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big ideas

australian curriculum

science 8

sally cash | geoff quinton | craig tilley | emma craven

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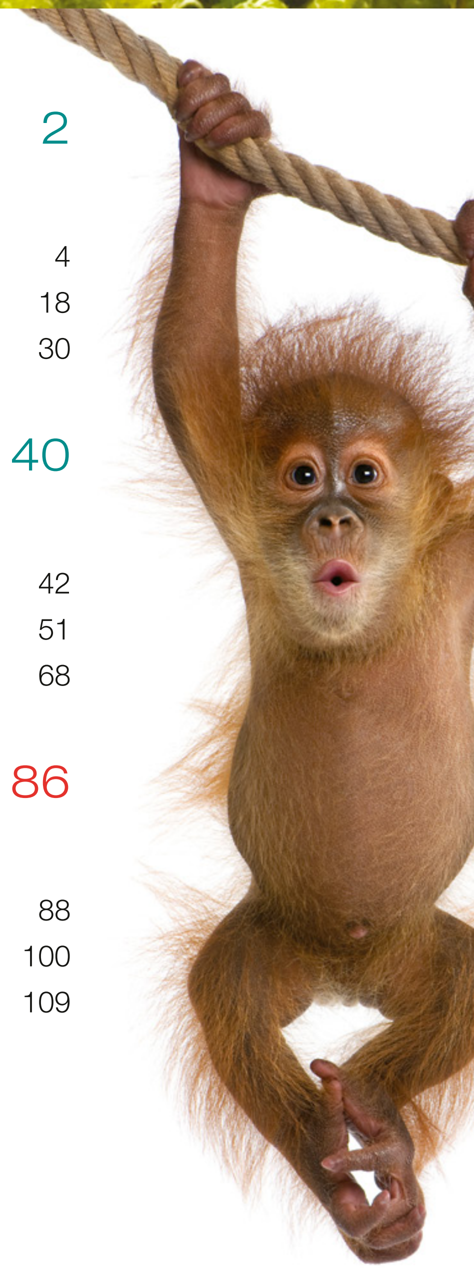
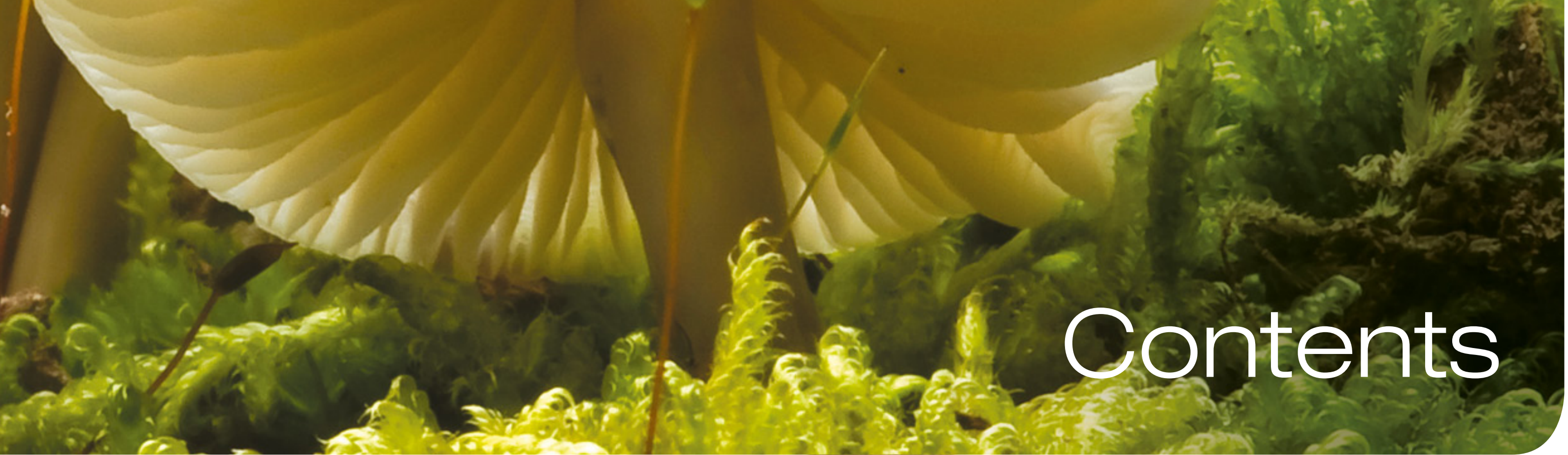




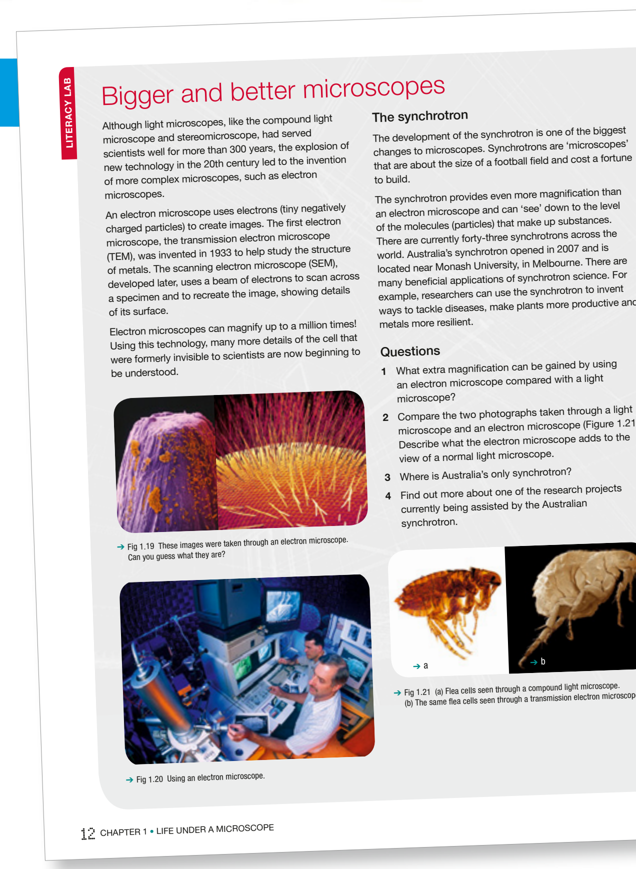
Contents

What is... Oxford Big Ideas Science?

Oxford Big Ideas Science is an innovative suite of resources completely aligned to the Australian Curriculum. Based on a big ideas framework, the pedagogy enables students to develop deep, transferable understandings and skills.

Why big ideas?

Research shows that students achieve greater success when the information they learn is connected to key concepts. *The Australian Curriculum: Science* has identified nine **key science concepts** or **big ideas** that are developed through the curriculum content. It is expected that by the end of Year 10, all students will have an understanding of these big ideas. Each chapter in the *Oxford Big Ideas Science* student books—from Year 7 to Year 10—is engineered to build student understanding of these big ideas or key concepts.



LITERACY LAB

Bigger and better microscopes

Although light microscopes, like the compound light microscope and stereomicroscope, had served scientists well for more than 300 years, the explosion of new technology in the 20th century led to the invention of more complex microscopes, such as electron microscopes.

An electron microscope uses electrons (tiny negatively charged particles) to create images. The first electron microscope, the transmission electron microscope (TEM), was invented in 1933 to help study the structure of metals. The scanning electron microscope (SEM), developed later, uses a beam of electrons to scan across a specimen and to recreate the image, showing details of its surface.

Electron microscopes can magnify up to a million times! Using this technology, many more details of the cell that were formerly invisible to scientists are now beginning to be understood.

Fig 1.19 These images were taken through an electron microscope. Can you guess what they are?

Fig 1.20 Using an electron microscope.

The synchrotron

The development of the synchrotron is one of the biggest changes to microscopes. Synchrotrons are 'microscopes' that are about the size of a football field and cost a fortune to build.

The synchrotron provides even more magnification than an electron microscope and can 'see' down to the level of the molecules (particles) that make up substances. There are currently forty-three synchrotrons across the world. Australia's synchrotron opened in 2007 and is located near Monash University, in Melbourne. There are many beneficial applications of synchrotron science. For example, researchers can use the synchrotron to invent ways to tackle diseases, make plants more productive an
metals more resilient.

Questions

1 What extra magnification can be gained by using an electron microscope compared with a light microscope?

2 Compare the two photographs taken through a light microscope and an electron microscope (Figure 1.21 Describe what the electron microscope adds to the view of a normal light microscope.

3 Where is Australia's only synchrotron?

4 Find out more about one of the research projects currently being assisted by the Australian synchrotron.

a

b

Fig 1.21 (a) Flea cells seen through a compound light microscope. (b) The same flea cells seen through a transmission electron microscop

12 CHAPTER 1 • LIFE UNDER A MICROSCOPE

What are the big ideas?

Biological sciences	Chemical sciences
• Diversity and evolution • Interdependence • Structure and function	• Properties and structure • Interaction and change
Earth and space sciences	**Physical sciences**
• Systems in space • Dynamic Earth	• Forces and motion • Energy and its transformations

Oxford big ideas...

- organises learning around the nine **big ideas** of science and revisits these ideas with increasing complexity
- sorts content into meaningful inquiry-based big questions and establishes learning priorities
- focuses on developing scientific and inquiry skills
- takes a truly integrated approach to Science Understanding, Science Inquiry Skills and Science as a Human Endeavour
- includes a brand new Discovering Ideas inquiry task at the start of every unit
- uses the six **overarching ideas** from the *Australian Curriculum: Science* to connect content across the disciplines of science
- seamlessly covers the big ideas, overarching ideas, general capabilities, cross-curriculum priorities and three strands from the *Australian Curriculum: Science*
- engages students with topical stimulus material, stunning imagery and step-by-step instructional skills photography
- includes a workbook, **obook** and teacher kit to offer the complete teaching package at each year level
- offers innovative digital resources including a digital workbook and **obook**.

ENGAGING LEARNING

Each student book chapter is designed to visually and creatively engage students with beautiful artwork, photographs, case studies, source material and in-depth coverage of the topic being studied.


ZOOMING IN

Different microscopes, different images

Images from microscopes will vary quite dramatically. Different microscopes produce different types of images because of the magnification, the way a specimen must be prepared, the way the specimen is treated by the microscope and the materials used in the process of viewing the specimen.

Fig 1.22 Stereomicroscope (SM).

Fig 1.23 Compound light microscope (LM).

Fig 1.24 Scanning transmission electron microscope (STEM).

Fig 1.25 Scanning electron microscope (SEM).

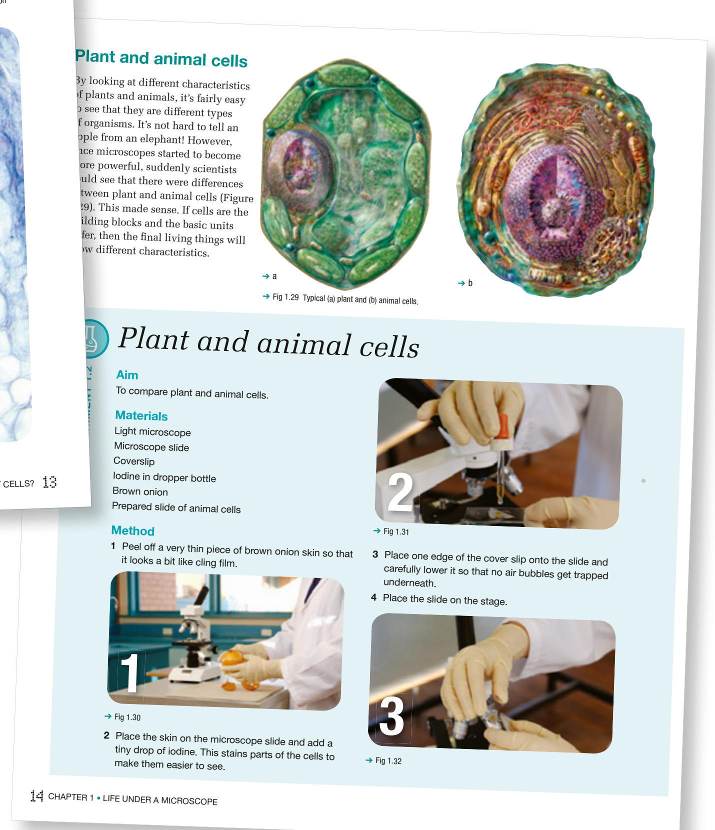
Fig 1.26 SM image of a wasp.

Fig 1.27 SEM image of a nerve cell.

Fig 1.28 LM image of a hair root.

UNIT 1.1 • HOW DO WE KNOW ABOUT CELLS? 13

Spectacular and current photographs bring science to life.


Plant and animal cells

By looking at different characteristics of plants and animals, it's fairly easy to see that they are different types of organisms. It's not hard to tell an apple from an elephant! However, once microscopes started to become more powerful, suddenly scientists could see that there were differences between plant and animal cells (Figure 1.29). This made sense. If cells are the building blocks and the basic units of life, then the final living things will show different characteristics.

a

b

Fig 1.29 Typical (a) plant and (b) animal cells.

Plant and animal cells

Aim

To compare plant and animal cells.

Materials

Light microscope
Microscope slide
Coverslip
Iodine in dropper bottle
Brown onion
Prepared slide of animal cells

Method

1 Peel off a very thin piece of brown onion skin so that it looks a bit like cling film.

Fig 1.30

2 Place the skin on the microscope slide and add a tiny drop of iodine. This stains parts of the cells to make them easier to see.

Fig 1.31

3 Place one edge of the cover slip onto the slide and carefully lower it so that no air bubbles get trapped underneath.

4 Place the slide on the stage.

Fig 1.32

14 CHAPTER 1 • LIFE UNDER A MICROSCOPE

Step-by-step instructional photography models correct skills and techniques.

Chapter openers introduce the key inquiry questions of the chapter and are designed to spark interest, elicit prior knowledge and unravel current misconceptions.

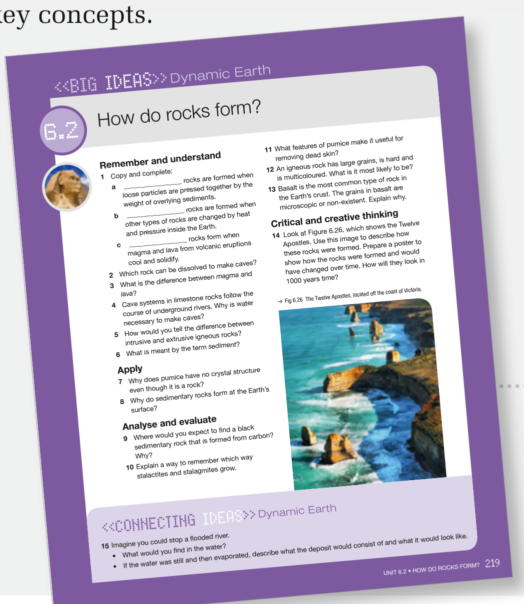
INQUIRY-BASED LEARNING

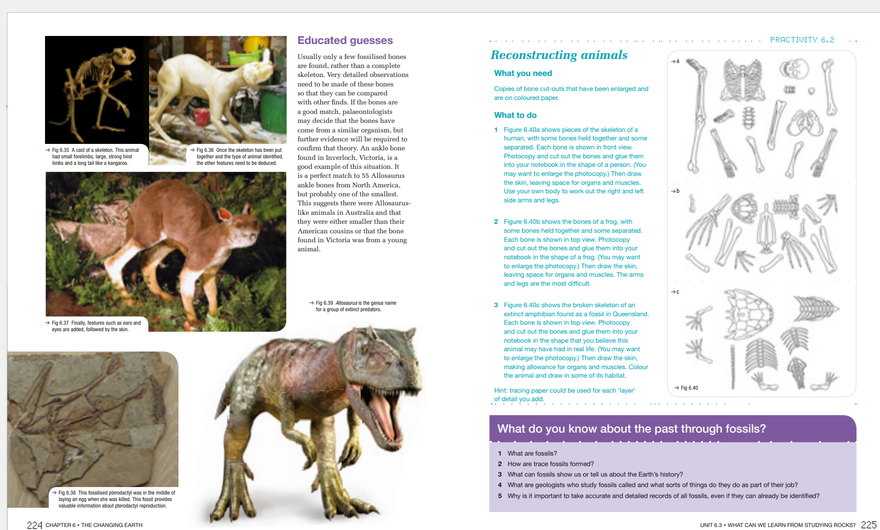
The *Australian Curriculum: Science* presents an opportunity to re-imagine the science classroom by integrating supported inquiry, collaborative inquiry and full student-directed inquiry. Experience first-hand an inquiry-based approach to science education.

Discovering Ideas tasks allow students to discover science themselves, before they have all the answers.

DEEP LEARNING

Content is designed for depth of learning. Concepts are revisited with increasing levels of complexity so that students gain a rich understanding of key concepts.



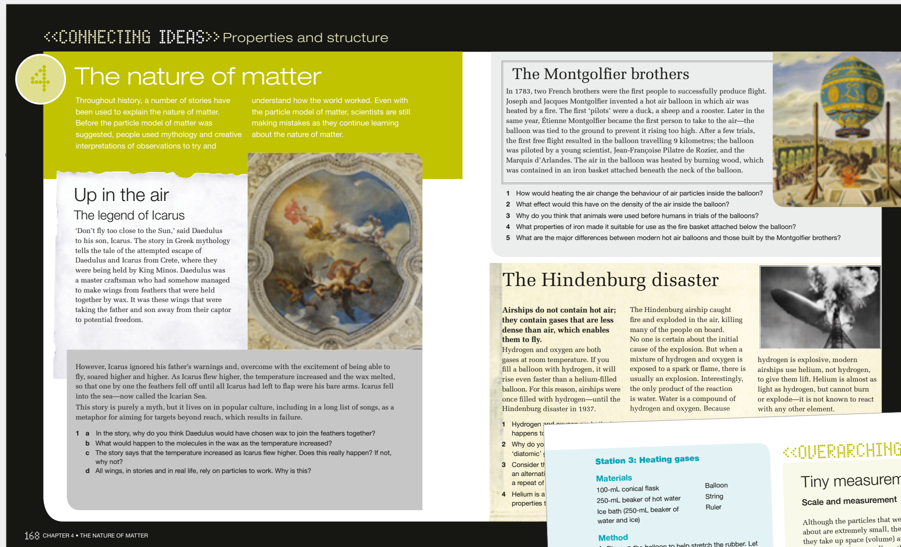


Big Ideas activity blocks at the end of each section use Bloom's Taxonomy and other strategies to cater for a multiplicity of learning styles.

Science as a Human Endeavour is integrated meaningfully throughout the chapters, providing depth and relevance.

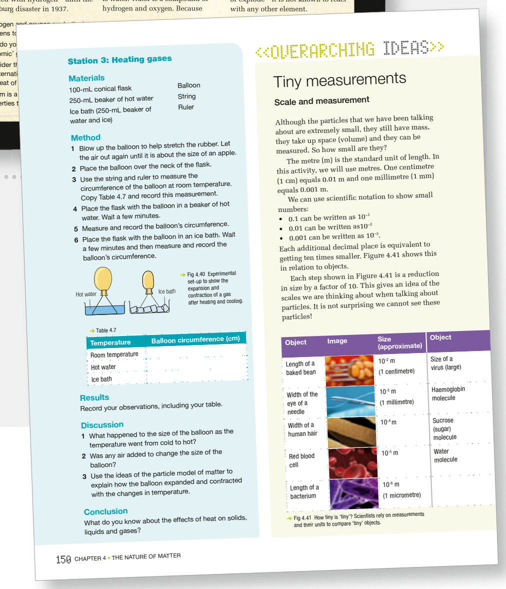
CONNECTED LEARNING

Oxford Big Ideas Science takes a truly integrated approach to Science Understanding, Science Inquiry Skills and Science as a Human Endeavour. The student book series uses the six overarching ideas from the *Australian Curriculum: Science* to connect content across the disciplines of science and seamlessly covers the big ideas, general capabilities, cross-curriculum priorities and three strands from the *Australian Curriculum: Science*.



The end-of-chapter Connecting Ideas task is a rich and engaging task that encourages students to connect their knowledge and understandings back to the big idea.

The Overarching Ideas task, found once in every student book chapter, uses the overarching ideas from the *Australian Curriculum: Science* to integrate and connect the disciplines of science.



INTEGRATED TEACHING AND LEARNING SUPPORT

obook

Oxford's next generation ebook—the **obook**—offers online and offline access to core student content.

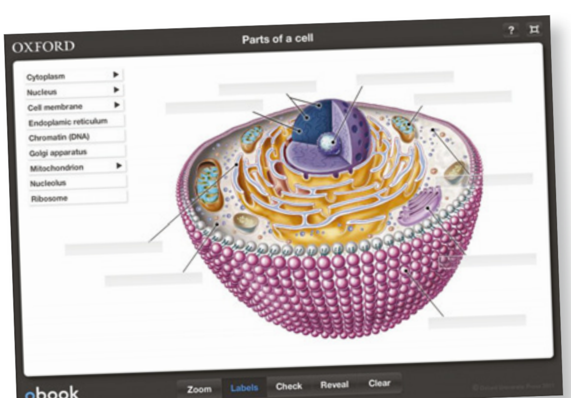
The **obook** provides the complete student textbook in an easy-to-read format for any device or screen size, with multimedia links, interactive learning objects, a note-taking study tool and dynamic question blocks. Oxford's obook is compatible with laptops, iPads, tablets and IWBs. *Oxford Big Ideas Science* **obooks** include access to the *Virtual Laboratory*—the online video portal. Speak to your Oxford representative about networking options.

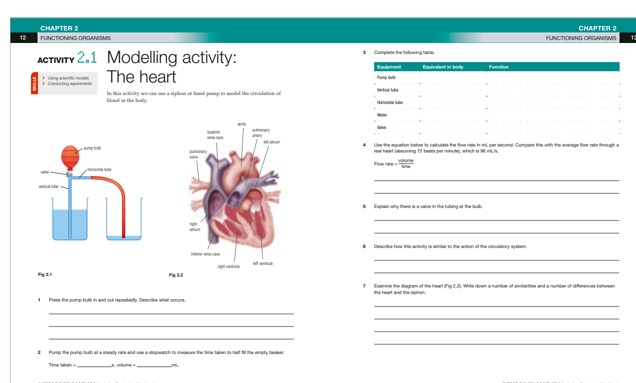
Workbook

Oxford Big Ideas Science is supported by a workbook at each of years 7–10. The workbooks provide extra practice of key skills and encourage an inquiry-based approach to learning—perfect for in-class or homework. An innovative digital workbook is also available.

Teacher kit

Each teacher kit includes all pages from the student book scaffolded with teaching strategies, lesson planning tips, assessment advice and suggested answers—everything you need to integrate Oxford resources into your teaching.





What is... The Australian Curriculum: Science?

Science understanding

Sub-strand	Content descriptor	Chapters
Biological sciences	• Cells are the basic units of living things and have specialised structures and functions	1
	• Multicellular organisms contain systems of organs that carry out specialised functions that enable them to survive and reproduce	2
Chemical sciences	• The properties of the different states of matter can be explained in terms of the motion and arrangement of particles	4
	• Differences between elements, compounds and mixtures can be described at a particle level	4
	• Chemical change involves substances reacting to form new substances	5
Earth and space sciences	• Sedimentary, igneous and metamorphic rocks contain minerals and are formed by processes that occur within the Earth over a variety of timescales	6
Physical sciences	• Energy appears in different forms including movement (kinetic energy), heat and potential energy, and causes change within systems	3

Science as a human endeavour

Sub-strand	Content descriptor	Chapters
Nature and development of science	• Scientific knowledge changes as new evidence becomes available, and some scientific discoveries have significantly changed people's understanding of the world	1, 2, 3, 4 & 6
	• Science knowledge can develop through collaboration and connecting ideas across the disciplines of science	1, 2, 3, 4 & 6
Use and influence of science	• Science and technology contribute to finding solutions to a range of contemporary issues; these solutions may impact on other areas of society and involve ethical considerations	1, 2, 3 & 5
	• Science understanding influences the development of practices in areas of human activity such as industry, agriculture and marine and terrestrial resource management	2, 3, 4, 5 & 6
	• People use understanding and skills from across the disciplines of science in their occupations	2, 3, 5 & 6

Science inquiry skills

Sub-strand	Content descriptor	Chapters
Questioning and predicting	• Identify questions and problems that can be investigated scientifically and make predictions based on scientific knowledge	ALL
Planning and conducting	• Collaboratively and individually plan and conduct a range of investigation types, including fieldwork and experiments, ensuring safety and ethical guidelines are followed • In fair tests, measure and control variables, and select equipment to collect data with accuracy appropriate to the task	ALL
Processing and analysing data and information	• Construct and use a range of representations, including graphs, keys and models to represent and analyse patterns or relationships, including using digital technologies as appropriate • Summarise data, from students' own investigations and secondary sources, and use scientific understanding to identify relationships and draw conclusions	ALL
Evaluating	• Reflect on the method used to investigate a question or solve a problem, including evaluating the quality of the data collected, and identify improvements to the method • Use scientific knowledge and findings from investigations to evaluate claims	ALL
Communicating	• Communicate ideas, findings and solutions to problems using scientific language and representations using digital technologies as appropriate	ALL

Key concepts (big ideas)

Big idea	Key concept	Chapter
Diversity and evolution	A diverse range of living things have evolved on Earth	N/A
Interdependence	Living things are interdependent and interact with each other and their environment	N/A
Structure and function	The form and features of living things are related to the functions that their body systems perform	1 & 2
Interaction and change	Substances change and new substances are produced by rearranging atoms through atomic interactions and energy transfer	5
Properties and structure	The chemical and physical properties of substances are determined by their structure	4
Systems in space	Earth is part of a solar system that is part of a larger universe	N/A
Dynamic Earth	Earth is subject to change within and on its surface over a range of timescales as a result of natural processes and human use of resources	6
Forces and motion	A range of forces affect the behaviour of objects	N/A
Energy and its transformations	Energy can be transferred and transformed from one form to another	3

Overarching ideas

Patterns, order and organisation	Chapters 2, 4 & 5
Form and function	Chapters 1, 2, 3 & 4
Stability and change	Chapters 3, 4, 5 & 6
Scale and measurement	Chapters 1, 4 & 6
Matter and energy	Chapters 3, 4 & 5
Systems	Chapters 1, 2, 3 & 6

General capabilities and cross-curriculum priorities

Literacy	All chapters
Numeracy	Chapters 1, 3, 4, 5 & 6
ICT	All chapters
Critical and creative thinking	All chapters
Ethical behaviour	Chapters 1, 2, 3 & 5
Personal and social competence	Chapters 1, 2, 3 & 5
Intercultural understanding	Chapters 2 & 4
Sustainability	Chapters 3, 5 & 6
Aboriginal and Torres Strait Islander histories and cultures	Chapters 2 & 6
Asia and Australia's engagement with Asia	Chapters 4 & 6

BIG IDEAS Structure and function

1 Life under a microscope

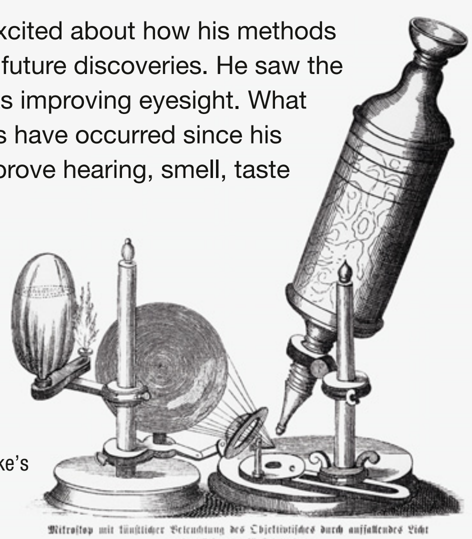
1.1 How do we know about cells?

It is the great prerogative of Mankind above other Creatures, that we are not only able to behold the works of Nature, or barely to sustain our lives by them, but we have also the power of considering, comparing, altering, assisting, and improving them to various uses … By the means of Telescopes, there is nothing so far distant but may be represented to our view; and by the help of Microscopes, there is nothing so small as to escape our inquiry; hence there is a new visible World discovered to the understanding.

The paragraph above is a section from Robert Hooke's *Micrographia*. He was the first man to discover and describe cells in 1665.

1 Why do you think it was such a big deal to have seen microscopic structures?

2 Hooke was excited about how his methods could lead to future discoveries. He saw the microscope as improving eyesight. What developments have occurred since his lifetime to improve hearing, smell, taste and touch?



→ Fig 1.1 Robert Hooke's microscope.

1.2 What do we know about cells?

Living things are all around us. We can see them grow and change, get sick and die, or even reproduce. Scientists have made many observations of living things over many thousands of years. They can identify what has gone in and what has come out. They can see big changes and predict future changes. However, it was not until the development of the microscope that scientists fully appreciated the tiny building blocks that make up living things. In fact, the microscope opened their eyes to a new world of miniature life forms.

The human body is made up of approximately 200 different types of cells, each with a different job. However, humans start off life as a single cell, which becomes a ball of similar cells. Eventually, the cells are 'given' their special jobs and they change to suit these jobs. Cells that haven't become specialised yet are called **stem cells**. Different types of stem cells differ in their ability to change into other types of cells. Scientists have discovered so much about cells since the days of Robert Hooke that they are now looking at ways to manipulate stem cells. Imagine being able to grow skin cells in a Petri dish—scientists are already doing this! What a fabulous development for burns victims!

1 If a stem cell is a cell without a job, describe an analogy (similar situation) using people instead of cells.
2 Do you think a part of your body that is constantly making new cells would have more or less stem cells? Explain.
3 Some stem cells are found only in embryos. What issues might arise from this?

→ Fig 1.2 Skin being grown in a Petri dish.

1.3 How do cells work together?

Your body is incredibly complicated. It is made of so many parts performing so many functions that learning about it can be a little overwhelming. Sometimes it helps to relate complicated things to something you are already familiar with; that is, to create an *analogy*.

Think of the human body as a big city. It has lots going on: different structures, people working in different jobs, communication and transport systems for connecting different areas, products being imported and made, wastes being created and disposed of and, all the time, it needs to respond to what is happening in the rest of the world.

1 From what you know about your body, do you think a city is a good analogy?
2 What would happen if people didn't ever work together in a city?
3 Think of five jobs your body undertakes. What would they be similar to in the city analogy?

→ Fig 1.3 Melbourne skyline.

1.1

How do we know about cells?

Scientists haven't always known that living things were made up of cells. Until recently, scientists were trying to understand the behaviour of the different types of matter in our bodies. Some theories, such as that of Hippocrates around 400 BCE, involved a balance of different types of matter making us normal, crazy, intelligent or even dead!

It was the invention of the microscope in the mid-17th century that finally helped scientists work out a reliable way of telling a living thing from a non-living one. The microscope allowed us to see the building blocks of life—the tiny units that form every living thing, from the smallest microscopic bacteria to the tallest eucalypt tree. Microscopes showed that each and every living thing is made up of **cells**.

<<DISCOVERING IDEAS>>

Under the microscope

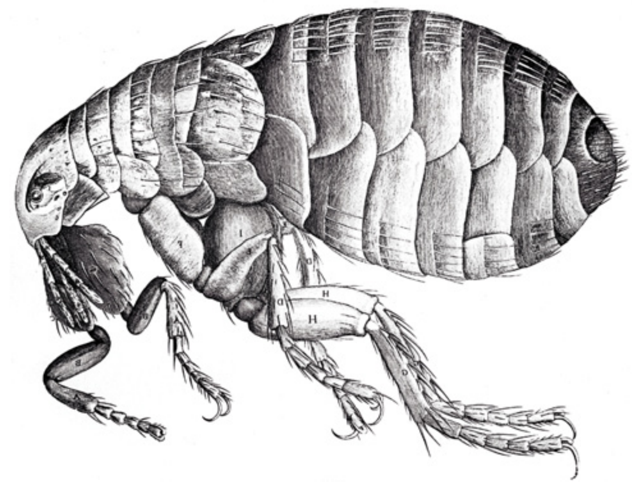
Use the stereomicroscopes that have been set up by your teacher to look at a drop of water from a pond.

- What do you think you are likely to see?
- Does it look like there's anything in the water?
- If you see something, draw it and try to explain what it may be.
- Share your discoveries with the class.

Discovering cells

When Robert Hooke published his book *Micrographia* in 1665 it became a best seller. Hooke had made one of the first microscopes. With it, he observed many types of living things and made accurate drawings of what he saw, as his detailed picture of the flea shows (Figure 1.4).

Hooke's most famous achievement, as far as science was concerned, was his diagram of very thin slices of cork (Figure 1.5). He was surprised to see that, under the microscope, the cork looked like a piece of honeycomb. He described the 'holes' and their boundaries in the 'honeycomb' as cells because they reminded him of the rooms in a monastery. Hooke had discovered plant cells.



➔ Fig 1.4 Robert Hooke's drawing of a flea.

Although some called *Micrographia* 'the most ingenious book ever', others ridiculed Hooke for spending so much time and money on 'trifling pursuits'. Thankfully for us, and for the whole science of microbiology, which developed from this discovery of cells, Hooke ignored the taunts and kept experimenting with microscopes.

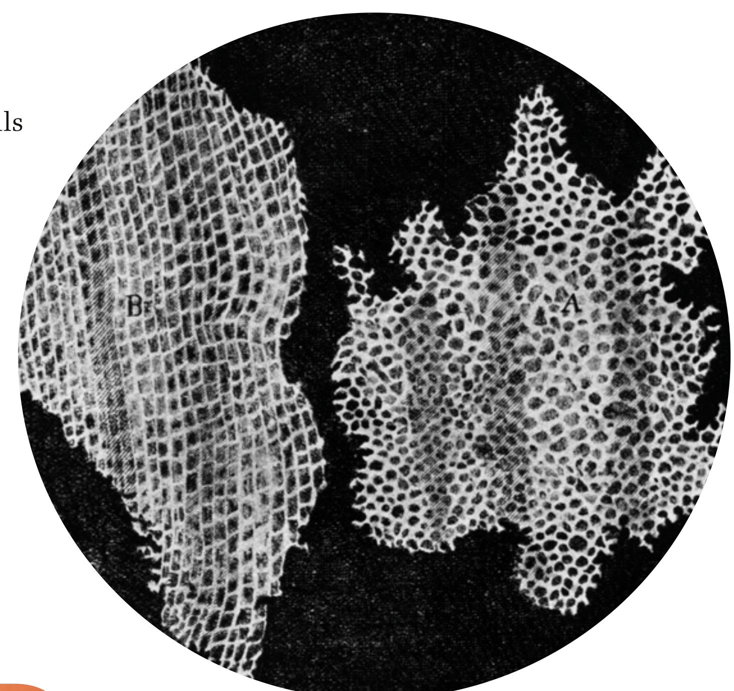
It was because of Hooke's important contribution to microbiology that other scientists went on to develop a further understanding of cells.

Cell theory

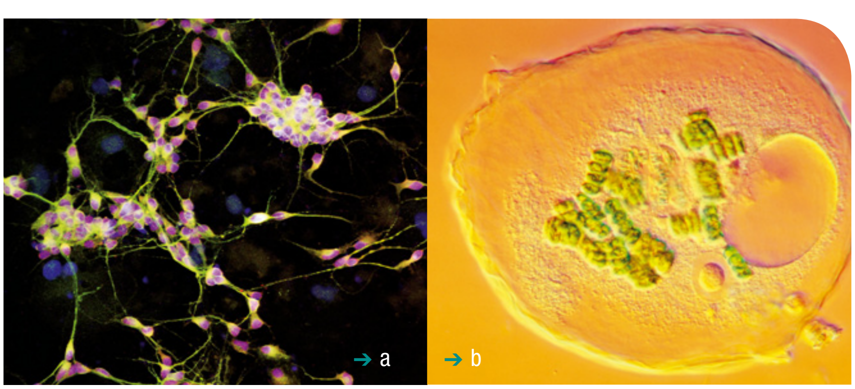
Cell theory describes the main ideas about the importance of cells and their role in living things. It was first proposed in 1839 by two German biologists, Theodor Schwann and Matthias Schleiden. In 1858, Rudolf Virchow concluded the final part of the classic cell theory. The combined cell theory included the following three principles:

- all organisms are composed of one or more cells
- cells are the basic unit of life and structure
- new cells are created from existing cells.

Any living thing that has more than one cell is referred to as multicellular, but there are many living things, such as bacteria, that consist of only one cell! These are called single-celled or unicellular organisms. Micro-organisms are often referred to as microbes.



➔ Fig 1.5 Robert Hooke's drawing of cork.



➔ Fig 1.6 (a) Human nerve cells make up multicellular humans, but (b) the amoeba survives as a unicellular organism.

PRACTIVITY 1.1

Looking at different cells

Several stations are set up around the laboratory with microscopes adjusted to show different kinds of cells.

Do not attempt to adjust any of the microscopes! Ask your teacher or laboratory technician to adjust the microscope if you think it has been bumped or has gone out of focus.

1 Look carefully at each specimen. Write down its name and a sentence that describes what you see.
2 Make a very simple pencil sketch of a part of the cells you see. For example, if there are many layers or rows of cells, just draw three or four layers.
3 If you can see anything inside a cell (it may only be a dark dot), mark this on your sketch.
   - Which cells, in your opinion, were the most unusual?
   - Which cells had very obvious walls around them?
   - Which cells were the smallest?
   - Which cells were the largest?
   - How did your view through the microscope compare with the images of the cells in Figure 1.6?
   - Describe some of the difficulties of drawing cells seen through a microscope.

What do you know about discovering cells?

1 Can cells be seen without a microscope?
2 Who invented the first microscope?
3 Why are cells called ‘cells’?
4 Name an organism that is made up of just one cell.
5 What does *multicellular* mean?
6 Name five multicellular organisms.
7 Why was the invention of the microscope important to our understanding of living things?
8 What are the three principles of the combined cell theory?

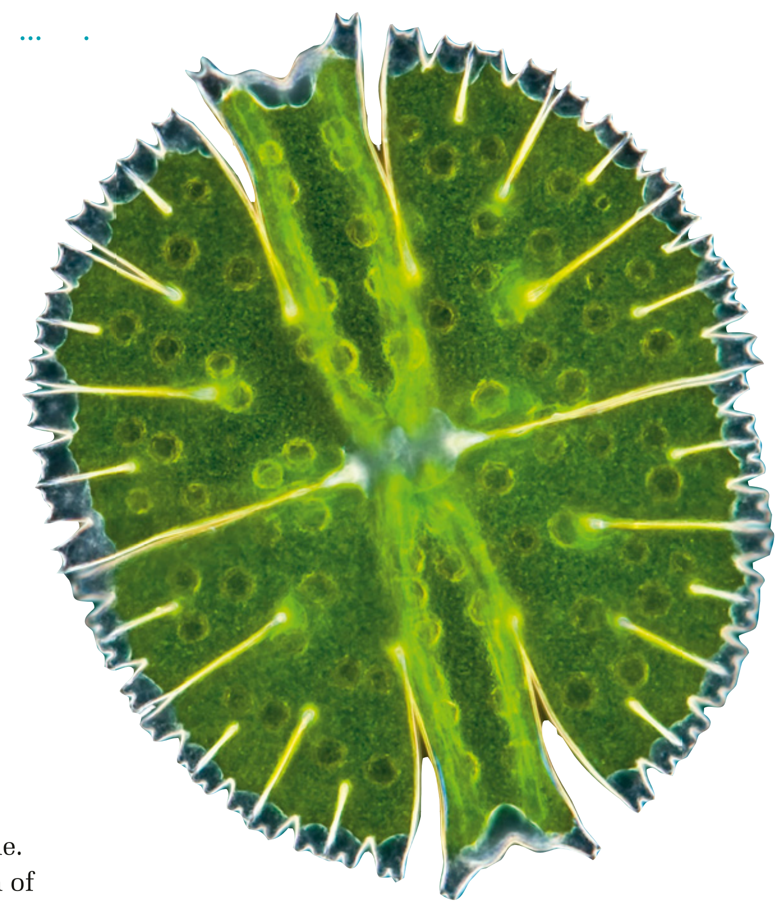
Limitations to cell size

Have you ever considered why single-celled organisms are so small? A single cell must meet all the requirements of a unicellular organism. The cell’s skin or membrane is particularly important because it provides a barrier between the inside of the cell and the external environment. The materials required for cell functioning and the waste products produced by these processes are all transported across the cell membrane. It is essential that the cell membrane provides a large surface area for the transport of so many molecules into and out of the cell.

Why are cells so small?

The surface of a cell is its cell membrane. Substances inside and outside the cell move across the membrane covering the cell. Cells need to maximise their surface area to make sure they maximise their ability to exchange substances with their environment.

The total space inside the cell is referred to as the cell’s volume. As a cell increases in size, its volume increases. A comparison of these two values as a fraction—the **surface area to volume ratio**—reveals exactly why cells are limited in size.



→ Fig 1.7 The irregular shape of unicellular desmids maximises their surface area to volume ratio.

NUMERACY LAB

Calculating the surface area to volume ratio

To calculate the surface area of an object, calculate the surface area of each side and then add the values for all sides together.

The surface area of one side of the green cube shown in Figure 1.8 is:

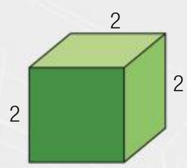
$2 \times 2 = 4 \text{ cm}^2$

There are six equal sides, so the total surface area is:

$4 \times 6 = 24 \text{ cm}^2$

Example

→ Fig 1.8



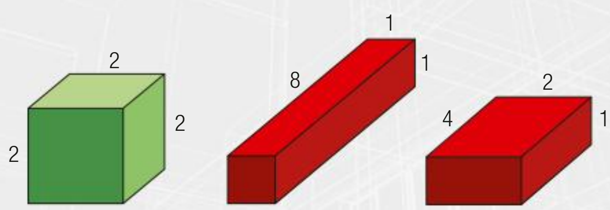
Your turn

1 Volume = height × width × length. Calculate the volume for all three shapes shown in Figure 1.9. Is the volume the same for the three shapes?

2 What is the surface area for each shape?

3 Which shape has the greatest surface area to volume ratio?

→ Fig 1.9



Answers

1 8 cm^3, 8 cm^3, 8 cm^3 2 24 cm^2, 34 cm^2, 28 cm^2

3 8:24, 8:34, 8:28

What do you know about limitations to cell size?

1 What is the surface area of a cell?

2 How does the surface area:volume ratio limit cell size?

3 Would a cell with a bigger surface area:volume ratio be able to meet its requirements for nutrients more effectively? Why or why not?

Structures matter

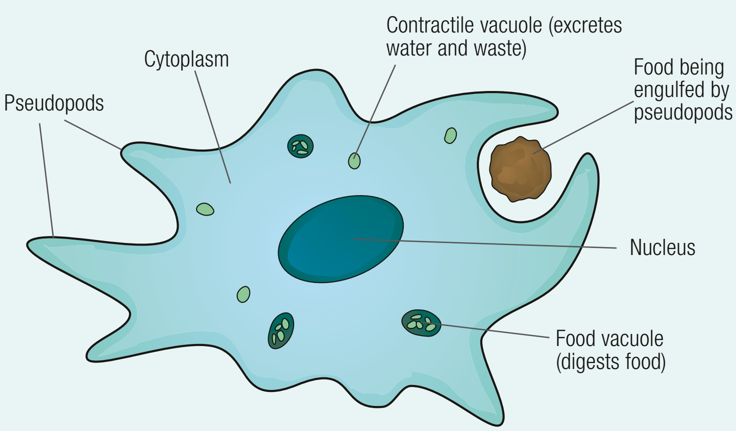
Form and function

Protists are an extremely diverse group of organisms that are mostly unicellular. Many live in water, some are photosynthetic (i.e. make their own food, like plants), some are herbivores and some are parasites. Depending on the lifestyle and food source of the organism, the form or structure of its cell will have evolved to suit.

The following protists have structures particular to their lifestyles.

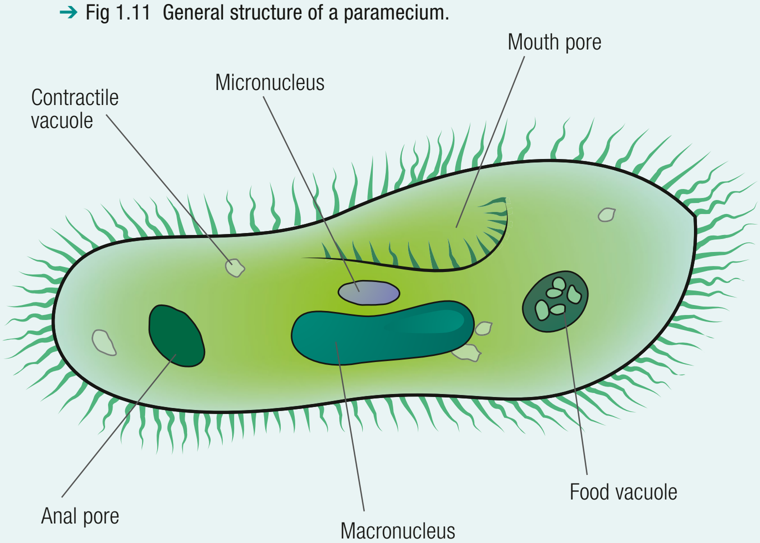
1 An *amoeba* can change the shape of its blobby body, creating foot shapes for movement and mouth shapes for swallowing food.

→ Fig 1.10 General structure of an amoeba.



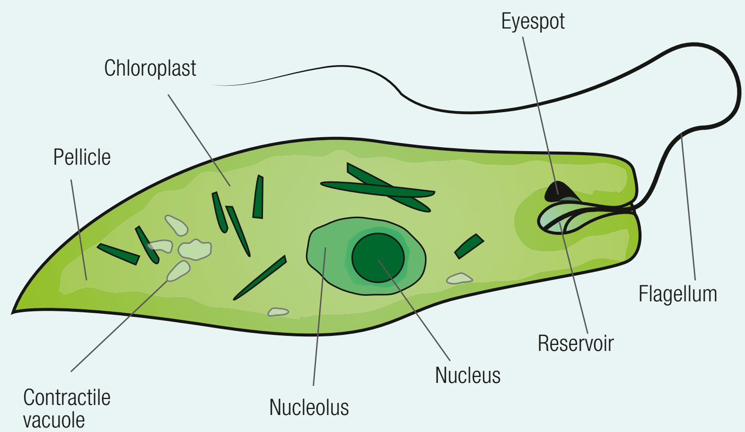
2 The *paramecium* plods along slowly with lots of tiny hairs called cilia that act like miniature oars.

→ Fig 1.11 General structure of a paramecium.



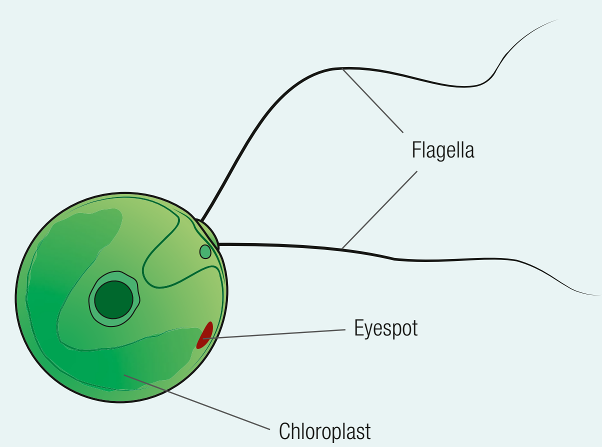
3 *Euglena* moves really quickly when it needs to, with a bullet-shaped body and a long tail called a flagellum to whip it into action.

→ Fig 1.12 General structure of euglena.



4 *Chlamydomonas* has an eye spot that can detect light for photosynthesis and two flagella that help it swim along in a breaststroke-like motion.

→ Fig 1.13 General structure of chlamydomonas.



Microscopy

You probably know people who wear glasses to help them read. The glass or plastic lenses magnify the size of the text. In the same way, **microscopes** magnify the size of the object placed under them.

The first microscopes were very basic. However, over time their magnifying ability has improved. Scientists can now look at images that have been magnified thousands of times using various systems of lenses. This makes it possible to study the structure of cells.

Types of microscopes

As a science student, you will probably use two types of light microscope: the stereomicroscope and the compound light microscope.

The stereomicroscope is used for viewing larger objects, such as insects (Figure 1.15). It can magnify up to 200 times and shows a three-dimensional view of small things.

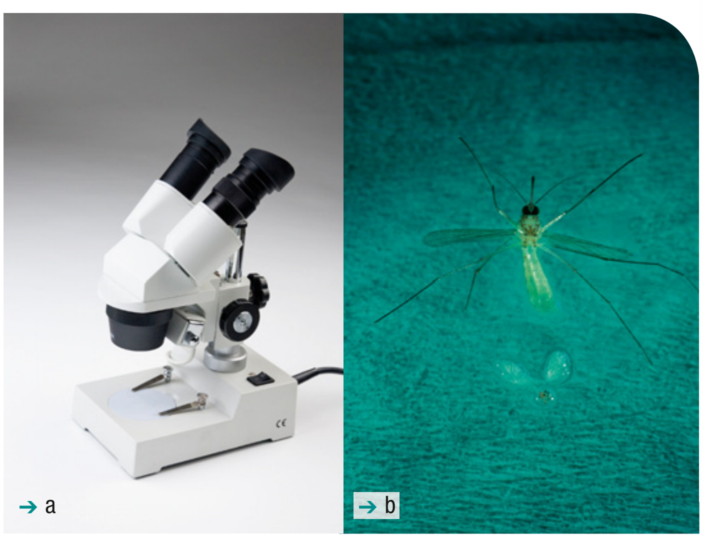
The compound light microscope (Figure 1.16) is used to observe thin slices of specimens, such as blood cells. It can magnify up to 1500 times. Its view is flat—that is, two dimensional. The specimen must be thin enough to allow light to pass through it.

The stereomicroscope has two **eyepieces** to look through, whereas the compound light microscope can have one or two eyepieces. The word *monocular* is used to describe a microscope with one eyepiece (mono = one). Microscopes with two lenses are called binocular (bi = two). The compound light microscope uses the effect of two lenses (one in the eyepieces and one further down the column called the **objective lens**) combined with light to give a greater magnification. It can be used to observe much smaller things than those seen under a stereomicroscope.

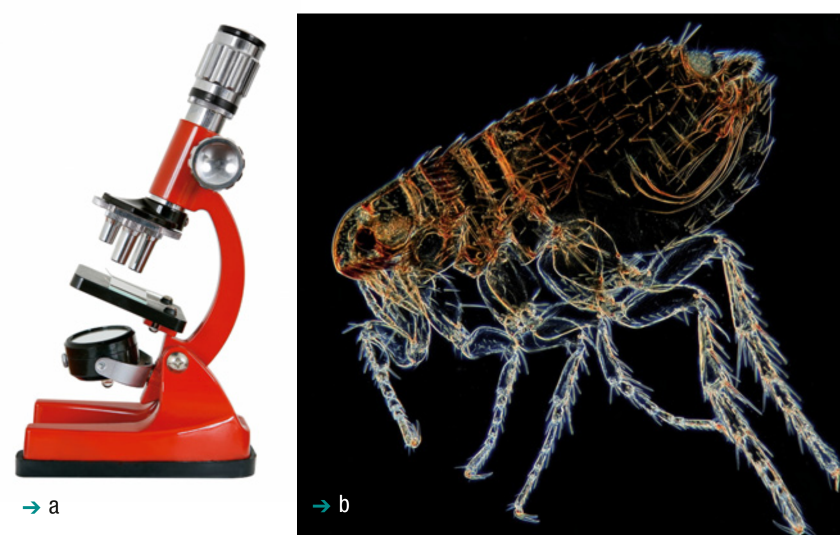
→ Fig 1.14 An insect eye is a complex system of lenses that gives the insect amazing vision.

Looking at cells

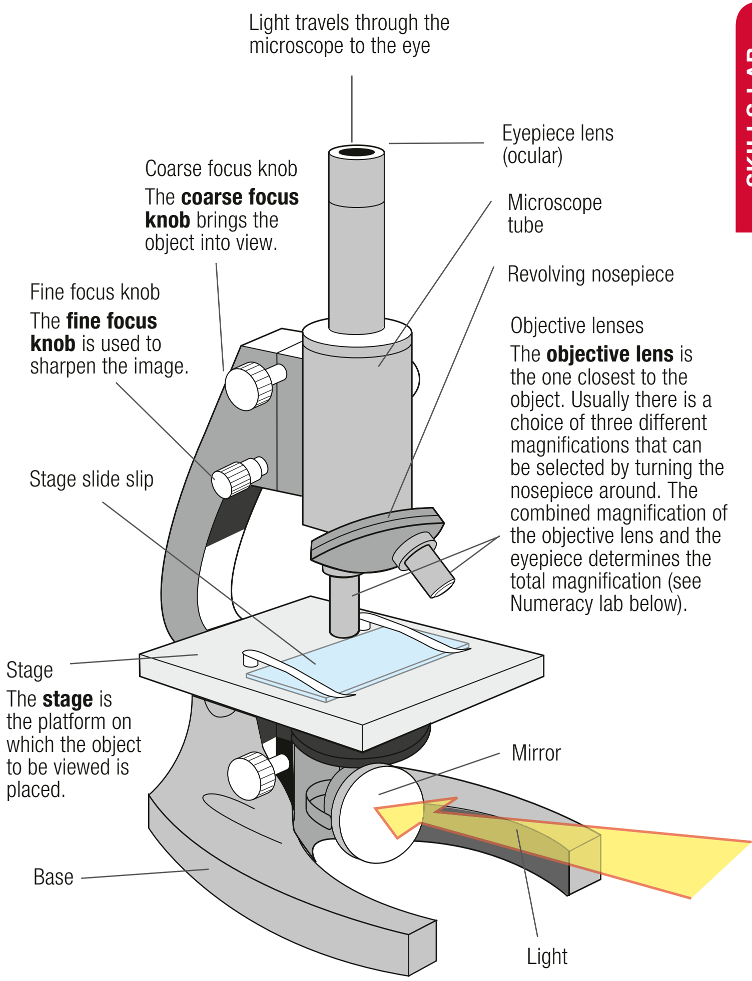
To look at cells clearly through a compound light microscope, very thin layers of a sample must be used. The light has to be able to get through or all you will see is a dark shadow—a bit like a leadlight window. Most cells are clear in colour, so a **stain**, like iodine, is used to help make them more visible by providing contrast.



→ Fig 1.15 (a) A stereomicroscope. (b) An insect, as seen under a stereomicroscope.



→ Fig 1.16 (a) A compound light microscope. (b) A flea, as seen under a compound light microscope.



→ Fig 1.17 Parts of a compound light microscope. This example is monocular because it has only one eyepiece.

SKILLS LAB

Ten tips for using a microscope

Microscopes are expensive, fragile instruments. They need to be handled carefully and used properly if they are going to help you see the microscopic world.

1 Always use two hands to carry a microscope—one hand should be around the main part of the instrument and the other underneath it.

2 Some microscopes have a built-in lamp. Others have separate lamps that need to be set up so they shine onto the mirror. Adjust the mirror to project the light through the stage onto the specimen. Do not allow sunlight to shine directly up the column.

3 Place the slide on the stage then select the objective lens with the lowest magnification first.

4 Look from the side and adjust the coarse focus knob so that the objective lens is *just above—and not touching*—the slide. Check which way you must turn the knob to move the objective lens away from the slide.

5 Use the coarse focus knob to bring the specimen into view. Then use the fine focus knob to help you see it more clearly.

6 If you want a higher magnification, rotate the objective lens to a higher magnification.

7 Draw what you see (as a record) using a pencil.

8 Work out the total magnification.

9 Write the magnification next to your sketch.

10 Label and date the sketch.

NUMERACY LAB

Working out magnification

To calculate the total magnification of a compound light microscope, multiply the magnification of the eyepiece lens by the magnification of the objective lens. These figures are marked on each lens.

Example

Eyepiece magnification	Objective lens magnification	Total magnification
×5	×10	×50
×10	×20	×200

Your turn

1 You need a magnification of ×100. What magnification should you use for your objective lens if your eyepiece magnification is ×5?

2 A photo of a slide under a microscope says it has been taken at a magnification of ×200. What combination of eyepiece and objective lens magnifications was used?

3 To view a slide at a magnification of ×100, what combinations of lenses are possible?

Answers **1** ×20 **2** ×10 and ×20 **3** ×5 and ×20; ×10 and ×10

EXPERIMENT 1.1

Getting to know your microscope

Aim

To experiment with a compound light microscope.

Materials

Compound light microscope
Microscope slide
Coverslip
Small piece of newspaper
Small piece of tissue paper
Hair (use your own)
1 cm sticky tape (transparent)
Eyedropper
Small beaker of water

Method

1 Cut out two small words from a piece of newspaper.
2 Place the cut out newspaper on the microscope slide and add two drops of water to help it 'stick' to the slide. Place a coverslip on top. This is called a **wet mount**.
3 Follow the instructions for using a microscope on page 10. On the lowest magnification, find one letter from the newsprint to focus on.
4 Move the slide slightly towards your body and observe what happens.
5 Move the slide slightly to the left and observe what happens.
6 Change the magnification and observe what happens.
7 Draw a diagram of the newspaper letter.

Take the newspaper out and prepare another slide using the tissue paper. Make sure the drop of water is added and the coverslip is placed over the top carefully.

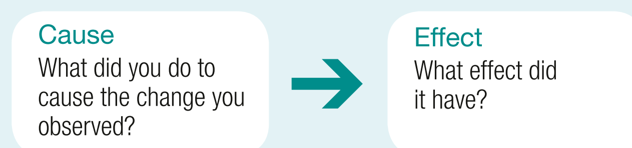
9 Sketch what you see.
10 Repeat with sticky tape and then a hair from your head.

Results

Include your diagrams here.

Discussion

1 Describe what the newspaper letter looks like through the microscope. What does this mean for all things you see through this type of microscope?

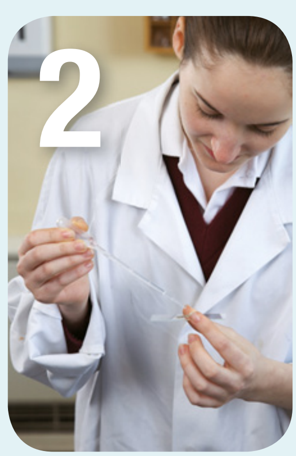


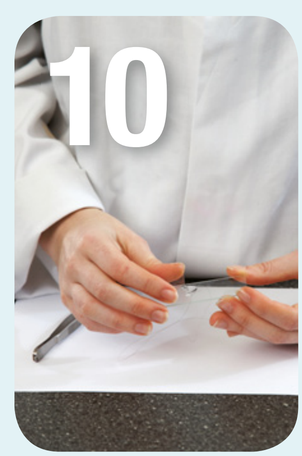
→ Fig 1.18 Cause-and-effect graphic organiser.

2 What features could you see on the tissue paper and sticky tape that you could not see with the naked eye?
3 Use a series of cause-and-effect graphic organisers, similar to that shown in Figure 1.18, to record the results of your experiment when you moved the slide different ways. For example, the cause link may be 'move the slide to the left'. Then write what happened in the effect link.

Conclusion

What do you know about compound light microscopes?



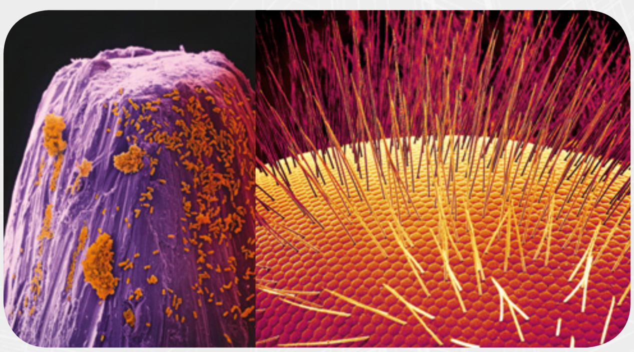


Bigger and better microscopes

Although light microscopes, like the compound light microscope and stereomicroscope, had served scientists well for more than 300 years, the explosion of new technology in the 20th century led to the invention of more complex microscopes, such as electron microscopes.

An electron microscope uses electrons (tiny negatively charged particles) to create images. The first electron microscope, the transmission electron microscope (TEM), was invented in 1933 to help study the structure of metals. The scanning electron microscope (SEM), developed later, uses a beam of electrons to scan across a specimen and to recreate the image, showing details of its surface.

Electron microscopes can magnify up to a million times! Using this technology, many more details of the cell that were formerly invisible to scientists are now beginning to be understood.



→ Fig 1.19 These images were taken through an electron microscope. Can you guess what they are?

→ Fig 1.20 Using an electron microscope.

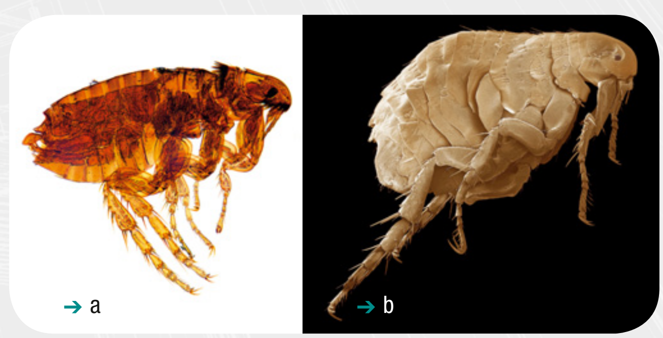
The synchrotron

The development of the synchrotron is one of the biggest changes to microscopes. Synchrotrons are 'microscopes' that are about the size of a football field and cost a fortune to build.

The synchrotron provides even more magnification than an electron microscope and can 'see' down to the level of the molecules (particles) that make up substances. There are currently forty-three synchrotrons across the world. Australia's synchrotron opened in 2007 and is located near Monash University, in Melbourne. There are many beneficial applications of synchrotron science. For example, researchers can use the synchrotron to invent ways to tackle diseases, make plants more productive and metals more resilient.

Questions

1. What extra magnification can be gained by using an electron microscope compared with a light microscope?
2. Compare the two photographs taken through a light microscope and an electron microscope (Figure 1.21). Describe what the electron microscope adds to the view of a normal light microscope.
3. Where is Australia's only synchrotron?
4. Find out more about one of the research projects currently being assisted by the Australian synchrotron.



→ Fig 1.21 (a) Flea cells seen through a compound light microscope. (b) The same flea cells seen through a transmission electron microscope.

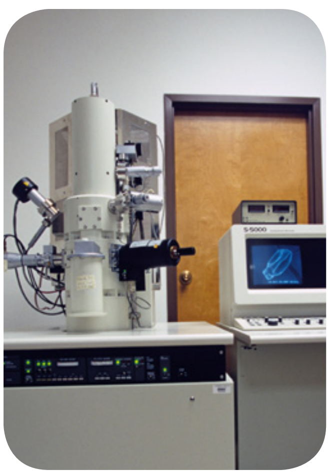
Different microscopes, different images

Images from microscopes will vary quite dramatically. Different microscopes produce different types of images because of the magnification, the way a specimen must be prepared, the way the specimen is treated by the microscope and the materials used in the process of viewing the specimen.

→ Fig 1.22 Stereomicroscope (SM).

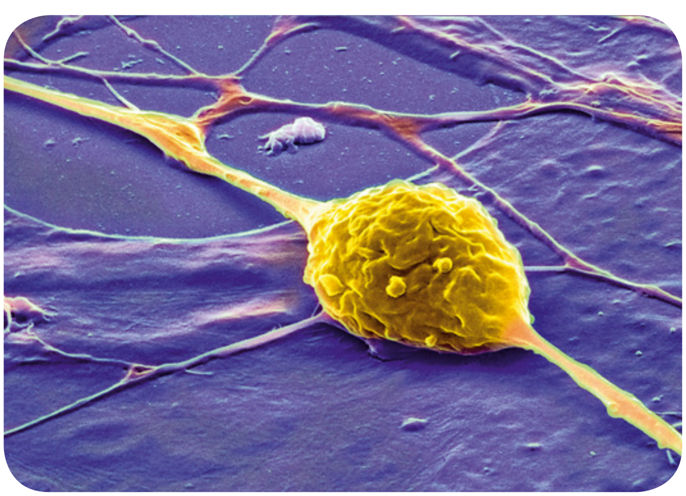
→ Fig 1.23 Compound light microscope (LM).

→ Fig 1.24 Scanning transmission electron microscope (STEM).



→ Fig 1.25 Scanning electron microscope (SEM).

→ Fig 1.26 SM image of a wasp.

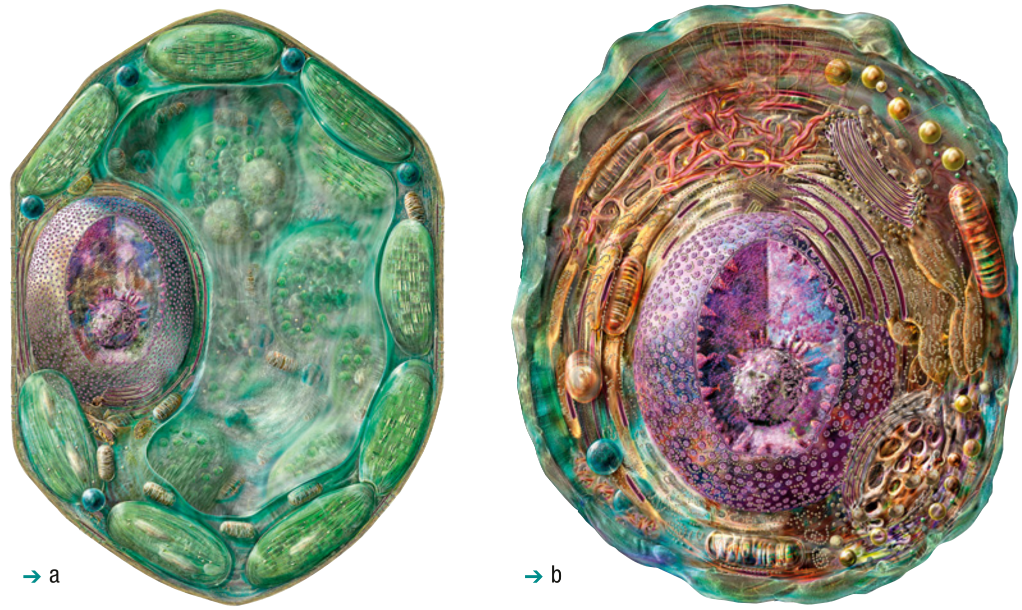


→ Fig 1.27 SEM image of a nerve cell.

→ Fig 1.28 LM image of a hair root.

Plant and animal cells

By looking at different characteristics of plants and animals, it's fairly easy to see that they are different types of organisms. It's not hard to tell an apple from an elephant! However, once microscopes started to become more powerful, suddenly scientists could see that there were differences between plant and animal cells (Figure 1.29). This made sense. If cells are the building blocks and the basic units differ, then the final living things will show different characteristics.



→ a → b

→ Fig 1.29 Typical (a) plant and (b) animal cells.

EXPERIMENT 1.2

Plant and animal cells

Aim

To compare plant and animal cells.

Materials

Light microscope
Microscope slide
Coverslip
Iodine in dropper bottle
Brown onion
Prepared slide of animal cells

Method

1 Peel off a very thin piece of brown onion skin so that it looks a bit like cling film.

→ Fig 1.30

2 Place the skin on the microscope slide and add a tiny drop of iodine. This stains parts of the cells to make them easier to see.

→ Fig 1.31

3 Place one edge of the cover slip onto the slide and carefully lower it so that no air bubbles get trapped underneath.

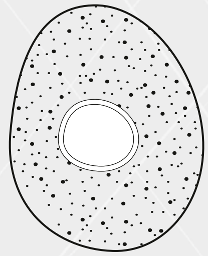
4 Place the slide on the stage.

→ Fig 1.32

SKILLS LAB

Specimen diagrams

What you see through a microscope is not always easy to represent in a sketch. Compare the diagram of an animal cell (Figure 1.33) with the image shown in Figure 1.29.



→ Fig 1.33 Diagram of an animal cell.

The diagram is, in many ways, like a summary or a simplification of what you see through the microscope. It is impossible to draw all the cells you see, so select those that seem to be typical and try to show how they fit together.

Tips for specimen diagrams

1 Always use a sharp lead pencil so you can erase and modify your diagram. Never colour or shade areas; if absolutely necessary, use dots or lines instead.

2 All diagrams should be large enough to view the details. Try to use about a quarter of a page for each diagram.

3 Draw a circle to represent your viewing area.

4 Use clear labels and appropriate scientific language.

5 Write the specimen name, date and magnification outside the circle.

5 Focus the microscope.

→ Fig 1.34

6 Draw the cells you observe. Don't forget to label your diagram and write down the total magnification.

7 Remove the slide and place the prepared slide of animal cells under the microscope. Focus the microscope.

8 Draw the cells you observe.

9 Write down the total magnification and label the diagram.

Results

Include your cell diagrams here.

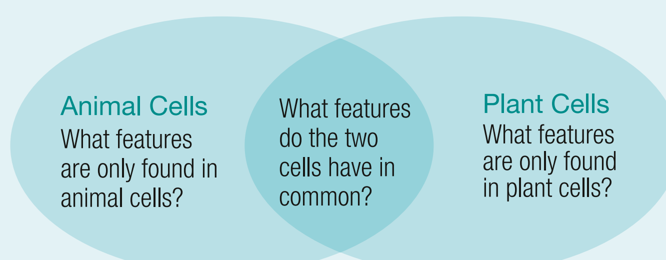
Discussion

1 What is the purpose of staining the onion skin cells?

2 What kind of living thing did the onion skin come from?

3 Compare the two sketches you have prepared with the images of plant and animal cells in Figure 1.29. List any differences and similarities.

4 Use the Venn diagram in Figure 1.35 to show how plant and animal cells are similar and how they are different.



→ Fig 1.35

Conclusion

What do you know about plant and animal cells?

What do you know about using microscopes?

1 What type or types of microscope have you used in your science class?
2 Write a short description of each type of microscope you have used, including whether it is monocular or binocular, its maximum magnification and what it is used to view.
3 Why do you look from the side when you adjust the coarse focus knob?
4 What is a wet mount? How is one prepared?
5 Explain why it is important to label and date your specimen drawings. Give three different reasons.
6 Why must very thin samples be used under a light microscope?
7 What is *microbiology*?
8 Complete the following magnification table for a compound light microscope by working out the missing values:

Eyepiece	Objective lens magnification	Total magnification
×5		×100
	×20	×300
×10	×50	
×30		×450
×5	×100	

9 Prepare a microscope safety postcard that you could mail to a science student at another school.
10 Complete Venn diagrams similar to Figure 1.35 on page 15, for stereomicroscopes and compound light microscopes.

1.1 How do we know about cells?

Remember and understand

1 Who was the first to describe cells?

2 What type of cells were the first cells to be drawn?

3 What is the cell theory?

4 When would you use a stereomicroscope instead of a compound light microscope?

5 Why does a specimen need to be really thin to be viewed under a light microscope?

Apply

6 What are the different lenses on a compound light microscope? Why are there different lenses?

Analyse and evaluate

7 Make up a table that compares the similarities and differences between light microscopes and electron microscopes.

8 Explain why unicellular organisms are always tiny and multicellular organisms are made up of so many cells.

9 Investigate why the image you see through a compound light microscope, but not a stereomicroscope, is upside down and back to front.

10 Light microscopes allow you to view living cells. Electron microscopes view either dead cells or cells that have been killed in the process of viewing them. In what situations might light microscopes be preferable to electron microscopes? Explain.

11 Identify the microscope most likely to have created the images in Figure 1.36.

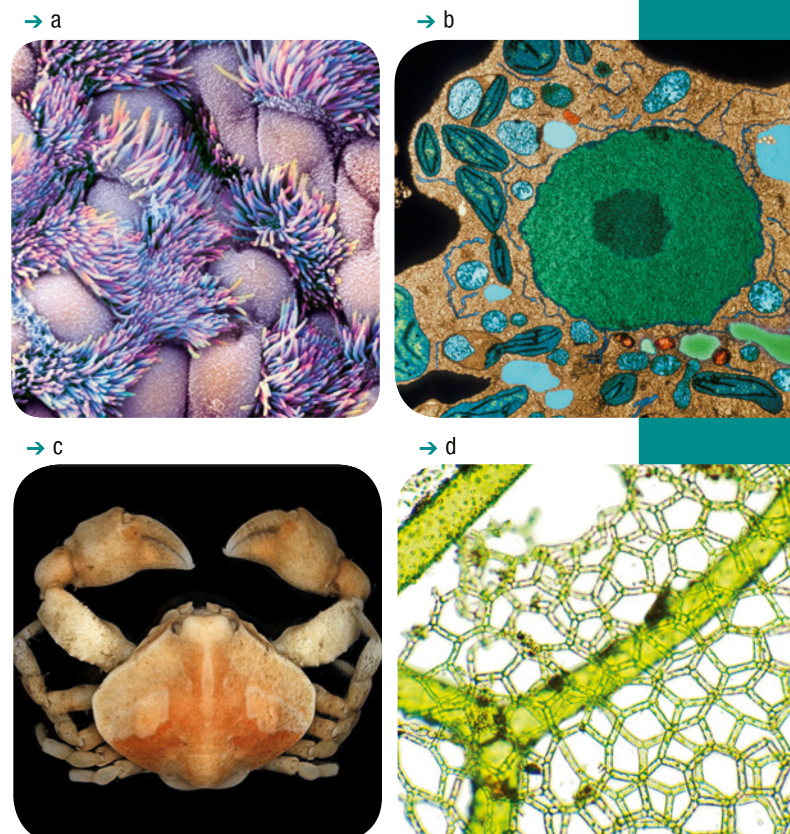


Fig 1.36

Critical and creative thinking

12 Use the lenses from an old pair of reading glasses to create a model of a light microscope. Describe how your model is similar and different to Hooke's microscope and modern compound light microscopes.

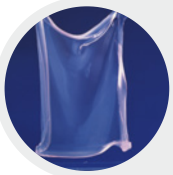
<<CONNECTING IDEAS>> Structure and function

13 a How has our understanding of how living things function changed with the development of the microscope?

b Is living matter different from non-living matter? Explain?

1.2

What do we know about cells?



One of the characteristics of an organism (living thing) is that it is composed of one or more cells. A cell is the basic unit of life. It is called this because it is the smallest unit of an organism that is considered living. But just as the basic unit of length—the metre—can be broken down into smaller parts (e.g. centimetres, millimetres, micrometres and even nanometres), the cell is made up of smaller parts too. Cells are made up of **organelles** (mini-organs), cytoplasm, DNA, nutrients, wastes and other substances. In scientific terms, a cell is actually quite big and it is made up of a lot of smaller parts that help it do its job.

<<DISCOVERING IDEAS>>

Under the microscope

Working in small groups, brainstorm the different jobs that a living organism would undertake to stay alive and be successful.

- Do you think the jobs you've listed apply to all organisms?
- Do you think the jobs of a cell will be similar or different to your list for an organism? Explain.
- Share your thoughts with the rest of the class.

Cell structures

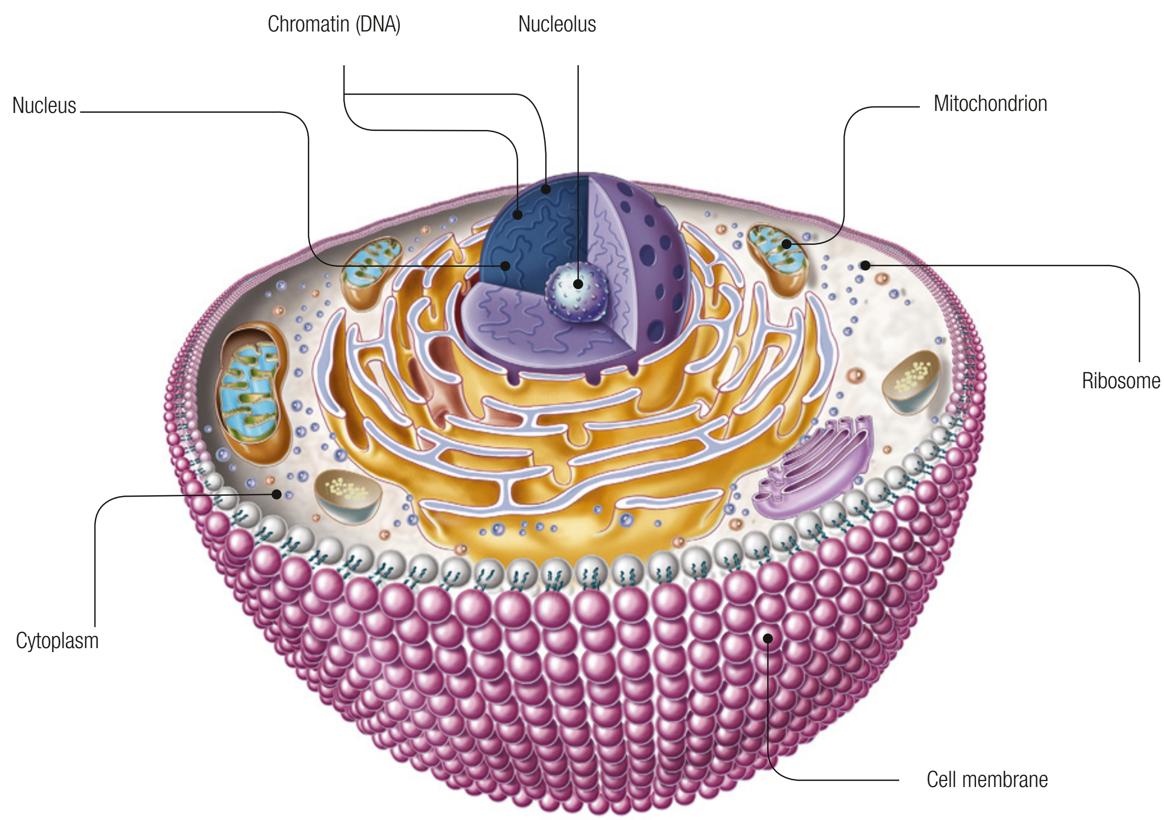
All cells, regardless of which type of organism they are found in, share the same basic structure. This basic structure includes three key features:

- **Cell membrane**—this acts like the 'skin' of a cell, forming a barrier around the cell. It controls the entry and exit of things into and out of the cell.
- **Cytoplasm**—this is the 'jelly-like' fluid inside the cell membrane that surrounds everything inside the cell. It helps provide structure to the cell and contains many dissolved nutrients and waste products.
- **DNA** (deoxyribonucleic acid)—this contains the instructions for every job your cells need to do and is passed from one generation to the next. The code for half your DNA came from your mother, whereas the other half came from your father. The same complete set of DNA is found in every one of your cells.

The main parts of cells and their functions are listed in Table 1.1. A diagram of an animal cell is shown in Figure 1.37.

→ Table 1.1

Part of cell	Function
Cell membrane	The cell membrane controls the entry and exit of things into and out of the cell and is covered in substances that help cells identify each other.
Cell wall	The cell wall is a layer surrounding the cell membrane that provides strength and structure to the cell. Animal cells do not have a cell wall. Cell walls are very important structures in plant cells, especially small plants that don't have a woody stem.
Nucleus	The nucleus is the control centre of the cell. It is surrounded by a nuclear membrane to separate the contents of the nucleus from the rest of the cell. The nucleus contains codes and instructions in the form of deoxyribonucleic acid (DNA).
Cytoplasm	The cytoplasm is the fluid-like part of the cell inside the cell membrane but outside the nucleus. It contains the cell's mini-organs, or organelles, and many dissolved substances that may be involved in chemical reactions or as food storage for the cell.
Vacuoles	Vacuoles are separate storage compartments within the cytoplasm that contain a watery fluid. They are very important in plant cells because they help provide support and structure to the cell, which assists the plants in growing upright and displaying their leaves to the Sun.
Ribosomes	Ribosomes are the site of protein production in the cell. Proteins are small molecules with many different roles. There are many different types of proteins. For example, some proteins are structural proteins (e.g. hair and nails), others are globular proteins (e.g. haemoglobin, which is found in red blood cells and helps transport oxygen through the bloodstream) and others still are involved in chemical reactions and the cell's own structure.
Mitochondria	Mitochondria are the 'powerhouse' of the cell, supplying the cell with energy through a process called cellular respiration.
Chloroplasts	Chloroplasts are found in plant cells and in some microorganisms. Their pigments are able to absorb the energy from the Sun to form chemical energy, which can be used by the plant and any animals that eat that plant. Solar energy is reacted with carbon dioxide and water to form glucose (chemical energy) and oxygen. This process is called photosynthesis.



→ Fig 1.37 Some key parts (organelles) of an animal cell.

EXPERIMENT 1.3

Looking at organelles

Aim

To prepare slides to view the organelles in the cells of a brown onion and an *Elodea* plant. You may wish to review Experiment 1.2 Plant and animal cells on page 14 for slide and microscope use.

Materials

Onion wedge

Leaf from an *Elodea* plant

Light microscope

Three glass slides

Three glass coverslips

Blotting paper

Methylene blue stain or iodine

Water

Method

Onion skin cell—unstained

Light microscopes depend on the light being able to pass through the specimen. When preparing a slide, it is important that the specimen is as thin as possible.

1 Between the fleshy layers of an onion there are some thin, transparent layers. These layers are one cell thick. Peel off a layer of this skin and put it onto a microscope slide.

2 Add one drop of water and then gently lower the coverslip so that no air bubbles are trapped.

3 Draw and label what you see. Try to identify the nucleus, which contains the DNA, and the cell membrane and cytoplasm.

4 Keep this slide for use in the next part of the experiment.

Onion skin cells—stained

Stains are often used on specimens because they add contrast to the image. Some highlight a particular feature of the cell.

5 Use another thin layer of onion skin to prepare a second slide as above.

6 Add a drop of methylene blue stain or iodine instead of the water before lowering the coverslip carefully so that no air bubbles are trapped. Be careful not to get the stain on your skin or clothes because it is very hard to remove.

7 Draw and label what you see. How does the use of the methylene blue stain or iodine change the appearance of the onion cells?

Elodea cells

8 Pick a small green *Elodea* leaf and put it onto a microscope slide.

9 Add one drop of water and then gently lower the coverslip so that no air bubbles are trapped.

10 Draw and label what you see. Try to identify the cell membrane and cytoplasm.

11 What other organelle is clearly visible in these cells?

Results

Include your labelled diagrams in this section.

Discussion

1 How does the use of a stain change the image of the onion cells?

2 Both types of cells viewed are from plants. Suggest why there are differences between each of the cell types. (Hint: Consider which part of the plant the cells come from.)

3 It is often difficult to identify the nucleus in the *Elodea* cells. Can you suggest why?

4 The *Elodea* cells contain another structure that is very prominent. What could be the role of this structure within the cell?

5 Can you suggest why it is not necessary to stain the *Elodea* cells?

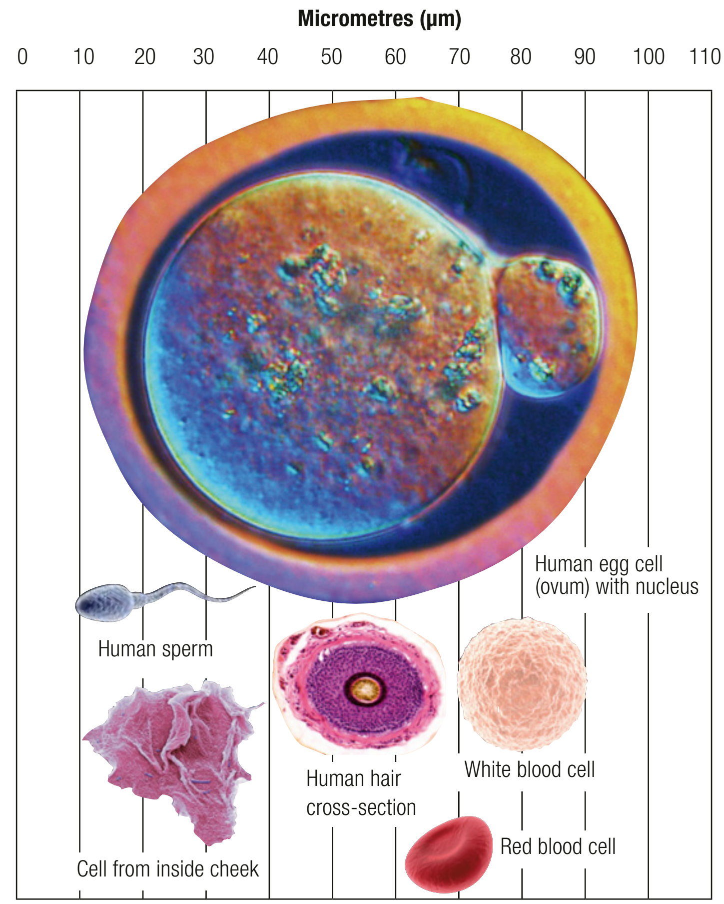
Conclusion

What do you know about the organelles in onion cells and *Elodea* cells?

Measuring cells and their parts

If you were to measure the length of your bedroom, you would probably use metres as a unit of measurement. If you were measuring the distance between two houses in neighbouring suburbs, you would select kilometres as a unit of measurement. Selecting appropriate units of measurement means that you do not need to deal with numbers that are really large or really small. Can you imagine measuring the distance between Melbourne and Sydney in millimetres? Because cells are microscopic in size, an appropriate unit of measurement is needed to measure them and their parts.

Look at 1 millimetre on your ruler. Now imagine that this 1 millimetre is divided into a thousand parts. One of those tiny parts is equal to 1 **micrometre** (μm). Cells and their parts are measured in micrometres. Cells vary in size depending on their function (Figure 1.38). A bacterial cell usually measures approximately 1 μm, whereas a plant cell may be up to 100 μm in size (equivalent to one-tenth of a millimetre).



→ Fig 1.38 A comparison of cell sizes.

PRACTIVITY 1.2

Comparing the size of cells and their parts

What you need

Sheet of poster paper
Pencil
30-cm ruler
Eraser

What to do

Part A

1 Using the scale of 1 cm = 1 μm, draw a series of circles to represent the average size of various cells and microbes according to the measurements given in Table 1.2.

→ Table 1.2

Cell type	Average diameter (μm)
Human cheek cell	30
Human red blood cell	7
Human white blood cell	25
Epidermal plant cell	50
Staphylococcus bacterium (spherical)	1
Escherichia coli bacterium (rod shaped)	3

2 Rank the cells and microbes from smallest to largest.

Part B

Organelles vary in size. Some organelles, such as chloroplasts, are large enough to be visible under the light microscope. Others, such as mitochondria, are usually too small to be visible.

1 Use the measurements given in Table 1.3 to add a chloroplast and mitochondrion (singular) to your set of diagrams.

→ Table 1.3

Cell organelle	Average size (μm)
Chloroplast	5 μm long × 1.5 μm wide
Mitochondrion	2 μm long × 1 μm wide

- Which of the cell organelles in Table 1.1 (page 19) are not visible under the light microscope?

2 Viruses are much smaller than even bacterial cells. For example, the influenza virus, which causes the flu, is 0.1 μm in diameter. Add the influenza virus to your diagrams.

EXPERIMENT 1.4

Measuring cells

Aim

To measure the size of various plant and animal cells using a mini-grid.

Materials

Onion cell slide (prepared in Experiment 1.2)
Other various prepared slides, such as human blood, nerve cells, leaf epidermis
Light microscope
Mini-grid slide

Method

1. Focus the onion cells under the light microscope.
2. Once in focus, estimate the average length and width of one cell in relation to the field of view.
3. Gently remove the slide and insert the slide containing the mini-grid.
4. Determine the length of the field of view and use this to calculate the average length and width of one onion cell.
5. Repeat this process for each of the other prepared slides.

Results

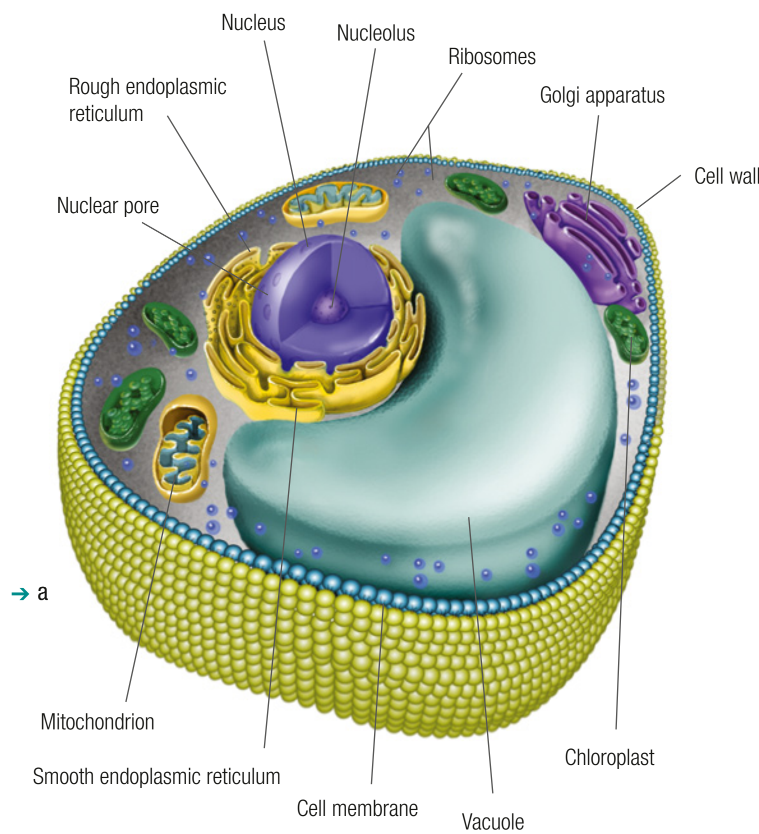
Rank the cells viewed in size from smallest to largest.

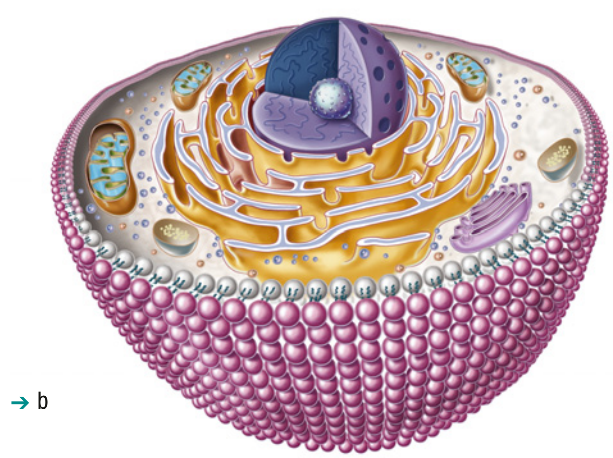
Discussion

Does your ranking match Table 1.2 from Practivity 1.2?

Conclusion

What do you know about the relative sizes of plant and animal cells?





→ Fig 1.39 Scientists know so much about the structures of (a) plant and (b) animal cells that they are able to create very detailed models and images.

What do you know about cell structures?

1. Name the unit used to measure the size of cells.
2. What is the function of the cell membrane?
3. Why do plant cells and fungi cells have a cell wall but animal cells do not?
4. In which organelle does cellular respiration occur?
5. What features of cells mean they are classified as living things? Remember MRNGREWW from Year 7?
6. Have a close look at the diagram of the cell and all its parts. You will notice that the cell membrane is represented by two layers of 'balls with double tails'. These shapes represent the particles making up the membrane. Are the other parts of the cell also made of smaller particles? Why aren't they represented by their particles in the diagram?

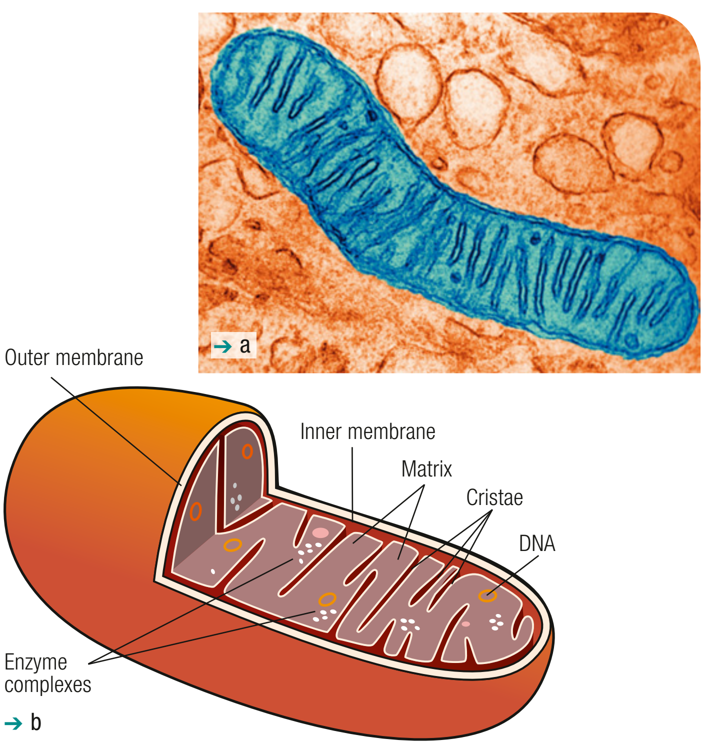
A closer look at organelles

As described in Table 1.1 (page 19), the different organelles in cells all have specific functions. These functions are necessary for the cell to survive. Some organelles, such as ribosomes, are part of the cytoplasm, whereas other organelles are separated from the cytoplasm by a membrane much like the cell membrane. These organelles, such as the nucleus and chloroplast, are called membrane-bound organelles. Different cell functions happen inside each of a cell's membrane-bound organelles, so the membrane keeps these functions separate from those in other membrane-bound organelles. This means that these functions can happen efficiently without interfering with other events taking place in the cell.

Let's take a closer look at three very important membrane-bound organelles in the cell—the mitochondria, ribosomes and chloroplasts.

Mitochondria

Mitochondria (*singular* mitochondrion) are the powerhouse of the cell, being the site of energy production in the cell. There may be several thousand mitochondria in a cell depending on what the cell does. For example, skeletal muscle cells contain a lot of mitochondria to make sure we have enough energy to run and jump when we need to.



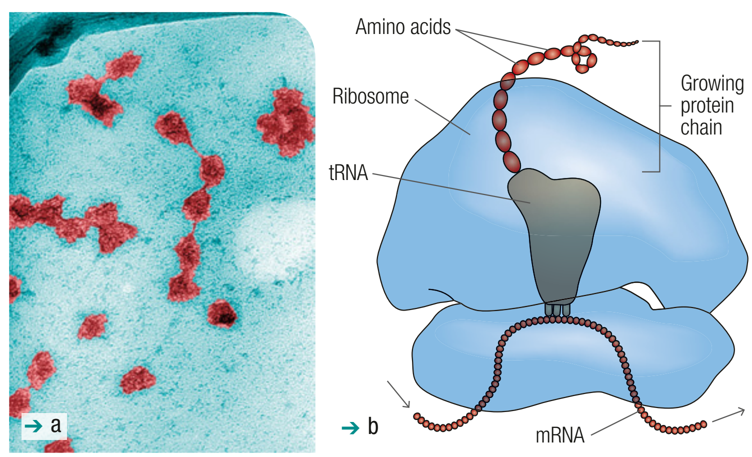
→ Fig 1.40 (a) Electron micrograph of a mitochondrion. (b) Schematic diagram showing the structure of a mitochondrion.

Mitochondria are like self-contained miniature power plants—they have their own DNA, make some of their own proteins and are able to grow and divide when a cell needs more of them.

Mitochondria are rod-shaped, membrane-bound organelles with an inner and outer membrane. The inner membrane is folded to increase the surface area of the membrane. The process of cellular respiration occurs inside the mitochondria. In this process, glucose (from the food we eat) and oxygen react to form water, carbon dioxide and energy. This energy is used by our bodies to help us function.

Ribosomes

Ribosomes are the site of protein production in the cell. These organelles use the codes from the DNA (in the form of mRNA) to assemble amino acids floating in the cytoplasm into a wide variety of proteins. A bit like Lego pieces, **amino acids** can be assembled into lots of different shapes and sizes, each with a different function. These amino acids have either been made by the body or come from proteins in foods that have been broken down. Essential amino acids are called 'essential' because they cannot be made by the body and must come from food.



→ Fig 1.41 (a) Electron micrograph ribosomes. (b) Schematic diagram showing the structure of a ribosome.

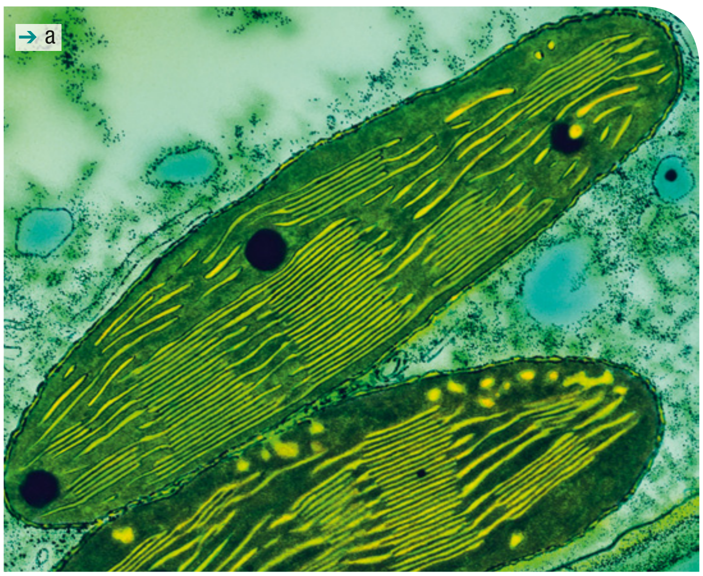
Proteins are grouped according to their structure and function. Structural proteins, as the name suggests, are important in the structure of cells, organelles and much larger organs, such as cartilage, hair and nails. Globular proteins are blob shaped and may be involved in taking messages around the body (hormones), helping chemical reactions occur (enzymes), fighting disease (immunoglobulins) or carrying substances (haemoglobin). These examples are just the start, so it's not surprising that there are scientists who focus solely on proteins!

Chloroplasts

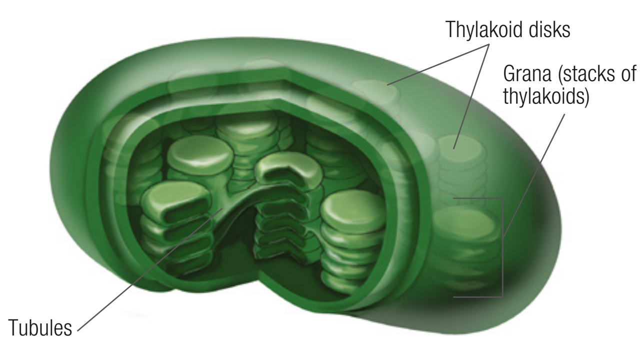
Chloroplasts are only found in plant cells and some unicellular organisms. These organelles are like microscopic solar panels that transform solar energy into chemical energy. In fact, the idea for solar panels came from studying how plants were able to harness energy from the Sun. Cells containing chloroplasts are mostly found on the tops of leaves.

The pigment in chloroplasts is usually green and called **chlorophyll**. You would have noticed that on hot days black, dull objects tend to heat up more than white, shiny objects—this is because different colours and materials react differently to heat and light energy.

→ a



→ b



→ Fig 1.42 (a) Electron micrograph of a chloroplast. (b) Schematic diagram showing the structure of a chloroplast.

Chlorophyll is perfectly suited to absorbing solar energy for a process called **photosynthesis**, which literally translates to 'making with light'.

Solar energy allows the particles of carbon dioxide and water molecules to be rearranged to form glucose and oxygen. Glucose can then be used as an energy source for the plant and any animal that eats that plant.

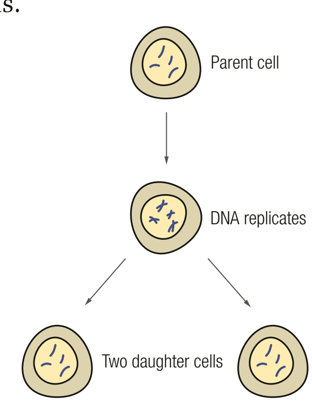
What do you know about looking closer at organelles?

1. Name three membrane-bound organelles.
2. What are some of the roles of proteins in organisms?
3. How is DNA related to protein production?
4. Why are most organelles surrounded by a membrane?
5. Where would you be more likely to find large numbers of mitochondria, in a muscle cell or a bone cell? Explain.
6. Food chains always begin with a plant. Which organelle explains the position of plants in food chains?

Making more cells

Cells, like organisms, need to carry out many functions for survival. They need to process many substances, harness energy and, ultimately, reproduce. The instructions for all these jobs are in the form of DNA—lengths of codes that can be 'read' when required to make sure jobs are done correctly. The DNA is stored in the **nucleus**, which is often referred to as the control centre or 'brain' of the cell.

When cells are ready to reproduce they simply split in half, but each new cell needs its own copy of the full set of DNA. The process of splitting in half needs to involve copying a new set of DNA and making sure one full set ends up in each of the new cells. The organelles are also roughly split into two groups. This process of cell division is called **mitosis**. New cells need to be made to replace old or damaged cells, help an organism grow or even carry out a specific job, such as in the case of red or white blood cells.

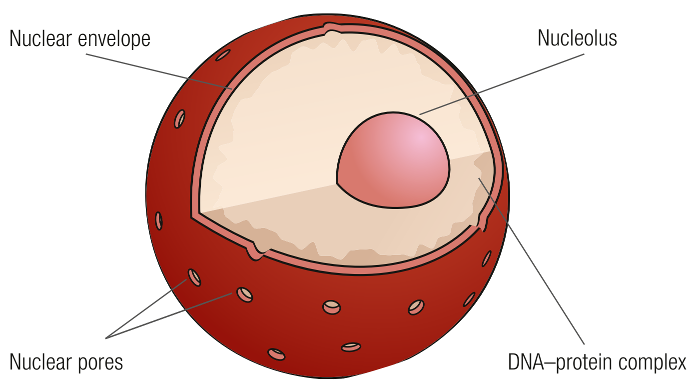


→ Fig 1.43 The process of mitosis.

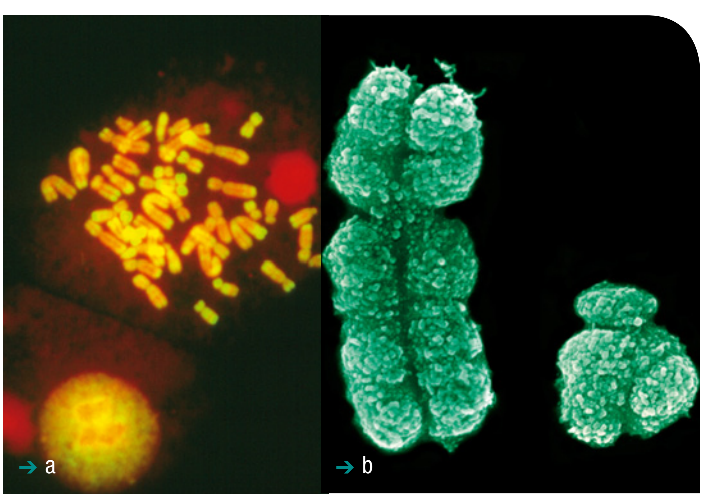
The cell nucleus

The **nucleus** is a membrane-bound organelle that is separated from the rest of the cell by a double membrane called the nuclear envelope (Figure 1.44). The nucleus also contains one or more suborganelles called nucleoli (*singular* **nucleolus**), which are involved in the production of proteins. The nuclear envelope has nuclear pores that allow the movement of substances into and out of the nucleus.

Long molecules of DNA are found in the nucleus. When a cell is not dividing, the DNA is found in unravelled strands in the nucleus. When a cell is dividing, the DNA strands coil up to form **chromosomes**, which can be seen easily with a light microscope (Figure 1.45). Chromosomes are like packets of genetic material that carry several sets of instructions for our cells. The number of chromosomes in an organism's cells varies among different organisms. Human cells have forty-six chromosomes, with twenty-three chromosomes coming from the mother and twenty-three from the father.



→ Fig 1.44 Structure of the cell nucleus.



→ Fig 1.45 (a) Light microscope and (b) electron microscope images of human chromosomes.

ZOOMING IN

Cancer: cell division out of control

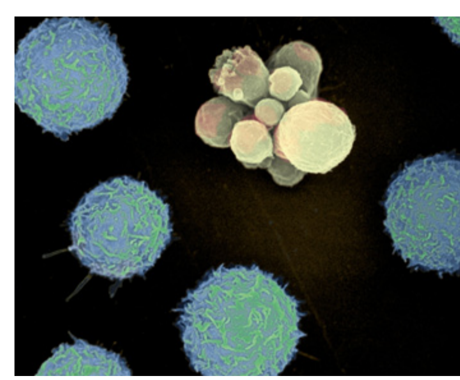
Cells do not survive indefinitely within an organism. They have a use-by date, after which they actually self-destruct. This ensures that cell division is controlled.

The term ***cancer*** describes a group of diseases that result from uncontrolled cell division. A cancer can form in any part of the body and affects humans and other animals. As an organism grows, cells reproduce to replace cells that are old or those that have died through injury. The process of a cell dying is a very normal and important part of the development and functioning of an organism. Programmed cell death is known as **apoptosis**. In fact, it was only through the programmed death of cells around your hands and feet that your fingers and toes formed during your early development.

If a cell experiences some kind of damage, the genetic material may also be damaged or altered. DNA may be damaged by a number of things, such as radiation, viruses or chemicals, called **mutagens**. Cancer-causing substances are called **carcinogens**. The change to the DNA results in a change in the instructions for the cell. Depending on this change, instructions may be lost or modified.

Damage to the genetic material may prevent a cell from self-destructing. When cell division gets out of control, a lot of cells grow. This is called a growth or tumour. The **tumour** is the cancer. The tumour may split off and spread throughout the body, causing secondary cancers. The secondary cancers can damage or destroy other organs.

There are two types of tumours: benign and malignant. Benign tumours do not spread and they are not normally fatal (causing death) unless they grow in a vital organ, such as the brain. In contrast, malignant tumours can spread to different parts of the body and can be fatal if their growth is not stopped.



→ Fig 1.46 The yellow cells are undergoing apoptosis, or programmed cell death.

What do you know about making more cells?

1 List three reasons why new cells need to be made.
2 Use diagrams to describe the steps involved in mitosis.
3 What is the name of the substance that provides instructions for the cell and where is it found?
4 What would happen if there were no nuclear pores?
5 What is *apoptosis*? When does it occur?
6 What are *chromosomes*? How many chromosomes do humans have?
7 How might the formation of chromosomes help organise genetic information?

Using cells to classify

A giraffe, worm and mushroom are all classified as living organisms, yet they have many differences. Although they all share cells as their basic building blocks, the structure and function of these cells are different. Single-celled or unicellular organisms, such as bacteria, are made of one cell only. Multicellular organisms, like us, are made of more than one cell and often many billions of cells. The different cells in a multicellular organism communicate and work together to produce a functioning organism.

Similarities and differences between the kingdoms

An organism's cell type can also be used to classify it. Organisms are classified into one of five groups, called kingdoms. Table 1.5 outlines the main characteristics of a typical cell for organisms from each of the five kingdoms.

The cells of organisms from each kingdom have similarities in their basic structure. This knowledge assists in the classification of existing and newly discovered organisms. Because cells are the basic building blocks of life, understanding the structure of cells enables us to understand better how organisms function.

Prokaryotes and eukaryotes

Cells are classified into two main groups—prokaryotic cells and eukaryotic cells. **Prokaryotic cells** are the most primitive cellular forms on Earth and are unicellular. They are much simpler in structure than eukaryotic cells and lack the membrane-bound organelles described in Table 1.2 (page 19); for example, they have no nucleus and the DNA is found free in the cytoplasm. Prokaryotes include the diverse range of bacteria.

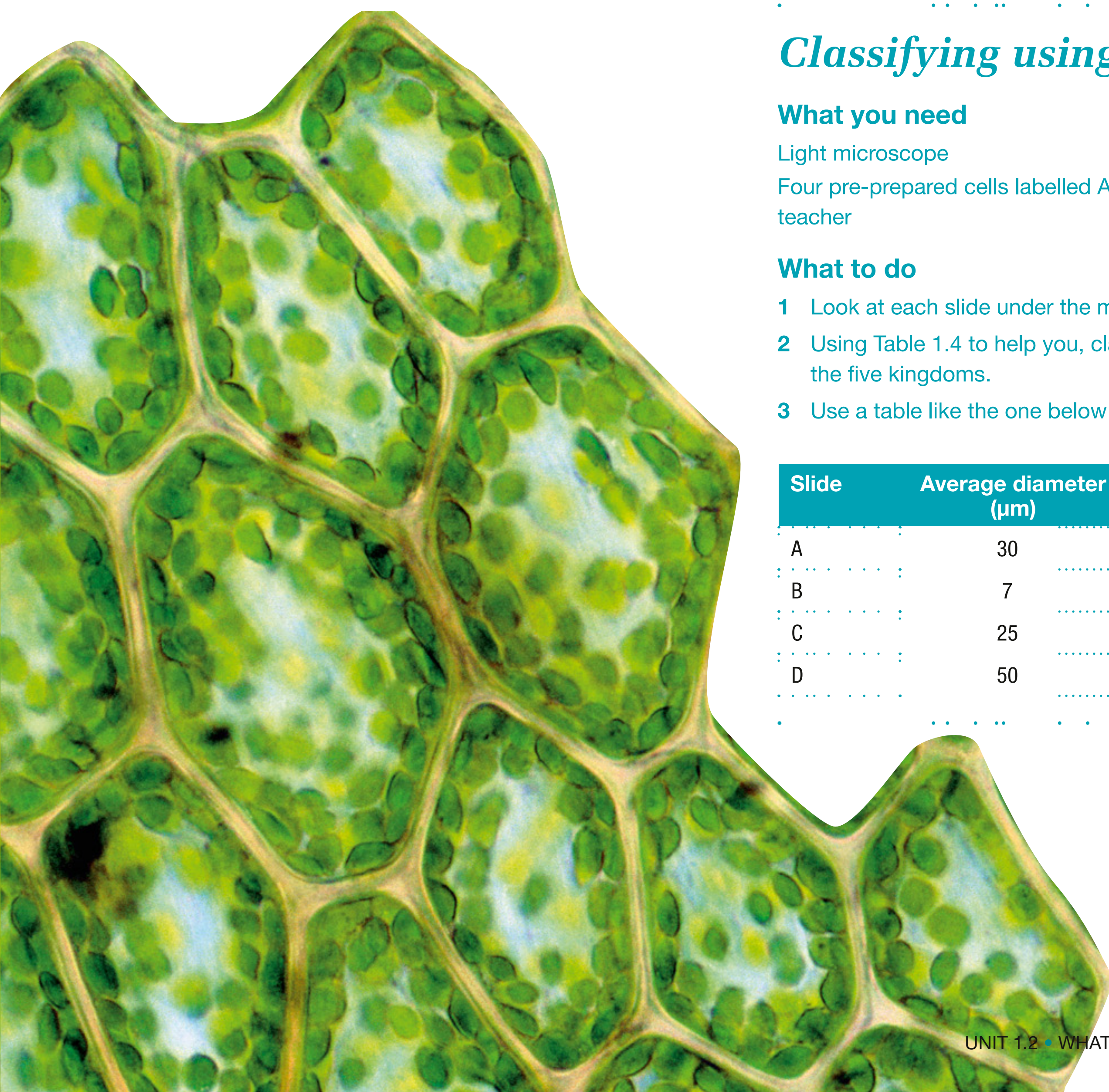
Eukaryotic cells are more complex cells and are found in organisms from each of the other four kingdoms—animals, plants, fungi and protists. Eukaryotic cells contain a nucleus as well as other membrane-bound organelles. Organisms that contain eukaryotic cells are called eukaryotes. Most eukaryotes are multicellular.

Fungal cells

Fungi have often been considered as types of plants, but with the development of the microscope scientists were able to see that fungal cells are not the same as plant cells at all. For example, fungal cells don't have chloroplasts, so they cannot photosynthesise, they don't have large vacuoles filled with liquid and their cell wall is made of chitin instead of cellulose.

→ Table 1.4 Characteristics of eukaryotic and prokaryotic cells.

Characteristic	Kingdom				
	Eukaryotes				Prokaryotes
	Animals	Plants	Fungi	Protista	Monera
Number of cells	Multicellular	Multicellular	Multicellular, some unicellular (e.g. yeasts)	Multicellular or unicellular	Unicellular
Cell wall	Absent	Present (cellulose)	Present (chitin)	Present in some	Present (murein)
Genetic material	Present	Present	Present	Present	Present
Nucleus	Present	Present	Present	Present	Absent
Mitochondria	Present	Present	Present	Present	Absent
Chloroplasts	Absent	Present	Absent	Present in some	Absent
Large vacuoles	Absent	Present	Absent	Present in some	Absent
Ribosomes	Present	Present	Present	Present	Present



PRACTIVITY 1.3

Classifying using cells

What you need

Light microscope

Four pre-prepared cells labelled A–D supplied by your teacher

What to do

1 Look at each slide under the microscope.

2 Using Table 1.4 to help you, classify each slide into one of the five kingdoms.

3 Use a table like the one below to present your results.

Slide	Average diameter (μm)	Kingdom
A	30	
B	7	
C	25	
D	50	

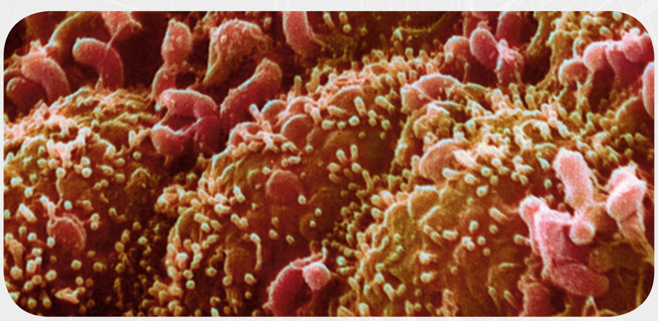
LITERACY LAB

Using similes

Scientists use models to explain complicated concepts or abstract ideas like the particle model of matter. Another useful tool for scientists is the use of similes. Similes are used to compare two things using the words 'like' or 'as'. Have you ever heard someone say that a sprinter moves as quick as lightning? Or that their little sister sticks to them like glue? These are both similes.

Similes in science

Similes are often used in creative writing, but they are also very useful in science. If you don't have the right scientific terminology to explain a concept, it is useful to explain the concept by comparing it to something that you do understand. When learning about cells, similes can be very helpful because you're dealing with structures that are far too small to see. The same applies to learning about matter—matter can be unbelievably tiny, like water molecules, or unbelievably massive, like the solar system. Similes should not be used in formal science reports but are good to use in chapter summaries or homework tasks.



Here are some similes that relate to this chapter:

- Cells are like building blocks.
- The cells in your body are like bricks in a house.
- The nucleus is like a control centre.
- The mitochondrion is like a power station.
- Cytoplasm is like a jelly that holds a cell's organelles in place.
- Your body is like a zoo because it contains so many microbes.

Simile challenge

Working in a small group, come up with a list of similes for animal and plant cell organelles (but don't copy the above ideas!). Present your similes to the class.

1 Were your similes the same or different from those of the other groups?

2 Why do you think using similes is useful?

3 Why shouldn't similes be used in formal reports?

4 In what other subjects could you use similes?

5 Did you find it difficult to come up with similes? Come up with a strategy for practising simile use.

What do you know about using cells to classify?

1 Give an example of a unicellular organism and a multicellular organism.

2 Suggest why a unicellular organism cannot grow as large as a multicellular organism.

3 Describe the two main differences between eukaryotic and prokaryotic organisms.

4 Where is DNA found in a prokaryotic cell?

5 Suggest why ribosomes are found in cells from each of the five kingdoms.

6 Table 1.4 shows that plants cells contain chloroplasts. Although a typical plant cell contains chloroplasts, chloroplasts are not found in all plant cells.

a Suggest why some plant cells may lack chloroplasts.

b In which part of a plant would you expect cells to contain many chloroplasts?

7 Examine Table 1.4 on page 27; then suggest which kingdom is often referred to as 'the rest'.

<<BIG IDEAS>> Structure and function

1.2 What do we know about cells?

Remember and understand

1 Explain two key ideas presented in the cell theory.

2 Explain why programmed cell death is necessary.

3 What is the benefit of using a stain when viewing some specimens?

4 Explain at least one similarity and one difference between a mitochondrion and a chloroplast.

Apply

5 A cell membrane is *partially permeable*. This means that only certain substances are able to cross the membrane. List some substances that would need to get into the cell and some that would need to get out.

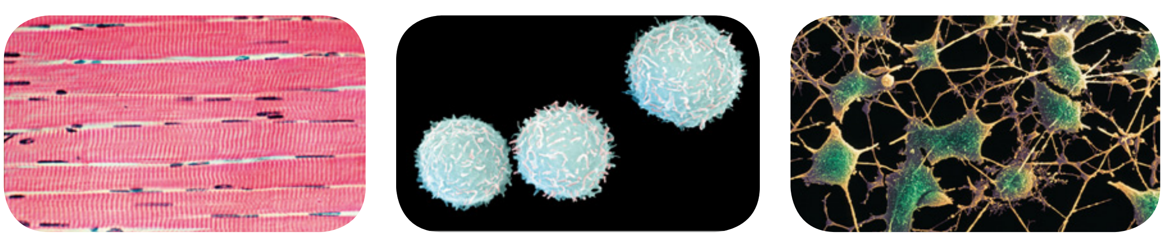
Analyse and evaluate

6 Figure 1.47 shows human nerve cells, white blood cells and a muscle cell. Identify each cell and explain how the shape and features of each cell enable it to perform a certain function within the human body.

7 Mutagens are substances that can potentially change the genetic material within cells and thus result in cancer. Find out about three substances that have been described as mutagens. Where are these substances found? How do scientists think they cause cancer? How can their effects be minimised?

8 Two students prepare slides from different sections of a spring onion under a light microscope in their school laboratory. James views a section of the green leafy part and observes many chloroplasts within each cell, but has difficulty identifying a nucleus in each cell. Emily views a section of the white stem part of the plant. She comments that a nucleus is clearly visible in most of the cells, but does not identify any chloroplasts.

- a Suggest why James identified many chloroplasts within each cell when they appeared to be absent from the cells viewed by Emily.
- b Emily commented that she could identify a nucleus in most cells. If a nucleus is not visible in a particular cell, does this mean that the cell does not contain a nucleus?



→ Fig 1.47

<<CONNECTING IDEAS>> Structure and function

9 Research the role of stomata and guard cells in plants. Find out how the stomata open and close in response to changing environmental conditions. Under what type of conditions are the stomata likely to open? What are triggers for the stomata to close? How does the shape of the guard cells assist the opening and closing of the hole?

1.3

How do cells work together?

Cells are often called the 'building blocks of life'. Think of the way bricks and other materials are used to build a house. Cells build living things in a similar way. However, there are often many more cells in living things than bricks in a house: an adult human body is made up of approximately ten trillion (10 000 000 000 000) cells. Elephants have even more.

Cells that make up unicellular organisms need to perform lots of functions, so they can be quite complex. Cells of multicellular organisms have different functions, so they come in different sizes and shapes to suit their functions. For example, your nerve cells are different from the cells that form your skin or muscles.

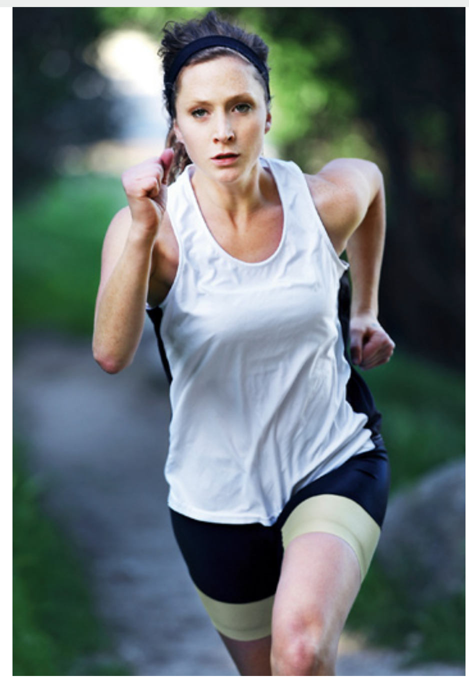
<<DISCOVERING IDEAS>>

Working together

Working in small groups, brainstorm the different jobs that a living organism would undertake to stay alive and be successful.

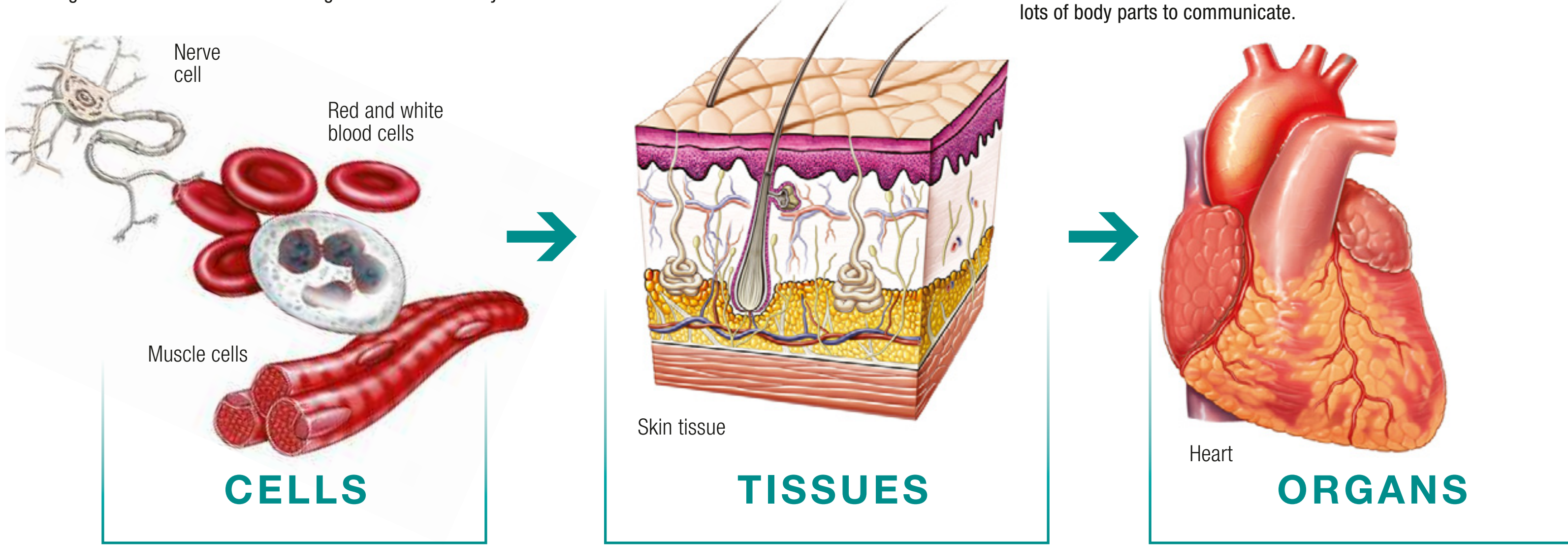
What communications need to happen in your body? Have you ever had a 'dead leg'? This was an example of a part of your body not being able to communicate with the rest of the body.

1 With a partner, try to list as many 'communication partnerships' of body parts as you can. You might like to start with your toes and slowly work your way up your body, identifying all possible options as you go.
2 For each 'communication partnership', suggest whether the communication is fast, slow, essential or just a bit helpful.



→ Fig 1.48 Any form of exercise or movement requires lots of body parts to communicate.

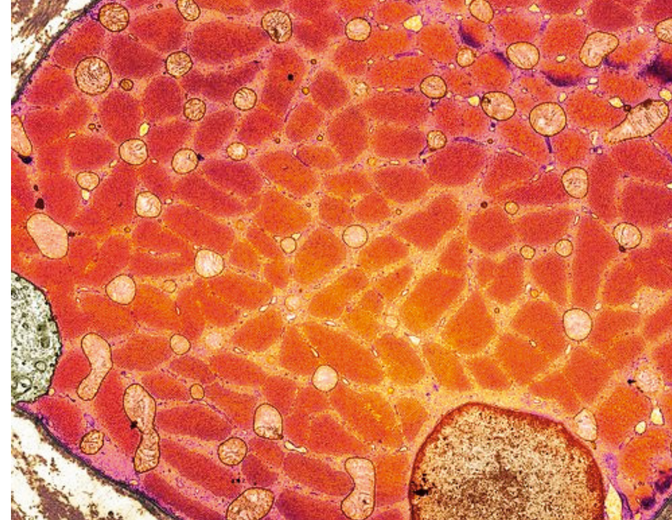
→ Fig 1.49 The different levels of organisation in the body.

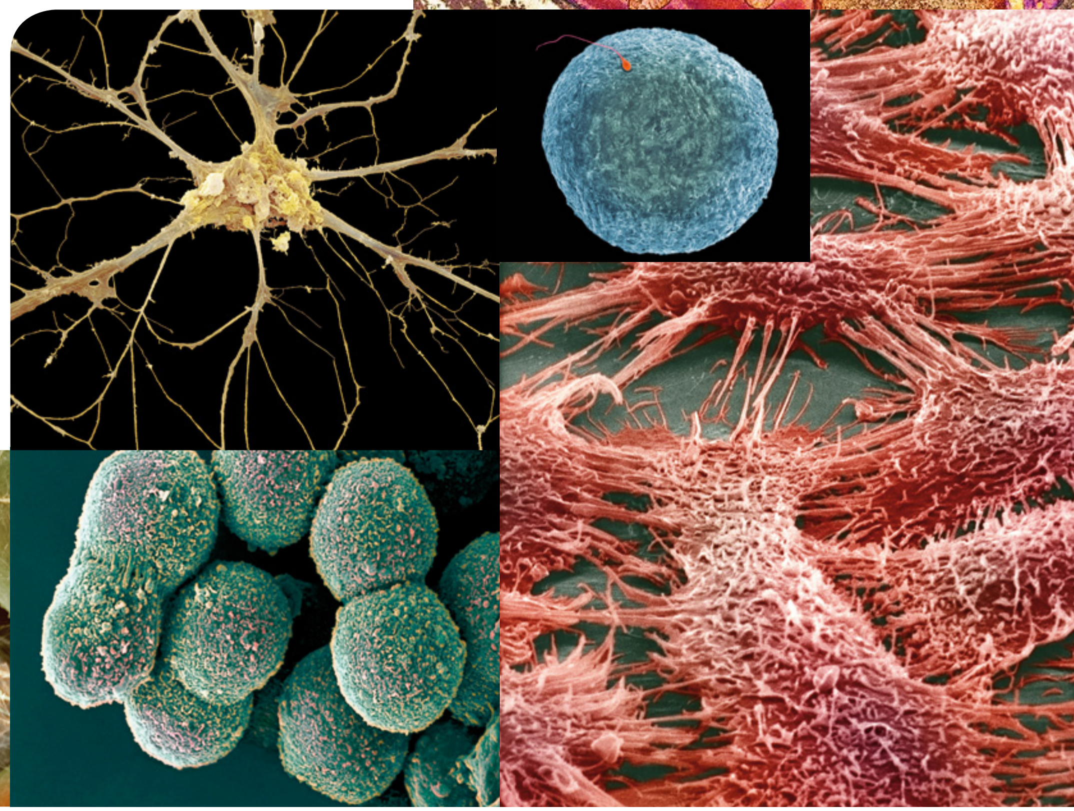


Cells to systems

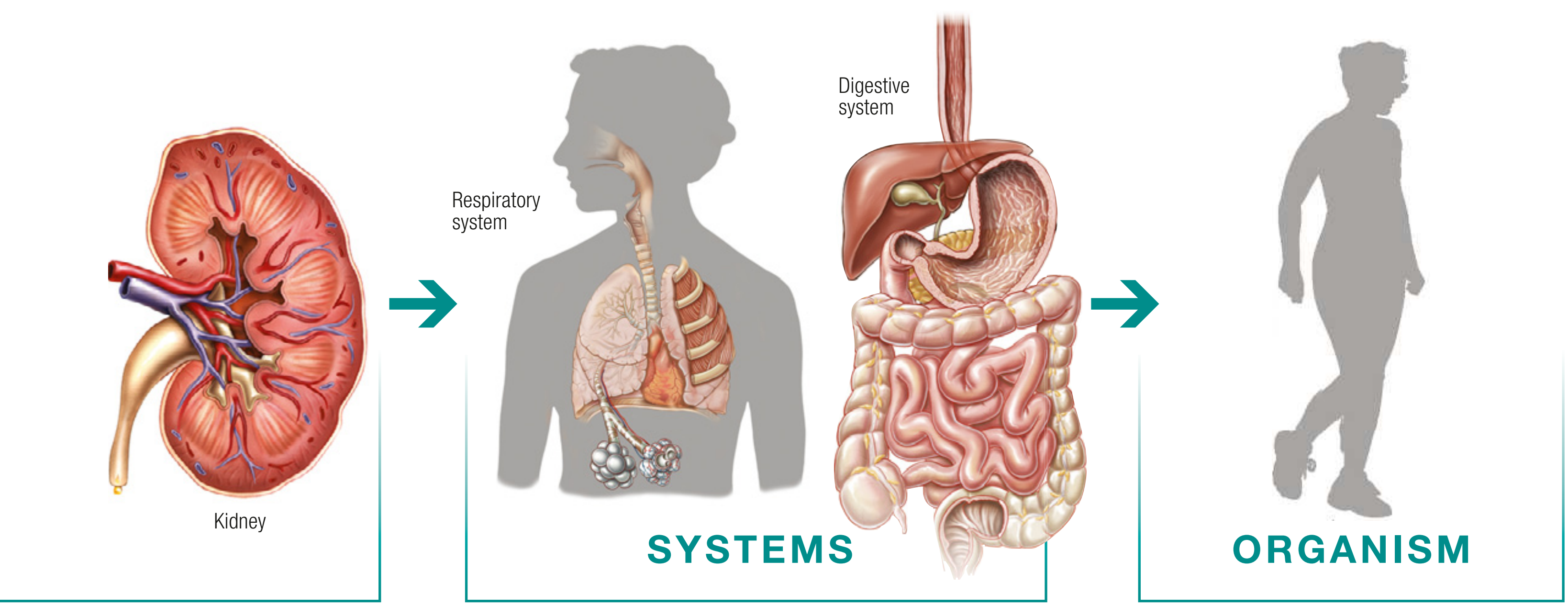
Because of the work scientists have undertaken using microscopes, we now know that the human body is home to a mixture of body systems all working separately and together to keep us alive. Similar to a business, our cells are like workers with different jobs: they work in teams to achieve different goals and keep the business successful.

Like all living things, we are made of different types of cells. Groups of cells that do a similar task are called **tissues**. Groups of tissues that work together are called **organs**. The liver, heart, eyes, brain and intestines are all examples of organs. When groups of different organs work together, they are called a **body system**. Our mouth, oesophagus, stomach and intestines make up the digestive system. All the systems then connect to ensure the survival of the whole organism (us!).





➔ Fig 1.50 Cells and tissues.



How many systems?

The answer to this question is not as straightforward as you may think! There are many different body systems. All your body systems work together and sometimes organs are involved in more than one system. Some systems are so complex that we describe systems within systems!

What do you know about cells to systems?

1. What is the difference between cells, tissues and organs?
2. Name three:
   - **a** types of cells
   - **b** types of tissues
   - **c** organs
   - **d** systems
3. Name at least two organs that belong to the following body systems:
   - **a** digestive system
   - **b** excretory system
   - **c** circulatory system
4. Which system is responsible for:
   - **a** transporting substances around the body?
   - **b** processing wastes?
   - **c** protecting soft inner organs?
   - **d** removing wastes?

Skeletal system
All bones, including spine, skull, pelvis and ribs

Gives body structure and supports and protects other organs; provides attachment for muscles

Digestive system
Mouth, stomach, small intestine, large intestine, rectum, anus

Breaks down food into substances small enough to be absorbed into the bloodstream; separates some waste

Respiratory system
Lungs, windpipe, diaphragm

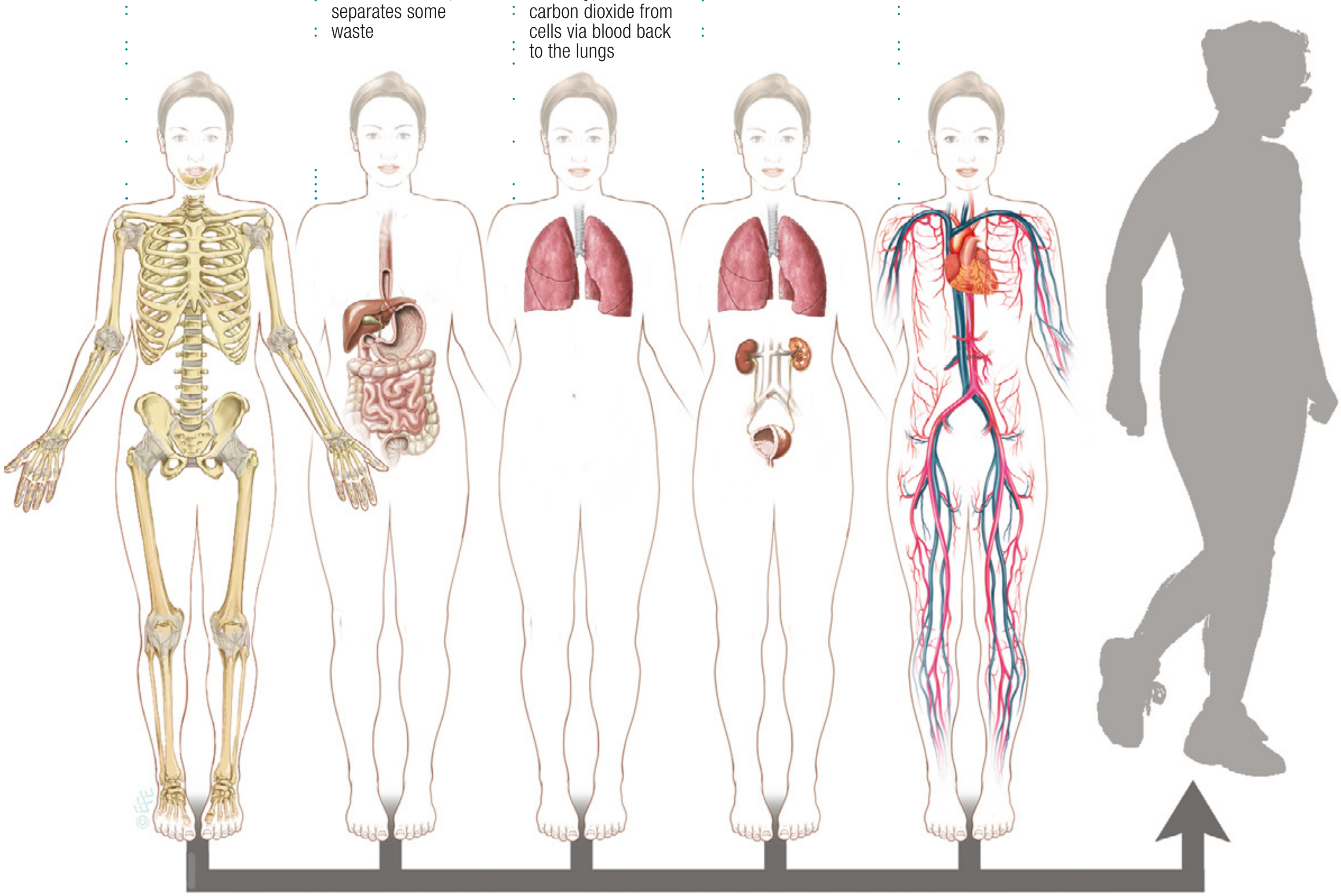
Filters oxygen from the air and transfers it to the blood so that it is taken to all other parts of the body; removes carbon dioxide from cells via blood back to the lungs

Excretory system
Kidneys, liver, bladder, urethra, skin, lungs

Processes and filters out wastes and controls the amount and content of body fluids

Circulatory system
Heart, veins, arteries

Carries oxygen and nutrients to cells and waste materials away from cells via the blood



➔ Fig 1.51 Our body systems work together.

Foreign cells in our systems

Unicellular organisms, such as bacteria, are living in and around us all the time. The average adult human has 1 kilogram of non-human life inside their large intestine alone. This kilogram is made up of thousands of different types of microbes. Bacteria and other microbes are essential for keeping our body healthy and working correctly. Without the microbes in our gut we would not be able to digest food properly, get rid of wastes or make essential vitamins. This is just one example of how microbes are essential for our survival. Other microbes, such as those that cause food poisoning, can be deadly.

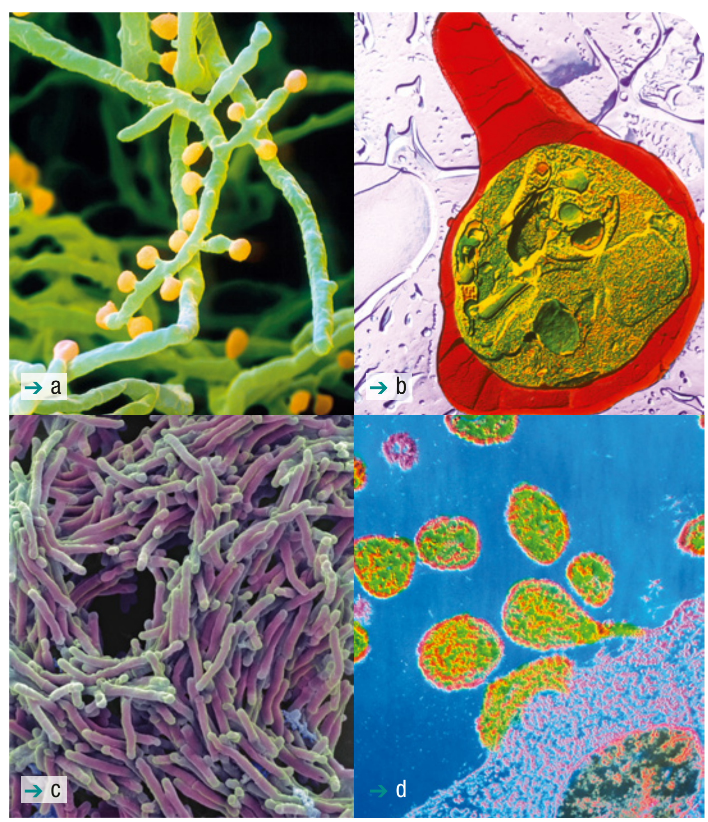
The microbes that live happily in our bodies are referred to as **natural flora** and it's the balance between natural flora and the microbes in our environment that we need to keep an eye on. The right amount of natural flora will protect us from foreign invaders, whereas too much of the natural flora can actually make us ill.

→ Fig 1.52 (a) *Staphylococcus epidermis*, (b) *Staphylococcus aureus* in the hair, (c) *Haemophilus influenza* in the nose, (d) *Chlamydia trachamates* in the eye, (e) *Esherichia coli* in the intestines.

Microbes causing disease

We have all been sick at some stage in our lives and much sicker at some times than others. Some forms of sickness are caused by pathogens. A **pathogen** is a micro-organism that can potentially cause a disease. With **infectious diseases**, the pathogen may be passed from one organism to another. Such diseases are said to be contagious. The host is an organism, such as a human, animal or plant, on which another organism lives. You will be investigating pathogens in more detail in Year 9. The **symptoms** of a disease are the changes that occur to an individual as a consequence of the disease.

Harmful microbes may be bacteria, fungi, protists, viruses or prions. All these microbes can invade the body and cause disease. You will probably be familiar with some diseases caused by harmful microbes. Fungi can cause infections such as tinea, which is also known as athlete's foot, and ear infections. Protists can cause malaria and dysentery. Bacteria cause diseases such as tuberculosis (also known as TB), pneumonia, Legionnaires' disease and cholera. Viruses can cause diseases like the common cold and flu, measles and herpes.



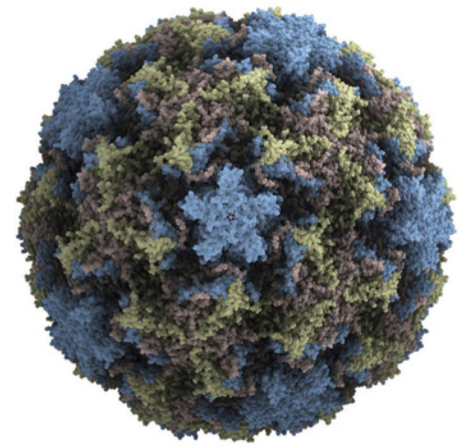
→ Fig 1.53 (a) *Trichophyton mentagrophtes*, cause of ringworm and tinea; (b) a red blood cell infected with malarial parasites; (c) tuberculosis bacteria; (d) Rubella virus.

ZOOMING IN

Viruses

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

Viruses are responsible for most of the common colds that we experience and cannot be controlled by antibiotics because they're hiding inside our cells. This also makes it much harder for our own immune cells to find and fight them, so our best defence is rest and to eat a healthy diet to let our bodies concentrate on getting rid of the viruses by themselves.



→ Fig 1.54 Human rhinovirus.

PRACTIVITY 1.4

Microbes all around

In this activity you will investigate the type of microbes found in the local environment. Most human pathogenic bacteria and fungi (those that are potentially harmful to humans) grow optimally at 37°C. For this reason, samples should be sealed with paraffin wax or tape and incubated at a maximum of 27°C. Do not reopen samples at any time and destroy them immediately after analysis.

What you need

Three Petri dishes (containing nutrient agar)

Two sterilised swabs

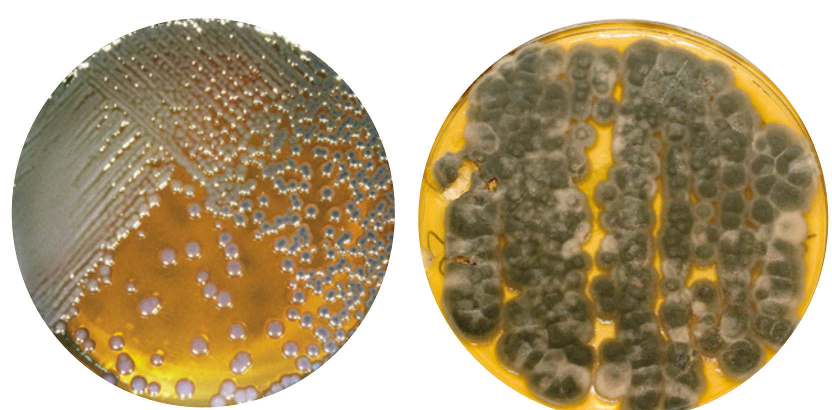
Paraffin wax strips or masking tape

Two incubators (set to 20°C and 27°C)

What to do

1. Two agar plates are to be used for growing microbes and the third is the control plate. The control plate should not be opened at any stage of the activity, but must be incubated alongside the sample plates.

2. Decide on a site around the school to be tested for microbes.
3. Keep the swabs sterile (germ free) until you reach the site.
4. Rub the swab over the site and then gently rub it across the surface of the agar in both directions. Take care not to damage the surface of the agar.
5. Quickly place the lid on the plate, seal it with a wax strip or tape and then incubate it, along with the control plate, at 20°C for 4–7 days.
6. Repeat for the second plate, but incubate this plate at 27°C for the same period of time.
7. Observe any bacterial and fungal growth. Some charts showing common types of bacteria and fungi may assist your identification.
8. At the end of the activity, dispose of the agar plates appropriately.



→ a → b

→ Fig 1.55 (a) Bacterial colonies growing on an agar plate. (b) Fungus tends to have a dusty or fuzzy appearance.

What do you know about foreign cells in our systems?

1 What type of micro-organism does our digestive system rely on? What does it rely on it for?
2 What is natural flora?
3 Can natural flora ever be harmful to our bodies?
4 What is a *pathogen*? What are the five main groups of pathogens?
5 Why is a virus not considered to be living?
6 How does a virus avoid being killed by our immune system?

Questions to consider

1 Describe the growth on your sample plates after the incubation period. A labelled diagram may assist your description. Did you observe the growth of both bacteria and fungi? What were some of the differences between them?
2 If your sample plate showed evidence of bacterial growth, do you think that there was more than one type of bacteria present? Justify your response.
3 Suggest why the agar plates were incubated at 22°C and 37°C for a period of 4–7 days.
4 Describe how the growth on the two sample plates differed. How do you think the temperature influenced this growth?
5 Suggest why there may be some differences between the growth on your plates and those of other students.
6 Explain why it is important that both the swab and plate are sterile and only exposed to the environment for a short period while collecting the sample.
7 If the control plate was sterilised appropriately prior to the beginning of this activity and then incubated alongside the sample plate, it should have showed no bacterial or fungal growth. Explain the purpose of the control plate.
8 What do your results suggest about microbes in your local environment?

LITERACY LAB

Flushing out the truth

Karl Kruszelnicki

Sometimes, if things are a bit rushed at work, we might grab a quick sandwich at our office desk. But you'd never be in such a hurry as to even dream of eating off the toilet seat because we all 'know' that toilets are really 'dirty' and loaded with germs. But, on average, per square centimetre your desk has fifty times more bacteria than your toilet seat!

This was discovered by Dr Charles Gerba, a microbiologist from the University of Arizona. He's Dr Germs …

Dr Gerba has also studied germ counts in the house and, by doing so, discovered the right way to flush the toilet: you should flush with the lid down.

If you flush with the lid up, a polluted plume of bacteria and water vapour erupts out of the flushing toilet bowl. The polluted water particles float for a few hours around your bathroom before they all land. Some of them will land on your toothbrush.

Fig 1.56 A bacterial plume rises from the toilet bowl when you flush.

Dr Gerba also found that, in the home, the kitchen sponge had the highest germ count, followed by the kitchen sink. The lowest bacteria count, out of fifteen household locations, was the toilet seat. He said (perhaps a little jokingly), 'If an alien came from space and studied the bacterial counts, he probably would conclude he should wash his hands in your toilet'. Dr Gerba went on to say what the alien might do in your sink.

So, if you flush with the lid up, you are probably brushing your teeth with toilet water. I guess that's one story to tell the males in your household so that they put the lid down, because if they put the lid down they have to put the seat down as well.

1 What conditions are needed for bacteria to multiply so quickly? Why would the kitchen sponge and the desktop provide these conditions?
2 What areas of your house would you consider the most germy? Why? Design an experiment to test your theory.

<<BIG IDEAS>> Structure and function

1.3 How do cells work together?

Remember and understand

1 What is a group of similar cells performing a similar function called?

2 Identify an organ that is involved in more than one system. Which systems does it play a part in?

3 What is the main function of the following systems:

- a digestive
- b circulatory
- c respiratory
- d muscular

4 What is the name given to a microorganism that causes disease?

5 Why is it important for the cells in multicellular organisms to work together?

6 How do the respiratory and circulatory systems rely on each other?

7 How do the muscular and skeletal systems rely on each other?

Apply

8 How does the digestive system ‘feed’ all the other systems?

9 What is the best thing to do if you contract an infectious disease? Explain.

Analyse and evaluate

10 If you were sick with a cold or flu, a doctor may prescribe antibiotics. But antibiotics are quite useless against viruses, the pathogens responsible for colds and flu. So why would a doctor prescribe antibiotics?

11 Why are unicellular organisms more complex in the structures they contain, whereas multicellular organisms contain relatively simple cells?

12 Mad cow disease, a disease caused by prions, spread from cattle to humans in the United Kingdom. Why do you think it took so long for scientists to work out what was causing the disease? How large are prions compared with bacteria and other pathogens? Prions affect healthy proteins by simply coming in contact with them. This turns ‘good’ protein into prion proteins. What does this tell you about the similarities that exist between cattle and human proteins?

Critical and creative thinking

13 Create a table that identifies the different groups of pathogens and common diseases they cause. In your table, provide information in separate rows or columns that compares and contrasts the features of each pathogen (e.g. how it is transmitted, the symptoms it causes etc.).

14 Write a very short creative story about a virus. Your story needs to be from the point of view of a cell. The first line of your story is: ‘Once upon a time, a virus arrived for an uninvited visit.’

<<CONNECTING IDEAS>> Structure and function

15 The connections between cells, tissues, organs, systems and organisms can be linked in a flow diagram. How are they connected? For each arrow in your flow diagram, write a short statement that connects the parts. Make reference to the structure and/or function of the parts.

>>ZOOMING OUT<<

Research

Linking big ideas

In this chapter three big questions were asked: How do we know about cells? What do we know about cells? How do cells work together? Think of a creative way to represent these questions and make links between them, using as many of the key words in the chapter as you can. You might use a concept map or mind map with each of the questions as major bubbles. You could choose to use diagrams only or perhaps draw a picture that shows all three aspects of the particles of life. The method of presentation that you select must enable you to share your ideas with others. Try to use similes to help you convey your ideas.

Stem cells

Stem cells are cells in multicellular organisms that haven't become specialised yet—they're like blank canvases. Find out what scientists have learned about stem cells, where they find them and what they hope to be able to do with them.

Organ transplants

Organ transplants are necessary when organs are diseased or damaged and fail to function effectively. Human organs are the best option for us because there is a greater chance of them 'communicating' with the rest of the body properly, but the availability of organs usually relies on someone dying. Some organs, like kidneys, can be donated leaving the donor with a single kidney that will filter their wastes. Find out about the options for organ transplants in Australia. What other animals are used as donors of organs and tissue? Are prosthetic (fake) organs possible? Which body parts can be replaced?

Discovery of penicillin

Research the story of the discovery of penicillin. Write the story in the form of a newspaper article.

Reflect

Me

1 What new science laboratory skills have you learned in this chapter?
2 What was the most surprising thing you found out about cells?
3 What were the most difficult aspects of this topic?

My world

4 Why is hot, soapy water usually just as effective as harsh cleaning chemicals for getting rid of microbes?
5 Why is it important not to take antibiotics unnecessarily?
6 Why is it best for you and others that you stay home and rest when you're unwell?

My future

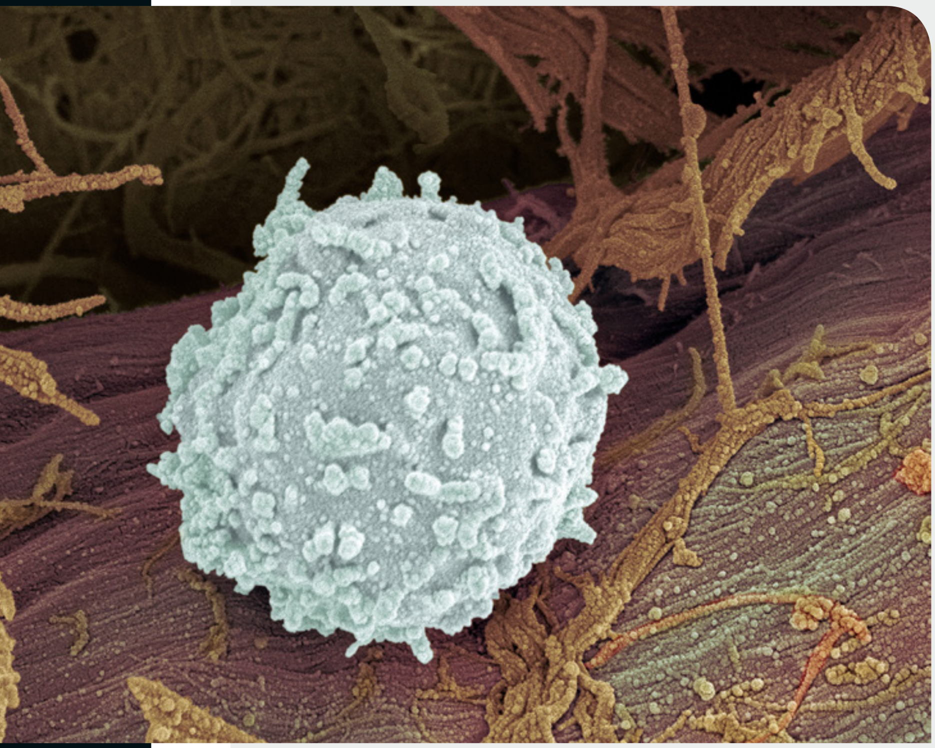
7 What sort of infectious diseases do you predict will present the greatest challenges to humans across this century?

Review

Key words

amino acid
apoptosis
body system
cancer
carcinogen
cell
cell membrane
cell theory
chlorophyll
chloroplast
chromosome
cytoplasm
deoxyribonucleic acid (DNA)
eukaryotic cell
eyepiece
infectious disease
micrometre
microscope
mitochondrion
mitosis
mutagen
natural flora
nucleus
objective lens
organ
organelle
pathogen
photosynthesis
prokaryotic cell
protein
respiration
ribosome
stain
surface area to volume ratio
symptom
tissue
tumour
wet mount

HIV/AIDS pandemic

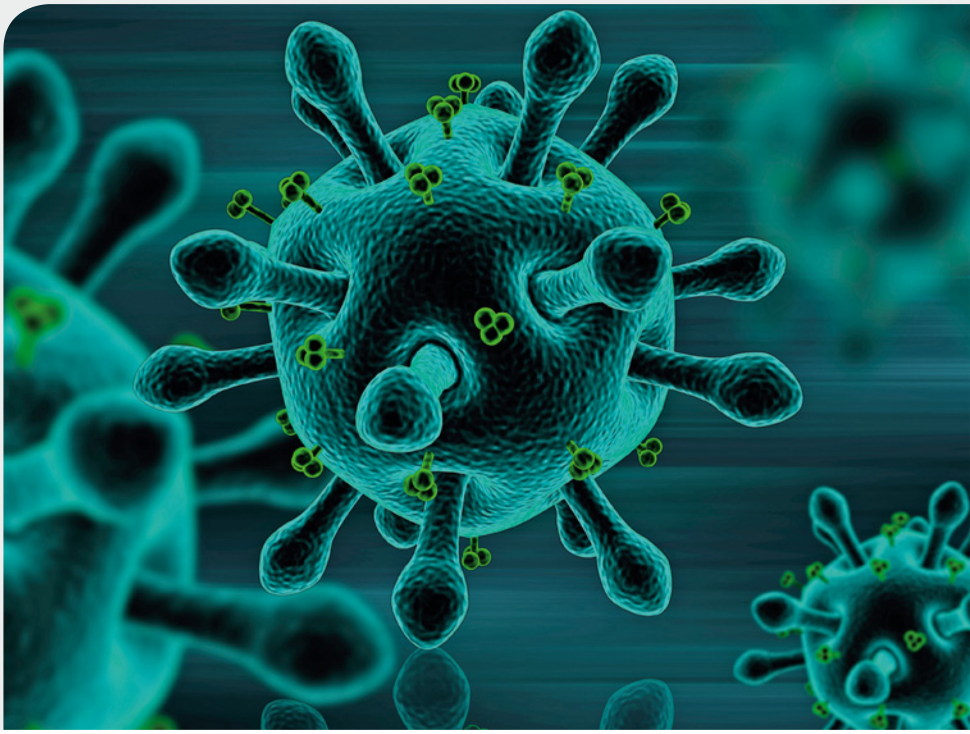


➔ Fig 1.57 A white blood cell.

In 1981, public health officials in the United States documented the presence of a new disease. This disease became known as AIDS—acquired immunodeficiency syndrome. However, it was not until 1985 that the cause of AIDS was discovered—a tiny virus that was named HIV—human immunodeficiency virus. HIV infection is described as a pandemic, which means that it is a disease that occurs in people throughout the world. This pandemic is still on the increase. In 2007, 33.2 million people worldwide were living with HIV and 1.1 million people died of AIDS. Since the beginning of the pandemic, more than 60 million people have been infected with HIV and more than 20 million of those have died.

HIV is called a retrovirus. This is because it makes more copies of itself, or replicates, backwards compared with living organisms—that is, it goes from RNA to DNA instead of the usual DNA to RNA. RNA is very similar to DNA in its function.

➔ Fig 1.58 The HIV virus.



The main host cell for HIV is a particular type of white blood cell known as a CD4+ T cell. These T cells are part of our immune system and help us fight infection. Infection with HIV results in gradual destruction of the number of CD4+ T cells in the body. This causes a deficiency in an infected person's immune system because they are no longer able to fight other infections.

Once inside the host cell, the RNA of HIV is able to make a copy of itself as DNA and insert itself into the host cell's DNA. This means that when the host cell divides, it is making new copies of its own DNA and the HIV's DNA at the same time. The host cell is tricked into making more HIV viruses.

Initial infection with HIV results in large amounts of virus in the blood because HIV replication occurs at a rapid rate. In fact, 108–109 new virus particles are made each day. People who are infected with HIV can pass it on to others within a few days of being infected themselves and are able to pass it on for the rest of their lives.

Screening tests are available to determine whether someone is infected, but these tests are not effective until 2 months after infection.

HIV can only be passed from person to person through contact with infected body fluids, such as blood, semen, vaginal secretions and breast milk. HIV is not spread through hugging, kissing, shaking hands, sharing eating utensils, toilet seats or attending school or work with someone who is infected with HIV. Nor is it transmitted through tears, saliva, urine, sputum, faeces or sweat.

→ Fig 1.59 Lesions of Kaposi's sarcoma can appear anywhere on the skin or on the internal organs of people with AIDS. This lesion has been outlined ready for removal with a ring of healthy tissue.

Initial infection with HIV results in a flu-like syndrome with fevers, swollen glands, sore throat, headache, lethargy, nausea, muscle and joint pain, diarrhoea and/or a rash.

AIDS is actually an advanced stage of chronic HIV infection. AIDS is diagnosed, on average, approximately 11 years after the initial infection with HIV. A diagnosis of AIDS is made when the immune system is so severely reduced that lots of infections develop. These infections would not normally develop in a person with a healthy immune system and are known as *opportunistic infections* because they infect when there is a 'perfect opportunity'. Common opportunistic infections include infections with fungi, such as *Candida albicans*, other viruses, such as hepatitis and herpes, protists and bacteria, such as those that cause tuberculosis. Opportunistic cancers can also develop, such as Kaposi's sarcoma and various lymphomas. Weight loss of 10% or more can occur, as can AIDS dementia complex.

→ Fig 1.60 Azidothymidine (AZT), sold as Retrovir or Retrovis, is used to delay the onset of AIDS.

Antiretroviral drugs are available for the treatment of AIDS. However, most doctors prefer not to prescribe these drugs until patients have symptoms of AIDS or their blood tests indicate that their immune system has almost collapsed.

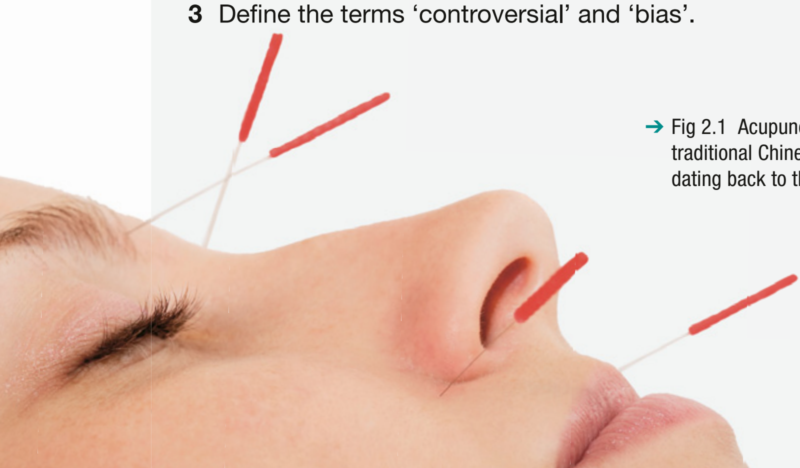
1 How is a retrovirus different from other viruses?
2 The letter 'I' in HIV stands for immunodeficiency. Why is this?
3 Viruses are often called parasites. How is the HIV virus a parasite?
4 Find out more about HIV and AIDS and present your findings to the class in an appropriate and interesting format. The AIDS Trust of Australia and World AIDS Day websites may provide good starting points. Alternatively, you might like to research another virus or pathogen of equal significance, such as hepatitis or syphilis.

2 Functioning organisms

2.1 How have we learnt about the human body?

The scientific study of the human body, called human anatomy, has been around for thousands of years and probably came from the desire to answer the questions 'what am I?' and 'how do I work?'. Knowledge was passed on from person to person and changed continually. Today, with the arrival of modern technology, this knowledge is changing faster than ever. For example, acupuncture, which originated in ancient China and can be traced back as far as the Stone Age, is still commonly practised today. Although the World Health Organization states that acupuncture can help with brain conditions and pain, the results of scientific investigations into acupuncture remain controversial, with some studies criticised for bias or the fact that they were not 'fair tests'.

1 Work with a partner to brainstorm a medical procedure that you think has been passed down through the ages and one that is a new procedure from the 20th or 21st centuries. (Hint: Think about modern technologies.)
2 What are you curious to learn about the human body? Write down at least three questions that you would like to answer.
3 Define the terms 'controversial' and 'bias'.



→ Fig 2.1 Acupuncture is a traditional Chinese medicine dating back to the Stone Age.

→ Fig 2.2 David Blaine attempts to hold his breath longer than any other human.

Our understanding of the human body has evolved from ancient times and continues to evolve today. In this chapter we look at this long history of curiosity and discovery, how it has led to our current understanding of some of the major body systems and whose job it is to look after the human body now. As you study this chapter you will investigate how organs and systems are set up (their structure) and become curious about what they actually do (their function).

2.2 What are some of my major systems?

Escape artist David Blaine attempted to beat the world record for breath-holding underwater in 2006 but failed to hold his breath for more than the existing record time of 8 minutes, 58 seconds. To even attempt this feat David had to practice ways to slow down his heart rate and, during the attempt, his body began to stop supplying oxygen to his hands and feet. For most of us, this sort of stunt is not only dangerous, but also potentially fatal. Our bodies need a continuous supply of oxygen to every cell in order to stay alive.

1. How many times a minute do you breathe? Get a partner to count for you.
2. Trees and plants take in carbon dioxide and release clean oxygen back into the atmosphere. Based on this, what do you think humans breathe in and then exhale (breathe out)?
3. If you can breathe in approximately half a litre of air when you are resting, do you think you would take in more or less air when you are exercising? Explain how you arrived at your answer.
4. Do you think breathing is related to one body system or many?

2.3 How are new organisms made?

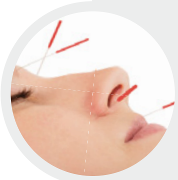
Reproduction is the term that describes the 'making of new organisms' and is something often associated with females. However, in seahorses it's the male that gets pregnant!

Female seahorses lay their eggs directly into a special pouch on the male's stomach. The male covers the eggs with sperm to fertilise them, then takes care of them until they're ready to hatch. Baby seahorses are miniature versions of their parents and are born in groups of up to 2000 at a time.

1. What is unusual about seahorse reproduction?
2. Do you know of any other animals that rely on the male to 'become pregnant'?
3. What is the name of the female cell and the male cell that join to start a new life?

→ Fig 2.3 Male seahorse giving birth.

2.1 How have we learnt about the human body?



World-famous scientist Marie Curie said ‘be less curious about people and more curious about ideas!’ She gave her life to this belief, discovering a dangerous new radioactive element that ended up killing her. Being a scientist is hardly ever about being right—it’s about being curious about ideas, as well as speculating (guessing) and often being wrong. Humans have always been curious about the structure and function of their bodies. Whether it was about ways to live longer or to cure illnesses, investigations of the human body go back as far as human existence. And what a thing to be curious about! We are an amazing mix of cells, chemicals, thoughts and feelings, and not one of us the same. These days there are so many different people who look after and discover even more about the amazingly complex human body.

<<DISCOVERING IDEAS>>

Aboriginal X-ray art

Australia is lucky to be home to the oldest surviving culture in the world, that of the Aboriginal people.

Aboriginal people were nomadic: they moved around season-to-season and depended on the land and what it gave them. They took only what was needed and celebrated their relationship with the land through ceremony and ritual, moving often so they did not deplete resources. One of the best ways to explore this relationship is through Indigenous art, some of which dates back as far as 30 000 years ago.

One example of Indigenous art is the wonderful X-ray art, which depicts animals or human figures with their internal organs and bone structures shown. This artwork demonstrates a sophisticated knowledge of animal and human anatomy and provides evidence that anatomical knowledge existed at least 6000 years ago, when some of these paintings were drawn.

Your task

1. Consider what X-ray art tells you about how much the Aborigines knew about the human body.
2. In the style of the Aboriginal X-ray art shown in Figure 2.4, use your knowledge to create your own X-ray art of a person or animal.

→ Fig 2.4 Aboriginal X-ray art from Kakadu National Park dated to 6000 BCE.

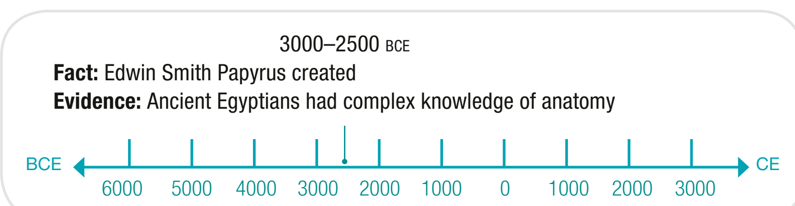
Searching for evidence

When a man named Edwin Smith purchased a piece of ancient papyrus (an early form of paper made from the papyrus plant) with writing on it from a dealer in the city of Luxor in Egypt in 1862, he did not know that he was changing the history of medicine. It wasn't until 1930 that the writing was translated, revealing that the ancient Egyptians had detailed knowledge of anatomy, including the heart and its vessels, the liver, kidneys, spleen, bladder and uterus. That papyrus is one of the earliest pieces of medical writing in existence today: the text has been dated back to 3000–2500 BCE.

One way science historians can trace the development of human knowledge about body systems is to look for evidence in art and ancient writings. Using modern techniques, it is often possible for scientists to date (determine the age of) rocks, papers, paints or other materials. This creates **evidence** (a fact that provides proof) of when the knowledge existed.

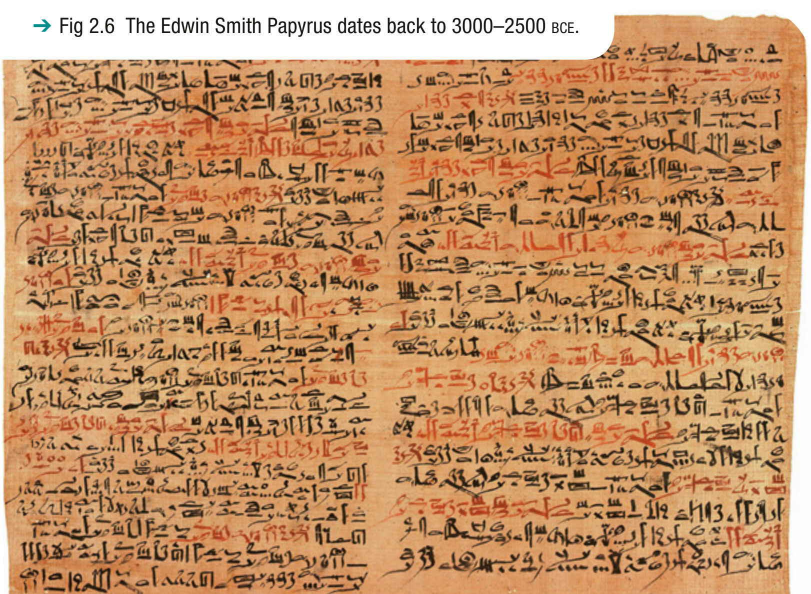
Eastern medicine

Traditional Chinese medicine dates back many thousands of years. Evidence from around 1600 BC (when the ancient Chinese started keeping written records) shows Chinese medicine to be very spiritual and related to how humans interact with their environment. Many observations were made—and not always on what could be seen or observed—involving a combination of science and spirituality. Traditional Chinese medicine encompasses things like acupuncture, herbal medicine made from dried plants and even physical activity, such as yoga and Chinese martial arts.



→ Fig 2.5

→ Fig 2.6 The Edwin Smith Papyrus dates back to 3000–2500 BCE.



What do you know about searching for evidence?

1 What is 'evidence'?
2 How can a piece of art give us an insight into the knowledge and understandings that existed at a certain time or place?
3 Why is it difficult to know *exactly* what the Aborigines and ancient Chinese understood about the human body?
4 Why are the examples of Aboriginal art shown in Figure 2.4 known as 'X-ray art'?
5 Why is it important that knowledge and understandings are communicated to future generations?
6 Use the information provided so far in this chapter to construct a timeline of understanding of the human body. Is this timeline accurate? Is written or artistic evidence the only way people would have communicated their understandings?

Dissections

Dissection—the process of disassembling and studying the internal structures of plants, animals and humans—has been used by scientists throughout history. Although it sounds gory, dissection is an essential learning tool for scientists. Dissecting organs and organisms isn't just 'chopping them up'. It requires careful techniques to make sure that the tissues aren't destroyed so that their structures can be analysed accurately—the **anatomy** of the body. Dissection also relies on care being taken with very sharp instruments, such as scalpels, because they can cut through the person using them without being felt until it's too late.

Egyptian investigations

The very first anatomists in the ancient Egyptian city of Alexandria performed dissections in the 3rd century BC to investigate how the human body worked.

➔ Fig 2.7 The process of mummification required organs to be removed. They were sealed in 'canopic' jars.

The Egyptians were very clean and quite fearful of illness; they believed that illness was caused partly by evil spirits and so doctors were also part *shaman* (spiritualists).

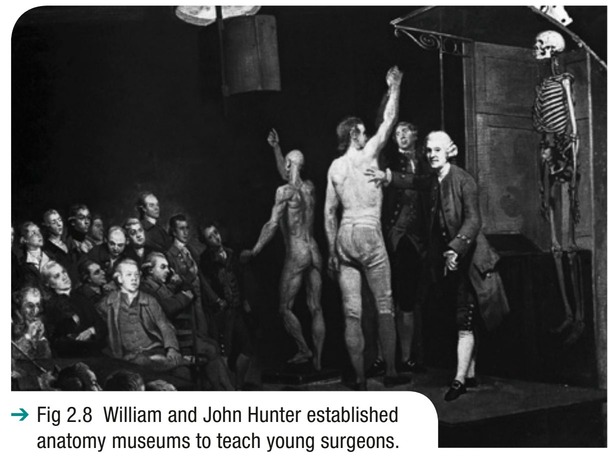
Perhaps because of this fear of illness, the Egyptians made many medical advances and learned much about the human body. Much of this knowledge about human body systems and organs likely came about from observations made during the mummification process. As part of this process, the Egyptians removed key organs from the body because they contained so much liquid that they interfered with mummification. (These organs were subsequently placed in 'canopic' jars to journey separately into the afterlife.)

The body snatchers

In 18th century Britain (1700s), the population had grown so rapidly that there was an urgent need for more doctors and surgeons. In response to this shortage, a number of schools were opened to teach surgical skills—but human bodies were needed to practice on. This was where the 'body snatchers' found a unique money-making opportunity.

Anatomists paid gangs to steal bodies from graveyards. In fact, the money was so good that people were murdered to keep up with the demand for bodies! Body snatchers were known as 'the Resurrectionists'—giving new life to the bodies of the dead.

Although many people thought the whole practice was a grisly business, without the work of 18th century anatomists such as William and John Hunter, who established anatomy museums for teaching young surgeons, our understanding of the human body would not have progressed so quickly. Some of the great discoveries of medicine took place in the 18th century, such as the smallpox vaccine, improvements in childbirth medicine and advances in dental surgery. All these advances were due to a greater understanding of how the human body's systems worked.



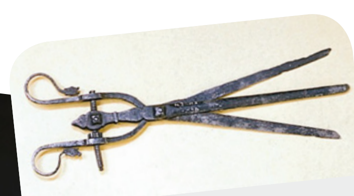
➔ Fig 2.8 William and John Hunter established anatomy museums to teach young surgeons.

Surgical instruments of the past

Doctors such as William and John Hunter didn't always have access to clean (sterile) and sharp cutting instruments, such as scalpels and precision saws—so what did they use? The fact cards below will give you an insight into the surgical instruments of the past. The idea of form (what something looks and feels like) and function (what something does) does not apply only to human body systems. Look at each of these surgical instruments from the past and, before you read the captions, see if you can guess their function based on how they look!

Amputation knife
Used to amputate damaged limbs (arms and legs)

Bullet remover
Used to remove bullets from flesh



Arrow remover
Used to remove arrows from flesh

Skull drill
Used to drill into the skull to perform brain surgery or to release pressure on the brain

Mechanical leech
Rotating blades cut skin; the cylinder creates a vacuum that sucks blood
Used in place of real leeches

Dissections

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

Step 1 Make sure you're wearing appropriate safety gear: gloves, lab coat and safety glasses.

Step 2 Set up your workspace, covering surfaces with newspaper that can be disposed of easily and collecting any dissection tools you may need.

Step 3 Collect your specimen for dissection. Identify all external structures.

Step 4 Pin the specimen to the dissection board to keep it from moving.

Step 5 Use probes to look inside any folds.

Step 6 Use forceps to hold and pull tissue.

Step 7 Use scalpels to cut carefully. Run the scalpel gently over the tissue several times to cut through. Do not dig the scalpel into the specimen or expect to cut through in one movement.

Step 8 Use scissors to cut when you can see what's under the structure you're cutting. Scissors with rounded ends are less likely to cause unnecessary damage than those with pointed ends.

Step 9 Fingers are always the safest way to 'look around' your specimen.

Step 10 When finished, your specimen should be wrapped in newspaper for disposal. Your instruments should be rinsed, cleaned and disinfected, and your hands should be washed thoroughly.

Dissection instruments and workspaces should be cleaned while you are still wearing your safety gear. Your lab coat and gloves should be on before you start your dissection and they shouldn't come off until the dissection is completely finished—this includes disposal and cleaning! The last things you should do are: remove your gloves and throw them in the bin; wash your hands thoroughly; and take off your lab coat and hang it up.

What do you know about dissections?

1 How is dissection different to just cutting up an organ?
2 Why is dissection a useful tool for scientists?
3 Without dissection, do you think our knowledge of human anatomy would be more or less advanced? Explain.
4 How could the structure or form of an organ give some insight into its function?
5 List three important safety rules that you must follow during a dissection.
6 Why might gloves *not* be essential for all dissections?
7 Name three tools that are used as part of a dissection. Include a sketch of each tool.
8 Why is it important to leave lab coats and gloves on until *after* the clean-up?
9 Draw your own 'surgical tool of the past'. Write a description of your tool's form and function and give it a name.

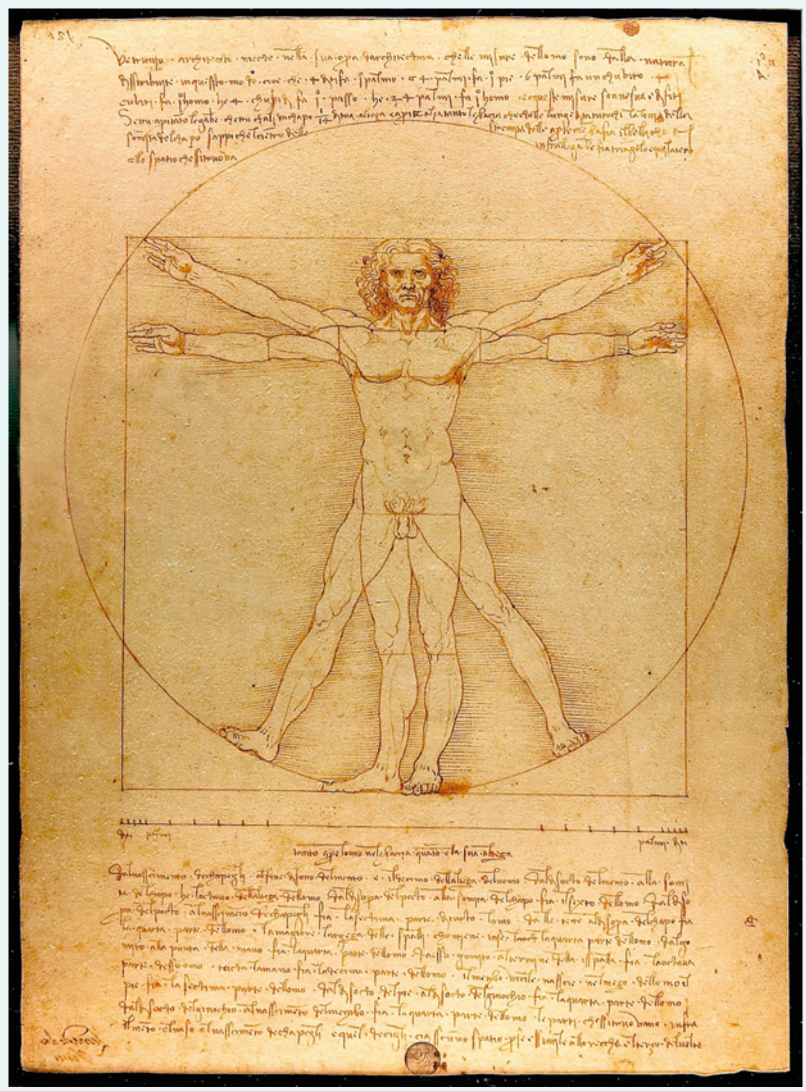
➔ Fig 2.9 Leonardo da Vinci.

<<OVERARCHING IDEAS>>

Working with Leonardo

Form and function

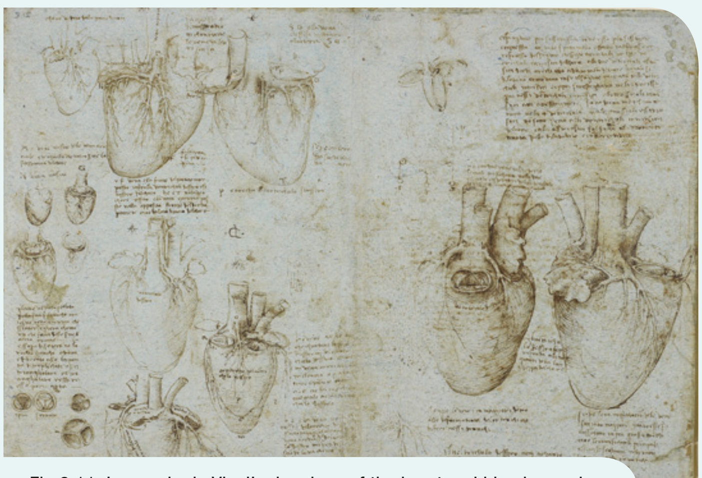
Leonardo da Vinci is famous as a painter, sculptor, architect, musician, engineer and cartographer (map drawer), but he also studied the human body in the late 1400s and early 1500s. He was involved in human and animal dissections and, from these, he drew beautiful and highly accurate drawings. Da Vinci was endlessly curious about the way things worked; he created flying machines and wonderful paintings and left hundreds of papers and notes on the human body.



➔ Fig 2.10 Vitruvian man, drawn by Leonardo da Vinci around 1487.

Many of Leonardo's illustrations of the heart were based on his studies of the organs of pigs and oxen. Leonardo began studying the human body through life drawing and by attending the public dissections that were occasionally held by the medical schools. He started drawing skeletons and then other body systems when he gained access to corpses from a local hospital.

Leonardo also studied the human heart and even constructed a model of the aortic valve, the one-way valve in the main artery of the heart, using glass. Leonardo was on the verge of discovering how blood circulates, but he never finished his work.



➔ Fig 2.11 Leonardo da Vinci's drawings of the heart and blood vessels.

Task

It's not every day that you get to work with someone famous like Leonardo da Vinci. Today you will get to work with Leonardo to complete some of his work on the human circulatory system.

Using the information above regarding Leonardo da Vinci's investigation of the human body, in particular the circulatory system, respond to the tasks below.

Part A: then

Leonardo's aim

To investigate how the heart and its valves worked to pump blood around the body.

Leonardo's method

1. What kind of evidence did da Vinci gather—was it first-hand (in person) or second-hand (taken from a book or other source)?
2. How did he gather this evidence?
3. How did he record this evidence?
4. What kind of model did Leonardo create to illustrate part of this theory?

Leonardo's theory

Leonardo's theory (the commonly held belief at the time) was that blood was made in the liver, cooled in the lungs, pumped by the heart and consumed in the muscles.

Part B: now

Your aim

To update Leonardo's theory based on new evidence regarding how the heart and its valves work to pump blood around the body. (Hint: Fast-forward to the circulatory system on page 56 to help you answer these questions.)

Current knowledge and understanding

1. What is known and understood about the heart today?
2. If you were asked to investigate the form and function of a heart, where would you look for information?

Explanation

3. How do we explain the form and function of the heart now?
4. How do we explain the form and function of the blood now?
5. How do we explain the form and function of the circulatory system now?

Model

6. Find an interactive or video model of the circulatory system or heart online and record the link.
7. Create a Slowmation video to model the flow of blood through the heart and lungs.

Current theory

8. How does the current theory of how the circulatory system works compare with the theory that existed when Leonardo was alive, that blood was made in the liver, cooled in the lungs, pumped by the heart and consumed in the muscles?

Looking after the human body

Do you ever feel like your body is everyone's business? Your doctor is checking your skin for moles, your mum is telling you to go outside and get some exercise, scientists are releasing more information on the human body every day and the Government is warning you about flu pandemics and the obesity crisis. People are telling you what to eat, how to sit, not to smoke, to wash your hands and to watch your weight (but not too closely)! It's a lot to take in and the modern person is bombarded with information about their body. Most of this information is based on scientific knowledge about your body and comes from terrific people looking out for you, and looking after your body.

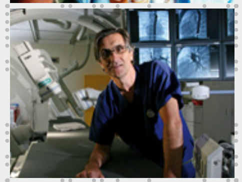
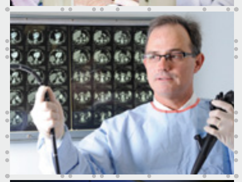
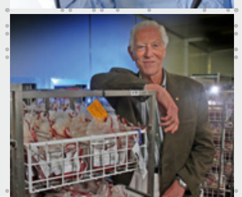
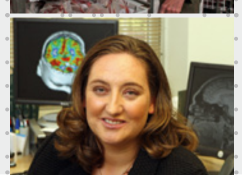
Types of doctors

Some people make the study of the human body their career and many of these people fall into the ancient profession of medicine. There are many different types of medical doctors ranging from GPs (general practitioners) to specialists who may focus on one particular body system or even one particular organ. Becoming a doctor is a very long process—but we trust doctors with our lives, so it's important they are trained to deal with any situation that arises with the human body.

Here is a small selection of doctors and some big questions they may spend their career exploring—have you ever heard of them?

What -ologist?

Table 2.1

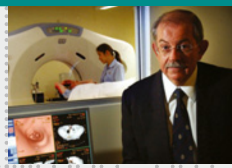
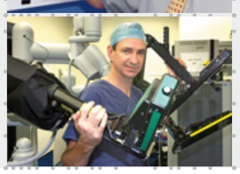
Doctor		Focus	Big question
Anaesthetist Dr Putli Bhabha, Queensland.		Anaesthetics	How can I keep a person from feeling pain during an operation?
Cardiologist Dr Luigi D'Orsogna, Consultant Paediatric Cardiologist at Princess Margaret Hospital		Heart	What is the link between obesity and heart disease?
Dermatologist Dr Stephen Shumack with a patient at his surgery in Sydney		Skin	Is this mole a melanoma?
Gastroenterologist Dr Cameron Bell from the Royal North Shore Hospital is encouraging people to get their bowel checked.		Digestive system	Why can't a person with Coeliac disease eat gluten?
Haematologist (heem-a-tol-ogist) Retired haematologist Dr Peter Schiff has the distinction of being the most prolific blood donor in Victoria		Blood	Can anyone donate blood?
Neurologist Dr Cassandra Szoeke who works for the CSIRO		Nervous system	What causes multiple sclerosis?

ZOOMING IN

Rewarding doctors

Tasmanian-born biological researcher Dr Elizabeth Blackburn won the Nobel Prize for Physiology or Medicine in 2009. Dr Blackburn co-discovered a special chemical that could prolong cell life and is the first Australian woman to win a Nobel Prize. Her work has opened a new field of science and could lead to medical breakthroughs such as interfering with cancerous cells and delaying the ageing process. The award, announced in Stockholm, includes a 10 million kronor ($A1.62 million) cash prize—not bad for a woman who was once asked 'What's a nice girl like you doing studying science?' by a family friend.

→ Fig 2.12 Dr Elizabeth Blackburn, the first Australian woman to win a Nobel Prize.

Doctor		Focus	Big question
Oncologist Phillip Yulie with new radiotherapy equipment in use at Mater Hospital, Crows Nest.		Cancer	Will we ever cure cancer?
Ophthalmologist Fred Hollows treats a patient in Vietnam.		Eyes	How can we eradicate preventable eye diseases?
Otorhinolaryngologist (oh-toh-ry-noh-la-ring-ol-ogist) Registrar Raefe Gundelach at the Hearing Clinic at the Community health centre in Bamaga.		Ear, nose and throat	What has caused this hearing loss?
Psychiatrist Professor Patrick McGorry, 2010 Australian of the Year.		The mind	Does this patient have depression?
Radiologist Gosford Hospital Radiologist Julian Hanson with scans from new satellite imaging technology in the Emergency Department		Interpretation of imaging technologies, such as X-rays and computed tomography (CT) scans	How can we better see inside the human body?
Urologist Urologist, Dr Peter Swindle, with the da Vinci robotic system at Greenslopes Private Hospital.		Kidneys and bladder—the urinary system	Is this prostate gland inflamed?

→ Fig 2.13 Some forensic doctors specialise in analysing bones.

→ Fig 2.14 Sports doctors look after the health of our sporting heroes.

New doctors

Medicine, like other fields of Science, is constantly evolving as more is understood about how the body works. Some doctors specialise not in a part of the body, but something else …

- Aged care deals with our ageing population.
- Sports medicine deals with the growing number of injuries due to sports.
- Travel medicine keeps people healthy as they travel the globe.
- Rehabilitation specialists help people recover from illness or injury.
- Post-surgical specialists help people recover from operations.
- Community medicine deals with the health issues that affect many people in a particular area.
- Forensic medicine deals with any aspect of health that may be relevant to a legal case.
- Space medicine looks after the health of humans in outer space!

What do you know about looking after the human body?

1 Why does it take so long to become a doctor?

2 Is there only one type of doctor? Explain.

3 In your own words, explain what the following people would look after: *gastroenterologist*, *dermatologist*, *urologist*, *radiologist* and *ophthalmologist*.

2.1 How have we learnt about the human body?

Remember and understand

1 What is the scientific name for the study of the structure of the human body?

2 What is a dissection?

3 What was Leonardo da Vinci famous for?

4 Why are dissections used in science?

→ Fig 2.15 Body snatchers stole corpses from graves.

5 What do you think the motivations were behind the earliest studies of the human body?

6 Why is Aboriginal X-ray art a form of scientific evidence?

7 Why were the body snatchers known as 'the Resurrectionists'?

8 Why might Leonardo da Vinci have constructed a glass model of the human heart?

Apply

9 What type of doctor do you think you'd need to see for:

a a heart attack?

b a chest infection?

c indigestion?

Analyse and evaluate

10 Human dissections sound like grisly work, so why do you think it was so important that they happened?

11 From the chapter, find an example of a scientific finding that is now untrue and has been updated. Do you think this is common in science? Why or why not?

12 Some studies of acupuncture have been criticised for not being fair tests. Design a fair test to assess whether acupuncture can provide pain relief for people who suffer from migraine headaches.

Ethical behaviour

13 Dissections and research involving animals have contributed significantly to our understanding of the human body. In fact, it would probably be fair to say that we couldn't have come this far without them. Critically evaluate the positives and negatives involved in using animals for medical research purposes. Discuss your points with a partner and share your thoughts with the class. Do you think animals should continue to be used in medical research?

14 Do you think it is a good thing to see a doctor every time you feel a little sick? What about avoiding doctors because you don't want to bother them with 'only a little illness'?

Critical and creative thinking

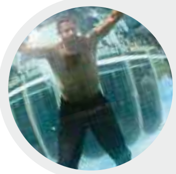
15 Create a picture scrapbook of copies of some of Leonardo da Vinci's best work on the study of the human body. Add some of your own images to the scrap book.

<<CONNECTING IDEAS>> Structure and function

16 Think about all you have learned so far in this unit. Take a few moments to reflect on the many thousands of years of knowledge that have shaped modern science's view of the human body. Now think about the knowledge that humans may have in another thousand years. Write a paragraph, or draw a labelled picture, to summarise your own big ideas about how we learn about the structures of the human body and how they function.

2.2

What are some of my major systems?



How do you know what's inside you and how it works? Doctors and teachers and textbooks provide information—but how do they know? In the previous unit we looked at some investigations of the human body throughout history and what we discovered was that scientific knowledge changes all the time. Today we know a lot about the human body's systems and how they work. You've no doubt heard of some of these systems, such as the digestive system or the skeletal system. How do these systems all fit together and how do they interact with each other to make sure we survive?

<<DISCOVERING IDEAS>>

Brown paper body brainstorm

What you need

Large pieces of butcher's paper

Several different-coloured felt-tipped pens

What to do

1. Working with a partner, spend 5 minutes brainstorming all the internal parts of the body you can think of. Write them down in your notebook as you brainstorm.
2. Unravel a couple of metres of butcher's paper along the floor.
3. One student lies down on the paper. Trace around them.
4. Spend a minute discussing the best way to illustrate the body shape with all the body parts from your brainstorming list. What is the best way to make use of the different-coloured pens?
5. Then, using the list you brainstormed and any other body parts you think of as you work, make a drawing of the inside of a human body.
6. Try to make connections between body parts where you can. For example, you may want to connect the stomach to the intestines.

How does the digestive system work?

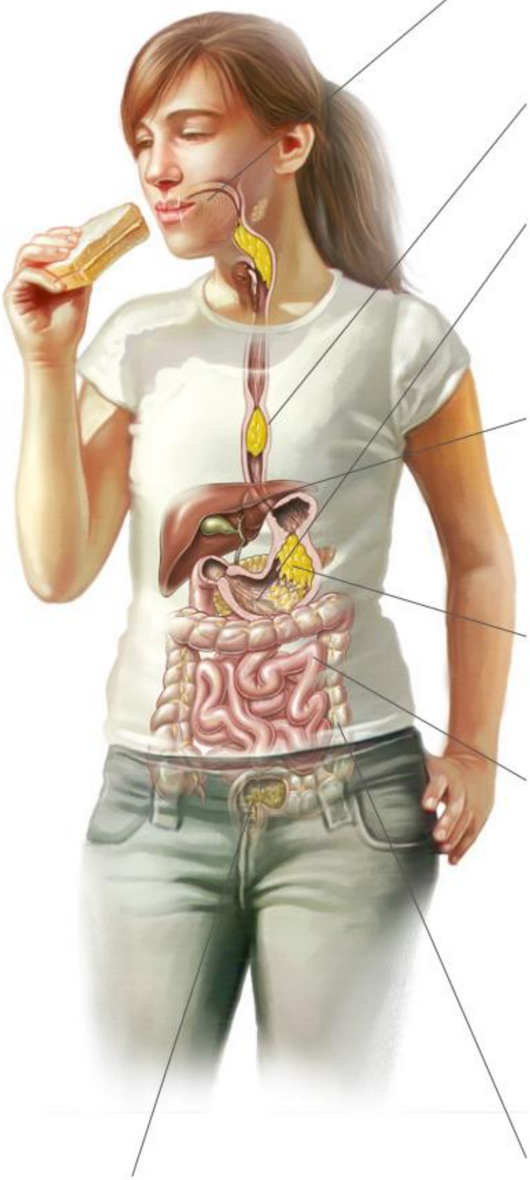
FUNCTION

Digestion is the process by which foods (and drinks) are broken down and absorbed into your blood for transport to your cells. The food we eat provides us with the energy to stay alive, the building materials for growth and repair and fibre to help move it all through. But what happens to the food we eat? Are tiny pieces of bread sent to each part of the body? No. The bread is broken down into smaller chemicals, called nutrients. Nutrients provide nutrition to the body. Nutrients are soluble substances that are absorbed by the blood and circulated around the body to where they are needed. Different types of foods provide us with different nutrients.

FORM

Your digestive tract is made up of a group of organs in the digestive system that form a tube travelling from your mouth to your anus. Along the way, food is broken down and absorbed across the intestinal walls into the blood. The internal walls of the intestines are wrinkly to increase their surface area for absorption into the blood. Food that is not required by the body remains in the digestive tract until the end, where it is released into the toilet. Figure 2.16 shows what happens as food moves down through the digestive tract.

➔ Fig 2.16 The structure of the digestive system with key parts labelled.



Teeth and mouth

The teeth are responsible for the physical breakdown of food and the tongue is important in pushing the food towards the teeth. Salivary glands make saliva, which contains enzymes to start chemical digestion.

Oesophagus

The oesophagus is a tubular muscle that forces food down to your stomach in a process called **peristalsis**.

Stomach

The stomach stores food for about 3 hours while it uses gastric juice to help digest the food. The food in your stomach looks nothing like what you ate for dinner. It is very runny, warm and smelly and has a totally different taste. This mixture is called **chyme**.

Liver and gall bladder

The liver makes a mixture of chemicals called **bile**, which is used to digest fat and neutralise (deactivate) stomach acid. The bile is stored in the gall bladder until food reaches the small intestine. Bile is then released into the small intestine through a tube called the bile duct. Food does not travel through the liver.

Pancreas

The pancreas makes pancreatic juice, which contains a mixture of digestive enzymes and also neutralises stomach acid. Food does not travel through the pancreas.

Small intestine

The small intestine is called small because it is quite narrow. If you laid a small intestine out in a straight line, it would be approximately 5 m long. The intestines are really important because they absorb the nutrients that feed all the cells of the body. The ability to absorb nutrients is increased by wrinkles, called **villi**, along the inner wall of the intestine that increase the surface area for absorption. Surface area is important in many systems of the body. Bacteria in the small intestine also help with digestion. Sometimes bacteria can produce foul-smelling gases, which escape out the rectum. Chyme takes about 5 or 6 hours to pass through the small intestine.

Large intestine

The large intestine is also called the colon and is wider but shorter than the small intestine. The large intestine is approximately 1.5 m long. By the time the chyme reaches the large intestine, most nutrients have been absorbed into the bloodstream. However, some vitamins are absorbed from the large intestine. Water is also absorbed into the bloodstream from the large intestine. Chyme stays in the large intestine for up to 14 hours, or sometimes longer.

Rectum and anus

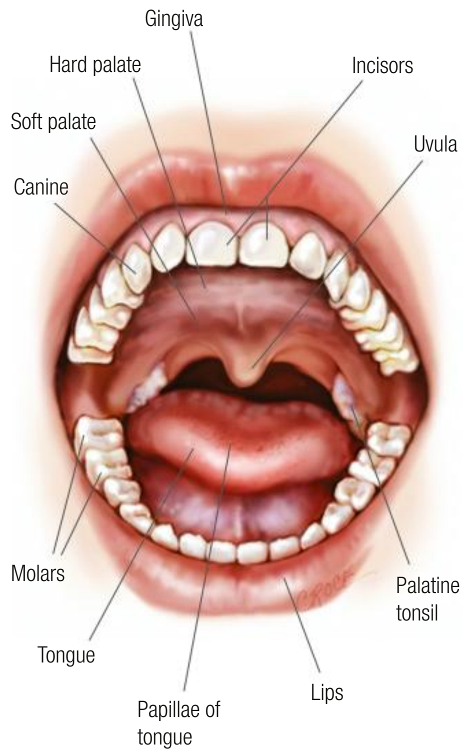
The rectum is the final part of the journey for what is now solid, undigested food, or **faeces**. The rectum stores faeces until it starts to become full. As the rectum starts to stretch, messages are sent to the brain to make you realise that you need to go to the toilet. Rectal muscles push the faeces out of the ring of muscle at the end of the rectum called the anus.

Your mouth

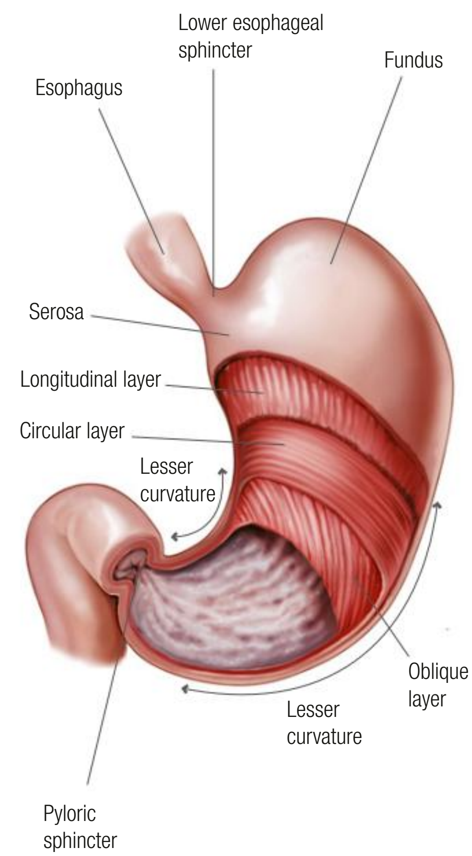
Your mouth is home to three main types of teeth: the front ones are called incisors, the pointy teeth next to the incisors are called canines and the rest of your teeth, which are flatter, are called molars. You also have a large muscular organ called a tongue that can push upwards, sideways and backwards. The mouth is also where saliva is found—saliva is mostly water, but also contains different types of enzymes.

Your stomach

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



➔ Fig 2.17 The teeth and mouth physically break down food.



➔ Fig 2.18 The stomach is a bag of layers of muscle which squeeze in different directions.

EXPERIMENT 2.1

Digesting protein

Aim

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

Materials

1% Pepsin solution
Dilute hydrochloric acid (1 M HCl)
Dilute sodium hydroxide solution (0.1 M NaOH)
Hard-boiled egg white
1-mL pipette
10-mL measuring cylinder
Water
Incubator (37°C)
Four test tubes and test tube rack
Permanent marker

Safety precautions

Bring the materials to the test tubes, rather than risking them being dropped when carrying them around the room.

Warning! Dangerous chemicals are involved—pour carefully, clean up all spills immediately and rinse your hands if you come into contact with any chemicals.

Method

1 Label four test tubes A, B, C and D with permanent marker.
2 Collect some hard-boiled egg white. Cut four cubes of approximately 1 cm^3 ensuring that the cubes are the same.
3 Put a cube of egg white in each tube.
4 Add 10 mL pepsin to tubes A, C and D.
5 Add 10 mL water to tube B.
6 Add ten drops of HCl to tubes A and B.
7 Add ten drops of 0.1 M NaOH to tube D.
8 Add ten drops of water to tube C.
9 Bind the four tubes with a rubber band and label the bunch with your initials.
10 Incubate for at least 24 hours at 37°C.

Results

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

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

Discussion

1 This experiment is a 'controlled' experiment. What do you understand this term to mean?
2 How can combining the class's data improve the accuracy of the interpretations?
3 Construct a sentence to explain how the comparison of tubes relates to the human stomach for A and B, A and C, and A and D.
4 In which test tube(s) has the protein been completely digested? How do you know?
5 Has the pepsin digested the protein? If so, how can you be sure?

6 What are enzymes?
7 Does HCl digest the protein by itself? How do you know?
8 Complete the following word equations to show what has happened in this experiment.

Tube A: protein + ____________ + ____________ → amino acids

Tube B: water + ____________ + ____________ → ____________

Tube C: pepsin + ____________ + ____________ → ____________

Tube D: pepsin + ____________ + ____________ → ____________

9 Why does the body digest protein? What would happen to the protein after it has been digested?
10 Predict what would happen if this experiment was repeated with carbohydrates instead of protein, leaving the rest of the experiment exactly the same.

Conclusion

What do you know about the function of pepsin and the conditions under which pepsin functions best?

The production line

The digestive system is like a production line in a factory. When we chew food, it is crushed to break it down into smaller parts. This is a physical, or mechanical, change. Further down the digestive tract, chemical changes happen, such as enzymes breaking food down into individual nutrients.

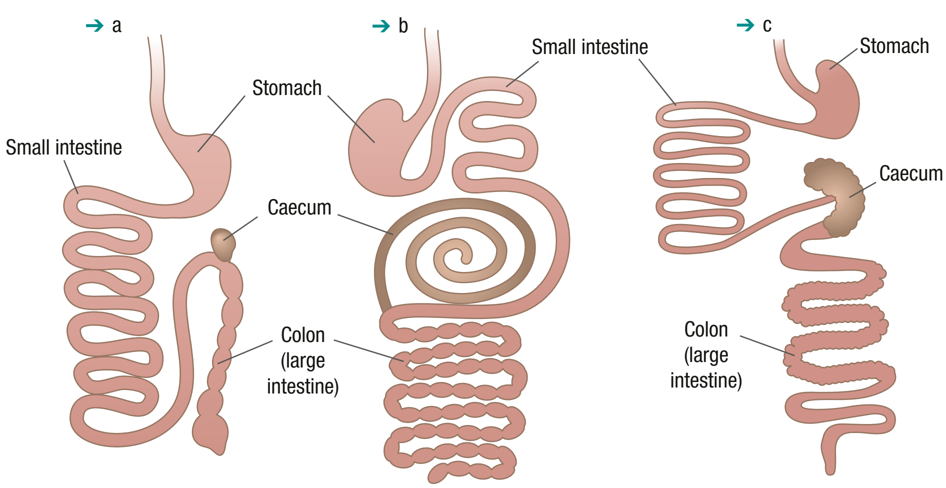
To help with digestion, the body makes special chemicals, including some called enzymes. **Enzymes** help make chemical reactions happen. They are found in fluids, such as bile and gastric juices. These fluids are supplied by some of the important organs that make up the digestive system, such as the salivary glands, the liver and pancreas.

PRACTIVITY 2.1

Digesting different diets

What to do

1 Examine the images below of the digestive systems of a carnivore, herbivore and omnivore.



→ Fig 2.19 The digestive systems of (a) a carnivore, (b) a herbivore and (c) an omnivore.

2 Work in small groups to discuss how the different digestive systems are suited to the diet of the animal. Identify similarities and differences between the digestive systems.

What do you know about the digestive system?

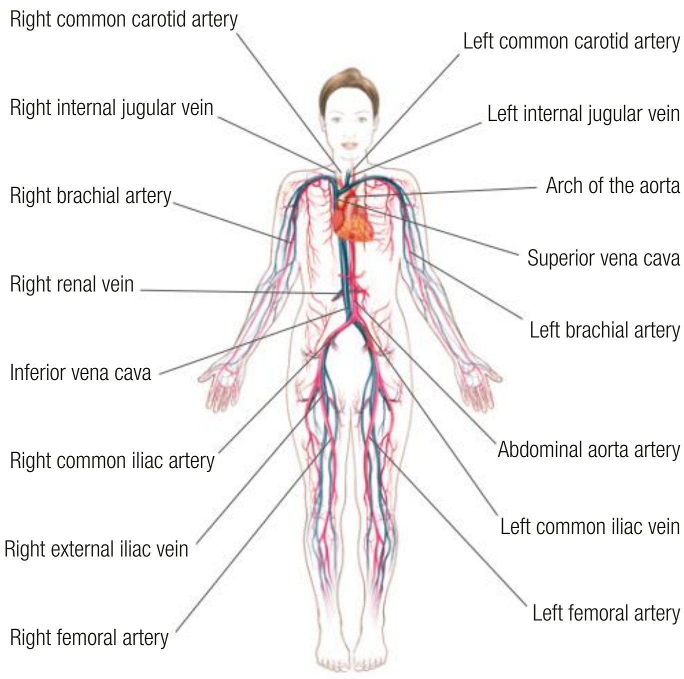
1 List, in order, the organs of the digestive system that food moves through, from the mouth to the anus.
2 How does saliva make it easier to eat dry biscuits?
3 What is the difference between mechanical and chemical digestion? Which occurs in the stomach?
4 What is the difference between the digestive system and the digestive tract?
5 Which organs are involved in digestion but do not have food pass through them?
6 Teeth would look very nice if they were all the same size and shape. What is the advantage of having different types of teeth in your mouth?
7 Can you think of any tools that may work the same way as incisors, canines or molars?
8 What are villi? What is their function? How does the length of the intestines contribute to this function?
9 Are digestive systems the same in all animals? Explain.

How does the circulatory system work?

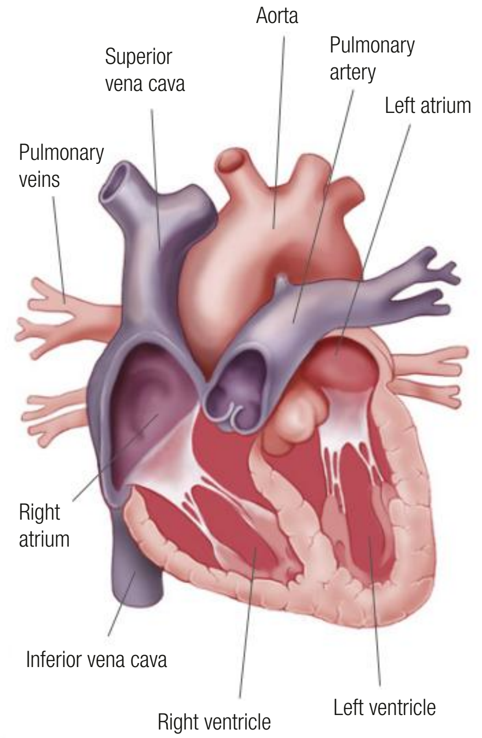
FUNCTION

The circulatory system is the body system responsible for moving blood around your body.

Many different substances, including nutrients and wastes, are transported in the blood, picked up from and dropped off at different locations.



→ Fig 2.20 The structure of the circulatory system with key parts labelled.



→ Fig 2.21 This diagram shows your heart, as well as some of the major blood vessels travelling to and from the heart. The diagram uses a convention that shows the arteries in red and the veins in blue.

FORM

The heart

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

Blood is a combination of cells, cell fragments, liquid and dissolved substances and each aspect is absolutely necessary.

- Oxygen is carried by the **haemoglobin** in **red blood cells** from the lungs to all the cells of the body, whereas carbon dioxide is dissolved in the **plasma**.
- Nutrients and wastes are also dissolved in the plasma for transport to and from cells.
- **White blood cells** travel in the blood to places where an immune response is needed—they fight germs.
- **Platelets** are cell fragments that travel in the blood to places where cuts need to be blocked—they fill the hole and **fibrinogen**, which travels dissolved in the plasma, glues it all together.

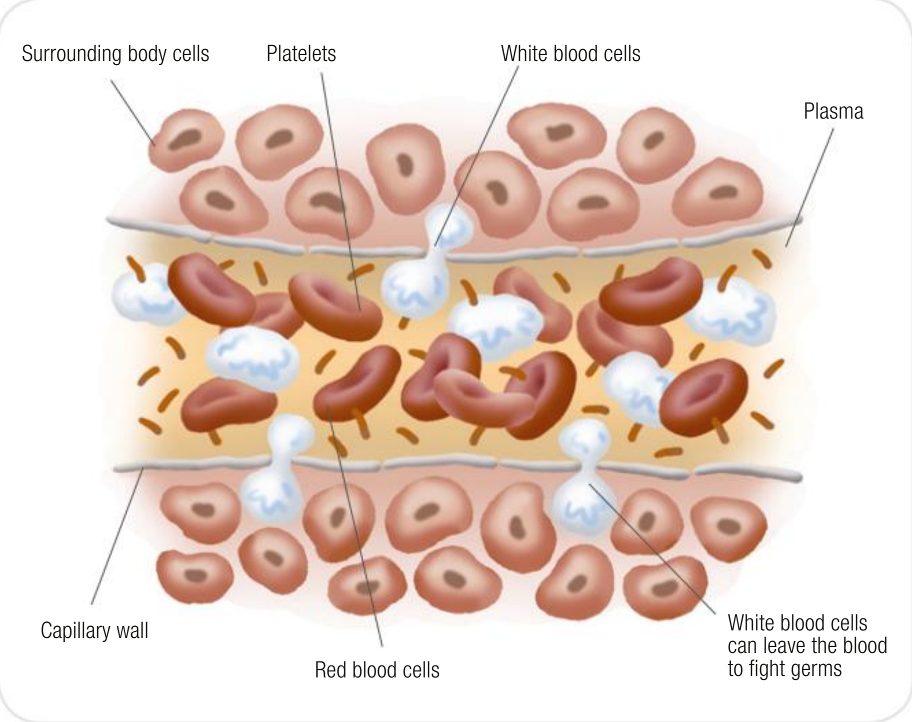
Blood vessels

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

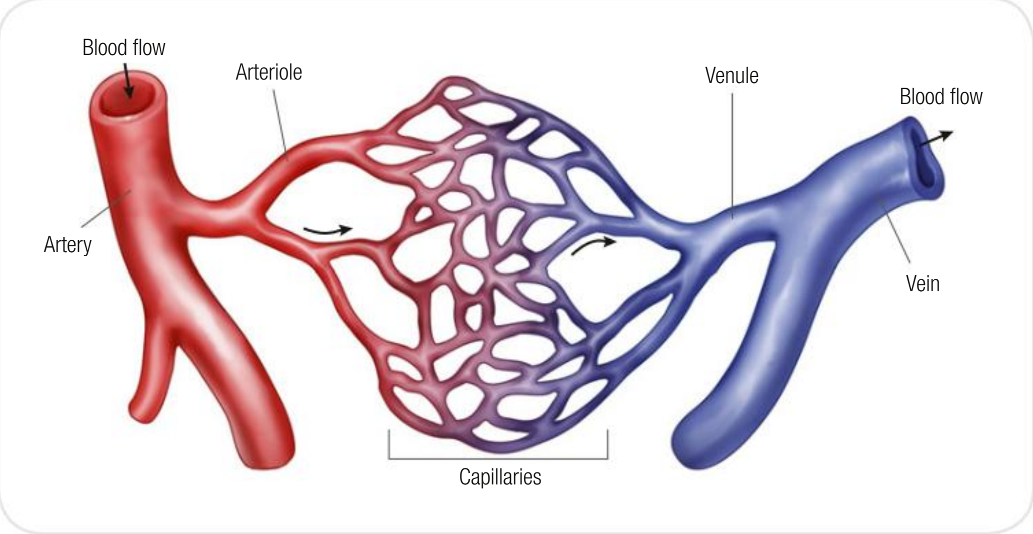
Arteries are the largest blood vessels. Arteries have thick, muscular walls to cope with high pressure and to squeeze the blood along. Arteries travel away from the heart—the blood is at a higher pressure here because it has just been pumped. Arteries branch into **arterioles** (smaller arteries).

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

Capillaries are possibly the most important of the blood vessels: their walls are only one cell thick to allow substances to easily pass in and out of the blood. Capillaries are the vessels connecting the arteries and veins; they are sometimes referred to as a capillary bed when they are in large numbers surrounding an organ.



➔ Fig 2.22 A cross-section of a blood vessel.



➔ Fig 2.23 Capillary bed, showing the relationship between arteries, veins and capillaries.

EXPERIMENT 2.2

Heart dissection

Aim

To explore the structure and function of a heart.

Safety precautions

Refer to the Skills Lab on page 45 for dissection skills and safety guidelines.

Materials

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

Method

1 Examine the outside of the heart and identify the left and right sides. Your fingers will work better than a probe for that.

2 Feel the right side of the heart. Compare the thickness of the right and left sides. Feel the muscle in the centre of the heart. Your fingers will work better than a probe for that.

3 Using a scalpel, cut open the right atrium and right ventricle. Pull back the wall and look inside to see the atrium and the ventricle. The ventricle is the chamber closest to the pointed end of the heart. The white tendons hold the valves in place.

4 Push a dissecting probe or your finger out through the artery leading from the right ventricle.
- What is this artery called?

5 Cut open the left side of the heart. Locate the atrium, ventricle and tendons holding the valves.

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

Results

Include labelled diagrams and observations here.

Discussion

Include responses to the questions above, as well as any further analysis.

Conclusion

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

When things go wrong in the circulatory system

A heart attack is usually caused by coronary heart disease (CHD), which is basically fatty deposits blocking important blood vessels in the heart—*coronary* refers to the heart's own blood vessels. The 'attack' occurs when the vessels become completely blocked or when a bit of the fatty deposit breaks off and travels into the heart. Heart muscle cells may be killed in the process.

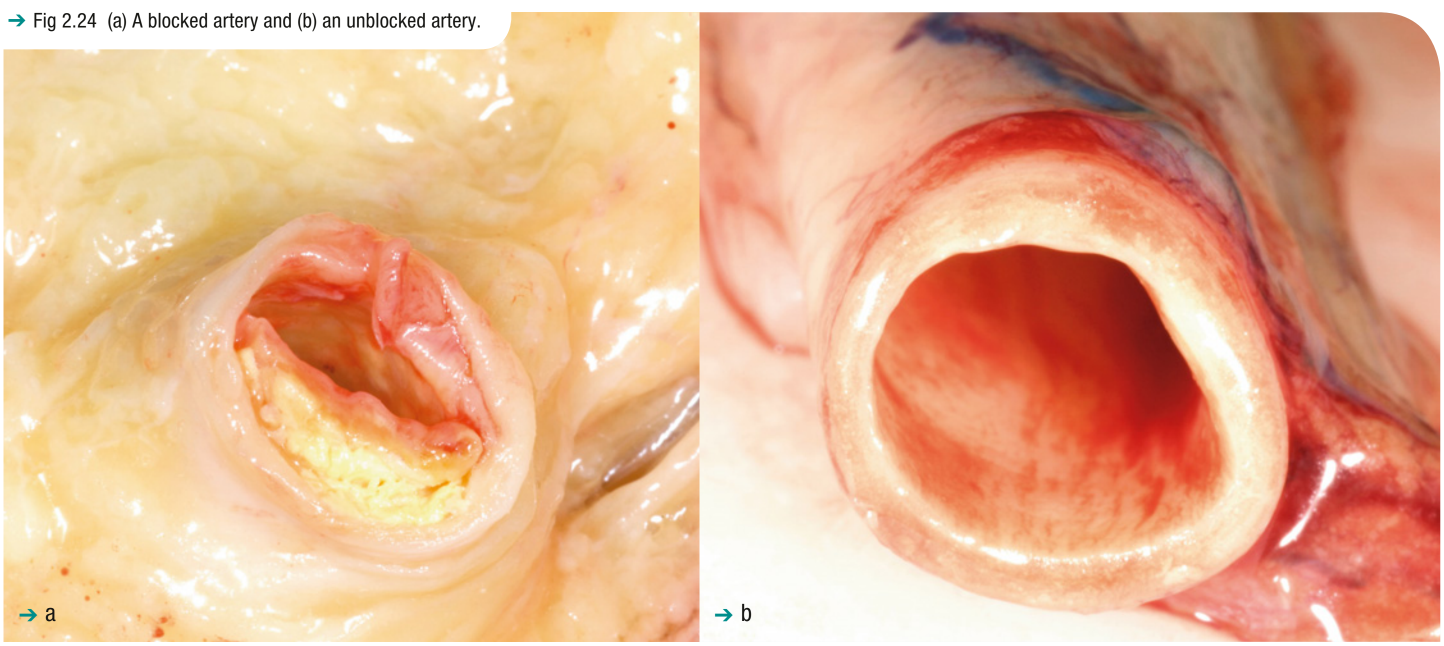
So how can you keep your heart healthy? Eating less fatty foods is a really good start, but it's not the only thing you can do.

The heart is a muscle and, like all muscles, it needs exercise to keep it strong. Regular exercise is all it needs. In people who are overweight or who smoke cigarettes, the heart needs to work much harder to do the same job. This is actually stressful for your heart. Elite athletes work their bodies very hard, so they need to make sure they have their hearts checked regularly by a doctor.

What do you know about the circulatory system?

1. Copy and complete: The circulatory system is the transport system for the body, delivering __________ and other ____________ to the cells and carrying wastes away for removal. _________ blood cells are responsible for carrying oxygen, ____________ blood cells fight germs, _____________ block cuts and ___________ is the liquid carrying them all.
2. Explain how the three blood vessel types differ in their structure, jobs and locations. Use diagrams in your answer.
3. How many chambers are there in your heart? Name them.
4. Use Figure 2.21 showing the structure of the heart to complete the following for the path of blood through the chambers of the heart: body → _____________ → ______________ → lungs → ____________ → ____________→ body.
5. Rewrite your answer to question 4, adding the names of the veins and the arteries involved.
6. From which body system does the circulatory system absorb nutrients?
7. Why would muscles need the heart to pump faster during exercise? What chemical reaction does this include?
8. Instead of the blood travelling directly from the lungs to the rest of the body, the blood returns to the heart first. What is the advantage of doing this?

→ Fig 2.24 (a) A blocked artery and (b) an unblocked artery.



How does the respiratory system work?

FUNCTION

The respiratory system is the body system responsible for breathing—getting oxygen from the air we inhale into our blood and getting rid of carbon dioxide that has been brought from our cells.

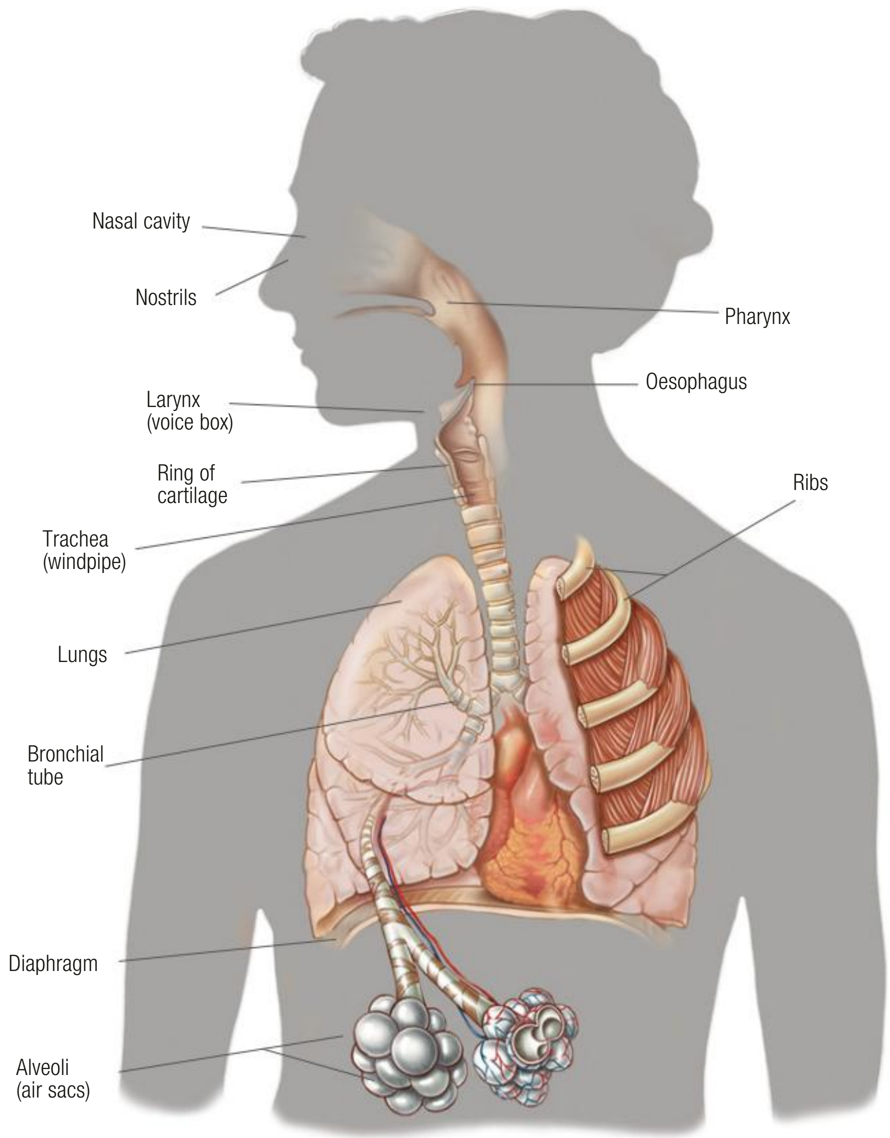
We breathe air in through our nose and mouth, cleaning it with hairs and wet surfaces as it travels to our throat or **pharynx**. At the bottom of the pharynx is a trapdoor called the **epiglottis** that controls the path of food and air. Food goes down the oesophagus to the stomach. Air needs to go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

For gas exchange to occur with blood, the blood vessels need to be able to get really close to the air. Oxygen is exchanged into the blood, whereas carbon dioxide is exchanged out of the blood.

FORM

The lungs

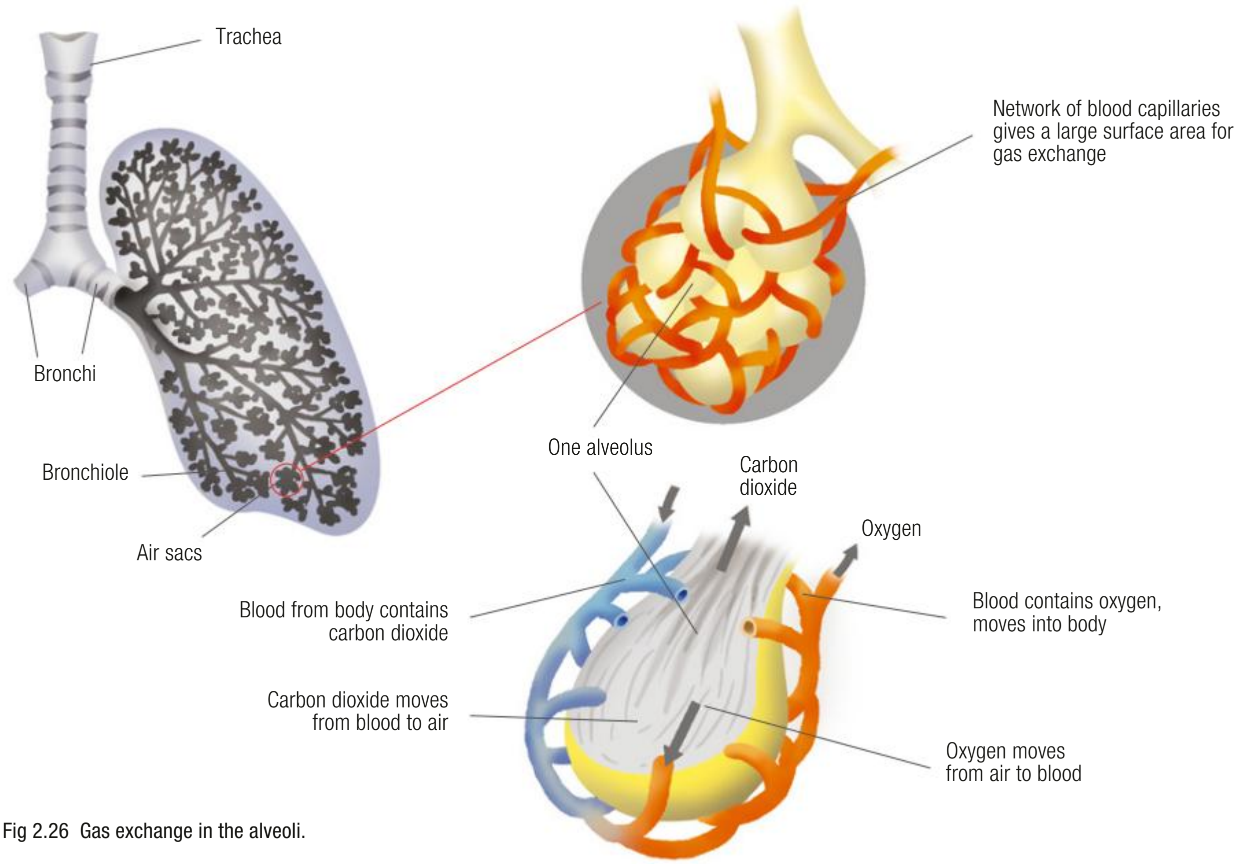
There are *two* lungs in our chest, changing in size every time we take a breath and they fill with air. The trachea branches into two to carry air into each lung. These branches are called **bronchi**. The lungs feel spongy to touch because they are home to millions of tiny air sacs called **alveoli**. If these air sacs were unravelled and flattened, they would have a surface area of approximately half the size of a tennis court. Each tiny alveolus is covered by a mesh of even smaller blood vessels called capillaries. The lungs are structured to have as many air sacs as close to as many blood vessels as possible.



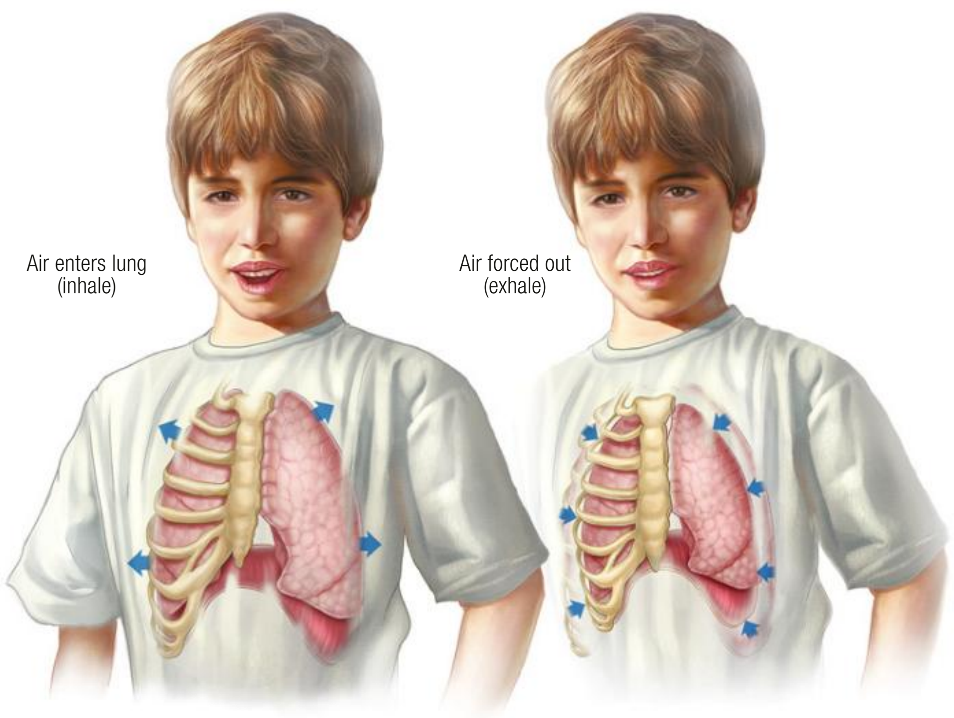
→ Fig 2.25 The structure of the respiratory system with key parts labelled.

The diaphragm

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



➔ Fig 2.26 Gas exchange in the alveoli.



➔ Fig 2.27 Inhalation and exhalation.

WHY DO WE WANT OXYGEN?

The respiratory system makes sure that every cell in your body gets the oxygen it needs. But why do cells need oxygen? Most of the food we eat is broken down to glucose, a simple sugar. To release energy from glucose, oxygen is required—this process is called **respiration**. This energy is then used for all the jobs the cell needs to perform, from making and breaking down substances to making new cells. You can see why people get confused about the difference between breathing and respiration—*respiration* is the actual process that happens in cells and *breathing* is the inhalation of oxygen and exhalation of carbon dioxide by your lungs and other organs in the respiratory system.

Fish dissection

What you need

A fish, complete with internal organs, from a fishmonger or market

Dissection tools

What to do

Part A

Use your dissection skills to open the abdomen and head of the fish and record your observations of the internal organs using labelled diagrams.

Questions to consider

1. What do you notice about the arrangement of the organs?
2. Are the systems clearly separated or are they intertwined?
3. Are certain organs a darker red colour than others?
4. What might this tell you about their blood supply?
5. What might this tell you about their importance?

➔ Fig 2.28

Part B

Identify and remove the gills of the fish. Reflect on the significant features of our lungs that make them such effective gas exchange organs.

Questions to consider

1. Do fish gills have similar features to lungs?
2. Do they have different forms to achieve the same function?

DESIGN YOUR OWN ...

Breathing and exercise

Adults normally breathe between twelve and twenty times per minute.

Challenge

Design and conduct an experiment to highlight the connection between breathing rate and exercise.

Questioning and predicting

Create your own hypothesis about the relationship between the number of breaths you take in a period of time and the amount of exercise you are doing or have just completed.

Planning and conducting

- What will you do to test your hypothesis? Think of the different types of exercise you have tried and how they affected your breathing rate. Are there health risks to consider? Do you breathe at the same rate when you're thinking about your breathing?
- Conduct your experiment and record your results in an appropriate format.

Processing, analysing and evaluating

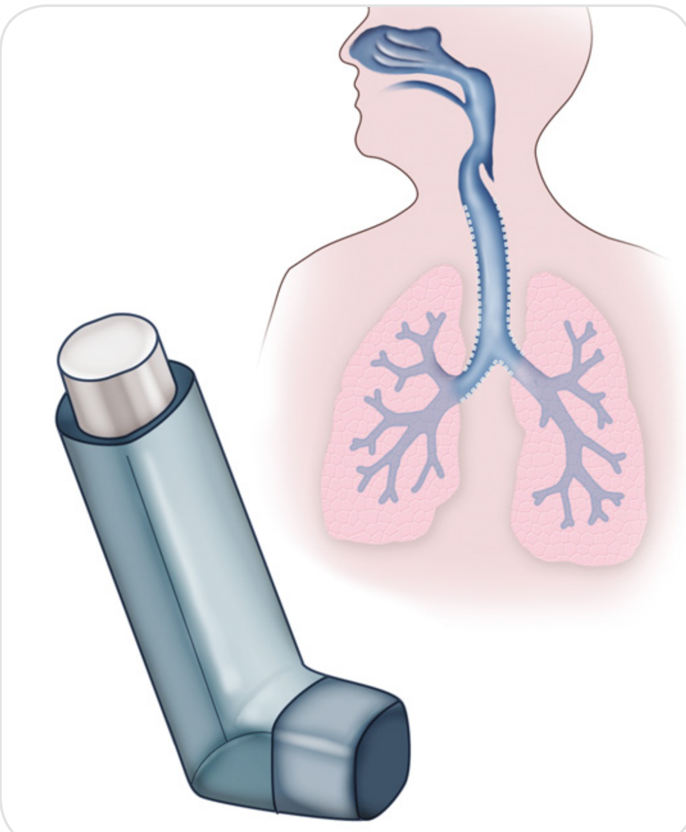
- How can you explain your results?
- Are there any variables you were unable to control?
- What do you know about the connection between breathing rate and exercise?

Communicating

Present your findings in a formal experimental report *so that someone else could perform the same experiment.*

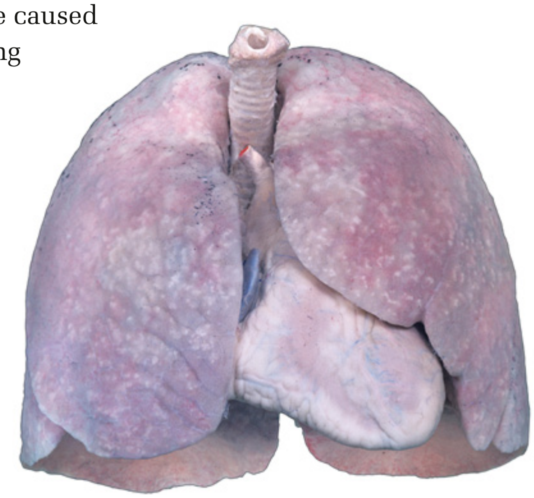
When things go wrong in the respiratory system

Asthma is quite common in our population, affecting more than one in ten Australians. Asthma is usually triggered by something in the environment, which causes the bronchi and bronchioles to swell, making it harder for air to pass. Asthma attacks can be reversed by drugs, such as Ventolin, that relax the airways.



→ Fig 2.29 Ventolin is commonly used for asthma attacks.

Smoking involves breathing toxic chemicals and tar into your lungs. The tar is like honey, covering the inside of the alveoli and stopping air from being exchanged. The toxic chemicals in the smoke kill the cells, destroying the alveoli, and travel through the blood to cause trouble all over your body. **Emphysema** is a disease that results from alveolar damage, but it's just one of many diseases that can be caused by smoking. Messing with the lungs is messing with the body's energy supply—energy is needed to fight germs, grow strong and have fun!



→ a

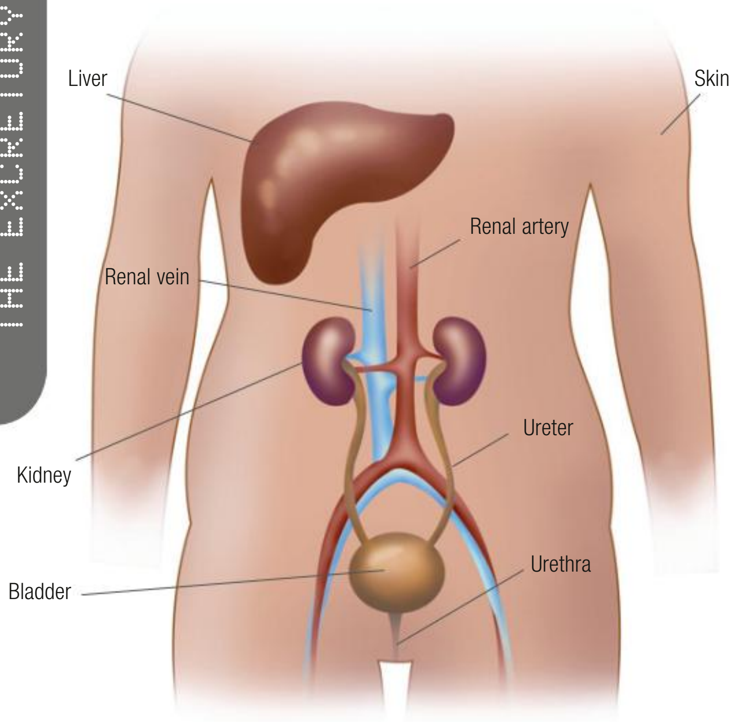
→ b

→ Fig 2.30 (a) Healthy lungs. (b) Smoker's lungs.

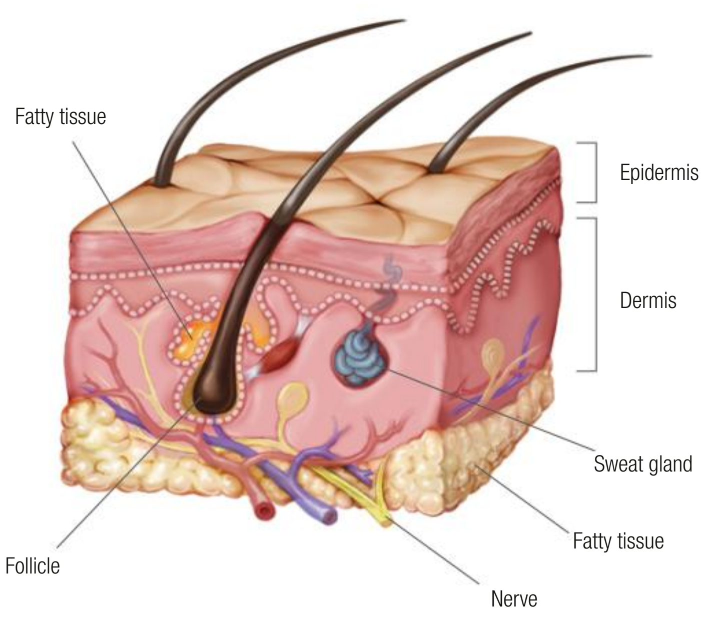
What do you know about the respiratory system?

1. Draw a simple diagram showing how air travels down from the mouth and nose to the alveoli at the end of the branches of the bronchioles.
2. Explain the term *gas exchange*.
3. At the same time that oxygen is passing into the blood, what gas is passing out of the blood back into the lungs?
4. What is the difference between respiration and breathing?
5. Write the sequence of steps in breathing in and breathing out.
6. What role does the epiglottis play?
7. Where do you think your larynx (voice box) is? In your pharynx, trachea or oesophagus? Explain.
8. How do the lungs increase their surface area?
9. In your own words, explain why we need to breathe.
10. Describe some health risks people take with their lungs. What can be done to avoid these risks?
11. Why do you think people risk the health of their lungs?

How does the excretory system work?



→ Fig 2.31 The structure of the excretory system with key parts labelled.



→ Fig 2.32 The structure of skin.

FUNCTION

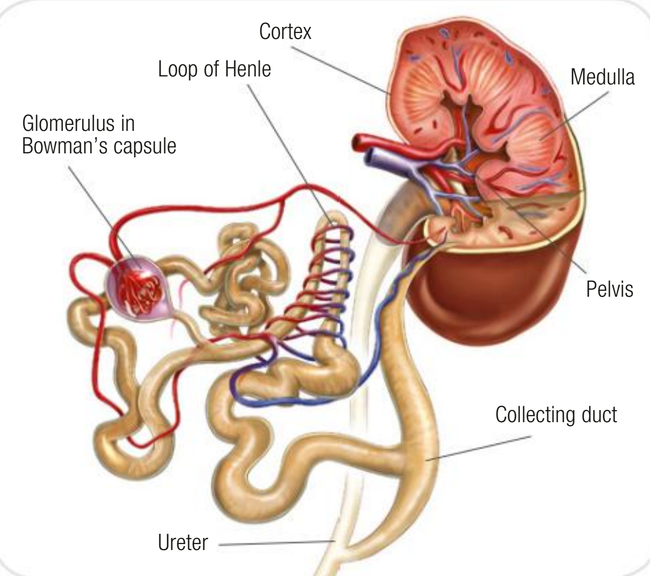
Our cells and our bodies create a number of waste products. To keep functioning correctly, these wastes need to be removed. The process of removing wastes is called **excretion**.

The organs of excretion are the kidneys, liver, lungs and skin. These organs make up the **excretory system**.

FORM

The kidneys

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



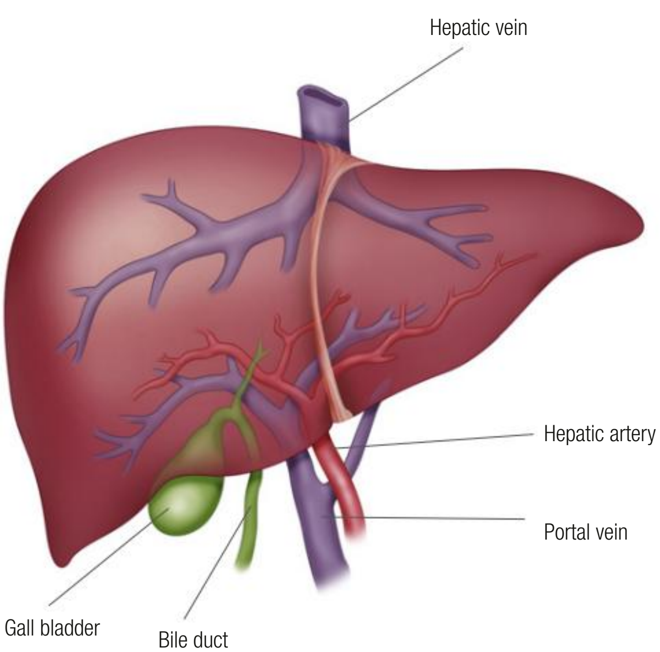
→ Fig 2.33 The structure of the kidneys. The nephron, shown in greater detail on the left, is the filtering unit of the kidney.

The skin

The skin plays a very important role in releasing waste heat by evaporation from wet skin. If you've ever licked your upper lip after exercise, you will know that your sweat is really salty. Sweat also contains waste products such as salts and urea.

The liver

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



➔ Fig 2.34 The structure of the liver with key parts labelled.

What is waste?

Our bodies produce a number of substances that need to be removed to avoid damage to our bodies. The human body, like all organisms, relies on a careful balance of inputs and outputs to work properly. Some substances are just taking up precious space, whereas others can actually harm us. Water is really important in controlling wastes because it can dilute harmful substances, diluting their impact at the same time. Water is also great for moving substances quickly and is essential for keeping our body temperature just right.

When your body digests proteins, it breaks them down into smaller molecules called **amino acids**. However, it cannot store the amino acids that it doesn't use up immediately. Your liver breaks down these amino acids into fats or carbohydrates. When it does this, it produces a very toxic substance called **ammonia**. The liver then uses energy to change the ammonia into a safer substance called **urea**, which is also filtered by the kidneys for removal.

➔ Fig 2.35 The salt that you eat helps substances move in and out of cells. However, if there is too much salt in your body, things get out of balance. Your body gets rid of the excess salt by filtering it out through the kidneys.

➔ Fig 2.36 Ammonia is a strong cleaning solution. Liquid ammonia can dissolve some metals, so you can imagine why it's not a good thing to have too much of it in your body.

➔ Fig 2.37 Protein digestion produces toxic ammonia.

EXPERIMENT 2.3

Kidney dissection

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

Materials
Sheep's kidney

Dissecting kit

Dissecting board

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

Results
Include your labelled diagrams here.

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

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

ZOOMING IN

Wee details about urine

Urine is the name given to the waste-containing liquid we excrete after filtering wastes from our blood through our kidneys. But have you ever wondered why it's called urine? The main waste product this fluid contains is urea, so the name 'urine' refers to this substance.

You will have noticed that sometimes your urine is darker and smells more strongly, sometimes it's lighter and has no smell and a toilet that hasn't been flushed smells awful! The amount of water in your urine can dilute the colour and smell. What you eat can also change the balance of substances in your urine. Stale urine contains urea that has converted back to ammonia, which has an even more revolting smell.

→ Fig 2.38 Bird poo also contains urine. The white crystals are uric acid.

Urea is the mammalian way of getting rid of excess nitrogen, usually from the protein in our diets. Many aquatic animals don't bother converting ammonia to urea and just release the ammonia straight into the water. Birds and reptiles change ammonia into uric acid—this acid can burn through the paint on cars!

What do you know about the excretory system?

1 What does the word *excretion* mean?
2 Can you think of any similarities between your excretory system and your respiratory system?
3 What are four organs involved in excretion?
4 Why does urine tend to be more concentrated in hot weather?
5 Why do we tend to drink a lot of water after a salty meal?
6 What effect would running a marathon have on the quantity and concentration of the urine?
7 If someone passes blood in their urine, it is a likely sign of infection. Can you think why?

2.2 What are some of my major systems?

Remember and understand

1 Name four things that the circulatory system transports around your body.

2 What is the gaseous waste product removed by the lungs?

3 Which of the following organs is not in the digestive tract: larynx, stomach, liver, small intestine. Which system does the odd one out belong to?

4 Our digestive tract is sometimes referred to as ‘our pipes’. Why do you think this is?

5 Describe how the digestive system and circulatory system work together.

6 What is the difference between respiration and breathing?

Apply

7 Why would muscles need more blood during exercise?

8 What is surface area? How is it increased in the digestive and respiratory systems? Why is it so important?

9 Sweating is often considered to be a bad thing. What is your perspective? Put forward an argument for your point of view. What do you think would happen if you didn’t sweat?

Analyse and evaluate

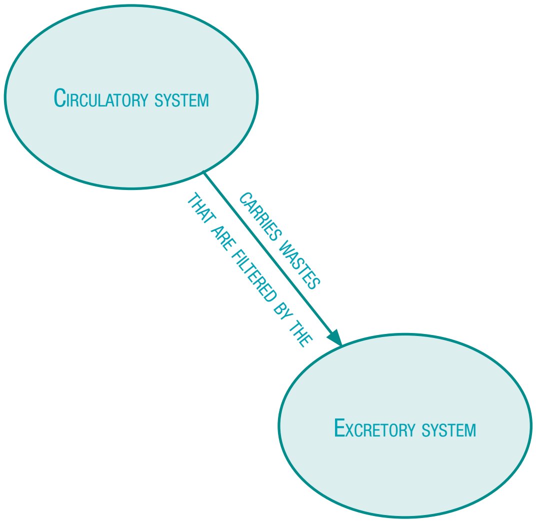
10 Some people have had the valves in their heart replaced with prosthetic valves, either made from synthetic materials or transplanted directly from a pig or cow heart. Why is it so important that the valves in a heart are functioning properly?

11 Mangrove trees get rid of excess salt through their leaves. This salt is often seen as white crystals on the underside of the leaves. Which system does this represent for the plant? How is this similar to humans? Which organ(s) is responsible for this in humans?

12 As well as breaking down amino acids and dead blood cells for excretion, the liver plays a role in both the digestive and circulatory systems. Research its role in each of these systems. In which system do you think it belongs? Justify your answer.

Critical and creative thinking

13 Use your understanding of the different systems of the human body to create a concept map detailing the connections between the systems. An example has been provided to help you get started.



<<CONNECTING IDEAS>> Structure and function

14 Revisit the brown paper body brainstorm that you did at the start of this unit. Look at the body you and your group created. Evaluate your own work by writing a short paragraph about how your knowledge of your major body systems has changed after completing this unit. Give yourself a score out of 5 for *then* and a score out of 5 for *now*.

2.3

How are new organisms made?

All living things reproduce, leaving new organisms to carry on when others die. In fact, the one thing all organisms have in common is the desire to survive and reproduce. But there isn't just one way to ensure you survive and there isn't just one way to reproduce either. The human race seems to be constantly seeking ways to live longer, control certain aspects of babies and help those who can't have babies naturally. Humans are also quite good at manipulating the reproduction of other organisms to increase or decrease their numbers or to change the features of the next generation.

<<DISCOVERING IDEAS>>

Human reproduction

Working in small groups, write down everything you already know about how human babies are made.
Use diagrams and words as appropriate.

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

- What do you know about pregnancy?
- Do you have anything in common with your parents? (For example, appearance, interests, abilities etc.)
- Can anyone make a baby? Is there a time in your life when you can't make a baby?
- Are all human babies made the same way?

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

Types of reproduction

You've probably been told that you look like your mum or your dad, or perhaps even a grandparent. This is entirely due to how you were made. A cell from your mum was fertilised by a cell from your dad and you ended up as a blend of both. So it makes sense that your grandparents' features are in there too, because they made each of your parents. Scientists now understand that a substance called DNA is responsible for the special code that determines your characteristics.

The two cells that joined to make you were called sex cells or **gametes**—an egg from your mum and sperm from your dad. Many organisms rely on gametes fusing to make new organisms and this process is referred to as **sexual reproduction**. Some organisms are able to reproduce without the joining of gametes; this is known as **asexual reproduction**.

Sexual reproduction

Sexual reproduction produces variations in a population. The **offspring** (babies) are all different from their parents, having new combinations of features. This variation is really important for the survival of the entire species. Imagine what life would be like if all humans were the same—we can't all be rocket scientists!

Reproducing sexually requires a significant amount of time and energy. Finding a mate can be hard and being pregnant certainly isn't the easiest job—some animals can't eat at all while they're pregnant!

→ Fig 2.40 The mouth-brooding frog doesn't eat at all while protecting the eggs it holds in its mouth.

Asexual reproduction

For some organisms, finding a partner to reproduce with is not an easy option. Some have found a way, but for those who live alone or are stuck to the one spot, asexual reproduction may be their only chance of continuing the species.

In asexual reproduction, the offspring are genetically identical to the parent. If an organism is really suited to an environment, the lack of variation can contribute to further success. However, if the environment changes in any way that becomes unsuitable for the organism, the entire species risks extinction. The simplest version of asexual reproduction is an organism splitting in half to form two new organisms. This is know as **binary fission**.

PRACTIVITY 2.3

Nature or nurture?

Your DNA doesn't control how you cut your hair or what you eat and the same goes for other organisms. Scientists have often had lengthy discussions about 'nature versus nurture'—whether DNA is responsible for certain features or whether the features are the result of lifestyle or even upbringing. Your DNA controls your *genetic* features, whereas the environment (lifestyle, education etc.) controls everything else and can change regularly.

As a class, brainstorm the features of an organism that are genetically controlled compared with those that are influenced by the environment. It may be easiest to begin with a human as the subject and then try other animals and even plants.

→ Fig 2.42 Identical twins are only identical according to their DNA.

→ Fig 2.41 In the mid-1800s, the population of Ireland relied very heavily on potatoes for food. When a fungus infected the potatoes, the lack of genetic diversity meant that all potato crops were wiped out and about 1 million people died of starvation.

What do you know about types of reproduction?

1. What does *reproduction* mean?
2. How does sexual reproduction differ from asexual reproduction?
3. What substance is responsible for family resemblances?
4. Is variation within a species essential? Explain.
5. What circumstances might make it difficult for an organism to reproduce sexually?

Reproduction in animals

The vast majority of animals reproduce sexually. They are also **sexually dimorphic**, which means that the males look physically different from the females. For baby animals to be born there needs to be **fertilisation** of an egg by a sperm. This could happen inside the female or male (**internal fertilisation**) or out in the open (**external fertilisation**). The fertilised egg, or **zygote**, then needs to be nourished and protected until it has grown into a baby ready to face the world. This period of time is called **gestation**, which most people know as **pregnancy**. How all this occurs, and what happens next, depends on the type of animal involved.

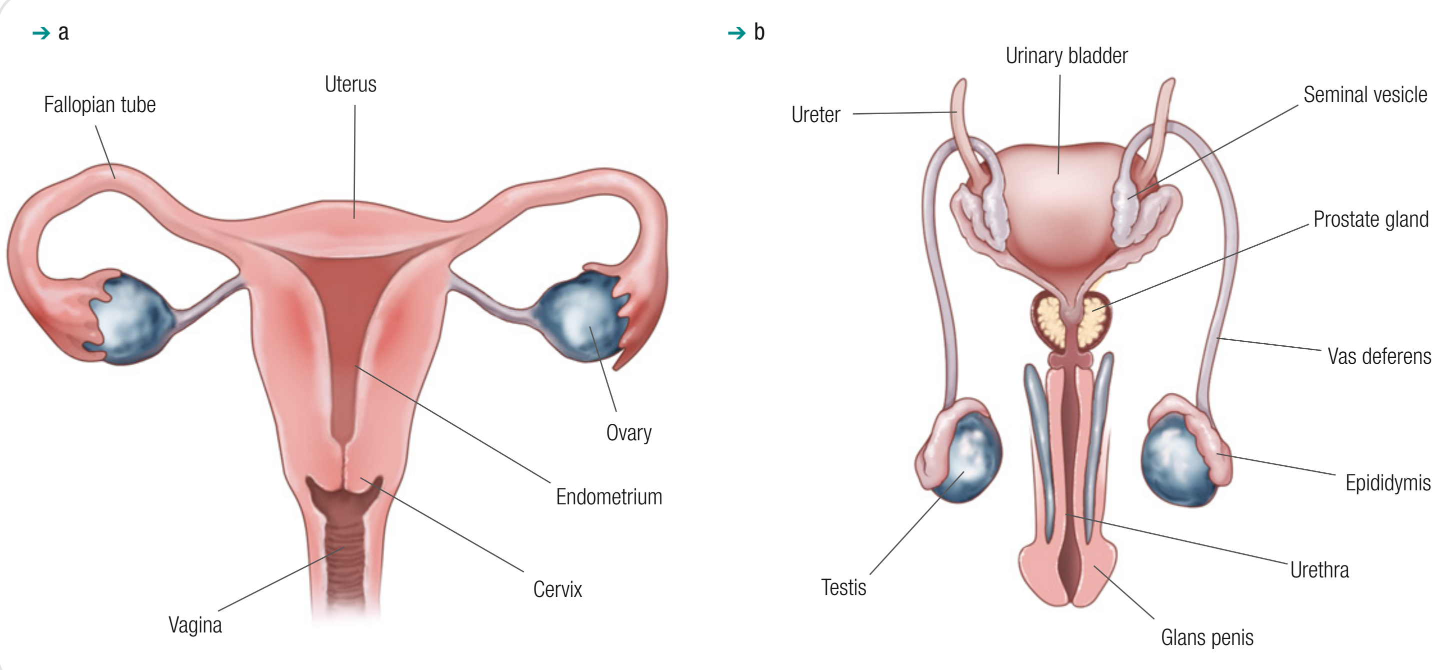
→ Fig 2.43 Marsupial foetuses finish developing in the pouch.

Vertebrates making babies

Mammals, such as humans, use internal fertilisation and the mother is responsible for nurturing the growing **foetus** until it is ready to face the world. Placental mammals keep the foetus in the uterus for this period, whereas marsupial foetuses crawl into the pouch for the final stages of development.

Monotremes, a very rare group of mammals, lay leathery eggs. All mammals suckle their young with highly nutritious milk from the mother to give them the best start in life.

Like monotremes, reptiles and birds lay internally fertilised eggs. Reptile eggs are leathery, whereas bird eggs have a hard shell. The eggs contain all the nutrients the foetus needs to develop fully, which is really important for reptiles because most reptiles leave their babies to fend for themselves.



→ Fig 2.44 Human (a) female and (b) male reproductory systems.

➔ Fig 2.45 Birds eggs are hard while reptile eggs are leathery.

➔ Fig 2.46 Some fish protect their eggs from predators.

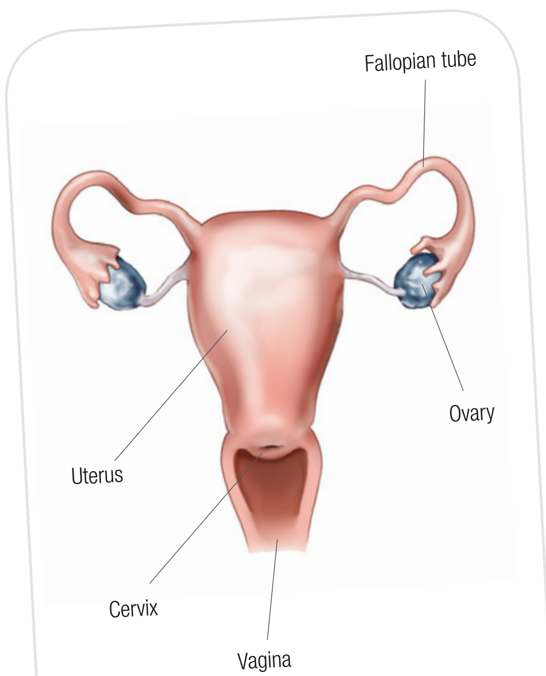
Amphibians and fish generally practise external fertilisation. This usually involves the female laying the eggs in the water and the male coating them with sperm. Often hundreds of eggs are laid at once so there's a greater chance of some surviving—they make a tasty snack for passing predators! Some parents will keep watch to ward off predators.

PRACTIVITY 2.4

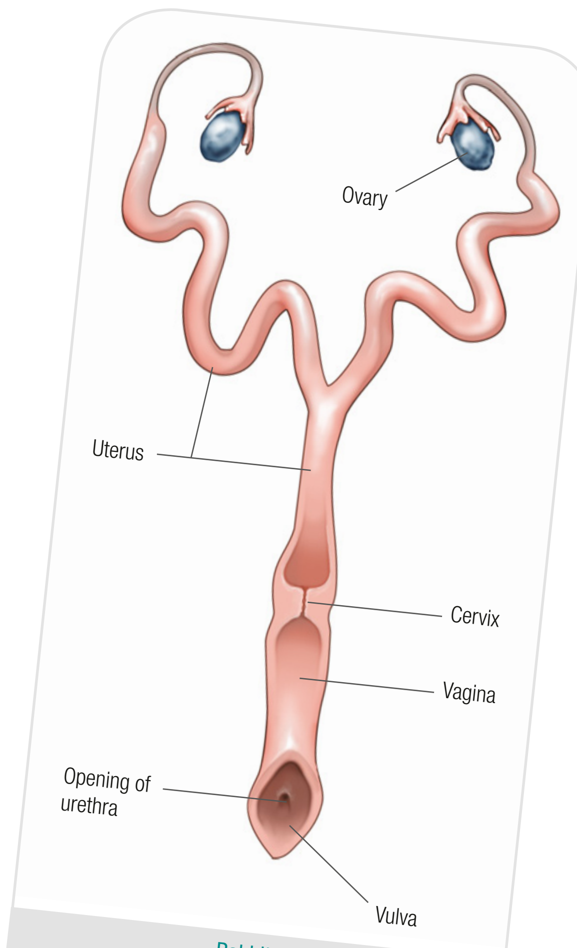
Structures for reproduction

The female reproductive system varies between vertebrates depending on the reproductive habits of the species. For example, humans have a uterus that is large enough and stretchy enough to hold one or two developing foetuses until they are fully formed, rats and rabbits have uteri large enough for multiple foetuses and amphibians have almost no uterus at all.

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



Humans
Have a uterus that is suited to growing usually one foetus at a time



Rabbits
Have two really long and stretchy uteruses; each can hold up to ten foetuses

Invertebrates making babies

Invertebrates account for approximately 95% of all animals, so it's not surprising that their reproductive strategies vary quite a lot.

Arthropoda, the group that includes insects, spiders and crustaceans, is the largest group of invertebrates.

Terrestrial (land) arthropods generally favour internal fertilisation because of the harsh conditions they often live in. Sometimes the sperm is transferred directly into the female's **oviduct** (similar to the vagina) and sometimes the sperm is packaged for delivery to the female in more complex ways. Most arthropods will then lay their eggs; insects and crustaceans tend to hatch as larvae, spiders as miniature adults.

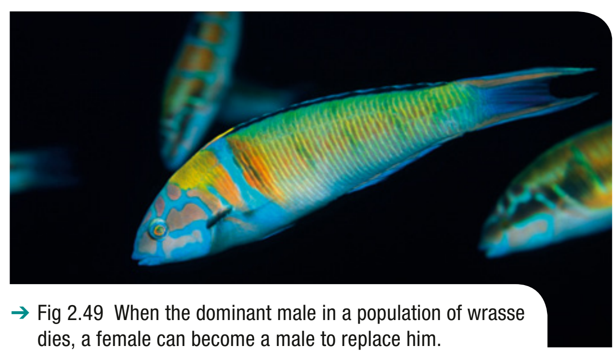
➔ Fig 2.47 A female fly lays eggs through her oviduct.

ZOOMING IN

Hermaphrodites

Hermaphrodites are organisms that have both male and female reproductive systems. This means they can reproduce sexually by themselves, but, in most cases, it results in organisms that can change sex by 'turning off' one system and 'turning on' the other. This helps to maintain genetic diversity within the species.

➔ Fig 2.48 When garden snails mate, both snails give and receive sperm, so both get pregnant.



➔ Fig 2.49 When the dominant male in a population of wrasse dies, a female can become a male to replace him.

➔ Fig 2.50 Even though Nudibranchs are hermaphrodites, they tend to find a partner to mate with. Whichever is fastest at injecting a chemical into the other will get to be the boy!

Asexual reproduction in animals

The variety of organisms and the environmental conditions they face have led to some amazing reproductive strategies to ensure species survival.

An amazing asexual reproductive strategy known as **parthenogenesis** involves unfertilised eggs hatching into new organisms.

Many children have spent time playing with worms in the garden and will have noticed that chopping them in half doesn't kill them—at least not straight away. Although earthworms will die if you cut them up, some organisms will actually form two new organisms from this **fragmentation**.

➔ Fig 2.51 The queen bee likes parthenogenesis because her unfertilised eggs always become male bees, which means no competition for her crown!

➔ Fig 2.52 The Crown of Thorns starfish is a pest on the Great Barrier Reef. Boats are making the situation worse—every time their propeller cuts up a Crown of Thorns sea star, the population of this pest increases!

What do you know about reproduction in animals?

1. Explain *sexual dimorphism* in your own words.
2. Why do animals that practise external fertilisation usually lay large numbers of eggs?
3. Which group of mammals has the longest gestation? Explain.
4. Which two vertebrate classes lay leathery eggs?
5. Why would terrestrial invertebrates fertilise their eggs internally?
6. When would parthenogenesis be useful for organisms that usually reproduce sexually?

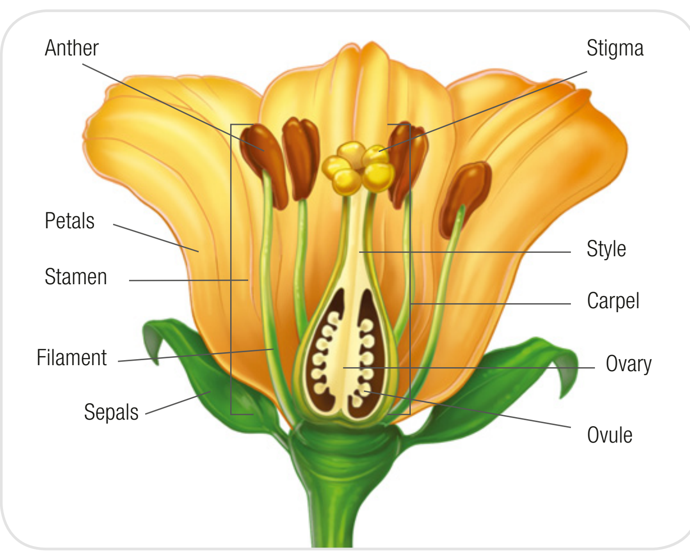
Reproduction in plants

Finding a mate can be very tricky if you are a plant. For this reason, asexual reproduction is more common in plants than in animals, and yet some plants have found a way to reproduce sexually.

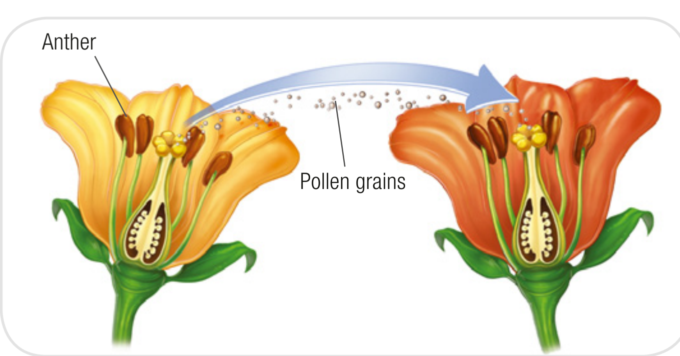
Flowers for sex

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

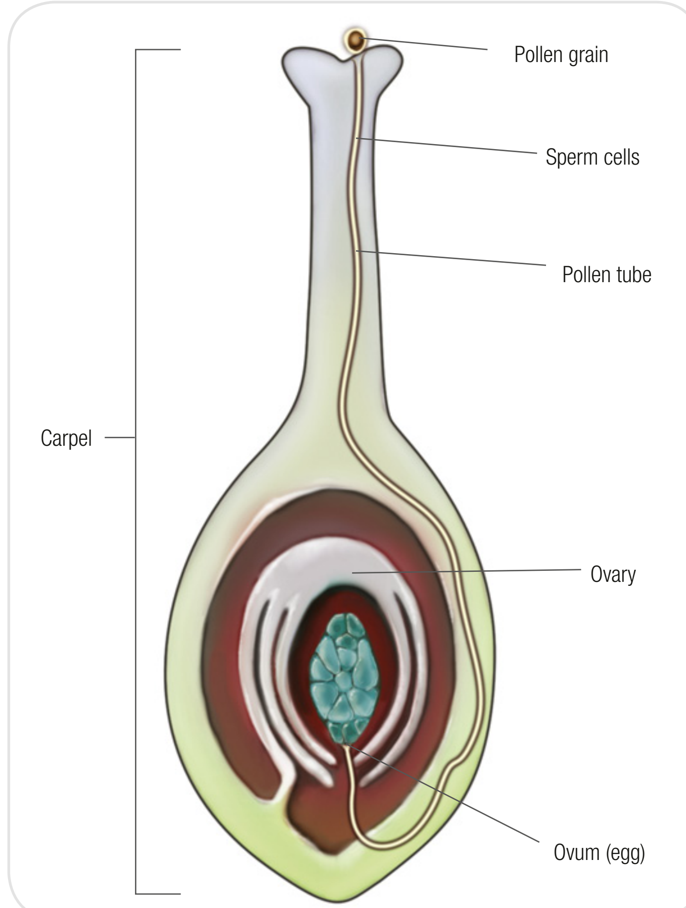
The female gamete, also called an ovum, is located at the base of the stigma inside the ovary. All these female parts together are called the **carpel**. For fertilisation to occur, the male gamete needs to find its way to the ovum. This requires **pollination**, the process of pollen attaching to the stigma and 'digging' a pollen tube down to the ovary.



→ Fig 2.53 Basic structure of a flower.



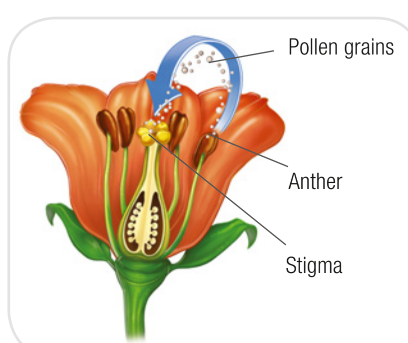
→ Fig 2.55 Cross-pollination.



→ Fig 2.54 Structure of the carpel with key structures labelled.

Flowers need assistance from other organisms (insects, birds or mammals) or the environment (wind or rain) for pollination to occur. **Self-pollination** involves pollen from a flower landing on its own stigma or that of another flower on the same plant. **Cross-pollination** occurs when pollen from a flower lands on the stigma of a flower on a different plant, producing greater variation. Just like animals, the pollen from one flower can only fertilise flowers from the same or similar species.

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



→ Fig 2.56 Self-pollination.

Not all flowers are the same

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

→ Fig 2.57 Rafflesia.

The colour of a flower is also important for attracting pollinators. Birds tend to pollinate red flowers, whereas insects may be more attracted to a wide range of colours. Mammals that feed at night will rely on strong scents and not on colour at all.

→ Fig 2.58 Bottlebrush.

Some flowers have modified structures to suit their pollinators. Birds may damage flowers with their sharp beaks when they drink the nectar, so flowers need to be strong. Insects can be small and need to be forced to brush against pollen, followed by the stigma, so the flower may be full of obstacles or simply a tight fit.

→ Fig 2.59 Daffodil.

EXPERIMENT 2.4

Flower dissection

Aim

To examine the main parts of a flower.

Materials

A flower (you can dissect any type of flower available; lilies and fuchsias are a good choice)

Scalpel blade or sharp knife

Newspaper

Hand lens

Method

1 Place the newspaper on the bench.
2 Cut the flower off the stalk.
3 Observe the flower. Identify the main parts of the flower from Figure 2.52.
4 Gently remove the sepals and petals.
5 Look for the stamen with anthers at the top. The anthers hold the pollen. You should be able to dust some pollen onto your finger.
6 Cut off the male parts at the bottom of the petal.
7 Observe the female part of the flower. It has the stigma at the top and the ovary at the bottom.
8 Cut the ovary lengthwise. In it you will see tiny white scales, which are the ovules. When the ova inside the ovules are fertilised by the pollen, they will grow to become seeds and the ovary will grow to become the fruit.
9 Clean up your bench by wrapping the flower in the newspaper. Wash your hands.

Results

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

Discussion

1 What colour is the filament (the stem of the stamen)? Why do you think this is?
2 How easy was it to clean the pollen from your fingers? Is this good for the flower?
3 How were the male and female parts arranged to encourage pollination? Explain.
4 Do you think the flower is more likely to be self-pollinated or cross-pollinated? Explain.
5 Do you think pollination is more likely to be by wind, water or animals? Explain.

Conclusion

What do you know about the parts of a flower?

Sexual spores

If you've ever had a good look at a fern you will have noticed that its leaves are usually quite different from the leaves of flowering plants. You will often see brown patches on the underside of fern fronds. These brown patches are specialised cells that make and release spores onto the ground. The **spores** are tiny reproductive structures that then grow into tiny heart-shaped plants called prothalli that are made up of male and female reproductive organs. Male and female gametes are produced and released when it rains to hopefully find a match for fertilisation. The little plant then dies, but the fertilised eggs grow into new ferns.

→ Fig 2.60 Fern 'sori' produce spores for reproduction.

→ Fig 2.61 Mosses also produce spores for sexual reproduction.

Vegetative reproduction

Asexual reproduction in plants is generally referred to as **vegetative reproduction**. Similar to the term vegetable, this refers to all non-flower parts of a plant. Vegetative reproduction generally involves a part of the plant breaking off and surviving as a new organism with no need for spores or seeds—a bit like fragmentation, but with structures that have been grown specifically to be broken off.

Vegetative structures include:

- plantlets—tiny plants that grow on either the parent stem or leaf or on roots

- adventitious buds—form shoots on roots

- suckers—roots that specifically head towards the ground's surface and produce shoots

- rhizomes—underground stems

- stolons (also known as runners)—stems running along the ground

- bulbs—these develop into segments as they grow, with each segment eventually capable of living separately

- tubers—grow on roots and can sprout into new plants

- corms—can be broken into pieces, each of which is capable of producing a new plant.

What do you know about reproduction in plants?

1. What is the name of the structure that holds a plant's sexual reproductive systems?
2. What is the difference between self-pollination and cross-pollination? Which produces more variety?
3. How is fertilisation different from pollination?
4. Draw a circular flow diagram using the following terms: *flower*, *pollen*, *seed*, *fruit*, *pollination*, *fertilisation*, *ovum*, *pollen*, *ovary* and *anther*.
5. Why are some flowers attractive and others tiny and plain?
6. How is a spore like a seed? How is it different?
7. Plants that are successful weeds often use both sexual and asexual reproduction. Mint is common in herb gardens and reproduces with little flowers as well as rhizomes. Why would it be difficult to get rid of mint once it has spread through a garden bed?

Influencing reproduction

It seems to be human nature to find ways to interfere with and influence various aspects of nature. Reproduction is certainly no exception.

There are many situations in which we wish to encourage reproduction. For example, when a human couple wants to have a baby and encounters troubles, technology can intervene; when a species is threatened with extinction, technology can reduce the threat; when certain features or characteristics are favoured, humans step in to influence the outcome; and when reproduction is just not an option, something can be done to prevent it.

Human reproduction

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

Unborn babies can be screened for problems. The amniotic fluid that protects the growing foetus can be tested (amniocentesis), as can the cells of the placenta (chorionic villus sampling). The problem with these tests is that they involve inserting a big needle into the belly, which may result in an infection or may interfere with the pregnancy, risking more problems than can be diagnosed. Thankfully, many issues can be spotted in an ultrasound—a lovely picture of what's going on inside, complete with heartbeats!

→ Fig 2.62 In IVF, eggs are injected with sperm for fertilisation.

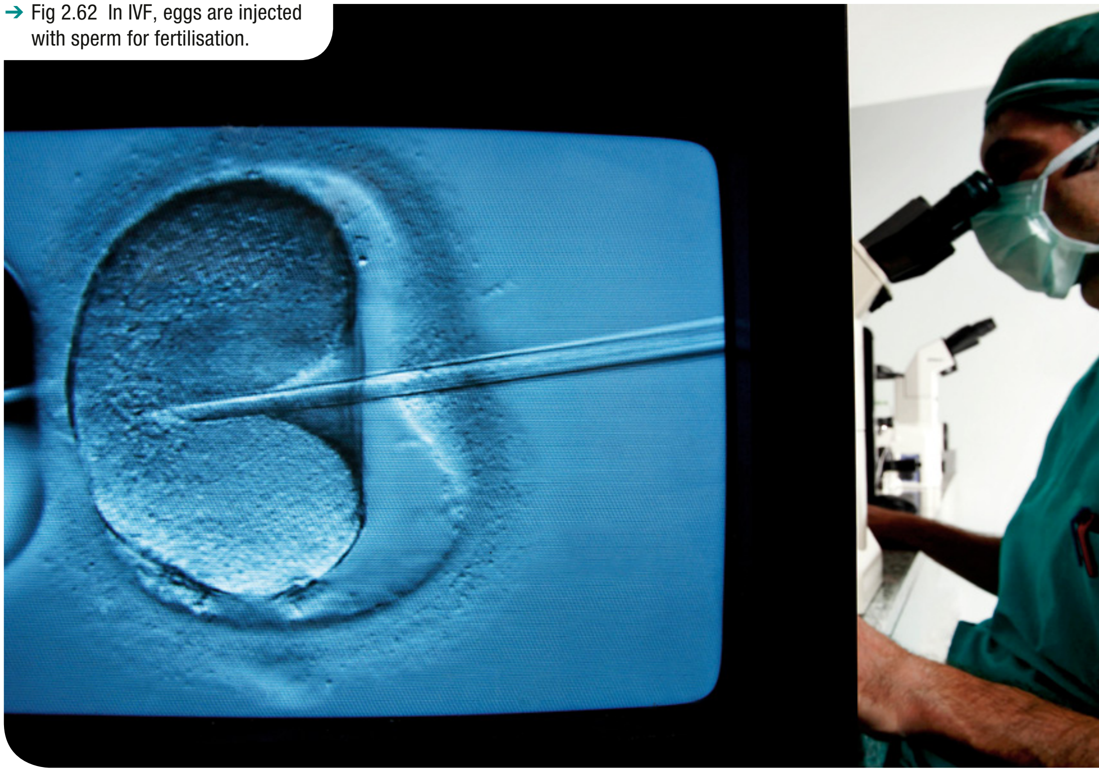


Fig 2.63 Ultrasounds allow the developing foetus to be seen.

Fig 2.64 Captive breeding programs are helping to save the bilby.

Preserving biodiversity

Humans rely on the diverse range of living things (biodiversity) for food, transport, tourism and even inspiration, so it's really important that we try to stop species becoming extinct.

Many scientists work out in the wild to try to help different organisms, but the most intensive programs are often happening in our zoos and sanctuaries. These are the captive-breeding programs.

When an animal is in a zoo, specialists of all types can observe and help the animal to breed. They might try to make the environment ideal or bring animals together at just the right time or even try animal IVF!

Selective breeding

There are many examples of animals and plants being bred to keep, lose or enhance characteristics by people choosing the 'partners'. For example, a cow that is known to produce lots of milk would be chosen to breed with a bull that is known to produce healthy, strong offspring. This would mean that there's a great chance of any female offspring being good milk producers and any male offspring being good meat producers.

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

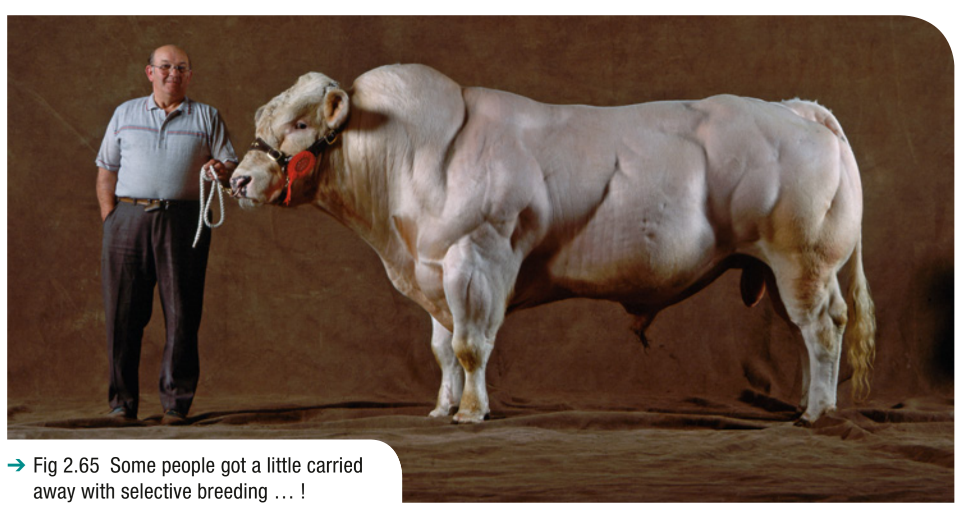


Fig 2.65 Some people got a little carried away with selective breeding … !

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

→ Fig 2.66 Labradors are known to have hip problems as the result of many years of inbreeding.

LITERACY LAB

Reproduction on a farm

Meet Farmers Al and Deb: they will tell us a bit about life on a farm, modern agriculture, careers and how important a knowledge of life cycles is to agricultural practices.

Please tell us a bit about your farm.

We have 50 hectares in the Granite Belt region of Queensland, an area well known for its orchards, vineyards and National Parks. Our farm is a mixed enterprise, with livestock, herb production and tourism combining to give us an enjoyable lifestyle, as well as a small income. Our aim is to work the farm along healthy chemical-free lines, trying to work with nature rather than against it.

What kinds of animals do you breed on the farm?

We breed sheep and cattle at Shadowbox Farm. More specifically, we breed Murray Gray cattle for yearling beef production and Poll Dorset x Suffolk ewes to produce fat lambs. On occasion, some of our cows produce too much milk for their calves, so we milk them ourselves and use the milk to make cheese, butter and ice cream. Our sheep produce wool and have to be shorn each October. However, the wool is not the good-quality fleece produced by Merino sheep and, when sold, barely covers the cost of the shearing. On the other hand, their lambs are very strong and robust. They grow very quickly and are highly desirable when they go to market. We also breed goats, chickens and horses, but in such small numbers that they do not contribute to our income. They do, however, contribute to the pleasure of working around the farm, like a hobby.

What is *agriculture* exactly?

Agriculture is, in broad terms, primary production. Any natural organic thing that can be grown or produced falls into the basket, whether it be animals like sheep, cattle and deer, or plants like wheat, flowers, herbs, fruit, vegetables and trees, or insects like honey bees, or fish like trout and salmon. Agriculture is basically the production of the very things humans need to stay alive—food, raw materials for clothing and timber for building and furniture making.

What do you like about working and living on a farm?

Farm life gives us a sense of achievement on a daily basis. There is never a reason to be bored. There are always many jobs and chores that must be prioritised and performed. We must work with the weather and time of year to determine what happens each day. Also, as a farmer, you tend to have a strong sense of community. We know just about everybody who lives within 5 kilometres in any direction and they know us. Theft is almost unheard of and doors are rarely locked. We all help each other when the need arises. We can't imagine living in a city or suburb where the sense of community has been forgotten.

Can you study to be a farmer?

A great many skills are required by a farmer, including mechanical, veterinary, engineering, financial and scientific. Researching, record keeping and workplace health and safety knowledge is also extremely important. As a result, there are many courses and training institutions around Australia to help young people into rural industries.

Where did you study? What kind of course did you do?

Debbie grew up on a dairy farm north of Brisbane where they milked 200 cows on 100 acres and, after the death of her father, established her own agistment business. Animal husbandry (management) has always been a huge part of Debbie's life. My own tertiary education was a 3-year Diploma of Applied Science in Agriculture course at Longerenong Agricultural College, Horsham, Victoria. People I graduated with went into Rural Banking, Stock and Station Agencies, the RSPCA, CSIRO, the Department of Primary Industries, agricultural research companies, agricultural chemical companies and, of course, farms. Those farms included dairy, poultry, beef, sheep, vegetable, orchard, vineyards, grain and herbs.

What advice can you give people interested in agriculture as a career?

If you are self-motivated and enjoy working to your own timetable, then perhaps life on a farm might suit you. A great deal of money is required to own or establish a farm (often in the millions), but many farms require managers and staff and are run like any other large business in the city. This means that there are opportunities for people with the right qualifications and skills to do very well in the rural sector.

How important is it for farmers to know about animals' life cycles? Can you give us an example or two from your farm?

Cycles are key factors to consider in any agricultural enterprise. If you are growing vegetables, planting too soon after winter can result in complete loss due to late frosts. Planting too late means the plant will cycle too quickly, often going to seed before producing a crop. So the farmer must work with the cycle of the season and the crop. This is also true of livestock production. The gestation (length of pregnancy) of various animals is different. Horses need 11 months, cattle 9 months and sheep 5 months. So it is important to join them (get them pregnant) at a time of year that allows the newborn the best chance of survival, and to grow fast enough for the market you are aiming for. For example, joining ewes at the start of February will mean the lambs are born in June—the coolest part of the year with the poorest nutrition in the feed. This would not give your lambs the best opportunity to survive and thrive. Joining in June would give you lambs in October, with warmer temperatures and better feed available in the paddocks. They would also have a good 7 months to grow before the next winter.

The cycles of drought and flooding rain are also important to remember. There are many, many good times to be had on a farm and lots of wonderful things that happen. But there is also heartache and hard times when each day seems harsher than the one before and, despite your best efforts, losses come to your crops and livestock. Resilience has always been the way of the Australian farmer—to bounce back, to take the losses in your stride and get on with it. Farming is hard work but, like everything else that is not easy, getting it right is very, very satisfying.

1 Read Farmer Al's definition of agriculture, then define it in your own words.

2 What examples are given about the importance of understanding the life cycle of plants and animals in agriculture?

3 Why is breeding animals at the right time so important?

4 How do you think scientific skills, knowledge and understanding would assist you as a farmer?

Contraception and desexing

It may sound silly, but many animals in captivity are on some form of **contraception** to stop them getting pregnant. This may be to control inbreeding, allow selective breeding or simply because there's not enough room or resources for more animals in the facility.

Desexing is a permanent contraceptive that involves either the male or female having their reproductive tubes 'tied', or blocked, or removed altogether.

Animals that are pets are very commonly required by local councils to be desexed. Cats, for example, often wander freely during the day and have many opportunities to breed with other cats in the neighbourhood—but who will look after all the kittens? If everyone's cats were free to breed, the neighbourhood would soon be swarming with kittens!

→ Fig 2.67 It's not a very happy life for domestic animals without food or shelter.

What do you know about influencing reproduction?

1. What is a test tube baby?
2. Why are babies less likely to be born with problems now compared with 50 years ago?
3. What is biodiversity? Why is it so important to preserve biodiversity?
4. Describe three examples of selective breeding.
5. Is selective breeding always a good idea?
6. Explain, in your own words, why it is necessary for zookeepers to control the reproduction of animals in the zoo.

Working with the RSPCA

LITERACY LAB

The RSPCA is a community-based charity, famous across Australia for its work with and for animals. Unlike humans, animals do not have a voice and so they cannot ask for help. The RSPCA is one of the best 'voices' for animals and their rights. One of the RSPCA's biggest campaigns is about desexing, mostly to do with cats. Every year, approximately 60 000 cats are brought in to the RSPCA; of these, over half have to be put down.

Task

Create a mathematical model (or diagram) demonstrating how many cats can be produced from two fertile cats. This task is exponential, meaning that when the two cats reach six months of age they can start to breed and, after 60 weeks, will have a litter of four kittens, after six months these four kittens will also be able to have kittens themselves and so on. Cats can start the breeding cycle almost straight after having kittens, which means, on average, cats can have three litters of kittens a year.

Include a graph that shows the growth of numbers of cats against time.

Questions to consider

1. Explain what desexing is and why it is important.
2. Based on your calculations, how many cats were produced after four years?
3. How would desexing the first mating pair change your results?
4. Do you think this was a 'fair test'? Explain the reasons for your answer.
5. What other factors could affect the number of cats?
6. Why do you think the RSPCA takes in so many more cats than dogs?

2.3 How are new organisms made?

Remember and understand

1 What is the scientific term for 'making new organisms'?

2 What is a gamete?

3 What are the common names for the two gametes in animals? In plants?

4 What is the difference between a foetus and a baby?

5 Which produces greater variation: sexual or asexual reproduction?

6 What is the function of a fruit?

7 Why do organisms that fertilise internally tend to produce fewer eggs than those that fertilise externally?

Apply

8 Use your understanding of sexual dimorphism to describe three features that differ between a male and a female in humans. Describe three that may differ in birds.

9 A farmer grows two types of corn on the farm. One type is terribly affected by the frosts in winter but produces really large, juicy corn cobs when it is protected. The other copes in winter without a problem but has only average corn cobs. What could the farmer do to improve his crops?

→ Fig 2.68 These dogs are from the same litter.

Analyse and evaluate

10 Examine the images in Figure 2.68, then give two features that are genetic and two that are environmental.

11 If a hermaphrodite reproduced alone, would it be considered sexual or asexual reproduction? Explain.

12 Skinks drop their tails when threatened, but their tails can grow back. Is this a type of asexual reproduction? Explain.

13 Some reptile eggs are affected by the temperatures they experience while incubating in the nest. For example, Within a single nest, the temperature may vary enough to produce a mix of both. How might warmer weather as a result of the enhanced greenhouse effect impact Green Sea Turtle populations?

→ Fig 2.69 Green Sea Turtle eggs produce female babies when the eggs are warmer and male babies when the eggs are cooler.

Critical and creative thinking

14 The life cycles and reproductive strategies of invertebrates are incredibly diverse. Choose an invertebrate to research and present your findings in the form of a poster or webpage to present to the class. Research projects could be shared in a mini-conference format.

<<CONNECTING IDEAS>> Structure and function

15 Humans don't reproduce asexually—ever. What consequences may there be if a human were able to reproduce asexually? What consequences may there be if many humans were able to reproduce asexually?

>>ZOOMING OUT<<

Research

Choose one of the following topics for a research project. A few guiding questions have been provided to get you started. Use a format that presents your findings in an informative and attractive way.

Huangdi Neijing

Research the *Huangdi Neijing*, also known as *The Inner Canon of Huangdi* or *Yellow Emperor's Inner Canon*. The *Huangdi Neijing* is an ancient Chinese medical text that has been used as the fundamental doctrinal source for Chinese medicine for more than two millennia.

Medical ethics

Research the term *medical ethics*. What does the term *ethics* mean? What practices have been found to be unethical and why? Find an example of a controversial medical treatment and outline both sides of the story.

Liver lover

You may have heard that drinking too much alcohol can damage your liver. Why is this? How much alcohol is too much alcohol? What does your liver do? What happens when it can't do its job anymore?

Tetanus and botulism

Tetanus and botulism are both progressive diseases of the muscles caused by a toxin from bacteria. Tetanus causes your muscles to contract and stay contracted. Botulism won't let your muscles contract at all. How do you think these diseases would affect the different parts of the body? Use the Internet and other sources to find out if you're correct.

Reflect

Me

1 What were the three most surprising things you learned about body systems?
2 What new laboratory skills did you learn?
3 What aspects of body systems would you like to investigate further?
4 What questions do you still have about how your body works?

My world

5 How do you think health conditions around the world compare to those in Australia?
6 How do you think health conditions where you live compare to those of Indigenous Australians living in isolated parts of Australia?

My future

7 What can you do now to keep your body healthy for many years to come?

Review

Key words

alveoli
anatomy
artery
asexual reproduction
asthma
blood
blood vessel
breathing
capillary
contraception
cross-pollination
digestion
digestive tract
dissection
emphysema
enzyme
excretion
fertilisation
foetus
fragmentation
gamete
gas exchange
ermaphrodite
in vitro fertilisation (IVF)
metabolism
nephron
nutrient
thenogenesis
pepsin
pollination
reproduction
respiration
selective breeding
self-pollination
sexual reproduction
spore
valve
vegetative reproduction
vein
zygote

2

Functioning organisms

David Blaine is an illusionist and 'endurance artist' from America. He is famous for feats that subject the human body to extreme conditions, such as being buried alive, encased in ice, living inside a bubble and hanging upside down for a long period of time.

In order to complete our work looking at the structure and function of the major body systems, we will use examples where David's body systems have become impaired or even shut down.

Crazy stunt #1: 'drowned alive'

On 1 May 2006, David Blaine was submerged in a 2.4-m diameter water-filled sphere in front of the Lincoln Center in New York for a planned 7 days and 7 nights, using tubes for air and nutrition. During his time in the sphere, David attracted large crowds and visits from celebrities like Chris Rock and Courteney Cox. During the stunt, doctors witnessed skin breakdown on David's hands and feet, as well as liver failure. In an interview, David spoke of the week-long fasting he did before the 'drowning alive' stunt to prevent the need to deal with solid waste issues. To deal with his urine, David wore an external, condom-style catheter.

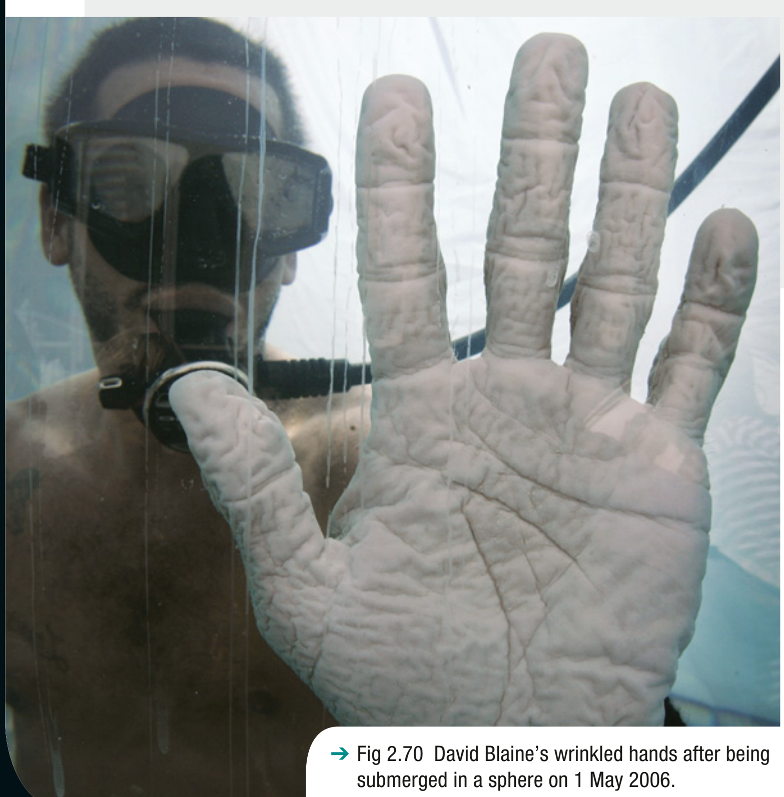


Fig 2.70 David Blaine's wrinkled hands after being submerged in a sphere on 1 May 2006.

Crazy stunt #2: holding his breath for 7 minutes

David concluded his 'drowned alive' stunt by attempting to hold his breath underwater to break the world record of 8 minutes, 58 seconds. He also decided that while attempting to break this record he would try to free himself from the shackles of handcuffs and chains. Blaine held his breath for 7 minutes, 8 seconds before showing signs of unconsciousness and had to be pulled out—failing in his attempt.

→ Fig 2.71 David Blaine holding his breath for seven minutes.

Crazy stunt #3: frozen in time

In 2000, David Blaine was 'frozen in time'—he was trapped in a massive block of ice located in Times Square, New York. He was only lightly dressed and seen to be shivering even before being sealed in by huge blocks of ice. One tube supplied him with air and water and another removed his urine. David was encased in the box of ice for 63 hours, 42 minutes, 15 seconds before being removed. The ice was transparent and resting on an elevated platform to show that David was actually inside the ice the entire time. David was eventually cut out of the ice (very carefully, with chainsaws). He emerged dazed and disoriented, was wrapped in blankets and, of course, taken to hospital. He later said that it took 'a month' before he was able to walk again.

→ Fig 2.72 David Blaine frozen in a block of ice in Times Square, New York, 2000.

1. What happened to David's body after being submerged for too long?
2. Which body systems suffered due to David's submersion and why?
3. Which system(s) is the liver a part of? Why was liver failure so dangerous to David?
4. Why did David start to lose consciousness?
5. Which systems would have suffered due to his holding his breath stunt?
6. How have the respiratory system and circulatory system been designed to work together?
7. Why was his 'frozen in time' stunt shorter than his 'drowned alive' stunt?

David's next challenge is ...

Design a new challenge for David. Although you may be tempted to tell him to take up golf or collect teapots, he would probably just ignore you anyway, so let's make his next challenge a daring one that will affect his body systems!

David's new task: select a new task for David

From what you know about the major body systems, write to David preparing him for what may happen to his body and warning him of the risks (which he will promptly ignore).

3 Making things happen

3.1 How do we experience energy?

→ Fig 3.1 All our electronic gadgets rely on electricity to run.

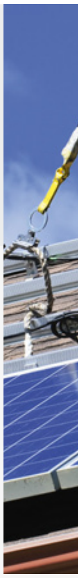
Energy is fundamental to our lives. It sustains life and, in some cases, such as a serious car crash, it can take life away. The food we eat contains the energy, or fuel, we need every day for our bodies to function correctly. We use electrical energy every day at home and at school. Our iPods and mobile phones rely on the energy stored in their batteries to work. Without energy there would be no life. So, what is energy and where does it come from? Have you ever attempted to explain energy to someone? What would you say?

1 Try explaining to someone in your class what energy means to you. Let them explain it to you. Which explanation is better and why?

2 What other forms of energy can you think of?

3 Is there an endless supply of energy on Earth or do you think it will run out one day? What is the evidence for your opinion?

3.2 How does energy change from one type to another?



Is it sunny outside today? If it is, your school or home could benefit from solar panels on the roof to transform the sunlight into usable electricity. This electricity could power the lights, computers, cooling or heating system—in fact, anything connected to a power point could run off the solar panels.

A solar panel system at home could pay for itself after 4–7 years and may last approximately 25 years. The electrical energy generated by the solar energy can be used in a wide range of appliances. In many of these appliances, the electrical energy will need to be changed—or transformed—one or more times for the appliance to do its job. For example, a toaster changes electrical energy into thermal (heat) energy.

We often use the word *energy* in our daily conversations, saying things like ‘I’ve got so much energy today!’ or ‘I feel drained of energy’. How do you feel when you say you have a lot of energy? How do you feel when you say you don’t have any energy? Energy is hard to define. Even scientists struggle to find a neat, single sentence to define energy because it is such a big, big idea and relates to so many different areas of science. One thing that all scientists agree on is that energy appears in different forms and makes things happen. Without energy nothing would move, nothing would change and nothing would happen. Energy cannot be created, nor can it be destroyed. However, it can change (we say it is ***transformed***) from one form into another.

→ Fig 3.2 Installing solar panels on your roof could make a big difference to your electricity bills. It is something your household should consider?

1 What do you think is meant by the term *pay for itself*?
2 Are there any problems that could happen with a solar panel array on the roof of your house?
3 What maintenance do you think solar panels would need?
4 What devices in your home need a supply of electrical energy? Do any have non-electric options? (For example, a whisk or wooden spoon could be used instead of an electric mixer in the kitchen.)

3.3 What is an engineer?

Our modern world is filled with many human-made inventions, constructions and designs. Have you ever stopped to think about who is responsible for the changes in technology, the way buildings are made and the way we live today? Who had the idea of distributing electricity around the country? Who thought of communicating by the air through television and radio? A lot of everyday tasks, like washing clothes, cooking and cleaning, have been simplified with new gadgets and time-saving machines. Transport is fast and efficient, with roads, bridges and cars constantly changing to make moving around the city and country trouble free. Because of their understanding of how to use energy efficiently, engineers have contributed to all these advances, as well as many we don’t see in our everyday lives.

1 Imagine you are living in 2100. How do you think you would travel to school?
2 What do you think will be the most significant change to the lives of people who live in your town or city in the year 2100?
3 Why do engineers need a good understanding of energy and how to use it?

→ Fig 3.3 Engineers create solutions to improve our lives.

3.1

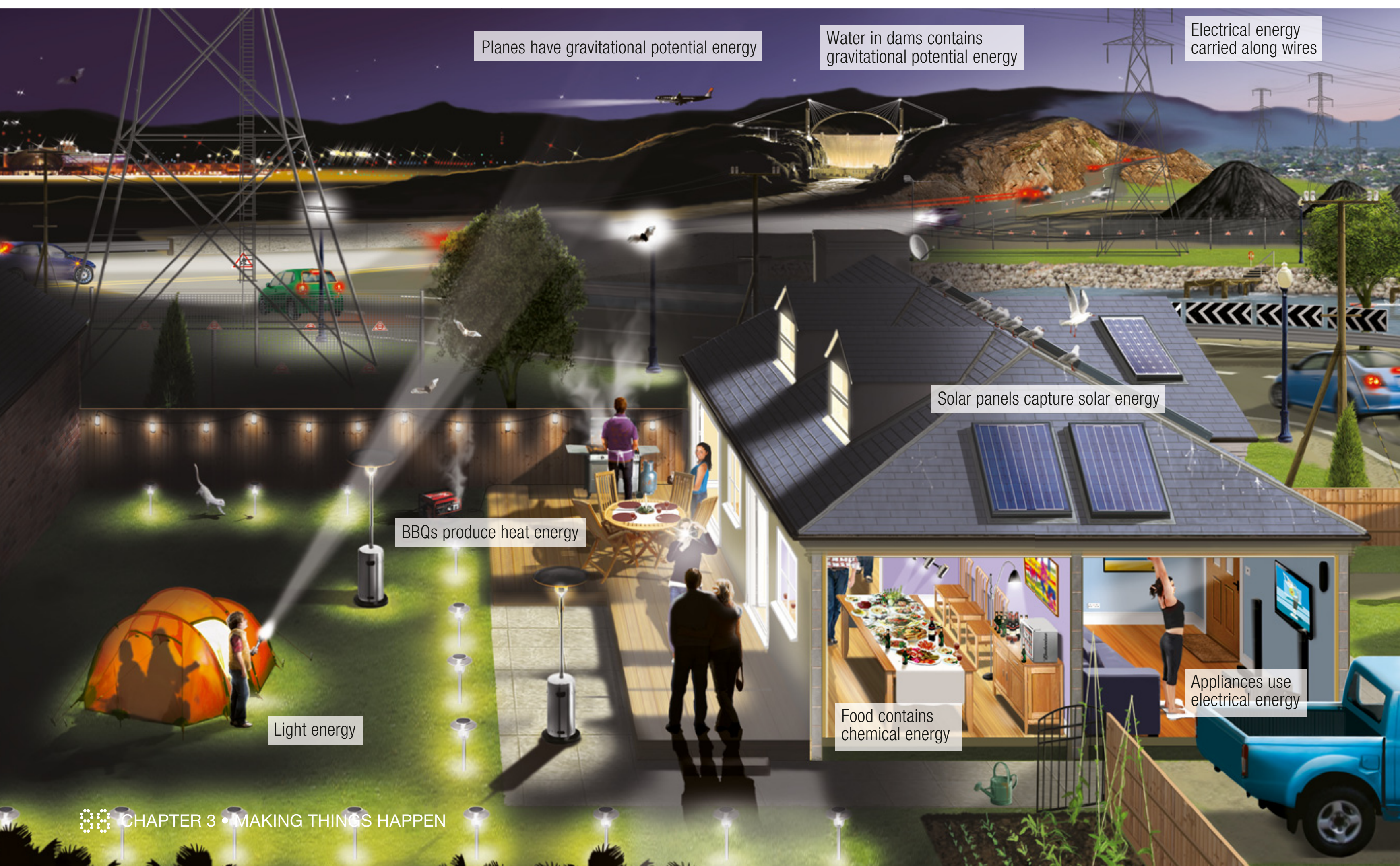
How do we experience energy?

Energy is all around us. We use electrical energy to wash our clothes, to keep our food cool and to watch television. We use thermal energy (heat) to cook our food and to heat our homes and water. Light energy helps us see when it is dark, and sound energy brings our favourite music to our ears. Without access to so many forms of energy, our 21st century lifestyles would be more like those of early humans. These are just a few examples of different types of energy. We experience the effects of energy every time something happens—for something to happen, energy is required. However, what happens exactly depends on the type and amount of energy involved.

Common types of energy

When you think about where you see **energy**, it's probably related to electricity. It is becoming more common to read and hear about how we need to be more energy efficient in our lives and, in these cases, the media are usually referring to us switching off lights.

→ Fig 3.4 Examples of energy use in the modern world.



<<DISCOVERING IDEAS>>

Different forms of energy

Figure 3.4 shows some different types of energy and examples of how we use each one in our everyday lives. Spend some time exploring this image.

1 In small groups, look at Figure 3.4 and identify as many types of energy shown as possible.

2 For each type of energy, can you think of another example?

3 X, Y and Z in Figure 3.4 do not have labels. Can you identify what type of energy is being used?

4 Create your own energy illustration showing either the energy you use every day or the energy used by a fictitious character, celebrity or other person.

→ Fig 3.5 Kerosene lamps were used for many years before the invention of electricity.

Light energy

Have you ever taken part in Earth hour, when people all across the world turn off their lights for one hour at night? It's actually a lot of fun. People light candles instead of using electric lights or they sit in the dark.

Light energy is essential to our lives and people have invented lots of devices to help us see in the dark. The humble electric light bulb revolutionised the world. Oil and gas lamps were popular in the old days and a torch helps us see at night when we go camping. But the best source of light is, of course, our Sun.

Sunlight

It takes just 8 minutes for the Sun's energy to travel the 146 million kilometres to Earth. The Sun gives off more energy in 1 second than the total energy ever used on Earth! The main reason life exists on Earth and not on other planets is because our atmosphere allows the right amounts of the different forms of light energy coming from the Sun to reach the surface. Plants rely on the light and heat from the Sun to make their own food and, of course, to provide food for animals.

→ Fig 3.6 Sunlight is essential for all life on Earth. Without it, it is doubtful whether life would exist.

Electric lighting

Humans have been using light energy for thousands of years in both simple and complex gadgets, but the most obvious use of light is for illumination. You may be using light for this purpose right now. What types of light globes are installed in the room you are in? Fluorescent tubes are common in schools. These are long glass tubes filled with mercury gas. This type of light globe doesn't generate heat, so it is more efficient than the older-style incandescent (or filament) light globes and uses less electricity. The Australian government phased out the sale of **incandescent** light bulbs from November 2009, replacing them with **compact fluorescent lights** (CFLs), which are used as an energy-saving alternative. Most CFLs are designed to replace existing filament globes and fit in the same sockets. The CFLs use less power than the filament globes and last much longer. **Light-emitting diodes** (LEDs) are also being used extensively for illumination in torches, traffic lights and garden lighting.

The relatively recent invention of **solar cells** to turn light from the Sun directly into electricity is now used to power many devices, such as calculators, street lights and even cars.

→ Fig 3.7 Compact fluorescent lights (CFLs) are an energy-saving form of lighting.

→ Fig 3.8 Solar-powered speed signs are becoming common all across our country and help save energy too.

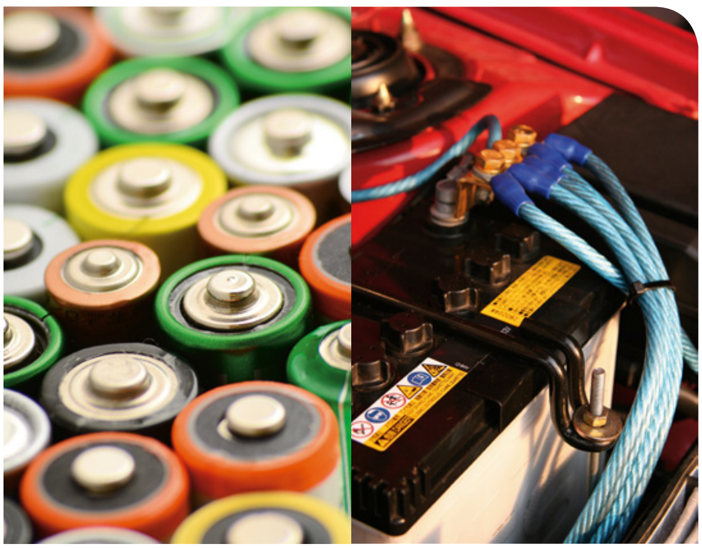
Heat energy

Heat is one of the best known of our energy types. We crave it in winter and we can get overwhelmed by it in summer. Heat energy is more scientifically known as **thermal energy**. Thermal energy can be generated by friction, such as rubbing your hands together or the rubbing of the tyres on the road. It is also commonly generated by burning chemicals or by electrical devices. We experience heat energy being transferred from one place to another as we heat up or cool down.

→ Fig 3.9 The heat of a 'burn-out' creates great clouds of smoke.

Electrical energy

All substances are made up of positive and negative electric charges that, when separated, have **electrical energy**—they are in a state of excitement and the positive and negative charges try to get back together again, just like the poles of magnets. If the charges are contained in a certain area, such as a wire, the separated charges can easily move back together. As they do so, the electrical energy they had as a result of being separated gets changed into some other form, such as light or heat energy. Chemical batteries use a chemical reaction to continually separate charges to produce electricity. Generators use magnetism to separate charges.



→ Fig 3.10 The chemical potential energy in batteries can be transformed into electrical energy to power almost anything.

What do you know about common types of energy?

1 Why does life exist on Earth and not on other planets?
2 Where does the energy in sunlight come from?
3 What advantages do CFLs offer over incandescent globes?
4 What other examples of light energy can you think of? (Hint: Think of devices that give out or use light energy.)
5 What are solar cells used for?
6 How is a battery different from a generator in how it produces electrical energy?

Potential energy

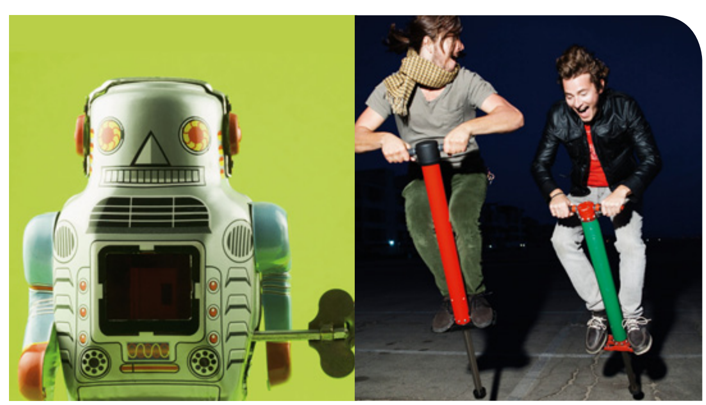
You've probably been told at some stage that you have 'shown potential', perhaps while playing a sport. What that means is you have demonstrated that you still have room for improvement—you've got more in you. **Potential energy** is similar—it is energy that is stored in objects and is waiting to be used. This stored energy can be the result of a change of shape (stretching or squashing) or an object's height above the ground.

→ Fig 3.11 Power riser jumping stilts rely on elastic potential energy.

Elastic potential energy

A trampoline has the ability to 'store' energy, or hold it, for later use or if things change. The springs and the mat of the trampoline stretch under our weight and hold this stored energy. The more they stretch, the more energy they hold. The energy is returned to our bodies when the springs and mat return to normal and throw us into the air. Energy that is stored through stretching or squashing is called **elastic potential energy**.

A bow and arrow is another example of energy being stored in this way. When the bow is stretched it holds elastic energy. When the bow is released, it pushes the arrow forward. Wind-up toys that you may have played with as a child work in a similar way. You wind up the spring inside the toy and, when you let go, it releases its stored energy. Springs have the advantage that they can be compressed (squashed) and stretched and so can work in opposite ways.



→ Fig 3.12 Wind-up toys (left) and pogo sticks (right) release the elastic energy of springs to provide motion.

Rubber band boats

What you need

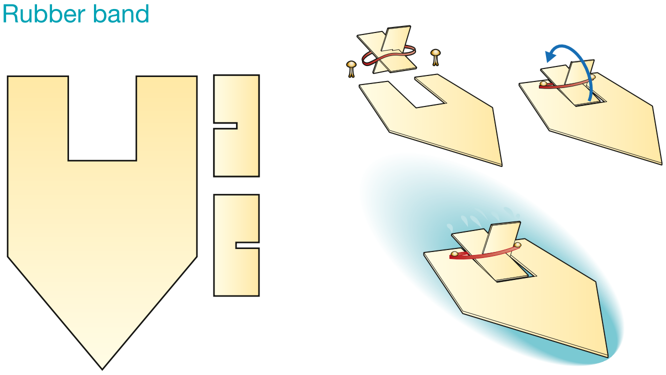
Waxed cardboard (milk cartons work well)

Water bath or swimming pool

Scissors

Butterfly pins

Rubber band



➔ Fig 3.13 The parts and method of assembly for a rubber band boat.

What to do

1. Cut out the waxed cardboard to match the diagram in Figure 3.13.
2. Put the rubber band around the propeller and attach it to the boat using butterfly pins.
3. Wind the propeller anticlockwise, place the boat in the water and release it.

Questions to consider

1. What happened to the boat when the propeller was released?
2. What type of energy is involved?
3. Is this potential energy? Explain.
4. How could you make the boat travel further? How are you changing the energy when you do this?

Gravitational potential energy

If we lift an object up to a height, it gains **gravitational potential energy** (abbreviated to just 'GPE').

➔ Fig 3.14 This television has GPE when raised above the ground.

The larger the mass and the larger the height, the more GPE the object gains. Have you ever noticed that falling a greater distance produces a greater 'thud' and can hurt more? This is because of the amount of GPE. As an object falls under the influence of gravity, the object's GPE can be transformed into other forms of energy. This happens when a child plays on a slide at the playground. As the child climbs up the ladder, their GPE increases. As the child comes down the slide, their GPE decreases but they go faster. The child may also feel the friction of the slide as heat or even as a zap of static electrical energy.

➔ Fig 3.15 Plastic slides are great at zapping us with static electricity, although it depends on the weather and the clothes we wear too.

Chemical potential energy

After we have done a lot of exercise, we often crave foods that we believe will restore our energy levels. These foods, usually sweet things, release stored chemical energy really quickly to satisfy our cravings. All foods have some energy stored in them, but the difference is how quickly the energy can be released. Energy drinks have become really popular in recent years, but do people drink them because they need the chemical potential energy these drinks contain?

→ Fig 3.16 Energy drinks do contain a lot of chemical potential energy, but they also contain other ingredients you may want to avoid.

Fuels, such as natural gas and petrol, provide us with energy too. A Bunsen burner uses the burning of natural gas to provide heat in the laboratory so you can perform your experiments. Petrol has chemical energy stored in it, as do explosives and batteries.

These devices all contain chemical potential energy that can be released when we need it. Some batteries can be recharged—the **chemical potential energy** (CPE) can be replaced. Your iPod and mobile phone batteries can be recharged many times without damage because they transform between chemical and electrical energy.

→ Fig 3.17 The chemical potential energy in dynamite can be released when the fuse is lit.

PRACTIVITY 3.2

Fruit and vegetable batteries

What you need

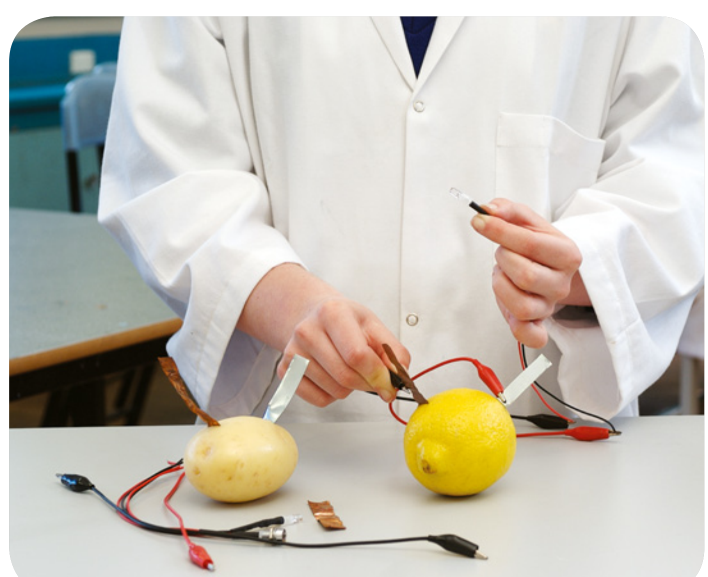
Copper metal (foil or uninsulated wire fine)
Galvanised nails
4 lemons per group
6 alligator clip leads (short)
LED (light emitting diode)
Multimeter (optional)

What to do

1 Roll lemons to soften skin and squeeze juice a little, within the lemon.
2 Slit the lemons and insert the copper foil. Use a marker to indicate positive +. At the opposite end of the lemon insert the galvanised nail and mark as negative –.
3 Connect the alligator leads from + copper to the – galvanised nail, along the lemons in series.
4 Connect alligator leads to the last copper and galvanised nail. Connect the lead connected from the copper, to the positive side of the LED (the long leg of the LED). Connect the galvanised nail lead to the negative side of the LED (short leg on LED). The LED will not glow if it is connected the wrong way around.
5 Darken the room and look carefully at the LED. It should have a faint glow.

Questions to consider

1 How is the lemon able to act like a battery?
2 How do you think a lemon can allow electricity to pass through it?



Biomass energy

Biomass energy is energy that is stored in plants and animals—it's a type of chemical potential energy. The most common way of releasing biomass energy is by burning the material, such as burning wood to produce heat. Another common use of biomass energy is to ferment the sugar of various plants to produce **ethanol** (pure alcohol). The ethanol can be used as a **biofuel**—biomass energy that is burned to power machines. In Australia, we sell petrol for cars that contains 10% ethanol. The bus company Ventura has several ethanol-powered buses that run on ethanol produced from sugar cane waste, producing significantly less emissions. These brightly coloured buses can be found travelling around Melbourne powered only by biofuel!

→ Fig 3.18 Some Ventura buses run on biofuel.

EXPERIMENT 3.1

Bio-power!

Aim

To discover the energy content of a Cheezel. (Note: A biscuit or marshmallow could also be used.)

Materials

Cheezels
Cork
Needle or short metal wire
Heat-proof mat
150-mL beaker
Water
Tripod and gauze mat
Thermometer
Long matches or oven lighter

Method

1 Push the eye of the needle into one end of the cork.
2 Now carefully push a Cheezel onto the sharp end of the needle, making sure you do not break it.
3 Place the cork with the Cheezel upright on the heat-proof mat.
4 Pour 20 mL water into the beaker and record the temperature.
5 Place the beaker of water on the gauze mat and tripod so that it is immediately above the Cheezel.
6 Light the Cheezel, using a long match or oven lighter. (It may take a while to catch alight.)
7 Allow the Cheezel to burn for 5 minutes or until it has gone out. During this time, record the temperature of the water every minute.

Results

Complete the following table for your results, using the formula below for calculating energy.

The amount of energy generated by burning the Cheezel is:

Energy (joules) = volume of water (mL) × 4.2 × change in temperature

Nuclear energy

Although nuclear energy is used throughout the world, it is not used in Australia at the moment. **Nuclear energy** involves the reaction of the nuclei of atoms. When atoms react in chemical reactions, they usually release only small amounts of energy. However, if the centres or nuclei of those atoms can be made to react, the amount of energy released is much, much larger. In fact, the amount of energy released is so huge that it can cause massive amounts of destruction. Australia is concerned about the risks associated with nuclear energy and will endeavour to find solutions before considering a nuclear power plant.

Nuclear power can also be used in explosive weapons and some countries in the world (but, again, not Australia) possess such weapons. Thankfully, they are not used very often because their destructive power is huge!

Fig 3.19 The energy released from a nuclear explosion is much, much greater than that from other types of explosions.

Table 3.1

Time (min)	Temperature (°C)	Volume of water (mL)	Energy generated (J)
0		100	
1		100	

Discussion

1. How does this experiment demonstrate how biofuels can be used to create energy?
2. What does this experiment suggest about Cheezels as an energy source for humans?
3. What type of energy does this experiment investigate?
4. What do you see as the difference between *chemical potential energy* and *biomass energy*?
5. How could you improve or alter this experiment?

Conclusion

What do you know about the energy content of a Cheezel?

What do you know about potential energy?

1. List four examples of devices or situations that involve potential energy.
2. What is an advantage of using 10% ethanol as a fuel source instead of just normal petrol?
3. Describe four devices, other than those mentioned already, that possess elastic energy.
4. What are some things that can go wrong with nuclear power?
5. Research the destructive power of modern nuclear weapons and compare them with the bombs dropped on Hiroshima and Nagasaki in Japan in 1945.
6. Find out which countries in the world are the major users of nuclear power.

Movement energy

The energy of movement is more scientifically called **kinetic energy** (KE). You have been using kinetic energy today and every day since you were born. Whenever objects or people move, they are using kinetic energy. The heavier an object is and the faster it is moving, the more kinetic energy it has. A fully laden truck travelling at 60 km/h has much more kinetic energy than a family car travelling at the same speed. This can be awful if the two come together in an accident. Cars are often designed with safety features to absorb the kinetic energy of a collision. Even a car's brakes are designed to absorb the kinetic energy and slow the car down safely.

Sound energy

Have you been at a very loud concert and stood near the huge speakers? If so, you will remember that you not only heard the deep bass sound, but also felt it in your body. You can feel the same vibrations in the car if you put your hand on the dashboard when the sound system is on full blast. Sound is made when things vibrate. Every time you make a sound—whether it be playing a musical instrument or speaking or singing or even whispering—you are making vibrations. Vibrations are simply tiny movements back and forth. Vibrations can occur in gases, liquids and solid things such as speakers … even the desk in front of you. Energy is needed to make sound. For example, unless a drummer uses energy to hit the drums, the drum skin will not start to vibrate and will not make a sound. So, do you think sound is really **sound energy** or a type of kinetic energy?

Sound energy

What you need

Tuning fork

Wooden table or wooden box

Acoustic guitar

Electric guitar

What to do

1. Hit a tuning fork on the sole of your shoe and then listen to the sound it makes.
2. Now repeat that process, but hold the tuning fork so it is standing on a wooden table or wooden box. What difference did the table make to the loudness of the sound?
3. Do it again, but see if you can feel the table or box vibrating this time. Why do you think this may have happened?
4. If possible, compare the sound of an electric unplugged guitar to that of an acoustic guitar. Which is louder? Why do you think this is so?
5. Now place your hand on the body of the acoustic guitar as it is played. Can you feel the vibrations? What about with the electric guitar? Does this help you explain why the acoustic guitar may be louder?

Questions to consider

1. How do you change the way you play a recorder so that it gives out more sound energy?
2. How does a pianist manage to play some notes softly and others very loudly?
3. When you want to yell or speak louder, how do you make the sound coming from your mouth louder?
4. How do drummers make their drums sound louder?

What do you know about movement energy?

1. What is the scientific term for *movement energy*?
2. When a person plays a musical instrument, what energy transformation is usually involved? (Give your answer as: From ________________ energy into ________________ energy.) Are all instruments exactly the same from this point of view?
3. When did you use kinetic energy today?
4. What features of a car would absorb:
   a. the car's kinetic energy in a collision?
   b. the driver's and passengers' kinetic energy in a collision?

3.1 How do we experience energy?

Remember and understand

1 Match these words and phrases with their correct meanings:

Word/Phrase	Meaning
Solar cells	The energy stored in a compressed spring
Nuclear energy	Another name for stored energy
Biomass energy	The energy of an object when lifted up
Elastic energy	Used widely throughout the world to generate electricity from atoms
Kinetic energy	Used to transform light energy into electrical energy
Gravitational energy	Possessed by all moving objects
Potential energy	Energy stored in plants and animals

2 Are the following true or false? For false statements, rewrite them to make them correct.
- **a** Springs only hold stored energy when they are stretched.
- **b** Nuclear energy provides much, much more energy than chemical reactions.
- **c** When an object is thrown up in the air it gains gravitational potential energy.
- **d** Sound energy is a type of potential energy.
- **e** Petrol contains nuclear energy.

3 What is the main form of energy in each of the following situations?
- **a** water flowing slowly over a waterfall
- **b** crops growing in the fields
- **c** the sun coming in through a window on a sunny day
- **d** a boy riding his skateboard
- **e** a stretched rubber band
- **f** a racing car travelling around the race track
- **g** a litre of petrol
- **h** a mobile phone battery
- **i** a clap of thunder
- **j** a stick of dynamite
- **k** a rollercoaster at the highest point of the ride
- **l** a rollercoaster at the lowest point of the ride

Apply

4 Visit a local playground and examine the play equipment. Take a digital photo of each piece of equipment and work out what types of energy are demonstrated as a child plays on each piece of equipment.

5 Examine ten electrical appliances you have at home and identify the energy type(s) each appliance is designed to produce. Record your findings in a table.

Analyse and evaluate

6 Compare the different forms of energy and what we use them for. Create a table with appropriate headings that allows you to quickly look up each type of energy.

7 The main job of a car travelling on the road is to produce kinetic energy in its wheels. What other parts of a car may demonstrate kinetic energy?

8 Think of your day today. How many different energy forms have you come across, possessed, used or witnessed? List them in order of use during the day. Which one was the most common and why?

<<BIG IDEAS>> Energy

Critical and creative thinking

9 Energy comes in many different forms. Create a poster that illustrates each type of energy with visual examples.

10 The massive earthquake and tsunami in Japan in March 2011 caused extensive damage to the Fukushima nuclear power plant, north of Tokyo, and created an emergency situation. Research this disaster and present a 2-minute news report to the class that highlights the issues surrounding the use of nuclear energy.

<<CONNECTING IDEAS>> Energy

11 Energy types rarely exist alone. They are always on the move, making things happen. Think about some of the things energy is responsible for. For each, identify the type or types of energy involved. If more than one type of energy is involved, link the different types with arrows. Try to include as many different scenarios as you can.

3.2

How does energy change from one type to another?

We use a huge range of devices every day. Some devices, such as earphones, produce sound. Some produce light or use light to analyse something, such as a barcode scanner at the supermarket. Others produce heat to cook our food or to dry and style our hair. Some don't perform any of these functions but help us in other ways, like recharging the batteries that power our mobile phones and iPods or storing or processing information, as in computers. All these devices are **energy transformers** because they convert one type of energy into another.

<<DISCOVERING IDEAS>>

Energy converters

Consider each device in the following table, the energy it uses to work (the energy input) and the useful energy it produces (the energy output).

1 Work in groups to fill in the gaps in the table.

Device	Energy input	Energy output
Drum		Sound
Hydroelectricity	Gravitational	
	Electrical	Sound
Light bulb		Light
Battery	Chemical	
Car engine		Kinetic
	Elastic	Kinetic
Gas heater		Heat
	Nuclear	Light
Solar panel	Solar energy	
Phone charger		Electrical

2 Discuss any patterns you see in the table. For example, are there any energy types that are more commonly 'inputs' rather than 'outputs'?

3 Extend the list with five more devices your group comes up with.

Energy jargon

Before investigating energy transformations any further, there are a few things you need to know.

Flow diagrams

How do we represent an energy transformation scientifically? Flow diagrams that use an arrow to represent the transformation process help with this idea:

1 The arrow points in the direction of the transformation.
2 The energy input is written at the back of the arrow.
3 The useful energy output is written at the tip of the arrow.

For example, the battery in a mobile phone transforms chemical energy into electrical energy. The previous sentence describes this energy transformation, but using a flow diagram it would be:

Chemical energy → Electrical energy

Sometimes there is more than one energy output, so we try to concentrate on the main one. Minor energy outputs are known as by-products. Think how you would write the energy transformation in a light bulb. What is the energy input? What is the main energy output? Is there a by-product (wasted energy)?

In some devices there are several energy transformations that make up an energy story, resulting in an energy chain. For example, the energy story in an iPod would be as described in the following sentences:

> The chemical energy stored in the battery is transformed into electrical energy. The electrical energy flows through the wires to the headphones, where it is transformed into kinetic energy as the tiny speakers in the headphones vibrate. This is then transformed into sound energy, which our ears pick up.

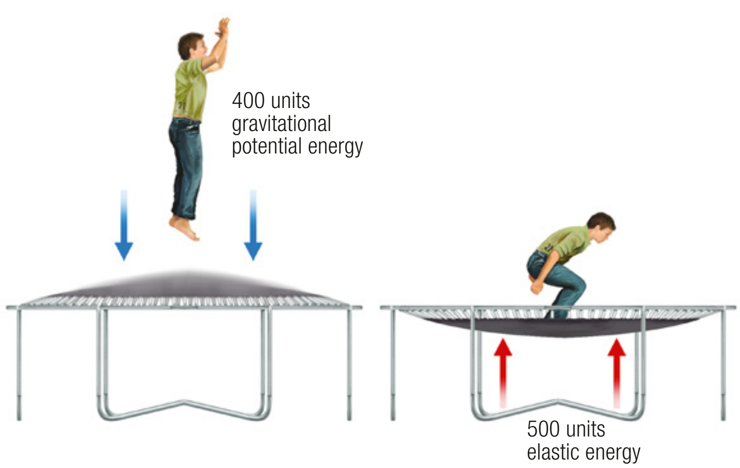
As a flow diagram, this energy chain would be:

→ Fig 3.20

Law of conservation of energy

Energy cannot be created or destroyed. This is called the **law of conservation of energy** and can be seen in any energy transformation.

If all the input energy could be added up and compared with all the output energy, it would always be the same. The total energy remains constant, but the type of energy will change—what goes in must come out!



→ Fig 3.21 500 units of energy are stored in the springs of the trampoline. At the highest point, the jumper has 400 units of gravitational potential energy. Where have the 100 'missing' units gone?

Energy efficiency

If a device like a trampoline transforms most of its input energy into the most useful output energy, then it is considered to be a very energy-efficient device. The less 'wasted' energy, the more energy-efficient the device. **Energy efficiency** is a calculation of the percentage of useful energy transformed.

Take the trampoline example in Fig. 3.21. The input energy was 500 units and the useful output energy was 400 units. This means that the trampoline is 400 ÷ 500 = 0.8, or 80%, efficient, which is not too bad. Most energy transformations for everyday appliances don't get this high. Scientists are constantly trying to design the best appliances possible with the highest efficiency ratings. This would make them better for the environment and cost less to power. Do you and your family always buy the most efficient appliances? Are you familiar with the star ratings on appliances? More stars mean that the appliance is more energy efficient. Not only is it good to know that less energy is being wasted, but it also means that, on your electricity and gas bills, you are paying for energy that is being used rather than for energy that is being thrown away.

NUMERACY LAB

Percentages

Percentages are just a measure of how two numbers relate to each other as if they were out of 100. The percentage symbol is %. To calculate what percentage A is out of B, you must first divide A by B then multiply your answer by 100.

Example

If you got a mark of 16 (A) out of 20 (B) in a test, as a percentage it's as if the test was out of 100. Remember to write the two numbers as a fraction then multiply by 100.

So, 16 out of 20 is $\frac{16}{20} \times 100 = 80\%$

Your turn

Calculate the percentage of the following:

1 14 out of 50 **2** 32 out of 60 **3** 19 out of 25

Answers **1** 28% **2** 53% **3** 76%

What do you know about energy jargon?

1. If you release a rubber band that had 10 units of elastic energy, 12 units of movement energy cannot be produced. Why not?
2. For the rubber band in question 1, what would its percentage efficiency be if 7 units of movement energy were produced? Where have the remaining 3 units of energy gone?
3. Draw a flow diagram for the main energy transformation for a car.
4. What are the by-product energy transformations for a car?
5. Draw an energy chain for how we get our energy from eating an apple. (Hint: Start with the Sun!)

Transformations for heat

The most important **energy transformations** in our lives are those that keep us comfortable, reduce our stress and entertain our brains. Let's begin with comfort—this usually means heat for vanity, food and body warmth.

A hairdryer has two basic components: a fan and a heating element. When plugged in and switched on, the fan motor spins and the heating element heats up. So, a hairdryer converts electrical energy into heat energy and kinetic energy. The air blown by the fan is directed over the heating element, generating warm air, which flows out of the hairdryer. Some hairdryers have different speed and heat settings that control the amount of electrical energy flowing to each part of the device.

Other heating devices, such as toasters, also use heating elements to convert electrical energy into heat energy. Heating elements are made of certain types of wires that heat up without melting when electricity flows through them.

Microwave ovens cleverly convert electrical energy into microwaves, which heat our food. Electric ovens are like oversized toasters and can have a fan in them, as does a hairdryer. Gas ovens and stoves use the chemical energy of the gas to produce heat by burning the gas. All these devices are very common and, in fact, our homes wouldn't be much use to us without our energy converters.

No doubt your house has some sort of heating or cooling system, depending on where you live. Electricity can be used to heat your home or water supply, but burning natural gas is another option, as is harnessing solar energy. All these heating and cooling devices are energy converters. If you wave a piece of cardboard in front of your face to cool yourself down, you are converting energy: the chemical energy inside your muscles is converted into kinetic energy (i.e. the movement of your hand) to assist the movement of thermal energy from your face into the surrounding air.

EXPERIMENT 3.2

Making an electric jug

Aim

To make an electric jug.

Materials

Power supply	Pencil
Thermometer	250-mL beaker
Heat-proof mat	Two connecting wires
Alligator clips	Blu-Tack

Approximately 70 cm of nichrome wire

Warning! **Do not allow the two alligator clips to touch while the power is on!**

Method

1. Coil the nichrome wire around the pencil, leaving a 10 cm straight section of wire at each end. Check that the coil will fit into the beaker.
2. Stand the beaker on the heat-proof mat and add 50 mL water to the beaker, ensuring the nichrome coil remains below the water level.
3. Connect the straight sections of the nichrome wire to a power supply set on 12 V DC and switch on the power. Use the Blu-Tack to hold the set-up in place on the top edges of the beaker.
4. Put the thermometer near the base of the beaker and check the temperature. Check the temperature again after 2, 4, 6, 8 and 10 minutes.

Results

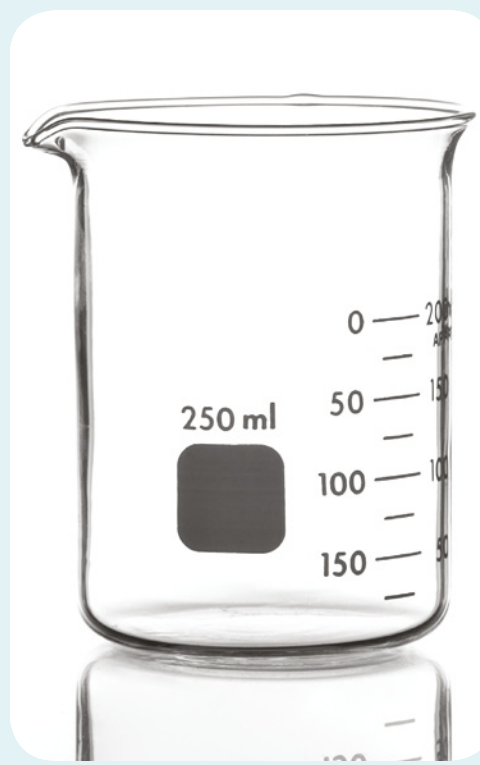
Record your results in a table, then convert these data to a time v. temperature line graph.

Discussion

1. What advantage does a coiled heating element have over a straight one?
2. Why must the two alligator clips not be allowed to touch while the power is on?
3. Approximately how long did it take for the water to get hot?
4. How could the speed of heating the water be improved?

Conclusion

What do you know about electric jugs?

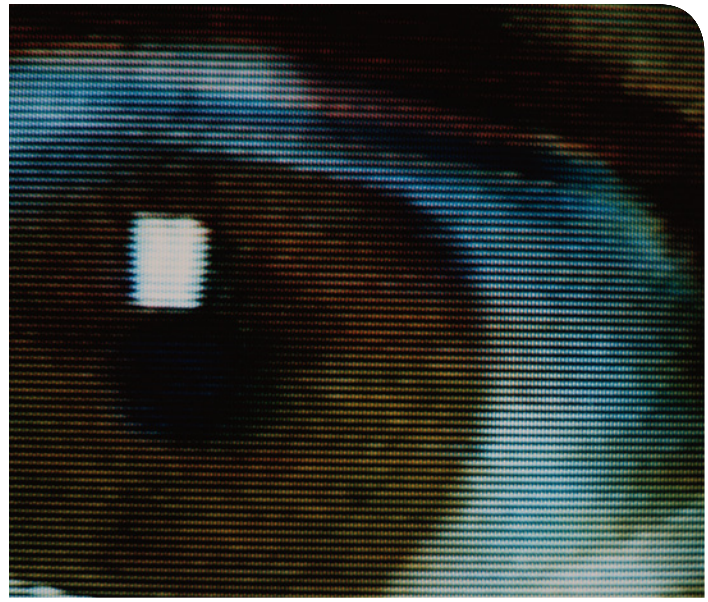


What do you know about transformations for heat?

1 How is electrical energy easily transformed into heat energy in a toaster or hairdryer? What other ways are possible of transforming electrical energy into heat energy?

2 Draw flow diagrams for the energy transformation process that happens in your house for:
  - a heating during winter
  - b cooling during summer.

3 A refrigerator cools the food inside it.
  - a How do you think it does this?
  - b Suggest possible energy transformations that may occur in a refrigerator.



→ Fig 3.22 The picture you see on the television screen is made up of thousands of coloured dots called pixels.

Transformations for entertainment

Humans are interesting creatures. They're one of the few animals in the animal kingdom that is known to do things just for fun. In fact, humans have taken entertainment to a whole new level. Massive amounts of time, energy and money are dedicated to entertaining ourselves.

These days, light is used extensively for entertainment. Television pictures are made up of thousands of dots of red, green and blue. The dots are known as pixels (one megapixel is one million pixels). When an electrical signal reaches them, the dots glow. Any colour can be produced by making different combinations of the dots glow with different combinations of brightness. To produce yellow, both the red and green dots glow. To make white, all three dots glow. Our eyes merge the colours from the dots together to make the colour we see. All the coloured dots over the entire screen merge to form the picture of the television show or DVD we are watching. There are LCD, plasma, LED and 3D televisions. Can you think of what the useful energy output of a television is?

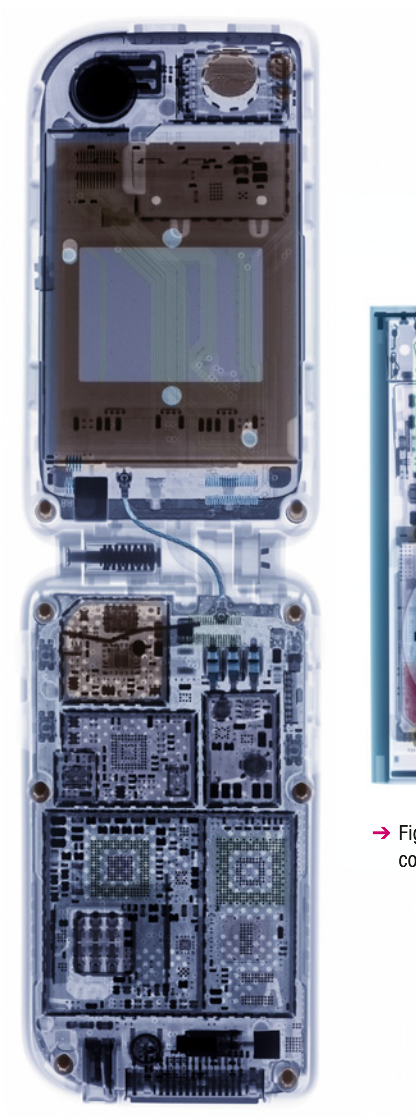
Both CD and DVD players use light energy from a laser to read the information stored on the CD or DVD. Tiny microscopic pits on the disc make up the digital code—a bit like a miniature version of Braille used by the visually impaired. The laser, which is a very pure type of light, reads the code, which is then transformed into sound, information or pictures. CD and DVD burners also use a laser but, instead of reading the code, the laser burns or etches the code onto the disc as a series of pits.

Speakers come in a range of sizes, from the tiny earphones that come with iPods or MP3 players to the huge speaker systems used at concerts. Earphones are simply a pair of tiny speakers that connect to an audio source. The music files stored on an iPod are transformed into electrical energy, which relies on the chemical energy in the battery. The wires carry the electrical energy and the tiny speakers transform the electrical energy into kinetic sound energy. If one or both of the wires break inside their plastic coating, the circuit will be broken and the speakers will stop working.

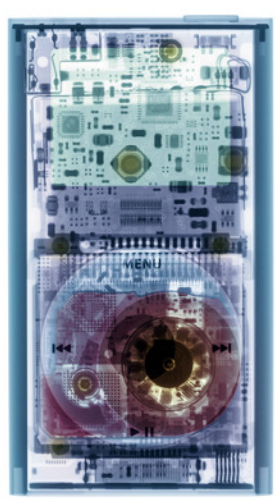
→ Fig 3.23 Earphones transform electrical energy into kinetic sound energy.

A mobile phone also uses a speaker to produce the sound of a person's voice or the various ring tones and beeps that the phone makes. Home phones use a speaker too, as do televisions, CD systems, radios and many other devices. They all transform electrical energy into sound energy.

The **microphone** in a mobile phone transforms the sound energy from our voice into electrical energy, which can then be sent as a radio wave signal to another phone. Nowadays, mobile phones have a lot of different parts inside them because of the number of jobs we want our phones to do. MP3 players also have a lot of parts and the amount of information that can be stored in them is increasing all the time.



➔ Fig 3.25 The internal components of a mobile phone.



➔ Fig 3.24 The internal components of an iPod.

A television **remote control** uses light energy to communicate with the television set. In fact, most remote controls use infrared light, which is the invisible type of light usually associated with heat. The remote control sends a pulse of infrared light that represents a particular command, such as to change the channel or increase the volume. An infrared light detector on the television receives the light signal and transforms it back into electrical energy, which then carries out the command.

➔ Fig 3.26 A television remote control uses an infrared LED to operate the television.

What do you know about transformations for entertainment?

1. Make a summary of the entertainment devices mentioned in this section and draw flow diagrams for the energy transformations they perform.
2. In addition to the examples already given, how else can light energy be used for entertainment?
3. What other remote control gadgets can you think of? Try to work out how they send their signals.

Transformations for transport

Transport is a vital part of our every day. Which form of transport did you use to get around today? Each form uses an energy conversion. Even walking uses energy. We know this because, when we walk a long way, we get very tired. Humans have invested a lot in improving transportation to reduce the energy they expend themselves. Getting from one place to another is much easier with a car and cars and trucks mean we can transport large quantities of goods in a short period of time.

→ Fig 3.27 Carrying materials can be made easier with machines.

When we ride a bicycle, the chemical energy stored in our bodies from the food we've eaten is transformed into kinetic energy and heat energy. A car engine also uses chemical energy that is stored in the petrol, converting it into sound, heat and electrical energy, but mainly into kinetic energy.

→ Fig 3.28 Cycling requires fuel from food, and by-products of heat and sound are produced by the rider.

Electric cars are being designed to run on the chemical energy stored in batteries, rather than petrol, to power an electric motor that makes the wheels turn. This will make electric cars less polluting and more energy efficient. **Hybrid cars** are already on our roads. These cars have both a petrol engine and an electric motor with large banks of batteries, usually under the floor. The Toyota Prius and the Hybrid Camry were two of the first hybrid cars on our roads, but many more are being designed. Plug-in cars that can be plugged into a power point at home to recharge their batteries overnight are also being designed.

→ Fig 3.29 Hybrid cars use both a petrol engine and an electric motor to send power to the wheels.

Public transport uses energy too. Trams and metropolitan trains convert electricity, harnessed from overhead wires, into kinetic energy to make them move.

→ Fig 3.30 Powerlines provide electrical energy for public transport.

Trains that travel to country areas or interstate usually run on diesel fuel and don’t need overhead electrical wires. The engines in these trains burn diesel fuel, transforming its chemical potential energy into kinetic energy. Ships and planes use a similar process in their engines.

➔ Fig 3.31 Powerlines aren't practical in rural areas, so diesel fuel is used.

➔ Fig 3.32 Aircraft use higher-quality fuels than road transport vehicles to minimise weight and waste.

Engine design is part of an engineer’s job. It is important to make the engines reliable (so they don’t break down) and efficient (so they can run for a long time on the minimum amount of fuel). These are challenges engineers need to face and overcome. Clever ideas are being trialled all the time to make more efficient engines for our transport requirements.

What do you know about transformations for transport?

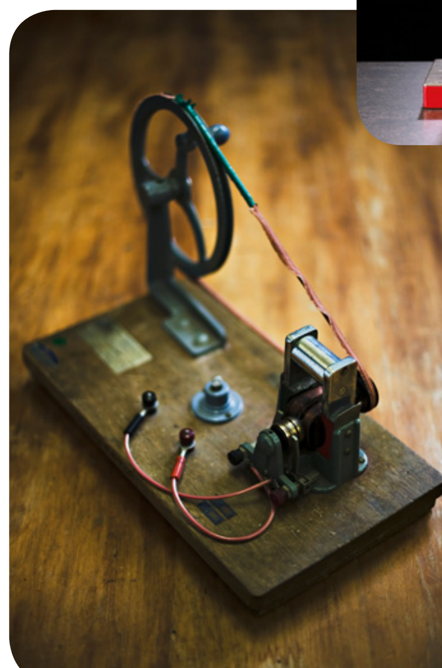
1 What advantages will electric cars have over petrol cars?
2 What is a hybrid car?
3 Why do country trains mostly use diesel instead of electrical wires?
4 How important is energy for transport?

PRACTIVITY 3.4

Investigating energy transformations

What you need

Model dynamo/generator
Model steam engine
Radiometer



What to do

1 Carefully identify the different parts of each of the devices shown above. In what ways are they similar? How do they differ?
2 Rotate the handle of the dynamo to make a lamp work.
3 Watch the model steam engine as it runs.
4 Shine a bright light on the vanes of the radiometer.

Questions to consider

1 What energy transformations are involved in each of the devices investigated?
2 Which of the devices is/are producing electrical energy? How do you know?
3 Suggest an application in the real world for each device.

3.2

How does energy change from one type to another?

Remember and understand

1 Name a device that transforms:
   a electrical energy into light energy
   b elastic energy into kinetic energy
   c electrical energy into sound energy
   d gravitational energy into electrical energy
   e kinetic energy into electrical energy
   f gravitational energy into elastic energy
   g chemical energy into light energy
   h light energy into electrical energy.

2 List the different types of light globe in order from most efficient to least efficient. Why are they so different?

3 List the different types of devices covered in this section and draw flow diagrams for the energy transformation processes they perform.

Apply

4 Use numbers in an example of your own to explain the law of conservation of energy.

5 Use numbers in an example of your own to explain energy efficiency.

Analyse and evaluate

6 Prepare and carry out an audit of your home lighting. How many of each type of light globe do you have? Could the lighting at your home be improved? Prepare a report with a summary of your findings and recommendations for improvement.

7 Research some of the advantages of LED lights.

8 Research on the Internet or at a hardware or lighting store and produce a costing for improving the lighting at your home based on your analysis in question 6.
   a Are there alternatives that would cost less?
   b What is the problem with expecting people to change their current lighting?

9 What is the percentage efficiency of a device if it transforms:
   a 20 units of input energy into 12 units of useful output energy?
   b 600 units of input energy into 500 units of useful output energy?

   In (a) and (b) above, where did the other energy (i.e. 8 units in (a) and 100 units in (b)) go?

Critical and creative thinking

10 Create an energy story that analyses the energy transformations in a device. There need to be at least four steps in the story. Convert your story into an energy chain, written in the correct format. Present your story and chain to the class in an entertaining and creative way.

<<CONNECTING IDEAS>> Energy

11 Many types of light energy were mentioned in this section and many other types of light energy exist. Research the electromagnetic spectrum. How does it organise light energy? Does visible light make up a large or small portion of this spectrum?

3.3

What is an engineer?

As our world's population continues to grow, the demands we are placing on the planet also increase. The need to use resources wisely and sustainably is becoming vital, and jobs are beginning to reflect these needs. Engineers invent gadgets and solutions to address these needs: they aspire to solve problems and to make the world a better place. Engineers make objects smaller, faster, healthier, cleaner, lighter, cheaper, more efficient, more sustainable and more environmentally responsible. Engineers are hands-on people. They use their scientific knowledge and maths skills to create solutions that improve our quality of life. All engineers need to have good communication skills: both written and oral. Engineers are good team members, but they are also able to solve problems on their own.

<<DISCOVERING IDEAS>>

Career choices

Copy the table below and interview your friends.

	Yes	No	Give an example
Do you like solving problems?			
Are you interested in how things work?			
Have you ever wanted to make something work better?			
Do you care about the environment?			
Do you want to help people live better?			
Would you like to put your ideas into action?			

1 What professions would accommodate the needs and interests of your friends?

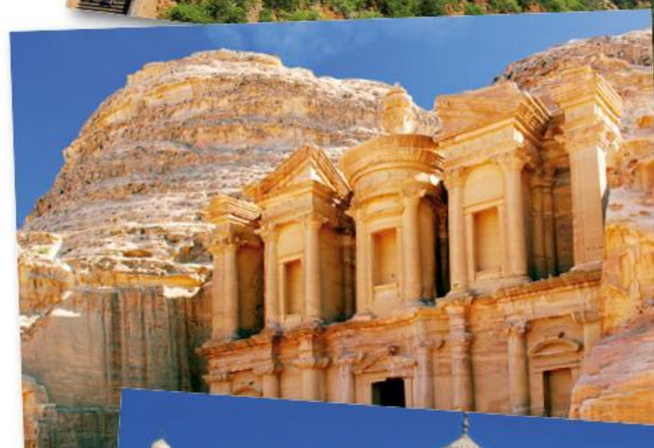
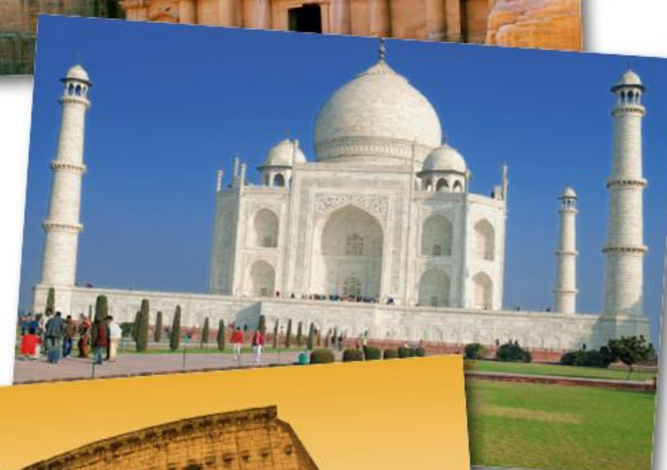
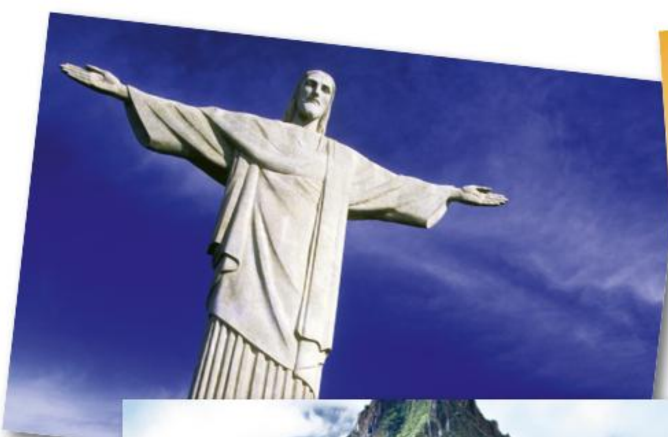
2 What professions might suit your needs and interests?

What are engineers?

The word *engineer* comes from the Latin words *ingeniator* or *ingenium*, which literally mean 'ingenious one'. **Engineers** provide solutions, shape future developments and generate ideas that make life easier. Some people regard the Great Wall of China to be one of the greatest engineering projects carried out by humans. Along with the Great Wall of China, six other amazing human-made engineering wonders were described as the New Seven Wonders of the World. These new wonders were chosen from a short list of 21 human-made structures and include:

- The Great Wall of China—a 6400-km long wall along China's northern borders
- Petra—an ancient city on the edge of the Arabian desert in Jordan
- Christ the Redeemer—a 38-m tall statue in Rio de Janeiro, Brazil
- Machu Picchu—a ruined city of the Incan civilisation in the Andes region of Peru
- Chichén Itzá—a temple city of the Mayan civilisation in Mexico
- The Colosseum—a sports stadium that could hold 50 000 spectators in Rome, Italy
- The Taj Mahal—a Muslim mausoleum in Agra, India.

All these New Seven Wonders of the World have been designed and built by people who are engineers.


→ Fig 3.33 The New Seven Wonders of the World.

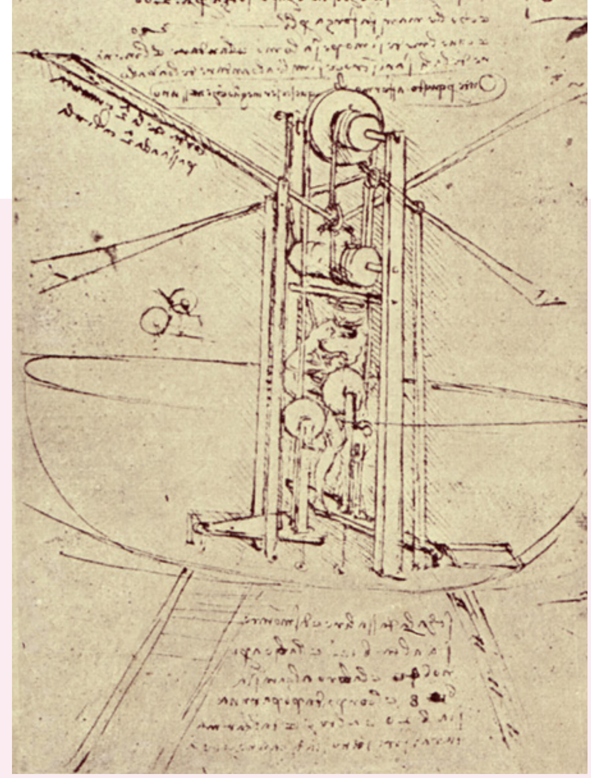
<<OVERARCHING IDEAS>>

The world's most famous engineer

Form and function, systems

Leonardo da Vinci lived from 1452 to 1519. He was, and still is, honoured as a great engineer, as well as a scientist and painter. Leonardo was curious about the world around him, keeping many journals of writings, observations and plans.

At one stage, Leonardo was employed as a military engineer, devising a plan to save Venice from attack. He was fascinated by flight, making observations of birds in flight and creating designs for a helicopter and hang-glider. Leonardo carefully analysed the form and function of materials before joining them in systems that harnessed and transformed energy according to his needs. As an engineer, Leonardo da Vinci conceived ideas that were ahead of his time. He was known as *the engineer general*.



➔ Fig 3.34 Leonardo da Vinci's design for a flying machine.

Different problems, different engineers

All engineers are problem solvers, but some know how to solve specific problems better than others. People who study to become an engineer choose an area of interest and concentrate their skills in that field. Just as you enjoy different sports and activities from other students in your class and at your school, different engineers are involved and associated with many different areas of your life. However, what they all have in common is a desire to 'invent', combining mathematics and creativity among other strengths.

Table 3.1 lists some of the types of engineers that have contributed to your life.

➔ Table 3.1 Types of engineers.

Field of engineering	Main area of interest
Civil engineer	Designs and develops infrastructure, like tall buildings, waste treatment, transportation and water-management systems, and manages construction projects
Electrical engineer	Applies the laws of electricity, light and magnetism to design and build power plants and power distribution grids, electronics and computers, DVD players and household appliances
Environmental engineer	Studies ways of protecting the environment, cleaning the environment and assessing the impact of human activity for sustainable development
Chemical engineer	Applies knowledge of chemistry to the manufacture, use and disposal of better plastics, medicines, materials and fertilisers
Mechanical engineer	Designs, manufactures and operates all things that move, from the microscopic parts of computers to gigantic gears, heating and refrigeration systems, biomechanics and automobiles
Other engineers	The traditional four fields of engineering have spawned many specialised engineering fields, including aerospace, biomedical, ceramic, computer and nuclear engineering

What do you know about engineers?

1 Why are there different types of engineers?

2 Connect these engineers with a description of their engineering field

Civil	Conserving and protecting the environment
Electrical	Designs things that move
Mechanical	Designs buildings, roads and bridges
Aerospace	Creates improved and safer materials
Environmental	Plans power distribution for a new housing estate
Chemical	Improves flying machines

3 On a map of the world, mark the location of each of the New Seven Wonders of the World.

  a Which is your favourite and why?

  b What type or types of engineer would be responsible for these wonders?

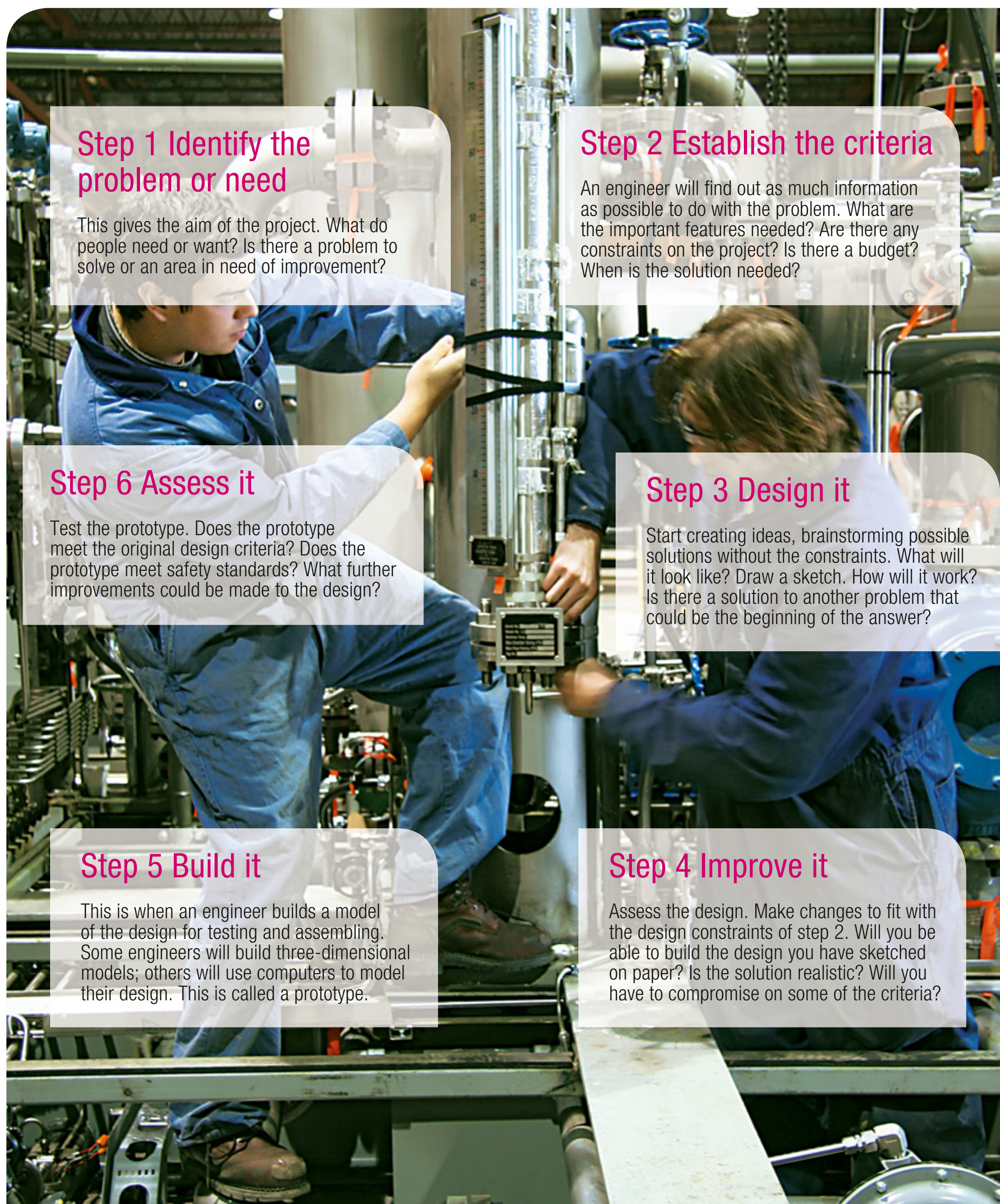
4 Which subjects that you currently study at school would be relevant to an engineering career?

5 Use the Internet or your library to find out about the many inventions Leonardo da Vinci drew. List these in your notebook, with a description of how they worked.

The engineering process

A large part of an engineer's work is problem solving. To help solve problems, all engineers follow a design process in the same way that a scientist uses a scientific method to carry out investigations. However, some engineering projects do not require all steps to be performed. The sequence of steps to follow when you design and evaluate a problem is shown in Figure 3.35.

Often an engineer will have to repeat some of these steps before the final solution is found. It is possible for the criteria to change or a better solution to be found when a prototype is being built and tested. This is what makes engineering exciting—solutions to problems are only limited by your imagination.



→ Fig 3.35 The engineering process.

DESIGN YOUR OWN ...

Aluminium foil boat

Challenge

Working in teams of four, and using the engineering design process on page 112, design and build a prototype aluminium foil boat that will successfully float and carry as much weight as possible.

Questioning and predicting

1 Identify the problem: to build an aluminium boat that can float and carry mass.

2 Establish criteria: you only have four 10-cm aluminium foil squares per group, sticky tape, some weights (e.g. coins) and a large bowl of water to test the boats. No other materials may be used in the design and construction.

Planning and conducting

3 Design it: what design features help a boat float? In your group, brainstorm boat designs. What shapes are best for a boat? Draw pictures of all your ideas. As a team, decide on which design you are going to build and test.

Processing, analysing and evaluating

4 Improve it: do you think your design will work? How many weights do you think your boat will hold before it sinks? Can you think of a better design?

5 Build it: now is the time to build your first boat, using only one of the sheets of aluminium foil. Label your boat 'prototype 1' with your group's name. Test your boat. Does it float? How many weights did your boat hold before it sank? Did it hold as many weights as you predicted? Record your results. Remove your boat from the water carefully as you may want to use it again.

Communicating

Consider the following questions as you communicate your work in a written report.

1 What did you learn about boat design from your prototype? How could your group's boat design be improved?

2 Return to the design process. With your new knowledge, how will you improve the design of your boat? Continue with the engineering design process until you have designed, built and tested four boats.

3 Which boat design held the most weight?

4 How did the loading of the weights affect the ability of the boat to float?

5 Are there any other areas of the design you would like to improve?

6 If you could use one other material in the boat, what would you choose and why? What would the boat look like?

YOUR ENGINEERING CHALLENGE (PART 1)

Leakywater Council swimming pool and waterslide

ENGINEERING STUDENTS WANTED

The Leakywater Council invites suitably qualified and experienced students to construct a prototype waterslide to supplement the Leakywater Olympic swimming pool. The prototype should comprise all parts of a successful waterslide that engages children of all ages in safe play.

A lot of engineering work begins as a *tender*, where a company, the government or an individual invites interested people to complete jobs. A response to a tender includes how you would like to complete the job and how much you would charge for your work. In this challenge, you will need to work as student engineers in a team and use the same problem-solving skills and creativity that real engineers use in finding a solution.

Applying the engineering process

Step 1 Identify the problem

Part of the problem has been presented to you in the newspaper announcement.

- What features do you think a waterslide should have? How many slides?

Step 2 Establish criteria

List the features of the waterslide in order of priority.

- What restrictions do you think the council would put on the design of a waterslide? (Remember that as a body loses height it loses gravitational potential energy and gains kinetic energy (i.e. it speeds up). You don't want the people travelling too fast on the slide.)

Step 3 Design it

Now it's time to be creative.

- What will your waterslide look like?
- Keep safety in mind. You don't want someone falling out of the slide halfway down.
- Don't make your design too complicated.

To build a waterslide prototype you will need to design a basic structure to support the slide. Designing structures is a big part of civil engineering and does not simply involve thinking up a design that looks good. The design also has to work and it must be made from the most suitable materials possible. Civil engineers also have to test their designs before they can be built. Civil engineers know about the physical properties of materials. They are interested in how different materials, such as wood, plastic, metal and ceramics, perform under different conditions. For example, tall buildings need to remain secure in high wind conditions and tunnels need to support forces from overhead rocks and soil.

EXPERIMENT 3.3

Investigating structures and materials using icy-pole sticks

Aim

To investigate the difference in strength of a material based on its orientation.

Materials

Icy-pole sticks (at least six per group)

A bucket with a handle

A second bucket full of water

100-mL measuring cylinder or jug

Two small blocks of timber with a 1.5-mm slot cut across them to hold the 'beam'

Warning! **It may be worthwhile performing this investigation outside or where the water will do the least amount of damage.**

Method

1. Place an icy-pole stick across the slots on the two blocks of timber to act as a 'beam' on its side.
2. Place the empty bucket at the centre of the 'beam'.
3. Add water to the bucket, 100 mL at a time. Record how much water is needed to make the 'beam' break.
4. Repeat this procedure twice more to determine an average breaking weight for the 'beam'.
5. Repeat the above process, but this time place the icy-pole stick flat across the two blocks of timber.
6. Record the amount of water needed to break this 'beam'.
7. Repeat twice more and calculate the average breaking weight for the flat 'beam'.

Results

Present your data and observations here.

Discussion

1. The 'beams' were both the same size. What comments can you make about the difference between the two ways the 'beams' were tested?
2. Were you surprised by the difference in how much water was needed to make the 'beams' break?
3. Which orientation do you think would be more suitable for construction? Use your investigation to justify your answer.

Conclusion

What do you know about how the strength of a material is affected by its orientation?

YOUR ENGINEERING CHALLENGE (PART 2)

Design a support structure for your waterslide prototype

You are now equipped with the knowledge to build a support structure for the waterslide prototype. Following the engineering design principles on page 112 (Fig. 3.35), and using icy-pole sticks, design and build a tower to support the model waterslide. How wide does your support tower need to be? How high will your model tower be?

Step 1 Identify the problem

Complete the following sentence:

- The prototype tower should be _____________ high and ________________ wide.

Step 2 Establish criteria

Your prototype tower will be constructed from icy-pole sticks and sticky tape.

- What sort of features should the structure of the waterslide have?
- Find examples of waterslides that show the types of designs you could use for your support structure.
- How do the examples support the slides?
- How do the examples provide access to the top of the slide?

Step 3 Design it

- What shapes are you going to use in the structure?
- How is the structure going to be held together?

Start with a sketch of the design. Remember to negotiate with the rest of your group—engineers must be able to work with other people.

Step 4 Improve it

Before you build the model, estimate the number of icy-pole sticks needed.

- What parts of the design may be difficult to build?
- Are there ways the model could be improved before you begin building?

Step 5 Build it

Follow your design and construct your prototype waterslide support structure.

- Is it as easy to build as you thought?
- Record any modifications you make to the design while building.

Step 6 Assess it

- Is the tower free standing?
- How much weight does the tower support? Does it need to be stronger?
- Is there any room for improvement? What other materials could be used to improve the performance of the tower?

Return to the beginning of the design process if the tower does not perform as desired or the tower does not meet the design criteria.

Chemical engineers

In addition to the structural aspects, there are many other engineering questions that must also be considered in any engineering project. For example, if your project needed electricity to make it work, electrical engineers would be called in. To assess the environmental impact of building your structure, environmental engineers would be consulted. Mechanical engineers would design any moving parts of the structure. Chemical engineers would decide what materials should be used to build the structure. Chemical engineers would also consider where the materials come from, whether they were being used sustainably and how much energy would be required to process and transport them.

YOUR ENGINEERING CHALLENGE (PART 3)

Choosing suitable waterslide materials

When building your waterslide prototype, a chemical engineer would be needed to consider what materials to use. The first step in deciding what materials are best for a specific purpose is to identify the characteristics needed. For example, do the materials need to be strong, light, rust proof, hard wearing, waterproof, smooth, cheap and/or environmentally friendly?

Determining the characteristics

- What should be the key characteristics of the materials you use for your waterslide prototype? Compile a list of all the components of the waterslide prototype (e.g. the tower, pool etc.).
- Brainstorm what characteristics are needed by the materials to build each of your components.

Choosing the right materials

Now you have considered the key material characteristics, you must choose the materials to build your prototype.

- In your groups, consider the materials listed in Table 3.2 (and any others you can think of) and choose those that you would use for each component of your waterslide prototype.
- Note down the reasons for your selection and how you would test the chosen materials to ensure they display the characteristics you identified.

➔ Table 3.2

Material	Approximate cost	Material	Approximate cost
Garden hose	$5 per metre	Pipe cleaners	$2 for 20
Toilet rolls	$0.75 each	Paper clips	$3 for 30
Icy-pole sticks	$5 for 20	Cardboard box	$2 each
Toothpicks	$3 for 50	Lunch box	$6 each
Sticky tape	$2.50 per roll	PVC tube	$8 each
Blu-Tack	$1 per strip	Plasticine	$4 for 250 grams
Wooden rulers	$2 each	Newspaper	$2 each
Plastic rulers	$3 each	Chopsticks	$1 each
Bubble wrap	$1 per metre	Forks	$1.50 each
Wooden rods	$1 each	Plastic wrap	$4 per roll
Ice-cream containers	$4 per container	Plastic bag	$0.10 each

Mechanical engineers

Mechanical engineers deal with forces and motion. This means that they design and improve things that have moving parts or have physical forces pushing or pulling on them. Mechanical engineers have produced some of the most important and useful inventions in history. Some examples are the zipper, the combination lock, the rotating doorknob and the yo-yo!

A closer look at pumps

Pumps are an important mechanical object that you will need to consider in your waterslide design. They are used to control the flow of liquids and gases. Mechanical engineers use pumps for a variety of applications. The two most basic types of pumps are:

1. dynamic pumps—these pumps accelerate fluids to very high speeds to build up pressure, which allows the fluid to be pushed in a certain direction
2. positive-displacement pumps—these pumps (e.g. spray bottle, siphon) force fluids into and out of sealed areas.

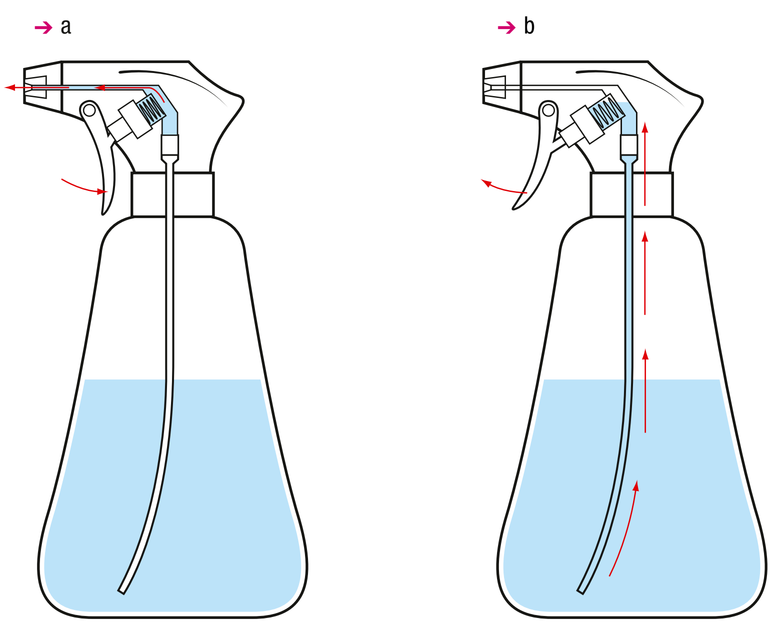
A spray bottle is a simple positive-displacement pump. When you squeeze the trigger, water from inside the sealed trigger head is pushed out of the nozzle. When you release the trigger, water is sucked from the bottle to replenish the water inside the sealed trigger head.

This pump works using one-way valves. These one-way valves only allow water to travel in one direction. They stop water flowing back down into the spray bottle and stop the air from flowing back into the nozzle. Figure 3.37 shows how a spray bottle works.

➔ Fig 3.36 Mechanical engineers work with forces and motion.

Choosing the best proposal

For engineers, thinking of new ideas is a fun challenge. An important part of the engineers' job is to dream, or *imagine*. Another important part of an engineer's job is to decide which dream is best. This is worked out through a proposal—a potential answer to the engineering problem. There may be three, four or seventy-six different proposals, but the lead engineer needs to work out which is the best. Choosing the best proposal can be difficult. How do we decide which is best? There are many methods of evaluating proposals. Engineers use assessment methods and organised systems to do this. Some people spend their working lives trying to work out the best way to evaluate proposals and projects. There is no single 'right' way of evaluating a proposal but, like anything, the more thorough the evaluation, the more likely a successful outcome will result.



➔ Fig 3.37 (a) When the trigger on a spray bottle is squeezed, water is sprayed out through the nozzle and cannot flow back down because of the one-way valve. (b) When the trigger is released, water is sucked up into the trigger head. Air cannot flow back into the trigger head from the nozzle because of the one-way valve.

YOUR ENGINEERING CHALLENGE (PART 4)

Pumping up the waterslide prototype

When designing your waterslide prototype, you will need to become a mechanical engineer to design the pump that will get the water up to the top of the slide. Using either a spray bottle pump or a siphon pump, design and build a pumping system for your waterslide prototype using the six steps of the engineering process. Steps 1 and 2 have been done for you. Some guiding questions have been provided for the other steps.

Step 1 Identify the problem

You need to provide water flow down the slide.

Step 2 Establish criteria

The water should be pumped from the pool below up to the top of the slide.

Step 3 Design it

1 What will the pump system look like?

2 What will you use to do the pumping?

3 How will you attach this pump to the waterslide?

4 What size and length of tubing will be required?

5 Where will you place your pump?

6 What safety factors do you need to consider?

Step 4 Improve it

7 Can you make your design better in some way?

8 Does your design meet your criteria?

9 Do you need to change anything to ensure that it does?

Step 5 Build it

10 How will you build your pump system?

11 What materials do you need (e.g. pump, plastic tubing, fasteners, valves)?

12 How much of each material will you need?

Step 6 Assess it

13 Now that it is built, what went right and what went wrong?

14 Did your water pump design turn out as you planned it?

15 What problems did you encounter?

16 How did you overcome these problems?

17 What worked well in your design?

→ Fig 3.38 Water pumps are an essential survival tool in many parts of the world.

Evaluating a proposal

When engineers evaluate proposals, the main two points they consider are:

1 whether a proposal will do the job it was asked to do
2 how well a proposal does that job.

Many other points also need to be considered, including:

- how long the proposal will take to build
- how much the proposal will cost
- whether all the proposed materials are available
- whether there is a significant impact on the environment.

The simplest way to compare proposals is to use something called a **cost–benefit analysis**. In a cost–benefit analysis, an engineer makes a list of all the negative impacts of a proposal (the costs) and another list of the positive impacts (the benefits). When all the proposals have been analysed in this way, the engineer can more easily compare the proposals and decide which one is best. The best proposal would have the most benefits and the least costs.

Criteria assessments are often used to evaluate projects.
A good criteria assessment table contains all the important aspects you want to measure. Engineers need to assess many aspects of each project before, during and after its completion. The assessment process aims to make sure that each project is as good as it can possibly be.

There are many examples of engineering assessments. Some of these include:

- social impact assessment—will the project have a good or bad impact on people's lives?
- risk assessment—what risks are there of the project failing?
- environmental impact assessment—what impacts will the project have on the environment?
- contamination assessment—will any chemicals used in the project contaminate plant or animal life?
- facility life assessment—how long will a structure survive (e.g. the lifespan of a bridge)?
- geotechnical hazard assessment—will there be any problems with digging if this is needed, such as near caves?

Most engineering companies use criteria assessments to work out how to proceed with a proposal in the best way. Nobody wants an engineering project to fail. However, sometimes engineering projects do fail and, when they do, the consequences may be disastrous.

What do you know about the engineering process?

1 Write your own definition of *engineering*.
2 Why do engineers work in teams?
3 What are some reasons to build a prototype of your design before finalising the project?
4 You don't always have to build an actual prototype of your design. How else could you test your design?

Evaluating proposals for your waterslide prototype

Should your proposal for the waterslide project be built? Is it good enough? Will it be a successful waterslide? These are important questions for any engineer. Often more than one design is considered for the final project. Different designs need to be compared and the best one needs to be determined.

Cost–benefit analysis

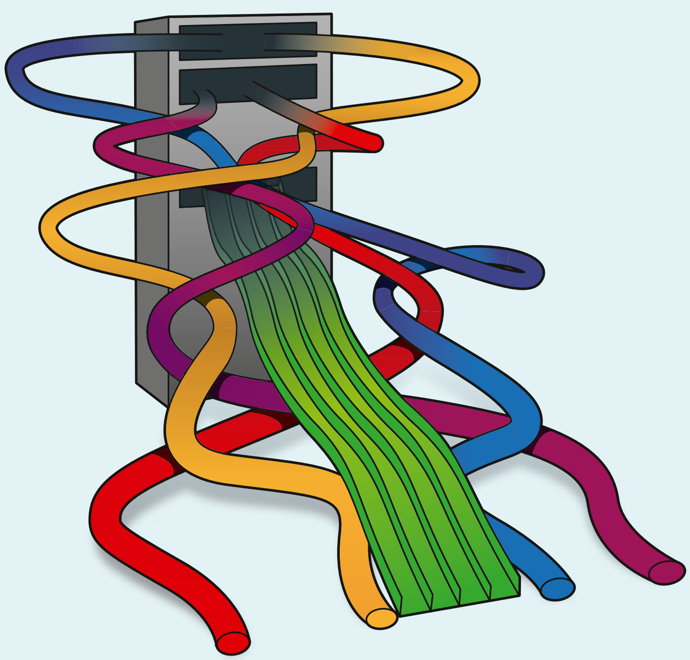
Working with one other group, conduct a cost–benefit analysis of your proposals for the waterslide project. Individually, write down a list of the costs and a list of the benefits for each proposal.

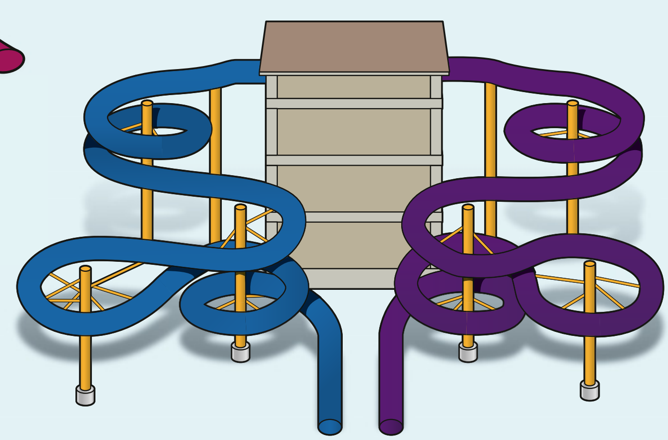
Criteria assessment

Consider the criteria assessment points listed on the left for your proposal. Some criteria will be impossible to predict given the unknown location of your waterslide. An analysis of how your proposal could accommodate any location will support your proposal in the absence of this information.

Justify your evaluation

Present your proposal to the rest of the class and justify why yours is the best design. Your teacher, or other members of the class, may give you feedback on your proposal.





3.3 What is an engineer?

Remember and understand

1 What subjects at school would an engineer be good at?

2 Who can call themselves an engineer? Why?

3 Who is known as *the engineer general*?

4 Why is the engineering process drawn as a continuous cycle?

5 How might an engineer apply an understanding of energy transformations to their job?

6 Why might you need to employ a chemical engineer if you were designing a new clothing range?

7 Why would an engineer not be needed to help design a picture frame?

Apply

8 List places and structures in your school that you think an engineer was involved with. Justify your decisions.

9 Your neighbours have designed a cubby house for their preschool-aged children to play in in their backyard. The design is simply rectangular walls with a sloped roof for the water to run backwards into the garden bed. What features should your neighbours include in the design to ensure that it is strong and safe for the children to play in?

Analyse and evaluate

10 Visit a playground in your community and identify how an engineer has used different shapes and materials for strength. Are the pieces of equipment safe for young and old children to use? Can you think of ways to improve the design of the play equipment?

11 Use the Internet to find out about a future-focused engineer. Create a profile about the engineer. What kind of projects have they worked on? What kinds of projects will they work on in the future?

12 Civil engineers play a vital role in disaster relief: they are involved in everything from building shelters to obtaining clean water, removing waste water and fixing transportation networks. Research some of the improvements that have been made to disaster relief.

Critical and creative thinking

13 An engineer is a good group member. Think back to how your group designed the waterslide. How well did your group work together to solve the problem? Were everybody's ideas considered? How did the group decide on which design to build? What compromises were made? How could your group work better together next time?

<<CONNECTING IDEAS>> Energy

14 Energy efficiency and applying the law of conservation of energy are becoming more important in the various fields of engineering. Identify and describe five different scenarios to support this statement.

>>ZOOMING OUT<<

Research

Choose one of the following topics on which to conduct further research. A few guiding questions have been provided for you but you should add more questions that you want to investigate. Present your findings in a format that best fits the information you have found and understandings you have formed.

Compact fluorescent lights

How do compact fluorescent lights (CFLs) work? How do they differ from fluorescent light globes? Why are CFLs initially more expensive to buy, but then more economical over time? What is the benefit of using CFLs?

Energy-efficient housing

In previous societies, energy efficiency was important because people had limited access to the types of energy supplies and their applications that we have today. Research how civilisations in tropical areas designed their homes to keep them cool and damp free. What different types of energy-efficient practices have humans used throughout the ages?

New and specialised engineering fields

Select one of the newer fields of engineering, like aerospace, biomedical or nuclear engineering. What does the engineer in that field do? What do they need to know? Who do they work with? Where do they work? What materials do they work with? Name a significant project the engineer has worked on.

Plastic banknotes

Investigate the history of how Australia used chemical engineering to develop plastic banknotes. Who did this work? Why did they do this? What problems were encountered? What are some of the features of our plastic banknotes?

Reflect

Me

1 What new science laboratory skills have you learned in this chapter?
2 What was the most surprising thing you found out about energy?
3 What were the most difficult aspects of this topic?

My world

4 Why is it important to understand energy?
5 How important is it for scientists to understand the law of conservation of energy?

My future

6 How might energy resources change in the future?
7 Do humans need to change the way they use energy?

Review

Key words

biofuel
biomass energy
chemical potential energy
compact fluorescent light (CFL)
cost–benefit analysis
criteria assessment
elastic potential energy (EPE)
electric car
electrical energy
energy
energy efficiency
energy transformation
energy transformer
engineer
ethanol
gravitational potential energy (GPE)
hybrid car
incandescent
kinetic energy (KE)
law of conservation of energy
microphone
nuclear energy
potential energy
remote control
solar cell
sound energy
speaker
thermal energy

3

Mousetrap cars

Many devices transform energy from one form to another. The humble mousetrap works on this principle. It uses the elastic energy stored in a spring as its input and converts that to kinetic energy as the trap springs shut. In this challenge activity, you will use the elastic potential energy of a 'loaded' mousetrap to build a model car that can run on its own mousetrap 'engine'.

When engineers design new machines they produce very detailed plans called *blueprints*. They also consider the concept of energy efficiency. For this challenge, you will need to work like an engineer, following the engineering process and using your understanding of energy transformations and energy efficiency to produce the best working model.

Design your own mousetrap car

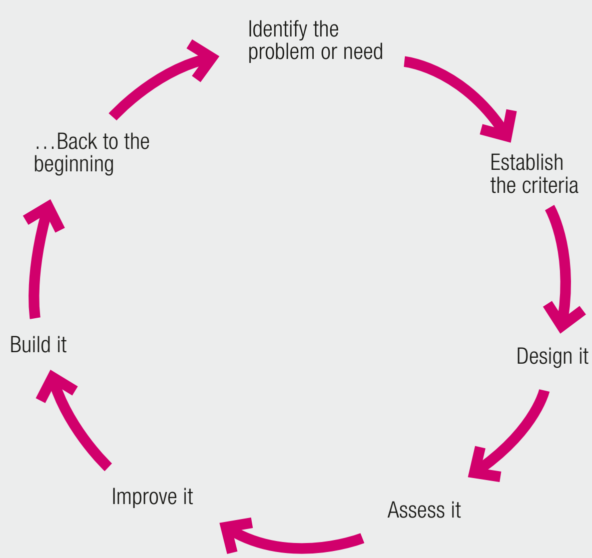
Challenge

Identify the problem: to build a vehicle powered by a household mousetrap.

Questioning and predicting

Establish the criteria: consider the engineering process you learned about in unit 3.3 and put your knowledge into practice. Some questions to consider are:

- How you will get the movement from the mousetrap to the wheels?
- How heavy or light will your machine be?
- What materials will you use to make the machine?
- How are you going to construct it?



Planning and conducting: engineering blueprints

Design it.

- Produce a detailed plan of your car design that shows how the elastic energy stored in the spring will be transferred to the wheels. Detail the materials you will use for each component. Remember, there may be some Lego parts you can incorporate into your car design and your school may be able to supply some of the equipment for you.

Improve it.

Build it.

- Build your prototype.

Processing, analysing and evaluating

Assess it.

1 How energy efficient is your model? If parts of your car rub too much on each other they will create friction and the car won't travel very far. For example, if the wheels or axles are too tight, they will create drag and slow your car down. Consider how to loosen or lubricate parts so this doesn't happen. Real cars use oil and grease for lubrication to prevent this happening.
2 How far did your car run?
3 What advantages did it have over other designs?
4 Did anything go wrong with your car?
5 How could your design be improved?
6 What types of energy were involved in your mousetrap vehicle?

Communicating

Imagine you had to explain to someone how you followed the engineering process so that they could build on your work. You want them to learn from your mistakes and understand why you made certain choices along the way. Present your thinking, processes, data and evaluation in a clear, interesting and appropriate way.

<<BIG IDEAS>> Properties and structure

4 The nature of matter

4.1 What are the states of matter?

Every substance around us that we can see, touch, taste and smell is a type of matter. Matter can be solid, liquid or gas. Each of these states of matter has special properties that make it different from the other states of matter. Look around you. What are the gases, liquids and solids in your environment? Now think about what is inside your body. What types of matter are inside you? Do the solids, liquids and gases have different roles to play inside your body?

1 Decide whether the following can be considered as matter: water, air, smells, bravery, coloured ink, team spirit, wind, liquid nitrogen, enthusiasm, loud noise.

2 Is the Earth made of matter? Is the space between the planets and galaxies made of matter?

3 Is snow the same as ice? Is ice the same as steam?

→ Fig 4.1 These are different types of matter, but how are they different?

The substances we use every day have features or **properties** that make them useful to us. Their strength, density and colour, in addition to many other properties, make them valuable. As scientists we want to know why different substances have different properties. Scientists often use models to explain observations and, in the case of matter, the model used is called the *particle model of matter*. The **particle model of matter** states that all substances, whether they are solids, liquids or gases, are made up of particles. This model can be used to describe both the structure of substances and their properties.

4.2 How can we explain the properties of matter?

To explain the properties of matter, we need to think about what matter is made from. Imagine taking an object made from a substance, such as a sheet of cooking foil made from aluminium. Now imagine being able to divide it in half and in half again. Imagine doing this over and over again. Do you think you could keep doing this forever? At what point would it be impossible to divide it any further?

In reality, there would be a point at which you could not divide the aluminium into smaller parts. At this point you would be left with a single particle of aluminium.

1. Do you think the particles of aluminium are close together in a piece of aluminium foil? Explain the reasons for your answer.
2. What do you think would happen to the particles of aluminium if the foil were heated enough to melt it?
3. If you used steel scissors to cut through the aluminium foil, what can you say about the strength of the forces holding the particles together in steel compared with the strength of the forces within the aluminium?

Fig 4.2 Could you keep cutting forever?

4.3 What is special about elements and atoms?

Many ancient civilisations believed that fire, water, earth and wind were the elements that all matter is made from. Ancient Greeks described fire, water, earth and wind as the *sacred elements*, along with a mysterious 'fifth element' known as the 'ether'. Eastern civilisations had similar ideas. The ancient Chinese listed their 'elements' as earth, water, metal, fire and wood. These elements were thought to be mixed together in different proportions to make known substances.

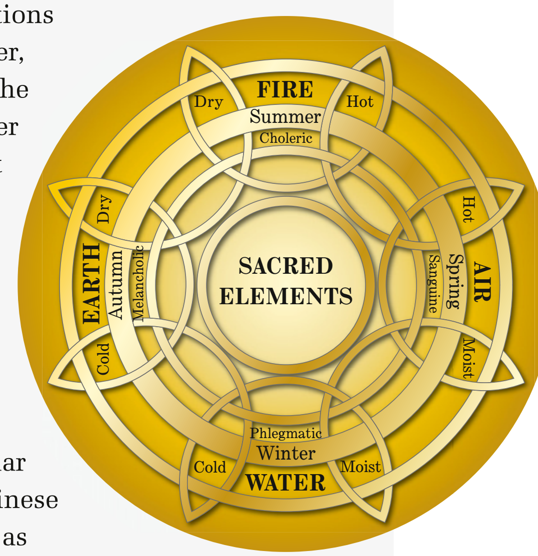


Fig 4.3 Sacred elements.

The idea of elements has been around a long time, but what are they really? What is it that we now know about their structure that allows us to explain why they are special?

1. Water was named as one of the ancient elements. Why is water no longer considered an element?
2. The elements described in ancient times differ from those described today. Why do you think people's ideas of elements have changed over time?
3. Earth, water, metal, air, wood and fire were all considered 'elements' by ancient civilisations. What did these people believe elements to be?

4.1

What are the states of matter?

Matter is the name given to all substances. To be called matter, the substance must have mass and volume. **Mass** is measured in kilograms and can be defined as the amount of matter. **Volume** is how much space the substance takes up and is normally measured in litres.

<<DISCOVERING IDEAS>>

Explaining 'nothing'

1. Try running with a plastic bag held above your head. What do you notice?
2. If you seal a plastic bag with nothing in it, why does it behave like a cushion?
3. What happens when you put a sealed plastic bag or balloon in the freezer? How can you explain this?

Solids, liquids and gases

There are three states of matter—solid, liquid and gas. Solids, liquids and gases are all around us. Steel, concrete, wood and plastic are all solids. Water and cooking oil are liquids. Carbon dioxide is a common gas—you can see it as bubbles in soft drinks. Air is a mixture of gases. The smell of a barbecue is caused by gases that leave the food as it is being cooked.

Many substances can be found in more than one state. Water is the most common substance that we experience in its different states of matter. In the freezer, liquid water solidifies into ice. On a cold night, frost (solid) forms from water vapour (gas) in the air. On a warm sunny day, puddles (liquid) will evaporate to become water vapour.

→ Fig 4.4 A glass of lemonade contains the three states of matter.

Although the ocean and iceberg shown in Figure 4.5 may look and behave very differently, they are both different forms of water. The ocean is liquid and the iceberg is solid. There is also water vapour, which is a gas, in the air. Clouds are made of small liquid water droplets. All these different states of water are made of the same 'building blocks', or water particles.

Pure water will always be the same anywhere on Earth—or on another planet. Water always has the same properties, no matter where it comes from.

It is usually obvious if a substance is a solid, liquid or gas. However, some substances seem to be made of more than one state of matter. Sometimes we can see the states of mixture, such as in honeycomb confectionery, which is a combination of solid and gas. But other times it is difficult to tell the state of mixtures. How would you classify slime and jelly?

→ Fig 4.6 Honeycomb is a combination of solid and gas. Or is it?

→ Fig 4.5 Solid water floats on liquid water.

ZOOMING IN

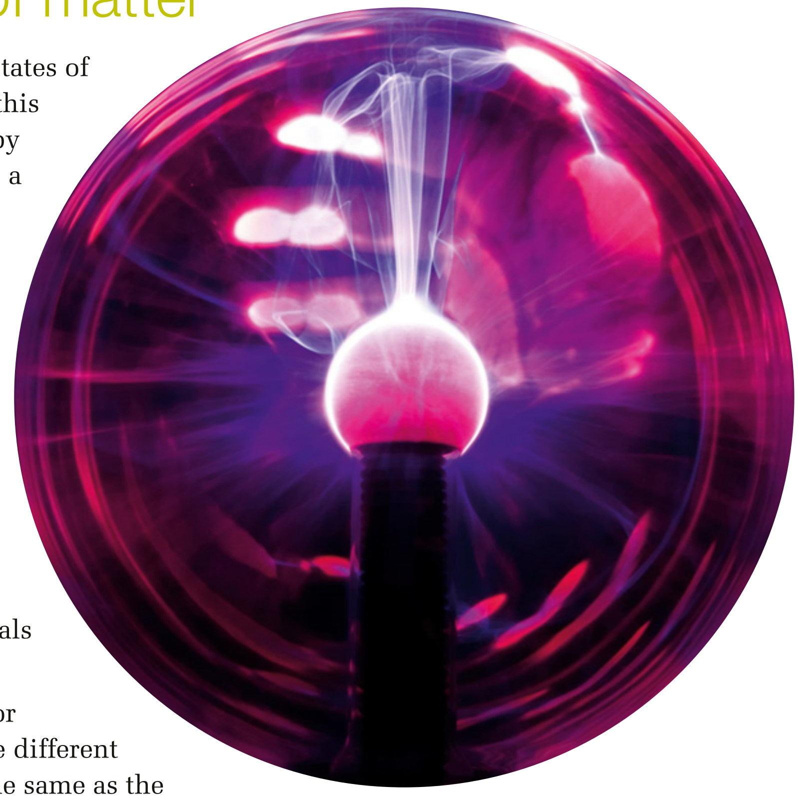
Plasma—the fourth state of matter

Although scientists long believed that there are three states of matter—solid, liquid and gas—they started to rethink this during the 20th century. Using new technologies and by studying the stars, scientists have realised that there is a fourth state of matter—**plasma**.

If gases are heated to extremely high temperatures, such as occur in stars such as the Sun, they change state to become plasma. Plasma only exists at very high temperatures, so it is rarely found on Earth itself. However, plasma is a very common state of matter in our universe. On Earth, plasma is found near lightning and in flames and fires.

Scientists can also produce 'cool' plasma found in plasma screen televisions, neon signs and fluorescent lights. In industry, specialised tools called plasma cutters use the high temperatures of plasma to cut metals precisely.

Note that the word 'plasma' has different meanings. For example, blood plasma refers to the fluid in which the different components of the blood are suspended—this is not the same as the plasma state of stars.



→ Fig 4.7 Plasma is the fourth state of matter.

Describing matter

The properties of a substance can be measured and are always the same for that substance if it is pure. Some substances are important to us because of particular properties. For example, one property of water is that it can be used to dissolve many other substances. This makes water useful for cleaning clothes, cooking and experiments in a chemistry laboratory.

The properties of substances can be divided into two groups: physical and chemical properties.

Physical properties are what we can observe and measure without changing the substance into something else. Examples of physical properties are colour, texture, boiling point, density, electrical conductivity, heat capacity and how readily that substance can dissolve other substances or be dissolved itself.

Chemical properties are what a substance does in a chemical reaction. Examples include bubbling, permanent colour change and permanent change of state.

Some properties of water, such as its refractive index (its ability to bend light rays), are important in studying the effects of water on light. Its heat capacity tells you how much energy needs to be added to increase its temperature. You will learn more about the properties of matter in the next unit.

→ Table 4.1 Properties of water

Physical property	Value
Melting point	0°C
Boiling point	100°C
Colour	Colourless
Density	1.00 g/mL at 25°C
Refractive index	1.33
Heat capacity	4.184 J/g per °C

Making slime

EXPERIMENT 4.1

Aim

To investigate the physical properties of 'slime'.

Materials

4% borax solution (10 mL)

6% polyvinyl alcohol polymer solution (50 mL)

Food colouring

100-mL beaker

Glass stirring rod or icy pole stick

Zip-lock bag

White tile

Safety

- Wear a lab coat or apron, safety glasses and disposable gloves throughout this experiment.
- Do not handle slime without gloves.
- Do not remove slime from the science laboratory.
- Write a risk assessment including safety advice from Safety Data Sheets for each chemical.

Method

1 Put the polyvinyl alcohol solution into the 100 mL beaker.

2 Add one drop of food colouring.

3 Add the borax solution.

4 Mix it well with a stirring rod.

5 Place the slime on a white tile and explore its properties.

6 Place the slime in the zip-lock bag and then in the fridge overnight. Explore slime's properties again.

Results

Write several statements to describe the substance that was produced.

Discussion

1 Can you pour slime?

2 Does slime have a fixed shape?

3 Will slime stretch and return to its original shape?

4 Can slime be compressed into a smaller size?

5 What can slime do that a liquid cannot?

6 When does slime seem more like a solid and when is it more like a liquid?

7 Does the texture of slime change after it has been handled? Why?

8 Would you classify slime as a solid, liquid or gas? Give reasons for your answer.

Conclusion

What are the physical properties of slime?

What do you know about solids, liquids and gases?

1 Decide whether these substances are found in two or more different states: computer ink, the contents of a bug spray in an aerosol can, fog on a rainy day.

2 Group the following substances according to their state of matter as a solid, liquid or gas, or even a combination of states: ice cream, chocolate bar, clouds, thick smoke, glass, honey, cake or bread, mashed potato, paper, peanut butter (smooth), cling wrap, play dough, sand, steam, slime.

3 What is meant by a property of a substance? Why are properties so important to us?

4 What are the similarities and differences between physical and chemical properties?

5 Decide whether the following properties are physical or chemical: malleability (the ability to be hammered into flat sheets), the ability to react with pure oxygen, the amount of vapour released at different temperatures and pressures.

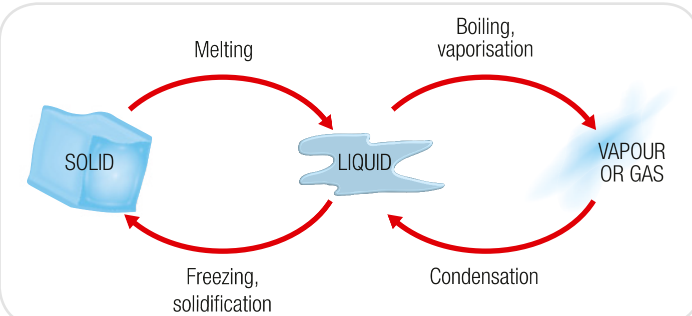
6 Select a common substance, such as cling wrap or vinegar. Name some of the physical properties of this substance.

Changing state

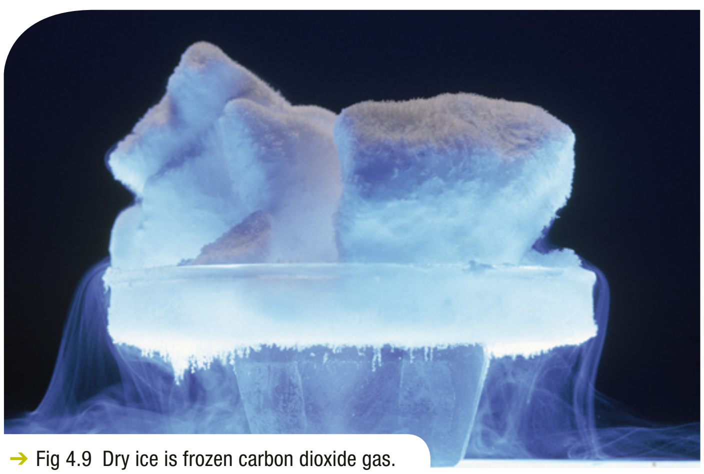
Substances can change between the three states. You are familiar with seeing water change state (for example, when ice blocks melt), but other substances may only ever be seen in one state. For example, aluminium has a high melting point and it is unlikely that you have ever seen liquid aluminium. Theoretically, all substances can be changed into different states if the temperature is hot (or cold) enough. Even gases, such as nitrogen, can be turned into a liquid at very low temperatures. 'Dry ice' is actually solidified carbon dioxide.

Volatile substances, such as methylated spirits and petrol, vaporise easily. Cooking oil does not vaporise if left at normal room temperatures. Cooking oil is not a volatile liquid.

Boiling occurs when we heat a liquid to change it into a gas. The boiling point of pure water is 100°C. At this temperature, liquid water will be changing state to become water vapour. Water left in the open at normal room temperature will gradually evaporate from the surface. But if the water is heated to its boiling point, then all the water will evaporate much more quickly.



→ Fig 4.8 Changing states.



→ Fig 4.9 Dry ice is frozen carbon dioxide gas.

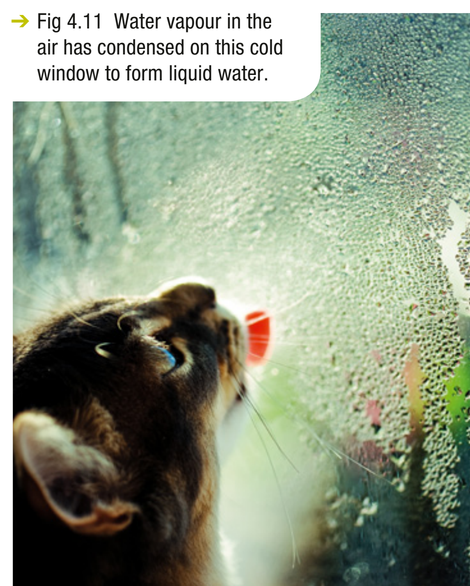
→ Fig 4.10 Water vapour is an invisible gas. What we see above boiling water is steam, which is made up of condensed droplets of water.

Vaporisation and condensation

When a liquid evaporates to become a gas, we say it has **vaporised**. A **vapour** is the gaseous form of a substance that is normally a solid or liquid at room temperature. For example, when water is turned into a gas, it is referred to as water vapour. Likewise, liquid petrol evaporates to become petrol vapour. Vapours that are smelly are often called **fumes**. However, remember that vapours and fumes are still gases and will behave like gases.

When a gas changes state to become a liquid, normally by cooling, we say it **condenses**. The most common condensation that you can observe is when water vapour in the air (or in your breath) condenses on a cold surface to form liquid water.

→ Fig 4.11 Water vapour in the air has condensed on this cold window to form liquid water.



Melting and freezing

When a solid is heated and changes state to become a liquid, we say it has **melted**. On **freezing**, or solidification, a liquid changes state to become a solid.

Sublimation

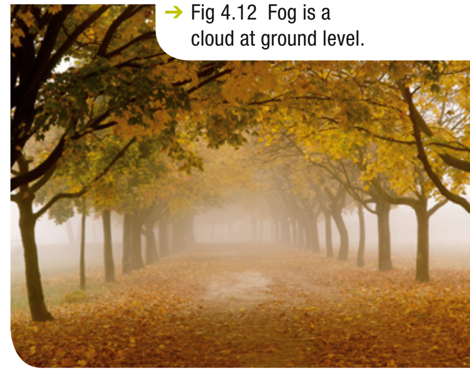
Some substances don't ever exist as liquids. They just change state from a solid to a gas or from a gas to a solid. This process is called **sublimation**. Dry ice (solid carbon dioxide) changes directly from a solid into a gas. Dry ice is often used to produce smoke effects on stage at concerts. However, the 'smoke' you see is not carbon dioxide, but clouds of water. When dry ice sublimes to form carbon dioxide gas, it cools the air quickly, which causes water vapour in the air to condense and form clouds.

Diamond is the hardest known substance on Earth. It also sublimes, but only at extremely high temperatures (above 3500°C).

Water in the air

Many people think that steam is a gas. However, steam is really a liquid. It is made of tiny droplets of water that are so small they float in the air. You see the droplets as a small white cloud. Often steam evaporates into the air to become water vapour.

Real clouds are also made of droplets of water. Clouds can evaporate and re-form in a different location. You can see condensation occurring when a cold drink is left in the open. Water vapour from the air condenses on the cold surface. Condensation only occurs on a cold surface.



→ Fig 4.12 Fog is a cloud at ground level.

→ Fig 4.13 From a distance, clouds appear to be white but, like fog, they are not thick. Aircraft regularly fly through clouds.

<<OVERARCHING IDEAS>>

Drinking water

Stability and change

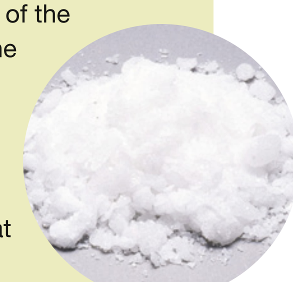
A glass of water on a table does not look as though it is changing. However, over time, the amount of water in the glass may change even if nothing is done to the water.

Discuss the following questions with other students and/or your teacher.

1 What will cause the level of water in the glass to drop?
2 How long would it take for you to notice a difference in the level of water?
3 How could you tell if the level is dropping when the change is only very small?
4 What would make the change in the level of water occur more quickly?
5 Would there be any situation that would result in an increase in the level of water in the glass?

What do you know about changing state?

1 Explain the meaning of these words or phrases:
   a states of matter
   b vaporisation
   c sublimation
   d condensation
   e volatile.
2 Draw a diagram showing the names of the states of matter and the names of the changes between these states.
3 Some people place camphor in their wardrobes to kill moths and silverfish. However, the camphor disappears within a few weeks. What do you think may happen to it?



4 Condensation forms on the outside of a cold container of water. Propose a series of tests or experiments that you could do to be sure that the condensation on the outside of the container did not soak through from the inside of the container.

4.1 What are the states of matter?

Remember and understand

1 What are the three common states of matter and the fourth state found at high temperatures?

2 Name the state of these forms of water: frost, rain, snow, dew, steam, vapour, condensation.

3 What is the difference between the physical and chemical properties of a substance?

4 What is the difference between mass and matter?

5 Sublimation is the name given to two changes of state. What are they?

6 What is the difference between a gas and a vapour?

7 On some mornings dew will form on cars and grass. Where does dew come from? How does it form?

Apply

8 Join these words into one sentence with the correct meaning:
- a matter, mass, volume
- b matter, particles
- c matter, solid, liquid, gas.

Analyse and evaluate

9 Explain the difference in meaning between:
- a vapour and gas
- b boil and evaporate
- c condense and vaporise
- d condense and sublime.

10 When you breathe out on a cold morning, your breath appears white and foggy. This only occurs when it is very cold. What is the white fog that you see?

→ Fig 4.14 Exhaling clouds!

Critical and creative thinking

11 Draw the water cycle and name the changes in state that are shown. You may need to think back to Year 7.

<<CONNECTING IDEAS>> Properties and structure

12 Carbon dioxide is normally described as a gas, however carbon dioxide can also be in the form of a solid. In this state, carbon dioxide is called dry ice. The properties of the two different states of the same substance are vastly different.
- a Describe three major differences between the properties of carbon dioxide gas and solid carbon dioxide (dry ice).
- b Suggest one way to convert carbon dioxide gas into dry ice. Explain why you think this will work.
- c The structure of a substance is how it is made up from smaller parts. Normally we cannot see the structure of chemicals because the parts are too tiny. Thinking about the properties of carbon dioxide as a solid and as a gas, what differences do you think there are between the structures of the two forms of the substance?

4.2

How can we explain the properties of matter?

For all substances, we can picture the particles they are made of as being tiny balls. By imagining what these tiny balls would do, we are building a model that helps explain why substances behave as they do. Real substances are not made of tiny balls. They are made of extremely small particles called *atoms* or molecules, which are difficult to visualise because they are so tiny. If we imagine the atoms or molecules as being tiny balls, then we are using a model or analogy. By imagining how the balls would behave when the substance is melting, dissolving or heated, we are comparing the atoms to the balls. This is our particle model of matter.

DISCOVERING IDEAS

Examining dyes

What you need

M&Ms (red is best)

250-mL beaker

What to do

1 Put 100 mL of water into the beaker.

2 Allow the water and the red M&Ms to settle.

Questions to consider

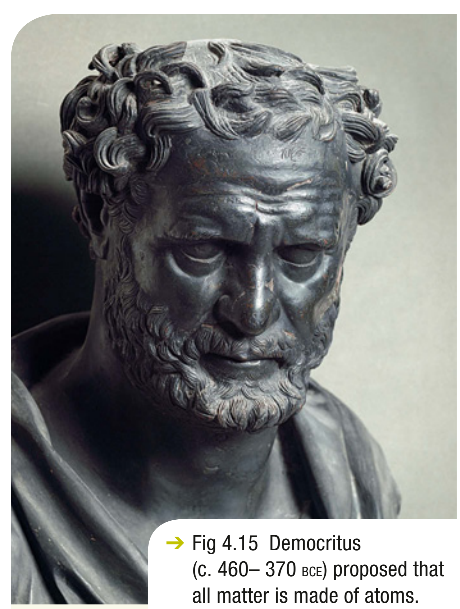
1 Describe your observations as the dye coating of the M&Ms mixed with the water.

2 How did the appearance of the water changed after you stirred it?

3 If the original dye was made up of lots of smaller particles:
- a What do you think has happened to these particles?
- b What does this tell you about the number of particles there must have been in the dye?
- c What does this tell you about the size of these particles?

The particle model of matter

Over 2400 years ago, Democritus, a Greek philosopher, put forward the idea that that all matter is made up of particles. He proposed that if you were to cut up these particles into smaller and smaller pieces, you would eventually have tiny particles that could not be cut up any more. Democritus called these particles *atomos*, which is Greek for 'indivisible'. This is the origin of the word *atom*.



→ Fig 4.15 Democritus (c. 460– 370 BCE) proposed that all matter is made of atoms.

It was not until 2000 years later, in the early 1800s, that the Englishman John Dalton developed Democritus's idea further. Dalton's ideas were based on the results of experiments performed by many earlier chemists. Dalton studied these results and proposed a model to explain them. His model was that matter is made of particles.

Dalton's ideas are outlined below:

- All matter consists of tiny particles called atoms.
- Atoms cannot be created or destroyed, and are indivisible.
- All atoms of the same element are identical, but different from atoms of other elements.
- When atoms combine to form compounds, each atom keeps its identity.
- Atoms combine to form compounds in simple whole number ratios. For example, hydrogen and oxygen combine in a ratio of 2:1 to form water, now written as H_2O.

➔ Fig 4.16 John Dalton (1766–1844) developed Democritus's ideas about particles.

This new understanding encouraged scientists to find out more and more about these tiny particles, eventually leading to the branch of science now called 'chemistry'.

We can add some new ideas to Dalton's list to help us explain everything about matter.

- The particles are too small to be seen.
- The particles are always moving. When it is hotter, the particles move faster; when it is cooler, the particles move slower.
- Particles have mass.
- Particles can join to make larger particles. When they combine, their masses add together.
- There are spaces between the particles.
- Forces hold the particles together to stop them from separating.

All these ideas or rules explain how particles act in real substances. The real particles follow these rules in all substances.

Solids

In solids, the particles are close together and are held together strongly by forces of attraction. The particles are not able to move around, but they vibrate about a fixed position. The particles are held in a regular arrangement, like people sitting in a full hall or theatre. The people may move around a bit in their seats, and bump the person next to them, but they don't move to another seat.

Liquids

In liquids, the particles are also close together, but are not held as strongly as in solids. The particles are like people in a crowd. Everyone is close together, but can move through the crowd. The people are not in a regular pattern, but are mixed at random. As people move around, they become separated from the person who was beside them and come into contact with different people.

Gases

In gases, the particles are far apart. They move quickly on their own and fill all the space available to them. The particles are like people running in all directions with a lot of space between them. Another analogy is to consider 100 high-bounce balls being thrown at high speed into your classroom. The balls would bounce off the walls, desks and chairs, in all directions and at high speed. Each ball is like a particle of gas.

➔ Fig 4.17 The particle model of matter explains the general properties of solids, liquids and gases. Small balls are often used to model particles, but you can use anything—even people!

What do you know about the particle model of matter?

1 Consider a school assembly. Everyone is sitting quietly in their seats in rows. When the assembly finishes, there is a crowd at the doors pushing to go through the doors to leave. When outside, the students run off in all directions as fast as they can. Explain which parts of this analogy represent a solid, a liquid and a gas.

2 Some people use analogies or models to compare the states of matter. What states do these situations most closely represent?

  a A swarm of bees crawling over each other
  b A thousand tennis balls tidily arranged in a large cardboard box
  c Eggs in trays in a large egg container
  d A school of fish darting in all directions as they avoid a predator.

3 What was the major difference between the ideas proposed by Democritus and Dalton?

The kinetic theory of matter

The particle model of matter is always true. Every observation and every experiment can be explained with this model. Because it is always true, it is now called a *theory*. Its full name is the 'kinetic molecular theory of matter', but it is also known simply as the 'kinetic theory'.

In the particle model of matter, the particles are always moving. The word 'kinetic' refers to anything that is moving. 'Molecular' refers to molecules, which are particles made of atoms. You will learn more about molecules later in this chapter.

Particle energy

The movements of people and particles are related to their **kinetic (movement) energy**.

- When people are sitting quietly, they have little kinetic energy. This is like a solid, in which the particles only vibrate.
- In a crowd, people are standing and moving around and have more kinetic energy. This is like a liquid, in which the particles jostle about. Particles in a liquid have more kinetic energy than particles in a solid.
- When people are running, they have much more kinetic energy. This is like a gas, in which the particles are moving fast and on their own. Particles in a gas have the highest amount of kinetic energy.

→ Fig 4.18 Some of the energy in storms and cyclones comes from the condensation of vapour into liquid, which we see as rain.

PRACTIVITY 4.1

Modelling matter

By now you should have a good idea about how the particle model of matter describes the structure of solids, liquids and gases.

What to do

Make a model of the three states of matter, using objects to represent the particles. Suitable items include table-tennis balls, coins, lollies, marbles and pieces of modelling clay. Alternatively, you can use objects from home.

Questions to consider

1. How well do your particles represent the characteristics of real particles?
2. How well does your model represent the position and arrangement of real particles?
3. Can your model represent the movement of real particles?
4. How well could your model help explain the properties of real substances, such as the melting of solids?
5. Is there a better material (or different objects) that you could use to represent the particles? How would this improve the model?

Using the kinetic theory of matter

The kinetic theory of matter can be used to explain many of the observations and measurements that we make about the substances around us.

Mass is the amount of matter in a substance and is measured in kilograms (kg). Mass depends on the number of particles and the mass of each individual particle.

A particular volume of solid or liquid has a greater mass than the same volume of gas because it has more particles in it. For example, a container of liquid nitrogen is much heavier than the same-sized container of nitrogen gas.

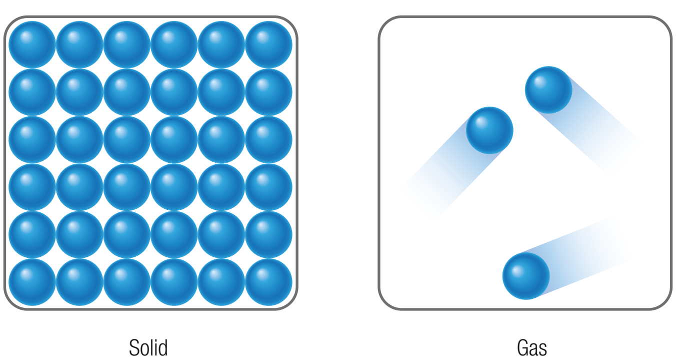


Fig 4.19 A container of a solid has more particles than the same container of gas.

A piece of lead has a much greater mass than the same-sized piece of aluminium. Both are metals that are made of atoms and the atoms (particles) in both are packed closely together. The difference is the mass of each atom.

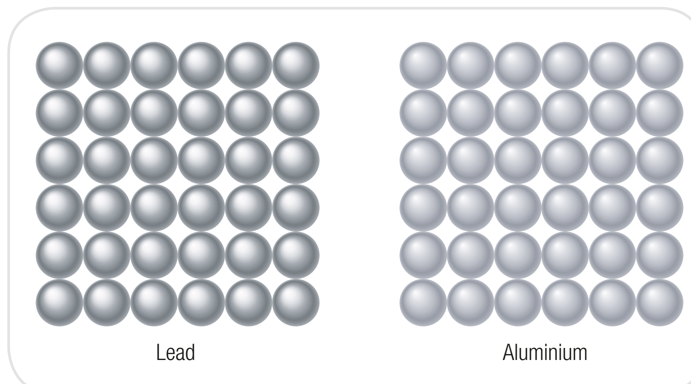


Fig 4.20 Lead atoms have a greater mass than aluminium atoms.

What do you know about the kinetic theory of matter?

1. Is there any difference between the particle model of matter and the kinetic theory of matter?
2. What is the meaning of *kinetic* in the kinetic theory of matter?
3. Rank the states solid, liquid and gas in order of energy content, from highest to lowest.
4. What is meant by *mass*?
5. How does the particle model of matter explain the different masses of different substances?
6. Why does a lump of lead have a greater mass than a lump of wood?

ZOOMING IN

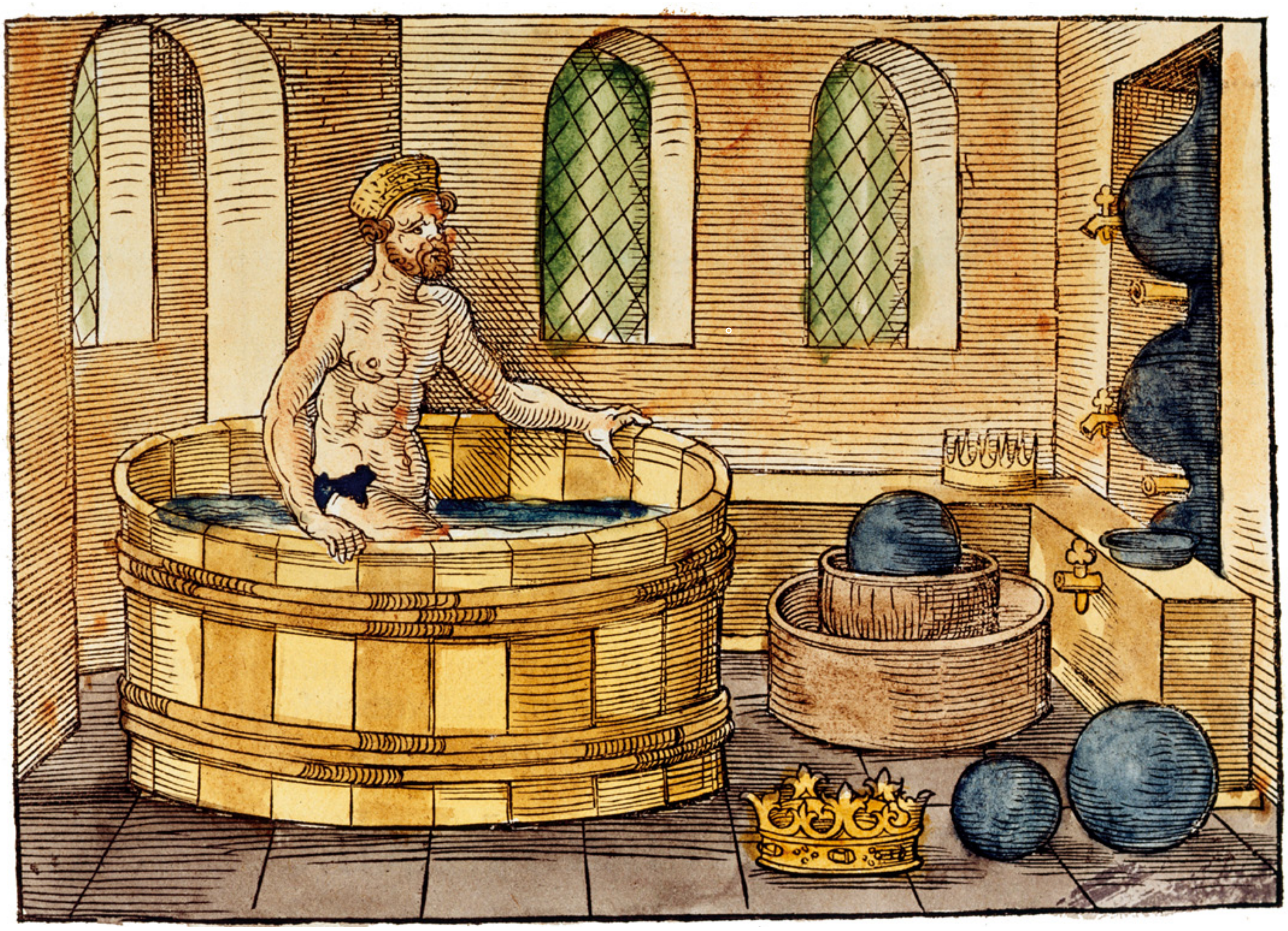
Archimedes in his bath!

Over 2000 years ago, the king of Syracuse (in Greece) asked Archimedes, the famous Greek philosopher and mathematician, how he could find out whether his crown was made of pure gold. The crown was the correct weight, but this did not guarantee that it was pure gold.

One day, Archimedes noticed that when he filled a bath, the water overflowed when he hopped in. Archimedes realised that a crown of pure gold would **displace** (push aside) the same volume of water as a pure gold lump of the same mass would, no matter what its shape.

Two pieces of pure gold always have the same density. If the crown and the lump of gold displaced the same volume of water, then the crown must be made of pure gold. Legend has it that Archimedes was so excited by this discovery that he leapt out of his bath and ran naked through the streets shouting 'Eureka!' ('I have found it!'). Archimedes had used one of the properties of gold, its density, to compare it with a different substance.

It turned out that the crown weighed less than the same volume of pure gold. The craftsman who made the crown had stolen some of the king's gold and replaced it with a less dense metal.



→ Fig 4.21 When Archimedes got into the full bath, the amount of water that overflowed was the same as his volume.

The properties of matter

Some important physical properties are discussed below.

Melting point and boiling point

The **melting point** and **boiling point** are the temperatures at which a substance melts and boils.

➔ Fig 4.22 (a) The temperature at which ice melts into water is the melting point. (b) The temperature at which water becomes steam is the boiling point.

Strength

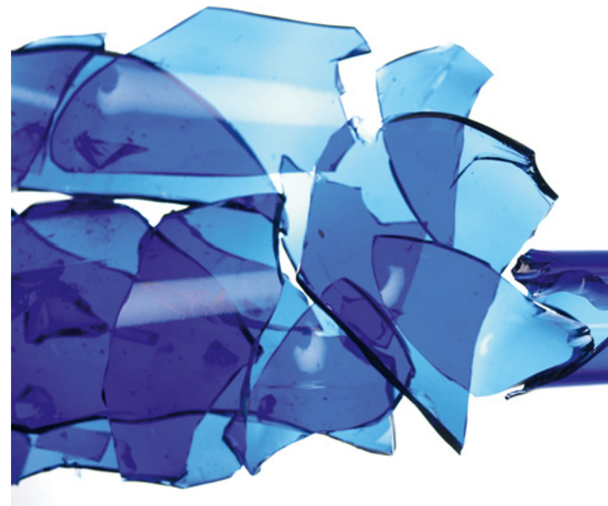
The idea of **strength** can be considered in different ways. A rubber band is easily stretched, but what about a piece of wire? Different wires made of different metals will break if stretched. **Tensile strength** is a measure of the force needed to break a stretched piece of wire. The opposite of tensile strength is **compressional strength**. Substances that can withstand large forces without being crushed have a high compressional strength.

➔ Fig 4.23 Reinforced concrete combines the tensile strength of steel with the compressional strength of concrete to produce a strong product.

Hardness

Hardness is the ability of a substance to scratch another substance. An iron nail will scratch a plastic ruler because the iron is harder than plastic. However, the iron nail will not scratch glass; this is because the iron is softer than glass. The order of hardness is glass (hardest), then iron, then plastic (softest).

Hardness is not the same as strength. A very hard substance may shatter easily. If this happens, the material would be described as *brittle* and therefore not very strong.



➔ Fig 4.24 Glass is a hard, but brittle, substance.

The particle model of matter explains hardness in terms of the forces that hold the particles together. The particles in hard substances, such as glass and iron, are held together very strongly and it is difficult to separate them. In plastic, the particles are not held together as strongly and they can be removed or scraped off. Therefore, plastic is not a hard substance.

There is a connection between hardness and melting. Substances that are hard have strong forces (or bonds) between their particles. These strong forces mean that for hard substances to melt, a lot of heat energy is needed. This is reflected by a high melting temperature.

Viscosity

Viscosity is the thickness or 'gooiness' of a liquid. Viscous liquids such as honey are hard to pour. Water has a low viscosity, cooking oil is more viscous and honey is very viscous. Engine oils used in different engines have different viscosities; this information is provided on the label.

→ Fig 4.25 Engine oils are labelled with viscosities.

Conductivity

Conductivity is how easily something moves through a substance. **Electrical conductivity** refers to how easily an electric current flows through a substance. Metals have a high conductivity, which means that they conduct electricity readily, and so they are commonly called 'conductors'. Materials such as rubber and plastic have a low electrical conductivity and do not conduct electricity.

Thermal conductivity refers to how easily heat moves through a substance. The plastic handles of saucepans have low thermal conductivity and these sorts of materials are commonly called 'insulators'.

Refractive index

Light bends when it passes from one substance to another. **Refractive index** is a measure of the degree of bending.

→ Fig 4.26 Diamond has the highest refractive index of any substance, which is why diamonds look so sparkly.

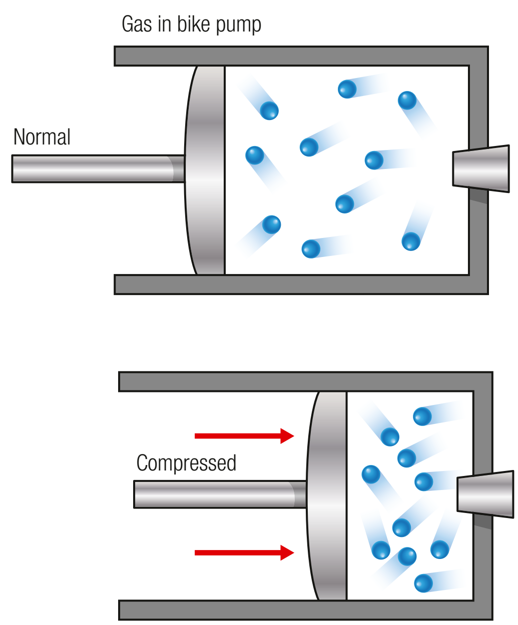
Heat capacity

Heat capacity is a measure of how much heat energy is needed to increase the temperature of a substance. Different substances have different heat capacities, so some will heat up more quickly than others. For example, different substances in food will heat at different rates in an oven. If you bite into the food, some parts of it could burn your mouth. Metals need only a small quantity of heat energy to increase their temperature, whereas water requires much more heat energy.

Compressibility

Compressibility refers to the ability of a substance to be compressed, or squashed. You can test for compressibility when substances are in a large plastic syringe or a pump.

If you put your finger over the end of a pump or syringe, you can compress the air inside the syringe. However, if you replace the air with water, you cannot compress the water. Similarly, if you filled the pump or syringe with sand, you would not be able to compress it.



→ Fig 4.27 When a substance is compressed, the space between particles is reduced.

In solids and liquids, there are no air spaces between the particles, so it is not possible to compress the particles together any closer. Solids and liquids are said to be **incompressible**. Gases, such as air, can be compressed. This is because the particles are spread out and there is a lot of space between them.

EXPERIMENT 4.2

Comparing states of matter

Aim

To investigate the characteristics of solids, liquids and gases.

Materials

Clamp
Water
Electronic balance
Plastic syringe
250-mL beaker
100-mL beaker
Stopper to fit syringe
Food colouring
Three different containers
Balloon

Method

1 Copy Table 4.2 and complete it as you work through the method.
2 Examine the clamp and record its data in Table 4.2. Measure and record the mass of the clamp.
3 One-third fill the 250-mL beaker with water. Add two drops of food colouring.
4 Pour the coloured water, in turn, into the three other containers. Record what happens to the shape of the water in each of the containers.
5 Half-fill the syringe with water and invert it onto the stopper on the bench. Make sure that the syringe is well sealed before compressing it. Record whether water can be compressed (i.e. take up less volume).
6 Set the empty 100-mL beaker on the electronic balance and press the TARE button. Pour in the water from the syringe and measure the mass of the water.
7 Draw the syringe full of air and invert the syringe onto the stopper. Compress the syringe. Record whether air is compressible and takes the shape of the syringe.
8 Record the mass of the empty balloon and then blow it up. Tie off the end and weigh the balloon again, this time with air in it. Subtract the mass of the empty balloon from that of the blown-up balloon to calculate the mass of the air inside the balloon. Record whether the air takes the shape of the balloon.

Fig 4.28 Testing the compressibility of air: (a) before and (b) after depressing the plunger on the syringe.

Results

Table 4.2

Matter	State of matter	Mass (g)	Able to take shape of container?	Able to be compressed?	Other characteristics observed
Clamp	Solid				
Water	Liquid				
Air	Gas				

Discussion

1 Which substances had a measurable mass?
2 Did each substance take up space?
3 Which states of matter took on the shape of their containers?
4 Which state of matter can be compressed into a smaller space? Describe what happened.
5 The particle model of matter states that all matter is made up of particles. Suggest how the particles in each of the three states may be arranged to explain your observations in this experiment.

Conclusion

Write a short paragraph to describe what you know about the states of matter.

→ Fig 4.29 The characteristics of solids, liquids and gases.

Diffusion

When the lid is taken off a bottle of perfume, the smell of the perfume spreads throughout the room. This occurs without any breeze or wind and is called **diffusion**. Perfume diffuses from the open bottle and spreads throughout the entire room. Other examples of diffusion include dye spreading out in water and tea spreading out from a tea bag in a cup of hot water. Stirring the water or cup of tea will mix the particles and speed up the rate of diffusion.

Diffusion occurs fastest in gases. This is because the particles in gases are moving freely and quickly and there is plenty of space between them. The particles in a gas will spread out quickly and take up all the space they can.

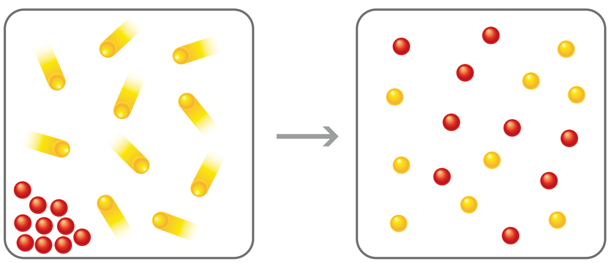


Fig 4.30 Before (left) and after (right) diffusion in a gas.

In liquids, the particles jostle against each other. They do not move far before colliding with another particle. As a result, particles in a liquid do not move very far or very fast. Diffusion in liquids is slow.

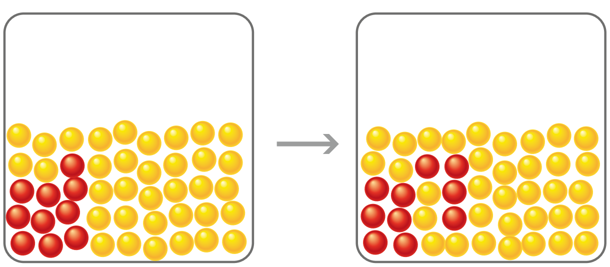


Fig 4.31 Diffusion is slow in liquids.

In solids, the particles are locked into position. The particles vibrate, but cannot move to a new location. So, the particles in a solid cannot spread out and diffusion does not occur in solids.

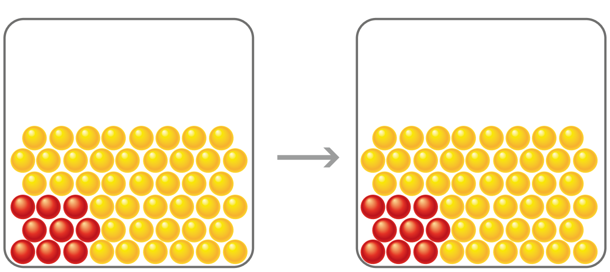


Fig 4.32 Solids don't diffuse.

PRACTIVITY 4.2

Making a cuppa

You can observe diffusion in a simple experiment.

What you need

Two large beakers
Hot water
Cold water
Two tea bags

What to do

1. Fill one beaker with hot water and the other with cold water.
2. Allow the beakers to sit still for a few minutes so that the movement of the water inside them is reduced.
3. Place a tea bag into each beaker. Brown colour from the tea leaves seeps into the water and then diffuses throughout the beaker of water.
4. Compare the speed of diffusion in hot and cold water.

Density

One way of comparing the 'heaviness' of two substances is to compare their density. Density is the mass of a certain volume of a substance. The density of a substance will affect its properties, such as its ability to float and its potential uses. (See Zooming In: Archimedes in his bath! on page 139.) Mathematically, density is the mass divided by volume. Density is often measured in grams per millilitre (g/mL).

One litre of water is heavier than one litre of air. We say that water has a greater density, or that it is more dense, than air. Sand has a greater density than water or air, but a lower density than lead.

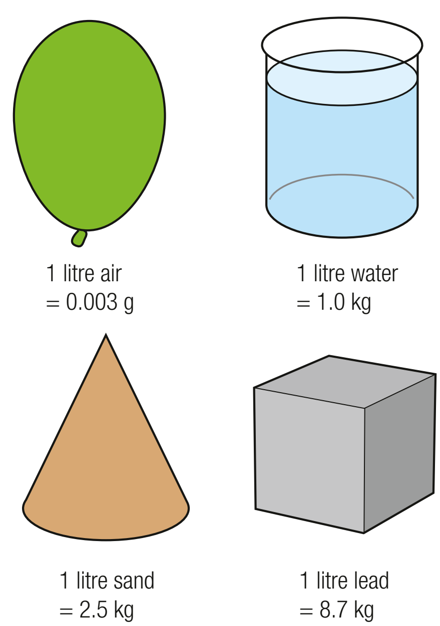


Fig 4.33 Density compares the mass of objects of the same volume.

The density of a substance is an important physical property. Density is used to help identify some minerals and gemstones. Brewers measure the density of fermented drinks, such as beer and wine, to find the sugar content.

The particle model of matter explains density in terms of both the mass and the closeness of the particles. Gases always have a low density because there is a lot of empty space between the particles. Solids normally have the highest density because there is no space between the particles.

Calculating density

To calculate the density of a substance, you first need to know its mass and volume. The most appropriate units for the substances you will be working with are grams (g) for mass and millilitres (mL) or cubic centimetres (cm^3) for volume. Millilitres tend to be used for the volume of liquids, whereas cubic centimetres are used for solids.

Note that 1 mL is the same as 1 cm^3. Therefore, grams per millilitre (g/mL) is the same as grams per cubic centimetre (g/cm^3).

The densities of some common substances are given in Table 4.3.

Fig 4.34 A hydrometer is used to test the density of beer.

Table 4.3 Densities of some common substances

Substance	Density (g/cm^3)
Air	0.001
Foam rubber	0.05
Wood	0.3
Oil	0.75
Water	1.0
Glass	2.6
Steel	7.8
Iron	7.8
Copper	8.9
Lead	11.3
Gold	19.3
Mercury	13.6

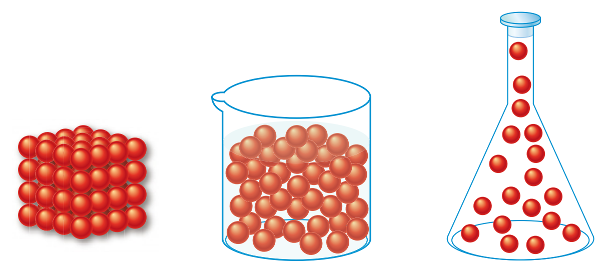


Fig 4.35 Gases have a low density.

NUMERACY LAB

How to calculate density

Example

A rock has a mass of 10 g and a volume of 2 cm^3. What is its density?

Note: we are measuring the volume of a solid, so we use cubic centimetres (cm^3) for the unit of volume.

To calculate density, use the following formula:

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

Thus, the density of the rock $= \frac{10}{2}\ g/cm^3$

$= 5\ g/cm^3$

A density of 5 g/cm^3 means that each cubic centimetre weighs 5 grams.

Your turn

1 Oil has a density of 0.75 g/mL. What is the mass of 10 mL oil?

2 Ice has a density of 0.9 g/cm^3. What volume of ice has a mass of 20 g?

Answers

1 7.5 g **2** 22 cm^3

EXPERIMENT 4.3

The density den

Three density experiments are set up around the laboratory. In two experiments, you will measure density in grams per millilitre (g/mL) to make it easier to work with liquids.

Station A

Aim

To measure the density of liquid water.

Materials

10-mL measuring cylinder
50-mL measuring cylinder
Electronic balance
Water
Calculator

Method

1. Copy Table 4.4 and use it to record your measurements.
2. Measure the mass of the 10-mL measuring cylinder. Record its mass in grams.
3. Remove the measuring cylinder from the balance and add 6.0 mL of water to it.
4. Measure the mass of the cylinder and water. Calculate the mass of the water by subtracting the mass of the cylinder from the combined mass of the cylinder and water.
5. Calculate the density of the water (see Numeracy lab on page 145) and record your answer. (Don't forget the units!)
6. Repeat the experiment with the 50-mL measuring cylinder and 20 mL of water. Calculate the density of the water.
7. To obtain a third measurement of the density of water, choose one of the two measuring cylinders and any amount of water. Measure the mass of the water and its volume. Calculate the density of the water.

Results

List the three results you obtained for the density of water. Calculate an average value.

Discussion

1. The standard value for the density of water is 1.00 g/mL at 25°C. How does your average value compare with this?
2. What could have caused your results to differ from the standard value of the density of water?
3. When you calculate the density of water, does the amount of water used make any difference ? Explain the reasons for your answer.
4. Why do scientists repeat experiments?

→ Table 4.4

	Mass of measuring cylinder (g)	Volume of water (mL)	Mass of measuring cylinder and water (g)	Mass of water (g)	Density of water (g/mL)
10-mL measuring cylinder		6			
50-mL measuring cylinder		20			
					Average =

→ Table 4.5

Substance	Length (cm)	Width (cm)	Height (cm)	Volume (cm^3)	Mass (g)	Density (g/cm^3)
Glass	4	3	2	$4 \times 3 \times 2 = 24$ cm^3	48	$48 \div 24 = 2$ g/cm^3

Station B

Aim

To measure the density of regular-shaped blocks made from different materials.

Materials

Several blocks made from different substances (e.g. wood, polystyrene, lead, zinc)

Ruler

Electronic balance

Calculator

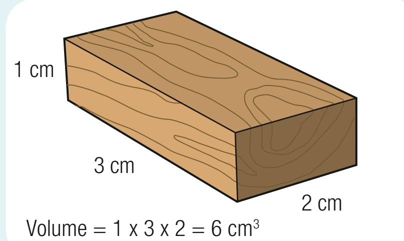
Method

1 Copy Table 4.5 and measure and record the mass of each of the blocks.

2 Calculate the volume of each block. (An example has been done for you in Figure 4.36.)

Results

Rank the blocks in order from least dense to most dense.



→ Fig 4.36 Calculating the volume of a regular-shaped block.

Station C

Aim

To measure the density of irregular-shaped objects.

Materials

Four different objects (e.g. spatula, a small rock, a lump of plasticine and an object of your choice) that each fit into the measuring cylinder

Electronic balance

100-mL measuring cylinder

Method

1 Copy Table 4.6.

2 Measure the mass of the first object. Record the mass, in grams, in your table.

3 Use the displacement method to work out the volume of the object. Approximately half-fill the measuring cylinder. To calculate the volume of the object, subtract the volume of water in the cylinder before the object was added from the volume after the object was added.

4 Calculate the density of the object.

5 Repeat the experiment with the remaining objects.

→ Table 4.6

Object	Mass (g)	Volume before (mL)	Volume after (mL)	Volume of object (after – before; mL)	Density (g/mL)

Results

Include your table here.

Discussion

1 What were some of the difficulties you had using the displacement method for calculating density?

2 What were some advantages of using the displacement method for measuring volume?

3 How does the density of water compare with those of the other objects you measured? Use the results from all the experiments to rank the objects from lowest to highest density.

4 How would our world be different if the density of water was five times as much (i.e. 5 g/mL)? How would this affect your mass, your life and the world generally?

Conclusion

What do you know about how density affects the behaviour of objects?

What do you know about the properties of matter?

1 Prepare a table and list some physical properties and their meanings.
2 Imagine you are selecting a substance to use to make a protective case for a mobile phone. What physical properties would be important to consider when choosing your substance? Explain your reasoning.
3 What is the difference between electrical conductivity and thermal conductivity?
4 Rank the following in order of compressibility: solid, liquid, gas.
5 If you placed a viscous liquid, such as oil, into a water pistol, what would be the effect? Explain your reasoning.
6 What is the meaning of *diffusion*?
7 How does the particle model of matter explain diffusion in:
  a liquids?
  b gases?
8 What would happen to a polished wooden table if you rubbed it with sand? Explain by using the idea of hardness.
9 Which two properties do you need to measure in order to calculate the density of an object?
10 Describe what happens when you slowly place something heavy, such as a rock, into a glass of water.
11 Would you rather lift 1 kg of concrete or 1 kg of rose petals? In your answer, consider the mass and volume of each.
12 Why do gases have a much lower density than solids and liquids?
13 If you could manipulate particles, how would you go about making a substance with a very high density?
14 Liquid water is unusual in that it has a higher density than solid water (ice). What does this tell you about the packing of particles in liquid water compared with that in ice?

Heating particles

Have you noticed that concreters often make grooves in concrete paths? Have you seen the soft black material between parts of buildings, and also on some footpaths and roads? Has your bike wheel got stuck in the gap between a bridge and the road?

All these examples relate to the expansion of objects as they get hot. All objects and substances expand (increase in size or volume) as their temperature increases. These objects contract (shrink) back to their original size when they are cooled back to their original temperature. The expansion is only small—approximately 10 mm in a 30-metre bridge—but it is very important for the strength of the object. Expansion effects are seen in bridges, railway tracks, power cables and large buildings.

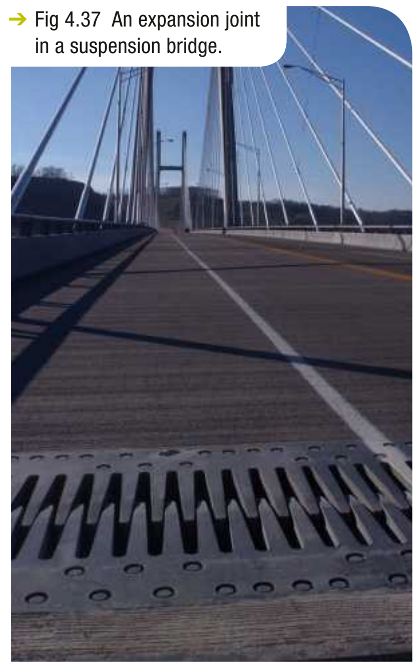


Fig 4.37 An expansion joint in a suspension bridge.


Fig 4.38 Train tracks would buckle in the heat without tiny gaps between the pieces.

EXPERIMENT 4.4

Effect of heat

Aim

Three activities are set up to determine the effect of heat on solids, liquids and gases.

Wear safety glasses and a lab coat, and tie long hair back, when using a Bunsen burner.

Station 1: Heating a solid

Materials

Ball and ring apparatus

2 x 250-mL beakers

Ice

Hot tap water

Method

1 Look at your ball and ring. Try passing the ball through the ring before heating and cooling. Record your observations.

2 Half-fill a 250-mL beaker with hot tap water. Place your ball in the hot water for 5 minutes. Keep the ring away from the hot water.

3 Try passing the ball through the ring. Record your observations.

4 Half-fill the other beaker with cold tap water and add ice. Put the ball in the iced water and leave it for 5 minutes. Keep the ring away from the iced water.

Results

Record your observations.

Discussion

1 What happened to change the size of the metal ball?

2 Use the kinetic theory of matter to explain what was happening to the particles in the solid when heat was applied.

3 Do objects return to their original length when they cool to their original temperature?

Station 2: Heating a liquid

Materials

100-mL conical flask

Bunsen burner and heating mat

Narrow glass tubing

Tripod

Gauze mat

Rubber stopper to fit tubing

Food colouring

Water

Felt-tipped pen

Safety

- Make sure the apparatus is not left unattended. The dye and water will spurt out the top of the glass tube if allowed to.
- The flask and its contents may be hot. Allow all equipment time to cool before handling it.

Method

1 Put two drops of food colouring in the flask and fill the flask right to the top with water.

2 Place the stopper fitted with the tube in the flask. Some water will rise up the tube. Using the felt-tipped pen, mark this first level on the tube.

3 Place the flask on the gauze mat on the tripod and heat gently.

4 After a few minutes of heating, turn off the Bunsen burner. Mark the level of the water in the tube again.

5 Watch what happens to the level of the water as it cools.

Results

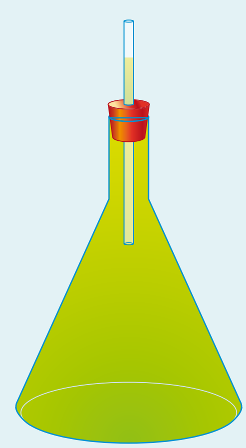
Record your observations.

Discussion

1 Describe what happened to the water in the tube as the flask was heated.

2 What happened to the level of the water in the tube as the water cooled?

3 Use the kinetic theory of matter to explain why the liquid expanded when heated.



→ Fig 4.39 Experimental set-up to show the expansion of a liquid after heating.

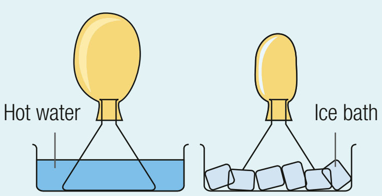
Station 3: Heating gases

Materials

100-mL conical flask
250-mL beaker of hot water
Ice bath (250-mL beaker of water and ice)
Balloon
String
Ruler

Method

1 Blow up the balloon to help stretch the rubber. Let the air out again until it is about the size of an apple.
2 Place the balloon over the neck of the flask.
3 Use the string and ruler to measure the circumference of the balloon at room temperature. Copy Table 4.7 and record this measurement.
4 Place the flask with the balloon in a beaker of hot water. Wait a few minutes.
5 Measure and record the balloon's circumference.
6 Place the flask with the balloon in an ice bath. Wait a few minutes and then measure and record the balloon's circumference.



→ Fig 4.40 Experimental set-up to show the expansion and contraction of a gas after heating and cooling.

→ Table 4.7

Temperature	Balloon circumference (cm)
Room temperature	
Hot water	
Ice bath	

Results

Record your observations, including your table.

Discussion

1 What happened to the size of the balloon as the temperature went from cold to hot?
2 Was any air added to change the size of the balloon?
3 Use the ideas of the particle model of matter to explain how the balloon expanded and contracted with the changes in temperature.

Conclusion

What do you know about the effects of heat on solids, liquids and gases?

<<OVERARCHING IDEAS>>

Tiny measurements

Scale and measurement

Although the particles that we have been talking about are extremely small, they still have mass, they take up space (volume) and they can be measured. So how small are they?

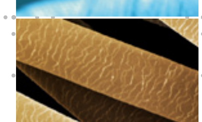
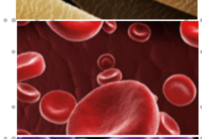
The metre (m) is the standard unit of length. In this activity, we will use metres. One centimetre (1 cm) equals 0.01 m and one millimetre (1 mm) equals 0.001 m.

We can use scientific notation to show small numbers:

- 0.1 can be written as 10^{-1}
- 0.01 can be written as10^{-2}
- 0.001 can be written as 10^{-3}.

Each additional decimal place is equivalent to getting ten times smaller. Figure 4.41 shows this in relation to objects.

Each step shown in Figure 4.41 is a reduction in size by a factor of 10. This gives an idea of the scales we are thinking about when talking about particles. It is not surprising we cannot see these particles!

Object	Image	Size (approximate)	Object
Length of a baked bean		10^{-2} m (1 centimetre)	Size of a virus (large)
Width of the eye of a needle		10^{-3} m (1 millimetre)	Haemoglobin molecule
Width of a human hair		10^{-4} m	Sucrose (sugar) molecule
Red blood cell		10^{-5} m	Water molecule
Length of a bacterium		10^{-6} m (1 micrometre)	

→ Fig 4.41 How tiny is 'tiny'? Scientists rely on measurements and their units to compare 'tiny' objects.

Kinetic theory and heat

The kinetic theory of matter explains expansion and contraction by considering the kinetic (movement) energy of the particles as the result of heat energy.

The particles inside the solid metal rod used in Experiment 4.4 vibrated a little faster and each one took up a little more space when the rod was heated. Each particle pushed the one next to it a little further away. This happened wherever the rod was heated. The increased space needed by the particles is seen by us as the rod increasing in size. A similar thing happens with liquids and gases. Applying heat energy causes the particles in the liquid or gas to gain more energy. The particles jostle more and speed up. As they move around faster, they take up more space and push the other particles further apart.

Expansion and contraction have many important applications such as liquid-in-glass thermometers. When an alcohol thermometer is placed in your mouth, the heat from your body causes the liquid inside to expand and move up the tube. (Normal body temperature is approximately 37°C.) Thermometers are filled with red- or green-coloured alcohol, but not the type of alcohol in alcoholic drinks.

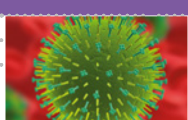
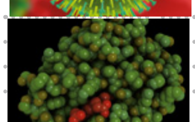
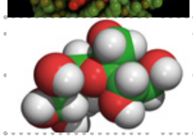
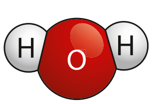
Image	Size (approximate)
	10^{-7} m
	10^{-8} m
	10^{-9} m (1 nanometre)
	10^{-10} m

Fig 4.42 Liquid-in-glass thermometers have a tube that narrows near the bulb. Once the alcohol has expanded, the narrow tube prevents the alcohol moving back into the bulb before the temperature can be read. After the temperature has been read, the thermometer is shaken to force the alcohol back into the bulb so that another reading can be taken.

Energy in particles

'Hot' and 'cold' are sensations that are important in our everyday life. How do 'hot' and 'cold' fit in with the kinetic theory of matter? In solids, liquids and gases, the particles have more kinetic energy as the substance gets hotter (increases in temperature).

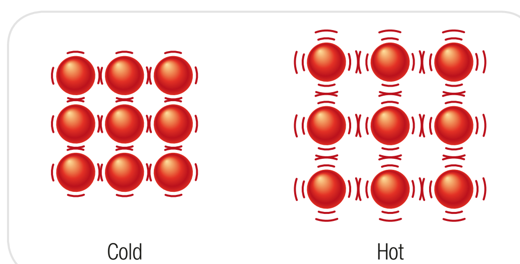


Fig 4.43 In a hot solid, the particles vibrate harder, faster and wider than in a cold solid.

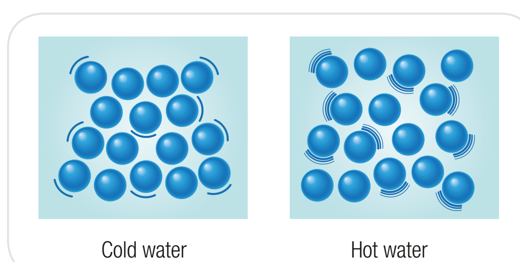


Fig 4.44 In a hot liquid, the particles jostle around faster and take up more space than in a cold liquid.

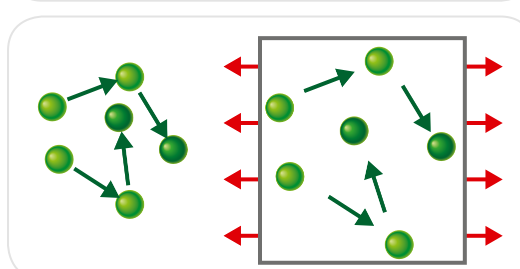
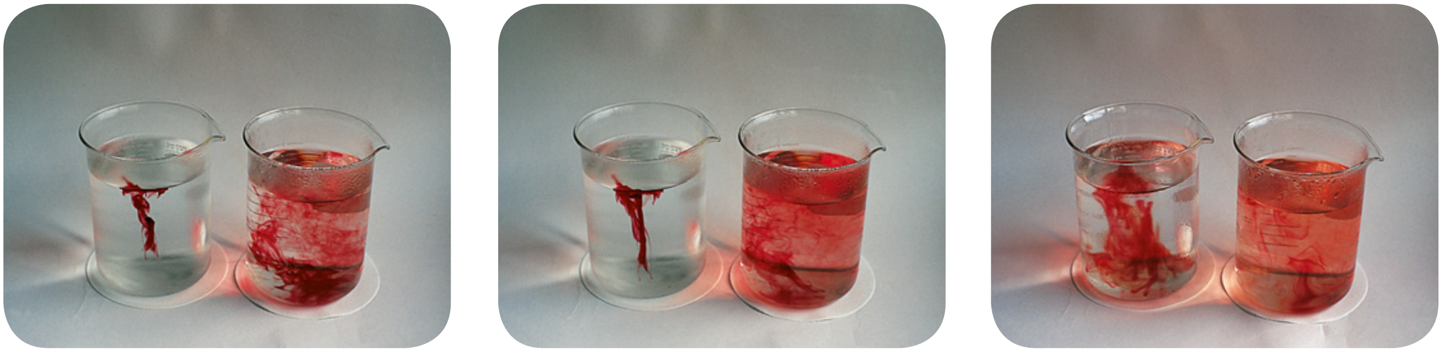


Fig 4.45 In a hot gas, the particles move faster, and collide with each other harder, than in a cold gas.

Differences in the movement of hot and cold particles can be seen in a beaker of water. As the particles move around, they cause diffusion. If the particles move faster, then diffusion should occur faster. You observed diffusion of tea in hot and cold water in Practivity 4.2.



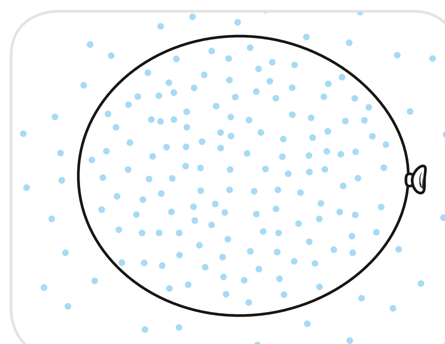
➔ Fig 4.46 Diffusion occurs faster in hot water than in cold water. The left-hand beaker in the images above contains cold water; the right-hand beaker contains hot water.

What do you know about heating particles?

1 What is the difference between the terms *expand* and *contract*?
2 When hot objects cool, do they return to their original length?
3 What precautions are taken with railway tracks and bridges to ensure that they do not buckle and bend on a hot day?
4 How can you be sure that when a solid is heated and expands in size, the increase in size is not caused by more atoms being added?

Particle pressure

When you blow into a balloon, you fill the balloon with air from your lungs. Your lungs push more air particles into the balloon. The air particles inside an inflated balloon are more compressed than the air particles outside the balloon. The force of the air particles inside the balloon pushes the balloon outwards. The force of the air pushing against something is called **air pressure**.



➔ Fig 4.47 The air particles inside a balloon are closer together than on the outside.

The air particles inside the balloon are moving quickly in all directions, with a lot of space between them. Some of the particles hit the balloon skin and push against it. One particle does not have much force, but billions of particles produce a measurable force. We measure this force when we measure air pressure.

Air pressure can be increased by increasing the number of particles or by having the particles exert a greater force when they collide with the balloon. When you pump up a tyre, the pump pushes more air into the tyre. More air contains more particles. The particles can exert a greater force if they are going faster. Particles in hotter gases are faster than those in cold gases because they have more energy. Hotter gases exert more pressure than cold gases.

➔ Fig 4.48 Car tyres need to be filled to a certain air pressure.

Fig 4.49 Bubbles get bigger as they rise because water pressure decreases.

Fig 4.50 'The bends' occur when a diver rises to the surface too quickly from deep under water. The nitrogen that had been dissolved in the blood suddenly becomes less soluble and forms bubbles in the blood. To prevent the bends occurring, divers must rise to the surface slowly—over 30 minutes or more—so that the nitrogen in the blood can be exhaled through the lungs. The treatment for the bends is to place the diver in a recompression chamber, in which the air pressure can be increased to simulate the water pressure deep under the ocean.

PRACTIVITY 4.3

Investigating particle pressure

Clean a thin plastic milk or juice container. When the container is 'empty', it contains air. Air consists of many air particles travelling at high speed.

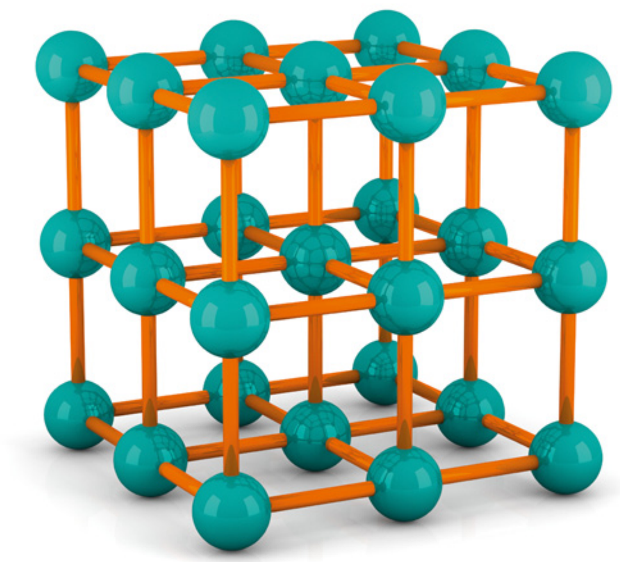
1 When the air in the container has reached room temperature, screw the lid on tightly and place the container in the refrigerator. Describe what happens and explain it in terms of the kinetic theory of matter.
2 Carefully pour a small amount of boiling water into the container and screw on the lid as quickly as you can. Describe what happens and explain it in terms of the kinetic theory of matter.

What do you know about particle pressure?

1 Explain, in terms of particles, the two factors that cause air pressure.
2 Explain the cause of water pressure. Why does the pressure increase as you go deeper?
3 A plastic pump container is used to squirt out liquid from a soap dispenser. These types of pumps always work best when they are nearly filled with water. Suggest how these pump containers work.
4 What is 'the bends'? What causes it and how is it treated?
5 Deep sea divers breathe a gas mixture called Helox. What gases do you think are mixed to form Helox? Why are these two gases used?

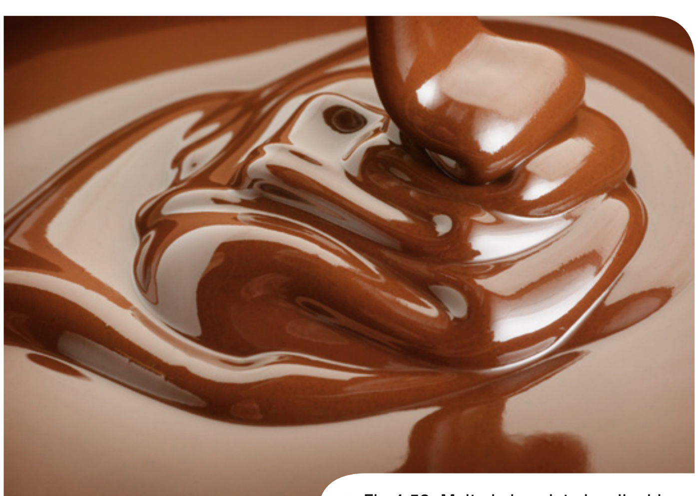
Changes of state and particle theory

In a solid, all the particles are in a regular arrangement (such as rows, columns and layers). A three-dimensional arrangement of particles in a regular pattern is called a **lattice**. The particles in a lattice are constantly vibrating.



➔ Fig 4.51 A lattice arrangement of particles.

When heat energy is added, the particles vibrate faster and take up more space. However, the particles are still held in place in the lattice by all the particles around them. As the substance becomes hotter, the particles gain more energy and vibrate faster. Eventually the particles have so much energy that they break free of the particles around them. The particles are still vibrating or jostling, but they are not held in place any more. The solid has melted to become a liquid.



➔ Fig 4.52 Melted chocolate is a liquid.

The particles in a liquid jostle around and between each other. As a liquid is heated, the particles gain more energy, move faster and take up more space. Eventually the particles gain enough energy to be able to break free of the forces that hold them together. This is vaporisation—when the particles break free and move on their own as a gas.

➔ Fig 4.53 Vaporisation explains steam rising from soup.

This process can happen in reverse. If the temperature is reduced, the particles will move more slowly. The attraction to other particles will now keep the particles close together. The gas has condensed into a liquid.

As the particles in a liquid lose energy, their movement slows. Eventually they are held in place by other particles and do not have enough energy to move on their own—they become particles locked into a lattice. The liquid has solidified or frozen to become a solid.

Remember that the main difference between a hot and cold substance is the energy in the particles.

➔ Fig 4.54 Solidification occurs when a substance cools.

From ice to steam

EXPERIMENT 4.5

Aim

To investigate the melting and boiling points of water.

Materials

250-mL beaker

Watch or clock

Bunsen burner and heating mat

Tripod stand

Gauze mat

Retort stand, clamp and boss head

Thermometer (0–110°C) or thermistor probe

Stirring rod

Crushed ice

Water

Safety assessment

- Steam and boiling water can both scald. Take great care when measuring the higher temperatures. If scalded, place the area of skin under cold running water for at least 2 minutes and show your teacher.
- Wear safety glasses and lab coat and tie long hair back when using a Bunsen burner.

Method

1 Place some ice and water into the beaker.

2 Wait until most of the ice has melted.

3 While you are waiting, prepare a tripod stand, Bunsen burner, heating mat and other equipment so you can heat the water in the beaker. Set up a clamp to hold a thermometer or a thermistor probe that is connected to a data logger.

4 Copy Table 4.8 into your workbook.

→ Table 4.8

Time (minutes)	Temperature (°C)
0	
1	
2	
3	
4	
5	

5 Place some crushed ice and a small amount of tap water in the beaker. Stir with the stirring rod for approximately 1 minute.

6 Measure and record the temperature of the water and ice mixture. This is the melting point of water. Record the temperature in your table at time 0.

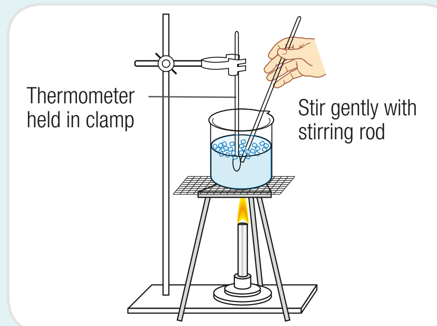
7 Set up the equipment as shown in Figure 4.55, checking to make sure the thermometer is not touching the bottom of the beaker and that it is secure in the clamp. Do not stir with the thermometer.

8 Light the Bunsen burner and start heating the ice and water.

9 Measure and record the temperature of the mixture in the beaker every minute until the water starts to boil and produce steam.

10 Continue heating for another 4 minutes, unless most of the water has evaporated.

11 Using graph paper, or a suitable computer program, draw a graph with temperature on the vertical axis and time on the horizontal axis.



→ Fig 4.55 Experimental set-up for measuring the melting point of ice.

Results

Record your observations, including your table and graphs.

Discussion

1 a At what temperature did you measure the melting point of ice?

b How does your measured melting point of ice compare with the standard measurement of 0°C?

2 a At what temperature did you measure the boiling point of water?

b How does your measured boiling point of water compare with the standard measurement of 100°C?

3 Were there times when it was difficult to read the thermometer? Why?

4 Compare your results with those of the rest of the class. Suggest why there is a variation in the answers.

Conclusion

What do you know about the melting and boiling points of water?

Latent heat

When you heat a substance, it may change state. When a substance is melting or boiling, the temperature does not change. So where does the energy go? The heat energy is absorbed by each particle as it changes to a new state of matter with a higher energy (e.g. solid to liquid or liquid to gas). The heat you have added is hidden, because it did not raise the temperature. This 'hidden heat' is called **latent heat**.

PRACTIVITY 4.4

Ice cube necklace

What you need

Ice cubes
Glass of water
Piece of cotton string
Salt

What to do

1 Float a few ice cubes in a glass of water.
2 Wet a piece of cotton string with water and lay the string on top of the ice cubes.
3 Sprinkle salt all over the string and wait for approximately 10 seconds.
4 Now lift the string and the ice cubes will be stuck to it. You've just made a very cool necklace!

What do you know about changes of state and particle theory?

1 Draw a diagram similar to that shown in Figure 4.56. Add labels to show the energy changes between states.

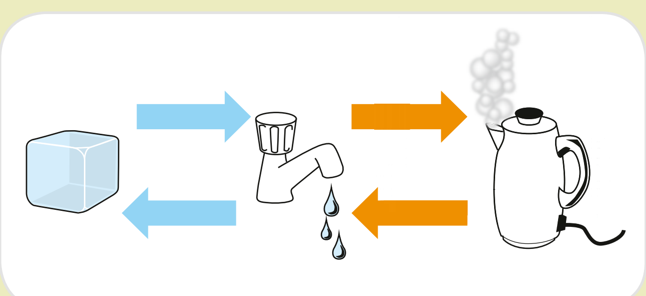


Fig 4.56

2 What is a lattice? Does it only occur in solids?
3 How does the movement of particles change as they get hotter?
4 What is the main difference between a hot and cold substance?
5 What is latent heat?
6 Which has the greater heat content— liquid water at 100°C or water vapour at 100°C?

4.2

How can we explain the properties of matter?

Remember and understand

1 Select one word to replace each phrase.
   a The spreading out of a substance, such as a dye or smell
   b The ability of one substance to scratch another substance
   c The ratio of the mass divided by the volume.

2 In which of the three states of matter do the particles have the most energy? Explain your reasoning.

Apply

3 Sand, stones and bricks have a low tensile strength but a high compressional strength. What does this mean?

4 Why is the thermal conductivity of materials important in designing a new style of saucepan?

5 When you are boiling water, the volume the water is reduced as it evaporates. Does this mean that the density of water changes?

6 How does the behaviour of particles change as the temperature increases?

7 Use the kinetic theory of matter to explain why the pressure inside car tyres will increase on a hot day.

Analyse and evaluate

8 A scuba diver exhales air directly into the water. As the bubbles rise to the surface they increase in size. Assuming that no gas in the bubbles dissolves in the water, how would the pressure of the gas in the air bubble change on its way to the surface?

9 The order of hardness of some common materials is: sand (hardest), tooth enamel, chalk, dental plaque (softest).
   a Use this information to explain why chalk is used in toothpaste as a cleaning agent.
   b What would happen if the chalk was replaced with fine grains of sand?

Critical and creative thinking

10 'The idea of particles is 2000 years old and is 200 years old.' Use the ideas of Democritus and Dalton to explain this statement.

<<CONNECTING IDEAS>> Properties and structure

11 You should now realise that the structure and properties of a substance can be explained by the particles that make up the substance. Explain the following observations by referring to the arrangement and/or the movement of the particles within the substance. You can use labelled diagrams to improve your answers.
   a Water left in an open bottle will gradually evaporate and, if the temperature of the water increases, the water will evaporate more quickly.
   b Mercury is a unique substance because it is the only metal that is liquid at room temperature, and it even gives off a vapour (which makes it very dangerous because this vapour can be breathed into our lungs).
   c Polythene can be produced in two different forms, high-density polythene (HDPE) or low-density polythene (LDPE). If the particles in both HDPE and LDPE are the same, suggest how the structure of the two substances would be different.
   d When you heat a piece of polythene it will melt. While it is liquid, it can be formed into a different shape and when it cools the polythene will stay in this new shape.
   e We can see steam, but we cannot see water vapour.

4.3

What is special about elements and atoms?

Particles are the small bits of matter that give substances their properties. Earlier in this chapter we studied physical and chemical properties, as well as evidence for particles, and explained physical properties using the particle model of matter. The particle model of matter is now known as the kinetic molecular theory. Another major theory that helps us link the properties of substances with their structure is the **atomic theory of matter**. The atomic theory helps us understand not just physical properties, but also chemical properties.

<<DISCOVERING IDEAS>>

What's in a name?

Marie Curie, Albert Einstein, Glenn Seaborg, Niels Bohr. These are all scientists who made great discoveries about the structure and behaviour of atoms. But they also have another thing in common. They all have elements named after them. Find out the actual names of the elements named after these scientists. Find out about the work of these people. What did they discover? Why has their work been so important? Look through some names of other elements. Are they named after people? Places? How they behave? Their appearance?

Find the name of an element that you haven't heard of before. (Figure 4.61 on page 160 will give you some possibilities.) Just from looking at the name, why do you think it has been given that name? Do you think that the element has been known for a long time or discovered relatively recently? What made you choose that element? Now try and find out a bit more about your element and write down five facts about it. Did you find out anything surprising about the element? Share your findings with others.

The atomic theory of matter

The atomic theory of matter states that all substances are made up of particles called **atoms**.

What are atoms?

In Unit 4.2 you learned about the ideas of Democritus and the Ancient Greeks. They used the word *atomos* to describe those particles that could not be divided up any further. The concept of the atom was also referred to in ancient Indian texts. John Dalton and other chemists in the 17th century onwards further developed the idea, using the term 'atom' to describe those particles that couldn't be broken down any further by chemical means.

The smallest atom in terms of mass is the hydrogen atom. Next is helium. Heavier atoms include those of lead and uranium.

What are elements?

An element is a pure substance made of only one type of atom. All the atoms in the element are identical. There are ninety different elements that are found naturally on Earth. Each element is made of a different type of atom. Another twenty or so atoms have been made artificially, but these are highly radioactive and decay within a second. These artificially made atoms are too large to be stable and they disintegrate almost as soon as they are made.

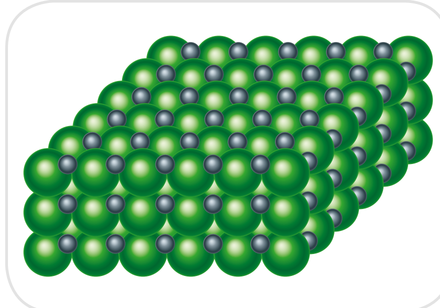
Elements cannot be broken down into other substances because they are already the simplest substances. They can be thought of as being 'elementary', which is the origin of the name *element*.

The element is the substance that can be observed and has properties that can be measured. Atoms are far too small to be observed and are incredibly difficult to measure.

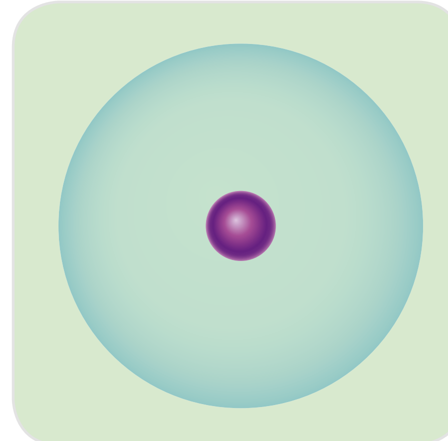
→ Fig 4.57 Not all metals are the same.

→ Fig 4.58 Alfoil is made of the element aluminium and each strip contains billions of aluminium atoms.

In the solid state, atoms of metals are held in a lattice. Most other elements, which are not metals, are called non-metals. Most non-metals are gases at normal temperatures. Some gases, such as neon and helium, are **monatomic**. This means that each gas particle is a single atom (mono = one). However, the atoms in other gases, such as oxygen, hydrogen and nitrogen, are **diatomic**. The atoms of these elements join together in pairs (di = two).



→ Fig 4.59 A metallic lattice.



→ Fig 4.60 Helium is monatomic.

Elements and the periodic table

The **periodic table** arranges all the elements in order of the size of their atoms. It also groups together elements with similar properties. The horizontal rows in the table are called periods. The vertical columns are called groups. The elements in a group often have similar properties, such as the way they look or how they behave.

Metals are found to the left of the zigzag line in the table and non-metals are found to the right.

On the periodic table, you will notice that elements are represented by their symbols, which consist of one or two letters: hydrogen has the symbol H; helium has the symbol He. Other symbols are oxygen (O), carbon (C), nitrogen (N), sulfur (S), gold (Au) and silver (Ag).

→ Fig 4.61 The periodic table.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
					1 H Hydrogen												2 He Helium
3 Li Lithium	4 Be Beryllium											5 B Boron	6 C Carbon	7 N Nitrogen	8 O Oxygen	9 F Flourine	10 Ne Neon
11 Na Sodium	12 Mg Magnesium											13 Al Aluminium	14 Si Silicon	15 P Phosphorus	16 S Sulfur	17 Cl Chlorine	18 Ar Argon
19 K Potassium	20 Ca Calcium	21 Sc Scandium	22 Ti Titanium	23 V Vanadium	24 Cr Chromium	25 Mn Manganese	26 Fe Iron	27 Co Cobalt	28 Ni Nickel	29 Cu Copper	30 Zn Zinc	31 Ga Gallium	32 Ge Germanium	33 As Arsenic	34 Se Selenium	35 Br Bromine	36 Kr Krypton
37 Rb Rubidium	38 Sr Strontium	39 Y Ytrium	40 Zr Zirconium	41 Nb Niobium	42 Mo Molybdenum	43 Tc Technetium	44 Ru Ruthenium	45 Rh Rhodium	46 Pd Palladium	47 Ag Silver	48 Cd Cadmium	49 Ga Indium	50 Sn Tin	51 Sb Antimony	52 Te Tellurium	53 I Iodine	54 Xe Xeon
55 Cs Caesium	56 Ba Barium	57–71	72 Hf Hafnium	73 Ta Tantalum	74 W Tungsten	75 Re Rhenium	76 Os Osmium	77 Ir Iridium	78 Pt Platinum	79 Au Gold	80 Hg Mercury	81 Tl Thallium	82 Pb Lead	83 Bi Bismuth	84 Po Polonium	85 At Astatine	86 Rn Radon
87 Fr Francium	88 Ra Radium	89–103	104 Rf Rutherfordium	105 Db Dubnium	106 Sg Seaborgium	107 Bh Bohrium	108 Hs Hassium	109 Mt Meitnerium	110 Ds Damstadtium								

Classifying elements

What you need

Cardboard

Felt-tipped pens

Scissors

What to do

1 Make up some cards like the ones shown in Figure 4.62 to represent the different elements.

2 Sort the cards into those with a one-letter symbol and those with a two-letter symbol.
- How many elements have a one-letter symbol?
- How many have a two-letter symbol?
- Why is classifying elements according to their symbol a bad idea?

3 Sort the cards according to the colour of the element.
- How many elements are silver coloured?
- How many elements have another colour?
- Why is classifying elements according to their colour a bad idea?

4 Sort the cards according to whether they are solids, liquids or gases.
- How many elements are solids, liquids and gases?
- Why is classifying elements according to their state a bad idea?

→ Fig 4.62

Cu **Copper** Solid brown, shiny	**Al** **Aluminium** Solid silver, shiny	**Mg** **Magnesium** Solid silver, shiny	**Cl** **Chlorine** Gas yellowish-green	**C** **Carbon** Solid black, dull	**S** **Sulphur** Solid yellow, dull
Fe **Iron** Solid grey, shiny	**P** **Phosphorus** Solid red, dull	**Pb** **Lead** Solid grey, shiny	**K** **Potassium** Solid silver, shiny	**Hg** **Mercury** Liquid silver, shiny	**O** **Oxygen** Gas colourless
H **Hydrogen** Gas colourless	**I** **Iodine** Solid grey, sparkly	**Ca** **Calcium** Solid grey, shiny	**Sn** **Tin** Solid silver, shiny	**Br** **Bromine** Liquid red-brown	**Zn** **Zinc** Solid silver, shiny

Elements can also be classified on the basis of their chemical properties. These include how they react with other substances, such as acids and the oxygen in the air. You will be learning more about the chemical reactions of elements in Chapter 4.

What are molecules?

Molecules are groups of two or more atoms that are bonded together. Substances made of molecules, such as water and carbon dioxide, are called **molecular substances**. Molecular substances can be elements (made of the same type of atoms), such as oxygen (O_2), or **compounds** (made of two or more different types of atoms bonded together), such as water (H_2O) and carbon dioxide (CO_2). We use a chemical formula to show the types and numbers of atoms that make up molecules.

Oxygen is an example of a **molecular element**. An oxygen molecule consists of two oxygen atoms joined together. Oxygen gas is a substance made of oxygen molecules. Pure oxygen gas consists of millions and millions of oxygen molecules, all exactly alike.

This means that the word 'oxygen' can be used in two different ways: it can be used to describe an atom or it can be used as the name of the substance. When you see the names of chemicals being used, check the way in which the name is being used—to describe the 'invisible' particle or the substance that is made from these particles.

Molecules of a compound contain atoms of two or more different elements. Carbon dioxide is a **molecular compound**. Its molecules contain carbon and oxygen atoms (Figure 4.64). Pure carbon dioxide gas (the substance) consists of millions and millions of carbon dioxide molecules.

Water is another molecular compound. A water molecule consists of one atom of oxygen joined to two atoms of hydrogen (Figure 4.65). Pure water consists of many millions and millions of water molecules. The water molecules are all identical.

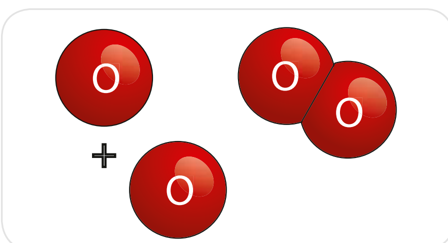


Fig 4.63 An oxygen molecule (O_2) is formed by two oxygen atoms.

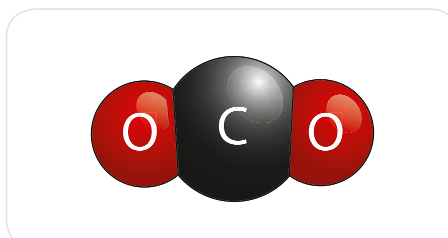


Fig 4.64 A carbon dioxide molecule (CO_2) is a compound made up of one carbon atom and two oxygen atoms.

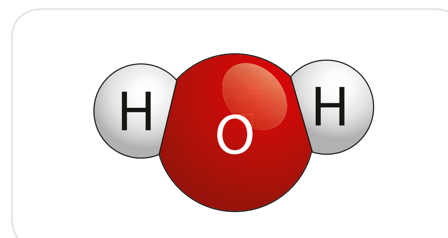


Fig 4.65 A water molecule is (H_2O) is a compound made up of two hydrogen atoms and one oxygen atom.

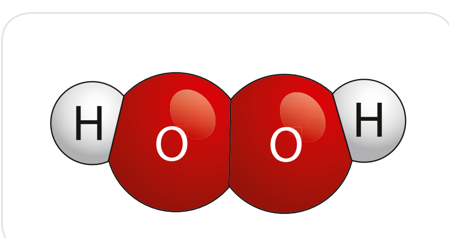


Fig 4.66 A hydrogen peroxide (H_2O_2) molecule is a compound made up of two hydrogen atoms and two oxygen atoms.

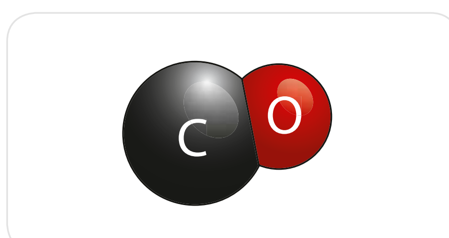


Fig 4.67 A carbon monoxide (CO) molecule is a compound made up of one carbon atom and one oxygen atom.

What do you know about the atomic theory of matter?

1 What is the connection between atoms and elements?
2 What are the two main types of elements?
3 Are molecules only found in compounds? Explain your answer.
4 Ammonia is a gas that contains molecules with the formula NH_3. What elements are present in ammonia and how many of each atom is there in each ammonia molecule?

Compounds and mixtures

You have seen that elements contain only one type of atom. However, you will know that there are far more substances than just the ninety naturally occurring elements. The vast range of substances we see around us are formed as the atoms of different elements combine together to form **compounds**. Compounds are different from mixtures because they are chemically joined or **bonded**.

A compound can be broken down into smaller and lighter substances. This process is called **decomposition** and involves breaking chemical bonds.

Not all elements will join with all other elements. How atoms combine together can be explained and predicted using the laws of chemistry. However, even with these laws, the number of possible combinations is truly mind blowing!

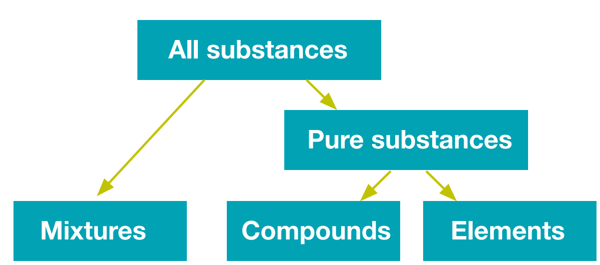
Most of the substances we use are compounds. By altering the numbers and types of atoms, chemists can alter the properties of these substances. Many of the substances that are important to our society are used because of their important properties. These compounds are made in factories or obtained from natural products. Some important compounds are pharmaceuticals, fertilisers, polymers and food materials.

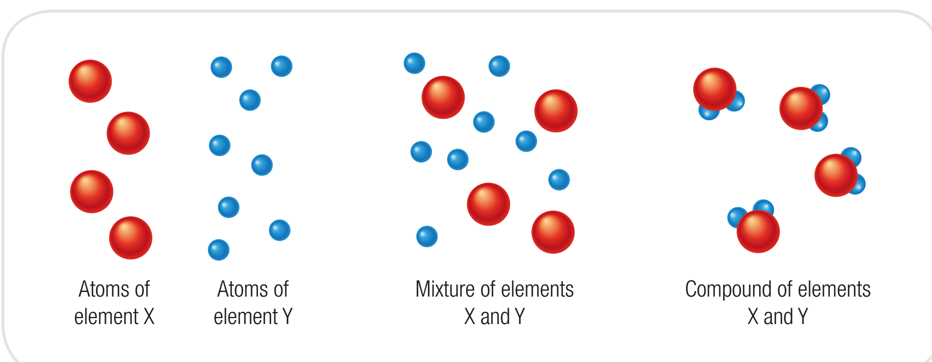
→ Fig 4.69 Most tablets and capsules are compounds of the active ingredients (the drug) mixed with substances to help it absorb into the blood and reach its desired target.

Some compounds are molecular, such as water and carbon dioxide. Other compounds are called **polymers**. The molecules in polymers are made of groups of atoms that repeat over and over—like the beads on a necklace. Plastics are examples of polymers. Other polymers include chemicals found in plants and animals, such as starch and proteins.

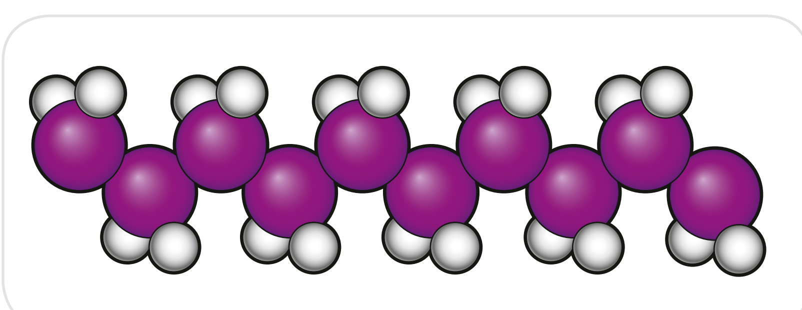
Other compounds do not contain molecules but exist in a lattice arrangement, with atoms held together in three-dimensional networks.

Elements and compounds are pure substances. The particles within one pure substance, whether they are atoms or molecules, are all the same. The following chart shows the different types of substances.





→ Fig 4.68 Mixtures are different from compounds.



→ Fig 4.70 A polyethylene molecule is made up of thousands of carbon atoms joined in a chain, with hydrogen atoms attached to the carbon chain.

Demonstration of the electrolysis of water

Your teacher will show you a Hoffman voltameter. This device uses an electric current to break water molecules into individual hydrogen and oxygen molecules. The electrical energy in the voltameter pulls the atoms apart.

Questions to consider

1. How can you confirm that the bubbles you saw were oxygen and hydrogen?
2. Your teacher may have pointed out that there was twice as much hydrogen gas formed as there was oxygen gas. Why is this? How does it relate to the formula of water as H_2O?

→ Fig 4.71 A Hoffman voltameter.

EXPERIMENT 4.6

Decomposing copper carbonate

Aim

To decompose copper carbonate.

Materials

Copper carbonate
Electronic balance
Plastic beaker
Test tube
Spatula
Bunsen burner and heating mat
Matches
Wooden tongs
Tripod stand
Paper towel

Safety

- Wear safety glasses and lab coat and tie long hair back when using a Bunsen burner.
- Use a yellow (cooler) safety flame for this experiment.
- Hold the test tube or crucible securely with the tongs and always point it away from yourself and others.
- Never place hot objects on the balance.

Method

1 Place a plastic beaker containing the test tube on the balance. Tare the balance so it reads zeros.
2 Using a spatula, add approximately 3 grams of copper carbonate into the test tube. Record the mass in grams (this is W1).
3 Set the Bunsen burner up on the heating mat. Light the flame, ensuring the hole is open and an orange (safety) flame is burning.
4 Using the wooden tongs to hold the top of the test tube, gently wave the base of the test tube over the flame twice. Record any changes. Continue to do this for 2 minutes, recording any changes. Be very careful to point the open end of the test tube away from others and yourself.
5 Allow the test tube and copper carbonate to cool. Wipe any black powder from the outside of the tube off with paper towel.
6 Place the test tube in the original plastic beaker. Check that the balance is zero. Reweigh the test tube and beaker and record the mass (mass) in grams (this is W2). Note any change in weight.

Results

Record your results in Table 4.9.

→ Table 4.9

Weight of copper carbonate before heating (W1) (g)	Weight of copper carbonate after heating (W2) (g)	Difference W1 – W2 (g)

Discussion

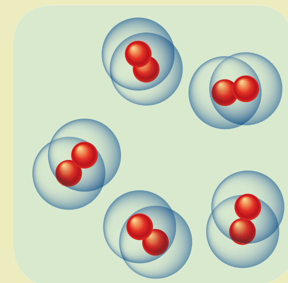
1 What happened to the copper carbonate? Consider the colour and any change in mass.
2 What evidence is there that copper carbonate is a compound and not an element?
3 What are the possible sources of error in this experiment?

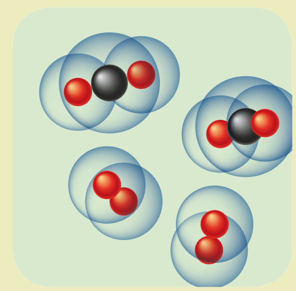
Conclusion

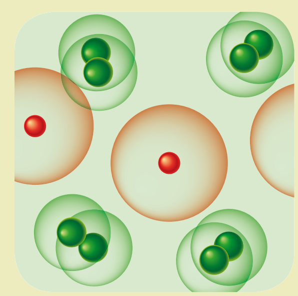
What happens when copper carbonate decomposes?

What do you know about compounds and mixtures?

1 Look at the diagrams below, which show (i) a mixture of an element and a compound, (ii) a mixture of two elements, and (iii) a pure element.







State which description matches which diagram, explaining your reasoning for each type of substance.

2 What are some elements that exist as molecules rather than single atoms?
3 What is meant by the *decomposition* of a compound?
4 What is the difference in meaning between the following groups of words?
   a atoms and molecules
   b elements and compounds
   c diatomic and monatomic
   d molecule, polymer and lattice.

<<BIG IDEAS>> Properties and structure

4.3 What is special about elements and atoms?

Remember and understand

1 What is *decomposition*? What happens in this process?

2 What is the correct word or words for the following descriptions?

 a A group of atoms chemically bonded together

 b A three-dimensional arrangement of particles in rows, columns and layers

 c Where energy breaks apart a compound into simpler substances or elements

 d A feature of a substance that you can observe and measure without destroying or changing the substance.

Apply

3 CH_4 is the formula for methane. How many atoms of which types are in a molecule of methane?

4 What is the connection between the following pairs of words?

 a molecules and atoms

 b molecules and compounds

 c monatomic and diatomic.

5 The heaviest naturally occurring element found on Earth is uranium. Why are bigger atoms not found naturally on Earth?

6 Use diagrams to explain the differences between monatomic substances, diatomic substances and substances made up of lattices.

Analyse and evaluate

7 If you heated a newly discovered substance and it decomposed into two new substances, was the original substance an element or a compound? Give reasons for your answer.

Critical and creative thinking

8 Many people have ideas they think will explain observations and events in science. For an idea to become a theory, it must be able to explain a range of observations. The idea must also be supported by evidence or observations.

 a Can you suggest what evidence would have been required to support the idea that all substances are made of atoms?

 b It is found that a substance cannot be broken down into a more simple substance. How could you use the theory of atoms to explain this observation?

<<CONNECTING IDEAS>> Properties and structure

9 Elements only contain one type of atom, whereas compounds contain a combination of different atoms. This difference in structure can explain some of the behaviours of elements and compounds. By referring to the arrangement of atoms, explain the following statements.

 a When an electric current is passed through water, it is possible to produce hydrogen gas and oxygen gas.

 b Early chemists, called alchemists, tried to turn lead and other metals into gold, but none of them succeeded.

 c When limestone, which is made of the compound calcium carbonate ($CaCO_3$), is heated strongly, carbon dioxide gas is produced. However, when iron is heated, no new substance is created.

>>ZOOMING OUT<<

Research

Choose one of the following topics for a research project. A few guiding questions have been provided for you, but you should add more questions that you want to investigate. Present your research in a format of your own choosing, giving careful consideration to the information you are presenting.

Universal matter

The matter in the universe is thought to be mostly gas, with hydrogen the most common gas. However, there are also different types of matter in planets, stars, quasars, black holes, neutron stars, dark matter etc. The idea of *solid*, *liquid* and *gas* states does not apply in the universe. What types of matter exist in the universe? Where are these types of matter found? Are there any types of matter that are not found in the universe?

State of the matter

The changes between the states of matter have many uses. Research some of these uses and their impact on our society. Some ideas are how refrigeration and air conditioning work; making moulds and casts, such as chocolate, iron and aluminium castings; obtaining medical-grade oxygen and nitrogen from the air; how the energy changes that occur during evaporation of water and the subsequent condensation of water vapour into rain affect thunderstorms and cyclones.

People matter

The discovery of air pressure is a long and interesting story. Research the background of Evangelista Torricelli, Blaise Pascal and Otto von Guericke. For example, Otto von Guericke built a large water thermometer in the front of his house and made the Magdeburg hemispheres. Two opposing teams of eight horses, working like a tug-of-war, could not pull the hemispheres apart.

Reflect

Me

1 Can I use models and diagrams to represent and explain things that are impossible to actually see?

2 What was the most challenging aspect of this chapter and why?

My world

3 How does knowledge of particles improve our understanding of the world around us?

4 How has knowledge of the structure of chemicals depended on modern technologies?

My future

5 What new materials do you think scientists will develop in the future?

Review

Key words

atom
atomic theory of matter
chemical property
chemistry
compound
compressibility
compressional strength
condensation
density
diffusion
element
hardness
incompressible
kinetic energy
lattice
mass
matter
molecule
particle
particle model of matter
physical property
plasma
pressure
property
states of matter
sublimation
tensile strength
vaporisation
vapour
volume

4 The nature of matter

Throughout history, a number of stories have been used to explain the nature of matter. Before the particle model of matter was suggested, people used mythology and creative interpretations of observations to try and understand how the world worked. Even with the particle model of matter, scientists are still making mistakes as they continue learning about the nature of matter.

Up in the air

The legend of Icarus

'Don't fly too close to the Sun,' said Daedulus to his son, Icarus. The story in Greek mythology tells the tale of the attempted escape of Daedulus and Icarus from Crete, where they were being held by King Minos. Daedulus was a master craftsman who had somehow managed to make wings from feathers that were held together by wax. It was these wings that were taking the father and son away from their captor to potential freedom.

However, Icarus ignored his father's warnings and, overcome with the excitement of being able to fly, soared higher and higher. As Icarus flew higher, the temperature increased and the wax melted, so that one by one the feathers fell off until all Icarus had left to flap were his bare arms. Icarus fell into the sea—now called the Icarian Sea.

This story is purely a myth, but it lives on in popular culture, including in a long list of songs, as a metaphor for aiming for targets beyond reach, which results in failure.

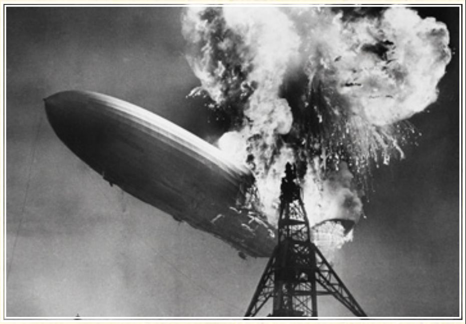
1 a In the story, why do you think Daedulus would have chosen wax to join the feathers together?
  b What would happen to the molecules in the wax as the temperature increased?
  c The story says that the temperature increased as Icarus flew higher. Does this really happen? If not, why not?
  d All wings, in stories and in real life, rely on particles to work. Why is this?

The Montgolfier brothers

In 1783, two French brothers were the first people to successfully produce flight. Joseph and Jacques Montgolfier invented a hot air balloon in which air was heated by a fire. The first 'pilots' were a duck, a sheep and a rooster. Later in the same year, Étienne Montgolfier became the first person to take to the air—the balloon was tied to the ground to prevent it rising too high. After a few trials, the first free flight resulted in the balloon travelling 9 kilometres; the balloon was piloted by a young scientist, Jean-Françoise Pilatre de Rozier, and the Marquis d'Arlandes. The air in the balloon was heated by burning wood, which was contained in an iron basket attached beneath the neck of the balloon.

1. How would heating the air change the behaviour of air particles inside the balloon?
2. What effect would this have on the density of the air inside the balloon?
3. Why do you think that animals were used before humans in trials of the balloons?
4. What properties of iron made it suitable for use as the fire basket attached below the balloon?
5. What are the major differences between modern hot air balloons and those built by the Montgolfier brothers?

The Hindenburg disaster



Airships do not contain hot air; they contain gases that are less dense than air, which enables them to fly.

Hydrogen and oxygen are both gases at room temperature. If you fill a balloon with hydrogen, it will rise even faster than a helium-filled balloon. For this reason, airships were once filled with hydrogen—until the Hindenburg disaster in 1937.

The Hindenburg airship caught fire and exploded in the air, killing many of the people on board.

No one is certain about the initial cause of the explosion. But when a mixture of hydrogen and oxygen is exposed to a spark or flame, there is usually an explosion. Interestingly, the only product of the reaction is water. Water is a compound of hydrogen and oxygen. Because hydrogen is explosive, modern airships use helium, not hydrogen, to give them lift. Helium is almost as light as hydrogen, but cannot burn or explode—it is not known to react with any other element.

1. Hydrogen and oxygen are both elements. When they are combined together, water is formed. What do you think happens to molecules of hydrogen and oxygen for water to be formed?
2. Why do you think a spark or flame is required for this process to happen? (Hint: Both oxygen and hydrogen are 'diatomic' gases—revise the meaning of this word.)
3. Consider the recent development of cars that run on hydrogen fuel cells. What are the advantages of using hydrogen as an alternative fuel? What are some of the dangers associated with its use? What safety measures are in place to avoid a repeat of the Hindenburg disaster on our roads and in petrol stations?
4. Helium is a very unreactive gas. Find helium on a copy of the periodic table and name another gas that will have similar properties to helium.

<<BIG IDEAS>> Interaction and change

5 Making new substances

Fig 5.1 Fireworks are an example of a spectacular chemical change.

5.1 What is chemistry?

We are surrounded by substances undergoing change. When this change involves one substance changing into a different substance, it is called a chemical change. Some of these changes are spectacular, such as fireworks or special effects used in movies. Some changes are not so dramatic, but can affect our lives in very important ways, such as photosynthesis in plants or the digestion of food in our bodies. These changes can happen very quickly or they may be so slow that they are hard to notice.

When a firework explodes in the sky, what do you think is being produced? How do we get different colours when fireworks are set off? What substances are required for a plant to grow? What types of chemicals are present in the food we eat? These are the types of questions that are answered using a knowledge of chemistry.

1 Name five substances that you have used today that you think have been made using a chemical change.
2 Describe a chemical change that occurs very slowly and, if you can, name what is made in that process.
3 Why is it important to be able to convert natural substances from the Earth into new materials?

5.2 How can you identify a chemical reaction?

Chocolate comes in many forms: simple chocolate bars, truffles, chocolate buttons. It can also be melted so fruit can be dipped into it. To melt the chocolate, it must first be heated; but what is happening to the chocolate? Is melted chocolate still chocolate? What happens when the chocolate cools down again? Is this a chemical change? What about the fun part, when we eat the chocolate? Will there be some chemistry happening then?

1 The melting of chocolate is a reversible process. Can you think of three other reversible processes?
2 Imagine chocolate getting so hot that it starts to smoke and go black. What do you think would happen to the taste of the chocolate? Would you still want to eat it? Explain your answers.
3 Do you think that chemistry has been used to make the chocolate in the first place? Give reasons for your answer.

Look at all the substances and materials around you. Where have they all come from? Some substances can be used in their 'natural' form, but most will need to be processed in some way (e.g. cleaning, purifying, mixing or shaping) before we can use them. Examples of such substances are wood, bamboo, wool, silk, cotton, water and salt.

Many substances that you use are not found in nature—they have been produced using chemistry. These substances include many foods, fuels and pharmaceuticals. Without chemistry these new materials would not exist. Without chemistry, living things would not be able to extract energy from their food or produce substances that enable them to grow.

5.3 How do we use chemical reactions?

→ Fig 5.2 Is this a chemical reaction or a physical reaction?

From very early times, humans have been able to use chemical changes to aid their survival. Discoveries of ancient flints, scratched and burnt and dated at almost 800 000 years old, suggest that even the predecessors of modern Homo sapiens had been able to start fires. Before this, our ancestors controlled and used fires that started naturally by lightning strikes. Around 5000 years ago, humans learned how to produce bronze, which was used to produce weapons. This process relies on being able to use a chemical change to produce copper metal from rocks called 'ores'.

Today, in addition to the natural chemical changes that are occurring in our environment and our bodies all the time, chemical changes are used in almost all aspects of our daily lives.

Today, in addition to the natural chemical changes that are occurring in our environment and our bodies all the time, chemical changes are used in almost all aspects of our daily lives.

1 Suggest why being able to create fire would have aided the survival of ancient humans.
2 Why would the use of bronze have been an improvement over the rocks and stones that had been used in the production of ancient weapons?
3 Describe one chemical change in the home that is used to produce heat and another that is used to produce an important material.

→ Fig 5.3 Properties such as melting points allow one metal to be used as a mould for another.

5.1

What is chemistry?

Chemistry is the part of science involved in the study of chemicals. Chemists, the people who study chemistry, find out about substances and how and why they change. This knowledge is essential to make many of the products we use every day.

<<DISCOVERING IDEAS>>

Everyday substances

Below is a list of common substances. Draw up a table similar to that shown, and then use it to classify the substances listed according to how you think they have been produced.

When you have completed the table, undertake some research to find out whether your classifications are correct.

instant coffee powder	gold bars	decaffeinated coffee
rainwater	tap water	rock salt
cane sugar syrup	coffee beans	white sugar crystals
raw sugar crystals	purified water	steel bars

Natural materials (raw materials)	Natural materials that have been purified	Products that have been produced by changing raw materials into new substances

Physical and chemical changes

Many substances are processed before we use them. This processing can sometimes change a substance's composition. Sometimes the material changes into a totally new chemical substance.

When substances interact, they may change. The changes can be noticed in many ways, such as by a change in colour, the formation of bubbles, a change in temperature or the formation of solids. When substances interact by heating, mixing or applying a force, they may change.

EXPERIMENT 5.1

Melting chocolate

Aim

To test whether melting chocolate is a physical or chemical change.

Materials

Cooking chocolate buttons (approximately ten)

2 x 100-mL beakers

250-mL beaker (as a water bath)

Thermometer

Stirring rod

Bunsen burner and heating mat or hotplate

Method

Part A

1. Place four to six buttons of cooking chocolate in a beaker.
2. Place a thermometer in the beaker.
3. Place the beaker in a water bath and heat it to 40°C.
4. Record your observations.

Part B

1. Place four to six buttons of cooking chocolate in a beaker.
2. Place a thermometer in the beaker.
3. Use a Bunsen burner to heat the chocolate rapidly to 60°C and then let it cool.
4. Record your observations.

Results

Record your observations, including any diagrams and photographs.

Discussion

1. What happened to the chocolate when it was heated and cooled gradually in part A?
2. Did a new substance form? Explain your answer.
3. What happened to the chocolate when it was heated in part B?
4. Could you tell the two different chocolates apart at the end based on their appearance?
5. Did a new substance form? How can you tell?

Conclusion

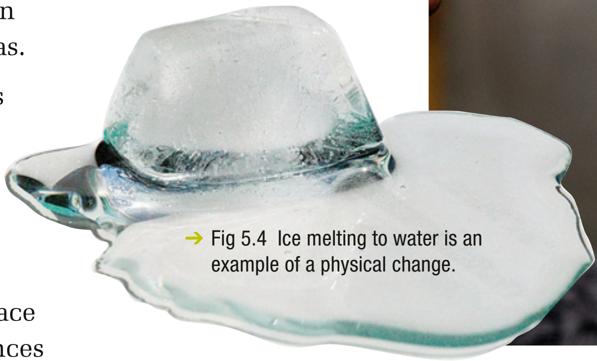
Is melting chocolate a physical or chemical change?

Physical changes

One way that substances can change is through a physical change. The substance still consists of the same particles, but it looks different. A cut diamond is made of the same material as an uncut diamond. Chocolate that has melted and solidified into a mould is the same as the original block of chocolate. A change in appearance or shape is called a physical change.

Physical changes can happen when a force is applied, when substances break down into smaller pieces and when substances change state between solid, liquid and gas.

Most physical changes are reversible, which means the change can be undone and the substance goes back to how it was. When you put water in the freezer, it turns to solid ice. When you take the ice out of the freezer and increase the temperature, it turns back into water. In this way we can deduce that a physical change has taken place because the water is still water and no new substances have been created. Similarly, melted chocolate can solidify again.



→ Fig 5.4 Ice melting to water is an example of a physical change.

→ Fig 5.5 Heating can cause physical and chemical changes.

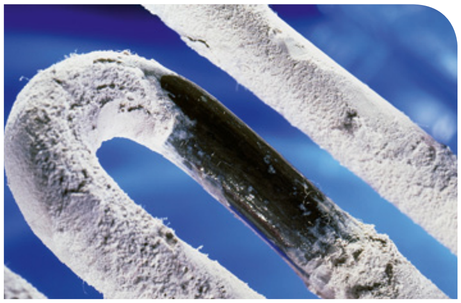
Chemical changes

Chemical changes occur when new substances are formed. We can usually identify a chemical change if one or more of the following occurs:

- **a gas is produced**, which we either see as bubbles or fizz or can smell the gas

- **a colour change occurs that is non-reversible**—heating an iron nail to red hot is a physical change because the red colour will disappear as the nail cools down; however, if the iron in the nail reacts with air and becomes rusty, it is a chemical change

- **light or heat is absorbed or produced**, which we know because the container gets cold or hot



- **a precipitate** (insoluble solid substance) **forms that does not go away**.

In every chemical reaction, one or more substances are changed into new, different substances with different physical and chemical properties. Chemical changes are usually not reversible—you cannot unburn toast!

Whether a change is physical or chemical depends on the substances, the temperature and how you mix them.

Physical change or chemical change?

When solid chocolate is heated gradually, it melts and changes shape; when cooled, it goes back to the solid state. It may have a different shape, but it is still chocolate. In this situation, a physical change has taken place because the chocolate is still the same substance: it is still made up of the same particles.

However, if you heat chocolate at too high a temperature, it burns. When it cools, it no longer tastes of chocolate, but of burnt chocolate. This is a chemical change, because a new substance is formed that is different from chocolate—you can tell by the taste and smell! This is why most chocolate recipes suggest heating chocolate over boiling water rather than over a hot plate, so that the chocolate does not get too hot and a chemical change does not take place.

→ Fig 5.6 Heating chocolate slowly causes it to melt—a physical change. If it is heated quickly and at a higher temperature, the chocolate will burn—a chemical change.

PRACTIVITY 5.1

Warming washing soda

Washing soda is a water conditioner. In some areas, the water does not lather soap properly and washing soda removes the chemicals in water that stop the soap from lathering. Washing soda is also known as Lectric soda crystals and its chemical name is sodium carbonate. It is a colourless crystalline solid sold in supermarkets.

What you need

Washing soda

Bunsen burner and heating mat

Test tube and test tube holder

What to do

1. Place the washing soda in the test tube to a depth of 1 cm.
2. Warm the washing soda gently, with the test tube facing away from yourself and other students.
3. Heat the test tube for a few seconds and then check the contents. Do you notice a change in colour or condensation in the test tube?
4. Reheat the test tube gently for another 10–30 seconds. Is there any change in the colour or condensation in the test tube now?

Questions to consider

1. What has happened to the washing soda?
2. Is the change a physical change or a chemical change? What is the evidence that supports your conclusion?

What do you know about physical and chemical changes?

1. What are the main differences between a physical and a chemical change?
2. Which change is more likely to be reversible, a physical or chemical change?
3. Identify the following as physical or chemical changes:
   a. Melting cooking chocolate into animal shapes
   b. Burning magnesium ribbon to form a white ash
   c. Boiling water and condensing the vapour
   d. Dissolving magnesium in acid to produce hydrogen gas
   e. Separating leaves from wood chips using a garden blower.
4. What is the evidence for a chemical change?
5. Imagine a burning candle. What is the evidence that the burning wick is a chemical change?
6. What was the evidence for a chemical change in each of the practivities?

The work of chemists

It is easy to forget just how much we rely on manufactured products in our life. Increasingly, many substances and materials are processed (i.e. changed) or manufactured before they are used. These substances, such as medicines, electronic components, composite materials in aircraft and polymers, only exist because of the work of chemists. Chemical engineers are also important because they help design the processes that ensure that the chemical changes used produce high-quality products with as little energy, pollution and waste as possible.

→ Fig 5.7 Many everyday items are the result of carefully considered chemistry.

PRACTIVITY 5.2

Magnesium in acid

Magnesium is a metal that reacts readily with acid.

What you need

Test tube and test tube holder

Magnesium ribbon (1 cm length)

1 M hydrochloric acid (5 mL)

Thermometer

What to do

1. Pour 5 mL acid into the bottom of a test tube. Measure its temperature with the thermometer.
2. Add the magnesium ribbon to the test tube. Measure its temperature again.
3. Observe what happens using sight, touch (the outside of the tube only!) and sound.

Questions to consider

1. What happened to the magnesium metal?
2. What evidence for a chemical change did you obtain from your senses?

Pharmacies (sometimes also called 'chemist shops') are where medicines are prepared and dispensed. A pharmacist (sometimes also called a 'chemist') has studied chemistry, but has specialised in the study of medicines and their effect on the body (called *pharmacology*).

→ Fig 5.8 Pharmacists are chemists with a specialisation.

Oil refinery

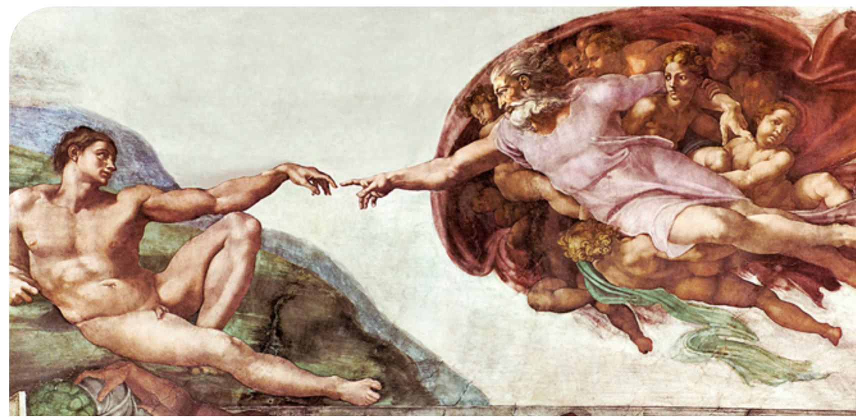
Petroleum, or crude oil, is an important product in our society. Oil is pumped from the ground and is carried in pipelines or tankers to refineries, where it is separated into its components. The low-value parts of the crude oil mixture are converted into high-value products, such as petrol, diesel and materials used to produce plastics. *Plastic* is the common name for a range of polymers used in items such as freezer bags, CD cases, shoes, furniture and clothing.

→ Fig 5.9 All these products come from petroleum.

Glues and adhesives

Glue was used in ancient Babylon 3500 years ago when King Nebuchadnezzar used bitumen to hold building stones together. Later, plant gums, egg white and animal products (such as gelatin) were used for gluing paper and wood. The paints used by the old masters were made using egg white, which helped to hold the parts of the paint mixture together.

In World War I, aircraft were made of wood. The wood was glued with casein glue (casein is a protein in milk) and albumin (a protein in the blood).



→ Fig 5.10 Older paints contained egg white to help hold the paint together.

Nowadays, many synthetic glues are used. Once shoes were made of layers of leather nailed and sewn together; now these layers are mostly glued. Glue is used to hold many things together, including the chips in chipboard and the layers in MDF board, plywood and in much furniture. Even the brake linings in cars are glued (bonded).

→ Fig 5.11 A glue is any substance that sticks things together.

PRACTIVITY 5.3

Making casein glue

Casein is a protein in milk. It can be extracted from milk and chemically changed so it has the properties of a glue.

What you need

Milk (70 mL for each group of students)
Vinegar (20 mL)
Ammonia solution (2 drops) (teacher use only)
250-mL beaker
Bunsen burner and heating mat
Tripod stand and gauze mat
Matches
Thermometer
Stirring rod
Sieve and 250-mL flask
Icy-pole sticks (for gluing together)
Disposable cleaning cloth

What to do

1. Pour 70 mL of milk into the 250 mL beaker.
2. Set up your Bunsen burner and heat the milk to no more than 50°C. Remove the milk from the heat using a heatproof glove.
3. Slowly add 20 mL of vinegar to the milk, with gentle stirring. Do not stir vigorously as you will break up the curd (lumpy bits) being formed. The curd should clump as much as possible.
4. Set up the sieve over the sink or a large beaker. Put a piece of disposable cloth over the sieve.
5. Gently pour the mixture through the cloth and sieve to filter the whey (liquid) from the curds (lumps of mainly protein). Once it has stopped dripping, very gently squeeze the cloth to remove any excess liquid.
6. Return the solids to the original 250-mL beaker and carry it to the fume cupboard for your teacher to add two drops of ammonia.
7. While your sample is in the fume cupboard, stir it well.
8. Take your sample and two icy pole sticks to your bench.
9. Spread your sample between the sticks and press them together. Leave them overnight and then test how well your glue has worked.

Questions to consider

1. Why is it important to wear safety glasses in this experiment?
2. What are the reactants used in this experiment? What are the products?
3. How could you compare the strength of different glues?
4. How do you think someone worked out that you could make glue from milk?

Dyes

Before the use of dyes, all clothes had the same colour—the off-white colour of natural fibres, raw cotton, silk and wool.

The first dye was obtained from murex whelk shells, a type of sea snail. It took 9000 shells to make enough dye for one Roman emperor's toga! Only the emperor had dyed clothes, and these were always purple. In fact, the whelk almost became extinct as a result of being hunted for its dye.

The soldiers in the British Army used to be known as 'red coats'. Their uniform consisted of a red coat, which was dyed using the liquid extracted from scale insects. This red dye, cochineal, is available today in supermarkets, but it is now made synthetically.

The first synthetic (or artificial) dye was discovered accidentally by William Perkin in 1878. He named his dye after its colour, mauve. Soon many other coloured dyes had been discovered and were being manufactured.

Computer printers use dyes when they print photographs. Modern inks do not fade, so the photographs last longer than photographs printed many years ago.

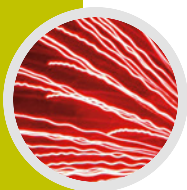
→ Fig 5.12 Dyes originally came from living organisms. Today they are mostly synthetic.

What do you know about the work of chemists?

1. What is the role of chemistry in purifying crude oil in an oil refinery?
2. Describe how chemists have improved on natural glues and adhesives.
3. What colour was the first natural dye and the first synthetic dye?
4. List five materials that are made by chemists.

<<BIG IDEAS>> Interaction and change

5.1 What is chemistry?



Remember and understand

1 Name some materials that are not changed before being used.

2 What changes might be observed during a chemical change?

3 What is the difference between a physical change and a chemical change?

4 What is the difference between a chemist and a pharmacist?

5 Complete the following sentences:
   - a ________ are important because they hold objects together.
   - b A person who dispenses medicines is a ________.
   - c Plastic is the common name for the group of chemicals known as ________.

Apply

6 In terms of the changes that are occurring, explain the differences between melting chocolate and baking a cake.

Analyse and evaluate

7 Dyes can be synthetic or natural in origin.
   - a Describe one advantage and one disadvantage of using natural dyes.
   - b Describe one advantage and one disadvantage of using synthetic dyes.

8 The use of chemistry to produce new materials has affected peoples' lives in a range of ways.
   - a Describe how new materials have changes the type of clothes that people wear.
   - b Describe how new materials have changed the type of food that people eat.

9 Describe a chemical change that maybe harmful to the environment if it is allowed to occur in an uncontrolled way.

10 The following are descriptions of interactions that occur around us in our daily lives. Describe what the products of these interactions might be and explain whether you think the changes described are useful or harmful.
   - a A bike is left out in the rain so that parts of the bike that are made of steel are in contact with water for a few hours.
   - b A barbecue fuelled by propane gas is turned on.
   - c A hairdresser adds bleach to someone's hair.

Critical and creative thinking

11 Think about what you do on a daily basis, including eating, washing, travelling, working and playing. Describe how these activities would be different if you were only able to use natural materials.

12 An environmental action group wanted to ban the use of chemicals in your school.

   Either:
   - a Write a letter to your school principal explaining why you think this would be a good idea;

   or:
   - b Write a letter to the leader of the environmental group explaining why you think this is a bad idea.

<<CONNECTING IDEAS>> Interaction and change

13 Substances can change when they interact with each other. In each of the following situations, a change is described. For each change, describe the interactions that have caused the change to occur. The first one has been done for you.
   - a Glue makes a bond between two pieces of wood. *Possible answer: The glue interacts with the oxygen in the air, which causes it to set hard, which joins the two pieces of wood together*
   - b Sugar turns into caramel.
   - c Charcoal burns in air to form the gas carbon dioxide.
   - d Starch is digested in our stomach to form simple sugars, such as glucose.
   - e A loaf of bread rises in an oven as carbon dioxide gas is produced.

5.2 How can you identify a chemical reaction?

Many substances change their form. Even in the kitchen, a whole range of substances change: ice melts to water, a chocolate bar is broken or melted, an egg is boiled, toast is burned or a pear goes squishy as it ripens. Can chemistry explain these changes? How do you know when these changes are the result of a chemical reaction?

<<DISCOVERING IDEAS>>

Exploring physical changes

Aim

To explore some different physical changes.

Materials

Aluminium drink can

Elastic band

Rock salt

Ice

Sugar cube

Vitamin C tablet

Slice of bread

Piece of cloth

Method

1 For each of the materials provided, find ways to change their appearance.

2 Record your method used and observations in Table 5.1

→ Table 5.1

Material	Method used	Has the substance changed?	Can the change be reversed/undone?

Results

Include your methods and observations, as recorded in Table 5.1, here.

Discussion

1 List three different ways a physical change can take place.

2 What did each change have in common?

Conclusion

What do you know about physical changes?

Chemical reactions

A chemical change can also be described as a **chemical reaction**. In chemical changes or reactions, chemical substances change to become new substances.

The substances that you start with are called **reactants**. They react or change to produce new substances. The substances that you finish with are called **products**. They are produced in the chemical change. There may be more than one reactant and product for each chemical change.

Chemical reactions are all around us. They not only occur in factories—they take place in our homes and in our bodies. Every process in your body requires chemical changes. Cooking food changes it chemically so it is more edible and easier to digest.

When you bake a cake, mixing the ingredients together produces a physical change. Baking the cake involves a chemical change.

Cooking often turns food brown. This is due to the sugar in the food caramelising— turning into brown caramel. The change forms a new substance and is not reversible. It is a chemical change.

What do you know about chemical reactions?

1 Name the reactant and product in the following chemical reactions.
   a Iron ore is made into a steel ship.
   b Bread is made from flour.
   c Freezer bags made from polythene are manufactured from ethene.
   d Nitrogen fertilisers are made from nitrogen gas and hydrogen gas.
   e Carbon dioxide is produced when petrol is burnt in a car engine.
2 Why is caramelisation a chemical reaction?
3 What is the evidence that baking a cake from egg, flour and butter is a chemical reaction?
4 What is the sugar formed as a result of the digestion of starch?
5 Why does digestion involve chemical reactions?

PRACTIVITY 5.4

Making caramel

What you need

Sugar
Test tube
Test tube holder
Bunsen burner and heating mat

What to do

1 Place a pea-sized amount of ordinary sugar into a dry test tube.
2 Wearing safety glasses and, with the test tube facing away from every one, gently heat the sugar.
3 If you are careful, the sugar grains will crumble (they lose water in a chemical reaction) and turn into a brown syrup. This brown syrup is caramel. You may see condensation on the inside of the test tube as the water is driven out of the sugar.
4 If you continue heating, or heat too strongly, you will burn the sugar. Charcoal residue is left behind. This is another chemical change.

Changes at the particle level

Pure substances can be either elements or compounds. In elements, the particles are atoms or groups of the same type of atom joined together to form molecules.

In compounds, different types of atoms are combined together, often to form molecules. Each molecule is made of atoms bonded together.

In both pure elements and pure compounds, the smallest particles in the substance are all identical to each other, whether they are individual atoms or molecules made up from a particular combination of atoms. To understand physical and chemical changes, we can consider what happens to the particles that make up substances.

In a physical change, the particles are rearranged so only the appearance of the substance changes. The atoms and molecules themselves do not change and so the properties of the substance do not change.

In a chemical change, a new chemical is made. This means that the atoms have been moved around into new arrangements. In some chemical changes, molecules can be separated to make new chemicals. Sometimes atoms and molecules join together to make new chemical substances with larger molecules. New substances have new particles and new properties. Both the physical and chemical properties of the new substance (the product) will be different from that of the original substance (the reactant).

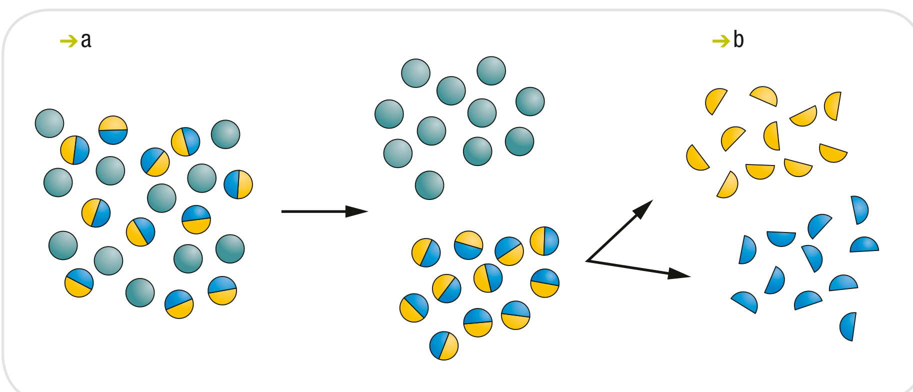


Fig 5.13 (a) In a physical change, only the appearance of the substance changes because the particles have been rearranged. (b) In a chemical change, new chemicals are made. These new chemicals are made of new particles.

EXPERIMENT 5.2

Reacting iron with copper sulfate

Aim

To demonstrate how a chemical change occurs when iron wool is placed into a solution of copper sulfate.

Materials

Piece of iron wool, about thumb size when rolled up

Tongs

~0.5 M copper sulfate solution

100-mL beaker

Method

1. Pour approximately 30 mL of the copper sulfate solution into a 100 mL beaker.
2. Use the tongs to place the iron wool into the copper sulfate solution.
3. Carefully observe the changes that occur to both the iron wool and the copper sulfate solution.

Discussion

1. What colours are the iron wool and copper sulfate solution at the beginning?
2. What happened when the iron wool was placed in the copper sulfate solution?

Conclusion

What evidence is there for a chemical change?

A chemical change is a chemical reaction

When a chemical change has occurred, we say a chemical reaction has taken place. A chemical reaction produces new chemicals. Some reactions, such as rusting, are slow, whereas some are explosively fast. Reactions can be started with heat energy or sometimes start by themselves.

Physical change = same particles before and after, with the same properties
Chemical change = different particles produced, with different properties

EXPERIMENT 5.3

Observing chemical reactions

Aim

To observe the reactants and products in chemical reactions.

Materials

Copper carbonate (solid)
Baking soda (sodium bicarbonate)
1 M hydrochloric acid
Two test tubes and test tube holder
Bunsen burner and heating mat
Matches
Wooden splint
Spatula

Method

Part A

1 Place a large spatula of copper carbonate in a test tube.
2 Set up the Bunsen burner.
3 Using a test tube holder, gently heat the test tube by passing it over the flame twice. Observe any changes and repeat until the powder changes colour.

Part B

1 Place the baking soda in a test tube to a depth of 0.5 cm.
2 Add an equal amount of 1 M hydrochloric acid to the test tube and observe.
3 Conduct a carbon dioxide test by holding a burning wood splint above the tube. If the flame goes out, carbon dioxide is present as one of the products of the chemical reaction.

Results

Include your observations here.

Discussion

1 What has happened to the copper carbonate?
2 What has the copper carbonate turned into?
3 Is this similar to the melting chocolate experiment? Why or why not?
4 What were the products of the baking soda and acid experiment?
5 Why does the flame on the burning splint go out if carbon dioxide is present?

Conclusion

What did you observe about the reactants and products of chemical reactions?

More chemical reactions

Burning is a chemical reaction. The correct scientific word for burning is *combustion*.

Magnesium is a metal that can burn fairly easily, giving off a lot of heat and bright, white light. Before any reaction starts, we know we have magnesium in the ribbon. When the magnesium interacts with the oxygen in the air, the reactants are magnesium and oxygen. The chemical reaction takes place when we see the magnesium ribbon burn. After the ribbon has burned, we are left with a white powder, magnesium oxide, as the product of the reaction.

TEACHER DEMONSTRATION

Burning magnesium

Aim

To demonstrate how a chemical change occurs when magnesium is ignited. Magnesium metal is the reactant and magnesium oxide is the product.

Materials

Piece of magnesium ribbon (2 cm)

Crucible tongs

Bunsen burner and heating mat

Safety

- Burning magnesium produces a bright white flame that emits ultraviolet light. Sit no closer than 5 m to the flame. To avoid looking at the burning magnesium directly, look at an object slightly away from the flame.
- The smoke from the burning ribbon produces a white smoke that is caustic. This smoke will damage the cells lining your nose and lungs. Do not breathe in the smoke.

Method

The teacher holds a piece of magnesium ribbon over the Bunsen burner flame and lights it.

Warning! Do not look directly at the flame or breathe in the smoke.

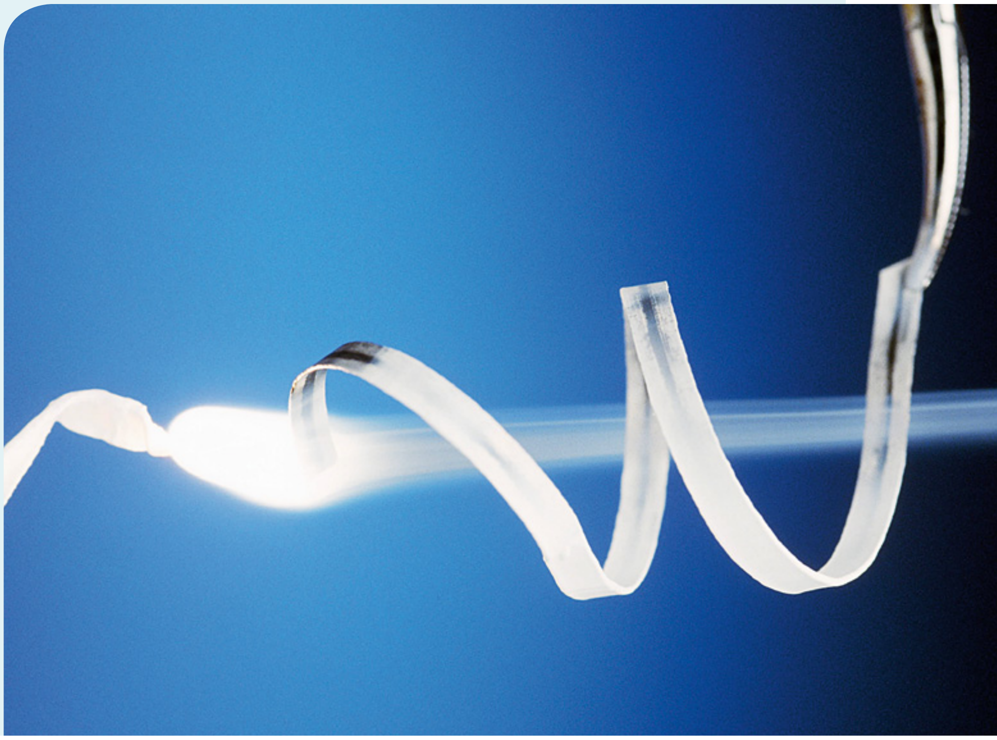
Questions to consider

1 What happens to the magnesium ribbon when it is lit?

2 What safety precautions need to be taken in this demonstration?

3 What is left once the magnesium reacts with the oxygen in air?

4 What evidence is there that a chemical reaction has taken place?



EXPERIMENT 5.4

Comparing reactants and products

Aim

To examine the physical and chemical properties of reactants and products.

Materials

Piece of magnesium ribbon (1 cm)

One pea-sized sample of magnesium oxide powder

20 mL of 1 M hydrochloric acid

Two test tubes and test tube rack

Method

1 Copy Table 5.2.
2 Examine each sample by looking and carefully moving the sample in the bottom of the test tube. Record your observations in your table.
3 Add 10 mL of 1 M hydrochloric acid into each test tube in the test tube rack.
4 Observe any reactions. Record your observations in Table 5.2.

→ Table 5.2

Substance	Colour	State	Shininess	Reaction with acid
Magnesium				
Magnesium oxide				

Results

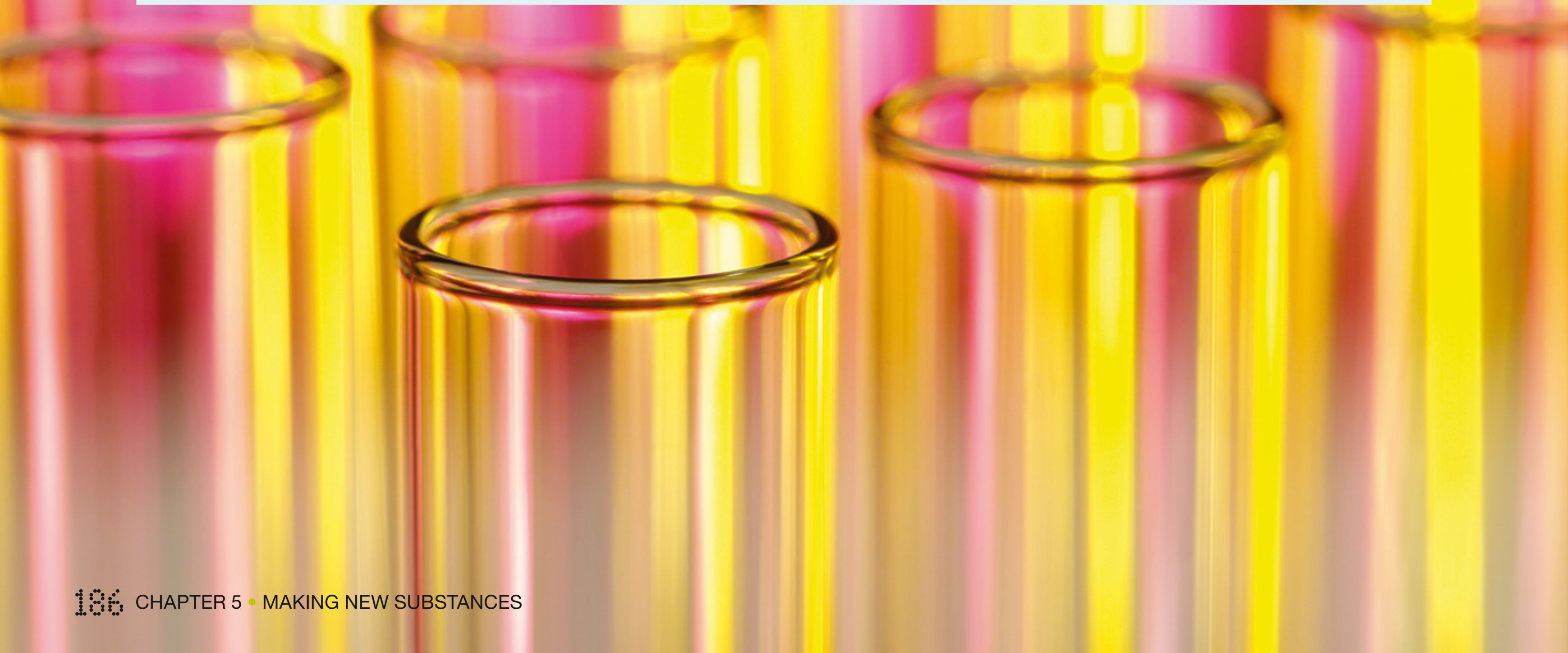
Write a short statement describing each sample.

Discussion

1 Do magnesium and magnesium oxide have the same physical properties?
2 Do magnesium and magnesium oxide have the same chemical properties?

Conclusion

What do you know about the physical and chemical properties of reactants and products?



Chemical equations

LITERACY LAB

Scientists use a shorthand technique to describe what happens to reactants and products in chemical reactions. This is called a chemical equation. The reactants are written on the left-hand side and the products are written on the right-hand side. An arrow represents the chemical change:

reactants → products

For magnesium ribbon burning in air, the chemical reaction could be represented by the following chemical word equation and chemical symbol equation:

Word equation:

magnesium + oxygen → magnesium oxide
(in air) (white powder formed)

Symbol equation:

$$2\ Mg + O_2 \rightarrow 2\ MgO$$

What do you know about changes at the particle level?

1 Copy and complete the table. In the final column, include details about the substance's properties near a flame.

Substance	Formula for substance	Colour	State at room temperature	Chemical properties
Hydrogen				
Oxygen				
Water				

2 How different are reactants and products in chemical reactions?

3 What does the arrow represent in the equation?

4 Why is it unnecessary to write an equation for a physical change?

5 Compared with a word equation, what extra information does a symbol equation contain?

<<OVERARCHING IDEAS>>

Chemical reactions

Stability and change

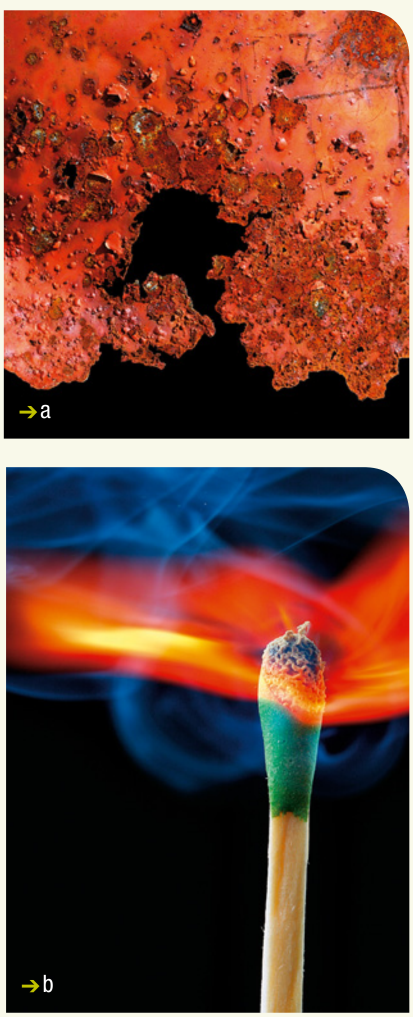
You have been observing a range of chemical changes. They all have one thing in common—the substances produced at the end of the reactions are different from the substances present at the start. However, there are also many differences between the changes that occurred. Some of the substances seemed to react immediately, but some took much longer. Some reactions required heating. How did you know that the reactions had finished?

The changes involved in chemical reactions can be fast or slow. When a gun is fired, a chemical reaction inside the bullet occurs in a fraction of a second. The rusting of an iron nail sitting in water can take a day or so. Other chemical reactions take place over days, weeks or even years. You may not be able to see change happening. Why can't you see these changes?

Stable substances do not react with other chemicals. Gold is a chemically stable metal because it does not react with substances such as air, water or even acidic solutions. Other substances, such as magnesium metal, only react when they are heated. Oxygen does not burn itself, but does allow other substances to burn in it. Is oxygen a stable substance?

Think about some stable substances and their uses. Are they useful because they are stable?

In chemistry, as in other areas of science, the ideas of stability and change are very important because chemistry is concerned with changing substances into different substances.



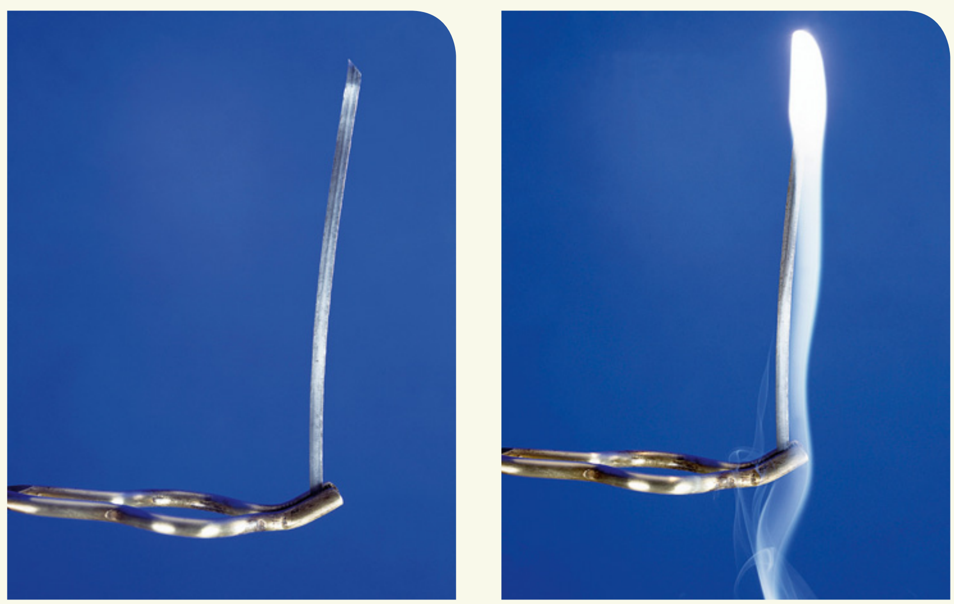


Fig 5.14 Magnesium must be heated before it will react with oxygen in the air.

Fig 5.15 (a) The chemical reaction that produces rust (iron oxide) can take a day or so. (b) When a match is struck, the combustion reaction of phosphorus is so fast that it appears to be almost instantaneous.

<<BIG IDEAS>> Interaction and change

5.2 How can you identify a chemical reaction?

Remember and understand

1 What is a reactant in a chemical change?

2 Bread is mainly made up of flour, sugar and yeast. Explain what chemical reaction happens to the sugar when you toast bread.

3 What is the difference between what happens to the particles in a physical change and what happens to the particles in a chemical change?

4 List three chemical reactions that you have observed today.

5 Using your knowledge of particles, explain why most physical changes can be reversed.

6 Using your knowledge of particles, explain why many chemical changes need heat energy to make them happen.

Apply

7 In one experiment, you observed the reaction between copper sulfate solution and iron to make copper and iron sulfate solution.

a Complete the following table to summarise the changes observed in this reaction.

Name of reactants	Description	Name of products	Description

b Use the information in the table to explain why this is an example of a chemical change.

8 When magnesium burns, a white powder is produced.

a What is causing this change?

b Do you think that the magnesium ribbon would have turned white if the magnesium was left in the air without it being set alight? Explain the reasons for your answer.

Analyse and evaluate

9 Chemists would never write a chemical equation for the melting of chocolate. Why is this?

10 When water is boiled, a physical change takes place. What happens when you boil an egg? What type of changes do you think are happening inside an egg? Explain your answer.

Ethical behaviour

11 In an experiment, students in a class were asked to bring to school a range of substances from their homes, including food, cleaning products from the laundry and cosmetic products from the bathroom. There were then asked to mix one of their substances with any other substance that they brought in. They were told to observe any changes and decide whether a chemical change had taken place. Write a short paragraph explaining whether you think this is a good experiment to carry out.

Critical and creative thinking

12 Doug was taking part in a science lesson and noticed a smell in the laboratory. He said to his teacher that a chemical reaction must have taken place because chemical reactions cause smells. Imagine you are Doug's teacher. Write a few sentences of explanation that you would say to Doug.

<<CONNECTING IDEAS>> Interaction and change

13 Limestone is a rock that is made up of the chemical calcium carbonate. The main source of the calcium carbonate in limestone are the shells of marine organisms. Over time, a range of interactions cause the shells to change into limestone. Find out what conditions are needed for the limestone to form. Explain whether you think this is a chemical or physical change.

5.3

How do we use chemical reactions?

Our bodies use chemical reactions every second of every day. We digest food, convert oxygen into carbon dioxide during respiration and build proteins from more simple compounds called amino acids. These chemical reactions are occurring all the time. Some use energy and some release energy. These reactions are essential for our survival. There are also chemical reactions that we can use and control in our daily lives. You have already seen examples of chemical reactions in cooking and the combustion of fuels to give us heat. Chemical reactions are also used to make substances that we use daily and the ability to produce these substances has changed the way we live in a number of ways.

<<DISCOVERING IDEAS>>

Making yoghurt

What you need

Clean jar brought from home

100 mL of whole milk

Teaspoon (as a measure and for stirring)

3 teaspoons of skim milk powder

1 teaspoon of fresh yoghurt (this contains live bacteria)

Aluminium foil

Fruit, such as berries, to act as a sweetener (3 days after you have made the yoghurt)

What to do

1 Ensure that the jar you are using to make your yoghurt has been washed in a dishwasher or rinsed in hot water. This will kill any stray bacteria that may contaminate your yoghurt.

2 Add the milk to the sterilised jar. Add the skim milk power to the jar and dissolve it in the milk.

3 Add the culture with the bacteria and stir.

4 Cover the jar with aluminium foil and leave it in a warm place for 3 days.

5 Check the jar daily. Yoghurt is the thick creamy part.

6 The yoghurt will taste sour. This is because it contains lactic acid, which was produced by the bacteria. Some commercial yoghurt is sweetened with sugar or fruit. Adding sugar is not recommended, because it has a high glycaemic index (GI) and the bacteria in your mouth could convert this sugar into acid to attack your teeth. Adding pieces of fruit, such as strawberries or other berries, is the best way to sweeten the yoghurt.

Questions to consider

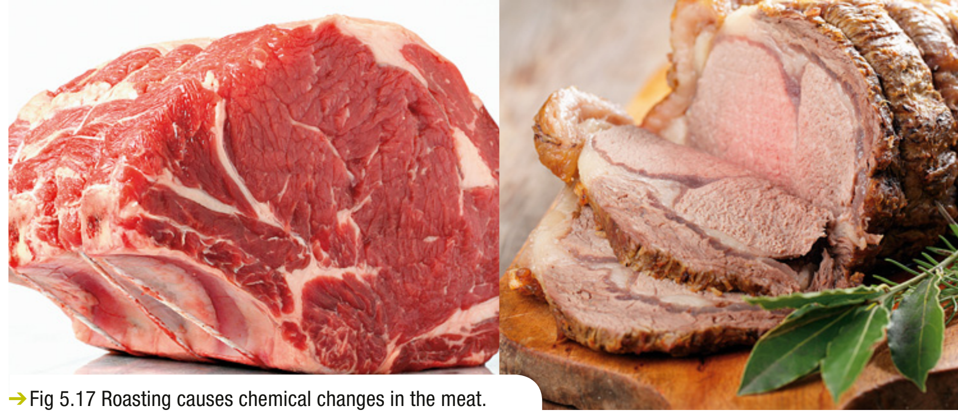
1 This activity will not work if you use frozen yoghurt as the source of live bacteria. Why do you think is this?

2 Why is it important to sterilise the jar before you start this activity?

3 How can you be sure that the correct bacteria are used in this activity?

Using chemical reactions

Chemical reactions are useful because they produce new chemical compounds for our society. Every manufactured substance around us has been produced by a chemical change. As we develop a greater understanding of chemical reactions, we are able to use them to our advantage in more ways.



→ Fig 5.17 Roasting causes chemical changes in the meat.

Reactions in cooking

Preparing and cooking food involves many physical and chemical changes to the food. There are other similarities between chemistry and cooking—some of the techniques, such as heating, mixing and filtering, used in cooking are similar to the tasks of a chemist.

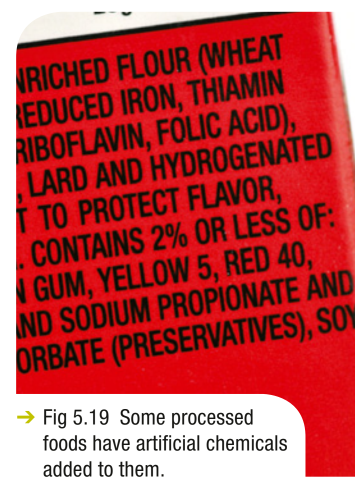
There are many chemical reactions in the kitchen. Baked vegetables and meat turn brown as the sugars are caramelised. Usually the sugar comes from the breakdown of the starch granules into starch molecules, followed by a chemical change into a sugar. Other chemical changes involve the breakdown of proteins in meat. A few vitamins may be destroyed by some cooking methods.

→ Fig 5.16 How would a chemist use these cooking techniques?

Some chemical changes are caused by micro-organisms. Sour milk forms when a bacterium converts milk sugar (lactose) into an acid (lactic acid). The taste of sour milk is unpalatable and the large numbers of bacteria in the milk may make you sick. Cheese is made by fungi that consume the sugars in milk and cause the protein to thicken. In making yoghurt, the bacteria act as a culture (a colony of micro-organisms) that is transferred to the new medium (milk).

Other chemicals are added to our food, including emulsifiers, flavourings, colourings, antioxidants and preservatives. These help keep the food stable, improve its appearance and increase its shelf life. Processed foods usually have a list of these additives on the packet.

→ Fig 5.18 Bacteria can cause chemical changes in dairy foods.



→ Fig 5.19 Some processed foods have artificial chemicals added to them.

New products

Many substances that we now take for granted, such as medicines, chemicals used in agriculture and construction, and plastics such as PVC and polythene, are made from chemical reactions.

These products are hard to make in the laboratory because they require high temperatures and some specialised conditions. A substance that you can make in the laboratory is nylon—a compound consisting of long molecules (called polymers).

TEACHER DEMONSTRATION

Making nylon fibre

Aim

To observe how two solutions, when mixed, can produce a totally new product—nylon thread.

Materials

5% 1,6-diaminohexane solution

5% adipoyl chloride solution in cyclohexane

Cyclohexane

Forceps or stirring rod

Two x 50-mL beakers

Glass Petri dish containing 50% alcohol (ethanol)/ water mix

Method

1. In beaker 1, mix 0.5 g of adipoyl choride and make up to 10 mL with cyclohexane. Stir it until the adipoyl chloride has dissolved.
2. In beaker 2, place 0.5 mL of 1,2-diaminohexane solution and make up to 10 mL with distilled water. Stir.
3. Gently pour the 1,6-diaminohexane solution from beaker 2 down the side of the beaker 1. Do not mix.
4. A skin will form at the interface of the two liquids. Lift the skin out with forceps and gently wind it around the length of the glass rod. The skin will continue to re-form for some time.
5. Unroll the thread into the Petri dish containing 50% alcohol and leave it to soak for 10 minutes.
6. Remove the thread from the alcohol solution and dry it between filter paper or paper towel.

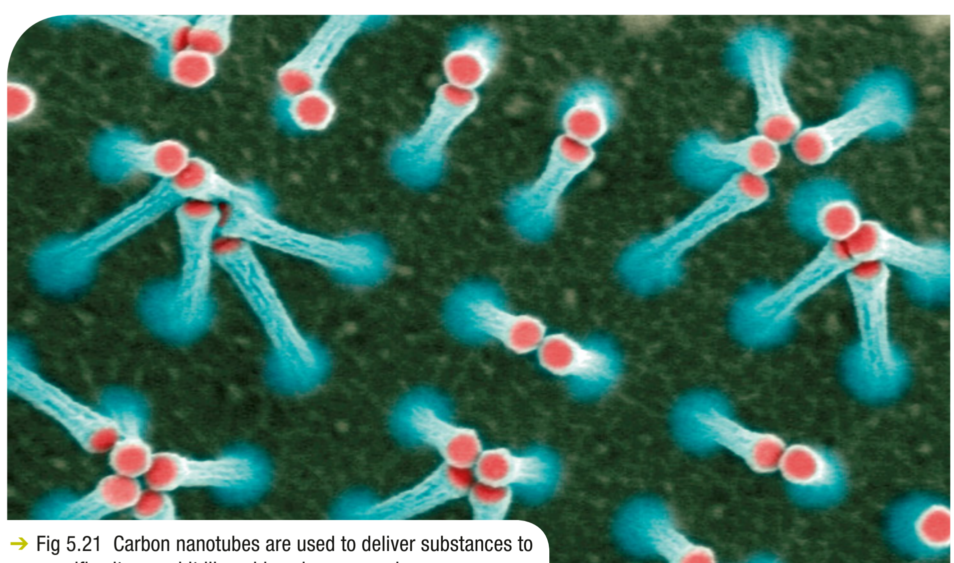
8. Examine the thread under a microscope and sketch its appearance.

Questions to consider

1. Describe the reactants used.
2. Describe the product formed.
3. What changes have taken place?
4. Why is this a chemical reaction?

→ Fig 5.20 Nylon thread is made by mixing two solutions.

One of the most exciting areas of new product development is nanotechnology, in which scientists manipulate individual atoms and molecules in substances such as silicon to design faster and smaller electronics components for computers, televisions and mobile phones. Nanochemists have also designed a vast array of new products that have many different uses—sunscreens and cosmetics, paints, clothes that don't wrinkle and socks that resist odour.



→ Fig 5.21 Carbon nanotubes are used to deliver substances to specific sites—a bit like addressing an envelope.

ZOOMING IN

Air bags in cars

An air bag in a car provides extra protection to the driver or occupant in the event of a collision. Air bags are designed to work in conjunction with seat belts—they fill rapidly with gas and then deflate (go down) rapidly after they have absorbed the force of the person. The bags deflate quickly because they are porous and the gas can escape fairly easily.

The air bag is activated by a sensor. The sensor detects the very sudden stopping of the car, such as in a high-speed collision. This generates an electric current, which detonates (explodes or ignites) a small amount of compound called sodium azide.

A driver's side air bag contains approximately 50 grams of sodium azide. This compound is heated electrically and detonates to produce 60 litres of nitrogen gas. The nitrogen gas fills the air bag within 40 milliseconds. By the time the driver's body impacts the air bag, the bag has filled and is deflating.

This means that the air bag is soft, not hard, when the driver's body hits it. In fact, after 2 seconds the air bag is fully deflated.

The nitrogen is made by the decomposition of the sodium azide. The sodium that is also produced in this reaction may be a health hazard, but it reacts with other chemicals in the air bag to produce an inert (unreactive) powder. This powder remains sealed inside the core of the air bag. Even if the air bag were cut apart, the powder would not harm you.

The passenger's side air bag is much larger than the driver's side air bag. So the passenger's side air bag has more sodium azide because more gas is needed to fill it.

Some newer air bags contain reactants other than sodium azide. Therefore, these bags produce different products from the reaction. But they still produce nitrogen gas at the same rate.

→ Fig 5.22 Air bags in cars fill rapidly with gas to protect the driver and passengers in a car crash.

Reactions for entertainment

Special effects at the movies

Movie makers use lots of chemistry to get the special effects they need to thrill their audience.

When an actor is 'shot', the bang of an imitation gun is caused by a small amount of gunpowder. The ingredients of gunpowder can be varied to produce different effects: smoke or smokeless gunpowder, or a bright flash from the pretend gun.

Specially qualified chemists are used to make explosions. They use different amounts of different ingredients and can make explosions to order: loud noise, lots of smoke, lots of flame etc.

→ Fig 5.23 Special effects in movies happen when chemical reactions are made to go faster.

Fireworks

Fireworks are made of the fuel (usually gunpowder), binders to hold everything together, a fuse to ignite the fuel, an oxidiser to provide the oxygen used in combustion, colour-producing chemicals and other substances that enhance the colours. The atoms that provide the colour of the firework are listed in Table 5.3. You can test some of these in Practivity 5.5.

Fireworks can be very dangerous. They must be kept in a cool, dry, spark-free environment. A range of instructions for making fireworks and other explosives is available on the Internet. These instructions do not take into account the purity of the ingredients, the grain size of the reactants, the manner in which they should be mixed and packed or the optimum conditions for mixing and storage. People who follow these instructions sometimes find that the ingredients react without warning. People have lost fingers and eyes when the reactions do not go according to plan.

→ Table 5.3 Atoms that produce the colour of fireworks

Colour of firework display	Atoms that produce the colour
Red	Strontium
Orange	Calcium
Yellow	Sodium
Green	Barium
Blue	Copper
Indigo	Caesium
Violet	Potassium
Gold	Iron or carbon
White	Aluminium or magnesium

→ Fig 5.24 Fireworks are an example of a spectacular chemical change.

PRACTIVITY 5.5

Flame tests

In this activity, you will observe the colour of flame when a chemical is placed in a Bunsen burner flame.

What you need

Bunsen burner and heating mat

Matches

1 M hydrochloric acid

Wire loops

Solid sample of sodium carbonate, copper carbonate, potassium carbonate, strontium carbonate

What to do

1. Set up your Bunsen burner, observing safety instructions. Light your burner on the safety (orange) flame.
2. Set your burner to the blue flame. Dip a wire loop in a small beaker of 1 M hydrochloric acid. Put the loop in the flame to clean it. Avoid getting too close to the flame. Stand back a little.
3. Take a loop of solid chemical and place it in the flame. Observe the colour of the flame. Try to avoid losing the solid down the Bunsen burner barrel. This could clog the burner and contaminate the flame for the next sample.
4. Clean your loop by dipping it in the 1 M hydrochloric acid and flaming it again.
5. Repeat steps 3 and 4 for the rest of the samples.

Question to consider

Why do you think the different substances produced different-coloured flames?

→ Fig 5.25 Sparklers burn more slowly than firecrackers.

Sparklers

A sparkler contains slow-burning gunpowder and also a sugar or starch binder that helps to hold the mixture together. The mixture burns in sequence rather than all at once. Flakes of metal are embedded in the gunpowder, and these produce the 'sparkling' effect. The flakes are made of aluminium or magnesium for white light and iron for yellow light.

Sparklers burn at a very high temperature, over 1000°C. This is why children should be supervised by a responsible adult when handling sparklers.

What do you know about using reactions?

1 Why is 'filtering' described as a physical change, whereas 'baking' is described as a chemical change?
2 What is the gas that is produced when baking a cake that causes the cake to rise?
3 Name an object that is made from PVC (polyvinyl chloride).
4 Why is nylon described as a synthetic material?
5 Why is it important that an air bag is not 'air tight'?
6 Why do different fireworks have different colours?
7 What metals cause the colours in sparklers?

5.3 How do we use chemical reactions?

Remember and understand

1 Why is it dangerous to mix chemicals, especially gunpowder, from recipes obtained from second-hand sources?

2 Describe three uses of chemistry in the home.

Apply

3 Design and complete a table that shows the ingredients in fireworks and the use of each ingredient.

4 Some of the chemical changes that occur with food are described as biochemical reactions. Why do you think that is?

Analyse and evaluate

5 Why are the skills of a chemist important in the theatre and movie making?

6 Why is nitrogen gas used to fill a car air bag rather than hydrogen gas?

7 A rock was analysed to find out what metals it contained. The rock was crushed into a powder and this powder was heated in a Bunsen flame. The flame produced was a bright orange, with some blue tinges on the outside. What metals might be present in the rock?

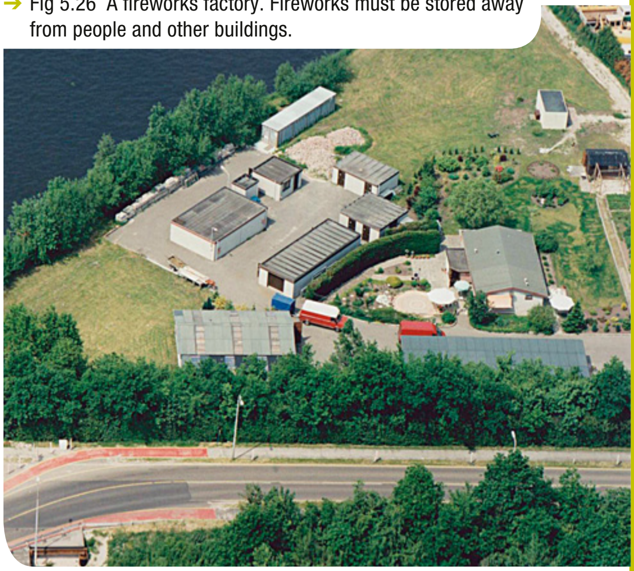
Critical and creative thinking

8 Consider a warehouse where chemicals used for the production of fireworks are stored. The regulations for the storage of the fireworks state that:

- smoking is prohibited
- the warehouse should be kept cool
- there should be no electrical equipment used
- the chemicals must be kept dry.

Explain why each of these four rules is important.

→ Fig 5.26 A fireworks factory. Fireworks must be stored away from people and other buildings.



<<CONNECTING IDEAS>> Interaction and change

9 Consider a burning sparkler. There are a number of chemicals that are used in the sparkler.

a Why are a range of chemicals required in the sparkler?

b What interactions take place between the chemicals that make up the firework and the surrounding air?

c How are the chemicals changed as the sparkler burns?

Research

Choose one of the following topics for a research project. Some questions have been included to help you begin your research. Present your report in a format of your own choosing.

Magic or chemistry?

Magicians use a range of tricks to deceive the audience into thinking magic is real. Some of these tricks use chemical reactions. What sort of chemical reactions are used by magicians? What sort of physical and chemical changes happen in tricks used by magicians? How does the 'magic' happen?

Explosives

The history of the development of explosives is fascinating. Who discovered them? When were explosives first used and how do they work? What are the main chemicals used and what types are there? What part did Alfred Nobel play?

Respiration

Respiration is a chemical process that occurs in our body and is essential for our survival. What are the reactants used in respiration? What are the products? Where in our bodies does respiration occur? Why is respiration such an important process?

Barbecue fuels

Most home barbecues burn LPG as the fuel. This is the gas that can be bought at hardware and camping stores in cylinders. What does LPG stand for? What chemicals are present in LPG? What are the advantages of gas barbecues over solid fuel barbecues? What safety precautions must be followed when storing LPG cylinders?

Reflect

Me

1 What new laboratory skills have I learned in this chapter?
2 Can I identify chemical reactions in the world around me?

My world

3 How has knowledge of chemistry improved our understanding of the world around us?
4 What materials do I use that have been produced using knowledge of chemistry?

My future

5 How can knowledge of chemical reactions help make our world safer in the future?
6 How can chemistry help us make the most of the Earth's resources?

Review

Key words

chemical change
chemical equation
chemical reaction
chemist
chemistry
combustion
compound
element
particle
petroleum
pharmacist
physical change
plastic
polymer
precipitate
product
property
pure substance
reactant
reversible
stable
symbol equation
synthetic
word equation

5

Acid sulfate soils

Acid sulfate soils are found around Australia's coastline, where most of the population lives. These soils were formed underwater a long time ago when the sea level was much higher. When the seas receded, the acid sulfate soils remained. These types of soils are found in muddy and sandy low-lying coastal areas, such as coastal plains, wetlands and mangroves. Under the right conditions, they can still form today, caused by the interactions between chemicals and living bacteria.

How are acid sulfate soils formed?

Acid sulfate soils contain compounds called iron sulfides (pyrite). They form when sea water (or water that contains a lot of chemicals called sulfates) mixes with waterlogged soils and sand that contain iron and some organic matter. This process occurs where there is not much oxygen present, such as in mangrove swamps. Some bacteria flourish under anaerobic conditions—that is, conditions without oxygen. These bacteria carry out chemical reactions that help form the pyrite.

The following are needed for pyrite to form:

- sulfur—usually from sea water
- a lack of oxygen (anaerobic conditions)
- anaerobic bacteria
- rotting material (e.g. mangrove leaves) to supply energy for the bacteria
- a source of iron—usually from mud or sand
- temperatures above 10°C

In an undisturbed and waterlogged state, acid sulfate soils cause few problems. However, when these soils are exposed to air, usually because of drainage or excavation works, a chemical reaction occurs and acids are produced in the soils, which can cause major environmental problems.

➔ Fig 5.27 This concrete bridge pylon is being destroyed by sulfuric acid from acid sulfate soils, which reacts with the carbonate in the concrete.

➔ Fig 5.28 Acid sulfate soils are commonly found around mangrove swamps and estuaries.

The effect of acid sulfate soils

Acid sulfate soils can produce sulfuric acid when exposed to the air and become strongly acidic. The sulfuric acid and toxins released when the soils are exposed to air end up in our estuaries and waterways. For example, it has been estimated that 72 000 tonnes of acid have been washed into Trinity Inlet in Cairns after 700 hectares of land containing acid sulfate soils was drained in the 1970s. This decreases the quality of the water, killing fish and damaging sensitive ecosystems. Acid sulfate soils have had huge effects on our fisheries. Acid run-off also affects human constructions, such as drains, pipes, bridges and foundations.

Changing colours

The presence of sulfuric acid causes toxic quantities of heavy metals to be released into the environment. The acid run-off from acid sulfate soils reacts with iron in surrounding rocks and soils, causing it to dissolve. This results in the water containing more iron compounds than normal. Jarosite is an iron compound. It is yellow in colour, which can make the soil yellow too.

As the sulfuric acid moves through the soil, it can also interact with clay containing aluminium. This causes soluble forms of aluminium to be released into the waterways. High levels of aluminium in the water cause suspended particles in the murky water to clump together and drop to the bottom. This makes the water go clear and turn a blue–green colour.

Questions to consider

1. How do you know that the formation of pyrite is a chemical reaction?
2. How are bacteria involved in changing the nature of the soil?
3. Why do you think that a temperature above 10°C is required for the interactions between the chemicals and the bacteria to cause a change?
4. Why are acid sulfate soils a particular problem where major building or landscaping work has been carried out?
5. What substances interact to form actual acid sulfate soils?
6. How would the water in an estuary be changed if sulfuric acid and toxins were washed into the estuary?
7. What changes do you think would occur to pipes and bridges if the metal in the bridges interacted with the acid from the actual acid sulfate soils?
8. How could knowledge of chemistry be used to reduce the effect of acid sulfate soils?
9. How can the colour of soils be used to identify actual acid sulfate soils?
10. What interactions cause the level of iron dissolved in water to increase?
11. Describe the changes caused by the interactions between aluminium compounds and solid particles suspended in the water.
12. Apart from affecting the colour of water, increased levels of aluminium in the water can be a risk to health. Find out why aluminium in water is dangerous to living things.

6 The changing Earth

6.1 What are the properties of rocks and minerals?

Minerals are the basic parts, or the building blocks, of all rocks. Just like buildings are made of bricks and living things are made of cells, so rocks are made of minerals.

Minerals display properties that make them useful to humans, such as their hardness, shininess and their ability to be shaped without breaking.

1 What are rocks made of?
2 Figure 6.1 shows two different minerals.
   - Identify each mineral.
   - Suggest which properties of each of mineral make them valuable to humans.
3 As a class, identify other minerals and suggest how they are used.

→ Fig 6.1 This 30-carat diamond ring is one of the largest in the world. It is valued at $2 million.

→ Fig 6.2 The Great Sphinx in Egypt has been badly weathered by wind and rain.

Uluru is a sandstone island mountain—a remnant of a mountain range that was slowly eroded away. Originally formed from sand deposited from fast-flowing streams in a fan shape, the horizontal layers of sand were then tilted vertically by extremely large forces during an episode of mountain building, possibly 300–400 million years ago. The uniform nature of the rock led to its survival while the surrounding rocks eroded away, as is the nature of our changing Earth.

6.2 How do rocks form?

Rocks look hard and tough. They are used to make roads, important buildings and monuments. Large rocks can be used to hold back the surf and ocean waves. Rocks seem to last forever—but they don't. They are slowly worn down and transported away by water, wind and ice. Even statues and buildings made from rock are worn away. The wearing away of rocks into smaller pieces is called **weathering**.

1 The Great Sphinx shown in Figure 6.2 was carved in a limestone quarry in Egypt that was formed at the bottom of the sea 50 million years ago. Shells can be found around the embankment and there was once a shoal and a coral reef here. What sort of process do you think would have formed the limestone?

2 What has happened now to the Great Sphinx statue?

3 'Stacks on the mill' was originally a schoolyard game where children would pile in a heap on top of someone.
   - If you were the child on the bottom, what would it feel like as more and more children piled on top of you?
   - How is this similar to the force and energy that changes rocks?

6.3 What can we learn from studying rocks?

Studying rocks helps us learn about the Earth, how it was created and how it has changed over billions of years. Scientists who study rocks are known as geologists. There are many different types of **geologists**. Those who study rocks are called petrologists. Petroleum geologists study sedimentary rocks and select the best places to drill for oil. **Palaeontologists** also study sedimentary rocks, but they are geologists who study fossils—the remains of plants and animals from the past—enclosed in the rock. By studying fossils, palaeontologists can help us learn about past life on Earth.

1 What does a petroleum geologist learn from studying rocks?

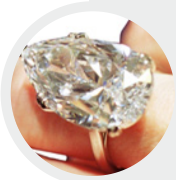
2 What do you think a mineralogist would study?

3 Look at Figure 6.3. What might these palaeontologists learn from this discovery?

→ Fig 6.3 Palaeontologists observe a 270-million-year-old dinosaur fossil found in Germany.

6.1

What are the properties of rocks and minerals?



Not all rocks look and feel the same. Each rock has characteristics that give clues to its identity, such as its colour or hardness. These are referred to as **properties**. By making careful observations of a rock's properties, geologists can tell where a rock came from and what has happened to it.

<<DISCOVERING IDEAS>>

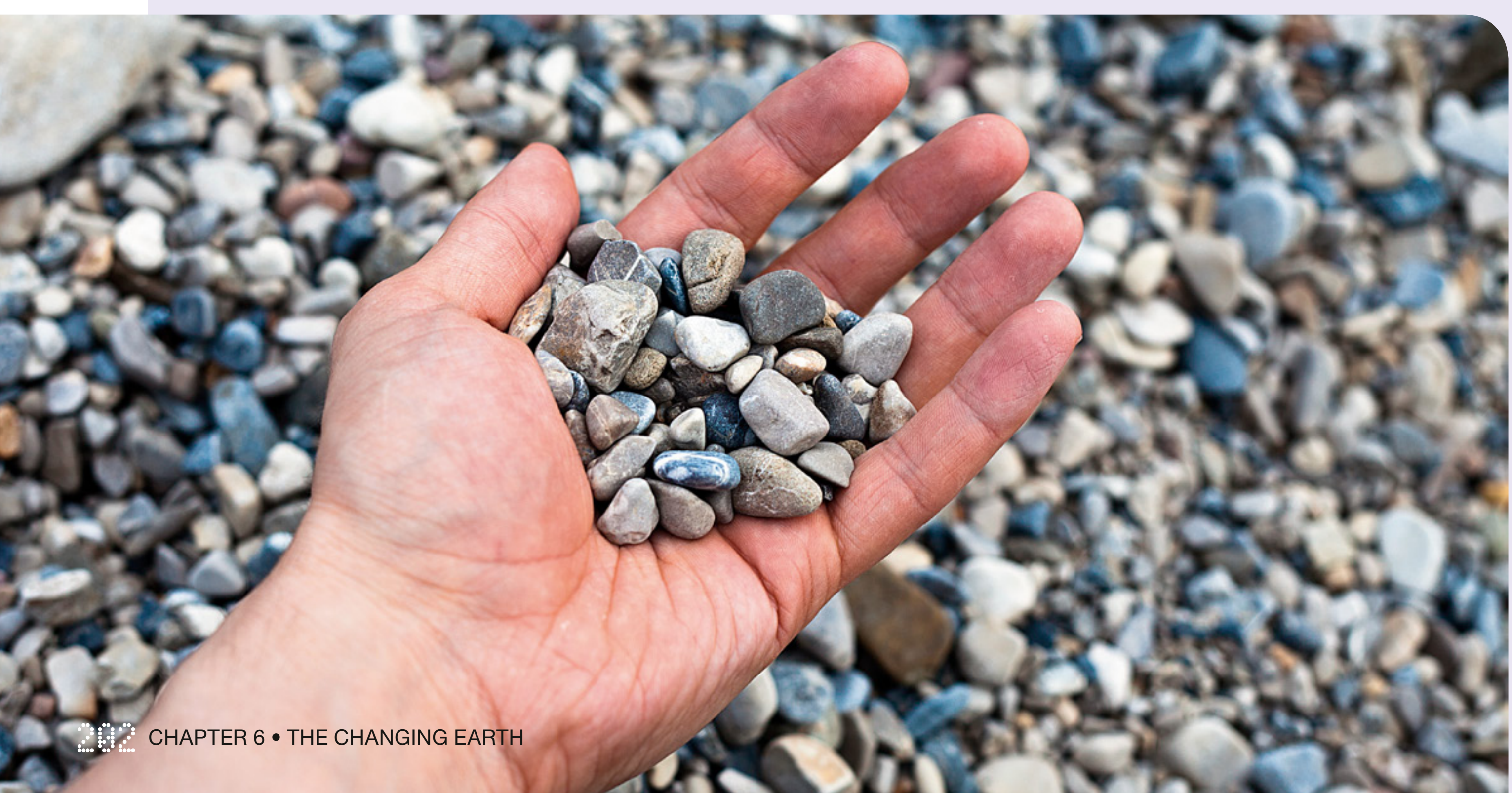
Rocks in your head!

How do you tell one rock type from another? In your mind, there are probably certain properties you look for to identify objects around you. What properties would you use to identify rocks? Do you know any particular types already? What do you know about them? Are there certain words you would use for rocks that wouldn't be used for anything else?

Working in small groups, suggest features that could be used to group rocks.

Find some rocks out in the schoolyard and, using the features you discussed in class, group them.

Did the class end up with the same ideas? If not, how did the properties differ? Would you consider the properties identified by your group as 'scientific'?



Identifying and selecting rocks

Humans select rocks for particular purposes because of their properties. Granite, for example, is selected for kitchen benchtops because it is the hardest building stone, it is not porous (it doesn't let liquid through), it does not change with temperature and it is resistant to damage from chemicals.

Rocks can first be identified by how they look. Coal, for example, is black or dark brown. The surfaces of pumice and scoria are full of holes. Conglomerates (as the name suggests) are rocks made up of individual stones that have become cemented together. Granite is made up of large crystals of the minerals quartz, mica and feldspar.

Geologists also use a range of other properties to help identify rocks, including:

- hardness
- lustre (shininess)
- transparency
- the shape of the crystals
- density
- streak (the colour of the powder of the mineral).

Table 6.1 lists some different types of rocks and how they can be identified. These rocks are shown in Figure 6.4.

→Table 6.1 Rock identification

Rock	Grain size	Hardness	Usual colour
Quartzite	Coarse	Hard	Light
Obsidian	Fine	Soft	Dark
Conglomerate	Mixed	Hard or soft	–
Coal	Fine	Soft	Dark
Limestone	Fine	Soft	Light
Slate	Fine	Soft	Dark
Granite	Coarse	Hard	Light
Scoria	Fine	–	Dark
Pumice	Fine	–	Light
Shale	Fine	Soft	–
Basalt	Fine or mixed	–	Dark
Marble	Coarse	Soft	Light
Sandstone	Coarse	Hard	Light
Gneiss	Coarse	Hard	Alternating light and dark bands
Schist	Medium to coarse	Medium	Medium
Rhyolite	Fine	Hard	Light

What do you know about identifying and selecting rocks?

1 What type of rock am I?

- **a** I am soft with distinctive layers.
- **b** I am dark with holes in my surface.
- **c** I am soft, shiny and used for jewellery.
- **d** I am white with coarse grains. I am used for sculptures.

What are minerals?

Properties of minerals

Rocks are made up of one or more minerals. A **mineral** is a naturally occurring solid substance with its own chemical composition, structure and properties. There are more than 4000 minerals known, but only approximately 150 of these are common. **Quartz** is the most common mineral and it is found in nearly every rock type. Quartz is made up of the two most common elements that make up the Earth: oxygen (O) and silicon (Si).

Quartzite
Coarse grain
Hard
Light colour

Obsidian
Fine grain
Soft
Dark colour

Conglomerate
Mixed grain
Hard or soft
Colour varies

Coal
Fine grain
Soft
Dark colour

Limestone
Fine grain
Soft
Light colour

Slate
Fine grain
Soft
Dark colour

Granite
Coarse grain
Hard
Light colour

Scoria
Fine grain
Dark colour

Pumice
Fine grain
Light colour

Shale
Fine grain
Soft

Basalt
Fine or mixed grain
Dark colour

Marble
Coarse grain
Soft
Light colour

Sandstone
Coarse grain
Hard
Light colour

Gneiss
Coarse grain
Crystals in layers

Schist
Medium to coarse grain
Layers, splits easily

Rhyolite
Fine grain
Often larger crystals
Light colour

→ Fig 6.4 Different types of rocks.

ZOOMING IN

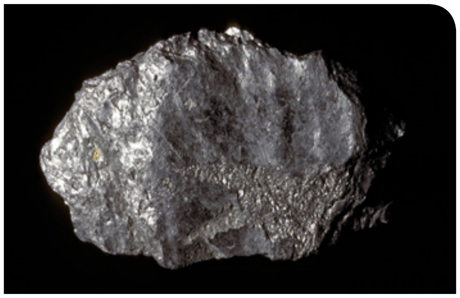
Quartz in watches

Quartz watches use quartz crystals to keep time. A property of the quartz crystal is that it generates an electric charge when mechanical pressure is applied to it. Depending on the type of quartz crystal, a quartz timepiece can accurately keep time to within 1 second every 10 years.

→ Fig 6.5 Under a microscope, the minerals that make up the rock olivine basalt can be seen as individual crystals.

Minerals are found in shapes called **crystals** (see Figure 6.5).

The structure of the crystal greatly influences a mineral's properties. For example, both diamond and graphite have the same chemical composition—they are both pure carbon. Graphite (which is the lead in a pencil) is very soft, whereas diamond is the hardest of all minerals. This difference arises because the carbon atoms in graphite crystals are arranged into sheets that can slide past each other, whereas in diamond crystals the carbon atoms form a strong, interlocking unit (see Figure 6.6).



→ Fig 6.6 The carbon atoms in (a) the mineral graphite are arranged in sheets, whereas in (b) a diamond they are interlocked.

Identifying minerals

To identify minerals correctly, geologists carefully examine the properties of rocks.

The main *colour* of the mineral is not a reliable property with which to judge rocks because many minerals are impure. For example, pure quartz is colourless, but impurities can cause it to be many colours, such as purple (amethyst), pink (rose quartz) or yellow (citrine). Even in one sample, the colour may change. The colour of a mineral is a guide to identifying it, but it cannot be relied on for correct identification.

Lustre is the shininess of the surface of the mineral (see Figure 6.7). Some types of lustre are:

- metallic—looks like a shiny new coin
- brilliant—very shiny, like a mirror
- pearly—a bit shiny, like a pearl or fingernail
- dull—not shiny at all
- earthy—like a lump of dirt.

→ Fig 6.7 The lustre of a mineral describes its shininess.

Streak is the colour of the powdered or crushed mineral. This colour can be seen by drawing with the mineral on a footpath. The colour of the line that the mineral leaves behind is its streak. Often the streak is different from the main colour of the mineral.

Hardness is how easily a mineral can be scratched. Some minerals are so soft that they can be scratched with a fingernail. Other minerals are so hard that they can scratch glass. A hard mineral is able to scratch a soft mineral and not get scratched itself. The hardness of a mineral is described by a number according to a scale invented by the Austrian geologist Friedrich Mohs. Mohs gave a hardness number to 10 common minerals (See Table 6.2): the softest mineral, talc, has a hardness of 1, whereas the hardest mineral, diamond, has a hardness of 10. These minerals can be used to find the hardness of any other mineral. A piece of copper (hardness 3.5) will be scratched by fluorite (hardness 4), but not by calcite (hardness 3). Copper will scratch calcite. This is because copper has a higher hardness number than calcite. The hardness of some common objects are:

- 2.5—fingernail
- 3.5—copper metal
- 6.5—iron nail
- 6.5—glass in microscope slide.

→ Table 6.2 Mohs hardness scale

Hardness	Example
1	Talc
2	Gypsum
3	Calcite
4	Fluorite
5	Apatite
6	Feldspar
7	Quartz
8	Topaz
9	Corundum
10	Diamond

PRACTIVITY 6.1

Testing the hardness of common substances

What you need

5-cm long iron nail

Glass microscope slide

Plastic disposable Petri dish

2 cm × 5 cm piece of copper sheet

Half a stick of chalk

What to do

1. Scratch the samples against each other and rank them in order of hardness from softest to hardest. When testing the hardness, scratch only a small part of the mineral or object. A 5-cm long scratch is all that is needed.
   - Which sample is the hardest?
   - Which sample is the softest?
2. Collect some mineral samples. Arrange them in order of hardness. Minerals such as feldspar, quartz and calcite are listed in Table 6.2.

Cleavage is the number of smooth planes that minerals break along.

Mica breaks into flat layers, like the pages in a heap of papers. Calcite has three cleavages because it breaks with three smooth surfaces: left and right; front and back; top and bottom.

→ Fig 6.8 Mica has one cleaveage. Minerals that demonstrate cleavage look like thin slabs stuck together.

→ Fig 6.9 Calcite is a transparent mineral.

Several minerals have unusual properties. Some minerals fluoresce in ultraviolet (UV) light: these minerals absorb UV light, which we cannot see, and emit it as visible light that we can see. Calcite is a transparent mineral. When you look through it, you see a double image.

A key to identifying minerals is given in Table 6.3.

EXPERIMENT 6.1

Identifying rocks

Aim

To identify a range of common rocks.

Materials

Rock samples (unnamed, perhaps labelled A, B, C, D etc.)

Hand lens

Table 6.3 (page 207), as well as a rock key from the Internet or the one supplied with your rock kit

Method

1 Find a rock identification key on the Internet or use the one that came with your rock kit.
2 Examine each rock sample with the hand lens and use the key to identify each of your rocks. Be aware of the following:
   - Crystals in rocks have straight edges and flat, shiny surfaces.
   - Grains are not shiny, but jagged or rounded and more like grains of sand.
   - Coarse grains are about the size of a grain of rice, medium grains are smaller but still visible to the naked eye and small grains are only visible with a hand lens or magnifier.

Results

Display your results in a table that identifies the rock sample (e.g. sample A), lists its main properties and gives its name.

Discussion

1 How hard was it to identify your rock samples?
2 Were there any samples you could not identify?
3 Compare your results with those of another group. Were there any differences between your results?
4 Ask your teacher for the names of your rock samples and see which ones you got right (hopefully all of them!).

Conclusion

Write a comment on the use of a key to identify common rock samples.

→ Table 6.3 Key for the identification of minerals

Lustre	Colour	Hardness	Description	Mineral
Non-metallic lustre	White or pale	Scratched by a fingernail	White to pale green Greasy feel Often flaky	Talc
	Increasing hardness		Vitreous lustre Breaks along cleavage planes to give smooth faces Often transparent	Gypsum
			Shiny lustre Breaks along one cleavage plane giving flat sheets that are flexible Transparent	Muscovite mica
		Hardness similar to that of a fingernail	Vitreous lustre Cleaves into tiny cubes Salty taste	Halite (rock salt)
		Scratched by a knife blade, scratches a fingernail	Pale colour, white or yellow, often transparent Three good cleavages, not at right angles Forms tiny blocks	Calcite
		Scratches a knife blade, may just scratch a microscope slide	White or grey Sometimes shows two cleavages at 90°	Plagioclase feldspar
			Pink or flesh coloured Cleavage same as plagioclase feldspar	Orthoclase feldspar
		Easily scratches a microscope slide	Vitreous lustre, transparent or milky No cleavage Forms six-sided crystals Conchoidal fracture sometimes seen	Quartz
Non-metallic lustre	Coloured minerals	Scratched by a fingernail	Black, shiny lustre Breaks along cleavage plane giving thin flexible sheets	Biotite mica
	Increasing hardness		Orange–red, earthy lustre, orange or red–brown streak	Bauxite
		Scratched by a knife blade	Orange–brown, earthy lustre, yellow–brown streak	Limonite
			Bright green, green streak	Malachite
		Scratches a fingernail	Bright blue, blue streak	Azurite
			Bluish purple, white streak, vitreous lustre Four cleavages giving pyramid shape in good specimens	Fluorite
			Greenish colours, white streak, greasy looking Poor cleavages	Apatite
		Hardness similar to that of a knife blade	Black Sometimes two cleavages Short, thick crystals, eight-sided, vitreous lustre	Augite
		Scratches a steel blade, but does not scratch a microscope slide	Glassy green grains, partly transparent	Olivine
			Pink or flesh coloured Sometimes shows two cleavages	Orthoclase feldspar
			Colour variable, vitreous lustre Amethyst = purple Rose quartz = pink Smoky quartz = grey Conchoidal fracture	Quartz varieties
Lustre is partly metallic, partly earthy	Black or coloured	Does not scratch a steel blade	Black to brown in colour, brown streak, vitreous lustre, sometimes metallic Often shows cleavage	Sphalerite
			Yellow–brown in colour, yellow to brown streak Dull lustre	Limonite
		Approximately the same hardness as a steel blade	Red or grey colour, red streak, red rubs off onto fingers	Haematite
		Scratches a steel blade	Black magnetic May be too hard for streak plate	Magnetite
Metallic lustre	Gold colour	Scratched by a steel blade	Dark brass colour, tarnishes to purple	Chalcopyrite
		Scratches a steel blade	Pale brass colour Crystals may be seen	Pyrite
	Silver colour	Scratched by a copper coin, but not by a fingernail	Very dense (heavy), grey streak Three good cleavages to form tiny cubes	Galena

→ Fig 6.10 Different types of minerals.

→ Table 6.4 Important ores and the metals they contain

Ore	Metal
Haematite, limonite	Iron
Bauxite	Aluminium
Galena	Lead
Rutile	Titanium
Pitchblende	Uranium
Molybdenite	Molybdenum
Cinnabar	Mercury
Malachite, azurite	Copper
Sphalerite	Zinc
Chalcopyrite	Copper
Pentlandite	Nickel
Cassiterite	Tin

Mineral resources

Minerals are important as a source of metals and other materials needed by our society. Some minerals, such as iron ore, have to be treated before they can be used. An **ore** is a mineral with a large amount of a useful metal in it. Some important ores and the metals they contain are listed in Table 6.4.

Australia is rich in mineral resources. It is the world's leading producer of lead, bauxite and alumina, diamonds (by volume), ilmenite, rutile and zircon (and synthetic rutile) and tantalum. It is the second largest producer of uranium, zinc and nickel, the third largest producer of iron ore, lignite, silver, manganese and gold, the fourth largest producer of black coal and copper and the fifth largest producer of aluminium. Demand for mineral resources worldwide is high, particularly due to increased demand from China as it becomes more and more industrialised.

Australia's mineral resources have always been in big demand. During the 1850s, after gold was initially discovered in Bathurst, New South Wales, hundreds of thousands of people migrated to Australia to take part in the Gold Rush in Victoria and New South Wales, during which the economy of the nation boomed. Because gold is chemically stable, it is almost always found as pure gold. This means that it can be collected without having to be smelted or refined. Gold is not only used in jewellery, but is also used in fine wires in electronics, as fillings for teeth and, because of its reflective properties, to protect satellites and spacecraft from solar radiation.

Australia is an old continent that is rich in **mineral sands**. Mineral sands are old beach sands with significant concentrations of heavy minerals, such as rutile, zircon and ilmenite. Rutile is a rich source of titanium dioxide, which is used as a pigment in paints, plastics and paper. You may have seen (or bought) little glass jars of mineral sands that are often sold as souvenirs.

Copper was the first metal to be used by humans. In Australia, copper is found as the mineral chalcopyrite in rocks that are over 250 million years old. Copper is a good conductor of electricity and is used in electrical generators and motors, for electrical wiring and in electronic goods, such as televisions. Copper is also used for water pipes because it doesn't corrode easily.

However, mineral resources are finite. One way to overcome this is to recycle materials. For example, aluminium can be recycled over and over again. A lot of energy is used to produce aluminium from bauxite, but once the metal has been made it can be recycled indefinitely. In fact, recycling aluminium uses only 5% of the energy needed to produce new aluminium. Recycling aluminium saves having to use coal to produce energy in power stations, which reduces the emission of greenhouse gases into our atmosphere. For a sustainable future, the world's mineral resources need to be used wisely.

What do you know about minerals?

1 What is a mineral?
2 What is an ore?
3 What is the difference between a mineral and an ore?
4 What are five of Australia's most important minerals?

→ Fig 6.11 Coloured sands reflect the concentrations and types of minerals they contain.

<<BIG IDEAS>> Dynamic Earth

6.1 What are the properties of rocks and minerals?

Remember and understand

1 Copy and complete:
  a An ______________ is a mineral with a large amount of useful metal in it.
  b ______________ is the most common metal.
  c Minerals are found in shapes called ______________ .
  d Rocks are selected for particular purposes because of their ______________ .

2 What is the meaning of:
  a lustre?
  b streak?
  c hardness?

3 Make a 'rock dictionary' of 20 rock words that you have learned so far.

4 How do geologists identify minerals?

5 Why is colour not a reliable guide for identifying minerals?

6 What properties of gold made it so valuable to early civilisations, such as the Incas of South America?

7 How are minerals different from rocks?

Apply

8 What is the lustre of these objects?
  a a shiny new nail
  b a rusty nail
  c a newly polished car
  d a mirror
  e bricks used for building a wall

Analyse and evaluate

9 Why is the hardness of fingernails, copper, iron and glass given half numbers?

10 A kitchen scourer can be used to clean stainless steel cutlery, but this type of scourer should not be used to clean silver-plated cutlery. Explain why.

11 Investigate why recycling aluminium uses only 5% of the energy needed to produce new aluminium.

12 Why do we need to recycle minerals? What minerals can be recycled? What forms can they be used in once they have been recycled?

13 Some famous works of art found in galleries around the world are made of marble. What are the properties of marble that make it ideal for sculpture? What are some of the properties of marble that may not make it appropriate for all works of art?

Critical and creative thinking

14 Some people say that Australia is a huge quarry. This is because Australia mines so many minerals and sells them. Working on your own, list the advantages and disadvantages of mining and selling minerals. Join with a classmate and combine your lists. Then join with another group and prepare another list containing the three best reasons for mining and the three best reasons against mining.

15 Find three small rocks from your backyard, school grounds or local park.
  a Take a digital photo of your rocks (or carefully draw them). Create a rock fact card for each rock like the ones on page 204.
  b Divide the class into small groups. Create a game using your group's fact cards.
  c Evaluate the success of your game. Did it help you learn more about the properties of rocks and minerals?

<<CONNECTING IDEAS>> Dynamic Earth

16 Imagine you are a geologist who is going to discover minerals in a remote part of Australia. You will need to take a test kit to help you identify the minerals you find. What items should go into your test kit to allow you to test for streak, hardness and so on?

How do rocks form?

Dead coral and broken shells can accumulate in the sea near reefs. The rock that forms from them is called limestone. Limestone made from broken shells is called shelly limestone. Limestone made entirely from coral is called coral limestone. If you find coral limestone in a quarry, like where the Great Sphinx is found in the desert in Egypt, you know that, long ago, this was a warm, tropical area near a coral reef.

<<DISCOVERING IDEAS>>

Making rocks

Do you know how rocks are made? In small groups, consider the different types of rocks you have already explored.

- What conditions would have been necessary to create them?
- Could you provide those conditions in a science laboratory?
- Where do you find rocks?
- How do rocks differ from one location to the next?

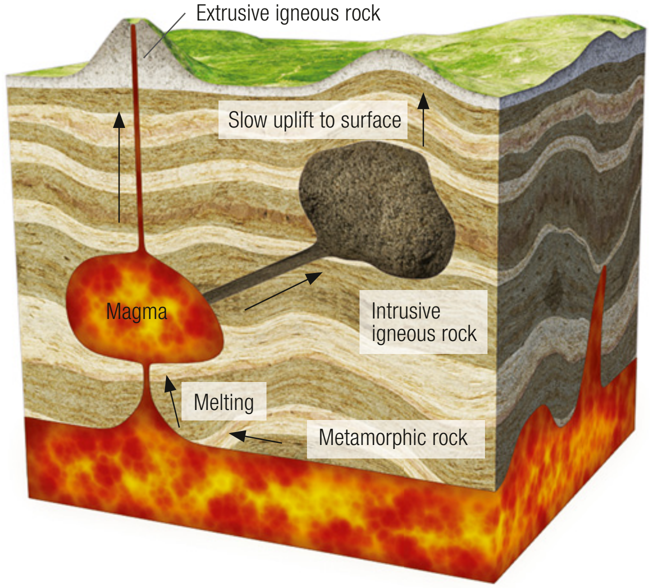
Rock formation

Rocks are broadly classified according to how they are formed. The three main types of rocks—igneous, sedimentary and metamorphic—all form in different ways.

Igneous rocks

Magma and lava from volcanic eruptions cool and solidify to form **igneous rocks**. The term ‘igneous’ comes from the Latin word *ignis*, which means ‘fire’. The hot, molten rock inside the Earth is called **magma** and its temperature may be over 1200°C. The magma chamber under a volcano is the source of molten rock for the volcano.

→ Fig 6.12 Igneous rocks are formed from volcanic magma.



In a volcanic eruption, the red-hot magma rushes out onto the surface of the Earth as **lava**. The cooler temperatures on the Earth’s surface help the lava to solidify quickly. Igneous rocks also form from magma under the ground. These igneous rocks look quite different from those formed on the Earth’s surface because they cool much more slowly.

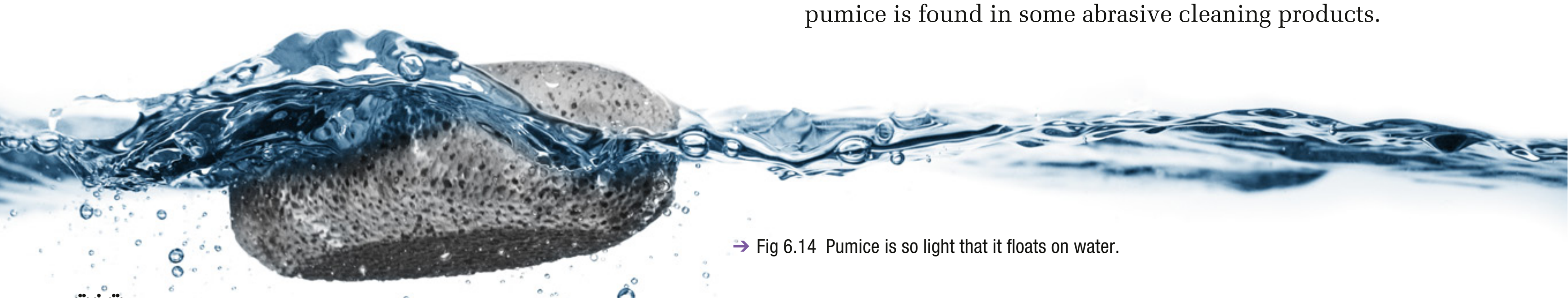
→ Fig 6.13 Granite is an intrusive igneous rock.

Intrusive igneous rocks

Intrusive igneous rocks form slowly beneath the surface of the Earth when magma becomes trapped in small pockets. These pockets of magma cool slowly underground (sometimes for millions of years) to form igneous rocks. The longer it takes for lava to cool, the bigger the rock crystals that grow. Intrusive igneous rocks have large crystals interlocked together. Granite is an intrusive igneous rock in which the crystals can be seen with the naked eye (see Figure 6.13). Although formed underground, intrusive igneous rocks reach the Earth’s surface when they are either pushed up through forces in the Earth’s crust or uncovered by erosion.

Extrusive igneous rocks

Lava cools much more quickly on the Earth’s surface to form **extrusive igneous rock**. Because the lava is cooling much more quickly, small crystals are formed in extrusive igneous rocks. Sometimes the lava cools so quickly that no crystals are formed at all. For example, pumice has no crystal structure. Pumice forms when hot, gas-filled lava cools very quickly. Pumice has many tiny holes that are formed by volcanic gases escaping from the cooling lava (see Figure 6.14). It is so full of holes that it is extremely light and can float on water. Pumice stones are used to scour hard skin from our feet and powdered pumice is found in some abrasive cleaning products.



→ Fig 6.14 Pumice is so light that it floats on water.

EXPERIMENT 6.2

What affects crystal size?

Aim

To grow crystals and determine what affects their size.

Materials

Bunsen burner

Matches

Heat-proof mat

Tripod

Gauze mat

Alum solution

Two Petri dishes

Evaporating dish

Safety glasses

250-mL beaker

Tablespoon

Method

1. Prepare a solution of alum by mixing 2½ tablespoons of alum with ½ cup of hot water. Stir until dissolved.
2. Pour roughly equal amounts of alum solution into the evaporating dish and the two Petri dishes.
3. Put one of the Petri dishes in the refrigerator.
4. Put the other Petri dish on a window sill.
5. Place the evaporating dish on the gauze mat.
6. While wearing safety glasses, gently heat the evaporating dish containing the alum solution over an orange (safety) flame. The orange flame is cooler and will allow for gentle boiling.
7. Continue heating the solution until nearly all the water has evaporated.
8. Observe the size of the crystals formed in the evaporating dish.
9. After 2 days, observe the size of the crystals formed in the two Petri dishes.
10. Observe the crystals formed in the refrigerator again after 4 or 5 days.

Results

Draw a labelled diagram of the crystals formed in the evaporating dish and in the two Petri dishes. Your diagram needs to show the different sizes of the crystals in the different dishes.

Discussion

Each of these crystals grew over a different time span. How does the time allowed for the crystal to form affect the size of the crystals?

Conclusion

What do you know about the factors affecting crystal size?

ZOOMING IN

The different looks of basalt

It is hard to understand why the same magma can solidify into different rocks. Or why two rocks that are not quite the same have the same name. The answer is in how igneous rocks form and what they are made of.

Basalt is the most common type of rock in the Earth's crust. Most of the crystals in basalt are microscopic or non-existent because the magma cools so quickly that large crystals are unable to form.

We commonly think of basalt as the building product we know as bluestone. However, basalt can look different depending on the type of volcanic eruption it came from and how quickly it cooled. Scoria is a type of basalt that's full of bubble holes. The lava was filled with gases when it began to cool and the holes in the scoria are where the gas bubbles once were. Scoria is a light rock that is often used for garden paths and as fill in drainage trenches.

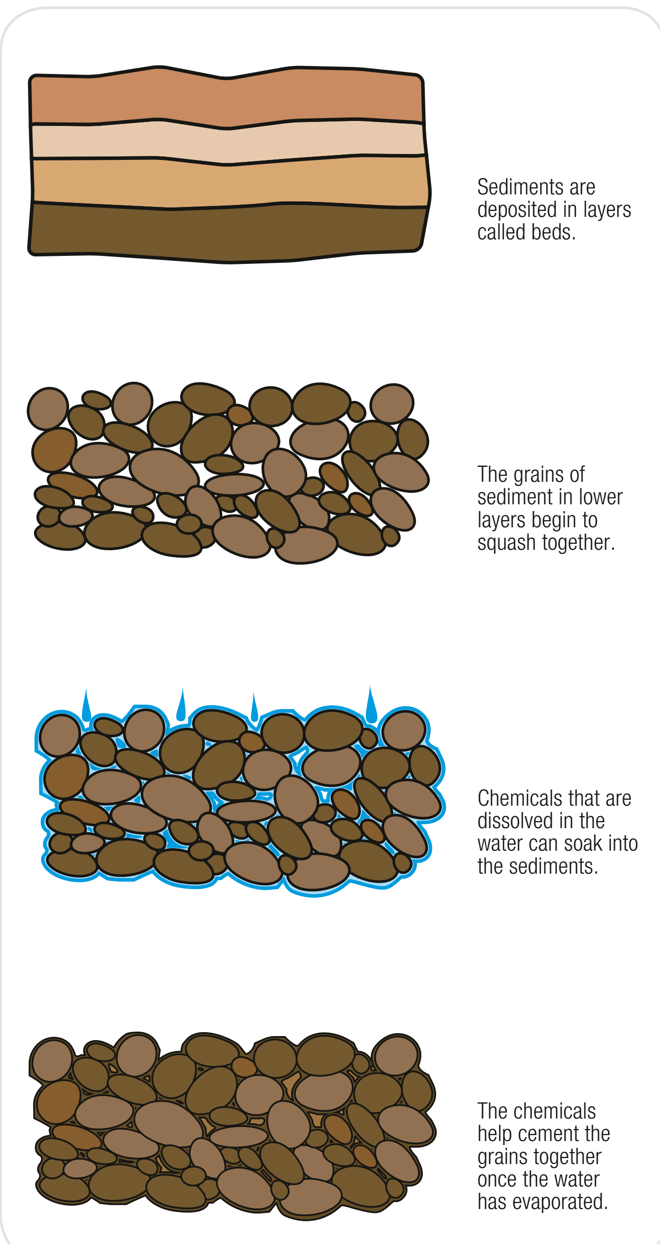
Obsidian is a smooth, black rock that looks like glass. It is formed when lava cools almost instantly and forms no crystals. Obsidian is used to make blades for surgery scalpels; the resulting blades are much sharper than those made from steel.

Fig 6.15 Basalt comes in different forms: (a) bluestone, (b) scoria and (c) obsidian.

Sedimentary rocks

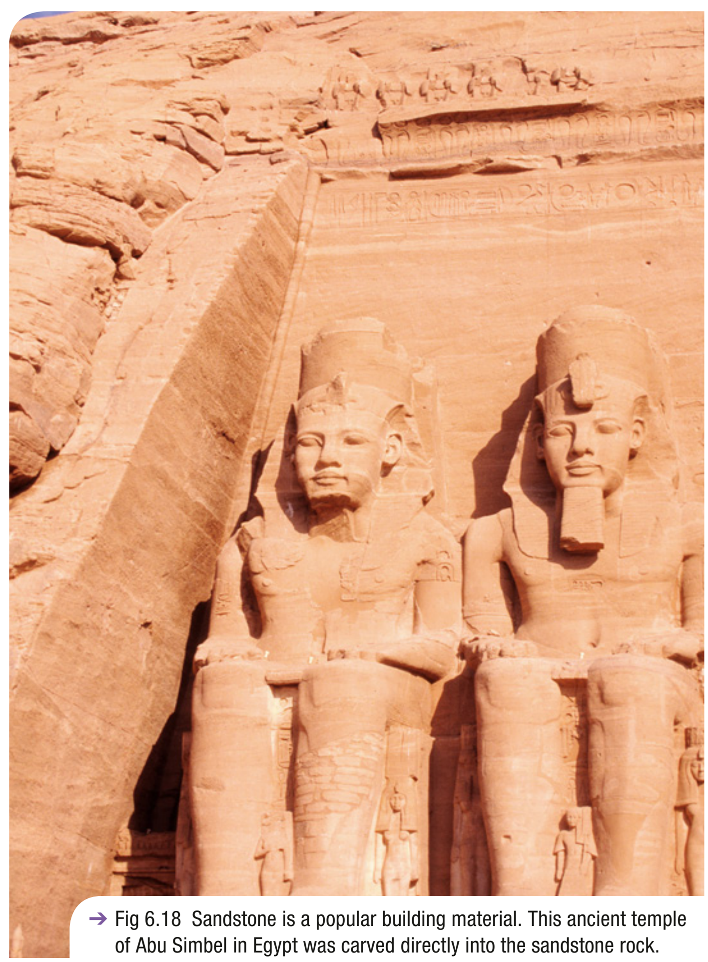
Sedimentary rocks are formed when loose particles are pressed together (compacted) by the weight of the overlying sediments. Sediments are rock particles, such as mud, sand or pebbles, that are usually washed into rivers and eventually deposited on the riverbed or in the sea. Sediments can also come from the remains of living things, such as plants and animals. Over thousands or even millions of years, these sediments form thick layers on the riverbed or sea floor. Pressure from the overlying sediments and water squeezes out air and gaps in the bottom layer. Over time, the compacted sediments become sedimentary rocks.

→ Fig 6.16 The formation of sedimentary rocks.



→ Fig 6.17 Shale (or mudstone) is the most common sedimentary rock. Shale is a fine-grained sedimentary rock made up of clay minerals or mud. This specimen clearly shows the layers of sediments that were compacted to form this rock.

The names of some sedimentary rocks give clues to the sediments that formed them—sandstone, mudstone, siltstone and conglomerate are all types of sedimentary rock. Sandstone, for example, is made up of sand deposited in environments such as deserts and beaches. Conglomerate (as the name suggests) is a mixture of all sizes of rocks that have become cemented together.



→ Fig 6.18 Sandstone is a popular building material. This ancient temple of Abu Simbel in Egypt was carved directly into the sandstone rock.

Fig 6.19 Conglomerate rocks have grains of different sizes. The sediments for these rocks were deposited in fast-flowing rivers during flooding or by glaciers.

Fig 6.20 Coal is formed from dead plant material.

Biological rocks

Sedimentary rocks are not always formed from the sediments of minerals or other rocks. Living things also break down and their remains are deposited as sediments. Shells and hard parts of sea organisms break down and are deposited in layers on the ocean floor. Eventually they cement together under pressure to form limestone.

The compaction of dead plant material can also help form sedimentary rocks. For example, coal is formed from dead plants that were buried before they had decayed completely. Pressure from the layers above may change the plant material into coal or oil.

Chemical rocks

Chemical sedimentary rocks form when water evaporates, leaving behind a solid substance. When seabeds or salt lakes, such as Lake Eyre, dry up, they leave a solid layer of salt behind. If the layer of salt is compressed under the pressure of other sediments, it may eventually form rock salt. When groundwater passes over limestone, it can pick up calcium carbonate from the limestone. When the water evaporates, it leaves behind the calcium carbonate once more. Various rock formations in caves are formed by this method.

ZOOMING IN

Limestone caves

The amazing long strands of rock found on cave floors and ceilings are composed of calcium carbonate from the limestone ceiling of the cave. A stalagmite grows from the floor towards the ceiling (they 'might' reach the ceiling one day) and a stalactite grows down from the ceiling (they hold on 'tight'). If these formations meet together in the middle, a column is formed.

Stalagmites and stalactites form when limestone rocks above are dissolved by acids in water. The acid and dissolved limestone make a solution that drips through the ceiling of the cave and is deposited on the stalagmites and stalactites, gradually increasing their width and length. When touring inside limestone caves with stalactites and stalagmites, do not touch these rock formations because they are generally still forming. Oil from the skin can interfere with stalagmite and stalagtite formation.

Fig 6.21 Stalagmites and stalactites in a limestone cave.

EXPERIMENT 6.3

Making sedimentary rocks

Aim

To make small samples of sedimentary rocks and compare them against real samples.

Materials

Dry clay
Mortar and pestle
Dry sand
Small, smooth pebbles
Plaster of Paris
Teaspoon
Four empty matchboxes
White tile

Method

1 Grind a lump of dry clay with a mortar and pestle until it is fine and powdery.
2 Using the teaspoon, mix the dry ingredients for each rock sample on a white tile according to the recipes below, but don't add the water just yet. You will need to prepare two shale samples so they can be used later in Experiment 6.4.

Rock	Dry clay (teaspoons)	Sand (teaspoons)	Plaster of Paris (teaspoons)	Pebbles (teaspoons)	Water (teaspoons)
Sandstone	½	4	½	0	2
Shale	5	½	0	0	2
Conglomerate	½	1	½	4	2

3 Pile up your ingredients into a little hill and make a small dip in the centre for the water.
4 Slowly add the water and stir until the ingredients are uniformly mixed. Be careful not to make the mixture too wet.
5 Press your mixture into an empty matchbox, label it with the rock type and your name and leave it to dry for 2 days.
6 When your 'rock' is dry, peel off the matchbox and examine your sample. Take digital photos of your samples and photos of the 'real' rocks for comparison. Keep your two shale samples for experiment 6.4 later.

Results

Include images of your rocks here, along with any statements about the process or products.

Discussion

1 How do your sedimentary rock samples compare with the real thing?
2 What were the differences between your samples and the real rocks?

Conclusion

What have you discovered about sedimentary rocks?

Metamorphic rocks

Metamorphic rocks are formed when other types of rocks are changed by incredible heat and pressure inside the Earth. When igneous, sedimentary or even metamorphic rocks are heated to extreme temperatures by magma, or when they placed under extreme pressure from the layers of rocks above them, they can change into a different type of rock. For example, basalt can be changed into hornfels, granite can be transformed into gneiss, shale can be changed into slate (see Figure 6.22) and limestone can become marble (see Figure 6.23).

Fig 6.22 Slate splits easily into flat sheets because of its flat, parallel crystal structure. This makes it a useful material for floor and roof tiles and as the base for billiard tables.

Fig 6.23 The Taj Mahal in India is made of marble, the metamorphosed form of limestone. With its dense composition and beautiful patterns, marble is also a popular material for sculptures and kitchen benchtops.

Metamorphic rocks are stronger than the original material because the particles have been fused together under great pressure or heat.

Bands can sometimes be seen in metamorphic rocks formed under high pressure. The bands tell us that the crystals were squeezed together to form new crystals in the new rock. Sometimes the crystals are squeezed together so tightly that they melt partially and form fewer, but larger, crystals. For example, when granite is squeezed under high pressure, the crystals change and the rock gneiss is formed (see Figure 6.24).

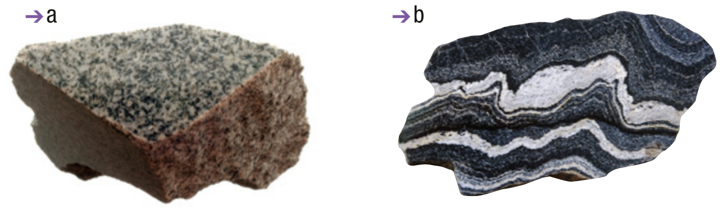


Fig 6.24 When granite (a) is subjected to high heat or pressure, it can change into the metamorphic rock known as gneiss (b). The bands on the gneiss show that the crystals have been squeezed together under immense pressure.

EXPERIMENT 6.4

Making a metamorphic rock

Aim

To make a sample of a metamorphic rock.

Materials

Two shale rock samples from Experiment 6.3
Bunsen burner
Tripod
Pipe clay triangle
Gauze mat
Evaporating dish
Tongs
Two 250-mL beakers

Method

1 Allow your shale samples made in Experiment 6.3 to dry for approximately 1 week.
2 Place one of the shale samples on a pipe clay triangle on top of a gauze mat and heat strongly over a blue Bunsen burner flame for about half an hour. If an evaporating dish is placed upside down over the shale, more heat will be retained.
3 After about half an hour of heating, carefully pick up the shale sample using the tongs and drop it into a beaker of water.
4 Drop the second, unheated shale sample into another beaker of water and observe what happens to the two rock samples.

Results

Record your observations in a table.

Discussion

1 What differences do you notice about the two rock samples when they are dropped into the water?
2 Can strong heat change the properties of rocks over time?
3 How different was your new metamorphic rock sample from the original shale sample? Was the method successful?

Conclusion

What do you know about the formation of metamorphic rocks?

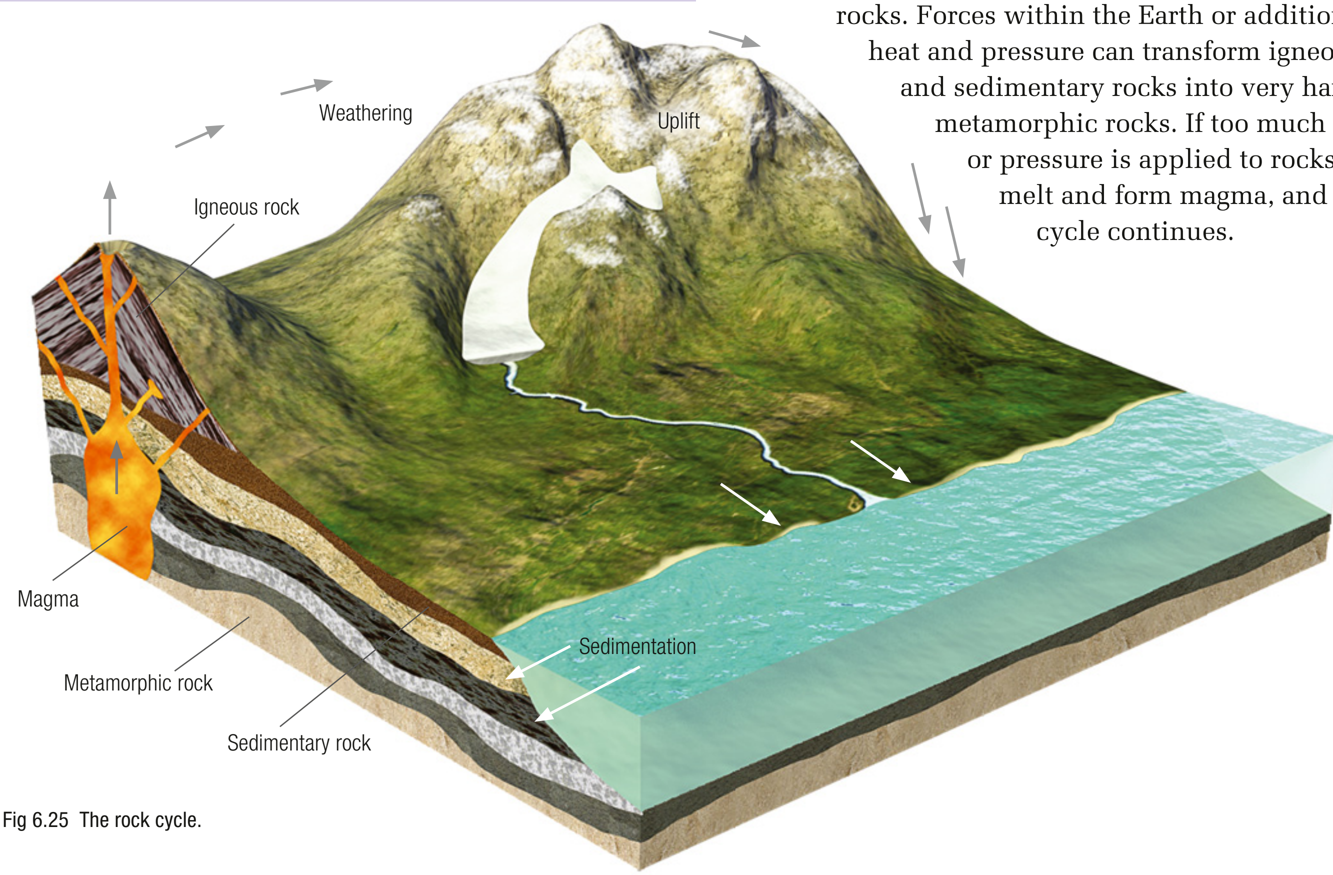
What do you know about rock formation?

1 How do stalactites and stalagmites form?
2 How do metamorphic rocks form?
3 How do sedimentary rocks form?
4 How do igneous rocks form?
5 Explain why pumice floats on water.
6 The ancient civilisations that discovered obsidian had a competitive advantage over those who didn't. Explain why.
7 What do plants have to do with coal?

The rock cycle

The **rock cycle** is an ongoing process that describes the formation and destruction of the different rock types. Magma and lava cool and solidify to form igneous rocks. Rocks are brought to the Earth's surface through the uplifting forces acting on land when tectonic plates collide. (Tectonic plates are the pieces of the Earth's crust.) On the surface, rocks are weathered (broken down into smaller pieces) by water, ice, wind, chemicals and biological forces.

The weathered particles are then removed by erosion, transported and eventually deposited. As the deposited sediments become covered with additional eroded sediments, layers form and are cemented together under pressure to form sedimentary rocks. Forces within the Earth or additional heat and pressure can transform igneous and sedimentary rocks into very hard metamorphic rocks. If too much heat or pressure is applied to rocks, they melt and form magma, and the cycle continues.



→ Fig 6.25 The rock cycle.

What do you know about the rock cycle?

1 List the different stages in the rock cycle as sentences that describe what happens. Use Figure 6.25 of the rock cycle to assist you.
2 Write a creative story of the 'life of a rock'. In a similar way to humans, rocks change with time. However, unlike humans, rocks don't always head in the same direction—they may move through the rock cycle, covering the same phase many times in many different ways. Rocks are never truly 'born' nor do they 'die'. What life does your rock experience?

6.2

How do rocks form?

Remember and understand

1 Copy and complete:

a ______________ rocks are formed when loose particles are pressed together by the weight of overlying sediments.

b ______________ rocks are formed when other types of rocks are changed by heat and pressure inside the Earth.

c ______________ rocks form when magma and lava from volcanic eruptions cool and solidify.

2 Which rock can be dissolved to make caves?

3 What is the difference between *magma* and *lava*?

4 Cave systems in limestone rocks follow the course of underground rivers. Why is water necessary to make caves?

5 How would you tell the difference between intrusive and extrusive igneous rocks?

6 What is meant by the term *sediment*?

Apply

7 Why does pumice have no crystal structure even though it is a rock?

8 Why do sedimentary rocks form at the Earth's surface?

Analyse and evaluate

9 Where would you expect to find a black sedimentary rock that is formed from carbon? Why?

10 Explain a way to remember which way stalactites and stalagmites grow.

11 What features of pumice make it useful for removing dead skin?

12 An igneous rock has large grains, is hard and is multicoloured. What is it most likely to be?

13 Basalt is the most common type of rock in the Earth's crust. The grains in basalt are microscopic or non-existent. Explain why.

Critical and creative thinking

14 Look at Figure 6.26, which shows the Twelve Apostles. Use this image to describe how these rocks were formed. Prepare a poster to show how the rocks were formed and would have changed over time. How will they look in 1000 years time?

→ Fig 6.26 The Twelve Apostles, located off the coast of Victoria.

<<CONNECTING IDEAS>> Dynamic Earth

15 Imagine you could stop a flooded river.

- What would you find in the water?
- If the water was still and then evaporated, describe what the deposit would consist of and what it would look like.

6.3

What can we learn from studying rocks?

One of the richest and most extensive fossil deposits in the world can be found at Riversleigh in north-west Queensland. Some of the fossils date back 15–25 million years ago, when the area was covered in lush rainforest. The mammal fossils, which have been preserved in limestone, have helped palaeontologists understand the story of mammals in Australia and include ancestors and representatives of kangaroos, rat-kangaroos, bandicoots, wombats, marsupial moles, thylacines, koalas, possums, pygmy possums, cuscuses, bats, rodents and platypuses. Fossils of crocodiles, snakes, lizards, turtles, lungfish, frogs, birds, snails, insects and other invertebrates have also been found.

<<DISCOVERING IDEAS>>

Fossil features

There's no time like the present to jump right in and be a palaeontologist!

➔ Fig 6.27 A fish fossil discovered in Australia.

What you need

A selection of fossils

What to do

For each fossil, write down as many observations as you can about the organism that it holds. Your observations will most likely be of physical features.

Questions to consider

1 What inferences can you make about the organism's lifestyle?

2 Is there any evidence to suggest that this organism lived alone or in groups?

3 Is there any evidence to suggest how this organism reproduced?

4 Is there any evidence to suggest what this organism ate?

5 What other information would you need to support your inferences?

Learning about the past through fossils

Planet Earth is 4.5 billion years old. The events on Earth are recorded in the rocks. From about 570 million years ago, the ancestors of the different plants and animals that now populate Earth came into being. The remains of some of these life forms are captured in the rocks as fossils. Fossils allow specialist geologists, known as palaeontologists, to build up a picture of Earth's long history.

What are fossils?

Fossils are the remains (or imprints) of animals or plants preserved in rock.

A fossil is evidence of life in the past. Fossilised evidence may be found in many forms, but is usually in the form of the hard parts that remain after decay—bones, teeth and shells. Sometimes, softer parts of an organism are preserved and even footprints or impressions of organisms are considered fossils. Palaeontologists study these remains to find clues about ancient life.

Through a process known as **petrification**, wood, bones, teeth and shells can be replaced chemically by minerals dissolved in water. Minerals slowly replace the original material as it decays, leaving a stone replica in the same shape as the original.

Sometimes the whole organism may be preserved as a fossil. Animals and plants trapped under frozen ground have been uncovered with flesh, hair and even stomach contents intact. Ancient insects have been found trapped in the sap of ancient trees (amber). Even animal droppings can be petrified—these are called coprolites. The remains of animals or plants sometimes leave an imprint in the rock. Remains can also be broken down by minerals in water, leaving a mould in the exact shape of the organism. **Trace fossils**, such as footprints, can also leave an impression in rocks.

→ Fig 6.28 Broome, Western Australia, is the site of many trace fossils. Can you spot the footprints?

→ Fig 6.29 If the conditions are just right, soft body parts can be fossilised.

→ Fig 6.30 This petrified tree trunk looks like a real tree, but its wood has been replaced by minerals to make it as hard as stone.

How do fossils form?

Fossils are usually only found in sedimentary rocks. These rocks are formed by the deposition of layers of sediments, such as mud, silt or sand. Any organism caught up in the mud and silt can eventually become part of the rock through the process of fossilisation. The fossils can be uncovered when the rocks are broken apart or weathered away. This process can take millions of years.

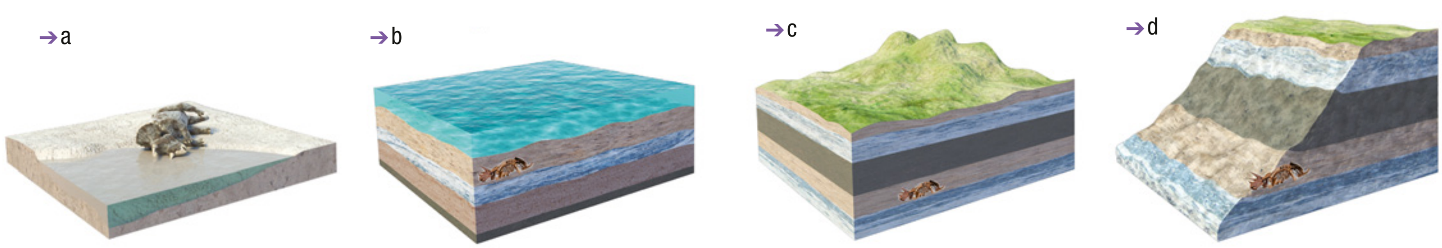
Steps in fossil formation

After the death of an animal, its body would usually be eaten by other animals. Its bones would be crushed or weathered, leaving no evidence of the remains. However, for fossils to form, parts of the animal must be left behind. This process is outlined below.

Step 1 When an animal dies in or near water (see Figure 6.31a), such as a river or a swamp, its remains can be quickly covered in sediment (see Figure 6.31b) and thus protected from being eaten. The soft parts of the body eventually decay, leaving behind the bones and teeth.

Step 2 Over millions of years, more and more layers of sediment are deposited. The sediment surrounding the buried remains transforms gradually into sedimentary rock. The bones and teeth may be replaced by minerals dissolved in water, which seeps into the remains. The shape of the animal remains the same, although it is generally flattened by the pressure of the sediments above (see Figure 6.31c).

Step 3 The layers of rock containing the fossilised remains may be pushed upwards and fractured, bent and moved by forces beneath the Earth's surface. Weathering and erosion eventually wear away some of the rock to expose one or more of the bones or teeth (see Figure 6.31d). Fossils can also be uncovered when digging mines or cuttings for roads. If fossilised remains are discovered, palaeontologists may start looking for other remains in the same area.



→ Fig 6.31 Formation of a fossil. (a) If an organism dies near water, it has a greater chance of being covered by sediment. (b) The sediment protects the body from predators and weathering. (c) Over millions of years, more sediment is deposited and the remains are transformed gradually into sedimentary rock. (d) Years of geological movement, weathering and erosion may eventually expose the fossil.

ZOOMING IN

Sabre-toothed tigers

All that we know about sabre-toothed tigers today comes from what we have learned from their fossilised remains. Sabre-toothed tigers are thought to have lived between 2.5 million and 10 000 years ago.

→ Fig 6.32 Skeletal remains of a sabre-toothed tiger.

These tigers are called sabre-toothed because of their canine teeth, which are extremely long (a 'sabre' is a type of sword). Palaeontologists found many complete skeletons of sabre-toothed tigers from the La Brea tar pits in Los Angeles. Hundreds of the animals became trapped in the sticky tar (asphalt), possibly while trying to feed on mammoths that were already trapped. The asphalt helped keep the fossils intact. By studying the fossils, palaeontologists have discovered that some sabre-toothed tigers had healed injuries that would have normally crippled the animal. Some palaeontologists suggest that this is evidence that the tigers lived in packs and provided food for old or sick members of the pack.

→ Fig 6.33 Reconstruction of a sabre-toothed tiger.

Building animals from bones

A **palaeontologist** is a person who studies fossils. Usually fossils are the only evidence of life forms that are now extinct. Palaeontologists are skilled in cleaning and preserving fossils, piecing parts of them together and reconstructing them into a life-like shape (see Figure 6.34). A palaeontologist's skills cover the areas of zoology, botany, anatomy, ecology and drawing. A palaeontologist also needs a lot of patience to rearrange bones to make a complete skeleton. A job description for a palaeontologist would be as follows:

- To search for the fossil remains of plants and animals and to conserve the sites where they are found.
- To collect as many specimens as possible, noting how and where they were found.
- To make copies of the fossil remains to preserve the original pieces.
- To reconstruct the plant or animal from the pieces of evidence.
- To make inferences about what the environment was like and how the plants and animals were adapted to living in this environment.
- To compare the reconstructed plants and animals with specimens from other places so that a more complete history of life on Earth can be obtained.

From a skeleton, a palaeontologist can make a likeness of an extinct animal. Once the bones are identified, the palaeontologist lays them on a table to get an idea of what the animal might look like. Casts are made of the original, fragile bones using light epoxy resin so that a model can be constructed. The skeleton is then pieced together.

Next, the muscles and internal organs are added. By looking at the shapes of the bones, and the muscle scars on them, palaeontologists can build up an idea of the muscles of the complete animal. The lifestyle of animals can also be deduced (carefully worked out) from their skeleton. Herbivores (grass eaters) have flat, rounded teeth, whereas carnivores (meat eaters) have sharp, pointed teeth. Fast-running animals have long slender bones with large attachments for muscles.

The colour of extinct animals is often deduced from living animals. Most mammals and large reptiles are dull coloured and many are camouflaged within their surroundings. Smaller reptiles and birds are more likely to be brightly coloured. Marine animals are often dark on top and light coloured underneath for camouflage from above and below. Some animals have feathers, fur or scales, whereas reptiles have textured or patterned skins.

→ Fig 6.34 A palaeontologist pieces together a replica of the skeleton of *Simosthenurus occidentalis*, the extinct leaf-eating kangaroo.

→ Fig 6.35 A cast of a skeleton. This animal had small forelimbs, large, strong hind limbs and a long tail like a kangaroo.

→ Fig 6.36 Once the skeleton has been put together and the type of animal identified, the other features need to be deduced.

→ Fig 6.37 Finally, features such as ears and eyes are added, followed by the skin.

Educated guesses

Usually only a few fossilised bones are found, rather than a complete skeleton. Very detailed observations need to be made of these bones so that they can be compared with other finds. If the bones are a good match, palaeontologists may decide that the bones have come from a similar organism, but further evidence will be required to confirm that theory. An ankle bone found in Inverloch, Victoria, is a good example of this situation. It is a perfect match to 55 Allosaurus ankle bones from North America, but probably one of the smallest. This suggests there were Allosaurus-like animals in Australia and that they were either smaller than their American cousins or that the bone found in Victoria was from a young animal.

→ Fig 6.38 This fossilised pterodactyl was in the middle of laying an egg when she was killed. This fossil provides valuable information about pterodactyl reproduction.

→ Fig 6.39 *Allosaurus* is the genus name for a group of extinct predators.

Reconstructing animals

What you need

Copies of bone cut-outs that have been enlarged and are on coloured paper.

What to do

1. Figure 6.40a shows pieces of the skeleton of a human, with some bones held together and some separated. Each bone is shown in front view. Photocopy and cut out the bones and glue them into your notebook in the shape of a person. (You may want to enlarge the photocopy.) Then draw the skin, leaving space for organs and muscles. Use your own body to work out the right and left side arms and legs.

2. Figure 6.40b shows the bones of a frog, with some bones held together and some separated. Each bone is shown in top view. Photocopy and cut out the bones and glue them into your notebook in the shape of a frog. (You may want to enlarge the photocopy.) Then draw the skin, leaving space for organs and muscles. The arms and legs are the most difficult.

3. Figure 6.40c shows the broken skeleton of an extinct amphibian found as a fossil in Queensland. Each bone is shown in top view. Photocopy and cut out the bones and glue them into your notebook in the shape that you believe this animal may have had in real life. (You may want to enlarge the photocopy.) Then draw the skin, making allowance for organs and muscles. Colour the animal and draw in some of its habitat.

Hint: tracing paper could be used for each 'layer' of detail you add.

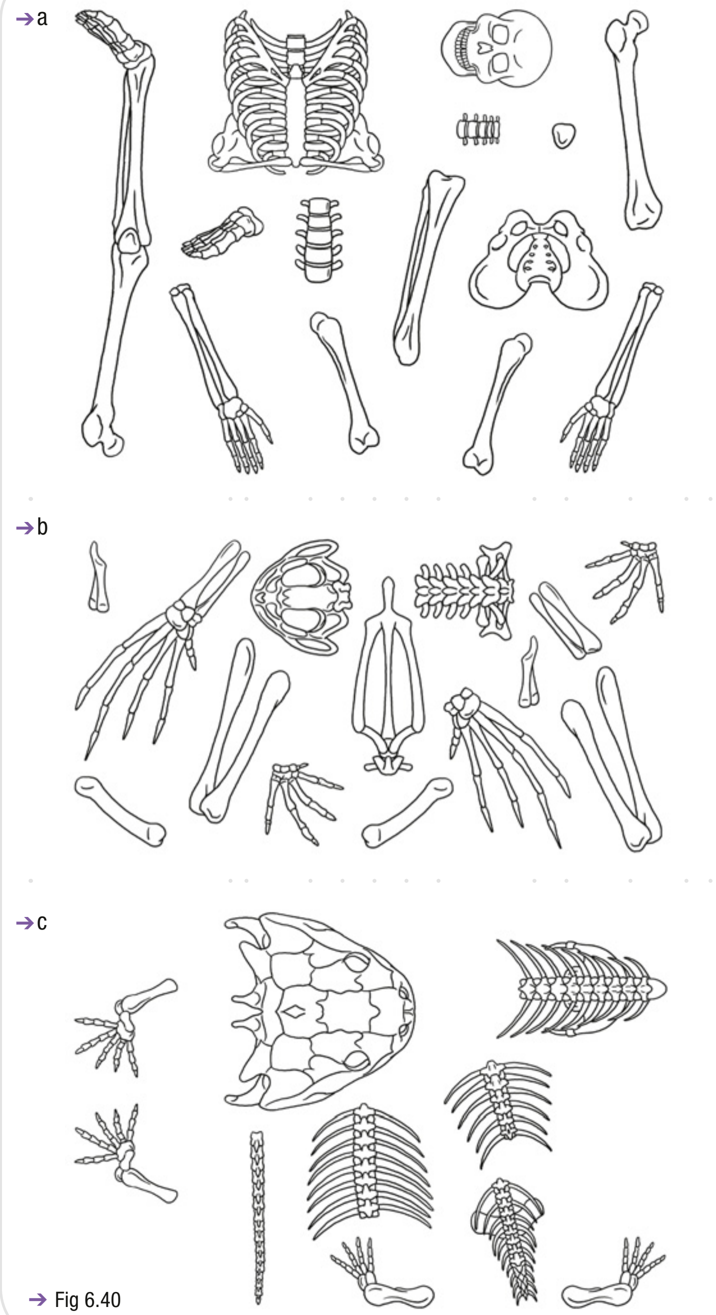


Fig 6.40

What do you know about the past through fossils?

1. What are fossils?
2. How are trace fossils formed?
3. What can fossils show us or tell us about the Earth's history?
4. What are geologists who study fossils called and what sorts of things do they do as part of their job?
5. Why is it important to take accurate and detailed records of all fossils, even if they can already be identified?

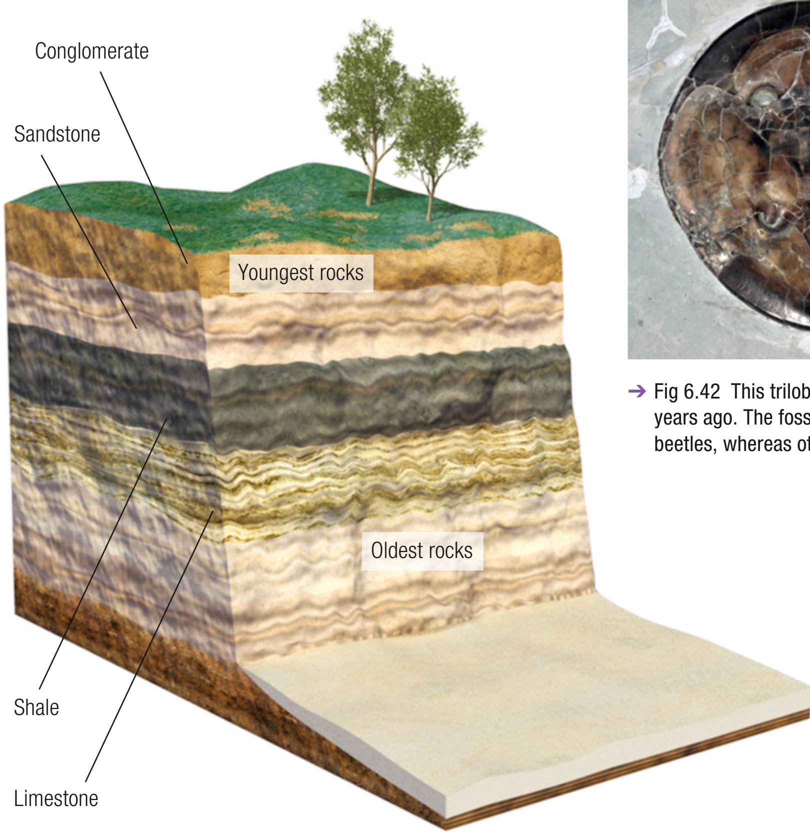
Finding the age of fossils

Extremely old rocks have fossils of simple animals in them, whereas rocks that are slightly younger have fossils of animals with shells. Rocks that are younger still have fossils of fish. Only the newest rocks have fossils of mammals. The variety and complexity of life has increased as the Earth has become older.

Comparative dating

Geologists can place rocks and fossils into a date order. They work this out from the different layers of sediment in rocks. When layers of sand or mud are deposited, the oldest sediments are at the bottom. Newer, or younger, sediments are deposited on top (see Figure 6.41). Working out the age of rocks as being younger or older than existing rocks is called **comparative dating** or relative dating. It is comparative because we are comparing the old with the new.

Different rocks that are the same age have the same type of fossils in them. These fossils are called **index fossils**. They are used to find rocks of the same age.



→ Fig 6.41 Comparative dating is used to work out the age of rocks and fossils.

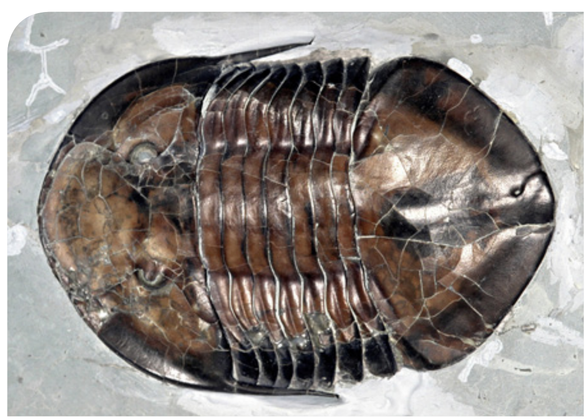
Radioactive dating

The actual age of a fossil, measured in millions of years, is found by looking at the amount of radioactivity left in rocks. For example, uranium (U) is a radioactive substance found in many rocks. It decays to lead (Pb) at a known rate. The age of rocks can be calculated by comparing the amounts of uranium and lead they contain. This is called **radioactive dating**.

The oldest rocks found on Earth have been dated at 4500 million years. This method has been checked using different radioactive atoms. This age is the same as that of meteorites that crash to Earth, as well as that of Moon rocks brought back to Earth by astronauts.

Geological time scale

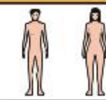
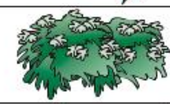
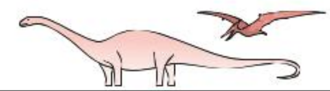
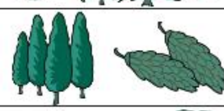
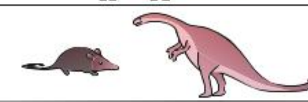
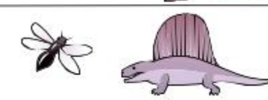
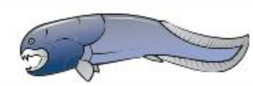
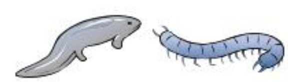
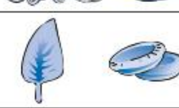
Geologists and palaeontologists use a similar time scale. Because they are dealing with such huge periods of time, they divide time into **eras** and **periods**. The time scale used is millions of years. The eras and periods are based on major events, such as ice ages, widespread volcanic activity or the mass extinctions of species. Each period has particular fossils associated with it. For example, the fossils in the Cambrian period include the first shells and trilobites (see Figure 6.42). These are different from the fossils found in the Triassic period, which include the first dinosaurs.



→ Fig 6.42 This trilobite fossil has been dated to 500 million years ago. The fossils of some trilobites are the size of beetles, whereas others are the size of dinner plates.

End of an era

The end of most periods is marked by a large number of extinctions. The most famous of these is the extinction of many plants and animals, including dinosaurs, at the end of the Cretaceous period. All the periods have been dated absolutely in millions of years using radioactive dating. The names and order of the periods, as well as their absolute age, are shown in the geological time scale in Figure 6.43.

Era	Period (millions of years)	Plant life	Animal life
Cenozoic (recent life)	Quaternary 2	Modern plants. 	Development of humans. 
	Tertiary 65	Forests of angiosperms. 	Mammals dominant over Earth. 
Mesozoic (middle life)	Cretaceous 142	Angiosperms take over from gymnosperms. 	Dinosaurs become extinct. Mammals develop, birds appear. 
	Jurassic 206	Gymnosperms abundant, first angiosperms appear. 	Age of reptiles, some flying reptiles. 
	Triassic 248	Age of gymnosperms. 	First mammals. Reptiles dominate land. Amphibians decline. 
Palaeozoic (ancient life)	Permian 290	Early seed plants develop. 	Many land vertebrates. Familiar insects develop. Some invertebrate sea life becomes extinct. 
	Carboniferous 354	First large forests. Rise of the gymnosperms. 	Insects become more common. First reptiles appear. 
	Devonian 417	Well-developed land plants. Ferns common. 	Fish and coral reefs common. 
	Silurian 443	First land plants. Many algae. 	Many coral reefs, shells. First animals on the land—amphibians and invertebrates. 
	Ordovician 493	Types of large algae found as fossils. 	Many invertebrates. First vertebrates, fish, found. 
	Cambrian 545	More types of algae. 	Animals with bodies protected by shells. 
Precambrian	Ediacaran 600	Algae—the simplest plants, lived in the water. 	Soft-bodied animals. Very few fossils found, except in special locations. Their bodies were jelly-like. 
	2500	Multicellular life develops in the shallow warm seas. Fossils are rarely found because of the great age of the rocks and the soft fragile bodies of these organisms.	
	Archaean 3800	Bacteria are abundant. Some lived in extreme environments; stromatolites were photosynthetic. Fossilised and living mounds are still found on Earth today. Oldest known sedimentary rocks, and oldest 'fossil' remains. They are chemical traces of living things.	
	Hadean 4500	Solidification of the Earth from a ball of molten rock.	

➔ Fig 6.43 Geological time scale.

What do you know about finding the age of fossils?

1 What is *comparative dating*?

2 What radioactive substances are used to date rocks?

3 What are *index fossils*?

4 What are the time periods used by geologists?

5 In what unit are these time periods measured?

The dinosaur age

The dinosaur age was between 250 and 65 million years ago. Dinosaurs were the most successful animals on Earth before humans. All we know about dinosaurs today comes from fossil evidence. Many dinosaur fossils have been found in particular rock types or outcrops at a few locations in Australia, such as Dinosaur Cove in southern Victoria and Winton in central Queensland. An almost complete skeleton of *Minmi paravertebrae* (see Figures 6.44 and 6.45) was discovered near Minmi Crossing in north-west Queensland in 1990. Fossils of dinosaurs in Australia have helped palaeontologists deduce how large they were, what they ate and where and how they lived.

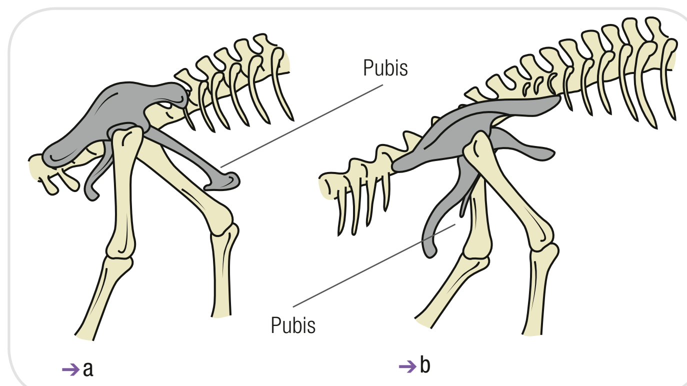
➔ Fig 6.44 *Minmi paravertebrae* was a small, armoured ankylosaur. Its armour was more like a shell and was heavy and hard. *Minmi paravertebrae* was a herbivore and its armour was presumably to protect it from predators. Even the belly of *M. paravertebrae* was protected by small bony plates.

➔ Fig 6.45 A reconstruction of *Minmi paravertebrae*.

Dinosaur classification

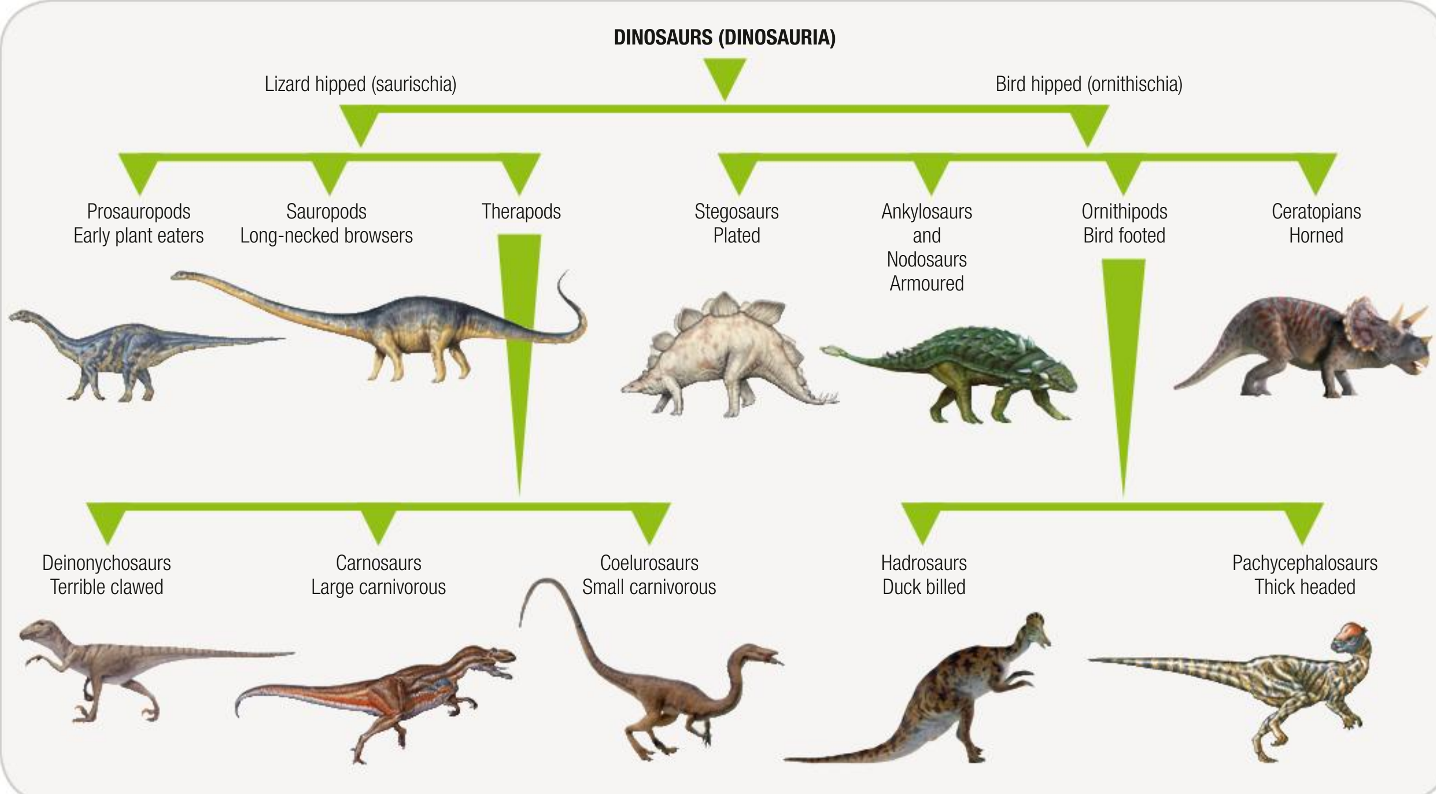
With so many different types of dinosaur fossils, scientists have classified dinosaurs into groups. The classification of dinosaurs is similar to that of other living things, which are normally classified according to their structural features—skeleton, skull shape, teeth, number of legs and the structure of their cells. Unfortunately, not all palaeontologists have agreed on a universal classification system for dinosaurs. The following groupings are those used in the most widely accepted classification system.

The dinosaur family is called Dinosauria and is divided into two main groups: lizard-hipped and bird-hipped dinosaurs (see Figure 6.46). These two main groups are further divided into subgroups, as shown in Figure 6.47.



➔ Fig 6.46 Dinosaurs are classified according to hip type. (a) Lizard-hipped dinosaur. (b) Bird-hipped dinosaur.

Scientists have learned a lot about what dinosaurs looked like, how they moved and what they ate. They are still unsure about whether dinosaurs were cold or warm blooded. Until recently, it was thought that dinosaurs were cold-blooded animals (like lizards). The body temperature of cold-blooded animals varies with their surroundings. As the temperature of their surroundings increases, their body temperature increases, as does their ability to move and function. Warm-blooded animals are able to maintain their own body temperature and can function fully in hot and cold temperatures. The discovery of dinosaur fossils at Dinosaur Cove in southern Victoria suggests that dinosaurs may, in fact, have been warm blooded. At the time of the dinosaurs, this part of Australia was located inside the Antarctic Circle: a cold-blooded animal could never have survived the freezing conditions. However, whether dinosaurs were, indeed, cold or warm blooded remains unknown.



➔ Fig 6.47 Dinosaur classification chart.

<<OVERARCHING IDEAS>>

Using evidence to deduce

Scale and measurement

The only evidence found worldwide of a dinosaur stampede is near Winton in Queensland. A large Theropod, which had steps of up to 2 m in length and walked at 9 km/h, approached from the north. After six steps the animal slowed down and, at the tenth step, it turned right. The smaller tracks show that there was then a stampede by 150 smaller Ornithopods and Coelurosaurs.

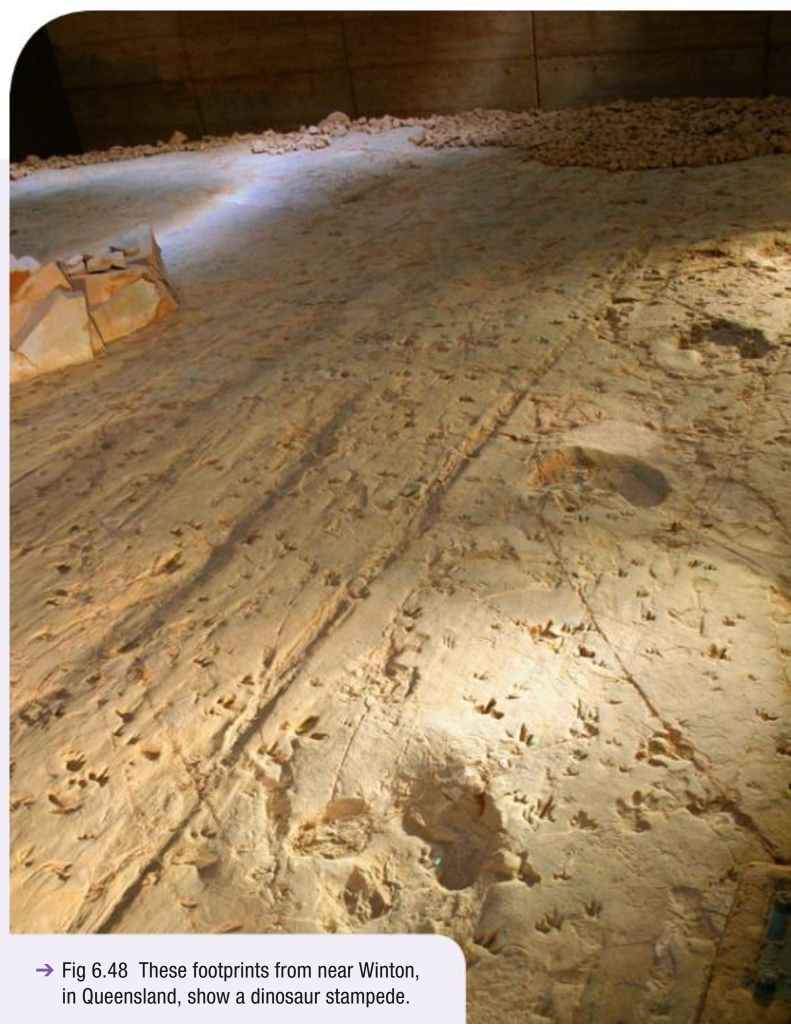
1 How would palaeontologists know the species of the dinosaurs involved in the stampede?

2 What information would help palaeontologists work out the weight of the dinosaurs?

3 How could the palaeontologists work out how fast the dinosaurs were travelling?

4 How could the palaeontologists tell that the Theropod slowed down?

5 Why do you think there was a stampede?



➔ Fig 6.48 These footprints from near Winton, in Queensland, show a dinosaur stampede.

Dinosaur extinction

Fossil evidence suggests that, 65 million years ago, approximately 70% of all species on Earth suddenly became extinct, including all dinosaurs. The disappearance of the dinosaurs is the most dramatic extinction of animals in the history of the Earth. Scientists argue about whether the extinction of the dinosaurs was sudden or gradual. Many different theories have been put forward, but the real reason for this mass extinction remains unknown.

The asteroid theory

The most widely accepted theory is that an asteroid, approximately 6–15 km in diameter, hit the Earth with the force of five billion atomic bombs. A huge crater, more than 180 km in diameter, was found buried at Chicxulub in Mexico in 1990, giving more support to this theory. The impact of the asteroid would have incinerated all plants and animals in its path, caused fires, generated earthquakes and tsunamis and scattered dust, debris and sulfuric acid into the atmosphere. Sunlight would have been obscured for months or even years and temperatures around the world must have fallen.

With the drop in temperature and lack of sunlight, plants probably stopped growing. Large plant-eating dinosaurs would have starved quickly and the meat-eating dinosaurs who preyed on them would have followed. Smaller nut- and seed-eating animals may have survived. As the dust finally settled and sunlight returned, dormant seeds would have sprouted and the animals that survived the impact would have prospered without dinosaurs to compete with.

The volcano theory

Volcanic eruptions shoot ash and other fragments high into the air. If there had been a large amount of volcanic activity approximately 65 million years ago, this too could have reduced levels of sunlight and dropped temperatures, leading to the extinction of the dinosaurs in the same way as proposed in the asteroid theory.

→ Fig 6.49 Dinosaurs became extinct approximately 65 million years ago.

Other theories

In 1980, the Nobel prize-winning physicist Luis Alvarez identified a layer of sedimentary rock found all over the world that marked the end of the Cretaceous period. This layer, known as the **KT boundary**, contained iridium, a rare radioactive element, in concentrations far greater than in any other layer of the ground. Iridium is known to exist in large amounts in most asteroids and comets, so Luis Alvarez theorised that an impact from space was the most likely cause of the extinction of the dinosaurs. Others suggested that volcanic eruptions could bring iridium from the Earth's centre, making this another likely explanation for the extinction of the dinosaurs.

This physical evidence makes any other theories for the extinction of the dinosaurs seem far less likely. Climate change, either due to natural cycles or the movement of the continents, has often been proposed as another theory. Yet another, less common, theory is that the seabeds dropped, causing significant changes to the Earth's albedo—its ability to reflect heat and light. However, the effects of such changes would have been very slow and many species would have evolved fast enough to survive. It is possible that the evidence for climate change is correct, but that it happened in addition to a major catastrophic event.

➔ Fig 6.50 The creamy layer of rock is the KT boundary. It marks the end of the Cretaceous period.

What do you know about the dinosaur age?

1 What are the two main groups of dinosaurs?
2 Why could less sunlight and reduced temperatures have led to the extinction of dinosaurs?
3 In what period did dinosaurs live?
4 Why do you think the dinosaurs are so well known, despite representing a tiny snapshot in time?

6.3 What can we learn from studying rocks?

Remember and understand

1 Copy and complete:
   a The geological time scale used is __________________ .
   b __________________ are used to find rocks of the same age.
   c __________________ can leave an impression in rocks.
   d A person who studies fossils is a __________________ .

2 Refer to the geological timescale in Figure 6.43.
   a During what period did dinosaurs become extinct?
   b When did the first land plants appear on Earth?
   c When did insects become common?
   d When did humans appear?

3 How do index fossils help identify rocks of the same age?

4 Explain why only simple fossils are found in the oldest types of rocks, whereas younger rocks have fossils of mammals.

5 Design a flow chart showing the steps in fossil formation.

6 Which dinosaur family do I belong to?
   a I have a long neck and eat by browsing.
   b I have a bill like a duck and people say that I have bird-like hips.
   c I have terrible claws and everyone is scared of me.
   d I have a thick head—but that doesn't make me any less clever than those Hadrosaurs!

Apply

7 Dinosaurs are grouped into lizard-hipped dinosaurs and bird-hipped dinosaurs. What does this tell you about how they moved?

8 Write a list of ten interview questions that you would ask a palaeontologist if you had the chance. Make sure that your questions will help you learn more about this branch of geology.

Analyse and evaluate

9 Why don't most organisms form fossils when they die?

10 A palaeontologist found a dinosaur skull but was not able to find any other bones in the area. Explain why this was the case.

11 If you were a palaeontologist searching for fossils, which types of rocks would you look for? Explain.

12 'Scientific ideas are not fixed—they have changed throughout history and continue to change.' Based on what you have learned in this unit, write a response to this statement. Do you agree or disagree? Make sure you back up your answer with evidence and fact.

Critical and creative thinking

13 In a format of your own choosing, demonstrate different ways that fossils can be formed and the types of fossils that are formed in this way.

14 Imagine that you are a world-famous scientist who is part of the team that has discovered how to reverse the geological timescale and bring dinosaurs back to life. Write a short science fiction story about the day the first dinosaur egg hatches.

<<CONNECTING IDEAS>> Dynamic Earth

15 Imagine you are living 10 million years into the future.
   a What might you find in the fossil record for the year 2012 in the area where you live?
   b Do you think there would be any human fossils?
   c What other objects from before 2012 might you find in the rocks?

Research

Formation of oil

Oil is formed from the compression and heating of dead marine plant material in mud over millions of years. Oil is made up of hydrocarbons, which are lighter than rock and water, so it often migrates up porous rock towards the Earth's surface.

- What is an oil reservoir?
- What conditions are needed for an oil reservoir to form?
- How is an oil field formed?
- In what other forms is oil found?

Gemstones

Which gemstones are found in Australia? Which gemstones are dug up by recreational fossickers? What do the gemstones look like?

Extraction of metals

Metals are extracted from their ores using a variety of methods. Some are heated, some are purified using electrical energy and some are extracted using chemical processes. Why are different metals extracted using different chemical or electrical processes? Find out about how some metals are extracted, such as copper and aluminium, and design a poster that shows the process of extraction.

New discoveries

Fossils are being found all over the world all the time.

- Where are the most recent finds?
- What animals or plants do they represent?
- What do the fossils reveal about these animals or plants?
- How important are these finds?

Reflect

Me

1 What new science laboratory skills have you learned in this chapter?
2 What was the most surprising thing you found out about studying rocks?
3 What were the most difficult aspects of this topic?

My world

4 Why is it important to understand how the Earth has changed?
5 Why is it important to understand how life on Earth has changed?

My future

6 What can you do now to make sure that humans don't become extinct like the dinosaurs?

Review

Key words

basalt
cleavage
coal
colour
comparative dating
crystal
era
erosion
extrusive igneous rock
fossil
hardness
igneous rock
index fossil
intrusive igneous rock
lava
limestone
lustre
magma
magma chamber
metamorphic rock
millions of years ago
mineral
obsidian
ore
palaeontologist
period
petrification
properties
pumice
quartz
radioactive dating
relative dating
rock cycle
scoria
sedimentary rock
streak
trace fossil
weathering

6 Evidence from Antarctica

The Earth's landmasses have not always been in the same position. About 200–500 million years ago, Antarctica, South America, Africa, Madagascar, Australia, New Guinea, New Zealand, Arabia and the Indian subcontinent all made up a southern supercontinent called Gondwana. This huge landmass extended from near the South Pole to near the Equator and mostly had a mild climate. Over time, Gondwana broke up, and the Antarctica we know today was formed about 25 million years ago. The changing climate and latitude greatly influenced the rocks formed on Antarctica. Although nearly the entire continent of Antarctica is covered with a thick layer of ice, making study of the rocks difficult, new techniques have been used to determine the types of rocks and minerals found in Antarctica. The Antarctic Peninsula formed by the uplift of metamorphic rock from seabed sediments. Volcanic activity occurred and intrusive igneous rock also formed. In east Antarctica, some of the rocks formed more than 3 billion years ago. This area is largely made up of a platform of metamorphic and igneous rocks, which form the base for more modern rocks, such as limestone, sandstone, coal and shale. Faulting has also occurred in some coastal areas.

➔ Fig 6.51 The Antarctic Peninsula.

➔ Fig 6.52 Ash from an Antarctic volcano.

Fig 6.53 Transantarctic mountains contain a wealth of valuable minerals.

About 500 million years ago West Antarctica was partially in the Northern Hemisphere with a mild climate. During this time, the rocks formed were largely sandstone, limestone and shale. Over the next 100 million years as Gondwana moved south and the climate cooled down, sand and silt were deposited in mountain areas. About 360 million years ago, glaciers formed, thus weathering the rock formations. In areas where fern-like plants grew in swamps, deposits of coal formed. Coal can be found near the Beardmore Glacier and as a low-grade form across many parts of the Transantarctic Mountains. Iron ore has also been found in significant deposits in the Prince Charles Mountains. However, the Protocol on Environmental Protection to the Antarctic Treaty has banned all exploitation of mineral resources by signatory states until 2048.

Although plant life is limited on Antarctica to mostly mosses and liverworts because of the extremeness of the climate, fossils provide evidence of a rich plant life in the past. Fossils of leaves and wood are abundant and indicate the existence of extensive forests in warmer times when Antarctica was part of Gondwana, and even in colder times when it was closer to the South Pole. Fossils of dinosaurs and marsupial mammals have also been found in Antarctica, indicating that they once roamed across its surface. Marine fossils of invertebrates, including shells with their original mother-of-pearl shell still intact, giant penguins and marine reptiles have also been found. In fact, dinosaur fossil evidence from Antarctica reveals that the extinction of dinosaurs was not as great as it was in a lot of other places around the world. But it still took 300 000 years for shallow marine communities of organisms to reappear. This sort of information has enabled scientists to understand how long it takes for communities of organisms to recover after mass extinction events.

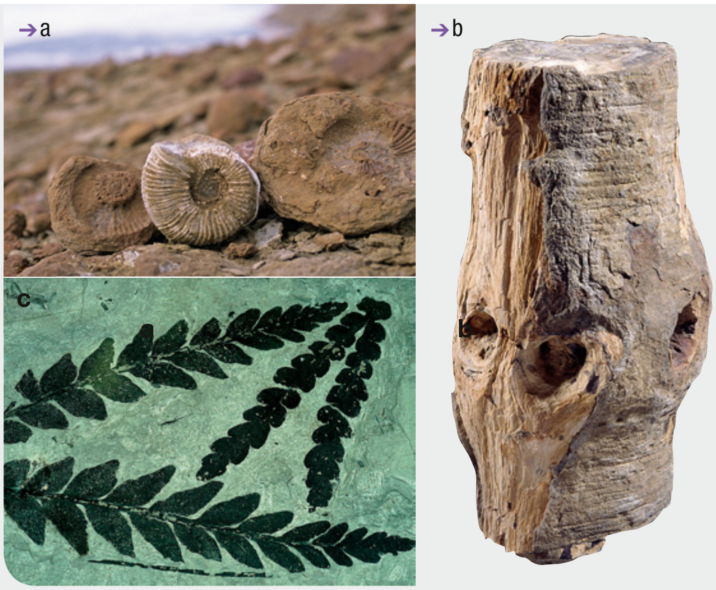


Fig 6.54 (a) Antarctic ammonite fossil, (b) A petrified conifer tree from Antarctica, (c) 260-million-year-old fossil leaf from Antarctica.

1 What types of rock formation processes have occurred in Antarctica?

2 What types of weathering processes have dominated in Antarctica?

3 What can you deduce about the past climate if sedimentary rocks such as sandstone, limestone and shale are found?

4 What sort of a climate would have existed on Antarctica for forests of trees and ferns to have existed?

5 Why do you think that mass extinction events such as of the dinosaurs were not as great on Antarctica as in other places in the world?

glossary

A

alveoli tiny air sacs in the lungs where gas exchange occurs

amino acid small molecule that makes up a protein

anatomy structure of an organism and its component parts; usually refers to human anatomy

apoptosis programmed cell death

artery thick, muscular-walled blood vessel that carries blood away from the heart under pressure

asexual reproduction type of reproduction not involving the fusing of gametes; where an organism can create offspring without a partner

asthma condition where the bronchi and bronchioles swell, making it harder to breathe; usually triggered by something in the environment

atom smallest particle of matter that cannot be created, destroyed or broken down (indivisible)

atomic theory of matter theory that all substances are made up of particles called atoms

B

biofuel any fuel produced from organic (once living) matter

biomass energy energy derived from plants and animals

blood liquid that circulates in the blood vessels and contains a combination of cells, cell fragments, liquid and dissolved substances

blood vessel tube in the body that carries blood

body system group of different organs working together, e.g. digestive system

breathing inhalation of oxygen and exhalation of carbon dioxide; not to be confused with respiration

C

cancer group of diseases that result from uncontrolled cell division

capillary blood vessel with a wall only one cell thick, allowing substances to easily pass into and out of the blood

carcinogen cancer-causing substance

cell (in *biology*) the building blocks of living things

cell membrane barrier around a cell that controls the entry and exit of things into and out of a cell

cell theory main idea about the importance of cells and their role in living things

chemical change change that results in a new chemical substance being formed; usually not reversible

chemical equation shorthand technique of showing what happens to the reactants and products in a chemical reaction

chemical potential energy energy stored in chemicals e.g. in food, fuel or explosives; also known simply as chemical energy

chemical property how a substance behaves in a chemical reaction, e.g. how it reacts with acid

chemical reaction procedure that produces new chemicals; same as a chemical change

chemist scientist who studies chemistry, finds out about substances and how and why they change

chemistry branch of science that deals with matter and changes that take place with it

chlorophyll green pigment found inside chloroplasts that absorbs solar energy and uses it in photosynthesis

chloroplast organelle found in plant cells that transform solar energy into chemical energy

chromosome packet of genetic material that carries several sets of instructions for our cells

cleavage number of smooth planes that minerals break along

coal type of sedimentary rock formed from dead plants that became buried before completely decaying

colour (in geology) guide to identifying a mineral but it cannot be relied on as many minerals are impure

combustion reaction where a substance is rapidly combined with oxygen, usually accompanied by a flame; burning

compact fluorescent light (CFL) type of fluorescent tube but in a smaller size, designed to replace incandescent light globes; also known as an energy-saver light globe

comparative dating process of working out the age of rocks as being younger or older than existing rocks; also known as relative dating

compound substance made up of two or more different types of atoms bonded together, e.g. water

compressibility ability of a substance to be compressed (squashed); gases can be compressed but solids and liquids cannot

condensation change of state from a gas to a liquid

contraception method used to prevent from getting pregnant

cost-benefit analysis list of the costs compared to the benefits; usually performed to analyse a proposed engineering project

criteria assessment table that contains the important aspects of a project that need to be measured; designed to make sure each project is as good as it can be

cross-pollination involves pollen from a flower landing on the stigma of a flower on a different plant, producing greater variation than self-pollination

crystal shape formed by minerals; the structure of the crystal greatly influences a mineral's properties

cytoplasm 'jelly-like' fluid inside the cell membrane that contains many dissolved nutrients and waste products

D

density mass of a certain volume of a substance

deoxyribonucleic acid (DNA) chemical that contains the instructions for every job performed by the cell; passed from one generation to the next

diffusion spontaneous spreading out of a substance through a liquid or gas e.g. the diffusion of perfume in air

digestion process by which food is broken down and absorbed into the blood for transport to the cells

digestive tract group of organs that form a tube travelling from the mouth to the anus

dissection process of dismantling and studying the internal structures of plants, animals and humans

E

elastic potential energy (EPE) energy stored through stretching or squashing, e.g. in a stretched spring or rubber band

electric car car that runs on the chemical energy stored in batteries rather than petrol; an electric motor alone makes the wheels turn; is plugged in to recharge

electrical energy energy associated with electric charge, either stationary (static) or moving (current)

element pure substance made up of only one type of atom, e.g. oxygen, carbon

emphysema disease that results from damage to the alveoli in the lungs; one of the diseases that can be caused by smoking

energy capacity for doing work; many different forms (e.g. kinetic, gravitational potential, chemical, nuclear); measured in joules

energy efficiency measure of the amount of useful energy transformed in an energy transformation process; usually expressed as a percentage of the input energy, e.g. 90% efficiency is very good

energy transformation conversion of energy usually from one type into another, e.g. in a toaster, the main energy transformation is from electrical to heat; can be expressed in a flow diagram

energy transformer device that converts energy from one form into another

engineer scientist who provides solutions, shapes future developments and generates ideas to make life simpler; different types who know how to solve problems in different fields, e.g. mechanical engineer, electrical engineer

enzyme chemical that helps make chemical reactions happen

era division of geological time that includes several periods

ethanol pure alcohol; added to petrol to improve the performance of the engine or can be used as a fuel in its own right, particularly popular in Brazil

eukaryotic cell complex cell that contain a nucleus and membrane-bound organelles

excretion process of removing wastes from the body

extrusive igneous rock rock formed quickly on the Earth's surface from cooling lava; small crystals or sometimes the lava cools so quickly that no crystals are formed at all

eyepiece lens where eye is placed when using a microscope

F

fertilisation stage of sexual reproduction involving the joining of a sperm and egg

foetus stage in the development of a human baby taken from when the baby acquires human features (normally after 8 weeks of development)

fossil remains or imprints of animals or plants preserved in rock

fragmentation type of asexual reproduction where an organism splits into fragments and each fragment grows into a new organism

G

gamete sex cell; in humans, the sperm and egg cells

gas exchange transfer of gases in and out of an organism; in humans, oxygen is exchanged from the lungs into the blood and carbon dioxide is exchanged from the blood into the lungs

geologist scientist who studies the origin, composition, structure and history of the Earth

gravitational potential energy (GPE) energy stored due to the height of an object, e.g. a child at the top of a slide

H

hardness ability of a substance to scratch another substance

hardness how easily a mineral can be scratched; described by a number on Mohs' hardness scale

hermaphrodite organism that has both male and female reproductive systems

hybrid car car that has both a petrol engine and an electric motor that uses batteries; the petrol engine recharges the batteries, e.g. Toyota Prius and the Hybrid Camry

I

igneous rock rock formed when magma and lava from volcanic eruptions cools and solidifies

in vitro fertilisation (IVF) type of assisted reproductive technology where an egg is fertilised by a sperm *in vitro* or 'in glass', meaning in a test-tube; hence the term 'test-tube baby'

incandescent emission of light from being hot; incandescent light globes have a filament that heats up and glows, emitting visible light

incompressible when a substance cannot be compressed; solids and liquids are incompressible

index fossil fossils that indicate the age of rocks; also known as guide fossils; different rocks that are the same age have the same type of fossils in them

infectious disease disease caused by the passing of a pathogen from one organism to another; also known as contagious

intrusive igneous rock rock formed slowly beneath the surface of the Earth when magma becomes trapped in small pockets; large crystals interlocked together

K

kinetic energy energy of movement; any moving object has kinetic energy

kinetic energy (KE) energy of motion or moving objects

L

lattice three-dimensional arrangement of particles in a regular pattern

lava molten rock that erupts from a volcano onto the surface of the Earth

law of conservation of energy scientific rule that states the total energy in a system is always constant and cannot be created or destroyed

limestone type of sedimentary rock formed by the cementing together under pressure of shells and hard parts of sea organisms deposited in layers on the ocean floor

lustre shininess of the surface of a mineral; there are various types including metallic, brilliant, pearly, dull and earthy

M

magma hot, molten rock inside the Earth from which igneous rocks are formed

magma chamber region under a volcano that acts as a source of molten rock for a volcano

mass amount of matter in a substance, usually measured in kilograms

matter anything that has mass and volume

metabolism chemical reactions that occur in the body

metamorphic rock rock formed when other types of rocks are changed by incredible heat and pressure inside the Earth

micrometre one millionth of a metre (μm)

microphone device that converts sound energy into electrical energy

microscope scientific instrument used to magnify the size of an object

mineral naturally occurring solid substance with its own chemical composition, structure and properties

mineral sand old beach sand that is rich in heavy minerals such as rutile, zircon and ilmenite

mitochondrion powerhouse organelle of a cell; the site of energy production; (plural mitochondria)

mitosis process of cell division to provide growth or repair

molecule group of two or more atoms that are bonded together, e.g. a water molecule

mutagen substance that may damage a cell's DNA

N

natural flora microbes that live happily in our bodies

nephron tiny structure in the kidneys that filters the blood

nuclear energy energy stored in the nucleus of an atom and released in nuclear reactors or explosions of nuclear weapons; much, much larger than the chemical energy released in chemical reactions

nucleus (in biology) control centre of a cell that contains all the genetic material (DNA) for that cell

nutrient soluble substance that an organism needs to live and grow; usually taken in from the environment

O

objective lens lens in the column of a compound light microscope

ore mineral with a large amount of a useful metal in it

organ group of tissues that work together, e.g. liver, heart, eyes, brain

organelle smaller part of a cell, each one having a different function

P

palaeontologist scientist who studies fossils

parthenogenesis asexual reproductive strategy where unfertilised eggs hatch into new organisms

particle building block of matter with mass and volume, usually represented as dots; this is a very general term and may refer to atoms, molecules or sub-atomic particles

particle model of matter theory that all matter is made up of very tiny particles

pathogen microbe that can potentially cause a disease

pepsin enzyme that breaks down proteins during digestion; requires a strongly acid environment, found in the stomach

period (in geological time) division of geological time, less than an era, that has special fossils associated with it; the end of most periods is marked by a large number of extinctions

petrification chemical replacement of wood, bones, teeth and shells by minerals dissolved in water

petroleum natural oil that is pumped from the ground; also known as crude oil

pharmacist specialises in the study of medicines and their effect on the body (pharmacology)

photosynthesis chemical process plants use to make glucose and oxygen from carbon dioxide and water

physical change change in the appearance of a substance; the substance still consists of the same particles, but it looks different; no new chemical substances are produced, e.g. melting and boiling

physical property can be measured or observed without changing a substance into something else, e.g. colour, boiling point

plasma state of matter that occurs when gases are heated to extremely high temperatures, e.g. inside stars

plastic one of a range of substances made from petroleum, usually fluid at some stage and allowed to set into a solid; most are polymers

pollination process that occurs in flowering plants when a pollen cell lands on the stigma

polymer long chain molecule made up of many simpler repeating units

potential energy energy stored in objects and waiting to be used, e.g. gravitational potential energy

precipitate insoluble solid substance

pressure force per unit area; particles exert pressure

product substance obtained at the end of a chemical reaction; written on the right of a chemical equation

prokaryotic cell primitive single celled organism that has no nucleus

property (in chemistry) characteristics or behaviours of something that are always the same, e.g. the density of gold

protein chain of amino acids that are an essential part of any cell

pure substance substance where all the atoms or molecules are the same, with no different substances (or impurities) present

Q

quartz most common mineral, found in nearly every rock type; made up of oxygen (O) and silicon (Si)

R

radioactive dating process of working out the actual age of a fossil by looking at the amount of radioactivity left in rocks

reactant substance used at the beginning of a chemical reaction; written on the left of a chemical equation

remote control electronic device used for the remote operation (i.e. at a distance) of a machine

reproduction making of new organisms

respiration breakdown of glucose and oxygen into water, carbon dioxide and energy; usually occurs in the mitochondria of a cell

reversible can be undone as in the case of some physical changes

ribosome cell organelle where protein production takes place

rock cycle illustration explaining how the three rock types (igneous, metamorphic and sedimentary) are related to each other and how they change from one type to another over time

S

sedimentary rock rock formed when loose particles are pressed together by the weight of the overlying sediments

selective breeding reproductive technique where animals and plants are bred to keep, lose or enhance a certain characteristic or to be immune to disease

self-pollination involves pollen from a flower landing on its own stigma or that of another flower on the same plant

sexual reproduction type of reproduction involving the fusing of gametes

solar cell used to transform sunlight directly into electrical energy; usually in the form of a panel; also known as a solar panel

sound energy type of kinetic energy made when things vibrate

speaker device that converts electrical energy into sound energy; also known by its full name: loudspeaker

spore tiny reproductive structure that, unlike a gamete, does not need to fuse with another cell to form a new organism

stable describes substances that do not react with other chemicals, e.g. gold

stain substance such as iodine, used to make cells more visible under a microscope

states of matter the forms that matter is found in: solid, liquid, gas and, more rarely, plasma

streak colour of a powdered or crushed mineral seen as the colour of the line left behind when the mineral is drawn along a surface

sublimation change of state straight from a solid to a gas or from a gas to a solid

surface area to volume ratio comparison between the surface area of a cell and its volume, as a fraction

symbol equation chemical equation where symbols and formulae are used instead of the names of the reactants and products

symptom changes that occur to an individual as a consequence of a disease

synthetic artificial or man-made material

T

thermal energy scientific term for heat energy

tissue group of cells that do a similar task

trace fossil impression of a once living organism left in rock, such as footprints

tumour growth or lump caused by a cell growing out of control

V

valve flap that stops blood from flowing backwards in the circulatory system

vaporisation change of state from a liquid to a gas; same as evaporation

vapour gaseous form of a substance that is normally a solid or liquid, e.g. water vapour

vegetative reproduction type of asexual reproduction where a part of a plant breaks off forming a new organism with no need for seeds or spores; similar to fragmentation

vein thin blood vessel that carries blood back to the heart

volume how much space an object takes up, usually measured in litres

W

wet mount slide prepared for viewing with a microscope that has a drop of water placed beneath the cover slip

word equation chemical equation where the names of the reactants and products are written in words

Z

zygote term used to describe a fertilised egg

index

The abbreviation 'vs' is used in the index for versus in the sense of 'contrasted with'.

A

B

C

D

E

F

G

H

I

K

L

M

N

O

P

Q

R

S

T

U

V

W

Y

Z

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