

• nelson •

# science 7

for the Australian Curriculum • NSW Stage 4

Elizabeth MCKENNA • Robert FARR • Karen LAMPMAN • Bill MATCHETT • Rebecca SMYTH • Katrina WALKER



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**Science 7**  
for the Australian Curriculum • **NSW Stage 4**

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**Nelson iScience 7 for NSW**

**1st Edition**

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# Introduction

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

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

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

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

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

# How to use Nelson iScience for NSW

The Nelson iScience for NSW series has been authored by practising teachers from across Australia to meet the requirements of the NSW Syllabus for the Australian Curriculum. The Nelson iScience for NSW series includes the content of the Australian Curriculum, while integrating the depth and full scope of the NSW syllabus.

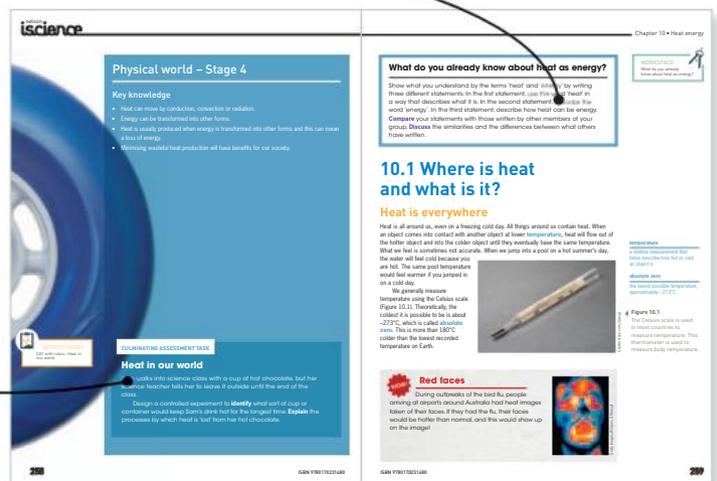
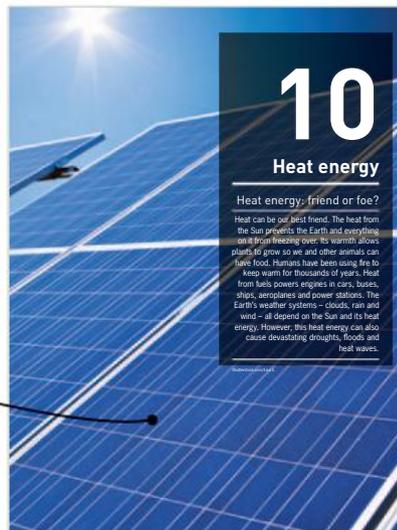
Nelson iScience for NSW has been designed for use by the students of the 21st century. It seamlessly integrates the use of Web 2.0 technology in the science classroom to research, analyse, record, collaborate and present material. Higher-order thinking skills are developed and reinforced throughout the series, providing students with strategies to manipulate information and ideas to tackle issues and assist with problem solving.

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

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

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

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







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

**WORKSPACES** are provided throughout each chapter.

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

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

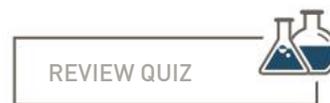
**INTERACTIVES** provide learning objects that the student can interact with and use at their own pace to reinforce their learning.

**ANIMATIONS** provide students with animated illustrations from the student text.

**WEBLINKS** link students to websites on the Internet.

**VIDEOS** link students to video clips to aid with learning and understanding.

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



## *Nelson iScience for NSW* NelsonNetBook

NelsonNetBook is a web-based and downloadable ebook for secondary schools, friendly to interactive whiteboards, computers and iPads. Optional Web 2.0 functionality enables class groups and individuals to add highlights, annotations, audio clips and weblinks. Visit the NelsonNet portal at [www.nelsonnet.com.au](http://www.nelsonnet.com.au) to find out more, to register or to log in if already registered.

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

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

## *Nelson iScience for NSW* teacher companion site

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

# Key question words

These key words are drawn from Bloom's Revised Taxonomy for the cognitive learning domain. They have been applied throughout this series in chapter questions. Many of these appear frequently in HSC documents and examinations.

The purpose behind this list is to help students prepare better for the HSC by showing them that certain key words are used similarly in examination questions across the different subjects they are studying. Importantly, they always have the same meaning. Students understand these words and what is expected.

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

**Account** Account for: state reasons for, report on; give an account of: narrate a series of events or transactions

**Analyse** Identify components and the relationship between them; draw out and relate implications

**Apply** Use, utilise, employ in a particular situation

**Appreciate** Make a judgement about the value of

**Assess** Make a judgement of value, quality, outcomes, results or size

**Calculate** Ascertain/determine from given facts, figures or information

**Clarify** Make clear or plain

**Classify** Arrange or include in classes/categories

**Compare** Show how things are similar or different

**Construct** Make, build, put together items or arguments

**Contrast** Show how things are different or opposite

**Critically analyse** Add a degree or level of accuracy depth, knowledge and understanding, logic, questioning, reflection and quality to analyse

**Critically evaluate** Add a degree or level of accuracy depth, knowledge and understanding, logic, questioning, reflection and quality to evaluate

**Deduce** Draw conclusions

**Define** State meaning and identify essential qualities

**Demonstrate** Show by example

**Describe** Provide characteristics and features

**Design** Create, or create a plan for a purpose

**Discuss** Identify issues and provide points for and/or against

**Distinguish** Recognise or note/indicate as being distinct or different from; to note differences between

**Evaluate** Make a judgement based on criteria; determine the value of

**Examine** Inquire into

**Explain** Relate cause and effect; make the relationships between things evident; provide why and/or how

**Extract** Choose relevant and/or appropriate details

**Extrapolate** Infer from what is known

**Identify** Recognise and name

**Illustrate** Clarify or explain by giving examples

**Interpret** Draw meaning from

**Investigate** Plan, inquire into and draw conclusions about

**Justify** Support an argument or conclusion

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

**Modify** Make small changes to something, especially to improve

**Outline** Sketch in general terms; indicate the main features of

**Predict** Suggest what may happen based on available information

**Propose** Put forward (for example a point of view, idea, argument, suggestion) for consideration or action

**Recall** Present remembered ideas, facts or experiences

**Recommend** Provide reasons in favour

**Recount** Retell a series of events

**Relate** Show a connection between two or more people or things

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

**Summarise** Express, concisely, the relevant details

**Synthesise** Put together various elements to make a whole



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An anatomical illustration showing a man with a full beard and a red robe, likely a physician or anatomist, examining a dissected human arm. The arm is held by another person whose hands are visible. The background is a textured, light blue and green. The man is looking intently at the arm. The illustration is in a classic, detailed style, possibly a woodcut or engraving.

# 1

## Studying science

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### How has science improved our lives?

---

What do a former grave-robbing student and the chief physician to the Roman gladiators have in common? They both studied medicine and human anatomy. Galen was doctor to the gladiators in the second century and recorded his medical knowledge in books. In 1543, the 28-year-old Andreas Vesalius dissected the corpses of executed criminals and made careful notes and drawings of what he saw. He then published a book on human anatomy that described hundreds of corrections to the work of Galen. Vesalius single-handedly advanced our understanding of human anatomy by 1000 years. This is only one example of how the work of one scientist helped to improve our lives.

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## Values and attitudes – Stage 4

### Key knowledge

- Scientific knowledge is based on evidence and our understanding of the world continually grows.
- Scientific advances can be applied to social and global issues today and for the future.
- Understanding how scientific knowledge and technological advances are achieved will help you to value scientific contributions.
- The continued study of science is important for society and our body of knowledge.
- Scientific research is affected by society and vice versa.

### CULMINATING ASSESSMENT TASK

### Scientist museum

- 1 Investigate** the life and work of an important scientist from history.
- 2 Identify** some of the key events and accomplishments of their life.
- 3 Evaluate** their importance to science and to society. Imagine finding items in the scientist's desk or laboratory.
- 4** Create an imaginative series of diary extracts, letters, speeches, newspaper articles, awards and other documents to **recount** their contributions and ideas. Be creative and make your archive of documents look aged and authentic. **Demonstrate** their importance by designing a plaque for your museum.
- 5** Display your plaque and archive of items along with those of the rest of the class to create a scientist museum.

#### ACTIVITY SHEET

CAT with rubric: Scientist museum

## What do you already know about science?

### Think

On your own, think about what you already know about science. Create a list of as many scientific words, names and discoveries as you can in 5 minutes.

### Pair

Pair up with someone else in your class.

### Share

Share your lists. Combine your ideas into one list. Join with another pair and talk about what you have all written. **Discuss** new things you would like to learn about science and write three questions to find the answers.

### WEB 2.0

As a class, create a Year 7 science wiki or other shared space. Capture all the names and discoveries (change to single words) listed by the class in a wordle. Take a screenshot of your wordle and upload it to the class wiki.

# 1.1 What is science?

The word 'science' comes from the Latin *scientia*, which means knowledge. These days it refers to a way of gaining knowledge by using observation and experimentation. This is known as the **scientific method**. The scientific method will be described in the next chapter. The study of science involves creativity and curiosity. Careful observations and experimenting gives us new ideas and information that can help us to understand our world. In this chapter, you will be introduced to a range of curious scientists throughout history and learn about why the study of science is important.

## Science born from curiosity

We all know that science is more than just a subject in school, but where and when did it all begin? Throughout human history, curious individuals have helped push human knowledge and understanding forward. In the days of Ancient Greece, 'scientists' were known as **philosophers**. Philosophers such as Aristotle (384–322 BCE) asked questions about animals and the universe and made countless observations about the natural world. These early thinkers tried to find the answers to questions such as 'Where did the universe come from?', 'Does the Sun revolve around the Earth?' and 'How do new living things come about?' Over time, the way people found the answers to these questions was improved to make the study of science consistent across the world.



### Spontaneous generation

From Ancient Greece to medieval Europe, people once believed that flies were produced by rotting meat and that mice could be made by keeping wheat husks and sweaty underwear in a jar for 3 weeks! This was known as 'spontaneous generation'. Careful scientific experiments proved that this was, of course, untrue.



Alamy/MiKA



### WEBLINK

Wordle

### scientific method

a set of rules that enables scientists to plan and conduct experiments in a consistent and repeatable way

### philosopher

a person who studies philosophy; a truth-seeker, thinker, academic or theorist

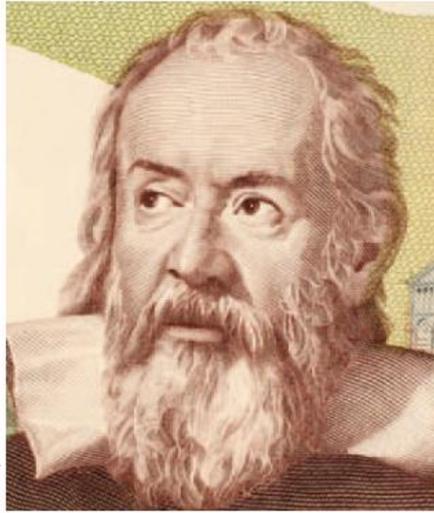
**physicist**

a scientist who specialises in physics, the study of the physical world

**astronomy**

the scientific study of the universe, especially the movement, position, composition, size and behaviour of astronomical objects

**Figure 1.1** ▶  
Galileo Galilei



iStockphoto

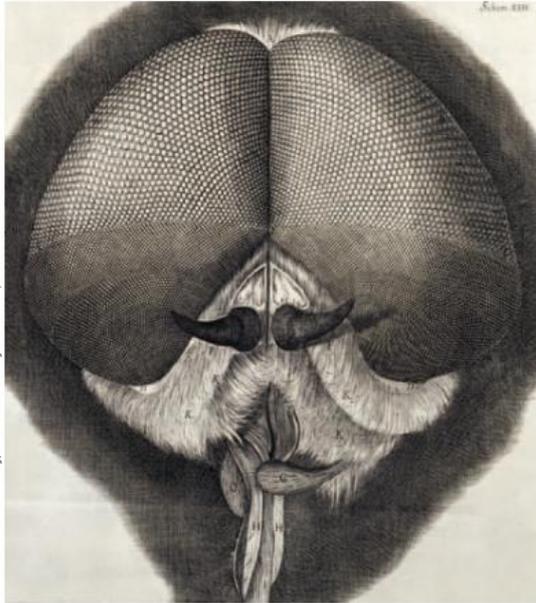
## Scientists from history

### Galileo Galilei

Galileo Galilei (1564–1642) was an Italian **physicist**, mathematician, astronomer and philosopher. He helped open the eyes of the world to new ways of thinking about the solar system and **astronomy**. The first practical telescopes were invented around 1600, and Galileo made great improvements to their design. Using his improved telescope, Galileo studied the Earth's moon and discovered four moons orbiting Jupiter. Today, these are called the Galilean moons. At that time most people thought the Sun revolved around the Earth. Galileo's discoveries supported the theory that the Earth and other planets revolve around the Sun.

**Figure 1.2** ▶

Robert Hooke's drawing of a fly's head from his book on microscopy, *Micrographia*



Science Photo Library/Natural History Museum, London

### Robert Hooke

Robert Hooke (1635–1703) was perhaps the greatest experimental scientist of the 17th century. He made countless contributions to biology, mechanics, architecture, physics, optics, human memory, microscopy, astronomy and **palaeontology**. He held the position of Curator of Experiments at the Royal Society in London for 40 years, and his drawings, plans and ideas formed the basis of some of Newton's laws, the first microscopes and the balance-spring watch. In later life, he was embroiled in controversial disputes with Isaac Newton. Mysteriously, when Hooke died, Newton took over at the Royal Society and all documents and portraits of Robert Hooke disappeared!

**palaeontology**

the scientific study of fossils

### Isaac Newton

Isaac Newton (1642–1727) was a British mathematician, physicist and astronomer. He is famous for his achievements in all three areas. He is widely credited with developing his three laws of motion and the law of universal gravitation. This law of universal gravitation built upon the important work of Robert Hooke and explains why the Moon orbits the Earth and why the Earth revolves around the Sun.

Newton is also credited with designing and constructing a working reflecting telescope, an improvement on Galileo's refracting telescope. He also conducted a series of experiments on the composition of light. The modern study of optics began with Newton's discovery that white light is made up of the same colours that can be seen in a rainbow.

After Newton seemingly borrowed many of Hooke's ideas, he wrote in a letter to Robert Hooke, 'If I have seen further, it is by standing on ye shoulders of giants'. It is important to remember that in science, new research is often based on previous research and it is not always easy to see who should get credit for discoveries.



iStockphoto

**Figure 1.3** ▲  
Isaac Newton

## Maria Sibylla Merian

Maria Sibylla Merian (1647–1717) was an extremely talented German artist. She had a keen eye for detail and was able to paint and sketch plants and animals with great precision. Merian's detailed observations of the **metamorphosis** of a butterfly made a very important contribution to science: she carefully observed what happened as a caterpillar changed into a chrysalis and then into a butterfly. Merian was one of the first scientists to study live insects rather than preserved specimens. Her work made her famous in the field of **entomology**.

## Marie Curie

Marie Curie (1867–1934) was a Polish-born research scientist, **chemist**, physicist and X-ray technician. She was an extremely dedicated scientist who actively promoted the use of radium to ease suffering. Curie was a pioneer in the field of radioactivity. She discovered two radioactive elements – polonium and radium – and established a radioactivity laboratory in Warsaw. Curie led the world's first studies into the use of radioactive **isotopes** in the treatment of cancer. She is the only person to receive Nobel Prizes in two different sciences – one in Physics (1903) and one in Chemistry (1911). Sadly, Curie died of an illness brought on by her exposure to the radium she studied.



Photoblibrary/Alamy/The Natural History Museum

### metamorphosis

change of form, such as a caterpillar to a butterfly

### entomology

the scientific study of insects

### ◀ Figure 1.4

One of Maria Sybilla Merian's detailed drawings of butterflies

### chemist

a scientist who studies the structure and behaviour of matter

### isotope

one of several forms of a chemical element

### ◀ Figure 1.5

Marie Curie was a pioneer in the study of radioactivity.

Photoblibrary/Image State



## Nobel Prize

The Nobel Prize is an international prize administered in Sweden. First awarded in 1901, it is regarded as one of the most prestigious awards in the fields of physics, chemistry, physiology or medicine, and literature. The Nobel Peace Prize is awarded for the promotion of world peace. Winners (known as Nobel Laureates) receive a medal and a cash award. Australia has a high proportion of Nobel Prize winners, considering its population size. Since 1915, 10 Nobel Prizes for science have been awarded to Australians.

### ACTIVITY SHEET

Australian Nobel Laureates



**micro-organism**

a living thing too small to see with the naked eye; for example, bacteria

**sterilise**

to disinfect by destroying micro-organisms

**antiseptic**

stops the growth of micro-organisms

**Joseph Lister**

Joseph Lister (1827–1912) was a British doctor and professor of surgery. He noticed the high death rate of patients after surgery and became determined to stop the spread of ‘ward fever’ that killed patients in hospitals. Using Louis Pasteur’s ideas that tiny, invisible **micro-organisms** could cause infection, Lister experimented with ways to kill these unseen pests. Lister introduced cleaner techniques for surgery by dressing wounds with bandages soaked in carbolic acid, **sterilising** equipment and ordering surgeons to wash their hands before surgery. These practices vastly improved the recovery of patients after surgery and **antiseptic** techniques like these are still used today.



Alamy/Pictorial Press Ltd.

**Figure 1.6** ▶

Joseph Lister pioneered the practice of antiseptic surgery.

**WEB 2.0**

Use an online timeline site such as Timetoast to create your timeline.

**ACTIVITY 1.1**

**Timeline - important moments in science**

In this activity you and your partner will create a timeline for some important moments in science.

- 1 Create a timeline using the dates of 10 important moments in science that you and your partner have researched. These may be discoveries or inventions, or new theories.
- 2 Add two important facts as summary statements to accompany each item.



**WEBLINK**  
Timetoast

## Issues in science

As you learn more about science, you will see that there are many issues involved. For example, it used to be illegal in most countries to dissect the dead bodies of people. It was thought that this was not **ethical**. Padua University in 16th-century Italy was one of the few places in Europe where such dissections were allowed. Scientists such as Vesalius and William Harvey came to Padua and made major discoveries about how the human body works, including the fact that the heart pumps the blood. Previously, research was based on animal experiments. Imagine if human dissection had never been allowed. This is one example of the many types of difficult issues that are a part of scientific research – issues for scientists and society. In your studies of science at school, and in current news stories, you will come across many more examples.



Corbis/Guido Bagliera/Grand Tour

### ethical

conforming to society's standard of right and wrong

### ◀ Figure 1.7

The anatomy theatre at Padua University where dissections took place in the 16th century

### ACTIVITY SHEET

Why is science important?



### ACTIVITY 1.2

## Science in the news

Find a short article in the news, either in a newspaper or from an online news website. Read it and:

- identify** the main issue
- identify** who the issue will affect
- assess** the article and state your opinion of what should be done, **justifying** your point of view.

### WORKSPACE

Science in the news





**WORKSPACE**

What have you learnt? 1.1

**QUESTIONS 1.1**

**What have you learnt?**

**Remembering**

- 1 **Define** the term 'science'.
- 2 **Recall** at least one achievement for each of the scientists mentioned in this section.

**Applying**

- 4 Look back at the scientists mentioned in this section. **Describe** examples in which you, or anyone you know of, have made use of any of their discoveries.
- 5 **Discuss** a struggle or problem that had to be faced by one of the scientists mentioned in this section.

**Analysing**

- 6 **Analyse** the success of Joseph Lister (page 6). Outline how he used science to act on an observation he made.

**Reflecting**

- 7 **Discuss** whether you think there might be more issues for scientists today or in Newton's time.

## 1.2 Being a scientist

Scientists are curious about many different things. Some scientists make discoveries, such as Newton's gravitational theory, that bring about major changes. The field of science develops as new needs arise and as new things are discovered. The discoveries of the scientists mentioned in the previous section led to further knowledge or advances in science. Without understanding gravitational theory, humans could not have designed a rocket to go to the Moon. Of course, we never would have gone to the Moon if some scientists had not first dreamed of doing so.



**INTERACTIVE**

What do scientists do?



**ACTIVITY SHEET**

Stereotypes of scientists

### Types of scientists

You might be already be familiar with these types of scientists.

- An astronomer studies stars, planets and other objects in the universe.
- A geologist studies the Earth, including rocks and soils and how they form.
- A biochemist studies chemical substances present in living things.
- A pharmacologist studies drugs and medicines.
- A botanist studies plants.
- A zoologist studies animals.
- A physicist studies aspects of the physical world, such as movement, light, sound and electricity.
- A chemist studies chemical substances, such as metals and other materials.

## ACTIVITY 1.3

## Science careers

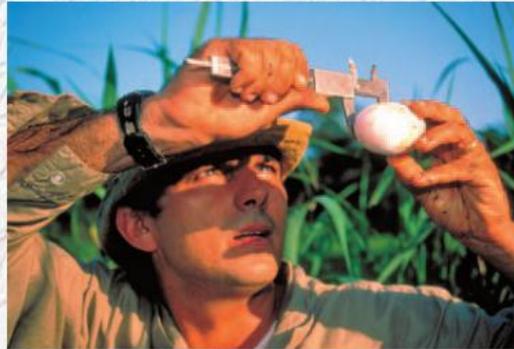
## Part A: Where do scientists work?

- 1 Look at the photos below. **Predict** where you think these scientists work and the types of things they do.



Science Photo Library/Jeremy Bishop

Vulcanologist



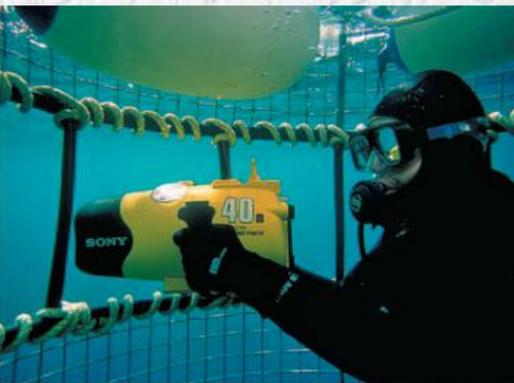
Visuals Unlimited/Peter Lane Taylor

Zoologist



Visuals Unlimited/Peter Lane Taylor

Botanist



Visuals Unlimited/Peter Lane Taylor

Marine biologist

## Part B: Science study and career

- 1 Choose one of the types of scientists from the photos in Part A.
- 2 **Investigate** which universities or training institutes in New South Wales offer courses that would enable you to become this type of scientist.
- 3 **Investigate** and **describe** what this type of scientist does in a typical day.
- 4 Present your findings as a marketing brochure or multimedia presentation for an imaginary Careers Day.

**WORKSPACE**  
Science careers



## WEB 2.0

Record your findings on the class wiki. Add another two '-ologist' words to the class wiki.



**WORKSPACE**  
Meet a scientist



**VIDEO**  
Meet a scientist

**ACTIVITY 1.4**

## Meet a scientist

1 Watch the video 'Meet a scientist', and write at least three questions about what you see.

### Extension

2 Find out about the Australian Synchrotron. Ask questions such as:

- Where is it?
- When was it built?
- What does it do?
- What types of scientists work there?
- Are there other synchrotrons in the world? If so, where are they?



**Figure 1.8** ▶

The Australian Synchrotron

## Heroes and rebels

Many scientists have risked their health for their research. Some have suffered illness and even death as a result of their work. Marie Curie died after years of working with radium. James Simpson inhaled chloroform to test it as a possible **anaesthetic** to dull the pain during surgery. Other scientists have swallowed parasite eggs to learn the effects of infection or have deliberately infected themselves with diseases such as yellow fever and cholera. These people risked their lives to find the answers.

Other scientists risked ridicule and punishment from society. Lister was not popular with doctors when he told them to sterilise their hands and surgical equipment against something they could not even see. Galileo was excommunicated (cut off) from the Catholic Church for his theories and put under house arrest. He was not pardoned for 360 years.

### **anaesthetic**

a drug that causes complete or partial loss of feeling

## ACTIVITY 1.5

## Science heroes?

- 1 **Investigate** two of the scientists shown below and write two facts that you discovered from your research.
- 2 **Define** the word 'hero'. Write your own definition of a hero. Look up the definition of 'hero' in a dictionary. **Compare** the two definitions.
- 3 Do you think either of the scientists you researched are heroes? **Justify** your answer.



Fred Hollows



Jane Goodall



Tim Flannery



Fiona Wood

WORKSPACE  
Science heroes?



## WEB 2.0

Contribute to the class wiki by adding two facts that you discovered from your research.

## Traits of a scientist

Scientists need to be good problem-solvers – just think of Marie Curie or Joseph Lister. Habits of Mind are personal qualities that are seen in good problem-solvers. Read about the Habits of Mind in Table 1.1. How many of these qualities do you possess?

**Table 1.1**   
Habits of Mind

Icon	Habit of Mind	This Habit of Mind is about:	Related terms	Question
	Striving for accuracy	Striving to be your best, to be accurate; setting high standards and looking for ways to improve	Perfection, sharp, clear, specific, mastery, quality control	How important do you think it is for a scientist to strive for accuracy?
	Applying past knowledge	Using what you already know to help you solve a problem or work through a similar situation	Recall, transfer, use again, reminds me, remember, just like the time when ...	When have you used your past knowledge to get out of a difficult situation?
	Remaining open to continuous learning	Learning from experience; having the confidence to admit when you do not know something	Being inquisitive, learning from experience, failing forward, life-long learning, self-evaluating	When do you think it is most important to be open to continuous learning?
	Thinking interdependently	Being a member of a team; working with and learning from others	Cooperative, collegial, collaborative, interconnected	Think of teams you are a member of. Which worked better, and why?
	Thinking flexibly	Looking at things in a number of different ways; being able to change your point of view; generating alternatives	Adaptable, bendable, options, open-minded, lateral thinking, creative, multiple solutions, diversity	When have you had to be flexible with your thinking or approach to a situation?
	Finding humour	Being able to laugh at yourself; finding the whimsical, humorous or unexpected	Witty, satirical, absurd, comic, funny, laughable	When was the last time that you were personally involved in a humorous situation?
	Creating, imagining, innovating	Generating new ideas; being original	Innovative, clever, unique, productive, generative, new, fresh, novel	Why do you think innovation is important?
	Managing impulsivity	Thinking before you act; taking the time to think things through; being careful, calm, thoughtful and deliberate	Strategic, patient, planned, considered, controlled, reflective	When did things get out of control after you overreacted to a situation?

Table 1.1 CONT. ▲

Icon	Habit of Mind	This Habit of Mind is about:	Related terms	Question
	Listening with empathy and understanding	Listening to and understanding others; making an effort to see the other person's point of view and emotion	Empathetic, attuned, attentive, caring, concentration, compassionate, respectful, summarising	How do you feel when the people you are talking to do not listen completely to what you are saying?
	Thinking about your thinking – metacognition	Being aware of your own thoughts, strategies, feelings and actions, and their effect on others	Self-aware, thinking aloud, self-evaluative, self-monitoring, inner thoughts, inner feelings, alertness, talk-aloud problem-solving	Do you think you should be taught how to think about your thinking? Why, or why not?
	Persistence	Persevering until the end without giving up; remaining focused and looking for ways to reach your goals when you are stuck	Never give up, perseverance, focused, try again, stand your ground, sustained, diligent, hang in there, relentless	What is something you persist at and enjoy?
	Questioning and posing problems	Knowing what you need; developing questions to get what you need; asking questions to find out what you need to know to solve a problem	Delving, investigative, curious, speculative, proof-seeking, probing, interrogative, inquisitive	Think of some questions that would assist you when solving problems. What types of things are good to ask or find out?
	Taking responsible risks	Being adventurous and trying new things	Being bold, courageous, daring; being a pathfinder, individualistic, free-spirited	Some people are more courageous than others. Why do you think this is so?
	Gathering data through all senses	Paying attention to the world around you; being observant; using all your senses to take things in	Sensing, physical, visual, tactile, interactive, sensitivity, clarity, learning from experiences	Which sense do you think people in general rely on the most, and why?
	Thinking and communicating with clarity and precision	Being clear when communicating; striving to be accurate in both the written and spoken word; avoiding over-generalisations	Speaking clearly, defining your terms, eloquent, having a command of language	What questions might you ask if you want someone to be clearer about what they are saying?
	Responding with wonderment and awe	Finding the world around you awesome and mysterious; being intrigued by beauty; being passionate	Wondrous, alive, amazement, fascination, marvel, energised, visionary, enthralled	Why do people react differently to things that might be considered awesome?

Source: From *Habits of Mind Across the Curriculum: Practical and Creative Strategies for Teachers*, edited by Arthur L. Costa and Bena Kallick, Alexandria, VA: ASCD. © 2009 by ASCD. Reprinted with permission. Learn more about ASCD at [www.ascd.org](http://www.ascd.org).



**WORKSPACE**

Scientists' Habits of Mind

**ACTIVITY 1.6**

## Scientists' Habits of Mind

- 1 Choose one scientist you have learnt about and **describe** the ways in which he or she would have used three Habits of Mind. (The workspace provides an example for you to follow.)
- 2 **Explain** how the habits you identified were useful to this scientist.



**WORKSPACE**

What have you learnt? 1.2

**QUESTIONS 1.2**

## What have you learnt?

### Remembering

- 1 **Recall** the area of study of a:
  - a zoologist
  - b geologist
  - c astronomer

- 2 **Recall** five Habits of Mind.

### Understanding

- 3 **Identify** the Habit of Mind that you would need to have to be willing to infect yourself with a disease.

### Applying

- 4 **Propose** three habits that you think are most important for a scientist to have.

### Reflecting

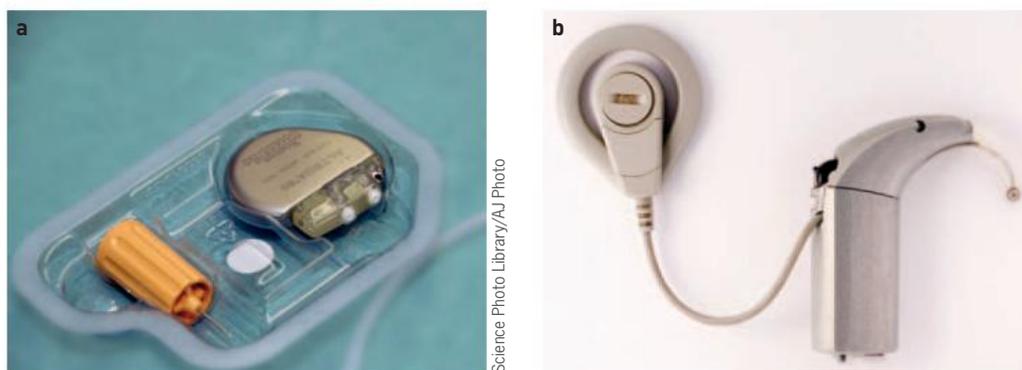
- 5 **Examine** your own Habits of Mind.
  - a **Identify** three that you think are your strengths. **Demonstrate** with an example.
  - b **Identify** other people in your class who have different strengths.
  - c **Discuss** the implications this could have for group work and team activities.

# 1.3 Science in Australia

The Commonwealth Scientific and Industrial Research Organisation, or CSIRO, is the main scientific research agency for Australia. Research into a wide variety of areas takes place in divisions such as Astronomy and Space Science, Energy Technology, Ecosystem Sciences and Materials Science and Engineering. Some of CSIRO's major achievements include sheep vaccines, polymer banknotes, solar energy, Aerogard insect repellent, Parkes Radio Telescope and a new flu drug.

There are many other state government scientific institutions as well as countless private companies, hospitals and universities. Scientific research also occurs in the laboratories of major companies, such as Holden, Kraft, Kellogg's, Telstra, Cadbury and L'Oréal.

In Sydney in 1928, Australians Mark Lidwell and Edgar Booth made the first artificial pacemaker for hearts (Figure 1.9). Professor Graeme Clark created the bionic ear, or cochlear implant, in 1979 to help with hearing in deaf people. Over the years, Australians have invented many things, from the dual-flush toilet, inflatable emergency escape slide and StaySharp knives, to ultrasound and spray-on skin. All of these were the result of necessity. For example, the dual-flush toilet was invented to cut water usage in our drought-ridden country and spray-on skin helps burn victims heal sooner. This is truly a proud legacy.



◀ **Figure 1.9**  
**a** The artificial pacemaker and **b** bionic ear are both Australian inventions.

### ACTIVITY 1.7

## Put on your thinking cap

Form a group of four with the following roles based on the Habits of Mind: Questioner, Innovator, Communicator and Persister. Together, choose a product you use in your daily life (maybe a gel pen, cereal, sports drink or iPod). Imagine all of the research required to make your product. All members can contribute to ideas, but assign the following roles:

- The Questioner should keep asking questions.
- The Innovator should use their imagination.
- The Persister should keep everyone in the group working.
- The Communicator should **construct** a flow diagram to organise the major steps and type of researcher at each step involved to make your product.

If you have time, research your product together to see if you were correct.



## Making Vegemite

Australian chemist Dr Cyril Callister invented Vegemite in 1923 to capture the rich source of vitamin B in brewer's yeast. Vegemite was slow to catch on, but soon doctors were recommending it for babies and other patients, and the army bought it in bulk during World War II. Today there are over 22 million jars sold per year.



dLibrary

## Australian scientists of today

During the 1980s at the Royal Perth Hospital, Professor Barry Marshall and Dr Robin Warren were studying painful upset stomachs and stomach ulcers. At that time, scientists believed that ulcers were caused by stomach acid, stress and eating spicy foods, but Warren disagreed. Although it was generally thought that the stomach was too acidic for bacteria to survive, Warren had seen bacteria on slides from stomach samples. The two researchers tried to grow samples of the bacteria, *Helicobacter pylori*, but were finding it difficult. By leaving some samples too long, they accidentally grew what they wanted. Needing to test their theory on a human stomach, Marshall bravely swallowed a whole dish of the live bacteria! He became painfully sick, developed a stomach ulcer and the rest is history.

The scientists found evidence for their theory and changed medicine and the lives of thousands of sufferers. These two great Australian scientists have been awarded the Warren Alpert Foundation Prize (USA), the Paul Ehrlich and Ludwig Darmstaedter Prize (Germany), the Florey Medal (Australia) and the Nobel Prize in Physiology or Medicine (2005).

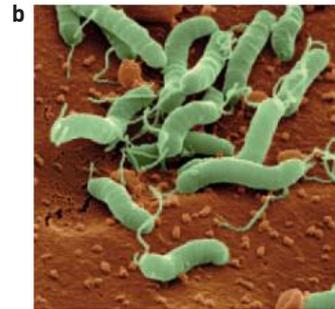


### WEBLINK

Marshall Nobel acceptance speech

Figure 1.10 ▶

**a** Australian scientists Barry Marshall and Robin Warren discovered that stomach ulcers are caused by the bacteria *Helicobacter pylori*. **b**.



### WEBLINK

Past NSW Tall Poppy winners



### WORKSPACE

What have you learnt? 1.3

The Australian Institute of Policy and Science created the Tall Poppy Campaign to reward and recognise intellectual and scientific excellence. It is the hope of this campaign that more young Australians will follow in the footsteps of great achievers such as Marshall, Warren and many other local innovators. The Florey Medal is awarded along with the Young Tall Poppy Science Awards to encourage continued excellence in Australian science.

### QUESTIONS 1.3

## What have you learnt?

### Understanding

- 1 **Recall** five Australian inventions.
- 2 **Recall** three places where scientific research takes place in Australia.

### Applying

- 3 **Predict** the outcome for ulcer sufferers if Marshall and Warren had not persisted with their research.

### Evaluating

- 4 Support or criticise the Tall Poppy program by **discussing** if it can successfully inspire more young scientists.

### Reflecting

- 5 **Assess** whether or not you think that Marshall and Warren deserved a Nobel Prize for their work and discuss your reasons.

# Chapter review

## Remembering

Many different types of scientists work in many different fields of science. The list below represents only a few of these scientists.

- Microbiologist
- Anthropologist
- Palaeontologist
- Meteorologist
- Agronomist
- Hydrologist
- Ecologist
- Entomologist
- Oncologist
- Oceanographer
- Seismologist
- Neurologist

- 1 **Identify** what each scientist listed above do.
- 2 **Recall** the names of three scientists and **identify** one of their major achievements.

## Understanding

- 3 a Did you notice that most of the names in the above list end in ‘-ologist’? **Investigate** what this means.  
b **Identify** two other ‘-ologist’ scientists to add to your list.
- 4 **Outline** two qualities, or habits, shared by the famous scientists you have learnt about.

## Applying

- 5 Barry Marshall was brave to experiment on himself. **Assess** whether or not you think it would have been ethical if he had tested the bacteria on his dog first.
- 6 Imagine you must assemble a science research team of five people. **Propose** the five main Habits of Mind you would want to be represented on your team.

## Evaluating

- 7 **Recall** four Australian science inventions. Imagine each had been proposed to you with a request for funding. **Evaluate** the worthiness of each based on your own criteria and rank them in the order you think they deserve funding from most worthy to least worthy. **Justify** your ranking.
- 8 In your opinion, which of the scientists you read about during this chapter has made the greatest contribution to science? **Discuss** the reasons for your choice.
- 9 **Assess** the impact of the Nobel Prize on the world of science.



**WORKSPACE**  
Chapter 1 review



**ACTIVITY SHEET**  
Chapter 1 checklist



**REVIEW QUIZ**  
Chapter 1



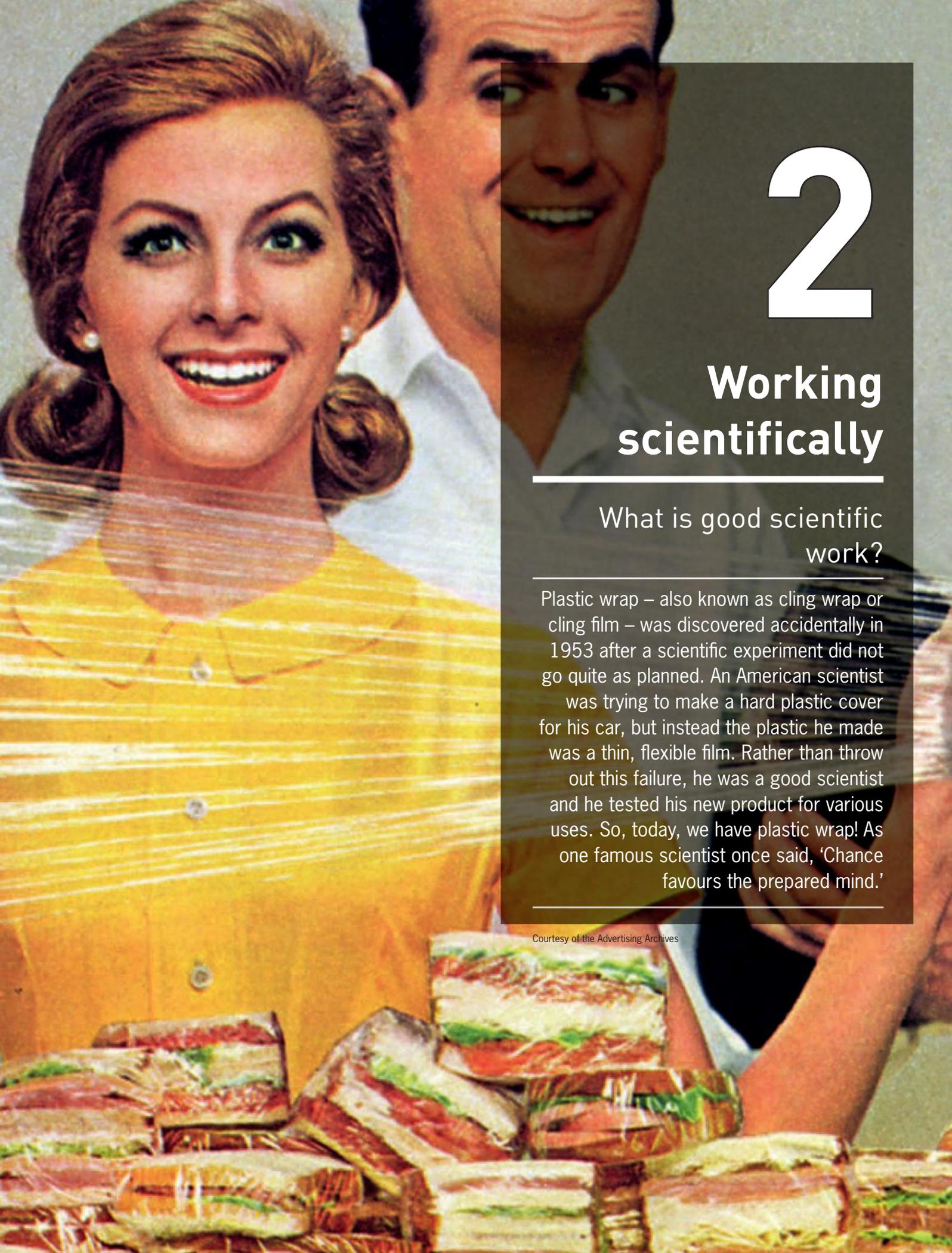


## Creating

- 10 Imagine that you are a famous scientist. **Construct** a letter of congratulations to yourself **outlining** your scientific accomplishments.

## Reflecting

- 11 **Discuss** how your understanding of science has changed since the start of this chapter.  
12 **Propose** ways to encourage more young people to become scientists.



# 2

## Working scientifically

---

What is good scientific work?

---

Plastic wrap – also known as cling wrap or cling film – was discovered accidentally in 1953 after a scientific experiment did not go quite as planned. An American scientist was trying to make a hard plastic cover for his car, but instead the plastic he made was a thin, flexible film. Rather than throw out this failure, he was a good scientist and he tested his new product for various uses. So, today, we have plastic wrap! As one famous scientist once said, 'Chance favours the prepared mind.'

---

Courtesy of the Advertising Archives

## Working scientifically – Stage 4

### Key knowledge

- Science inquiry skills (observing, questioning, inferring and predicting) are required to investigate problems.
- Independent, dependent and controlled variables are elements of fair testing in experimental design.
- A scientific report is made up of a number of elements such as an aim, hypothesis, equipment list, method, results and conclusion.
- A safety audit is used to minimise risks when conducting an experiment.
- Following a method correctly improves the likelihood that the results collected represent what is being tested.
- Qualitative data is information that is collected but that does not have a numerical value.
- Quantitative data is numerical information that can be collected using equipment such as stopwatches, rulers or thermometers.
- Scientific ideas and findings can be communicated in a variety of ways, such as diagrams, tables and graphs.



#### ACTIVITY SHEET

CAT with rubric: Do TV ads tell the whole truth?

#### CULMINATING ASSESSMENT TASK

### Do TV ads tell the whole truth?

How reliable are advertisers' claims, and are they backed up by scientific testing? **Investigate** a common household product. Design a fair test to find out if that product is the best at what it does. For example: Which sticky tape is the stickiest?

## What do you already know about working scientifically?

Which brand of plastic wrap is the strongest?

- 1 In groups of two or three, brainstorm possible ways to determine which of three different brands of plastic wrap is the strongest.
- 2 Observe and feel each brand of plastic wrap. **Predict** which brand you think will be the strongest.
- 3 **Propose** a method to test the strength of each plastic wrap. Write a list of the materials you would need to do this and outline your testing process.
- 4 Write down how you would test the plastic wraps. Suggest what you think you would see.

### Feedback

- 1 **Discuss** your method with the class. How many groups followed the same process of testing the three plastic wraps?
- 2 Make a list of any other things that could affect your outcome, other than the strength of the plastic wrap.

*At the end of this chapter your teacher may let you conduct your investigation.*

### WORKSPACE

What do you already know about working scientifically?



## 2.1 Safety in the laboratory

No matter where a scientist or science student works, the first priority is always safety. To be safe in your workplace, you need to be alert at all times. Many accidents occur as a result of careless behaviour.



Shutterstock.com/newphotoservice

◀ **Figure 2.1**  
Scientists must wear suitable safety gear.

## Laboratory safety rules

The following rules are common in most school laboratories. You should always observe them. You can also add some of your own rules to this, based on the set-up of your school laboratory.

- 1 Do not enter the laboratory unless accompanied by a teacher.
- 2 Never run in the laboratory.
- 3 Never eat or drink in the laboratory.
- 4 Do not touch any equipment or chemicals until instructed to by your teacher.
- 5 Never taste or smell any chemicals. Your teacher will instruct you if you can smell the chemicals, but always waft the gas towards your nose with your hand.
- 6 Tell your teacher immediately if you spill any chemicals, break any glassware, or burn or cut yourself.
- 7 Use the appropriate safety gear when conducting an experiment, such as lab coats and safety glasses.
- 8 Tie back long hair before conducting experiments, especially when using a Bunsen burner.
- 9 Point test tubes away from you and other students, especially when heating them.
- 10 Do not touch hot equipment. After heating, allow the equipment to cool down before you put it away.
- 11 Always follow your teacher's instructions about disposing of chemicals.
- 12 Clean up your working area and equipment after use.
- 13 Wash your hands immediately after conducting an experiment.



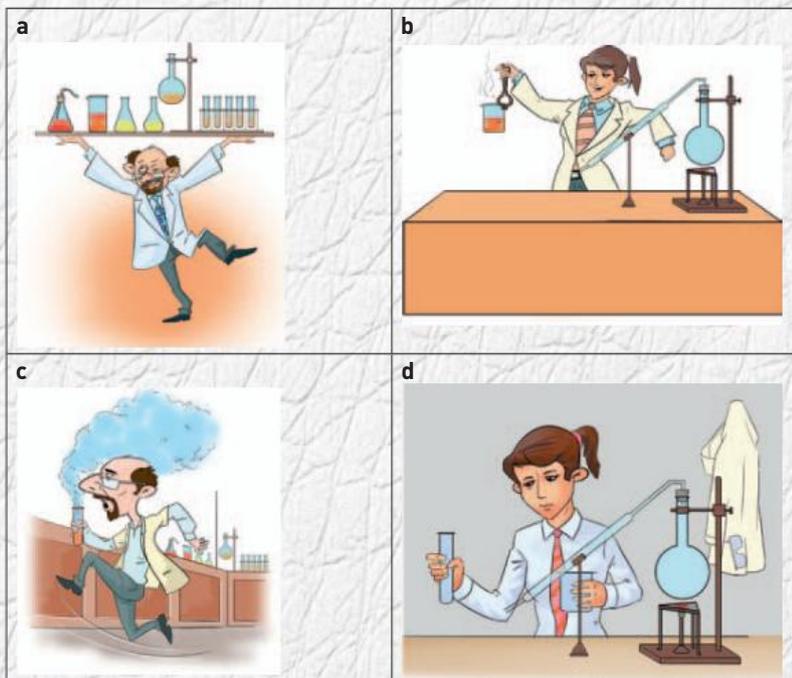
### WORKSPACE

Recognising unsafe behaviour in the laboratory

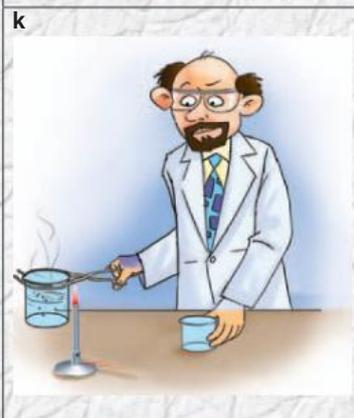
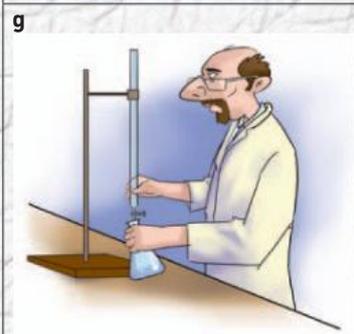
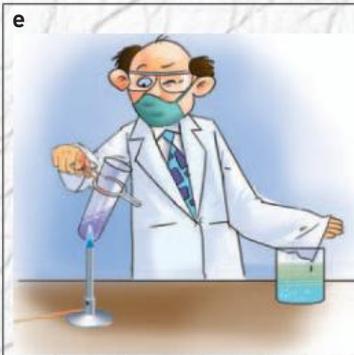
### ACTIVITY 2.1

## Recognising unsafe behaviour in the laboratory

Write sentences for each of the laboratory hazards a – d, describing why the behaviour is dangerous and which safety rule is not being observed correctly.



## ACTIVITY 2.1





**WORKSPACE**

What have you learnt? 2.1

**QUESTIONS 2.1**

**What have you learnt?**

**Remembering**

- 1 **Identify** five reasons why you need to be aware of safety when working in the science room or laboratory.

**Understanding**

- 2 **Describe** the action you would take if:
  - a a chemical is spilt in the science laboratory
  - b you smell leaking gas
  - c you see students running in the laboratory
  - d you are feeling dizzy or having difficulty breathing.

**Applying**

- 3 **Compare** the safety 'rules' you follow in the kitchen to those of the laboratory.
- 4 **Identify** three places in everyday life where you see safety signs.

## 2.2 Laboratory equipment

Scientists use a variety of equipment for different purposes.

### Safety equipment

Safety equipment is available to keep you safe during science classes. Your teacher will let you know when you need to wear safety gear. Figure 2.2 shows some of the safety equipment you will use during science lessons this year. Safety glasses and lab coats protect your eyes and your skin and clothes. Latex gloves protect your hands when using chemicals that may irritate the skin. You will use heat mitts to protect your hands when handling hot objects.

**Figure 2.2** ▼

Safety equipment used in the science laboratory



Shutterstock.com/LeDo

Safety glasses



Alamy/tanistock

Laboratory coat



Shutterstock.com/Ashwin

Heat mitts

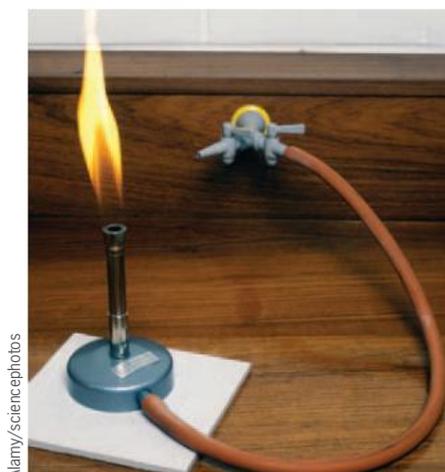
## Heating equipment

At certain times during your science classes, you will need to heat substances. You can use either an electronic hot plate or a gas Bunsen burner (Figure 2.3). An electronic hot plate is used to heat substances without a flame, especially when the substances you are heating are flammable. A Bunsen burner is used to heat substances or equipment.



Alamy/LAMB

Electronic hot plate



Alamy/sciencephotos

Bunsen burner

When using a Bunsen burner, you also need to use a heat-proof mat to protect the laboratory bench, a tripod and a gauze mat (Figure 2.4) to spread the heat evenly over the base of the equipment being heated.

## Measuring equipment

Some equipment is used for measuring. Measuring cylinders are used to accurately measure the volume of liquids. They have a scale on the outside that allows accurate measurement. Electronic balances are used to accurately measure and record the mass of substances. Thermometers measure and record the temperature of substances (Figure 2.5).

Electronic balance

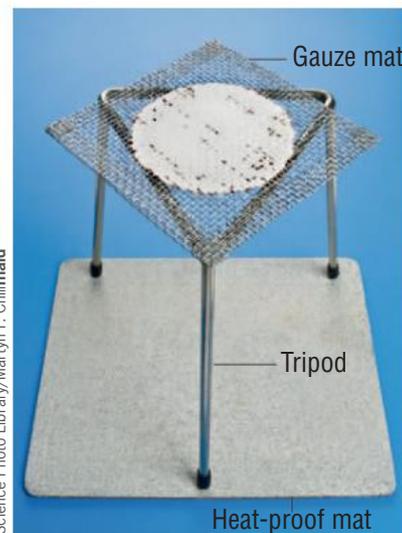


Shutterstock.com/Gtranquility

Thermometer



Shutterstock.com/Bart\_J



Science Photo Library/Martyn F. Chillmaid

▲ **Figure 2.4**

A heat-proof mat, a tripod and gauze mat are used with a Bunsen burner.

◀ **Figure 2.5**

Some common measuring equipment in the science laboratory

## Equipment that holds substances

Different types of vessels are used to hold solids or liquids, depending on what you are doing. Beakers are used to hold or measure out approximate volumes of liquids. We use conical flasks (Figure 2.6) to hold liquids when swirling is required to mix the contents. The narrow neck keeps the liquids from splashing out of the container. Test tubes are used to hold small amounts of substances. Watch glasses are also used to hold small amounts of solids or liquids, often when they need to be weighed. They can also be used when heating liquids. When heating liquids to high temperatures we use evaporating basins. They are made of heat-resistant material so they do not crack when heated. To heat solids to very high temperatures, we use a crucible and lid, held by a pipe clay triangle.

**Figure 2.6** ▶

These pieces of equipment are used for holding solids and liquids.

Beaker



Shutterstock.com/olivier

Conical flask



Shutterstock.com/Constantine Pankin



Shutterstock.com/Africa Studio

Test tubes in a test-tube rack



Alamy/Phototake Inc.

Evaporating basin

Test-tube holders are used to hold test tubes. These are important because sometimes the test tubes are hot. A retort stand with boss-head and clamp (Figure 2.7) is used to secure other pieces of equipment, often during heating.

**Figure 2.7** ▶

Equipment for holding other pieces of equipment

Test-tube holder



Boss-head and clamp



Retort stand

Shutterstock.com/Ian Kalcicak



**WEBLINK**

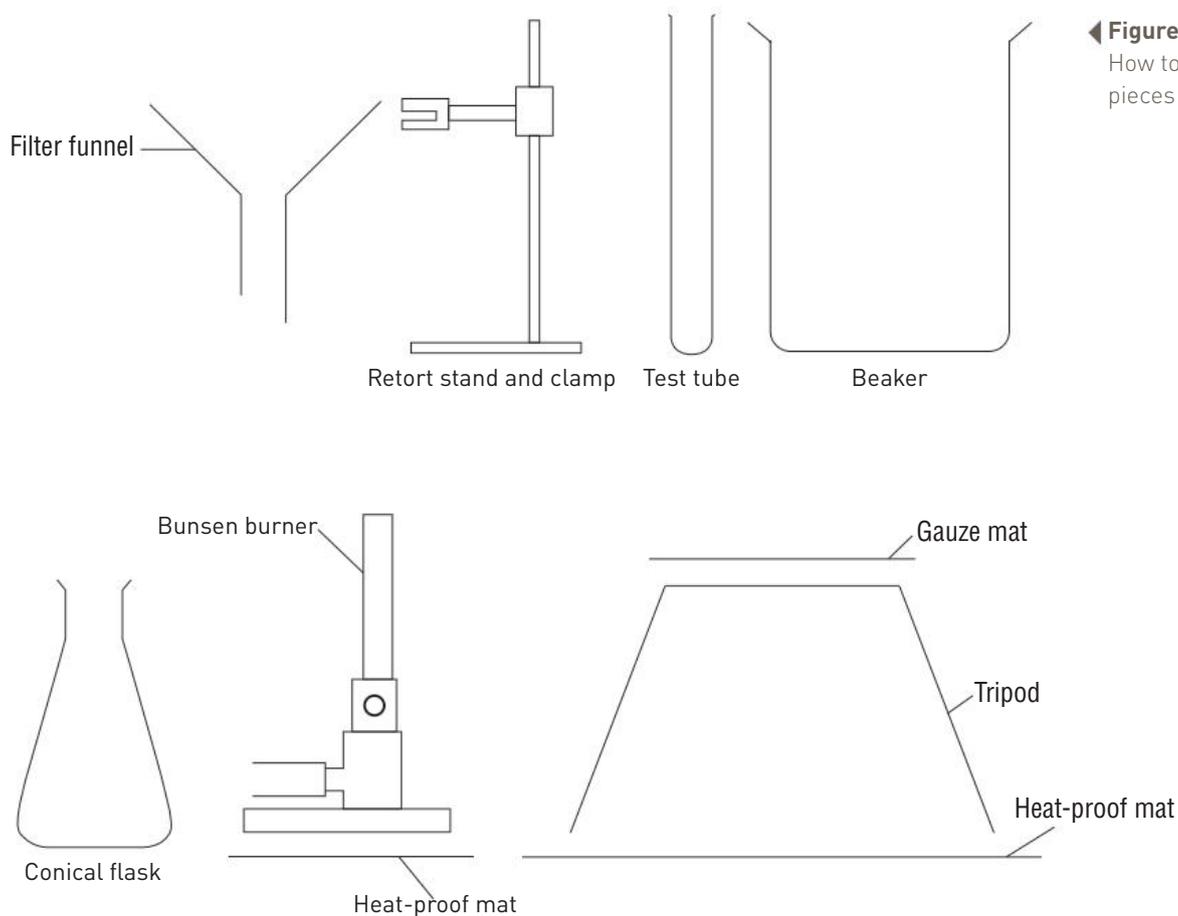
Mix 'n' match: knowing your equipment

## Drawing laboratory equipment

In science, there are certain 'rules' to follow to ensure that you draw good, accurate scientific diagrams.

- 1 Give your drawing a title.
- 2 Use a sharp pencil.
- 3 Draw single lines using a ruler. Do not shade or colour in.
- 4 Draw your diagrams in two dimensions. (Try to imagine you have cut down the middle of the apparatus, and then draw only the outline of what you would see.)
- 5 Make your diagram a good size, about the size of the palm of your hand.
- 6 Use labels to name the piece(s) of equipment. Draw a straight, ruled line from the label to the piece of equipment you are drawing. Make sure the line touches the diagram.
- 7 If a number of pieces of equipment are set up together, draw them as they are set up and in the correct proportions.

Figure 2.8 shows how to draw some common pieces of science equipment.



◀ **Figure 2.8**  
How to draw some common pieces of equipment

ACTIVITY 2.2

## Drawing laboratory equipment

- 1 Use a camera, phone or other recording device to take photos of the pieces of laboratory equipment identified so far in this chapter.
- 2 Use a computer program to draw up a table, with the column headings 'Photo of equipment', 'Function of equipment' and 'Scientific diagram of equipment'.
- 3 Complete columns 1 and 2 and then print the document.
- 4 Hand-draw the equipment according to the rules for drawing scientific diagrams. Your teacher will help you with any pieces you are unfamiliar with.

## The Bunsen burner

Figure 2.9 shows the important parts of the Bunsen burner.

**Figure 2.9** ▶  
The important parts of the  
Bunsen burner



### Lighting a Bunsen burner safely

In the laboratory, Bunsen burners are used to heat things over a flame. The Bunsen burner is connected by a rubber tube to the gas inlet. When the gas is turned on, a match is used to light the Bunsen burner as it burns the gas.

You need to follow a particular order of steps to safely light a Bunsen burner.

- 1 Put on your safety glasses.
- 2 Make sure the gas tap is closed.
- 3 Place the Bunsen burner on a heat-proof mat.
- 4 Connect the rubber tube to the gas inlet.
- 5 Make sure the collar is turned so that the air hole is closed.
- 6 Light a match and bring it close to the top of the barrel.
- 7 With your other hand, turn the gas tap on slowly until you see the orange flame.
- 8 Put out the match and place it on the heat-proof mat.
- 9 Leave the Bunsen burner on the orange flame until you need to use it for heating.



A Bunsen burner has two types of flames – the **safety flame** and the **heating flame**. The safety flame is orange in colour. It is called the safety flame because it is easy to see and is a lower temperature than the heating flame. The safety flame is only used when lighting the Bunsen burner, or when we are in between heating something. The safety flame is like this because the air hole is closed. Therefore, only a small amount of oxygen is present so the gas does not burn completely.

To heat something over the Bunsen burner, you need to use the blue flame. The blue flame is much hotter than the safety flame. By turning the collar, you can open the air hole and allow more oxygen into the barrel. This causes the gas to burn completely, producing a blue, less visible flame. If you look closely, you will see two areas: an inner ‘bluer’ cone, surrounded by a larger, much less visible cone (Figure 2.10). The hottest part of the blue flame is at the tip of the inner cone. Be careful heating equipment such as test tubes when using this flame because it can cause them to crack if they get too hot. This is why you need to constantly move a test tube back and forth through the flame.

### ACTIVITY 2.3

## Getting your Bunsen burner licence

Learn the steps for lighting the Bunsen burner. Practise lighting the Bunsen burner in class while your teacher supervises. Your teacher will call you up individually and observe you lighting the Bunsen burner. Once you have completed this activity safely and confidently, you will have obtained your licence.

### QUESTIONS 2.2

## What have you learnt?

### Remembering

- Identify** two pieces of equipment that you could use to:
  - hold water
  - pick up something.
- Identify** the pieces of equipment you would need to heat up 50 mL of water.

### Understanding

- If the liquid you were heating was flammable, **identify** the piece of equipment you would use to heat it. **Explain** your choice.
- Explain** why a conical flask, beaker and measuring cylinder all have different uses, even though they all have volume scales on them.

### Applying

- Describe** how you would accurately transfer 1.3 g of salt to a watch glass from a saltshaker. **Identify** the scientific equipment you would use and the steps you would follow.

### safety flame

the orange flame of the Bunsen burner

### heating flame

the blue flame of the Bunsen burner

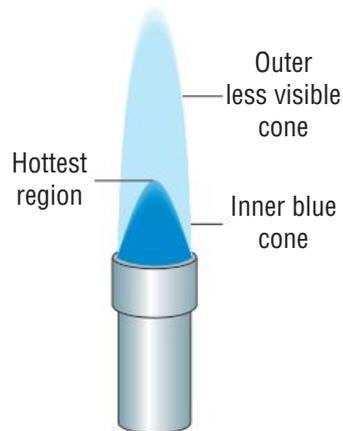


Figure 2.10

The heating flame of the Bunsen burner is blue.

### VIDEO

How to use a Bunsen burner to heat a test tube

### WORKSPACE

What have you learnt? 2.2

QUESTIONS 2.2

6 Create a scientific diagram of the equipment required to heat 100 mL of water.

**Analysing**

7 Science equipment can be grouped according to its use.

- a **Propose** a new way to group 10 pieces of equipment of your choice.
- b Create a table to demonstrate your grouping.

## 2.3 Collecting data

### Observing, inferring and predicting

Working scientifically is a way of thinking and behaving that can happen anywhere. You have probably been working scientifically for years without even knowing it. It involves particular skills such as asking questions, making observations and proposing ideas about what you think is happening.

We use our senses every day to make observations. You may see bubbles in a soft drink when you open the lid, and you may hear the gas escape. If you leave the soft drink for long enough, it may look and taste different because the drink has gone flat. **Observations** are statements of what you can see, hear, smell, feel or taste. Observations are very important in science because they are what we use to try to determine why things happen.

An **inference** is an explanation you make based on your observations. For instance, if you observe a crying baby, you may infer that the baby is hungry or tired or needs a clean nappy.

Often you may try to work out what will happen, before it actually does. This is called a **prediction**. Predictions are an important part of science because they start you thinking more deeply about what might happen and what to look for during an experiment. Some predictions are more accurate than others depending on how well we understand a situation. The less we know about something, the harder it is to predict what will happen. Your prediction may only be a guess. In science, it is important that you do not change your prediction if it is later shown to be incorrect.

**observation**

a statement of what you can see, hear, smell, feel or taste

**inference**

an explanation based on observations

**prediction**

a statement of what might happen



**WORKSPACE**  
Observing, inferring and predicting

EXPERIMENT 2.1

### Observing, inferring and predicting

**Aim**

To observe what happens when vinegar is added to baking soda

Possible risks	Safety precautions
Vinegar is a weak acid and may hurt your eyes if it splashes into them.	Wear safety glasses.
You may cut yourself if glassware breaks.	Place the test tube in a test-tube rack and do not remove it.

## EXPERIMENT 2.1

### Materials

- large test tube in a test-tube rack
- spatula
- baking soda
- vinegar
- plastic dropper

### Method

- 1 Predict what you will observe during and after the experiment.
- 2 Add one level spatula of baking soda to the test tube.
- 3 Using the dropper, add the vinegar drop by drop to the test tube.
- 4 Continue adding vinegar until you see no more changes.

### Results

- 1 **Describe** your observations during and after the experiment.

### Discussion

- 2 **Compare** your actual observations with your prediction. How close were they?
- 3 Try to infer what happened in the experiment.
- 4 **Compare** your observations, predictions and inferences with those of the rest of the class. How were they similar? How were they different?
- 5 **a Describe** how easy or difficult it was to make your (i) observations, (ii) predictions and (iii) inferences.  
**b Explain** why this was the case in each situation.

## Types of information

During science experiments, you will have to collect information, or **data**, of different types, in different ways and using many different pieces of equipment. The type of information you collect depends on the experiment you are doing, how you are doing it, and what you want to find out.

### Qualitative information

**Qualitative data** includes almost any information that is not numerical, such as the colour of a substance, whether a liquid is see-through or cloudy, or if something floats or sinks in water. These examples are based on observation alone, and measuring equipment such as rulers, stopwatches or thermometers are not used. In the activity at the beginning of the chapter, qualitative data included how the plastic wrap felt when you touched it. You cannot put a numerical figure on how something felt.

#### data

information that is gathered from surveys and experiments and used for making calculations or drawing conclusions

#### qualitative data

information that is not numerical, so cannot be measured

When a gas is given off, sometimes you can smell it or you might be able to see it as bubbles in a liquid. An observation such as ‘A slow, steady stream of bubbles was given off’ is more informative than ‘Bubbles were seen’.

The more accurate and detailed you are with your observations, the more you are working and thinking scientifically. So before you begin any activity or experiment, read through the instructions carefully. Remind yourself that you need to look for as many changes as you can. Predict what you think might happen, so you can be ready if these changes occur. And think about the scientific language you will use when writing your observations. It should be written in such a way that another person would understand exactly what you observed, even if they didn’t see it.

## Quantitative information

**Quantitative data** can be counted or measured and expressed as numbers. The time taken for water to boil is an example of data that is counted. This is because we are measuring a quantity such as time. To say that your dog has brown, floppy ears would be qualitative information, but to say he has two ears would be quantitative. To collect quantitative data, we use measuring equipment such as electronic balances, rulers, thermometers and stopwatches. Some measuring equipment used to collect quantitative data is shown in Figure 2.11.

### quantitative data

numerical information that is counted or measured and expressed as numbers

Electronic balance



Shutterstock.com/Gtranquility

Measuring tape



Shutterstock.com/Seregam

Thermometer



Shutterstock.com/Gjermund Alsos

Stopwatch



Shutterstock.com/Hannah Gieghorn

Figure 2.11

Measuring instruments used to gather quantitative data

**record**

write down

Qualitative data describes a quality, whereas quantitative data measures a quantity. Table 2.1 outlines the differences between them. Read through the examples in the table. Complete the activity sheet ‘Differences between data’ to **record** examples of your own.

Table 2.1

The difference between qualitative and quantitative data

Qualitative data	Quantitative data
<p>Think: <b>qualitative = quality</b></p> <p>This data describes what is observed. It does not measure anything. It looks at things like colours, textures, smells, tastes, appearances and perceptions.</p>	<p>Think: <b>quantitative = quantity</b></p> <p>This data deals with numbers and things that can be counted or measured and represented graphically or in charts and tables.</p>
<p><b>Example 1: A café</b></p> <p>The walls are textured, like stone.</p> <p>The cabinets have glass doors and stainless steel counters.</p> <p>There are wooden tables, and chairs with leather seats.</p> <p>There are floral curtains on the windows.</p>	<p><b>Example 1: A café</b></p> <p>The café measures 10 m × 15 m.</p> <p>There are 4 separate glass cabinets, each measuring 2 m × 1 m × 1 m.</p> <p>There are 12 circular tables with a diameter of 75 cm.</p> <p>The front window measures 150 cm × 180 cm.</p>



### ACTIVITY SHEET

Differences between data

Table 2.1 CONT. ▲

Qualitative data	Quantitative data
<b>Example 2: A Year 7 Science class</b> The students are friendly. There is a mixture of boys and girls. The students are noisy and playful.	<b>Example 2: A Year 7 Science class</b> There are 26 students in the class. There are 14 girls and 12 boys. The students are aged 12 or 13.
<b>Example 3: A birthday party</b> There are lots of boys and girls. There is a chocolate birthday cake. There are party pies, sausage rolls and cupcakes. There are balloons, loud music and streamers. There is cordial or water to drink.	<b>Example 3: A birthday party</b> There are 8 boys and 6 girls. There is one birthday cake, with 8 candles. There are 2 dozen sausage rolls, 3 dozen party pies and 24 cupcakes. There are 40 balloons. There are 6 L of red cordial, 2 L of green cordial and 6 L of water.

## Measurement

To get the best results from your experiments, it is important to use the correct equipment. Different equipment is used to measure different quantities in different units. Quantities such as temperature, length, mass and time have units. For example, length (or distance) can be measured in units such as millimetres, centimetres, metres and kilometres. Table 2.2 shows some of these.

Table 2.2 ▲

Units of measurement and common laboratory equipment used to measure them

Quantity	Units and symbols	Laboratory equipment examples
Time	Second (s) Minute (min) Hour (h)	Stopwatch
Temperature	Degrees Celsius (°C)	Thermometer Temperature probe
Length	Millimetre (mm) Centimetre (cm) Metre (m) Kilometre (km)	Ruler
Mass	Gram (g) Kilogram (kg)	Electronic balance
Volume (liquids)	Millilitre (mL) Litre (L)	Measuring cylinder
Volume (regular solids)	Centimetres cubed (cm <sup>3</sup> ) Metres cubed (m <sup>3</sup> )	Ruler (length × breadth × height)

### Using a measuring cylinder

A measuring cylinder measures the volume of liquids more accurately than beakers or conical flasks do. But you can still record the volume incorrectly if you do not read the measuring cylinder correctly. The video 'How to measure a liquid' shows how to measure a liquid accurately using a measuring cylinder.

**VIDEO**  
How to measure a liquid



**meniscus**

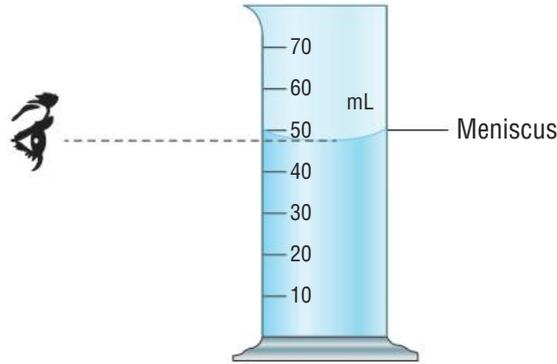
the curved part on the surface of a liquid in a container

**Figure 2.12** ▶

How to read a measuring cylinder – read the volume at eye level so that you are reading from the bottom of the meniscus curve.

The level of a liquid, such as water, is not flat in a measuring cylinder, as shown in Figure 2.12. The water ‘creeps’ up the side of the glass, causing it to look curved.

The curved part on the surface of the liquid is called the **meniscus**. You must read the volume at eye level so that you are reading from the bottom of the meniscus curve to be accurate.



**WORKSPACE**

What have you learnt? 2.3

**QUESTIONS 2.3**

**What have you learnt?**

**Remembering**

- 1 **Define** meniscus.
- 2 **Recall** five examples of measuring equipment.

**Understanding**

- 3 Write a sentence in which you use examples to **contrast** qualitative and quantitative data.

**Applying**

- 4 **Identify** whether the following sets of data are qualitative or quantitative.
  - a 106 more people like chocolate milk than strawberry milk.
  - b Sheryl prefers to buy red shirts than green shirts.
  - c Louise caught the bus to school 26 times and walked 11 times.
  - d Naman likes the smell of chocolate more than the smell of bananas.
  - e Daniel likes using black pens instead of blue pens.
- 5 **Explain** the purpose of gathering data.

**Creating**

- 6 Do all scientists gather the same sort of data? **Discuss**, using examples.

**Reflecting**

- 7 In your opinion, which is more accurate: qualitative or quantitative data? **Explain** your reasoning.

## 2.4 The scientific method

Scientists have devised a consistent approach to conducting a scientific investigation. This is called the scientific method, and is a set of steps that enables scientists to plan and conduct experiments in a consistent and repeatable way.

There are several basic steps of the scientific method.

- Ask a question.
- Formulate a hypothesis.
- Plan and carry out the investigation.
- Collect and analyse the data.
- Draw conclusions and evaluate the investigation.

### Ask a question

Using observations of the world around you, formulate a question. The question could begin with what, why, how, which, who or where. Examples are:

- What happens when salt is added to water?
- Which glue is the best for sticking wood to cardboard?
- Why can't my pen write on greasy paper?

### Formulate a hypothesis

After you pose a question, you make an educated guess (a prediction) about what you think might happen. This is called a **hypothesis**. A hypothesis needs to be able to be tested in a scientific way. The hypothesis is written as a statement, often using 'if . . . then . . .'.

'If salt is added to water, then the water will boil at a higher temperature.' can also be written as 'The more salt is added, the higher temperature at which the water boils'.

It is not possible to 'prove' a hypothesis. The results of an experiment will either support or **refute** a hypothesis. Either way, a hypothesis is just a statement explaining what you think might happen. It does not matter if it is incorrect, only that it is relevant to your aim (purpose) and written correctly.

#### hypothesis

an educated guess or prediction that can be tested in a scientific way, usually written in the form: 'if . . . then . . .'

#### refute

to show to be false; to disprove

### Plan and carry out the investigation

Imagine you want to work out whether water evaporates more quickly from a glass, plastic or metal cup. You are investigating how the type of material affects the evaporation of the water. So you set up an experiment. All of the containers are of a different size. You pour different amounts of water into each container and place one in the fridge, one in the sun and one on a table inside. After an hour you check the glass. After a day you check the plastic cup. After a week you check the metal cup. You find that there is no water left in the metal cup so you decide that water evaporates faster from metal than plastic or glass. But can you really say this?

First, you didn't measure the same amount of water. Second, the cups were all different sizes. Third, they were placed in different spots at different temperatures, and, finally, they were checked after different amounts of time. How do you know that the results you gathered were only due to the type of cup you used? The fact is, you don't.

Any scientific investigation must be a **fair test**. To create a fair test, you need to understand variables. A **variable** is any factor that can change, or vary. Usually in an

#### fair test

a scientific investigation in which there is an independent variable and one or more dependent variables; all other variables are held constant (controlled)

#### variable

a factor that could influence the result of an investigation

investigation or experiment, several variables can affect the results. For example, in the investigation of water evaporation the variables were size and type of container, volume of water, temperature and time.

It is important to carefully plan an experiment. In order for an experiment to be a fair test, only one variable can be changed. All other variables must be kept the same (held constant). You must set up your investigation so that you are testing what you think you are testing, and so that it is clear that nothing else is influencing the results.

When testing how water evaporates from different types of containers, you need to measure the level of water in each cup over time.

- The **independent variable** is the variable you deliberately change in your experiment. In our example, the independent variable is the type of material the cup is made of – glass, plastic and metal.
- The **dependent variable** is the variable that you measure or observe. It is affected by the change you made to the independent variable. In our example, the dependent variable is the amount of water that evaporates (measured by the decrease in water level in each cup).
- **Variables held constant** (or 'controlled variables') are all of the other variables that need to stay the same throughout the experiment. The variables that could affect the results in our example include the size of the container, the amount of water added, the starting temperature of the water, where the cups are placed, and the time they are left for. You would need to keep all these variables exactly the same.

Sometimes in an experiment we need to have a **control**. This is an identical set-up to the rest of the experiment, but does not include the variable being tested (the independent variable). This can give a baseline to compare the other data against. In our example, there is no control as it is impossible to have a set-up of water that does not have a container holding it.

An experiment is called a **valid experiment** if it is designed in a way that allows you to collect results that are suitable to answer the aim. To ensure that an experiment is valid you should:

- use the most appropriate available equipment to make your measurements
- make sure all variables are held constant (except the one you are testing)
- conduct the experiment across a range of measurements (if possible)
- have a control (if possible).

Repeat the experiment to check the **reliability** of your investigation. If you get similar or identical results, you can be fairly sure this was not due to luck or accident. If the results are the same, it is a reliable investigation. If you keep getting different results, the investigation isn't reliable. This means there must be some part of the experiment that is not controlled properly.

Repeatability is an important part of the scientific method. If a scientific finding is to be taken seriously, other scientists must be able to follow the same method and achieve the same results.

## Collect and analyse the data

Before you start an experiment, you need to think about the data you will collect. In our example, you will be recording how much water has evaporated from each container. How will you measure the height of the water? Will you use a pen mark on the side of the container? Will you use a small ruler placed into each cup? How often will you check on the containers? Every day or every hour? Will you repeat the experiment? How will you record or display this data? Will you write it down, video it, or both?

When you have collected all the data, what are you going to do with it? How are you going to analyse it or work out what it is telling you? How are you going to determine if your data is accurate?

### independent variable

the factor that you choose to vary in your investigation

### variable held constant

a factor that needs to be kept the same throughout a scientific investigation so that it does not influence the results

### dependent variable

the factor that changes as a result of changes in the independent variable; the factor that is measured or counted

### control

a scientific set-up that does not include the independent variable to be tested; used to provide baseline data

### valid experiment

when the results collected allow you to achieve the aim



### INTERACTIVE

Fair test – growing lettuce

### reliability

when the results collected in an experiment are very similar or the same after a number of repeat trials

## Draw conclusions and evaluate the investigation

Once you have worked out what your data is telling you, you need to look back at your aim. Does the data support or refute the hypothesis? Have you achieved your aim?

You also need to review your experimental method. Did you encounter any problems, limitations or faults that would need fixing if you were to carry out this investigation again?

### EXPERIMENT 2.2

## Fair testing – which paper towel?

### Your challenge

Working in a group of two or three, plan and carry out a fair test to find out which paper towel is the most absorbent. Make sure that you test at least three different types of paper towels.

### This might help

Reread the section on the scientific method (pages 34–6).

- **Identify** your question.
- What is your hypothesis?
- **Identify** the equipment you will need.
- **Describe** any risks involved with this experiment. **Identify** how you will manage (control) these risks to stay safe.
- **Identify** your independent and dependent variables.
- **Identify** the variables that need to be held constant in order for this to be a fair test.
- **Describe** how you will collect your results and what measuring equipment you will use.
- **Describe** how you could best display and analyse your results.

### QUESTIONS 2.4

## What have you learnt?

### Understanding

- 1 Consider the steps involved in the scientific method. Do you think this is a logical way to conduct scientific research? **Explain** your answer.
- 2 **Explain** what might happen if you left out one of the steps of the scientific method.
- 3 Would it matter if you changed the order of the steps of the scientific method? **Explain** any possible consequences.

### WORKSPACE

Fair testing – which paper towel?



### ACTIVITY SHEET

Investigating temperature



### WEB 2.0

Using online software, such as Gliffy or Draw Anywhere, create your own flowchart to show that you understand the steps of the scientific method. Upload your creation to the class wiki.

### WORKSPACE

What have you learnt? 2.4



### QUESTIONS 2.4

4 **Describe** the difference between a variable held constant and a control.

#### Applying

5 **Consider** an experiment to test whether the size of an ice block affects the time it takes to melt. For this experiment, **identify** the:

- a hypothesis
- b independent variable
- c dependent variable
- d variables held constant.

#### Reflecting

6 Do you think some steps of the scientific method are more important than others? If so, which steps, and why?

## 2.5 Analysing and presenting data

### raw data

all the data that is collected during an investigation

### mean

average; the sum of all of the values divided by the number of values

Suppose that you have carried out an investigation and have collected your data. What will you do with the data? You will need to analyse and present it so that other people will understand it.

### Finding an average

For some investigations, you will collect a large amount of quantitative data. It may not be appropriate to display all this **raw data**. In many cases, you will want to find an average value, or **mean**. To find the mean:

- add all the data for one variable together to obtain a total
- divide the total by the number of pieces of data.

For example, you may want to find out the average height of a group of students: Alex 163 cm, Brianna 158 cm, Cam 172 cm, Daniel 180 cm, Dora 163 cm, Ellie 150 cm, Huang 168 cm, John 175 cm and Milly 155 cm.

Adding all the data gives:

$$163 + 158 + 172 + 180 + 163 + 150 + 168 + 175 + 155 = 1484$$

Dividing by the number of pieces of data gives:

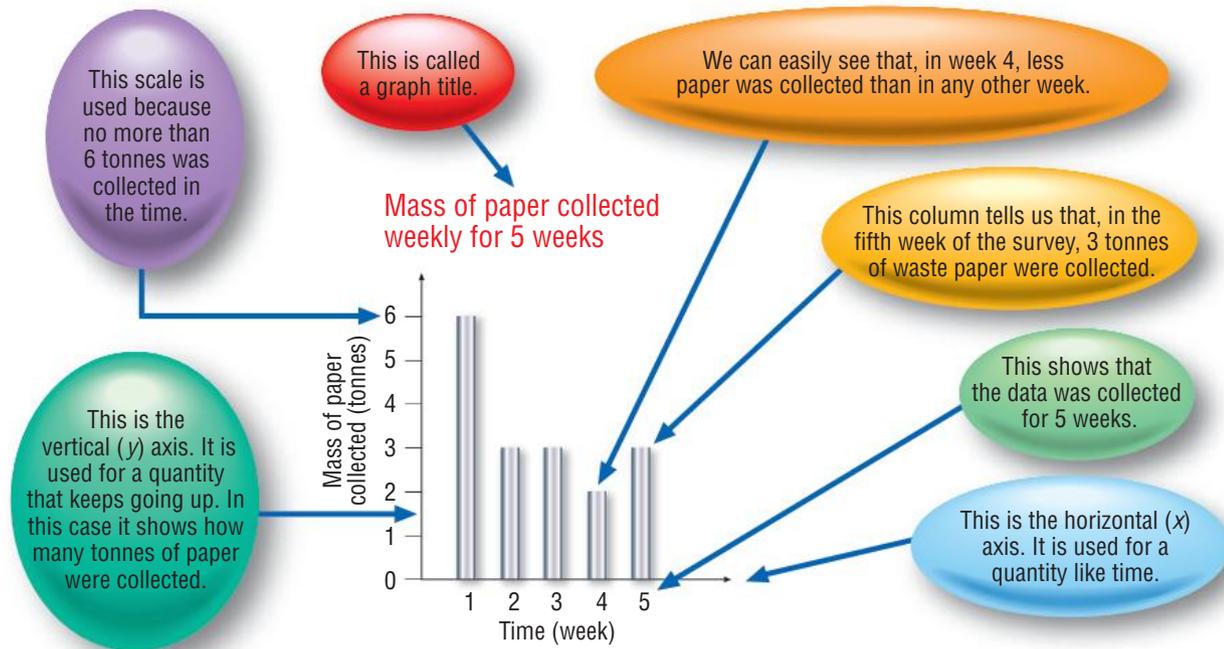
$$\begin{aligned} \text{Average height} &= \frac{\text{total of heights}}{\text{number of students}} \\ &= \frac{1484}{9} \\ &= 165 \end{aligned}$$

The average height of the students is 165 cm.

## Generating graphs

Tables and graphs are often used to organise and present data. Graphs can visually represent the data in a form that is more quickly understood than a large table. A graph often makes it easier to see patterns or trends in the data.

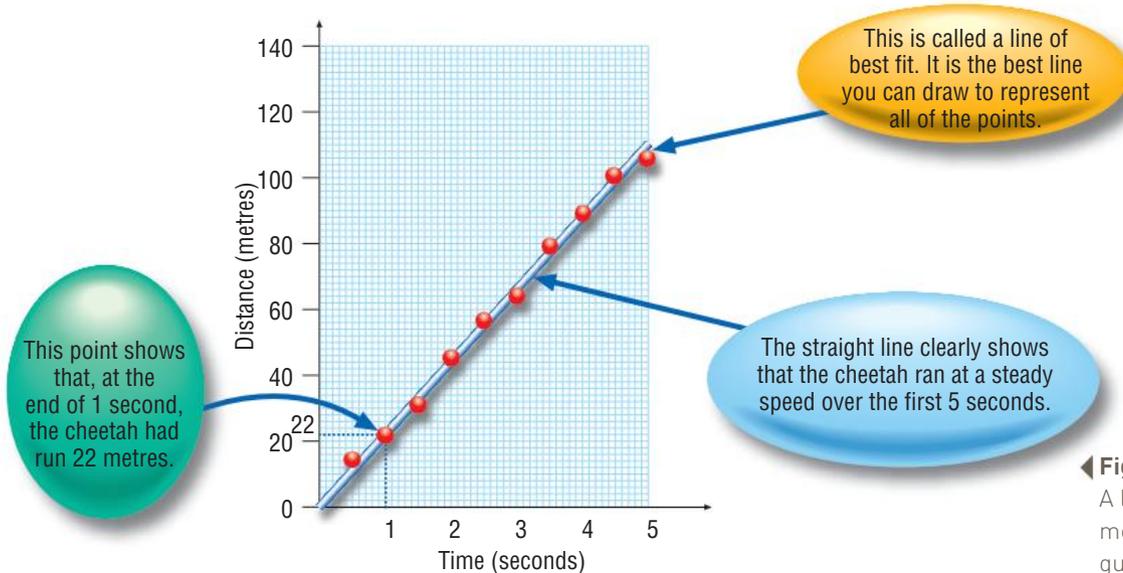
You can draw graphs by hand or on graph paper by using software such as Excel. Two of the most common types of graphs in science are the column graph (Figure 2.13) and line graph (Figure 2.14). A column graph is used for measurements that are not related to one another. A line graph is useful for measuring changes in a quantity over time.



**Figure 2.13**

A column graph is used for measurements that are not related to one another.

### Distance run by a cheetah chasing its prey over 5 seconds



**Figure 2.14**

A line graph is useful for measuring changes in a quantity over time.

Mass of carbon dioxide gas produced from powdered seashells and hot vinegar over 75 seconds

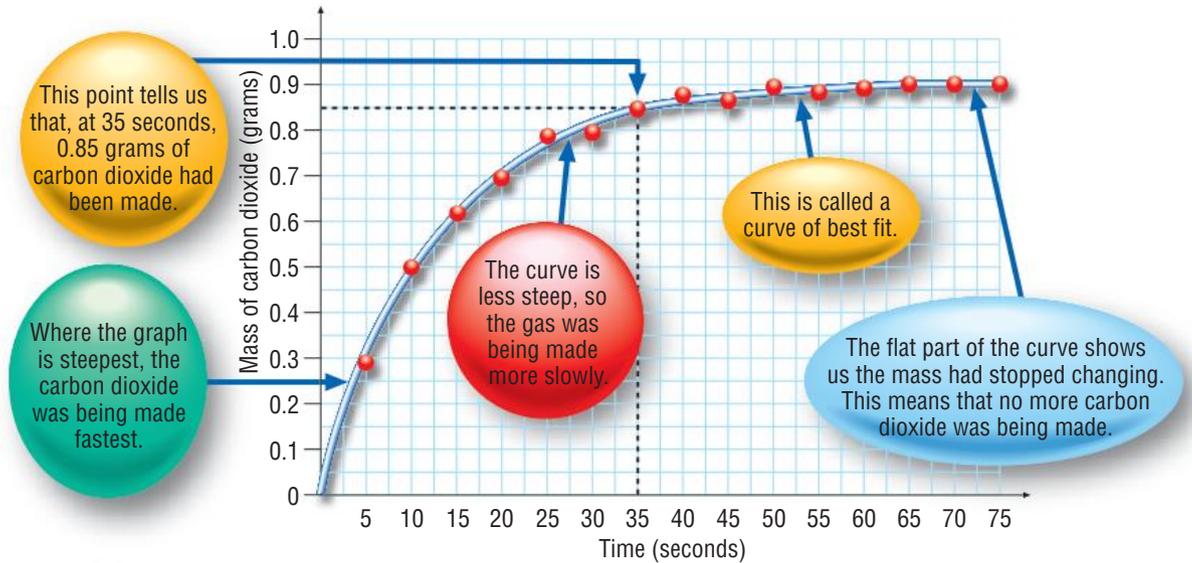


Figure 2.15

Interpreting a curved line graph

Sometimes an axis would be too long to fit on the page if it showed all possible values, starting at zero. Instead, a broken scale can be used. Look at the graphs in Figure 2.16; they show the same data but use different scales.

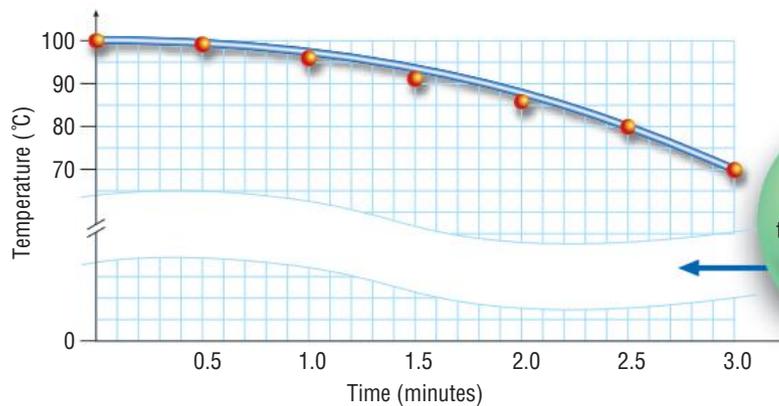
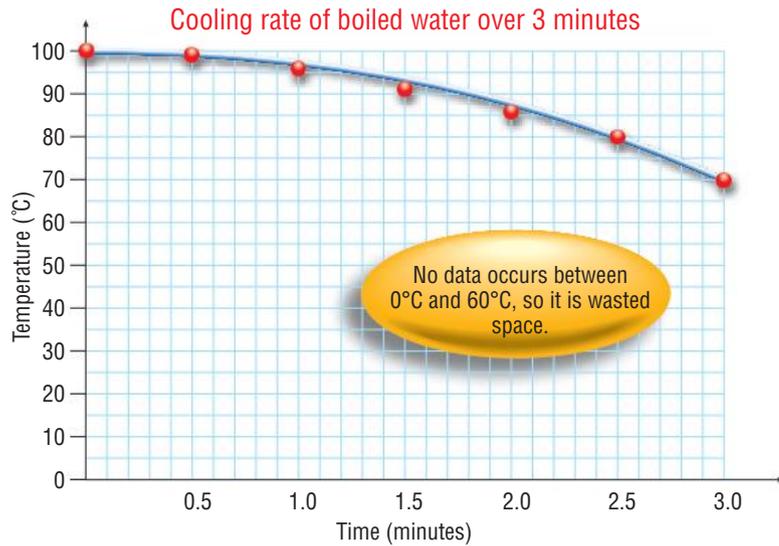


Figure 2.16

Graphs of the same data using an unbroken scale (top) and a broken scale (bottom)

Sometimes a space will also be used to indicate that the vertical scale has been broken.

## ACTIVITY 2.4

## Using a spreadsheet to create a graph

- 1 The following data shows the cooling of boiled water over  $2\frac{1}{2}$  minutes. Identify the type of graph that would be appropriate for this data. Explain your choice.

Time (min)	Temperature (°C)
0.0	100
0.5	99
1.0	97
1.5	93
2.0	87
2.5	80

- 2 Enter the data into an Excel spreadsheet.
- 3 Highlight the data and insert a chart. Select 'Line' and click on an option that shows the points, as well as the lines. Is this a suitable type of graph for this data? **Explain** your answer.
- 4 Create a new graph using 'XY (Scatter)'. Is this a suitable type of graph for this data? **Explain** your answer.
- 5 **Describe** what you have discovered about using Excel to create a line graph

## WORKSPACE

Using a spreadsheet to create a graph



## Checking your data analysis

You can use the following checklist to help decide whether you have meaningful results that can be used to support or refute your hypothesis.

- Is your data accurate?
- Would repeating the investigation produce the same or similar results?
- Is there enough data to support or refute your hypothesis?
- Have you summarised your data with an average, if appropriate?
- Have you checked that all your calculations are correct?
- Have you used the most appropriate type of graph for your data?
- Does your graph have a meaningful title?
- Is the independent variable shown on the x-axis?
- Is the dependent variable shown on the y-axis?
- Are appropriate values and units of measurement marked along the axes?
- Did you use an appropriate scale for each axis?

## WEBLINK

Graph analysis checklist



## ACTIVITY SHEET

Graphing checklist





**WORKSPACE**

What have you learnt? 2.5

**QUESTIONS 2.5**

**What have you learnt?**

**Understanding**

- 1 Choose two different types of graphs and **outline** when they are used.
- 2 **Describe** what a broken scale on a graph indicates.
- 3 **Identify** the variables shown on the:
  - a vertical axis of a graph
  - b horizontal axis of a graph.

**Applying**

- 4 Look back at the data for the students' heights on page 38. Two students were absent on the day the measurements were taken. Steven's height is 167 cm and Anand's height is 161 cm. Include this extra data and recalculate the average for the group.

**Analysing**

- 5 An activity in your science class required you to measure the temperature in your science classroom over a 4-hour period. Your results are shown in the table.

Time (min)	Temperature (°C)
0	14
30	16
60	19
90	21
120	21
180	23
240	17

- a Show this data as a graph.
- b Use your graph to **determine** the lowest temperature during the 4-hour period.
- c Use your graph to **determine** the highest temperature during the 4-hour period.
- d From your graph, **determine** the temperature of the room at 45 minutes.

**Evaluating**

- 6 Use your answer to Question 5 to **explain** whether your choice of graph was the most suitable way to display the data.

## 2.6 Writing a scientific report

A scientific report is a systematic way of displaying what you have done and what you have found. It should always follow the order of title, aim, hypothesis, materials, method, results, discussion and conclusion. It should also be written so that another person could understand exactly what you were trying to test, what you did, and what you found out.

### Title

The title of your report should reflect what your investigation is about.

### Aim

The aim states the purpose of your investigation. It is expressed in general terms and often begins: 'To investigate . . .' or 'To determine . . .'

### Hypothesis

The hypothesis is more specific than the aim. It is a prediction of what you think might happen. It is a statement that might or might not be true, and is often written in the form: 'If . . . then . . .' Your investigation will test the hypothesis by collecting data to support or refute it.

### Materials

This is a list of the equipment and materials you will need to carry out your investigation. It should include numbers and/or quantities such as 'three 250 mL beakers' or '2.5 grams of salt'.

### Method

The method is a set of step-by-step numbered instructions that show exactly what you will do to carry out your investigation. Remember that other people should be able to repeat your investigation using these instructions.

### Results

The results section is extremely important. Results show what you have found in your investigation. The results section can include tables that you have created to display your data or information. The results section can also include graphs and any calculations you have made when analysing your data. Remember that, when drawing a graph, it must have a title and be labelled appropriately, and the independent variable should be on the x-axis. If your graph includes numerical data, you should use an appropriate scale.

In the results section, you make clear statements about trends and observations, but never make conclusions about what you think has happened. You may say, 'The temperature doubled every minute', but do not analyse why this happened.

## Discussion

This is where your results are summarised, described and analysed. However, the discussion relates only to the results that you obtained in the investigation. Do not discuss what should have happened or what you would have liked to happen. You should also discuss the significance of your findings and how they may be applied to real life. Any problems encountered during the investigation are discussed here, as well as possible ways to improve the experiment.

## Conclusion

The conclusion is a clear statement of what your investigation found. A conclusion is usually a statement that answers your aim. Never restate your results in your conclusion.

## Extra information in a scientific report

A risk assessment or safety audit is often also done in an experiment. This is where you identify any possible safety risks, and assess how you are going to manage them. Although it is not a general heading in a scientific report, it is often useful to write it (and place it) after you have written your method. Throughout the *iScience for NSW* series, however, the safety box has been placed first to alert teachers and students.

## Example of a scientific report

### The effect of light on the growth of parsley

#### Aim

To investigate if light affects the growth of parsley over 2 weeks

#### Hypothesis

If a parsley plant is exposed to light, then it will grow more than it would have grown without being exposed to light.

#### Materials

- 6 parsley seedlings
- 6 small rectangular pots, each measuring 4 cm × 4 cm × 6 cm
- potting mix
- 100 mL measuring cylinder
- water
- 30 cm ruler
- lamp

## Method

Possible risks	Safety precautions
Potting mix contains fungal spores and bacteria that could be harmful to health.	Use potting mix in a well-ventilated area and wear gardening gloves.

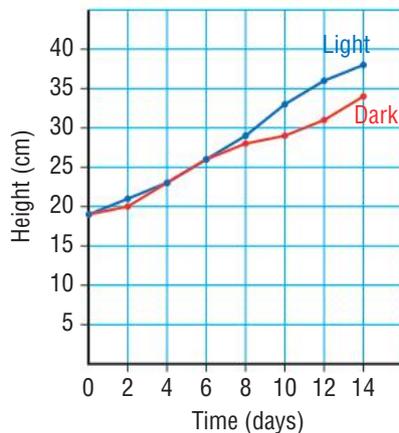
- 1 Fill each pot with the same type and amount of potting mix.
- 2 Select six parsley seedlings of the same height, the same species and the same level of health, from the same nursery.
- 3 Plant one parsley seedling into each pot.
- 4 Measure the initial height of each seedling and record it to the nearest centimetre. (These are the heights on day 0.)
- 5 Label three pots with the letter L to show which seedlings would receive light. Place these under the turned-on lamp.
- 6 Label three pots with the letter N to show which seedlings would receive no light. Place these into a dark cupboard.
- 7 Water all plants with 20 mL of water each day.
- 8 Measure and record the height (in centimetres) of the seedlings every second day for 2 weeks.
- 9 Run the experiment for 2 weeks.

## Results

The table shows the average height of parsley plants, with and without light over 14 days.

Time (days)	Average height of parsley plants (cm)	
	Light	Dark
0	19	19
2	21	20
4	23	23
6	26	26
8	29	28
10	33	29
12	36	31
14	38	34

Height of parsley seedlings grown in the light and dark



◀ The plants in the dark grew  $34 - 19 = 15$  cm.

The plants in the light grew  $38 - 19 = 19$  cm (that is, 4 cm more than the plants in the dark).

### Discussion

Six parsley seedlings were grown under identical conditions, except that three were grown under a lamp and three were grown in a dark cupboard. Results showed that the parsley plants that grew in the light grew 4 cm taller than the ones that grew in the dark. This suggests that light is not required for plants to grow but, if there is light, plants can grow more. This supports the hypothesis. At weekends, neither group of plants received any water. As this affected all plants equally, the final results would not have been affected. Any future investigations of this type should include more plants under each condition. This would provide more data and also improve the reliability of the experiment. It would also prevent problems arising if any of the plants died during the experiment.

### Conclusion

Parsley plants grown in the light grow more than parsley plants grown in the dark over the same amount of time.



### WORKSPACE

What have you learnt? 2.6

### QUESTIONS 2.6

## What have you learnt?

### Understanding

- 1 **Explain** why it is important that scientific experiments are repeatable.
- 2 **Outline** the important elements of a scientific report.
- 3 In the parsley plant investigation on pages 45–6, **identify** the control. **Explain** the purpose of a control.

### Applying

- 4 Suppose that you repeated the experiment about parsley plants, but this time you also used a different type of potting mix for each plant. **Predict** the effect this would have on the results of the investigation.
- 5 **a Explain** what the effect on the results would be if one of the parsley plants had died during the investigation on pages 45–6.  
**b Propose** how you could modify the design to overcome this problem.

### Evaluating

- 6 Can you say conclusively that all parsley plants will grow more if grown in the light? **Explain** your answer.

## 2.7 What makes a good scientist?

### Honesty and ethics

Scientists should always be honest in their reporting. For example, they must not leave out some of their data if it doesn't show what they were hoping to find. They must explain the methods they used so that other scientists can understand their results, and try the experiment themselves.

Scientists need to be very careful about acknowledging the contributions and help of other people. Whenever scientists make use of another person's work, reports or findings, they must acknowledge the sources they used.



#### How sweet it is!

In 1879, Russian-born chemist Constantin Fahlberg was experimenting with different uses for coal tar in the laboratory at Johns Hopkins University, Maryland, USA. One evening he left the laboratory to go home, but failed to wash his hands. While eating a bread roll for dinner, he noticed that it tasted sweet. Fahlberg and the head of the laboratory, Ira Remsen, published several articles about this sweet substance. Later, Fahlberg named it saccharin, and he grew wealthy when it became widely used as a sweetener. However, Remsen was angry that he didn't get any credit for a discovery that had been made in his laboratory.

Corbis/Michael A. Keller



### Teamwork

Not many scientists work alone; most work in teams. This is often because many scientists specialise in a particular field. To work well as a team, scientists need a range of skills. Most of your classwork in science will involve working collaboratively in groups or teams. You might like to complete the activity sheet 'Working in a team' to help you identify what makes a good team. You could carry out the experiment about temperature changes to see how well you work in a team.

Consider the following hints for teamwork.

- Listen respectfully to all team members' ideas and opinions. Use the Habit of Mind 'listening with empathy and understanding'. This means that you make a conscious effort to understand other people's thoughts, ideas, points of view and emotions.
- Be prepared to compromise if your team cannot agree on some point.
- Plan your team's work so that each member of the team has a fair share of responsibility. Refer to the Habits of Mind to identify the strengths of individual team members, and allocate tasks accordingly. It is often a good idea to appoint a team leader who oversees the team's progress, and someone who reports back to the teacher or class.
- Draw up a chart to record what was done and by whom. You could also include a plan on how to progress if someone in the team is unable to complete a task.

**ACTIVITY SHEET**  
Working in a team



**ACTIVITY SHEET**  
Team experiment –  
temperature changes



#### WEB 2.0

Use Google Docs to draw up a chart for everyone to contribute to. This will be a good way to monitor progress.



**WORKSPACE**  
Chapter 2 review



**ACTIVITY SHEET**  
Chapter 2 checklist



**REVIEW QUIZ**  
Chapter 2

## Chapter review

### Remembering

- 1 **Recall** the headings that should be used in a scientific report, in order.
- 2 **Define** the term 'mean' and **describe** how to calculate it.
- 3 **Recall** five examples of laboratory equipment and state their use.
- 4 **Recall** four safety rules for the laboratory.

### Understanding

- 5 **Describe** the difference between qualitative and quantitative data. Give an example of each.
- 6 **Explain** why it is important to gather data in a science investigation.
- 7 When designing an investigation, **describe** the factors you must consider to make it a fair test.

### Applying

- 8 List three questions you would ask a research scientist about preparing for an investigation, recording data and reporting the results.
- 9 Write a hypothesis for each of the following questions.
  - a Why do my black clothes get hotter than my white clothes in summer?
  - b What would make my model car go faster?
  - c Will plants grow more if I give them more water?

### Analysing

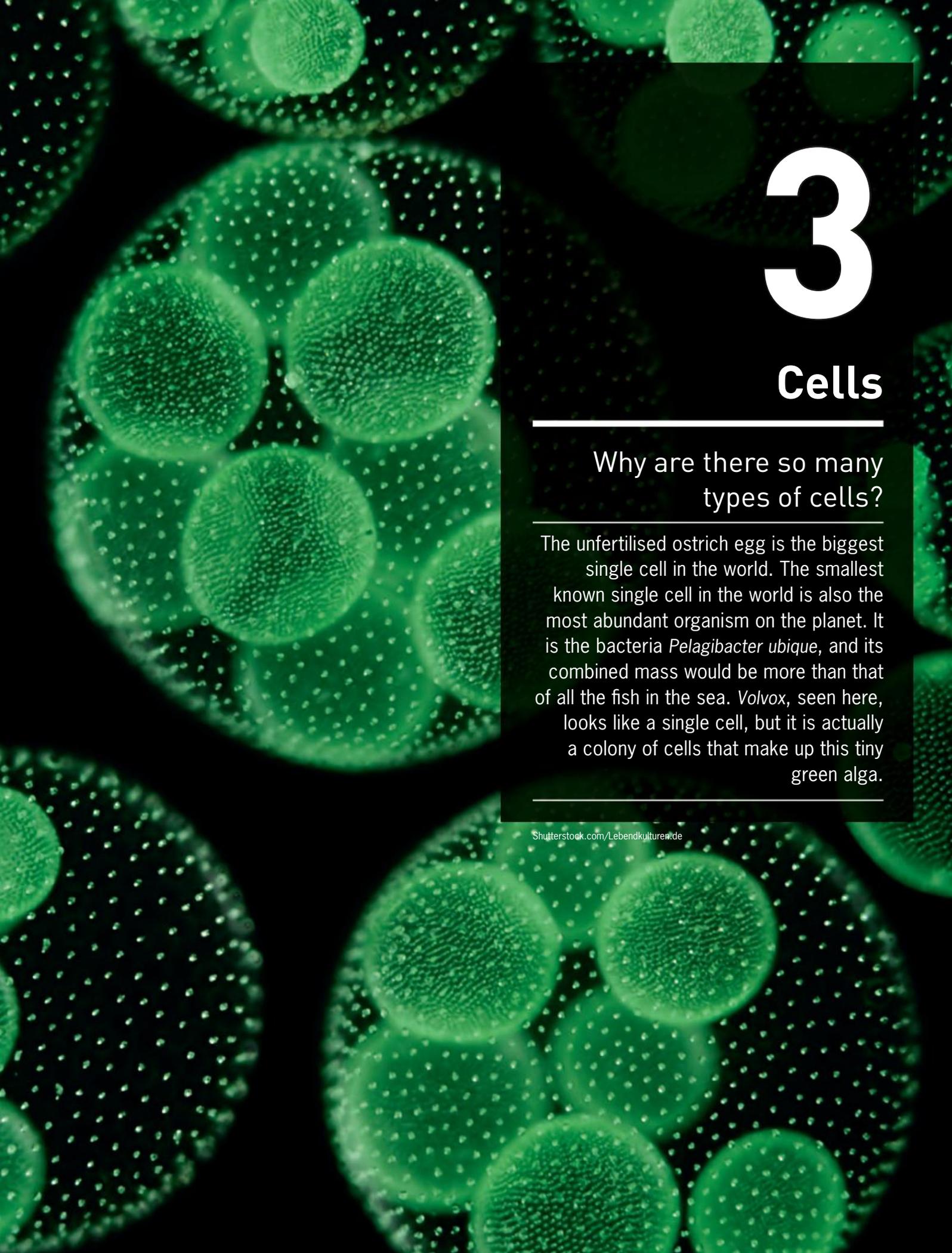
- 10 Olivia and Ethan decided to test whether red flowers lasted longer than white flowers. They put a red rose in a small cup of water on the bathroom shelf, and a white carnation in a large jar of water on the bench in the garden shed. After three days the white flower had died, but the red flower was still alive. They concluded that red flowers lasted longer than white flowers.
  - a **Explain** why this was not a fair test.
  - b Was Olivia and Ethan's conclusion valid?
  - c Rewrite their method to make this a fair test.

### Evaluating

- 11 In your opinion, what might happen if every scientist were to report their scientific discoveries in a different way?

### Reflecting

- 12 Do you think it is important to write school science reports in a consistent way? Give reasons for your answer.



# 3

## Cells

---

Why are there so many types of cells?

---

The unfertilised ostrich egg is the biggest single cell in the world. The smallest known single cell in the world is also the most abundant organism on the planet. It is the bacteria *Pelagibacter ubique*, and its combined mass would be more than that of all the fish in the sea. *Volvox*, seen here, looks like a single cell, but it is actually a colony of cells that make up this tiny green alga.

---

## Living world – Stage 4

### Key knowledge

- Living things are made up of cells.
- The structure of cells is specialised to allow them to perform their function.
- Cells may contain organelles, including a cell wall, cell membrane, cytoplasm, nucleus and chloroplast.
- Respiration is the break down to food to provide energy for use in cells.
- Cells divide to form new cells.
- Unicellular organisms are single-celled and multicellular organisms are organisms with more than one cell.
- There are different types of micro-organisms, such as bacteria and protists.
- Micro-organisms can be helpful or harmful to living systems.
- The creation of antibiotics to treat bacteria/infections has been a result of scientific discovery.



#### ACTIVITY SHEET

CAT with rubric: Model of a cell

### CULMINATING ASSESSMENT TASK

#### Model of a cell

In this task you will construct a 3D model of a cell or a unicellular organism. Your model must be no bigger than a loaf of bread and no smaller than a mobile phone and not hand-drawn. For instance, you may use dried foods, beads, yarn, felt or other materials to create your model. Research a cell or unicellular organism, or model a red blood cell, macrophage, neuron, adipose cell, plant cell or paramecium.

Your model must include a label with your name, type of cell, size of cell, where it is found and description of how three of its structures relate to their function.

## What do you already know about cells?

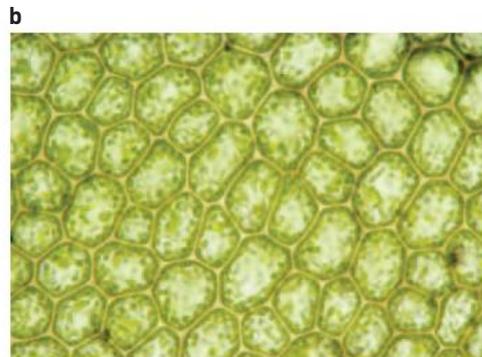
- 1 In your class, brainstorm your combined knowledge about cells.
- 2 Split the class into five groups. Each person in the group will develop their own questions about cells. The questions can start with 'What', 'Where', 'How', 'Which', 'Who' or 'When'. The group will then answer other group members' questions from their existing knowledge.
- 3 When each group has developed their questions and answered them, identify any questions you had difficulty answering. Discuss them with the rest of the class.

## 3.1 What are cells?

A **cell** is the basic building block of all living things. Living things can be made up of either one cell (**unicellular**) or many cells (**multicellular**). Scientists have estimated that there are about  $10^{14}$ , or 100 trillion, cells in the human body.



Getty Images/MedicalRF.com



Science Photo Library/John Durham

### cell

the basic structural unit of all living things

### unicellular

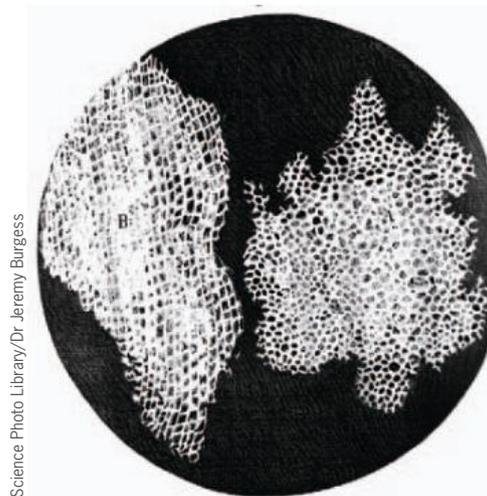
consisting of a single cell

### multicellular

consisting of many cells

◀ **Figure 3.1**  
**a** Unicellular bacteria,  
**b** leaf cells from a  
 multicellular plant

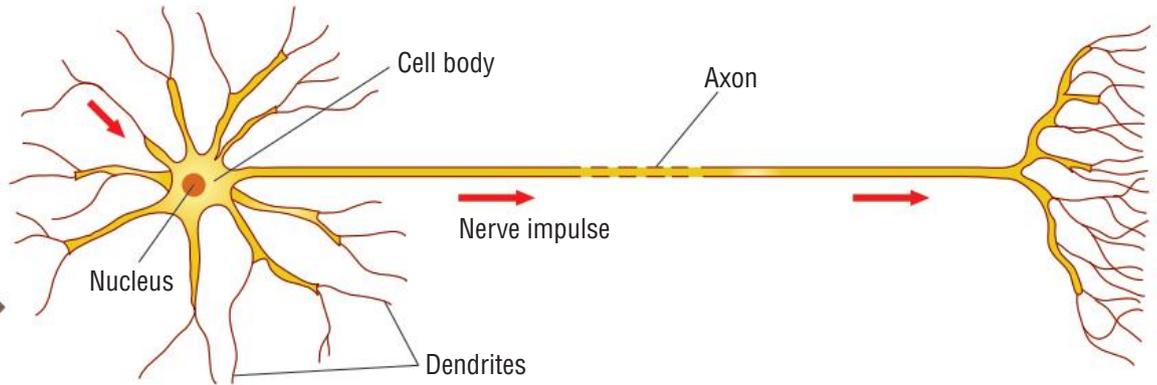
The word 'cell' might conjure up the image of a room in a prison, but it actually comes from the name of the small cubicles where monks prayed in the Middle Ages. The name reflects the function of a cell – an individual, repeating unit, which is part of a bigger structure or system. In 1665, Robert Hooke first observed the cellular structure of cork by looking down a simple microscope (see Figure 3.2).



Science Photo Library/Dr. Jeremy Burgess

◀ **Figure 3.2**  
 Cork cells as Robert Hooke  
 saw them in 1665 under a  
 simple microscope.

## Cell structure and function



**Figure 3.3** ▶  
A neuron with cell body and axon

Although you can't see them, cells are in every single living thing. They are uniquely adapted for their function. Their structure suits their purpose in life. An example of this is a human nerve cell or neuron (Figure 3.3), which has a very long axon, or projection from the cell body, along which messages are transmitted. The cell would be too small to see, but the axon of this cell could be over a metre long, if it carried messages from your spine to your big toe.

A human sperm cell is also very suited to the function that it must perform. Its sole purpose is to transport genetic information (**DNA**) from the male parent to the DNA of the female parent in the egg or ovum. To do this, sperm have a 'head' containing the genetic information and a tail to help them swim. Sperm also contain special **organelles** to provide them with energy. You can see human sperm in Figure 3.4.



Science Photo Library/Eye of Science

**Figure 3.4**  
Human sperm cells

### DNA

deoxyribonucleic acid, the genetic material found inside cells

### organelle

a specialised part of a cell that has a specific function

### cell theory

the basic theory in modern cell biology – cells are the basic units of all living things

## Cell theory

Since Hooke's discovery of the cell, humans have learnt a great deal about cells. The development of the microscope has enabled scientists to study cells in more detail. They have been able to examine the internal structure of the cell, its functions and how it reproduces. These observations were used by Theodor Schwann, Matthias Schleiden and Rudolf Virchow when they proposed the **cell theory** in 1839.

There are three basic ideas to the cell theory:

- The smallest living thing is a cell.
  - Cells are the basic building blocks of all organisms.
  - Cells are generated from cells; that is, new cells are formed from the division of parent cells.
- What does this mean for life? Remember that theories in science are explanations. What does cell theory explain?

Because the smallest living thing is a cell, all the structures inside cells (organelles) are not considered to be living. You will learn about these organelles later in the chapter. Individually, they are not alive. It is only the cell as a whole unit that can be alive.

Cell theory also states that if we can't find evidence of cells in something, then it is not living. All living things we know about have cells (or a single cell).

Cell theory also states that cells don't just appear from nowhere, spontaneously. So life can't appear from nowhere. New cells are made from another cell when it divides. Cells, and therefore life, can only come from other cells, hence from other living things. This is an essential concept in evolution. Ultimately, life on Earth is thought to have evolved from the first primitive single-celled (unicellular) organisms.

## QUESTIONS 3.1

## What have you learnt?

### Remembering

- 1 **Define** the terms 'unicellular' and 'multicellular'.
- 2 **Recall** the three essential ideas in the cell theory.

### Understanding

- 3 **Outline** what a cell is.

### Analysing

- 4 Do you think the name 'cell' is appropriate? **Explain** your reasoning.

### Creating

- 5 **Propose** how Schwann, Schleiden and Virchow may have built on the work of others to formulate their cell theory.
- 6 **Explain** why cell theory is a scientific theory and not a law or a model.

### WORKSPACE

What have you learnt? 3.1



## 3.2 The size of cells

With the exception of eggs, cells are small. Cells are usually measured in **micrometres ( $\mu\text{m}$ )** (one-millionth of a metre). Objects this size are too small to see with the unaided eye, so you need a microscope to help you see cells. There are many different cells of many different sizes. Table 3.1 gives the sizes of some cells. Smaller objects such as viruses are measured in **nanometres (nm)** (one-billionth of a metre).

### micrometre ( $\mu\text{m}$ )

one-thousandth of a millimetre, or  
one millionth of a metre

### nanometre (nm)

one-billionth of a metre

**Table 3.1** ▲

The different sizes of cells

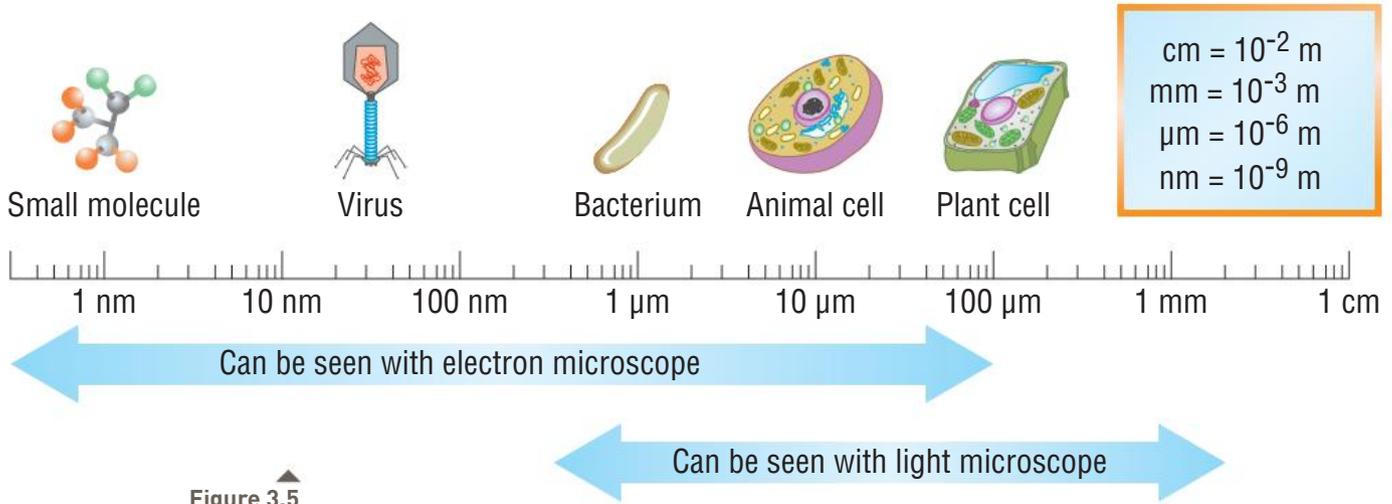
Cell	Size
Hen's egg	30 mm (3 cm)
Large amoeba (a unicellular animal-like organism)	800 $\mu\text{m}$ (0.8 mm)
Human egg (ovum)	100 $\mu\text{m}$
Plant cell	100 $\mu\text{m}$
Animal cell	10–100 $\mu\text{m}$
Sperm cell	7 $\mu\text{m}$
Bacterial cell	1 $\mu\text{m}$

### WEBLINK

How big?



Naturally, there is a very good reason why cells are small. But to understand why, you must first know what happens inside cells, and this means you need to see inside them.



**Figure 3.5**

The relative sizes of cells, viruses and molecules



©Science and Society/SuperStock

**Figure 3.6**

This version of the microscope invented by Hans and Zaccharias Janssen is from about 1876.

## The microscope

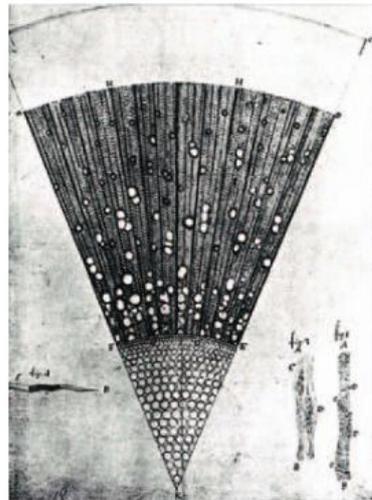
The first microscope was invented in 1590 by two Dutch brothers, Hans and Zaccharias Janssen. Their microscope consisted of two metal cylinders and a simple lens (Figure 3.6). The microscope quickly became an essential tool for scientists.

In 1665, English experimental scientist Robert Hooke looked down his simple microscope to see his now famous image of cork cells (Figure 3.2). In 1675, Antoni van Leeuwenhoek, a Dutch draper, made his own lenses and incorporated them into handmade microscopes. These microscopes were able to magnify objects very clearly.

Technology has advanced so much that there are now many different microscopes and microscopy techniques to help visualise cells.

**Figure 3.7**

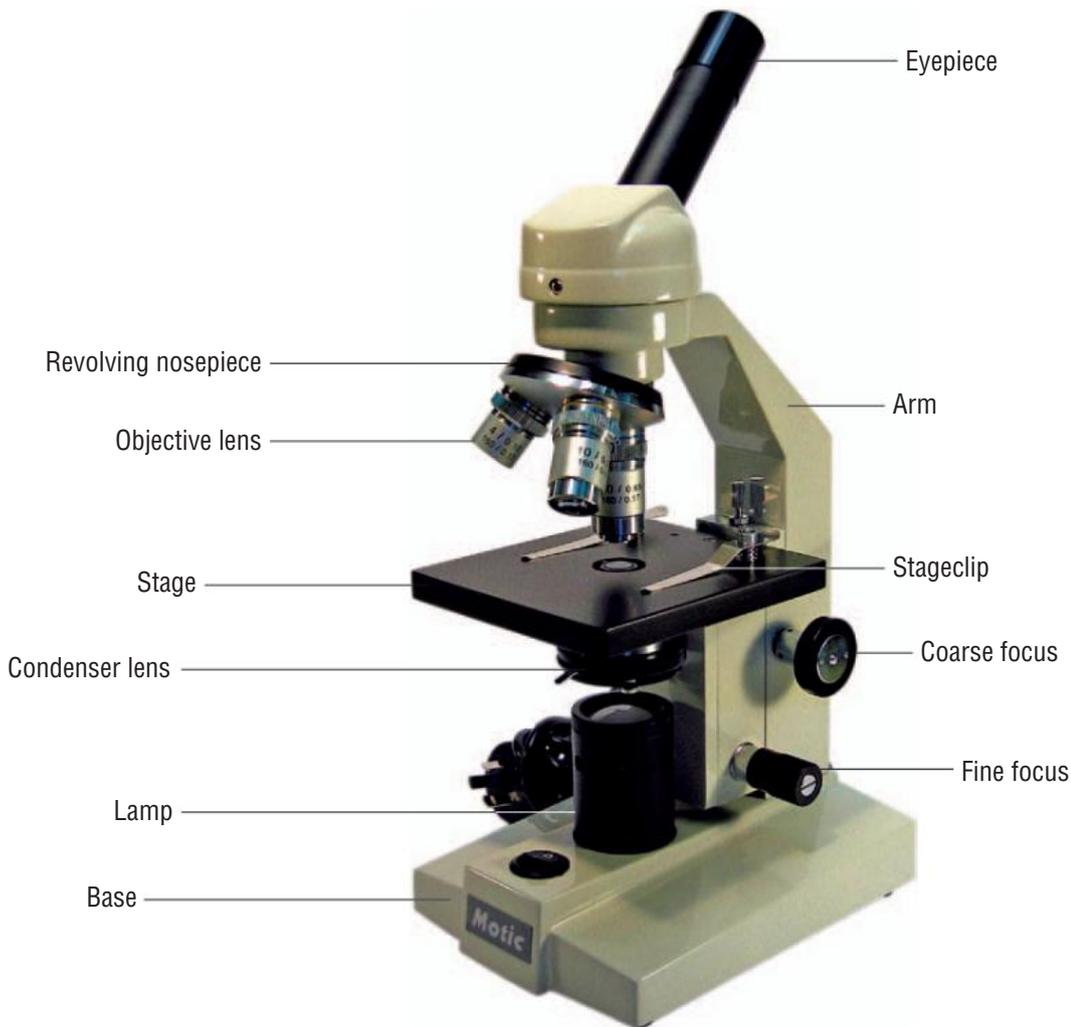
Drawing of a section of an ash tree made by van Leeuwenhoek



### WEB 2.0

Use the Google advanced search features to generate a timeline of the development of microscope.

The most basic type of microscope is the **light microscope**, in which light passes through the **specimen**. A series of lenses magnify the specimen. The **objective lens** is a magnifying lens. The most common objective lenses are 4×, 10× and 40× magnification. Together with the **eyepiece** magnification (often 10×), a specimen can be magnified 40, 100 or 400 times. At these magnifications, you can clearly see the cell boundary, or cell membrane, along with some of the organelles, of which the **nucleus** (plural 'nuclei') is one.



### light microscope

a microscope that uses light to view the specimen

### specimen

a sample to be examined or observed

### objective lens

a lens that focuses light from the specimen and directs it into the eyepiece

### eyepiece

a lens through which the eye views the image formed by the objective lens

### nucleus

the part of the cell containing genetic material and bound by the nuclear membrane

◀ **Figure 3.8**

A light microscope

### WEB 2.0

Research information about the first microscopes. Use this information to prepare a multimedia presentation about the invention and development of the microscope.

### ACTIVITY 3.1

## Microscope crossword

Create a crossword using the names for the parts of a light microscope. Remember to include a clue for each word. Once complete, upload your crossword to the class wiki so that others in your class can download and complete it.

### WEBLINK

Correct microscope use



### ACTIVITY SHEET

Parts of a microscope



### WEBLINK

Puzzle maker



wet mount

a glass slide that holds a specimen in a liquid such as water for viewing under the microscope



ACTIVITY SHEET

How to use a microscope safely



WORKSPACE

Using a light microscope to see cells



ACTIVITY SHEET

Biological drawing



ACTIVITY SHEET

Ratio of red and white blood cells

## Magnification

Both the eyepiece and objective lens of the microscope contain magnifying lenses. When calculating the total magnification, it is important to remember to use both. For example, if the eyepiece contains a  $10\times$  lens, and the objective lens contains a  $10\times$  lens, then the total magnification is  $10 \times 10 = 100\times$ . When you draw a biological specimen, you should make a note of the total magnification at which it was viewed. This is so someone else looking at your drawing will know how big the specimen is in real life.

In Experiment 3.1, you will use a microscope to examine cells and in Experiment 3.2 you will prepare your own slide of biological material. This is called a **wet mount**, as the specimen is mounted in a drop of water.

### EXPERIMENT 3.1

## Using a light microscope to see cells

Possible risks	Safety precautions
Microscopes are heavy (and expensive) pieces of equipment and could do serious damage to your foot if you drop one on it.	Carry the microscope with two hands and always use it on a level surface. Enclosed shoes must always be worn in science laboratories.
Slides are made of glass, and edges are sharp, so can cut you.	Report any breakages to your teacher immediately. Do not clean up broken slides with your bare hands: use a dustpan and brush.

### Aim

To use the light microscope to view a prepared slide of human blood.

### Materials

- prepared slide with a sample of human blood
- light microscope

### Method

- 1 Place one slide onto the microscope stage. With the lowest power objective lens in place, and using the coarse adjustment knob, bring the image into focus.
- 2 Look at the slides using the medium and high power objective lenses. Remember, when you are using the highest power objective lens, you will only need to use the fine adjustment knob to focus. If you try to use the coarse adjustment knob, you may break the slide.

## EXPERIMENT 3.1

## Results

- 1 **Identify** the red and white blood cells. Your teacher will help you to do this.
- 2 Make a biological drawing of the samples at highest power magnification. Label them and record the magnification. Scan your drawings and save them into your workspace. Refer to the activity sheet 'Biological drawing'.

## Discussion

- 3 **Describe** any problems you encountered while using the light microscope.
- 4 Draw a flowchart to show the steps in setting up and using a light microscope.
- 5 **Describe** the obvious differences between red and white blood cells.
- 6 **Calculate** the ratio of red blood cells to white blood cells. Refer to the activity sheet 'Ratio of red and white blood cells'.

## WEB 2.0

Use a drawing application such as Gliffy, Inspiration or Visio to create your flowchart for question 4.

## EXPERIMENT 3.2

## Preparing slides

WORKSPACE  
Preparing slides



Possible risks	Safety precautions
Microscopes are heavy (and expensive) pieces of equipment and could do serious damage to your foot if you drop one on it.	Carry the microscope with two hands and always use it on a level surface. Enclosed shoes must always be worn in science laboratories.
Slides are made of glass, and edges are sharp, so can cut you.	Report any breakages to your teacher immediately. Do not clean up broken slides with your bare hands: use a dustpan and brush.
Scalpels are sharp and can cut you.	Always cut away from yourself. Carry the scalpel in a tray with the point facing down. Never run when carrying it. Always use a cutting board. Place the scalpel in the middle of the board, so that it doesn't fall off the edge. Report any cuts to your teacher immediately.
Iodine is toxic and can stain.	Wash your hands after completing the activity. Clean up any iodine spills immediately. Never eat or drink in a science laboratory.

◀ EXPERIMENT 3.2

**Aim**

To prepare your own slide of biological material (a wet mount).

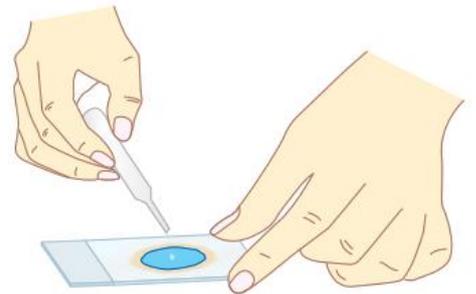
**Materials**

- light microscope
- microscope slides
- coverslips
- pipette
- onion
- forceps
- scalpel
- cutting board
- iodine stain in a dropper bottle (Extension)
- water

**Method**

**Preparing the slide**

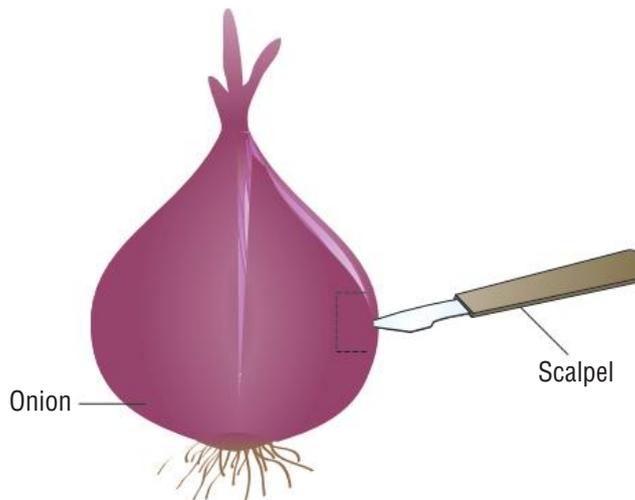
- 1 Use the pipette to place one drop of water onto the middle of the microscope slide (Figure 3.9).



**Figure 3.9** ▶

Place a drop of water onto the slide.

- 2 Use the scalpel to cut a small piece of onion (Figure 3.10).

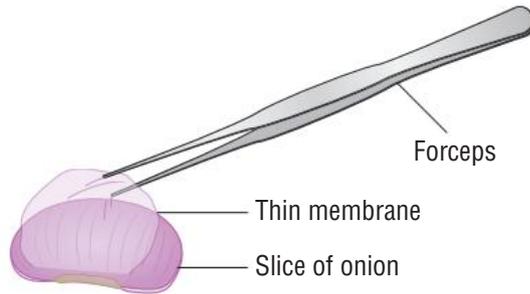


**Figure 3.10** ▶

Cut a small piece of onion.

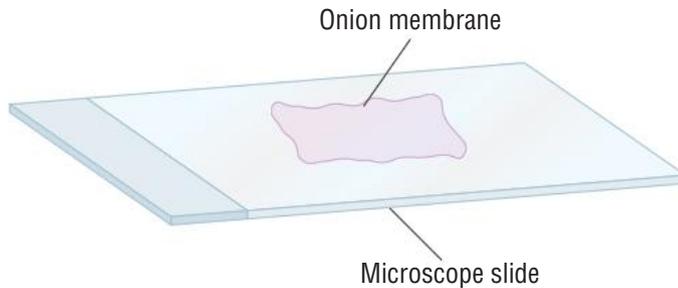
### EXPERIMENT 3.2

- Use the forceps to peel a small piece of thin membrane from the onion (Figure 3.11).



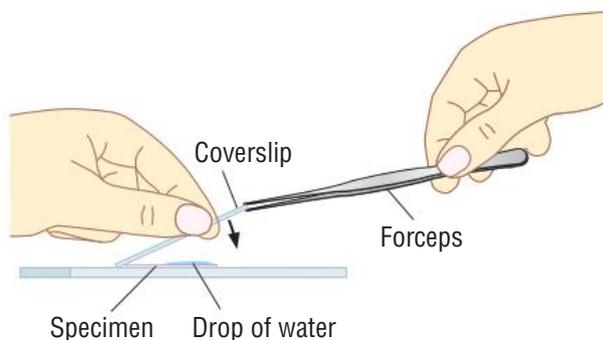
◀ **Figure 3.11**  
Peel a piece of membrane from the onion.

- Lay the thin membrane flat onto the drop of water (Figure 3.12).



◀ **Figure 3.12**  
Lay the membrane onto the drop of water.

- Carefully lower the coverslip. To do this without trapping air bubbles underneath it, you need to place one end of the coverslip so it rests on the slide. Use the forceps to lower the other end of the coverslip onto the water drop and specimen (Figure 3.13).



◀ **Figure 3.13**  
Lower the coverslip onto the specimen.

### Viewing the slide

- Place the slide onto the microscope stage and secure it with stage clips. With the low power objective lens in place, and using the coarse adjustment knob, bring the image into focus.
- Look at the slide using medium and high power objective lenses. Remember when you are using the high power objective lens that you will only need to use the fine adjustment knob to focus. ▶

### EXPERIMENT 3.2

#### Results

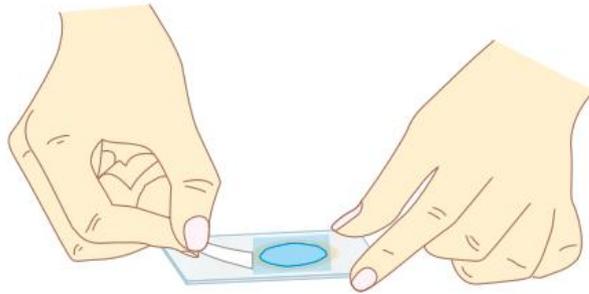
- 1 Make a biological drawing of the sample at an appropriate magnification. Remember the rules for drawing a biological specimen.

#### Extension

- 2 You can use a stain to assist you in seeing the different parts of the onion cells more clearly. Place one drop of iodine stain at the edge of the coverslip. Draw the iodine under the coverslip by placing a piece of paper towel on the other side of the coverslip (Figure 3.14).

Figure 3.14 ▶

Draw the iodine under the coverslip with a piece of paper towel.



WEBLINK  
Onion cells

#### WEB 2.0

If you have a digital microscope, take a photo of your specimen at 100× and 200× magnifications. Load these images onto the class wiki.



ACTIVITY SHEET  
First important priorities



ACTIVITY SHEET  
Examining pond water

#### resolution

the ability to clearly distinguish between two separate but adjacent structures

#### Discussion

- 3 **Describe** the differences you observed between plant and animal cells (use observations from Experiment 3.1).
- 4 **Compare** what you saw with the onion cells in the weblink 'Onion cells'.

#### Extension

- 5 **Describe** how the stain improved your ability to see parts of the cells.

## Resolution

**Resolution** is the ability to clearly distinguish between two separate structures. If you look at two lines close together on a page, you can clearly see there are two lines when you are close up. However, from a distance, you will not be able to say for sure whether there are two lines or just one. From a distance, your resolution is not as good.

Electron microscopes (Figure 3.15) give greater magnification and greater resolution than light microscopes. This gives us a much clearer idea of what is in a cell. They can be used to see the detailed structure of a cell.

The **transmission electron microscope** passes beams of **electrons**, rather than light, through the specimen to be viewed. This allows much higher magnifications to be achieved and gives a clearer image, showing much more detail than a light microscope can. An electron microscope can magnify up to 2 000 000 times. A light microscope begins to lose resolution at 2000 times.



Science Photo Library/Steve Allen

### transmission electron microscope

a microscope that passes beams of electrons rather than light through the specimen to view it at very high magnification

### electron

a negatively charged particle

#### ◀ Figure 3.15

An electron microscope is a highly specialised and expensive piece of equipment.

A **scanning electron microscope** produces three-dimensional images of the specimen (Figure 3.16).



PhotoLibrary.com/Getty Images/Science Photo Library

### scanning electron microscope

a microscope in which the specimen is examined using a moving electron beam from which the electrons are reflected to form a magnified, three-dimensional image

#### ACTIVITY SHEET

Who uses microscopes in their daily job?



#### ◀ Figure 3.16

This image of a honey bee, *Apis mellifera*, was produced by an electron microscope.



**WORKSPACE**

What have you learnt? 3.2

**QUESTIONS 3.2**

**What have you learnt?**

**Remembering**

- 1 **Identify** the parts of the microscope involved in focusing the image.
- 2 **Identify** the units commonly used to measure a cell. Compare the size of these units to metres.
- 3 **Recall** why water is added to a wet mount.

**Applying**

- 4 Complete the following table of microscope magnifications.

<b>Eyepiece magnification</b>	<b>Objective lens magnification</b>	<b>Total magnification</b>
×10		×40
	×10	×100
×8	×40	

**Analysing**

- 5 **Explain** the purpose of using a stain on a wet mount.
- 6 **Describe** how the invention of the microscope enabled us to understand more about the structure of cells.
- 7 **Compare** an onion cell with a red blood cell. Record the similarities and differences using a graphic organiser of your choice.

**Evaluating**

- 8 **Discuss** the benefits and limitations of using wet-mount slides compared to prepared slides (like the blood slides you used).

## 3.3 Different types of cells

Microscopes have allowed us to see that living things are made from very different types of cells.

Think about the fact that houses have the same basic plan, but can still be very different. Houses tend to have the same types of rooms, but they differ in number and size. Houses are generally built to suit the requirements of the people who live there.

The same is true of cells. There is a basic plan for all cells, but there are variations in size, shape and structures within them. Even though there are basic features that remain the same, the form of a cell changes depending on what organism it is found in and the job it does. The structure of the cells in an organism plays a major role in classification (see Chapter 4). Classification divides living things into groups with features in common (Figure 3.17).

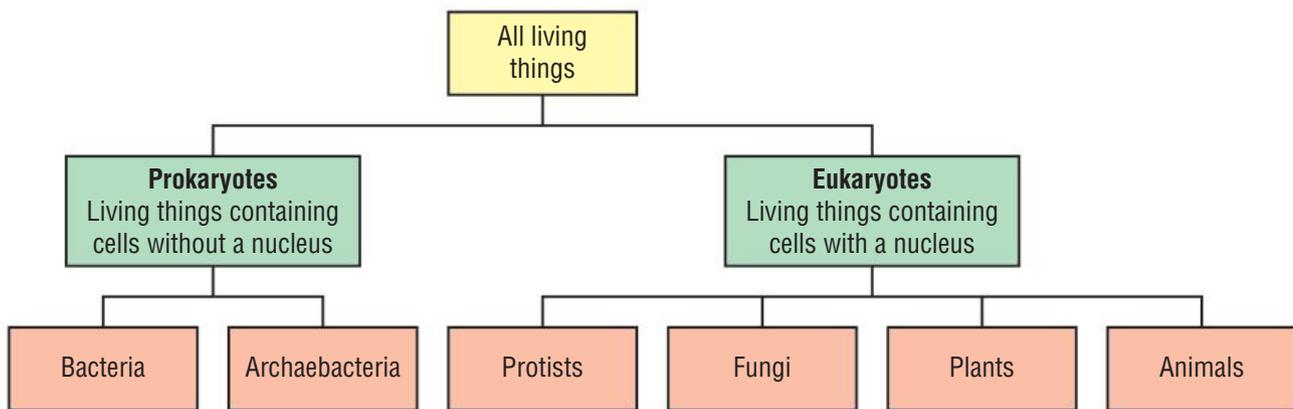


Figure 3.17

Living things are classified according to whether or not their cells have a nucleus.

**prokaryotic**

without a nucleus

**pathogens**

organisms that cause disease

## Prokaryotic cells

Cells with a simple structure, and which do not have a nucleus, are called **prokaryotic** cells. These cells include organisms from the kingdoms Bacteria and Archaeobacteria (Figure 3.17).

### Bacteria

Bacteria are the simplest life forms on Earth and were most likely the first to appear. Although they are mostly thought of as disease-causing **pathogens**, they also play crucial roles in the environment, producing much of the oxygen we breathe and keeping the cycles in nature continuing.

Bacteria exist in a large number of different shapes, from simple rods and spheres to corkscrew spirals (Figure 3.18).

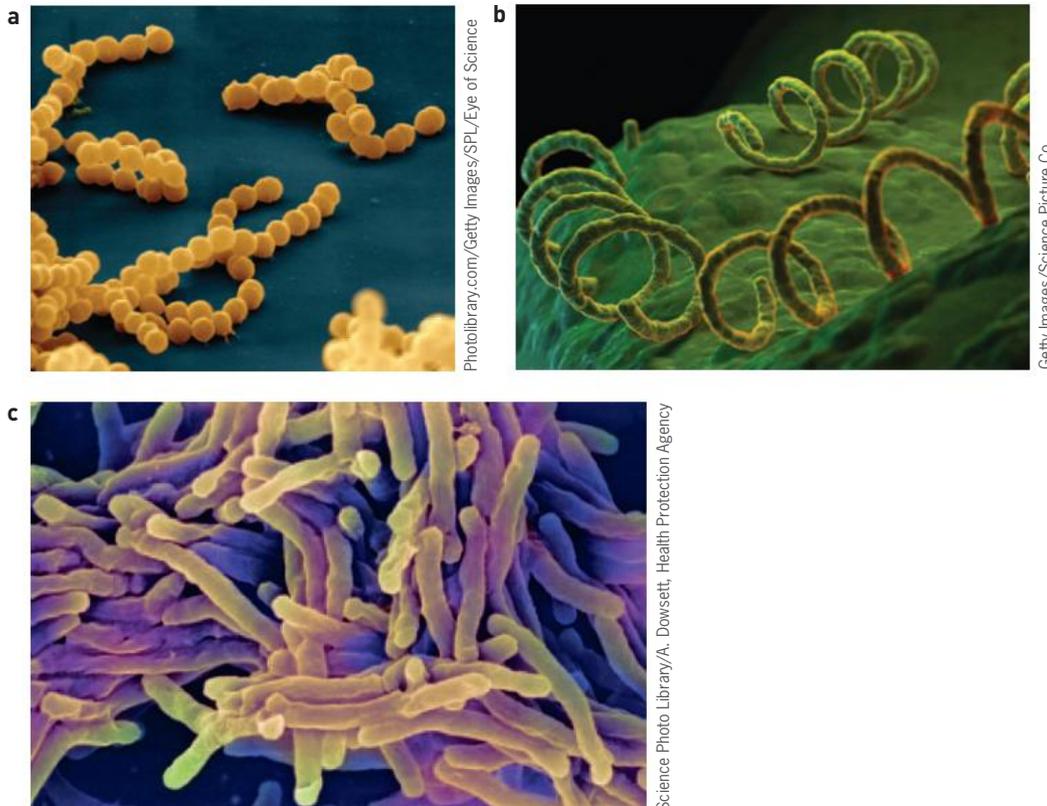


Figure 3.18

**a** The spherical bacterium *Streptococcus pyogenes*, which causes a 'strep' sore throat; **b** the spirochaete bacterium *Treponoma pallidum*, which causes syphilis; and **c** the rod-shaped bacterium *Mycobacterium tuberculosis*, which causes the lung disease tuberculosis

**capsule**

the outside covering of some bacteria

**flagellum**

a tail-like structure used for movement

**cell wall**

the outer structure of bacterial and plant cells

**cell membrane**

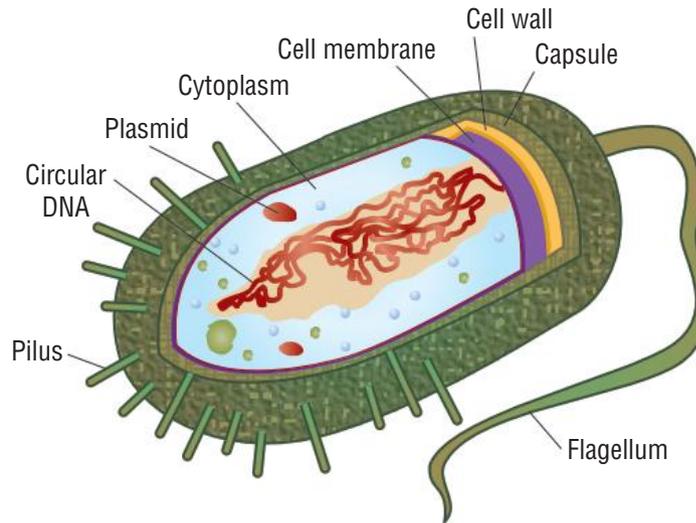
a membrane enclosing the cytoplasm of the cell

**pili**

hair-like extensions found on some bacteria and used for reproduction

**Figure 3.19** ▶

Internal structure of a bacterial cell



**cytoplasm**

a jelly-like substance in which organelles are located within a cell

**asexually**

without sex; involves only one parent

**binary fission**

splitting of one cell into two equally sized daughter cells

Most of the bacterial cell is jelly-like **cytoplasm** in which the cell contents float. The genetic material, DNA, is organised into one circular strand that floats within the cytoplasm.

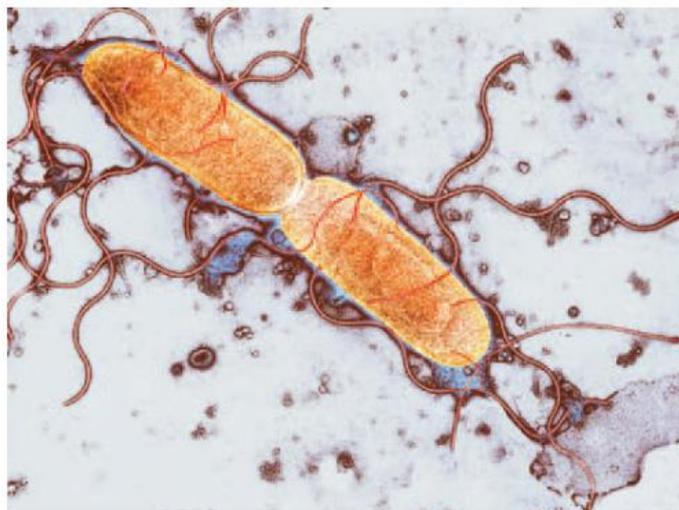
Bacteria mostly reproduce **asexually** by **binary fission**, which literally means splitting in two (Figure 3.20). The bacterium copies its DNA and then the cell divides into two, so each cell has a copy of the DNA. This process requires only one bacterial cell and the resulting two cells are exactly the same as each other.



**ACTIVITY SHEET**  
Bacterial cells

**Figure 3.20** ▶

*Salmonella* bacteria reproducing by binary fission



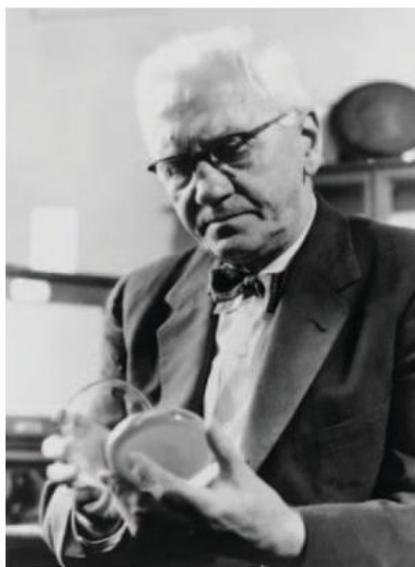
Science Photo Library/Hazel Appleton, Centre for Infections/Health Protection Agency

## Antibiotics

Scottish scientist Alexander Fleming could be described as the first microbiologist. In 1928, he discovered that a mould growing on a dish of bacteria stopped the bacteria's growth. The **active agent** isolated from this mould is now known as the antibiotic penicillin (antibiotic means 'against life').

Australian Howard Florey built on the work of Fleming. Florey was awarded a Nobel Prize in 1945 for developing a substance of 'immediate value to mankind'. Penicillin became a practical drug used against bacterial infections and has saved countless lives.

Today there is a vast range of antibiotics. Antibiotics target cell structures that only bacterial cells have. For this reason, they only kill bacteria, leaving animal cells (including human ones) unharmed. Because of antibiotics, bacterial infections have gone from being rapid and terrifying killers to being an easily treatable inconvenience.



Science Photo Library/St. Mary's Hospital Medical School

### active agent

a chemical within a substance that does the work

◀ **Figure 3.21**  
Alexander Fleming discovered penicillin.

### ACTIVITY 3.2

## What if penicillin was never discovered?

Complete a consequences and sequels (C&S) chart to list the various possible consequences of not having penicillin.

### WORKSPACE

What if penicillin was never discovered?



### WEB 2.0

Share your C&S chart on the class wiki.

## WOW! Viruses

If cells are the basic subunits of all living things, where do viruses fit in? Viruses are much smaller than cells. They range from around 10 to 300 nanometres (nm) (one-billionth of a metre) in diameter, whereas cells range from 10 to 100  $\mu\text{m}$  (or from 0.01 to 0.1 mm) in diameter. Viruses do not have all the features used to identify living organisms (see Chapter 4), so they are not classified as living things.



Photolibrary.com/Getty Images/SPL/Pasieka

## Archaeobacteria

Archaeobacteria are ancient organisms, which can exist in extreme environments of high temperatures, high salinity and high acidity, as well as in 'normal' environments. The DNA of archaeobacteria is located within the cytoplasm, as it is in bacteria.



Shutterstock.com/PavelSvoboda

**Figure 3.22** ▶

Archaeobacteria can exist in extreme environments such as volcanic hot springs.

### eukaryote

a living cell that contains a nucleus

### mitochondria

organelles in which energy is released for use by the cell

### vacuole

a membrane-bound sac found inside a cell

## Eukaryotic cells

If a cell contains a nucleus, it is part of the group known as the **eukaryotes** (pronounced 'you-carry-oats'). Eukaryote translates as 'good nucleus'. The nucleus is a special membrane-bound structure within the cell that keeps the DNA separate from the rest of the cytoplasm. Eukaryotic cells are found in animals, plants, fungi and protists.

### Animal cells

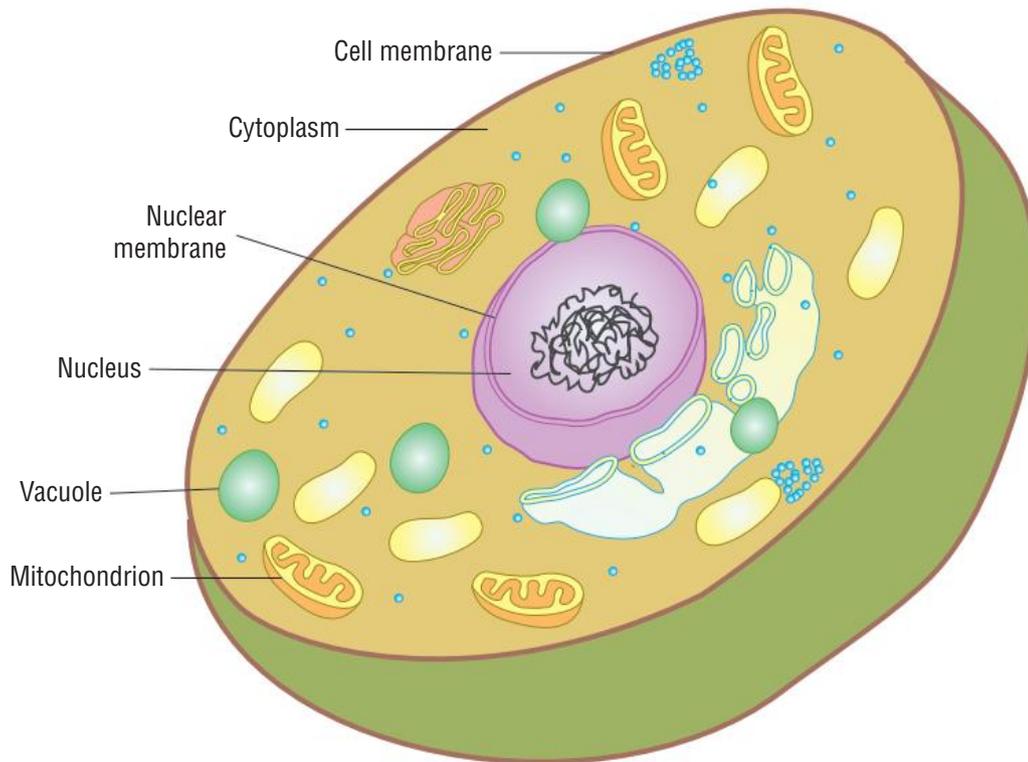
All animal cells have a similar basic cell structure, and include organelles such as a nucleus, **mitochondria** (singular 'mitochondrion'), **vacuoles** and cell membranes (Table 3.2).

**Table 3.2** ▲

Structure of animal cells

Structure	Description	Functions
Cell membrane	Thin, skin-like outer covering of the cell	Contains the cell and controls what enters and leaves the cell
Cytoplasm	Jelly-like fluid inside the cell	Suspends organelles and enables dissolved substances to move around the cell
Mitochondrion	Small organelle surrounded by a membrane	Releases energy from nutrients within the cell
Nucleus	Structure surrounded by a nuclear membrane	Contains DNA
Vacuole	Small water-filled compartment surrounded by a membrane; may also contain wastes and toxins	Stores and removes water from cell

A typical animal cell and its structure is shown in Figure 3.23.



◀ **Figure 3.23**  
A typical animal cell

#### ANIMATION

Plant and animal cells



#### VIDEO

Animal cells: general structure



#### VIDEO

Animal cells: types and functions



## Plant cells

All plants have a similar basic cell structure. Plant cells contain all the structures already outlined for animal cells. They also have some added structures, such as cell walls and **chloroplasts** (Table 3.3).

**Table 3.3** ▲

Plant cell structures not found in animal cells

Structure	Description	Function
Cell wall	Rigid outer covering of a plant cell; made of cellulose	Gives the plant cell shape and protection
Chloroplast	Large green organelle	Photosynthesis
Large vacuole	Large water-filled compartment surrounded by a membrane	Structural support

#### chloroplast

a chlorophyll-containing organelle found in plant cells, in which photosynthesis occurs

#### VIDEO

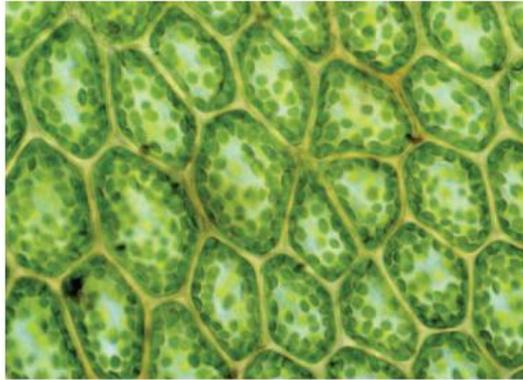
Leaf and plant cell structure



#### VIDEO

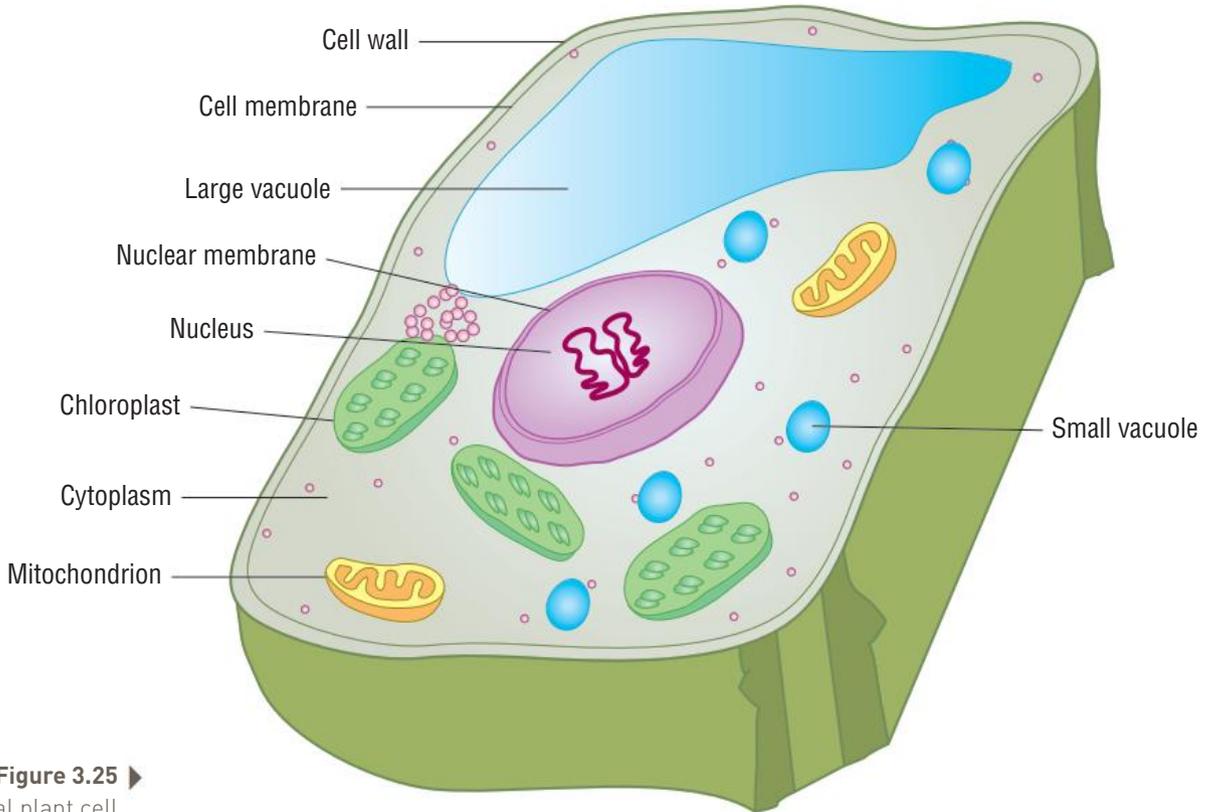
Plant cells: types and function





Science Photo Library/John Durham

**Figure 3.24** ▶  
Cell walls and chloroplasts are clearly visible in these plant cells.



**Figure 3.25** ▶  
A typical plant cell

**heterotroph**

an organism that cannot make its own food but must eat other organisms to obtain nutrients



Science Photo Library/David mack

**Figure 3.26** ▶  
Fungal cells

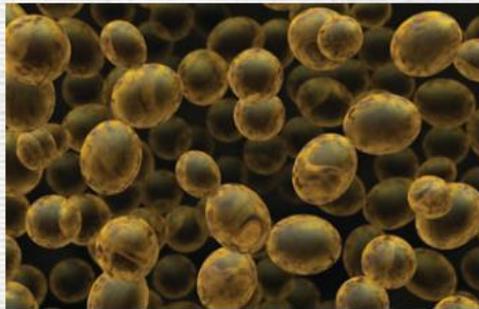
**Fungal cells**

Although fungi are a separate group from plants and animals, their basic building block is still the cell. A fungal cell has a nucleus containing DNA, and other similar organelles, such as vacuoles. Fungi have a cell wall, but it does not contain cellulose as plants' cell walls do. Fungi are **heterotrophs** – they do not photosynthesise but obtain nutrients from the decomposition of other organisms. Fungi, therefore, have some characteristics of plant cells and some of animal cells.

WOW!

## Budding

Fungal cells, such as the yeast cells shown, reproduce by budding. Each cell grows a bud. The bud grows larger and eventually breaks off to become an independent fungal cell.



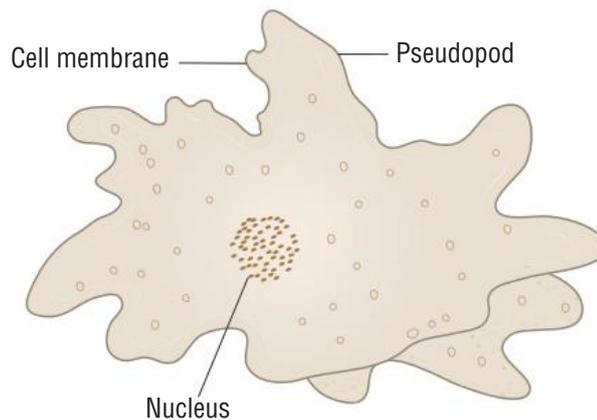
Shutterstock.com/Knorre

## Protists

### Amoeba

Protists are unicellular eukaryotic organisms. Protists include a number of organisms that can cause diseases in humans. Dysentery is a disease of the gut in which the sufferer is unable to retain fluids in the body. Amoebic dysentery is caused by the protist amoeba, which can exist as a single cell in water.

Some protists, for example amoeba, can move by using pseudopodia (singular pseudopod), or 'false feet'. Even though amoeba are tiny, they can move around in moist areas to find food and survive.



◀ **Figure 3.27**  
An amoeba

### Euglena

*Euglena* can obtain nutrients in two different ways. Depending on the conditions, *Euglena* can either eat other organisms (acting as a heterotroph) or use photosynthesis when light is available to produce its own food.

Science Photo Library/Aurelien Celette,  
Mona Lisa Production

◀ **Figure 3.28**  
You can see the chloroplasts inside these *Euglena*.



**WORKSPACE**

What have you learnt? 3.3

**QUESTIONS 3.3**

**What have you learnt?**

**Remembering**

- 1 **Identify** the process by which bacteria reproduce.
- 2 **Identify** two features of prokaryotic cells.
- 3 **Identify** the type of substance that specifically kills bacteria.

**Understanding**

- 4 **Identify** the main feature that differentiates a eukaryotic cell from a prokaryotic cell.
- 5 Complete the following table.

Structure	Animal cell	Plant cell	Fungal cell
Cell wall	Absent		
Cell membrane		Present	
Nucleus			
Cytoplasm			
Mitochondrion			
Vacuole	Small		
Chloroplast			

**Applying**

- 6 Write two possible questions for each of the following answers.
  - a Cytoplasm
  - b Flagellum
  - c Cell membrane

**Analysing**

- 7 Are all bacteria harmful? **Explain** your answer.
- 8 **Explain** how Fleming and Florey made a significant contribution to humanity.

**Evaluating**

- 9 'Without bacteria there would be no life on Earth.' **Justify** or **refute** this statement.

**Creating**

- 10 **Construct** a table to **compare** six different cell organelles and **summarise** their functions.

## 3.4 Movement of substances into and out of cells

There is a reason why cells are so small. A cell receives all its requirements through its cell membrane. It also passes all its waste from inside the cell to outside the cell through the cell membrane. Therefore, the total area of the cell membrane is very important. For the cell to function normally, the cell membrane must be large enough to allow sufficient requirements through and all the wastes out.

### Diffusion

Small particles are able to pass through the cell membrane by the process of **diffusion**. Think of how the smell of dinner cooking moves from the kitchen and slowly spreads through the doorways to the rest of the house. Like the doorways in your house, the cell membrane has tiny holes or pores, which allow small particles to move through, but not large particles. If a substance is in a high concentration inside the cell, then it will tend to move through the cell membrane to the outside. The reverse is also true: if a substance is in high concentration outside the cell, then it will move into the cell. This movement is diffusion.

Substances that are required by the cell diffuse inside. Outside the cell, water, simple sugars and oxygen are in high concentration, so they will move through the cell membrane to the inside of the cell. Here they are used in processes that produce wastes. The wastes diffuse out of the cell.

### Respiration

The most important process in a cell is **respiration**. Respiration, in biology, is the release of energy for use in the cell. Do not confuse this with breathing! Respiration is essential for life. If any cell stops respiring, it begins to die because it has no energy available to it.

For respiration to occur, most cells need to obtain **glucose** (a simple sugar) and oxygen from their environment. This is why you need to eat food and breathe air. In eukaryotic cells these are used by the mitochondria. Mitochondria release the energy trapped in glucose. This energy is then available for use by the cell to perform all its functions, such as making complex molecules, or helping you move your muscles to run. Prokaryotic cells do not have mitochondria, but respiration still occurs in their cytoplasm to provide them with energy.

Glucose is the immediate source of almost all the energy used by the cells of living things on Earth. The energy in glucose comes originally from the Sun. Green plants convert the Sun's energy to glucose in a process called **photosynthesis**.

The main waste product cells need to remove is carbon dioxide. Carbon dioxide is a toxic gas produced during respiration. It must be removed from cells or it will kill them. This is why you breathe out carbon dioxide.

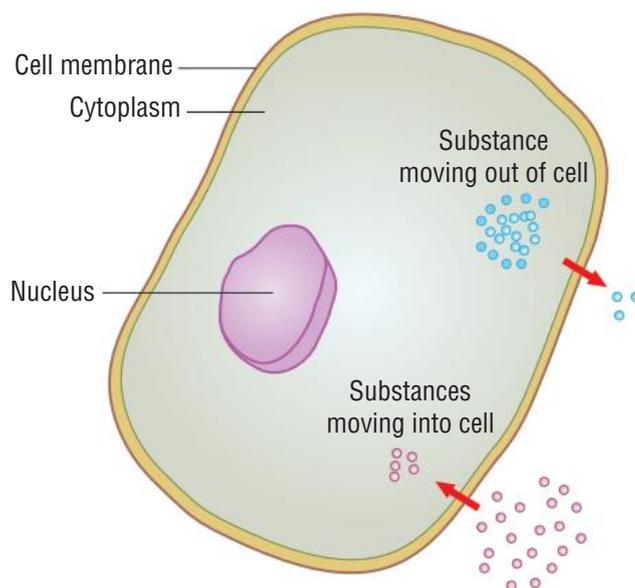
Glucose, oxygen and carbon dioxide all enter or leave cells by diffusion. This is a slow process, so multicellular organisms have transport systems in their bodies to help with this, such as the digestive and circulatory systems.

#### diffusion

the movement of gas or liquid particles from a region of high concentration to a region of low concentration

#### Figure 3.29

Substances diffuse through the cell membrane from areas of high concentration to areas of low concentration.



#### respiration

a process that releases energy from glucose for use in a cell

#### glucose

a simple sugar that is an important energy source for living organisms

#### photosynthesis

a process performed by green plants, which uses the Sun's energy to make glucose from carbon dioxide and water

#### ANIMATION

Diffusion through the cell membrane





**WORKSPACE**  
Surface area and volume

**EXPERIMENT 3.3**

## Surface area and volume

Possible risks	Safety precautions
Equipment and desks in the science laboratory may be contaminated with chemicals.	Do not eat the apples or drink the juice.
The knife may be sharp and could cut you.	Always cut away from yourself and on a cutting board. Never run when carrying the knife. Report any cuts to your teacher immediately.

The cell membrane (surface area) has to be large enough to service the inside of the cell (volume). We can model this using an apple and blackcurrant juice. Pieces of apple will act as cells of different sizes, and blackcurrant juice will act as the nutrient that diffuses into the cell.

### Aim

To demonstrate the effect of surface area and volume on the rate of exchange.

### Materials

- apple
- ruler
- knife
- blackcurrant juice (such as Ribena®)
- beaker or cup
- digital camera

### Method

- 1 Cut cubes of apple into different sizes. These are your cells. Cubes of  $1\text{ cm}^3$  and  $8\text{ cm}^3$  (that is,  $1\text{ cm} \times 1\text{ cm} \times 1\text{ cm}$ , and  $2\text{ cm} \times 2\text{ cm} \times 2\text{ cm}$ ) will be a good starting point.
- 2 Place the cubes of apple into a beaker of blackcurrant juice and leave them for at least 6 hours.
- 3 Take digital photos of your cubes to include in your report.

### Results

- 1 Cut open the apple cubes to see how far the juice has moved into the apple. Measure the distance with your ruler.
- 2 Record your results in a table.

### EXPERIMENT 3.3

#### Discussion

- 3 What percentage of the apple has been dyed by the juice? **Calculate** the volume of the cube that has not changed colour. Subtract it from the volume of the entire cube, to determine the volume that has changed colour. Convert this to a percentage by using the formula:

$$(\text{volume that has changed divided by total volume}) \times 100$$

- 4 **a Compare** the percentage of penetration of the juice for the two sizes of apple.
- b** What would this mean for the centre of the apple? Relate this simulation to diffusion of requirements into a cell. **Explain** how this process might limit how big cells can be.

#### Extension

- 5 Design an experiment to investigate whether shape affects the rate of diffusion.

### EXPERIMENT 3.4

## Open-ended investigation: diffusion and temperature

Design an investigation to test whether diffusion is affected by temperature. Remember to use the scientific method described in Chapter 2. That is:

- Ask a question.
- Formulate a hypothesis.
- Plan and carry out your experiment.
- Collect and analyse data.
- Draw conclusions and evaluate your investigation.

#### Things to think about

- 1 What medium (liquid or gas) are you going to investigate?
- 2 What are your independent, dependent and controlled variables?
- 3 What are the risks and how will you manage them?
- 4 How are you going to record and display your results?
- 5 Relate your findings to living animals – what could your results mean?

#### WORKSPACE

Open-ended investigation: diffusion and temperature





**WORKSPACE**

What have you learnt? 3.4

**WEB 2.0**

Create a crossword by using words from the glossary throughout this chapter. Swap crosswords with another student and complete them.



**WEBLINK**  
Crossword

**QUESTIONS 3.4**

**What have you learnt?**

**Remembering**

- 1 **Identify** three things required by a cell that must enter a cell through the membrane.
- 2 **Identify** the process by which most requirements enter cells.
- 3 **Identify** the process by which cells gain energy.
- 4 **Identify** the organelle in which this process occurs.
- 5 **Identify** the part of the cell that provides the surface area of the cell.

**Applying**

- 6 **Explain** why a cell membrane is important to a cell.
- 7 **Describe**, giving examples, how a cell's structure suits its function.

**Creating**

- 8 **Explain** diffusion so that an 8-year-old child could understand it.

**Reflecting**

- 9 **Explain** why cells must be small.

# 3.5 Making new cells

Cells need to reproduce for a number of reasons.

As you grow from a baby to a child to an adult, the number of your cells increases dramatically. If you cut yourself, your cells need to increase in number to heal the wound. You shed skin cells every day as they wear out. You need to replace these cells. Bones grow longer by adding new cells. Red blood cells, such as those in Figure 3.30, only live for 120 days – these, too, need replacing.

**mitosis**

a process in cell division that forms two nuclei, so the cell can divide to make two identical daughter cells

**parent cell**

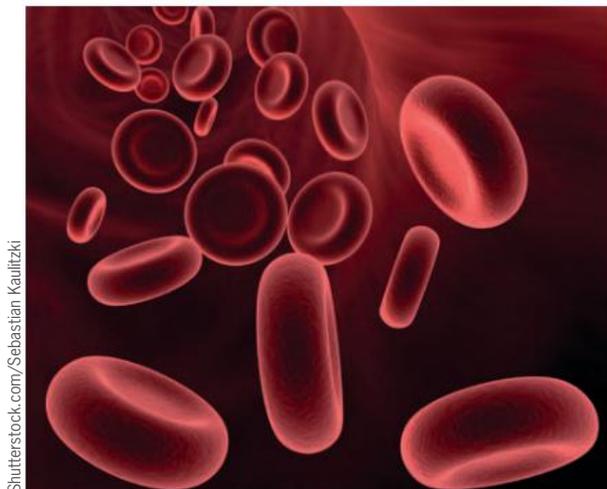
the original cell that divides to form two cells

**daughter cells**

two cells produced as a result of cell division

**Figure 3.30** ▶

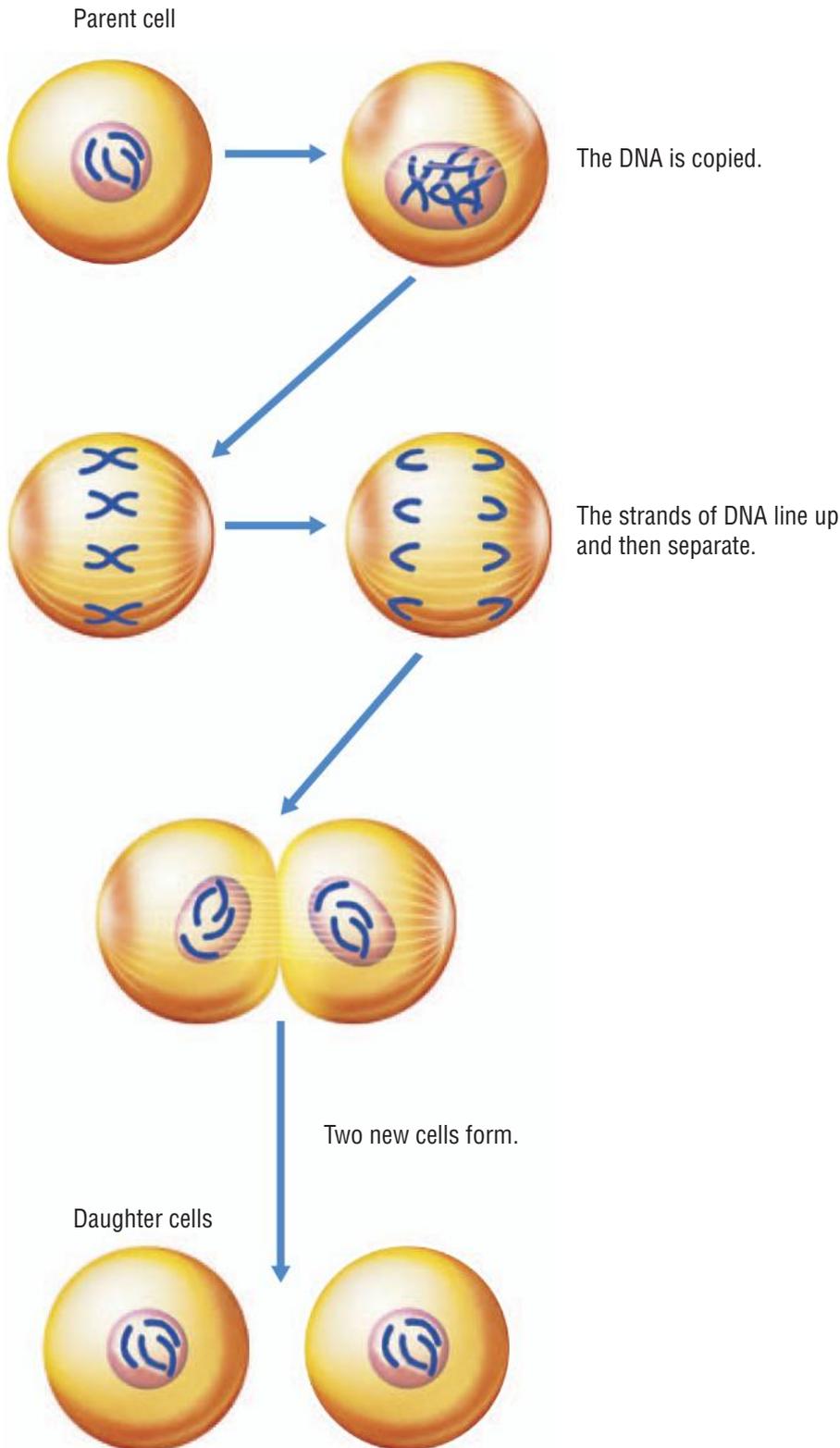
Red blood cells only live for 120 days, so must be replaced.



## Mitosis

To make new cells so you can grow, repair your body or replace lost cells, a cell makes another copy of its DNA. The cell and DNA then divide by an orderly process called **mitosis**. During mitosis the nucleus of one cell (the **parent cell**) divides to form two nuclei. These then form two cells (the **daughter cells**). The process has to be orderly as each daughter cell has to obtain exactly the same type and amount of DNA from the parent cell.

This is similar to photocopying a book, and then dividing the pages up. It does not matter whether you get the original page or the photocopy, as long as you get a copy of every page of the book. Finally, the cell divides into two, and each new cell gets a full copy of the DNA.



VIDEO  
Cell division: mitosis



◀ **Figure 3.31**  
The different stages of mitosis: the orderly division of the cell

**stem cells**

cells that can divide by mitosis to become a variety of cells

**WEB 2.0**

You can use modelling clay to model mitosis. Photograph each step and make a stop motion video. Upload the video to the class wiki.



**WEBLINK**

Stem cell treatment for macular degeneration

**Figure 3.32** ▶

This is how a person suffering from macular degeneration would see the world.



**WORKSPACE**

What have you learnt? 3.5

## Stem cells

Most cells either live for a while and then die, like red blood cells or skin cells, or stay in your body for the rest of your life, like nerve cells. Most cells, therefore, do not reproduce and so do not undergo mitosis. **Stem cells** are cells in your body that can divide by mitosis and make new cells, which can become a variety of different cells. Some stem cells are found in bone marrow. These stem cells divide to become red and white blood cells.

Researchers from Georgetown University Medical Centre in Washington, USA, have taken adult skin cells and treated them so they act like stem cells. These stem cells have then been treated to grow into retinal cells found in the eye. The retina is the part of the eye that detects light and enables you to see.

The aim of this research is to eventually use stem cells to replace damaged retinal cells in patients suffering from macular degeneration. Macular degeneration is the loss of retinal cells, leading to loss of central vision. Figure 3.32 shows how a person with macular degeneration views the world. This process has so far only been carried out in the laboratory. More work is yet to be done to make it safe for treating humans.



Science Photo Library/Argentum

**QUESTIONS 3.5**

### What have you learnt?

**Understanding**

- 1 **Contrast** stem cells with other cells.
- 2 **Identify** the reasons why cells reproduce.

**Analysing**

- 3 **Explain** why all cells are not the same shape and size.

**Evaluating**

- 4 Red blood cells only live for 120 days. **Describe** the implications of this for:
  - a a blood donor
  - b a receiver of donated blood
  - c the blood bank.

## 3.6 Micro-organisms

**Micro-organisms**, or **microbes**, are microscopic organisms. These can be types of bacteria, archaeobacteria, protists, some fungi or even some animals and plants. They can be unicellular or multicellular, and they can be beneficial or harmful to humans.

Harmful micro-organisms include the bacteria that cause the diseases bubonic plague, cholera, leprosy, anthrax, whooping cough, tetanus, tuberculosis, syphilis, gangrene, meningococcal disease and many types of gastroenteritis and diarrhoea.

However, a number of beneficial bacteria do important jobs in your body and in everyday life. *Escherichia coli* (*E. coli* for short) lives in the guts of humans and other primates and makes vitamins and suppresses harmful bacteria. *Lactobacillus* and *Streptococcus* species are found in yoghurt and help digest the milk sugar lactose. Some yoghurt manufacturers add a second *Lactobacillus* strain, *Lactobacillus acidophilus*, which is thought to have additional health benefits. Fungi in your body compete with these bacteria to keep populations in a healthy balance. Yeasts are microscopic fungi that are involved in the production of breads, wine and many other foods.

Micro-organisms are also major **decomposers** in our ecosystem. When organisms die or parts of their bodies are discarded (such as leaves, hair and skin), it is micro-organisms that are largely responsible for the breakdown of this dead matter. They return the nutrients to the environment so the cycles in nature can continue. Without decomposers, we would quickly become swamped by dead matter, and soon run out of available nutrients in the ecosystem. Life would die out.

Additionally, bacteria are often used in genetic engineering: for example, bacteria have been genetically engineered to produce human insulin for the treatment of diabetes.

### micro-organism

a microscopic organism, such as a bacterium, protist or tiny fungus, plant or animal

### microbe

a micro-organism

### decomposer

an organism that feeds on and breaks down dead organisms

### QUESTIONS 3.6

## What have you learnt?

### Remembering

- 1 **Define** the term 'micro-organisms'.

### Understanding

- 2 **Describe** three harmful effects of micro-organisms on living things.
- 3 **Describe** three beneficial effects of micro-organisms on living things.

### WORKSPACE

What have you learnt? 3.6





## Chapter review

### Remembering

- 1 **Identify** two structures found in plant cells but not in animal cells.
- 2 **Recount** the steps you would take to view a prepared slide on highest power under the microscope.

### Understanding

- 3 **Account** for why cells were not observed until 1665.

### Applying

- 4 **Identify** one technological development that enabled us to have our modern understanding of cells. **Describe** how the development contributed to our understanding.

### Analysing

- 5
  - a **Contrast** the organelles of a plant leaf cell with a human muscle cell.
  - b **Predict** how a cell wall would affect the function of a muscle cell.
  - c Under the microscope, you see three features of the leaf cell easily. Suggest what these might be and **justify** your answer.

### Evaluating

- 6 Imagine our world today if the microscope had never been invented. **Appreciate** the impact of this invention by describing a world without it.
- 7 Four students were having an argument over which is the most important organelle in a cell. Athena said the nucleus was most important, as without it the cell would not know what to do. Ming said that the mitochondrion was most important, as without it a cell would not have any energy to do anything. Lisha said the cell membrane was most important, as without it there would be no cell. Jozef said all were equally important, as the cell needed them all to survive. The teacher said Lisha's answer was probably most correct but Jozef's understanding was better.

**Evaluate** the teacher's point of view.

### Creating

- 8 'The structure of a human sperm cell is ideally suited to its function.' **Justify** this statement, giving at least three reasons.
- 9 Humans can live for 3 weeks without food and 3 days without water, but only 3 minutes without oxygen. **Explain** why oxygen is so vital for life.
- 10 Imagine you have the opportunity to interview Alexander Fleming or Howard Florey. **Identify** three questions you would ask.



**WORKSPACE**  
Chapter 3 review



**ACTIVITY SHEET**  
Chapter 3 checklist



**REVIEW QUIZ**  
Chapter 3



# 4

## Classification

---

How are living things classified?

---

Europeans first encountered the Australian platypus in 1798. Captain John Hunter, Governor of New South Wales, sent a pelt and sketch to scientists in Great Britain. The British scientists thought it was a fake and that someone had sewn a duck's beak onto a beaver pelt. They tried to cut the pelt apart with scissors to find the stitches that held it together. The platypus was like no other animal they had ever seen: it appeared to be part mammal as it had hair, but it had a beak like a bird. The scientists struggled to classify the platypus. It did not fit with their knowledge of how the animal kingdom was organised.

---

Getty Images/Jason Edwards

## Living world – Stage 4

### Key knowledge

- Classification helps order the diversity of living things so they can be better described, remembered and identified.
- The similarities and differences in structural features between organisms is the basis for classifying them into different groups.
- Plants and animals can be easily identified by using simple dichotomous keys.
- Specific structural features are used to group organisms into their kingdoms.
- Bacteria, fungi, plants and animals are four of the main kingdoms.
- Technology and scientific evidence have given rise to a change in classification hierarchy.



**ACTIVITY SHEET**  
CAT with rubric: Leaf classification

### CULMINATING ASSESSMENT TASK

#### Leaf classification

Take photos of 10 leaves from different plants that are found in your area. Create a digital presentation of the 10 leaves. Consider how you will present your work, who the audience will be and what your teacher wants you to show. In your presentation:

- **describe** each leaf and insert a photo
- **identify** 10 features of the leaves that you can use to classify them (look at similarities and differences)
- **construct** a dichotomous key to classify the leaves
- if you can, **identify** the common name and scientific name for each plant from which you collected the leaves
- **examine** the scientific names of the plant or leaves and evaluate whether they are suitable.

**WORKSPACE**

What do you already know about classification?

## What do you already know about classification?

You probably know more about classification than you think. In the cutlery drawer in your kitchen, are the knives, forks and spoons grouped together? This is an example of classification. But why do we classify? By the end of this chapter, you should be able to give a clear explanation to this question.

Find out what you already know about classification by completing the **KWL** chart in the workspace. This chart will help you organise what you already **Know**, and what you **Want** to know. At the end of the chapter, complete the final column with what you have **Learnt**.

# 4.1 Classifying living things

Over the course of history, many people have tried to make more sense of living things by classifying them into smaller groups based on similar features.

Living things were first classified by Greek philosopher Aristotle about 2500 years ago. He classified living things as either plants or animals. He then subdivided animals into land dwellers, water dwellers and air dwellers.

The indigenous people of the Arctic have lived for thousands of years on the food provided by the land and sea. They have developed a detailed and complex system of **classification** of the native animals and plants, as well as a deep understanding of the environment in which they live. This enables them to be successful hunters, gatherers, fishers and reindeer herders. Each generation passes this knowledge on to their children, who in turn are able to live off the land.

### classification

the grouping of things according to how similar they are



Glow Images/White Fox

◀ **Figure 4.1**

The indigenous people of the Arctic pass their knowledge on to the next generation.

Figure 4.2 ▼

*Kindal kindal* – the macadamia nut has one of the hardest shells.



Shutterstock.com/HamsterMan

***kindal kindal***

Aboriginal name for macadamia nut

***warrakan***

Aboriginal name for bird/large birds

***djikay***

Aboriginal name for small birds

***lidjilidji***

Aboriginal name for finches

## Aboriginal classification systems

Australian Aborigines traditionally have a close relationship with the land. It is the source of their shelter and food, so they understand that it needs to be treated with respect. They also have a detailed knowledge of the plants and animals around them, and how these can be used to assist them with survival. Although there are many plants and animals in Australia, Aboriginal people usually only give a specific name to those that have a special use or significance to them.

The macadamia nut formed an important part of the Aboriginal diet and it was given the name ***kindal kindal***. The nuts from the macadamia tree have one of the hardest shells of any nut. They are difficult to crack without smashing their contents. Queensland Aborigines made special 'nutting stones', which consisted of pieces of rock with a number of depressions ground into them. Nuts were placed into the depressions and cracked with a blow from a stone.

The Yolngu people live on Milingimbi Island, just off the coast of Arnhem Land in far north Australia. They too have developed a highly structured system of classifying plants and animals, in which animals showing similar features are grouped together. Birds are placed in a group called ***warrakan***. Within this group is a subgroup for small birds, called ***djikay***. Within this subgroup is another smaller group for finches, called ***lidjilidji***. This system of classification is interesting because each larger group is made up of all the subgroups below it.

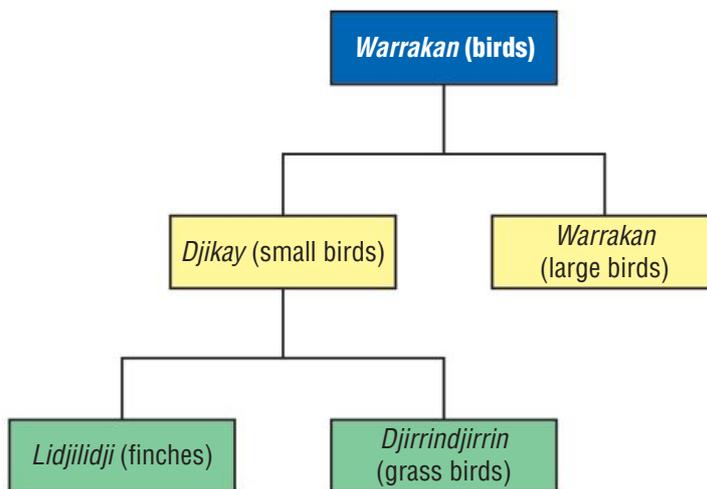


Figure 4.3 ►

The Yolngu system for classifying birds

***beri-beri***

a deficiency in vitamin B1, which results in inflammation of the nerves and heart failure



### It's all in the preparation!

The nardoo plant (Aboriginal for clover-fern) is a favourite food among Aboriginal people. Nardoo seeds are ground and roasted, and then used to make seedcakes. Roasting the seeds is essential – to ensure the protein thiaminase becomes inactive. Thiaminase removes thiamine (vitamin B1) from the body, leading to the disease ***beri-beri***. During their epic journey from Melbourne to the Gulf of Carpentaria in 1861, explorers Burke and Wills tasted nardoo seedcakes given to them by Aboriginal people. They liked them so much that they made them for themselves, but unfortunately they neglected to roast the seeds. As a result of eating a lot of seedcakes, they became very weak and eventually died of starvation.

## Living or non-living?

Look at Figure 4.4, a photo of ‘dog vomit’ slime mould (*Fuligo septica*) on a fallen tree. Is the substance living or non-living? Scientists have created a list of criteria to determine whether something is living or non-living. If the answer to each criterion is yes, the object is living.

- Is it made up of cells (unicellular, such as an amoeba; or multicellular, such as a frilled-necked lizard)?
- Is it able to move? (This can be movement within the cell known as **cytoplasmic streaming** – see weblink ‘Cytoplasmic streaming’.)
- Does it respond to stimuli (such as light, temperature or touch)?
- Does it grow and develop?
- Does it produce waste?
- Does it **respire**?
- Does it require water and food in some form?
- Can it reproduce itself to produce more individuals like itself?



Getty Images/John Wright

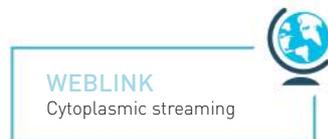


### cytoplasmic streaming

the movement of the contents of a living cell

### respire

the cellular process where oxygen and glucose react to produce carbon dioxide and water vapour; energy is released in the reaction



◀ **Figure 4.4**  
Is this living or non-living?



### Amazing slime

Some Japanese researchers claim that slime moulds can find the shortest way around a maze made of **agar** to find food.

### agar

a jelly-like substance, derived from seaweed, that provides a surface on which to grow micro-organisms



**WORKSPACE**

What have you learnt? 4.1

**QUESTIONS 4.1**

**What have you learnt?**

**Remembering**

- 1 **Identify** the eight features of living things.
- 2 **Identify** one Aboriginal classification system and **explain** the basis on which it classifies living things.

**Understanding**

- 3 **Outline** some of the reasons why Australian Aborigines classify and name plants and animals.
- 4 **Compare** the difference between unicellular and multicellular organisms and provide an example.

**Applying**

- 5 **Account** for why Aristotle's classification system proved to be inadequate.
- 6 Viruses can only survive and reproduce if they are inside a living cell of a host organism. **Identify** whether viruses are living or non-living. **Justify** your answer.
- 7 You have just finished a voyage to a far-away planet where you made the following observations of a blue slime-like mould on a rocky outcrop.
  - 1 When a torch is shone on the object, it moves to find darkness.
  - 2 Over a period of 3 weeks, there has been no sign of it consuming food and thus no waste has been identified
  - 3 Searching the planet, we have found another area that also shows signs of the object.
  - 4 There appears to be no water in gas or liquid form on the planet; the atmosphere consists largely of carbon dioxide and smaller amounts of nitrogen, hydrogen and methane.
  - 5 A small sample of the mould viewed under the microscope indicates that the object is made of numerous cells.

**Deduce** from these observations whether the object is living or non-living. **Explain** your reasoning.

**Evaluating**

- 8 Indigenous knowledge is usually passed from one generation to the next by storytelling. There is an old African proverb that says, 'When a knowledgeable old person dies, a whole library disappears.' **Interpret** what you think this statement means.

**Creating**

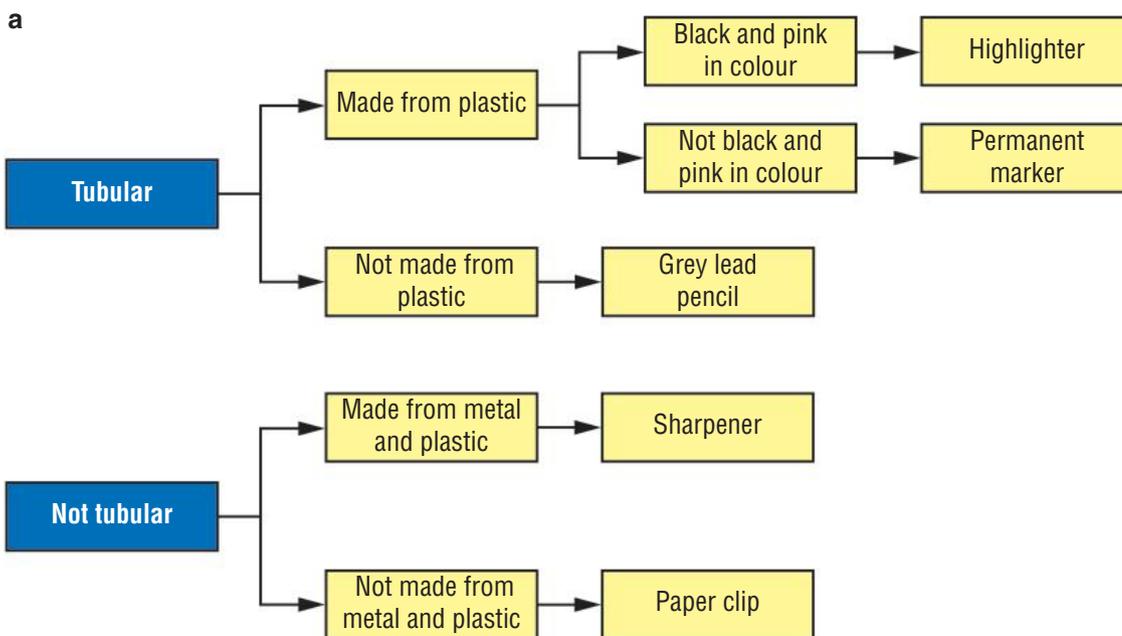
- 9 Start a mind map that **summarises** the new information that you have learnt. As you progress through this chapter, you will add more information to this mind map.

## 4.2 Dichotomous keys

There are many different ways in which a scientist can classify. The easiest way to represent a lot of information is by using a key. Keys can be pictorial, or written as a flowchart or table. The most common type of key is a **dichotomous key**. The key is dichotomous because at each step of the key there are two (di-) choices (-chotomy).

There are two main types of dichotomous key – flowchart or tabular (also known as sentence keys). Both consist of a series of two-part statements that describe features of the things being classified. At each step of the dichotomous key, you are presented with two choices. As you make a choice about a particular structural **characteristic**, you are led to a new branch of the key. Eventually, you will be led to the name of the living or non-living thing you are trying to identify.

Figure 4.5 shows a collection of items from a student's pencil case and two ways of classifying these items: a flowchart dichotomous key and a tabular dichotomous key.



**b** Starting by answering the first question, then follow the steps to label each item.

- |                                      |                  |
|--------------------------------------|------------------|
| 1 a Tubular                          | Go to 2          |
| b Not tubular                        | Go to 3          |
| 2 a Made of plastic                  | Go to 4          |
| b Not made of plastic .....          | Grey lead pencil |
| 3 a Made of metal and plastic .....  | Sharpener        |
| b Not made of plastic .....          | Paper clip       |
| 4 a Black and pink in colour .....   | Highlighter      |
| b Not black and pink in colour ..... | Permanent marker |

### dichotomous key

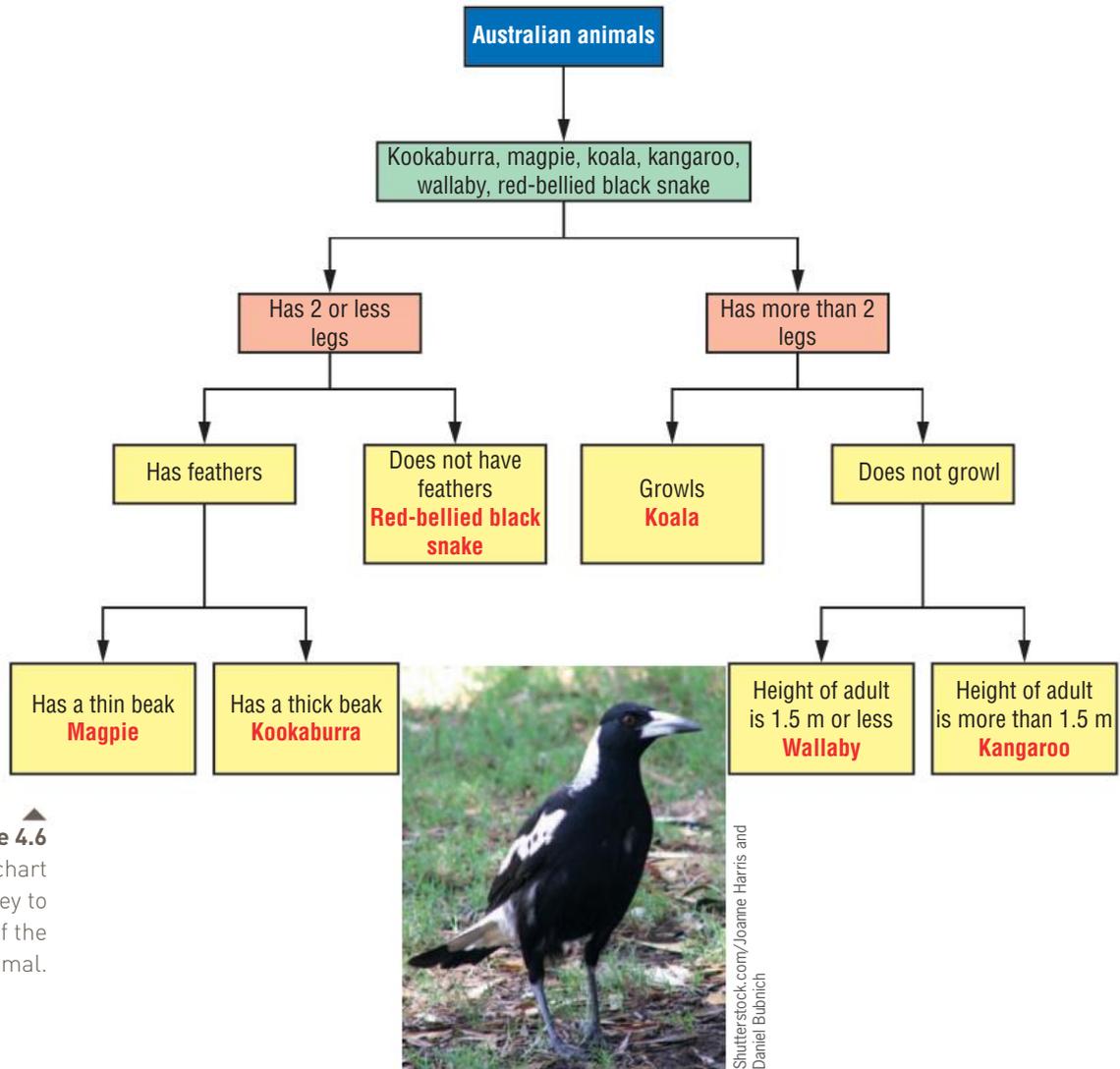
a tool that is used to organise or classify information; at each branch, there is a two-part statement

### characteristic

a feature of an organism

◀ **Figure 4.5**  
Classifying items in a pencil case using a **a** flowchart dichotomous key and **b** tabular (sentence) dichotomous key

To determine the name of the organism in Figure 4.6, we will use the key shown. Our main heading is 'Australian animals'. The first question posed is 'Does it have two or fewer legs, or more than two legs?' By answering this question, we follow the key down to the next question: 'Does it have feathers or not?' Continue down the key. What animal is it? As a challenge, try to convert the flowchart key into a tabular (sentence) key. Remember to only use structural features.



**Figure 4.6**  
Use this flowchart dichotomous key to determine the name of the Australian animal.

## Constructing a dichotomous key

When constructing a dichotomous key, first find a single distinguishing feature that will divide the group into two. Continue to separate each of the groups until each object has its own separate set of features.

A tabular dichotomous key is usually shown as a set of numbered choices, with each choice having two alternatives. Depending on the choice you make, you will be directed to another part of the key. Continue doing this until you end up at a name. For example:

- 1 a Body is a round shape                      Go to 2
- b Body is an elongated shape                Go to 3

It is often easier to create a flowchart key first (Figure 4.6) and then set the information into a tabular dichotomous key format, by following these steps.

- 1 Start at the first choice and label this 1a and 1b.
- 2 Move down to the left-hand branch of the flowchart and label this 2a and 2b.
- 3 Move along the same row to the right branch and label this 3a and 3b.
- 4 Continue doing this until you have finished. Remember to always start from the left as you move down a row.
- 5 List the choices down your page and provide the headings. For example:
  - 1 a Has two legs or less
  - b Has more than two legs
  
  - 2 a Has feathers
  - b Has scales
- 6 Next to each choice, write either which choice to go to next or the name of the organism. For example:
 

1 a Has two legs or less	Go to 2
b Has more than two legs	Go to 3
2 a Has feathers	Go to 4
b Has scales	Red-bellied black snake



#### ANIMATION

Constructing a dichotomous key

### EXPERIMENT 4.1

## Constructing a dichotomous key

### Aim

To create a dichotomous key to identify a range of lollies.

Possible risks	Safety precautions
Equipment and desks in the science laboratory may be contaminated with chemicals.	Do not eat any of the lollies.

### Materials

- a variety of different lollies for each group of students; for example, one piece of each of Jaffa, Lifesaver, bubble gum, chewing gum, sour snake, Kit Kat, jelly baby.

### Method

- 1 Using the example and process given above, create a dichotomous key for your lollies.
- 2 Share your key with the rest of the class.



#### WORKSPACE

Constructing a dichotomous key



#### ACTIVITY SHEET

Key to identify your clothes

◀ EXPERIMENT 4.1

**Results**

- 1 Did all the class produce the same key?
- 2 Try another group's key to classify your lollies. Did it work just as well? If not, explain why.
- 3 Use your key to classify a tic tac. What happens? Why?

**Conclusion**

- 4 Write a set of rules for using a dichotomous key.



**WORKSPACE**  
A dichotomous key to identify insects

EXPERIMENT 4.2

**A dichotomous key to identify insects**

Each member of the class is to bring in a photograph of two different insects. Remember, insects have six legs and spiders have eight legs.

Possible risks	Safety precautions
Some insects may bite or be poisonous.	Do not handle the insects.



**WEBLINK**  
Online insect key

**Materials**

- online dichotomous key
- photos of insects

**Method**

- 1 Work in groups of four. Each group should have eight insects.
- 2 Use the online key to identify the order to which each insect belongs.

*Hint:* The key is dichotomous because at each level it has two choices. You must select one of the two choices and then go to the part of the key indicated by that choice. For example, if your insect has eyes, then proceed to level 4 (missing out levels 2 and 3). That is:

- |                               |               |
|-------------------------------|---------------|
| 1 a Insect does not have eyes | Go to level 2 |
| b Insect has eyes             | Go to level 4 |

- 3 Using a photo of each insect, note the order to which it belongs. Present your results on a poster or in a multimedia presentation.

## QUESTIONS 4.2

## WORKSPACE

What have you learnt? 4.2



## What have you learnt?

### Remembering

- 1 **Define** the term 'classification'.
- 2 **Recall** two ways of representing a dichotomous key.

### Understanding

- 3 **Outline** what a dichotomous key is.
- 4 **Account** for the reason why a key is described as dichotomous.
- 5 Could you identify a fish by using a key that had been produced to identify insects? **Explain**.

### Applying

- 6 Consider the following list of organisms:  
platypus, gum tree, koala, bottlebrush, tea tree, kangaroo  
Use your knowledge of classification to **apply** a classification system for these objects.

### Evaluating

- 7 **Evaluate** whether a flowchart or a tabular dichotomous key is best to use to classify objects.
- 8 Find two places in your home where some sort of classification system is used. **Explain** what the system is, and how it assists in organising the items. Can you think of a better system to use?
- 9 **Evaluate** what are the best types of features on which to base a classification system.

### Creating

- 10 Add a branch to your mind map and name it 'dichotomous key'. Add information to this branch that **demonstrates** what you have learnt and understand.

# 4.3 Linnaean classification system

## A little bit of history

Carl von Linné was born on 23 May 1707, at Stenbrohult, in southern Sweden. His father, a Lutheran pastor, was a keen gardener and young von Linné showed a deep love of plants from a very early age. He disappointed his parents by showing no desire for the priesthood; instead, he entered the University of Lund in 1727 to study medicine. A year later, he transferred to the University of Uppsala, the most prestigious university in Sweden. Most of von Linné's time at Uppsala was spent collecting and studying plants. Despite being poor, he organised expeditions to Lapland in 1731 and to central Sweden in 1734 to study plants. In 1735, he published the first edition of his classification of living things, the *Systema Naturae*, for which he corresponded with Europe's great botanists. In 1741, he gained a professorship at Uppsala. Here he restored the University's garden (arranging the plants according to his system of classification). Carl von Linné Latinised his name to Carolus Linnaeus. He is considered to be the father of **taxonomy**.



PhotoLibrary.com/The Bridgeman Art Library

**WEBLINK**  
*Systema Naturae*

**ACTIVITY SHEET**  
More about Linnaeus's work

**VIDEO**  
Interview with a taxonomist

### taxonomy

the science of classification and naming living things

**Figure 4.7** ▶

Carolus Linnaeus

### scientific name

the Latin name given to classify each organism

### universal

across the whole world



## The Australian connection

Linnaeus arranged to have 19 of his students sent on trade and exploration voyages to all parts of the world. His most famous student, Daniel Solander, was the naturalist on Captain James Cook's first round-the-world voyage. Solander brought back the first plant collections from Australia and the South Pacific to Europe.

## Why do we use the Linnaean classification system?

The word for 'cat' is different in different languages: *katze* in German, *chat* in French, *gatto* in Italian, *katinas* in Lithuanian and *kath* in Welsh. It makes it difficult to talk about cats if you are not speaking the same language. However, if you ask an English, German, French, Italian, Lithuanian or Welsh scientist what the **scientific name** for a cat is, the answer will be the same: *Felis catus*.

Carolus Linnaeus invented a system of classification that is **universal** – it is used all over the world. It ensures that scientists from any country can communicate easily about any living thing.



**Figure 4.8** ▲

A cat is a *Felis catus* in any language.

Shutterstock.com/Peter Radacsi

## The seven levels of classification

In the Linnaean system of classification, each time the living things were grouped, the amount of similarity between the members of the group increased. Each living thing was first placed into a kingdom based on its basic physical characteristics. Members of each kingdom were then further grouped, the more similar members being placed into the same group or phylum. Members of each phylum were then grouped again, the more similar members being placed into the same group or class. There are seven levels of classification of living things: **kingdom**, **phylum** (animals) or **division** (plants), **class**, **order**, **family**, **genus** and **species**.

Tables 4.1 and 4.2 show examples of how the Linnaean method of the seven levels of classification are used to classify humans and an Australian river red gum.

**Table 4.1** ▲

Classification of humans (*Homo sapiens*)

Level of classification	Features	Organisms in group
Kingdom Animalia	Complex, multicellular organisms that eat other living things	Earthworms, sponges, beetles, frogs, birds, whales, cows, dogs, horses, lemurs, baboons, monkeys, apes, humans
Phylum Chordata	Possess a backbone	Frogs, birds, whales, cows, dogs, horses, lemurs, baboons, monkeys, apes, humans
Class Mammalia	Possess hair, feed their young on milk	Whales, cows, dogs, horses, lemurs, baboons, monkeys, apes, humans
Order Primates	Eyes point forwards, reduced number of teeth, nails instead of claws at the end of fingers and toes	Lemurs, baboons, monkeys, apes, humans
Family Hominidae	<b>Bipedal</b> , large brain	Apes, humans
Genus <i>Homo</i>	Small teeth and jaws, able to make and use tools, able to speak	Humans
Species <i>sapiens</i>	Small teeth and jaws, able to make and use tools, able to speak	Humans

### kingdom

a group of similar phyla or divisions

### phylum

a group of similar animal classes

### division

a group of similar plant classes (used instead of phylum)

### class

a group of similar orders

### order

a group of similar families

### family

a group of similar genera

### genus

a group of similar species

### species

a group of organisms that are capable of interbreeding and producing fertile offspring

**ACTIVITY SHEET**  
A dog by any other name



### bipedal

able to walk on two feet

ACTIVITY 4.1

## Seven levels

Create a mnemonic to help you remember the order of levels of classification. The funnier you make it, the easier it will be to remember! KPCOFGS ... Koalas pour confetti on fluffy green shoes!



## Bizarre names

Some of the more bizarre scientific names that have been given to organisms include *Pieza kake* (a Brazilian fly), *Agra phobia* (a ground beetle), *Ytu brutus* (a water beetle), *Verae peculya* (a wasp), *Phthiria relativitae* (fly), *Heerz tooya* and *Heerz lukenatcha* (two species of closely related wasps).

Table 4.2 ▲

Classification of river red gum (*Eucalyptus camaldulensis*)

Level of classification	Features	Organisms in group
Kingdom Plantae	Complex, multicellular organisms that produce their own food by photosynthesis	Eucalypts, pine trees, pomegranates, guavas, grasses, ferns, mosses, green algae
Class Magnoliopsida	Dicotyledons – have two seed leaves (see Activity sheet ‘Monocot or dicot?’)	Eucalypts, pomegranates, guavas
Order Myrtales	Woody plants, often with flaky bark	Eucalypts, pomegranates, guavas
Family Myrtaceae	Leaves contain essential oils; leaves are evergreen	Eucalypts, guavas
Genus <i>Eucalyptus</i>	Gumnuts covered by a woody cap	Eucalypts
Species <i>camaldulensis</i>	Can grow up to 45 m tall, pointed gumnut	River red gums



ACTIVITY SHEET  
Monocot or dicot?

You will notice in Table 4.1 (page 91) that the genus name for humans is *Homo*, and the species name is *sapiens*. The scientific name for humans is made up of the genus name together with the species name – *Homo sapiens*. In Table 4.2, you can see that the genus name for the river red gum is *Eucalyptus* and the species name is *camaldulensis*, so its scientific name is *Eucalyptus camaldulensis*. This two-word naming system for all species is known as **binomial nomenclature**.

**binomial nomenclature**  
a two-word naming system



Shutterstock.com/John Carnemolla

◀ **Figure 4.9**  
*Eucalyptus camaldulensis*

There are some important scientific **conventions** you need to know about when using binomial nomenclature.

- These names are Latinised so they are shown in *italics*.
- The genus name always begins with a capital letter and the species name is always lower case.
- A genus name may be abbreviated to its first letter, such as *E. camaldulensis*, if it has already been spelled out in full in a piece of scientific writing.

#### conventions

the rules by which things are usually done

## Kingdom level

In Linnaeus' time, living things were first grouped according to whether they were plant or animal. Plants were classified into the kingdom Plantae, and animals into the kingdom Animalia. However, once microscopes were invented, scientists were able to see the cells of living organisms. It became apparent that it was not a straightforward matter of classifying living things as either plant or animal.

In 1866 a third kingdom, Protista, was proposed. This kingdom contained organisms made up of only one cell – single-celled organisms. The modern system of classification divides all organisms into six kingdoms based on how similar they are to one another (see Table 4.3, page 94). The more similar the organisms, the more closely related they are thought to be.

Organisms are classified into kingdoms according to:

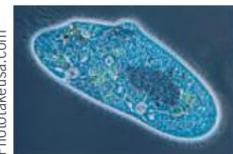
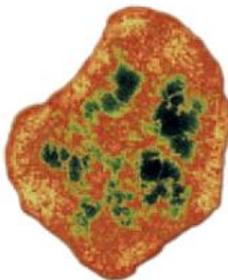
- the number of cells that make up the organism
- how organised or complex their cell or cells are
- how they gain their nutrition.

Refer to Chapter 3 to review the structural differences between the cells of the six kingdoms.

**WEBLINK**  
The animal kingdom



**Table 4.3** ▲  
The six kingdoms

Kingdom	Features	Example
Plantae	<ul style="list-style-type: none"> <li>Complex, multicellular plants and algae</li> <li>Gain their nutrition through photosynthesis</li> </ul>	 <p>Alamy/Jack Cox – Imags of Nature</p> <p>Acacia trees, eucalypts, tea trees, banksias</p>
Animalia	<ul style="list-style-type: none"> <li>Complex, multicellular</li> <li>Gain their nutrition through ingesting other living organisms</li> </ul>	 <p>Shutterstock.com/Susan Flashman</p> <p>Eagles, kangaroos, cows, snakes</p>
Fungi	<ul style="list-style-type: none"> <li>Complex, multicellular</li> <li>Gain their nutrition through breaking down or decaying other organisms</li> </ul>	 <p>Shutterstock.com/Aleks.k</p> <p>Mushrooms, toadstools</p>
Protista	<ul style="list-style-type: none"> <li>Complex, single-celled organisms with a nuclear membrane (that is, their cells are organised)</li> </ul>	 <p>Photoblibrary.com/Phototakeusa.com</p> <p><i>Paramecium aurelia</i></p>
Archaeobacteria	<ul style="list-style-type: none"> <li>Simple, single-celled organisms that live in the absence of oxygen (<b>anaerobic</b>)</li> <li>Live in extreme environments such as volcanic vents, salt pans, the Dead Sea and hot springs</li> <li>Can make or seek their nutrients for energy</li> </ul>	 <p>Visuals Unlimited, Inc./Dr. Terry Beveridge</p> <p><i>Methanogen archaee methanococcus</i></p>
Bacteria	<ul style="list-style-type: none"> <li>Simple, single-celled organisms that are genetically different from archaeobacteria</li> <li>Many cause disease</li> <li>Can make or seek their nutrients for energy</li> </ul>	 <p>Science Photo Library/Hergen Berger</p> <p><i>Clostridia</i> (tetanus and gangrene), <i>Streptococci</i> (scarlet fever, pneumonia), <i>Spirilla</i> (cholera)</p>

**anaerobic**  
without oxygen

## Changes to the classification system

Since the time of Aristotle, vast changes have occurred to the way scientists classify living organisms. There have been huge leaps in scientific understanding and major advances in technology. This has meant that the number of kingdoms scientists can identify has increased from two (animals and plants) to six, and the Linnaean system is now used to classify the natural world.

However, even today, some living things do not comply with these rules. Consider slime moulds (*Physarum polycephalum*) and Euglenas. Slime moulds were originally classified into the kingdom Fungi; however, they also have some features of the kingdom Protista. The body of slime moulds is not divided into separate cells, which means they are unicellular, like all Protists. However, slime moulds have the ability to cluster together and act as a multicellular organism, unlike other Protists. Slime moulds eat fungal spores and bacteria and move by flowing across a surface. When food becomes scarce, the slime mould will develop fruiting bodies that produce spores, like members of the Fungi kingdom do. When conditions become more favourable, the spores germinate to produce more slime moulds. Further research on their cell structure will help to identify which kingdom they best fit, or whether a new kingdom must be created for these unique organisms.

The genus *Euglena* includes a single-celled aquatic organism that can reproduce by splitting in two. *Euglena* can eat food as animals do, but when exposed to light it can also produce its own food by photosynthesis. According to the Linnaean classification system, this unusual set of characteristics means that *Euglena* is neither a plant nor an animal. Instead it has been placed in the diverse kingdom of Protista. Some scientists are arguing for a new kingdom (Excavata) to help solve the Euglena problem.



Science PhotoLibrary/Eye of Science

▲ **Figure 4.10**

The slime mould (*Physarum polycephalum*) is hard to classify because it has features that fit both kingdoms Fungi and Protista.



Science Photo Library/Aurelien Colette, Mona Lisa Production

◀ **Figure 4.11**

*Euglena* is neither a plant nor an animal, which makes it hard to classify.



**WORKSPACE**

What have you learnt? 4.3

**QUESTIONS 4.3**

**What have you learnt?**

**Remembering**

- 1 **Define** 'binomial classification'.
- 2 **Recall** the scientific name of humans.
- 3 **Identify** the seven levels of classification in order of increasing similarity.

**Understanding**

- 4 **Describe** one advantage of the Linnaean classification system.
- 5 **Explain** why the Linnaean two-kingdom system was replaced by today's six-kingdom system.

**Applying**

- 6 The first edition of *Systema Naturae* had only 13 pages. The 13th edition was published in 1770 and had 3000 pages. **Propose** why the book increased in size so much.
- 7 You think that you have stumbled upon a new organism when you were exploring the outback of Australia. When reviewing the classification keys, you have been unable to identify a species name. Thus you decide to go back to the start and determine the kingdom in which it should be classified. You have observed and taken samples to identify some key features. Your most significant observation is:

'The organism walks on four legs and appears to prey on ants.'

**Identify** and **justify** the kingdom to which this organism belongs.

**Analysing**

- 8 Look at the information provided in the third column of Tables 4.1 and 4.2. **Account** for the types of features used.
- 9 *Panthera leo* is the scientific name for lion.
  - a **Identify** the genus.
  - b Refer to Table 4.1. Determine the levels of classification into which lions and humans both fit.

**Evaluating**

- 10 **Evaluate** whether the Linnaean classification system benefits scientists across the world.

**Creating**

- 11 **Demonstrate** what you have learnt in this section by adding to your mind map.

## 4.4 Kingdom Animalia

All animals fall into the kingdom Animalia. Animals are first separated according to whether they have a backbone. An animal that has a backbone is known as a **vertebrate**. For example, whales, boars, brumbies and wombats are vertebrates with an internal skeleton (**endoskeleton**). An animal that does not have a backbone, such as a King Island crayfish, is known as an **invertebrate**. Invertebrates have an external skeletal system – an **exoskeleton**.

### Vertebrates

The classes of vertebrates are Fish, Amphibia, Reptilia, Aves and Mammalia.

#### The fish classes

Technically, **Fish**, or Pisces, is a superclass, which can be divided into the three subclasses **Agnatha** (jawless fish), **Chondrichthyes** (cartilaginous fish) and **Osteichthyes** (bony fish). Each subclass of fish has its own characteristics.

Jawless fish:

- do not have scales; their bodies are covered in slime
- breathe oxygen through gills; they do not have lungs
- are **ectothermic** (their body temperature changes according to the environment)
- have vertebrae made of cartilage
- have sharp teeth but lack a jaw; they consume food by shredding it.
- lay eggs that do not have a shell.

Cartilaginous fish, which include all sharks, skates and rays:

- have a jaw
- are covered in scales
- breathe oxygen through gills
- are ectothermic
- have vertebrae and skeleton made of cartilage
- have paired fins
- give birth to live young or produce an egg surrounded by a case.

Bony fish:

- have a jaw
- are covered in scales and a thin layer of mucus
- breathe oxygen through gills, which in most species are covered by an **operculum**
- are ectothermic
- have vertebrae and skeleton made of bone
- have paired fins
- give birth to live young or allow offspring to develop externally.



Getty Images/Marevision



Getty Images/Gerard Soury

#### endoskeleton

an internal skeletal system

#### exoskeleton

an external skeletal system

#### invertebrate

an organism lacking a spinal column or vertebrae

#### vertebrate

an organism with a spinal column or vertebrae

#### Fish

a class of vertebrates that includes all fish

#### Agnatha

a subclass of fish known as jawless fish

#### Chondrichthyes

a subclass of fish known as cartilaginous fish

#### ectothermic

when an organism's body temperature changes according to the environment

#### Osteichthyes

a subclass of fish known as bony fish

#### Figure 4.12

The lamprey is an example of a jawless fish.

#### VIDEO

Walking shark discovered

#### Figure 4.13

The draughtboard shark is an example of a cartilaginous fish.

#### operculum

a flexible protective covering over the gills of most bony fish



**WORKSPACE**  
Cartilaginous fish

**ACTIVITY 4.2**

**Cartilaginous fish**

- 1 **Investigate** which species of cartilaginous fish produce live young and which species produce eggs.
- 2 Make a table to **summarise** your findings.

**Amphibia**

a class of vertebrate that includes all amphibians

**metamorphosis**

the change of form during development from larva to adult, such as from tadpole to frog



**Long fish!**

According to the *Guinness World Records*, the oarfish is the longest bony fish alive, reaching up to 17 m in length. It is usually only seen when it washes up dead after large storms. In February 2010, it was sighted off the Gulf of Mexico. Now scientists think that its natural habitat is tropical waters, including off the coasts of Australia.



Getty Images/Mike Hargreaves



Shutterstock.com/Eduard Kyslynsky

**Figure 4.14**

The green tree frog belongs to the class Amphibia.

**Amphibia**

The class **Amphibia** includes all frogs, toads, salamanders and newts. Amphibia:

- are ectothermic
- have moist skin that can absorb water and oxygen
- do not have scales
- have a backbone and usually have four legs
- spend most of their time in water; however, they have lungs, which allow them to spend time on land
- lay eggs (containing no shell)
- change form during their lifetime (undergo **metamorphosis**).

## Reptiles

The class **Reptilia** includes lizards, turtles, crocodiles and snakes.

Reptilia:

- have scales
- are ectothermic
- have claws on their toes, unless they do not have legs (such as snakes)
- lay eggs on dry land.



Getty Images/Jason Isley/Scubazoo

### Reptilia

a class of vertebrates that includes all reptiles

#### VIDEO

The Olive Ridley turtles



#### Figure 4.15

The Olive Ridley sea turtle is a reptile.

## Aves

The class **Aves** includes all birds, including the flightless penguins, emus and cassowaries.

Aves:

- are **endothermic** (they have a constant body temperature)
- are covered in feathers to insulate and usually allow flight
- have a backbone and two legs
- possess lungs
- lay nutrient-rich eggs with an external shell.



Shutterstock.com/Bill Perry

#### ACTIVITY SHEET

Class Aves



### Aves

a class of vertebrate that includes all birds

#### endothermic

can regulate body temperature by generating its own heat

#### Figure 4.16

The emu is the largest bird in Australia. It belongs to the class Aves.

## Mammalia

There are three different subclasses in the class **Mammalia**: **placental mammals**, **marsupials** and **monotremes**. All mammals are **warm-blooded** (can generate their own heat), have a fur covering and feed milk to their young. However, the three subclasses have their own specific characteristics.

Organisms such as koalas, wombats and possums are known as marsupials. These organisms give birth to underdeveloped live young that mature, feeding on milk, in the mother's pouch for several months before they are strong enough to move out of the pouch and graze.



Shutterstock.com/Robyn Butler

#### Figure 4.17

A wombat is a marsupial.

### Mammalia

a class of vertebrates that includes all mammals

#### placental mammals

the largest subclass of mammals

#### marsupials

a subclass of mammals

#### monotremes

a subclass of mammals

#### warm-blooded

an organism that generates its own heat to regulate its body temperature



**WORKSPACE**  
Pouches



**WEBLINK**  
Newborn baby grey kangaroo

**ACTIVITY 4.3**

**Pouches**

**Compare** and **contrast** the features of the pouch of a bandicoot and wallaby.

**cloaca**

the cavity opening that releases excretory and reproductive products

**defecatory**

removal of faeces

**Figure 4.18** ▶

The echidna is a monotreme.

Shutterstock.com/clearviewstock



Monotremes have characteristics that are common to both mammals and reptiles. There are only two different monotremes in the world and both are native to Australia – the echidna and the platypus. These animals, like all mammals, are warm-blooded, have a fur covering and feed milk to their young. However, they do not give birth to live young. Monotremes lay eggs with an exterior shell, as reptiles do. They only have one opening, the **cloaca**, which their urinary, **defecatory** and reproductive systems feed into. This is also similar to reptiles.

Placental mammals are the largest subclass of mammals, with approximately 4000 named species. Species include large animals such as the elephant and

whale through to the smallest animals such as the spinifex hopping mouse.

Placental mammals give birth to live young. The young have been nourished inside the mother's **uterus** by the specialised sac, the **placenta**. Placental mammals have three openings for the urinary, defecatory and reproductive systems.

**uterus**

an organ in female placental animals in which the embryo develops

**placenta**

a specialised sac that nourishes the developing foetus in placental mammals

**Figure 4.19** ▶

The spinifex hopping mouse is a placental mammal.

Getty Images/Jason Edwards



# Invertebrates

Four phyla (plural of 'phylum') of invertebrates are Cnidaria, Arthropoda, Echinodermata and Mollusca.

## ACTIVITY 4.4

### Researching invertebrates

- For each phyla of invertebrates listed above:
  - investigate** the key features for classification
  - identify** examples of three organisms.
- Construct** a table to list your example organisms and **describe** the features.

#### Extension

- Construct** a dichotomous key to classify three different invertebrate organisms.

#### WORKSPACE

Researching invertebrates



#### WEBLINK

Bug types



## QUESTIONS 4.4

### What have you learnt?

#### Remembering

- List four features of the class Reptilia.
- Define** the term 'metamorphosis'.
- Identify** the three forms of reproduction found in the class Mammalia.

#### Understanding

- Identify** the following classes of vertebrates according to these features.
  - Gills, aquatic, bony skeleton, scales
  - Lays eggs with external shell, backbone, body covered in feathers
  - Skeleton made of cartilage, gills, fins

#### Applying

- Classify** the following as being either endothermic or ectothermic: green turtle, penguin, blue whale, cassowary, brown snake, cane toad, jaguar, tiger shark, Murray cod, singing honeyeater.
- Construct** a dichotomous key to classify a sea turtle, shark and tree frog.

#### Analysing

- Distinguish** between the different types of eggs produced by the vertebrate classes.
- You are looking through a book on the fish found in Australian waters and you notice that all the sharks and rays are separate from typical aquarium fish. **Propose** a reason for this separation based on classification.

#### WORKSPACE

What have you learnt? 4.4



## 4.5 What is a species?

### fertile

able to produce offspring

### hybrid

offspring resulting from a mating between two different species

### sterile

unable to produce offspring

As shown in Tables 4.2 and 4.3, the lowest level of classification is the species level. A species is often defined as a group of organisms that is capable of interbreeding and producing **fertile** offspring.



Shutterstock.com/pa1tov

**Figure 4.20**

A liger is the result of a cross between a lion and a tiger. It is a hybrid and not a species.

In captivity, a male lion and a female tiger can interbreed and produce a **hybrid** species known as a liger (Figure 4.20). Ligers are faintly striped. They weigh approximately 450 kg and consume around 23 kg of raw meat every day. Although female ligers are fertile, male ligers are **sterile** – they cannot breed and produce offspring. So, because it is not possible to cross two ligers to produce fertile offspring, the liger is not classed as a species.

### Smaller than species

According to the Linnaean system of classification, the smallest grouping possible is species. At species level the organisms are structurally and genetically similar, enabling them to mate to produce fertile offspring. However, it is possible to further divide organisms within species into smaller groupings. Consider the domestic dog, *Canis lupus familiaris*. Dogs are a diverse species: they can be different colours, have different fur lengths and markings, and can vary greatly size and eye colour (Figure 4.21).



#### ACTIVITY SHEET

Can you name the hybrid?



#### WEBLINK

Switcheroo Zoo

**Figure 4.21**

The dog species includes many different breeds of dogs.



Shutterstock.com/cynoclub

Each type of dog has different traits, temperament and history. The dog species has been divided into **breeds**, such as beagle, Australian sheep dog, golden retriever and pomeranian. 'Breed' is a term used only for domestic animals such as cats, horses, cows and dogs. A breed comprises dogs that possess a similar appearance, temperament and behaviour. This is important if you are breeding dogs to show, or you want a dog to have certain traits. For instance, working dog breeds

**breed**  
a group of organisms from the same species that possess a similar appearance, temperament and behaviour

such as border collies and kelpies are bred specially for herding sheep and cattle. If you only breed dogs from the same breed together, you can be sure that they will **breed true** – that is, they will possess characteristics that are true to that breed. Breeding dogs of different breeds together will result in a **crossbreed**, which would display characteristics of both breeds. For example, if you were to breed a labrador and poodle, you would get a labradoodle, which would have characteristics of both parents, such as the poodle's non-shedding fur and the labrador's build.

Cats are also a domestic animal that have a multitude of breeds. Go to the 'Cats' weblink to see some of the different cats found in Australia.

## Naming new species

It is not known how many species live on Earth. What is known is that only a very small percentage of them have been studied, described and named (some estimates are at 2%). Approximately 1.2 million species within the plant and animal kingdoms have been named; 57% of these are insects, including 400 000 species of beetles, 20 000 of which are found within Australia.



Peter Halasz/Creative Commons

### breed true

offspring that result from the breeding of two purebred parents and that possess characteristics that are true of that breed

### crossbreed

offspring resulting from a mating between two different breeds

#### WEBLINK

Cats



#### Figure 4.22

The Australian bombardier beetle, *Pheropsophus verticalis*, is one of the 2500 different species of the family Carabidae.



#### WEBLINK

Top 10 list of new species

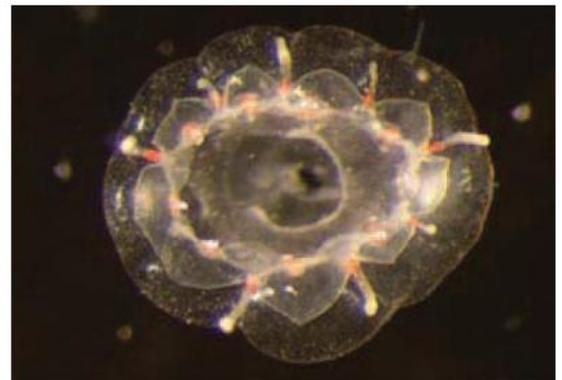


### Be careful of your enemies!

Linnaeus had a habit of naming new species of plants according to what their flower's sexual parts looked like. Johann Georg Siegesbeck, a German working at the St Petersburg Botanical Garden, was infuriated by this and tried to have Linnaeus's books banned. Linnaeus responded by finding the most ugly, smelly and small flower he could and naming the genus *Siegesbeckia*. This genus is now commonly known as the 'easy-to-ignore daisies'.

Scientists are constantly finding, studying and naming new species. In 2008, some 18 225 new species were studied, described and named. Each year scientists compile a list of the top 10 new species. Visit the weblink to see the top 10 species for this year. Try to work out what the criteria for judging were.

In 2010, scientists in Tasmania discovered a new species of jellyfish in the Derwent River. It is only a few millimetres wide and looks a little like a flying saucer. The new species has been given the name *Csiromedusa medeopolis*, meaning 'jellyfish from CSIRO' (Figure 4.23). It is so different from every other species of jellyfish that it has not only been put into a new species, or a new genus, a whole new family has also had to be made for it.



Shutterstock.com/Jiri Vaclavek

#### Figure 4.23

*Csiromedusa medeopolis* is a new type of jellyfish.



WORKSPACE

What have you learnt? 4.5

QUESTIONS 4.5

## What have you learnt?

### Remembering

- 1 **Define** the term 'species'.

### Understanding

- 2 **Propose** whether members of the kangaroo species *Macropus greyii* and *Macropus rufus* could interbreed and produce fertile offspring. **Explain** your answer.
- 3 **Distinguish** between a species and a breed.
- 4 **Identify** how scientific names are derived and the conventions used to write them.

### Applying

- 5 Search on the Internet to find the scientific names for the following organisms. Show the scientific name and the abbreviated form of that name, and **explain** how the name was chosen for that species.
  - a Sturt desert pea
  - b Firewood banksia
  - c California sea hare
  - d Spectacled bear
- 6 **Analyse** why it would be important for a farmer to breed using only one species of wheat.
- 7 **Identify** three things that you know about members of the species *Telopea mongaensis* and *Telopea aspera* just by looking at their names.
- 8 **Identify** three more interesting or bizarre scientific names and share these with the class by uploading to the class wiki. Accurately list the source of each name.

### Creating

- 9 **Outline** what you have learnt by adding new branches to your mind map.

### Reflecting

- 10
  - a Find out why Latin is the language used for naming species.
  - b **Discuss** whether you think this is a good choice of language.
  - c **Identify** where else Latin is used in science.



## Chapter review

### Remembering

- 1 **Identify** three features shared by all members of the kingdom Plantae.
- 2 **Identify** three features shared by all members of the kingdom Animalia.

### Understanding

- 3 What are two species that do not fit the Linnaean system of classification of living things? **Explain** why.
- 4 **Describe** how scientific understanding and advancement led to the change of the classification of organisms.

### Applying

- 5 Consider the list of features of living things. Based on these features, **assess** whether fire is a living thing.
- 6 **Explain** how your own name (first name and surname) could fit the rules of binomial nomenclature. How is our naming system similar to binomial nomenclature? How is it different?
- 7 **Describe** a situation in which classification affects your life.
- 8 **Explain** how the species name *Ornithorhynchus anatinus* complies with the rules of binomial nomenclature. Determine the common name of the *Ornithorhynchus anatinus*.
- 9 **Clarify** whether or not organisms in the same genus are more closely related to each other than are organisms in the same:
  - a class
  - b species.
- 10 **Identify** whether members of the species *Aspergillus niger* are more or less closely related to:
  - a *Helleborus niger*
  - b *Aspergillus clavatus*.

Questions 11–13 refer to Table 4.4.

**Table 4.4** ▲

The big cats

Common name	Scientific name
Bobcat	<i>Lynx rufus</i>
Lynx	<i>Lynx canadensis</i>
Mountain lion	<i>Puma concolor</i>
African lion	<i>Panthera leo</i>
European wildcat	<i>Felis sylvestris</i>
Tiger	<i>Panthera tigris</i>
Jaguar	<i>Panthera onca</i>

**WORKSPACE**  
Chapter 4 review



**ACTIVITY SHEET**  
Chapter 4 checklist



**REVIEW QUIZ**  
Chapter 4





- 11 **Identify** how many genera are represented in Table 4.4.
- 12 **Identify** how many different species are represented in Table 4.4.
- 13 The scientific name for the domestic cat is *Felis catus*. **Deduce** which cat(s) in Table 4.4 are most closely related to the domestic cat.
- 14 **a Discuss** why a tadpole would be difficult to classify.  
**b Identify** a way to overcome this problem.

## Analysing

- 15 **Outline** why structural features rather than colour are used to classify organisms.
- 16 **Account** for why the Linnaean system of classification does not include breeds.
- 17 Could an organism's diet be used as a basis for a classification system? **Explain** why or why not.
- 18 **a Predict** whether the current six-kingdom classification system will change in the future.  
**b Explain** your answer.
- 19 Five whys is a technique designed to **critically analyse** the real reason for a situation. It is completed by simply asking 'Why?' five times. The answer to each question will prompt you to ask another 'Why?' question. Complete a five whys beginning with the question 'Why do we need classification?'

## Creating

- 20 **a Predict** what would happen if you used the number of pages to classify the books in the school library.  
**b Propose** how you would go about finding the book you wanted.

## Evaluating

- 21 Do you think that the Linnaean system of classification and binomial nomenclature is the best system that we could have? **Clarify** your answer by giving reasons for your opinion for classifying and naming living things.

## Reflecting

- 22 Complete the final column of the KWL chart you started at the beginning of this chapter.
- 23 At the start of this chapter you were asked 'why do we classify'. With your understanding of this chapter, **explain** in your own words why classification is necessary.



# 5

## Matter

---

How does heat change the properties of matter?

---

People have been making glass for thousands of years. They have been practising glass-blowing since the time of Ancient Rome. By blowing air into heated, molten glass through a tube, glass can be formed into various shapes while it is soft. Most glass-blowing is done at temperatures as high as 900–1000°C. The heat changes the properties of the glass as it becomes molten, almost liquid. The glass can be coloured by adding different substances. Adding cobalt makes glass blue and uranium makes it green.

---

## Chemical sciences – Stage 4

### Key knowledge

- Particles are always moving and interacting.
- How particles move affects how matter behaves.
- The movement of particles increases when heat energy is added but decreases when heat energy is removed.
- The particle theory helps to explain the effect of increases and decreases in heat energy on solids, liquids and gases.
- Matter can change state when heat energy is added or removed.
- Examples of changes of state are processes such as melting, evaporation, boiling, condensation and freezing.
- When substances change state their physical properties (such as density) can change. Some of these changes can be explained using the particle theory of matter.
- Models help to explain properties of different states of matter, but their applications are restricted.

### CULMINATING ASSESSMENT TASK

## Keeping cool

Before refrigeration was invented, ice was used to keep food cool. Since ice did not stay frozen in inland Australia, people used a Coolgardie safe.

You will **investigate** this solution and then **propose** a design for an alternative cooling device and **explain** the design and function of your invention.



ACTIVITY SHEET  
CAT with rubric: Keeping cool

**WORKSPACE**

What do you already know about matter?

## What do you already know about matter?

- 1 Work in groups of three to answer these questions about water.
  - a **Describe** as many differences as you can between water in the form of a solid, a liquid and a gas.
  - b What can the solid do that the liquid and gas can't?
  - c What can the liquid do that the gas and solid can't?
  - d What can the gas do that the liquid and solid can't?
- 2 List as many solids, liquids and gases you can think of in 2 minutes.
- 3 Write five questions about matter that you do not know the answers to.

# 5.1 Matter

Everything around us is made up of **matter**. Matter is anything that has **mass** and takes up space (has a **volume**). The chair you sit on, the air you breathe, the food you eat and the water you drink are all classified as matter. This is because they all have mass (they can be weighed) and they all take up space (their volume can be measured).

Matter occurs in three different states: **solid**, **liquid** and **gas**. Each of these **states of matter** has its own set of **properties** – they look and behave differently to one another.

### EXPERIMENT 5.1

## Is air matter?

### Aim

To investigate whether air can be classified as matter

### Materials

- balloon
- 1 m piece of string
- metre ruler
- electronic balance

### Method

- 1 Use the electronic balance to find the mass of the balloon. Record the mass of the balloon in grams.

### matter

anything that takes up space and has mass

### mass

the amount of matter that makes up a substance

### volume

the amount of space something occupies

### solid

a state of matter in which the particles vibrate in fixed positions close to each other

### liquid

a state of matter in which the particles are close together but move freely past one another

### gas

a state of matter in which the particles are very far apart and move with lots of energy

### states of matter

solid, liquid and gas

### properties

the features of a substance



**WORKSPACE**  
Is air matter?

**EXPERIMENT 5.1**

- Use the ruler and the piece of string to measure the circumference of the balloon at the widest point. Record this in centimetres.
- Predict** whether the balloon will weigh more, less or the same with air in it. Record your prediction.
- Blow up the balloon, tie it off and repeat steps 1 and 2.

**Results**

- Record your results in an appropriate table containing the mass and circumference of the balloon before and after, as well as any observations you have made.

**Discussion**

- Explain** why the balloon had a greater circumference after it was blown up.
- Compare** the volume of the balloon before and after it was blown up. **Explain** the difference.
- Compare** the mass of the balloon before and after it was inflated. **Explain** the difference.
- Try to squash the balloon a little bit. Can you squash it? **Explain** your answer.

**Conclusion**

- Write a conclusion that answers the aim.

A ham sandwich is made up of bread, butter, ham and lettuce. If you looked more closely at the lettuce under a microscope, you would see that it is made of plant cells containing organelles such as a nucleus and chloroplasts (see Chapter 3). If you could zoom further and further into a cell, you would see tiny little units called **particles**. These particles are often called the 'basic building blocks' of matter. All matter, living and non-living, is made up of particles.

**particle**

a tiny unit of matter; a building block of matter



**WEBLINK**  
Zooming in

**model**

a simplification or representation of what we think is happening



**INTERACTIVE**  
Types of matter: particles

## The particle model of matter

Because particles are too small for us to see, it is hard to imagine what they look like and what they are doing. To help us with this, scientists develop **models**. A model is a simplification or representation of what we think is happening. It can be a description, a diagram, a role-play, a mathematical equation or even a physical structure. Models are useful when talking about matter because, even though we cannot see particles, it allows us to understand that they can look different and behave in different ways.

The interactive 'Types of matter: particles' uses circles of different colours and sizes to model the particles of different substances. The particles of diamond, water, and argon *look* different because diamond, water and argon are different substances. Diamond is made of diamond particles, water is made of water particles and argon is made of argon particles.

The particles are *arranged* in different ways. In diamond they are close together, in liquid water they are moving freely, and in argon gas they are much further apart. This is because the particles in solids, liquids and gases behave in different ways.

Scientists have formulated ideas to explain the behaviour of matter in its different states. The results of their experiments are summed up in the particle model of matter, which explains how the particles that make up substances behave in different situations.

The particle model of matter states that:

- all matter is made of particles, which have mass and take up space
- particles are attracted to one another
- these particles are always moving
- the more energy the particles have, the faster they will move.

In science, a **theory** is an explanation of things that happen around us from a set of related observations. These observations can be made from nature or through scientific experimentation. Scientists form hypotheses, make observations and then test them repeatedly (sometimes over a very long time). If the observations and results are the same over a range of different situations, then the hypothesis will become a theory. A theory is generally accepted to be true until evidence disproves it. Theories are used to predict future events. So far, all evidence of matter is supported by the particle model. This means that it can also be referred to as the **particle theory of matter**. The word ‘kinetic’ means movement. Because particles are always moving, the particle theory is also referred to as the kinetic theory of matter.

## Properties of matter and the particle model of matter

Solids, liquids and gases have a number of properties that can be explained using the particle model. These properties include shape, volume, flow (their ability to be poured), and ability to be **compressed**.

### Solids

Ice is water in the solid state. Ice holds its shape – until it melts. You can’t squash an ice cube, although it may start to melt. Sand is also a solid, so why doesn’t it hold its shape? Each individual grain of sand does hold its shape. The individual grains are solid.

There are attractions between particles of a solid, holding them very close to each other. The particles are moving but they do not have enough **energy** to break these attractions. The particles simply vibrate in a fixed position (see Figure 5.1). There is no empty space between the particles so they cannot be pushed any closer together. For this reason, solids cannot be compressed and will thus have a fixed volume at constant temperature. This means that if you tried to squash a solid, nothing would happen. Its volume would stay the same. A solid also keeps its shape and does not **flow** (cannot be poured).

### theory

an explanation of things that happen around us from a set of related observations

### particle theory of matter

a set of statements that explains the behaviour of particles in solids, liquids and gases

WEBLINK  
States of matter



### compressed

to be squashed to take up less space

### energy

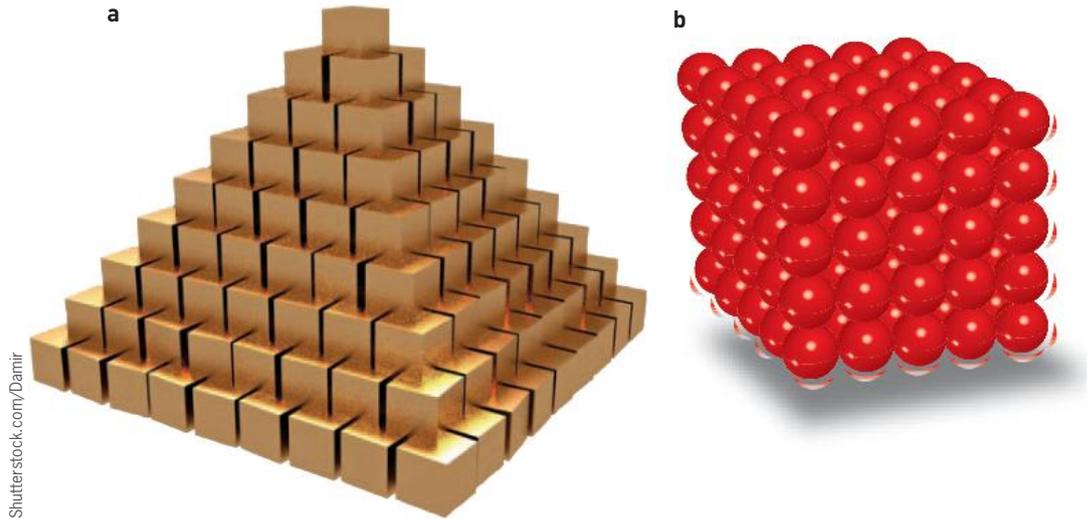
the ability to do work, such as moving or talking

### flow

able to be poured

**Figure 5.1** ▶

**a** Solids keep their shape and volume and cannot be compressed. **b** The particles stick very close together in a neat order. They just twist and wobble in their spot.



## Non-Newtonian fluids

Some materials can act like a solid and a liquid at the same time. They are called non-Newtonian fluids. You can make a non-Newtonian fluid by mixing cornflour with a little water. (Don't make it too runny.) The fluid will slip through your fingers like a liquid, but if you hit it, it will be hard like a solid!



### WEBLINK

Non-Newtonian fluids



### WORKSPACE

Creeping oobleck

### ACTIVITY 5.1

## Creeping oobleck

Oobleck is a non-Newtonian fluid made by mixing cornflour with a little water. Watch the video of creeping oobleck in the weblink 'Creeping oobleck'.

- 1 What changes would you make to the set-up to change the movement of the oobleck?
- 2 Make some oobleck and create a short movie to show how it moves.

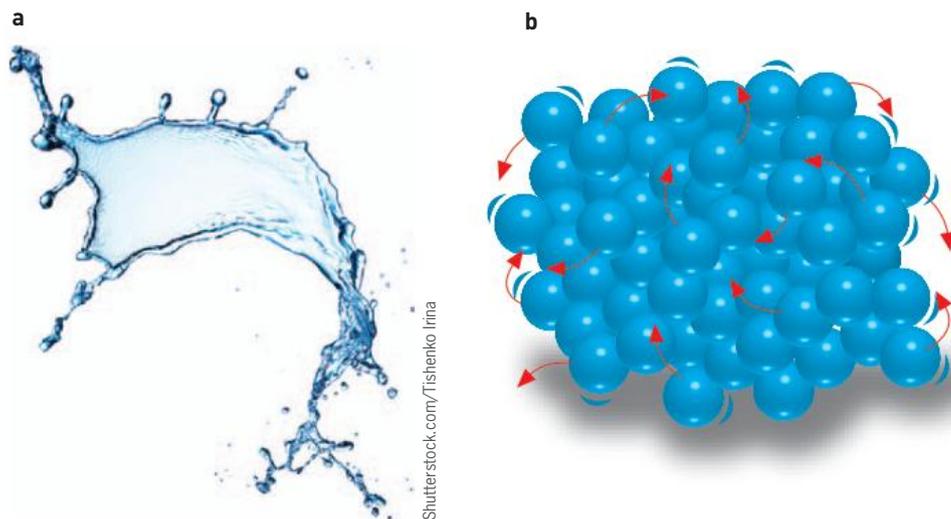


### WEBLINK

Creeping oobleck

## Liquids

To form a liquid from a solid, you must add energy. This can be done by heating the solid. The particles absorb the heat energy and move faster and faster. This gives them enough energy to break the attractions to other particles. They can then move around each other freely, so the liquid will not hold its shape. Instead, it flows to take the shape of its container. However, the particles are still as close to one another as possible – there is no space between them, so they cannot be pushed closer together. This means liquids cannot be compressed and the volume of a liquid is fixed at a constant temperature. You cannot squash a liquid into a smaller space without some leaking out.



◀ **Figure 5.2**

**a** Liquids do not hold their shape and they can flow.  
**b** The particles in a liquid stick very close together but not in a neat order. They mingle and move among each other, as well as twist and wobble.

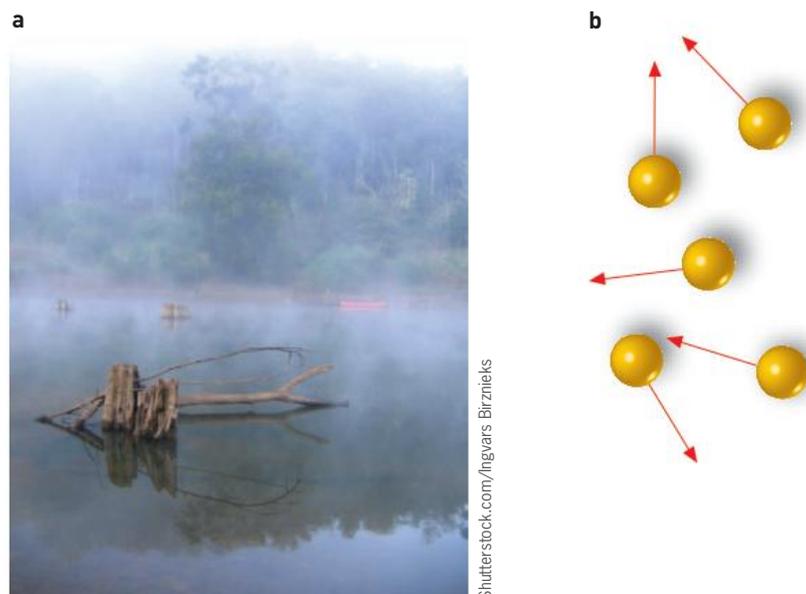
## Gases

Gases are also called **vapours**. The particles in a gas have even more energy than those in liquids. You can give these particles more energy by heating them. It causes the particles to move even more. They can move in any direction and can easily break free of each other. Particles in a gas bounce off each other and off the walls of their container. This means a gas cannot hold its shape or its volume. The shape and volume are said to be variable. A gas flows to take the shape and volume of its container.

Steam is water in the gaseous state. You can see it billowing out of a boiling kettle and spreading out to fill a room. If you left the kettle boiling, the steam would fill the room. It all came from just the water in the kettle! Gases take up all the available space because the particles have enough energy to move freely away from each other. It is possible to force gas particles back together because there is a lot of space between them. You can push the particles closer together (until they touch each other and form a liquid or solid). So, gases can be compressed.

### vapour

a gas



◀ **Figure 5.3**

**a** Gases such as this fog (water vapour) cannot hold their shape or volume.  
**b** The particles in a gas are far apart. They move freely away from each other.

**INTERACTIVE**  
 Types of matter: solids,  
 liquids, gases





**WEBLINK**

Aboriginal medicine



## Using vapours

Vapours can be used to administer medicines. All you have to do is breathe them in – no tablets getting stuck in your throat, no vile-tasting medicine. Aboriginal people knew how to extract vapours from medicinal plants and inhale them to treat different conditions.



**WORKSPACE**

Hazardous gases

**ACTIVITY 5.2**

## Hazardous gases

Consider what you know about the behaviour of gas particles. Why do you think we need to have specific hazard signs warning us about hazardous gases? Conduct some research to **identify** at least three Hazchem signs that deal with gas safety. **Explain** what each means.



**WORKSPACE**

Physical properties of a solid, liquid and gas

**EXPERIMENT 5.2**

## Physical properties of a solid, liquid and gas

### Aim

To investigate the physical properties of a solid, liquid and gas.

### Materials

- three plastic drink bottles with lids
- water
- access to a freezer

### Method

#### Day 1

- 1 Put the lid on one bottle with only air inside it. Make sure it is tightly sealed. This will represent water as a gas.
- 2 Fill one of the bottles to the top with water and put the lid on so there is no air inside at all. Leave this bottle at room temperature.
- 3 Fill the third bottle to about 2 cm below the top with water. Put the lid on and give it to your teacher to freeze overnight. ▶

## EXPERIMENT 5.2

### Day 2

- 4 Compare the three bottles. Try squashing them.
- 5 Remove the lid of each bottle and place your hand just above the opening (but not touching it). Squeeze the bottle again.
- 6 Try to pour the contents of each bottle into the sink.

### Results

- 1 **Describe** your observations for all three bottles on days 1 and 2.
- 2 **Construct** a table to display your results.

### Discussion

- 3 Make up a model to **explain** the following physical properties for the three states of matter:
  - ability to be compressed
  - shape (whether they hold their shape or take the shape of the container around them)
  - volume (whether it is fixed or variable)
  - flow (ability to be poured).

### Conclusion

- 4 Write a conclusion to answer your aim.

## QUESTIONS 5.1

### What have you learnt?

#### Remembering

- 1 In the following table, place a tick for each property that solids, liquids and gases exhibit.

Property	Solids	Liquids	Gases
Hold their shape			
Hold their volume			
Can be compressed			
Take up space			
Have mass			
Add some more features of your own			

### WORKSPACE

What have you learnt? 5.1



### QUESTIONS 5.1

#### Understanding

- 2 **Identify** three solids, three liquids and three gases.
- 3 **Identify** the following as solids, liquids or gases.
  - a A rock
  - b Fog
  - c Honey
  - d Fur
  - e An iceberg
  - f The smell of a flower
  - g Butter

#### Applying

- 4 **Identify** the following sentences as true or false. If they are false, rewrite them to make them true.
  - a Liquids hold their volume, but solids do not.
  - b Gases take up the same amount of space as liquids.
  - c Liquids and solids are not compressible but gases are.
  - d Solids hold their shape while liquids and gases only hold their volume.
  - e A set quantity of matter will have the same mass whether it is solid, liquid or gas.
  - f There is much more space between the particles in a gas than there is between the particles in a solid.
  - g Gases are always made of much smaller particles than solids are.
- 5 **Explain** how the particles in ice move compared with the particles in water and steam. Use a diagram to aid your explanation.

#### Analysing

- 6 A substance is in a container. When the container is tipped, the substance flows. **Describe** any further information you would need about the substance to determine what state it was in.
- 7 **Explain** why you can walk through a sheet of water (such as a waterfall) but not a sheet of glass.
- 8 If you stick a pin into a pillow, nothing happens; but if you stick a pin into an inflated balloon, it bursts and goes flat. **Explain** why, referring to the state of the matter inside each object.

## 5.2 Changing state

When water **boils** or **freezes**, it changes from one state to another. Any change between solid, liquid and gas is called a **change of state**. Changing state is a **physical change**, not a chemical change, as no new substances are formed. The substance is still the same substance because the particles themselves have not changed in any way. Only the way the particles move, how far apart they are and the amount of energy they possess, changes.

For a change of state to occur, energy must be added or removed. To change a solid ice cube into a liquid, you must provide the water particles in the ice with more energy, often by adding heat. The heat energy makes the particles move faster until they possess enough energy to break free of each other. The movement overcomes the attractions that hold the particles together.

If you want to freeze something, you must take energy out of it. This means the particles move more slowly, and come closer together.

This explains why you get cold when you wear wet clothes. The water particles in your wet clothes take energy (heat) out of your body. They absorb the energy and use it to break free of the other water particles. They can then **evaporate**. Your body heat is taken away by changing the water from a liquid to a gas, so your clothes get dry and you get cold!

This is also how sweating cools you down. On a cold day, if you run around and get warm and then get wet (by sweating or being rained on), you can sometimes see steam coming off your wet clothes. The water on your clothes absorbs your body heat and evaporates. When it hits the cold air, it **condenses** again. You see this as steam.

### Melting and evaporation

There are many names for changing state. They depend on what state the matter starts and finishes in.

**Melting (liquefying)** refers to a solid becoming a liquid. For example, when ice melts, it becomes liquid water. This process always occurs at a temperature of 0°C for pure water. This temperature is known as the melting point of water. Different substances have different melting points.

**Vapourisation** refers to a liquid turning into a gas. This can occur in two different ways: boiling or evaporation.

When a liquid is **boiling** you observe gas bubbles throughout the entire liquid. Boiling only occurs when a liquid is heated to a specific temperature called the boiling point. Different substances have different boiling points. Pure water always boils at a temperature of 100°C. The boiling point of a liquid called ethanol is always around 78°C (if it is pure).

When a liquid changes state to a gas without boiling, it evaporates. Evaporation occurs on the surface of a liquid and can occur at any temperature. It is evaporation, not boiling, that dries your clothes on the clothesline.

Melting, boiling and evaporating all need energy to be added to the substance to move the particles further apart. Heating is the most common way of adding energy.

### Condensation and freezing

Condensing (also called liquefying) refers to a change of state from a gas to a liquid. In order to do this, gas particles must lose energy. This is often done by removing heat energy (that is, by cooling the gas). This will cause the gas particles to move more slowly

#### boil

to change state from a liquid to a gas at a rapid rate

#### freeze

to change state from a liquid to a solid

#### change of state

a change from one physical form (solid, liquid or gas) to another

#### physical change

a change that does not involve a chemical reaction; the form of the substance changes but the kind of substance remains the same; no new substances are formed

**VIDEO**  
Changes of state



**ACTIVITY SHEET**  
Changes of state



#### evaporate

to change state from a liquid to a gas at a slow rate

#### condense

to change state from a gas to a liquid

#### melt (liquefy)

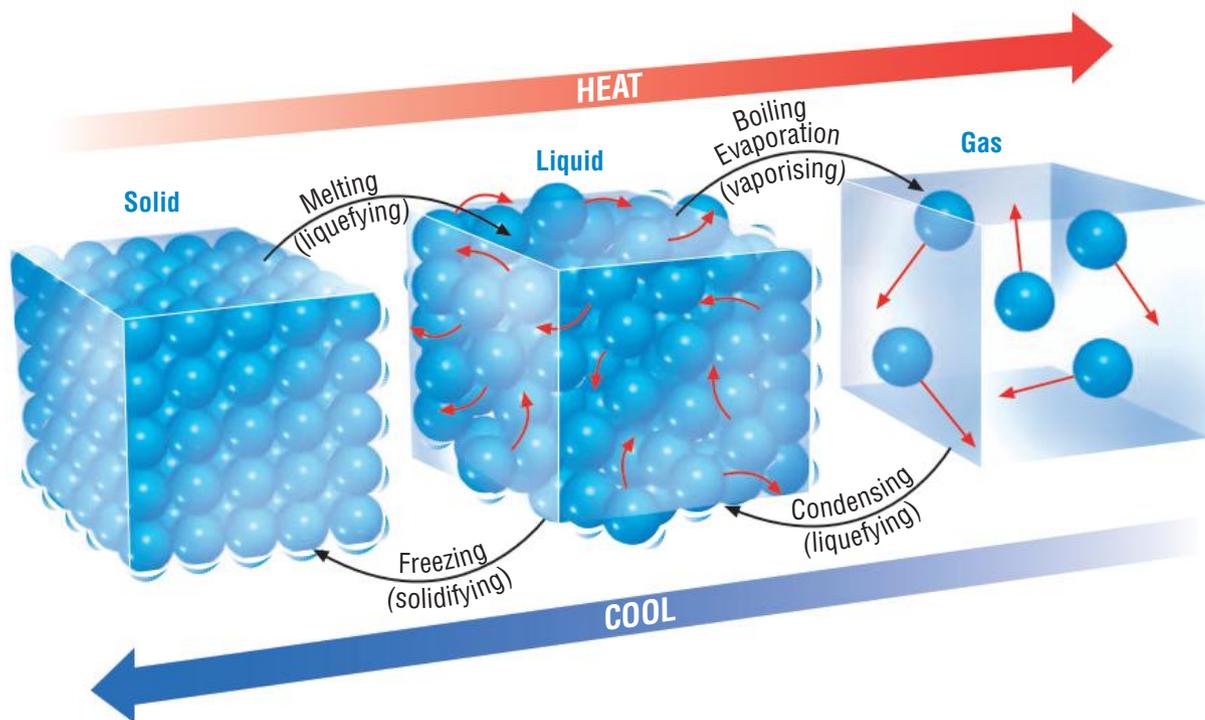
to change state from a solid (or a gas) to a liquid

#### vaporise

to change state from a solid or a liquid to a gas (evaporate, boil or sublime)

**ACTIVITY SHEET**  
Making weather happen





**Figure 5.4**  
Changes of state



Alamy/Phil Degginger

**Figure 5.5** ▶  
Dry ice is solid carbon dioxide. On heating, it sublimates to form a gas.

and so stay closer together. This changes the form of the gas to a liquid. You see this when a mirror ‘fogs’ up after a hot shower. The steam (water as a gas) hits the cold mirror, is cooled down and changes to tiny droplets of liquid water. Ethanol vapour changes to a liquid around 78°C. How does this compare to the boiling point of ethanol?

Freezing (solidifying) is the process of a liquid turning into a solid. Again, the substance must lose energy to bring the particles closer together. We take heat energy out of liquid water to freeze it. Ice is still made of water; it is just solid water, not liquid water. Liquid water freezes to become solid water (ice) at 0°C. How does this compare with the melting point of water?

## Sublimation

Some substances **sublime**. This means they go directly from solid to gas. Dry ice, which is used in smoke machines, is solid carbon dioxide. It does not form a liquid. If you heat it, it goes straight to being a gas from a solid. This is called sublimation. The reverse of this is **deposition**, which is sometimes also called sublimation or reverse sublimation. Removing energy from carbon dioxide gas brings the particles closer together, creating dry ice.

### sublime

to change state directly from a solid to a gas without going through a liquid phase

### deposition

the change of state from a gas directly to a solid without going through a liquid phase

## EXPERIMENT 5.3

## Changing state

WORKSPACE  
Changing state



Possible risks	Safety precautions
Bunsen burners, hot plates and hot equipment can burn.	Before touching anything that has been heated, hold your hand over it. If you feel heat coming off it, do not touch it.
Glassware can break and broken glassware can cut.	Set up your experiment in the middle of the bench, so you are less likely to knock it over. Take care when using glass equipment. Report any breakages to your teacher immediately.

INTERACTIVE  
Changes of state

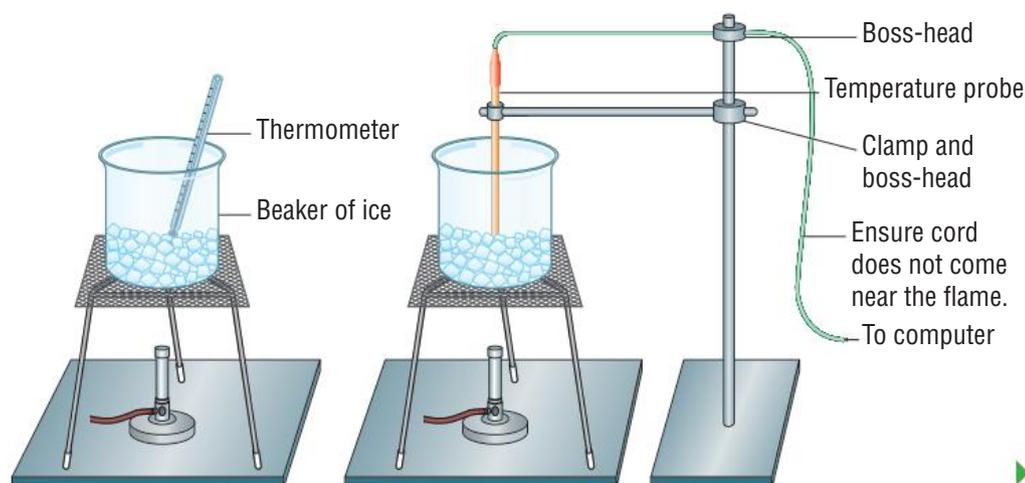


## Materials

- crushed ice
- 250 mL beaker
- tripod
- gauze mat
- heat-proof mat
- Bunsen burner
- thermometer or temperature probe and data logger
- boss-head and clamp
- stirring rod

## Method

- 1 Before you begin, determine the independent and dependent variables in this experiment, and write an aim.
- 2 Set up the equipment as shown in Figure 5.6.



◀ **Figure 5.6**  
How to set up your equipment

### EXPERIMENT 5.3

- 3 Half-fill the beaker with crushed ice. Add enough water to just cover the ice. Stir well with the stirring rod. Record the temperature every minute for 5 minutes if you are using a thermometer, or every 15 seconds if you are using a data logger. Remember to record your initial temperature as time = 0 in minutes or seconds.
- 4 Light your Bunsen burner. Using a blue flame, start heating the icy water.
- 5 Continue recording the temperature every minute (or 15 seconds) until the water has been boiling for five consecutive minutes.
- 6 Turn the Bunsen burner off and keep recording the temperature of the water every minute (or 15 seconds) for a further 10 minutes.

#### Extension

- 7 If you are using a temperature probe and data logger, allow the water to cool until it is safe to touch. Put the probe into the cooled water and put the whole lot into the freezer. Keep recording the temperature as the water freezes. This may require leaving it overnight.

#### Results

- 1 **Construct** a table for your temperature recordings, or use a spreadsheet such as Excel.
- 2 **Construct** a graph of temperature against time (independent variable on the horizontal axis). If using a spreadsheet, use the graph wizard to graph your data.

#### Discussion

- 3 **Explain**, using the terms 'particles' and 'energy', why the ice melted.
- 4 **Explain**, using the terms 'particles' and 'energy', why the water boiled.
- 5 **Explain** your choice of graph.
- 6 Use your results to **describe** what happened to the temperature of the water as the ice melted.
- 7 When did the temperature start to rise? What happened first?
- 8 **Analyse** your results to **describe** what happened to the temperature as the water boiled.
- 9 **Predict** what would happen to the temperature when all the water had boiled away.

### EXPERIMENT 5.3

**10 Describe** what is happening to the particles in the water in terms of energy and movement when the:

- a water is solid
- b ice is melting
- c water is all liquid and being heated
- d water is boiling
- e water is a gas.

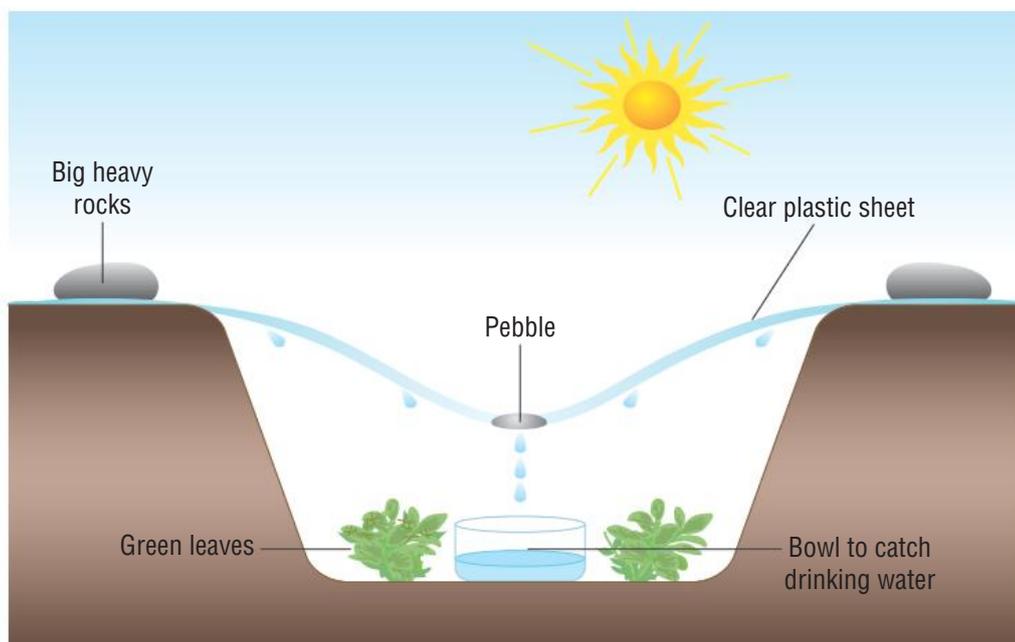
### Conclusion

**11 Summarise** your conclusion.

## Using our knowledge of states of matter

Different substances evaporate at different temperatures. We can use the differences in evaporation temperatures to our advantage. Imagine you have been shipwrecked and washed up on a desert island where there is no fresh water. You cannot drink the sea water. It will make you sick and leave you more dehydrated than before you drank it. How can you get water?

Making a bush still is an old trick. The term 'still' comes from distillation, which is the separation technique being used. You will learn more about this in Chapter 6.



◀ **Figure 5.7**  
Making a bush still to collect water

Figure 5.7 shows you how to make a bush still. Dig a hole in the sand. You can do this on the beach, so the hole has some sea water in it. Put a clean container in the centre and a clear sheet of plastic over the top, securing the edges carefully. In the very centre of the plastic, just above the container, place a pebble. Leave the still in the sun, and at the end of the day you should have some fresh water in your container to drink. The water evaporates but the salt in the sea water does not. The water vapour then condenses to make the drinking water. Alternatively, you could line the hole with green leaves and obtain the water that evaporates from the leaves.

**INTERACTIVE**  
Interpreting changes of state





**WORKSPACE**

What have you learnt? 5.2

**QUESTIONS 5.2**

**What have you learnt?**

**Understanding**

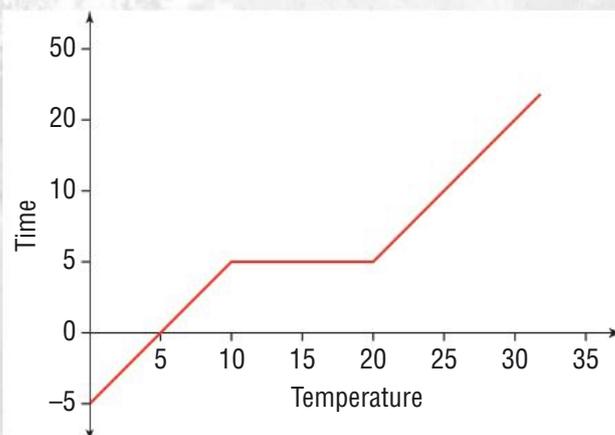
- 1 **Identify** whether the following state changes require the addition or removal of energy.
  - a Boiling
  - b Condensing
  - c Freezing
  - d Evaporating
- 2 **Recall** the state of matter (solid, liquid or gas) formed in the following situations.
  - a A gas condenses.
  - b A liquid evaporates.
  - c A solid sublimates.

**Applying**

- 3 Mercury is the only metal that is a liquid at room temperature ( $25^{\circ}\text{C}$ ). Its boiling point is  $357^{\circ}\text{C}$ . It melts at  $-39^{\circ}\text{C}$ .
  - a **Identify** the temperature at which mercury freezes.
  - b **Identify** the temperature at which mercury condenses.
  - c What would the state of the mercury be in:
    - i Antarctica, when it is  $-50^{\circ}\text{C}$
    - ii the Simpson Desert, when it is  $56^{\circ}\text{C}$
- 4 Write a statement that links energy to the distance between particles.  
**Describe** why this occurs.

**Analysing**

- 5 A student drew a graph of what they thought happened to the temperature when ice was heated. Figure 5.8 shows what they drew.
  - a **Identify** two things missing from their graph.
  - b **Identify** two things wrong with the way they have drawn their graph.



**Figure 5.8** ▶  
Student graph of water being heated

### QUESTIONS 5.2

- 6 What do you think is in the bubbles when water boils? **Account** for your reasoning.
- 7 Use the particle model to **explain** why baking bread smells so much better than cold bread.
- 8 **Propose** a reason why it is best not to dry off sweat with a towel when you are hot. Use scientific terms in your answer.

#### Reflecting

- 9 How do you apply knowledge of changes of state in your daily life? **Outline** two examples.

## 5.3 Evidence for the particle model of matter

Throughout time, scientists have tried to explain what things are made of and why substances behave as they do. They have used observations and experiments to develop their ideas to improve their understanding. As early as the fifth century BCE, Greek philosopher Democritus considered that if you were to continually break a piece of matter in half and half again, there would come a point where it could no longer be broken in half. He called this smallest piece of matter a 'particle'.

Around 60 BCE, a Roman philosopher named Lucretius wrote a poem that described what he thought was happening when 'particles' of dust moved randomly in sunlight. In 1827, Scottish botanist Robert Brown used a microscope to view pollen grains moving around randomly in water. He saw that they didn't stay in one place even when the water appeared to be still. This random motion had also been described in 1785 by Dutch physiologist Jan Ingenhousz. Unfortunately for Ingenhousz, the term used to describe this random movement is 'Brownian motion'.

In 1905, Albert Einstein provided an explanation for the random movement of the pollen grains. He suggested that the water particles were travelling in random directions and continually colliding with the pollen grains, jostling them about.

You can't see water particles, but you can see that water moves, and the effect of this movement on other substances. You can model this by floating some small polystyrene balls on the surface of water in a beaker. The balls don't stay in one place, even when the water looks still.

We can make other observations that provide indirect evidence that particles move. If someone walks past who is wearing perfume, we can *smell* it. The perfume particles must move to our nose. If we add too much salt to a cold stew and do not stir it, the whole dish would end up *tasting* salty, not just the top of it. The salt particles must move throughout the stew. If we stir hot tea with a metal spoon, we will *feel* the handle get hotter. The particles in the spoon must move and pass on their heat in order for us to detect it.

ACTIVITY SHEET  
Movement in water





Alamy/Sciencephotos

## Diffusion

In Chapter 3 you learnt that substances move in and out of cells by the process of diffusion – the movement of particles from an area of high concentration to an area of low concentration until the particles are evenly distributed. Diffusion occurs most commonly in gases and liquids. It is how smells carry through air and how flavours and colours from tea leaves form a drink. It is responsible for many vital processes in life. It is how the foods we eat and the oxygen we breathe get into all our cells and the wastes get out. Diffusion is so essential that if it stopped we would die!

Although all the particles in a liquid are moving around each other, you cannot see this because the particles are too small. However, you can see the overall effect. If you carefully place a small purple crystal of potassium permanganate into a beaker of water, all of the water will eventually turn purple. Diffusion causes this mixing. Potassium permanganate particles are purple, so you can ‘see’ them slowly spread throughout the water. They move, even though the water seems quite still. The particles of water and potassium permanganate move around each other and this causes them to mix.

**Figure 5.9**

Diffusion of potassium permanganate through the water. Eventually all of the water will turn purple.

## Expansion and contraction

If you were to place delicate drinking glasses into hot water, then quickly into cold water and then back into hot again a number of times, the glasses would likely crack. This would happen because of the way the glass particles move when we heat and cool them.

When you heat a substance, the particles move faster and spread out, taking up more space. This causes the substance to **expand**.

When you cool a substance, the particles move more slowly and come closer to one another, taking up less space. This causes the substance to **contract**.

You cannot always see expansion and contraction occurring, but you can sometimes see the effects, such as in railway tracks on a hot day (Figure 5.10).

It is important to remember that the tiny particles that make up a substance remain the same size all the time. Particles do not expand or contract. Particles always stay the same size, but when they are heated or cooled they move further apart or closer together. The overall substance expands or contracts, not the particles.



**VIDEO**  
Diffusion: what makes things smell?



**VIDEO**  
Potassium permanganate

**expand**

to increase in size

**contract**

to decrease in size

**Figure 5.10**

The metal lines of railway tracks have gaps in them to allow the tracks to expand on a hot day. These railway tracks have expanded so much that they have buckled.

Newspix/News Limited/Calum Robertson



This is how a thermometer in your school laboratory works. It has a small bulb at the bottom drawn up into a very thin tube that runs up the length of the thermometer. This bulb contains a small amount of liquid ethanol.

If you place the bulb of a thermometer into something hot, the liquid ethanol inside the bulb heats up. This causes the particles to move faster and take up more space. As the liquid expands, the only place it can go is up the thin tube inside the thermometer shaft.

If you place the thermometer into something cold, the ethanol particles move more slowly, come closer together and thus take up less space. The liquid ethanol inside the thermometer contracts and you see it move down the shaft of the thermometer.

#### EXPERIMENT 5.4

WORKSPACE  
Expansion and contraction



## Expansion and contraction

### Aim

To determine whether solids, liquids and gases expand and contract when heated or cooled.

Possible risks	Safety precautions
Bunsen burners, ball and ring apparatus, and hot equipment can burn.	Before touching any equipment that has been heated, allow it to cool. Wear heat mitts when removing equipment after heating.
Glassware can break and broken glassware can cut.	Set up your experiment in the middle of the bench, so you are less likely to knock it over. Clamp any unsteady glassware (such as the conical flasks) using a boss head and clamp. Take care when using glass equipment. Report any breakages to your teacher immediately.

### Materials

- ball and ring apparatus
- balloon
- 2 conical flasks
- cork and glass-tube assembly
- 2 large beakers
- crushed ice and hot water
- water coloured with food dye
- heat mitts
- tongs
- heat-proof mat

### EXPERIMENT 5.4

#### Method A: Solids

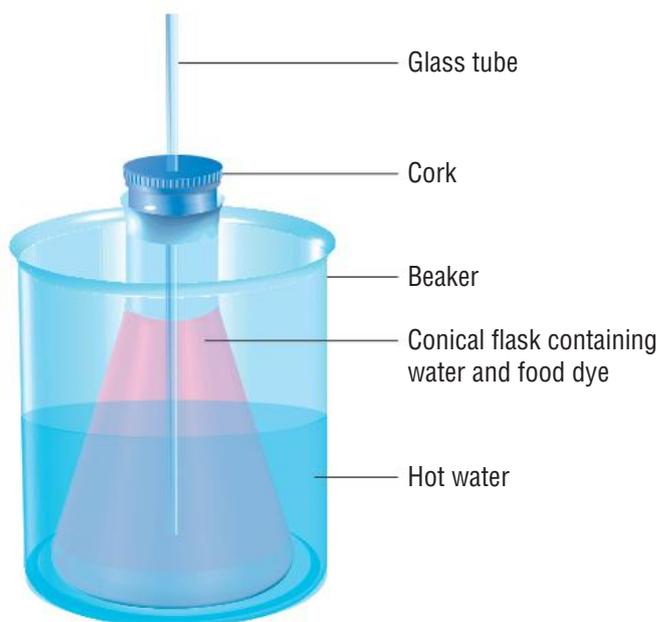
- 1 If you have a ball and ring apparatus, try to place the ball through the ring.
- 2 Use the Bunsen burner to heat the ring (keep the ball away from the heat) for 2 minutes. Using tongs and/or wearing heat mitts, very carefully try to fit the ball through the ring.
- 3 Leave the apparatus to cool on the heat-proof mat while you complete the other activities.
- 4 Try to fit the ball through the ring again after waiting for at least 15 minutes. Record your observations.

#### Method B: Gases

- 5 Place the balloon over the top of an empty conical flask.
- 6 Fill a large beaker a third of the way with hot water. Half fill another large beaker with crushed ice.
- 7 Place the conical flask in the large beaker containing hot water. Leave for a few minutes until you observe changes to the balloon.
- 8 Using heat mitts, remove the conical flask and place it into the large beaker containing crushed ice. Observe what happens to the balloon.

#### Method C: Liquids

- 9 Fill a conical flask completely to the top with the coloured water and fit the cork and glass-tube assembly into the neck of the conical flask as shown in Figure 5.11. Make sure some coloured water has moved slightly up the tube.



**Figure 5.11** ▶  
Equipment set up for expansion and contraction of liquids.

### EXPERIMENT 5.4

- 10 Place the conical flask in the large beaker, filled a third of the way with hot water. Observe the movement of the coloured water in the tube.
- 11 Wait a minute and then use heat mitts to remove the conical flask from the hot water and place it into the large beaker containing crushed ice. Observe what happens to the coloured water in the tube.

#### Results

- 1 Record your observations in a series of before and after scientific diagrams. Make sure they are labelled correctly.

#### Discussion

- 2 Use the particle theory of matter to **explain** what happened when the solid, liquid and gas were heated.
- 3 Use the particle theory of matter to **explain** what happened when the solid, liquid and gas were cooled.

#### Conclusion

- 4 Complete this sentence:  
When \_\_\_\_\_, liquids and \_\_\_\_\_ are heated, they \_\_\_\_\_.  
When \_\_\_\_\_, liquids and \_\_\_\_\_ are cooled they \_\_\_\_\_.

## Density

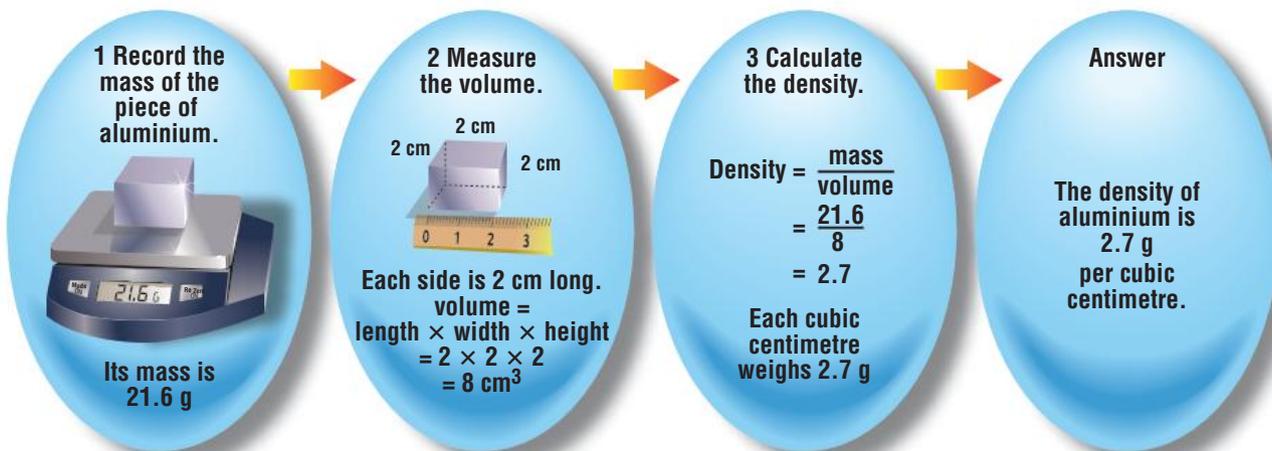
Around 250 BCE, Archimedes (a Greek mathematician) was given the task of finding out whether his king's new crown was made of real gold. Wondering how to do this, he had a bath. Archimedes noticed that as he got into his bath, water spilled out onto the ground. He realised that the amount of space (volume) his body occupied 'pushed' out the same volume of water. He further realised that if he placed the king's crown into a container of water, he could compare it to a sample of pure gold of the same volume in another container of water. If the water levels were the same, then the crown was made of gold. It has been said that Archimedes then ran naked through the streets shouting 'Eureka!' ('I have found!'). Archimedes had discovered how to determine the volume of an irregular object.

**Density** is a physical property of a substance and refers to the relationship between the mass of a substance and the amount of space it takes up (its volume). Because density is related to mass and volume, if you change either of these things, it can change the density of a substance. The density of a substance can be measured using the formula:

$$\text{Density} = \frac{\text{mass of a substance (g)}}{\text{volume of a substance (mL or cm}^3\text{)}}$$

#### density

the amount of mass (g) in a unit of volume (cm<sup>3</sup>)



**Figure 5.12**  
Calculating the density of a cube of aluminium

### Density and mass

Look at Figure 5.13. The three cubes (gold, silver and aluminium) have the same volume (1 cm × 1 cm × 1 cm = 1 cm<sup>3</sup>). So they occupy the same amount of space. But the readings on the electronic balances show that gold has a much greater mass than silver and aluminium. The particles in gold, silver and aluminium are as close to each other as they can get because they are all solids. So the only way to explain why the gold cube has a greater mass than the other two metals is that the individual particles of gold have a greater mass than the individual silver and aluminium particles.



**Figure 5.13**  
Metals of the same volume have different masses.

When a substance with heavier particles (such as gold), occupies the same amount of space as a substance with lighter particles (such as aluminium), we say that the gold is more dense than the aluminium. This is because the volume is the same, but the mass is different. Refer back to the density formula (density = mass/volume), and use the data from Figure 5.13, and you will see this in your calculations.

Density affects how substances float in other substances, such as water. If a golf ball and a same-sized polystyrene ball were added to a beaker of water, the golf ball would sink and the polystyrene ball would float. This is because, although they have the same volume, they have different masses. The polystyrene ball is less dense than the golf ball.

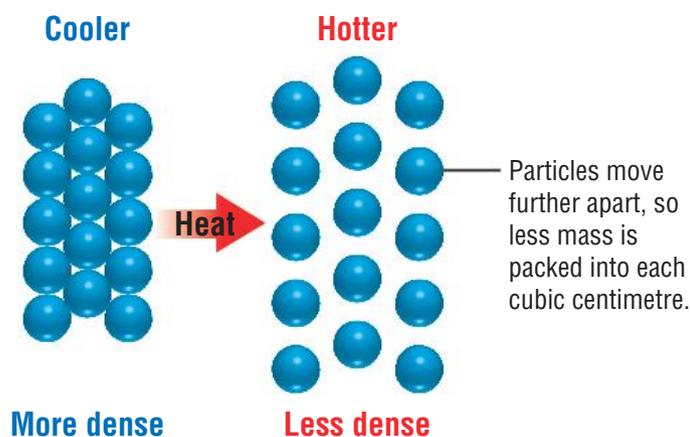
### Density and volume

The density of a substance also depends on its volume. A 1 kg bag of feathers would take up more space than the 1 kg of salt, even though they have the same mass. Their volumes are different, so they will have different densities.



**ACTIVITY SHEET**  
Floating fruit!

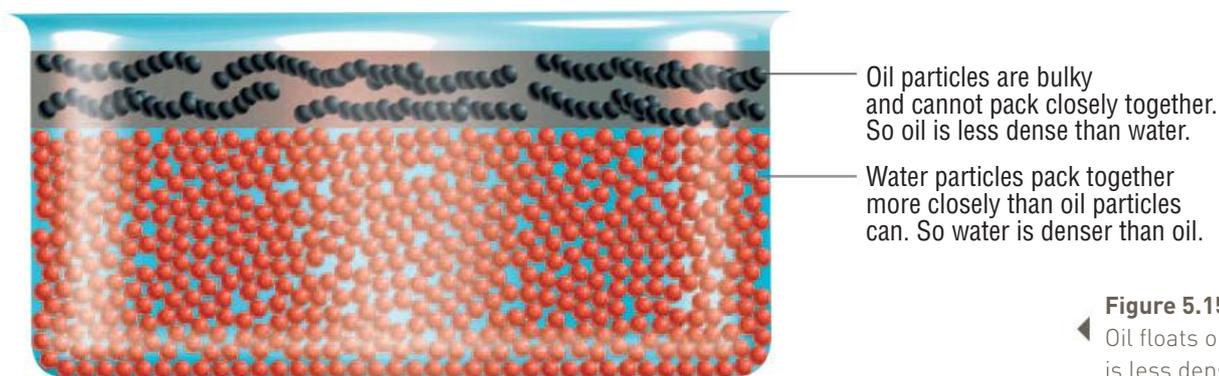
Changing the volume of a substance without changing its mass alters the density of the substance. If the volume of a substance increases (say, by heating it) but no extra mass is added, the particles move further apart and the substance becomes less dense. If the volume decreases (by cooling it), the volume will decrease because the particles move closer together. The substance will become more dense. Less dense substances float on more dense substances.



◀ **Figure 5.14**

When a substance is heated or cooled, its volume changes and so does its density.

Oil floats on top of water. This is because oil and water have different densities. Oil particles cannot pack as closely together as water particles can. This makes oil less dense than water.



◀ **Figure 5.15**

Oil floats on water because it is less dense.



## Amazing water

Water behaves differently from most substances on Earth. Frozen water floats in liquid water because it is less dense than the liquid water. This is highly unusual. Icebergs should really be sitting at the bottom of the sea!

Shutterstock.com/Achim Baque





## Dead Sea

The water in the Dead Sea, which borders Israel and Jordan, is almost 10 times as salty as normal sea water. This makes it incredibly buoyant. It holds people up because it is so much denser than they are.

Shutterstock.com/robert paul van beets



### WORKSPACE

What have you learnt? 5.3

### QUESTIONS 5.3

## What have you learnt?

### Remembering

- 1 **Define** the following terms.
 

a Diffusion	c Expand
b Density	d Contract

### Understanding

- 2 Does 1 kg of hot water take up more space than 1 kg of cold water? **Apply** the particle model in your answer.
- 3 Draw a diagram to **demonstrate** why:
  - a particles in gas move faster than those in liquid
  - b diffusion is faster in air than water.
- 4 Use the particle model to **describe** density.

### Applying

- 5 Which type of matter exerts more pressure on a container: a gas, a solid or a liquid? **Justify** your answer.
- 6 **Explain** why 1 kg of flour takes up more space than 1 kg of lead.
- 7 Engineers who build bridges make sure that there are expansion joints between the lengths of road (Figure 5.16). **Discuss** why this is necessary.

### Analysing

- 8 You place 3 drops of green food colouring into a glass of still water. After 5 minutes the whole glass of water is green, yet you have not stirred it.
  - a Use the particle model to **explain** what has happened.
  - b **Predict** any differences you would expect if you had used sparkling mineral water instead of still water.
- 9 **Explain** why bottles that contain gas (such as for your barbecue) have to be made of very strong metal.

### Creating

- 10 **Construct** a diagram to **synthesise** your understanding of expansion and contraction.



Getty Images/Matt Meadows

**Figure 5.16**

Expansion joints in a bridge

# Chapter review

## Remembering

- Recall** the correct scientific term used to describe the following situations.
  - A solid turns into a liquid.
  - A gas turns into a liquid.
  - A liquid turns into a solid.
  - A gas turns into a solid.
- Identify** the:
  - boiling point of water
  - temperature at which liquid water freezes
  - temperature at which water vapour condenses
  - melting point of water.

## Understanding

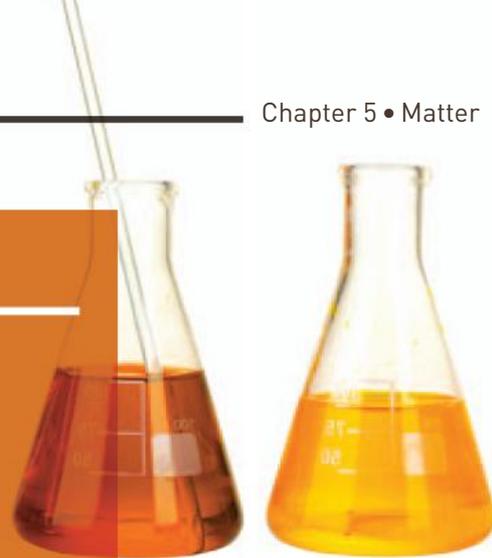
- Explain** the difference between evaporation and boiling.
- In each of the following situations, **identify** which object would have more energy and **explain** why.
  - Solid butter or melted butter
  - Honey or the smell of honey

## Applying

- Describe** how you would expect liquid nitrogen to behave and **compare** it with the behaviour of solid nitrogen and gaseous nitrogen.
- In each of the following situations, **identify** which process requires the addition of the most heat.
  - Melting ice or melting a metal from the same temperature
  - Evaporating vegetable oil or evaporating water
  - Subliming carbon dioxide or subliming iodine (Hint: What other information do you need to be able to answer this?)
- 'Gases exert much more pressure than solids.' Decide whether this statement is true or false and explain your answer.
- Explain** why cordial diffuses into water quickly, but if it is added to solid ice it doesn't mix.
- a Predict** whether gaseous cordial would diffuse into gaseous water more or less quickly than mixing the two liquids.  
**b Explain** your answer in terms of particles.
- Propose** why it is easier to float while holding your breath than when you let it out.

## Analysing

- Explain** why if you open a bottle of soft drink when it's hot, it sprays everywhere, but when it's cold it doesn't.



**WORKSPACE**  
Chapter 5 review



**ACTIVITY SHEET**  
Chapter 5 checklist

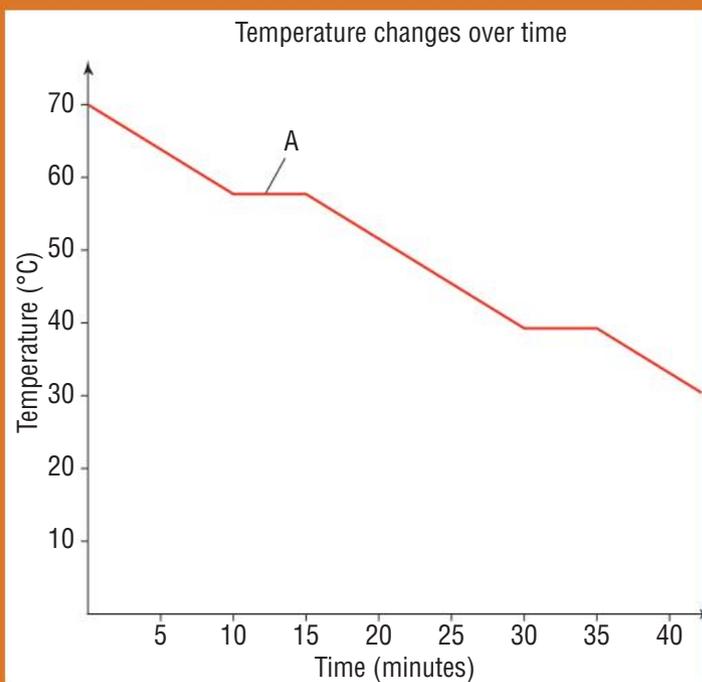


**REVIEW QUIZ**  
Chapter 5





- 12 You have two clear plastic soft-drink bottles, full and sealed with fizzy drink, but one had gone flat and the other hadn't. **Propose** how you could tell which is which without opening them.
- 13 **Explain** why the bathroom mirror fogs up after you have a hot shower without the fan on.
- 14 **Explain** why a burn from steam is much worse than a burn from boiling water.
- 15 Figure 5.17 shows a graph of the change of state of an unknown substance.
- Identify** whether the substance is being heated or cooled. Give reasons for your answer.
  - Identify** the process occurring at A.
  - Identify** the name given to the temperature at which this process occurs.
  - Identify** the melting point of this substance.
  - Use your graph to **determine** in which state this substance would exist at 43°C.
  - Extrapolate** your graph to determine the time at which the substance reaches 20°C.



**Figure 5.17** ▶  
Changes of state of a substance

## Creating

- 16 When ice is heated, where does the heat go?

## Reflecting

- 17 Go back to the questions you wrote in 'What do you already know about matter?' Revise your answers on the basis of what you have learnt in this chapter. Are any questions still not answered? How might you go about finding the answers?
- 18 **Construct** a concept map of all the glossary terms in this chapter. Make as many links as possible between them.

# 6

## Mixtures

---

How can an understanding of separation techniques be used to improve our lives?

---

Since ancient times, people have developed new technologies to make life easier. Winnowing is an ancient method of separation used in agriculture to obtain wheat grain for food. After wheat was harvested, it was placed in a shallow basket called a winnow, and then tossed in the air. The chaff – the light, dry casing covering the wheat seeds – would blow away in the wind, leaving the heavier grain in the winnow. You may have heard the expression ‘to separate the wheat from the chaff’. This means to separate the relevant or useful parts of information from irrelevant information. In the same way, many useful substances are often found mixed with other less useful substances. Scientists have developed processes to separate mixtures so we can get what we want and get rid of the ‘chaff’.

---

## Chemical world – Stage 4

### Key knowledge

- Water is a universal solvent, dissolving many substances at home, in nature, and in industry.
- Solutions are mixtures of solutes dissolved in solvents.
- Mixtures can have varied physical properties. As such, specific processes are required to separate particular mixtures into their components.
- Mixtures can be separated using physical processes such as sieving, sedimentation and decanting, filtration, evaporation, distillation, crystallisation and chromatography.
- Physical separation processes are used in everyday life.
- All types of occupations use separation processes and require an understanding of the science involved in order to do their job.

### CULMINATING ASSESSMENT TASK

## An everyday physical separation

**Investigate** one of the suggested everyday applications of physical separation techniques. You will apply your understanding of mixture separation by outlining the techniques used and describing the scientific processes involved. Use the weblinks, videos or activity sheets provided to guide your research.



#### ACTIVITY SHEET

CAT with rubric: An everyday physical separation

## What do you already know about separating substances?

### Challenge

Work with a partner. Your teacher will provide you with a mixture containing leaves, small pebbles, sand, salt and iron filings. Design a method to separate each substance from the mixture. Your aim is to end up with each substance isolated and intact.

- 1 Construct a flowchart (on A3 paper or using Web 2.0 software) to plan the processes you will use to separate the mixture. If you are having difficulty, you may ask for a hint card.
- 2 Once you have completed your flowchart, check with your teacher. Modify your plan if necessary.
- 3 Stick your flowchart on the wall of the laboratory. Look at those created by other groups.

### Feedback

- 1 How many of the flowcharts followed the same method as yours?
- 2 How many different types of methods were there?
- 3 Is there more than one way to do this activity and still end up with each substance in the mixture separated? If so, what does this activity teach you about solving problems?

### WORKSPACE

What do you already know about separating substances?



### WEB 2.0

Use a drawing application such as Gliffy, Inspiration or MindNode to create your flowchart.

## 6.1 Pure and impure substances

The particles that make up substances are too small for us to see. One grain of sugar contains millions upon millions of tiny sugar particles. The important thing to remember is that substances are different because their particles are different. Sugar particles are not like water particles.

Hot chocolate is a drink made by mixing together cocoa powder, hot water and milk. Hot water is made up of one substance – water – but milk is made up of a couple of liquids mixed together. One way to classify all of the non-living material around us is by whether it is made up of only one type of particle (like water) or a combination of different particles (like milk).

A **pure substance** is made up of only one type of particle – nothing else has been added. Sugar is made up of only sugar particles, so it is a pure substance. Oxygen gas is made up only oxygen particles. If a substance is pure, no matter where a sample comes from, it will be made up of only one type of particle, with nothing else added.

Figure 6.1 shows what sugar and water would look like if we could magnify them enough to see their particles. Each red circle represents a sugar particle. Each blue circle represents

### pure substance

a substance made up of only one type of particle

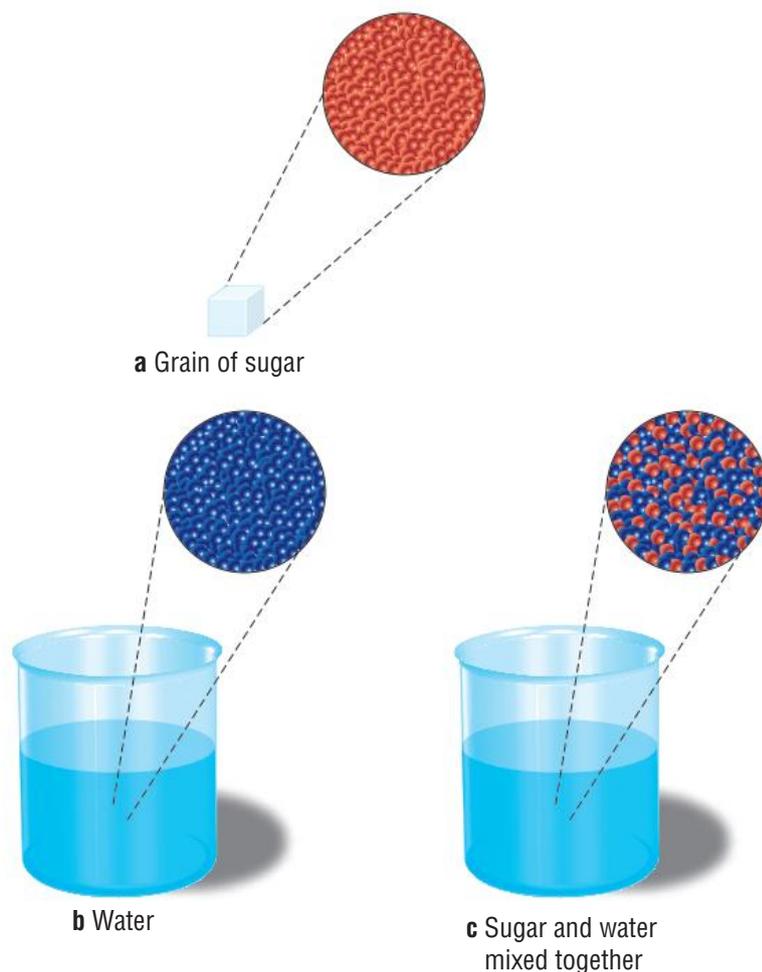


Figure 6.1 ▶

**a** A tiny grain of sugar is magnified to show what the particles would look like. **b** Water is magnified to show what the particles would look like. **c** Sugar is added to water and stirred. It does not look any different from the water, but what if it was magnified?

#### impure substance (mixture)

a substance made up of two or more different types of particles, physically combined

#### alloy

a mixture of two or more metals (or sometimes a metal and a non-metal) that have been melted, combined and then allowed to harden

#### proportion

the amount of one part in relation to the whole or to other parts; ratio

a water particle. Sugar is only made up of red circles and water is only made up of blue circles. This makes them both pure substances as they are each made up of only one type of particle.

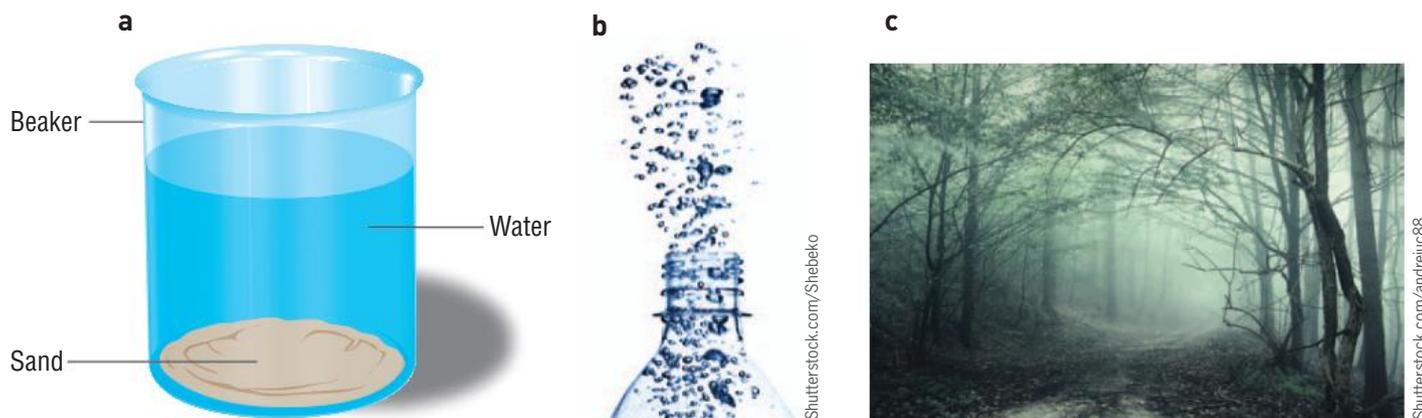
But what if we added some sugar to the beaker of water and stirred? The red and blue circles are now evenly mixed together. The substance in the beaker in Figure 6.1c can no longer be called a pure substance because different particles are mixed together. When two or more different types of particles are physically combined, it is called an **impure substance (mixture)**.

Air is a mixture. It is a combination of a number of different gases, mainly oxygen, carbon dioxide and nitrogen. Methylated spirits is a mixture made by adding together two liquids – ethanol and methanol. The metals copper and tin are both solid pure substances; however, when they are melted, mixed together and allowed to harden, they form a mixture called an **alloy**. A copper and tin alloy is called bronze.

Some mixtures are made up of substances that are in different states at room temperature, such as solid sand mixed with liquid water (Figure 6.2a). Soda water is made up of the gas carbon dioxide combined with liquid water under pressure (Figure 6.2b). Even fog is a mixture, with small droplets of water spread throughout the air close to the ground (Figure 6.2c).

The particles in a mixture are not always evenly spread out. For example, sand mixed with water will eventually sink to the bottom (see Figure 6.2a). This means that the amount, or **proportion**, of sand will be different in different parts of the mixture.

Simple mixtures may be just a combination of a couple of different pure substances. More complex mixtures, such as hot chocolate, may be a combination of pure substances and mixtures.



**Figure 6.2**

Mixtures that are made up of substances in different states include: **a** sand mixed with water, **b** soda water (a mixture of water and carbon dioxide) and **c** fog (a mixture of water and air).



### Food foam - a mixture used in cooking

Molecular gastronomy is the study of the physical and chemical processes that occur during cooking. It is also the name given to a style of cooking that uses equipment similar to that used in the laboratory – together with ingredients from the food industry – to create surprising new forms of food. One technique used in molecular gastronomy is frothing. Food juices are mixed with gelatine, and air is pumped through this to produce foam, such as the dairy foam on top of the dish of asparagus, beetroot and goat's cheese shown. Foam is a mixture of a liquid and a gas.



Shutterstock.com/Danie Nel



#### INTERACTIVE

Types of matter – pure substances and mixtures



#### ACTIVITY SHEET

Identifying pure substances and mixtures

## Physical properties

Chemical substances have different features called **physical properties**. These include colour, hardness, state at room temperature, degree of solubility, melting point and boiling point. Gold and silver are both shiny metals but they are different colours. Ice will melt at 100°C but solid salt will not. Oxygen is a gas at room temperature but water is a liquid.

By observing substances around us, we are able to classify them into groups based on their similarities and differences. How would you compare the physical properties of the substances in Figure 6.3? The substances are all mixtures. They are similar because they all look like liquids, but they also have properties that are different. The sports drink is green and **transparent**. The milk is white and cloudy. The oil and water are different colours and do not appear to mix. Mixtures can be classified into different groups based on the physical properties of the substances they are composed of.



#### ACTIVITY SHEET

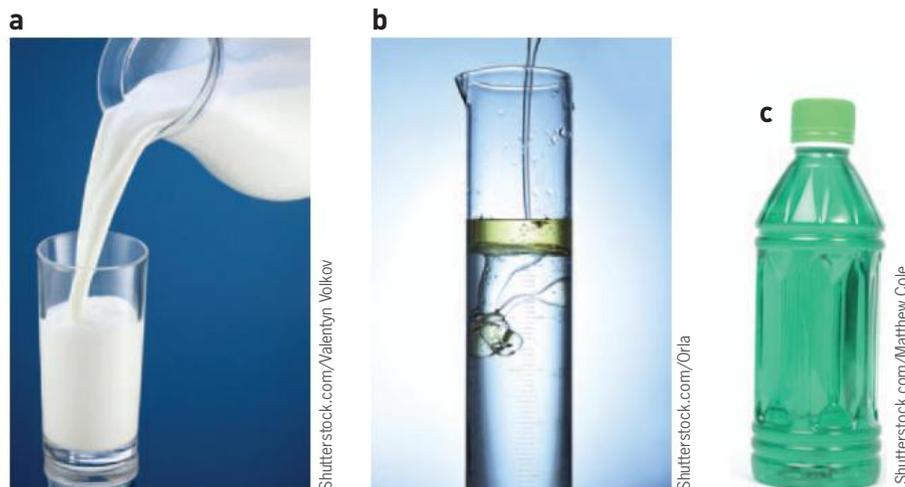
Comparing physical features

#### physical property

a physical feature of a substance, such as colour, hardness, state at room temperature, degree of solubility, melting point, boiling point

#### transparent

clear, see through; allowing light to pass through a material



**Figure 6.3** ▶

How would you compare the physical properties of **a** milk, **b** oil mixed with water and **c** a green sports drink?

### ACTIVITY 6.1

## Organise your work

Create a mind map, concept map or lotus diagram to assist you in organising the concepts studied throughout this chapter. Add important key words, facts and ideas as you work through the chapter. This tool will help you remember things, sort your learning and assist with revision.



### WORKSPACE

What have you learnt? 6.1

### QUESTIONS 6.1

## What have you learnt?

### Understanding

- 1 **Identify** an example of a mixture made up of a:
  - a solid in a liquid
  - gas in a liquid
  - liquid in a liquid
  - gas in a gas.

### Applying

- 2 A bowl contains equal amounts of M&Ms, jelly beans, Skittles and tic tacs. Six people each take one scoop of lollies from the bowl to fill their lolly bags.
  - a **Identify** whether the lollies in the bowl are an example of a pure substance or a mixture. **Explain** your answer.
  - b Do you think that the lollies would be evenly mixed throughout the bowl so that each person's lolly bag will have the same number of M&Ms, the same number of jelly beans, and so on? **Justify** your answer.

### QUESTIONS 6.1

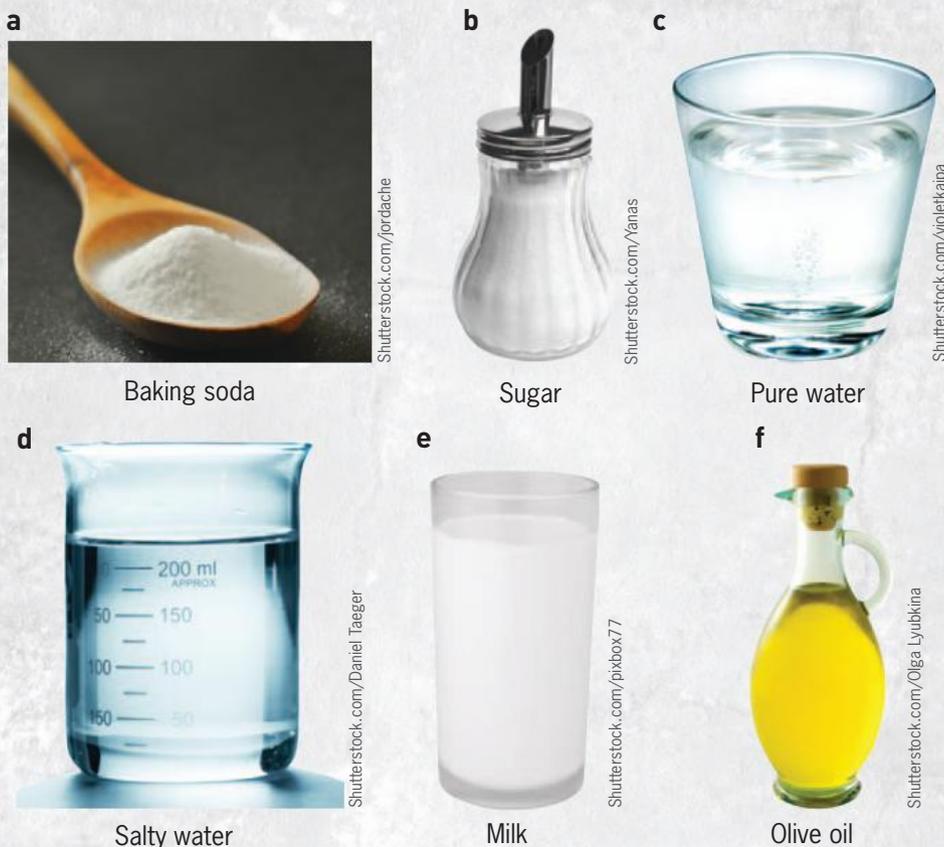
d Do you think the proportions in a mixture are always the same, or can they vary? **Demonstrate** support for your answer by providing different examples of common mixtures.

3 Look at the substances in Figure 6.4.

a **Identify** whether these substances are pure or impure.

b **Describe** the physical properties of each substance.

c **Classify** the substances into groups based on one physical property. **Classify** them again based on a different physical property.



◀ **Figure 6.4**

In how many ways could you classify these substances?

4 a Choose one mixture you listed in Question 1, and describe how it could be separated into the substances that make it up.

b **Outline** the physical properties of the components of the mixture that make your separation technique possible.

### Evaluating

5 **Consider** the following uses of the word 'amalgam'.

- Dentists use amalgam to fill cavities in teeth. Dental amalgam is an alloy of mercury and other metals.
- The word 'caravan' is an amalgam of 'car' and 'van'.
- Amalgam is the name of a fictional character from Marvel Comics. Her power allows her to absorb the powers of dying characters, combining them with her own.

### QUESTIONS 6.1

Use these examples to **evaluate** the following statement made by a Year 7 student.

'The word amalgam cannot be used when referring to pure substances, only mixtures.'

#### Creating

- Write a paragraph to **demonstrate** how you would explain the difference between a pure substance and a mixture to a Year 3 student.

## 6.2 Types of mixtures



**WORKSPACE**  
Classifying mixtures

### EXPERIMENT 6.1

#### Making different mixtures

In this experiment you will be making different types of mixtures by adding a range of substances to water.

Possible risks	Safety precautions
Substances can get in your eyes.	Wear safety glasses at all times.
Some of the substances are flammable and volatile.	Perform the experiment away from naked flames and in a well-ventilated room.
Methylated spirits and kerosene can irritate skin and eyes.	Minimise contact with the skin, wash hands immediately after use. Wear safety glasses and identify where the eye wash station is in the laboratory.

#### Aim

To classify a range of mixtures based on the similarities of their physical properties.

#### Materials

- 12 test tubes and test-tube rack
- plastic droppers
- water
- small spatula or spoon
- cork (not rubber) stoppers
- a variety of substances such as table salt, milk, tea leaves, sand, vinegar, jelly crystals, methylated spirits, olive oil, powdered chalk, cream, small pieces of cork, kerosene
- camera, mobile phone or notebook computer (optional)

## EXPERIMENT 6.1

### Method

- 1 Work in a group of two or three.
- 2 Look at the variety of substances. Think about what might happen when these are mixed with water and then allowed to settle for 15 minutes. Predict which mixtures might 'belong' together.
- 3 Label the test tubes (salt and water, milk and water, and so on).
- 4 Using a spatula or spoon, add a small level spoonful of each solid to the appropriate test tube. (Clean the spatula or spoon after each substance.)
- 5 Using a clean plastic dropper, add 2 cm of liquid to the appropriate test tube. (Clean the dropper after each substance.)
- 6 Use a clean plastic dropper to add enough water so that the test tubes are half full.
- 7 Stopper the test tubes and carefully shake each mixture from side to side for 1 minute. Observe what happens.
- 8 Place each test tube in the test-tube rack and allow the mixtures to settle for 15 minutes. Observe.

### Results

- 1 Record your observations of each mixture in a table. **Describe** how each of the mixtures appeared after 1 and 15 minutes. You could comment on such things as the colour of the mixture, whether you can see through it, how many layers there are, or if any substances are floating.

### Discussion

- 2 **Classify** the mixtures into groups based on the similarities of their physical properties. **Explain** your groupings.
- 3 **Compare** your original predictions with the end results. How close were they?

### Extension

- 4 In your group, brainstorm ways in which you might be able to separate the mixtures to get the original substances back. Write a brief paragraph to outline one of your ideas.

### Reporting

Choose one of the following.

- If you made a video, edit your footage. As you watch the video, write a script outlining what is happening to each mixture.
- Draw a series of labelled before-and-after scientific diagrams for each group of mixtures in this activity. Provide a short explanation for each classification.

#### WEB 2.0

You could upload your edited footage, report or diagrams to VoiceThread and add your comments.

WEBLINK  
VoiceThread



**dissolve**

when a substance is mixed with another and the particles from both substances spread out evenly until they are too small to see

**soluble**

dissolves in another substance

**solute**

in a solution, the substance that dissolves in another substance

**solvent**

in a solution, the substance that dissolves another substance

**solution**

a mixture created when a solute dissolves in a solvent

**aqueous**

a solution is aqueous if water is the solvent



**VIDEO**

Solutions and how they work



**WEBLINK**

Shaking a can of soda water – is the spray here to stay?

## Solutions

When a sugar cube is added to a cup of tea and stirred, the small, white solid grains seem to vanish. When a substance seems to vanish like this, we say that it **dissolves**. We say that the sugar is **soluble** in the hot water or tea. The tea now tastes sweet.

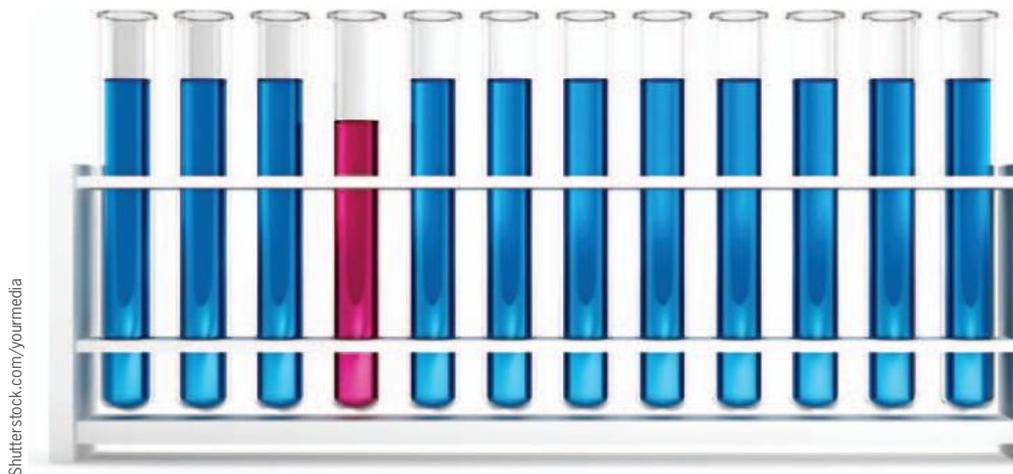
The substance that dissolves is called the **solute**. The substance that does the dissolving is called the **solvent**. Together, the solute and the solvent form a type of mixture known as a **solution**. In a sugar–water solution, the sugar is the solute because it is the substance that dissolves. The water is the solvent because it does the dissolving.

If water is the solvent, the solution formed is called an **aqueous** solution. Water is sometimes called the universal solvent because it can dissolve so many substances. However, not everything dissolves in water. For example, nail polish does not come off in water, but it does come off in another solvent called acetone. Other liquid solvents include ethanol, kerosene and turpentine.

So why is a solute – such as sugar – no longer visible after it dissolves in water? The millions of tiny particles that make up the grains of sugar become separated from one another until they are spread out evenly among the water particles, too small for us to see.

You are already familiar with many solutions. A salt solution is formed when salt (a solid solute) dissolves in water (a liquid solvent). Vinegar is a solution made when acetic acid (a liquid solute) dissolves in water (a liquid solvent). Soda water is made when carbon dioxide (a gas solute) dissolves in water. We know there is a gas dissolved in soda water because when we open the bottle, we see bubbles and hear some of the gas escape.

All solutions are clear; they can also be coloured. If blue food colouring is added to water, we can still see through the solution. It can be described as blue (its colour) and transparent (because we can see through it).



Shutterstock.com/yourmedia

**Figure 6.5**

Transparent solutions can still be coloured.



**ACTIVITY SHEET**

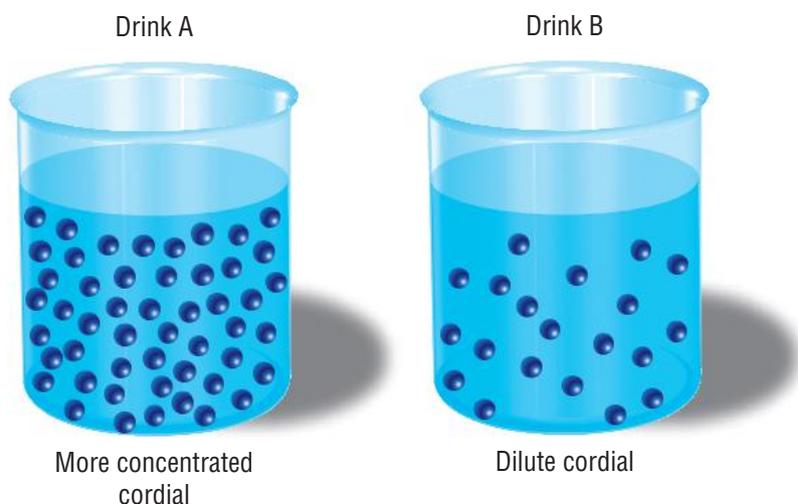
Using your senses

### Concentrated and dilute solutions

To make up a pleasant cordial drink, you need to add about 50 mL of cordial to 200 mL of water. Let's call this drink A. It is a solution because a solute (cordial) has been dissolved in a solvent (water). We can make another cordial drink by adding only 25 mL of cordial to 200 mL of water (drink B).

Drink A tastes sweeter, has more flavour and is darker in colour than drink B. Many people would say that drink A is 'stronger' than drink B, but the correct scientific term is 'more **concentrated**'. This means that drink A has more solute in it than drink B (in the same amount of solvent).

Similarly, scientists do not say that drink B is a weaker solution; rather, they would describe it as more **dilute**. There is less solute added to the same amount of solvent. Figure 6.6 shows what the particles would look like in concentrated and dilute cordial solutions. So the next time someone asks for a stronger glass of cordial, you can tell them that what they really mean is a more concentrated cordial solution.



### concentrated

one solution is more concentrated than another if there is more solute dissolved in the same amount of solvent

### dilute

one solution is more dilute than another if there is less solute dissolved in the same amount of solvent

◀ **Figure 6.6**

Two cordial solutions – what are the differences?

## Suspensions

When sand is mixed with water it does not dissolve – sand is **insoluble** in water. Sand and water form a **suspension** – a mixture of an insoluble solid and a liquid or solution. The solid eventually settles to the bottom of the container.

## Colloids

A **colloid** is also a mixture made from two or more substances that are insoluble in one another. But the insoluble particles of both substances are fairly small, so they are not heavy enough to settle as they do in a suspension such as sand and water. Instead, the particles remain evenly spread throughout one another. The particles in a colloid are larger than in a solution, so the mixture appears cloudy, not clear. Colloids may look transparent, **translucent** or **opaque** depending on the concentration of the particles. Fog is a good example of this. 'Thick' fog is harder to see through than a thin mist of fog.

Ink is a colloid. It has solid pigment particles spread evenly in a liquid of oil or water. Ink is not a solution because the solid pigment particles do not dissolve in the oil or water. It is not a suspension either because the mixture does not settle.

### suspension

a mixture of at least one insoluble solid in a liquid or solution, where the insoluble substance settles to the bottom of the container over time

### insoluble

does not dissolve in another substance

### colloid

a mixture of two or more insoluble substances that remains evenly mixed, not settling over time

### translucent

cannot be seen through, but light can pass through

### opaque

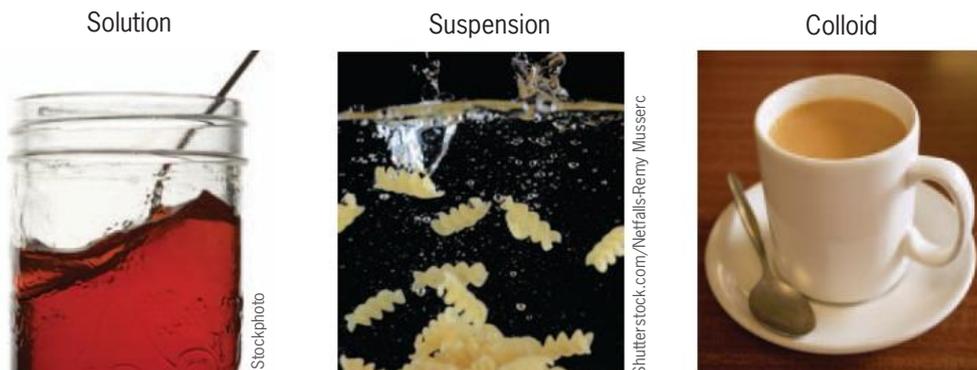
light cannot pass through

Smoke is also a colloid. It has small solid particles of ash mixed with air. Whipped cream is a colloid because gas particles are mixed with liquid cream.

Figure 6.7 shows some everyday examples of mixtures.

**Figure 6.7** ▶

The cordial mixture is a solution – it is transparent and a solute has dissolved in a solvent. The mixture of pasta and water is a suspension – the solid pasta has not dissolved and is settling to the bottom. The white tea is a colloid – the mixture is translucent, with small insoluble particles of milk spread evenly throughout the tea solution.



**WORKSPACE**  
What have you learnt? 6.2

**WEB 2.0**

Use the weblink 'Puzzle maker' and the new words you have learnt so far to make a puzzle. Upload your puzzle to the class wiki for others to complete.

**WEBLINK**  
Puzzle maker

**QUESTIONS 6.2**

**What have you learnt?**

**Remembering**

- 1 **a** Recall all the key terms so far that start with 's'.  
**b** Write a sentence that uses all of the words.  
**c** Draw a labelled diagram for each.
- 2 **Define** the following terms.

<b>a</b> Dissolve	<b>d</b> Solvent	<b>g</b> Dilute
<b>b</b> Soluble	<b>e</b> Solution	<b>h</b> Concentrated
<b>c</b> Solute	<b>f</b> Aqueous	

**Understanding**

- 3 **Identify** whether the following statements are true or false. If a statement is false, rewrite it to make it true.
  - a** Solutions are always transparent.
  - b** Solutions are always colourless.
  - c** A solution always has water in it.
  - d** When acetone removes nail polish, the nail polish is the solute and acetone is the solvent.
  - e** In a suspension, particles always fall to the bottom of the container.
- 4 **a** Look back at your results from Experiment 6.1 'Making different mixtures'. Which of the mixtures were solutions?  
**b** For each solution, **identify** the solute and the solvent.  
**c** **Identify** the mixtures that were suspensions or colloids. Give your reasons in each case.

## QUESTIONS 6.2

### Applying

- 5 Bottles containing three white powders have had their labels removed. You know that they are chalk powder, baking soda and powdered milk.
- Describe** a safe method you could use to determine which powder is which.
  - Explain** how the method allows their identification.
- 6 A student is testing three pure substances (A, B and C), which are all solids. She prepares three beakers, each with 100 mL of water at the same temperature. She adds 5.0 g of substance A (in 1.0 g amounts) to the first beaker and stirs the mixture. She repeats this for the other substances and beakers. The student's observations are shown in Table 6.1. **Classify** the types of mixtures she created when she added A, B and C to the water. Give reasons for each classification.

**Table 6.1** ▲

Mixing substances with water

Substance	Observations when mixed with 100 mL of water
A	As each 1 g amount is added, it dissolves instantly. After all of the solid has been added, it is no longer visible. The mixture is transparent.
B	As each 1 g amount is added, the solid floats about in the water. After 20 minutes, the solid has settled to the bottom of the container. None of the solid has dissolved.
C	Each 1 g amount seems to mix immediately. The mixture is cloudy. It does not separate into layers. After 20 minutes, there is still only one cloudy layer.

- 7 The hydrosphere refers to all the water on the Earth. Hydroelectricity uses water to produce electrical energy. A phobia is a fear of something. Use this information to **describe** why oil is called a hydrophobic substance.
- 8 Kerosene and water are both solvents. They are not soluble in one another. A mystery liquid is clear and colourless. It does not dissolve in water, but it does dissolve in kerosene.
- Identify** the solvent for the mystery liquid.
  - Outline** the similarities between the mystery liquid and water.
  - Outline** the similarities between the mystery liquid and kerosene.

## 6.3 Common mixtures



Figure 6.8

Many mixtures are created in the kitchen.



**ACTIVITY SHEET**  
Making mixtures in the kitchen



**WEBLINK**  
The components of blood



**ACTIVITY SHEET**  
Donating blood

Figure 6.9

Indigenous Australians use natural ochre mixtures in all forms of their art.



### In the kitchen

Have you ever realised that cooking is a scientific pastime? When you cook, you wear protective clothing such as an oven mitt and an apron. You follow a set of instructions, just like a method, but call it a recipe. You use specialised equipment such as eggbeaters, mixing spoons and measuring cups. You make observations throughout the cooking process, follow safety rules, and clean and pack up your equipment when you are finished.

When preparing food, the recipe often requires you to mix two or more ingredients together in some way. However, the mixtures you make when cooking are not all the same. They may look different because they have different properties.

When cooking pasta you often add salt to the water before it boils. This forms a salt solution. Once the water is boiling, you add the pasta. The pasta often falls to the bottom of the saucepan and it does not dissolve. Adding the pasta to the salted water has created a suspension.

Olive oil and lemon juice mixed together in a particular ratio make a tasty salad dressing. But you need to shake the mixture just before you pour it on your salad because the liquids separate easily. Salad dressing is a colloid.

### In the body

Blood is a vital part of your body. It carries oxygen and glucose to our cells, supplying us with the energy we need to stay alive. Blood helps us fight infections and transports waste products from cells to other organs so that they can be removed from the body. If you cut yourself, blood acts at the site of the cut to stop you from bleeding.

Blood is a mixture of around 50% water (plasma), with red and white blood cells, and other substances suspended in it.

### In art

In art classes, you have probably used a range of different mixtures. These might include paint, and mixtures of clay for pottery or ceramics. Glue is also a mixture. The word

'collage' comes from the French term *coller*, meaning 'to stick or glue'. When making a collage, you glue a range of different materials onto paper or canvas. That is, you make a mixture (a collection of different materials) using another mixture (glue).

#### Mixtures in Indigenous art

Indigenous Australian artists use specific types of clay rock called ochres for their traditional painting. These contain minerals that give them a red, yellow or white colour. The ochre is crushed to a fine powder, and then mixed with a 'binder' to form paint. Binders include saliva, honey, egg yolks, tree resins, animal fat or even blood. By mixing red and yellow, the artists can make orange paint. Black comes from crushed charcoal

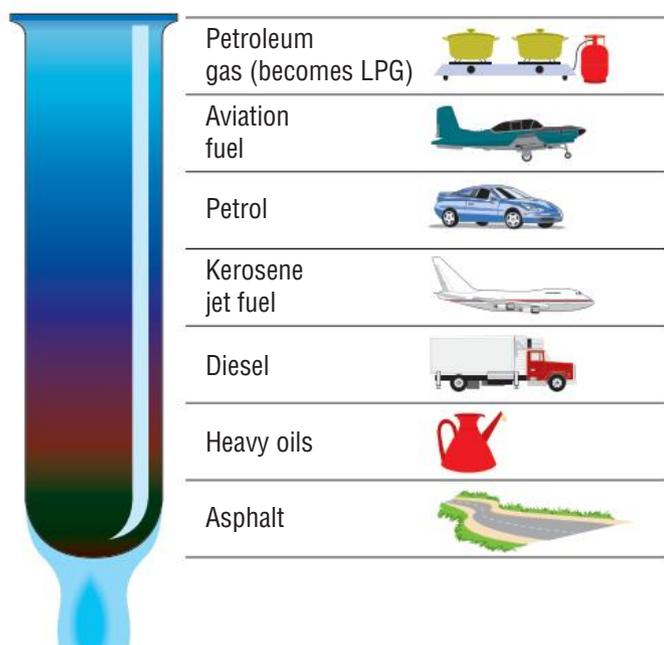
(from burning wood on a fire), mixed with a binder. Today, many Indigenous artists use both modern paints and traditional methods, but their work still features the traditional colours of red, yellow, white, black and orange.

## In energy and materials production

Petrol, polystyrene cups and nylon stockings all contain chemicals that are derived from the same substance – crude oil.

Often called petroleum, crude oil is a dark, thick liquid. It is a naturally occurring mixture that is found in the Earth's crust. Crude oil itself is not a useful mixture. The useful components in crude oil can be separated because they have different boiling points.

Most crude oil is used as a source of energy, providing petrol, kerosene and diesel. Only a small percentage of the crude oil obtained is used by the petrochemical industry to produce plastics, solvents and pharmaceuticals.



◀ **Figure 6.10**

Crude oil is a mixture of many different useful substances, such as petrol, kerosene and diesel.

### QUESTIONS 6.3

## What have you learnt?

### Remembering

- 1 **Identify** three different mixtures that you would find in the kitchen.
- 2 **Identify** the physical property that allows the components of crude oil to be separated.

### Reflecting

- 3 **Predict** how the world would be different if we ran out of crude oil in 2030.

### WORKSPACE

What have you learnt? 6.3





**INTERACTIVE**  
Matter and evaporation –  
liquid to gas



**VIDEO**  
Extracting salt from  
a salt solution



**ACTIVITY SHEET**  
The rate of evaporation  
of water



**WORKSPACE**  
Using evaporation to  
separate a salt solution

## 6.4 Separating solutions

While many mixtures are useful as they are, we sometimes want only certain parts of them. A number of techniques can be used to separate different types of mixtures into their component substances. The process we choose is based on the type of mixture, as well as the physical properties of the substances that make it up.

### Evaporation

Evaporation (see Chapter 5, page 117) is a technique that can be used to separate a solution when we only want to keep the solute. If we leave a salt solution in the sun, the water will evaporate but the salt will not, no matter how long we leave it. We can retrieve the salt because the water (solvent) evaporates, leaving the salt (solute) behind.

If we use a Bunsen burner to heat a salt solution, the water will evaporate more quickly. Heating can decrease the time taken to separate a solution (increases the rate of evaporation).

#### EXPERIMENT 6.2

### Using evaporation to separate a salt solution

Possible risks	Safety precautions
A blue Bunsen burner flame is hard to see and very hot, so you may burn yourself.	Leave the Bunsen burner on the safety flame when not in use, so the flame is easily visible.
Equipment will become hot.	Always use a heat-proof mat with heating equipment. Use tongs or heat mitts to remove the evaporating basin from the tripod and gauze mat.
Hot water or steam may burn you. Salt can spit out of the evaporating basin.	Wear safety glasses and a lab coat, and stand a safe distance away while heating the salt solution.

#### Aim

To separate salt from water.

#### Materials

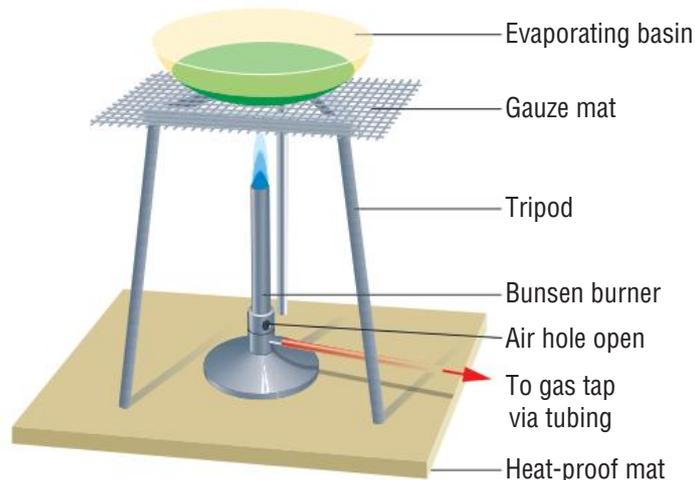
- table salt
- water
- 250 mL beaker
- spatula
- large evaporating basin
- Bunsen burner, tripod, heat-proof mat and gauze mat

## EXPERIMENT 6.2

- tongs or heat mitts
- watch glass
- stereomicroscope, hand lens, digital microscope or camera (for extension)

### Method

- 1 Use the spatula to add four level spoonfuls of salt to 100 mL of water in the 250 mL beaker, and stir until dissolved.
- 2 Set up the evaporating equipment according to Figure 6.11.
- 3 Pour 50 mL of the salt solution into the evaporating basin. Carefully heat the solution until a crust of white powder becomes visible around the inside of the evaporating basin.
- 4 Reduce the heat and place a watch glass three-quarters of the way over the evaporating basin to avoid any spitting. Keep heating the solution until there is only a small amount left.
- 5 Turn off the Bunsen burner. Remove the watch glass when you see no more spitting. Let the evaporating basin cool. Place it in a drying oven or leave it on the windowsill until the remaining water has evaporated.



◀ **Figure 6.11**  
Equipment used to evaporate a solution in the laboratory

### Results

- 1 Display your observations in an appropriate form such as a table or a set of scientific diagrams.

### Discussion

- 2 **Describe** what happened when the salt was added to the water.
- 3 **Explain** why the salt solution decreased in volume as it was heated.
- 4 **Explain** why the salt was left in the evaporating basin but the water was not. ▶

EXPERIMENT 6.2

**Conclusion**

- 5 Write a conclusion.
- 6 Use a graphic organiser to **summarise** what you have learnt from this experiment.

**Extension**

- 7 Use a stereomicroscope, hand lens, digital microscope or the zoom function on a camera to observe the crystals of the salt before and after the experiment. In both cases, **describe** the crystals in terms of size and colour.
- 8 Draw a few crystals or take a digital image.
- 9 **Compare** the salt crystals before and after the activity. **Discuss** what you observe.

## Crystallisation

Copper sulfate is a solid made up of small blue crystals. If you add a teaspoon of copper sulfate to 100 mL of water at a temperature of 20°C, it will all dissolve. We call this an **unsaturated solution** because you can add another teaspoon of copper sulfate to the water and it will also dissolve.

At a temperature of 20°C you can add up to 21 g of copper sulfate to the water and it will still all dissolve. But no more copper sulfate will dissolve after this point. The copper sulfate solution is now called a **saturated solution**.



**WEBLINK**

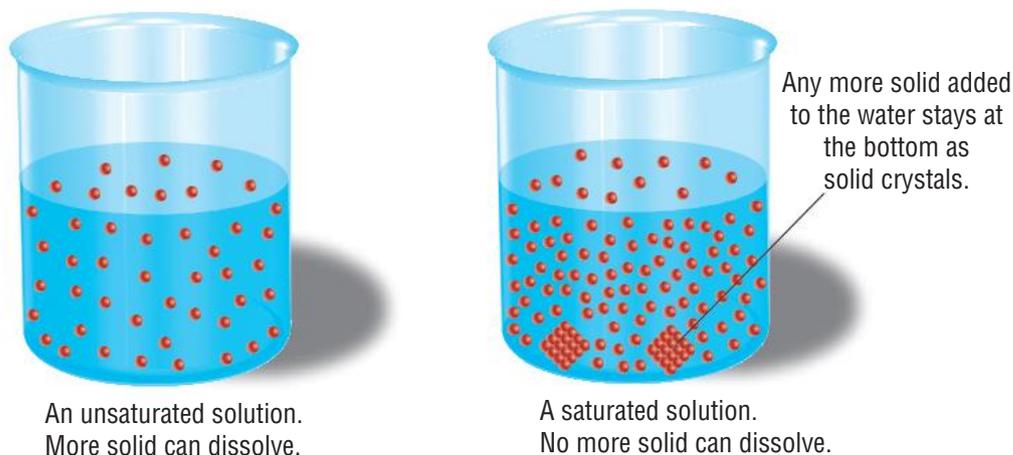
Crystallisation of copper sulfate

**unsaturated solution**

a solution that is able to dissolve more solute at the current temperature

**saturated solution**

a solution in which no more solute will dissolve at the current temperature



**Figure 6.12** ▶

The difference between an unsaturated (left) and a saturated (right) solution

Increasing the temperature of a solution increases the solubility of the solute in the solvent. For example, if the temperature of the saturated copper sulfate solution is increased to 80°C, you can dissolve almost 55 g of copper sulfate in 100 mL of water. If you then cool this solution back to 20°C, only 21 g of the copper sulfate would be soluble. The extra 34 g would come out of solution and form crystals at the bottom and on the sides of the beaker.

The process by which crystals are formed from a saturated solution is called **crystallisation**. This can be done either by cooling a saturated solution from a higher temperature to a lower one or by evaporating off some of the solvent.

### crystallisation

the process by which solid crystals form from a saturated solution, as a result of decreasing the temperature of the solution or slowly evaporating the solvent



## The Dead Sea

The Dead Sea, which borders Israel and Jordan, is one of the saltiest bodies of water on Earth – more than eight times saltier than the ocean. It is called the Dead Sea because very few organisms can live in such a salty environment. The coastline is crusted with solid salt because there is too much salt to be dissolved in the amount of water present.



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## Distillation

**Distillation** is a process used to separate solutions with different boiling points. It can be used when you want to keep both the solute and the solvent. In the laboratory, you can use distillation equipment (Figure 6.13) to separate a solution as it is heated. The substances in the mixture (in the round-bottomed flask) have different boiling points. A substance with a lower boiling point will change to a gas first, separating it from any substances with higher boiling points. As each component boils, it is cooled and turned back into a liquid (**condenses**) in the condenser to form a **distillate**.

### distillation

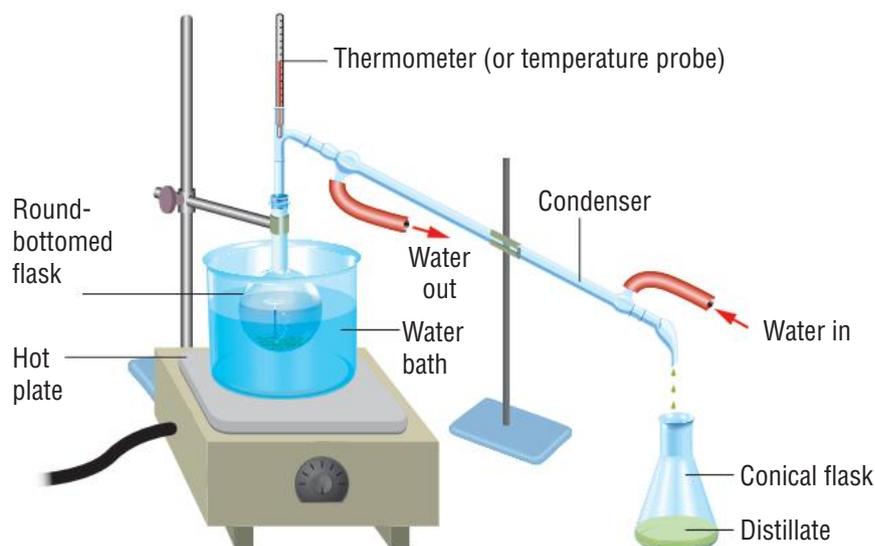
a process that separates solutions on the basis of their different boiling points

### condense

to change from a gas to a liquid by lowering the temperature of the gas to below its boiling point

### distillate

the product obtained by condensing vapours given off during distillation



### VIDEO

Distillation of essential oils



◀ **Figure 6.13**  
Distillation equipment used in the laboratory

**fractional distillation**

a type of distillation used to separate a mixture when the boiling points of its components are very close to one another



**ACTIVITY SHEET**

Does ink contain water?

**Figure 6.14** ▶

Fractional distillation separates crude oil into many useful components.

**chromatography**

a process used to separate small amounts of mixtures

**chromatogram**

a visual display of the results of chromatography



**WEBLINK**

Chromatography - is black really black?



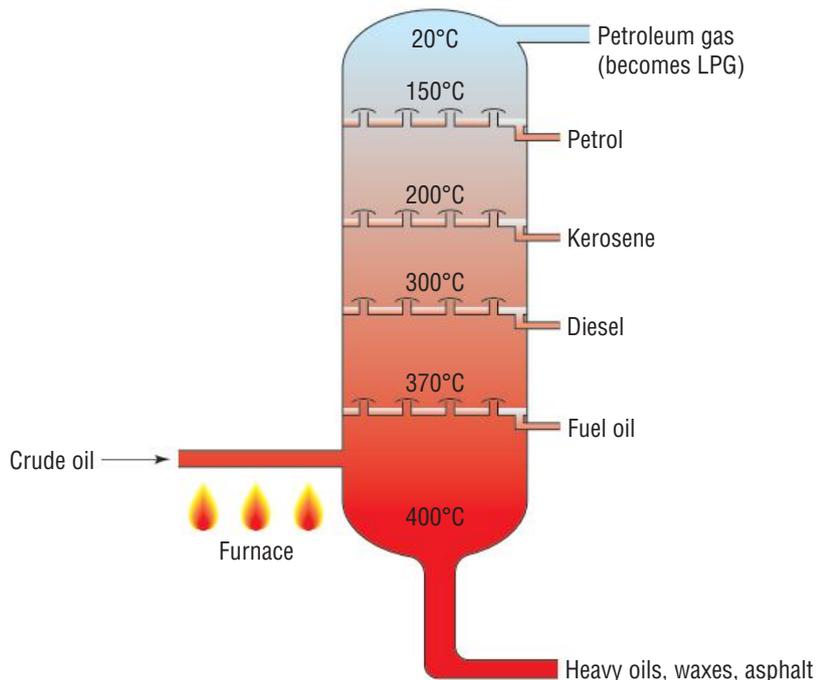
**ACTIVITY SHEET**

Paper chromatography of spinach leaves

**Figure 6.15** ▶

Note how different colours from the dye have separated at different places along the chromatography paper.

Crude oil can be separated into its components by distillation. However, because the useful substances in the mixture have boiling points that are very close to one another, a special form of distillation called **fractional distillation** must be used (Figure 6.14).



## Chromatography

**Chromatography** literally means ‘colour writing’ and is used to separate very small amounts mixtures. There are many different types of chromatography. Paper chromatography can be used to separate different colours in mixtures, such as food colourings, pigments or dyes. These are carried by a solvent at different rates along the chromatography (or filter) paper and so are separated from one another at different points on the paper. Figure 6.15 shows this on a paper **chromatogram**.

Other more complicated forms of chromatography are applied in many areas of science. Forensic scientists use gas chromatography to separate small amounts of mixtures, such as blood and urine samples, to test for the presence of drugs or alcohol.



Science Photo Library/Andrew Lambert Photography

## QUESTIONS 6.4

## WORKSPACE

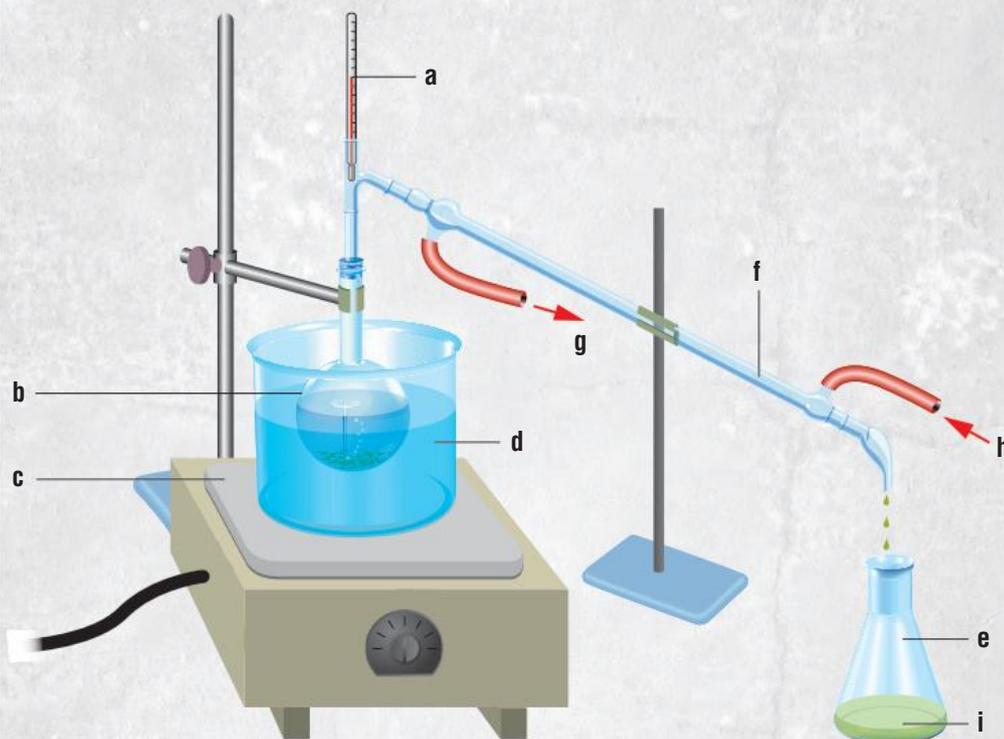
What have you learnt? 6.4



## What have you learnt?

### Remembering

- 1 **Identify** the parts of the distillation equipment labelled **a-i** in Figure 6.16.



◀ **Figure 6.16**  
Distillation equipment

### Understanding

- 2 **Identify** whether the following statements are true or false. If a statement is false, rewrite it to make it true.
- Only solutions can evaporate.
  - If a salt solution is left on the windowsill for long enough, the solute will evaporate, leaving the solvent behind.
  - Increasing the temperature of a solution will increase the solubility of the solute in the solvent.
  - Crystallisation can occur only by cooling a saturated solution.
- 3 **Describe** the function of the following parts of the distillation equipment.
- Thermometer
  - Condenser
  - Water bath and hot plate
- 4 **Explain** why distillation is used instead of evaporation to separate some solutions.

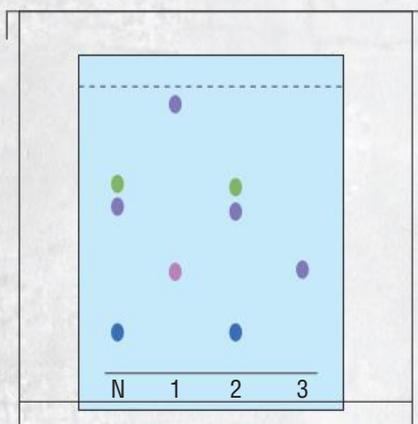
QUESTIONS 6.4

Applying

- 5 Draw labelled scientific particle diagrams showing what happens to the solute and solvent in a salt solution when they are separated by evaporation by boiling. Write a paragraph below your diagram to **explain** what is happening over time as the solution is heated.
- 6 The Dead Sea receives very little rainfall. The air is dry and temperatures are high all year round. Use this information and your understanding of saturated solutions to **explain** why the Dead Sea coastline is covered in solid salt.

Analysing

- 7 There has been a break-in at a jewellery store. A note written in black ink has been found inside the store. Police have detained three suspects: (1) the store owner (who came from home after being notified), (2) a young woman



(who reported hearing the alarm and notified police) and (3) the local security guard. Each suspect had a different black ink pen, which the police have confiscated. Chromatography was used to **compare** each pen with the ink on the note. The results are shown in Figure 6.17.

- a **Identify** who owned the pen like the one that was used to write the note. Explain how you determined this.
- b Does this mean that person was the thief? **Justify** your answer.

Evaluating

- 8 Use the information in Figure 6.18 to answer the questions.
  - a The equipment used for distillation has changed since this illustration from 1873. **Outline** the differences between the equipment shown and the apparatus we use in the laboratory today.



- b **Describe** how improvements in technology have made the process of distilling solutions easier today than in 1873.
- c If you were able to travel back in time to 1873, what changes to the set-up would you suggest to the scientist using this equipment? **Explain** how you think this could have changed our lives today.

Figure 6.17 ►

A chromatogram of the ink samples of the three suspects compared with the ink from the note (N) found at the scene

Figure 6.18 ►

Distillation equipment used in Paris in 1873

## 6.5 Separating suspensions

### Sieving or straining

**Sieving** (or **straining**) is a process often used in the home to separate mixtures. It is most useful when the particle size of one or more of the substances is relatively large. A tea strainer collects tea leaves from a teapot, but allows the tea solution to pass through into the cup. A colander drains the water from washed lettuce leaves or from cooked pasta. Strainers and colanders all have fairly large holes to allow the water or solution to drain out (see Figure 6.19).

#### sieving (straining)

a process of separation used mainly to separate larger solid particles from mixtures; the larger particles are too big to pass through the holes in the sieves (or strainers)



◀ **Figure 6.19**

Examples of sieving or straining: straining herbal tea and draining water from lettuce

### Sedimentation and decanting

A simple way to separate a suspension such as sand and water is to allow it to settle over time. The sand particles are denser than the water, so they fall to the bottom of the container. This is called **sedimentation** and the substance that settles is called the **sediment**. The liquid can be carefully poured off the sediment (often down a glass rod) into another container. This is called **decanting** (see Figure 6.20). Decanting is not a very precise way to separate a suspension: it can stir up some of the solid particles and these may be poured out with the liquid. For this reason, the last bit of liquid is usually left in the container with the sediment and not all the solid is recovered.

#### sedimentation

a process in which denser insoluble particles in a mixture fall to the bottom of a container

#### sediment

the insoluble substance that settles at the bottom of the container during sedimentation

#### decanting

a process of separating a solid–liquid suspension that has been allowed to settle; pouring the liquid slowly down a glass rod



◀ **Figure 6.20**

Decanting a suspension

### filtration

a separation process used to separate suspensions by using a filter

### fluids

a term used to describe liquids and gases because they can flow

### filter

a device containing small holes or pores that allow some substances to pass through but not others; used to separate a suspension

### filter paper

a special type of paper used for filtering, available in a range of pore sizes

### residue

the substance that does not pass through the filter paper when filtering a suspension

### filtrate

the substance that passes through the filter when filtering a suspension



#### WEBLINK

Man vs Wild:  
Filtering dirty water so it's safe



#### ANIMATION

Filtering a suspension

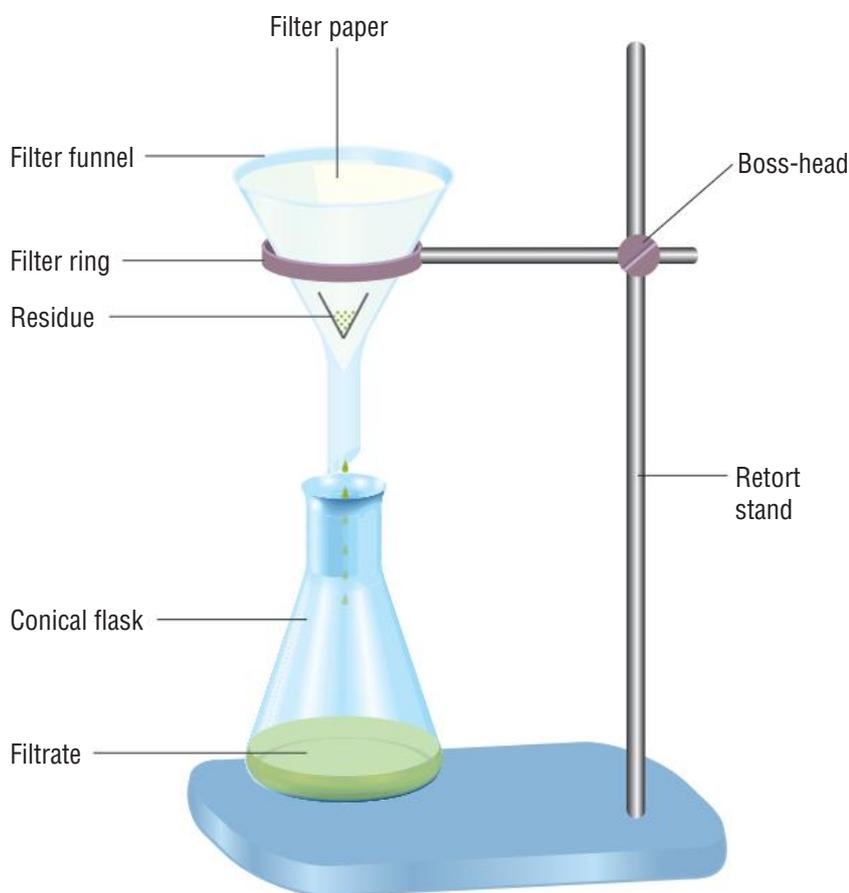
**Figure 6.21** ▶

Filtration apparatus used in the laboratory to separate a suspension

## Filtration

**Filtration** is used to separate solid particles from a liquid or gas (called a **fluid**) by passing the mixture through a **filter**. Filters have very small holes (or pores) that allow some substances to pass through but not others. These holes are much smaller than in equipment used to sieve, sift or strain.

In the laboratory, to separate a suspension such as sand and water, you can pour the mixture into **filter paper**. The water particles are smaller than the pores in the filter paper so the water passes through. However, the sand collects in the filter paper because the particles are bigger than the pores in the paper. The substance collected in the filter paper is called the **residue**. Sand is the residue. The fluid that passes through is called the **filtrate**. Water is the filtrate. Filtration is a useful separation technique because you can retrieve both the filtrate and the residue from the suspension.



### EXPERIMENT 6.3

## Using filtration to separate sandy water

### Aim

To separate sand from water.

### Materials

- sand (that has been dried in an oven)

**EXPERIMENT 6.3**

- water
- spatula or spoon
- watch glass
- electronic balance
- 100 mL measuring cylinder
- 250 mL beaker
- conical flask
- glass rod
- filter paper (that has been dried in an oven)
- filter funnel
- wash bottle
- filter ring
- retort stand and clamp
- access to an oven

**Method**

- 1 Predict whether the mass of sand collected will be the same at the beginning and the end of the experiment.
- 2 Put the filter paper and 2 teaspoons of sand onto a watch glass and use an electronic balance to find the total mass in grams.
- 3 Use the measuring cylinder to add 150 mL of water to the 250 mL beaker.
- 4 Add all of the sand to the 250 mL beaker and stir with the glass rod.
- 5 Set up the filtration equipment as shown in Figure 6.21.
- 6 Fold the filter paper and place it in the filter funnel.
- 7 Slowly pour the suspension into the filter paper, a small amount at a time, until all of the suspension has been added.
- 8 If there is sand left in the beaker, use the wash bottle to add extra water to wash all of the remaining sand into the filter paper.
- 9 Allow the apparatus to sit until no more changes are observed. Place the filter paper containing the wet sand onto the same watch glass you used before and dry it in an oven.
- 10 When dry, use the electronic balance to find the mass of the sand, filter paper and watch glass.

**WORKSPACE**

Using filtration to separate sandy water



### EXPERIMENT 6.3

#### Results

- 1 Use a table to record the mass of sand, filter paper and watch glass before and after the experiment. **Outline** any observations made.

#### Discussion

- 2 **Identify** the filtrate and the residue.
- 3 **Compare** the mass of sand, filter paper and watch glass before and after filtration. **Account** for any differences.
- 4 **Describe** what you would have observed if you had sieved or decanted the mixture.
- 5 **Explain** what happened in the experiment using the particle theory.

#### Conclusion

- 6 **Outline** why filtration is a good technique to use to separate a suspension such as sandy water.

### Filtration at home

Filtration is often used in the home. Vacuum cleaners contain dust bags with small pores that separate solid dust particles from the air. Cars use air filters to remove dust and dirt so that it does not damage the engine. Clothes dryers trap lint so that it doesn't end up all over your clothes. You might also use a filter to improve the taste and clarity of your drinking water in a special jug or through a device on a tap.

In Australia, water is carefully monitored and managed by a number of processes. The drinking water that is piped to our homes is collected in dams. We cannot drink dam water because it also contains other substances, some of which may be harmful. Germs, wastes and other pollutants need to be removed from the water before it reaches our taps as the clear, colourless, odourless liquid we drink every day. Furthermore, once the dirty water (wastewater) leaves our toilets, showers, laundries and sinks, it needs to be treated before it re-enters lakes, rivers, streams or oceans. Because all of the water we use ultimately ends up in the environment, these pollutants must be removed. This water is treated using physical, chemical and even biological separation techniques.

Increased population growth and variable weather patterns have resulted in the increasing need to conserve water in the dams for drinking purposes so we can manage water for the future. One method of producing drinking water that does not rely on rainfall is **desalination**. This process removes the salt from sea water by pumping it under high pressure through membranes that have microscopic pores. The pore size of this type of filter can be approximately 150 000 times smaller than the diameter of a hair on your head.

This membrane technology is also used by Sydney Water at the St Marys Advanced Water Recycling Plant. It is the only plant in the world that uses this technology purely for environmental purposes. Here, wastewater is treated to such a level that it is purer than drinking water. It is pumped to the Hawkesbury–Nepean River to maintain the river's flow and reduce the volume of nutrients entering the waterway. This means that less water from the nearby Warragamba Dam is used for these purposes, meaning more water is stored in the dam for drinking. This has conserved up to 18 billion litres of water in the dam every year since the plant opened in 2010.



**VIDEO**  
Drinking water from  
sea water

#### desalination

an industrial process of removing  
salt from sea water



◀ **Figure 6.22**

Filters **a** separate grounds from coffee, **b** remove lint from the air in a clothes dryer and **c** prevent dust from the air being sucked into a car engine.



### Penguins and salt

Penguins can drink salt water. A gland just above their eyes, called the supraorbital gland, filters excess salt from their bloodstream, and the salt is excreted from their nasal passages.

#### EXPERIMENT 6.4

### Student investigation: Separating a mixture

Each pair of students will be given a number of different 'contaminated' water samples. As a team, use your knowledge to plan how to separate your mixture using the separation processes described in this chapter. Provide your teacher with a plan, an equipment list and a safety audit.

When you carry out your investigation, make sure that you observe all of the safety precautions outlined, as well as any others your teacher has suggested. Present your findings in a scientific report.



**WORKSPACE**

What have you learnt? 6.5

**QUESTIONS 6.5**

**What have you learnt?**

**Remembering**

- 1 **Define** the following terms.
  - a Sediment
  - b Decant
  - c Filtrate
  - d Residue

**Understanding**

- 2 Place the methods of decanting, filtration and sieving in order from most to least accurate when separating a suspension of sandy water.
- 3 You are at the movies, sharing a box of popcorn. You shake the box occasionally to make sure the largest, best, bits of popcorn are on top. **Describe** what you will find when you get to the bottom of the box. **Explain** the method(s) of separation you used here.

**Applying**

- 4 Baleen whales and flamingos are called filter feeders. **Describe** what you think the structure of their mouths would look like.
- 5 When using a mop to clean the kitchen floor, the water in the mop bucket can get dirty very quickly as the small dirt particles are mixed with the water. Some floor cleaners contain chemicals called flocculants that cause these fine dirt particles to clump together, forming larger, heavier particles.
  - a **Identify** the separation technique that would occur after the fine dirt particles clump together.
  - b What advantages might this have:
    - i when cleaning the floor
    - ii for the environment?
- 6 A gardener wants to plant a lemon tree in a large pot. The label on the tree says that the soil needs to be well drained. The gardener is trying to decide whether to use soil from the garden or one of two different potting mixes he has in the shed. Describe an experiment he could carry out to determine which of these has the best drainage.

**Evaluating**

- 7 View the video 'Separation techniques in the kitchen – making a cup of tea'. **Outline** how could you improve on the script of this video using the information you have learnt so far about mixtures and separation.
- 8 Find a recipe (or make up your own) for a dish that uses a number of separation processes. **Identify** the types of mixtures used in the recipe and to explain the separation processes involved.



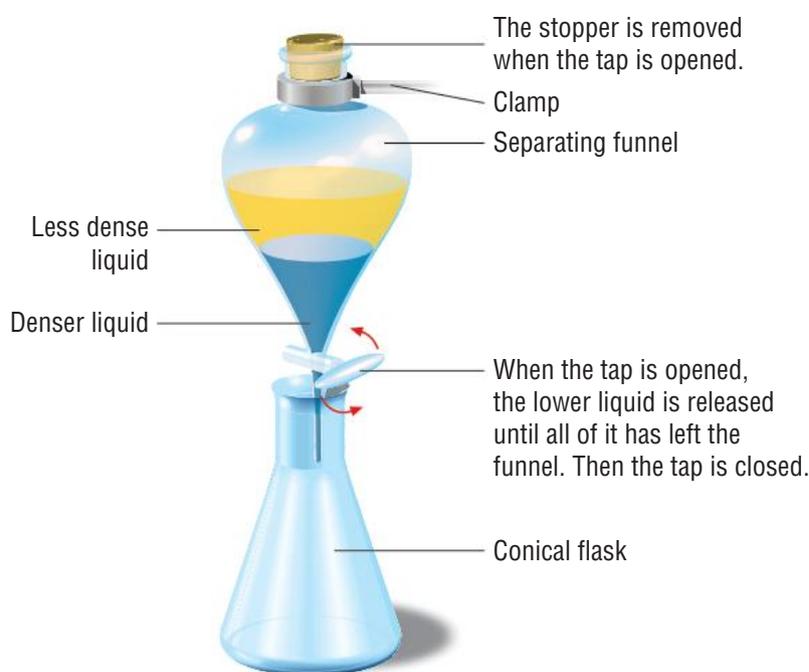
**VIDEO**

Separation techniques in the kitchen – making a cup of tea

## 6.6 Importance of separation techniques

On 20 April 2010 the largest marine oil spill in history occurred after an explosion on the Deepwater Horizon oil rig in the Gulf of Mexico that resulted in the release of hundreds of millions of litres of crude oil into the water. The oil leak was not stopped for almost three months. This human-caused disaster had a devastating effect on the local wildlife and ecosystems, and also local fishing and tourism industries.

Oil spills often result in an oil slick, where the oil layer seems to ‘sit’ on top of the water. An oil-and-water mixture can be separated using a piece of equipment called a **separating funnel** (see Figure 6.23).



### separating funnel

a piece of equipment used to separate a suspension of two insoluble liquids in the laboratory

### WEBLINK

Create your own flashcards

### ACTIVITY SHEET

Separating mixtures

◀ **Figure 6.23**

Using a separating funnel

### QUESTIONS 6.6

## What have you learnt?

### Understanding

1 **Explain** why we need to filter dam water before it is safe to drink.

### Applying

2 **Outline** why a gigantic separating funnel could help clean up oil spills.

### WORKSPACE

What have you learnt? 6.6



## Chapter review

### Remembering

- 1 **Define:**
- a chromatography
  - b crystallisation
  - c suspension
  - d sediment
  - e residue

### Understanding

- 2 **Distinguish** between a pure substance and a mixture. Provide an example of each to support your answer.
- 3 a **Describe** what you would observe if a teaspoon of salt was added to a glass of hot water and stirred.
- b **Explain** why this occurs.
- c i What type of mixture is salt and water?  
ii What is the salt called?  
iii What is the name given to the water?
- d If you kept adding teaspoon after teaspoon of salt to the glass of water, do you think the salt would continue to dissolve? **Explain** your answer.
- 4 **Identify** which technique(s) could be used to:
- a collect salt from sea water
  - b determine the colours used in making black jelly beans
  - c remove large pebbles from a mixture of soil, leaves and dirt
  - d collect drinking water from sea water
  - e remove sliced vegetables from boiling water
  - f determine if an Olympic sprinter has any illegal chemicals in his or her blood.

### Applying

- 5 a In Figure 6.6 on page 143, the blue spheres represent the particles of the solvent (water). The red spheres represent the particles of the solute (cordial). Write a paragraph to describe the difference between the two mixtures.
- b Count the number of solvent particles in each beaker. What did you find?
- c Count the number of solute particles in each beaker. What did you find?
- d How do your answers to b and c support your understanding of the terms 'concentrated' and 'dilute'?
- 6 **Describe** how you could use laboratory equipment to make rose-scented water.
- 7 **Compare** the filter paper used in the laboratory with a microscopic membrane filter used in a desalination plant.



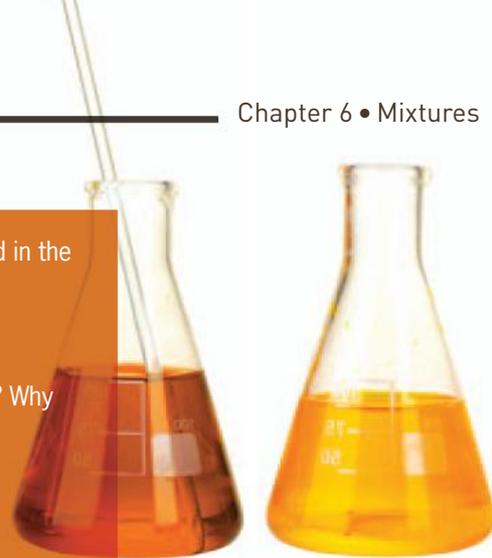
**WORKSPACE**  
Chapter 6 review



**ACTIVITY SHEET**  
Chapter 6 checklist



**REVIEW QUIZ**  
Chapter 6



- 8
- Compile a list of all of the separation techniques you can think of that are used in the home.
  - Classify** the techniques into groups based on how similar they are.
  - Explain** your reasons.
  - Which separation techniques investigated in this unit are not used in the home? Why do you think they are not used?
  - Can you think of an invention that could allow one of the separation techniques outlined in part **d** to be implemented in the home?

## Analysing

- 9 **Compare** crude oil and milk as mixtures. Identify at least two similarities.
- 10 A mixture of sand, salt and water to be separated in the laboratory weighed 235.6 g. After the mixture was filtered, the residue was wet and the filtrate weighed 202.9 g. The filtrate was then distilled until 4.03 g of white powder was left in the round-bottomed flask.
- Identify** the residue, the filtrate and the distillate.
  - From the data given, **determine** the mass in the original mixture of the:
    - sand
    - salt
    - water.
- 11 A student was observing the effect of temperature on the solubility of two different substances: potassium nitrate and sodium chloride. For each substance, he recorded the mass in grams that would dissolve in 100 mL of water at different temperatures (shown in Table 6.2).
- Identify** the independent and dependent variables.
  - Identify** the variables that would need to be held constant in this experiment.

**Table 6.2** ▲

Solubility of potassium nitrate and sodium chloride in 100 mL of water

Temperature of solution (°C)	Mass of potassium nitrate dissolved in 100 mL (g)	Mass of sodium chloride dissolved in 100 mL (g)
10	21.9	35.8
20	31.6	35.9
30	45.3	36.1
40	61.3	36.4
60	106.0	37.1
80	167.0	38.0
100	245.0	39.2

- Enter the data into a spreadsheet (or use graph paper). Plot each set of points on the same axes, adding one line (or curve) of best fit for potassium nitrate and another for sodium chloride.



- d **Account** for the use of a line graph as the best type of graph to represent this data.
- e Using your graph, write a general statement regarding the effect of temperature on solubility.
- f Use your graph to calculate the:
- mass of potassium nitrate soluble in 100 mL of water at 50°C.
  - mass of potassium nitrate that could be dissolved in 50 mL of water at 50°C
  - temperature at which the same mass of each substance is dissolved in 100 mL of water
  - substance that is more soluble in water. **Explain** your answer.

**12** You are making coffee after dinner. Uncle Gilligan asks for a strong cup of coffee. For his cup, you add 2.3 g of coffee powder to 250 g of water. For each of the other cups, you add 1.5 g of coffee powder.

- a Calculate the percentage of coffee powder in a 'normal' cup of coffee.

Hint:

$$\text{Percentage of coffee} = \frac{\text{mass of coffee}}{\text{mass of water}} \times 100$$

- b Calculate how much more coffee powder (as a percentage) Uncle Gilligan has in his cup.
- c **Explain** why Uncle Gilligan's request for a 'strong' cup of coffee might not be the expression that a scientist would use.

## Evaluating

**13** 'When scientists combine advancements in technology with their understanding of how to separate mixtures, it can only have a beneficial effect on society and the environment.'

**Evaluate** this statement, giving examples.

## Creating

**14** Salt is only slightly soluble in a liquid called ethanol. Ethanol has a boiling point of approximately 78°C. Write a detailed method you could use in the laboratory to separate a mixture of sand, ethanol and salt. The sand and salt must be reclaimed as solids and you must also reclaim the liquid ethanol. **Explain** how each separation process allows the collection of each substance.

**15** Complete the organising tool you started in Activity 6.1.

## Reflecting

**16** Think back to what you knew about separating mixtures in everyday life at the beginning of the chapter.

- a **Identify** some methods you have used at home in the past without realising they were separation techniques.
- b **Describe** some examples that you had not previously thought of as mixtures.



# 7

## Our solar system

How can we use models to help us understand our solar system?

For most of human history, people believed that the Sun, Moon, stars and planets moved around the Earth. They observed – just as we do today – that the Sun, stars and planets move across the sky. Early astronomers constructed models with the Earth at the centre. However, as measurements became more accurate, they realised that Earth-centred models did not work. Polish astronomer Copernicus was the first to provide mathematical support for the opposing idea that the Sun was at the centre of our revolving planets. Fearing punishment from the Catholic church, he delayed publication for decades. His model was published in the year of his death, 1543.

Corbis/Bettmann

PHILIP...  
1497-1550  
SOLARIUM  
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POLONICUS ERAT

## Earth and space sciences – Stage 4

### Key knowledge

- The positions of the Sun, Earth and our Moon with respect to each other relate to why day, night, seasons and eclipses occur.
- Scientists make models, theories and laws to explain the movements of celestial bodies.
- Cultural and historical models and theories are fixed or replaced as new scientific evidence emerges.
- New technology leads to continued discovery and increases our understanding of our solar system.

### CULMINATING ASSESSMENT TASK

## Lost in space

Throughout this chapter, you will design and construct a variety of three-dimensional models to demonstrate and explain solar or lunar phenomena observed from Earth. For the culminating assessment task, you will make a movie to explain how one of these models illustrates the relevant solar or lunar phenomenon.

### What to do

- 1 Choose one of the models that you make in this chapter.
- 2 **Construct** a series of storyboards to show what needs to be filmed.
- 3 Use the storyboards to **create** the movie.



### ACTIVITY SHEET

CAT with rubric: Lost in space

## What do you already know about our solar system?

Use the table in the workspace to answer the following questions. In the second column, write the ideas you have at the start of the chapter. Fill in the third column as you work through the chapter.

- 1 **Describe** what you already know about:
  - a the position of sunrise throughout the year
  - b the position of sunset throughout the year
  - c how we measure the year
  - d seasons
  - e Moon phases
  - f solar and lunar eclipses.
- 2 **Construct** a diagram that shows as many parts of the solar system as you can recall.

### WORKSPACE

What do you already know about our solar system?



# 7.1 The solar system and beyond

The objects seen in the night sky have caused awe in people since the human race started looking up at the sky. Ancient farmers first started observing the sky to work out the best times to plant crops. Before the invention of the telescope allowed scientists to study the sky, people had to observe the universe using only the naked eye.

Ancient people thought that everything in the sky was part of a series of spheres, a little like the layers of an onion. Some 'stars' were wanderers. They appeared to move constantly compared to the other stars. We now call these wanderers the planets.

Ancient people were able to see most of the objects in the **solar system**, and described Mercury, Venus, Mars, Jupiter and Saturn.

The centre of our solar system is the Sun. More than 99% of the total mass of the solar system is found in the Sun. Due to its size, it exerts a large gravitational field that attracts all the other objects in the solar system. Eight planets orbit the Sun, but they all take a different amount of time to do so.

While we think of the Earth as being large in comparison to us, relative to the rest of the solar system, it is quite small. Most of the solar system is empty space. The distance between the planets is huge.

The Sun is 8 light-minutes away from the Earth. A **light-minute** is the distance light travels in a minute. This means that it takes 8 minutes for light to reach the Earth from the Sun.

## The Sun

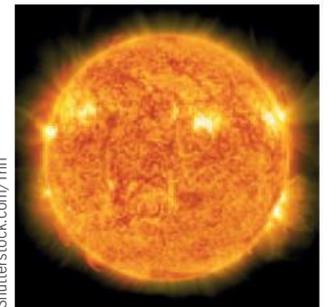
The Sun is a large ball of gas. This gas is held together by the attractive force of gravity. Most of the gas is hydrogen and helium. These gases are undergoing nuclear fusion – simple atoms are converted into more complex atoms. This process releases a huge amount of energy, which is what we feel and see as sunlight.

### solar system

a star (such as our Sun) and all the planets and objects orbiting it

### light-minute

the distance light travels in 1 minute



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**Figure 7.1**

The Sun is the centre of our solar system.

**solar year**

the time taken for a planet to make one complete orbit around the Sun (for Earth, this is about 365.25 days)

**day**

the time taken for a planet to spin on its axis (on Earth, this is 24 hours)

**rotation**

the spin of a planet on its axis

The temperature of the surface of the Sun is about 5500°C. At its core it is around 14 million degrees Celsius.

## Mercury

Orbiting closest to the Sun is Mercury. Rocky and desolate, Mercury has no atmosphere because all gases are burnt off due to its closeness to the Sun. Mercury orbits the Sun every 88 days. While its **solar year** is short, its **day** is double the length of its year, as the time it takes to make one complete revolution on its axis is actually 176 days.

Mercury's slow **rotation** has a curious effect on its surface. While the surface facing the Sun boils at over 400°C, the side facing away from the Sun is freezing at nearly -200°C.



Diameter: 4900 km  
 Average distance from Sun: 58 000 000 km  
 Time to orbit Sun: 3 months  
 Time to turn on axis: 1400 hours  
 Tilt of axis: 23.5°  
 Orbital speed: 48 km/s  
 Mass:  $3 \times 10^{23}$  kg  
 Type of planet: Terrestrial (small and rock, like Earth)

**Figure 7.2** ▶

Mercury is the closest planet to the Sun.

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## Venus

Venus was named after the Roman goddess of love, as it is often the brightest object in the night sky, particularly at dusk and dawn, reflecting a great deal of the Sun's light that shines on it.

While Venus is the second closest planet to the Sun, its surface is the hottest – nearly 500°C. This is due to a thick atmosphere of sulfuric acid and carbon dioxide that traps the heat from the Sun. Much of this sulfuric acid is thought to have come from active volcanoes.

Some scientists are concerned that increased amounts of gases, such as carbon dioxide in the Earth's atmosphere, might create a Venus-like surface in the future.



Diameter: 12 000 km  
 Average distance from Sun: 108 000 000 km  
 Time to orbit Sun: 7.5 months  
 Time to turn on axis: 5830 hours  
 Tilt of axis: 2.7°  
 Orbital speed: 35 km/s  
 Mass  $5 \times 10^{24}$  kg  
 Type of planet: Terrestrial

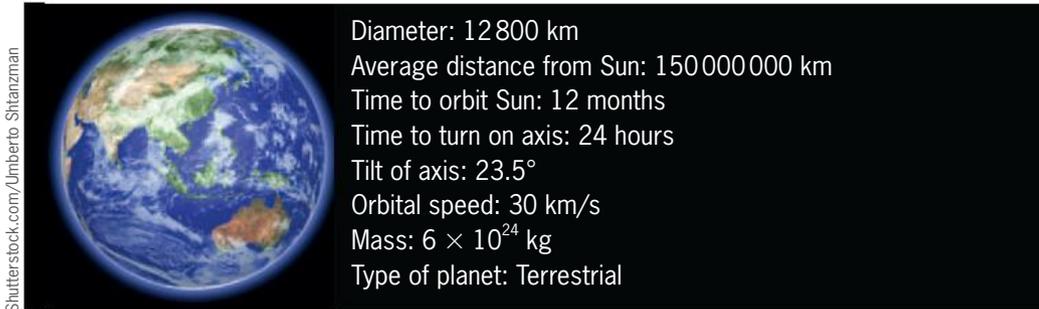
**Figure 7.3** ▶

Venus is the second planet from the Sun.

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## Earth

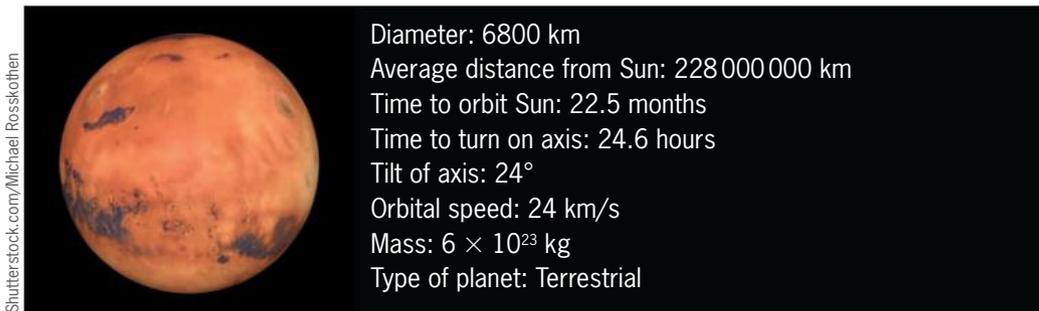
Earth is the only known planet that has liquid water on its surface. This has allowed life to flourish. The Earth's surface is constantly being changed. Forces such as water and wind weather and erode its surface, and forces deep under the crust generate magma, which comes to the surface and creates new rock.



◀ **Figure 7.4**  
Earth is the third planet from the Sun.

## Mars

Mars was named after the Roman god of war due to its angry, red colour. It is smaller than the Earth, which means that it has a weaker gravitational force, making it easier for atmospheric gases to escape into space. This, and its large distance from the Sun, means that it is much cooler than the Earth. Scientists are currently working on how to send astronauts to Mars in the future for exploration and possible colonisation.

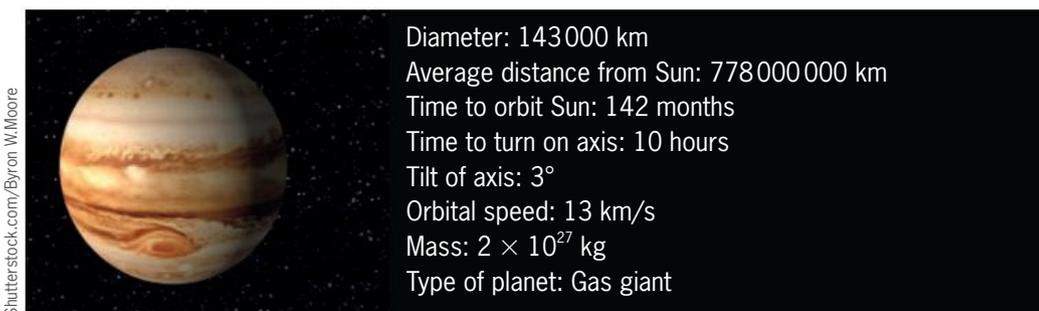


◀ **Figure 7.5**  
Mars is the fourth planet from the Sun.

## Jupiter

Jupiter is a huge planet made of gas. It was one of the first objects that Galileo looked at with a telescope. He was able to observe Jupiter's large red spot and some of its moons.

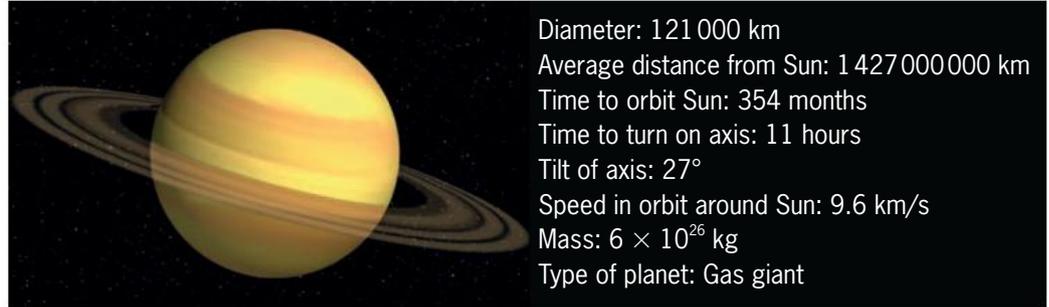
The red spot is thought to be a giant storm in Jupiter's atmosphere. It is amazing to think that this storm has been raging for well over 400 years. Jupiter's surface is so cold that hydrogen, which is normally a gas, exists as a liquid there.



◀ **Figure 7.6**  
Jupiter is the fifth planet from the Sun.

## Saturn

Saturn is well known for its large system of rings surrounding it. These rings are thought to be from a moon that may have broken apart. Other planets also have rings but most of these are quite faint and hard to observe.



Diameter: 121 000 km  
 Average distance from Sun: 1 427 000 000 km  
 Time to orbit Sun: 354 months  
 Time to turn on axis: 11 hours  
 Tilt of axis: 27°  
 Speed in orbit around Sun: 9.6 km/s  
 Mass:  $6 \times 10^{26}$  kg  
 Type of planet: Gas giant

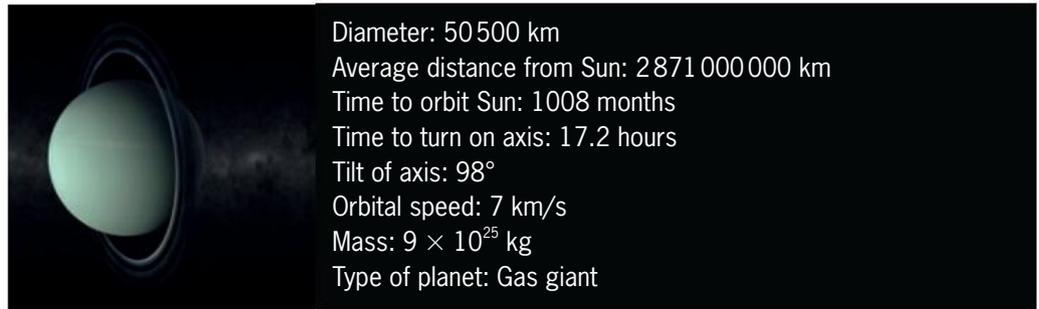
iStockphoto

**Figure 7.7** ▶

Saturn is the sixth planet from the Sun.

## Uranus

Uranus was discovered in 1781 by William Herschel. It has since been observed that Uranus rotates on its axis on its side compared to the other planets in the solar system.



Diameter: 50 500 km  
 Average distance from Sun: 2 871 000 000 km  
 Time to orbit Sun: 1008 months  
 Time to turn on axis: 17.2 hours  
 Tilt of axis: 98°  
 Orbital speed: 7 km/s  
 Mass:  $9 \times 10^{25}$  kg  
 Type of planet: Gas giant

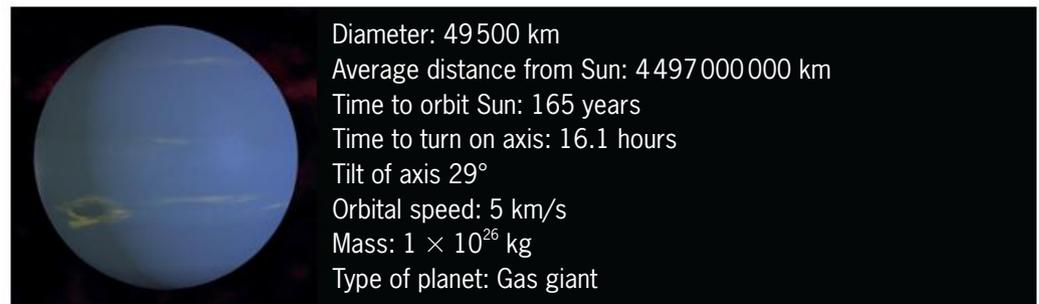
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**Figure 7.8** ▶

Uranus is the seventh planet from the Sun.

## Neptune

The last 'official' planet in the solar system, Neptune was predicted to exist by Urbain Le Verrier. This prediction was based on his observations of Uranus, which 'wobbles' in its orbit. Le Verrier inferred that there must be another planet further out. This was confirmed by Johann Gottfried Galle in 1846. Galileo also observed Neptune, but he thought it was just a star.



Diameter: 49 500 km  
 Average distance from Sun: 4 497 000 000 km  
 Time to orbit Sun: 165 years  
 Time to turn on axis: 16.1 hours  
 Tilt of axis 29°  
 Orbital speed: 5 km/s  
 Mass:  $1 \times 10^{26}$  kg  
 Type of planet: Gas giant

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**Figure 7.9** ▶

Neptune is the eighth planet from the Sun.

## Dwarf planets and other solar system objects

In 2006, the International Astronomical Union declared a new classification for solar system objects not quite big enough to be classed as planets.

You may have seen old posters that had Pluto listed as the ninth planet. However, Pluto is now classed as a dwarf planet along with other solar system objects such as Ceres, Haumea, Makemake and Eris.

This far out at the edge of the solar system is a region called the Kuiper Belt. The Kuiper Belt is larger than the asteroid belt between Mars and Jupiter, and could contain hundreds of millions of objects. Many of these objects may be over a kilometre in diameter.

At the very edge of our solar system is the Oort Cloud, thought to be a collection of ice, dust and fragments left over from the formation of the solar system. It is from here that many of the comets, including the famous Halley's Comet, originate. Halley's Comet flies from the edge of the solar system and is visible from Earth every 75 years.



Getty Images/Digital Vision

◀ **Figure 7.10**

Halley's Comet, which is visible from Earth every 75 years.

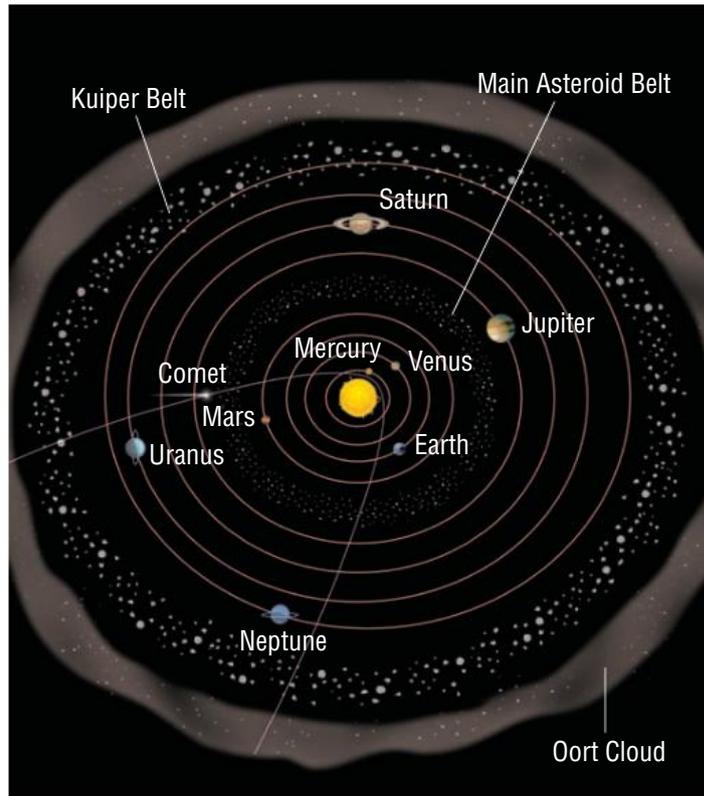
### ACTIVITY 7.1

## Planetary data

**Construct** a creative summary of the data from the planets in the solar system.

**WORKSPACE**  
Planetary data





**Figure 7.11** ▶

The solar system, showing the revolution of the planets around the Sun. The time this takes is different for different planets.



**WORKSPACE**

Why are there differences?

**ACTIVITY 7.2**

**Why are there differences?**

- 1 **Propose** why the concept of a day and year might be different on planets other than Earth.
- 2 **Compare** your reasons with those proposed by other students.
- 3 **Investigate** how you would find out the real answer. Try this and upload your answer to the class wiki.



**WORKSPACE**

Solar system objects

**EXPERIMENT 7.1**

**Solar system objects**

**Aim**

To identify the relative sizes and distances on the main objects in the solar system

**Materials**

- numerous spherical objects of different sizes, such as marbles and balls

## EXPERIMENT 7.1

### Method

- 1 Use the data from Activity 7.1 to organise the spherical objects as the planets. If you have time, you could construct your own planets from papier-mâché or Styrofoam.
- 2 Work out an appropriate scale for the distance between the planets along a 100m line.
- 3 Use an appropriate source to find out the distance from Earth to the nearest star other than the Sun. Discuss how this information could be incorporated into this activity.

### Discussion

**Critically analyse** how this activity has helped your idea of the relative distances and sizes of objects in the solar system.

## QUESTIONS 7.1

### What have you learnt?

#### Remembering

- 1 **Identify** three dwarf planets.

#### Understanding

- 2 **Identify** the planet that:
  - a is closest to the Sun
  - b is furthest from the Sun
  - c takes the longest time to orbit the Sun
  - d takes the shortest time to turn on its axis.

#### Analysing

- 3 **Calculate** how much longer Saturn takes than Jupiter to orbit the Sun.
- 4 If a 'year' is one orbit of the Sun, **calculate** how long a year is for Saturn (in Earth days).

#### Evaluating

- 5 Mars is known as the red planet. **Evaluate** whether 'Mars' is an appropriate name. **Justify** your answer.
- 6 **Construct** a table to **compare** the masses and diameters of five planets.
- 7 Research the types of telescopes available to astronomers and what they have revealed about the solar system.

### WORKSPACE

What have you learnt? 7.1



## 7.2 The positions of the Earth and Sun

When ancient people started looking at the sky, they saw patterns. The most obvious pattern was that the Sun rose in the east and set in the west. As the seasons changed, the Sun's starting point would change, but it would eventually return to its starting position.

Different tribes and different cultures across the world tried to explain what they could observe in many different ways.

Aboriginal tribes such as the Yolngu talked of the Sun being Walu, the sun woman. She would light a torch in the morning, cover herself in red ochre and carry the torch across the sky.

The Egyptians told the story of Ra, who rose in the morning as a newborn and went through a whole lifespan through the course of a day, to set in the evening as an old man. At night, he travelled through the afterlife to be reborn the next day.

Look at Figure 7.12. Which side is sunrise?



### ACTIVITY SHEET

Compass points

**Figure 7.12** ▶

The movement of the Sun across the Australian sky from sunrise to sunset during one day. Can you see where Walu's red ochre is falling into the sky?

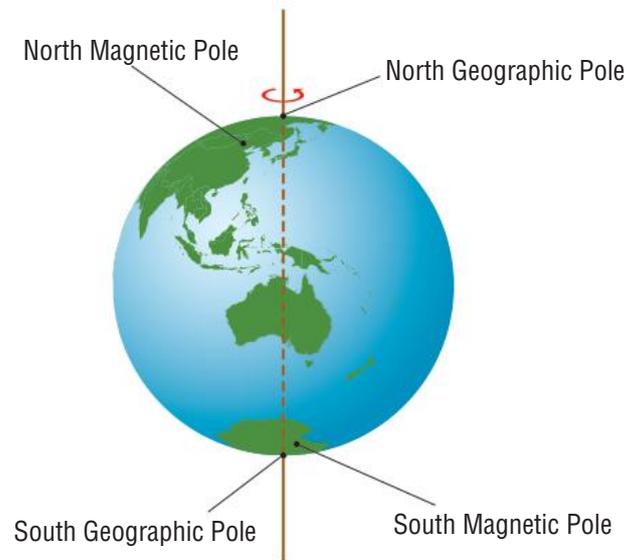


Getty Images/Science Photo Library

### Time by the Sun

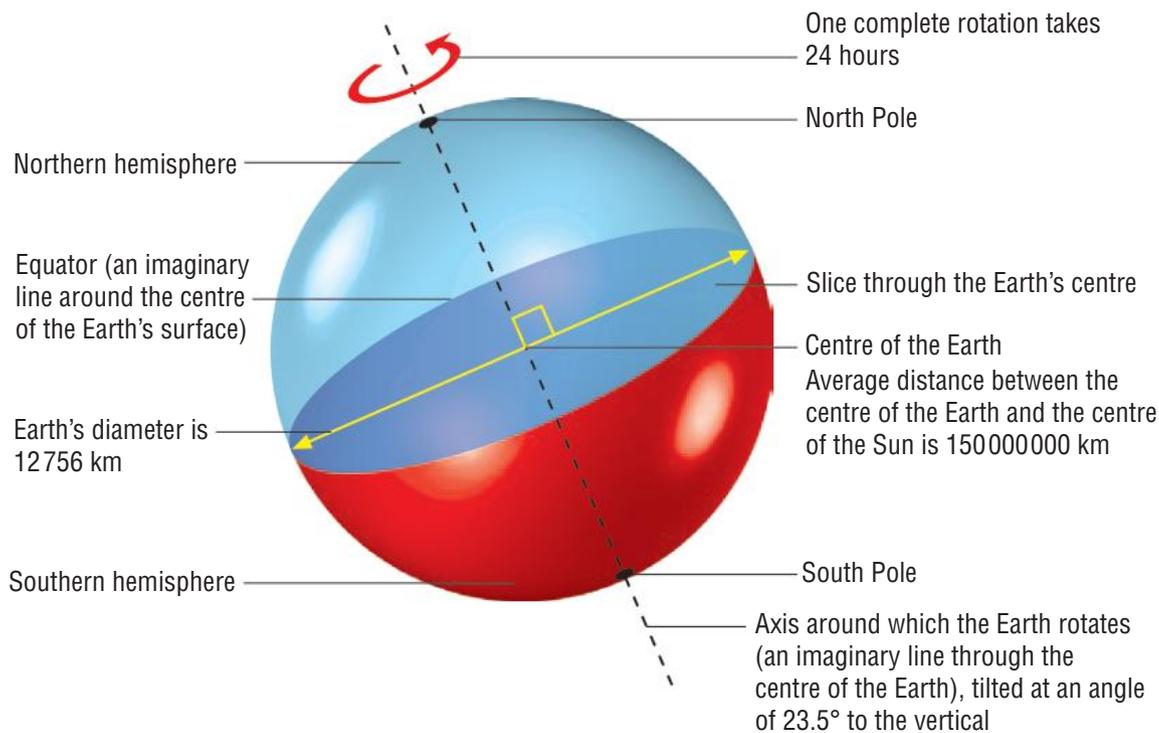
Most of the time values such as days and years are governed by the way the Earth moves around the Sun.

While we often call the time when the Sun is out the 'day', and the time when there is no shining the 'night', astronomers have a different idea of what a day is. The astronomical definition of a day is the time it takes the Earth to make one complete rotation on its axis. On Figures 7.13 and 7.14 you will see that there is an imaginary line going through the Earth from the North Pole to the South Pole. This is the point around which the Earth spins. Luckily, you are moving along with it as the Earth is spinning at more than 1600 km/h at the equator!



**Figure 7.13**

The Earth's geographic poles are not at the same places as its magnetic poles.



► **Figure 7.14**  
Planet Earth's vital statistics

In the previous section, we saw how we can measure the days and years of other planets relative to the Earth. If you lived on Venus, you would think that years were much shorter than days.



## Two types of North Pole

True north is the direction to the North Geographic Pole. A compass is a little magnet that spins so as to point towards the North Magnetic Pole. The geographic pole is not at the same place as the magnetic pole, so there is a difference between the magnetic north to which a compass points and true north. If you are a long way from either pole, this does not matter much, but finding true north is a tricky business when you are close to either one!

From Melbourne, the South Magnetic Pole is  $11^\circ$  to the west of geographical south. From Perth, the difference is  $2^\circ$  to the east.

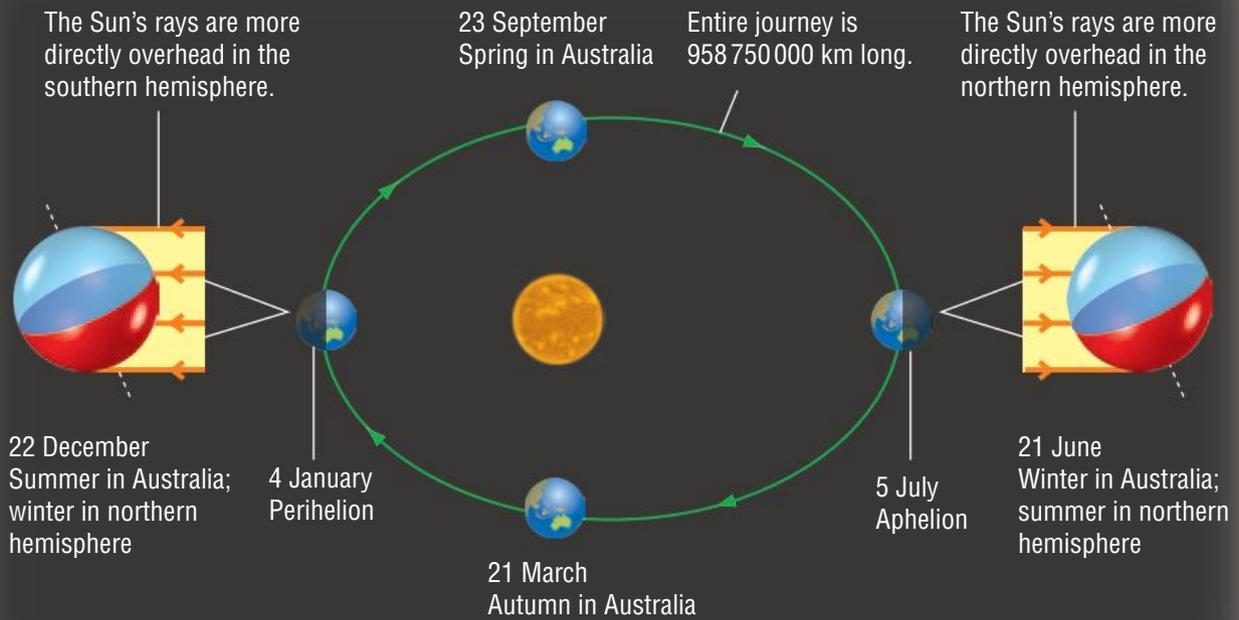
Different cultures produce different explanations for the Sun's movement in the sky. These stories have great meaning within a culture because they assist the people to understand who they are and their relationship to the environment, land and sky around them.

ACTIVITY SHEET  
Aboriginal dreaming



## Seasons

Each year, weather patterns change in a reasonably regular pattern called the seasons. European ideas about seasons (spring, summer, autumn, winter) do not always fit into the Australian experience. Indigenous people have 50 000 years' experience of Australia's weather and seasons. Their ideas often differ from clan to clan, and country to country. In different parts of Australia, Indigenous people developed different calendars. These were based on some similar and some quite different ideas about weather, plant growth and animal movement. Throughout Australia there are considerable differences in seasons, whether you use a European or an Indigenous model.



**Figure 7.15** ▾

The seasons are caused by the Earth's tilt.

### Earth's tilt

the angle that the Earth's equatorial plane makes with the Sun's equatorial plane

Seasonal weather patterns are affected by the Sun. The Sun heats the land and the sea, which then heat the atmosphere. The more time the Sun spends above the horizon during the day, the greater the heating effect.

The seasons are caused by the **Earth's tilt**. As the Earth revolves (or orbits) around the Sun, the tilt affects the amount of time the Sun shines on parts of the Earth. The hotter months of the year occur on the parts of the Earth that are tilted more directly towards the Sun; the colder months occur on the parts of the Earth that are tilted away from the Sun, receiving indirect rays.

Figure 7.15 shows that, on 22 December, the entire southern half of the globe can be in sunlight, but part of the northern hemisphere is never illuminated. The reverse occurs on 21 June when more of the Sun's energy is concentrated in the northern hemisphere, which experiences summer, while the energy in the southern hemisphere is spread out over a larger distance, and it experiences winter.

People who live near the equator are exposed to the same amount of daylight all year round. They generally have 12 hours of daylight and 12 hours of night time, so they do not have four separate seasons.

As Figure 7.15 shows, the Earth's orbit is an **ellipse**. The nearest point of the orbit to the Sun is called **perihelion** and the furthest point is **aphelion**.

People sometimes think that the seasons are caused by the Earth's distance from the Sun. Figure 7.15 shows that the Sun is closest to the Earth in December, which is summer in Australia but winter in the northern hemisphere. Similarly, the Earth is furthest from the Sun during the northern summer. So Earth's distance from the Sun cannot explain the seasons (see WOW! box: The Moon caused the seasons).

We need to be a little more precise to understand fully. The plane of the Sun's equator (the **Sun's equatorial plane**) is an imaginary flat surface sliced through the centre of the Sun and extended out to space beyond Earth. The **Earth's equatorial plane** is inclined at an angle of  $23.5^\circ$  to the Sun's equatorial plane.

**ellipse**

oval shape

**perihelion**

the closest position of Earth to the Sun

**aphelion**

the furthest position of Earth from the Sun

**Sun's equatorial plane**

an imaginary flat surface sliced through the Sun's equator, which spreads out across the solar system

**Earth's equatorial plane**an imaginary flat surface sliced through the Earth's equator, inclined at an angle of  $23.5^\circ$  to the Sun's equatorial plane**ACTIVITY 7.3****Seasons**

- Choose a country in the Northern Hemisphere and **describe** its seasons.
  - Construct** a timeline that shows when that country's seasons occur.
- Compare** the names for the seasons in different countries.
- Complete a force field analysis to **evaluate** if you would live in this country based on your knowledge of their seasons.

**WORKSPACE**  
Seasons**INTERACTIVE**  
Seasons**WOW! The Moon caused the seasons**

Early in the history of the Earth, a large object crashed into it. This caused the Earth's orbit to tilt. This is the tilt that causes the seasons. Over the course of 100 000 years, the material leftover from the collision collected together, cooled and formed the Moon. The Moon has been revolving around the Earth ever since.

From Melbourne, the South Magnetic Pole is  $11^\circ$  to the west of geographical south. From Perth, the difference is  $2^\circ$  to the east.



Shutterstock.com

**ACTIVITY SHEET**  
Solar crossword



**WORKSPACE**  
All day and all night.



**ANIMATION**  
Earth's tilt



**ACTIVITY SHEET**  
Star signs and the equinoxes



**WORKSPACE**  
Earth's tilt

**ACTIVITY 7.4**

## All day and all night

- 1 **Compare and contrast** the physical and emotional effects that you might experience if you lived in a place where there was no night or no daylight hours.
- 2 Use a plus delta chart to **outline** the advantages and disadvantages of living in a country where there are 24 hours of daylight.
- 3 Imagine that you are going to live in Barrow, Alaska. Table 7.1 shows the average hours of daylight for each month over the course of a year.
  - a Complete a force field analysis for living in Barrow in January and in June. **Outline** the advantages and disadvantages of living there.
  - b If you had to live in Barrow, Alaska, for one month each year, which month would you choose, and why?

**Table 7.1** ▲  
Hours of daylight in Barrow, Alaska

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
0.00	4.05	9.20	14.13	19.44	24.00	24.00	24.00	14.45	11.03	5.52	0.00

**ACTIVITY 7.5**

## Earth's tilt

### Aim

To design and construct a model that shows how the Earth's tilt affects the seasons

### Materials

- stiff cardboard
- cutting instrument
- ruler
- protractor

### ACTIVITY 7.5

- florist's wire or pipe cleaners
- polystyrene balls (two different diameters)
- marker pens
- digital camera

#### Method

- 1 Use the materials listed to construct a model to show the Earth's orbit around the Sun.
- 2 On the model, show:
  - a the angle of tilt
  - b how this angle affects the places where the Sun shines on the Earth at different times of the year.

#### Discussion

- 1 **Evaluate** the effectiveness of this model.
- 2 **Describe** how you might improve this activity.

### WEB 2.0

Take digital images of the stages in the construction of your model. Upload these to the class wiki.

**ANIMATION**  
Solar year



**ACTIVITY SHEET**  
Solar years on different planets



## Time zones

With the Earth spinning on its axis, the Sun shines on different parts of the Earth at different times. When the Sun rises on the east coast of Australia, it is still dark on the west coast. The Sun takes a few hours before it rises in the west. This means that it would not make sense to have the same time over all of Australia, which is why there are three time zones – Eastern Standard (AEST), Central Standard (ACST) and Western Standard Time (AWST). In summer, most states have daylight saving, which is designed to give more time for people to enjoy the sunlight during summer.

If you lived in Russia, you would have to deal with as many as nine time zones!

## Equinox and solstice

The Sun rises at different positions each day. It also sets in different positions. These changes affect the number of hours of daylight.

The **equinox** occurs when the Sun rises directly east and sets directly west. This happens twice a year. The whole planet experiences 12 hours of daylight and 12 hours of night. The word 'equinox' comes from the Latin *aequus* (equal) and *nox* (night), because around the equinox, night and day have approximately equal length. In Australia, the autumn equinox occurs around 21 March and the spring equinox around 23 September.

**ACTIVITY SHEET**  
Time zones



**ACTIVITY SHEET**  
The Sun moves



**INTERACTIVE**  
Earth rotation – night and day



### equinox

two days a year when there are 12 hours of daylight (equal lengths of day and night); in the southern hemisphere these are 21 March (autumn equinox) and 23 September (spring equinox)

**solstice**

the longest or shortest day of the year, when the Sun reaches its highest or lowest local solar zenith for the year; in the southern hemisphere these are 22 December (summer solstice) and 21 June (winter solstice)



**WORKSPACE**

What have you learnt? 7.2

The day on which the Sun reaches its highest altitude for the year, 22 December, is known as the longest day or the summer **solstice**. Similarly, 21 June, when the Sun reaches its lowest point for the year, is known as the shortest day or the winter solstice. The word 'solstice' comes from the Latin *sol* (sun) and *sistere* (to stand still). This is because, for a few days around each solstice, the highest point of the Sun seems to be the same each day – it appears to be stationary.

**QUESTIONS 7.2**

**What have you learnt?**

**Remembering**

- 1 **Define** the term 'day'.
- 2 **a Outline** the three main Australian time zones.  
**b Identify** the time zone where you live.

**Understanding**

- 3 **Identify** how the Sun affects the seasons.
- 4 **Identify** the times of the spring and autumn equinoxes. **Propose** why they are significant.

**Applying**

- 5 It takes 5 hours to fly from Sydney to Perth. If you were flying to Perth on 12 January, leaving Sydney at 10 a.m., **calculate** the time you would arrive in Perth.
- 6 **Describe** how the Sun can be used to measure the time taken for one year to pass.
- 7 Draw and label a diagram to **demonstrate** the meaning of Earth's aphelion and perihelion.
- 8 **Compare** a European description of spring with an Indigenous description of the same time of the year.

**Creating**

- 9 Add more information to the graphic organiser you started at the beginning of this chapter.

**satellite**

an object that orbits the Earth



**VIDEO**

Moon landing celebrated

# 7.3 The Moon

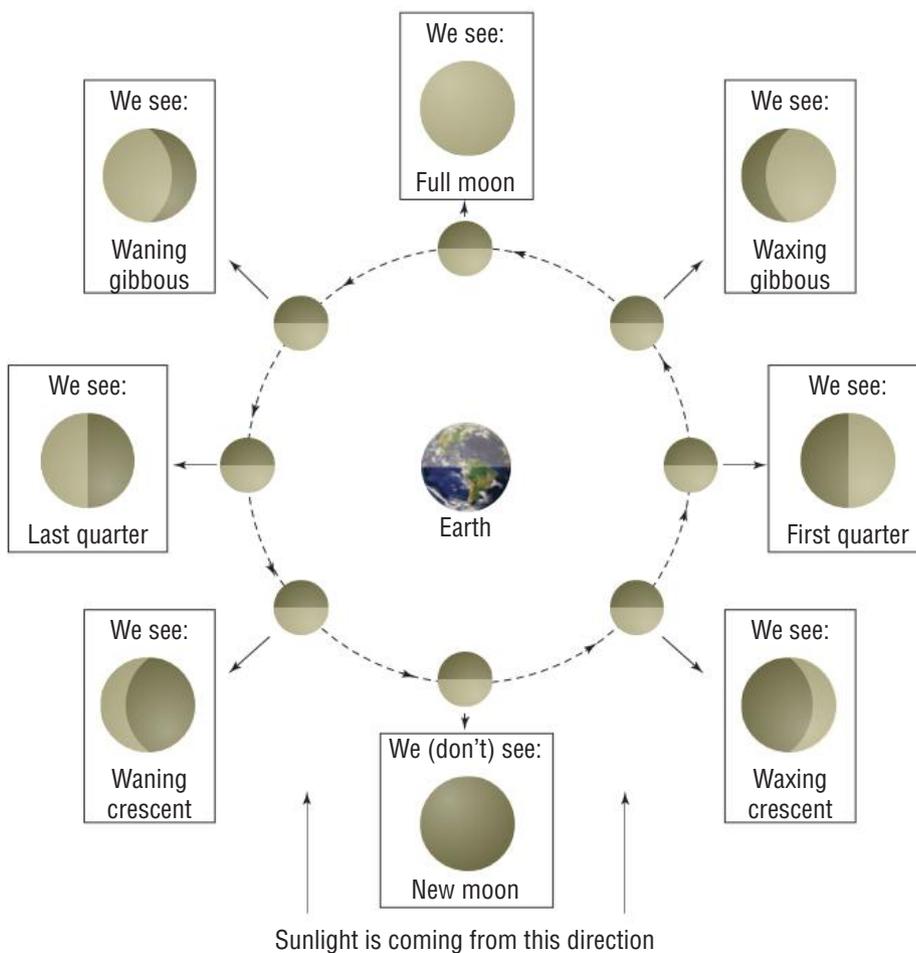
The Moon is the Earth's only natural **satellite**. The Moon has different apparent shapes at different times, as you can see by looking at the night sky. It also rises at different times.

The Moon has a side that we never see from the Earth's surface. This is because the Moon rotates on its axis. This rotation takes about 29.4 days, which is as long as it takes for the Moon to go once around the Earth. So we always see the same face of the Moon turned towards us.

## Moon phases

As the Moon revolves around the Earth, different amounts of sunlight reflect off the Moon towards the Earth and we see different phases of the Moon. When the Moon rises around sunset, it appears as a complete circular disc. This phase is the **full moon**. The Sun, just below the horizon in the west, shines into the sky towards the east and the Moon moves into these rays. If the Moon is higher in the sky at sunset, less of the illuminated part of the Moon can be seen from Earth. Similarly, when the Sun is able to reflect off the Moon in the hours before sunrise, a different phase will be seen.

**New moon** occurs when the side of the Moon that is facing the Earth is not lit by the Sun and hence is not visible from Earth.



### ACTIVITY 7.6

## Tracking the Moon

Over the course of this chapter, note when the Moon is visible during the day. Collate all the data from your class and include the time of day and the phase of the Moon.

### ACTIVITY SHEET

Moon factsheet



#### full moon

the phase of the Moon when all of the illuminated side is visible from Earth

#### new moon

the phase of the Moon when the side of the Moon that is facing Earth is not lit by the Sun and hence is not visible from Earth

#### ◀ Figure 7.16

Phases of the Moon: the diagram seems to suggest that eclipses are quite frequent – two a month!

### INTERACTIVE

Lunar cycles – Moon phases



### VIDEO

Explaining an eclipse



### VIDEO

Lunar eclipse



## Eclipse

The Sun shines on the Earth and the Moon; a shadow is behind both. When the Moon moves into the Earth's shadow, an eclipse of the Moon occurs (Figure 7.17). When the Earth moves into the Moon's shadow, an eclipse of the Sun occurs (Figure 7.18).

Figure 7.16 (previous page) shows a typical diagram that is used to explain Moon phases. But there is something wrong. Eclipses are quite uncommon. Yet Figure 7.16 seems to suggest that at the new moon, the Earth will be in the Moon's shadow and an eclipse of the Sun should occur. Similarly at full moon, the Sun's rays appear to be blocked by the Earth, so instead of seeing the Moon's disc, it should be eclipsed by the Earth's shadow. The problem occurs because we are trying to represent the Moon, Earth and Sun in a two-dimensional diagram when they actually move in a three-dimensional space.

**Figure 7.17** ▶

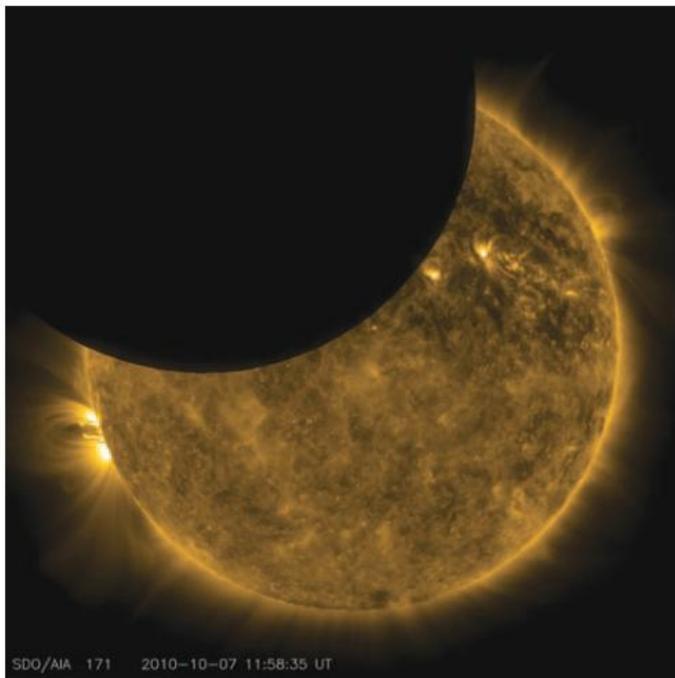
Time-lapse photographs of an eclipse of the Moon. The Moon passes into and out of the Earth's shadow.



NASA/David Corntner

**Figure 7.18** ▶

Eclipse of the Sun. The Moon's shadow stops sunlight reaching the Earth.



NASA

## EXPERIMENT 7.2

**WORKSPACE**  
 Modelling the Moon


## Modelling the Moon

### Aim

To demonstrate how the Moon moves around the Earth

### Materials

- 1 large and 1 smaller spherical objects, such as sports or Styrofoam balls
- large torch
- digital camera

### Method

- 1 With a partner demonstrate the relative movement between the Earth and Moon.
- 2 Darken the room and use the torch as a source of light from the Sun to demonstrate how the amount of light may change on the Moon.
- 3 Record this with a camera.

### Discussion

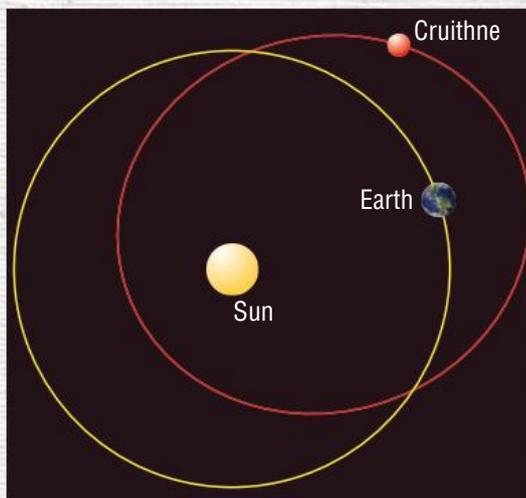
Use the images you have recorded to **demonstrate**:

- a how phases of the Moon occur
- b why an eclipse of the Moon and of the Sun occur only occasionally.



### The Earth's second moon?

In 1986, astronomers at Siding Spring, near Coonabarabran in New South Wales, discovered a 5 km wide **asteroid**, now named 3753 Cruithne (pronounced kroo-EEN-yuh) or 1986 TO, which they thought might be orbiting the Earth. The asteroid takes 364 Earth days to travel around the Sun. It is not our second moon, because its orbit is affected by the Sun's gravitational pull.


**WEBLINK**  
 Cruithne


### asteroid

a naturally occurring, relatively small rock in space

**WEB 2.0**

Use Google Earth to locate Coonabarabran.



**WORKSPACE**  
Corkscrew asteroids



**WEBLINK**  
Corkscrew asteroids



**WORKSPACE**  
What have you learnt? 7.3



**ACTIVITY SHEET**  
Blue and harvest moons



**ACTIVITY SHEET**  
Careers in Earth and space sciences

### ACTIVITY 7.7

## Corkscrew asteroids

Use the weblink 'Corkscrew asteroids' to make a list of Earth co-orbital asteroids, and draw some of their orbits as they corkscrew around near Earth.

### QUESTIONS 7.3

## What have you learnt?

### Understanding

- 1 Starting and ending with the new moon, **describe** the different phases of the Moon.
- 2 **Describe** why the phases of the Moon occur.
- 3 **Explain** what an eclipse of the Moon is.

### Applying

- 4 **Construct** a diagram to represent an eclipse of the Sun.

### Analysing

- 5 In an eclipse of the Sun, some parts of the Earth are in full shadow and some parts are only in partial shadow. **Construct** a diagram to show how this occurs.

## 7.4 Ocean tides

Even while the Earth is moving around the Sun, it is large enough to exert a big enough gravitational field to keep the Moon in orbit.

However, the Moon is big enough to exert a large gravitational field back on the Earth. It isn't big enough to pull the Earth too much, but it is big enough to move the water on the Earth's surface. We observe this as **tides**.

### tide

the change of sea level during the day at a particular location

**Figure 7.19** ▶

Tides change the water level at the same place at different times of day.

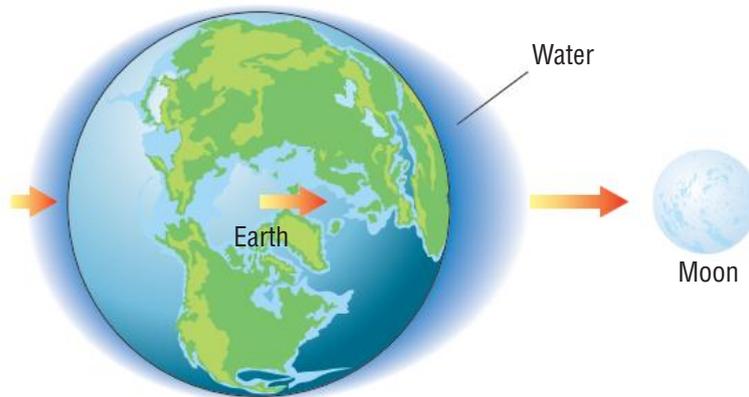


Alamy/Bill Brooks



Every day, the water level at the beach rises and falls with the tides. At low tide, there is a lot of beach to play on. At high tide, there is less beach. Tides occur as a result of the gravitational pull by the Moon and the Sun on the oceans. The Moon provides about two-thirds of the gravitational force that affects the tides. The Sun provides the rest, less because it is further away.

The Moon pulls most strongly on the water nearest it. It pulls on the rest of planet Earth slightly less, with the weakest force being experienced on the side furthest away from the Moon. Thus, the water nearest the Moon is pulled further away from planet Earth (Figure 7.20). This causes a bulge, a high tide. Furthest from the Moon, planet Earth is pulled away from the water, so another, smaller bulge (high tide) occurs. The effect of all this is to draw water away from the places in between. They experience low tide.



◀ **Figure 7.20**

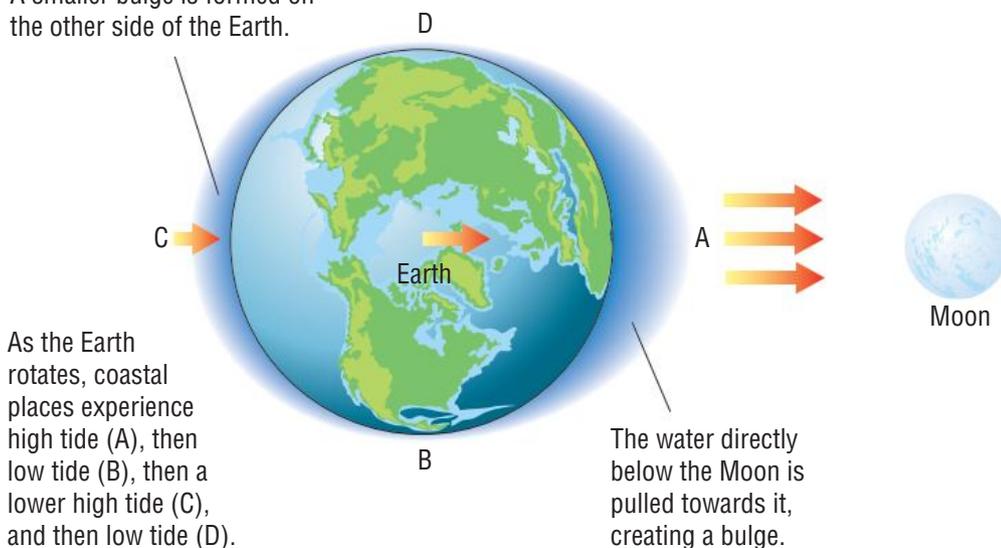
Comparison of the size of the Moon's gravitational pull on water nearest to it, on planet Earth, and on the water furthest from it

High and low tides occur approximately every 6 hours, since it takes about 24 hours for the Moon to travel around Earth, drawing the tides around the Earth in its wake (Figure 7.21).

Next, let us add in the Sun's gravitational effect, which is less than half the effect of the Moon. At new moon, the Sun and the Moon are on the same side of the Earth, and the tides are highest because the gravitational effects combine. These high tides are called spring tides (Figure 7.22).

A smaller spring tide also occurs at full moon, when the Sun and Moon are on opposite sides of the Earth (Figure 7.23 on page 186).

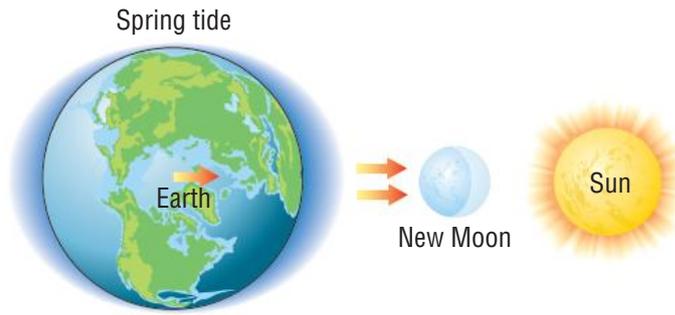
A smaller bulge is formed on the other side of the Earth.



◀ **Figure 7.21**

High tides occur at places in line with the Moon (A and C). Low tides occur in between (B and D). There are approximately six hours between high and low tides.

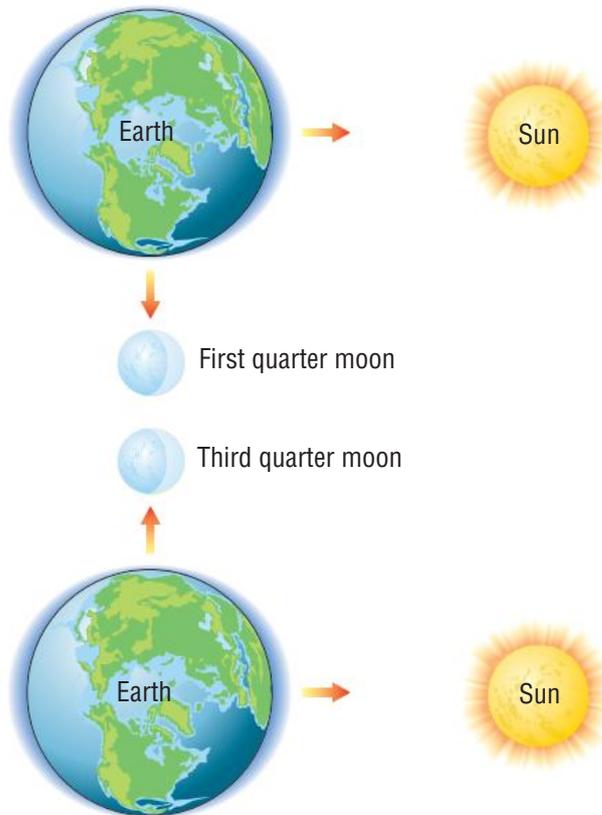
**Figure 7.22** ▶  
Spring tide at new moon.  
The effects of the Moon and  
Sun are combined.



**Figure 7.23** ▶  
Spring tide at full moon



The tides are at their smallest (neap tides) when the Moon and Sun are exerting their gravitational pulls at right angles to each other (Figure 7.24).



**Figure 7.24** ▶  
Neap tides at quarter phases  
of the Moon

## ACTIVITY 7.8

## The Moon's effect on tides

### Aim

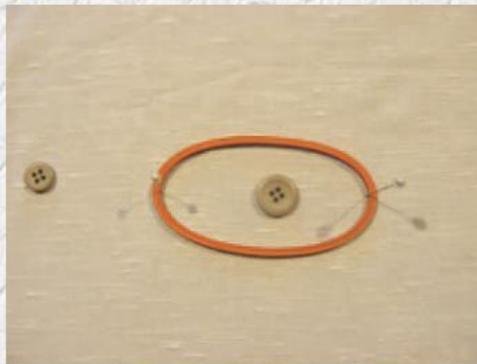
To create a model to demonstrate how the Moon causes high tides and low tides on Earth

### Materials

- two circular counters or buttons of different diameters
- circular rubber band, larger in diameter than the larger counter or button
- two pins
- dissecting board, thick cardboard or polystyrene sheet
- camera or video recorder

### Method

- 1 Position the larger button to represent the Earth, the smaller one to represent the Moon, and the rubber band to represent the surface of the water around the Earth.
- 2 Stick the pins just on the inside of the rubber band circle and in line with the Moon and Earth (Figure 7.25).
- 3 Lightly draw around this arrangement.
- 4 Use the pin between the Moon and Earth to pull the rubber band towards the Moon. Mark the new front edge of the rubber band (water).
- 5 Move the Earth button towards the Moon, but less than the rubber band (water). Mark the new front edge of the Earth button.
- 6 Move the second pin towards the Moon, but less than the Earth. Mark the new edge of the rubber band.
- 7 When you are ready, use the camera to record these steps (1–6) and provide a commentary to explain how this activity demonstrates two high tides opposite each other and two low tides a quarter of the globe away.



### WORKSPACE

The Moon's effect on tides



◀ **Figure 7.25**  
Modelling high and low tides



**WEBLINK**

Storyboard generator



**WEBLINK**

Tidal information



**WORKSPACE**

What have you learnt? 7.4

**ACTIVITY 7.8**

**Discussion**

- 1 Click on the weblink 'Tidal information' and locate the information about the tides. **Create** a basic flowchart to direct others to find this tidal information.
- 2 List three things you found on the weblink that you did not expect to find, and **explain** why you were surprised.
- 3 Most newspapers list tide times for the day.
  - a Collect the tide times for five consecutive days.
  - b Present these in a table.
  - c **Interpret** the patterns from the table.
  - d Use your knowledge of science to **explain** these patterns.
  - e **Describe** the purpose of a tide chart.
- 4 **Recall** where else you would find tide charts.

**QUESTIONS 7.4**

**What have you learnt?**

**Remembering**

- 1 **Identify** which two large objects cause the tides.

**Understanding**

- 2 **Describe** the process by which tides are produced.

**Applying**

- 3 **Construct** a diagram to demonstrate the effect of multiple forces acting on the Moon.
- 4 **Outline** how it is possible to have high tides on opposite sides of the Earth at the same time? Refer only to the Moon's effect.

**Analysing**

- 5 Sketch a diagram to show the Moon and Sun on the same side of the Earth. Use the diagram to help **explain** what happens to the tides in this case.
- 6 **Identify** the types of people who would need to know about tides.

**Evaluating**

- 7 **Evaluate** how your understanding of tides has changed as you have done this topic.

## 7.5 Pioneers of astronomy

In many ways the history of astronomy is very closely linked to the history of civilisation. Many ancient monuments were also used for early astronomy, such as the pyramids, which were used for ceremonies and burials by the Egyptians and Mayans. Astronomy was a useful tool for knowing when to grow crops or collect food for the winter. It is thought that Stonehenge in England was also constructed for this purpose.



Shutterstock.com/WitR

◀ **Figure 7.26**  
Pyramids in Egypt were designed with the stars in mind.



Shutterstock.com/Matthew Jacques

◀ **Figure 7.27**  
Stonehenge may have been used by Ancient Britons as a tool to tell them when to start growing crops.

Ancient astronomy was restricted by the basic technology at the time – most observations had to be made by carefully looking at the sky. New technology has meant that the science of astronomy has made great discoveries in the last 500 years.

## Aristarchus of Samos

Aristarchus of Samos (c. 310–c. 230 BCE) was a Greek astronomer who proposed that the Sun was the centre of a very large spherical universe in which stars, planets and the Earth revolved about the Sun. He believed the Earth rotated, which caused the Sun and stars to move across the sky. Aristarchus used geometry to estimate that the Sun was about 20 times further away from the Earth than the Moon. (In fact, it is about 400 times further away.)

## Ptolemy

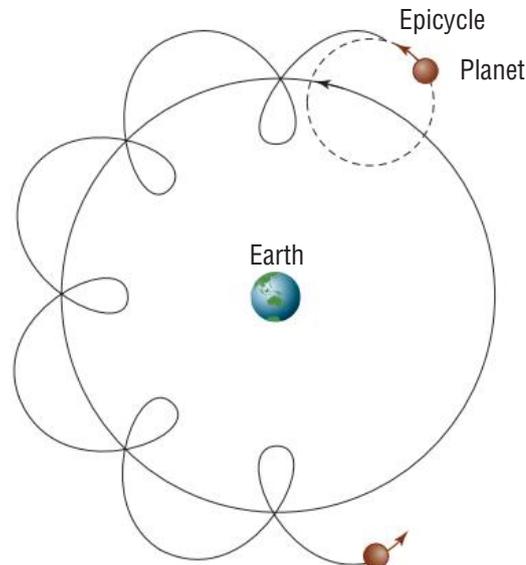
A Greek working in Alexandria (Egypt), Ptolemy (c. 85–c. 165) based his model of the universe on accurate observations and mathematical skill. In the Ptolemaic geocentric (Earth-centred) model, the Sun, planets and stars all revolved about the Earth. The planets travelled in circles and **epicycles** about the Earth (see Figure 7.28).

### epicycle

a circle that rolls around another circle; used to describe planetary motion from an Earth perspective

**Figure 7.28** ▶

The Ptolemaic model, showing a planet on an epicycle



**Figure 7.29** ▲

Omar Khayyam accurately measured the length of a year.

## Muhammad Al-Battani

Syrian-born Muhammad Al-Battani (c. 858–929) was famous for his astronomical theories, his observations of star positions and his accurate calculation of the length of the solar year (365 days 5 hours 46 minutes 24 seconds). Al-Battani used geometry and trigonometry to show that the distance from Earth to the Moon changes, and that these changes affect eclipses.

## Omar Khayyam

Omar Khayyam (1048–1131) (Figure 7.29) was an extraordinary Iranian mathematician, astronomer and poet. He measured the length of one year, accurate to one day in 5000 days. His observations contributed to the reform of the medieval Jalali calendar.

## Nicolaus Copernicus

A Polish mathematician, astronomer, physician, church lawyer, peace negotiator and public administrator, Nicolaus Copernicus (1473–1573) compared his own accurate observations with those of other astronomers, including Al-Battani. Finding gaps and errors in the Ptolemaic geocentric model, he proposed that the centre of the universe was near the Sun. The Earth and planets revolved in circles about the Sun. His heliocentric model improved on Ptolemy's model, but still needed epicycles.

## Tycho Brahe

Danish astronomer Tycho Brahe (1546–1601) (Figure 7.30) made extremely accurate astronomical observations that paved the way for others to argue convincingly for the heliocentric model of planetary motion. He was convinced that the Moon and Sun revolved around the Earth, while the planets revolved about the Sun.



Science Photo Library/Gianni Tortoli

◀ **Figure 7.30**  
Tycho Brahe in his  
observatory

## Galileo Galilei

You read in Chapter 1 that Galileo Galilei (1564–1642) improved the telescope and used it to make many important discoveries. Through his observations, Galileo became convinced of the usefulness of Copernicus’s heliocentric model rather than the Ptolemaic model. He observed phases – like those of the Moon – for Mercury and Venus, and deduced that these two planets must come between Earth and the Sun. Like Copernicus, Galileo was aware that the data he collected, and the heliocentric circular orbits of planets, did not fit perfectly.

### ACTIVITY 7.9

#### Pioneers of astronomy

Use a notetaking application such as OneNote to produce a map with scrollovers. On your map, show major locations and achievements associated with famous astronomers. Add other astronomers, such as Regiomantus, Kepler and Flamsteed.



#### WORKSPACE

What have you learnt? 7.5

### QUESTIONS 7.5

#### What have you learnt?

##### Understanding

- 1 **Calculate** the time between Ptolemy’s model of the solar system and that of Copernicus.
- 2 **Construct** a table of information that summarises each astronomer, the century they worked in and their major ideas.

##### Applying

- 3 **Construct** a diagram to compare a geocentric universe with a heliocentric universe.

##### Analysing

- 4 Research one astronomer not mentioned in this chapter to find out how they contributed to our understanding of the universe. In your presentation you should refer to any limitations in the equipment they had available to them.
- 5 **Analyse** reasons why the geocentric model of the universe was the accepted model for so long.

##### Reflecting

- 6 a **Outline** why the discoveries made by the pioneers of astronomy helped us compile our knowledge of the universe.  
b **Evaluate** which of the astronomers you think made the most contribution to modern knowledge.



## Chapter review

### Remembering

- 1 **Define:**
  - a solstice
  - b eclipse
  - c satellite
  - d neap tide

### Understanding

- 2 **Outline** how the Earth's tilt explains seasons.
- 3 On a diagram that shows the Sun's equatorial plane and its relationship to the Earth's equatorial plane, **demonstrate** the Earth's orbit and the positions of each equinox and each solstice.
- 4 **Construct** a diagram to show the phases of the Moon, starting from the full moon.
- 5 **Describe** why we always see the same face of the Moon.

### Applying

- 6 **Propose** why a knowledge of calendars may be useful to an Indigenous clan.
- 7 Use a diagram to **outline** how tides are formed.

### Analysing

- 8 Janis says, 'Each day, I see that the Sun goes around the Earth.' Minh says, 'No, the Earth goes around the Sun.' Both are right. **Justify** both answers.
- 9 **Describe** why the Sun never set in parts of Antarctica near the South Geographic Pole during the summer months.
- 10 **Outline** what would happen to the seasons if the Earth's equatorial plane was tilted at  $30^\circ$  to the Sun's equatorial plane.
- 11 The Moon only ever shows one side to the Earth. **Analyse** why this means that the Moon must rotate once on its axis every month.
- 12 a If you were to watch the Earth and Moon system from the Sun, **outline** the shape of the Moon's path.  
b Draw a diagram to **justify** your answer.
- 13 The Sun and Moon are on different sides of the Earth. **Explain** how this will affect tides.
- 14 Diagrams of the Moon's phases seem to indicate that two eclipses occur per month. **Describe** why this does not occur. **Describe** how this has helped you to read diagrams in science books.

**WORKSPACE**  
Chapter 7 review



**ACTIVITY SHEET**  
Chapter 7 checklist



**REVIEW QUIZ**  
Chapter 7





## Evaluating

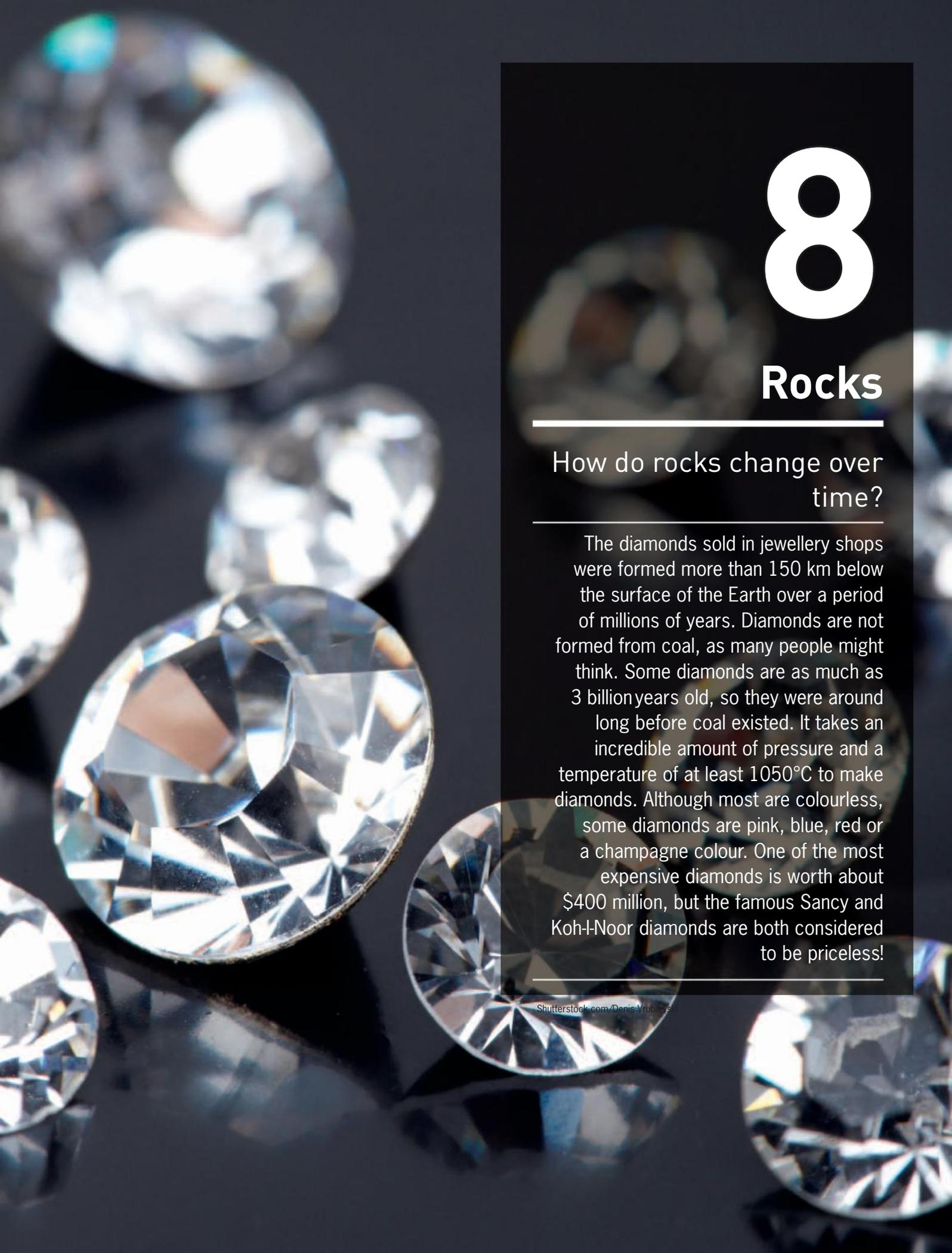
- 15 During this chapter, you produced a number of models to assist you in understanding the Earth's place in space. **Evaluate** how well you think this approach assisted your understanding. **Explain** your answer.
- 16 Choose one of these early astronomers discussed in this chapter and **justify** why, in your opinion, this person made a great contribution to our modern understanding of astronomy.

## Creating

- 17 A lunar eclipse occurred on 15 June 2011. Write a newspaper article reporting on this phenomenon. In your article, clearly **outline** how this eclipse occurred. Source a photo from the Internet to illustrate your article.

## Reflecting

- 18 **Describe** how your knowledge about our solar system has changed as a result of reading this chapter. Refer back to the table you produced at the beginning of this chapter and complete the last column.
- 19 **Discuss** whether or not there is more to learn about our solar system. If so, will we need new technology?



# 8

## Rocks

---

How do rocks change over time?

---

The diamonds sold in jewellery shops were formed more than 150 km below the surface of the Earth over a period of millions of years. Diamonds are not formed from coal, as many people might think. Some diamonds are as much as 3 billion years old, so they were around long before coal existed. It takes an incredible amount of pressure and a temperature of at least 1050°C to make diamonds. Although most are colourless, some diamonds are pink, blue, red or a champagne colour. One of the most expensive diamonds is worth about \$400 million, but the famous Sancy and Koh-I-Noor diamonds are both considered to be priceless!

---



## Earth and space sciences – Stage 4

### Key knowledge

- The Earth is made up of the core, mantle, crust and lithosphere.
- The landscape changes due to weathering (both physical and chemical), erosion and deposition.
- Sedimentary, igneous and metamorphic rocks contain minerals and are formed during the rock cycle over very long periods of time.
- Rocks can be classified into groups using properties that you can see.
- Fossil formation requires specific conditions.
- The age of rocks can be determined due to where they occur in the layers of the Earth.
- There are many careers (such as mining) that require knowledge of rocks and rock formation, and this understanding helps us make informed decisions about managing Earth's resources.



**ACTIVITY SHEET**  
CAT with rubric: Pet rock

### CULMINATING ASSESSMENT TASK

#### Pet rock

Your teacher will provide you with a rock sample. **Synthesise** your knowledge of rocks by **classifying** your rock sample, **describing** the processes that formed it and **discussing** the uses and value of such rocks.

## What do you already know about rocks?

Create a mind map about what you know about rocks. You could use Activity sheet 'Rock cycle mind map' or mindmapping software. As you continue through this chapter, add information to your mind map to demonstrate your understandings and connections.

Here are some ideas to start you thinking about rocks and why we study rocks and associated geological processes.

- 1 **Describe** where rocks come from.
- 2 **Outline** why there are so many different kinds of rocks.
- 3 **Discuss** some of the uses we have for rocks.
- 4 **Predict** what will happen to rocks over a long period of time.
- 5 Write down three questions about rocks you would like answered.

### WORKSPACE

What do you already know about rocks?



### ACTIVITY SHEET

Rock cycle mind map



### WEB 2.0

You could use software such as eDraw Mindmap to create your mind map.

### WEBLINK

eDraw Mindmap



### ACTIVITY SHEET

Geological timeline



# 8.1 The Earth

## Geological time scales

The Earth is made from rocks. To investigate what happens to rocks, you will need to use a time scale that covers the age of the Earth. The Earth is currently estimated to be 4600 million (4.6 billion) years old.

Many structures have been on Earth for very long periods of time. The pyramids in Egypt are thought to be 4000 years old. Dinosaurs became extinct 65 million years ago (65 mya). Can you think of something that happened more than 65 mya?

Understanding time can be very difficult. For example, imagine you live to be 100 years old and then are born again, live to 100 again, are born again and so on. Every 1000 years, you will have lived 10 times. How many times would you have lived in 1 million years?

To have been able to see dinosaurs, you would have had to have lived 650 000 times! On a timeline, your age of less than 100 years would be a very small fraction of time when compared with the age of the Earth (4.6 billion years). A rock can be billions of years old, which makes our timeline for measuring age too small. In 1 million years, there are 10 000 lifetimes of 100 years.



Shutterstock.com/Joao Virissimo

◀ **Figure 8.1**  
Australia as seen from space



### How heavy is the Earth?

The mass of the Earth is 5 973 600 000 000 000 000 000 000, or  $5.97 \times 10^{24}$  kg.

**weathering**

the break down of rock by the action of water, growing plants, heat, cold and ice

**erosion**

the displacement of soil, mud and rock by the action of wind, water, ice or gravity

## The dynamic Earth

We see the effects of **weathering** on rocks every day. Weathering is when forces cause rock to break apart into smaller pieces. Big rocks break down to become small rocks and eventually end up as small particles the size of a grain of sand. Over many years, weathering turns rock into soil.

An ocean wave contains a great deal of energy. When a wave hits the coastline, this energy causes part of the rock along the coastline to break off. The water carries the broken pieces of rock away. This process is called **erosion**. New rocks replace those rocks that have been weathered and eroded away. The Twelve Apostles off the coast of Victoria were formed by erosion (Figure 8.2).



Shutterstock.com/CSLD

**Figure 8.2** ▶

Weathering and erosion of the Twelve Apostles, Port Campbell National Park, Victoria



Getty Images/Robin Smith

**Figure 8.3** ▶

The Kiama Blowhole, New South Wales, is another feature formed by weathering and erosion.



**WORKSPACE**

The Twelve Apostles and Kiama Blowhole

**ACTIVITY 8.1**

### The Twelve Apostles and Kiama Blowhole

- 1 Type 'Twelve Apostles Port Campbell' or 'Kiama Blowhole' into an image search engine. Choose an image and take a screen grab. Add this to your workspace.
- 2 **Describe** three interesting facts about the formation you have chosen and how it relates to weathering and erosion.

Erosion can be a major problem on the land. In places where plants have been destroyed or removed, there is nothing holding the soil together. When it dries out, this soil can be carried by the wind. This soil is full of nutrients, which are then lost from that environment.

On occasions this erosion can cause great dust storms. This happened in 2009 when great clouds of red dust blanketed the east coast of Australia (Figure 8.4).

**WEBLINK**  
The dynamic Earth



Getty Images/Jack Reynolds

◀ **Figure 8.4**  
Dust storms in Sydney  
in 2009

## Weathering

Many processes can cause weathering.

### Physical weathering

Physical weathering occurs when actions such as wind and waves hit and break the rock. It is physical in that it is breaking the rock without changing the chemical structure of the rock, just changing its shape and size through direct contact.

Physical weathering can also occur when rocks get hot and cold. As rocks heat up, the particles in the rock will heat up. Solids generally expand when heated. If one part of the rock heats more than another, then this puts stress on the rock. Cracks appear and, sometimes, parts of the rock can fall off.

### Chemical weathering

Chemical weathering occurs when a chemical reacts with part of a rock and weakens or breaks it apart.

Rain contains small amounts of dissolved chemicals, such as carbon dioxide and sulfur dioxide. This causes the water to become acidic. If acidic rain falls on a rock, it will dissolve a small part of the rock. Over time, this will cause changes in the rock that will cause it to fall apart.



**WORKSPACE**  
Modelling weathering

**EXPERIMENT 8.1**

## Modelling weathering

### Aim

To demonstrate some of the processes involved in weathering of rocks

Possible risks	Safety precautions
The rocks may break.	Wear safety glasses.
Hydrochloric acid may irritate your skin.	If you get acid on your skin, wash it with plenty of water.

### Materials

- samples of rocks such as shale, granite and marble
- safety glasses
- tongs
- water bath
- hydrochloric acid
- Bunsen burner and heat-proof mat

### Method

#### Physical weathering

- 1 Hold a rock in the tongs and then place it in the hottest part of the Bunsen burner's blue flame for about 10 seconds.
- 2 Put the rock in the water bath.
- 3 Repeat steps 1 and 2 a couple of times.
- 4 Repeat steps 1–3 with the other rocks.

#### Chemical weathering

- 5 Place a piece of marble in a beaker.
- 6 Add several drops of dilute hydrochloric acid and observe what happens.

### Results

- 1 **Construct** a table of observations and results

### Discussion

- 2 **Compare** and **contrast** the different types of weathering in this activity and predict how these processes could work in a real-life situation.

## Formation of common landforms

The processes of weathering and erosion have shaped every part of the land.

Rivers have formed from the small trickles of water flowing from mountains, pulled by the force of gravity towards the oceans. As this water moves, its energy may be enough to break off a small piece of rock or move a small bit of dirt or clay. Rocks at the start of a river tend to be sharper than those nearer the ocean. Rocks nearer the ocean tend to be smoother, having been bumped and pushed from further upstream.

Rivers are constantly changing. A billabong is formed when an old part of a river branches off from the main river, as built up sand, soil and rock cause a new part of the river to form.

The Twelve Apostles and Kiama Blowhole were formed by the action of weathering and erosion on soft rock that was worn away while harder rock remained.

### EXPERIMENT 8.2

## Changes to landforms over time

### Aim

To demonstrate how water can cause changes to landforms over time

### Materials

- stream tray
- sand
- rubber hose

### Method

- 1 Half fill the stream tray with sand. Flatten the sand and then slightly elevate one end of the tray.
- 2 Connect the rubber hose to a tap and fix the other end of the hose to the elevated end of the tray.
- 3 Turn on the tap so that a steady, but gentle, stream of water comes out of the hose.
- 4 Sketch the path eventually made by the water.
- 5 Flatten the sand again and repeat steps 1–4 several times using objects such as rocks to change the path of the water flow.

### Discussion

- 1 **Describe** the effect of the water on the sand over time.
- 2 **Explain** how objects placed in the path of the water changed the flow.

### WORKSPACE

Changes to landforms over time



### VIDEO

Rock under the dunes



## Structure of the Earth

The Earth is divided into layers: the crust, mantle, outer core and inner core.

The outer layer of the Earth is called the crust. This is the part that we live on. It can range in thickness from five or so kilometres under the deep oceans to about 70 km on the highest land.

Below the crust is the mantle. The mantle is extremely hot because of the pressure and friction from the surrounding rocks. It is so hot that the rocks in the mantle are molten – they have changed state from solid to liquid.

The part of the crust that is solid and rigid and makes up the rocks on the surface is called the **lithosphere**. This includes the rocks on the surface and the solid rocks further in the crust and upper mantle.

Below the lithosphere is the bottom part of the crust and upper part of the mantle, which is called the **asthenosphere**. Here the rock is soft and partly molten. This means it is able to flow, or move around. This is where **magma** comes from. Sometimes, this magma spurts out of the crust to form **lava**.

Below the crust and mantle is the outer core. The outer core is made of very hot, liquid metal. It is thought that movement of the outer core causes the Earth's magnetic field, which protects life on Earth from the dangerous radiation from the Sun.

In the very middle is the inner core, which is also made of metal, but the very high pressure keeps it in a solid state.

### **lithosphere**

the solid part of the Earth's crust

### **asthenosphere**

the partly molten, upper part of the Earth's mantle

### **magma**

molten rock found beneath the surface of the Earth

### **lava**

hot molten rock that is expelled during a volcanic eruption



**WEBLINK**  
Pressure



**WEBLINK**  
Convection currents within the Earth's mantle

**Figure 8.5** ▶

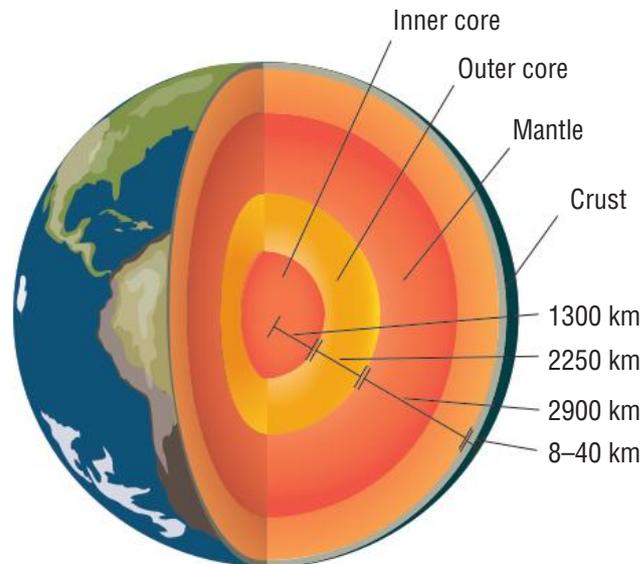
The Earth is usually divided into four main parts: inner core, outer core, mantle and crust.

### **convection current**

the movement of molecules in a gas or liquid, usually from an area of high temperature to an area of lower temperature

### **volcano**

an opening in the Earth's crust that allows magma and gases to escape to the surface



## Volcanoes

The Earth is in a process of constant change over very long periods of time. Its structure provides the energy and forces needed for geological processes that continually shape our physical environment. Deep within the Earth, enormous pressures and high temperatures drive **convection currents** (see Chapter 10, page 265) in the Earth's mantle (Figure 8.5), allowing liquid rock (magma) to reach the surface through **volcanoes** and cracks in the Earth's surface.

## EXPERIMENT 8.3

## WORKSPACE

Modelling convection currents in the mantle



## Modelling convection currents in the mantle

Possible risks	Safety precautions
Hot water can cause burns and scalds. Potassium permanganate crystals can burn your hands and stain your clothing.	If you get burnt, tell your teacher and immediately place the burn under cold water. Handle crystals with gloves and tweezers only, and be especially careful not to spill any of the crystals on yourself.

### Aim

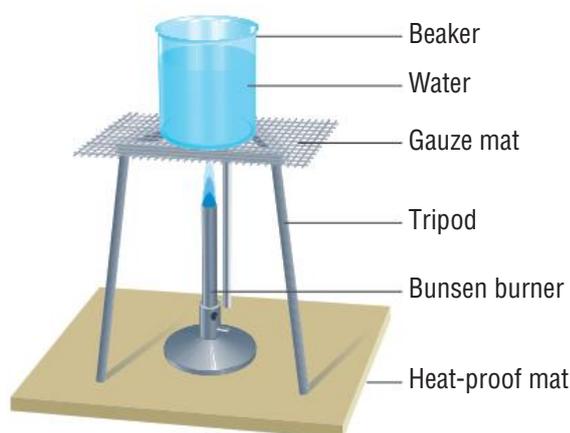
To show how convection currents move

### Materials

- beaker
- Bunsen burner, heat-proof mat, tripod, gauze mat
- potassium permanganate crystals
- water
- forceps or tweezers

### Method

- 1 Set up the experiment as shown in Figure 8.6.
- 2 Start the Bunsen burner and heat up one edge of the beaker.
- 3 Use a pair of forceps or tweezers to carefully place some small pieces of potassium permanganate crystals in the bottom of the beaker just above where the Bunsen burner flame is heating.



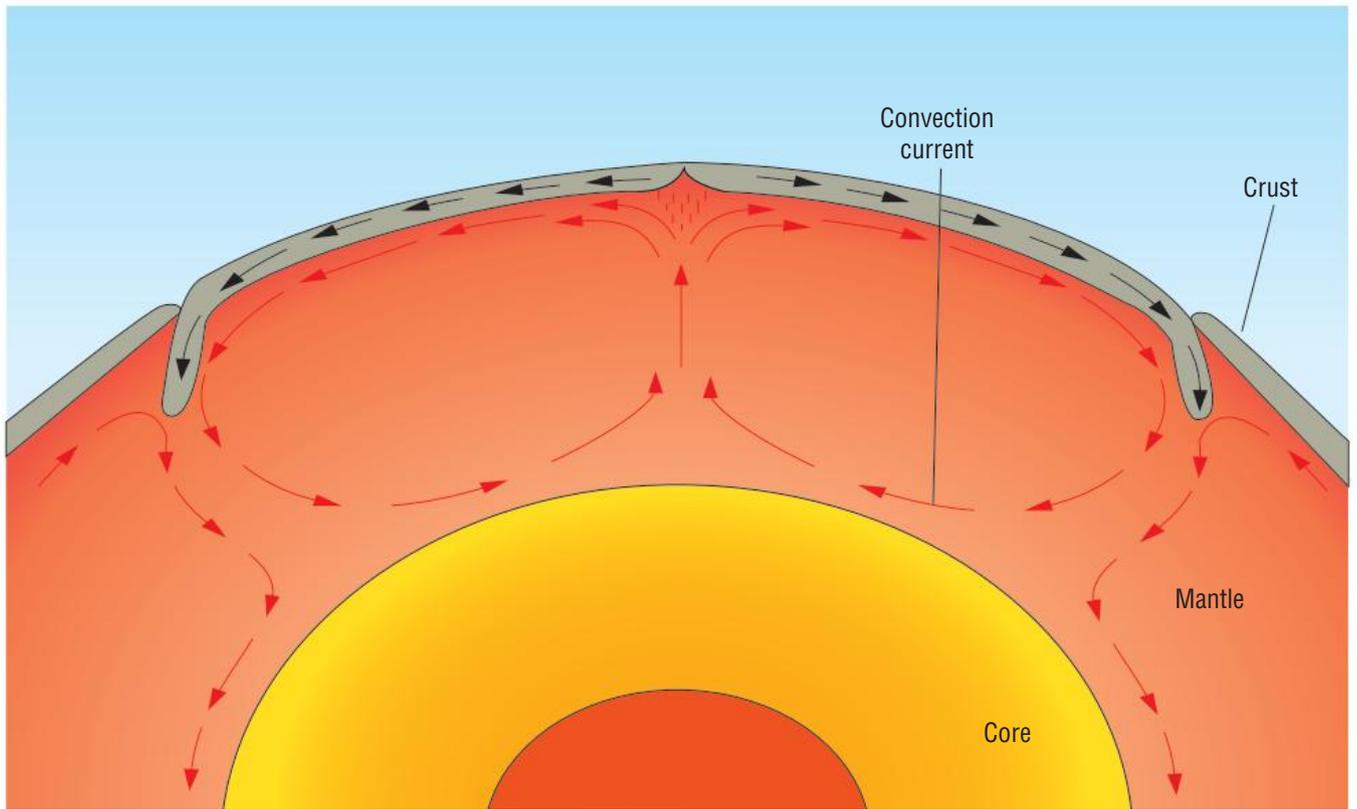
◀ **Figure 8.6**  
Experimental set-up

### Results

- 1 Sketch a diagram to show the path of the trails made by the potassium permanganate crystals.

### Discussion

- 2 **Describe** how the experiment shows the movement of hot liquids.
- 3 **Critically analyse** how effective this experiment is as a model for demonstrating convection currents.



**Figure 8.7**

Convection currents within the Earth bring molten rock to the surface.

**dormant**

describes a volcano that has not erupted for a long period of time

**extinct**

describes a volcano that is unlikely to erupt again

**Figure 8.8**

This lava is pouring from a fissure or crack in the Earth's crust.



Shutterstock.com/Peter Zurek



**WEBLINK**  
Kilauea eruption



**WEBLINK**  
The restless Earth



**How hot is the Earth?**

Temperatures increase the deeper we go below the Earth's surface. Molten rock exists between 650°C and 1200°C at 80–100km beneath the surface of the Earth. The centre of the Earth at 6400km is estimated to be approximately 5600°C.

## ACTIVITY 8.2

## Are there any volcanoes in Australia?

**Identify** a volcano, extinct or dormant, in Australia.

- 1 What kind of volcano is it?
- 2 When was it last active?
- 3 What links are there between the volcano and the local indigenous peoples?

In Australia, the Kanawinka Global Geopark in south-west Victoria (Figure 8.9) encompasses regions of recent volcanic activity around 5000 to 5 million years ago.



Newspix/News Limited/Darren Mcnamara



### WORKSPACE

Are there any volcanoes in Australia?

### WEB 2.0

Locate Kanawinka Global Geopark and Kerguelen Plateau using Google Earth. Take a screen grab of each and upload them to the class wiki.



### WEBLINK

Our constantly changing planet



### WEBLINK

Japan earthquake

◀ **Figure 8.9**  
Kanawinka Global Geopark,  
Victoria



### WEBLINK

Kanawinka Geopark

**WOW!**

## Kerguelen Plateau

Kerguelen Plateau is one of the largest volcanic **plateaus** in the world. It is found under water about 3000 km south-west of Fremantle in Western Australia. It is nearly three times the size of Japan and four times the size of the British Isles.

### plateau

an area of highland, usually consisting of relatively flat open country

**geothermal**

heat generated within the Earth



Shutterstock.com/Pichugin Dmitry

**Figure 8.10** ▶

This hot water is produced by hot rock geothermal systems in Australia.

## Heat sources

**Geothermal** energy is heat energy that is generated and stored within the Earth. It increases with depth. So as you descend beneath the surface of the Earth, heat increases as well as pressure. This subjects rock to heat energy and forces that make them soften, bend and then melt.



**WORKSPACE**  
Geothermal energy

**ACTIVITY 8.3**

### Geothermal energy

Create an electronic or hand-drawn diagram of the Earth, showing it as a cross-section. You could design a poster or PowerPoint presentation. Label the following layers of the Earth: crust, upper mantle, lower mantle, outer core and inner core. Also indicate the depths of the layers, approximate temperatures and mantle convection currents.

**Extension**

Approximately 80% of the heat within the Earth comes from the **radioactive decay** of potassium-40, uranium-238, uranium-235 and thorium-232. Find out what radioactive decay is and how it releases energy. Add this information to your diagram.

**radioactive decay**

the break down of unstable atomic nuclei to emit energy

## QUESTIONS 8.1

## What have you learnt?

### Remembering

- 1 **Define** physical and chemical weathering, using examples.
- 2 **Define** the term 'erosion'.

### Understanding

- 3 In science we use very big and small numbers. **Describe** how old the Earth is in:
  - a millions of years
  - b billions of years.
- 4 **Explain** why we might call the Earth the 'dynamic Earth'. **Justify** your answer.
- 5 **Describe** how a volcano might form.

### Applying

- 6 **Outline** how heat energy beneath the surface of the Earth is generated. **Propose** why this energy is important to our existence on Earth.
- 7 Humans first appeared on Earth 6 million years ago. If the age of the Earth is measured in hours and it was 24 hours old, **calculate** how long humans would have been in existence.

### WORKSPACE

What have you learnt? 8.1

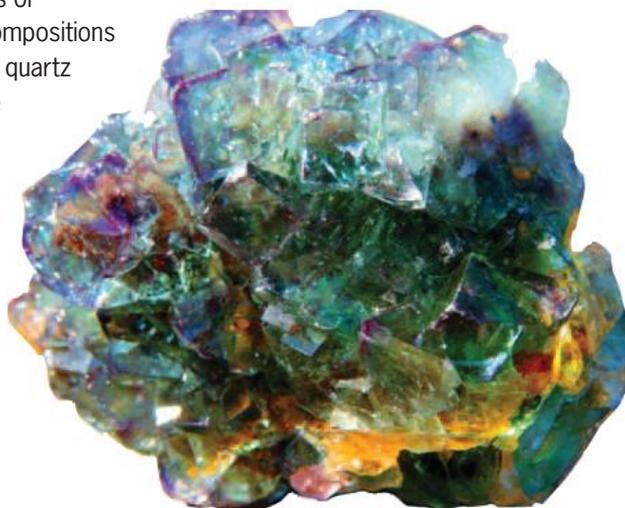


## 8.2 What are rocks?

Magma below the surface of the Earth rises and often breaks through the crust in volcanic eruptions in the form of lava. This lava could be called 'new rock'. As this rock cools, it solidifies. Its structure and properties are determined by how fast it cools and its mineral composition.

**Minerals** are chemical elements or compounds with specific chemical compositions and **crystal** structures. For example, quartz has a chemical formula of  $\text{SiO}_2$ . Table salt ( $\text{NaCl}$ ) is also known as halite. Graphite is just carbon (C) with a particular crystal structure that makes it different from diamond crystals. Fluorite is calcium fluoride ( $\text{CaF}_2$ ). Fluorite is shown in Figure 8.11.

**Rocks** are collections of one or more minerals into solid structures.



Shutterstock.com/Randall Stewart

### mineral

chemical elements or compounds with regular chemical compositions and crystal structures found in rocks

### crystal

substance in which the particles are arranged in a regular, repeating pattern

### rock

a collection of one or more minerals into a solid structure

**ACTIVITY SHEET**  
ABC of minerals



**WEBLINK**  
Minerals



◀ **Figure 8.11**

Fluorite is a mineral made of calcium fluoride,  $\text{CaF}_2$ .



**WORKSPACE**  
Crystal formation

**EXPERIMENT 8.4**

## Crystal formation

Possible risks	Safety precautions
Salol can cause skin irritations.	Wear an apron and safety glasses. Be careful not to get any salol on your skin. Wash your hands after the activity.

In this investigation you will investigate how temperature affects crystal formation.

### Materials

- ice cubes and hot water
- 2 microscope slides
- 3 small beakers and 1 large beaker
- monocular microscope or hand lens
- dropper
- salol (phenyl salicylate)
- safety glasses
- flip cam or mobile recording device

### Method

- 1 Electronically record your experiment. Describe the individual steps and your observations as you proceed.
- 2 Put a microscope slide in a small beaker of hot water and another slide into a beaker of iced water.
- 3 In the third small beaker, put some salol (approximately 25 mL).
- 4 If the salol is a solid, then place the small beaker containing the salol into a warm water bath in the big beaker.
- 5 Remove the slide from the warm water and place it on the bench. Add a couple of drops of salol onto the slide.
- 6 Repeat this with the slide from the cold beaker.
- 7 Wait for the salol to dry. Use your monocular microscope or hand lens to look carefully at the two slides.
- 8 Record your observations.

### Discussion

- 1 **Describe** the differences you observed in how quickly the hot and cold slides cooled.
- 2 **Describe** the differences you observed when the salol was added to each slide.

## EXPERIMENT 8.4

- 3 **Propose** a hypothesis that links temperature to crystal size.
- 4 **Describe** any unanswered questions that you have about crystal formation.
- 5 **Propose** how you could answer these questions scientifically. Using information and knowledge from previous activities, can you **predict** the expected results from an investigation?

## ACTIVITY 8.4

## Common minerals

- 1 **Investigate** the following common minerals: bauxite, quartz, magnetite, pyrite, hematite, and calcite. Include their chemical formulas and crystal structures. **Demonstrate** your findings as a chart, a table or an interactive multimedia presentation.
- 2 Complete a five whys analysis, beginning with the question: 'Why do people research minerals?' Upload your final answer to the class wiki.



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**WORKSPACE**  
Common minerals



◀ **Figure 8.12**  
Various volcanic rocks, minerals and crystals

## Types of rocks

Rocks can be classified into three types: igneous, sedimentary and metamorphic. The properties of each type of rock are determined by how it was made, the geological processes, and its mineral and chemical composition.

## Igneous rocks

**Igneous** rocks are formed when molten rock (magma) cools and solidifies either below (**intrusive**) or above (**extrusive**) the Earth's surface. The rate at which the magma cools determines the rock's properties. An igneous rock can take minutes or millions of years to form, depending on its rate of solidification and cooling of magma. Magma itself takes millions of years to be formed as tectonic plates slide under each other and melt.

Intrusive igneous rocks such as diorite (Figure 8.13), gabbro and granite have



Shutterstock.com/Tyler Boyes

**WEBLINK**  
Virtual rock kit

**igneous**

rocks formed from molten rock below the surface of the Earth

**intrusive**

igneous rock that has cooled beneath the ground

**extrusive**

igneous rock that has cooled above the ground

◀ **Figure 8.13**  
Diorite is a coarse-grained intrusive igneous rock.

**Figure 8.14** ▶

Pumice is a fine-grained extrusive igneous rock.

**sedimentary**

rocks formed by layers of sediment

**deposition**

when sediment settles on top of a layer of material

**compaction**

when pressure is applied to a sediment

**cementation**

when the space between sediments fills with another mineral, which hardens

**banded iron formation (BIF)**

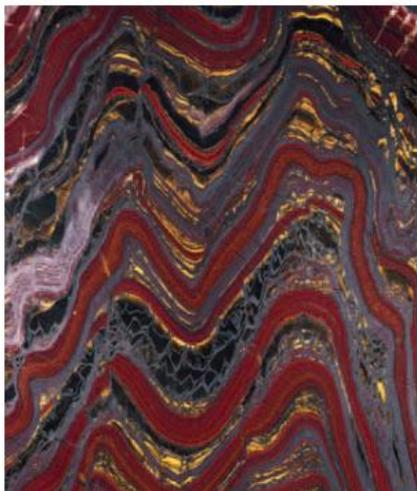
a type of sedimentary rock containing iron oxide layers

**Figure 8.15** ▶

Limestone is a sedimentary rock that consists mainly of calcium carbonate ( $\text{CaCO}_3$ ).

**Figure 8.16** ▶

Halite or rock salt is a chemical sedimentary rock formed from the evaporation of sea water.



Science Photo Library/Dirk Wiersma

coarse grains. Intrusive igneous rocks have larger crystals than extrusive rocks because they take longer to cool and solidify below the surface because it is hotter there.

Extrusive igneous rocks such as basalt, obsidian and pumice (Figure 8.14) have much smaller crystal formations than intrusive igneous rocks because of the faster cooling rates that occur on the surface.

## Sedimentary rocks

**Sedimentary** rock is formed in layers. Usually the layers at the top are younger than the layers further down. This is useful for palaeontologists searching for life in the past, as it has allowed them to guess at the ages of some of the fossils they have found.

There are a variety of sedimentary rocks because these rocks can form in different ways. They are formed when a sediment settles on top of a layer of other material. The layers are squeezed and compacted under pressure and the spaces between sediments fill with other minerals, which then harden. All of these rocks require a very long time for the processes of weathering, erosion, **deposition**, **compaction** and **cementation** to occur. These processes can take millions of years.

The city of Sydney is built upon a large layer of sandstone. Many buildings in the Sydney business district were built using this sandstone.

**Banded iron formations (BIFs)** are an interesting type of sedimentary rock. These are mostly composed of bands of iron oxide minerals. These iron oxides are thought to have formed when the Earth's atmosphere was flooded with oxygen from the photosynthesis by the Earth's first plants.

Banded iron formations are a valuable mineral resource for iron. The Pilbara region in Western Australia has many of these formations.

**VIDEO**  
Uses of limestone

**ACTIVITY SHEET**  
Visualising BIFs

**WEBLINK**  
BIF

**Figure 8.17** ▶

Banded iron formations at Jasper Knob in Michigan, USA

## ACTIVITY 8.5

## Visualising BIFs

The activity sheet contains your concept map showing key components in the formation of banded iron formations. The link between each component has a process associated with it. Add explanations to each of the links (processes) between each of the components.

## Fossil formation

**Fossils** (from the Latin word *fossus*, meaning ‘having been dug up’) are the preserved remains or traces of previous life on Earth. This includes animals, plants, and other organisms that lived a long time ago. These could include remains such as whole organisms frozen in ice, or traces of organisms such as bones, shells or footprint or feather impressions made in rock (Figure 8.18).

### fossil

the preserved remains or traces of previous life on Earth



Shutterstock.com/NaturSports

◀ **Figure 8.18**

Trilobites were hard-shelled organisms that existed hundreds of millions of years ago. Now extinct, their fossils are found in rocks all over the world.

Not all living organisms will end up as fossils. Most are eaten or decayed before fossilisation can occur. The conditions required to produce a fossil are very specific. To produce a fossil, living or dead organisms must be buried very quickly. This can occur when a volcano spews out lava, such as happened in Pompeii, Italy, or when sediment falls to the bottom of the lake. A fast burial is important so that predators or scavengers don't eat the dead remains. It also means that there is no oxygen available for bacteria to decay the dead organism.

Over time, the lava or sediment hardens to form rock. More and more layers are deposited on top of it (hence the sedimentary nature of fossils) and the lower layers are compacted by the weight of the upper layers. If the rock is broken open by erosion, the dead organism can decay and leave a **mould**. Alternatively, the dead organism can be replaced by minerals. If mineralisation occurs, then internal features and cellular details can sometimes be seen in the fossil. Sometimes a whole animal can be fossilised. The frozen woolly mammoth in Figure 8.19 was found in Siberia in 2007 by a reindeer herder. It had been perfectly preserved for more than 40 000 years.

**ACTIVITY SHEET**  
Story of fossils



### mould

a fossil that consists of the space left by a decayed organism



Alamy/ITAR-TASS Photo Agency

**Figure 8.19** ▶

This frozen baby woolly mammoth found in Siberia was perfectly preserved for more than 40 000 years.



**WORKSPACE**  
How to make a fossil

**ACTIVITY 8.6**

**How to make a fossil**

**Aim**

To make your own fossil mould

**Materials**

- 1 cup of used coffee grounds
- $\frac{1}{2}$  cup of cold coffee
- 1 cup of plain flour
- $\frac{1}{2}$  cup of salt
- large mixing bowl
- waxed paper
- round cookie cutter
- several objects with which to make your mould

**Method**

- 1 Mix the coffee grounds, cold coffee, flour and salt in the mixing bowl.
- 2 Knead the dough until it is soft.

### ACTIVITY 8.6

- 3 Spread the dough onto the waxed paper.
- 4 Cut out round shapes using a cookie cutter.
- 5 Press your objects into the round shapes to make fossil moulds.
- 6 The dough will harden overnight.
- 7 Take photos of your fossil mould and upload them to the class wiki. Comment on other students' moulds.

#### Discussion

How does this activity **compare** to the process of fossil formation?

#### metamorphic

rocks that are changing

#### density

the amount of mass (kg or g) in a unit of volume (cm<sup>3</sup>)

## Metamorphic rocks

**Metamorphic** rocks are igneous or sedimentary rocks that have changed. The word 'metamorphic' comes from the Greek words *meta*, meaning 'change', and *morphe*, meaning 'form'. So it literally means 'change form'. Metamorphic rock is rock that is changing its form.

If sedimentary and igneous rocks experience higher pressures and intense heat, their properties, such as **density** and crystal structure, will start to change. This process of change takes millions of years and doesn't stop.

An example of metamorphic rock, gneiss (pronounced 'neece'), is shown in Figure 8.20. Gneiss is formed from metamorphosed granites (igneous) or sandy marine sediments. This happens due to the heat and pressure of the surrounding rocks deep within the Earth.

Metamorphic rocks are difficult to identify. They have properties of the original rock they are changing from, but they also have new properties due to the changes the rock has undergone.

## The rock cycle

Within the Earth, a great deal of heat is generated by processes such as pressure and radioactive decay. This heat generates convection currents in the asthenosphere.

Rising magma can also escape through cracks in the Earth's crust. It cools and solidifies, creating new igneous rock. This new rock is exposed to the forces of weathering and erosion. Sediments of eroded rock build up over tens of thousands of years and form layers. The lower layers of sediment are compressed and squeezed under increasing pressure to form sedimentary rock.

Deep sedimentary layers are subjected to very large amounts of heat and pressure. This process changes them into metamorphic rock, or pushes them up onto the surface to be weathered again.

Metamorphic rock can be thrust up onto the surface of the Earth to be weathered, or pushed lower to melt and become magma and start the cycle of rock formation again. This cycle of pressure, heat, cooling and weathering is called the **rock cycle** and is shown in Figure 8.21.

Rocks cycle around these processes for millions of years. James Hutton was an 18th-century geologist who first proposed the idea of a rock cycle. He described it as having 'no vestige of a beginning, and no prospect of an end'.



Shutterstock.com/Tom Grundy

**Figure 8.20**

Gneiss is a metamorphic rock formed when pressure and heat are applied to igneous granite made of sandy marine sediments.

#### rock cycle

the cycle of pressure, heat, cooling and weathering that rocks move through

#### WEBLINK

Interactive rock cycle



#### ACTIVITY SHEET

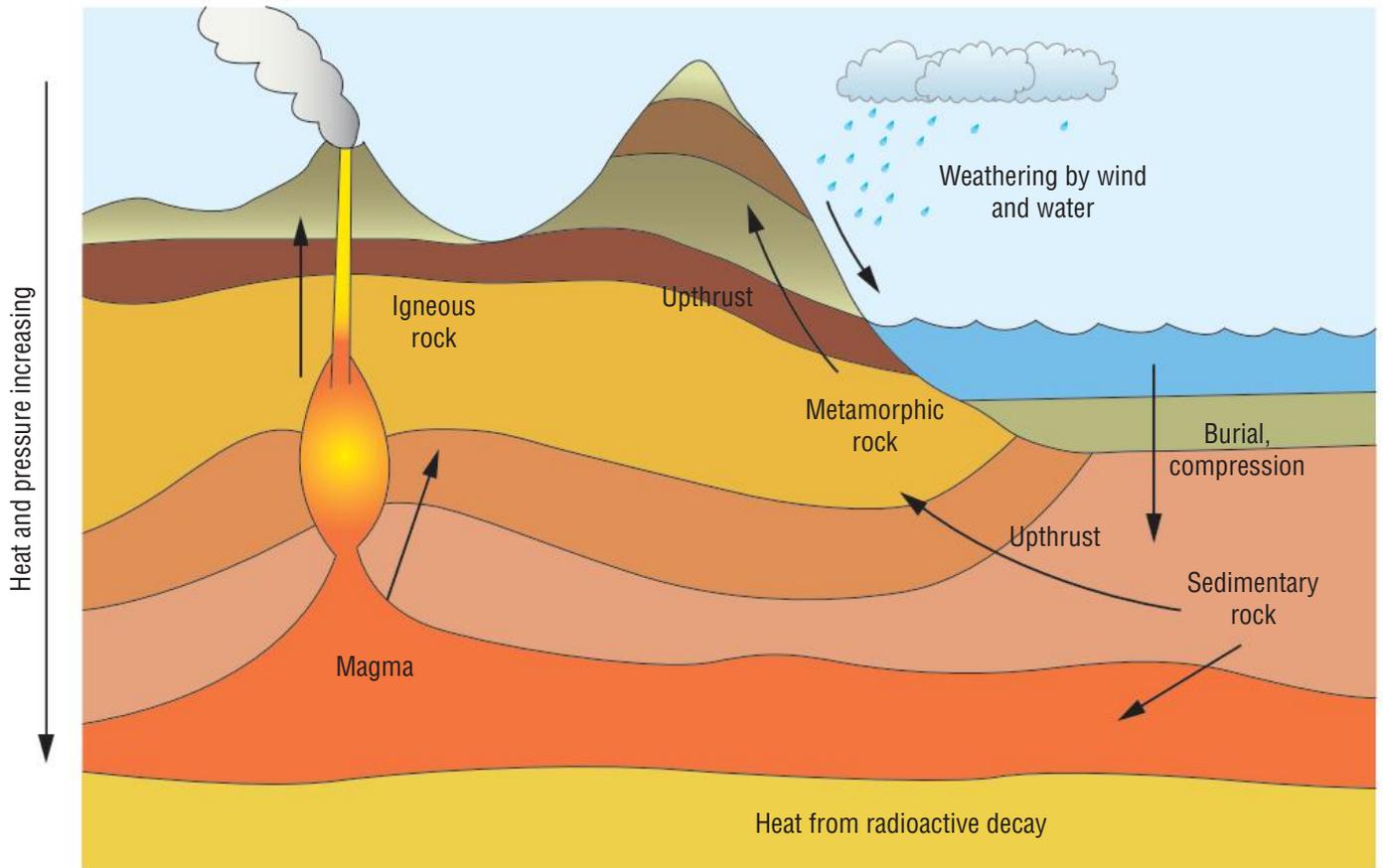
Rock cycle sugar cubes



#### ANIMATION

Rock cycle





**Figure 8.21** ▼  
The rock cycle



**WEBLINK**  
The rock cycle



**ACTIVITY SHEET**  
The rock cycle flowchart

## Properties of rocks

The properties of rocks relate to the types of minerals they are made of. These properties can help you classify rocks and have some idea about the geological processes that made them.

Some common properties of minerals are:

- colour
- lustre
- density (specific gravity)
- crystal shape and size
- hardness
- cleavage
- streak
- magnetism.

## ACTIVITY 8.7

## Properties of rocks

Briefly **explain** what each property of rock refers to. Give two examples that clearly show each particular property. Present a photo to illustrate each property. Present your findings as a chart or online presentation.

### Extension

Describe your favourite gemstone in terms of its properties. Where can your favourite gemstone be found?

**WORKSPACE**  
Properties of rocks



**WEBLINK**  
Properties of rocks



## Density of rocks

The density of a rock is the ratio of its mass (grams) to its volume (cm<sup>3</sup>). For example, 10 g of rock with a volume of 5 cm<sup>3</sup> has a density of  $\frac{10}{5} = 2 \text{ g/cm}^3$ . The density of water is 1 g/cm<sup>3</sup>. Table 8.1 lists the densities of some different rock types.

**Table 8.1** ▲

Densities of some different rock types

Name	Rock type	Density range (g/cm <sup>3</sup> )	Average density (g/cm <sup>3</sup> )
Coal	Organic sedimentary	1.1–1.4	1.25
Limestone	Sedimentary	2.3–2.7	2.5
Sandstone	Sedimentary	2.2–2.8	2.5
Gypsum	Sedimentary	2.3–2.8	2.55
Marble	Metamorphic	2.4–2.7	2.55
Rock salt	Sedimentary	2.5–2.6	2.55
Shale	Sedimentary	2.4–2.8	2.6
Granite	Intrusive igneous	2.6–2.7	2.65
Mica schist	Metamorphic	2.5–2.9	2.7
Quartzite	Metamorphic	2.6–2.8	2.7
Gneiss	Metamorphic	2.6–2.9	2.75

(continued)

Table 8.1 CONT. ▲

Name	Rock type	Density range (g/cm <sup>3</sup> )	Average density (g/cm <sup>3</sup> )
Slate	Metamorphic	2.7–2.8	2.75
Diabase	Igneous	2.6–3.0	2.8
Dolomite	Sedimentary	2.8–2.9	2.85
Basalt	Igneous	2.8–3.0	2.9
Diorite	Igneous	2.8–3.0	2.9
Gabbro	Igneous	2.7–3.3	3.0
Peridotite	Igneous	3.1–3.4	3.25



**ACTIVITY 8.8**

## Graphing rock densities

Figure 8.22 shows one way of graphing the data in Table 8.1. You are going to create other graphs.

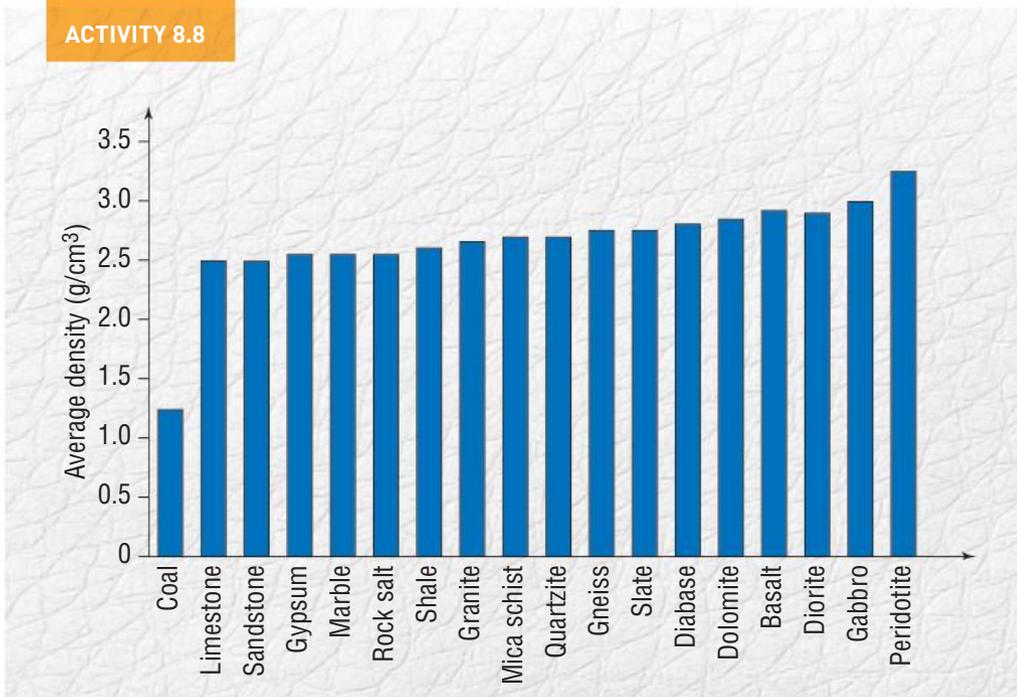
- 1 Download or enter the data in Table 8.1 into a spreadsheet.
- 2 Using the chart wizard, regraph the information into two different graphs. Ensure that you label the graph when prompted.
- 3 **Compare** and **contrast** the three different graphs.
- 4 Which graph do you find the easiest to read? **Explain** why. Paste your graphs and your responses into your class wiki or poster.

### Analysing the data

Look at Table 8.1 and its bar graph in Figure 8.22.

- 1 **Identify** the label you would put on the horizontal axis.
- 2 **Identify** the label you would put on the vertical axis.
- 3 **Identify** the title you would put above this graph.
- 4 **Extrapolate** a relationship between rock type and average densities.

## ACTIVITY 8.8



◀ **Figure 8.22**  
Densities of different rock types

## QUESTIONS 8.2

## What have you learnt?

### Remembering

- Rocks are categorised into three groups.
  - Name these groups.
  - Outline** the characteristics of each group.

### Understanding

- Complete the sentence 'Rocks are ...' using the following words: 'minerals', 'two', 'crystals' and 'different'.
- Describe** what a crystal is and two factors that determine its size.
- Outline the conditions required for fossilisation to occur. Relate this to the formation of sedimentary rock.
- Some minerals are magnetic. **Identify** the elements that would be present in these minerals to allow them to have this property.

### Applying

- Rocks contain useful minerals. **Describe** why hematite would be a useful mineral.
- Explain** why a kangaroo that dies on a grass plain near Gundagai is unlikely to form a fossil.

### Analysing

- Propose** what you think James Hutton meant by his statement 'no vestige of a beginning, and no prospect of an end'.

### WORKSPACE

What have you learnt? 8.2





**WEBLINK**  
Use of minerals



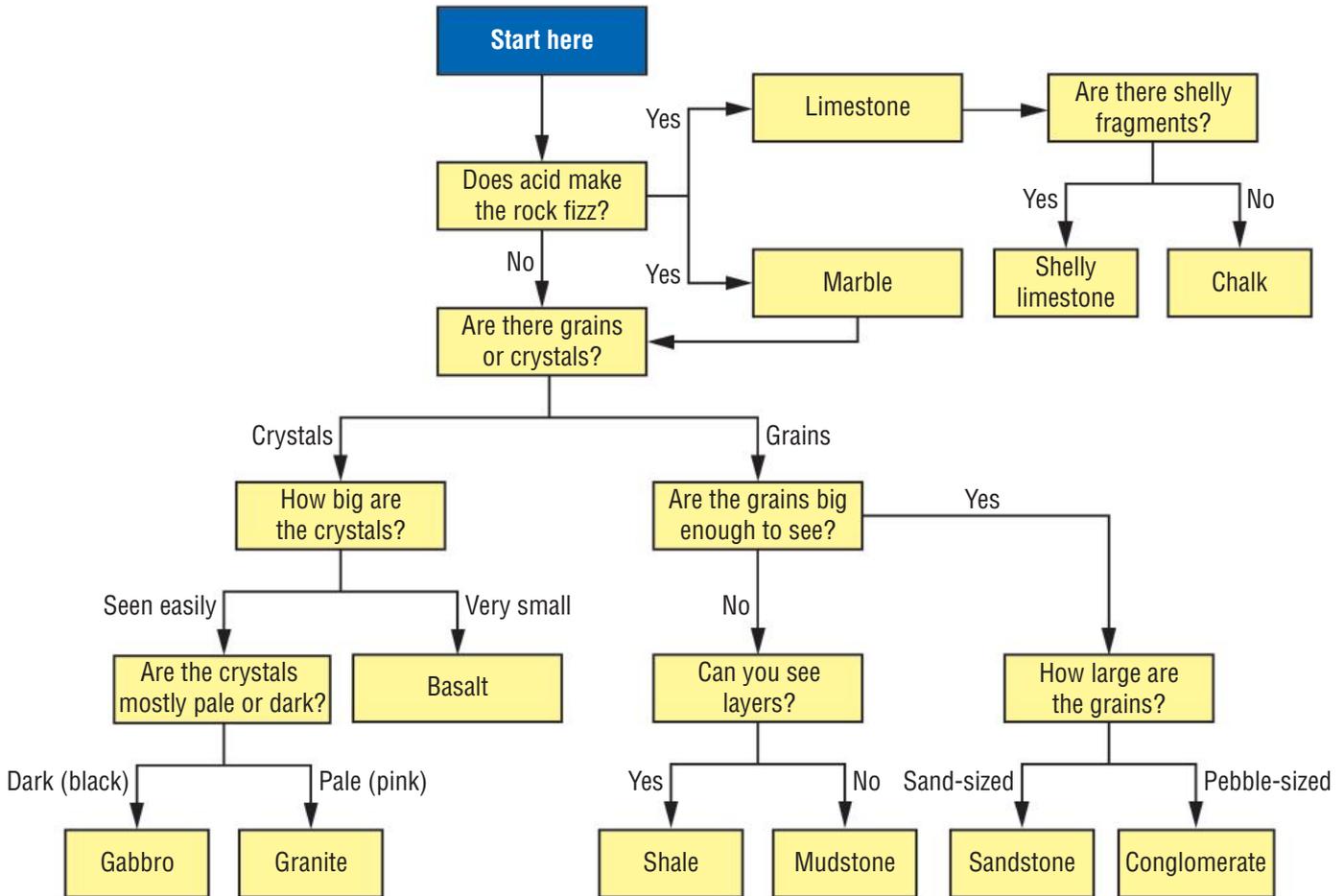
**WEBLINK**  
Collecting evidence  
from the Earth

# 8.3 Using rocks

## Identifying rocks

Minerals have a wide range of uses in steel production, electronics and medical or chemical applications. It is important to be able to identify a rock and the minerals it contains.

You can identify minerals by using a dichotomous key. You will have learnt about dichotomous keys when classifying living organisms (see Chapter 4). A dichotomous key consists of a series of choices. This leads you to identify the type of thing you are looking at. Figure 8.23 shows one key that can be used to identify rocks.



**Figure 8.23** ▼

Rock identification keys have questions with two distinct answers.

## ACTIVITY 8.9

## Making a rock identification key

To identify a rock, you need to be able to determine its:

- physical properties, such as its appearance, hardness, crystals and grain size
- chemical properties, such as whether it reacts with acid.

- 1 Gather all the information covered so far in this chapter about each of the three different types of rocks.
- 2 Put this information into a table with three columns with headings 'Igneous', 'Sedimentary' and 'Metamorphic'.
- 3 Work out one question that would assist you in separating a rock into one of the three groups. Remember, each question must have a Yes or No answer or be a statement about what type of rock you have.

Hint: Start with a question that considers whether the rock is igneous or sedimentary. Metamorphic rocks are rocks in the process of changing from igneous to sedimentary, so they will have similar properties to both. This makes it harder to identify them.

- 4 Continue asking questions about the rocks until you have enough to create a rock identification key. You might need to refer to Chapter 4 to see how a key is created.


**WORKSPACE**

Making a rock identification key


**WEBLINK**

How are rocks classified?

## ACTIVITY 8.10

## Using your rock identification key

### Materials

- your rock identification key from Activity 8.9
- rock samples

### Method

- 1 Work in groups of two. Work out any safety precautions you will need to take.
- 2 Use the rock identification key to identify a number of rock samples.
- 3 Develop ways to effectively test your key.
- 4 Work together to decide how to best evaluate your results from using your key.


**WORKSPACE**

Using your rock identification key

ACTIVITY 8.10

**Discussion**

- 1 For each of the three rock types, **describe** a physical characteristic you would easily notice.
- 2 **Identify** the rock type that shares some properties of the other two types. **Justify** your answer.
- 3 **Outline** some advantages of being able to identify a rock.
- 4 **Describe** some things other than rocks that are classified in science. **Outline** why the classification of things is important in science.
- 5 Add what you have learnt to your mind map from the start of this chapter.
- 6 Write up your investigation according to your teacher's instructions.

**synthetic**

made in a laboratory, not occurring in nature

**natural**

something that is grown or occurs in nature

## Rocks as valuable resources

Everything we use is made of either **synthetic** (made in a laboratory, such as plastic) or **natural** ingredients. Rocks and minerals are naturally occurring ingredients. To be useful to us, they have to be collected and processed.

An **ore** is a type of rock that contains valuable minerals. Most often the valuable mineral is a metal (see Chapter 6). For example, iron ore contains the metal iron, and copper ore contains the metal copper. Mining is the process of extracting ore from the ground.

Ores usually do not exist in the ground in a pure state that is ready to use. Metal ores are normally **oxides**. This means the metal has reacted with oxygen. Aluminium (Al) is the most common metal in the Earth's crust. It reacts with oxygen to produce aluminium oxide ( $\text{Al}_2\text{O}_3$ ). The ore bauxite (Figure 8.24) contains about 70%



Science Photo Library/Jean-Claude Revy/ISM

**Figure 8.24** ▶

Bauxite is an ore that contains a large amount of aluminium oxide.

**ore**

a rock containing valuable minerals

**oxide**

a compound formed when an element reacts with oxygen

aluminium oxide. Bauxite is the best ore to mine to extract the aluminium. Australia is one of the top producers of bauxite, producing almost one-third of the world's output.

Governments now require environmental impact studies to be carried out before mining can occur. These studies will determine the effect mining will have on the environment and what will need to be done to restore the site (**remediation**) when the mining is finished.

**remediation**

the restoration of something to its original state

## ACTIVITY 8.11

## Disciplines of science in mining

Working in a group or individually, **investigate** a mining occupation from a particular **science discipline**. You could choose engineering geologist, environmental geologist, hydrologist, mineralogist, petrologist, palaeontologist, sedimentologist or another agreed on by your teacher.

- 1 Present an overview of what your scientist does in their particular discipline.
- 2 **Explain** where you could study the discipline and what is involved.
- 3 **Discuss** how the discipline is used in the mining industry.
- 4 Present your investigation as a brochure that could be used to inform people of possible mining careers.

### science discipline

a specialist area of study in science, such as chemistry, physics and biology

### ACTIVITY SHEET

Aboriginal use of rocks and minerals



### VIDEO

Smelting copper and tin



### WEBLINK

Mining industry skills



WOW!

## The super pit

The super pit in Kalgoorlie, Western Australia, is a very big hole. It is currently the largest open-cut gold mine in Australia. Up to 28 000 kg of gold is mined there every year.



Alamy/Bill Bachman

## Uses of mined ores

The minerals extracted from the ground enable us to enjoy a range of manufactured items. Everything we have is grown, made from petroleum products (plastics, synthetic material) or manufactured from raw materials extracted from mined ores.

A typical mobile phone might weigh 120 g. It will have approximately 9% aluminium, 19% copper, 8% iron, 1% nickel and 1% tin. This may not seem a lot; however, when you multiply it by the number of mobile phones purchased each year, you start to get very large numbers. In 2010, the number of 10–40 year olds in Australia was approximately 9.6 million. If one-third of those people have a mobile phone, that is 3 200 000 phones – 3 200 000 multiplied by 9% (Al) of 120 g is 34 560 kg of aluminium!



Shutterstock.com/Robert Davies

◀ **Figure 8.25**

Mobile phones contain a lot of metal, including aluminium, copper, iron, nickel and tin.

ACTIVITY 8.12

## Reduce, reuse and recycle

Use the data presented on page 221 as the basis for an advertising campaign to ban the manufacture of new mobile phones, in favour of recycling. Present your campaign as a movie, podcast, radio announcement, brochure or another format agreed on with your teacher.



WORKSPACE  
Metals calculator

ACTIVITY 8.13

## Metals calculator

Choose an item from Table 8.2. Use the data for your chosen item to present information on the metals required to manufacture that item. Work out how much of each metal would be required to provide that item for 1000 users in Australia and 1 000 000 000 users worldwide.

**Table 8.2** ▲  
Amount of metal in some common items

Metal	Percentage of the metal in a . . .		
	Car (mass 1400 kg)	TV (mass about 15 kg)	Refrigerator (mass 65 kg)
Aluminium	8% (112 kg)	2% (0.3 kg)	3% (1.95 kg)
Copper	1.5% (21 kg)	3% (0.45 kg)	4.5% (2.9 kg)
Gold	0.002% (0.028 kg)		
Iron	69% (966 kg)	10% (1.5 kg)	
Lead	0.7% (9.8 kg)		
Magnesium	0.15% (2.1 kg)		
Nickel	0.3% (4.2 kg)		
Zinc	0.7% (9.8 kg)		

## Sustainable development

Sustainable development means using resources but also preserving the environment. So we continue to mine, farm and cut trees for timber for our needs, but ensure that future generations will also have enough resources to meet their needs. The mining industry in Australia has developed standards and practices to reduce the environmental impact of mining. Figure 8.26 shows a mining site in Western Australia before and after it has been rehabilitated.

**a**



Image courtesy of Alcoa of Australia

**b**



Image courtesy of Alcoa of Australia

◀ **Figure 8.26**

**a** Mining near the South Dandalup Dam, in Western Australia, in 1980;  
**b** the same area, rehabilitated, in 2001



Alamy/Penny Tweedie

◀ **Figure 8.27**

Aboriginal elder teaching boys to hunt in central Australia

Traditionally, indigenous cultures in Australia – Aboriginal and Torres Strait Islanders – have a strong relationship with the land. Land is very important to all their physical and spiritual needs. Figure 8.27 shows traditional land use by Australian Aboriginal people.

For at least 65 000 years, the Australian continent has supported its indigenous populations with food, shelter and their spiritual needs. If this balanced, sustainable relationship between its people and the land is to be maintained, young and older Australians must develop and act in ways that respect the land and that provide us with a liveable environment.

ACTIVITY 8.14

## Sustainability debate/blog

Can mining be sustainable? Choose a position on this question (agree or disagree) and prepare notes containing facts and examples. Your arguments must cover Indigenous peoples and mining industry aspects. Prepare a debate or blog your point of view.



WORKSPACE

What have you learnt? 8.3

QUESTIONS 8.3

## What have you learnt?

### Remembering

- 1 a **Define** the term 'ore'.
- b **Outline** why we mine ores.

### Understanding

- 2 Everything you have is made from synthetic or natural materials or a combination of both. **Explain** the difference between synthetic and natural materials.

### Applying

- 3 a Look at the bird's eye view of the massive super pit (in the WOW! box on page 221). **Calculate** the fraction of the housing shown in the photo that would fit into the pit.
- b As an environmental scientist, **discuss** ways in which the super pit and its surrounding land could be restored after the mining had stopped.
- 4 China and India have a combined population of more than 2 billion people. If one in every three people has a car, **calculate** how much iron would be used to manufacture those cars. Use Table 8.2 on page 222 to help you.
- 5 Use the partial quote '... by living in harmony with our environment' and the term 'sustainability' in one or two sentences to **describe** what we should be doing now to ensure future generations have the resources to survive.

### Analysing

- 6 Australia is the world's largest producer of bauxite. **Propose** what the short-term and long-term consequences would be if bauxite mining ceased in Australia tomorrow.

# Chapter review

## Remembering

- 1 **Identify** how many years the geological time scale for Earth covers.
- 2 Complete the sentence by supplying the missing words.  
The dynamic and often violent Earth provides the \_\_\_\_\_ and forces needed for \_\_\_\_\_ processes to form new \_\_\_\_\_.

## Understanding

- 3 All rocks are minerals, but a mineral is not a rock. **Explain** what this means.
- 4 Write a paragraph that **describes** the rock cycle. Include the following 11 key terms and phrases: igneous rock, metamorphic rock, sediment, magma and lava, sedimentary rock, slow-cooling crystals form, lava from volcanic eruptions, weathering and erosion, compacting and cementing, heat and pressure, melting.

## Applying

- 5 Write a paragraph about a mineral to **describe** its chemical formula, some of its properties and why it is useful.
- 6 Label each rock a–c as igneous, metamorphic or sedimentary. **Justify** your choices.

a



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b



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c



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**WORKSPACE**  
Chapter 8 review



**ACTIVITY SHEET**  
Chapter 8 checklist



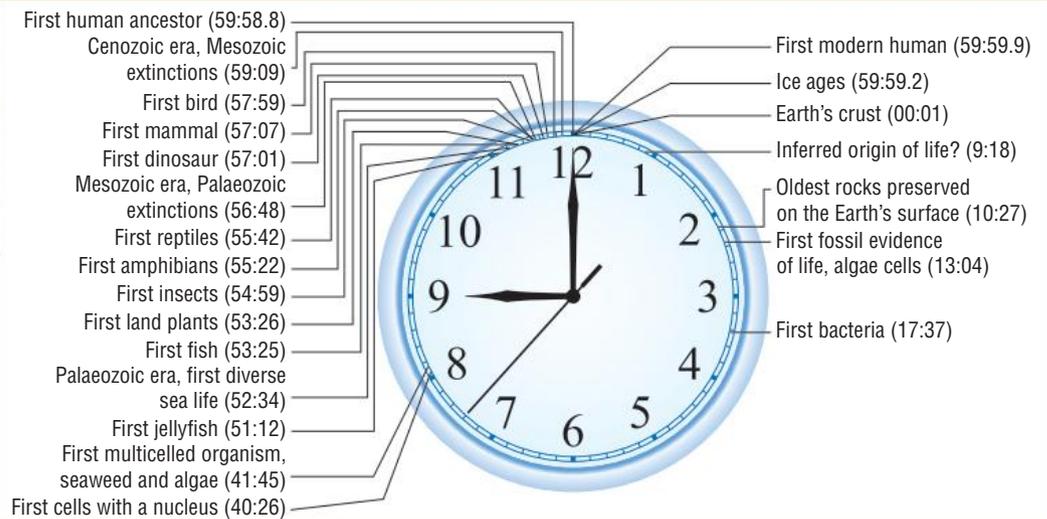
**REVIEW QUIZ**  
Chapter 8





**Figure 8.28** ▶

Geological time clock –  
4.6 billion years in 1 hour



## Analysing

- Rock density is the ratio of a rock's mass (grams) to its volume ( $\text{cm}^3$ ). As density increases, the amount of rock (mass) within a fixed volume increases. **Evaluate** how the mass for a fixed volume of rock can increase due to natural forces.
- Use the one-hour geological timeline clock in Figure 8.28 to **construct** a timeline of the life of the Earth.

## Evaluating

- The Earth's crust contributes a very small fraction to the Earth's mass. With the increasing world population and demand for metal ores, the future supply of raw materials for manufacturing is going to become limited. **Critically evaluate** possible solutions to this situation.
- The world is going to run out of oil. Scientists are developing alternative fuels and power sources. Will we run out of minerals to manufacture everything we use? If we were going to run out of these raw materials, **explain** what we could do now to prevent this.
- In the 18th century James Hutton said: 'The present is the key to the past.' **Evaluate** how you can use this brief statement to explain the rock cycle.

## Creating

- Volcanoes are important for the formation of new land on Earth. **Outline** what would happen if all the volcanoes on Earth were to become dormant for the next million years.

## Reflecting

- The dynamic geology of the Earth provides the energy and forces needed to recycle rocks. **Describe** the future that would exist for humans if the rock cycle were to cease.

A low-angle, upward-looking photograph of a roller coaster track. The track is dark blue and curves sharply upwards and then downwards. The sky is a clear, bright blue with some light, wispy white clouds. The perspective makes the tracks appear to converge towards the top of the frame.

# 9

## Forces

---

How do invisible forces affect objects?

---

Forces are invisible. You can't see them, but you can feel some of them. If you have ever been whacked in a pillow fight, then you have been hit with a very large force. It is a good thing it only happens for a short period of time! On a roller coaster, you are also exposed to large forces. Jet pilots need special suits to stop them from losing consciousness when they experience massive forces while flying.

---

## Physical sciences – Stage 4

### Key knowledge

- A force is a push or a pull.
- A force causes objects to change speed and direction (due to an unbalanced force).
- Friction is a contact force that occurs when two surfaces rub together, producing heat.
- Friction occurs in our everyday lives and its effects depend on a variety of factors. Heat is produced when there is too much friction; e.g. un-oiled gears in an engine.
- Some forces act at a distance, such as electrostatic and magnetic forces and gravity.
- Simple machines use the application of forces to make jobs easier.
- We can use our knowledge of forces to develop technological solutions to assist us in our everyday lives, such as the production of air bags and seat belts to minimise impact force in a car crash.
- Mass and weight have a different meaning due to the effects of gravity.

### CULMINATING ASSESSMENT TASK

## Working with people with physical disabilities

**Apply** your knowledge of forces and simple machines by completing the activity sheet 'Physical disability design brief' to create, **construct**, test and **evaluate** an aid for a person with a physical disability. You must **demonstrate** how the use of forces and simple machines combine to produce the desired result.



#### ACTIVITY SHEET

CAT with rubric: Working with people with physical disabilities

## What do you already know about forces?

- 1 Work with another student to construct an imaginary creature out of plasticine.
- 2 Write clear instructions, in steps, on how to make your creature.
- 3 Swap instruction sheets with another pair of students. (Do not show them your creature!)
- 4 **Construct** the other students' creature, using their instructions and more plasticine.
- 5 **Compare** the creature you made from the other students' instructions with the creature they made from your instructions.
- 6 In your workbook, sketch the creatures you made.
- 7 **Discuss** what you found out about giving and receiving instructions. How successful do you think you all were in giving and receiving instructions?
- 8 Write the word 'FORCE' in the middle of a sheet of paper. Around this word, write down other words to **describe** what you did to the plasticine to mould it into the shape you wanted.
- 9 Watch the video 'Pushes and pulls' and **identify** all the effects that force has on objects.

### WORKSPACE

What do you already know about forces?



### VIDEO

Pushes and pulls



## 9.1 Finding forces

It is impossible to move around and do things without applying forces. A **force** can be seen as a push, pull or twist applied to an object by another object. Did you use the words 'push', 'pull' or 'twist' when you were describing how to make your creature in the opening activity?

However, there are plenty of examples where this simple idea is not as obvious, such as electricity, magnetism or gravity.

A better definition of a force is anything that causes a change in an object's speed, direction or shape. For example, when you push someone on a swing, they change speed and direction. When you pull on a wet jumper, it changes shape.

### Drawing forces

You cannot actually see a force. You can only see its effect on an object. However, you can represent a force. You can use an arrow to represent the size and direction of a force. The arrow starts where the force is applied and points in the direction that the force pushes or pulls. Figure 9.1 shows a girl kicking a soccer ball. The start of the arrow shows the point of contact of the force and the end of the arrow shows the direction the force is working.



Shutterstock.com/Amy Myers

### force

any influence that causes a change in the speed, direction or shape of an object

◀ **Figure 9.1**

The arrow shows the size and direction of the applied force.



Alamy/jaileybug

**Figure 9.2** ▶

Even a small force can move big objects.



**WORKSPACE**  
Forces in action

### ACTIVITY 9.1

## Forces in action

Work in groups of three.

### Aim

To demonstrate some basic forces

### Materials

- digital camera
- ball
- plasticine

## ACTIVITY 9.1

**Method**

- 1 Read the following paragraph.

'When we walk, run, talk and listen, forces are being applied. We push on things and we pull on things. We jump and we bump. We twist and we squeeze. We mould and pinch clay into pots. We chisel and smooth marble into statues. We cut and hammer wood. We throw and catch and slide. We dive and swim and float. We fly and glide and fall and bounce. All these activities, and many more besides, involve forces.'

- 2 **List** all the verbs used to describe forces in the paragraph.
- 3 In your group, role-play six situations that show some of these verbs in action.
- 4 Take digital photos of your role-plays.

**Results**

- 1 Download the photos to your workspace. On each photo, use digital drawing tools and menus to **identify** some forces by:
  - a drawing a force arrow on the photo
  - b labelling the arrow.
- 2 Write an appropriate caption under each photo.

**Discussion**

- 3 **Analyse** the forces involved in each situation in terms of how increasing or decreasing each force would change the final outcome.

## WEB 2.0

Create a word cloud with Wordle or Tagxedo, listing all the verbs in the paragraph. Share your work with the rest of the class by uploading your completed photos to the class wiki.

**WEBLINK**  
Wordle



**WEBLINK**  
Tagxedo



**WORKSPACE**  
What have you learnt? 9.1



## QUESTIONS 9.1

**What have you learnt?****Remembering**

- 1 **Define** the term 'force'. Give two examples.
- 2 **Outline** three ways that forces can affect objects.

**Understanding**

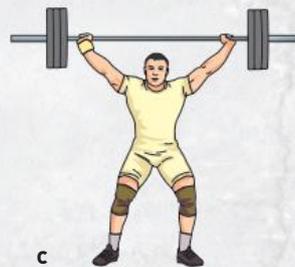
- 3 On a force diagram, where do force arrows start and finish?

**Applying**

- 4 Use a diagram, or create an animation on your computer, to **describe** how the following words relate to force.
  - a Bump
  - b Squeeze
  - c Drag
  - d Throw

**QUESTIONS 9.1**

5 Draw arrows to show two forces in each of the following situations.



**Analysing**

6 For each force applied, in Question 5, **identify** whether it is a push or a pull.

**Evaluating**

7 **Outline** two ways in which your ideas about forces have changed as a result of what you have learnt so far.

**Creating**

8 Imagine that you have been asked to **explain** forces to a young child. Write a script to **describe** what you would say.



**WORKSPACE**  
Pushing and pulling

**ACTIVITY 9.2**

**Pushing and pulling**

- 1 Consider the following examples.
- You reach out with your finger to turn on a light switch.
  - You grab a rope with your hand and pull it.
  - You throw a ball into the air.

In each example, **identify** the object that is:

- a applying the force
- b receiving the force.



**ACTIVITY SHEET**  
Hidden forces

### ACTIVITY 9.2

- 2 **Describe** at least two more examples. **Identify** the object in each that is:
- applying the force
  - receiving the force.

## 9.2 Balanced and unbalanced forces

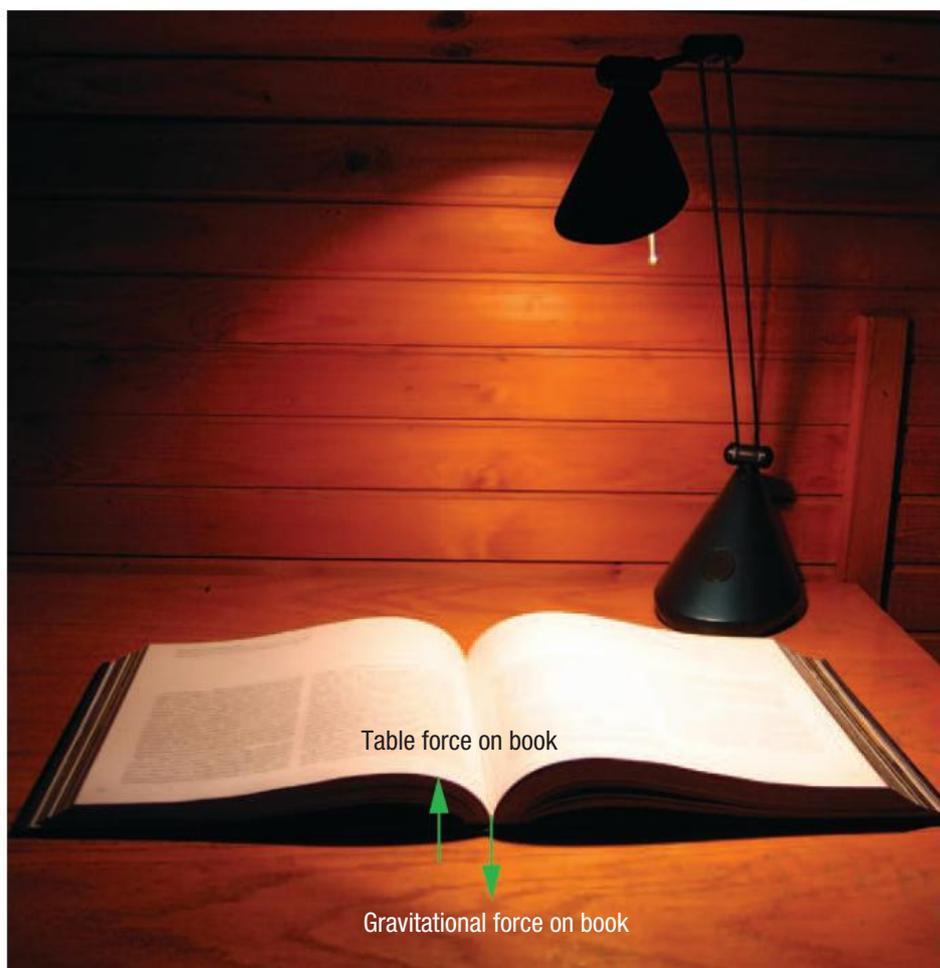
All the forces acting on a particular object add up to make a **total force**, or **net force**, on the object. A book on a table is not moving. The forces on the book are equal. The table applies a force upwards. This stops the book being pulled down to the ground by the gravitational force. The forces acting on the book are **balanced forces**; that is, the two forces are equal in size, opposite in direction and acting on the same object. If the object is not moving, balanced forces make no difference. The book just stays there.

### total force (net force)

the sum of all the forces acting on an object

### balanced forces

forces acting on the same object, whose combined effect is zero



Shutterstock.com/markomatovic

◀ **Figure 9.3**

This book is not moving, so the upward and downward forces acting on it must be equal in size and opposite in direction.

### unbalanced forces

forces acting on the same object, whose combined effect is to speed up the object, slow it down or to change its direction

If you removed the table from under the book, the upward force by the table acting on the book would be removed. The forces acting on the book would no longer be balanced. The book would fall to the floor and the **unbalanced forces** acting on the book would cause it to speed up. They can also cause objects to slow down or change direction.

## Coping with unbalanced forces

Unbalanced forces can have a huge effect on our safety and wellbeing. A number of laws have been passed to help keep us safe.

In 1964, it became compulsory to wear a seatbelt in a car in South Australia and Victoria. These were the first such laws in the world. These laws are based on ideas published by Sir Isaac Newton in 1687. Among his many ideas about forces was his first law of motion, which stated that an object will move at a constant speed unless acted on by a force.

If a car is travelling at 60 km/h, the occupants of the car are also travelling at 60 km/h. If the car stops suddenly due to a collision, the car will stop but the occupants will continue travelling at 60 km/h, through the windscreen or onto the steering wheel and dashboard. However, if the occupants are restrained by a seatbelt, the force will be absorbed by the stretch in the belt.

Modern cars have many safety features designed to protect passengers. These include airbags, laminated windscreens and antilocking brakes.

**Figure 9.4** ▲

Seatbelts prevent car occupants from striking the interior of the car.



Corbis/Tim Wright

## ACTIVITY 9.3

## Designing seatbelts

Work in groups of three.

- 1 **Outline** all the factors you would need to consider when designing a seatbelt or harness for a baby, toddler, teenager, adult or elderly passenger.
- 2 **Compare** your list with those of the rest of the class.
- 3 **Analyse** how one safety device has made being an occupant of a car safer. Show your information as a one-page infographic.

WORKSPACE  
Designing seatbelts



Road safety doesn't just apply to cars. In 1991, it became compulsory to wear a bicycle helmet while riding a bike in Australia. Like seatbelts, bicycle helmets are designed to reduce the force of impact on the skull as the head hits the road or pavement in an accident. The sudden stop can cause the brain to collide with the skull, which leads to concussion. Helmets usually have a hard plastic coating on the outside and softer polystyrene on the inside, which is designed to reduce some of the force applied when coming to a sudden stop.

Figure 9.5

A cyclist can feel secure with their helmet firmly attached.



Shutterstock.com/Rihard Stadler



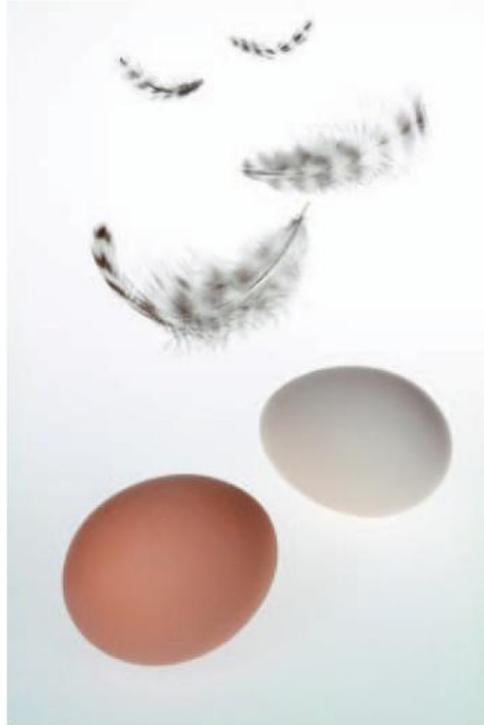
**WORKSPACE**  
Save an egg

**EXPERIMENT 9.1**

**Save an egg**

**Aim**

To design a device, similar to a bike helmet, that will effectively prevent an egg from cracking in a fall from a height of one storey.



Shutterstock.com/Foto-Ruhrgebiet

**Figure 9.6** ▶

What device would be most effective to protect an egg if it fell from a height of one storey?

**Materials**

- egg
- digital camera or video camera
- any other materials you see fit

**Method**

- 1 Sketch three potential device designs in your workspace.
- 2 **Assess** your designs and **construct** the device you feel is going to be the most effective. **Outline** your reasons.
- 3 Place the egg in your device and drop it from a height of one storey, or 3 metres.

**Results**

- 1 Use the camera to record the design, construction and testing of your device and present your story in a multimedia presentation.

**Discussion**

- 2 How successful was your device in reducing the force applied to the egg? **Account** for why it was or was not successful. **Explain** how you measured the success.
- 3 **Propose** improvements for your design.
- 4 On the basis of your findings, **describe** how you would improve the design of a bike helmet. Suggest how:
  - one part could be made bigger
  - something could be added
  - something could be removed.

## QUESTIONS 9.2

## What have you learnt?

### Remembering

- 1 **Outline** an example of:
- a a balanced force
  - b an unbalanced force.

### Understanding

- 2 **Explain** what is meant by total force.
- 3 **Describe** the effects of an unbalanced force on an object. Give an example.
- 4 You throw a ball in the air. **Identify** what is applying the force and what is receiving it.

### Applying

- 5 **Explain** why the following sentence suggests that forces act in pairs:  
'You cannot touch someone without them touching you.'
- 6 A car is moving along a straight road at a constant speed of 60 km/h. Are the forces on it balanced or unbalanced? **Explain**.

### Evaluating

- 7 Science often provides reasons why some laws are introduced into society. **Evaluate** whether you think it is important that people understand the reasons for our seatbelt law.

### WORKSPACE

What have you learnt? 9.2



## 9.3 Contact forces and non-contact forces

### Contact forces

A **contact force** is a force where one object actually touches, or is in contact with, another object. For example, a finger touches a light switch or a hand touches a ball.

Whenever one object pushes on another object, it is usually easy to identify which object is applying the force and which object is receiving it. However, sometimes it is not so obvious. When you push on a wall, it is clear that you are applying the force to the wall. What is not so clear is that the wall is also pushing on you.

Have you ever noticed how you sometimes push off a wall to help you to change direction or to go around a corner? You apply a large push force on the wall so that the wall can apply the same size push force on you. This helps you to change direction.

#### contact force

a force applied by one object on another object when they are touching each other

We use the force by the ground on us all the time – to help us walk, run and jump. In these cases, we apply a large push force on the ground, and the ground applies the same size push force on us. This enables us to move forwards.

We do not usually think about walls, floors and the ground exerting forces, but they do!



Getty Images/White Packet

**Figure 9.7** ▶

When you push on the wall, the wall is also pushing on you.

### friction

the force applied by one surface on another

## Frictional forces

**Friction** is one of the most common forces around you. It is the force that slows down a toy as it rolls across the floor. It is the force that stops you slipping over while you are walking.

Friction occurs because surfaces will always have irregularities, or bumps. When two materials touch, these bumps hit each other and cause the moving objects to lose energy, usually as heat, light and sound. You may have seen sparks flying off a part of a car if it is dragging along the ground.

Cars are good examples of friction at work. There is friction between the car body and the air. As the car moves through the air, the air pushes against the panels and windows. This is why modern cars have streamlined surfaces (Figure 9.8).



Shutterstock.com/oksana\_perkins

**Figure 9.8** ▶

High-performance cars are designed to slip through the air.

There is friction between the wheels and the road. The wheels use friction to speed up and slow down the car. As the wheel turns, the friction between the rubber in the tyre and the road causes the car to move forward. When the car needs to slow down this friction grips the road, allowing the car to slow.

There are times when this friction between tyre and road fails, such as on a wet or an icy road. Water and ice on the road prevents the rubber of the tyre gripping the road. The tyres will most likely spin in place and the car will be hard to control on the slippery surface. This is why people in snowy countries use special snow tyres in the winter for more grip, or add chains to the tyres to create friction.

A car motor is composed of many moving metallic parts. When metal moves against other metal, there is usually a large amount of friction. This means that the parts of a motor need to be lubricated with oil. Otherwise, it will not work and fail, potentially causing massive damage to the engine. Oil is used to reduce friction in many machine parts.

### EXPERIMENT 9.2

WORKSPACE  
The effect of friction



## The effect of friction

### Aim

To measure the effect of friction on the time it takes for a toy car to descend on a ramp

### Materials

- toy car
- stopwatch
- three boards, each 1 m long, with different surfaces: carpet, wood, rubber matting

### Method

- 1 Set up the three boards so that they are all 10 cm high at the top end.
- 2 **Predict** which surface you think the car will roll down the fastest. Write this as your hypothesis, stating whether the board has the most or least friction.
- 3 Pick a starting point and release the car to roll down the first of the boards. Measure the time taken to reach the bottom of the board. Repeat the measurement so that you have a total of 10 times, and then find the average time.
- 4 Repeat step 3 with the second and third boards.

### Results

- 1 Use your results to complete the following table.

Surface	Time taken for car to roll down ramp (s)										
	1	2	3	4	5	6	7	8	9	10	Average
Carpet											
Wood											
Rubber matting											

EXPERIMENT 9.2

Discussion

- 2 **Identify** the surface with the most friction and the surface with the least friction.
- 3 Was your hypothesis correct? **Explain** why or why not.
- 4 **Outline** the independent and dependent variables and variables held constant during this experiment.
- 5 **Propose** ways of improving this experiment.

Ice-skaters try to minimise the amount of friction their skates exert on the ice. This allows them to glide smoothly and in some cases very fast (Figure 9.9).



Shutterstock.com/Vladislav Gajic

Figure 9.9 ▶

An ice-skater needs to reduce friction to slide smoothly.

**non-contact force**

a force applied by one object on another object when they are not touching each other

**magnet**

an object that produces a magnetic field

**magnetic field**

a region where a magnetic force acts

**magnetic force**

a force applied by a magnet on another magnet or a magnetic material

**magnetic material**

a material that is not a magnet but is affected by a magnetic force

## Non-contact forces

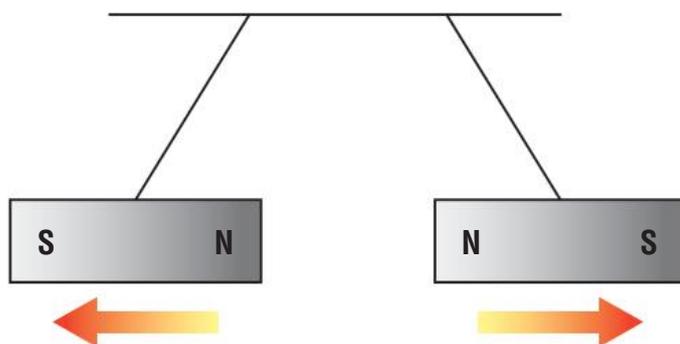
A **non-contact force** is a force by one object on another object from some distance away. There are three obvious forces in which there is no contact between objects, yet a force is applied: magnetic force, electrostatic force and gravitational force. These are interactions in which a force is experienced, even though objects do not touch.

### Magnetic force

A **magnet** is an object that is surrounded by a magnetic field. This **magnetic field** causes a **magnetic force** to act on other magnets and other **magnetic materials**. Magnets attract (pull) some objects towards them, or repel (push) them away.

**ACTIVITY SHEET**  
Investigating forces:  
Skateboarding

A bar magnet has two ends, or poles. One pole is the north (north-seeking) pole and the other pole is the south (south-seeking) pole. If you place two bar magnets so that their north and south poles are facing each other, they will be attracted to each other. If you place two bar magnets so that both their north poles are facing, they will repel each other (Figure 9.10). The rule of magnets is that opposite poles attract and like poles repel.



◀ **Figure 9.10**

Forces by magnets: unlike poles attract, like poles repel.

This is how magnetic compasses work. The compass needle is a little magnet, which aligns itself to the Earth's magnetic field. You can see this for yourself by bringing two magnetic compasses close together and seeing the effect they have on each other.

Table 9.1 shows the four possibilities for forces between two bar magnets.

**Table 9.1** ▲

Effect of the ends of one magnet on the ends of another magnet

Magnet 1	Magnet 2	
	North end	South end
North end	Repel	Attract
South end	Attract	Repel

### EXPERIMENT 9.3

## Exploring magnetic forces

### Part A

#### Aim

To investigate how magnetic fields interact with each other.

#### Materials

- two bar magnets
- string or cotton
- three retort stands, boss-heads and clamps
- a variety of materials: wood, cork, nail, cubes of different metals

**WORKSPACE**  
Exploring magnetic forces



**VIDEO**  
Magnetic field lines



**ACTIVITY SHEET**  
Drawing magnetic field lines



**ACTIVITY SHEET**  
Mapping the field lines of a magnet



◀ EXPERIMENT 9.3

**Method**

- 1 **Predict** what will happen when a force is applied to different ends of a bar magnet by another bar magnet.
- 2 Hang the bar magnets from different retort stands. Make sure they are horizontal and can swing freely. (You may have to experiment with different ways of doing this.)
- 3 **Identify** one magnet by the letter 'P' and the other by 'Q'.
- 4 **Identify** the north and south ends (poles) of P and Q.
- 5 Bring the north pole of Q towards the north pole of P. Record your observations in the results table.
- 6 Separate the magnets.
- 7 Bring the north pole of P up to the north pole of Q.
- 8 Test all the different combinations of north and south poles as they are brought towards each other.

**Results**

- 1 Record your observations in the data table, adding more rows as required. (The first force pairs are shown.)

Test	Force applied by	Force received by	Effect (attract/repel)
North pole of Q towards north pole of P	North pole of Q	North pole of P	
North pole of P towards north pole of Q	North pole of P	North pole of Q	
South pole of Q towards south pole of P	South pole of Q	South pole of P	
South pole of P towards south pole of Q	South pole of P	South pole of Q	
North pole of Q towards south pole of P			

- 2 **Construct** a diagram to show your understanding of how magnets attract.

**Discussion**

- 3 **Explain** what you can conclude from your observations.



## EXPERIMENT 9.3

### Part B

#### Aim

To investigate the effect of a magnet on other materials.

#### Method

- 1 Modify the method in Part A to test whether a magnet (or magnetic material) will influence a non-magnetic material.
- 2 For each material tested, **predict** what you think will happen.

#### Results

- 1 Record your data and **account** for your results.

#### Discussion

- 2 **Discuss** how your results compared with your predictions.
- 3 Research where magnets are used in everyday life and relate these to your results.

## Electrostatic force

Electric charges can cause objects to stick together. Some objects can become electrically charged. The force exerted by these electrically charged objects on other electrically charged objects is called an **electrostatic force**.

You can experience an electrostatic force when you least expect it. Occasionally you may experience a shock when you touch metal objects such as door handles. This may happen when you are wearing synthetic clothing and moving across a carpet. As you move, your body may pick up an electrostatic charge from the carpet, and the synthetic clothing often stops the charge from leaving your body. However, you will definitely notice when you touch the handle and the charge leaves your body.

The Van de Graaff generator (Figure 9.11) is a common piece of laboratory equipment. It makes a large electrostatic charge by a rubber belt moving quickly across a piece of metal. As the belt moves, electrons move from the dome and are taken away by the rubber belt. This leaves the dome with a positive charge.



Alamy/Sciencephotos

#### electrostatic force

a force applied by an electrically charged object on another electrically charged object

◀ **Figure 9.11**  
A Van de Graaff generator makes electrostatic charge.



**WORKSPACE**

Creative and critical thinking

**ACTIVITY 9.4**

**Creative and critical thinking**

- 1 Briefly **describe** a situation in nature in which electrostatic forces can be seen. **Outline** what causes the build-up of charge.
- 2 **Compare** your ideas with another student's and then with those of the whole class.
- 3 Search on the Internet to find where electrostatic charges are found in severe weather, volcanic eruptions and dust storms.
- 4 **Critically analyse** the accuracy and validity of the information you have found on the Internet.



**WORKSPACE**

Exploring electrostatic forces

**EXPERIMENT 9.4**

**Exploring electrostatic forces**

**Aim**

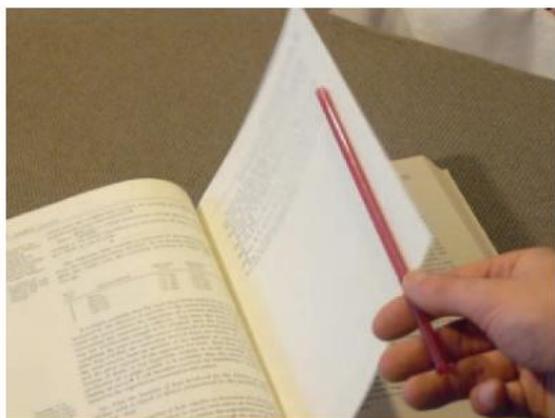
To demonstrate the effects of electrostatic charges.

**Materials**

- balloon
- piece of woollen cloth
- tissues
- plastic comb
- drinking straw
- thin-paged book such as a dictionary
- digital camera (optional)

**Figure 9.12** ▼

You can even use electrostatic force to turn the pages of a book by rubbing a drinking straw with a tissue.



**Method**

- 1 Blow up the balloon and tie the end. Rub the balloon with the woollen cloth. See whether you can stick the balloon to the wall.
- 2 Use the woollen cloth to rub the plastic comb. See whether you can pick up small pieces of tissue paper without touching them, using only the comb.
- 3 Rub the straw with a tissue. See whether you can turn the pages of the book without touching them, using only the straw.

**Results**

- 1 Record your observations, either in a table or using a digital camera.
- 2 In each instance, outline which object is applying the force and which object is receiving it.

## EXPERIMENT 9.4

## Discussion

- 3 **Describe** the type of force that is being applied here.
- 4 **Predict** whether you can 'bend' a thin stream of tap water without touching it, using only a plastic ruler and a woollen cloth. Video your results and upload your video to the class wiki.

## Gravitational force

Every mass attracts every other mass. This effect is not noticeable for most ordinary things. However, the mass of the Earth is huge compared with our mass. We experience the effect of the Earth's mass every day. It is called **gravity**, although a better term is **gravitational force**. This is the non-contact force where objects with mass attract one another. The Earth is much bigger than other objects on or near it, so it appears that all objects fall. This is because the Earth's gravity pulls objects towards the centre of the Earth. An object falls because the forces on the object are unbalanced.

If we were on the Moon, we would observe things fall, but they would fall at a slower rate than on Earth. This is why astronauts on the Moon appeared to float when they were moving.

## Mass and weight

Mass is the amount of material inside an object. Objects weigh different amounts depending on their mass. **Weight** is the force applied to a mass by another mass – usually by a much larger mass, such as the Earth. Although we usually refer to weight in kilograms (kg), the correct unit for weight is the newton (N) because it is a force. Mass is different from weight because your mass does not change, but your weight can change depending on which planet you are on.

You can lose weight by flying to the Moon because the Moon has a smaller effect on your mass than the Earth does. For example, an astronaut might say they weigh 60 kg. This is correct on Earth, but on the Moon, where the force of gravity is lower, she would weigh one-sixth of this, about 10 kg. It seems as though her mass has changed, but this is not the case.

In fact, the astronaut will have the same 60 kg of mass on Earth as she does on the Moon. However, the force by the Earth's mass on her 60 kg will be about 600 N. On the much smaller Moon, the force by the Moon's mass on her 60 kg would be about 100 N (Figure 9.13).

**gravity, gravitational force**

a force applied by one mass on another mass; often associated with the gravitational force applied by the Earth's mass on the mass of objects on or near the Earth

**weight**

the measurement of the force due to gravity acting on a mass, measured in newtons (N)

## ACTIVITY SHEET

Forces needed to hold up different masses

## ACTIVITY SHEET

Mass and weight on the Earth and Moon

◀ **Figure 9.13**

This person has the same mass of 60 kg on the Earth and the Moon. However, on Earth the weighing scale (weight) reads 600 N, and on the Moon, where gravity is lower, it reads 100 N.



**WORKSPACE**  
Gravity on other worlds

**ACTIVITY 9.5**

**Gravity on other worlds**

- 1 Write a three-page narrative that describes the forces an astronaut experiences on a voyage to the Moon, Mars or Jupiter.  
Your narrative should include the words 'force', 'mass' and 'weight'.
- 2 **Compare** your narrative with that of another student.



**WORKSPACE**  
Different forces

**ACTIVITY 9.6**

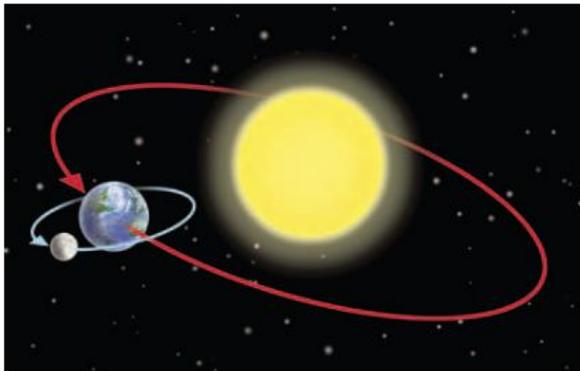
**Different forces**

**Outline** how different forces on the Earth and Moon:

- a affect people with disabilities
- b could be used to assist people with disabilities.

**Figure 9.14** ▼

The Earth has been captured by the gravitational force exerted by the Sun.



**Earth is captured by the Sun**

In space, your speed will not increase or decrease unless you are influenced by the gravitational force of a large object, such as a planet or the Sun.

That is what happens to the Earth. As it travels along on a straight path, the Sun's gravitational force keeps pulling on it. The gravitational force exerted by the Sun on the Earth pulls the Earth towards the Sun and so the Earth constantly changes direction (Figure 9.14). But the Earth is going just fast enough to go right around the Sun in its orbit. This is the Earth's revolution around the Sun. It takes a year for the Earth to complete one orbit of the Sun. The other planets in our solar system are also captured by the Sun's gravitational force, and each has its own revolution and orbit time (see Chapter 7).



**Sir Isaac Newton**

Sir Isaac Newton has given his name to the unit of force, the newton (N). Newton was born the year that Galileo died and is probably most well known for having an apple fall on his head while sitting under an apple tree. This is thought to have been the inspiration for his law of gravity. Whether this story is true or not, the tree shown here is a direct descendant of the apple tree from Newton's boyhood home in Lincolnshire, UK. It is located at the Babson College in Massachusetts, USA.



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**VIDEO**  
Gravity

## ACTIVITY 9.7

## Amusing forces

**Critically analyse** the forces applied on circular-type rides at an amusement park. Annotate video and/or still images to show the force pairs applied.

Add in the gravitational force as well. Don't forget to go on the rides and feel the forces acting on you!



◀ **Figure 9.15**  
Chain swing ride at an amusement park

## QUESTIONS 9.3

## What have you learnt?

### Remembering

- 1 **Describe** three examples of contact forces.
- 2 **Describe** three examples of non-contact forces.
- 3 **Outline** the rules for magnetic forces between two magnets.

### Understanding

- 4 a **Define** the term 'mass'.  
b **Clarify** how mass and gravitational forces are related.

### Applying

- 5 A straw can be used to change the pages of a book without touching it. **Explain** how this is done.

### Analysing

- 6 **Contrast** mass and weight. **Explain** their difference by referring to astronauts on Earth and the Moon.
- 7 **Outline** how it is possible for the Earth to be pulled by the Sun, yet not end up smashing into the Sun.
- 8 Use diagrams to help you **describe** what a field force is.

### Evaluating

- 9 'Gravity is just a force between masses.' **Critically analyse** this statement.

### WORKSPACE

What have you learnt? 9.3



# 9.4 Putting forces to work: machines

## How machines help us

### machine

a tool that makes a task easier to do

### simple machine

one of five basic types of machine from which all other machines are made

### inclined plane

a sloping ramp

A **machine** is a tool that makes it easier for us to do a task by multiplying the amount of force applied. Hammers, chisels, ramps, wheelbarrows and scissors are machines. More complicated tools are made from simple machines. **Simple machines** are useful for all sorts of purposes, including assisting people with disabilities.

## Simple machines

All tools or machines are made up of five simple machines: inclined plane, lever, pulley, wheel and axle, and gear wheel.

### Inclined plane

An **inclined plane** is a sloping ramp that helps us to move things up and down. It is much easier to push or pull a heavy box up a ramp than it is to lift it up above your head. You would have to move the box a greater distance up the ramp, but you would not have to exert so much force to move it. If you were bringing the box down several floors of a building, you could drop it out of the window or bring it down a slope in a more controlled way.

Stairs are a combination of a ramp with little vertical steps. Ramps are used as an alternative to stairs; for example, ramps assist people in wheelchairs who cannot go vertically up and down on stairs. Access ramps for people with disabilities have flat sections as well as ramps (Figure 9.16). This slows downward movement and allows rest sections for upward movement.

Craft tools such as wedges, chisels and screws use inclined planes. The thread on a screw is an inclined plane that spirals around. Roads and walking tracks spiral around mountains using ramps.



iStockphoto

Figure 9.16 ▶

Ramps allow easy access to buildings for people in wheelchairs.



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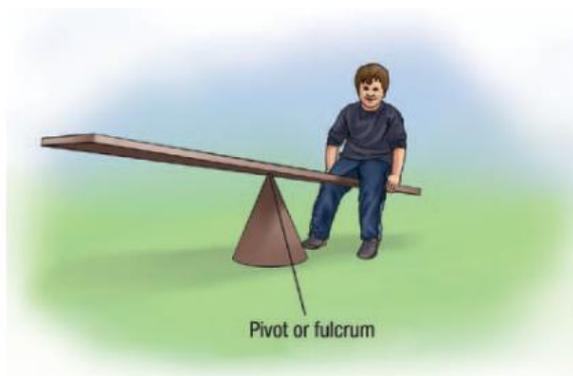
Figure 9.17 ▶

A mountain road is a series of ramps and turns like a screw.

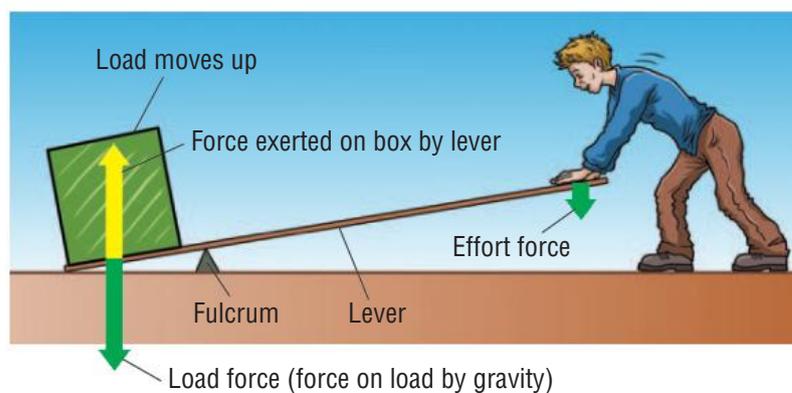
## Lever

If you wanted to shift a heavy load, you could use a **lever**. This is a plank or bar that turns around a stationary **pivot** or **fulcrum** that does not move. A see-saw is a typical lever (Figure 9.18).

If you sit on one end of a see-saw, you make it rotate. You can balance it with two people who sit at the right places. To balance the see-saw, the heavier person needs to sit closer to the pivot than the less heavy person (Figure 9.19).



A lever can be used to shift a heavy load (Figure 9.20). The **load** applies a **load force** to the lever. The load is moved when we apply the **effort force** far enough away from the pivot. On a see-saw, you need only apply a small effort force, directed down on the beam, to overcome the load force.



### lever

a solid plank or bar that rotates around a point

### fulcrum (pivot)

the point around which a lever rotates

### ACTIVITY SHEET

The screw



◀ **Figure 9.18**

One person on a see-saw makes it rotate.

◀ **Figure 9.19**

Two people seated at the right places can balance a see-saw.

### load (load force)

a force applied by an object, which must be overcome for the object to be moved by a machine

### effort force

a force applied to a machine to move a load

### VIDEO

Measuring forces: Building pyramids



◀ **Figure 9.20**

A lever at work



**VIDEO**

Levers in your lives



**ACTIVITY SHEET**

Investigating levers

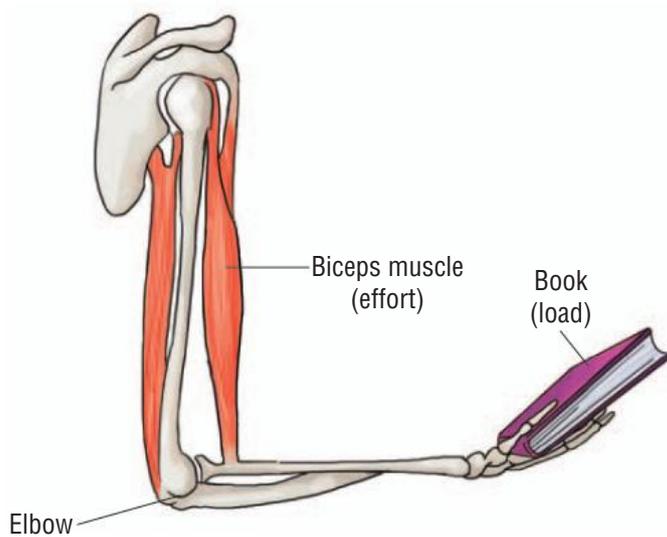
**Figure 9.21** ▶

The forearm is a lever in which the effort (biceps muscle) is between the pivot (elbow) and load (book).



**WORKSPACE**

Looking at levers

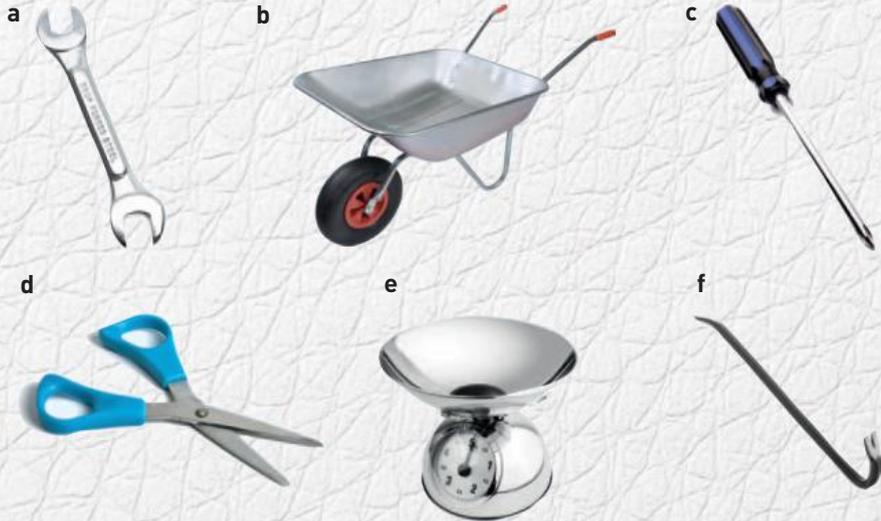


There are different forms of levers, depending on the positions of the load force, effort force and fulcrum. Your forearm is a lever, where the effort force (biceps muscle) is exerted between the load force (at the end of your arm) and the pivot point (your elbow) (Figure 9.21).

**ACTIVITY 9.8**

**Looking at levers**

In small groups, look carefully at the following levers.

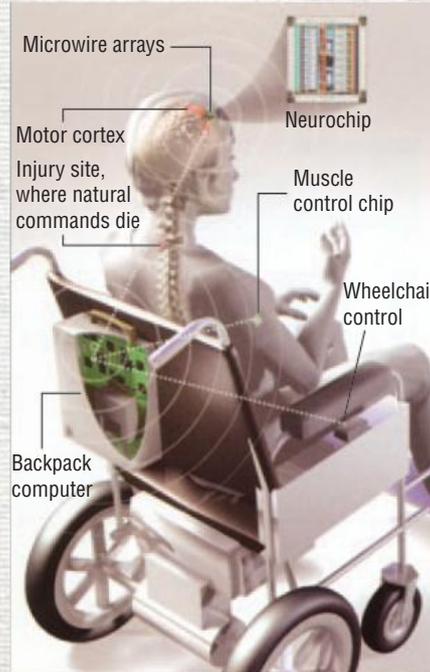


- 1 Which of these levers have you used?
- 2 **Describe** where you have seen any of the others being used.
- 3 **Identify** where the effort force and the load force are in relation to the pivot in each case. For example, in a see-saw the pivot is between the load and the effort. **Evaluate** whether this true for each of these situations.
- 4 **Discuss** whether everyone in your group agrees on where the effort and load are placed in relation to the pivot in each example. **Explain** any differences.
- 5 **Compare** your findings with those of other groups.

**WOW!**

## Bionic arms

Bionic arms are artificial arms that respond to the wearer's thoughts. You just think your way to the action, and the bionic arm moves. When you think about reaching for a drink, your brain produces an electrical signal. For a person with a bionic arm, the signal is picked up by a microchip that has been put inside their brain. The microchip sends the signal to a small computer that the person is wearing. From there, the signal goes to another microchip, which stimulates their nerves and muscles. Finally, the bionic arm moves.



### pulley

a wheel with a groove around the edge

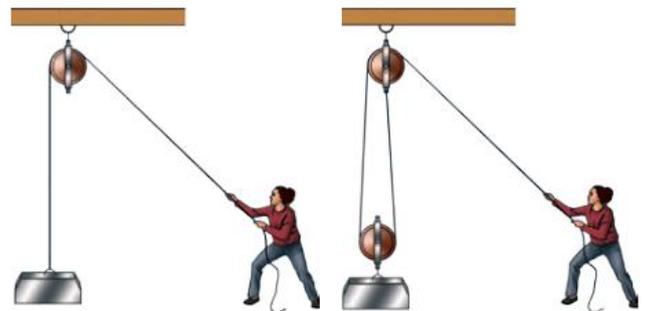
INTERACTIVE  
Pulleys



## Pulley

A **pulley** makes vertical lifting easier. A pulley is a wheel with a groove around the edge. A string, rope or chain fits inside this groove. You pull downwards on the rope to lift something upwards.

Pulleys are used to raise garage doors or lift heavy objects on farms, in factories and on building sites. Can you think of examples where you have seen pulleys in action? The more pulleys in use together, the easier it is to lift things, even though you have to pull the rope a long way. The advantage is that you do not have to pull very hard to lift quite large loads.



▲ **Figure 9.22**  
Pulley systems used to lift loads.

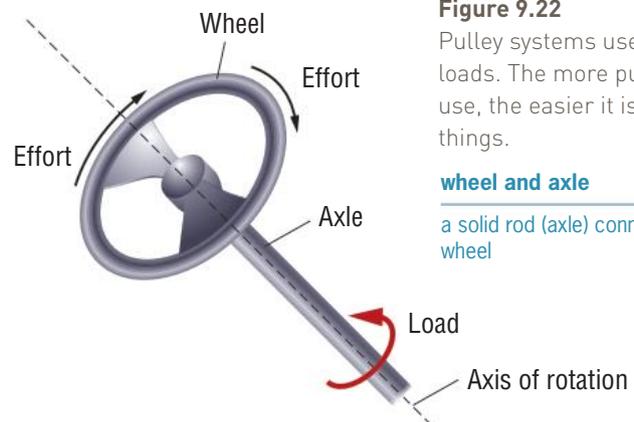
The more pulleys you use, the easier it is to lift things.

### wheel and axle

a solid rod (axle) connected to a wheel

## Wheel and axle

The wheel is often said to be the most important human invention. What would life be like without wheels? There would be no bicycles, cars or trains; no door handles, fans or screwdrivers. A **wheel and axle** is made from a solid rod (axle) connected to the wheel. When the axle turns, the wheel turns. A car steering wheel uses a wheel and axle machine. The axle, which is inside the steering column, only turns a little bit, but the wheel turns more. The load opposes the required movement of the steering wheel. A large movement of the steering wheel a long way from the axle causes the axle to turn enough to steer the vehicle.



▼ **Figure 9.23**  
Steering wheel and axle

**gear, gear wheel**

a toothed wheel

**driving gear**

a gear that is moved by an external force

**driven gear**

a gear that is affected by the rotation of the driving gear

**gear ratio**

the ratio of number of teeth on the driven gear to the number of teeth on the driving gear

### Gear wheel

A **gear**, or **gear wheel**, is a toothed wheel. The teeth of one gear wheel fit into the teeth of another gear wheel. One wheel is made to turn by an external force, such as that provided by your legs on a bicycle. This is called the **driving gear**. The gear that goes around as a result of the driving gear is called the **driven gear**.

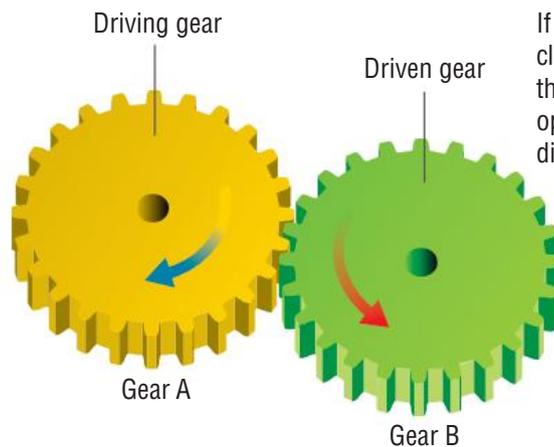
The driving gear transfers its circular movement to the driven gear. As a result, the driven gear rotates in the opposite direction to the driving gear.

When the gear wheels do not have the same number of teeth, the driven gear can go faster or slower than the driving gear. In Figure 9.25, the driving gear C has three times more teeth than the driven gear D. So the fan attached to the axle of gear D goes three times faster than gear C.

The **gear ratio** is the ratio of the number of teeth on the driven gear to the number of teeth on the driving gear. For example, in Figure 9.25, gear D has 8 teeth and gear C has 24 teeth. The gear ratio is 8:24, which can be simplified to 1:3. A chain is used for motorbikes and bicycles to transfer the rotation of the driving gear to the driven gear. You choose the gear ratio that best suits the conditions.

**Figure 9.24** ▶

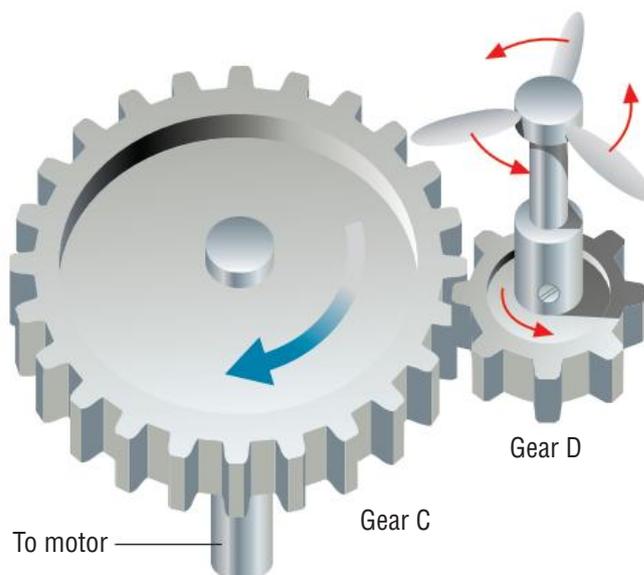
Gear A causes gear B to turn in the opposite direction. They turn at the same rate because they have the same number of teeth.



If gear A turns in a clockwise direction, then gear B will turn in the opposite (anticlockwise) direction.

**Figure 9.25** ▶

Changing the speed of rotation with gear wheels





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◀ **Figure 9.26**  
On a bicycle the rotations of the gear wheels are connected by a chain.

### ACTIVITY 9.9

## Making simple machines

### Aim

To construct examples of simple machines.

### Materials

- Lego kit and/or recycled materials
- digital camera

### Method

- 1 Construct a model of each simple machine from the available materials.
- 2 Use your model to demonstrate a task, such as lifting a load.

### Results

- 1 Use the camera to record your machine working

### Discussion

- 2 **Critically analyse** your models' effectiveness in demonstrating real-world models of machines.

**WORKSPACE**  
Making simple machines



**ACTIVITY SHEET**  
Get into gear



**ACTIVITY SHEET**  
Types of gears





**WORKSPACE**

What have you learnt? 9.4

**QUESTIONS 9.4**

## What have you learnt?

### Remembering

- 1 **Identify** an example of each type of simple machine.

### Understanding

- 2 Draw a diagram to illustrate the way a slope works to lift things up high.
- 3 **Outline** 10 places where you would see a screw at work (such as the lid of a jar).

### Applying

- 4 Use a diagram to **identify** the load, effort and pivot on a wheelbarrow.
- 5 **Describe** how can you pull downwards, yet lift something up.
- 6 **Outline** the use of a machine that doubles the speed of rotation of a toothed wheel.

### Analysing

- 7 **Outline** 10 things you could not do if there were no wheels.
- 8 **Describe** which gear you would choose to pedal a bicycle up a hill. Why would you choose this gear?
- 9 **Describe** which gear you would choose to pedal a bike on a long flat surface. Why would you choose this gear?
- 10 **Evaluate** how a person with a physical disability uses one simple machine to assist them.

# Chapter review

## Remembering

- 1 **Define** the term 'force'.
- 2 **Outline** three different categories of simple machines.

## Understanding

- 3 **Describe** why forces always act in pairs. Use an example in your description.
- 4 The poles of two magnets are brought close to each other. They stick together. **Demonstrate** this in an illustration.

## Applying

- 5 Use diagrams to **explain** how the following words relate to force.
  - a Jump
  - b Pinch
  - c Catch
- 6 **Compare** and **contrast** contact and non-contact forces.
- 7 You pick up a 2 kg packet of rice from the floor. Use diagrams with arrows to **identify** the forces involved.
- 8 'You cannot push someone without them pushing you.' **Explain** this statement.
- 9 Use diagrams to **compare** and **contrast** the load and effort forces of a see-saw and human forearm.
- 10 Sand is often sprinkled across icy roads. **Propose** an explanation for this.

## Analysing

- 11 A basketball falls towards the ground.
  - a **Describe** the contact and non-contact forces applied to it.
  - b **Analyse** which force is larger. Use a diagram to support your analysis.
- 12 **Explain** how you can lift heavy objects upwards while pulling downwards.

## Evaluating

- 13
  - a Go back through this chapter and **identify** three key words you have studied. **Define** and **illustrate** each of these ideas.
  - b **Evaluate** which of these affects you the most in your daily life.

## Creating

- 14 You want to raise a heavy box and place it on the top shelf (about 1.6 m off the ground). **Describe** two simple machines that you could use to do this. **Explain** how each of them would work.



WORKSPACE  
Chapter 9 review



ACTIVITY SHEET  
Chapter 9 checklist



REVIEW QUIZ  
Chapter 9





## Reflecting

- 15 **Explain** how forces affect a person with a physical disability.
- 16 **Describe** the relationship between force and effort.
- 17 **Outline** how your study of simple machines has affected the way you think about tools and equipment.
- 18 **Create** a mind map that shows connections between all the things you have learnt about forces.
- 19 **Outline** how your understanding of tools and equipment has been affected by your study of forces and machines.



# 10

## Heat energy

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### Heat energy: friend or foe?

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Heat can be our best friend. The heat from the Sun prevents the Earth and everything on it from freezing over. Its warmth allows plants to grow so we and other animals can have food. Humans have been using fire to keep warm for thousands of years. Heat from fuels powers engines in cars, buses, ships, aeroplanes and power stations. The Earth's weather systems – clouds, rain and wind – all depend on the Sun and its heat energy. However, this heat energy can also cause devastating droughts, floods and heat waves.

---

## Physical world – Stage 4

### Key knowledge

- Heat can move by conduction, convection or radiation.
- Energy can be transformed into other forms.
- Heat is usually produced when energy is transformed into other forms and this can mean a loss of energy.
- Minimising wasteful heat production will have benefits for our society.



#### ACTIVITY SHEET

CAT with rubric: Heat in our world

### CULMINATING ASSESSMENT TASK

## Heat in our world

Sam walks into science class with a cup of hot chocolate, but her science teacher tells her to leave it outside until the end of the class.

Design a controlled experiment to **identify** what sort of cup or container would keep Sam's drink hot for the longest time. **Explain** the processes by which heat is 'lost' from her hot chocolate.

**WORKSPACE**

What do you already know about heat as energy?

## What do you already know about heat as energy?

Show what you understand by the terms 'heat' and 'energy' by writing three different statements. In the first statement, use the word 'heat' in a way that describes what it is. In the second statement, describe the word 'energy'. In the third statement, describe how heat can be energy.

**Compare** your statements with those written by other members of your group. **Discuss** the similarities and the differences between what others have written.

# 10.1 Where is heat and what is it?

## Heat is everywhere

Heat is all around us, even on a freezing cold day. All things around us contain heat. When an object comes into contact with another object at lower **temperature**, heat will flow out of the hotter object and into the colder object until they eventually have the same temperature. What we feel is sometimes not accurate. When we jump into a pool on a hot summer's day, the water will feel cold because you are hot. The same pool temperature would feel warmer if you jumped in on a cold day.

We generally measure temperature using the Celsius scale (Figure 10.1). Theoretically, the coldest it is possible to be is about  $-273^{\circ}\text{C}$ , which is called **absolute zero**. This is more than  $180^{\circ}\text{C}$  colder than the lowest recorded temperature on Earth.



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### temperature

a relative measurement that helps describe how hot or cold an object is

### absolute zero

the lowest possible temperature, approximately  $-273^{\circ}\text{C}$

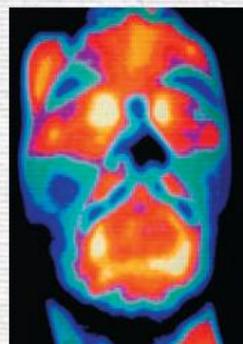
### Figure 10.1

The Celsius scale is used in most countries to measure temperature. This thermometer is used to measure body temperature.

**WOW!**

## Red faces

During outbreaks of the bird flu, people arriving at airports around Australia had heat images taken of their faces. If they had the flu, their faces would be hotter than normal, and this would show up on the image!



Getty Images/Williams & Metcalf

## Heat is a form of energy

Everything contains particles, which are always moving, vibrating, tumbling, rotating or sliding around. The energy of these moving particles is what we call heat. The particles in a hot object move faster than those in a colder object. As an object becomes hotter, its particles move around faster. Compare your classroom when you are doing a dance class or playing basketball to when you are sitting watching a movie. You might even feel the room getting warmer or colder depending on the amount of movement.

Sometimes adding more heat energy can cause an object to change its state from solid to liquid, or from liquid to gas. This is what happens to the water in a beaker being heated over a Bunsen burner. The water particles begin to move so fast that they fly apart from each other to form steam. Liquid water cannot be heated above 100°C. After this it becomes steam, and its particles move even faster. This is why steam can be much hotter than hot water and is able to cause very serious burns.



### WORKSPACE

Modelling the behaviour of particles as they get hotter

### ACTIVITY 10.1

## Modelling the behaviour of particles as they get hotter

### Aim

To model the behaviour of particles of water as they get hotter.

### Materials

- container or box with a transparent lid, about the size of a lunch box
- sufficient dry rice to half-fill the container
- video camera

### Method

- 1 Half-fill the container with rice.
- 2 Jiggle the container very slightly and observe the motion of the grains of rice.
- 3 Vibrate the container so that the grains of rice move around each other.
- 4 Shake the container more and more vigorously.

### Results

- 1 Record your results in a short video with a narration that clearly **describes** what you are modelling.

### Discussion

- 2 **Describe** how the motion of the rice grains changes as the container is shaken more vigorously.
- 3 **Explain** how the particles (rice grains) gain energy as the container is shaken more vigorously.
- 4 **Construct** an analogy that links this model with the particle model of matter.
- 5 **Describe** how you would show matter at absolute zero ( $-273^{\circ}\text{C}$ ) in your model.

### Extension

- 6 **Explain** why models can be useful when trying to explain a scientific concept.

## QUESTIONS 10.1

## What have you learnt?

## Remembering

- 1 **Define** the term 'absolute zero'.

## Understanding

- 2 **Distinguish** between how the particles in a hot object behave differently from the particles in a cold object, assuming you could see these particles.

## Applying

- 3 **Explain** why steam can cause worse burns than hot water.
- 4 **Outline** what happens to the particles in a cake mix when the cake is placed in a hot oven to cook.

## Creating

- 5 In a small group, **demonstrate** as a role play the behaviour of particles in cold or hot objects.

## WORKSPACE

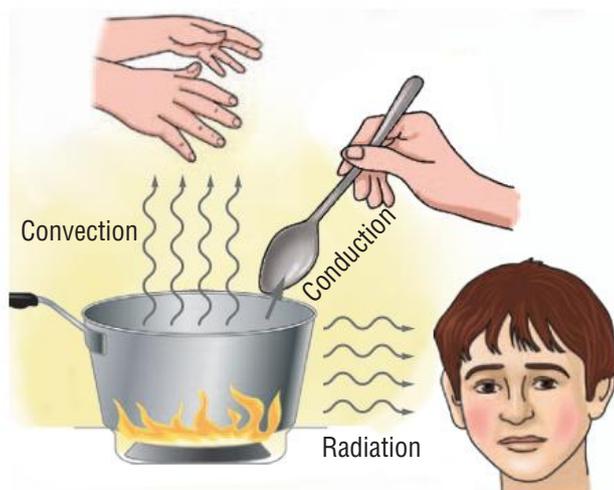
What have you learnt? 10.1



## 10.2 Heat transfer and cooling

Energy with that 'ouch!' factor when you touch a hot or cold surface is called heat or **thermal energy**. Heating and cooling are processes that transfer energy. To heat something, you transfer energy from a hotter object to a cooler object. To cool something, you transfer energy from a hotter object to a cooler object. The 'ouch!' factor has to do with energy transfers. If you touch something hot, it transfers heat energy to you. If you touch something cold, you transfer your heat energy to it.

Thermal energy can be transferred in three ways: **conduction**, **convection** and **radiation** (Figure 10.2). Heat energy is being transferred around us all the time. Baking a cake, sitting in the sunshine, eating an ice-cream on a hot day – these all involve the transfer of heat.

**thermal energy**

a form of energy; the same as heat energy

**conduction**

the transfer of heat energy through matter in direct contact

**convection**

the transfer of heat from one place to another by the movement of an area of warmer fluid (liquid or gas) into an area of cooler fluid

**radiation**

the transfer of heat energy from place to place without the need of a material

◀ **Figure 10.2**

Heat can be transferred by conduction, convection and radiation.

## Conduction

Conduction is the transfer of thermal energy within a solid object or between objects in direct contact. A good conductor can transfer heat easily; for example, the metal of a saucepan transfers heat from the stove to the food in the saucepan. Imagine everyone in your class standing in a tight group, all touching the person next to them. If someone pushes a student on the outside of the group, the movement would be transferred through the whole group. The students conduct the 'heat' being added from the outside. Non-metals, such as glass and ceramics, are usually poor conductors. If an object does not conduct heat well, it is called an **insulator**. The handle of a saucepan is designed as an insulator.

### insulator

an object that does not conduct energy well

There are many everyday examples of conduction. The heat from a stovetop passes through the base of a saucepan and into the food being cooked (Figure 10.3). A sandwich maker allows heat to conduct into the sandwich until it is cooked. Any situation where a hot solid is in contact with another solid will allow heat to conduct into the cooler object.

Figure 10.3 ▶

When a saucepan is heated by conduction, the insulated handle remains cool.



**WORKSPACE**  
Transferring heat energy by conduction

### EXPERIMENT 10.1

## Transferring heat energy by conduction

Possible risks	Safety precautions
The copper rod will get very hot.	Do not touch any part of the rod once you start heating it.
Bunsen burners and hot equipment can burn.	Follow the rules for using a Bunsen burner. When you have finished the experiment, turn off your Bunsen burner and leave everything to cool down while you finish writing up the experiment. Only pack up when the apparatus has cooled down.

### Planning

Before you do the experiment, read through all the steps. Write down what you think is the purpose of this experiment. Discuss it with your partner before you finalise your purpose statement.

Decide what data you will need to collect. How will you record your data? Will you need a data table? (Remember: Record data directly into a properly

## EXPERIMENT 10.1

constructed data table.) Discuss the data table with your partner before finalising it.

### Materials

- copper rod 20–30 cm long
- large test tube
- thermometer or temperature probe and data logger
- Bunsen burner and heat-proof mat
- retort stand, boss-head and clamps
- digital camera

### Method

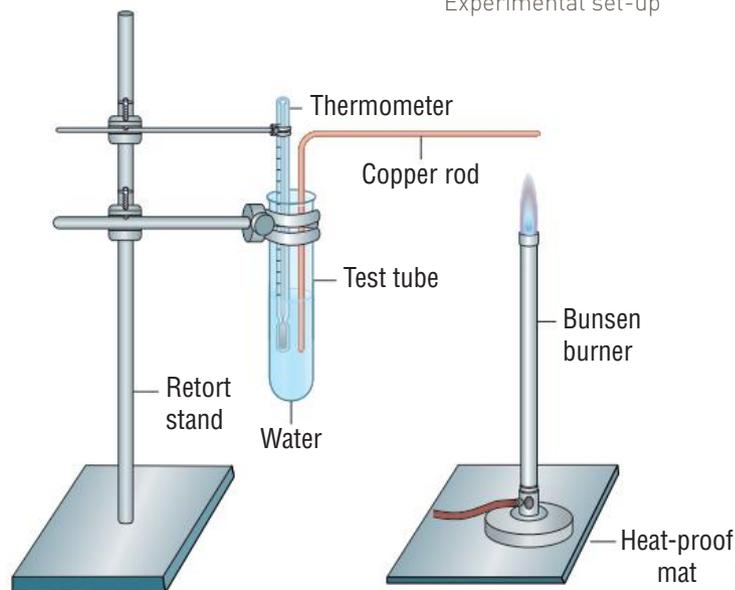
- 1 Hold the test tube in a clamp and two-thirds fill it with water.
- 2 Bend the copper rod at right angles and stand it in the test tube. Adjust it so that it sticks out to the side, away from the retort stand (see Figure 10.4).
- 3 Place the Bunsen burner on the heat-proof mat and slide it under the end of the copper rod that is sticking out of the test tube. You may need to adjust the height of the test tube so that the end of the rod is about 5–7 cm above the Bunsen burner.
- 4 Place the thermometer in the test tube. You may need to use a second clamp to hold the thermometer so that it does not rest on the bottom of the test tube. Wait until the temperature stays constant and record this initial temperature.
- 5 Light the Bunsen burner and use a blue flame to heat the tip of the copper rod that is not in the water.

### Results

- 1 In your data table, record the temperature of the water every minute for 10 minutes. Also record anything you see happening in the test tube.
- 2 Look for bubbles on the rod.

### Discussion

- 3 **Identify** the temperature of the water after 10 minutes. Calculate how much the temperature has changed.
- 4 **Describe** where the bubbles formed on the copper rod. What happened to the number of bubbles and the place where they formed?



▼ **Figure 10.4**  
Experimental set-up

## EXPERIMENT 10.1

**Describe** how the number of bubbles relates to the temperature. Insert one or more annotated digital images into your report.

- 5 **Explain** how you could tell whether the rod heated evenly or whether one part was hotter than another.
- 6 **Discuss** if you would expect this way of heating the water to be faster or slower than just putting the Bunsen burner under the test tube.
- 7 Record any problems you experienced in completing this experiment.  
**Describe** how you could improve on the way you carried out this experiment.

### Conclusion

- 8 Write your own conclusion about energy being transferred. Your conclusion should be consistent with the purpose you decided on at the beginning.

### Extension

- 9 Design an experiment to measure the effect of different masses of a substance on the amount of energy transferred. (Hint: You could heat copper or aluminium blocks and plunge them into a beaker of water.) If your teacher is satisfied that your proposal is safe and sensible, conduct this experiment and report your findings.



## Feeling temperature

Imagine it is a freezing cold morning and you are the first one out of bed. You walk into the bathroom and the tile floor feels really cold, so you quickly step onto the bath mat. Does the bath mat feel warm? Not really. But it does feel much warmer than the tiles. How can this be? After all, the tiles and the bath mat have both been in the same room long enough to reach the same temperature as the surrounding air. The difference lies in the rate at which energy is transferred from our warm feet to the cold surroundings. This depends on the material on which we are standing. The bath mat is slower to conduct the heat energy from our feet than the tiles are.



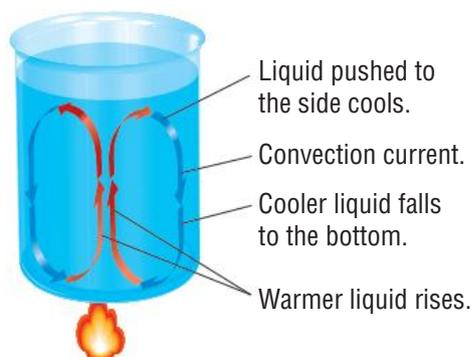
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## Convection

Convection is the transfer of thermal energy in **fluids**, either liquids or gases. Hotter fluids rise above cooler ones. For example, hot air in a room tends to rise to the ceiling and cold air falls to the floor. Convection currents in a liquid are illustrated in Figure 10.5.

Hot air from ducted heating systems comes through the ducts in the floor and rises. Cold air from cooling systems falls from ceiling height to the floor.

Examples of convection can be seen all around you. On a sunny day, warmer air begins to rise in a convection current. As it rises, the air cools and clouds form. Glider pilots can use these upward moving convection currents to keep their gliders in the air for many hours. Giant convection currents in the air can move very fast, causing turbulence for aircraft and producing thunderstorm clouds that reach as high as 20 km above the Earth's surface. The twinkling of stars at night is due to convection currents in the atmosphere and not because the stars themselves are actually twinkling. The light moving through the convection currents is distorted. The same sort of effect can be seen when you look through the air above a heater in winter.



### fluid

a term used to describe a liquid or gas because they can flow

◀ **Figure 10.5**

Convection current in a liquid

**ANIMATION**  
Convection currents



### EXPERIMENT 10.2

## Come in spinner

#### Possible risks

The candle flame and the air above it can get quite hot.

#### Safety precautions

Take care to keep your hands where they cannot be burned.

The air above a lighted candle moves upwards by convection. This can be used to make a spiral mobile or wind spinner move.

#### Aim

To make a convection current move a spiral mobile or wind spinner.

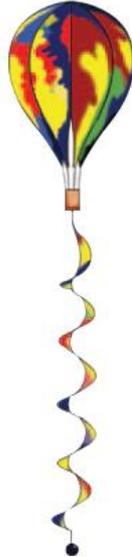
#### Materials

- aluminium foil
- scissors
- cotton thread
- candle
- video recording device

EXPERIMENT 10.2

Method

Figure 10.6 ▶  
Decorative wind spinner



- 1 Cut a 15cm square piece of aluminium foil. From this square, cut a spiral with at least four turns to it.
- 2 Attach 30cm of cotton thread to the centre of the spiral.
- 3 Let the spiral gently fall into the shape of a wind spinner.
- 4 Hold the spiral about 30cm above the lighted candle flame.
- 5 Use a video recorder to record what happens.
- 6 Repeat steps 1–5, holding the spiral at different heights above the flame and using:
  - a the same area of foil but different numbers of turns
  - b larger areas of foil with the same number of turns as for each of the 15 cm square trials.
- 7 In all trials, observe what happens for different heights above the flame.

WEB 2.0

Upload your video to the class wiki.

Results

Make a commentary to go with your video. Include comment on making the spirals, the area, the number of turns and the way each spiral spins when held at different heights above the flame.

## Radiation

If you stand close to a bonfire, you can feel the heat of the fire, but the air between you and the fire can still be cold. The heat from the fire is reaching you by radiation. You feel this heat because your body absorbs the radiant heat energy. In extreme cases, such as a bushfire, heat radiation can be deadly (Figure 10.7). The particles in your body can be made to vibrate faster and hence heat up by this heat radiation.



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Figure 10.7 ▶  
Heat radiation from a bushfire can be extremely dangerous.

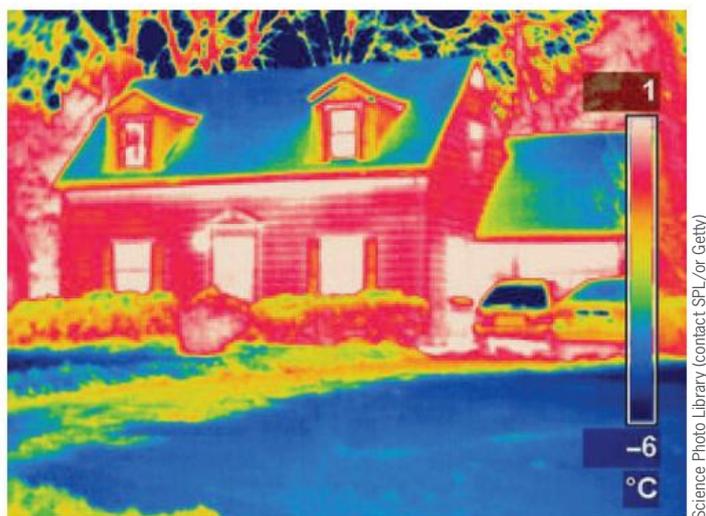
WOW!

## How cold is space?

Deep space is really, seriously cold! But it is not the coldest thing we know. The temperature of deep space is about  $-270^{\circ}\text{C}$ . On Earth scientists have produced temperatures  $3^{\circ}\text{C}$  lower than that. Radiation of heat energy from the Sun travels through the emptiness of space to reach us here on Earth. The heat from the Sun cannot get to us by conduction or by convection because there is no matter to transfer the energy. Without radiation of heat from the Sun, we would all be at a temperature of about  $-270^{\circ}\text{C}$ .

## Preventing transfer of heat energy

Heat energy is transferred from place to place by conduction, convection and radiation. There are various ways of preventing these transfers. Insulators stop heat transfer by conduction and radiation. The best way to stop heat transfer from rooms by convection is to stop heated liquids and gases, especially air, escaping through gaps. A thermograph uses an infrared camera to measure temperature. Figure 10.8 shows a thermogram of a heated house on a cold night. Heat loss by conduction is greatest when the temperature difference is greatest. The temperature scale is shown on the right of the image. You can see areas such as windows, where there are significant heat losses.



◀ **Figure 10.8**

Thermogram of a heated house on a cold night

## Insulation

Any material that prevents heat from being easily transferred by conduction or radiation is an insulator. Foam plastic makes a good drink insulator. Insulating materials are used in roofs and wall cavities. On a cold day they prevent heat transfer from a warm house to outside. On a hot day they prevent heat transfer from outside into a cool house. Air is a good insulator, so materials that trap air, such as blankets or fur, also make good insulators (Figure 10.9). Animals that require good insulation against cold conditions use feathers, fur, hair or a thick layer of blubber to protect themselves from losing too much body heat. For many months of the year, whales live in waters that are just above  $0^{\circ}\text{C}$ . At these temperatures a person would die within minutes from **hypothermia**.

VIDEO

Heat loss in an old house

ACTIVITY SHEET

Heat transfer

### hypothermia

a condition caused by loss of body heat; it can lead to death

**Figure 10.9** ▶

Thick fluffy material traps layers of air. This makes it good insulation for use above ceilings.



Getty Images/Dorling Kindersley



**WEBLINK**

Picking up a red hot space shuttle insulation tile with bare hands



**WORKSPACE**

What have you learnt? 10.2

NASA's space shuttles used a layer of insulating tiles to protect the spacecraft from the heat generated when re-entering Earth's atmosphere. Outside the space shuttle, temperatures could be nearly 2000°C – enough to melt metal. In 2003, several of these insulating tiles failed, causing the space shuttle *Columbia* to disintegrate, killing all seven astronauts on board.

**QUESTIONS 10.2**

**What have you learnt?**

**Remembering**

- 1 **Recall** the three ways that heat can be transferred.
- 2 **Identify** an example of each of the three ways that heat can be transferred.

**Understanding**

- 3 **Explain** how we know that the Earth receives heat from the Sun by radiation.

**Applying**

- 4 **Distinguish** between how heat is transferred by conduction and by convection.
- 5 **Describe** one other example where you have felt heat by radiation.

**Creating**

- 6 **Outline** how the heat eventually reaches your feet when you walk on hot sand at the beach on a summer's day.

**Reflecting**

- 7 Write a paragraph to **describe** how our world would be different if heat energy could never be transferred between objects.

# 10.3 Improving energy efficiency

## Reducing heat loss

Energy can be changed from one type into another. There are many different types of energy. When energy changes from one type into another, we say an **energy transformation** has taken place. Heat energy is often produced when energy transformations occur.

No energy transformation process is completely efficient. An efficient process is one in which the amount of energy we start with is close to the amount of useful energy we get afterwards. Often, energy is not completely transformed in the way that we intend. In many electrical devices energy is lost as heat. For example, heat loss occurs in light globes. While light globes are designed to produce light, incandescent light globes get very hot, wasting most of the energy they use. Fluorescent lights do not get as hot and waste much less energy.

The following equation shows how the efficiency of a product can be calculated as a percentage, or fraction out of 100:

$$\text{Efficiency (\%)} = \frac{\text{useful energy produced}}{\text{energy at the start}} \times \frac{100\%}{1}$$

## Energy transformations in cars

Car engines are about 20% efficient. This means that for every 100 units of energy put into a car to make it go, only about 20 units can be used. Almost all the rest is transformed into heat and transferred away from the engine. Energy is measured in joules (J). Efficiency can be calculated as follows.

Energy at the start = 100 J

Useful energy produced = 20 J

$$\begin{aligned} \text{Efficiency (\%)} &= \frac{\text{useful energy produced}}{\text{energy at the start}} \times \frac{100\%}{1} \\ &= \frac{20 \text{ J}}{100 \text{ J}} \times \frac{100\%}{1} = 20\% \end{aligned}$$

In the engine, the energy contained in the fuel is transformed into heat that helps drive the working parts of the engine. But a lot of that energy is wasted as the motor gets hot. Hot exhaust gases are released, and the surrounding car body and air get hot. Because there is so much waste heat, cars have cooling systems to make sure the engine does not melt. The radiator is part of a car's cooling system.

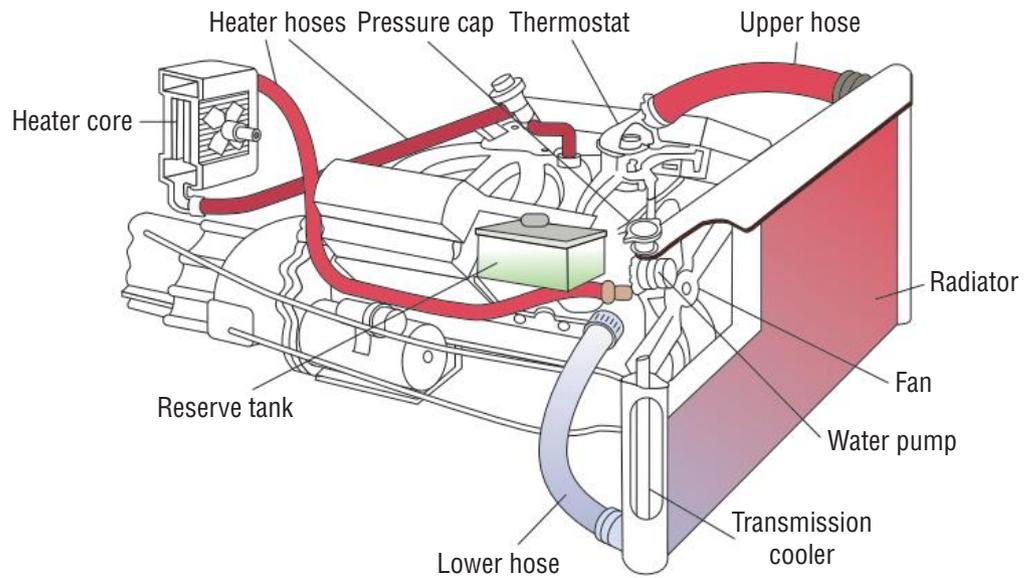
Some car brakes are air-cooled. When the brakes are applied, there is a lot of **friction** between the wheels and the brakes. Friction is caused by two surfaces rubbing together. Friction transforms the energy of moving objects into heat energy. If the heat is not transferred to the air, the brakes would get superhot and become soft. Then you could not stop properly! The brakes on racing cars can be seen glowing red-hot as the cars pass.

### energy transformation

when energy changes from one type into another

### friction

the force applied by one surface on another



**Figure 10.10** ▶

The radiator is part of a car engine's cooling system.

### cogeneration

the use of waste energy from one process in another process, especially waste heat in the generation of electrical energy

### climate change

a long-term change in the Earth's climate, which may be due to natural processes or human activity

## Cogeneration

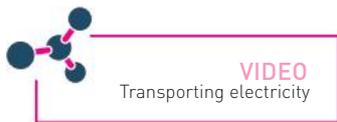
**Cogeneration** is when waste energy from one process is used in another process. As a result, less fuel needs to be burned to produce electricity. This results in fewer gases such as carbon dioxide being produced. Carbon dioxide is involved in **climate change**. Cogeneration is also called combined heat and power (CHP) generation.

Burning fuel in power plants usually produces more heat than electricity. Coal-fired power plants only convert about 30% of the energy available from the fuel into electricity. That means 70% of the available energy is converted mostly into heat rather than electricity. Heat is also produced when electricity is transferred along power lines to consumers such as households, but in this case it is lost to the air.

Waste heat in power plants can be used in two ways. It can be used directly to heat nearby buildings or produce steam for turbines in other industrial processes, including further electricity production. The buildings and industry have to be quite close to the power station because heat cannot be effectively transferred very far.

If smaller, gas-fired power stations are built closer to where the electricity is to be used, then you can still heat local buildings and the local swimming pool. The waste heat can be used to provide heat for steam turbines in other industries.

Some industrial processes also produce waste heat, which can be captured and used to produce electricity via steam turbines.



### ACTIVITY 10.2

## Case study: a cogeneration project

Cogeneration (CHP) is used in Australia, North America and Europe. Use advanced internet search features to find an example of a CHP project.

**1 Describe** the situation in which the CHP project has been established.

## ACTIVITY 10.2

- 2 **Explain** why this CHP project was set up.
- 3 **Describe** how this CHP system works.
- 4 **Identify** where and how the electricity is generated.
- 5 **Describe** how the heat is used.
- 6 **Identify** how much energy is saved by this CHP project.
- 7 **Identify** what annual reduction in climate-changing (greenhouse) gases the project achieves.
- 8 Draw a Sankey diagram for your CHP system to show heat loss and how the heat losses are used.

**Extension**

- 9 Find out about trigeneration. Is there a CHP or trigeneration project near you? If so, arrange a visit or write a report about it.

## QUESTIONS 10.3

**What have you learnt?****Remembering**

- 1 **Define** what is meant by the term 'cogeneration'.

**Understanding**

- 2 **Describe** 'conduction' as applied to thermal energy.
- 3 **Describe** two examples of where radiant thermal energy is applied.

**Applying**

- 4 **Discuss** the statement: 'Cooling is just the same process as heating.'
- 5 **Explain** why car brakes need to be cooled.
- 6 If 200J of energy was available at the start of a process, but only 40J of useful energy was produced, how efficient was the process?

**Analysing**

- 7 **Compare** and **contrast** conduction and convection.
- 8 **Describe** how you could reduce or re-use the heat energy that is wasted in a car engine.

**Creating**

- 9 Light globes with filaments transform electrical energy into light and heat. The heat radiates into the air. It is not very useful for our purpose (lighting a space), so it is effectively wasted.

## WORKSPACE

What have you learnt? 10.3



QUESTIONS 10.3

Fluorescent globes are more efficient than filament globes because they transform more of the input electrical energy into light energy, with very little waste heat.

Create a flowchart using the above information.

## 10.4 Reducing energy consumption



Getty Image/Universal Images Group

**Figure 10.11** ▶

Two men pump water from a mine in about 1550.

Have you ever dug a hole in the sand at the beach? At some depth, water fills up the bottom of the hole. This happens for all holes in the ground. Sooner or later, the hole fills up with water. This is what happens in mines. If you are a mining company, and you want to dig up resources such as coal, the water in the mine limits how deep you can go. Until the early 18th-century, water limited how deep a mine could be dug. The water was pumped out by person-power or horse-power (Figure 10.11).

Then the steam engine was invented, and things changed rapidly.

**combustion**

the burning of a fuel, usually with air



**WEBLINK**

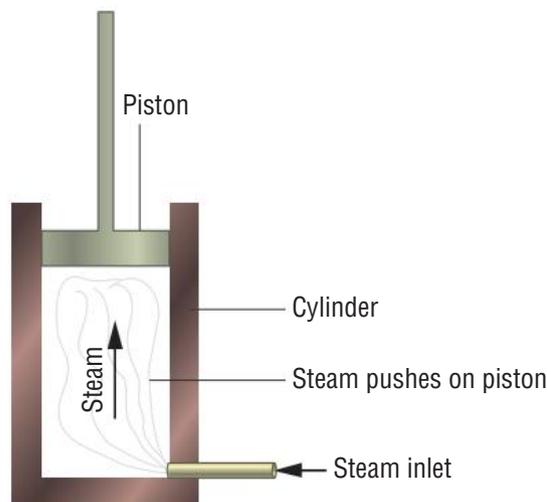
Newcomen engine

### External combustion engines

Steam engines were the first really effective engines. In a steam engine, fuel is burned to produce heat. The heat boils water and turns it to steam. The steam expands and pushes on a piston, which moves and makes wheels go around (Figure 10.12).

The burning, or **combustion**, of the fuel takes place outside the cylinder, so the steam engine is an *external* combustion engine.

From about 1700 onwards, steam was used for pumps in mines, engines in trains and ships and in manufacturing industries, such as the production of cotton cloth. The most successful of these engines was made by English blacksmith and inventor Thomas Newcomen (1663–1729). Newcomen's engine, more than any other steam engine, powered the beginnings of the industrial revolution in England, 50 years before any other country.



**Figure 10.12** ▶

In a steam engine, steam is sent into a cylinder, which expands and moves a piston up and down.

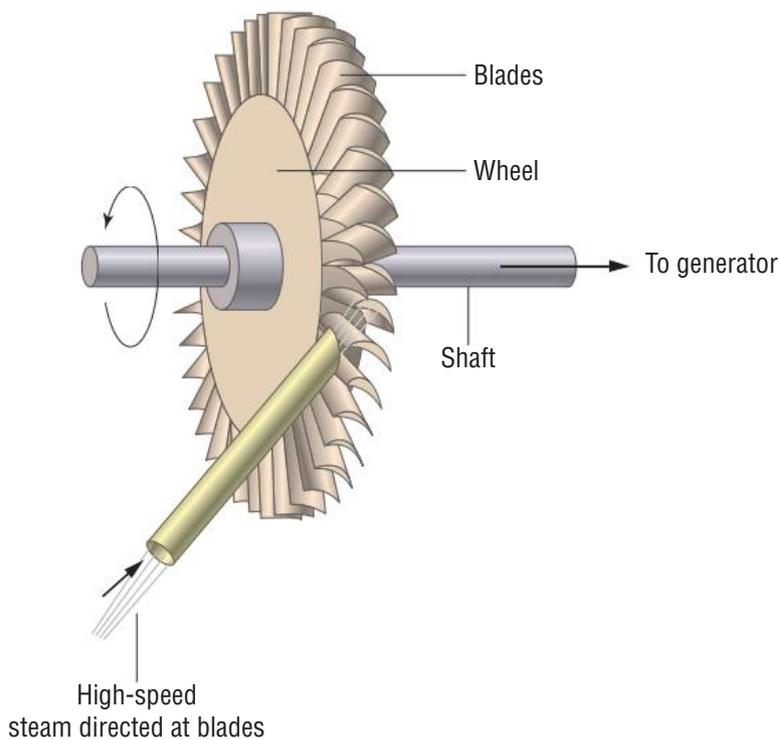
## Watt's steam engine

Between 1769 and 1782, Scottish engineer and inventor James Watt (1736–1819) improved on Newcomen's design to make a more efficient steam engine. You can see Watt's engine in Figure 10.13.

Newcomen's engine needed the cylinder to be alternately hot and cold. By investigating the scientific principles of the steam engine, Watt discovered several ways to make the engine more efficient. He invented a way to switch the steam input from the bottom to the top of the engine at just the right moments. This meant that the steam could work on the piston in both directions. The cylinder now needed to be hot all the time. He wrapped the working cylinder in a steam jacket, made from wood, which is an insulating material. Watt also made sure that no steam could escape through gaps in the machine. He sealed any gaps with grease and the heavy liquid metal mercury. This saved enormously on fuel costs. For every 1000 kg of coal used by Newcomen's engine, Watt's steam engine used only 250 kg.

## Steam turbines

Today's steam engines and their even more useful cousins, steam turbines, are much more efficient. In a steam turbine, high-speed steam is directed at fans connected to a wheel. The wheel spins rapidly. Steam turbines are used to generate electricity and have many industrial applications. A basic design of a steam turbine is shown in Figure 10.14.



**Figure 10.13**  
Watt's improved steam engine. The working steam cylinder and piston was seven and a half times more efficient than previous engines.

**WEBLINK**  
Watt's steam engine



**Figure 10.14**  
Basic design of a steam turbine



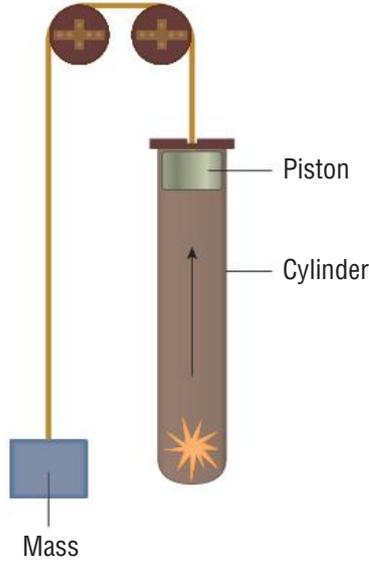
Corbis/Stefano Bianchetti

**Figure 10.15**

Christiaan Huygens invented the internal combustion engine.

## Internal combustion engines

The first 'explosion engine' was invented in 1666 by Dutch mathematician and physicist Christiaan Huygens (1629–95) (Figure 10.15).



**Figure 10.16**

Christiaan Huygens' explosion engine of 1666

You can see this first internal combustion engine in Figure 10.16. The explosion took place inside the cylinder, so this was the first *internal* combustion engine.

At the bottom of the cylinder, the gas was ignited. The gas expanded, forcing the piston up. The hot gases escaped from holes in the side, so then the piston was able to fall as a result of reduced air pressure and the pull of gravity. As the piston fell, it lifted an attached mass.

Modern engines found in cars, buses and trucks all use this same principle today. They can use petrol, diesel or gas as a fuel. While they are an improvement on the earlier types of engines, much of the energy they produce is wasted in the form of heat. Only a tiny fraction of the heat wasted is ever used, mainly in winter to heat the inside of the vehicle.

## Four-stroke engines

In 1876, German engineer Nikolaus Otto (1832–91) invented the four-stroke, internal combustion engine. This is still the basic design of engines used today. Figure 10.17 shows the four strokes of the Otto engine: intake, compression, combustion and exhaust.

At intake, the piston moves down, drawing fuel gas into the cylinder via the fuel intake valve. During compression, the piston moves up, compressing the fuel gas. Combustion occurs when the compressed gas is ignited by the spark plug, causing the gas to explode and the piston to move down. The piston then moves up, pushing the burnt gases out via the exhaust valve.

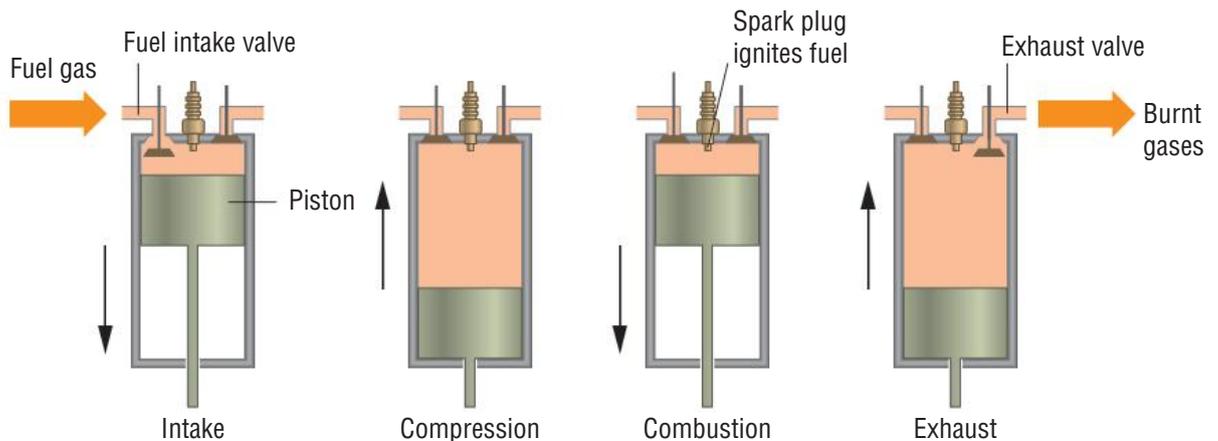


**WEBLINK**

Otto internal combustion engine

**Figure 10.17**

The four-stroke Otto internal combustion engine





Science Photo library/G. Brad Lewis

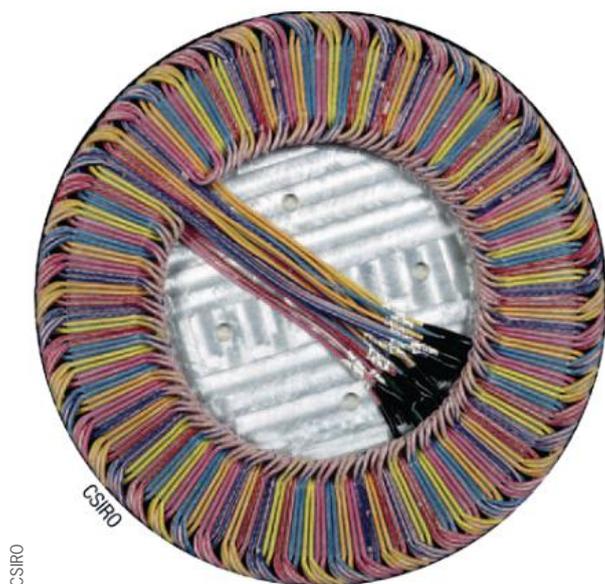


Science Photo Library/Laurent Douek/Look at Sciences

## Solar-powered engines

Combustion engines need to burn a fuel. The products of this burning are pollutants such as carbon dioxide, which contributes to climate change. Sulfur dioxide is also produced. It comes down with the rain as an acid and ruins plants and buildings. Combustion engines and the fuels they carry are quite heavy. A lot of the energy released during combustion is required just to get this mass to move. Solar energy is a non-polluting form of energy that can be used to power solar vehicles. Solar panels, which are lightweight compared with combustion engines, are located on the roofs of vehicles. They transform sunlight into electrical energy. You can see two solar-powered cars in Figure 10.18.

Scientists, engineers and technologists from the Commonwealth Scientific Industrial Research Organisation (CSIRO) have developed a solar engine that is so small and lightweight that it can be fitted into the wheel of a solar vehicle (see Figure 10.19). When the Sun shines on the vehicle's solar panel, the electrical energy produced drives the engine very efficiently. The car can travel at 110 km/h. There are no polluting gases to damage the environment.



CSIRO

▼ **Figure 10.18**  
Solar cars

**VIDEO**  
Electric cars



◀ **Figure 10.19**  
This lightweight solar engine fits inside the solar car's wheel.



**WEBLINK**

Solar car challenge

**EXPERIMENT 10.3**



North-East Local Learning and Employment Network (NELLEN) Inc.

**Open-ended investigation: solar car challenge**

How fast and how far can you make a remote-controlled solar car go? Your school could work with industry to build and race solar cars against other schools.

**Figure 10.20** ▶

Model cars on the grid at the Solar Car Challenge.



**WORKSPACE**

What have you learnt? 10.4

**QUESTIONS 10.4**

**What have you learnt?**

**Remembering**

- 1 **Identify** the one factor that, up until 1700, most limited the depth to which mines could be dug.
- 2 **Identify** the invention that made it possible for mines to be dug deeper.
- 3 **Identify** two types of engine that involve the burning of fuels.

**Understanding**

- 4 **Describe** the changes Otto made to Huygens' explosion engine.
- 5 **Identify** the two problems for solar cars that were solved with the invention of the CSIRO engine-in-a-wheel.

**Applying**

- 6 **Explain** why the use of grease and the liquid metal mercury improved the efficiency of James Watt's steam engine.
- 7 **Create** a flowchart that shows the four strokes of the Otto engine.

**Analysing**

- 8 **Explain** why the steam engine was so important for the industrial revolution.

**Reflecting**

- 9 **Propose** a persuasive argument explaining why it would or would not be possible to replace combustion engines with solar engines.
- 10 **Describe** the role of engineering skill in technological developments. In your answer refer to engines made by Newcomen and Watt.



## Chapter review

### Remembering

- 1 **Recall** the three forms of heat energy transfer and **define** each.
- 2 **Define** 'insulator'.
- 3 **Identify** three things you can do to prevent heat loss in your house.
- 4 **Identify** two environmental problems that solar cars can help to overcome.

### Understanding

- 5 **Distinguish** between a thermal conductor and a thermal insulator.
- 6 **Distinguish** between an insulator and insulation, using examples.
- 7 **Describe** how cogeneration can use heat that is otherwise wasted.
- 8 **Identify** similarities in the way in which we feel heat from the Sun and how we feel heat from a fire.
- 9 **Identify** the purpose of a car radiator.
- 10 **Describe** the purpose of solar panels on a solar car.

### Applying

- 11 **Describe** why it was important for our society to have developed more efficient engines.
- 12 Electricity power stations are often a long way from manufacturing plants. **Identify** two reasons why this might be a problem if you wanted to include a power station in a CHP system.
- 13 **Complete** a five whys analysis on the statement: 'Discuss why it is important to learn about early inventions and scientific discoveries.'
- 14 **Explain** why it is useful to have electricity generated close to where it is used.

### Analysing

- 15 One litre of petrol is capable of transforming 36 000 J of energy. However, in a car, only 12 000 J of this energy can be used to make the car go. **Calculate** the efficiency of this energy transformation.
- 16 Waste heat is a serious problem for all energy transformation processes. **Explain** how waste heat from one process is, or could be, used in another process.
- 17 **Describe** why it might be a good idea to locate a heated swimming pool in the same building as an ice-skating rink.
- 18 A Sankey diagram is a type of flowchart that uses arrows of various sizes to indicate the amount of energy moving through a system. **Create** a Sankey diagram to show the energy transformations in a steam engine.

**WORKSPACE**  
Chapter 10 review



**ACTIVITY SHEET**  
Chapter 10 checklist



**REVIEW QUIZ**  
Chapter 10





**WEB 2.0**

Share your wordle with the class by uploading it to the class wiki.

## Evaluating

- 19 **Discuss** ways in which an animal such as a snake or lizard is able to warm its body by heat transfer.
- 20 **Describe** the role of scientific and engineering skill in technological developments. Support your answer with reference to engines made by Huygens and Otto.
- 21 **Describe** why cogeneration is part of the fight to help reduce the rate of climate change.
- 22 **Identify** the factors that you think contribute to a successful scientific discovery or invention.

## Creating

- 23 **Construct** a wordle using all the glossary terms in this unit. Make the terms that you think are the most important larger than the other terms.

## Reflecting

- 24 **Discuss** the consequences for our world if the four-stroke engine had never been invented.
- 25 **Construct** a list of all the new things you have learnt about energy in this chapter.

# Appendix

## How to write a bibliography

Whenever we do research it is very important that we acknowledge where we get our information from. We can do this by including information about the source in a bibliography at the end of our report or assignment.

In a bibliography we list each source in alphabetical order by the author's surname. If there is no author, the title is used instead, ignoring the words 'A' and 'The'.

The information below shows the information needed, and the order in which it is listed, for different types of resources.

### Books

Author's surname followed by their initials

Year of publication in brackets

Title in italics or underlined

Edition (if relevant)

Publisher and the place of publication

(If the author is unknown, put the book title first.)

For example:

Denning, A. (1994) *The craft of woodcarving*, Sandstone: London.

### Encyclopaedia (printed)

Title of article in single quotation marks

Year of publication in brackets

Title of encyclopaedia in italics or underlined

Volume number

Publisher and place of publication

Page number(s)

For example:

'Minerals in Australia' (1996) *The World Book Encyclopedia*, Vol. 6, World Book: Sydney, p. 308.

### Encyclopaedia (online)

Title of article in single quotation marks

Year of publication

Title of encyclopaedia in italics or underlined

[Online]

<URL address>

[Date accessed in square brackets]

For example:

'Jupiter' (2006) *Encyclopaedia Britannica Online School Edition* [Online]  
<[www.school.eb.com.au/all/comptons/article-9345009](http://www.school.eb.com.au/all/comptons/article-9345009)> [accessed 10/11/2006].



## Journals, magazine or periodicals (printed)

Author's surname followed by their initials

Year of publication in brackets

Title of article in single quotation marks

Title of magazine or journal in italics or underlined

Volume number if relevant

Issue number if relevant

Page number(s)

For example:

Choi, C. (2003) 'Cleaner living', *Scientific American*, Vol. 289, No. 5, p. 32.

## Journals, magazines or periodicals (online)

Author's surname followed by their initials

Year of publication in brackets

Title of article in single quotation marks

Title of magazine or journal in italics or underlined

Volume number if relevant

Issue number if relevant

Page number(s)

[Online]

<URL address>

[Date accessed in square brackets]

For example:

Coghlan, A. (2003) 'GM crops can be worse for environment', *New Scientist.com* [Online]  
<[www.newscientist.com/hottopics/gm/gm.jsp?id=ns99994283](http://www.newscientist.com/hottopics/gm/gm.jsp?id=ns99994283)> [accessed 9/1/2013].

## Newspaper

Author's surname followed by their initials

Year of publication in brackets

Title of article in single quotation marks

Title of newspaper in italics or underlined

Date

Page number

For example:

Shaw, P. (1996) 'Mining shares drop', *The Age*, 31 August, p. 1.

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## Internet

Author's surname followed by their initials (if identified)

Last update (if identified) in brackets

Title of article in italics or underlined

Sponsor name

[Online]

<URL address>

[Date accessed in square brackets]

For example:

Ward, C. (2004) *Australian bush fires burn on*, Disaster Relief, [Online]

<<http://disasterrelief.org/Disasters/020104Austfires4>> [accessed 10/1/2013].

## Audiovisual materials

Title in italics or underlined

Year of publication in brackets

[Type of media in square brackets]

Publisher and place of publication

For example:

*Diet and Health* (1997) [videocassette] Classroom videos: Melbourne.

# Glossary

**absolute zero** the lowest possible temperature, approximately  $-273^{\circ}\text{C}$

**active agent** a chemical within a substance that does the work

**agar** a jelly-like substance, derived from seaweed, that provides a surface on which to grow micro-organisms

**Agnatha** a subclass of fish known as jawless fish

**alloy** a mixture of two or more metals (or sometimes a metal and a non-metal) that have been melted, combined and then allowed to harden

**Amphibia** a class of vertebrate that includes all amphibians

**anaerobic** without oxygen

**anaesthetic** a drug that causes complete or partial loss of feeling

**antiseptic** stops the growth of micro-organisms

**aphelion** the furthest position of Earth from the Sun

**aqueous** a solution is aqueous if water is the solvent

**asexually** without sex; involves only one parent

**asteroid** a naturally occurring, relatively small rock in space

**asthenosphere** the partly molten, upper part of the Earth's mantle

**astronomy** the scientific study of the universe, especially the movement, position, composition, size and behaviour of astronomical objects

**Aves** a class of vertebrate that includes all birds

**balanced forces** forces acting on the same object, whose combined effect is zero

**banded iron formation (BIF)** a type of sedimentary rock containing iron oxide layers

**beri-beri** a deficiency in vitamin B1, which results in inflammation of the nerves and heart failure

**binary fission** splitting of one cell into two equally sized daughter cells

**binomial nomenclature** a two-word naming system

**bipedal** able to walk on two feet

**boil** to change state from a liquid to a gas at a rapid rate

**breed** a group of organisms from the same species that possess a similar appearance, temperament and behaviour

**breed true** offspring that result from the breeding of two purebred parents and that possess characteristics that are true of that breed

**capsule** the outside covering of some bacteria

**cell** the basic structural unit of all living things

**cell membrane** a membrane enclosing the cytoplasm of the cell

**cell theory** the basic theory in modern cell biology – cells are the basic units of all living things

**cell wall** the outer structure of bacterial and plant cells

**cementation** when the space between sediments fills with another mineral, which hardens

**change of state** a change from one physical form (solid, liquid or gas) to another

**characteristic** a feature of an organism

**chemist** a scientist who studies the structure and behaviour of matter

**chloroplast** a chlorophyll-containing organelle found in plant cells, in which photosynthesis occurs

**Chondrichthyes** a subclass of fish known as cartilaginous fish

**chromatogram** a visual display of the results of chromatography

**chromatography** a process used to separate small amounts of mixtures

**class** a group of similar orders

**classification** the grouping of things according to how similar they are

**climate change** a long-term change in the Earth's climate, which may be due to natural processes or human activity

**cloaca** the cavity opening that releases excretory and reproductive products

**cogeneration** the use of waste energy from one process in another process, especially waste heat in the generation of electrical energy

**colloid** a mixture of two or more insoluble substances that remains evenly mixed, not settling over time

**combustion** the burning of a fuel, usually with air

**compaction** when pressure is applied to a sediment

**compressed** to be squashed to take up less space

**concentrated** one solution is more concentrated than another if there is more solute dissolved in the same amount of solvent

**condense** to change state from a gas to a liquid

**condense** to change from a gas to a liquid by lowering the temperature of the gas to below its boiling point

**conduction** the movement of heat energy through matter

**contact force** a force applied by one object on another object when they are touching each other

**contract** to decrease in size

**control** a scientific set-up that does not include the independent variable to be tested; used to provide baseline data

**convection** the transfer of heat from one place to another by the movement of an area of warmer fluid into an area of cooler fluid

**convection current** the movement of molecules in a gas or liquid, usually from an area of high temperature to an area of lower temperature

**conventions** the rules by which things are usually done

**crossbreed** offspring resulting from a mating between two different breeds

**crystal** substance in which the particles are arranged in a regular, repeating pattern

**crystallisation** the process by which solid crystals form from a saturated solution, as a result of decreasing the temperature of the solution or slowly evaporating the solvent

**cytoplasm** a jelly-like substance in which organelles are located within a cell

**cytoplasmic streaming** the movement of the contents of a living cell

**data** information that is gathered from surveys and experiments and used for making calculations or drawing conclusions

**daughter cells** two cells produced as a result of cell division

**day** the time taken for a planet to spin on its axis (on Earth, this is 24 hours)

**decanting** a process of separating a solid-‘liquid’ suspension that has been allowed to settle; pouring the liquid slowly down a glass rod

**decomposer** an organism that feeds on and breaks down dead organisms

**defecatory** removal of faeces

**density** the amount of mass (kg or g) in a unit of volume (cm<sup>3</sup>)

**dependent variable** the factor that changes as a result of changes in the independent variable; the factor that is measured or counted

**deposition** the change of state from a gas directly to a solid without going through a liquid phase

**deposition** when sediment settles on top of a layer of material

**desalination** an industrial process of removing salt from sea water

**dichotomous key** a tool that is used to organise or classify information; at each branch, there is a two-part statement

**diffusion** the movement of gas or liquid particles from a region of high concentration to a region of low concentration

**dilute** one solution is more dilute than another if there is less solute dissolved in the same amount of solvent

**dissolve** when a substance is mixed with another and the particles from both substances spread out evenly until they are too small to see

**distillate** the product obtained by condensing vapours given off during distillation

**distillation** a process that separates solutions on the basis of their different boiling points

**division** a group of similar plant classes (used instead of phylum)

**djikay** Aboriginal name for small birds

**DNA** deoxyribonucleic acid, the genetic material found inside cells

**dormant** describes a volcano that has not erupted for a long period of time

**driven gear** a gear that is affected by the rotation of the driving gear

**driving gear** a gear that is moved by an external force

**Earth co-orbital asteroid (ECA)** a near-Earth asteroid that revolves around the Sun with a period similar to Earth’s year

**Earth’s equatorial plane** an imaginary flat surface sliced through the Earth’s equator, inclined at an angle of 23.5° to the Sun’s equatorial plane

**Earth’s tilt** the angle that the Earth’s equatorial plane makes with the Sun’s equatorial plane

**ectothermic** when an organism’s body temperature changes according to the environment

**effort force** a force applied to a machine to move a load

**electron** a negatively charged particle

**electrostatic force** a force applied by an electrically charged object on another electrically charged object

**ellipse** oval shape

**endoskeleton** an internal skeletal system

**endothermic** can regulate body temperature by generating its own heat

**energy** the ability to do work, such as moving or talking

**entomology** the scientific study of insects

**epicycle** a circle that rolls around another circle; used to describe planetary motion from an Earth perspective

**equinox** two days a year when there are 12 hours of daylight (equal lengths of day and night); in the southern hemisphere these are 21 March (autumn equinox) and 23 September (spring equinox)

**erosion** the displacement of soil, mud and rock by the action of wind, water, ice or gravity

**ethical** conforming to society's standard of right and wrong

**eukaryote** a living cell that contains a nucleus

**evaporate** to change state from a liquid to a gas at a slow rate

**exoskeleton** an external skeletal system

**expand** to increase in size

**extinct** describes a volcano that is unlikely to erupt again

**extrusive** igneous rock that has cooled above the ground

**eyepiece** a lens through which the eye views the image formed by the objective lens

**fair test** a scientific investigation in which there is an independent variable and one or more dependent variables; all other variables are held constant (controlled)

**family** a group of similar genera

**fertile** able to produce offspring

**filter** a device containing small holes or pores that allow some substances to pass through but not others; used to separate a suspension

**filter paper** a special type of paper used for filtering, available in a range of pore sizes

**filtrate** the substance that passes through the filter when filtering a suspension

**filtration** a separation process used to separate suspensions by using a filter

**Fish** a class of vertebrates that includes all fish

**flagellum** a tail-like structure used for movement

**flow** able to be poured

**fluids** a term used to describe liquids and gases because they can flow

**force** any influence that causes a change in the speed, direction or shape of an object

**fossil** the preserved remains or traces of previous life on Earth

**fractional distillation** a type of distillation used to separate a mixture when the boiling points of its components are very close to one another

**freeze** to change state from a liquid to a solid

**friction** the force applied by one surface on another

**fulcrum (pivot)** the point around which a lever rotates

**full moon** the phase of the Moon when all of the illuminated side is visible from Earth

**gas** a state of matter in which the particles are very far apart and move with lots of energy

**gear ratio** the ratio of number of teeth on the driven gear to the number of teeth on the driving gear

**gear, gear wheel** a toothed wheel

**genus** a group of similar species

**geothermal** heat generated within the Earth

**glucose** a simple sugar that is an important energy source for living organisms

**gravity, gravitational force** a force applied by one mass on another mass; often associated with the gravitational force applied by the Earth's mass on the mass of objects on or near the Earth

**heating flame** the blue flame of the Bunsen burner

**heterotroph** an organism that cannot make its own food but must eat other organisms to obtain nutrients

**hybrid** offspring resulting from a mating between two different species

**hypothermia** a condition caused by loss of body heat; it can lead to death

**hypothesis** an educated guess or prediction that can be tested in a scientific way, usually written in the form: 'If . . . then . . .'

**igneous** rocks formed from molten rock below the surface of the Earth

**impure substance (mixture)** a substance made up of two or more different types of particles, physically combined

**inclined plane** a sloping ramp

**independent variable** the factor that you choose to vary in your investigation

**inference** an explanation based on observations

**insoluble** does not dissolve in another substance

**insulator** an object that does not conduct heat (or sound) well

**intrusive** igneous rock that has cooled beneath the ground

**invertebrate** an organism lacking a spinal column or vertebrae

**isotope** one of several forms of a chemical element

**kindal kindal** Aboriginal name for macadamia nut

**kingdom** a group of similar phyla or divisions

**lava** hot molten rock that is expelled during a volcanic eruption

**lever** a solid plank or bar that rotates around a point

**lidjilidji** Aboriginal name for finches

**light microscope** a microscope that uses light to view the specimen

**light-minute** the distance light travels in 1 minute

**liquid** a state of matter in which the particles are close together but move freely past one another

**lithosphere** the solid part of the Earth's crust

**load (load force)** a force applied by an object, which must be overcome for the object to be moved by a machine

**machine** a tool that makes a task easier to do

**magma** molten rock found beneath the surface of the Earth

**magnet** an object that produces a magnetic field

**magnetic field** a region where a magnetic force acts

**magnetic force** a force applied by a magnet on another magnet or a magnetic material

**magnetic material** a material that is not a magnet but is affected by a magnetic force

**Mammalia** a class of vertebrates that includes all mammals

**marsupials** a subclass of mammals

**mass** the amount of matter that makes up a substance

**matter** anything that takes up space and has mass

**mean** average; the sum of all of the values divided by the number of values

**melt (liquefy)** to change state from a solid (or a gas) to a liquid

**meniscus** the curved part on the surface of a liquid in a container

**metamorphic** rocks that are changing

**metamorphosis** the change of form during development from larva to adult, such as from tadpole to frog

**micro-organism** a living thing too small to see with the naked eye; for example, bacteria

**microbe** a micro-organism

**micrometre ( $\mu\text{m}$ )** one-thousandth of a millimetre, or one millionth of a metre

**mineral** chemical elements or compounds with regular chemical compositions and crystal structures found in rocks

**mitochondria** organelles in which energy is released for use by the cell

**mitosis** a process in cell division that forms two nuclei, so the cell can divide to make two identical daughter cells

**model** a simplification or representation of what we think is happening

**monotremes** a subclass of mammals

**mould** a fossil that consists of the space left by a decayed organism

**multicellular** consisting of many cells

**nanometre (nm)** one-billionth of a metre

**natural** something that is grown or occurs in nature

**new moon** the phase of the Moon when the side of the Moon that is facing Earth is not lit by the Sun and hence is not visible from Earth

**non-contact force** a force applied by one object on another object when they are not touching each other

**nucleus** the part of the cell containing genetic material and bound by the nuclear membrane

**objective lens** a lens that focuses light from the specimen and directs it into the eyepiece

**observation** a statement of what you can see, hear, smell, feel or taste

**opaque** light cannot pass through

**operculum** a flexible protective covering over the gills of most bony fish

**order** a group of similar families

**ore** a rock containing valuable minerals

**organelle** a specialised part of a cell that has a specific function

**Osteichthyes** a subclass of fish known as bony fish

**oxide** a compound formed when an element reacts with oxygen

**palaeontology** the scientific study of fossils

**parent cell** the original cell that divides to form two cells

**particle** a tiny unit of matter; a building block of matter

**particle theory of matter** a set of statements that explains the behaviour of particles in solids, liquids and gases

**pathogens** organisms that cause disease

**perihelion** the closest position of Earth to the Sun

**philosopher** a person who studies philosophy; a truth-seeker, thinker, academic or theorist

**photosynthesis** a process performed by green plants, which uses the Sun's energy to make glucose from carbon dioxide and water

**phylum** a group of similar animal classes

**physical change** a change that does not involve a chemical reaction; the form of the substance changes but the kind of substance remains the same; no new substances are formed

**physical property** a physical feature of a substance, such as colour, hardness, state at room temperature, degree of solubility, melting point, boiling point

**physicist** a scientist who specialises in physics, the study of the physical world

**pili** hair-like extensions found on some bacteria and used for reproduction

**placenta** a specialised sac that nourishes the developing foetus in placental mammals

**placental mammals** the largest subclass of mammals

**plateau** an area of highland, usually consisting of relatively flat open country

**prediction** a statement of what might happen

**prokaryotic** without a nucleus

**properties** the features of a substance

**proportion** the amount of one part in relation to the whole or to other parts; ratio

**pulley** a wheel with a groove around the edge

**pure substance** a substance made up of only one type of particle

**qualitative data** information that is not numerical, so cannot be measured

**quantitative data** numerical information that is counted or measured and expressed as numbers

**radiation** the transfer of heat (thermal) energy from place to place without the need of a material

**radioactive decay** the break down of unstable atomic nuclei to emit energy

**raw data** all the data that is collected during an investigation

**record** write down

**refute** to show to be false; to disprove

**reliability** when the results collected in an experiment are very similar or the same after a number of repeat trials

**remediation** the restoration of something to its original state

**Reptilia** a class of vertebrates that includes all reptiles

**residue** the substance that does not pass through the filter paper when filtering a suspension

**resolution** the ability to clearly distinguish between two separate but adjacent structures

**respiration** a process that releases energy from glucose for use in a cell

**respire** the cellular process where oxygen and glucose react to produce carbon dioxide and water vapour; energy is released in the reaction

**rock cycle** the cycle of pressure, heat, cooling and weathering that rocks move through

**rock** a collection of one or more minerals into a solid structure

**rotation** the spin of a planet on its axis

**safety flame** the orange flame of the Bunsen burner

**satellite** an object that orbits the Earth

**saturated solution** a solution in which no more solute will dissolve at the current temperature

**scanning electron microscope** a microscope in which the specimen is examined using a moving electron beam from which the electrons are reflected to form a magnified, three-dimensional image

**science discipline** a specialist area of study in science, such as chemistry, physics and biology

**scientific method** a set of rules that enables scientists to plan and conduct experiments in a consistent and repeatable way

**scientific name** the Latin name given to classify each organism

**sediment** the insoluble substance that settles at the bottom of the container during sedimentation

**sedimentary** rocks formed by layers of sediment

**sedimentation** a process in which denser insoluble particles in a mixture fall to the bottom of a container

**separating funnel** a piece of equipment used to separate a suspension of two insoluble liquids in the laboratory

**sieving (straining)** a process of separation used mainly to separate larger solid particles from mixtures; the larger particles are too big to pass through the holes in the sieves (or strainers)

**simple machine** one of five basic types of machine from which all other machines are made

**solar system** a star (such as our Sun) and all the planets and objects orbiting it

**solar year** the time taken for a planet to make one complete orbit around the Sun (for Earth, this is about 365.25 days)

**solid** a state of matter in which the particles vibrate in fixed positions close to each other

**solstice** the longest or shortest day of the year, when the Sun reaches its highest or lowest local solar zenith for the year; in the southern hemisphere these are 22 December (summer solstice) and 21 June (winter solstice)

**soluble** dissolves in another substance

**solute** in a solution, the substance that dissolves in another substance

**solution** a mixture created when a solute dissolves in a solvent

**solvent** in a solution, the substance that dissolves another substance

**species** a group of organisms that are capable of interbreeding and producing fertile offspring

**specimen** a sample to be examined or observed

**states of matter** solid, liquid and gas

**stem cells** cells that can divide by mitosis to become a variety of cells

**sterile** unable to produce offspring

**sterilise** to disinfect by destroying micro-organisms

**sublime** to change state directly from a solid to a gas without going through a liquid phase

**Sun's equatorial plane** an imaginary flat surface sliced through the Sun's equator, which spreads out across the solar system

**suspension** a mixture of at least one insoluble solid in a liquid or solution, where the insoluble substance settles to the bottom of the container over time

**synthetic** made in a laboratory, not occurring in nature

**taxonomy** the science of classification and naming living things

**temperature** a relative measurement that helps describe how hot or cold an object is

**theory** an explanation of things that happen around us from a set of related observations

**thermal energy** a form of energy; the same as heat energy

**tide** the change of sea level during the day at a particular location

**total force (net force)** the sum of all the forces acting on an object

**translucent** cannot be seen through, but light can pass through

**transmission electron microscope** a microscope that passes beams of electrons rather than light through the specimen to view it at very high magnification

**transparent** clear, see through; allowing light to pass through a material

**unbalanced forces** forces acting on the same object, whose combined effect is to speed up the object, slow it down or to change its direction

**unicellular** consisting of a single cell

**universal** across the whole world

**unsaturated solution** a solution that is able to dissolve more solute at the current temperature

**uterus** an organ in female placental animals in which the embryo develops

**vacuole** a membrane-bound sac found inside a cell

**valid experiment** when the results collected allow you to achieve the aim

**vaporise** to change state from a solid or a liquid to a gas (evaporate, boil or sublime)

**vapour** a gas

**variable** a factor that could influence the result of an investigation

**variable held constant** a factor that needs to be kept the same throughout a scientific investigation so that it does not influence the results

**vertebrate** an organism with a spinal column or vertebrae

**volcano** an opening in the Earth's crust that allows magma and gases to escape to the surface

**volume** the amount of space something occupies

**warm-blooded** an organism that generates its own heat to regulate its body temperature

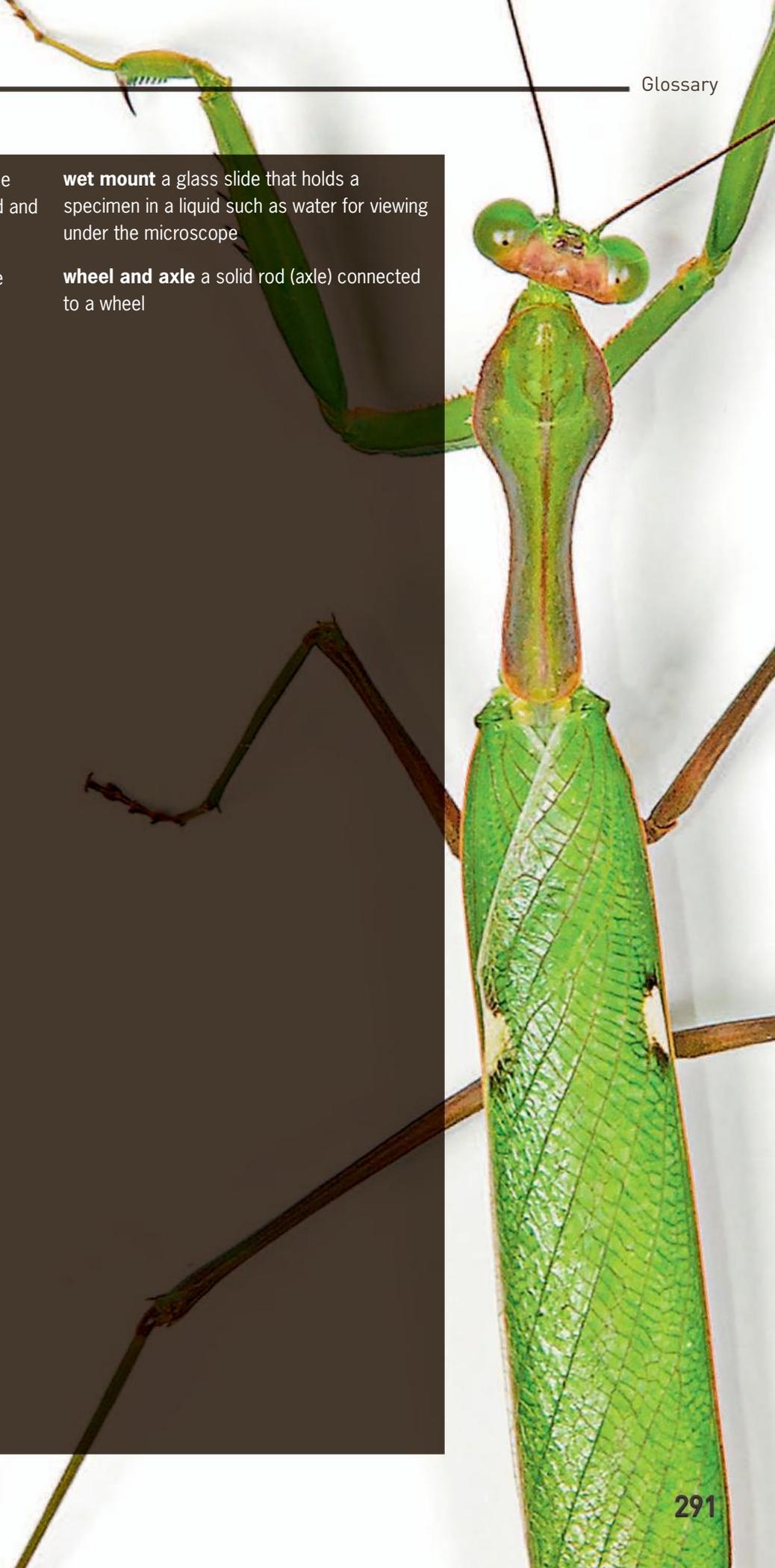
**warrakan** Aboriginal name for bird/large birds

**weathering** the break down of rock by the action of water, growing plants, heat, cold and ice

**weight** the measurement of the force due to gravity acting on a mass, measured in newtons (N)

**wet mount** a glass slide that holds a specimen in a liquid such as water for viewing under the microscope

**wheel and axle** a solid rod (axle) connected to a wheel



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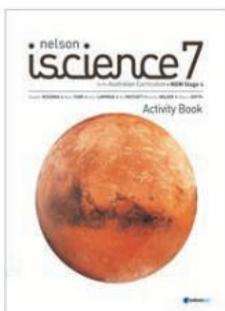


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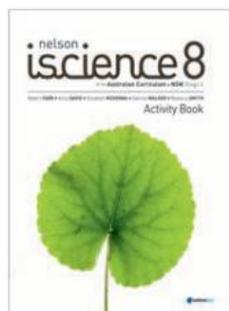


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