think these suggestions could work? Explain your answer.

3 What other suggestions can you make that may assist farmers to protect native animals?

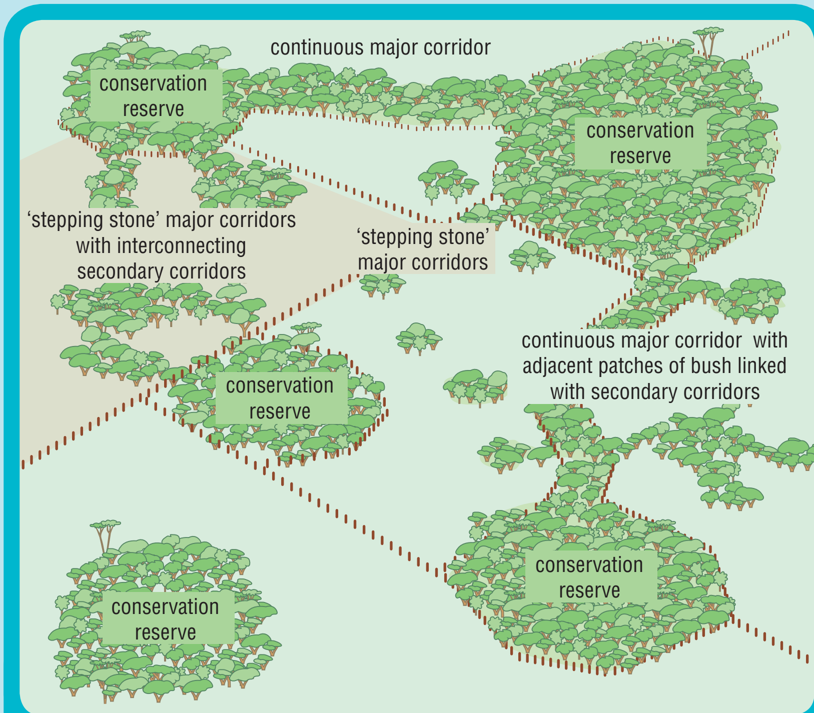


Fig 3.12.12 Isolated areas of bush should be linked.

Review questions

Interactive CW Crossword

Second-hand data

1 The diagrams in Figure 3.13.1 show the structure of some circulatory systems in fish, amphibians and mammals.

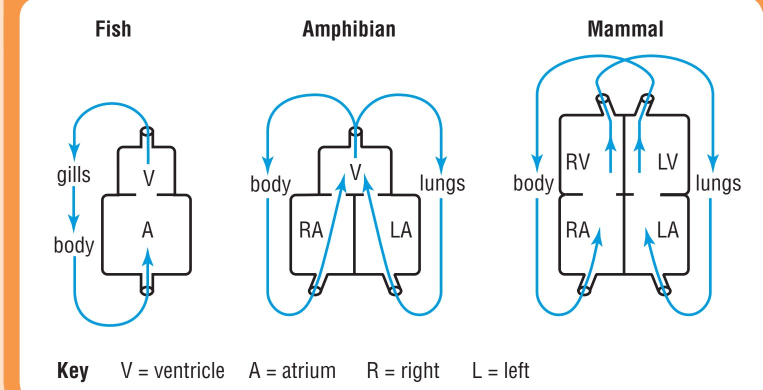
a Compare the number of chambers in the hearts of these three classes of chordate.

b Describe the differences in the way the blood circulates in these three classes.

c Fish blood passes through two capillary networks—the gills and the body—in one circuit. The blood pressure is low in the body capillaries, which means that oxygen is supplied slowly to the fish. What is different about the amphibian heart and what advantages does it give?

d How is the mammal heart superior to the amphibian heart in the oxygenation of the blood?

Fig 3.13.1 The circulatory systems in fish, amphibians and mammals



Open-ended questions/experimental design

2 You are an ecologist working for the state government department responsible for conservation and land management. Your task is to advise the state and local governments on the management of the area shown in Figure 3.13.2. You need to make a report on the suitability of the land uses for this area. Your report needs to outline:

a how the area is being used

b what problems could develop from this use

c how the possible problems could be prevented or solved

d whether each use is appropriate for the area or should be banned.

The science concepts supporting your conclusions must be presented.

3 In a recent book, an ecologist suggested that the minimum population size needed to ensure that a species survives is between 50 and 500 individuals. Imagine a new disease-causing type of bacteria has just entered a population of mammals. For this situation, apply the concepts you have learnt about biodiversity, inheritance and natural selection to explain what the scientist meant. Your answer should be about one page in length.

4 To understand how any ecosystem can exist and survive, you need to know about the flow of energy and matter through the system. The following questions relate to this idea.

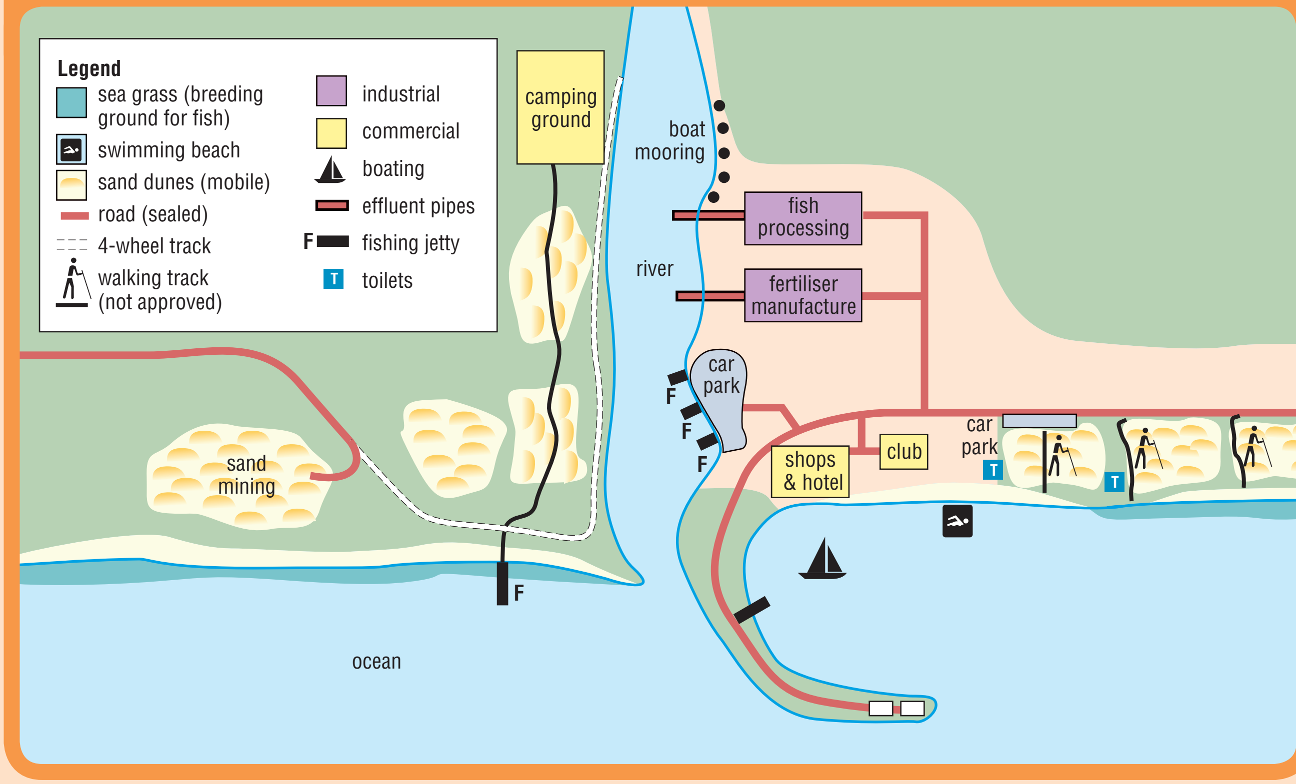
a Matter, such as carbon or nitrogen, ‘cycles’ in an ecosystem. Explain what this means, and why it is important.

b Energy does not cycle like matter does. Explain how it enters ecosystems and what happens to it as it flows through the ecosystem. Choose an example of a food chain to help explain.

c Explain how non-biodegradable poisons, such DDT in the past and other more modern pesticides, can become concentrated in food chains, building up to high levels in top carnivores. A pyramid of biomass will help you explain.

d Explain, using the carbon or nitrogen cycles as an example, how habitat destruction may affect the cycling of matter in an ecosystem.

Fig 3.13.2 A coastal ecosystem



Extended investigations/research

5 As you learnt in Focus 3.6, albinism is an inherited condition controlled by a single gene. In this condition the cells do not produce the pigment called melanin, which produces the colour in your skin, hair and eyes. The production of this pigment is under the control of genes. Albinism occurs in many different animals, including humans. You can identify an albino from an animal that just has white skin or fur because in an albino the iris of the eye appears as pink or light blue.

This task requires you to research some aspects of albinism.

a Albinism is found in many animal species. Find an example of an albino animal (different from the example given in the text). Identify the area in which it was found and any special features it may have. You should also include a picture of the animal you have identified.

b How does albinism affect the chance of animals surviving in the wild?

c Find an example of a pedigree diagram for the inheritance of albinism and explain how you think albinism is inherited from the evidence in the pedigree.

d Use a Punnett square to show how predictions of albinism occurring in future generations can be made.

6 Design and conduct an experiment testing the effect of light, moderate and strenuous exercise on the human respiratory and circulatory systems. For your experiment you will need to find out from your teacher how to measure pulse rate and breathing rate. Your teacher may also want you to investigate blood pressure changes. If so, find out how to measure blood pressure. When discussing your results, explain how these changes in the circulatory and respiratory systems enable us to exercise.

Homework book 3.20 Life and Living crossword

Homework book 3.21 Sci-words

4 Natural and processed materials

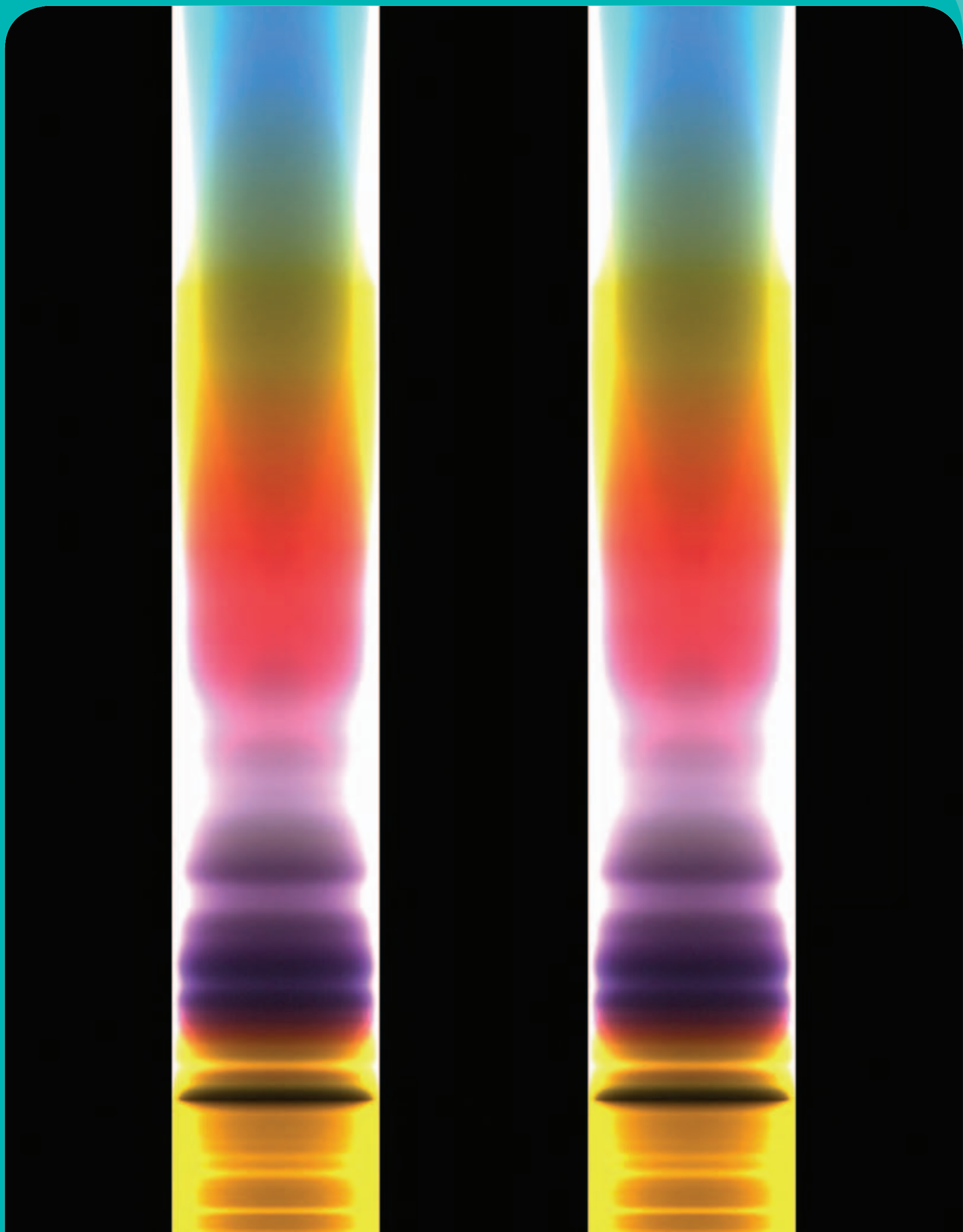
Curriculum guide learning focus

- atoms and atomic structure
- grouping of substances based on properties
- relating chemical properties to structure
- bonding and structure
- relating properties to uses of materials
- physical and chemical change and the kinetic theory
- common chemical symbols, formulae and equations
- families of substances such as organic compounds like polymers
- sustainability and the role of chemistry

This section on Natural and Processed Materials also contains work that will help students with the outcomes of Investigating, Communicating Scientifically, Science in Daily Life, Acting Responsibly and Science in Society.

Outcome level descriptions

The outcome level descriptions for Natural and Processed Materials covered in this section of the book are mainly NPM 5.



FOCUS 4•1 Chemical bonding and uses

Context

If you know how atoms bond together you can begin to understand why materials have so many different properties. In Focus 5.6 of *Science Aspects 2* you learnt about molecules and ions. You should also have learnt about bonding in Focus 5.7. If you have not covered these two Foci, it would be a good idea to work through them before starting this Focus. In this Focus you are going to continue your bonding journey to explore the different groups of materials that can be formed. Having a knowledge of bonding gives the scientist the skills to produce new and exciting materials with improved properties.

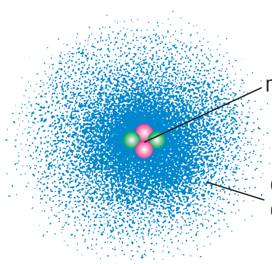
Atomic structure and bonding revisited

You cannot start a discussion about bonding without reviewing the structure of the atom. In Focus 5.6 in *Science Aspects 2* you began your journey into the structure of the atom by looking at the structure of a typical atom. The central **nucleus** is composed of **protons** and **neutrons**, while most of the atom is composed of the electron cloud containing **electrons**. The number of protons within the nucleus determines the type of atom and its position in the periodic table. You should also recall that the number of electrons is equal to the number of protons in an electrically neutral atom.

Interactive CW Animation

The electrons within the electron cloud of the atom are at the heart of bonding. Bonding involves the sharing or transfer of electrons between atoms.

Fig 4.1.1



In *Science Aspects 4* you can explore the structure of the atom in even more detail if you wish to understand this at a higher level. There you will see that the number of electrons in the electron cloud determines the type of bonding in an atom. You will also explore how atoms form bonds with other atoms (the same or different) so that they become more **stable**.

When atoms bond they become more stable. This means they are more likely to stay together than to remain apart. This can occur in three main ways:

- by giving an electron or electrons to other atoms
- by taking an electron or electrons from other atoms
- by sharing an electron or electrons with other atoms.

These three main types of bonding are described in Figure 4.1.2.

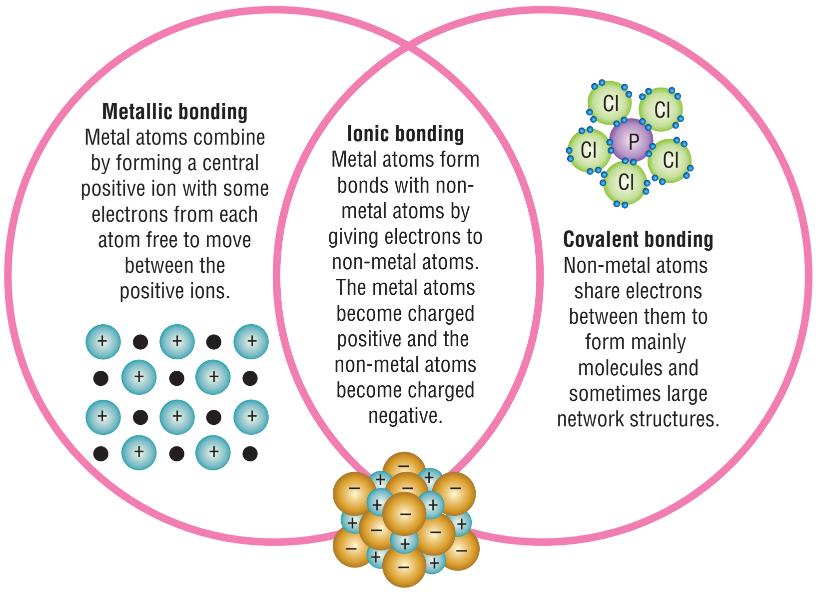


Fig 4.1.2

Metal atoms are bonded by metallic bonding. Covalent bonding the sharing of electrons. Ionic bonding involves the transfer of electrons from metals atoms to non-metal atoms.

Bonding and lattices

Crystals of gold Fig 4.1.3

Science Snippet

Crystals of gold

Crystals of gold are extremely rare but can be found. All substances form crystals or lattices. In crystals the atoms, ions or molecules are arranged in regular patterns, which accounts for their organised and structured shapes.

All substances can form solid crystals or lattices. How the atoms are bonded determines the properties of each of these lattices. You need to be aware of these special properties when selecting materials for a particular purpose. You will now explore the main types of lattices—metallic, ionic and covalent.

Metallic lattices

When you think of metals, what are some of the special properties that come to mind? Is it their strength? Is it their ability to be bent into a range of shapes, or even stretched into thin wires, or is it their shiny surfaces? All these special properties can be explained by exploring how atoms are arranged in metal lattices.

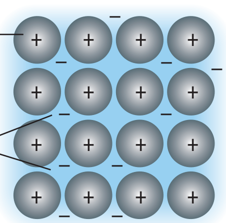


Fig 4.1.4 Many of the special properties of metals can be explained by the strong bond which exists between the free-moving outer electrons of the metal atoms and their strong attraction to the central positive metal ion.

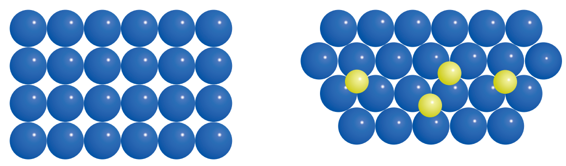
The outermost electrons in metal atoms are free to move throughout the positive metal ions. These electrons are often referred to as **mobile electrons**. But the positive metal ions cannot move out of their positions. Because the electrons can move about but the positive ions cannot, the force between the electrons and ions is constantly changing direction. This force is therefore called a **non-directional** force of attraction. This type of force means that metals can be bent or pressed into a variety of shapes or pulled into thin wires without shattering. The strength of these non-directional forces is also responsible for the high melting point of most metals. The atoms in metal lattices are also tightly packed, which results in them being more dense than many other non-metals.

Fig 4.1.5 The non-directional forces between the mobile electrons and positive metal ions mean that metals can be bent and still keep their inner strength without shattering, as would happen with many non-metal lattices. This pipe-bending machine takes advantage of this property.

An **alloy** is usually a mixture of metals, but in the case of some steels it is a mixture of a metal (iron) and a non-metal—carbon. Adding small amounts of different atoms to a metal changes the structure of the metal lattice and therefore changes the properties of the metal. In most cases the lattice becomes more **rigid** and as a result the alloy is **harder** and stronger than its base metal. Steel, for example, is much harder than pure iron (wrought iron). Brass (copper and zinc) and bronze (copper and tin) are both harder than pure copper.

The strength of these alloys is often due to the fact that atoms of a different size in the crystal stop atoms slipping past each other so easily. The impurities seem to lock the rows of atoms together.

Fig 4.1.6 In alloys, different metal atoms change the way in which the atoms are packed and change the properties. Generally they make the metal lattice harder and stronger.



The mobile electrons that make up metals are also carriers of electric charge. When electrons enter the metal a similar number of mobile electrons from the metal leave (or are displaced) from the other end. In this way a constant movement of electrons and therefore negative electric charge is maintained through the metal. The mobile electrons in the metal lattice also readily carry thermal energy and so metals are also good conductors of heat.

Ionic lattices

Ionic substances are formed when an atom (generally a metal) loses an electron(s) to a non-metal atom (or group of atoms). The metal becomes a **positive ion** (**cation**) and the non-metal becomes a **negative ion** (**anion**). Different atoms can form different charged ions. You can review this in Foci 5.7 and 5.9 of *Science Aspects 2* before you continue reading here.

In solids, these positive and negative ions form three-dimensional **ionic lattices** that have the following properties:

- They are hard and brittle.
- They have high melting points and boiling points.
- They are non-conductors when solid but if the solid is melted or dissolved in water they become conductors.

Science Snippet

All that glitters could be a metal!

Another common property of metals is that they have a shiny surface—at least when they are freshly cut, cleaned or produced from their ore. The freely moving electrons within the metal lattice readily reflect light, which makes them appear shiny. This is called 'metallic lustre'. Non-metals do not have these freely moving electrons, so they often appear dull.

These properties of ionic lattices give us clues as to how the ionic lattice is arranged. The diagram in Figure 4.1.7 shows the arrangement of the sodium and the chloride ions in a lattice of sodium chloride.

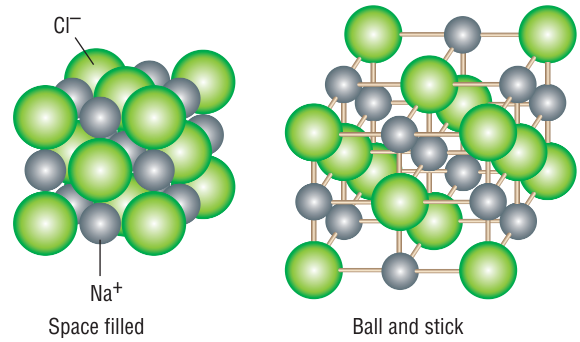
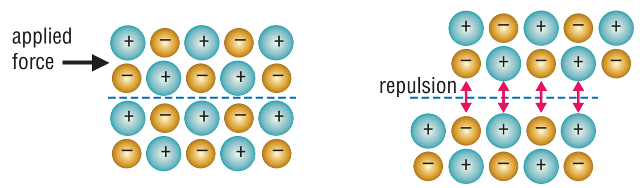


Fig 4.1.7 Ionic lattices. The diagram on the left is called a **space-filled model** and best shows how the ions are packed in 3-D space in the lattice. The diagram on the right is called a **ball-and-stick model** and best shows the angles and arrangement of the ions within the 3-D lattice.

Compare this diagram of the ionic lattice with that of the metal lattice. Did you notice that in ionic lattices there are no moving electrons between the ions? This means that the attraction between the ions within the lattice acts in a particular direction—that is, between each other. A force applied to a section of an ionic lattice can cause the rows of ions to slip. Then whole rows of ions of the same charge can come close to each other. Because they are the same electric charge, they will repel each other. This repulsion is so strong it can cause the crystals to shatter. So it is the repulsion that blows the crystal apart. This property of shattering under a force is described as being **brittle**. This is shown in Figure 4.1.8.

Fig 4.1.8 Pushing on an ionic lattice can cause it to shatter. Ionic crystals are said to be brittle.

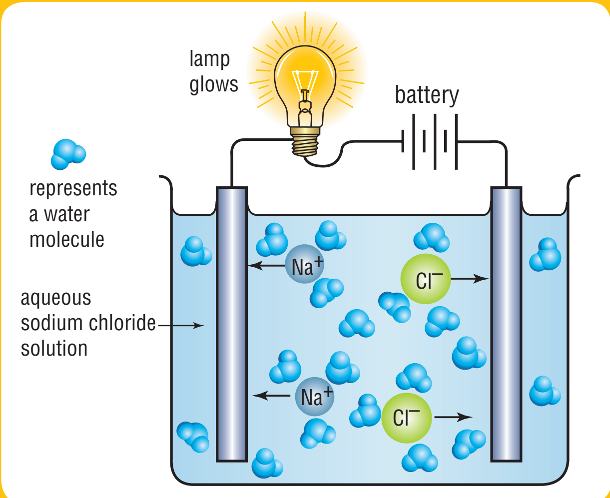


The force of attraction between the positive and negative ions is strong. This means that to melt an ionic solid we would need to apply a lot of thermal energy. As a result, melting and boiling points of ionic solids are generally very high. For example, to melt sodium chloride we need a temperature of 801°C, while aluminium oxide melts at 2045°C. Compare this to melting sulfur at 113°C, tin 232°C or sugar 192°C.

This strong attraction between the positive and negative ions does not allow ions to freely move within the lattice. Unlike metals, when a voltage is applied to an ionic solid there is no movement or flow of electrons or ions through the ionic lattice. So ionic solids do not conduct electricity as solid crystals.

Many ionic solids are soluble in water. Water has the ability to interact with the positive and negative ions and to break down the solid lattice. As a result the ions are free to move in solution. When a voltage is applied to ionic solutions, the positive ions move to the negative side of the applied voltage while the negative ions move to the positive side of the applied voltage. This ion movement produces a movement of charge or a current.

Fig 4.1.9 When a voltage is applied across an ionic solution there is a movement of ions, which can be detected as an electric current.



As you might expect, when ionic solids are melted, the ions are no longer held in a tight lattice and are free to move. As with solutions, molten ionic substances will also conduct an electric current. This is because the ions will move when a voltage is applied across the molten ionic substance.

Covalent substances

Covalent bonding involves atoms sharing electrons to become more stable. Depending on how the electrons are shared the result is two different types of substance. One type is made of individual (**discrete**) molecules, and is called a **covalent molecular** substance. The other is made of one large interconnected **network** and is called a **covalent network** substance. Covalent molecular and covalent network substances have very different properties, even though in both cases the atoms are bonded by sharing electrons.

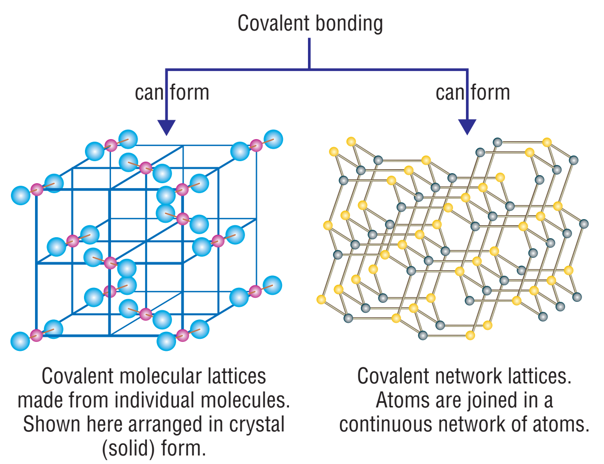


Fig 4.1.10 Both covalent molecular substances and covalent network substances involve atoms sharing electrons. While covalent molecular substances contain individual (discrete) molecules with weak attractive forces between them, covalent network substances consist of large networks of interconnected atoms.

The way that the atoms are arranged in both covalent molecular substances and covalent network substances results in substances with some very different properties, as shown in the following table.

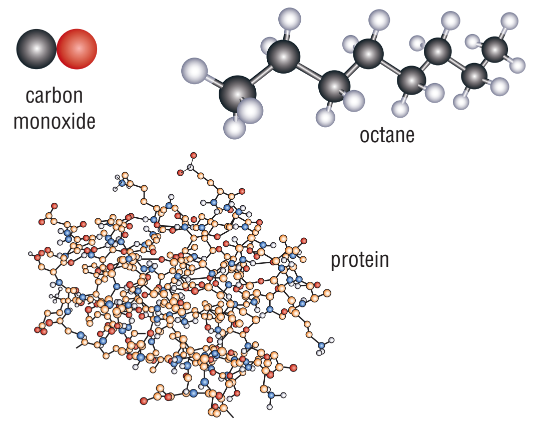
Properties of covalent molecular substances	Properties of covalent network substances
Low melting and boiling points (often under 250°C)	High melting and boiling points (often well above 250°C)
Non-conductors of electricity when either solids or liquids	Non-conductors of electricity when either solids or liquids
Solids are often soft and often have an odour	Solids are often very hard and brittle

You can explain these properties in terms of how the atoms are arranged.

Covalent molecular substances

Covalent molecular substances make up the largest group of substances! The millions of organic compounds (see page 250, Focus 5.8, *Science Aspects 2*) are all covalent molecular substances. All covalent molecular substances are made up of individual molecules. The forces between these molecules are very weak compared with the strong electrostatic forces found between ions in ionic solids, or between electrons and ions in metals.

Fig 4.1.11 Covalent molecular substances can range from simple molecules as carbon monoxide molecules through to large complex protein molecules.



The weak bonds between the molecules in a covalent molecular solid (called **intermolecular forces**) means that the molecules can be easily separated. As a result, covalent molecular substances have much lower melting points, typically below 250°C.

Would you expect covalent molecular substances to be good conductors of electricity in the solid or liquid state? In order for a substance to be conductor of electricity there must be charged particles (such as ions or electrons) present. These are not present in covalent molecular substances and as a result they do not conduct electricity either as a solid, in solution or when they are melted.

Another important property of covalent molecular substances is their ability to produce an odour. This can also be explained by the weak forces between the molecules. As covalent molecules gain thermal energy they can escape from the substance. If these small amounts of vaporised molecules reach your nose they can be smelt. If the temperature of a covalent molecular substance is increased, the number of molecules leaving the substance increases and so does the strength of the odour. The weak force between covalent molecules can also be used to explain why most covalent molecular substances are softer than ionic solids or metals.

Covalent network substances

Covalent network substances are special in that the atoms in the lattice are not arranged to form individual molecules but rather form a large interconnected network.

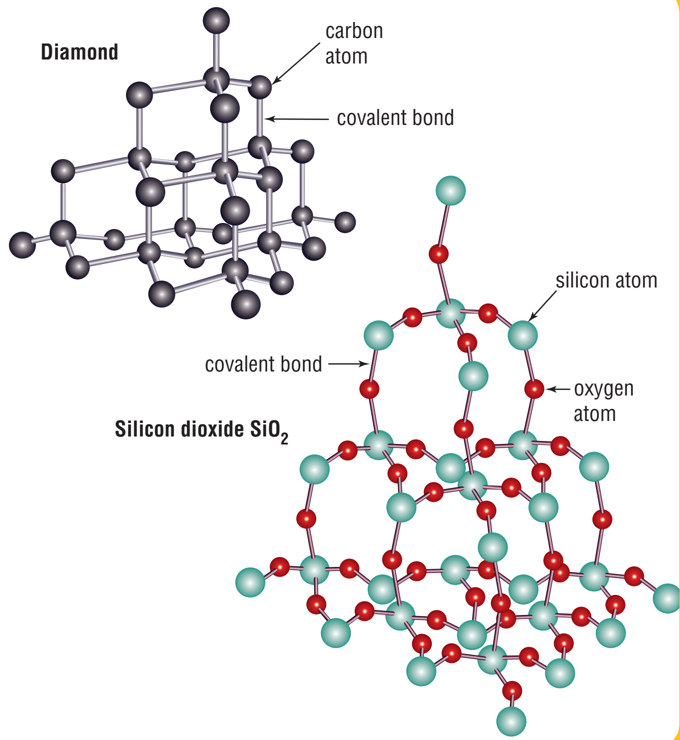


Fig 4.1.12 In covalent network substances, such as diamond and silicon dioxide, the atoms join together in continuous network. Can you think of some special properties this would give the network solid?

Covalent network substances such as diamond have very high melting points. Diamond has a melting point of 3820°C while silicon dioxide melts at 1710°C. These high melting points can be explained in terms of the arrangement of the atoms in the large network. A lot of thermal energy is required to break the individual atoms out of the continuous network.

As with covalent molecular substances, there are no charge carriers (ions or electrons) in covalent networks substances so they are not conductors in either the solid or liquid state.

All atoms within a covalent network substances are held within a rigid network lattice structure, which explains why are they are very hard yet brittle.

Relating properties of materials to their uses

In this Focus you have explored the special properties of the four main groups of substances. These are summarised in the concept map in Figure 4.1.13.

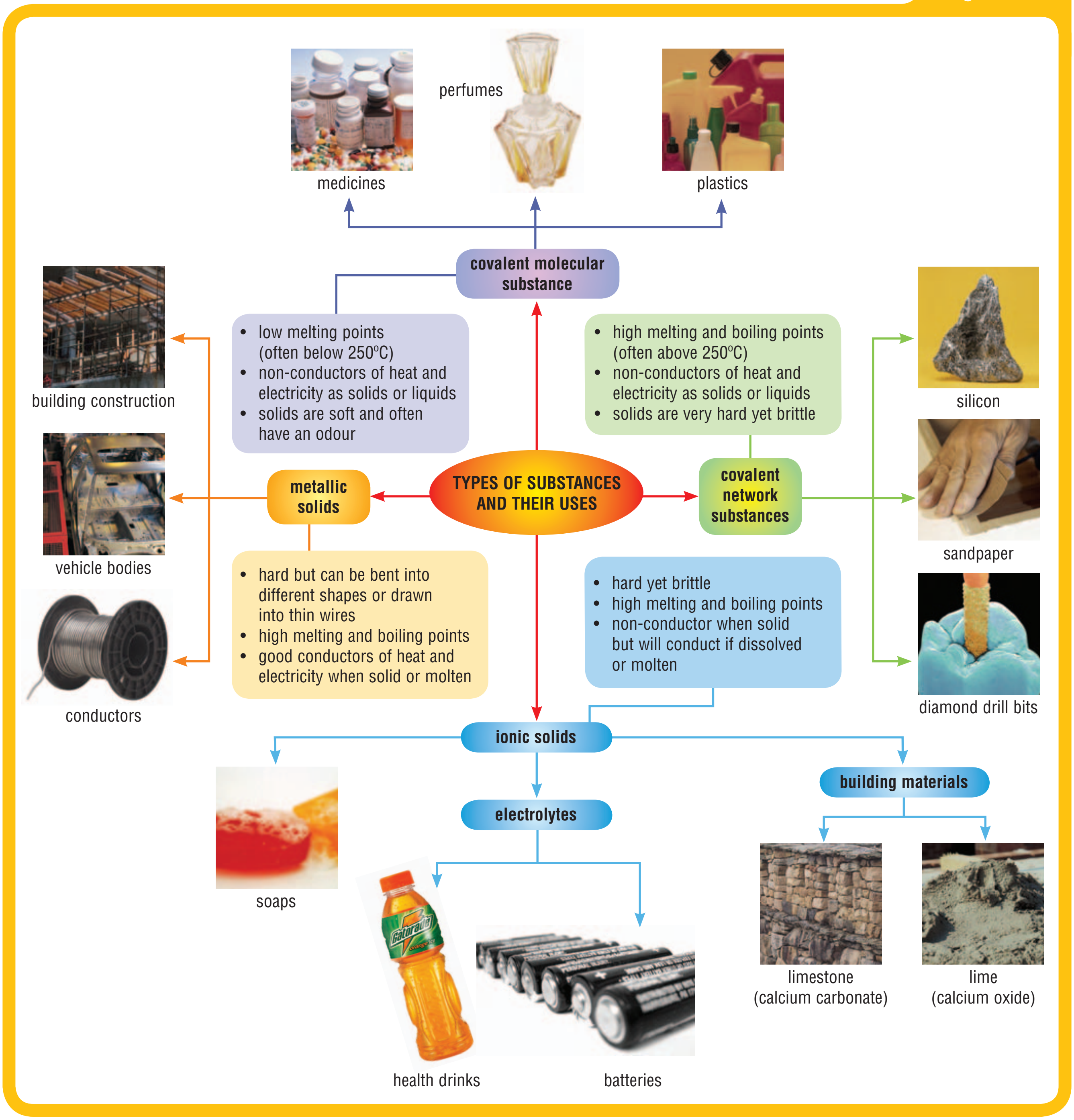
We choose materials for a purpose because of their special properties. Can you think of some special uses for some of these materials? Some samples have been included in the concept map.

Homework book 4.1 Sticking together

Prac 1 p. 193

Drag and Drop Interactive

The properties of the main groups of substances can often be related to their special properties. *Fig 4.1.13*



4•1 FOCUS [Questions]

Use your book

Atomic structure and bonding revisited

1 Describe the general structure of an atom, making sure you include the following terms—nucleus, electron cloud, electrons, protons and neutrons.

2 Why do atoms form chemical bonds with other atoms?

3 Outline, in terms of electrons, how atoms form bonds with other atoms.

4 Copy the following table into your notes. The table lists the types of particles present and how they are arranged in metallic, ionic and covalent substances. Complete your copied table in your notes. You can select from the following list of particles to do the second column: metal ions, electrons, negative ions, atoms.

Type of substance	What particles would be present	How these particles are arranged in the solid (a diagram can be used)
Metallic substance		
Ionic substance		
Covalent substance		

Bonding and lattices

5 Explain the following properties of metals in terms of the way the particles are arranged. Refer to your answer to question 4 above to help you.

a Metals are strong.

b Metals can be bent into different shapes (malleable) or stretched into thin wires (ductile), without breaking.

c Metals have high melting points.

d Metals are good conductors of heat and electricity.

6 Outline, using a simple diagram to show structure, why alloys tend to be harder and more brittle than the pure metal from which they came.

7 Silver chloride is an ionic solid consisting of the silver ion (Ag^{1+}) and chloride ion (Cl^{1-}) arranged in an ionic lattice. Explain the following properties of silver chloride:

a Silver chloride crystals are hard and brittle.

b Solid silver chloride will not conduct an electric current but if we melt the silver chloride or dissolve it in water it will.

c Silver chloride has a fairly high melting point (455°C) and a very high boiling point (1550°C).

8 Two oxygen atoms bond together to form an oxygen molecule (O_2). The bond between the atoms is a covalent bond. What happens between the electrons of each atom to form a covalent bond?

9 The table below describes four materials that contain substances bonded covalently:

a Classify each of the substances above as either 'covalent molecular substances' or 'covalent network' substances.

b Explain why you made your choice in each case.

Covalent molecular substances

10 Naphthalene, the main component of mothballs, is an organic compound that consists of molecules of $C_{10}H_8$. Explain the following properties of this substance.

a It is a non-conductor of electricity as a solid and when melted.

b It has a relatively low melting point of 80.5°C.

c It has a very distinctive odour (mothballs).

d It is soft.

Name of substance	Chemical formula	How are the particles arranged	Melting point
Dry ice—solid carbon dioxide	CO_2	Consists of molecules of carbon dioxide	Sublimes (changes from solid to gas) at –78°C
Silicon dioxide (main component of sand)	SiO_2	Silicon and oxygen atoms are interconnected at a ratio of one silicon atom to two oxygen atoms	1710°C
Solid water	H_2O	Consists of molecules of water—H_2O	0°C
Graphite	C	Consists of layers of carbon atoms joined in a continuous interconnected network	3650°C

>>

Covalent network substances

11 Explain why silicon dioxide (sand) is used as an abrasive on sand paper. In your answer refer to the way that the atoms are arranged within the silicon dioxide.

12 Covalent molecular substances such as silicon dioxide, diamond and graphite have very high melting points (1710°C, 3820°C and 3650°C respectively). Explain this observation in terms of how the atoms are arranged in this substance.

Use your head

13 The table below contains a description of a variety of materials along with some uses made of these materials. In your notes classify each of substances A to G as a metallic solid, ionic solid, covalent molecular solid or covalent network substance.

14 The following list names the substances A to G in question 13 in random order.

quartz, ethanoic acid crystals, sodium iodide, plastic, aluminium, silicon, diamond

Based on the properties and uses of these materials, identify each material A to G by name.

Investigating questions

15 Carbon is found in many different forms. Two of these forms, diamond and graphite, are network solids. Though both are networks solids, they have different properties. Research both these forms of carbon and compare and contrast their properties. Use diagrams if possible to explain how the arrangement of the atoms in the network accounts for these differences.

16 In 1985 another form of carbon was discovered. These molecules are called **fullerenes**. They include a covalent molecular form of carbon called **buckminsterfullerene** or the **buckyball**. Use the Internet to research **buckyballs**.

- Describe the structure of buckyballs. What is their chemical formula?
- In terms of the way that atoms are bonded, why are buckyballs molecules and not a network solid?
- What are some of the potential uses of buckyballs?

Substance	Description and properties of substance	Uses
A	This material forms soft, crumbly crystals and has a melting point of 16.6°C	Used to produce plastics such as soft drink bottles Dilute solutions are edible and often used as flavouring for salad dressing and similar foods
B	This material forms very hard colourless crystals. It does not dissolve in water and has a melting point of over 3000°C	A highly valued gemstone used in jewellery An excellent abrasive and cutting material used on drill bits and engraving tools
C	This material forms colourless crystals that have a melting point of 661°C. The crystals are hard and brittle and dissolve in water. The solid does not conduct electricity but when dissolved in water a conducting solution is produced	Used in some industrial processes Edible in low concentration and often added to normal table salt (sodium chloride) to treat and prevent iodine deficiencies
D	This material forms silver-coloured crystals. It is very hard and does not conduct electricity very well. It has a melting point of 1414°C	In the pure form, used to produce semi-conductor devices required for computers and many electronic devices Used to produce photovoltaic devices that convert energy in sunlight into electrical energy
E	This material is very hard and melts at a temperature of 1610°C. It does not conduct electricity in either solid or molten form. It forms colourless crystals	One of the most common crystals in the Earth's crust Used in the manufacture of glass, paints and abrasives Used in electronic devices
F	This material is reasonably soft and can be bent into different shapes. It has a melting point of 660°C. It conducts in the solid and molten state	Very common building and structural material. It is relatively light yet strong and used to manufacture aeroplanes, rockets, bus bodies and cars
G	This material is easily scratched. It is black with a melting point of 185°C. It is a non-conductor of electricity	Used for a huge range of products, including food containers, appliance casings, plumbing pipes, eye glass frames etc.

4•1 FOCUS

[Practical activity]

Prac 1 Focus 4.1

Testing properties

Purpose

To test the properties of a range of materials and relate these to their use.

Requirements

Your teacher will supply you with a range of substances, including aluminium, copper, zinc, magnesium, sodium chloride, sodium iodide, copper sulfate, water, solid iodine, sulfur, sugar and clean sand (silicon dioxide). Your teacher may supply you with other substances.

Safety note: Sodium iodide is toxic—do not touch it with bare hands, handle carefully and wash your hands at the completion of the activity. Iodine will stain clothing—work on newspaper or a bench protector. Any heating is to be done by the teacher in a fume hood (particularly sulfur and iodine), as the fumes may be toxic. Heat materials in a crucible and take great care when handling these materials. Your teacher will provide further safety guidance.

Procedure

You are to design your own investigations to test the following properties of each of your materials:

- electrical conductivity of all the solids
- electrical conductivity of solutions of solids (for those that will dissolve in water)
- electrical conductivity of molten solid (teacher demonstration only)
- malleability
- lustre
- hardness
- other properties as you decide.

Do not proceed until you have checked with your teacher.

Design your own results table and record your observations as you proceed.

You will find it useful to refer back to Foci 5.6 and 5.7 of *Science Aspects 2* when designing your investigation.

Questions

1 Classify each of the materials you tested as ionic solids, metallic solids, covalent molecular or covalent network substances based on their observed properties.

2 Suggest and research uses for each of these materials based on their properties.

FOCUS 4.2

Solubility

Context

We all know that when we stir some sugar into a cup of tea or coffee it dissolves. We have a 'solution'. But solutions go so much further than this. Have you considered that the air we breathe is a solution? Did you know that the hiss of gas as you open a can of cola is a soluble gas coming out of solution? In this Focus you will also look at how you can measure solubility. You will also explore the tools that allow you to predict what happens when different soluble substances are mixed. Knowing about solutions and the factors that affect solubility is not only useful in the laboratory, it is also important in helping our environment when you consider such things as the run-off of water-soluble fertilisers.

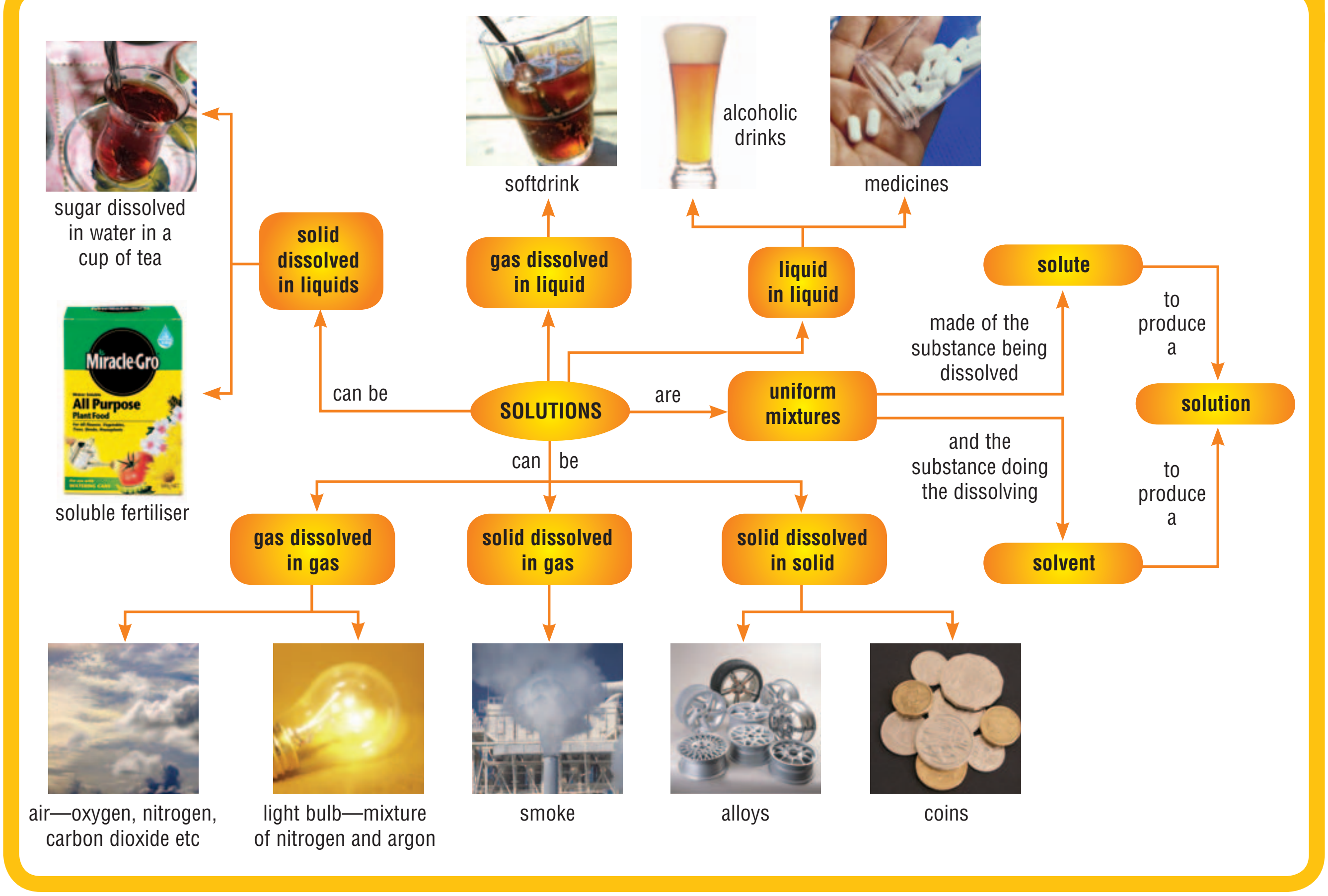
Types of solution

So what is a solution? In *Science Aspects 1* you first explored solutions. Solutions are uniform mixtures. Uniform means that the particles of the substance being dissolved (the solute) and the particles in which the solute is dissolved (solvent) are mixed evenly. There are thousands of examples of solutions, both natural and human-made. In this Focus you will mainly discuss the dissolving of solids in liquids. But it is important to note that there are many different other examples of solutions, as shown in Figure 4.2.1.

Interactive CW Animation

While solids in liquids are a common type of solution, there are many other examples of solutions.

Fig 4.2.1



Measuring concentration

When a solute is dissolved in a solvent, the resulting solution has a concentration. The term **concentration** refers to how much of the solute is dissolved in the solvent. We use terms such as **concentrated** and **dilute** to describe this. A concentrated solution is one in which a lot of solute is dissolved in the solvent while a dilute solution contains only a small amount of dissolved solute. However, the concentration of solutions often needs to be measured accurately, such as in manufacturing, cleaning, prescription drugs and medicine. There are several ways of expressing the concentration of a solution. In this Focus you will look at concentration expressed as:

- grams per litre (g per L or g L^{-1})
- percentage composition by mass.

Fig 4.2.2 There are several units for expressing concentration. In alcoholic drinks the concentration of the alcohol dissolved in the drink is expressed as a percentage of the total volume.

Grams per litre (g per L or g L^{-1})

If you took a litre of sea water and evaporated all the water away you would be left with about 20 grams of salt (sodium chloride). In other words, the concentration of the salt is 20 grams per litre or 20 g per L (g L^{-1}). If you know the amount of dissolved solute and the volume of solution you can use the following relationship to work out the concentration of any solution:

$$\text{concentration (grams per litre)} = \frac{\text{mass of solute (g)}}{\text{volume of solution (L)}}$$

Follow this example: Kate dissolves 100 g of sugar in 250 mL of water. What is the concentration of the sugar in grams per litre?

mass of solute = 100 g

volume of solution = 250 mL ($\frac{250}{1000}$ = 0.25 L)

$$\begin{array}{c}\text{concentration}\\ \text{(grams per litre)}\end{array} = \frac{\text{mass of solute (g)}}{\text{volume of solution (L)}} = \frac{100\text{g}}{0.25\text{L}} = 400 \text{ g L}^{-1}$$

Percentage composition by mass

When we use this method of measuring concentration, we express the amount of solute dissolved in the solution as a percentage of the mass of the whole solution. This can be shown as an equation:

$$\begin{array}{c}\text{percentage composition}\\ \text{(concentration)}\end{array} = \frac{\text{mass of dissolved solute (g)}}{\text{mass of solution (g)}} \times 100$$

Work through the type example below which shows you how to apply this equation. If people are dehydrated or have lost a lot of blood they are often put on a 'saline drip'. A 500 g sample of saline solution is found to contain 0.5 g of salt. What is the percentage composition (concentration) of salt in saline?

mass of solute = 0.5 g

mass of solution = 500 g

$$\begin{array}{c}\text{percentage composition}\\ \text{(concentration)}\end{array} = \frac{0.5}{500} \times 100 = 1\%$$

The saline solution is 1% salt.

Saturated and unsaturated solutions

If you add a small amount of soluble material to water at a certain temperature it will dissolve. If you keep on adding solute you would eventually get to the point where no more of the solute will dissolve at that temperature. At this point, you would have a saturated solution. A **saturated solution** is one where no more of the solute will dissolve at that temperature and pressure. At any point before the saturation point, the solution is said to be **unsaturated**.

The saturation point occurs at different points for different solutes. For example, salt reaches its saturation point at about 360 g per litre.

The following table shows some solubilities in grams per litre of a range of common materials.

Substance and formula	Solubility (grams per litre) at 20°C
Salt (sodium chloride)—$NaCl$	360 g per L
Sugar (sucrose)—$C_{12}H_{22}O_{11}$	2000 g per L
Magnesium hydroxide—$Mg(OH)_2$	0.012 g per L
Ammonium chloride—NH_4Cl	297 g per L
Barium sulfate—$BaSO_4$	0.00115 g per L

Under certain conditions, it is possible to dissolve solute past its saturation point. This has to be done carefully and in very clean conditions. These types of solutions are said to be **supersaturated**. Some supersaturated solutions (such as supersaturated sugar) are very stable, while others are very unstable and the smallest disruption to the solution, such as movement or dust, will cause the extra solute to crystallise out of solution.

Factors that affect solubility

Dissolving is more complicated that you might think! Whether or not a substance will dissolve in another substance or how much of it will dissolve depends on a number of factors including:

- how the solvent and solute interact
- the temperature of the solvent
- the pressure (for gases dissolving in liquids).

How the solvent and solute interact

Dissolving is a more complicated process than you might think. From a macroscopic (observations made with the eye) point of view, nothing much appears to be happening other than the solute 'disappearing' into the solvent. At the atomic level, however, dissolving involves the interaction of the solute with the solvent. Solute particles will only dissolve when they have some way of interacting with the solvent particles. If there is no interaction between the particles the solute will not dissolve and we classify the solute as being 'insoluble' in that solvent.

Fig 4.2.4 Iodine is insoluble in water (test tube on the left), as there is no interaction between the iodine and water molecules. If, however, the crystals are placed in a solvent such as methylated spirits, they readily dissolve.

Fig 4.2.3 Many supersaturated solutions are unstable and the slightest disruption, such as the addition of a small seed crystal, will cause crystals of the solute to form in the solution.

Science Snippet

Toffee—a supersaturated solution

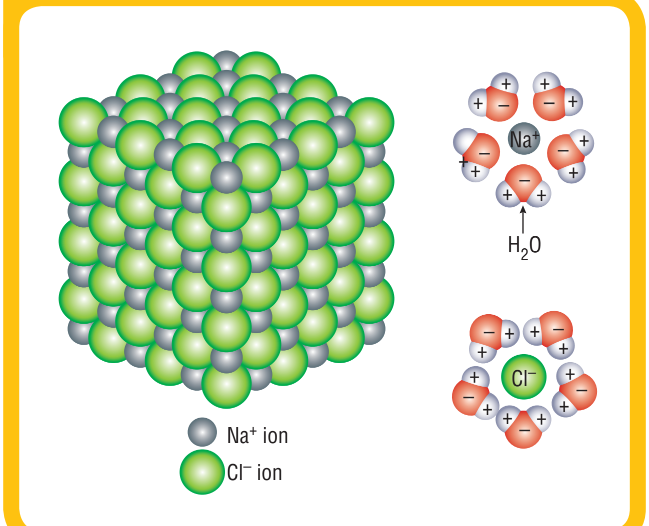
To make toffee, sugar and many other materials are heated up as they are dissolved. More sugar stays in solution after the solution is cooled than would normally. This is usually quite an unstable state and the sugar would normally crystallise. To help prevent this happening, toffee (and other lollies such as caramels) are often mixtures of different sugars. A mixture of sugars is more difficult to crystallise as the different sugars disrupt the crystal-forming process. Adding fat (as in the form of butter) also disrupts the crystal-forming process, thus keeping the toffee free of crystals and smooth!

The terms 'soluble' and 'insoluble' are used in reference to water. Water is called the **universal solvent** because it is a very common solvent with wide dissolving properties. You will explore the special properties of the water molecule in more detail in your upper school chemistry courses. The special properties of water as a solvent are largely related to its shape. While the water molecule does not have an overall electric charge the oxygen end of the water is slightly negative while the hydrogen end is slightly positive. Molecules that have a slight charge separation are said to be **polar** molecules. This very slight charge separation means that the water molecule can interact with the charged particles of ionic substances, causing them to dissolve. You will see at a later section in this Focus that there are some ionic substances that are not soluble in water. These ionic substances have very stable ionic lattices. Water molecules also interact with other solutes that have oxygen and hydrogen atoms or are polar.

Interactive CW Animation

QuickTime CW Video

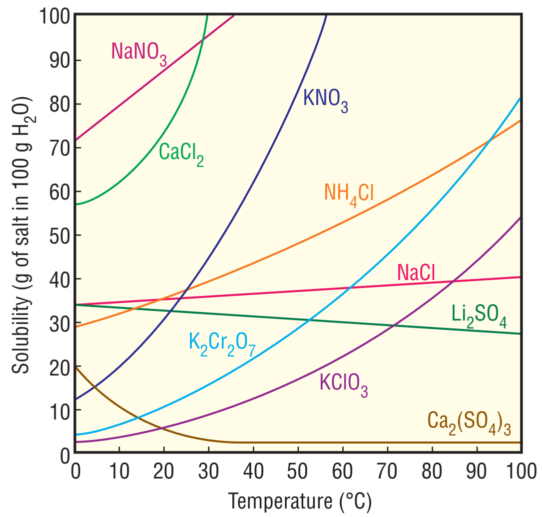
Fig 4.2.5 Water molecules interact with many solutes because of their special 'polar' structure. Water molecules readily interact with ionic substances that have charged particles.



Many substances, such as oils, do not have this polar structure and are said to be **non-polar**. This means that they will not interact with the water molecule and are insoluble in water. To dissolve oil-based materials a non-polar solvent is used. Solvents such as kerosene, turpentine and petrol are non-polar and are commonly used to dissolve oil-based solutes.

The effect of temperature on solubility

For most solid solutes, increasing the temperature increases their solubility. Such is the wonder of chemistry that there are a few substances which show the opposite trend. You can see this in Figure 4.2.6.



The solubility increases with temperature for most substances. Fig 4.2.6

Gases are less soluble at higher temperatures. You may have noticed bubbles of air on the inside of a glass of water that is left to stand on a hot day. As the glass of water warms up, more and more of the dissolved air comes out of solution. You can see this in Figure 4.2.7.

Fig 4.2.7 As the temperature of this glass of water increases, bubbles of dissolved air come out of solution and can be seen on the side of the glass.

The decreased solubility of gases with temperature has very important environmental considerations. All aquatic life is dependent on the dissolved oxygen in water. Heat energy escaping from industry and energy production into our waterways increases water temperature and decreases the amount of dissolved oxygen in the water. This can severely affect aquatic organisms. The dumping of heat into our waterways is termed **thermal pollution**.

Fig 4.2.8 Many fish kills have been linked to decreased oxygen levels as a result of thermal pollution reducing the concentration of dissolved oxygen in water.

Gas pressure

Pressure has no effect on the solubility of solid materials but the solubility of gases is directly related to the pressure. The greater the pressure, the greater the solubility of the gas. You would have first-hand experience with the solubility of carbon dioxide in fizzy drinks. When cans or bottles of soft drink are opened you can hear the fizz of the carbon dioxide as it comes out of solution with the reduced pressure due to the lid coming off.

Prac 1 p. 201

Science Snippet

Watsa widget?

Most beers are made fizzy using carbon dioxide, just as soft drinks are. When the beer is poured out of the can some of the carbon dioxide bubbles come out of solution, causing the beer to have a 'head'. In many beers this head quickly settles. Some beers contain a mixture of nitrogen and carbon dioxide gas. To help them stay frothier they contain a widget. A widget is a small sphere that is filled with nitrogen and contains a hole and floats just below the surface of the beer. When the can is opened, the pressure inside immediately drops and the compressed gas inside the sphere quickly forces the beer out through the tiny hole into the can. As the beer rushes through the tiny hole, this agitation causes the CO_2 that is dissolved in the beer to form tiny bubbles, which rise to the surface of the beer. These bubbles help to form the head and keep the beer smoother and frothier for longer.

Solubility rules and precipitation reactions

In this section, a knowledge of writing chemical formulas will be helpful. Foci 5.9 and 5.11 of *Science Aspects 2* would be worth revising or learning first before going much further.

If you only know about word equations you will not understand this section.

Many ionic substances are soluble but some are not. Some substances only dissolve fractionally and are marked in the solubility table to follow as being

Fig 4.2.9 When the soluble solutions of potassium iodide and lead nitrate are mixed, yellow insoluble lead iodide is produced. This is called a precipitation reaction.

slightly soluble. When some soluble ionic substances are mixed together it is possible that the new combination of ions may produce an ionic substance that is not soluble. This new insoluble ionic substance will then come out of solution. This type of chemical reaction is called a **precipitation reaction**.

You may well have already seen the reaction that occurs between potassium iodide solution and lead nitrate solution. This reaction can be represented by a word equation and a chemical equation:

$$\begin{matrix}\text{potassium} & & \text{lead} & & \text{lead} & & \text{potassium}\\ \text{iodide} & + & \text{nitrate} & \rightarrow & \text{iodide} & + & \text{nitrate}\\ \text{solution} & & \text{solution} & & \text{solid} & & \text{solution}\end{matrix}$$

$$2KI\ (aq) + Pb(NO_3)_2\ (aq) \rightarrow PbI_2\ (s) + 2KNO_3\ (aq)$$

The use of the phases (aq) and (s) after each of the substances is very important. The (aq) indicates that they are soluble salts, as they are dissolved in water (aqueous). The (s) after the lead iodide (PbI_2) means 'solid', and indicates that this ionic substance is insoluble in water. In order to predict which combination of ions will produce a precipitation we use a table of solubilities. These make up what is called the **solubility rules** and can be summarised as in the following table.

1	All K^+, Na^+ and NH_4^+ salts are *soluble*
2	All NO_3^- salts are *soluble*
3	All Cl^-, Br^-, I^- salts are *soluble except* Ag^+ and Pb^{2+} salts of these ions
4	All SO_4^{2-} are *soluble except* Ba^{2+}, Pb^{2+}, Ca^{2+} and Ag^+ salts of these ions
5	All CO_3^{2-} salts are *insoluble except* Na^+, K^+ and NH_4^+ salts of these ions
6	All OH^- compounds are *insoluble except* Na^+, K^+, Ba^{2+} and NH_4^+ compounds of this ion
7	All S^{2-} salts are *insoluble except* Na^+, K^+ and NH_4^+ salts of these ions
8	$CaSO_4$ and $Ca(OH)_2$ are *slightly soluble* $PbCl_2$ and PbI_2 are *slightly soluble*

Using the solubility rules it is possible to immediately identify whether ionic substances are soluble or insoluble. (Note that some ionic substances are listed as 'slightly soluble'.) If you identify an ionic substance as being soluble, you can then assume that if this substance is placed in water it will break down (**dissociate**) into its ions.

Example

Predict what happens if you attempt to dissolve the following ionic substances in water: barium sulfate ($BaSO_4$) and potassium nitrate (KNO_3). Show any relevant dissociation reaction.

$BaSO_4$—When you refer to the table (rule 4) you can see that barium sulfate is insoluble. Therefore when barium sulfate is placed in water it will not dissolve. It will either fall to the bottom of the beaker or produce a suspension that could be filtered.

KNO_3—When you refer to the table (rule 2) you can see that all nitrates are soluble. This tells you that when potassium nitrate is placed in water it will dissolve and dissociate into its ions. This can be represented by the following equation.

$$KNO_3\ (s) \rightarrow K^+\ (aq) + NO_3^-\ (aq)$$

The solubility table can also be used to predict whether a precipitation reaction will occur when two soluble ionic solutions are mixed.

Example

Solutions of sodium chloride and silver nitrate are mixed together. Does a reaction occur? If so, predict what substance would be produced and write a chemical equation to represent this.

1 Write out an equation to represent the two solutions being mixed. They can both be indicated as (aq) as they are soluble:

$$NaCl\ (aq) + AgNO_3\ (aq) \rightarrow$$

2 Look at the two possible new combinations of ions one at a time and check out the solubility table to see if an insoluble substance is produced. The solubility table tells you that, of the two possible combinations, silver chloride would produce an insoluble salt. Sodium nitrate is soluble and will remain in solution.

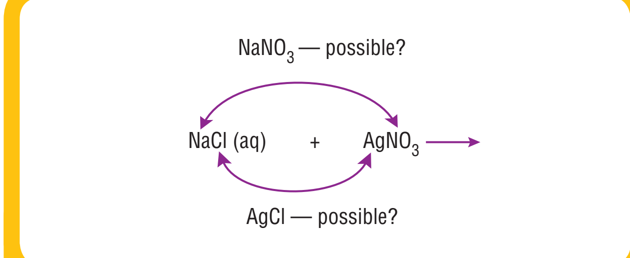


Fig 4.2.10 Diagram for step 2

3 Write out an equation that identifies the insoluble substance formed with an (s). You can also use the symbol (ppt), which indicates that it precipitates or falls out of solution. The other possible combination can be represented with an (aq) to indicate that it remains in solution and is soluble.

$$NaCl\ (aq) + AgNO_3\ (aq) \rightarrow AgCl\ (s) + NaNO_3\ (aq)$$

4 If required you can go to a final step, which shows you a summary of the equation. It is called a **net ionic** equation. A net ionic equation uses only the ions that produce the precipitate. The other ions are termed **spectator ions**, as they do not play an active role. They are left out of the equation.
Net ionic equation:

$$Na\mathbf{Cl\ (aq)} + \mathbf{Ag}NO_3\ \mathbf{(aq)} \rightarrow \mathbf{AgCl\ (s)} + NaNO_3\ (aq)$$

gives:

$$Ag^+\ (aq) + Cl^-\ (aq) \rightarrow AgCl\ (s)$$

Homework book 4.2 I'm saturated!

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FOCUS 4•2 [Questions]

Use your book

Types of solution

1 What is a solution? In your answer use terms such as 'solute', 'solvent', 'mixture' and 'uniform'.

2 Give an example of the following types of solutions:
- solid dissolved in a liquid
- gas dissolved in a gas
- gas dissolved in a liquid
- liquid dissolved in a liquid
- solid dissolved in a solid
- solid dissolved in a gas.

Measuring concentration

3 Describe what is meant by a concentrated solution and a dilute solution.

4 What are the two units of concentration used in this Focus?

5 35 g of salt is dissolved in 500 mL of water. What is the concentration of the salt in grams per litre?

Saturated and unsaturated solutions

6 What is meant by a saturated, an unsaturated and a supersaturated solution?

7 Describe how you would make a saturated solution.

8 Describe how would attempt to make a supersaturated solution.

Factors that affect solubility

9 A solute will not dissolve in a substance unless there is some interaction between the solute and solvent particles. What do you understand by this statement?

10 Explain why water is called the 'universal solvent'.

11 Explain the difference between a polar and a non-polar solvent.

12 What is the effect of temperature on the solubility of most solid substances in water?

13 Write a paragraph to describe the effect of temperature and pressure on the solubility of gases.

14 Explain how an increase in the temperature of environmental water sources such as rivers and lakes can cause fish kills.

Solubility rules and precipitation reactions

15 Describe what happens during a precipitation reaction.

16 Use the solubility rules to determine the solubility of the following ionic solids:

a silver nitrate ($AgNO_3$)
b potassium sulfate (K_2SO_4)
c sodium hydroxide ($NaOH$)
d calcium carbonate ($CaCO_3$)
e potassium sulfide (K_2S)
f silver sulfate (Ag_2SO_4)
g calcium hydroxide ($Ca(OH)_2$).

17 The following ionic substances are mixed as shown below:

i Na_2SO_4 (aq) + $BaCl_2$ (aq)
ii K_2S (aq) + $Ca(NO_3)_2$ (aq)

Use the solubility rules to determine the following:

a Is a precipitate formed? If so, identify its name. If not, write NO REACTION.
b Write a net ionic equation for any precipitates that are formed (remember, in a net ionic equation you include only the ions that are involved in the reaction).

Use your head

18 Explain why salt water is a solution while a shovelful of sand mixed with concrete is not.

>>

19 The solubility of the salt sodium nitrate ($NaNO_3$) is 88 g per 100 mL of water (or 880 g per litre) at 20°C.

a Why does the temperature need to be quoted with the solubility?

b Identify the following solutions as being saturated, unsaturated or supersaturated.

i 500 g of sodium nitrate is dissolved in a litre of water at 20°C.

ii 92 g of sodium nitrate is dissolved in a litre of water at 20°C.

c One of the solutions in part b is a supersaturated solution. Explain how such a solution could have been made.

d Why are supersaturated solutions unstable?

20 Calculate the percentage by mass of the solute in the following solutions:

a a 50 g solution containing 5 g of sodium nitrate

b a 10 g solution containing 500 mg (milligram) of iron sulfate.

21 You are given a solution and told that it is either saturated, unsaturated or supersaturated. Describe how you would determine which it was. Assume you are given some crystals of the solute and a stirring rod.

22 You spill some cooking oil on your clothing. Explain why water will not dissolve the oil yet a non-polar solvent such as white spirits will.

23 Identify which of the following pairs of solutions would produce a precipitate. Write a net ionic equation for those that do. If no reaction occurs, write NO REACTION.

a barium nitrate ($Ba(NO_3)_2$) and potassium hydroxide (KOH)

b calcium nitrate ($Ca(NO_3)_2$) and sodium carbonate (Na_2CO_3).

Investigating questions

24 Draw a diagram of a water molecule and show why it is called a **polar molecule**. Use this diagram to show why water can dissolve ionic substances.

25 Investigate the types of solvents that are used in the **dry-cleaning** process. Explain why these different solvents are used to remove stains.

26 Another common unit of concentration is **parts per million**. Find out about this unit of concentration and where it is used.

4·2 FOCUS [Practical activities]

Solubility variables

Prac 1 Focus 4.2

DYO

Purpose

To explore some factors that affect solubility.

Requirements

Students in consultation with their teacher will need to determine their requirements.

Procedure

1. Brainstorm with your group a list of factors that might affect the solubility.
2. Select *two* of these variables.
3. *Write a hypothesis that includes your two variables.*
4. Design an investigation that will test these two variables. You will need to make sure that your investigation is controlled and fair.
5. *Design a suitable data table for your results.*
6. Discuss any safety issues with your teacher.
7. Have your investigation approved by your teacher before you commence.

Questions

1. Write a conclusion for your investigation by referring back to your hypothesis.
2. Outline how you ensured that your investigation was 'fair'.

Solubility—testing the rules

Prac 2
Focus 4.2

Purpose

To use the solubility rules to predict the outcome of precipitation reactions and to compare your observations with the solubility rules. You will also gain further skills in writing net ionic equations if you can do these.

Solubility rules

1	All K^+, Na^+ and NH_4^+ salts are *soluble*
2	All NO_3^- salts are *soluble*
3	All Cl^-, Br^-, I^- salts are *soluble except* Ag^+ and Pb^{2+} salts of these ions
4	All SO_4^{2-} are *soluble except* Ba^{2+}, Pb^{2+}, Ca^{2+} and Ag^+ salts of these ions
5	All CO_3^{2-} salts are *insoluble except* Na^+, K^+ and NH_4^+ salts of these ions
6	All OH^- compounds are *insoluble except* Na^+, K^+, Ba^{2+} and NH_4^+ compounds of this ion
7	All S^{2-} salts are *insoluble except* Na^+, K^+ and NH_4^+ salts of these ions
8	$CaSO_4$ and $Ca(OH)_2$ are *slightly soluble* $PbCl_2$ and PbI_2 are *slightly soluble*

Requirements

Dropper bottles containing dilute (0.1M) solutions of a range of nitrate salts containing the following positive ions (cations)—Ca^{2+}, Na^+, Mg^{2+}, Al^{3+}, Ba^{2+}, Fe^{3+}, Pb^{2+}, Cu^{2+}, Zn^{2+}, Ag^+; dropper bottles containing dilute (0.1M) solution of a range of sodium salts containing the following negative ions (anions)—Cl^-, CO_3^{2-}, OH^-, PO_4^{3-}, S^{2-}, SO_4^{2-}; white ceramic/plastic depression tiles (or test tubes if tiles not available).

Procedure

1 *Design a table that will allow you to store data for all of the possible combination of cations and anions that you will be testing.* (Hint—put the anions across the top of the table and the cations down the side. You can then use a system of ticks where precipitates form.)

2 Predict which of the combinations should produce a precipitate by referring to your solubility rules. *Indicate this on your results table by placing a small tick in the corner of the relevant section in the results table.*

For phosphates you are going to create your own rule from your results. (Phosphate is not shown in the table opposite.)

3 Mix a small quantity of the positive ions (as the nitrate) with the negative ions (as sodium salt) one at a time. This is best done in a white depression tile. Make sure you know which depression contains each solution. *A quick sketch on a piece of paper may help.*

4 For each combination *indicate if a precipitate forms by adding 'ppt' to the relevant box in the data table*. *Record the colour of any precipitates formed.*

5 Repeat for all of your possible combinations, making sure that you do not contaminate your ions. Be careful to thoroughly wash the tile if you have to use the same depression again.

Questions

1 Compare your observations with your solubility predictions. Explain some possible reasons for any differences.

2 Write equations for any reactions that occurred. (If you understand net ionic equations write these instead for each reaction.)

3 What rule seems likely for phosphates?

FOCUS 4.3 Separating substances

Context

Very few substances are found in nature as pure elements or compounds. Instead, they are found as mixtures. There are many situations in industry and our homes where we require pure forms of substances. This means we must use a range of techniques including filtration, crystallisation, distillation and chromatography. In this Focus you explore these separation techniques further.

Dissolving and the kinetic theory

Fig 4.3.1 Over time the crystals of permanganate dissolve and diffuse throughout all the solvent.

In Focus 4.2 you explored how dissolving involves the solvent particles interacting with the solute particles. This interaction allows the solvent particles and the solute particles to have some form of attraction. In many molecular and ionic substances, the solvent particles surround the solute particle as they interact with it to dissolve it. This process is sometimes referred to as **solvation**.

When solute particles are solvated, energy is exchanged between the solution and the surroundings. Some solutions absorb energy from their surroundings when they dissolve. These types of solutions become cooler when they dissolve and are said to have **endothermic heats of solution**. Most solutions,

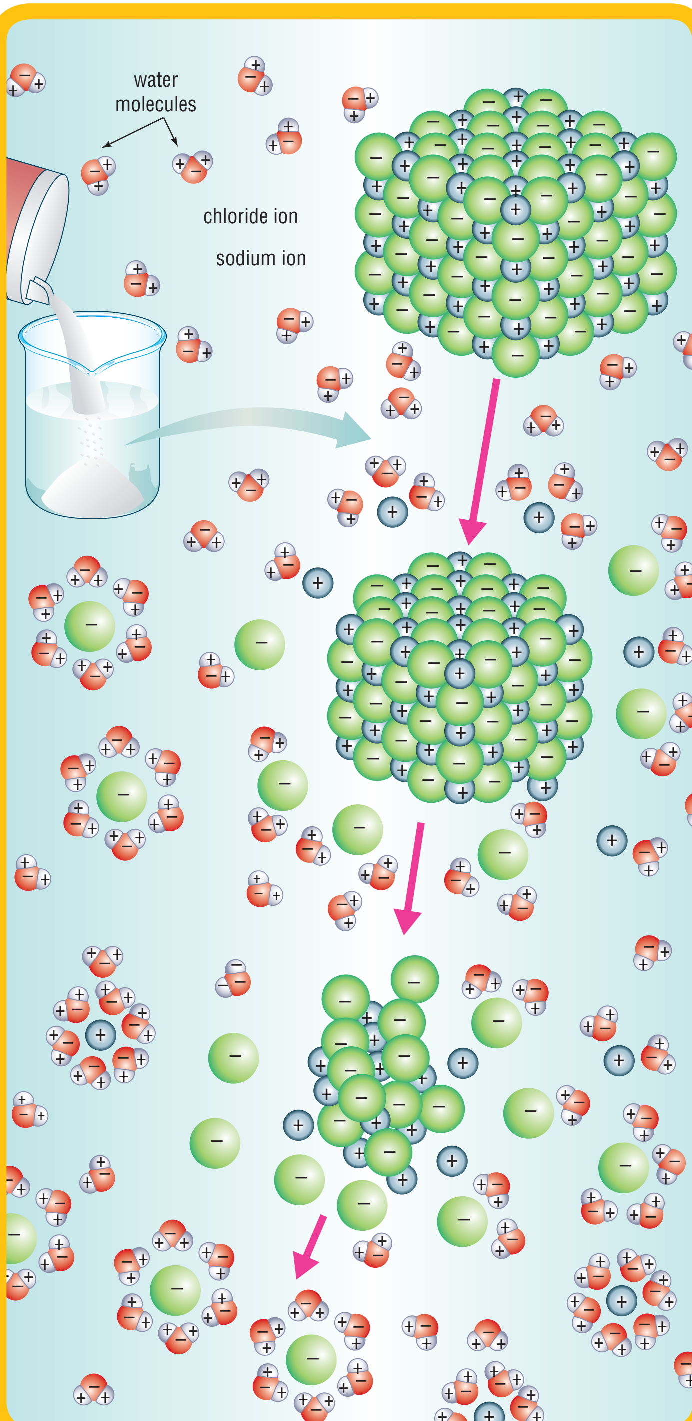


Fig 4.3.2 Solvent molecules such as water interact with solute particles such as ions by surrounding them. This process is called solvation.

however, release heat energy to their surroundings and are said to have **exothermic heats of solution**.

When sugar is dissolved in water, the water molecules interact with the sugar molecules (through the polar bonding of the water). Sugar molecules start to break off the sugar crystals and since the kinetic theory tells you that the water molecules are in constant motion, they can move the dissolved sugar molecules away from the crystal. This random movement of sugar particles is called **diffusion** and over time the dissolved sugar particles spread themselves evenly through the solvent, creating a **uniform solution**. Understanding the particle theory helps us understand some of the variables that can affect the rate at which something dissolves. Some of these variables include:

- stirring
- temperature
- state of subdivision of solute
- amount of solute already dissolved.

Fig 4.3.3 Stirring increases the rate at which a solute will dissolve by pushing new solvent to the surface of the solute.

You would be aware that stirring increases solubility rate if you have ever made yourself a hot drink where you needed to dissolve sugar. No doubt you used a teaspoon to stir the water to help dissolve the sugar faster. Stirring increases the rate at which a substance will dissolve by forcing fresh solvent particles up to the solute and by moving non dissolved solute to areas of solvent which do not have solute dissolved in it.

Effect of temperature on dissolving rate

Warm liquid solvents dissolve a solid or liquid solute faster than cold liquid solvents do. As a solvent absorbs thermal energy the average kinetic energy of the particles increases. This increased motion of the solvent particles increases the rate at which solute particles dissolve.

Gases not only dissolve less in warmer liquid solvents, they also dissolve more slowly. An increase in the kinetic energy (movement) of the solvent and gas particles results in more gas particles being able to break away from the attraction force between the solute (gas) and solvent and more gas particles escape the solution. An example of how this may be important is the oxygen levels of the oceans. There is less oxygen in the oceans near the equator than in the polar regions because the oceans are warmer near the equator.

State of subdivision of the solute particles

Solute and solvent interaction takes place at the surface of the solute. If you increase the surface area of the solute by grinding or cutting it into smaller pieces, the surface area is increased. This means a greater number of solute and solvent particles interacting and therefore an increase in the solubility rate.

Amount of solute already dissolved

As a solute dissolves, more and more of the solvent becomes involved in solvating the solute. So fewer solvent particles are available to dissolve the remaining solute, and the rate at which more solute will dissolve decreases.

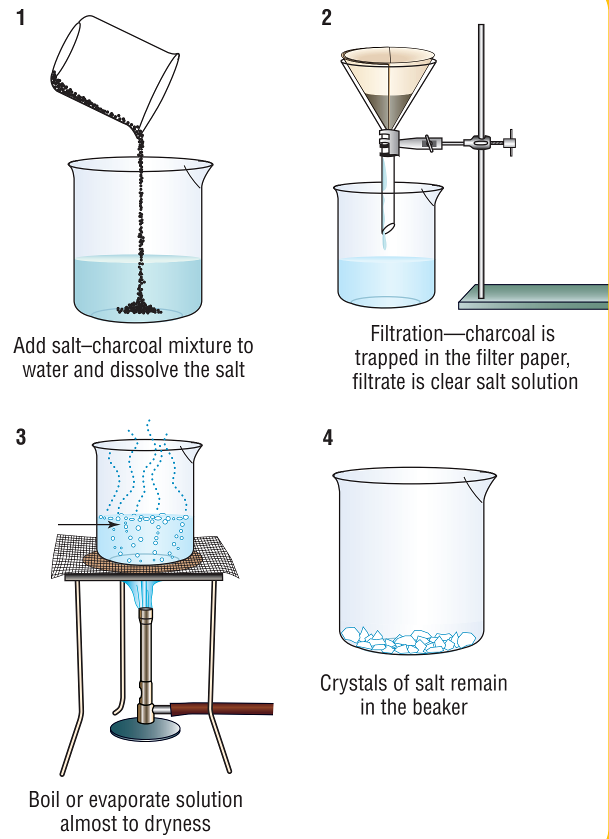
Separation of mixtures

In *Science Aspects 1* you explored the use of a range of separation techniques. Your journey continues in this Focus as you revisit some of these methods in more detail. You will explore the processes of filtration, distillation and chromatography as well as some other special processes, such as water purification.

Filtration

Filtration is a very effective process for removing insoluble solids. The use of filtration can also be a key step in a separation process where one of the materials is insoluble and the other is soluble. For example, a dry mixture of salt and sand could easily be separated by adding water to the mixture, stirring to dissolve the salt and then filtering the mixture. The insoluble sand could be filtered, leaving a salt solution. The salt solution could then be **evaporated** to dryness to leave the salt.

Fig 4.3.4 Filtration can be used to remove insoluble materials from a solution.



Activated carbon filtration systems are used to purify water and air. Under an **electron microscope** you can see the **micropores** that allow air or water to move through them. Impurities are **adsorbed** onto the carbon. Adsorption is caused by a mutual attraction between the carbon particles and impurities.

The pores in the carbon are **activated** by passing very hot steam through it. Activation opens up the pores in the carbon to give it a large surface area. One gram of activated carbon can have an active surface area of greater than 400 square metres (a tennis court is about 260 square metres). A blocked filter can be **regenerated** by strong heating, which burns off organic impurities that have been captured in the pores.

Fig 4.3.5 Micropores allow large volumes of air or water through while adsorbing impurities into the carbon.

Activated carbon filters have many applications in industry and domestic use, including cleaning up environmental spills, groundwater filtration, drinking water filtration and gas masks.

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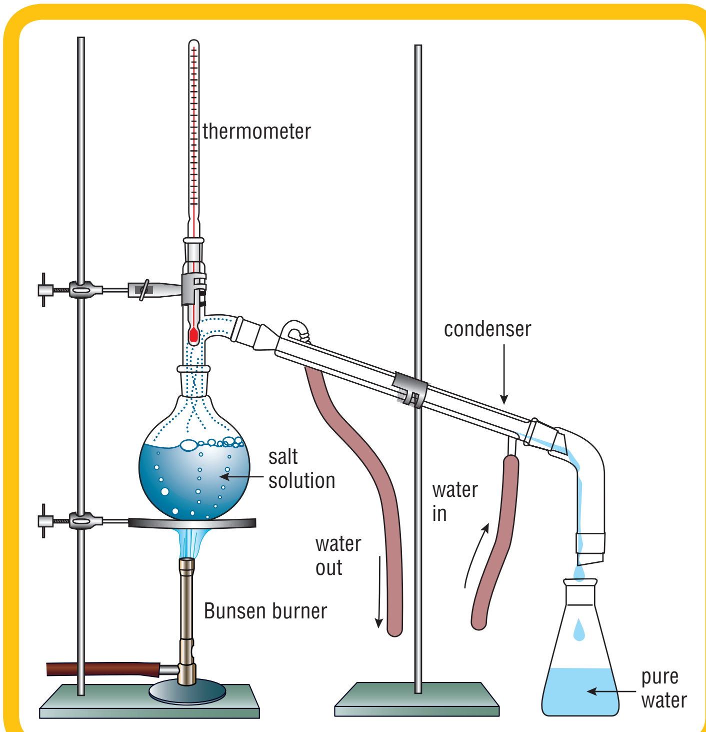
Fig 4.3.6 Activated carbon water filter systems can be used to remove small amount of impurities and odours from domestic water supplies.

Distillation

Distillation is generally used to purify liquids into their various components. You explored this process in *Science Aspects 1*. Distillation can be used to separate any mixture whose components have different boiling points. The component with the lowest boiling point boils off first and is cooled in the condenser, where it condenses back to the liquid and can be collected. A typical distillation set-up that is found in schools is shown in Figure 4.3.7. Follow the process through for yourself from the solution to the pure water.



Distillation is used to remove a mixture of substances that have different boiling points. *Fig 4.3.7*

Worldwide there about 1500 **desalination plants**, the majority of which use distillation. This not only makes the process expensive in terms of the fuel to heat the salt solution, but large volumes of greenhouse gases are also produced. The expense of the process means that it is only used where other means are not possible. Other desalination plants use processes such as **evaporation** using solar energy, or **membrane processes** such as reverse osmosis.

Vacuum distillation is a process that is used when delicate solutions need to be separated. Strong heating can break down or denature biological chemicals such as proteins. By creating a vacuum over the top of the solution, the boiling point of the liquids is reduced as liquids boil when the pressure of their vapour is equal to the atmospheric pressure.

As well as applications in medicine, vacuum distillation is used in oil processing and the production of alcoholic drinks, where lower temperatures are required to prevent the materials decomposing before they reach their boiling point.

Science Snippet

Freshly squeezed water

Desalination plants such as those being built for Perth use a membrane to produce desalinated water. Water is forced through special membranes that do not allow the passage of salts. The process requires lots of energy and produces more concentrated salt solutions that need to be returned to the environment. The process is called reverse osmosis.

Fig 4.3.8 By placing a partial vacuum over the solution, the boiling point of the solvent(s) is reduced and thus less heat is required to separate the substances.

Fractional distillation

Substances such as crude oil consist of a large number of different substances or **fractions**. These substances vary from gases with low boiling points right through to large high-melting-point solids such as bitumen.

Steady state fractional distillation is the process that is used to separate the oil fractions. Steady state refers to the continuous feed of crude oil into the fractional distillation tower. The main steps in the process are:

1. Crude oil is heated to about 600°C, using steam.
2. The mixture boils and most substances go into the vapour phase.

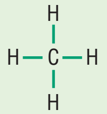
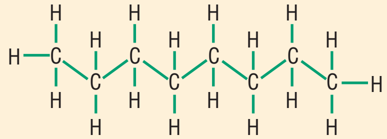
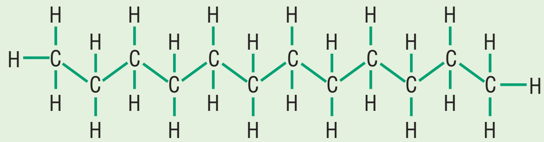
Name	Boiling point range °C	Example
petroleum gases	<5	 methane CH_4
petrol	20–200	 octane C_8H_{18}
kerosene	180–260	 dodecane $C_{12}H_{26}$

Fig 4.3.9 Crude oil contains various substances (fractions) that contain different numbers of carbon atoms in their molecules. As the number of carbon atoms in the molecule increases, so does the boiling point.

3 The vapour enters the fractional distillation column (see Figure 4.3.10) at the bottom. The column is filled with trays that slow the movement of the vapour down and collect any liquids that form at various heights in the column. The trays contain holes or 'bubble caps', which allow the vapour to rise higher in the column.

4 There is a temperature gradient in the column, which ranges from about 400°C at the bottom to about 25°C at the top. The different vapours rise up the column and gradually cool until each substance reaches a temperature equal to its boiling point, where it condenses to a liquid.

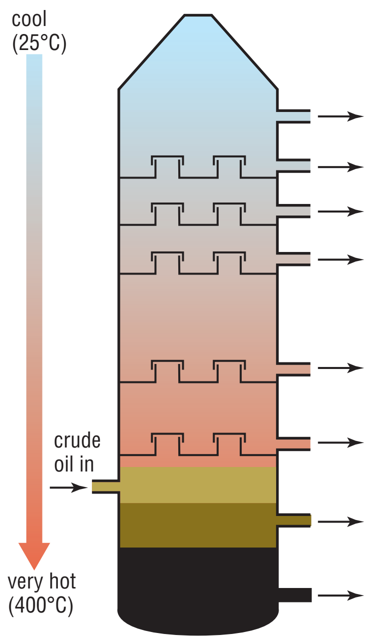
5 The trays collect the different fractions, which can be run off into storage vessels.

The separated components require further processing before they can be used as fuels.

Steam distillation

Some mixtures of organic compounds decompose if they are heated to the high temperatures required for fractional distillation. The process of **steam distillation** can be used to separate these substances. It involves passing steam into the mixture, which depresses the boiling points of the substances, allowing them to boil at lower temperatures. The substances can then be distilled as usual. Steam distillation can also be combined with vacuum distillation to separate very heat-sensitive materials.

Fig 4.3.10 Fractional distillation of crude oils



Name of fraction	How many carbons in chain?	What is it used for?
Gas	1–4	Fuel
Petrol	4–10	Fuel for cars
Kero	10–16	Fuel for jets
Diesel oil	16–20	Fuel for central heating. Can also be cracked to make smaller molecules
Lubricating oil	20–30	Oil for machines like cars. Can be cracked
Fuel oil	30–40	Fuel for ships and power stations
Paraffin wax	40–50	Waxy papers, candles, polishing
Bitumen	50 and over	Roads

Drag and Drop CW Interactive

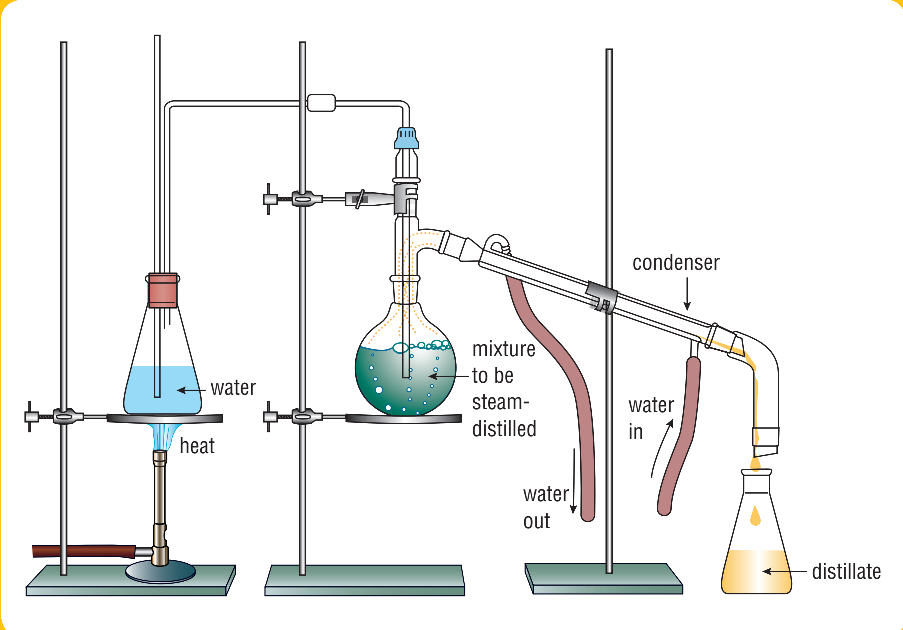
Science Snippet

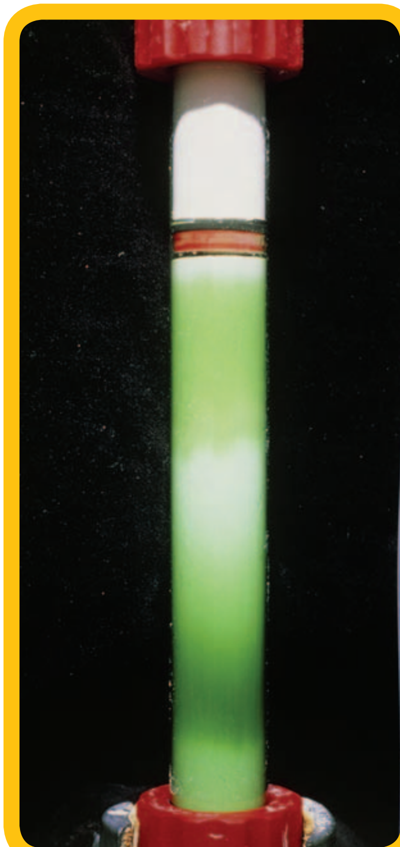
How essential are essential oils?

Essential oils are highly concentrated oils that are extracted from plants by the process of steam distillation. They have many different uses, such as in perfumes, aromatherapy, cosmetics, incense, medicine and household cleaning products, and even as flavouring for food and drinks. Essential oils are generally named after the plant from which they are extracted, such as oil of eucalyptus, oil of lavender, oil of peppermint, oil of clove, etc. The essential oils industry is a valuable and important industry in Australia.

Steam distillation can be used to separate mixtures of substances that would decompose if heated directly.

Fig 4.3.11





Different materials have different retention times in the column. The separated materials can be tapped off from the bottom of the column.

Fig 4.3.12

Chromatography

Chromatography was developed at the start of the 20th century to separate small amounts of plant materials that could not be separated successfully by any other process. There are several different types of chromatography, including **column chromatography**, **paper chromatography** and **gas chromatography**.

Column chromatography

Column chromatography was the first method to be developed. It involves dissolving the mixture to be separated in a solvent. This mixture is then passed into the top of a column containing an unreactive substance called the **stationary phase**. The first substance to be used was crushed calcium carbonate but there are a variety of stationary phase materials, depending on what is being separated. The different substances in the mixture pass through the column at different speeds, depending on how much they are attracted (**adsorbed**) to the stationary phase. The time that a substance stays within the column is called the **retention time**. Those that are strongly attracted to the stationary phase will pass through more slowly and have a longer retention time, while those that are less strongly attracted will pass through quickly and will have a lower retention time.

Paper chromatography

In paper chromatography, the stationary phase is a material-like filter paper called **chromatography paper**. A small spot of the mixture solution is placed on the chromatography paper about one centimetre from the base. This substance is **adsorbed** into the paper. The paper is then placed in a solvent, which moves up the chromatography paper, meets the mixture and dissolves it. The solute is then carried up the paper in the solvent. Those substances that are more strongly attracted to the paper will move more slowly than those that are less strongly attracted.

QuickTime CW Video

Paper chromatography is used to separate substances such as dyes, drugs or toxins in small amounts of samples. Small glass plates with a thin coating of gel are now often used in place of the paper. This is called **thin layer chromatography**.

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Fig 4.3.13

In paper chromatography the stationary phase is paper. More strongly adsorbed materials move more slowly through the paper.

Gas chromatography

This is very similar to column chromatography but the mixture is in the gas phase. The different substances in the gas mixture have different retention times in the column. An **inert** gas such as helium, argon or nitrogen is used in place of solvents to move through the column. At the end of a column is a range of detection devices, such as a **mass spectrometer**, which can be used to determine the size of the molecules in the mixture.

Gas chromatographs are often linked with detection devices, which give the operator detailed information about the mass of the different molecules in the mixture.

Fig 4.3.14

Homework book 4.3 Freshly squeezed daily

Homework book 4.4 Separating similar stuff

4·3 FOCUS [Questions]

Use your book

Dissolving and the kinetic theory

1 What is solvation? Draw a diagram of water particles that describes how they cause substances to dissolve.

2 Describe the difference between endothermic and exothermic heats of solution.

3 Explain how a soluble substance such as sugar or salt would eventually spread through a solvent. In your explanation use terms such as ‘diffusion’ and ‘uniform solution’.

4 Describe what effect the following variables have on the dissolving rate: stirring, temperature, state of subdivision of solute, amount of solute already dissolved.

Filtration

5 What sort of substances can be removed from a mixture by filtration?

6 Describe how active carbon filtration systems can be used to purify water and air.

7 Activated carbon filter systems need to be activated and regenerated periodically. Describe what happens during these processes.

Distillation

8 Describe how two materials could be separated by the process of distillation.

9 Explain why vacuum distillation is used when heat-sensitive materials are being separated.

>>

10 Steady-state fractional distillation is used to separate crude oil. Define what is meant by the terms 'steady-state' and 'fractional'.

11 Outline how the process of steam distillation could be used to remove volatile oils from the leaves of a plant.

Chromatography

12 Write a summary of the process of column chromatography, making sure that you include the following terms:

stationary phase, retention time, solvent, adsorbed.

Use your head

13 Water is said to be a 'polar molecule'. Describe how this characteristic helps water to solvate ions when it is used to dissolve ionic substances.

14 Design an investigation that would allow you to determine whether a substance had an endothermic or exothermic heat of solution.

15 In many cooking processes, caster sugar is used in the place of normal sugar. Caster sugar is more finely ground than normal sugar. Explain, in terms of solubility, the advantages of using caster sugar.

16 Describe how a desalination plant based on distillation might work. This process is said to be expensive in terms of both money and the environment. Explain this statement.

17 Describe the type of substances extracted towards the top of a crude oil fractional distillation tower. How do these differ from the substances found at the bottom of the tower?

18 Copy the following table into your notes, completing the second column by describing how you could best separate the mixtures outlined.

Mixture	Description of separation method
Separate water from a muddy water mixture	
Separate salt from a mixture of sand, salt and water	
Identify small amounts of different insecticides found on the skins of fruit	
Separate waste oils into their different types of oils	

Investigating questions

19 The production of essential oils in Australia is a large industry. Explain how the process of steam distillation is used by describing the production of one essential oil.

20 Beer companies produce low-alcohol beers by the process of vacuum distillation. Describe how this process works and why it is used in the production of reduced alcohol beers.

21 Describe how a forensic scientist might use chromatography to identify the type of ink used in a pen while investigating a fraud case.

22 The photograph below shows a DNA finger print that can be used to match DNA found at a crime scene to DNA of a suspect.

Fig 4.3.15 DNA fingerprinting uses the process of electrophoresis to separate DNA.

The process used to separate the DNA fragments is called **electrophoresis**. Describe how this process is similar to chromatography.

4·3 FOCUS [Practical activities]

Prac 1 Focus 4.3

DYO

Design your own separation investigation

Purpose

To design and carry out a separation process to separate the solids from a mixture of charcoal, salt, sand and water.

Requirements

Mixture of charcoal, salt, sand and water; students in consultation with their teacher will need to determine further requirements.

Procedure

1. Discuss with your group a possible procedure for separating this mixture based on the properties of each of the substances. You need only the solids purified. You do not need to recover the water.
2. *Draw flow chart that shows the procedure you will use.*
3. *Design a suitable data table for your results.*
4. Discuss any safety issues with your teacher.
5. Have your investigation approved by your teacher before you commence.
6. Carry out your investigation, *recording your observations as you go.*

Questions

1. Write a conclusion that outlines how successful your separation was.
2. How would you have to modify your investigation to recover the water from the mixture as well? If you have time and the permission of your teacher you could carry out this investigation too.

Prac 2 Focus 4.3

Paper chromatography

Purpose

To explore how different molecules (ink) can be separated using chromatography.

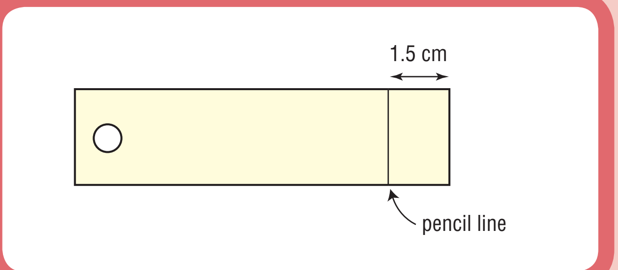
Requirements

10 cm strip of chromatography paper; ruler; three different transparency pens (water-soluble)—red, blue and black; pencil or stirring rod; 250 mL beaker; 50 mL water, hole punch.

Procedure

1. Punch a hole in one end of the chromatography paper. The hole should be wide enough for a pencil or stirring rod to pass through so that you can suspend it inside the beaker.
2. *Draw a line 1.5 cm up from the non-punched end of the paper as shown in the diagram.*

Fig 4.3.16 Set-up for Prac 2



3. Use the black pen to *draw a dot about 2–3 mm wide on the middle of the pencil line.*
4. Use the red and blue pen to put dots on either side of the black dot.
5. Suspend the paper from the hole using a pencil or stirring rod into a 250 mL beaker of water that contains about 50 mL of water. Make sure that the water sits below the pencil line and the dots.
6. *Observe and record what happens as the water travels up the paper.*

Questions

1. What is meant by the 'mobile phase' in chromatography, and what was the mobile phase in your investigation?
2. What is meant by the 'stationary phase' in chromatography, and what was the stationary phase in your investigation?
3. Which colours travelled the furthest? What can you say about their strength of adsorbtion onto the paper?
4. What does this investigation tell you about the colours in a black pen?

Extra for experts

5. Describe what modifications you would need to make to this investigation to separate non-water-soluble colour pens. You might like to try this for yourself with your teacher's permission.

FOCUS 4•4

Structure and uses of polymers

Context

We could call this the plastic age. After the Second World War there was an explosion in the development and use of plastics. Often they have replaced other materials because they have better properties, such as strength and density. The word 'polymer' gives us a clue to the structure of this group of substances. The word 'polymer' comes from a Greek word and means 'many parts'. In this Focus you will explore the structure of polymers and how these 'many parts', called monomers, join together to give polymers their special and varied properties and uses.

Common properties of polymers

Polymers are often called 'plastic'. The term 'plastic' means 'can be moulded into shapes'. While this property is one of the special properties of polymers, there are several others:

- They are all carbon based (**organic**) molecules.
- Many are obtained from crude oil extracts.
- Several have important functions in cells and are made in living things.
- They consist of very long molecules made from repeating units called **monomers**.

What is it about plastics that has made them so popular? Consider some of these special properties and where they might be useful. Plastics:

- do not conduct electricity or heat
- are strong and light
- are unreactive with oxygen or water, making them weather-resistant
- can be coloured
- can have other materials added to them to make them stronger.

Given these properties, it is no surprise that plastic is such a well-used material. The table opposite outlines the names of a range of plastics and their uses. How many do you recognise?

Science Snippet

Green shopping bags—made not to last!

There are many problems associated with the use of normal plastic shopping bags. Not only do they sit in landfill sites for many decades, they can find their way out into oceans, where they are ingested by marine animals—often killing them. So welcome to the new green 'biobag'. These new environmentally friendly plastic bags are made mainly from corn starch and other biodegradable polymers and generally break down in 4–12 weeks, depending on conditions.

Fig 4.4.1 Polymers have replaced many materials, such as glass, wood and metals, because of their advantages, particularly their strength and weight.

Plastic	Use
Polyethene	Milk crates, rubbish bins, buckets, plastic shopping bags, cling wrap, squeezy bottles
Acrylic	Safety glasses, clear screens
PVC (polyvinyl-chloride)	Plastic guttering, raincoats
Nylon	Nylon rope, fabrics, car parts, carpets
Polystyrene (no bubbles)	Yoghurt and other food containers
Polystyrene (with bubbles blown through it)	Insulation in eskies, disposable coffee cups, packaging for protection
Melamine	Unbreakable dishes, coating for cupboards and benches
Urea formaldehyde	Electric switches and plugs
Phenol formaldehyde	Saucepan handles

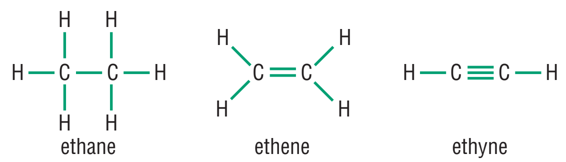
Drag and Drop CW Interactive

Monomers and polymers

Bonds between carbon atoms

To understand how polymers are formed you need to explore the bonds that form between carbon atoms, which form the 'backbone' of all polymers. The carbon atoms join to each other to form a chain, which is described as being like a backbone.

Fig 4.4.2 Organic compounds contain a backbone of carbon, with other elements such as hydrogen bonded to the carbon atoms. The molecules in this diagram have a backbone of two carbon atoms.

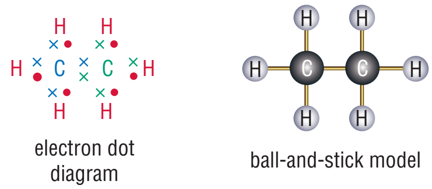


In Focus 5.8 of *Science Aspects 2* you were introduced to organic compounds. You might like to review this before going any further.

Carbon is a very special atom with the ability to form up to four bonds with other atoms by sharing electrons. These shared electrons are called **covalent bonds**. The covalent bonds between carbon atoms can be single, double or triple covalent bonds, depending on how the electrons are shared.

In **single carbon bonds**, the carbon atom shares only one of its electrons with another atom (carbon or otherwise). In the structure of ethane in Figure 4.4.3, the X represents the electrons that belong to carbon. Note that they share only one electron with the other carbon and hydrogen atoms.

Fig 4.4.3 Single carbon bonds



In **double carbon bonds**, each carbon atom shares a pair of its electrons with the other carbon atom (and sometimes non-carbon atoms such as oxygen). Note that in the structure of ethene in Figure 4.4.4, two pairs of electrons are shared between the two carbon atoms in the molecule.

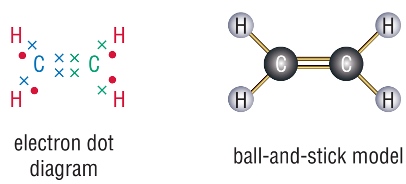


Fig 4.4.4 In double carbon bonds, each carbon atom shares two pairs of electrons.

In a similar way, carbon-to-carbon bonds can be formed by sharing three pairs of electrons to form **triple bonds**.

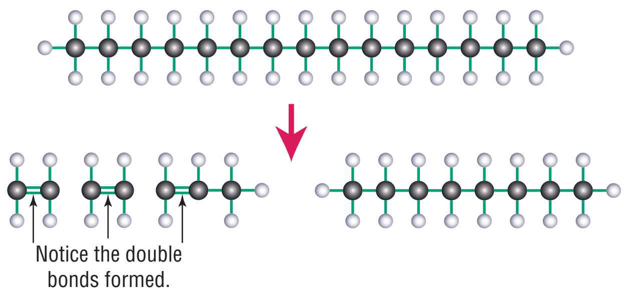
Polymerisation

The starting point for all polymers is a monomer. Think of a monomer as being like a paperclip. Given the right circumstances paperclips can be joined together in large numbers to form a chain.

One of the simplest cases you can investigate is that of ethene. Ethene is commonly formed by the **cracking** of long hydrocarbon chains formed during the fractional distillation of crude oil (see Focus 5.3).

Ethene and other molecules being formed by the cracking (breaking) of long chain hydrocarbons. The longer molecules can be 'cracked' further if required.

Fig 4.4.5



In a special chemical reaction known as **polymerisation**, the double bonds between the carbon atoms in ethene can open up and join to form a long-chain polymer known as **polyethene**. This reaction is the opposite to that of cracking the hydrocarbon shown in Figure 4.4.5., but the chain formed ends up being much longer. Polyethene is known as a **polymer** because it is made of repeating units of ethene. 'Poly' means many. The units that are repeated are known as the **monomer**. 'Mono' means one.

Interactive CW Animation

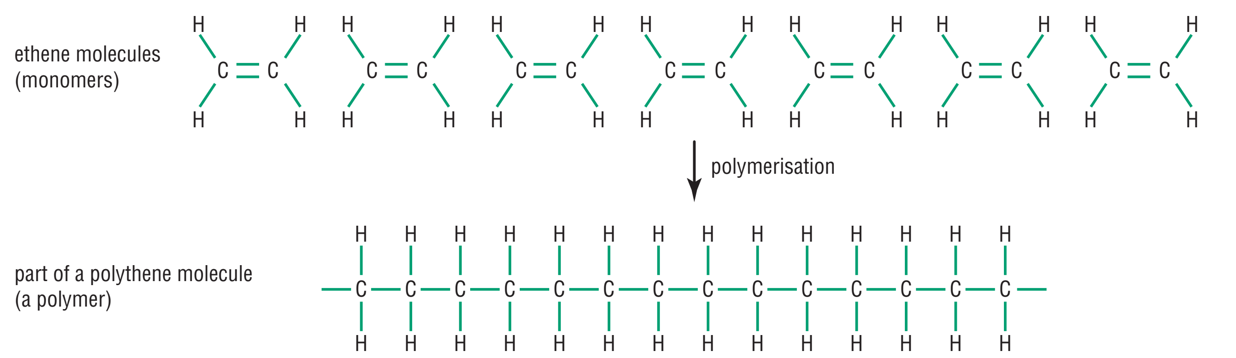
Polymerisation occurs under heat and pressure and requires the addition of a chemical known as a **catalyst** (see Focus 5.10 in *Science Aspects 2*), which assists chemical reactions to get started without itself being used.

By using different monomers, different polymers can be formed, as shown in Figure 4.4.7.

Monomer	Polymer
$CH_2{=}CH_2$ ethene or ethylene	$-(CH_2-CH_2)_n-$ poly(ethene) or polyethylene
$CH_2{=}CHCl$ chloroethene or vinyl chloride	$-(CH_2-CHCl)_n-$ poly(vinyl chloride)
$CH_2{=}CHCH_3$ propene or propylene	$-(CH_2-CHCH_3)_n-$ poly(propene) or polypropylene
$CF_2{=}CF_2$ tetrafluoroethene	$-(CF_2-CF_2)_n-$ poly(tetrafluoroethene) e.g. teflon
$CH_2{=}C(OOCCH_3)(CH_3)$ methyl methacrylate	$-(CH_2-C(OOCCH_3)(CH_3))_n-$ poly(methyl methacrylate) eg perspex

Fig 4.4.7 Different polymers can be formed by using different monomers.

Fig 4.4.6 Polymers have replaced many materials, such as glass, wood and metals, because of their advantages, particularly their strength and weight.



Types of plastics

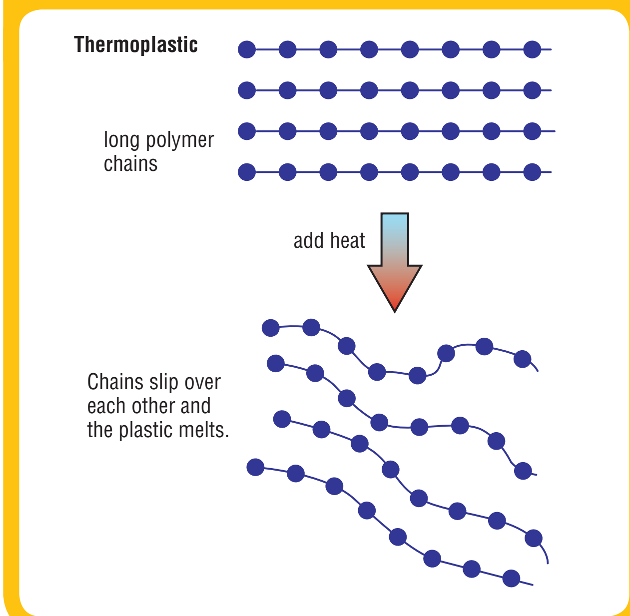
The properties of plastics are not just dependent on the atoms that are present. As you have explored in your previous chemistry, the way that the atoms are bonded and arranged determines many of the properties of materials. Plastics can be classified into three main groups—**thermoplastics**, **thermosetting plastics** and **elastomers**, depending on how the polymer chains interact.

Thermoplastics

Thermoplastics make up most of our recyclable plastics. When heated they become soft and when they are cooled they become hard again. From a recycling point of view they can be heated and remoulded into new shapes.

In thermoplastics the long chains of polymers are not cross-linked. This means that when heated, individual chains can move or change shape without damaging other chains. Individual chains are held together by fairly weak bonds.

Fig 4.4.8 Thermoplastics can be heated and reshaped without damaging the long polymer chains. The long chains are not cross-connected.

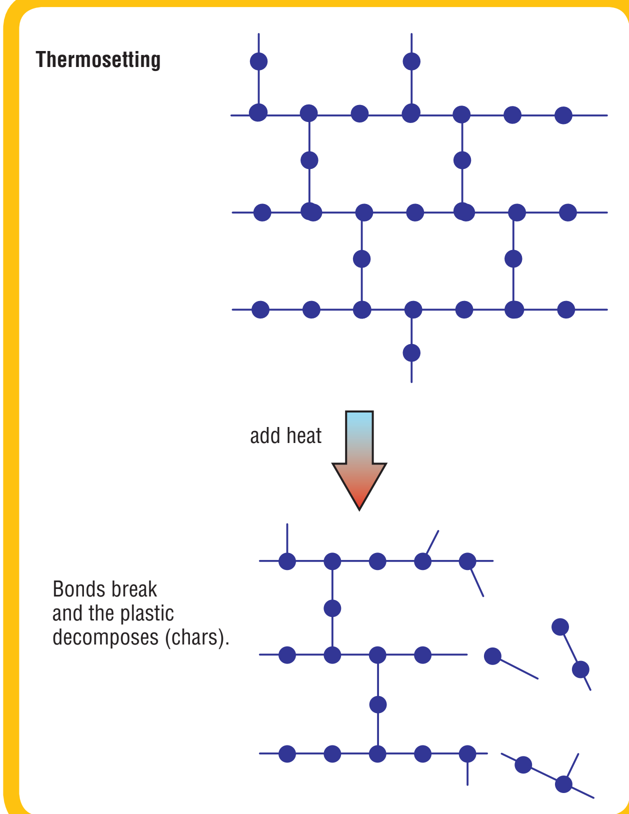


Thermoplastics are provided to manufacturers as pellets, powder or granules, to be melted and shaped by a variety of processes that you will explore in a later section. Examples of thermoplastics are acetal, acrylic, cellulose acetate, nylon, polyethylene, polystyrene, vinyl and nylon.

Thermosetting plastics

In thermosetting plastics the long chains are interconnected. This has the effect of locking the plastic into a hard and brittle giant molecule. As a result thermosetting plastics tend to be hard and brittle. When heated, individual chains cannot move without affecting other chains. As a result, thermosetting plastics simply char but do not go soft and cannot be remoulded, making them unsuitable for recycling. Examples of thermosetting plastics are polyesters, polyurethane, Teflon and silicone.

Fig 4.4.9 Thermosetting plastics have many cross-linked chains. Heating causes them to decompose rather than go soft.

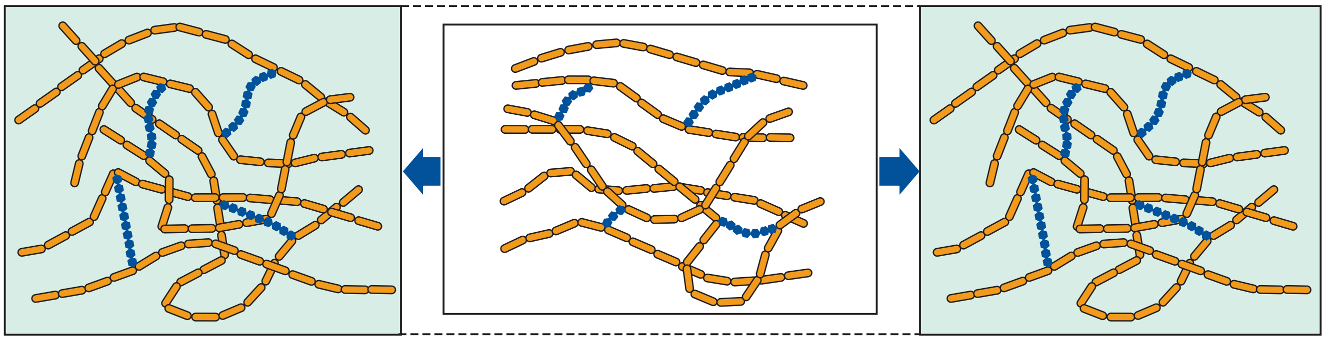


Homework book 4.5 The plastic Teflon

Elastomers

Elastomers have the property of being able to be stretched but will return to their original size when the stretching force is released. This property is a result of the overlapping polymer chains and a degree of cross-linking, which helps to restore the chains to their original positions when they have been 'straightened out'.

Fig 4.4.10 Elastomers can be stretched due to the overlapping of the polymer chains. The cross-links help to return them to their original position.



Elastomers
– consist of partially coiled chains with some cross-linking
– the chains can be stretched out but return to their original arrangement when the distorting force is removed

As with thermosetting plastics, elastomers cannot be recycled as the chains decompose when heated. Examples of elastomers are vulcanised rubber, as used in car tyres, and styrene.

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Shaping plastics

Plastics can be moulded and shaped in a variety of ways, including **extrusion moulding**, **blow moulding** and **injection moulding**. In thermosetting plastics the shaping process has to be combined with the manufacture of the plastic but in thermoplastics, pellets or powder of the plastic can be used.

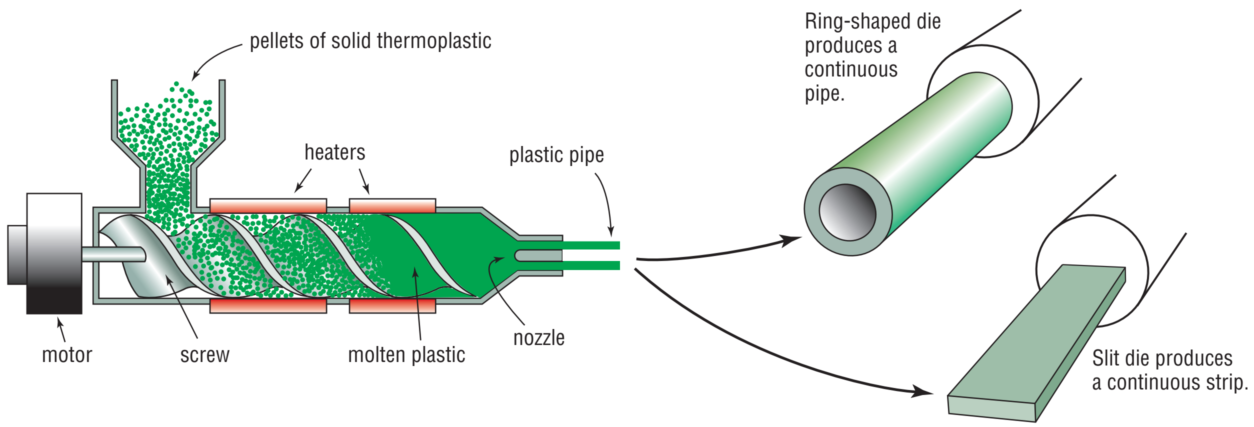
Extrusion moulding

Extrusion moulding is used to make pipes, hoses, drinking straws and rods. A screw constantly feeds the pellets into the nozzle. The shape of the nozzle determines the shape of the plastic 'extruded' from the end.

Blow moulding

Blow moulding is the process by which hollow plastic shapes are produced, such as a bottle. There are several different types of blow moulding but the most common is called injection blow moulding, which is shown in Figure 4.4.12.

In extrusion moulding the shape of the nozzle determines the shape of the extruded plastic. Fig 4.4.11



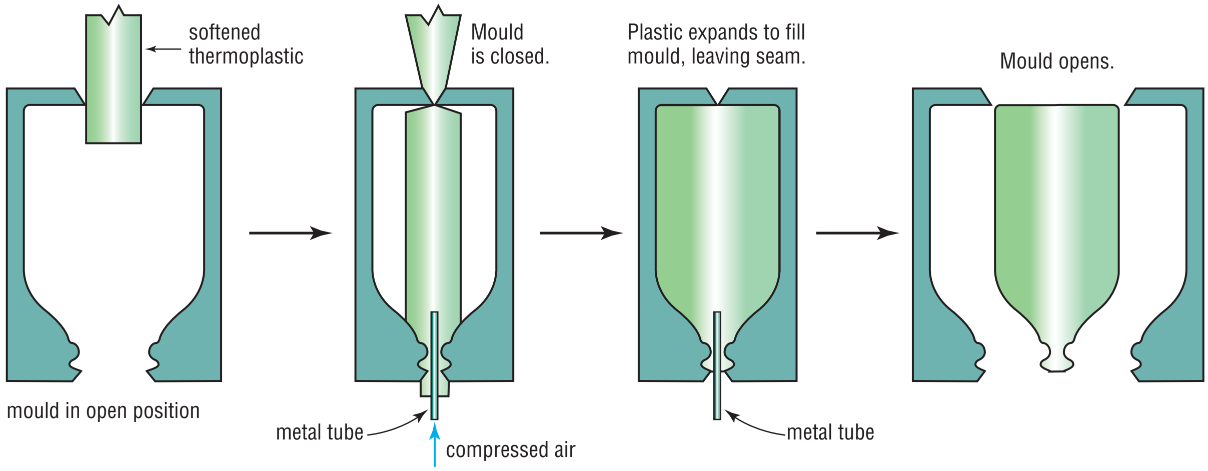
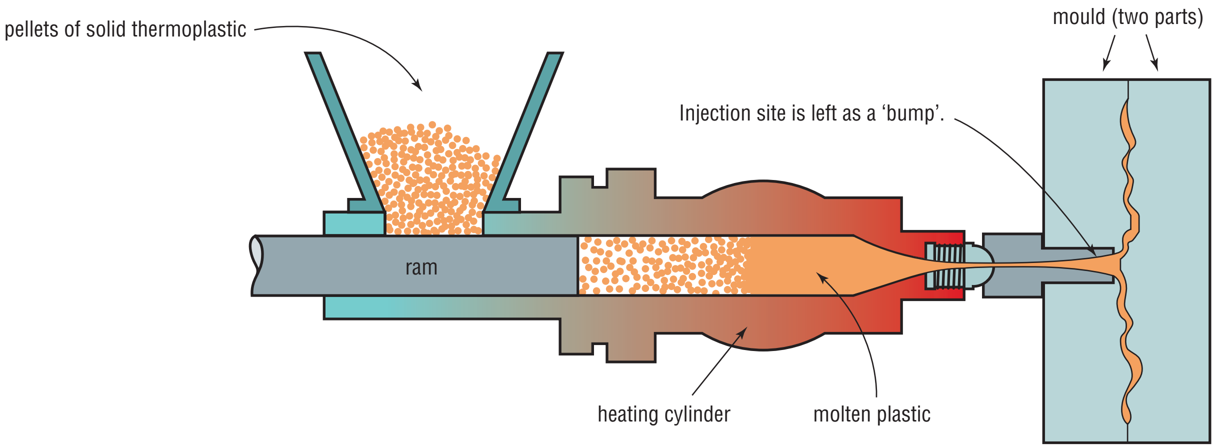


Fig 4.4.12 Injection blow moulding is used to produce bottles.

Injection moulding

Injection moulding is used to produce any desired shape. The molten plastic is injected at high pressure into the mould, which can be split to remove the finished product.

Fig 4.4.13 Injection moulding can be used to produce any shape required.



Natural polymers

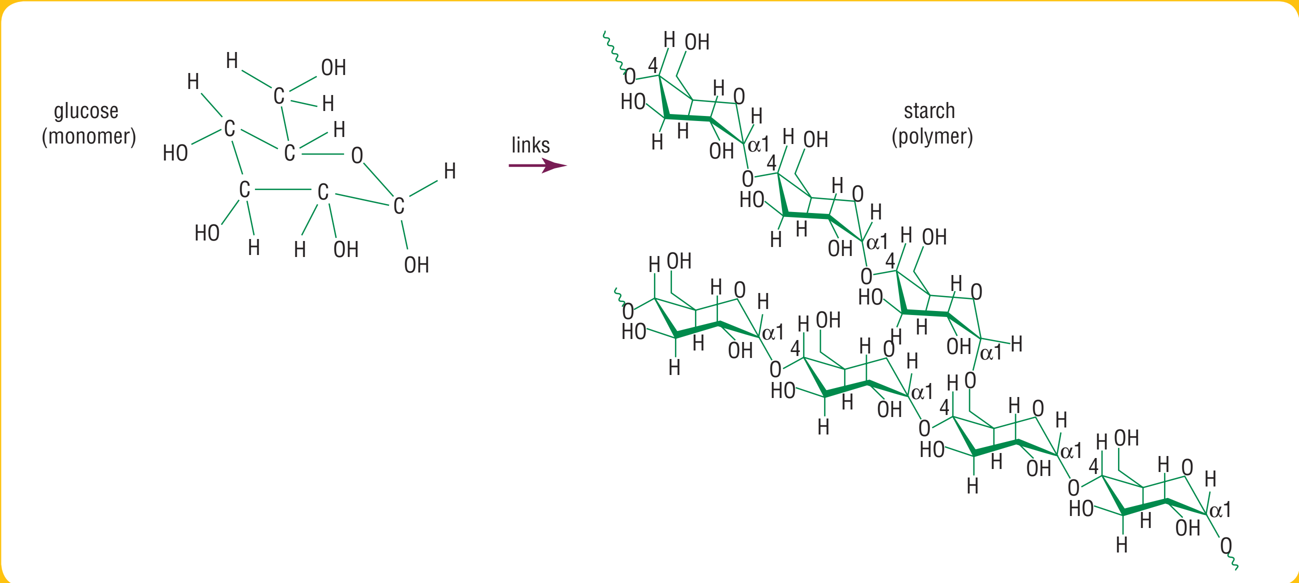
Nature invented polymers first. In this section you will explore some naturally occurring polymers, such as:

- polysaccharides—this group of polymers includes not only a large range of sugars essential for life but the code for life itself, DNA (deoxyribose nucleic acid)
- polypeptides—these are formed into proteins, some of which form structures in cells, and some of which form the enzymes that control all of the chemical reactions in our body.

Polysaccharides

Polysaccharides are commonly known as carbohydrates, which include a range of naturally occurring polymers such as starch and cellulose. Polysaccharides are made from repeating units of **monosaccharides**. You can see this in Figure 4.4.14.

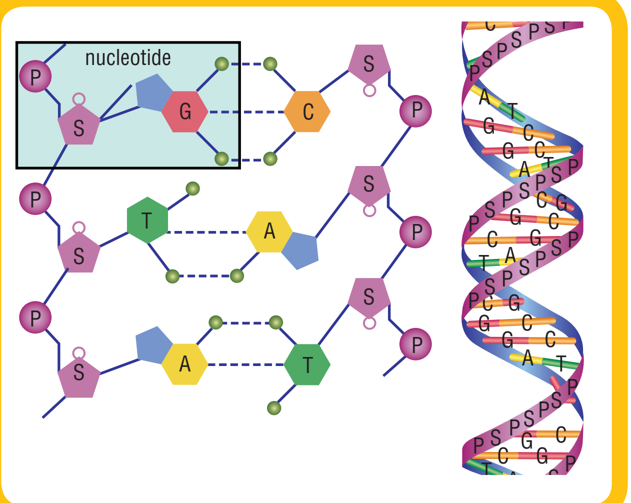
Fig 4.4.14 Monosaccharides such as glucose link and form cross-links to form polymers such as starch. Part of a starch molecule is shown here.



Apart from starch, another very common polysaccharide is cellulose, which forms the basis of all plant cell walls. Wood, paper and cotton all contain cellulose.

Deoxyribose nucleic acid (DNA) is also a polymer. The monomer units of DNA are called **nucleotides**. Nucleotides consist of a monosaccharide known as **deoxyribose** connected to a phosphate group and a nitrogen containing base. There are only four different types of nucleotides, which are given one-letter abbreviations—**adenine** (**A**), **guanine** (**G**), **cytosine** (**C**) and **thymine** (**T**). The nucleotides join in long polymers with different sequences of nucleotides (containing A, G, C or T bases). It is this sequence of bases that is the genetic information within the DNA. The DNA molecule is formed when two polymer chains of DNA interact to form the **double helix** structure that is found within the chromosomes of the nucleus that code for all of our genetic information.

Fig 4.4.15 DNA is a polymer. The monomers are called nucleotides. There are four of these and their different sequences contain the genetic code for your body.



Polypeptides (proteins)

Proteins form essential substances in your body, such as haemoglobin in blood, and antibodies produced by plasma cells in your immune system. Proteins also form **enzymes**, which control all of the chemical reactions in your body, including chemical respiration and digestion.

Science Snippet

Thirsty polymers!

The polymer crystals that are found in nappies are thirsty! Half a kilogram of these crystals can absorb up to 200 litres of water. The crystals are very similar in structure to collagen. Collagen is the most abundant polymer found in mammals. These crystals are used in sewage plants, cleaning up liquid spills, conditioning soil, ore processing and paper and textile plants. They are also used in sweat bands to provide a source of moisture for cooling by evaporation. They can be 'dehydrated' and 'rehydrated' many times.

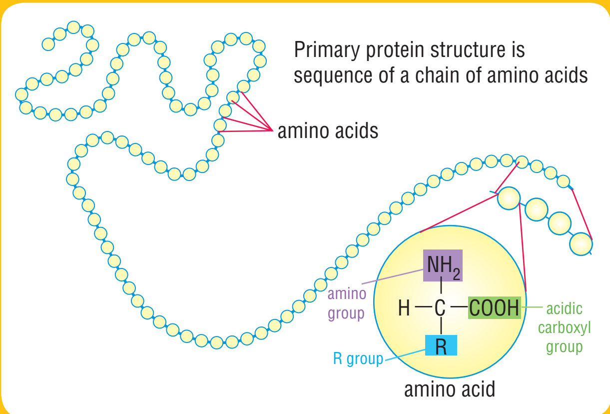


Fig 4.4.16 Proteins are polymers that inspired the development of plastics such as nylon. The monomers are called amino acids.

Proteins are very similar in their chemical bonding to plastics such as nylon. The monomers for proteins are **amino acids**. There are 20 amino acids whose sequence and number in the protein polymers form all the different proteins in your body.

Proteins form the major structures of the tissue that makes up living things. Proteins are the key substances in materials such as skin, hair, fingernails and muscle. Collagen is the most common protein in the body of a mammal. It is a long, fibrous structural protein, which is the main component of cartilage, ligaments and tendons, and is also found in skin, teeth and bones. Its strength is due to its bonding. The amino acid chains arrange themselves into a structure similar to the double helix of DNA but composed of three strands of amino acids called a tropocollagen unit. This arrangement gives collagen its great strength.

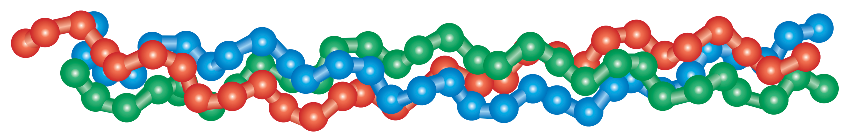


Fig 4.4.17 The 'triple helix' structure of collagen gives it its great strength. Collagen is the protein found in tendons, ligaments and bones.

Homework book 4.6 Monomer meets monomer

Prac 2 p. 221

4•4 FOCUS [Questions]

Use your book

Common properties of polymers

1 What does the word 'plastic' mean?

2 What are the main properties of polymers that have led to them replacing more conventional materials such as metals?

3 Identify the name of at least ten plastics that you have used today. Refer to the table on page 213 if you need to.

Monomers and polymers

4 Write a paragraph that defines the terms 'monomers' and 'polymers' and explains how these terms relate to each other.

5 Carbon can form single, double and triple bonds. Use diagrams to illustrate how these bonds are different.

6 Describe the process of hydrocarbon 'cracking' and why it is important in the production of monomers such as ethene.

Polymerisation

7 What happens to monomer units during the process of polymerisation?

Types of plastics

8 Explain the difference between a thermoplastic and a thermosetting plastic.

9 What is the unique property of elastomers? Explain this property in terms of how the monomers are arranged.

Shaping plastics

10 What is meant by 'extrusion moulding'? Support your answer by giving some examples of shapes that are produced.

11 Explain how a plastic bottle can be produced by 'blow moulding'

Natural polymers

12 Describe the structure of polysaccharides. In your description include the name of the monomer units found in polysaccharides and include some examples of polysaccharides.

13 Describe the structure of proteins. In your description include the name of the monomer units found in proteins and include some examples of proteins.

>>

Use your head

14 Many polymers are based on the structure of ethene. Ethene has a carbon-to-carbon double bond. Explain how this double bond assists in the formation of polymer chains.

15 Explain why most recyclable plastics are thermoplastics and not thermosetting plastics.

16 In terms of the base pairs found on nucleotides, what do you think would make one person's DNA different from another person's DNA?

17 Collagen is a very important structural polymer found in all of our bodies. What sort of body structures contain collagen? Explain how the function of collagen in these body structures is related to the arrangement of the monomers in collagen.

Investigating questions

18 Many polymers, such as polystyrene, are made as foams. Explain how these foams are made. Give some other examples of polymer foams and how they are used.

19 The arrangement of amino acids in proteins gives the protein its 'primary structure'. Investigate what is meant by the secondary and tertiary structure of proteins. What are some of the important properties of proteins that result from these secondary and tertiary structures?

20 Polymers that are formed when carbon-to-carbon double bonds open and link are called '**addition polymers**'. Another type of polymerisation reaction is called **condensation polymerisation**. Find out how these types of reactions work.

21 Investigate the size and importance of the plastic industry to Australia's economy. Write a brief report giving some examples of plastics produced in Australia.

FOCUS 4•4 [Practical activities]

Plastics

Prac 1
Focus 4.4

Purpose

To investigate the properties of a range of common plastics.

Requirements

A range of plastics cut into 2 cm × 2 cm strips (examples are polythene, polystyrene, PVC, Perspex, nylon), scissors, 250 mL beaker, detergent, turpentine, acetone, dilute hydrochloric acid (1M), magnifying glass, tongs, spirit burner, fume hood.

SAFETY NOTE: Plastics must be burnt in a fume cupboard only, as toxic smoke can be produced. Do not breathe fumes from burning plastic. Safety glasses must be worn at all times.

Procedure

1 You will be testing a range of plastics. Your teacher may get you to test all the plastics or just a sample of the plastics to combine the results with the class. Discuss this with your teacher.

2 *Copy the following data table into your notes.*

>>

	Polythene	Polystyrene foam	PVC	Perspex	Nylon
External appearance					
Internal appearance					
Flexibility					
Texture					
Ease of scratching					
Density					
Effect of solvent					
Description of burning					

3 *In your table describe the external appearance of your plastic.* Can you see through it? Use terms such as transparent, translucent and opaque.

4 Cut a small section of the polymer and observe the cut of the cross-section. Can you see bubbles or is it a smooth consistency? *Record your observations in the table.*

5 Try bending a piece of the plastic. Is it flexible or stiff? *Record your observations in the table.*

6 Rub the plastic with your finger—how would you describe the texture? Smooth or rough?

7 How easily can your plastic be scratched? If you can scratch it with your fingernail it is soft. If you need the scissors it is hard.

8 To check the density add about 200 mL of water to a 250 mL beaker. Add two drops of detergent to the water (to reduce the surface tension of the water). Add the plastic to the water. Does it sink (more dense than water) or float (less dense than water)?

9 Divide a plastic sample into three small squares. To one square add a drop of turpentine, to the other add a drop of acetone and to the third add a drop of HCl. Leave for a few minutes and then *record your observations. Describe whether the plastic has dissolved, gone soft or remained unchanged.*

10 This final section must only be done in a fume hood —try burning a small piece of each type of plastic using a spirit burner flame. You need to describe the following:

- Was any smoke produced? If so what colour?
- Did the plastic burn with a flame? What colour was the flame?
- Did the plastic char? Did drops of burning plastic fall from the plastic?

Questions

1 The table below summarises some of the properties of thermoplastics compared with thermosetting plastics. Use this table to classify your plastics.

Thermosetting	Thermoplastics
Harder and brittle	Softer
Insoluble in most solvents	Can dissolve in some solvents
Tend to be opaque	Excellent light transmission
Dense	Less dense
Burn and char rather than melt	Burn on their own relatively easily
Harder and brittle	

2 Which type of plastic would you use for the following purpose?

a A windscreen for a boat.
b Pipes in a chemical factory.
c A flexible rubber breathing tube for some SCUBA gear.
d Some gears for a gearbox in an electric car.
e A sealant to seal a shower screen.

Prac 2
Focus 4.4

Making nylon

Purpose

Your teacher will demonstrate how to make nylon, a type of plastic. Nylon is a thermoplastic polymer formed by condensation polymerisation.

Requirements

2.2 g 1,6–diaminohexane, 5 g anhydrous sodium carbonate, 2 mL sebacoyl chloride or adipoyl chloride, 50 mL cyclohexane, two 250 mL beakers, tweezers, glass stirring rod, water.

SAFETY NOTE: This demonstration must be done in a fume hood.

Procedure

1 Dissolve 2.2 g of 1,6–diaminohexane and 5 g of anhydrous sodium carbonate in 50 mL of water.

2 In another beaker, mix 2 mL of sebacoyl chloride or adipoyl chloride in 50 mL of cyclohexane.

3 Gently pour the 1,6–diaminohexane solution down the side of the beaker and onto the top of the cyclohexane solution without mixing the two solutions.

4 Gently lift part of the nylon formed between the solutions using tweezers. Pull a strand out and hang it over a stirring rod. Carefully wind as much nylon out of the beaker as you can.

Questions

1 What do you think would happen if the solutions were mixed rather than just be allowed to interact at a surface?

2 Let the nylon dry and then check its properties. Explain why this fibre is not very useful. Nylon is, however, a thermoplastic. What could you do with the strand if you wish to produce a nylon nut and bolt combination?

FOCUS 4•5

Organic chemistry

Context

More than 90 per cent of the chemicals around you, eaten by you and even smelt by you are organic compounds — from the fuel that drives all of our transport to the food that replenishes our energy to the dishwashing detergent that we use to clean our dishes.

Organic compounds now extend well beyond the chemicals found in plants and animals and include a huge range of substances made artificially by organic chemists in laboratories and chemical plants. At the heart of these millions of compounds is the element carbon. Carbon is found in all organic compounds and its unique properties give it the ability to form so many different type of substances that not only make our life more pleasant but also make life itself possible. Welcome to the wonderful world of organic chemistry.

What is an organic compound?

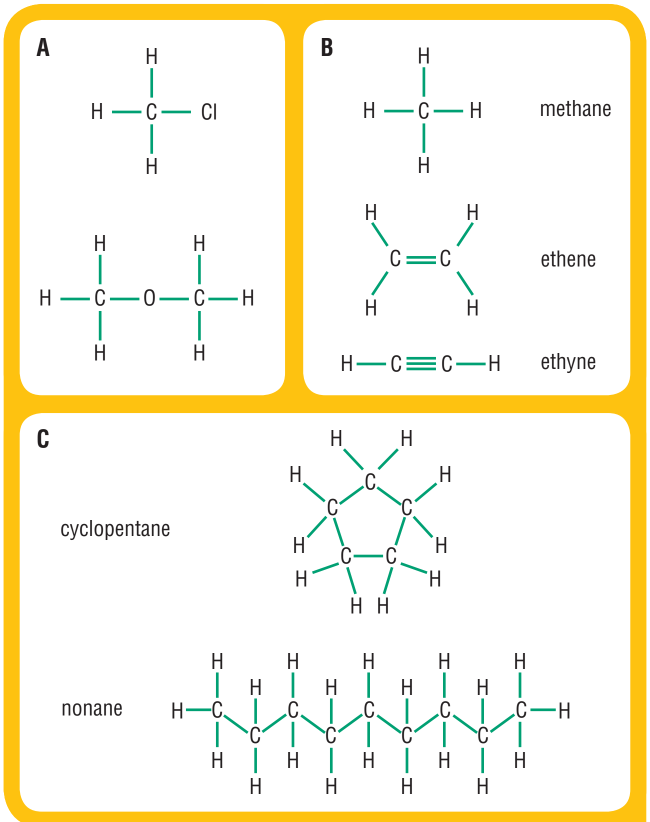
Organic compounds were introduced in Focus 5.8 of *Science Aspects 2*. Organic compounds were once considered a class of chemical compounds that occurred naturally and could be found in the bodies of plants and animals. While this is still true, many organic compounds are synthesised in laboratories. Many of the polymers you explored in Focus 4.4 are a good example of synthetic organic compounds.

Organic compounds make up more than 90 per cent of the compounds that surround you. Can you identify some of these in this photograph?

Fig 4.5.1

Carbon is the only chemical element that has the unique properties required to produce the millions of organic compounds. Some of these special properties were explored in Focus 4.4 and include the following:

- Carbon-to carbon bonds are very strong. Carbon normally forms four covalent bonds. These bonds can be with other carbon atoms to form chains or with other non-metal atoms such as oxygen, hydrogen, sulfur, nitrogen and other atoms.



Carbon can bond with a range of non-metal elements other than itself (a) and can form single, double or triple covalent bonds (b) and form long chains or rings (c).

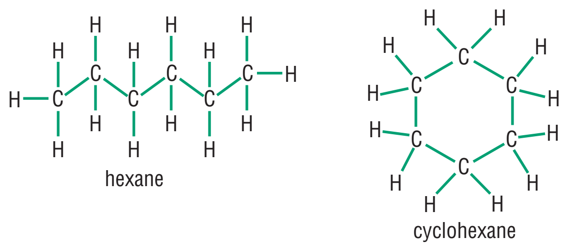
Fig 4.5.2

- The bonds that carbon forms with itself can be single, double or triple bonds.
- Carbon atoms can join to form long chains (as in polymers) and rings.

Hydrocarbons

Hydrocarbons are organic compounds that contain only carbon and hydrogen and can exist as straight chains (**aliphatic**) or in rings (**cyclic**).

Fig 4.5.3 Hydrocarbons can occur as aliphatic or cyclic compounds.



The number of bonds between the carbon atoms alters the properties of hydrocarbon. Hydrocarbons with only single-carbon bonds are called **alkanes**, those with double bonds are called **alkenes** and those with triple bonds are called **alkynes**.

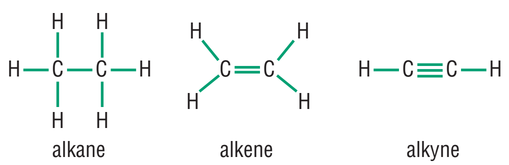


Fig 4.5.4 Hydrocarbons can occur with single bonds only (alkanes), double bonds (alkenes) or triple bonds (alkynes).

Name	Formula	Phase	Boiling point (°C)	Example of use
Methane	CH_4	Gas	–162	Natural gas—used for heating
Ethane	C_2H_6	Gas	–89	Refrigerant
Propane	C_3H_8	Gas	–42	Gas for cooking, transport
Butane	C_4H_{10}	Gas	–0.5	Rubber manufacture
Pentane	C_5H_{12}	Liquid	36	Fuel and solvent
Hexane	C_6H_{14}	Liquid	69	Filling for thermometers
Heptane	C_7H_{16}	Liquid	98	Fuel
Octane	C_8H_{18}	Liquid	126	Fuel (petrol)
Nonane	C_9H_{20}	Liquid	151	Fuel (petrol)
Decane	$C_{10}H_{22}$	Liquid	174	Fuel (petrol)
Dodecane	$C_{12}H_{26}$	Liquid	216	Solvent
Hexadecane	$C_{16}H_{34}$	Liquid	287	Fuel (diesel)
Eicosane	$C_{20}H_{42}$	Solid	343	Wax (candles)

The length of the hydrocarbon chain plays a big part in determining the properties of the substance and therefore what it is used for. Look carefully at the table at the bottom of this page. Can you see any trends or patterns in the properties of the hydrocarbons in this table as the length of the carbon chain increases? You might like to discuss this with the rest of your class.

Interactive CW Animation

Organic compounds are named according to the number of carbon atoms in the molecule. For example, 'meth' means one carbon atom, 'eth–' refers to two carbon atoms, 'prop' refers to three carbon atoms and so on. The naming of organic compounds is subject to a number of international rules determined by a group of scientists known as the **International Union of Physical and Applied Chemists (IUPAC)**. This allows chemists, regardless of their country origin, to name and discuss organic compounds across the world. You will explore this process when your senior school journey in organic chemistry continues.

Functional groups

Every organic compound has its own special properties, which are determined by the atoms and the bonds that make up the molecule. These special groups of atoms or bonds are called **functional groups**. For example, in hydrocarbons such as alkenes, it is the carbon-to-carbon double bond (–C=C–) that gives the molecule its special properties. In this Focus you will explore the following functional groups and their applications in a range of everyday applications:

- alcohols
- carboxylic acids
- esters.

Science Snippet

What is the world's smelliest substance?

According to the *Guinness Book of Records*, this title is won by the substance called ethyl mercaptan, which is said to smell like a combination of rotten cabbage, garlic, onions, burnt toast and sewer gas! Wow! What a combination. The functional group responsible for this smell is the –S-H group. Compounds that contain sulfur are often smelly. Rotten egg gas, for example, is hydrogen sulfide (H_2S).

Alcohols

Alcohols are organic compounds in which the carbon chains contains one or more of the hydroxy (–OH) group, which is an oxygen joined to a hydrogen atom. The following table shows the first three alcohols in the series. Note how they are named and some of their special properties, and that their names all end in '–ol'.

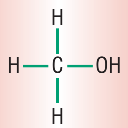
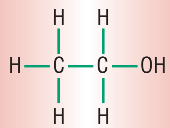
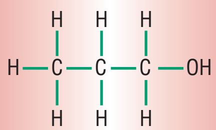
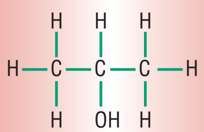
Structure of alcohol	Name	Uses
	methanol	Solvent for varnish Windscreen washer cleaning fluid
	ethanol	Component of all alcoholic drinks Solvent in industry and medicine
	1 propanol	1 propanol Solvent in the pharmaceutical industry
	2 propanol	2 propanol Rubbing alcohol, solvent

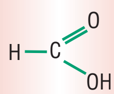
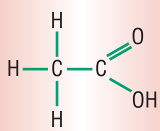
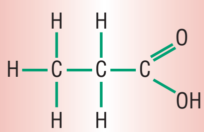
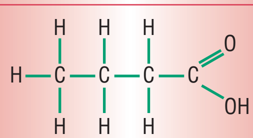
Fig 4.5.5 The stinging sensation from an ant bite or a bee sting is a result of the methanoic acid, which is the simplest of all the carboxylic acids.

Esters

Esters are a very important group of organic compounds that have very characteristic smells and flavours and are often used in the food industry, as you will explore later in this Focus. They are produced when alcohols and carboxylic acids react. A common example is ethyl ethanoate, which gives nail polish remover its characteristic sweet odour. It is formed when ethanol and ethanoic acid react together as shown in Figure 4.5.6.

Carboxylic acids

Carboxylic acids contain the function group –COOH, which is a carbon, two oxygen atoms and a hydrogen atom at the end of a carbon chain. The names of carboxylic acids always end with '–oic'. The first four carboxylic acids, along with their uses, are shown in the following table. Their IUPAC and the common (or trivial) name for these substances are also given. Trivial names have a historic significance and are sometimes still used.

Structure of carboxylic acid	Name (trivial name shown in brackets)	Uses/sources
	Methanoic acid (formic acid)	Used in medicine, food preservation and textile industry. Is responsible for the 'sting' in bee and ant stings
	Ethanoic acid (acetic acid)	Is the main component of vinegar. Is also used in the production of polymers and in the tanning industry
	Propanoic acid (propionic acid)	Used as an anti-fungal and anti-mould agent in baking bread and ointments
	Butanoic acid (butyric acid)	Causes the odour of 'rotten socks' and body odour

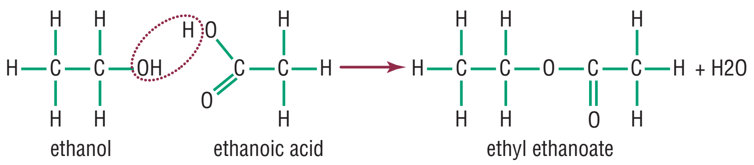


Fig 4.5.6 Alcohols react with carboxylic acids to form esters. Esters have a number of characteristic properties, such as their sweet odour, and are often used in the food industry as flavour enhancers.

To save time, a visual shorthand has been developed in organic chemistry to represent the hydrocarbon backbone. In this shorthand, hydrogen atoms are not shown and the carbon atoms are represented by lines. Using this shorthand, the triglyceride in Figure 4.5.7 would be represented as shown in Figure 4.5.8.

►**Homework book 4.7** Developing a tougher polymer

Organic chemistry in action

In the last Focus you explored one very important use of organic chemistry—the production of polymers. In this section you will look at some more applications of organic chemistry, including the production and uses of soaps and detergents. You will then explore a subject popular with everyone—food! Organic compounds are used to produce a huge range of flavourings in both food and drink.

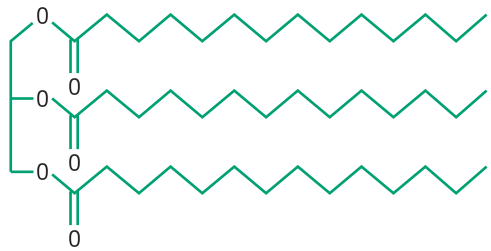


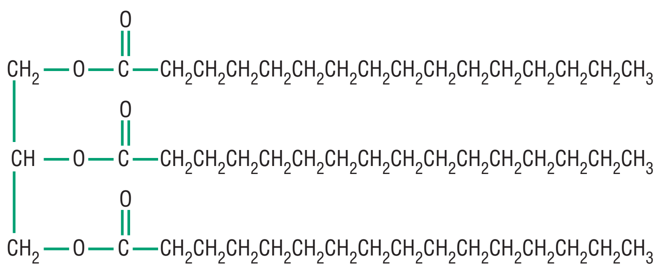
Fig 4.5.8 Large organic compounds are often represented in a shorthand where the hydrogen atoms are to the left and carbon atoms are represented as straight staggered lines.

Keeping clean—the production and use of soaps and detergents

The ancient Egyptians are believed to have been some of the earliest organic chemists. There is evidence that soap was produced in ancient Egypt from the reaction between animal fat and wood ash, which produced a crude alkali.

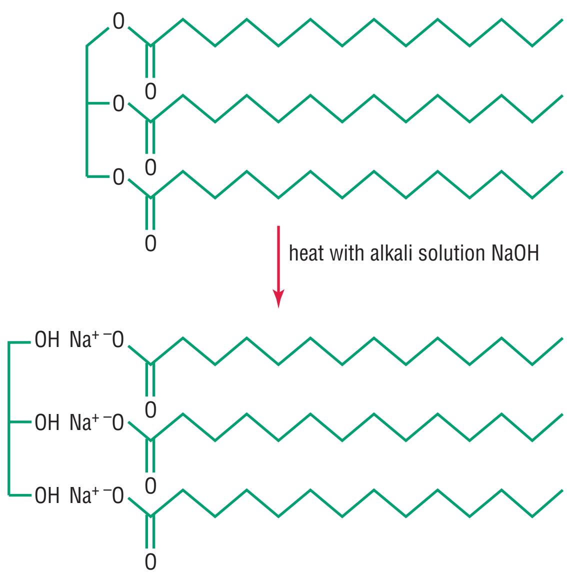
One of the main reactants in the production of soaps is animal fats. Animal fats are varied in structure but all are esters that are known as **triglycerides**.

Fig 4.5.7 Animals fats are the main reactant in soaps. They are esters know as triglycerides. The 'tri' refers to the backbone of three esters that make up a fat molecule. The structure and length of the long hydrocarbon extensions can vary.



Soaps are produced in a chemical reaction known as **saponification**. In this process animal fats are heated with strong solutions of an alkali such as sodium hydroxide.

Fig 4.5.9 In saponification triglycerides are heated with an alkali solution such as sodium hydroxide.



In saponification one triglyceride forms three molecules of soap and an alcohol known as 1, 2, 3 propanetriol (glycerol). Note the special structure of the soap molecule. It is a long hydrocarbon chain for most of the molecule, with a charged end consisting of the positive ion of the alkali and the carboxylic acid of the triglyceride. It is this structure that gives soap its special properties.

Detergents are similar to soaps in structure in that they contain a long hydrocarbon chain and a charged end. The structure of detergents includes a special hydrocarbon ring structure known as 'benzene'. Benzene is a very stable six-carbon ring structure that forms the basis of many organic compounds. You will explore benzene and its derivatives in your senior school chemistry.

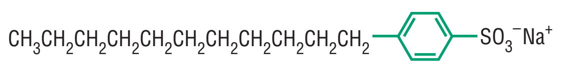
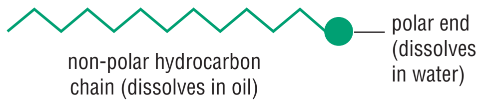


Fig 4.5.10 A detergent molecule is similar to a soap molecule in that it contains a long hydrocarbon chain with a charged end.

To understand how soaps and detergents are successful in removing oil-based stains from clothing and other surfaces you need to refer back to Focus 4.2. In this Focus you explored the 'polar' nature of water. The polar nature of water allowed it to interact and dissolve substances that contained charged sections such as ionic substances. Substances that do not contain any charge separation were said to be **non-polar**. The success of soaps and detergents is due to their ability to be able to dissolve in water yet still interact with oil-based materials. Soaps and detergents have a dual nature—the long hydrocarbon ends of the molecules are non-polar and can interact with oil-based substances, while the charged ends can interact with water. When soaps and detergents are added to water they 'dissolve' and form a negative ion, called the surfactant ion, after the positive ion (sodium or potassium) goes into solution. Soap and detergent molecules are often represented as a general structure showing the long non-polar end and the charged polar end.

Fig 4.5.11 Soaps and detergents have both polar sections and non-polar sections so that they can dissolve in both water and non-polar materials such as oil and grease.



The polar and non-polar sections of surfactant ions allow them to dissolve in both the water and the oil-based substance. This allows the oil material to be removed from the surface of the material being cleaned.

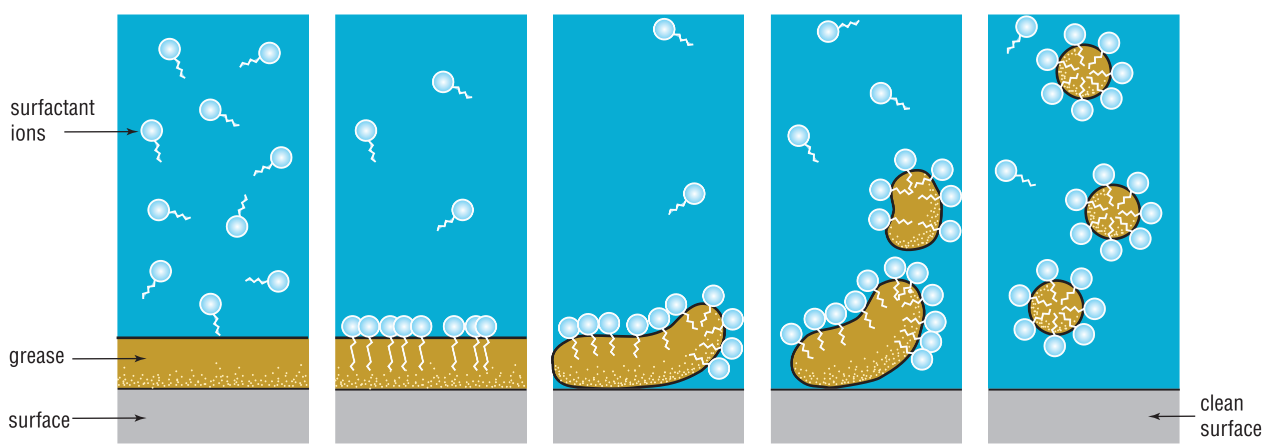


Fig 4.5.12 Surfactant ions dissolve in water. The non-polar end dissolves in the oil-based stain while the polar end remains dissolved in the water. Movement and stirring help the surfactant to remove the oil-based stain of the surface being cleaned. The oil that is removed forms small droplets.

The oil-based material removed from the material forms small droplets called **micelles**, which float to the surface. You may have seen these droplets floating on the water after washing up a greasy pot or pan.

QuickTime CW Video

Prac 1 p. 231

Organic solvents

Many organic chemicals are used as solvents in industry. While their use has been very important for developing a wide range of substances that have improved our lifestyle, it has now been identified that many of them are contributing to environmental pollution as well as being dangerous to handle. You will explore this more in Focus 4.6 (Chemistry and sustainability). The following table shows some common organic solvents and their uses.

Organic solvent (trivial name in brackets)	Formula	Industrial use
Hexane	C_6H_{14}	Solvent in glues
Benzene	C_6H_6	Solvent in the production of drugs, dyes, synthetic rubber and plastics Carcinogenic (cancer-causing)
Methyl benzene (toluene)	C_6H_5-CH_3	Solvent in paint thinners, rubber production, glues and disinfectants
Ethoxyethane (diethyl ether)	CH_3CH_2-O-CH_2-CH_3	Solvent for industrial processes such as rubber extraction
Chloro-methane (chloroform)	CH_3-Cl	Solvent used in the production of synthetic rubber

Organic solvents are difficult to handle because they are all flammable and their vapours are flammable and toxic. Some organic solvents, such as benzene, are well-known cancer-causing substances (carcinogenic). They must always be handled with gloves, as they can be absorbed through the skin and many will irritate the skin.

Science Snippet

White spirit

One of the most common organic solvents in the paint industry is 'white spirits'. It is actually a mixture of several hydrocarbons, from C_7 (seven carbons in the chain) to C_{12} molecules. It is used for cleaning, filling aerosols, in wood preservatives and in varnishes.

The food industry

The organic chemist has a very important role in the food and drink industry. Most of the food that we eat is 'organic' in the true sense that the chemicals in the food are organic compounds. Many food products are now labelled as 'organic', which refers not to the compounds in the food but in how the foods were produced. 'Organic' or 'organically grown' often refers to the fact that the food materials were not treated with any inorganic fertilisers or treated with inorganic pesticides or herbicides.

Some of the most important applications of organic chemistry in the food industry are the use of organic compounds as food additives.

Food additives

Many of the food additives used in industry are organic compounds and are added to food for a variety of reasons, as shown in the following table.

Drag and Drop CW Interactive

Food additive category	Uses and examples
Acids	'Sharpen' the flavour of foods, eg ethanoic acid, tartaric acid, lactic acid
Anti-caking agents	Keep powders flowing smoothly
Antioxidants	Used as a preservative. Generally thought to be beneficial to human health
Bulking agents	Bulk up the food so that it goes further, eg starch
Colouring agents	Artificially colour foods to make them look more 'natural' and appealing
Emulsifiers	Keep foods that are not soluble 'mixed', eg mayonnaise, ice-cream
Flavourings	Give food a particular taste and smell. They may be obtained from natural foods or entirely artificial
Humectants	Prevent foods from drying out
Preservatives	Prevent decay due to the action of bacteria and fungi, allowing foods to last longer after opening
Stabilisers	Thicken foods to give a firmer texture
Sweeteners	Artificially sweeten food. Many of them are low in kilojoules
Thickeners	Make food thicker without changing other properties such as taste

A numbering system for food additives has been developed so that you can be informed about what you are eating. This allows you to make decisions about the substances that you consume. For some people with food allergies this is particularly important. For example, if you are shopping for a 'stir fry' meal you might find this on the label:

> Ingredients—pork (30%), wheat flour (10%), capsicum, pineapple, green beans, sweet corn, sugar, tomato paste, pineapple concentrate, water, thickener (1422), acidity regulators (270, 260), soy sauce, salt, flavours, thickener (415).

Fig 4.5.13 Food additive codes on the labels of food products allow us to make choices about the foods that we eat.

Science Snippet

Chinese Restaurant syndrome

Some people have a reaction to the food additive monosodium glutamate (MSG). It is used as a flavour enhancer in many Chinese meat dishes. It has been linked to many reactions such as migraines, nausea, gastric upsets, heart palpitations and even hair loss! Many restaurants now advertise their meals as 'MSG free' in response to these problems.

There are many sources (books, the Internet) which you can use to identify the names of food additives from the codes you see on food labels. For example, thickener 1422 is acetylated distarch adipate and thickener 415 is xanthum gum.

Flavourings are an important aspect of food. Many of the flavours in food such as fruits are caused by functional groups such as esters. These esters can be found naturally in many foods or can be used as food additives in foods such as yoghurts and other sweets. Esters are also used in many common fragrances, such as those found in air fresheners.

The following table lists some of the more common flavourings and fragrances produced by esters.

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Name of ester	Flavour/fragrance
Allyl hexanoate	Pineapple
Benzyl acetate	Pear, strawberry
Ethyl butyrate	Banana, pineapple, strawberry
Ethyl cinnamate	Cinnamon
Ethyl heptanoate	Apricot, cherry, grape, raspberry
Propyl isobutyrate	Rum

Homework book 4.8 Additive alert!

Fermentation

Fermentation is used in the preparation of a range of food and drinks, including foods such as bread, cheese and yoghurt, and alcoholic drinks such as beer and wine.

In fermentation, microbes convert the sugar in foods to products such as ethanol or acids.

Fermented foods are formed in many different ways and many of the processes have developed over hundreds and even thousands of years.

Science Snippet

So how long have humans been drinking wine?

Scientists believe that they discovered wine residue in pottery dating back to 6000 BC but because of the age of the chemicals this is inconclusive. Domestic grapes were first grown about 3000 years ago in Egypt and the process of making wine from this era is well recorded. As for present times there are vintages dating back to the 1790s that are still said to be drinkable! Mind you, they are also very expensive!

Fig 4.5.14 Fermented food products such as breads, cheese, pickled vegetables and wine form an important part of our diet.

Organic chemists have been important in refining and controlling these processes as well as developing additives to enhance their flavour and use.

The following table shows some of the products and processes of food fermentation.

Food product	Fermentation process
Beer	A mixture of barley and hops is fermented by yeast. The starch in barley is broken down into glucose, which is then acted on by yeast
Bread	Yeast ferments the sugar in the bread mix to carbon dioxide and ethanol. The carbon dioxide causes the bread to rise (leaven). The alcohol is evaporated and lost during the cooking process
Yoghurt	Yoghurt is a product of fermented milk products. The major food acid produced is lactic acid, which gives yoghurt its sour taste
Cheese	Cheese is also a fermented milk product but its production is more complex, involving a lactic acid culture. Rennet is also added to break down the protein in milk to form curds.

There is a large range of other fermented food products involving dairy products. Fermentation is also used to prepare a large range of beverages, such as whisky (fermented corn and rye), cider (fermented apple juice), sake (fermented rice) and, of course, wine (fermented grape juice).

Organic chemists

This Focus has introduced you to wonderful world of organic chemistry. It is a large branch of chemistry and many people train specifically in the area of organic chemistry. You have explored a few of the important products of organic chemistry in this Focus as well as in Focus 4.4 (polymers) but there are many other areas where the organic chemist is employed, including paints, herbicides and pesticides, explosives, pharmaceutical drugs and petrochemicals, and the chemistry of living things—biochemistry.

The organic chemist plays an important role in providing us with the substances that enhance our way of life and standard of living. The organic chemist plays an equally important role in making sure that these materials are produced in a responsible way as far as our environment and the generations to follow are concerned. This important concept is known as sustainable or ‘green chemistry’ and will be explored in the next Focus.

Homework book 4.9 Glues with real mussel

4•5 FOCUS [Questions]

Use your book

What is an organic compound?

1 Give the modern definition of an organic compound. How does this definition vary from older definitions?

2 Describe the unique properties of the carbon atom that make it suitable to form the millions of organic substances found on our planet.

Hydrocarbons

3 What are hydrocarbons, and in what forms can they exist?

4 Describe, with the aid of diagrams, the difference between the hydrocarbon groups of alkanes, alkenes and alkynes.

5 The length of the hydrocarbon chain determines the ‘prefix’ that is used in naming organic compounds. Copy and complete the table opposite, which relates the number of carbons in the chain to the prefix name. A couple of examples have been done for you.

Number of carbon atoms in the chain	Prefix name for organic compound
1	Meth–
2	
3	
4	
5	
6	
7	Hept–
8	
9	
10	

6 a What do the letters ‘IUPAC’ stand for?
b What is the role of this organisation in the naming of organic compounds?
c Why is this important for organic chemists?

>>

Functional groups

7 Describe what is meant by a 'functional group'?

8 Copy and complete the following table, which identifies functional groups.

Name of functional group	Formula of functional group
Alkenes	
Alkynes	
Alcohols	
Carboxylic acids	

Keeping clean—the production and use of soaps and detergents

9 What is the main functional group of a 'triglyceride'?

10 What is the name given to the process of producing soap from animal fat?

11 How are soaps similar to detergents? Draw a diagram of both a soap and detergent molecule to support your answer.

12 Use 'shorthand' to draw a soap molecule and label the 'polar' and 'non-polar' end of the molecule. Explain how this structure helps the soap molecule to dissolve an oil-based stain.

Organic solvents

13 Give some example of organic solvents. What special precautions must be made when handling them?

The food industry

14 The term 'organically grown' is often used to describe vegetables. What does this term mean?

15 How can food additives be identified when you are reading a food label?

Fermentation

16 What are generally the reactant and products in the fermentation process?

Organic chemists

17 Give an example of the types of industries that would employ an organic chemist.

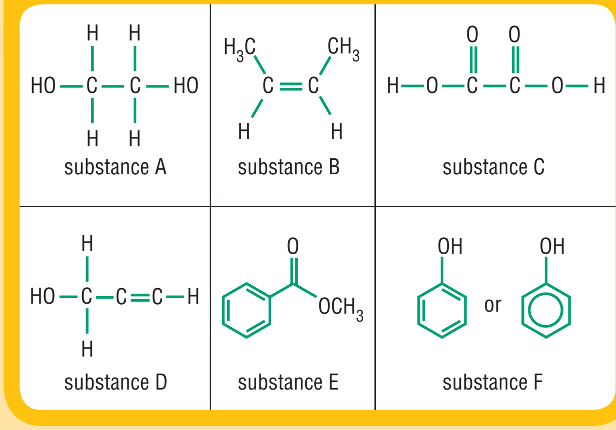
Use your head

18 Refer back to the table on page 223 which shows the formulas of hydrocarbons and their boiling points. What is the relationship between the length of the hydrocarbon chain and the boiling point of the hydrocarbon?

19 **a** Copy into your notebook the structures for substances A to F in Figure 4.5.15. Classify each substance in your diagrams into one of the following groups: hydrocarbon (alkane), hydrocarbon (alkene), hydrocarbon (alkyne), alcohol, carboxylic acid; ester.

b On the diagram you have drawn highlight the functional group (with a highlighter pen if you have one) in each of the substances:

Fig 4.5.15 Substances to classify for question 19



20 Organic solvents such as hexane (C_6H_{14}), benzene (C_6H_6) and methyl benzene (C_6H_5- CH_3) are insoluble in water while the solvent ethanol (CH_3CH_2-OH) is reasonably soluble in water. Suggest a possible reason for this.

21 A piece of cloth has accidentally been stained with oil. You have a choice of a range of solvents including water, white spirit (a mixture of hydrocarbons from C_7 to C_{12} in length) and ethanol. Which of these solvents would you test first? Explain your answer.

Investigating questions

22 Micelles are formed when soaps and detergents are used to clean oily substances from materials. Explain how they are formed. What shape are they? Why are they this shape?

23 Research food additive codes. Are the same codes used in Australia as in Europe? Visit your local shopping centre and identify the food additive codes on a range of different meals that you would eat at home.

24 Search a range of newspapers and locate jobs for which an organic chemist would be employed. Describe the type of work and chemical products they would work with.

25 Investigate some more organic functional groups found in organic chemistry. Draw an example of substances that contain these functional groups.

4•5 FOCUS [Practical activities]

Prac 1 Focus 4.5

Making soap

Purpose

To make soap. Prior to mass production many people used to make their own soap. The chemical reaction is called **saponification** and involves heating triglycerides (esters) with an alkali (sodium hydroxide).

SAFETY NOTE: All heating must be done on a hot plate. Sodium hydroxide is very caustic and you must wear safety glasses at all times. Use a water bath where directed. (A water bath consists of a small beaker in a larger water-filled beaker, which is then heated. This prevents the contents of the smaller beaker being heated directly. This is very important when flammable substances are being heated)

When you are testing your soap at the end of the investigation do so carefully. If the sodium hydroxide has not been washed out carefully it will irritate your skin. Test on a very small area of skin first and if any irritation occurs then wash the area with water immediately.

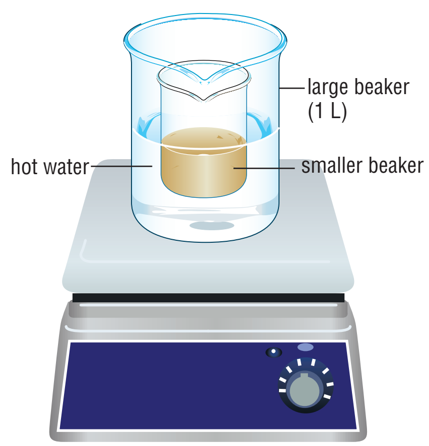
Requirements

Safety glasses, lard (cooking fat), two 250 mL beakers, 1 litre beaker, hot plate, triple beam balance or electronic balance sodium hydroxide pellets, methylated spirits, olive oil, solid sodium chloride, distilled water, fine gauze (or strainer), ice, glass stirring rod, spatula, measuring cylinder.

Procedure

1. Put on your safety glasses. Measure out 10 g of lard or fat into a 250 mL beaker.
2. Melt the lard or fat in a water bath as shown in Figure 4.5.16.

Fig 4.5.16 A water bath



3. In another 250 mL beaker dissolve 10 grams of sodium hydroxide pellets in 50 mL of distilled water.

   SAFETY NOTE: This solution will be very caustic. Handle carefully and wear your safety glasses at all times.
4. Add 10 mL of methylated spirits to your sodium hydroxide solution.
5. Add the sodium hydroxide solution slowly and carefully to the melted lard with continuous stirring.
6. Continue to heat the mixture in the water bath for 30 minutes. When you get to within the last 5 minutes of heating, add 10 mL of olive oil. Move onto the next step before this step is finished.
7. Prepare your salt solution by dissolving 120 g of sodium chloride in 500 mL of distilled water.
8. Pour the hot soap solution into the brine and stir well. Curds should form.
9. Carefully strain the solution through a fine strainer or gauze.
10. Wash the curds with ice-cold water to remove any remaining sodium hydroxide.
11. Squeeze the curds dry and shape into a block of soap.
12. Cut off a section of your soap and place it into a beaker with a little water. Stir it vigorously to see if it will lather.
13. Try lathering the soap on your hands using a small piece of the soap.
14. Wash your hands with water very carefully.

Questions

1. How well did your soap lather?
2. Why were the curds washed in cold water?
3. Describe what happens to the triglycerides during the saponification reaction. Use a diagram to support your answer.
4. Research the commercial production of soap. What are some other substances that can be added to the soap? How do they improve the final product?

Prac 2
Focus 4.5

'Esterday—making esters!

Purpose

To react a alcohol with a carboxylic acid to produce an ester.

Requirements

Safety glasses, 500 mL beaker for a water bath, hot plate, alcohols and organic acids (see table below), measuring cylinder, test tubes and racks, concentrated sulfuric acid, stirring rod, test tube holders.

SAFETY NOTE: Take great care when using concentrated sulfuric acid. Safety glasses must be worn at all times. Solutions must only be heated in a water bath as alcohols are flammable. DO NOT use a Bunsen burner.

When smelling substances make sure that you waft odours towards you.

The esters you can make will depend upon the availability of alcohols and organic acids in your lab. You can select from the combination given in the following table. The list also tells you how much of the concentrated sulfuric acid needs to be added to each reaction. The trivial names for the substances are given in brackets.

Organic acid and mass or volume required	Alcohol and volume required	Drops of concentrated sulfuric acid required
Salicylic acid —1 g	Methanol (methyl alcohol) —2 mL	10 drops
Ethanoic acid (acetic acid) —3 mL	1-octanol (octyl alcohol) —2 mL	10–15 drops
Methanoic acid (formic acid) —4 mL	Ethanol —2 mL	20 drops
Butanoic acid (butyric acid) —2 mL	Ethanol —2 mL	15–20 drops
Butanoic acid (butyric acid) —2 mL	Methanol —2 mL	15–20 drops

Procedure

1. Prepare a hot water bath by half-filling a 500 mL beaker with water and placing it on a hot plate. Get it to the point where it is boiling slowly.
2. Determine with your teacher which of the alcohol/acid mixtures you are going to prepare.
3. Use the table below (left) to add the required amounts of carboxylic acid into a test tube. Add the required volume of alcohol. CAREFULLY add the sulfuric acid to the mixture. (Your teacher may want to do this for you, or may want you to do this at the front desk where your teacher can watch. Ask what you have to do.)
4. Use a pair of tongs to hold the test tube carefully in the hot water bath for about a minute.
5. Take the test tube containing your ester out of the water bath and carefully waft the odour towards you.
6. Carefully note the smell and *record it in a suitable table, which clearly indicates which alcohol and acid were used to produce the ester.* Try to compare the odour of your ester with known smells such as fruits. You may like to get the opinions of others in your classroom.
7. Repeat this activity for other alcohols and acids as directed by your teacher.

Questions

1. Compare the odours from your investigation with the odours from the following table. Which of these do you agree with? If you do not agree, what may be some reasons for this?

Organic acid used	Alcohol used	Essence (odour) of ester produced
Salicylic acid	Methanol (methyl alcohol)	Wintergreen ('Dencorub'-type smell)
Ethanoic acid (acetic acid)	1-octanol (octyl alcohol)	Orange
Methanoic acid (formic acid)	Ethanol	Rum
Butanoic acid (butyric acid)	Ethanol	Pineapple
Butanoic acid (butyric acid)	Methanol	Apple

2. The sulfuric acid that is used in the 'esterification' reaction is said to be a catalyst. What is a catalyst?
3. Why were the acid, alcohol and catalyst (sulfuric acid) warmed?
4. What are some common foods that would use 'esters' to provide the flavour?

Extra for experts

5. Using your knowledge of esters and available materials, explain how to make a 'scratch and sniff' book of common fruits for a young child.

FOCUS 4·6 Chemistry and sustainability

Context

It is largely thanks to advances in our understanding of chemistry that our average life expectancy has increased from about 47 in 1900 to the mid-70s at the start of the 21st century. This is due largely to better pharmaceuticals, cleaner water and the use of better materials to produce our clothing and homes. This has come at a large environmental price. Our atmosphere is showing many signs of abuse. Our waterways are often polluted and millions of tonnes of plastic and other toxic rubbish lie in landfill sites. We owe a lot to chemistry but chemistry also owes the environment a fair go. A lot of our chemical industries are going 'green'. 'Green principles' acknowledge the importance of chemistry in developing a sustainable society. We must work towards a 'sustainable' future so that our environment can support us not only for our lifetime but for those who will follow.

What has chemistry ever done for us?

Just look around you to answer this question. Chemistry has brought us the lifestyle we enjoy today:

- Chemistry and health—as a result of new and improved pharmaceutical drugs the average life expectancy has increased markedly. Other drugs such as disinfectants and antibiotics, as well as immunisations, help us on a daily level and have given hope and extended lives in many third world countries and countries hit by natural disasters.
- Water purification and water treatment—with the population increasing in many capital cities, such as Perth, the pressure on our water supplies is immense. We are increasingly reliant on groundwater, which requires considerable chemical treatment. In developing countries, clean fresh drinking water is vital to their continued development. It is chemistry that has made this possible.
- Agriculture and food production—it is chemistry which has produced the fertilisers that can keep the soil fertile enough to grow the food we require. Chemical preservatives also extend the usable time of these foods and allow them to be distributed across the globe. Packaging developed by chemists also supports the global distribution of foods to all countries.

Fig 4.6.1

Developments in chemistry have led to the development of a huge range of pharmaceutical drugs that have extended lives and improved lifestyles for billions of people.

We can only feed the inhabitants of our planet by using millions of tonnes of fertilisers, produced in large chemical plants such as this.

Fig 4.6.2

- Polymers—as we have already explored in Focus 4.4, polymers can be used to replace existing materials made from non-renewable resources or more expensive resources. Polymers can also be lighter and stronger and more economical than existing resources. Polymers can be used to insulate our homes and appliances such as refrigerators, saving us money on heating and cooling.
- Pollution control—while chemistry produces pollution it is also vital in controlling pollution. Catalytic converters on vehicles prevents millions of tonnes of toxic gases escaping from our vehicles into the atmosphere each day. Chemistry can also be used to monitor the condition of our air and waterways and provide valuable feedback to industry and other monitoring bodies.
- The digital age—the development of semiconductors and lasers has only been possible through chemistry, as only materials of incredible purity can be used in these products.
- Fuels and transport—production of the fuels that we use in our cars and in the jets that move millions of people around our planet each year have been made possible by chemistry. Chemistry not only makes possible the production of fossil fuels from crude oil but also leads the development of alternative fuel sources such as hydrogen fuel cells.

Why do we need sustainable chemistry?

You have just read about some of the ways that chemistry is so vital to our lives. However, these advances have come at a price. Some of the social and environmental issues facing us and the chemical industry include:

- Depletion of resources—many raw metals such as iron, aluminium and a range of less abundant metals are being consumed at a rate that cannot be maintained. In many cases recycling of these materials is expensive or not feasible.

Fig 4.6.3 Many raw resources are being mined and exported at a rate that cannot be sustained.

- Toxic emissions and wastes—unfortunately the 20th century is littered with examples of rivers and landfills filled with toxic materials that find their way back into the food chain. Many of the toxic emissions are the result of chemical processes using solvents or highly toxic catalysts that need to be stored or have been dumped into the ecosystem. The top 20 toxic wastes in our environment are lead, arsenic, mercury, vinyl chloride, benzene, polychlorinated biphenyls (PCBs), cadmium, benzopyrene, chloroform, benzofluroanthene, DDT, arochlor 1260, trichloroethylene, aroclor 1260, trichlorloethyelene, arochlor 1254, chromium, chlordane, dibenz[a, h]anthracene, hexachlorobutadiene, DDD and dieldrin. Some of these substances, such as the pesticide DDT, have found their way into our food chains (and us), while many other toxic wastes and solvents have been linked to diseases such as cancer.

- Atmospheric pollution—the production of chemicals requires a lot of energy at every step of the process, including transporting the raw materials, production and transporting the finished products. Most of the energy from production and transport comes from the burning of fossil fuels. Many millions of tonnes of greenhouse gases are produced by the chemical industry each year. Many chemical industrial processes also involve the production of a range of atmospheric pollutants, including sulfur dioxide, particulate matter, carbon monoxide, nitrogen dioxide, ozone, hydrocarbons, benzene and ToMPs (toxic organic micro pollutants).

Science Snippet

The flaming river

On the 22 June in 1969 the Cuyahoga River in Cleveland, Ohio, USA caught on fire! The river burned for half an hour. This is how *Time* magazine described the river:

Some river! Chocolate-brown, oily, bubbling with subsurface gases, it oozes rather than flows. 'Anyone who falls into the Cuyahoga does not drown,' Cleveland's citizens joke grimly. 'He decays' … The Federal Water Pollution Control Administration dryly notes: 'The lower Cuyahoga has no visible signs of life, not even low forms such as leeches and sludge worms that usually thrive on wastes.' It is also—literally—a fire hazard.

While this was a chemical industry environmental disgrace, it did lead to radical changes in the way the chemical industry in Ohio had to dispose of and use dangerous solvents in their industry.

- Thermal pollution—energy production and many chemical industries produce large amounts of wasted heat energy. This low-grade heat energy makes its way into the atmosphere and into waterways, where it can affect marine life.

None of us wishes to return to a pioneer lifestyle but clearly our environment cannot continue to cope with these threats. The move in the chemical industry is now towards **sustainable chemistry**. Sustainable chemistry means the development of a chemical industry that:

- manufactures chemical products that do not harm either our health or the environment
- uses industrial processes that reduce or eliminate hazardous chemicals
- designs more efficient processes that minimise the production of waste materials.

Sustainable chemistry is also called **green chemistry**, as it implies a friendlier relationship with the environment and, most importantly, a relationship that can be sustained into the future. The responsibility of green chemistry does not lie just with industry. It is up to the consumer (us) to support the initiatives and embrace some of the changes.

Science Snippet

Heavy metal is not just a type of rock music!

In 2000 a Hungarian gold mine (owned by an Australian company) released 100 000 cubic metres of water full of cyanide and other heavy metals (heavy metals are metals with atomic masses greater than those of copper). With the exception of gold and bismuth, heavy metals are extremely toxic. Five cities and many more major towns were left without drinking water as cyanide levels rose to 700 times the acceptable limit. It was also estimated that up to 40 per cent of the total life in the river was destroyed.

Fig 4.6.4

Many materials, such as plastics, end their life in landfill sites, where they can take centuries to break down.

In 1984 a cloud of methyl isocyanate gas escaped from the Union Carbide plant in Bhopal, India. An estimated 3000 to 7000 people died instantly and 15 000 to 20 000 died from its effects years after the disaster. In total it was estimated that 570 000 people were affected by this chemical disaster.

Fig 4.6.5

Green chemistry

Green chemistry is a philosophy or a way of doing things. It is an approach that chemists use when planning a production pathway to a particular product to ensure that its production is not only sustainable but also economical and environmentally friendly.

Prac 1
p. 241

Science Snippet

Fill up your fuel tank at the fish and chip shop!

Biodiesel is a fuel that is manufactured from biological sources such as waste cooking oil. Unlike normal diesel fuel, biodiesel is biodegradable and non-toxic and has fewer emissions than standard diesel fuel. It can run in standard diesel engines, without the need for any modification. It can be made in your backyard and is cheaper than buying diesel from the fuel pumps … and as an added bonus, when the engine is running it smells like a fish and chip shop!

The 12 principles of green chemistry

1. Prevent—it is far better to prevent waste than to have to clean up waste after it has been created.
2. Consider atom economy—chemical reactions should be designed so that as many of the reactant atoms as possible end up as products. Reactant atoms that are not used in products often end up as pollution.
3. Use less hazardous chemicals—chemical reactions should be designed to use or generate substances that are not toxic to human health or the environment.
4. Design safer chemicals—chemists should explore the production of chemicals that have the desired effect but minimise their toxicity.
5. Use safer solvents—chemists need to explore using safer solvents, such as water, rather than organic solvents, such as benzene, which are very toxic to human health and the environment.
6. Design for energy efficiency—chemists need to consider how much energy is required for a chemical reaction and attempt to minimise it. Where possible, chemical reactions should be performed at ambient temperatures and pressures. Alternative energy sources should be considered and, where possible, energy should be recycled through the process.
7. Use renewable reactants (feedstocks)—chemists should design processes that use renewable reactants rather than depleting non-renewable resources.
8. Reduce derivatives—chemists should design chemical reactions that reduce unwanted derivatives that can end up as waste products.
9. Use catalysts—chemists should use catalysts wherever possible, as they reduce waste energy and improve atom efficiency.
10. Design for breakdown—chemists should design products that at the end of their lifetime will break down into non-toxic materials in the environment rather than add to landfill.
11. Undertake real-time analysis for pollution—chemists should design processes that can be maintained continuously and, should any problems be detected, can be shut down before environmental spills occur.
12. Plan for safer chemistry and accident prevention—chemists should design chemical processes that use chemicals that are safer to handle in the event of an accident in terms of fires and explosions.

Case studies in sustainable chemistry

Many chemical industry companies have embraced the principles of green chemistry while many others have been forced to do so by government laws. The examples here show some of the changes that have been made to move us towards a sustainable society.

Manufacture of analgesic drugs

A common group of pharmaceutical drugs are the analgesics or ‘pain-killing’ drugs. One of the most common of these drugs, **ibuprofen**, which has sales in the billions of dollars every year, has traditionally been produced in a very environmentally unfriendly way.

Ibuprofen is an analgesic produced in large amounts. Traditionally it has been produced with a low useful-atom ratio, a number of unwanted waste products unable to be reused or recycled.

Fig 4.6.6

> **Science Snippet**
>
> **Hydrogen from sugar—how sweet is that!**
>
> Scientists at a sugar confectionary company in England have recently demonstrated how bacteria can produce usable amounts of hydrogen gas, as they use high-sugar waste products left over from food production. The hydrogen being produced is used in a fuel cell. This waste product has typically been going into landfill but now scientists are hopeful that they can use the waste products to recycle energy by turning it into hydrogen gas. The scientists are also exploring the idea that this could be a clean way to produce hydrogen gas for use in fuel cells in cars!

Ibuprofen is now produced in a far more sustainable way. The atom efficiency for the new 'green' process has been improved from 40 per cent to 99 per cent, with the waste products being substances such as ethanoic acid, which can themselves be used.

Preparation of polymers

The main reactant for the manufacture of polymers such as nylon, polyurethane, lubricants and plasticisers is **adipic acid** ($HOOC(CH_2)_4COOH$). Adipic acid is produced in the hundreds of thousands of tonnes to satisfy the need for these polymers.

Adipic acid has typically been produced from benzene (C_6H_6), which is in the top 20 of toxic waste chemicals. It is a highly toxic substance and is a known carcinogen (cancer-causing) chemical. Handling and disposing of benzene was a very dangerous process both to the workers and to the environment. A new process, developed using green chemistry principles, has replaced benzene with a far safer chemical—glucose! Glucose can be extracted from plant products. Chemists have also developed a far safer catalyst from genetically modified bacteria. These types of catalysts are called **bioenzymes**, as they originate from living materials.

Adipic acid is a reactant in the production of many plastics. Instead of using benzene as one of the main reactants it can be produced from glucose (a sugar), using a bioenzyme as a catalyst.

Fig 4.6.8

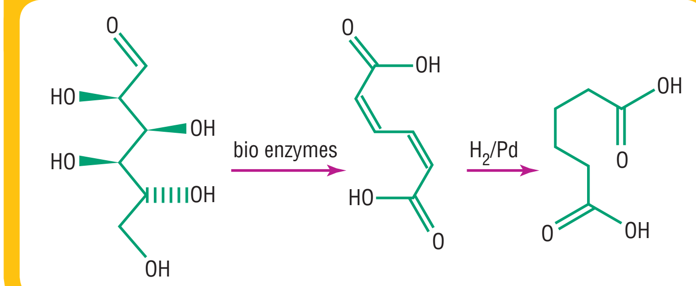


Fig 4.6.7 Many polymers have traditionally been produced using very toxic chemicals such as benzene.

Dry cleaning goes 'green'

Millions of tonnes of clothing is dry-cleaned each year. The solvent most used is **perchloroethene** (**perc**), which is described as being a central nervous system depressant and is listed as a hazardous air pollutant. Chemists have developed a number of alternatives but two of the new processes to emerge have been the use of liquid carbon dioxide in high-pressure systems and a new silicon-based solvent. In both cases the solvent is nearly 100 per cent recovered and reused.

Fig 4.6.9 Dry-cleaning has gone green with a new range of solvents that are much safer to handle and can be recycled and reused.

Superheated water

Water is one of the most versatile solvents we have and it has the advantages of being readily available, non-toxic and non-flammable. Unfortunately, in many industrial processes organic materials are only slightly soluble in water at normal temperatures. However, when water is heated to 374°C and pressures of greater than 200 times atmospheric pressure are applied, it becomes an excellent solvent. It is now replacing organic solvents in many processes, such as dyeing in the clothing industry. Many chemical reactions also have their reaction rate increased by the use of microwaves—called 'continuous microwave reactors' (CMRs). Decreased solvent volumes or safer solvents such as water can be used under these higher temperature and pressure conditions.

Recycling plastics

Worldwide, about 80 million tonnes of plastics are produced every year. Australia produces about one million tonnes of plastic each year. Much of this has the potential to end up in landfill sites. In Focus 4.4 you explored thermoplastics. Most thermoplastics can be recycled. Plastic manufacturers have undertaken to stamp plastic products with codes that aid in the collection and processing of these plastics. The following table shows the codes, name of the plastic, description, uses of the plastic and uses of the recycled plastic. The use of a plastic identification code does not indicate that the plastic can be recycled but allows for its handling. In Australia at the moment, Code 1, 2 and 3 plastics are generally recycled but this can vary depending on your location. These codes not only serve to help the city council or plastic recyclers. They remind you that you have responsibility to put these plastics in the recycling bin and not the general rubbish, where they will end up as landfill.

Fig 4.6.10 A million tonnes of plastics are produced in Australia each year. Plastic recycling plants are essential to ensure that not all of this ends up as landfill.

Plastic identification code	Name of plastic	Description	Used in	Some uses for plastic made from recycled waste plastic
1 PETE	**polyethene terephthalate** PET	Clear, tough plastic. May be used as a fibre	Soft drink and mineral water bottles, filling for sleeping bags and pillows, textile fibres	Soft drink bottles, (multi-layer) detergent bottles, clear film for packaging, carpet fibres, fleecy jackets
2 HDPE	**high-density polyethene** HDPE	Very common plastic, usually white or coloured	Crinkly shopping bags, freezer bags, milk and cream bottles, bottles for shampoo and cleaners, milk crates	Compost bins, detergent bottles, crates, mobile rubbish bins, agricultural pipes, pallets, kerbside recycling crates
3 V	**unplasticised polyvinyl chloride** UPVC	Hard, rigid plastic, may be clear	Clear cordial and juice bottles, blister packs, plumbing pipes and fittings	Detergent bottles, tiles, plumbing pipe fittings
	plasticised polyvinyl chloride PPVC	Flexible, clear, elastic plastic	Garden hose, shoe soles, blood bags and tubing	Hose inner core, industrial flooring
4 LDPE	**low-density polyethylene** LDPE	Soft, flexible plastic	Lids of ice-cream containers, garbage bags, garbage bins, black plastic sheet	Film for builders, industry, packaging and plant nurseries; bags
5 PP	**polypropylene** PP	Hard, but flexible plastic—many uses	Ice-cream containers, potato crisp bags, drinking straws, hinged lunch boxes	Compost bins, kerbside recycling crates, worm factories
6 PS	**polystyrene** PS	Rigid, brittle plastic. May be clear, glassy	Yoghurt containers, plastic cutlery, imitation crystal 'glassware'	Clothes pegs, coat hangers, office accessories, spools, rulers, video/CD boxes
	expanded polystyrene EPS	Foamed, lightweight, energy-absorbing thermal insulation	Hot drink cups, takeaway food containers, meat trays, packaging	
7 OTHER		All other plastics, including acrylic and nylon		Drag and Drop cW Interactive

Green chemistry and you

There are many benefits of sustainable (green) chemistry for industry. These include economic savings, reduction in environmental impact and the costs of cleaning it up and increased quality of work life for employees. 'Green' items are easier to market than 'non-green' items, and this is of mutual benefit to industry and the environment.

As consumers you also play a vital role in supporting sustainable chemistry. You can do this by:

- understanding the key principles of green chemistry
- making sensible choices when you purchase items
- choosing to use these objects wisely through their working life
- disposing of them in an environmentally sustainable way when their life is finished.

The road to a sustainable society is one that every member of this planet has to travel.

Homework book 4.10 Recycling

Homework book 4.11 DDT dilemma

Homework book 4.12 Challenges of tomorrow

FOCUS 4·6

Questions

Use your book

What has chemistry ever done for us?

1 Describe ten chemicals you have used today that made your life easier.

2 List the major sectors of chemical industry that benefit our lives.

Why do we need sustainable chemistry?

3 Give the names of some resources that are being depleted.

4 Make a list of the top ten toxic wastes. Underline those that you had heard of prior to reading this Focus. What does this tell you about the importance of being informed about sustainability?

5 Describe some of the more common air pollutants. What are the main sources of these pollutants?

6 What is thermal pollution? What effect can it have on the environment?

Green chemistry

7 Define what is meant by 'green chemistry'.

8 Describe what you understand by the term 'atom efficiency' during a chemical reaction.

9 Many industrial chemical reactions occur in solvents such as benzene. Describe some of the advantages of exchanging this solvent for other solvents, such as superheated water.

10 What is meant by a 'feedstock' as it applies to a chemical reaction? Why must the chemical industry source renewable feedstock when designing chemical processes?

11 What are catalysts? How are they used to support the principles of green chemistry?

12 What is the advantage of analysing for pollution in real time as opposed to waiting for a spill or accident to be reported?

Case studies in sustainable chemistry

13 Ibuprofen is a very common analgesic. What are analgesics? How was the production of ibuprofen improved in line with green principles of chemistry?

14 What are bioenzymes? How were they used to improve the production of nylon?

15 Superheated water is now being used to replace many toxic organic solvents in chemical processes. What is superheated water?

16 Explain why it is not possible to recycle all plastics.

Use your head

17 The European commissioner for the environment recently made the following statement:

'It is no secret that **human activity**, coupled with population growth, is stretching our **planet's natural resources** to breaking point. Rainforests, fish stocks, agricultural soils and certain animal species are under threat due to the **indiscriminate exploitation** of our natural resources and relentless urbanisation. We cannot allow the consumption of resources—**both renewable and non-renewable**—to exceed the **environment's carrying capacity**.'

Look at the words that have been bolded in this statement. Write down what you think each of these term means from a chemistry perspective.

18 The chemical maleic anyhdyride is widely used in the production of polymers such as polyesters. It contains only the elements carbon, hydrogen and oxygen. It is also used in paint production. It can be produced from a range of feedstocks (base reactants) including benzene, butane (C_4H_{10}) and butene (C_4H_8). The following table below shows the 'atom efficiency' of each of the elements for the various feedstocks.

Percentage of atoms that end up as products	Benzene feedstock	Butane feedstock	Butene feedstock
Carbon	67	100	100
Hydrogen	33	25	20
Oxygen	33	50	43

a Which of the feedstocks is the most efficient?

b Which of the feedstocks is the least efficient?

c What are some of the possible fates of atoms if their efficiency in a reaction is less than 100 per cent?

d It is often important for the carbon efficiency to be much higher than the hydrogen or oxygen atom efficiency. What is a possible reason for this? (Hint: Think of a potential pollutant containing carbon.)

Investigating questions

19 Find out more about the Bhopal disaster in 1984. What was the company (Union Carbide) producing? How did the accident occur? Which of the 12 principles of 'green chemistry' were not followed?

20 Investigate at least five of the top 20 toxic wastes given on page 234 to research the industrial process they are used in and their potential effect on the environment.

21 Organise a debate in your class on the following topic: 'Chemistry has to go green!'

22 Organise a survey of students at your school, parents and other community members. Your survey should include questions such as:

a What do you think it means to have a sustainable society?

b Would you be prepared to pay extra for goods that are produced in a environmentally sustainable way?

c What responsibility do you have to help in developing a sustainable future?

Summarise your findings and prepare a report for your class. Feel free to include some questions of your own.

4·6 FOCUS

[Practical activity]

Prac 1 Focus 4.6

Fuels from vegetables—biodiesel

Diesel fuel is produced and used in the millions of litres every week. It is a non-renewable energy source that contributes substantially to air pollution. Biodiesel is a viable alternative to diesel (see Science Snippet on page 236).

Purpose

To explore the production of biodiesel and relate its production to the principles of green chemistry.

Requirements

Canola oil (100 mL per group), conical flask (250 mL), methanol (15 mL per group), 9M potassium hydroxide solution (about 1 mL per group), two 100 mL flasks, 25 mL measuring cylinder, 100 mL measuring cylinder, Beral or teat pipette, stirring rod, electronic balance or triple beam balance.

SAFETY NOTE: Methanol is flammable. Potassium hydroxide is corrosive and very exothermic when dissolving in water.

Take great care when handling chemicals and wear safety glasses at all times.

Do not attempt to ignite your fuel unless under the direction of your teacher and with their permission.

Procedure

1. Measure out 100 mL of vegetable (canola) oil into a conical flask.
2. To this add 15 mL of methanol.
3. Slowly and carefully add 1 mL of potassium hydroxide. Do not spill it on your skin.
4. Stir or swirl the mixture for 10 minutes.
5. Allow the mixture to settle and separate. Carefully observe any colour changes that occur.
6. The biodiesel is formed as the top layer. The bottom layer is the 'glycerol' or waste layer.
7. Use the Beral or teat pipette to draw off the biodiesel (top) layer.
8. Measure the volume of biodiesel produced.

Questions

1. What evidence did you have that a chemical reaction occurred between the methanol–potassium hydroxide mixture and the vegetable oil?
2. What volume of biodiesel did you produce? Given that this volume is directly proportional to the atom efficiency, estimate the atom efficiency for the process using this relationship:

$$\text{Atom efficiency estimate} = \frac{\text{volume of biodeisel produced (mL)}}{\text{volume of vegetable}} \times 100$$

Extra for experts

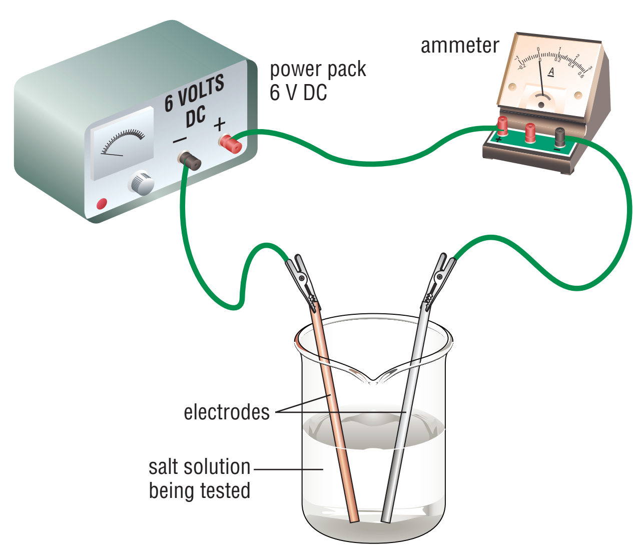
3. Under strict teacher supervision you could test the burning of your biodiesel by burning controlled volumes of the biodiesel in a spirit burner. You could compare this with normal 'petrodiesel' fuel. You could compare factors such as energy output and particular output (smoke).
4. Research the various proportions of mixtures (biodiesel: petrodiesel) that engines use. Can diesel engines run on pure biodiesel without modification? Write a report on your findings.

Review questions

Second-hand data

1 Kate was researching salt swimming pools. She knew that one of the key compounds found in pool water was sodium chloride and she was interested in knowing its concentration. Kate had been to the swimming pool shop with her dad when he had the water tested. She knew that one way to measure the concentration of salt in water was to measure the conductivity of the water.

As part of her open investigation at school, Kate set up the following activity. She prepared some known concentrations of salt (in grams per litre) and measured the conductivity of these solutions (in mA). Kate made sure that she used distilled water to dissolve the salt. She then compared this to the swimming pool water. The results are shown in the table below.



Kate's equipment set to measure the conductivity of the salt solutions

Fig 4.7.1

Concentration of NaCl (gL^{-1})	0 (distilled water)	1	2	4	6	8	10	pool water
Conductivity (mA)	0	50	96	158	215	300	380	125

a Prepare a line graph of the data and draw a line of best fit.

b Use the graph to estimate the concentration of the swimming pool water in grams per litre.

c Given that sea water is approximately four times more concentrated than the salt water in a swimming pool, what do you estimate would be the conductivity for sea water?

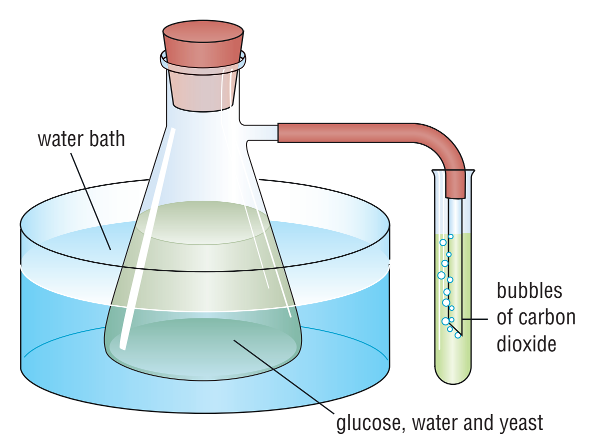
d Explain why Kate used distilled water when preparing her different salt solutions.

e Write a paragraph that describes why solid sodium chloride does not conduct an electric current, yet if it is dissolved in distilled water it does. You should include relevant diagrams in your explanation.

2 Yeast is a living organism that feeds on carbohydrates such as glucose ($C_6H_{12}O_6$) to produce carbon dioxide (CO_2) and ethanol (C_2H_5OH). This can be represented by the equation:

$C_6H_{12}O_6\ (aq) \rightarrow 2C_2H_5OH\ (l) + 2CO_2\ (g)$

Fig 4.7.2 Diagram for question 2



The carbon dioxide that is produced by the yeast can be seen as bubbles rising up through the sugar solution as shown in Figure 4.7.2.

Kate and Joshua designed an investigation to explore the effect of temperature. They prepared water baths of various temperatures and measured the number of bubbles of carbon dioxide produced per minute. They did this by controlling the temperature of the water bath. To ensure that the investigation was fair, they decided to both set up the investigation and combine their data. Their results are shown in the following table.

b Use a line graph to represent the data you have obtained.

c Use your graph to determine the temperature at which the yeast were the most active.

d Explain what you think happens to the yeast after 55°C? What evidence do you have for this from your results?

Temperature of water bath (°C)		0	5	15	25	35	45	55	65	75
Bubbles per minute	Joshua	0	6	34	64	48	2	0	0	0
	Kate	0	4	36	56	50	3	0	0	0

a Joshua and Kate obtained slightly different results for each temperature. What should be done with these two results? Copy the table above and add the extra information that is needed.

e What else do you think Joshua and Kate did to make sure that their investigation was 'fair'.

[Open-ended questions/experimental design]

3 The forensic laboratory in your capital city has commissioned you to determine which solvent would be best to use in the chromatography process to separate the dyes in permanent and non-permanent marking pens.

To help you with this investigation your teacher will supply you with the following:

- a permanent black pen (permanent overhead marking pen) and a non-permanent black pen
- a variety of solvents—water, ethanol, propanol, methylated spirits etc.
- chromatography paper.

Your investigation must be designed to show all the elements of a 'fair investigation', including the control of variables. If you have access to a digital camera you may also wish to visually record your results. Your report back to the forensic laboratory must contain:

- feedback on the solvent that resulted in the best separation of the permanent marker and the non-permanent marker
- any digital photographic evidence to support your conclusion
- data related to the **retention time** of the dyes within the paper and how this was measured to ensure the fairness of your investigation.

Going further

Permanent marker pens sometimes contain solvents such as **xylene** or **toluene**. These solvents are often said to be 'non-polar'. Explain the similarities between these substances and the most successful solvents you found in the chromatography process for both the permanent and the non permanent pens.

4 Water that contains calcium (Ca^{2+}) or magnesium (Mg^{2+}) ions is said to be 'hard water'. Hard water interferes with the action of soaps, preventing them from lathering or forming a froth. Detergents and shampoos are said not be affected as much by hard water.

You are going to test to see if detergents are better than soaps in forming a lather in hard water. Below are some guidelines that may help in your investigation:

- Distilled water does not contain any dissolved ions and is considered to be 'soft water'.
- You can make a standard 'hard water' solution by dissolving 2 g of magnesium sulfate in 100 mL of distilled water.
- A measure of the effectiveness of soap can be determined by measuring the height of the lather produced when a small piece of soap (1 spatula tip) is shaken in a test tube half-filled with water (hard or soft) a standard number of times.

>>

Your investigation must be designed to show all the elements of a 'fair investigation', including the control of variables. If you have access to a digital camera you may also wish to visually record your results.

Your report should include:

- a discussion of how you made sure that your investigation was fair
- a hypothesis relating the hardness of the water to the amount of lather that can be produced
- a conclusion based on your data that relates back to your hypothesis.

Going further

- Use your local tap water rather than distilled water. How does the lather production compare? Compare your local water with the 'standard hard water' from your investigation.
- How do shampoos compare with soaps and detergents? If you have time and the permission of your teacher you may like to try this investigation.
- Some shampoos are advertised as being suitable for use in hard water. These are often used for people who are travelling across the Nullarbor where the water is particularly hard. If you can obtain some of this shampoo you could design an investigation to test its effectiveness by comparing it with normal shampoo.

[Extended investigation/research]

5 One of the best known forms of carbon is diamond. However, you might not be aware that there are seven other forms of carbon—graphite, lonsdaleite, C60, C540, C70, amorphous carbon (coal and soot) and carbon nanotubes. These different forms are called **allotropes**.

a Research several different allotropes of carbon and describe how the structure of the different allotropes contributes to their special properties.

b Carbon nanotubes (also known as 'buckytubes') are extremely strong and have some unique electrical properties. Research nanotubes and explore:

- some of the special properties of nanotubes
- how the arrangement of the carbon atoms accounts for these special properties
- their use as contrast agents in medicine
- what existing materials could be replaced by nanotubes in the near future.

6 Investigate a local chemical industry. You may even like to arrange to visit the company. Draw up a table listing the 12 principles of 'green chemistry' and report on how this industry measures up to the principles. You could design a scoring system for each of the principles so that you and your classmates can compare different chemical industries in your local area.

Homework book 4.13 Natural and Processed Materials crossword

Homework book 4.14 Sci-words

Appendix 1: The periodic table

Altenative group numbers	Group I	Group II											Group III	Group IV	Group V	Group VI	Group VII	Group VIII
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Period 1	**H** Hydrogen 1 1.008																	**He** Helium 2 4.00
Period 2	**Li** Lithium 3 6.94	**Be** Beryllium 4 9.01											**B** Boron 5 10.8	**C** Carbon 6 12.0	**N** Nitrogen 7 14.0	**O** Oxygen 8 16.0	**F** Fluorine 9 19.0	**Ne** Neon 10 20.2
Period 3	**Na** Sodium 11 23.0	**Mg** Magnesium 12 24.3											**Al** Aluminium 13 27.0	**Si** Silicon 14 28.1	**P** Phosphorus 15 31.0	**S** Sulfur 16 32.1	**Cl** Chlorine 17 35.5	**Ar** Argon 18 39.9
Period 4	**K** Potassium 19 39.1	**Ca** Calcium 20 40.1	**Sc** Scandium 21 45.0	**Ti** Titanium 22 47.9	**V** Vanadium 23 50.9	**Cr** Chromium 24 52.0	**Mn** Manganese 25 54.9	**Fe** Iron 26 55.8	**Co** Cobalt 27 58.9	**Ni** Nickel 28 58.7	**Cu** Copper 29 63.5	**Zn** Zinc 30 65.4	**Ga** Gallium 31 69.7	**Ge** Germanium 32 72.6	**As** Arsenic 33 74.9	**Se** Selenium 34 79.0	**Br** Bromine 35 79.9	**Kr** Krypton 36 83.8
Period 5	**Rb** Rubidium 37 85.5	**Sr** Strontium 38 87.6	**Y** Yttrium 39 88.9	**Zr** Zirconium 40 91.2	**Nb** Niobium 41 92.9	**Mo** Molybdenum 42 95.9	**Tc** Technetium 43 98	**Ru** Ruthenium 44 101.1	**Rh** Rhodium 45 102.9	**Pd** Palladium 46 106.4	**Ag** Silver 47 107.9	**Cd** Cadmium 48 112.4	**In** Indium 49 114.8	**Sn** Tin 50 118.7	**Sb** Antimony 51 121.8	**Te** Tellurium 52 127.6	**I** Iodine 53 126.9	**Xe** Xenon 54 131.3
Period 6	**Cs** Cesium 55 132.9	**Ba** Barium 56 137.3	**La*** Lanthanum 57 138.9	**Hf** Hafnium 72 178.5	**Ta** Tantalum 73 180.9	**W** Tungsten 74 183.9	**Re** Rhenium 75 186.2	**Os** Osmium 76 190.2	**Ir** Iridium 77 192.2	**Pt** Platinum 78 195.1	**Au** Gold 79 197.0	**Hg** Mercury 80 200.6	**Tl** Thallium 81 204.4	**Pb** Lead 82 207.2	**Bi** Bismuth 83 209.0	**Po** Polonium 84 (209)	**At** Astatine 85 (210)	**Rn** Radon 86 (222)
Period 7	**Fr** Francium 87 (223)	**Ra** Radium 88 (226)	**Ac**** Actinium 89 (227)	**Rf** Rutherfordium 104 (261)	**Db** Dubnium 105 (262)	**Sg** Seaborgium 106 (266)	**Bh** Bohrium 107 (264)	**Hs** Hassium 108 (277)	**Mt** Meitnerium 109 (268)	**Ds** Darmstadtium 110 (271)	**Rg** Roentgenium 111 (272)	**Uub** Ununbium 112 (277)						

*Lanthanides 58–71	**Ce** Cerium 58 140.1	**Pr** Praseodymium 59 140.9	**Nd** Neodymium 60 144.2	**Pm** Promethium 61 (145)	**Sm** Samarium 62 150.4	**Eu** Europium 63 152.0	**Gd** Gadolinium 64 157.2	**Tb** Terbium 65 158.9	**Dy** Dysprosium 66 162.5	**Ho** Holmium 67 164.9	**Er** Erbsium 68 167.3	**Tm** Thulium 69 168.9	**Yb** Ytterbium 70 173.0	**Lu** Lutetium 71 175.0
**Actinides 90–103	**Th** Thorium 90 232.0	**Pa** Protactinium 91 231.0	**U** Uranium 92 238.0	**Np** Neptunium 93 (237)	**Pu** Plutonium 94 (244)	**Am** Americium 95 (243)	**Cm** Curium 96 (247)	**Bk** Berkelium 97 (247)	**Cf** Californium 98 (251)	**Es** Einsteinium 99 (252)	**Fm** Fermium 100 (257)	**Md** Mendelevium 101 (258)	**No** Nobelium 102 (259)	**Lr** Lawrencium 103 (262)

Legend

- metals
- metalloids
- non-metals
- noble gases (non-reactive non-metals)

H — symbol
Hydrogen — name
1 — atomic number
1.008 — atomic mass

(209) atomic mass of the longest-lived isotope

Index

Numbers in **bold** refer to definition terms in **bold** type in the text.
Numbers in *italic* refer to illustrations/data tables in the text.

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