OXFORD SCIENCE 8

AUSTRALIAN CURRICULUM

* A SPELEOLOGIST (SCIENTIST WHO STUDIES CAVES) PEERS DOWN INTO A GIANT CLOUD-FILLED VOID TO THE FLOOR, MORE THAN 240 M BELOW. CLOUD LADDER HALL IS ONE OF THE LARGEST CAVE CHAMBERS IN THE WORLD. CHONGQING, CHINA

HELEN SILVESTER

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HELEN SILVESTER

OXFORD UNIVERSITY PRESS
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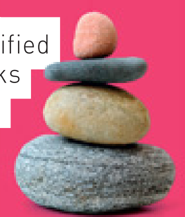
SCIENCE 8

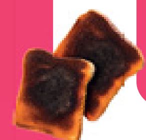
Science toolkit
Scientists work collaboratively and individually, in the laboratory and in the field, to plan and conduct investigations safely and ethically. Scientists make predictions, control variables and record their results accurately. Scientists communicate their results using scientific language.

Rocks and minerals
Rocks have useful properties and can be classified as sedimentary, igneous or metamorphic. Rocks contain minerals and are formed by processes within the Earth over different timescales.

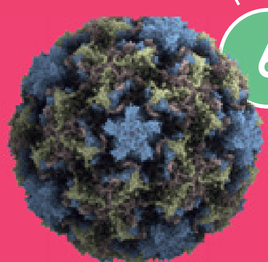


Energy
Energy appears in different forms and can be transferred and transformed to cause movement and change.

Chemical elements
The properties of matter can be explained using the particle model.



Physical and chemical change
Physical change is a change in the shape or appearance of a substance. Chemical change involves substances reacting to form new substances.

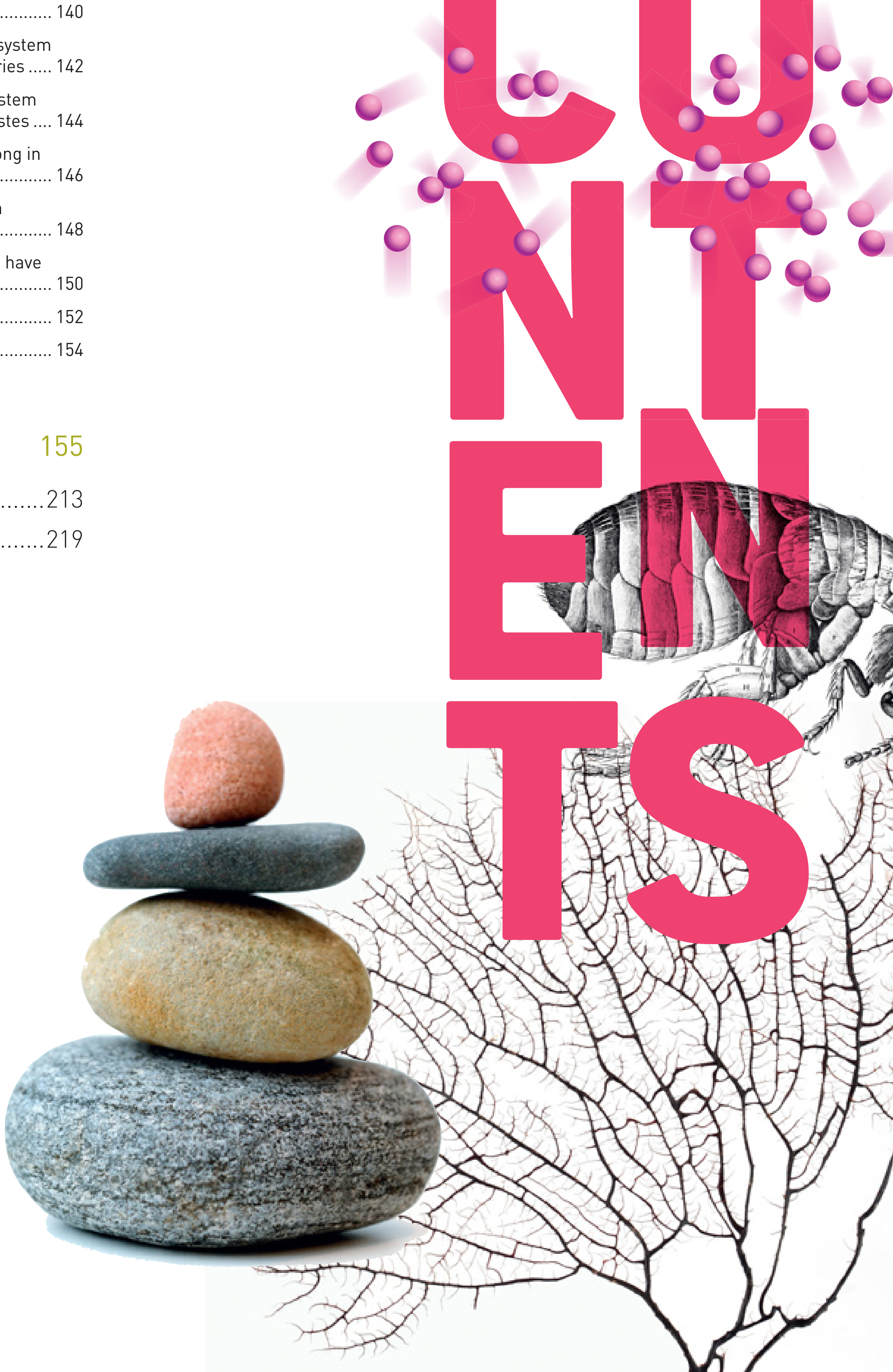


Cells
All living things are made of cells. Cells have specialised structures and functions.

Surviving
Humans, and other multi-cellular organisms, survive using systems of organs that carry out specialised functions.

Reproducing
Humans, and other multi-cellular organisms, reproduce sexually or asexually using systems of organs that carry out specialised functions.

CONTENTS



Using Oxford Science

Oxford Science is a series developed to meet the requirements of the Australian Curriculum: Science across Years 7 to 10. Taking a concept development approach, each double-page spread of Oxford Science represents **one concept** and **one lesson**.

What if?

Student-directed inquiry is encouraged throughout this series using a simple questioning technique. As the series progresses, students discover that their own *What if* questions are actually testable '*if and then*' hypotheses. For example, 'What if *the bubble is touched with a finger*' becomes 'If *the bubble is touched with a finger*, then *it will pop*'.

Concept development

Students are given access to the chapter concepts at the start of every chapter. Each double-page spread of this series represents **one concept**. Students explore concepts one-by-one encouraging incremental learning and, by the end of the chapter, complete understanding.

The unit heading introduces the concept.

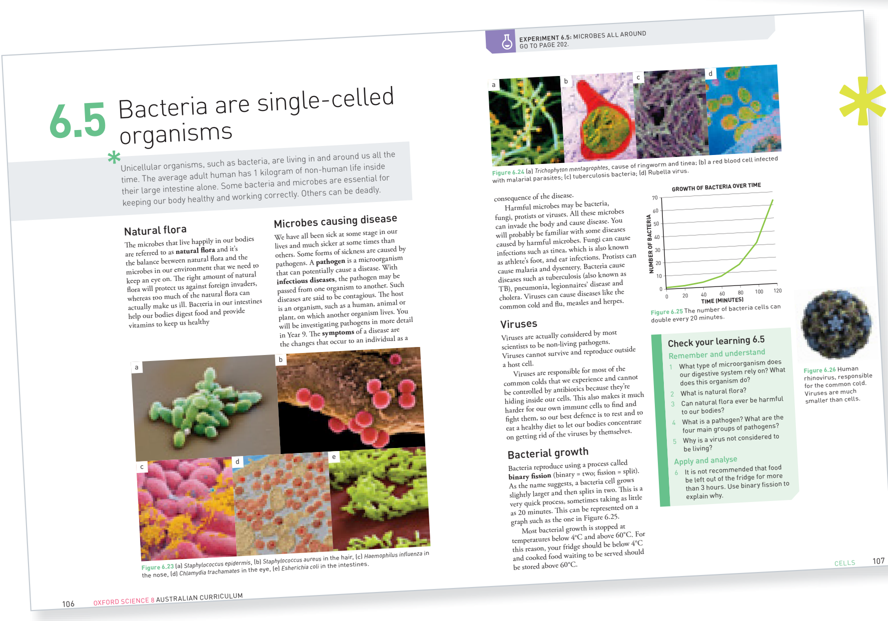
Each unit begins with a short summary of the concept.

Body text elaborates on the concept in clear and accessible language.

Every spread is linked to one or more experiment, challenge or skills task as a practical application of the concept.

Diagrams and photos are used to illustrate the concept and engage students.

Every double-page spread ends with **Check your learning** questions, allowing students to consolidate their understanding. Questions are graded according to Bloom's Taxonomy – catering for a range of abilities and learning styles.



Accessibility and engagement

Oxford Science has been engineered to be accessible to all science students. We believe that science students are served best when they are free to focus on learning the knowledge and skills of science in simple accessible language, crafted into short sentences. Students will be engaged by the inclusion of stunning photography throughout.

Science as a human endeavour

Concepts are linked to real-world applications in the highly engaging **Science as a human endeavour** spreads. The **Extend your understanding** questions on this spread are designed to be used flexibly as either homework tasks or as an extended project.

Experiments

Uniquely, experiments are organised at the end of the book in an extended experiments chapter, rather than being confined to each double-page spread. There is a link on most double-page spreads to an experiment, challenge or inquiry task to ensure that practical activites remain aligned to the content.

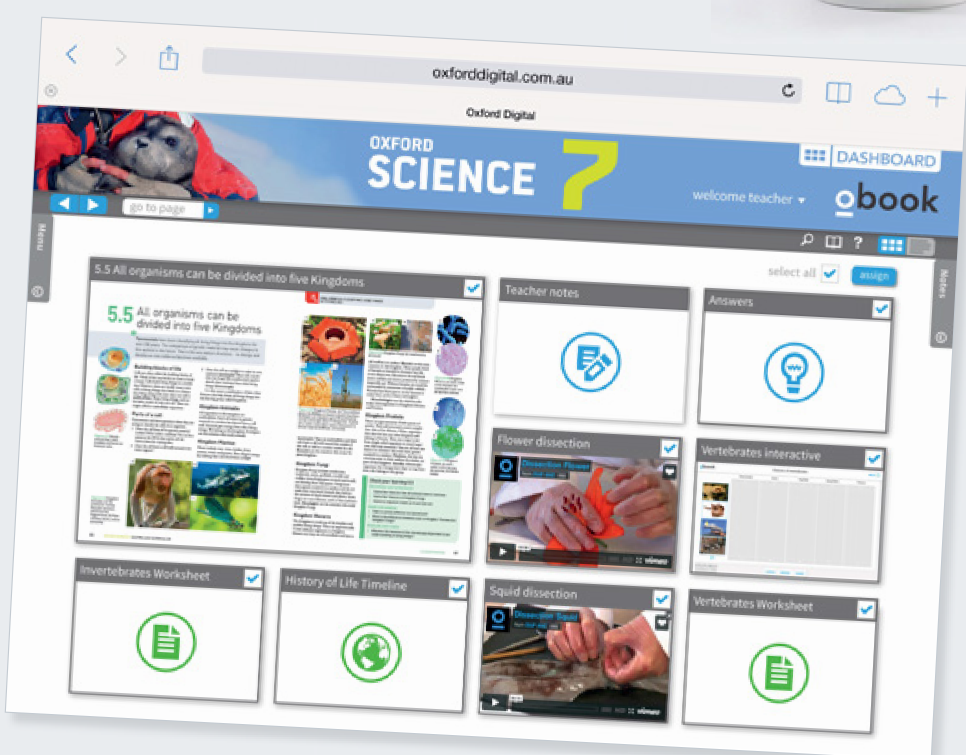
Integrated teaching and learning support

obook assess

obook assess provides an interactive electronic version of the student book in an easy-to-read format. It features multimedia links, interactive learning objects, videos, note-taking, highlighting and bookmarking tools, and live question blocks. **obook** is compatible with laptops, iPads, tablets and IWBs, and also offers page view (in flipbook format) that can be used offline. **assess** provides 24/7 online assessment designed to support student progression and understanding.

DASHBOARD

Oxford Science is supported by teaching strategies, lesson ideas, planning tips, assessment advice and answers to all activities. **obook assess** allows teachers to manage their classes by assigning work, tracking progress and planning assessment. Teacher Dashboard is your online lesson control centre, which allows you to instantly preview or assign related teacher resources to deliver incredibly engaging digital learning experiences. Students can also toggle from their obook to the Dashboard to interact with student resources for each topic.



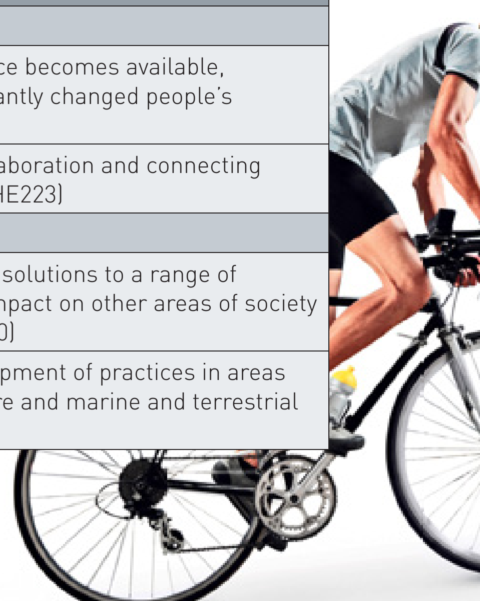
Australian Curriculum: Science 8 scope and sequence

SCIENCE 8 LEVEL DESCRIPTION (ABBREVIATED)

The Science Inquiry Skills and Science as a Human Endeavour strands are described across a two-year band. In their planning, schools and teachers refer to the expectations outlined in the Achievement Standard and also to the content of the Science Understanding strand for the relevant year level to ensure that these two strands are addressed over the two-year period.
The three strands of the curriculum are interrelated and their content is taught in an integrated way. The Science as a Human Endeavour strand can provide relevant contexts in which science can be taught. The order and detail in which the content descriptions are organised into teaching/learning programs are decisions to be made by the teacher. In Year 8, students are introduced to cells as microscopic structures that explain macroscopic properties of living systems. They link form and function at a cellular level and explore the organisation of body systems in terms of flows of matter between interdependent organs. Similarly, they explore changes in matter at a particle level, and distinguish between chemical and physical change. They begin to classify different forms of energy, and describe the role of energy in causing change in systems, including the role of heat and kinetic energy in the rock cycle. Students use experimentation to isolate relationships between components in systems and explain these relationships through increasingly complex representations. They make predictions and propose explanations, drawing on evidence to support their views.

SCIENCE CONTENT DESCRIPTIONS	
Chapter 6	Cells are the basic units of living things and have specialised structures and functions (ACSSU149)
Chapter 7, Chapter 8	Multi-cellular organisms contain systems of organs that carry out specialised functions that enable them to survive and reproduce (ACSSU150)
Chapter 4	The properties of the different states of matter can be explained in terms of the motion and arrangement of particles (ACSSU151)
Chapter 4, Chapter 5	Differences between elements, compounds and mixtures can be described at a particle level (ACSSU152)
Chapter 5	Chemical change involves substances reacting to form new substances (ACSSU225)
Chapter 2	Sedimentary, igneous and metamorphic rocks contain minerals and are formed by processes that occur within Earth over a variety of timescales (ACSSU153)
Chapter 3	Energy appears in different forms including movement (kinetic energy), heat and potential energy, and causes change within systems (ACSSU155)

SCIENCE AS A HUMAN ENDEAVOUR (YEAR 7–8)	
Nature and development of science	
Chapter 4, Chapter 6, Chapter 7, Chapter 8	Scientific knowledge changes as new evidence becomes available, and some scientific discoveries have significantly changed people's understanding of the world (ACSHE119)
Chapter 2, Chapter 6, Chapter 7	Science knowledge can develop through collaboration and connecting ideas across the disciplines of science (ACSHE223)
Use and influence of science	
Chapter 1	Science and technology contribute to finding solutions to a range of contemporary issues; these solutions may impact on other areas of society and involve ethical considerations (ACSHE120)
Chapter 8	Science understanding influences the development of practices in areas of human activity such as industry, agriculture and marine and terrestrial resource management (ACSHE121)



SCIENCE AS A HUMAN ENDEAVOUR (YEAR 7–8)	
Chapter 3, Chapter 5, Chapter 6	People use understanding and skills from across the disciplines of science in their occupations (ACSHE224)

SCIENCE INQUIRY SKILLS (YEAR 7–8)	
Questioning and predicting	
All Chapters	Identify questions and problems that can be investigated scientifically and make predictions based on scientific knowledge (ACSIS124)
Planning and conducting	
All Chapters	Collaboratively and individually plan and conduct a range of investigation types, including fieldwork and experiments, ensuring safety and ethical guidelines are followed (ACSIS125)
All Chapters	In fair tests, measure and control variables, and select equipment to collect data with accuracy appropriate to the task (ACSIS126)
Processing and analysing data and information	
All Chapters	Construct and use a range of representations, including graphs, keys and models to represent and analyse patterns or relationships, including using digital technologies as appropriate (ACSIS129)
All Chapters	Summarise data, from students' own investigations and secondary sources, and use scientific understanding to identify relationships and draw conclusions (ACSIS130)
Evaluating	
All Chapters	Reflect on the method used to investigate a question or solve a problem, including evaluating the quality of the data collected, and identify improvements to the method (ACSIS131)
All Chapters	Use scientific knowledge and findings from investigations to evaluate claims (ACSIS132)
Communicating	
All Chapters	Communicate ideas, findings and solutions to problems using scientific language and representations using digital technologies as appropriate (ACSIS133)

YEAR 8 ACHIEVEMENT STANDARD
By the end of Year 8, students compare physical and chemical changes and use the particle model to explain and predict the properties and behaviours of substances. They identify different forms of energy and describe how energy transfers and transformations cause change in simple systems. They compare processes of rock formation, including the time scales involved. They analyse the relationship between structure and function at cell, organ and body system levels. Students examine the different science knowledge used in occupations. They explain how evidence has led to an improved understanding of a scientific idea and describe situations in which scientists collaborated to generate solutions to contemporary problems.Students identify and construct questions and problems that they can investigate scientifically. They consider safety and ethics when planning investigations, including designing field or experimental methods. They identify variables to be changed, measured and controlled. Students construct representations of their data to reveal and analyse patterns and trends, and use these when justifying their conclusions. They explain how modifications to methods could improve the quality of their data and apply their own scientific knowledge and investigation findings to evaluate claims made by others. They use appropriate language and representations to communicate science ideas, methods and findings in a range of text types.

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SCIENCE TOOLKIT 1

1.1 Science laboratories contain hazards

1.2 Dissection is an important science skill

1.3 Scientists design their own experiments

1.4 Scientists keep a logbook and write formal reports

1.5 Tables and graphs are used to present scientific data

What if?

Observations

What you need:

A4 paper, notebook and pen

What to do:

1 Look at the picture on this page for 30 seconds.

2 Cover the picture with the A4 paper.

3 Write down all the things you observed in the picture.

4 Check your answers. How many things did you observe?

What if?

» What if you had more time to observe the picture?

» What if you knew that you had to write an observation list before you viewed the picture?

» What if you repeated the test?

1.1 Science laboratories contain hazards

Science is a practical subject that includes hands-on laboratory investigations. You will be using many pieces of equipment, chemicals and other materials that are hazardous. A **hazard** is something that has the potential to put your health and safety at risk. You must learn to recognise the risks involved with working in a science laboratory and the appropriate safety procedures in case something goes wrong.

Figure 1.1 Lab coats, safety glasses and gloves protect your body and clothing.

Chemical safety

A chemical may be listed as hazardous if it is considered dangerous for a person to touch, or **inhale**. Most of the chemicals you will use in your school science laboratory are safe to use provided appropriate precautions are taken. When working with chemicals, you should always wear a buttoned-up lab coat to protect your skin and clothes. Safety glasses should cover your eyes, long hair should be tied back and close-toed shoes should always be worn. Occasionally you will need to wear gloves. Never taste, smell or mix chemicals unless specifically directed by your teacher as this may cause a harmful reaction.

When observing chemical reactions ensure that you do not lean over any open containers and never breathe in any gases that may be produced. If your teacher instructs you to smell anything in the laboratory, use your hand to gently waft the gas towards your nose. If you have any concerns tell your teacher immediately.

Figure 1.2 Never smell anything in the laboratory unless instructed to. What piece of safety equipment should these students be wearing?

Hazard symbols

In Australia, and many other countries, hazard symbols (see Figures 1.3 to 1.11) are used to indicate the level of risk or danger of a substance. Hazard symbols are required by law in many situations and you may see some in your science laboratory.

Safe disposal of chemicals and other materials

Safely disposing of chemicals is just as important as safely using them. Not everything can be poured down the sink. Some schools have acid neutralising traps in the drains that allow dilute acids to be disposed of in this way. Other chemicals can react with the acid traps or are toxic for the environment. As a result, these chemicals must be collected at the end of the class and disposed of appropriately by your teacher. These chemicals include **corrosive** liquids, grease and oils, biohazardous wastes and toxic solids. Table 1.1 lists the safe disposal techniques for various materials.

Table 1.1 Safe disposal of materials.

MATERIAL	EXAMPLES	WHAT TO DO WITH IT
Biohazardous waste	Animal cells and tissue	Solids should be collected by your teacher. Deactivate liquid with bleach (1 part bleach to 9 parts water) for 30 minutes before pouring down the drain.
Grease and oils	Vegetable oils Machinery oil	Collect in a bottle and place in regular rubbish. Dispose of as hazardous chemical waste.
Corrosive liquids	Weak acids Strong acids or alkalis	Pour down the drain. Neutralise the acid or alkali and pour down the drain.
Solids	Play dough	Place in regular rubbish.
Hydrogen peroxide	> 8%	Dilute before pouring down the drain.

Figure 1.3 Health hazard Substance can cause serious health effects if touched, inhaled or swallowed.

Figure 1.4 Flammable Substances that catch fire easily.

Figure 1.5 Exclamation mark Substance that can cause irritation (redness or rash).

Figure 1.6 Gas cylinder Contains gas under pressure. Released gas may be very cold. Gas container may explode if heated.

Figure 1.7 Corrosive Substances that are corrosive (destructive) to living tissues, such as skin and eyes. Also used for substances that are corrosive to metals.

Figure 1.8 Exploding bomb Substances that may explode if exposed to fire, heat, movement or friction.

Figure 1.9 Flame over circle – oxidising Provides oxygen to make other substances burn more fiercely.

Figure 1.10 Environmental hazard Substance is toxic to marine organisms and may cause long-lasting effects in the environment.

Figure 1.11 Skull and cross bones – toxic Can cause death if touched, inhaled or swallowed.

Figure 1.12 Pouring substances down the drain can be a hazard.

Check your learning 1.1

Remember and understand

1 What is the purpose of:
  - a a lab coat?
  - b safety glasses?
  - c gloves?
  - d close-toed shoes?

2 Why would you be unlikely to find a substance with the skull and crossbones hazard symbol in a school science laboratory?

3 What precautions might you take when using a substance labelled with the exclamation mark hazard symbol?

4 What is an acid neutralising trap used for?

Apply and analyse

5 Some acids are considered corrosive. Research the word 'corrosive' and write its definition. What precautions should you take when handling acids?

6 Why should you never randomly mix chemicals together in a science laboratory?

7 Some people are allergic to the latex found in gloves. How could you tell if someone is allergic to a substance and what alternative safety precautions might be taken?

1.2 Dissection is an important science skill

Dissection (*Latin: to cut to pieces*) is the process of cutting apart and observing something to study it. Dissection requires the use of specialised equipment and techniques.

Dissections

Scientists throughout history have used dissections. Although it sounds gory, dissection is an essential learning tool for scientists. Dissecting organs and organisms isn't just 'chopping them up'. It requires careful techniques to make sure that the tissues aren't destroyed so that their structures (**anatomy**) can be analysed accurately. Dissection also relies on care being taken with very sharp instruments, such as scalpels.

Figure 1.13 Scissors Used for cutting skin and other tissue. Dissection scissors often have rounded tips, which are less destructive to the tissue being cut.

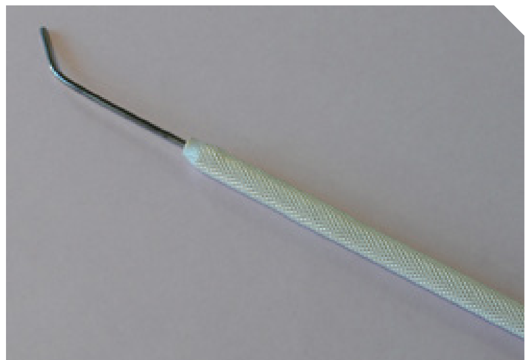


Figure 1.14 Probe Used to look at and explore a specimen, and to probe openings.

Figure 1.15 Scalpel Small and extremely sharp steel blade used for precision cutting.

Figure 1.16 Forceps or tweezers Hinged instrument used for grasping and holding tissues.

Figure 1.17 Early surgical equipment.

Surgical instruments of the past

Early anatomists (scientists who do dissections) didn't always have access to sterile (clean) and sharp cutting instruments, such as scalpels and precision saws for dissections. Dissections were performed with the same tools surgeons used in early operations.

Hands-on dissection

Some science skills are best learnt by doing! Follow the steps in Skills Lab 1.2 to learn how to dissect a chicken wing.

Safety first

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

Check your learning 1.2

Remember and understand

1 How is dissection different to just cutting something up?
2 Why is dissection a useful tool for scientists?
3 List three important safety rules that you must follow during a dissection.
4 Why might gloves *not* be essential for all dissections?
5 Name three tools that are used as part of a dissection. Include a sketch of each tool.
6 Why is it important to leave lab coats and gloves on until *after* the clean-up?

Apply and analyse

7 Without dissection, do you think our knowledge of human anatomy would be more or less advanced? Explain.
8 Draw your own 'surgical tool of the past'. Write a description of this tool and give it a name.

1.2
SKILLS LAB

Materials

- Chicken wing
- Newspaper
- Specimen track
- Forceps
- Probe
- Scalpel
- Dissection scissors
- Plastic bag for disposal

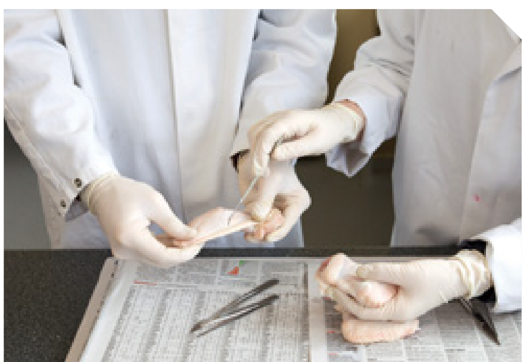
Dissecting a chicken wing

Here you will dissect a chicken wing, and step by step, you will practise the correct skills and techniques of dissection to ensure you stay safe and sterile.

After dissecting your specimen, draw a labelled diagram.

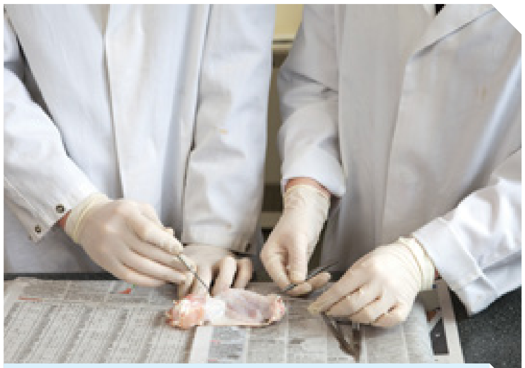
Step 1 Make sure you are wearing appropriate safety gear: gloves, lab coat and safety glasses.

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



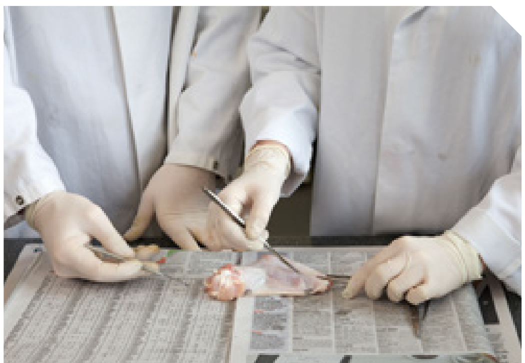
Step 3 Collect your specimen for dissection. Identify all external structures.

Step 4 You may want to pin the specimen to the dissection board to keep it from moving.



Step 5 Use probes to look inside any folds.

Step 6 Use forceps to hold and pull tissue.



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

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

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

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

1.3 Scientists design their own experiments

As a scientist you will need to design your own experiments that can be repeated by other scientists. This requires you to control all the variables in the experiment. This is called **fair testing**.

Balloon rockets

Before continuing, complete Experiment 1.3A on the opposite page.

Asking 'What if?'

A **variable** is something that can affect the results of an experiment. You can find out how a variable affects the results by asking a 'what if' question.

> What if the balloon was blown up more?
> What if the string had less friction?
> What if the string had more friction?
> What if the straw was shorter?

Each of these questions asked what would happen if the **independent variable** were increased or decreased. Only one variable should be changed at one time.

The impact of this change is measured at the end of the experiment. This is called the **dependent variable**. In this experiment, the dependent variable is the distance the balloon rocket travels. All the other variables must be kept the same. They are called **controlled variables**.

Now try changing the independent variable in Experiment 1.3B.

What if the straw were shorter?

IF the straw were shorter THEN the balloon rocket would travel further.

Independent variable: the variable that is deliberately changed.

Dependent variable: the variable that is tested at the end.

Figure 1.18 A **hypothesis** describes the expected relationship between the independent variable and the dependent variable. A 'what if' question can be changed into a hypothesis by removing the 'what' at the start, and adding a 'then' at the end of the question.

Check your learning 1.3

Remember and understand

1 What are the three types of variables in an experiment?

2 Why is it important for an experiment to be reproducible?

3 How do you change a 'what if' question into a hypothesis? Use one of the 'what if' questions you did not test as an example.

4 Were there any variables that you could not control in your balloon rocket experiment?

Apply and analyse

5 Most experimental methods are checked by other scientists. Can you suggest a reason for this?

1.3A EXPERIMENT

Making a balloon rocket

Materials

- 1 balloon
- A long piece of string
- Sticky tape
- 1 plastic straw
- 1 tape measure

Method

1 Tie one end of the string to a chair.

2 Place the other end of the string through the straw.

3 Tie the loose end of the string to a second support so that the string is pulled tight.

4 Blow the balloon up and stick it to the straw. (Do not tie the end of the balloon.)

5 Measure the circumference of the balloon with the measuring tape.

6 Release the end of the balloon so that the straw slides along the string.

7 Measure how far the balloon rocket moved along the string.

8 Repeat this experiment twice more with the same balloon blown up the same amount. You now have a reproducible test for your balloon rocket.

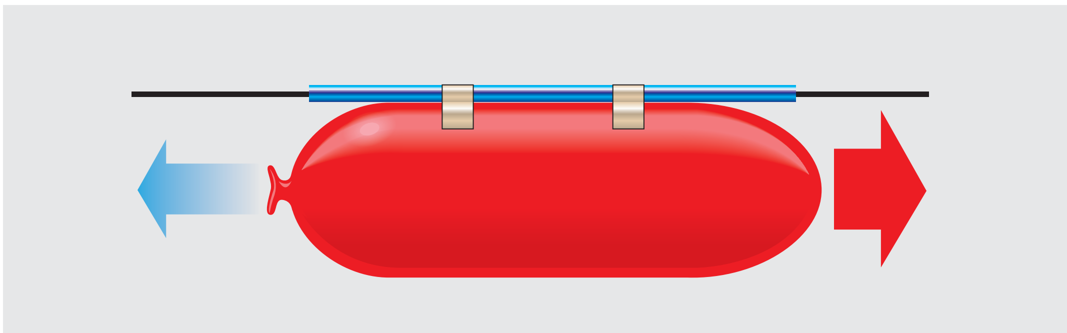


Figure 1.19 When the balloon rocket is released, the straw will slide along the string.

1.3B EXPERIMENT

Changing the independent variable

Aim

To determine factors that affect the distance a balloon rocket will travel.

Method

1 Choose one of the following questions to investigate.
- What if the balloon was blown up more?
- What if the string had less friction?
- What if the string had more friction?
- What if the straw was shorter?

2 Now, follow these steps.
- Write a hypothesis for your enquiry.
- What *independent* variable will you change from the first method?
- What *dependent* variable will you measure/observe?
- What variables will you need to control to ensure a fair test?
- How will you control them?
- Test your hypothesis. Repeat your test at least three times to make sure your results are reliable.

Results

Record your results in a table. Include the units for all measurements.

Discussion

1 Was your hypothesis supported? Use evidence from your results to support your answer.

2 Write a summary of your results.

1.4 Scientists keep a logbook and write formal reports

A science logbook is used to record the details of the work done in a science laboratory. It contains information that the scientist may otherwise forget and provides evidence of the planning, changes and results of an experiment.

Creating a logbook

There are some basic rules to creating and using a logbook.

1 Use a bound notebook or an electronic device that is backed up regularly. Loose papers become lost, and electronic devices can fail. Ensure that the style of records you use is reliable.

2 Label your logbook with your name, phone number, email address, school and teacher's name. Logbooks can become lost. Labelling the logbook with your contact details (and those of your school and teacher) ensures that it will find its way back to you.

3 The second page of the logbook should contain a table of contents. Each page should be numbered to help you find the relevant experiments.

UNIT/SUBJECT	EXPERIMENT TITLE	PAGE NUMBER

4 Always date every entry.

Check your learning 1.4

Remember and understand

1 What is the purpose of a laboratory logbook?
2 Why should an electronic logbook be backed up regularly?
3 A student made a mistake and ripped the page out of their logbook. Why would this be the wrong thing to do?
4 Why is it important to make sure the writing in your logbook is legible?
5 How is a logbook different to a formal science report?
6 Suggest one reason why it is important to include the date of the experiment in the logbook.
7 Why should you reflect on each experiment before starting the next experiment?

GO TO PAGE 159.

1 February 2016

Aim

To determine the relationship between the distance elastic is pulled back and the distance a marshmallow moves.

Method

Refer to page 159 of Oxford Science 8. Please note: 1 cm wide elastic was tied around the base of the chairs from Experiment 1.4.

Measurements

	Distance marshmallow has moved			
Distance elastic pulled back	Attempt 1	Attempt 2	Attempt 3	Average
1 cm	20 cm 3 mm	23.4 cm	19.9 cm	21.2 cm
2 cm				
3 cm				
4 cm				

20.3
23.4
+ 19.9
63.6
$63.6 \div 3 = 21.2$ cm

Observations

The elastic came undone after the third attempt so we had to do it up again.
We tried to make it the same tightness as before.

Conclusion

When the elastic was pulled back, more elastic gained more energy. This energy went into the marshmallow so that it could move further when released. We should have tested with the elastic pulled back ~~more~~ different distances.
Next time the same person should do the pulling back.

Aim and hypothesis of the experiment.

The method used or the page number of the method. Record any changes to the method.

Record any measurements you made to the maximum number of digits provided by the equipment. (You can round them off later. If you don't record them then you cannot get them back later.)

Show all calculations (even when adding simple numbers).

Include any ideas, explanations, diagrams, graphs, sketches or mistakes that happened. Write everything down even if it seems unimportant. You may not remember it weeks or even months later.

Do not rewrite any entries. Try to keep it as neat as you can but it is not a formal report. It is more important that you record your data and observations. If you make a mistake, put a single line through it. Do not white it out, as it may be useful again later.

Include a conclusion or reflection for each experiment to make sure you understood why you got the results you did.

You may need to write up a formal report for your experiment. If you have completed your logbook well, you will find all the details of the report easily available.

Glue or staple in any photocopies to prevent them falling out.

1.5 Tables and graphs are used to present scientific data

Graphs make the information (data) you gather in an experiment easier to analyse. Graphs show what happened. Patterns in the data can be seen and this enables predictions about what might happen if you continued the experiment.

Common features in graphs

There are four features all graphs have in common.

1. A descriptive title of what the graph shows.
2. A grid that is used to plot the points or data.
3. The independent variable on the horizontal axis.
4. The dependent variable on the vertical axis.

Interpreting graphs

Line graphs are the most common graphs that are drawn in scientific reports. These graphs are used to show the relationship between the independent variable and the dependent variable. The shape of the graph gives a hint of how the two variables are related.

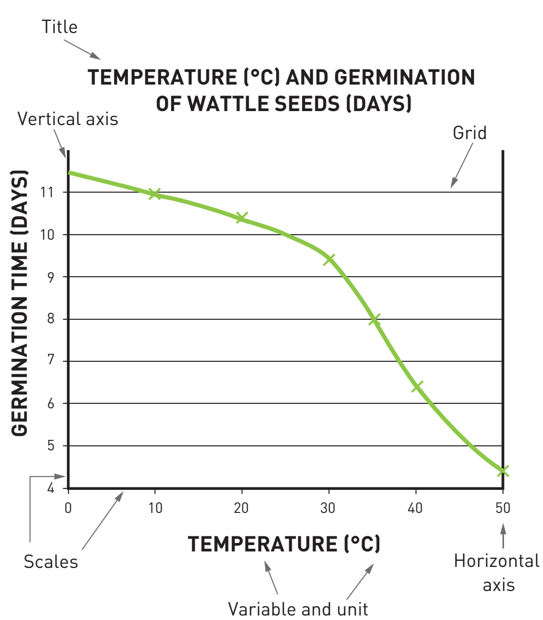
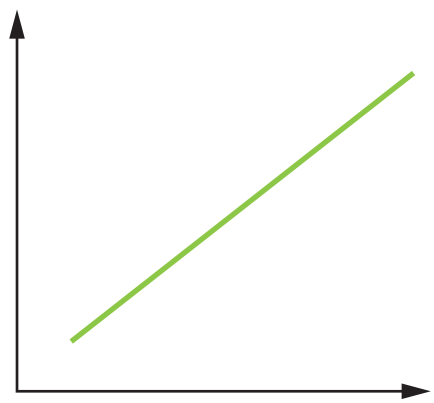
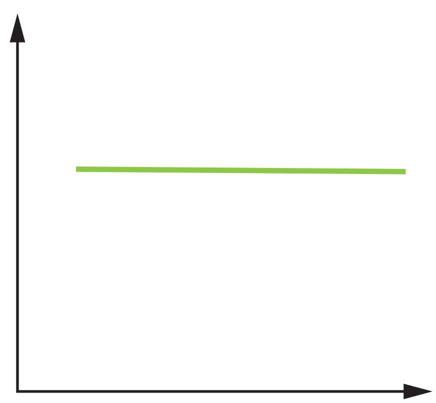


Figure 1.20 The independent variable (temperature) should be on the horizontal axis and the dependent variable (germination time) should be on the vertical axis.

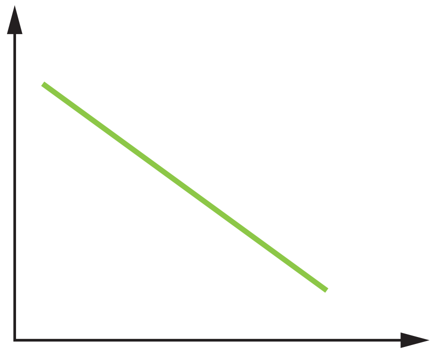


When the line slopes upwards, this means the dependent variable increases as the independent variable increases. This is called a **directly proportional relationship**.

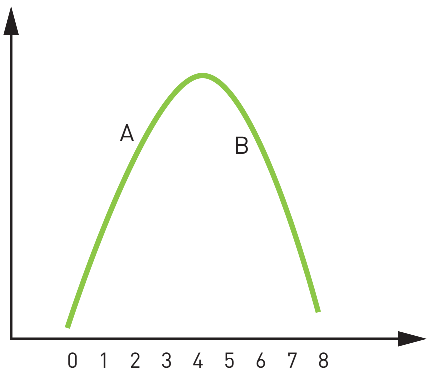


When the line is horizontal, it means the dependent variable is not affected by the independent variable.

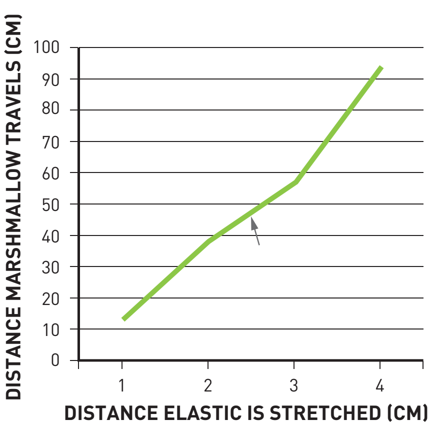
If the line is sloped down, then the dependent variable decreases as the independent variable increases. This is called an **inversely proportional relationship**.



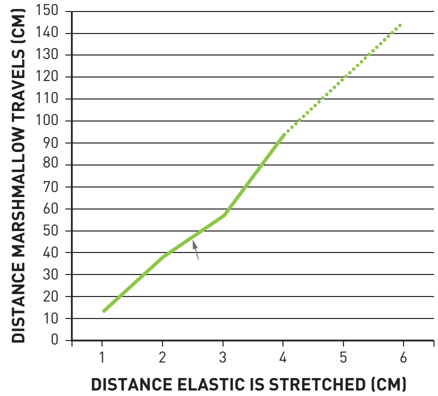
Occasionally a graph is curved. These graphs should be divided into sections. Section A (between 1 and 4) shows a directly proportional relationship. Section B (between 4 and 7) shows an inversely proportional relationship.



Sometimes you may have recorded the results for a set of whole numbers. An example of this is pulling back the elastic and marshmallow in the previous experiment 1 cm, 2 cm, 3 cm and 4 cm. If you draw an accurate line graph of your data, then you may be able to use the graph to see what would happen if you pulled back the marshmallow 2.5 cm.



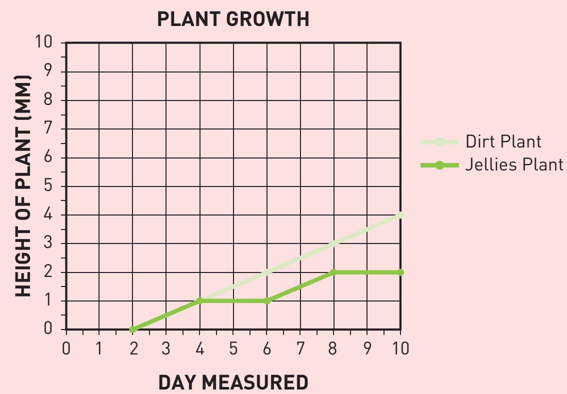
A graph can also be used to extrapolate results. This means you can continue the shape of the graph to determine what would happen if you continued the experiment.



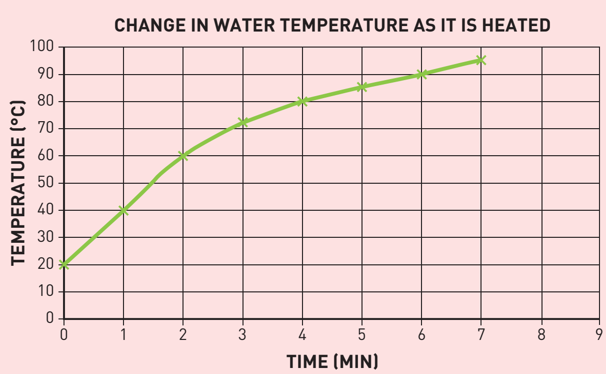
Check your learning 1.5

Remember and understand

1. What features should all graphs have in common?
2. What does 'extrapolate results' mean?
3. Describe the relationship between the independent variable and dependent variable in the following graph.



4. Extrapolate the following graph to determine what would happen if the water were heated for 8 minutes.



Apply and analyse

5. Explain why graphs are often used in scientific reports.

* REVIEW

1

Remember and understand

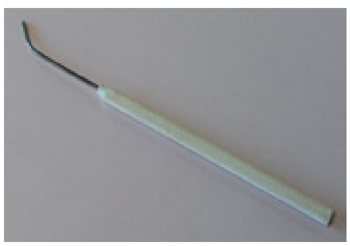
1 When are the following symbols or objects used?

a

b

c

d



2 How should you dispose of hazardous waste from dissections?

3 Define the following words:

a dissection

b anatomy

c dependent variable

d hypothesis.

4 Describe the information that should be included in an experimental logbook.

5 Why is it important to include any changes you make to an experimental method in your logbook?

6 How do you determine the average of a set of results?

7 What are the four common features that should be present on all graphs?

8 What is the difference between the independent variable and the dependent variable?

9 How should you safely dispose of:

a newspaper used for dissections?

b vegetable oil?

c weak acid?

d strong acid?

Apply and analyse

10 What dissection tools do you have in the science laboratory?

11 How can you make sure an experiment is a fair test?

12 Why should you wash science equipment thoroughly before putting it back?

13 What might happen if you put play dough down the sink?

14 What is the difference between a logbook and a formal written report? When should a formal written report be used?

Evaluate and create

15 Draw a graph from the data below that show how much Enza has grown in her first 8 years.

AGE (YEARS)	HEIGHT (CM)
1	75
2	86
3	91
4	99
5	105
6	110
7	117
8	121

Extrapolate the results to determine how tall Enza will be when she is 10 years old.

16 Answer the following questions about the graph on the next page.

a What label should be on the x-axis?

b What label should be on the y-axis?

c Which year was the number of road deaths at the highest level?

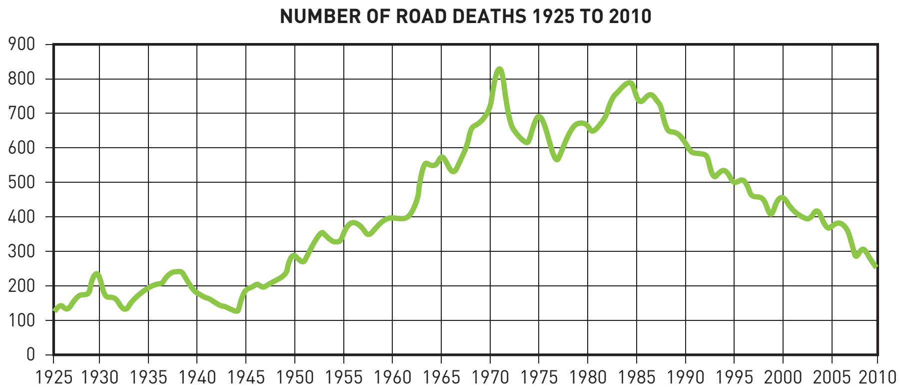
d How many road deaths were there in 1965?

e Describe the trend in:

i 1945–1965

ii 1975–1985

iii 1990–2010.



f What could have caused the trend from 1985 to the current day?

17 One of the first scientists to record their dissections was Leonardo da Vinci. Create a picture scrapbook of copies of some of Leonardo da Vinci's best work on the study of the human body.

18 Scientists present formally written reports in scientific journals. Many of these reports must be examined by other scientists before they will be accepted for printing. Suggest a reason for this.

Ethical understanding

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

Research

20 Choose one of the following topics for a research project. A few guiding questions have been provided for you, but you should add more questions that you want to investigate. Present your research in a format of your own choosing, giving careful consideration to the information you are presenting.

a **Testing sticky tape**

Design an experiment to test the strength of different types of sticky tape. What is your independent variable? How will you measure your dependent variable? List all the variables that could affect the results. How will you control these? What materials will you need? Write out a method in a step-by-step manner.

b **Early anatomists**

Research how early anatomists such as the Egyptians or the Greeks made their discoveries. What was the relationship between barbers (male hairdressers) and surgeons? Who were they allowed to dissect legally according to King Henry VIII? How do current surgeons learn anatomy?

c **Laboratory chemicals**

There are many chemicals that are banned from use in school laboratories. Research one of these chemicals. When was it banned? Why is it considered dangerous for use by students? Is it still used in other workplaces? What precautions need to be taken by the people who work with this chemical?

KEY WORDS

1

anatomy
structure of an organism and its component parts; usually refers to human anatomy

controlled variables
variables that will remain unchanged through the experiment

corrosive
a substance that is destructive to living tissues, such as skin and eyes, or to some types of metals

dependent variable
variable that may change as a result of the experiment

directly proportional relationship
the dependent variable increases as the independent variable increases

dissection
the process of disassembling and studying the internal structures of plants, animals and humans

fair testing
experiment where only the independent variable is changed and all other variables are kept constant

hazard
something that has the potential to put your health and safety at risk

hypothesis
a statement that describes the expected relationship between the independent variable and the dependent variable

independent variable
a variable (factor) that is changed in an experiment

inhale
to breathe in

inversely proportional relationship
the dependent variable increases as the independent variable decreases

variable
something that can affect the results of an experiment

ROCKS AND MINERALS

2

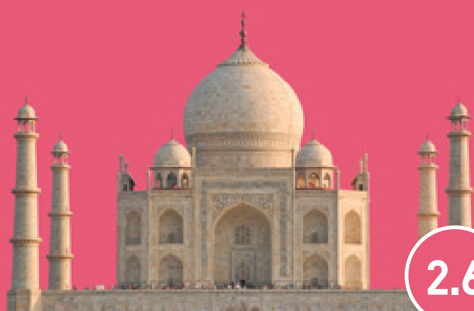
2.1 Rocks have different properties

2.2 Rocks are made up of minerals

2.3 Minerals are a valuable resource

2.4 Igneous rocks develop from magma and lava

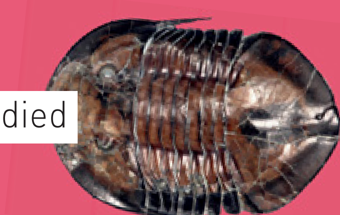
2.5 Sedimentary rocks are compacted sediments



2.6 Metamorphic rocks require heat and pressure

2.7 The rock cycle causes rocks to be re-formed

2.8 Weathering and erosion can be prevented



2.9 Rocks are studied by geologists

What if?

Rocks

What you need:

selection of different rocks for each group

What to do:

1 Divide into groups of four.
2 Examine each rock carefully. Identify the properties that the rocks have in common and the different features of each rock.
3 Group the rocks according to their similarities. Give each group a name that helps identify the rocks.
4 Record the names and the properties of the rocks on a piece of paper.

What if?

What if another group were given your rocks? Could they use the properties you identified to separate the rocks into the same groups?

2.1 Rocks have different properties

Rocks don't all look and feel the same. Each rock has characteristics that give clues to its identity, such as its colour or hardness. These characteristics are referred to as **properties**. By making careful observations of a rock's properties, **geologists** (scientists who study rocks) can tell where a rock came from and what has happened to it.

Identifying and selecting rocks

We select rocks for particular purposes because of their properties. For example, granite is selected for kitchen benchtops because it is the hardest building stone, it is not porous (it does not let liquid through), it is not affected by temperature and it is resistant to damage from chemicals.

You can identify rocks first by how they look. Coal is black or dark brown. Pumice and scoria are covered with holes. Conglomerates are made up of individual stones cemented together. Granite is made up of large crystals of the minerals quartz, mica and feldspar.

Geologists also use a range of other properties to help identify rocks, such as colour, layering, weight and the presence of crystals or grains (see Figures 2.1 to 2.5).

Table 2.1 lists some different types of rocks and how they can be identified.

Figure 2.1 Weight and density are less if rocks contain large gas holes that were produced when the rock was formed. In pumice, the holes can be the size of a match tip or smaller. In scoria, the holes are often the size of a pea.

Figure 2.2 Layers in rocks can look very different. Some rocks have different-coloured layers that line up like ribbons. Gneiss usually has alternating layers of colours, often black and white. Sandstone has layers of different-sized grains of sand. Wind or water distributes the sand so that the rock ends up being different shades of the same colour.

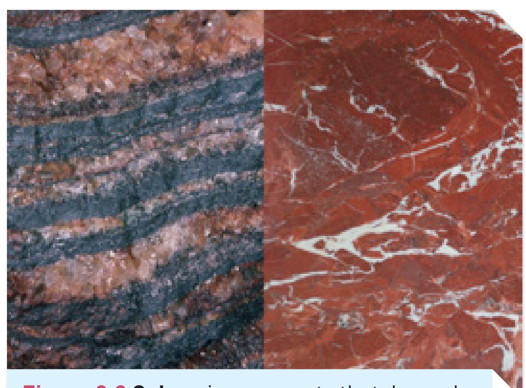


Figure 2.3 Colour is a property that depends on the chemicals in the rocks. For example, some red rocks contain a lot of iron, which has reacted with oxygen in the air ('rusted') to form red iron oxide. Other red rocks don't contain iron, so a rock cannot be identified solely by its colour.

SKILLS LAB 2.1: IDENTIFYING ROCKS
GO TO PAGE 160.

Figure 2.4 **Crystals** are small pieces of organised particles that have smooth sides and sharp edges. They are usually just one colour and often reflect light off their flat surfaces. Crystals in a rock can be different sizes.

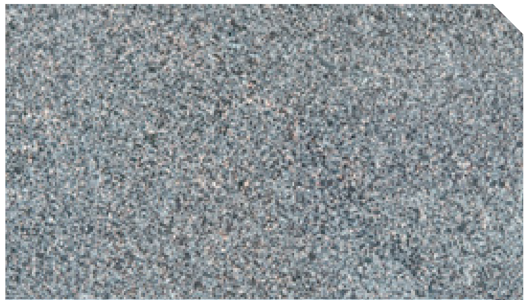


Figure 2.5 **Grains** are small pieces of material. The size of the grain can be used to identify the type of rock. Large grains (larger than a grain of rice) are said to be coarse. Smaller grains that can still be seen with the eye are medium grained. Fine grains cannot be seen without a microscope.

Table 2.1 Rock identification.

ROCK	GRAIN SIZE	HARDNESS	USUAL COLOUR	DENSITY
Basalt	Fine or mixed	–	Dark	2.8–3
Coal	Fine	Soft	Dark	1.3
Conglomerate	Mixed	Hard or soft	–	–
Gneiss	Coarse	Hard	Alternating light and dark bands	2.6–2.3
Granite	Coarse	Hard	Light	2.6–2.7
Limestone	Fine	Soft	Light	2.3–2.7
Marble	Coarse	Soft	Light	2.4–2.7
Obsidian	Fine	Soft	Dark	2.6
Pumice	Fine	Soft	Light	0.6
Quartzite	Coarse	Hard	Light	2.6–2.8
Rhyolite	Fine	Hard	Light	2.4–2.6
Sandstone	Coarse	Hard	Light	2.2–2.8
Schist	Medium to coarse	Medium	Medium	2.5–2.9
Scoria	Fine	–	Dark	0.9
Shale	Fine	Soft	–	2.4–2.8
Slate	Fine	Soft	Dark	2.7–2.8

Check your learning 2.1

Remember and understand

1 Use Table 2.1 and Figure 2.6 to name these rocks.
   a I am light in colour with a fine grain. I am considered soft.
   b I am light in colour with holes in the surface.
   c I am soft, shiny and dark in colour. I am often used for flooring.
   d I have mixed grains and my colour can vary.

2 What properties are used to identify different types of rocks?

3 Name two different uses for different types of rocks.

4 Why must properties other than colour be used to identify a rock?

5 What branch of science is the study of rocks?

Apply and analyse

6 Pumice has a density of 0.6. Water has a density of 1. Would you expect the pumice stone to float or sink? Explain your reasoning.

Figure 2.6 These are some of the many different types of rocks.

2.2 Rocks are made up of minerals

Rocks are made up of one or more minerals. A **mineral** is a naturally occurring solid substance with its own chemical composition, structure and properties. There are more than 4000 minerals known, but only approximately 150 of these are common.

Figure 2.7 The individual mineral crystals of the rock olivine basalt can be seen under a microscope.

Properties of minerals

Minerals are found as crystals.

The structure of a crystal greatly influences a mineral's properties. For example, diamond and graphite have the same chemical composition – they are both pure carbon. Graphite (which is the 'lead' in a pencil) is very soft, whereas diamond is the hardest of all minerals. This difference arises because the carbon particles in a graphite crystal are arranged into sheets that can slide past each other, whereas the carbon particles in a diamond crystal form a strong, interlocking unit.

a

b

Figure 2.8 (a) The carbon atoms in the mineral graphite are arranged in sheets. (b) In a diamond, the carbon atoms are interlocked.

Identifying minerals

To identify minerals correctly, geologists carefully examine the properties of rocks.

The colour of a mineral is a guide to identifying it, but it cannot be relied on for correct identification. Colour is not a reliable property because many minerals are impure. For example, pure quartz is colourless, but if it contains impurities it can be many colours, such as purple (amethyst), pink (rose quartz) or yellow (citrine). Even in one sample, the colour may vary.

Lustre is the shininess of the surface of the mineral. Some types of lustre are:

- metallic – looks like a shiny new coin
- brilliant – very shiny, like a mirror
- pearly – a bit shiny, like a pearl or fingernail
- dull – not shiny at all
- earthy – looks like a lump of dirt.

Figure 2.9 The lustre of a mineral describes its shininess.

SKILLS LAB 2.2: TESTING THE HARDNESS OF COMMON SUBSTANCES
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Streak is the colour of the powdered or crushed mineral. This colour can be seen by drawing with the mineral on a footpath. The colour of the line that the mineral leaves behind is its streak. Often the colour of the streak is different from the main colour of the mineral.

Hardness is how easily a mineral can be scratched. Some minerals are so soft that they can be scratched with a fingernail. Other minerals are so hard that they can scratch glass. A hard mineral can scratch a soft mineral and not get scratched itself. Austrian geologist Friedrich Mohs (1773–1839) invented a scale to describe the hardness of a mineral. Mohs gave a hardness number to ten common minerals (see Table 2.2): the softest mineral, talc, has a hardness of 1; the hardest mineral, diamond, has a hardness of 10. These minerals can be used to find the hardness of any other mineral.

A mineral will scratch another mineral with a lower hardness number but not one with a higher hardness number. A mineral will be scratched by another mineral with a higher hardness number but not one with a lower hardness number. So, copper (hardness 3.5) will be scratched by fluorite (hardness 4), but not by calcite (hardness 3). Copper will scratch calcite. Fingernails have a hardness number of 2.5; iron nails and a glass microscope slides have a hardness number of 6.5.

Table 2.2 The Mohs scale of mineral hardness. Every mineral will scratch the minerals above it.

HARDNESS	MINERAL
1	Talc
2	Gypsum
3	Calcite
4	Fluorite
5	Apatite
6	Feldspar
7	Quartz
8	Topaz
9	Corundum
10	Diamond

Cleavage is the tendency of a mineral to break into a number of smooth planes. Minerals that demonstrate cleavage look like thin slabs stuck together.

Mica breaks in one direction into flat layers, like the pages in a pile of papers. Calcite breaks along three cleavage planes: left and right, front and back, and top and bottom.

Several minerals have unusual properties. Some minerals fluoresce in ultraviolet (UV) light: these minerals absorb UV light, which we cannot see, and emit it as visible light, which we can see. Calcite is a transparent mineral. When you look through it, you see a double image.

Figure 2.10 Mica has one cleavage plane – it breaks into thin sheets of rock.

Figure 2.11 Calcite is a transparent mineral.

Check your learning 2.2

Remember and understand

1 Define:
   a hardness
   b lustre
   c streak
   d cleavage.

2 What does it mean if a mineral has a hardness of 1 on the Mohs scale?

3 Name a mineral that has a Mohs hardness of 10.

4 How would you describe the lustre of gold?

Apply and analyse

5 Obsidian has a hardness of 6 on the Mohs scale and was prized by ancient peoples for its sharp edge. Describe what type of minerals would damage the sharp edge of an obsidian blade.

2.3 Minerals are a valuable resource

Minerals are an important source of metals and other materials. An **ore** is a mineral with a large amount of a useful metal in it. Some minerals, such as iron ore, have to be treated before they can be used. Some important ores and the metals they contain are listed in Table 2.3.

Mineral resources

Australia is rich in mineral resources. It is the world's leading producer of lead, bauxite and alumina, diamonds (by volume), ilmenite, rutile and zircon (and synthetic rutile) and tantalum. It is the second largest producer of uranium, zinc and nickel; the third largest producer of iron ore, lignite, silver, manganese and gold; the fourth largest producer of black coal and copper; and the fifth largest producer of aluminium. Worldwide demand for mineral resources is high, particularly due to increased demand from China as it becomes more and more industrialised.

Table 2.3 Important ores and the metals they contain.

ORE	METAL
Bauxite	Aluminium
Cassiterite	Tin
Chalcopyrite	Copper
Cinnabar	Mercury
Galena	Lead
Haematite, limonite	Iron
Malachite, azurite	Copper
Molybdenite	Molybdenum
Pentlandite	Nickel
Pitchblende	Uranium
Rutile	Titanium
Sphalerite	Zinc

Figure 2.12 Coloured sands indicate the concentrations and types of minerals they contain.

Gold

Australia's mineral resources have always been in big demand. During the 1850s, after gold was discovered in Bathurst, New South Wales, hundreds of thousands of people migrated to Australia to take part in the Gold Rush in Victoria and New South Wales. During this time, Australia's economy boomed. Gold is chemically stable, so it is almost always found as pure gold. This means that it can be collected without having to be smelted or refined. Gold is used in jewellery, in fine wires in electronics, as fillings for teeth and, because of its reflective properties, to protect satellites and spacecraft from solar radiation.

Mineral sands

Australia is an old continent that is rich in mineral sands. Mineral sands are old beach sands with significant concentrations of heavy minerals, such as rutile, zircon and ilmenite. Rutile is a rich source of titanium dioxide, which is used as a pigment in paints, plastics and paper. You may have seen glass jars of mineral sands that are often sold as souvenirs.

Copper

Copper was the first metal to be used by humans. In Australia, copper is found as the mineral chalcopyrite in rocks that are over 250 million years old. Copper is a good conductor of electricity and is used in electrical generators and motors, for electrical wiring and in electronic goods, such as televisions. Copper is also used for water pipes because it does not corrode easily.

Recycling minerals

Earth's mineral resources are finite – they are not renewed. However, they can be recycled. For example, aluminium can be recycled

EXPERIMENT 2.3: TESTING THE MINERALS IN TOOTHPASTE
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over and over again. A lot of energy is used to produce aluminium from bauxite, but once the metal has been refined it can be recycled indefinitely. Recycling aluminium uses only 5 per cent of the energy needed to produce the same quantity of aluminium from bauxite. So recycling aluminium saves us from having to use coal to produce energy in power stations, which reduces the emission of greenhouse gases into our atmosphere.

Mobile phones and minerals

Many electronic devices such as mobile phones use the minerals niobium and tantalum. These minerals are found in the ore coltan, which is mined in the Congo River Basin in Africa. Unfortunately, this forest region is also home to endangered gorillas and mining is threatening their habitat. Recycling the minerals in old mobile phones helps to reduce the impact of mining on the ecosystem in this region.

MINERALS IN TOOTHPASTE

Toothpaste contains a variety of minerals that perform different roles when cleaning your teeth. Fluorite (calcium fluoride), found in granite and limestone, makes teeth more resistant to decay. Mica reflects light and is used in toothpaste, paints, roofing and rubber products to make them sparkle. Silica, mined from sand, makes the toothpaste thicker and sodium carbonate is used as a whitening agent.

Figure 2.14 Toothpaste contains minerals that help clean your teeth.

Figure 2.13 The minerals in mobile phones can be recycled.

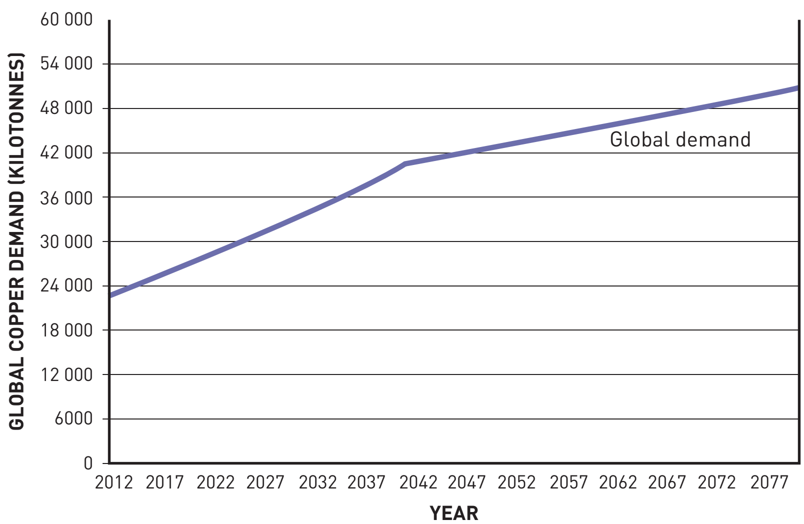

Figure 2.15 Global copper demand is projected to continue to increase.

Check your learning 2.3

Remember and understand

1 What is a mineral?
2 What is an ore?
3 Name two uses of copper.
4 What are five of Australia's most important minerals?

Apply and analyse

5 Use the graph in Figure 2.15 to describe how the global demand for copper will change after 2042. Suggest a reason for this change in demand.

2.4 Igneous rocks develop from magma and lava

Rocks are broadly classified according to how they are formed. The three main types of rocks – igneous, sedimentary and metamorphic – form in different ways. **Igneous rocks** form when magma and lava from volcanic eruptions cool and solidify.

Magma and lava

The term 'igneous' comes from the Latin word *ignis*, which means 'fire'. The hot, molten rock inside the Earth is called **magma** and its temperature can be more than 1200°C. The magma chamber under a volcano is the source of molten rock for the volcano (Figure 2.16).

In a volcanic eruption, the red-hot magma rushes out onto the surface of the Earth as **lava**. The cooler conditions at the Earth's surface help to solidify the lava quickly. Igneous rocks also form from magma under the ground. These igneous rocks look quite different from those formed on the Earth's surface because they cool much more slowly.

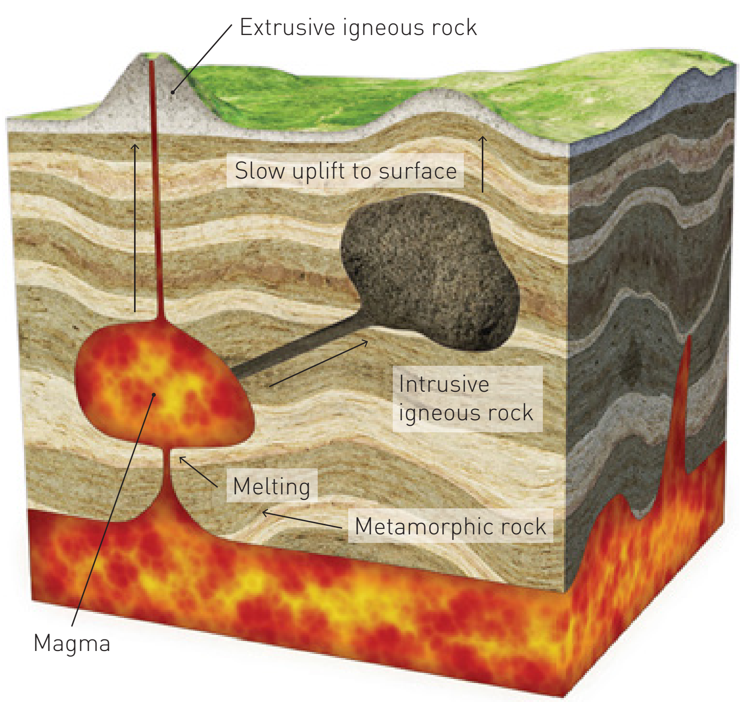

Figure 2.16 Igneous rocks are formed from volcanic magma.

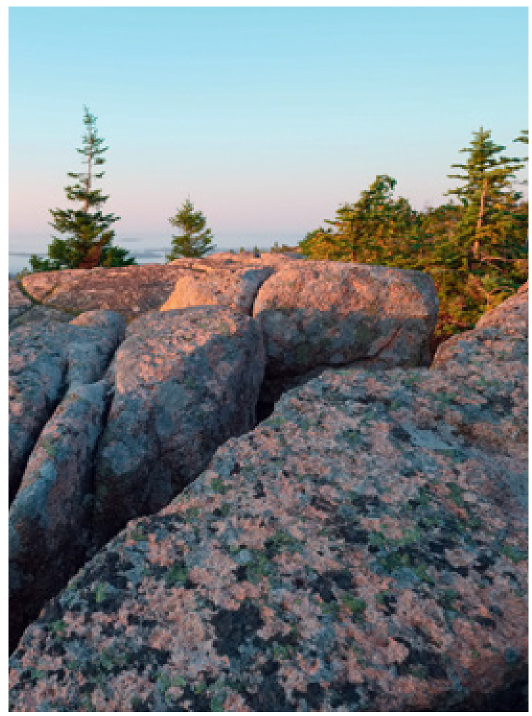

Figure 2.17 Granite is an intrusive igneous rock.

Intrusive igneous rocks

Intrusive igneous rocks form slowly beneath the surface of the Earth when magma becomes trapped in small pockets. These pockets of magma cool slowly underground (sometimes for millions of years) to form igneous rocks. The longer it takes for lava to cool, the bigger the rock crystals that grow. Intrusive igneous rocks have large crystals locked together. Granite is an intrusive igneous rock in which the crystals can be seen with the naked eye. Although formed underground, intrusive igneous rocks reach the Earth's surface when they are either pushed up by forces in the Earth's crust or uncovered by erosion.

EXPERIMENT 2.4: WHAT AFFECTS CRYSTAL SIZE?
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Extrusive igneous rocks

Lava cools much more quickly on the surface of the Earth. This causes it to form **extrusive igneous rock**. Because the lava is cooling much more quickly than the magma underground, the crystals that are formed are small. Sometimes, the lava cools so quickly that no crystals are formed. For example, pumice has no crystal structure. Pumice forms when hot, gas-filled lava cools very quickly. The many tiny holes in pumice are formed by volcanic gases escaping from the cooling lava (see Figure 2.18). It has so many holes that it is extremely light and can float on water. Pumice stones are used to scour hard skin from feet, and powdered pumice is found in some abrasive cleaning products.

Figure 2.18 Pumice contains many holes, which make it light enough to float on water.

The different forms of basalt

Magma can solidify into many different igneous rocks, which can vary in appearance. This is because of how igneous rocks form and what they are made of.

Basalt is the most common type of rock in the Earth's crust. Most of the crystals in basalt are microscopic or non-existent because the lava cools so quickly that large crystals do not form.

We commonly think of basalt as the building product bluestone. However, basalt can look different depending on the type of volcanic eruption that produced it and how quickly it cooled. Scoria is a type of basalt that is full of bubble holes. The lava was filled with gases when it began to cool and the holes in the scoria are where the gas bubbles once were. Scoria is a light rock that is often used for garden paths and as fill in drainage trenches.

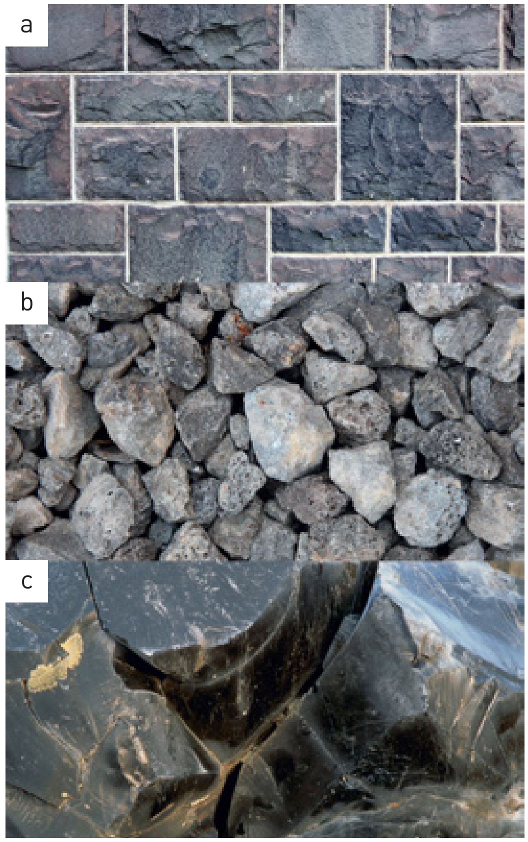

Figure 2.19 Basalt comes in different forms: (a) bluestone, (b) scoria and (c) obsidian.

Obsidian is a smooth, black rock that looks like glass. It is formed when lava cools almost instantly and forms no crystals. Obsidian is used to make blades for surgery scalpels; the resulting blades are much sharper than those made from steel.

Check your learning 2.4

Remember and understand

1 What does the term 'igneous' mean?
2 How do igneous rocks form?
3 What type of rock is produced by magma that cools deep below the Earth's crust?
4 Name an igneous rock that would float on water.

Apply and analyse

5 The ancient civilisations that discovered obsidian had a competitive advantage over those who didn't. Explain why.

2.5 Sedimentary rocks are compacted sediments

Sedimentary rocks are formed when loose particles are pressed together (compacted) by the weight of the overlying sediments. Sediments are rock particles, such as mud, sand or pebbles, that are usually washed into rivers and eventually deposited on the riverbed or in the sea. Sediments can also come from the remains of living things, such as plants and animals.

Sediment

Over thousands or even millions of years, sediments form thick layers on the riverbed or sea floor. Pressure from the overlying sediments and water squeezes out air and any gaps in the bottom layer. Over time, the compacted sediments become sedimentary rocks.

The names of some sedimentary rocks are clues to the sediments that formed them – sandstone, mudstone, siltstone and conglomerate are all types of sedimentary rock. Sandstone is made up of sand deposited in environments such as deserts and beaches. Conglomerate is a mixture of all sizes of rocks that have become cemented together.

Figure 2.20 Shale (or mudstone) is the most common sedimentary rock. Shale is a fine-grained sedimentary rock made up of clay minerals or mud. This specimen clearly shows the layers of sediments that were compacted to form this rock.

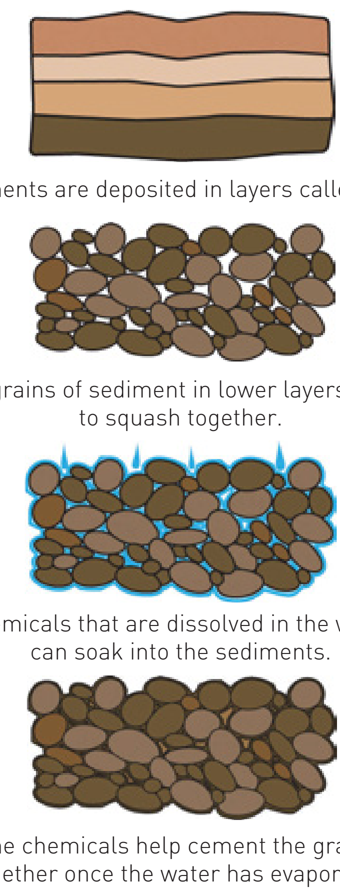

Figure 2.21 Sedimentary rocks form over long periods of time.

Figure 2.22 Sandstone is a popular building material. This ancient temple of Abu Simbel in Egypt was carved directly into the sandstone rock.

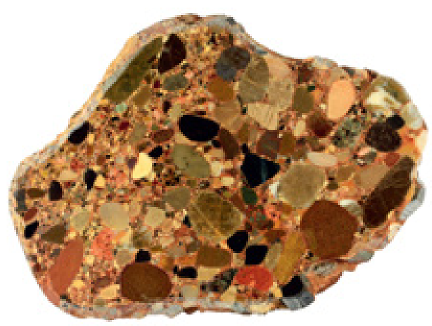

Figure 2.23 Conglomerate rocks have grains of different sizes. The sediments for these rocks were deposited in fast-flowing rivers during flooding or by glaciers.

EXPERIMENT 2.5: MAKING SEDIMENTARY ROCKS
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Biological rocks

Sedimentary rocks are not always formed from the sediments of minerals or other rocks. The remains of living things also break down and are deposited as sediments. Shells and hard parts of sea organisms break down and are deposited in layers on the ocean floor. Eventually, they become cemented together under pressure to form limestone.

The compaction of dead plant material can also help form sedimentary rocks. For example, coal is formed from dead plants that were buried before they had completely decayed. Pressure from the layers above can change the plant material into coal or oil.

Figure 2.24 Coal is formed from dead plant material.

Chemical rocks

Chemical sedimentary rocks form when water evaporates, leaving behind a solid substance. When seabeds or salt lakes, such as Lake Eyre in South Australia, dry up, they leave a solid layer of salt behind. If the layer of salt is compressed under the pressure of other sediments, it may eventually form rock salt.

Limestone caves

When groundwater passes over limestone, it can dissolve calcium carbonate from the limestone. When the water evaporates, it leaves behind the calcium carbonate. Various rock formations in caves are formed by this method.

The amazing long strands of rock found on cave floors and ceilings are composed of calcium carbonate from the limestone ceiling of the cave. A stalagmite grows from the floor towards the ceiling (they 'might' reach the ceiling one day) and a stalactite grows down from the ceiling (they hold on 'tight'). If these formations meet in the middle, then they form a column.

Stalagmites and stalactites form when limestone rocks are dissolved by acids in water. The acid and dissolved limestone form a solution that drips through the ceiling of the cave and is deposited on the stalagmites and stalactites, gradually increasing their width and length. It is important that visitors to limestone caves do not touch the stalactites and stalagmites because they are generally still forming. Oil from skin can interfere with stalagmite and stalactite formation.

Figure 2.25 Stalagmites and stalactites form in limestone caves.

Check your learning 2.5

Remember and understand

1. How do sedimentary rocks form?
2. How do stalactites and stalagmites form?
3. How do chemical sedimentary rocks form?

Apply and analyse

4. A student claims that sandstone is made up of sand. Do you agree or disagree? Explain.
5. What do plants have to do with coal?

2.6 Metamorphic rocks require heat and pressure

Metamorphic rocks are formed when other types of rocks are changed by incredible heat and pressure inside the Earth. When igneous, sedimentary or even metamorphic rocks are heated to extreme temperatures by magma, or when they are placed under extreme pressure from the layers of rocks above them, they can change into different types of rock.

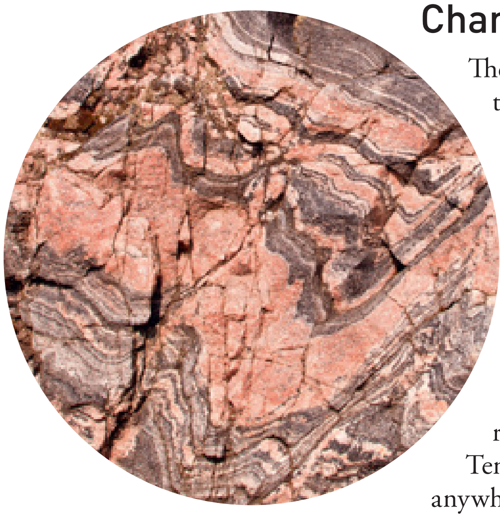

Figure 2.26 Foliation occurs when rock is subjected to uneven pressure.

Change in appearance

The combination of high temperatures and pressures causes differences in the appearances of the metamorphic rock. (Metamorphism means 'change in form'.) As you go deep underground, the temperature gradually increases. Miners in the West Wits minefield in South Africa, who work up to 3.9 kilometres below ground, report temperatures as high as 60°C. Temperatures can get much higher anywhere magma intrudes.

The pressure of the earth above the rock also contributes to the different appearance of metamorphic rocks. Bands can occasionally be seen in metamorphic rocks formed under high pressure. Sometimes the pressure is uneven, causing the rock crystals to twist. This is called **foliation**.

Change in the minerals

Metamorphic rocks also change chemically. Some metamorphic minerals (sillimanite, kyanite and garnet) only form at high temperatures and pressures. They are called **index minerals** because they can tell us the history of what happened to the minerals – the temperature and pressure they were exposed to. Other minerals, such as quartz, can withstand the high temperatures and pressures and can sometimes be found in metamorphic rocks. The heat and temperature can cause some crystals to change their size and shape.

Recrystallisation occurs when the crystals are squeezed together so tightly that they partially melt and form fewer, but larger, crystals. For example, when granite is squeezed under high pressure, the crystals change and the rock gneiss is formed (see Figure 2.27).

Metamorphic rocks are stronger than the original material because the particles have been fused together under great pressure or heat.

a

b

Figure 2.27 When granite (a) is subjected to high heat or pressure, it can change into the metamorphic rock known as gneiss (b). The bands on gneiss show that the crystals have been squeezed together under immense pressure.

EXPERIMENT 2.6: MAKING A METAMORPHIC ROCK
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Figure 2.28 Slate cleaves easily into flat sheets because of its flat, parallel crystal structure. This makes it a useful material for floor and roof tiles and as the base for billiard tables.

Figure 2.29 The Taj Mahal in India is made of marble, the metamorphosed form of limestone. With its dense composition and beautiful patterns, marble is also a popular material for sculptures and kitchen benchtops.

Check your learning 2.6

Remember and understand

1. How do metamorphic rocks form?
2. Where do metamorphic rocks form?
3. A student claimed that a rock had to be igneous because it had quartz crystals. Are they correct? Explain.
4. Describe a foliated rock.

Apply and analyse

5. Which type of rock is stronger: sandstone or marble? Explain your reasoning.

2.7 The rock cycle causes rocks to be re-formed

The **rock cycle** is an ongoing process that describes the formation and destruction of the different rock types. **Weathering** is the breaking down of rocks and minerals through the movement of water and animals, and the extremes of temperature. **Erosion** is the movement of the sediment to another area.

Physical weathering

Mechanical, or physical, weathering occurs when a physical force is applied to a rock. It includes the breakdown of rocks by non-living things.

In desert areas, the days are very hot and the nights are freezing cold. This daily heating and cooling affects only the outside of the rock. This is because rocks do not conduct heat very well. Sometimes the outside of the rock can peel off, just like an onion skin. This process is called **onion-skin weathering** and the round rocks produced in this way are called **tors**.

When water freezes at night, it expands and takes up more space. When water freezes in the crack of a rock, it expands and pushes hard against the rock around it. This can make the crack larger. When the ice melts during the warmer day, water fills the crack again. The next night, ice forms again and makes the crack even larger. This process is repeated many times until part of the rock is split off. This process is called **frost shattering**.

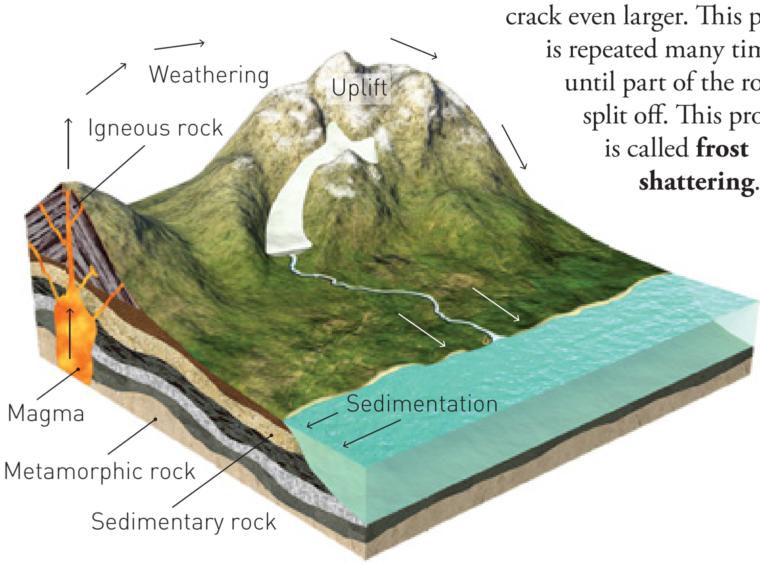

Figure 2.30 The rock cycle.

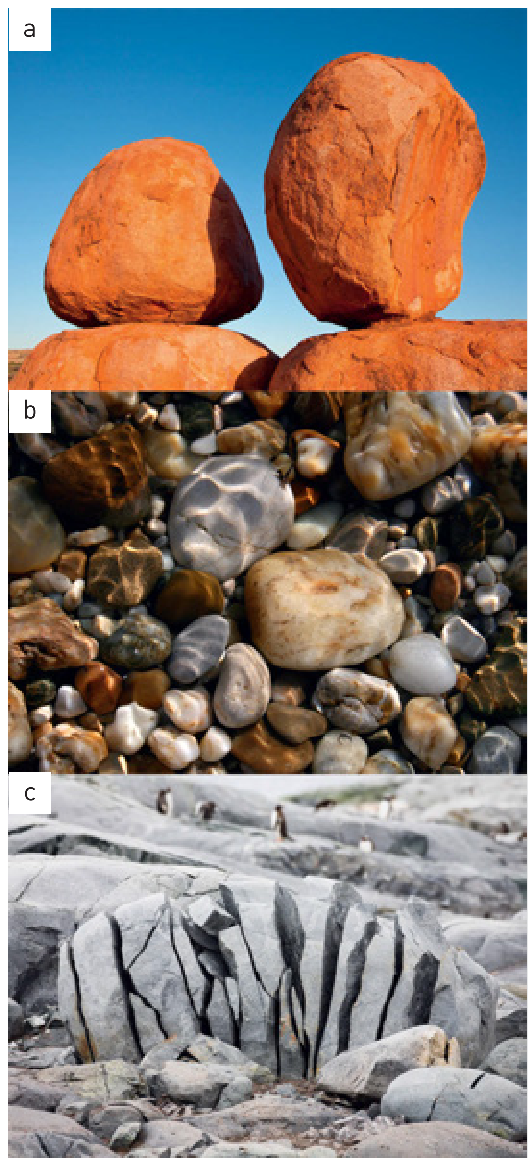

Figure 2.31 Physical weathering can include (a) onion-skin weathering, (b) abrasion in moving water and (c) frost shattering.

SKILLS LAB 2.7: MODELLING THE ROCK CYCLE
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Chemical weathering

Chemical weathering changes the minerals in the rock. Carbon dioxide in the air mixes with the water to form a weak acid rain (a much weaker acid than vinegar). When the acid rain falls on rocks such as limestone, a chemical reaction changes the minerals in the rock and the minerals are washed way (eroded). You can see evidence of this type of weathering in old statues.

Figure 2.32 Chemical weathering can be caused by acid rain.

Biological weathering

Biological weathering can start with a seed falling into a crack in the rock. Soil in the rock encourages the seed to grow. As the roots grow, they push on the cracks in the rock, eventually causing the rock to break.

Over time, the large rocks are broken down into smaller rocks, which are broken down into sediment. The sediment is carried by wind and water to an area where it accumulates. Gradually, the sediment becomes buried under many layers, re-forming as sedimentary rock.

Heat and pressure

As more layers form on top of the sedimentary rock, it is put under pressure. Over time the layers sink deeper to where the temperatures start increasing. Increased temperature and pressure causes physical and chemical changes in the rock, transforming it into metamorphic rock. If the temperature continues to rise, the rock will melt, turning it into its liquid form, magma.

Magma is also put under great pressure, causing it to seek any available space. Gradually it makes its way to the surface where it can cool as igneous rock. Over time it is exposed to wind and water. The cycle continues.

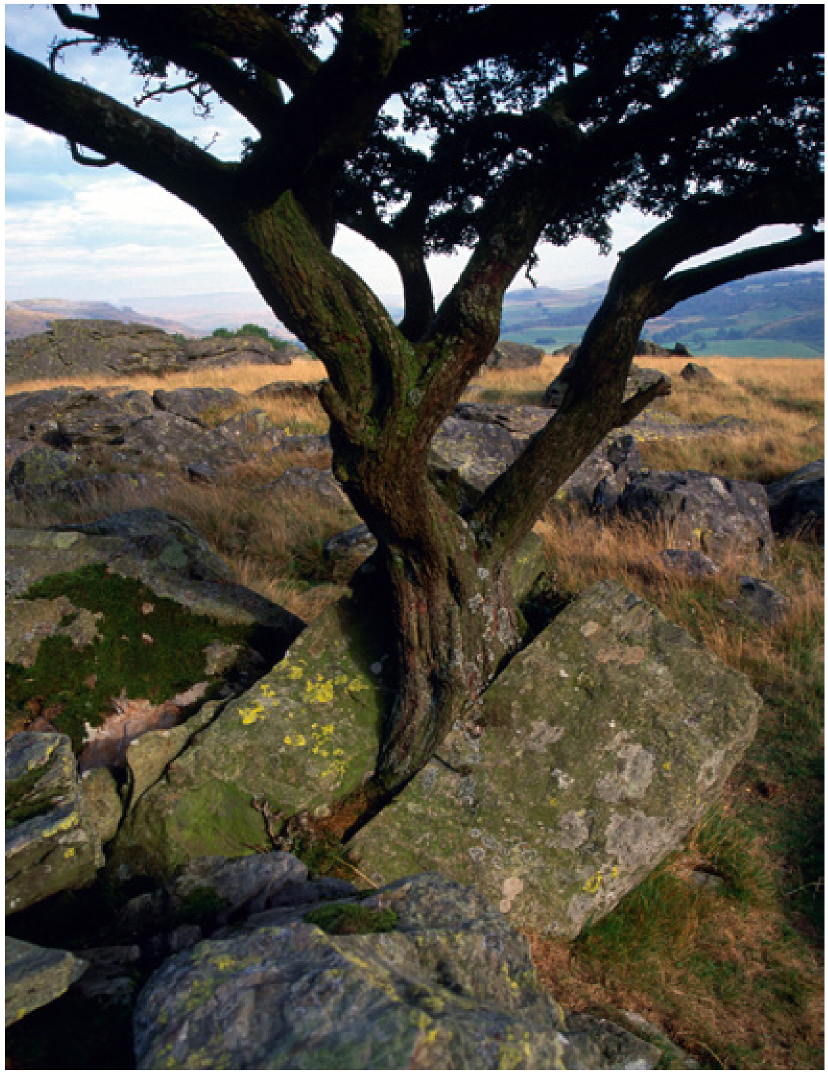

Figure 2.33 Biological weathering can be caused by plant roots.

Check your learning 2.7

Remember and understand

1 Describe the different stages in the rock cycle. Use the rock cycle diagram in Figure 2.30 to assist you.

Apply and analyse

2 Write a creative story of the 'life of a rock'. Rocks change with time, as do humans. However, unlike humans, rocks are never truly 'born', nor do they 'die' – they can move through the rock cycle, covering the same stage many times in many different ways. What life does your rock experience?

//SCIENCE AS A HUMAN ENDEAVOUR//

2.8 Weathering and erosion can be prevented

Figure 2.35 Footpaths, roads and roofs affect how water moves around the land.

Humans are very good at changing their environment to suit their needs. However, this has changed the rate of rock weathering and erosion. This has resulted in flooding and poor food production. Soil erosion engineers are helping to solve this problem.

Preventing erosion

The population of Australia has been steadily increasing for many years and as a result we have needed to build more houses and grow more food. Building houses means building roads and footpaths around the houses. Instead of trees and grasses lining a riverbank, footpaths and roads can be built right up to the edge of the water flow.

The roots of plants interlace the soil, helping it resist the movement of wind and rain. If plants are removed, then the topsoil will erode.

Rain falling on concrete paths and roads is not absorbed into the soil. Instead, it flows off the road and carries away further soil layers. This can slowly remove the support beneath the built structures, causing them to collapse. The loose soil and rocks can trigger damaging mudslides. Engineers are responsible for developing ways to solve this problem.

Figure 2.34 Australia's population has increased dramatically since the beginning of the 20th century.

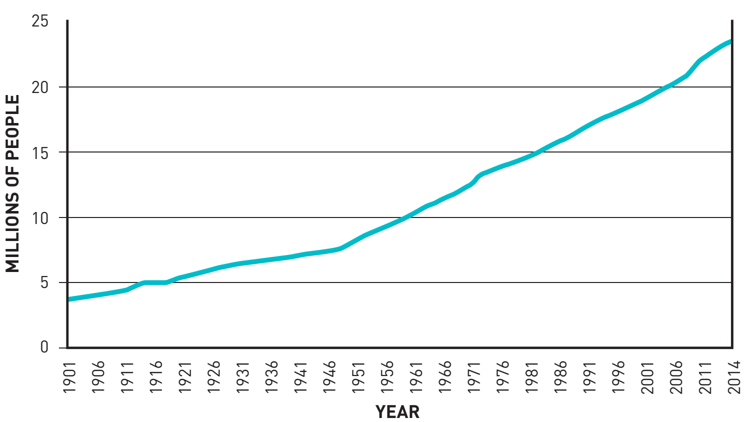

Figure 2.36 Soil erosion can lead to many problems.

CHALLENGE 2.8: PREVENTING SOIL EROSION
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Engineering solutions

Figure 2.37 Engineers try to minimise erosion by controlling the flow of water with dams and levees.

Figure 2.38 Groynes are built on beaches to remove some of the energy of the waves. They protrude from the beach and trap the sand, preventing its erosion.

Figure 2.39 Terraces may be built to allow water to follow a set path that is protected from erosion by man-made structures such as drains, or by plants. This reduces the force of the water, making it less likely to cause damage.

Figure 2.40 New products have been developed that allow water to move through instead of contributing to run-off. This allows the water to be absorbed into the soil and join the groundwater.

Figure 2.41 Temperature erosion causes materials such as concrete to crack. Footpaths have grooves in them to allow for their expansion during hot weather.

Figure 2.42 Regular cleaning prevents the build-up of moss and pollution that might contribute to biological or chemical erosion.

Extend your understanding

1. What is the difference between weathering and erosion?
2. Name two ways erosion can affect food production.
3. What does a soil engineer do?
4. How could an engineer prevent erosion of soil by water?
5. Find an area near your school that has been affected by erosion. Suggest a way that you could prevent further erosion.

2.9 Rocks are studied by geologists

Planet Earth is 4.5 billion years old. The events on Earth are recorded in the rocks. From about 570 million years ago, the ancestors of the different plants and animals that now populate Earth evolved. The remains of some of these life forms are captured in the rocks as fossils. Fossils allow specialist geologists, known as **palaeontologists**, to build up a picture of Earth's long history.

Figure 2.43 Broome in Western Australia is the site of many trace fossils such as these footprints.

What are fossils?

Fossils are the remains (or imprints) of animals or plants preserved in rock.

A fossil is evidence of life in the past. Fossilised evidence may be found in many forms, but usually consists of the hard parts that remain after decay – bones, teeth and shells. Sometimes, softer parts of an organism are preserved and even footprints or impressions of organisms are considered fossils. Palaeontologists study these remains to find clues about ancient life.

Figure 2.44 If the conditions are just right, soft body parts can be fossilised.

How do fossils form?

Fossils are usually only found in sedimentary rocks. These rocks are formed by the deposition of layers of sediments, such as mud, silt or sand. Any organism trapped in the mud and silt can eventually become part of the rock through the process of fossilisation. The fossils can be uncovered when the rocks are broken apart or weathered away. This process can take millions of years.

Extremely old rocks contain fossils of simple animals, whereas slightly younger rocks have fossils of animals with shells. Rocks that are younger still have fossils of fish. Only the newest rocks have fossils of mammals. The variety and complexity of life has increased as the Earth has become older.

CHALLENGE 2.9A: USING EVIDENCE TO DEDUCE
GO TO PAGE 166.

CHALLENGE 2.9B: RECONSTRUCTING ANIMALS
GO TO PAGE 167.

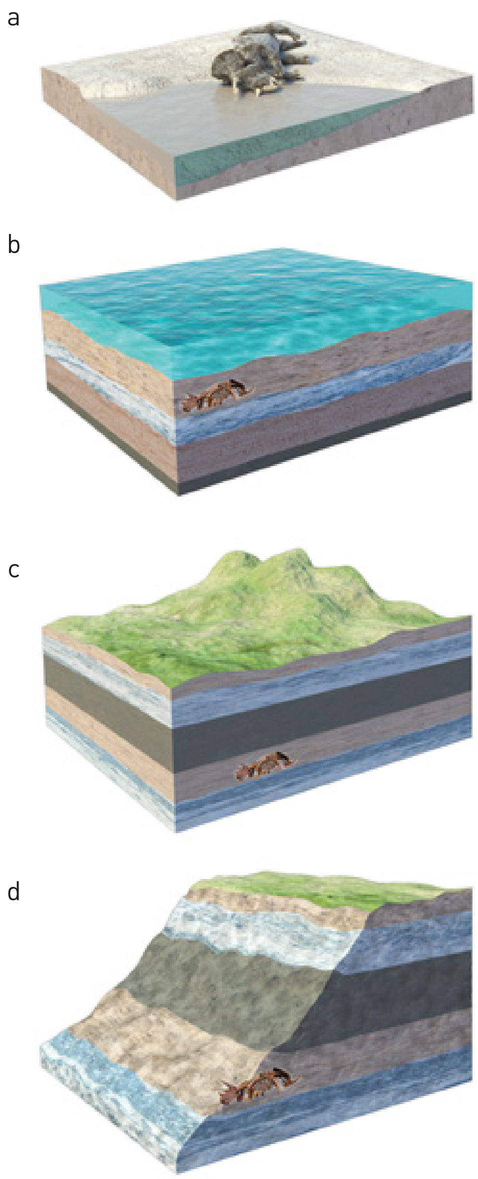

Figure 2.45 Formation of a fossil. (a) If an organism dies near water, it has a greater chance of being covered by sediment. (b) The sediment protects the body from predators and weathering. (c) Over millions of years, more sediment is deposited and the remains are gradually transformed into sedimentary rock. (d) Years of geological movement, weathering and erosion may eventually expose the fossil.

Comparative dating

Geologists can place rocks and fossils into a date order. They work this out from the different layers of sediment in rocks. When layers of sand or mud are deposited, the oldest sediments are at the bottom. Newer, or younger, sediments are deposited on top (see Figure 2.46). Working out the age of rocks as being younger or older than rocks of known age is called **comparative dating** or relative dating. It is comparative because we are comparing the old with the new, the bottom layers with the top.

Different rocks that are the same age have the same type of fossils in them. These fossils are called **index fossils**. They are used to find rocks of the same age.

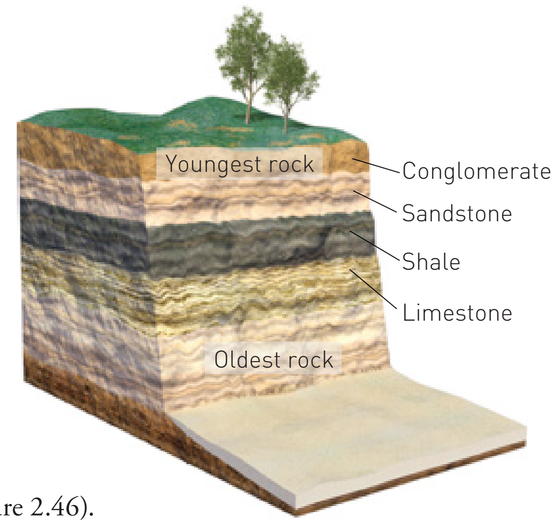

Figure 2.46 Comparative dating is used to determine the age of rocks and fossils.

Radioactive dating

The actual age of a fossil, measured in millions of years, is found by looking at the amount of radioactivity left in rocks. For example, uranium (U) is a radioactive substance found in many rocks. It decays to lead (Pb) at a known rate. So, as rocks age, the amount of uranium decreases and the amount of lead increases. The age of rocks can be calculated by comparing the amounts of uranium and lead they contain. This is called **radioactive dating**.

The oldest rocks on Earth have been dated at 4500 million years. This method has been checked using different radioactive atoms. This age is the same as that of meteorites that crash to Earth, as well as that of Moon rocks brought back to the Earth by astronauts.

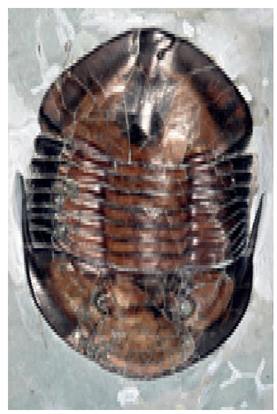

Figure 2.47 This trilobite fossil has been dated to 500 million years ago. The fossils of some trilobites are the size of beetles, whereas others are the size of dinner plates.

Extend your understanding

1 What are fossils?
2 How are fossils formed?
3 What can fossils show us or tell us about the Earth's history?
4 What are geologists who study fossils called and what sorts of things do they do as part of their job?
5 How do scientists find out how old a rock is?

2

Remember and understand

1 Copy and complete the following sentences.

a An _________ is a mineral with a large amount of useful metal in it.

b _________ rocks are formed when loose particles are pressed together by the weight of overlying sediments.

c _________ rocks are formed when other types of rocks are changed by heat and pressure inside the Earth.

d _________ rocks form when magma and lava from volcanic eruptions cool and solidify.

2 Define:

a lustre

b streak

c hardness.

3 What is the difference between magma and lava?

4 How do geologists identify minerals?

5 Why is colour not a reliable guide for identifying minerals?

6 What properties of gold made it valuable to early civilisations, such as the Incas of South America?

7 How would you tell the difference between intrusive and extrusive igneous rocks?

8 Cave systems in limestone rock follow the course of underground rivers. Why is water necessary to form caves?

9 Explain why only simple fossils are found in the oldest types of rocks, whereas younger rocks have fossils of mammals.

10 Design a flow chart of how fossils are formed.

Apply and analyse

11 Why do sedimentary rocks form at the Earth's surface?

12 Why does pumice have no crystal structure even though it is a rock?

13 Explain the difference between weathering and erosion.

Evaluate and create

14 If you were a palaeontologist searching for fossils, which types of rocks would you look for? Explain.

15 A kitchen scourer can be used to clean stainless steel cutlery, but this type of scourer should not be used to clean silver-plated cutlery. Explain why.

16 Explain a way to remember which way stalactites and stalagmites grow.

17 Why should we recycle minerals? What minerals can be recycled? What forms can they be used in once they have been recycled?

18 Some famous works of art are made of marble. What are the properties of marble that make it ideal for sculpture? What are some of the properties of marble that may not make it appropriate for all works of art?

Critical and creative thinking

19 Some people say that Australia is a huge quarry. This is because Australia mines so many minerals and sells them. Working on your own, list the advantages and disadvantages of mining and selling minerals. Join with a classmate and combine your lists. Then join with another group and prepare another list containing the three best reasons for mining and the three best reasons against mining.

20 Look at Figure 2.48, which shows the Twelve Apostles. Use this image to describe how these rocks were formed. Prepare a poster to show how the rocks were formed and would have changed over time. How will they look in 1000 years' time?

21 Imagine you are a geologist who is going to discover minerals in a remote part of Australia. You will need to take a test kit to help you identify the minerals you find. What items should go into your kit to allow you to test for streak, hardness and so on?

Figure 2.48 The Twelve Apostles, located off the coast of Victoria.

Research tasks

22 Choose one of the following topics for a research project. Some questions have been included to help you begin your research. Present your report in a format of your own choosing.

a Formation of oil

Oil is formed from the compression of dead marine-plant material in mud over millions of years. Oil is made up of hydrocarbons, which are lighter than rock and water, so it often migrates up through porous rock towards the Earth's surface.

- What is an oil reservoir?
- What conditions are needed for an oil reservoir to form?
- How is an oil field formed?
- In what other forms is oil found?

b Gemstones

- Which gemstones are found in Australia?
- Which gemstones are dug up by recreational fossickers?
- What do the gemstones look like?

c Extraction of metals

Metals are extracted from ore using a variety of methods. Some are heated, some are purified using electrical energy, and some are extracted using chemical processes. Why are different metals extracted using different chemical or electrical processes? Find out how some metals are extracted, such as copper and aluminium, and design a poster that shows the process of extraction.

KEY WORDS

2

cleavage
number of smooth planes a mineral breaks along

colour
property of rocks and minerals used to identify them

comparative dating
determining the age of rocks by comparing them to rocks of known age

crystal
small, organised particle in rocks, which has smooth sides and sharp edges

erosion
movement of sediment to another area

extrusive igneous rock
rock formed at the Earth's surface by quickly cooling lava

foliation
occurs when rock is subjected to uneven pressure

fossil
remains (or imprint) of an animal or plant preserved in rock

frost shattering
process of weathering in which repeated freezing and melting of water expands cracks in rocks so that eventually part of the rock splits off

geologist
scientist who studies rocks

grain
small rock particle; grain size can be used to identify rock type

hardness
how easily a mineral can be scratched; measured on the Mohs hardness scale

igneous rock
rock formed by cooling magma and lava

index fossil
fossil found in different rocks, that can be used to determine age of rocks

index mineral
a mineral that only forms under a particular temperature and pressure; used to determine the history of the mineral

intrusive igneous rock
rock formed underground by slowly cooling magma

layer
property of rocks used to identify them

lava
hot, molten rock that comes to the surface of the Earth in a volcanic eruption

lustre
shininess

magma
hot, molten rock inside the Earth

metamorphic rock
rock formed from other rock that has experienced intense heat and pressure

mineral
naturally occurring solid substance with its own chemical composition, structure and properties

onion-skin weathering
weathering of rock where the outside of the rock peels off

ore
mineral containing a large amount of useful metal

palaeontologist
scientist who studies fossils

property
characteristic

radioactive dating
determining the age of rocks by comparing the amounts of uranium and its decay product lead

rock cycle
process of formation and destruction of different rock types

sedimentary rock
rock formed from compacted mud, sand or pebbles, or the remains of living things

streak
colour of powdered or crushed mineral

tor
round rocks produced by onion-skin weathering

weathering
breakdown of rocks and minerals by movement of water and animals, and extremes of temperature

weight
property of rocks used to identify them

ENERGY 3

3.1 Energy can be transferred

3.2 Potential energy is stored energy

3.3 Moving objects have kinetic energy

3.4 Energy can be transformed

3.5 Energy cannot be created or destroyed

3.6 Energy efficiency can reduce energy consumption

3.7 Solar cells transform the Sun's light energy into electrical energy

3.8 Engineers use their understanding of energy to solve problems

What if?

Rolling cars

What you need:

ramp, permanent marker, large toy car, tape measure, weights, Blu Tack

What to do:

1 Set the ramp up on the floor so it is at an angle.
2 Draw a starting line at the top of the ramp.
3 Place the large toy car on the starting line. Release the car.
4 Measure how far the car rolls from the bottom of the ramp.

What if?

» What if weight were added to the car? Would it roll further?
» What if the ramp were placed at a different angle?
» What if the ramp were longer?

3.1 Energy can be transferred

All objects have energy. Energy is the ability to do work. It is how things change and move. It cannot be created or destroyed. Moving objects, stretched objects and objects high off the ground all have energy. When energy is passed from one object to another, it is said to be **transferred**.

Figure 3.1 We use energy to walk and carry things.

Where does energy come from?

We have all felt the energy of the Sun on a hot day. It can warm our skin and even cause sunburn. Plants are very efficient at absorbing the energy of the Sun. The energy is transferred from the Sun to the plant. This can be shown using a flow diagram (see Figure 3.2) where an arrow shows the direction of energy flow.

The plant uses the energy to grow. Eventually animals (including us) eat the plants and the energy is transferred again (see Figure 3.3).

We use the energy for moving, including walking. This also produces heat that then warms up the air around us (see Figure 3.4).

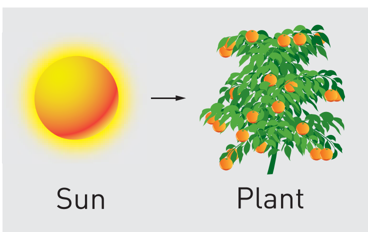

Figure 3.2

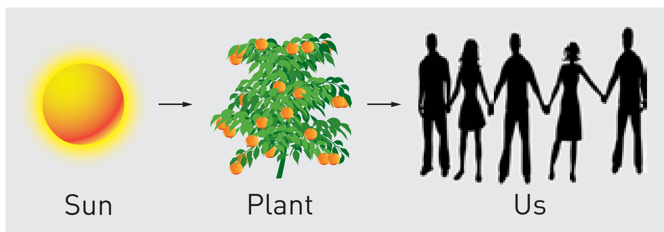

Figure 3.3

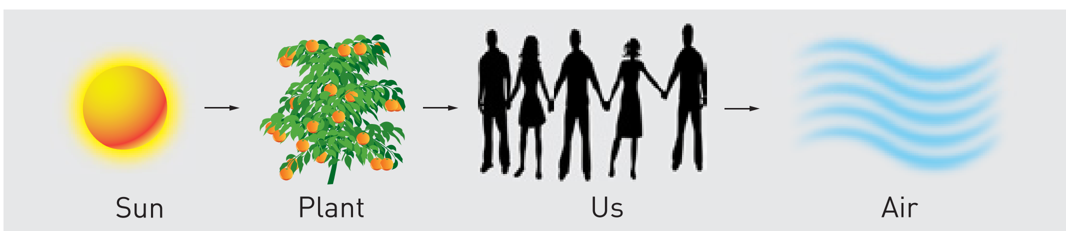

Figure 3.4

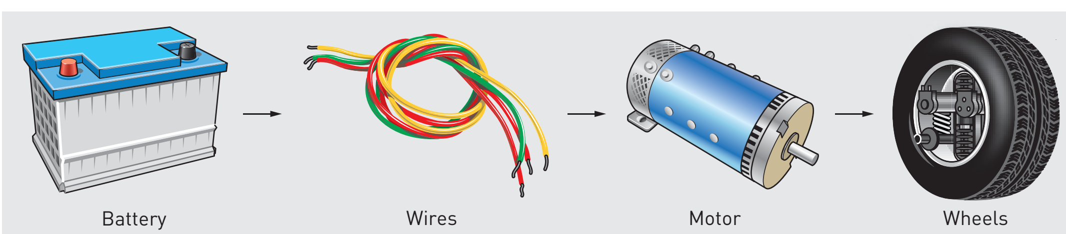

Figure 3.5

SKILLS LAB 3.1: DRAWING FLOW DIAGRAMS OF ENERGY TRANSFER
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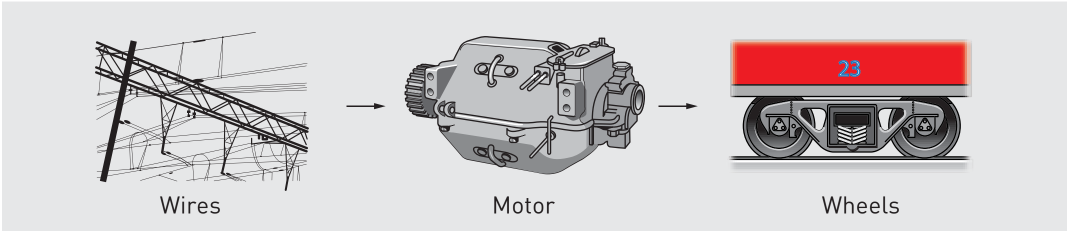

Figure 3.6

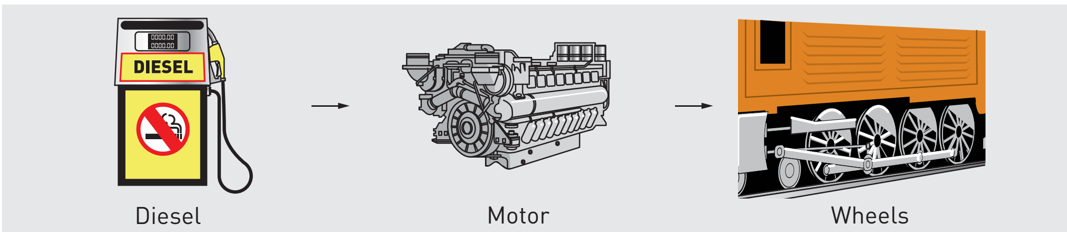

Figure 3.7

Where does energy go?

Electric cars are being designed to use the energy stored in batteries, rather than petrol, to power an electric motor that makes the wheels turn. This can be shown using a flow diagram (see Figure 3.5).

Public transport uses energy too. Trams and metropolitan trains transfer the electrical energy from the overhead wires into the motor that makes the wheels move (see Figure 3.6).

Trains that travel to country areas or interstate usually run on diesel fuel and don't need overhead electrical wires. The engines in these trains burn diesel fuel, transferring the energy into wheel movement via the motors (see Figure 3.7). Ships and planes use a similar process in their engines.

Figure 3.9 Powerlines provide electrical energy for public transport.

Figure 3.8 Hybrid cars use both a petrol engine and an electric motor to send power to the wheels.

Figure 3.10 Aircraft use higher quality fuels than road transport vehicles to minimise weight and waste.

Figure 3.11 Powerlines aren't practical in rural areas, so diesel fuel is used.

Figure 3.12 Earphones transfer energy in batteries to our ears as sound.

Figure 3.13 The internal components of a mobile device.

Energy transfers for entertainment

Both CD and DVD players need to transfer energy from the batteries to wires. The energy is then transferred to a laser light, enabling it to read the information stored on the CD or DVD. Tiny microscopic pits on the disc make up the digital code – a bit like a miniature version of Braille used by the visually impaired. The laser, which is a very pure type of light, reads the code, transferring its energy to the speakers and the screen.

A mobile phone also uses a speaker to produce the sound of a person's voice or the various ring tones and beeps that the phone makes. Home phones use a speaker too, as do televisions, CD systems, radios and many other devices. They all transfer energy from the battery to the wires, then to the speaker to make sound.

A television **remote control** transfers energy from the device through the air as light, and into the television set (see Figure 3.14). In fact, most remote controls use infrared light, which is the invisible type of light usually associated with heat. The remote control sends a pulse of infrared light that represents a particular command, such as to change the channel or increase the volume. An infrared light detector on the television receives the light signal and transfers it back into electrical energy, which then carries out the command.

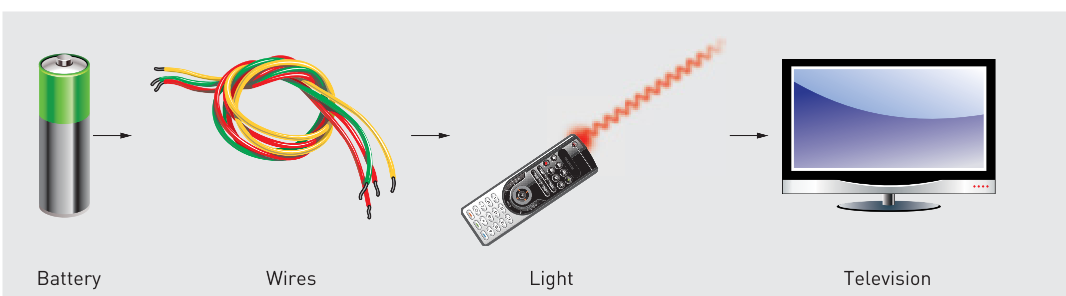

Figure 3.14

Figure 3.15 A television remote control uses an infrared light-emitting diode (LED) to operate the television.

Check your learning 3.1

Remember and understand

1 What is energy?

2 What type of devices could the following flow diagrams represent?

a wires → motor → air

b battery → wires → light globe

c sun → muscles → bicycle

3 Make a summary of the entertainment devices mentioned in this section and draw flow diagrams for the energy transformations they perform.

4 Why is the direction the arrows point in a flow diagram important?

5 Copy Figure 3.16 and label each stage in the flow diagram.

Apply and analyse

6 Why do country trains mostly use diesel instead of electrical wires?

7 How important is energy for transport?

8 What is the ultimate source of all energy?

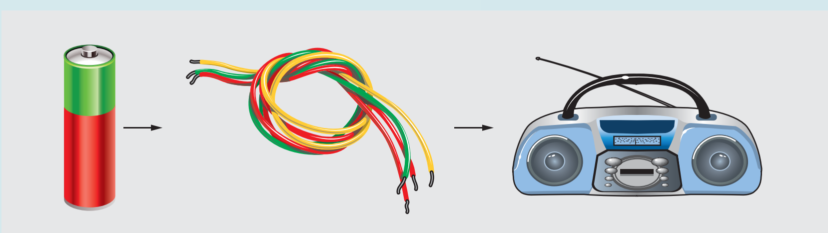

Figure 3.16

3.2 Potential energy is stored energy

Potential energy is energy that is stored in objects and is waiting to be used. This stored energy can be the result of a change of shape (stretching or squashing) or an object's height above the ground. This energy can be stored in many forms. Gravitational potential energy is the energy stored in an object that is high above the ground. Elastic potential energy is the energy stored in an object that has changed in shape. Chemical potential energy is the energy that is stored in any chemical. Nuclear potential energy is the energy stored in the centre of an atom.

Figure 3.17 Power riser jumping stilts rely on elastic potential energy.

Elastic potential energy

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

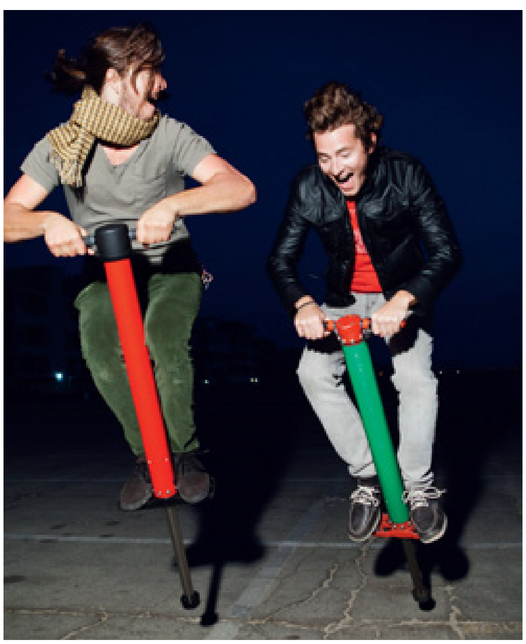

Figure 3.18 Pogo sticks release the elastic energy of springs to provide motion.

Gravitational potential energy

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

The larger the mass and the larger the height, the more GPE the object gains. Have you ever noticed that falling a greater distance produces a greater 'thud' and can hurt more? This is because of the amount of GPE. As an object falls down, the object's GPE can be

Figure 3.19 This television has GPE when raised above the ground.

EXPERIMENT 3.2: WHAT IF THE AMOUNT OF ELASTIC POTENTIAL ENERGY WERE INCREASED?
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transformed into other forms of energy. This happens when a person plays on a slide at the playground. The higher they climb, the more GPE they get. When they slide down, the GPE decreases. The person gains movement energy. They may also feel the friction of the slide as heat or even as a zap of static electrical energy.

Chemical potential energy

After we have done a lot of exercise, we often crave foods that we believe will restore our energy levels. These foods, usually sweet things, release stored chemical energy really quickly to satisfy our cravings. All foods have some energy stored in them, but the difference is how quickly the energy can be released.

Figure 3.20 Energy drinks contain chemical potential energy.

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

These devices all contain chemical potential energy that can be released when we need it. Some batteries can be recharged – the **chemical potential energy** (CPE) can be replaced.

Nuclear energy

Although nuclear energy is used throughout the world, it is not used in Australia. **Nuclear energy** involves the reaction at the centre of atoms. When atoms react in chemical reactions, they usually release only small amounts of energy. However, if the centres or nuclei of those atoms can be made to react, the amount of energy released is much, much larger. In fact, the amount of energy released is so huge that it can cause massive amounts of destruction.

Figure 3.21 The energy released from a nuclear explosion is much, much greater than that from other types of explosions.

Check your learning 3.2

Remember and understand

1 List four examples of devices or situations that involve potential energy.
2 What type of energy is stored in a battery?
3 We get our energy from the chemicals in food. What type of energy is this?
4 Biofuel is an alternative source of energy that comes from burning the energy stored in plants. What type of potential energy is biofuel?
5 Describe four devices, other than those mentioned already, that possess elastic energy.

Apply and analyse

6 Describe how a person might use a bow to shoot an arrow. What type of potential energy is used in this process?
7 Name three countries that use nuclear power to generate electrical energy.

Figure 3.22 Plastic slides are great at zapping us with static electricity, although it depends on the weather and the clothes we wear.

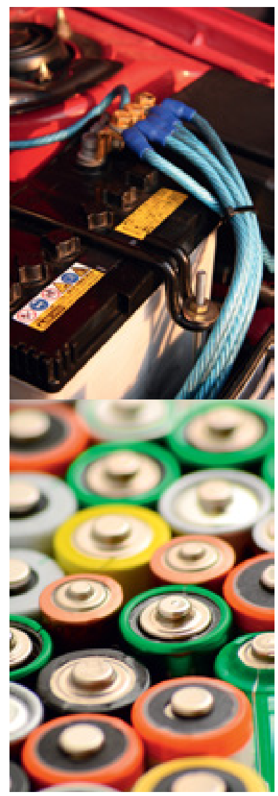


Figure 3.23 The CPE in batteries can be transformed into electrical energy to power almost anything.

3.3 Moving objects have kinetic energy

The energy of movement is more scientifically called **kinetic energy** (KE). Whenever objects or people move, they are using kinetic energy. The most common way we think of kinetic energy is when we see a moving object. It takes energy to force an object such as a car to start moving. Once it is moving, the energy has passed to the car. It is this energy that is called kinetic energy. The faster the object is moving, or the more mass the object has, the greater the kinetic energy. Even objects too small to be seen can have kinetic energy.

Figure 3.24 Kerosene lamps were used for many years before the invention of electricity.

Light energy

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

Light energy is one type of energy that our eyes can usually detect. We see a range of colours (red, orange, yellow, green, blue and violet) in the visible spectrum, but the light we see is part of a larger group that is called electromagnetic radiation. This large group includes ultraviolet light, microwaves and x-rays. The study of light energy is known as optics.

The main reason life exists on Earth and not on other planets is because our atmosphere allows the right amounts of the different forms of light energy coming from the Sun to reach the surface. Plants rely on the light and heat from the Sun to make their own food and, of course, to provide food for animals.

Figure 3.25 Sunlight is essential for all life on Earth. Without it, it is doubtful whether life would exist.

CHALLENGE 3.3: EXPLORING SOUND ENERGY
GO TO PAGE 171.

Figure 3.26 Solar-powered speed signs are becoming common all across our country and help save energy too.

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

Heat energy

Heat energy is more scientifically known as **thermal energy**. Thermal energy can be generated by friction, such as by rubbing your hands together or by the rubbing of the tyres on the road. It is also commonly generated by burning chemicals or by electrical devices. We experience heat energy being transferred from a high temperature place to a lower temperature place as we heat up or cool down. For example, an ice block feels cool because it takes the thermal energy away from our hands.

Figure 3.27 The heat of a 'burn-out' creates great clouds of smoke.

Electrical energy

All substances are made up of positive and negative electric charges that, when separated, have **electrical energy.** This means that they are in a state of excitement and are trying to get back together again. If the positive and negative charges are locked together in one area, such as a wire, the separated charges can easily move back together. As they try to connect, the electrical energy they had when separated gets changed into the light, heat or movement we are used to seeing from electrical lights, heaters or motors.

Sound energy

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

Check your learning 3.3

Remember and understand

1. What is the scientific term for 'movement energy'?
2. What is moving in electrical energy?
3. What is moving when a guitar produces sound energy?
4. What is another name for heat energy?
5. What are solar cells used for?
6. What features of a car would absorb the driver's kinetic energy in a collision?

3.4 Energy can be transformed

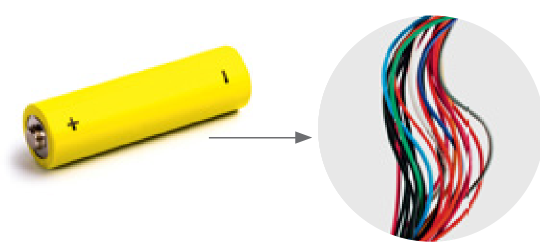
When energy is changed from one type of energy to another, we say it has been **transformed**. For example, when the energy in a battery is transferred to the wires in a circuit, the energy is transformed from chemical potential energy into electrical energy. Water at the top of a waterfall has gravitational potential energy. This is transformed into kinetic energy as the water moves down to the bottom of the waterfall. Before investigating energy transformations, there are a few things you need to know.

Flow diagrams

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

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

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



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

In some devices there are several energy transformations that make up an energy story, resulting in an energy chain. For example, the energy story in a mobile device would be described in the following way:

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

As a flow diagram, this energy chain would be:

Figure 3.28 Chemical energy in the mobile device battery is transformed into the sound energy that we hear.

CHALLENGE 3.4: ENERGY CONVERTERS
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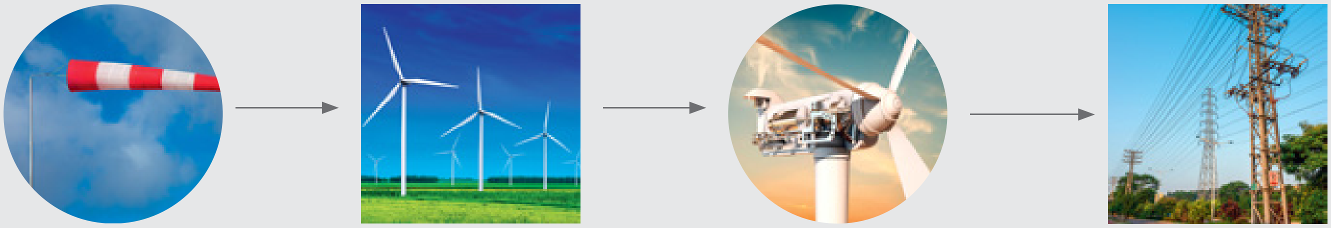

Figure 3.29

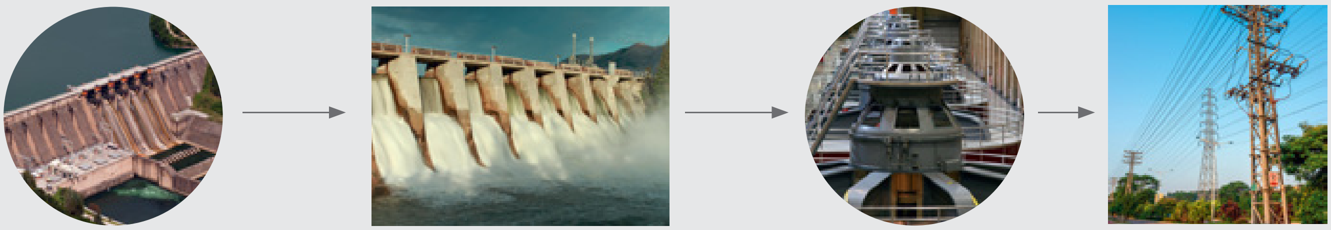

Figure 3.30

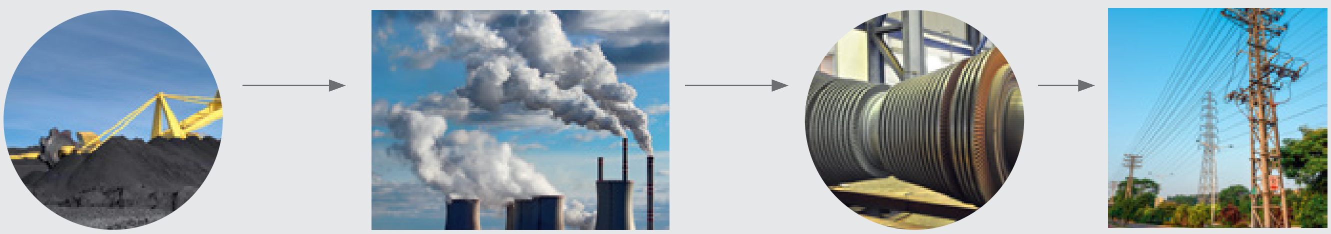

Figure 3.31

Generating electricity

There are many ways of generating electricity. Wind generators use the wind to turn a turbine. The kinetic energy of the wind is transferred to the kinetic energy of the turbines. The turbines then transform this energy into electrical energy (see Figure 3.29).

Hydroelectricity plants have large dams that store water. The large amount of water is usually part of the way up a hill. Therefore the water has gravitational potential energy. Pipes control the flow of water down through the turbine, transforming the gravitational potential energy into kinetic energy of the turbine (see Figure 3.30).

Coal based electricity generators use the coal to heat water. The resulting steam rises, forcing the turbines to turn and transforming the kinetic energy into electrical energy (see Figure 3.31).

You use the electrical energy that comes from these generating plants for many different things: charging your mobile phone, cooking dinner, turning on a light. Energy may take many shapes or forms before you can use it.

Check your learning 3.4

Remember and understand

1. For each of the electricity generators above, draw a flow diagram of the energy transformations.
2. Where does the energy stored in coal come from?
3. What is the difference between energy transformation and energy transfers?
4. Suggest one way energy can be transferred without being transformed.

Apply and analyse

5. Draw a flow diagram for the main energy transformation for a car.
6. Draw an energy chain for how we get our energy from eating an apple. (Hint: Start with the Sun!)

3.5 Energy cannot be created or destroyed

Energy cannot be created or destroyed. This is called the **law of conservation of energy** and can be seen in any energy transformation. Sound and heat energy are often generated as a result of energy transformation. As these forms of energy are difficult to reuse, they are called waste energy. Efficient transformations produce less waste energy.

Law of conservation of energy

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

This is considered the law of conservation of energy. No energy can be created or destroyed. The energy at the end must be equal to the energy present at the beginning. When you lift an object up in the air, you are adding gravitational potential energy. This energy did not just appear. The kinetic energy of your hand was conserved and transformed into the gravitational energy of the object. When the object is dropped, the energy is not destroyed. The gravitational energy is once again transformed into kinetic energy.

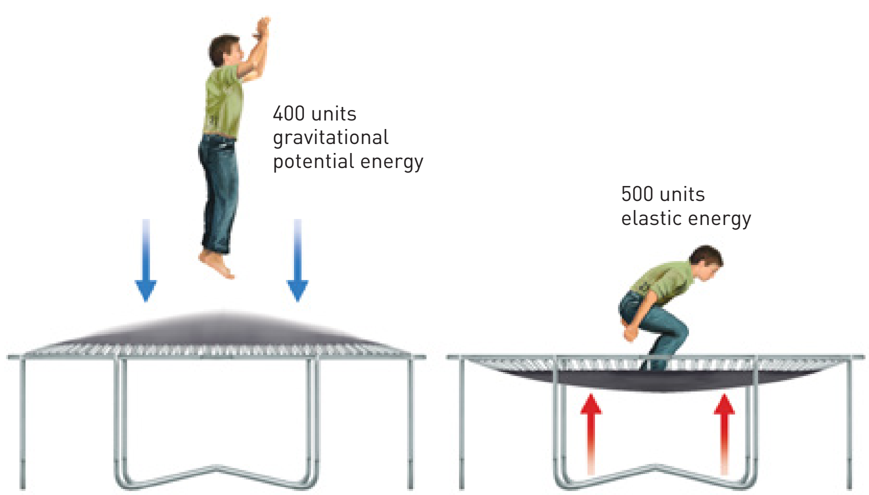

Figure 3.32 Five hundred units of energy are stored in the springs of the trampoline. At the highest point, the jumper has 400 units of gravitational potential energy. Where have the 100 'missing' units gone?

Energy efficiency

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

$$\text{Efficiency} = \frac{\text{Useful energy output}}{\text{Energy input}} \times 100$$

Take the trampoline example in Figure 3.32. The input energy was 500 units and the useful output energy was 400 units. This means that the trampoline is 400 ÷ 500 × 100 = 80% efficient, which is not too bad. Most energy transformations for everyday appliances don't get this high. Scientists are constantly trying to design the best appliances possible with the highest efficiency ratings. This would make them better for the environment and cost less to power. Do you and your family always buy the most efficient appliances? Are you familiar with the star ratings on appliances? More stars mean that the appliance is more energy efficient. Not only is it good to know that less energy is being wasted, but it also means that, on your electricity and gas bills, you are paying for energy that is being used rather than for energy that is being thrown away.

EXPERIMENT 3.5: WHAT IF YOU BOUNCED A BALL?
GO TO PAGE 172.

Heat and sound waste energy

If no system is 100% efficient, but the energy cannot be destroyed, then where does the energy go? In most cases, the energy is transformed into heat and sound energy. Think what happens when you drop a ball on the ground. The ball starts with gravitational potential energy, which is transformed into kinetic energy when you drop it. When the ball hits the ground it makes a noise. The larger the noise, the more sound energy was generated. If you bounce a ball many times in a row, you might be able to feel the ball start to warm up. Heat energy is generated. Both the heat and sound energy dissipate into the air. They are not lost or destroyed. We cannot reuse them. They are by-products of the main energy transformation.

Check your learning 3.5

Remember and understand

1 What is the law of conservation of energy?

2 The sun provides heat and light energy to our planet every day. If this energy is not destroyed, where does it go?

Apply and analyse

3 If you release a rubber band that had 10 units of elastic energy, 12 units of movement energy cannot be produced. Why not?

4 For the rubber band in question 3, what would its percentage efficiency be if 7 units of movement energy were produced? Where have the remaining 3 units of energy gone?

5 A student claimed energy was lost when she bounced a ball. Was she correct?

6 What are the by-product energy transformations for a car?

//SCIENCE AS A HUMAN ENDEAVOUR//

3.6 Energy efficiency can reduce energy consumption

* Knowledge and understanding of energy transformations is not just limited to scientists. A variety of people use this knowledge in their everyday lives.

Using electricity

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

Other heating devices, such as toasters, also use heating elements to convert electrical energy into heat energy. Heating elements are made of certain types of wires that heat up without melting when electricity flows through them. The thermal energy is then passed to the air, which then passes the heat to the bread, toasting it.

Microwave ovens cleverly convert electrical energy into microwaves, which heat our food. Electric ovens are like oversized toasters and can have a fan in them, as does a hair dryer. Gas ovens and stoves use the chemical energy of the gas to produce heat by burning the gas. The more efficient this transformation, the less energy is wasted.

Heating and cooling your house

No doubt your house has some sort of heating or cooling system, depending on where you live. You probably use electricity or gas to do this. In a hot environment, energy is needed to remove the heat from inside your home, allowing it to cool down. The warm air inside the house is moved over cool pipes in the air conditioner. The thermal energy of the house air is passed to the refrigerant inside the pipes and then is carried outside the house. If the house is well designed, then the thermal energy remains outside and the house stays cool.

Figure 3.33 Insulation prevents heat energy being transferred between the inside and the outside of the house.

Architects design homes to help control the flow of thermal energy. They can add a variety of features that help limit the amount of heating or cooling your house needs.

Insulation

Lining the inside of the walls, floors and roof of your house can make sure that the heat is not transferred between the outside air and the inside of the house. This means you will keep the heat inside on a cold day, and outside on a hot day.

Window awnings

One of the main places heat is transferred is through a window. On a hot day, the light and heat from the Sun easily penetrate a window.

CHALLENGE 3.6: DESIGN AN ENERGY EFFICIENT HOUSE
GO TO PAGE 173.

This transfers the heat into the house. An awning on a window can limit this. Limiting the number of windows facing the Sun can also help prevent the heat being transferred into the house.

Veranda

A veranda works much like an awning, but it also prevents the heat and light from the Sun from shining on the walls. This prevents the heat from being transferred to the walls, and then to the air inside.

Extend your understanding

1 Draw flow diagrams for the energy transformation process that happens in your house for:
   a heating during winter
   b cooling during summer.
2 A refrigerator cools the food inside it.
   a How do you think it does this?
   b Suggest possible energy transformations that may occur in a refrigerator.
3 How does an architect use their knowledge of energy efficiency?
4 How do window awnings and verandas keep a house cool in summer?
5 The temperature inside and outside a house was measured over 24 hours and displayed in Figure 3.34. From the graph, determine if the house was insulated. Give evidence to support your answer.

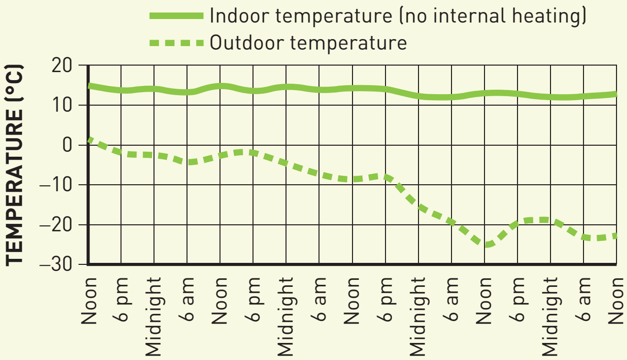

Figure 3.34

6 Study Figure 3.35, which shows how much energy is used by different household appliances.
   a Which appliance uses the most energy?
   b The clothes dryer uses more energy than the electric blanket. Use energy transformations to explain why.
   c Many people switch their appliances off at the wall rather than use the standby function (where the television is still on but the screen is dark). Use energy efficiency to explain possible reason for this.

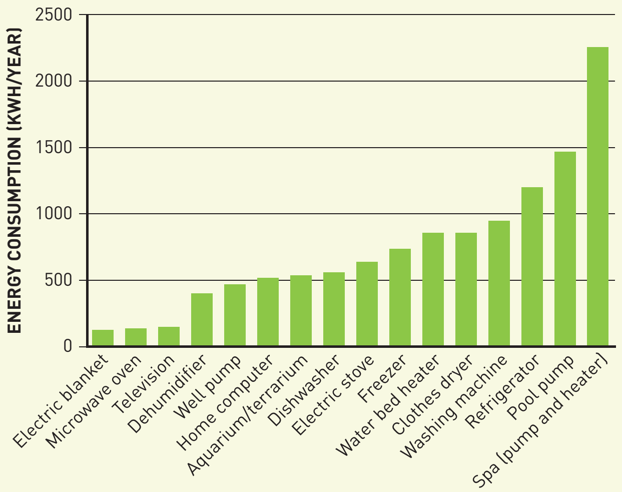

Figure 3.35

//SCIENCE AS
A HUMAN ENDEAVOUR//

3.7 Solar cells transform the Sun's light energy into electrical energy

*

A solar cell is any device that transforms the Sun's light energy into electrical energy. The number of households using light energy to heat water or power heating and cooling devices is growing rapidly every year. Eventually we may even use cars powered by solar energy to drive to school.

Using solar energy in Australia

Australia is often known as the sunburnt country. This is a reference to the large number of hours each day that the Sun shines. Australia is a big country and the number of hours varies greatly depending on the location and the time of year. Solar energy is often measured in the number of peak sunlight hours every day (see Figure 3.36). This is then averaged out over the whole year. For example, in the Hunter Valley in New South Wales, the number of peak hours can be as low as 4.0 hours/day in winter and as high as 6.5 hours/day in summer. Over a year this averages out to 5.6 hours/day. In Tasmania the average number of peak hours is 3 hours/day. In Queensland, Northern Territory and Western Australia, the average number of peak hours each day is 6.

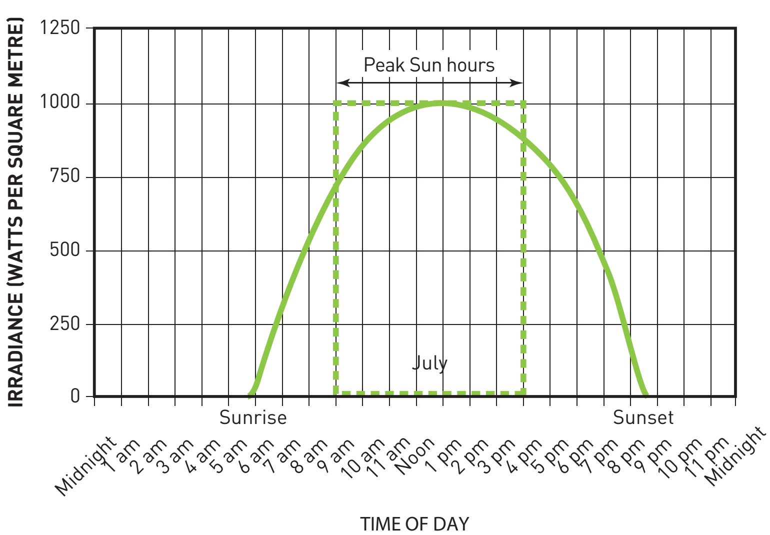

Figure 3.36

Converting light energy into chemical potential energy

Using light energy to power a house has its problems. The most common time people use electrical energy is not during the time that the light energy is available. This means the light energy often needs to be stored so that it can be used at night. The light energy is transformed into potential chemical energy in a battery so that it can be used to heat water, provide light or make energy for cooking.

Capturing the light energy

Solar panels are a collection of solar cells called **photovoltaic cells (PVCs).** When light shines on the surface of these PVCs, the light energy is transformed into electrical energy. The most efficient PVCs currently convert 30 per cent of the energy they receive from the Sun.

Solar cars

Most current solar-powered vehicles only carry one person. They are lightweight (approximately 600 kg) so that they are more energy efficient. Although using a solar car for your everyday travel is not currently practical, with more research it may be in the future.

CHALLENGE 3.7: DURING WHAT TIME OF THE DAY DOES THE SUN PRODUCE THE MOST ENERGY?
GO TO PAGE 174.

1883
First solar cell invented by Charles Fritts. Solar cell = selenium (semiconductor) with a thin layer of gold.

1941
Silicon solar cell invented by Russell Ohl has efficiency of 1%.

1954
Gerald Pearson, Calvin Fuller and Daryl Chapin improved the efficiency to 6%. Silicon strips were used to create the first solar panels.

1955
The first solar car invented was a tiny 35 cm vehicle created by William G. Cobb of General Motors.

1962
International Rectifier Company designed the first solar car that could be driven.They converted a vintage 1912 Baker electric car to run on approximately 10 640 PVCs.

1977
Alabama University professor Ed Passerini constructed his own solar powered car called 'Bluebird'.

1980
Englishman Alain Freeman road-registered a 3-wheeler solar car with a solar panel on the roof.

1980
Arye Baunstein and colleagues at Tel Aviv University (Israel) designed a solar car with a solar panel on the roof and hood of the car. The car was recorded reaching 65 km/h with a top speed of 80 km/h.

1982
Larry Perkins and Hans Tholstrup constructed and drove the 'Quiet Achiever', a home-made vehicle, from the east coast of Australia to the west coast. Their feat is recognised in the World Solar Challenge, a solar car race that allows solar car designers to compete in a race across Australia every two years.

1987
GM Sunracer completed a 3010 km trip in California with an average speed of 67 km/h.

2014
A solar-powered family car (with four seats) called 'Stella' was driven 613 km from Los Angeles to San Francisco.

1880 1890 1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000 2010

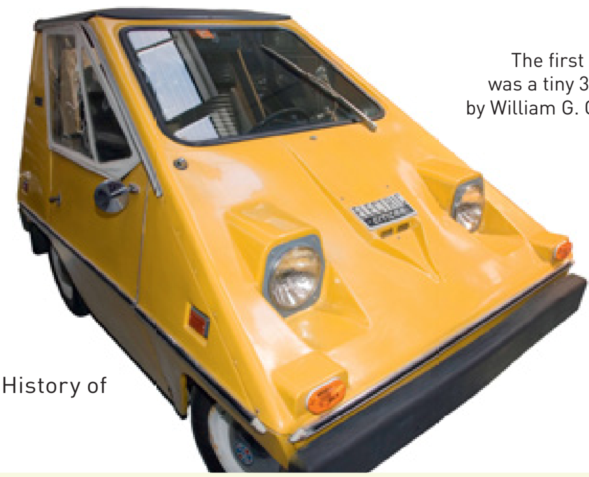

Figure 3.37 History of solar cars.

Extend your understanding

1. What advantages will solar cars have over petrol cars?
2. What do we call a cell that captures the light energy from the Sun?
3. Why does light energy often need to be stored as chemical energy before it can be used?
4. Use Table 3.1 to determine which city has the highest average amount of sunshine. How does this compare to your nearest city?
5. Research when the next World Solar Challenge will occur. How far is the race? Where does it start and finish?

Table 3.1 Solar energy production in Australian cities.

CITY	AVERAGE DAILY PRODUCTION OF 2 KW SYSTEM (kWh)
Adelaide	8.4
Alice Springs	10.0
Brisbane	8.4
Cairns	8.4
Canberra	8.6
Darwin	8.8
Hobart	7.0
Melbourne	7.2
Perth	8.8
Sydney	7.8

//SCIENCE AS
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3.8 Engineers use their understanding of energy to solve problems

Figure 3.39 Mechanical engineers work with forces and motion.

*The word 'engineer' comes from the Latin words *ingeniator* or *ingenium*, which literally mean 'ingenious one'. Engineers provide solutions, shape future developments and generate ideas that make life easier. All engineers are problem solvers, but some know how to solve specific problems better than others. People who study to become engineers often choose an area of interest and concentrate their skills in that field.

Figure 3.38 Water slides transform the gravitational potential energy of the water into kinetic energy. Reducing friction of the slide makes it more efficient.

Chemical engineers

Chemical engineers combine existing materials and develop new materials. These materials can then help other engineers build structures. Chemical engineers would also consider where the materials come from, whether they were being used sustainably and how much energy is required to process and transport them.

Mechanical engineers

Mechanical engineers deal with forces and motion – designing and improving things that have moving parts or have physical forces pushing or pulling them. This includes large structures such as water slides where the gravitational potential energy at the top is used to provide kinetic energy (speed) at the slide's base. Reducing the friction of the slide makes it more efficient, and therefore more of the potential energy will be transformed into kinetic energy (speed) at the base. Mechanical engineers have produced some of the most important and useful inventions in history including the zipper and the yo-yo!

Electrical engineers

Electrical engineers design and organise electrical equipment. This equipment may be used for satellites, computers and medical equipment. They are also involved in developing electricity supplies, including the development of alternative energy sources.

Civil engineers

Civil engineers research, plan and design structures. They know about the physical properties of materials. They are interested in how different materials perform under different conditions. For example, tall buildings need to remain secure in high winds.

EXPERIMENT 3.8: INVESTIGATING STRUCTURES AND MATERIALS USING ICY POLE STICKS
GO TO PAGE 175.

CHALLENGE 3.8: LEAKYWATER COUNCIL SWIMMING POOL AND WATERSLIDE
GO TO PAGE 176.

Evaluating a proposal

When engineers design and evaluate different options for a project there are three main points to consider.

1 Will the option do the job it is expected to do?
2 How well does the option do that job? Is there a better way?
3 Is the option cost-effective?

Other points also need to be considered, such as how long each option will take to build, cost, availability of materials and impact on the environment.

The simplest way to compare different options for a project is to use a **cost–benefit analysis**. In a cost–benefit analysis, an engineer makes a list of all the impacts of each option, such as the benefits to the community, potential profits to the owner and the environmental impacts. These are then compared to the cost of each option. When all the options have been analysed in this way, the engineer can more easily compare the options and decide which one is best. The best option would have the most benefits and the least costs.

Projects are designed and evaluated using many different **criteria.** Appropriate criteria include all the aspects you want to design for and measure. Engineers need to assess many aspects of each project before, during and after its completion. The design and assessment process aims to ensure that each project is the best option that fulfils all the criteria needed.

There are many examples of engineering assessments.

- **Social impact assessment** – Will the project have a good or bad impact on people's lives?
- **Risk assessment** – What might happen if the project fails?
- **Environmental impact** – What impacts will it have on the environment?
- **Contamination assessment** –Will any chemicals used in the project contaminate living things?
- **Strength and facility life assessment** – What sort of loads will the structure need to withstand? How long will a structure survive?
- **Geotechnical hazard assessment** – Will there be any problems with digging the soil?

Most engineering companies use criteria assessments to work out the best way to proceed with a proposal.

Extend your understanding

1 Write a definition of 'engineering'.
2 What is the difference between civil engineers, electrical engineers, chemical engineers and mechanical engineers?
3 What are some reasons to build a prototype of your design before finalising the project?
4 What type of criteria might be considered by an engineer before starting a project?
5 What would be the social impact of a water slide?

Remember and understand

1 Match these words and phrases with their correct meanings:

WORD/ PHRASE	MEANING
Kinetic energy	The energy stored in a compressed spring.
Nuclear energy	Another name for stored energy.
Potential energy	The energy of an object when lifted up.
Elastic energy	Used widely throughout the world to generate electricity from atoms.
Gravitational energy	Possessed by all moving objects.

2 Are the following true or false? For false statements, rewrite them to make them correct.

a Springs only hold stored energy when they are stretched.

b When an object is thrown up in the air it gains gravitational potential energy.

c Sound energy is a type of potential energy.

d Petrol contains nuclear energy.

3 What is the main form of energy in each of the following situations?

a Water flowing slowly over a waterfall.

b A rollercoaster at the lowest point of the ride.

c The Sun coming in through a window on a sunny day.

d A boy riding his skateboard.

e A stretched rubber band.

4 Name a device that transforms:

a electrical energy into light energy

b elastic energy into kinetic energy

c electrical energy into sound energy

d gravitational energy into electrical energy

e kinetic energy into electrical energy.

5 Why might you employ a chemical engineer if you were designing a new clothing range?

Apply and analyse

6 Use numbers in an example of your own to explain the law of conservation of energy.

7 Use numbers in an example of your own to explain energy efficiency.

8 What is the percentage efficiency of a device if it transforms:

a 20 units of input energy into 12 units of useful output energy?

b 600 units of input energy into 500 units of useful output energy?

c In (a) and (b) above, where did the other energy (i.e. 8 units in (a) and 100 units in (b)) go?

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

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

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

12 List the places and structures in your school that you think an engineer was involved with. Justify your decisions.

Evaluate and create

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

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

15 Energy types rarely exist alone. They are always on the move, making things happen. Think about some of the things energy can do. For at least two of these, identify the

type or types of energy involved. If more than one type of energy is involved, link the different types with arrows. Try to include as many different scenarios as you can.

Research

16 Choose one of the following topics for a research project. A few guiding questions have been provided for you, but you should add more questions that you want to investigate. Present your research in a format of your own choosing, giving careful consideration to the information you are presenting.

a **Compact fluorescent lights**

How do compact fluorescent lights (CFLs) work? How do they differ from fluorescent light globes? Why are CFLs initially more expensive to buy, but then more economical over time? What is the benefit of using CFLs?

b **Energy-efficient housing**

In previous societies, energy efficiency was important because people had limited access to the types of energy supplies and their applications that we have today. Research how civilisations in tropical areas designed their homes to keep them cool and damp free. What types of energy-efficient practices have humans used through the ages?

c **New and specialised engineering fields**

Select one of the newer fields of engineering like aerospace, biomedical or nuclear engineering. What does the engineer in that field do? What do they need to know? Who do they work with? Where do they work? What materials do they work with? Name a significant project the engineer has worked on.

d **Plastic bank notes**

Investigate the history of how Australia used chemical engineering to develop plastic bank notes. Who did this work? Why did they do this? What problems were encountered? What are some of the features of our plastic bank notes?

* KEY WORDS

3

chemical potential energy
energy stored in chemicals, e.g. in food, fuel or explosives; also known simply as chemical energy

cost–benefit analysis
list of the costs compared with the benefits; usually performed to analyse a proposed engineering project

criteria
the important aspects of a project that need to be measured; designed to make sure each project is as good as it can be

elastic potential energy
energy stored through stretching or squashing, e.g. in a stretched spring or rubber band

electrical energy
energy associated with electric charge, either stationary (static) or moving (current)

energy efficiency
measure of the amount of useful energy transformed in an energy transformation process; usually expressed as a percentage of the input energy, e.g. 90% efficiency is very good

gravitational potential energy
energy stored due to the height of an object, e.g. a child at the top of a slide

kinetic energy
energy of motion or moving objects

law of conservation of energy
scientific rule that states that the total energy in a system is always constant and cannot be created or destroyed

nuclear energy
energy stored in the nucleus of an atom and released in nuclear reactors or explosions of nuclear weapons; much, much larger than the chemical energy released in chemical reactions

photovoltaic cells (PVCs)
an electrical device that converts light energy into electrical energy, *see* solar cells

potential energy
energy stored in objects and waiting to be used, e.g. gravitational potential energy

remote control
electronic device used for the remote operation (i.e. at a distance) of a machine

solar cell
used to transform sunlight directly into electrical energy; usually in the form of a panel; also known as a solar panel

sound energy
type of kinetic energy made when things vibrate

thermal energy
scientific term for heat energy

transferred
said of energy that has moved from one object to another

transformed
changed one form of energy into another form of energy

CHEMICAL ELEMENTS

4

4.1 The properties of matter can be described

4.2 Scientists' understanding of matter has developed over thousands of years

4.3 The particle model explains matter

4.4 The particle model can explain the properties of matter

4.5 Increasing kinetic energy in matter causes it to expand

4.6 Atoms and elements make up matter

4.7 Atoms bond together to make molecules and compounds

What if?

M&Ms

What you need:

M&Ms (red is best), 250 mL beaker

What to do:

1. Put 100 mL of water into the beaker.
2. Place one M&M in the centre of the beaker.
3. Allow the water and the red M&M to settle.
4. Time how long the colour takes to reach the walls of the beaker.

What if?

» What if the water were warm? Would the colour move faster or slower?
» What if the water were chilled?
» What if you stirred the water?

4.1 The properties of matter can be described

Matter is the name given to all substances. To be called matter, the substance must have mass and volume. **Mass** is measured in kilograms and can be defined as the amount of matter a substance has. **Volume** is how much space the substance takes up and is normally measured in litres.

Solids, liquids and gases

There are three major states of matter – solid, liquid and gas. Solids, liquids and gases are all around us. Steel, concrete, wood and plastic are all solids. Water and cooking oil are liquids. Carbon dioxide is a common gas – you can see it as bubbles in soft drinks. Air is a mixture of gases. The smell of a barbecue is caused by gases that leave the food as it is being cooked.

Many substances can be found in more than one state. Water is the most common substance that we experience in its different states of matter. In the freezer, liquid water solidifies into ice. On a cold night, frost (solid) forms from water vapour (gas) in the air. On a warm sunny day, puddles (liquid) will evaporate to become water vapour.

Although the ocean and iceberg shown in Figure 4.2 may look and behave very differently, they are both different forms of water. The ocean is liquid and the iceberg is solid. There is also water vapour, which is a gas, in the air. Clouds are made of small liquid water droplets. All of these different states of water are made of the same 'building blocks', or water particles.

Pure water will always be the same anywhere on Earth – or on another planet. Water always has the same properties, no matter where it comes from.

Figure 4.1 A glass of iced lemonade contains the three states of matter.

Figure 4.2 Solid water floats on liquid water.

EXPERIMENT 4.1: COMPARING STATES OF MATTER
GO TO PAGE 178.

It is usually obvious if a substance is a solid, a liquid or a gas. However, some substances seem to be made of more than one state of matter. Sometimes we can see the states of a mixture, such as in honeycomb confectionery, which is a combination of solid and gas. But other times it is difficult to tell the state of mixtures. How would you classify slime or jelly?

Describing matter

The properties of a substance can be measured and are always the same for that substance if it is pure. Some substances are important to us because of particular properties. For example, one property of water is that it can be used to dissolve many other substances. This makes water useful for cleaning clothes, cooking and experiments in a chemistry laboratory.

The properties of substances can be divided into two groups: physical and chemical properties.

Physical properties are what we can observe and measure without changing the substance into something else. Examples of physical properties are colour, texture, boiling point, density, electrical conductivity, heat capacity and how readily that substance can dissolve other substances or be dissolved itself.

Chemical properties are what a substance does in a chemical reaction. Examples include bubbling, permanent colour change and permanent change of state.

Some properties of water, such as its refractive index (its ability to bend light rays), are important when studying the effects of water on light. Its heat capacity tells you how much energy needs to be added to increase its temperature.

Table 4.1 Properties of water.

PHYSICAL PROPERTY	VALUE
Melting point	0°C
Boiling point	100°C
Colour	Colourless
Density	1.00 g/mL at 25°C
Refractive index	1.33
Heat capacity	4.184 J/g per °C

Figure 4.3 Honeycomb is a combination of solid and gas. Or is it?

Check your learning 4.1

Remember and understand

1 Group the following substances according to their state of matter as a solid, a liquid or a gas, or even a combination of states: ice cream, chocolate bar, clouds, thick smoke, glass, honey, cake or bread, mashed potato, paper, peanut butter (smooth), cling wrap, play dough, sand, steam, slime.

2 What is meant by a property of a substance?

3 Why are the properties of matter so important to us?

4 What are the similarities and differences between physical and chemical properties?

Apply and analyse

5 Decide whether the following properties are physical or chemical: malleability (the ability to be hammered into flat sheets), the ability to explode, the amount of vapour released at different temperatures.

6 Select a common substance, such as cling wrap or vinegar. Name some of the physical properties of this substance.

//SCIENCE AS A HUMAN ENDEAVOUR//

4.2 Scientists' understanding of matter has developed over thousands of years

Science involves developing hypotheses, testing them with reproducible experiments and modifying ideas. When an idea becomes supported by all the current evidence, then it becomes a **theory**. The particle theory of matter has been tested and refined by scientists for more than 2000 years.

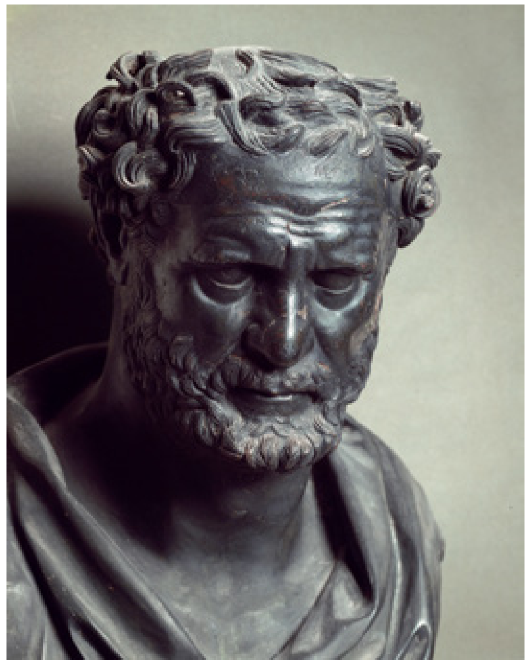


Figure 4.4 Democritus (c. 460–370 BCE) proposed that all matter is made of atoms.

Democritus

Over 2400 years ago, Democritus, a Greek philosopher, put forward the idea that that all matter is made up of particles. He proposed that if you were to cut up these particles into smaller and smaller pieces, you would eventually have tiny particles that could not be cut up any more. Democritus called these particles *atomos*, which is Greek for 'indivisible'. This is the origin of the word **atom.**

John Dalton

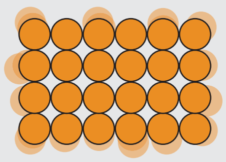
It was not until more than 2000 years later, in the early 1800s, that the Englishman John Dalton developed Democritus's idea further. Dalton's ideas were based on the results of experiments performed by many earlier chemists. Dalton studied these results and proposed a model to explain them. His model was that matter is made of particles.

Dalton's ideas are outlined below.

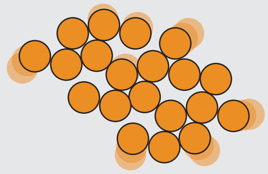
- All matter consists of tiny particles called atoms.
- Atoms cannot be created or destroyed, and are indivisible.
- All atoms of the same element are identical, but different from atoms of other elements.
- When atoms combine to form compounds, each atom keeps its identity.
- Atoms combine to form compounds in simple whole number ratios. For example, hydrogen and oxygen combine in a ratio of 2:1 to form water, now written as H_2O.

Figure 4.5 John Dalton (1766–1844) developed Democritus's ideas about particles.

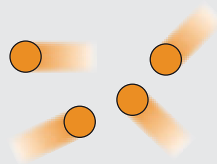
Solids
The particles are close together. They are held in a regular arrangement and vibrate around a fixed point.



Liquids
The particles are close together, but they can move and slide over each other.



Gases
The particles are far apart and move quickly on their own. They spread out to fill the space available to them.



Modern chemistry

This new understanding encouraged scientists to find out more and more about these tiny particles, eventually leading to the branch of science now called **chemistry**.

We can add some new ideas to Dalton's list to help us explain matter.

> Particles are too small to be seen.
> Particles are always moving. When it is hotter, the particles move faster; when it is cooler, the particles move slower.
> Particles have mass.
> Particles can join to make larger particles. When they combine, their masses add together.
> There are spaces between particles.
> Forces hold particles together to stop them from separating.

All these ideas or rules explain how particles act in real substances. The real particles follow these rules in all substances.

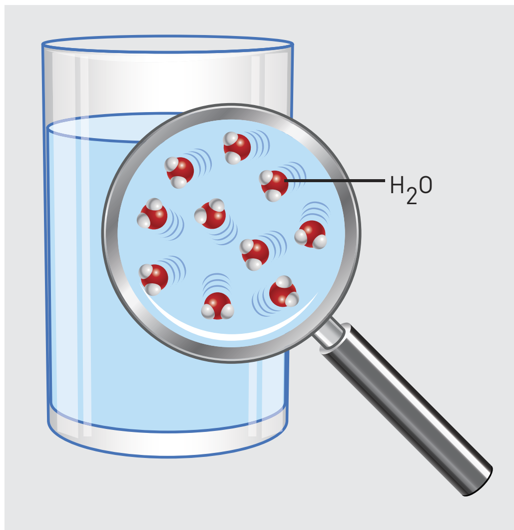


Figure 4.6 A glass of water is made of molecules. Each molecule contains two hydrogen atoms and one oxygen atom.

Extend your understanding

1 What was the major difference between the ideas proposed by Democritus and Dalton?
2 How is an 'idea' different from a 'theory'?
3 Consider a school assembly. Everyone is sitting quietly in their seats in rows. When the assembly finishes, there is a crowd at the doors pushing to go through them to leave. When outside, the students run off in all directions as fast as they can. Explain which parts of this analogy represent a solid, a liquid and a gas.
4 Some people use analogies or models to compare states of matter. What states do the following situations most closely represent?
   a A swarm of bees crawling over each other.
   b A thousand tennis balls tidily arranged in a large cardboard box.
   c Eggs in trays in a large egg container.
   d A school of fish darting in all directions as they avoid a predator.

4.3 The particle model explains matter

Matter is made of extremely small particles called atoms, which are difficult to visualise because they are so tiny. If we imagine the atoms as being tiny balls, then we are using a model or an analogy. By imagining how the balls would behave if the substance were melting, dissolving or heated, we are comparing the atoms to the balls. This is the **particle model of matter**.

The kinetic theory of matter

The particle model of matter is always true. Every observation and every experiment can be explained with this model.

In the particle model of matter, the particles are always moving. The word 'kinetic' refers to the energy of anything that is moving. This means we can use the particle theory of matter to describe how the amount of **kinetic energy** in each particle determines the state of the matter (solid, liquid or gas). For this reason, the particle model can also be called the kinetic theory of matter.

Figure 4.7 Some of the energy in storms comes from the condensation of vapour into liquid, which we see as rain.

Particle energy

The movement of people and particles are related to their kinetic (movement) energy.

> When people are sitting quietly, they have little kinetic energy. This is like a solid, where the particles only vibrate.

> In a crowd, people are standing and moving around and have more kinetic energy. This is like a liquid, where the particles jostle about. Particles in a liquid have more kinetic energy than particles in a solid.

> When people are running, they have much more kinetic energy. This is like a gas, where the particles move fast and on their own. Particles in a gas have the highest amount of kinetic energy.

Using the kinetic theory of matter

The kinetic theory of matter can be used to explain many of the observations and measurements that we make about the substances around us.

Mass is the amount of matter in a substance and is measured in kilograms (kg). Mass

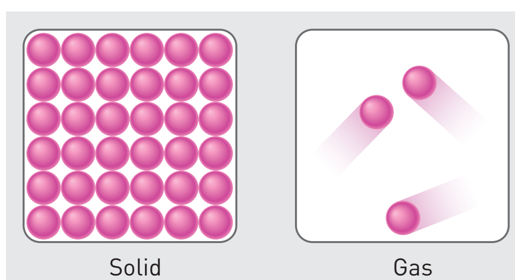


Figure 4.8 A container of a solid has more particles than the same container of gas.

CHALLENGE 4.3A: MODELLING MATTER
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CHALLENGE 4.3B: MAKING A CUPPA
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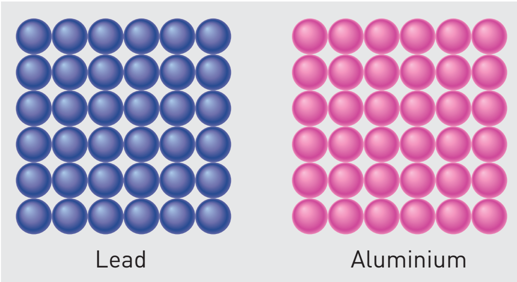

Figure 4.9 Lead atoms have a greater mass than aluminium atoms.

depends on the number of particles and the mass of each individual particle.

A particular volume of solid or liquid has a greater mass than the same volume of gas because it has more particles in it. For example, a container of liquid nitrogen is much heavier than the same-sized container of nitrogen gas.

A piece of lead has a much greater mass than the same-sized piece of aluminium. Both are metals that are made of atom particles that are packed closely together. The difference is the mass of each atom particle. Lead atoms have a greater mass than aluminium atoms.

Diffusion

When the lid is taken off a bottle of perfume, the smell of the perfume spreads throughout the room. This occurs without any breeze or wind and is called **diffusion**. Another example of diffusion is tea spreading out from a tea bag in a cup of hot water. Stirring the cup of tea will mix the particles and speed up the rate of diffusion.

Diffusion occurs fastest in gases. This is because the particles in gases are moving freely and quickly and there is plenty of space between them. The particles in a gas will spread out quickly and take up all the space they can.

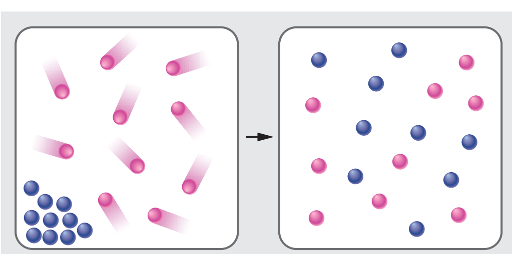

Figure 4.10 Before (left) and after (right) diffusion in a gas.

In liquids, the particles jostle against each other. They do not move far before colliding with another particle. As a result, particles in a liquid do not move very far or very fast. Diffusion in liquids is slow.

In solids, the particles are locked into position. The particles vibrate, but cannot move to a new location. So, the particles in a solid cannot spread out and diffusion does not occur in solids.

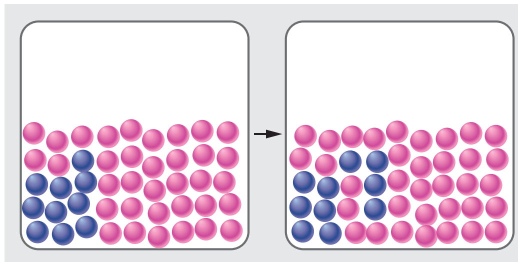

Figure 4.11 Diffusion is slow in liquids.

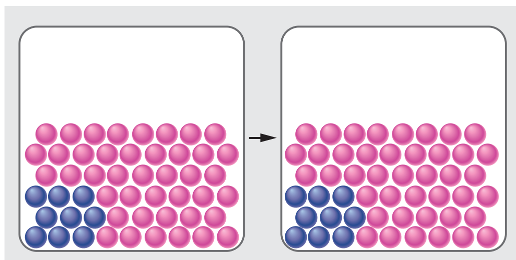

Figure 4.12 Solids don't diffuse.

Check your learning 4.3

Remember and understand

1. Is there any difference between the particle model of matter and the kinetic theory of matter? Explain your answer.
2. What is the meaning of 'kinetic' in the kinetic theory of matter?
3. Rank the states solid, liquid and gas in order of energy content, from highest to lowest.
4. What is meant by 'mass'?
5. How does the kinetic molecular theory (or particle model) of matter explain the different masses of different substances?
6. Why does a lump of lead have a greater mass than a lump of wood?
7. How does the kinetic molecular theory of matter explain diffusion in:
   a. liquids?
   b. gases?

4.4 The particle model can explain the properties of matter

Understanding how particles move can help us explain the physical properties of matter. This includes how much force the substance can withstand (strength), its ability to scratch other objects (hardness), its thickness (viscosity), how much it can be compressed (compressibility) and the number of particles in a certain volume (density).

Figure 4.13 Reinforced concrete combines the tensile strength of steel with the compressional strength of concrete.

Strength

The idea of strength can be considered in different ways. A rubber band is easily stretched, but what about a piece of wire? Different wires made of different metals will break if stretched. **Tensile strength** is a measure of the flexibility of the links or bonds between the particles. The bonds between the particles in steel are stronger than the bonds between tin particles. Another type of strength is compressional strength. Substances that can withstand large forces without being crushed have a high compressional strength.

Hardness

Hardness is the ability of a substance to scratch another substance. An iron nail will scratch a plastic ruler because the iron is harder than plastic. However, the iron nail will not scratch glass because the iron is softer than glass. The order of hardness is glass, then iron, then plastic.

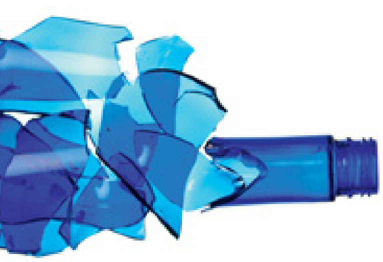

Figure 4.14 Glass is a hard, but brittle, substance.

Hardness is not the same as strength. A very hard substance may shatter easily. If this happens, the material is described as 'brittle'. The particle model of matter explains hardness in terms of the forces that hold the particles together. The particles in hard substances are held together very strongly and it is difficult to separate them. In plastic, the particles are not held together as strongly and can be removed or scraped off. Therefore, plastic is not a hard substance.

There is a connection between hardness and melting. Substances that are hard have strong forces (bonds) between their particles. These strong forces mean that for hard substances to melt, a lot of heat energy is needed. These substances usually have a high melting temperature.

Viscosity

Viscosity is the thickness or 'gooiness' of a liquid. It describes how easily the particles move around each other. Viscous liquids are hard to pour. Water has a low viscosity, cooking oil is more viscous and honey is very viscous. Engine oils used in engines have different viscosities.

Figure 4.15 Engine oils are labelled with viscosities.

EXPERIMENT 4.4: THE DENSITY DEN
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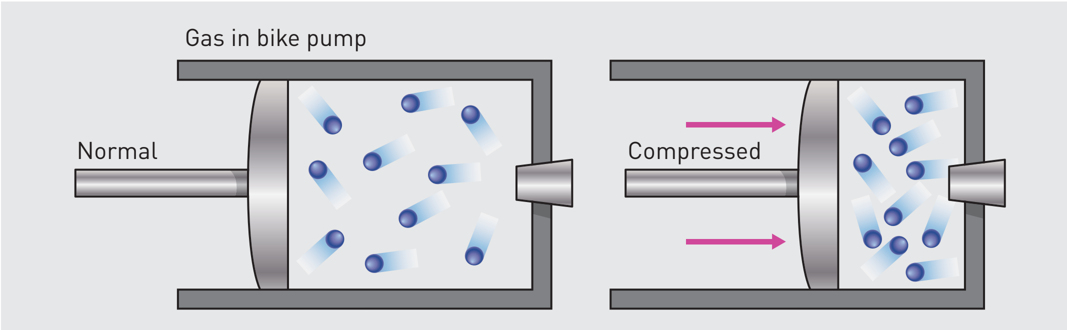

Figure 4.16 Compression reduces the space between particles.

Compressibility

Compressibility refers to the ability of a substance to be compressed. You can test for compressibility when substances are in a plastic syringe.

If you put your finger over the end of a syringe, you can compress the air inside it. However, if you replace the air with water, you cannot compress the water. Similarly, if you filled the syringe with sand, you would not be able to compress it.

In solids and liquids, there are no empty spaces between the particles, so it is not possible to compress the particles together any closer. Solids and liquids are said to be **incompressible**. Gases, like air, can be compressed. This is because the particles are spread out and there is space between them.

Density

One way of comparing the 'heaviness' of two substances is to compare their density. Density is the mass of a certain volume of a substance. The density of a substance will affect its properties, such as its ability to float. Density is the mass divided by volume. Density is often measured in grams per millilitre (g/mL) or grams per cubic centimetre (g/cm^3).

One litre of water is heavier than one litre of air. We say that water has a greater density than air. Sand has a greater density than water or air, but a lower density than lead.

The particle model of matter explains density in terms of both the mass and the closeness of the particles. Gases always have a low density because there is a lot of empty space between the particles. Solids normally have the highest density because there is no space between the particles.

The densities of some common substances are given in Table 4.2.

Table 4.2 Densities of some common substances.

SUBSTANCE	DENSITY (G/CM^3)
Air	0.001
Foam rubber	0.05
Wood	0.3
Oil	0.75
Water	1.0
Glass	2.6
Steel	7.8
Iron	7.8
Copper	8.9
Lead	11.3
Gold	19.3
Mercury	13.6

Check your learning 4.4

Remember and understand

1 Prepare a table and list the physical properties mentioned in this chapter and their meanings.

Apply and analyse

2 Rank the following in order of compressibility: solid, liquid, gas.

3 If you placed a highly viscous liquid, such as oil, into a water pistol, what would be the effect? Explain your reasoning.

4 What would happen to a polished wooden table if you rubbed it with sand? Explain by using the idea of hardness.

5 Why do gases have a much lower density than solids and liquids?

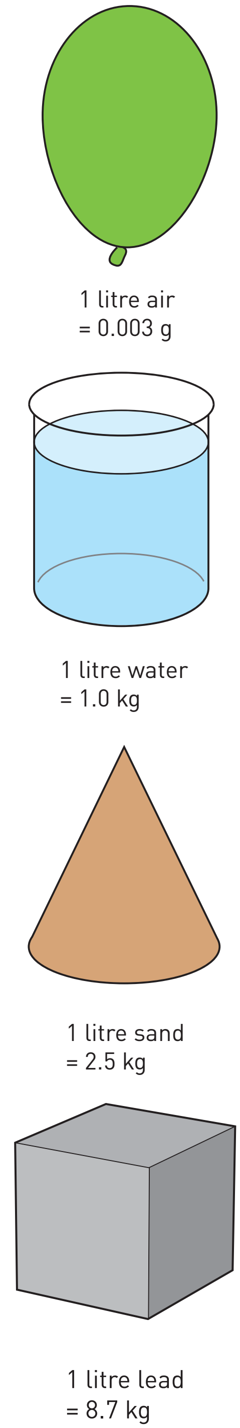

Figure 4.17 Density compares the mass of objects of the same volume.

4.5 Increasing kinetic energy in matter causes it to expand

When you heat matter, you are passing on heat energy to the particles. This means the particles start moving faster. The kinetic energy of the particles increases. This can be used to explain melting and boiling. The **melting point** and **boiling point** are the temperatures at which a substance melts and boils, respectively.

Figure 4.18 Vaporisation explains steam rising from soup.

Heating particles

Gold is usually a solid at room temperature (20°C). Like all solids, the particles in gold are packed tightly together. When solid gold is given heat energy, the gold particles start vibrating faster and faster. When the temperature reaches 1064°C the particles have enough kinetic energy to move around each other, just like the particles in a liquid. The gold has melted.

If you continue heating the gold, the particles continue to gain kinetic energy, move faster and take up more space. Eventually, when the temperature reaches 2807°C, the gold particles have enough kinetic energy to break free from the other gold particles, and move off on their own as a gas.

This process can happen in reverse. If the temperature is reduced, the particles will move more slowly. The attraction to other particles will now keep the particles close together. The gas has condensed into a liquid.

As the particles in a liquid lose energy, their movement slows. Eventually they are held in place by other particles and do not have enough energy to move on their own – they become particles locked into a solid. The liquid has solidified or frozen.

Figure 4.20 Solidification occurs when a substance cools.

Remember that the main difference between a hot and a cold substance is the kinetic energy in the particles.

The differences in the movement of hot and cold particles can be seen in a beaker of water. As the particles move around, they cause diffusion. If the particles move faster, then diffusion should occur faster.

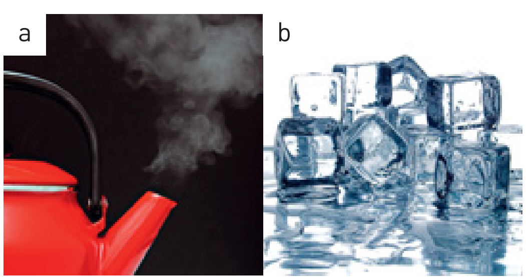

Figure 4.19 (a) The boiling point of water. (b) The melting point of ice.

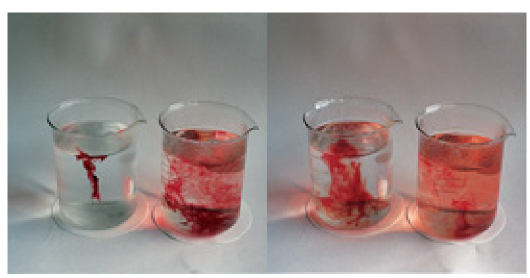

Figure 4.21 Diffusion occurs faster in hot water (right beaker) than in cold water (left beaker).

EXPERIMENT 4.5A: EFFECT OF HEAT
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EXPERIMENT 4.5B: FROM ICE TO STEAM
GO TO PAGE 184.

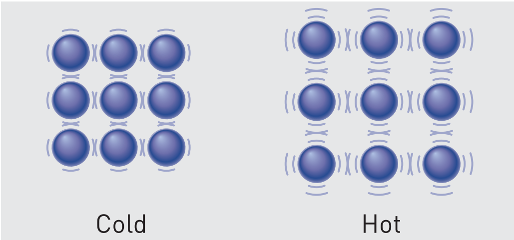

Figure 4.22 In a hot solid, the particles vibrate harder, faster and wider than in a cold solid.

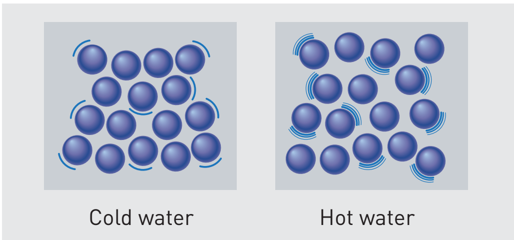

Figure 4.23 In a hot liquid, the particles jostle around faster and take up more space than in a cold liquid.

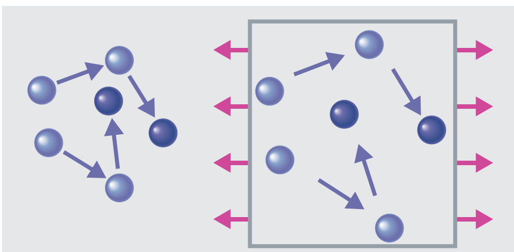

Figure 4.24 In a hot gas, the particles move faster, and collide with each other harder, than in a cold gas.

Heat causes expansion

All objects and substances expand (increase in size or volume) as their temperature increases. These objects contract (shrink) back to their original size when they are cooled back to their original temperature. The expansion is only small – approximately 10 mm in a 30 metre bridge – but it is very important for the strength of the object. Expansion effects are seen in bridges, railway tracks and large buildings.

Applying heat energy causes the particles in the liquid or gas to gain more energy. The particles jostle more and speed up. As they move around faster, they take up more space and push the other particles further apart.

Expansion and contraction have many important applications such as liquid-in-glass thermometers. When an alcohol thermometer is placed in your mouth, the heat from your body passes to the liquid inside the thermometer, causing it to expand and move up the tube. Thermometers are filled with red- or green-coloured alcohol, but not the type of alcohol in alcoholic drinks.

Figure 4.25 An expansion joint in a suspension bridge.

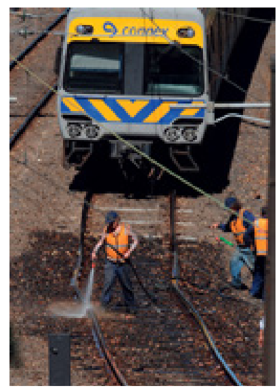

Figure 4.26 Train tracks would buckle in the heat without tiny gaps between them.

Check your learning 4.5

Remember and understand

1 Draw a diagram similar to that shown in Figure 4.27. Add labels to show the energy changes between states.

2 How does the movement of particles change as they get hotter?

3 What is the difference between the terms 'expand' and 'contract'?

4 When hot objects cool, do they return to their original lengths?

Apply and analyse

5 What precautions are taken with railway tracks and bridges to ensure that they do not buckle and bend on a hot day?

6 How can you be sure that when a solid is heated and expands in size, the increase in size is not caused by more particles (atoms) being added?

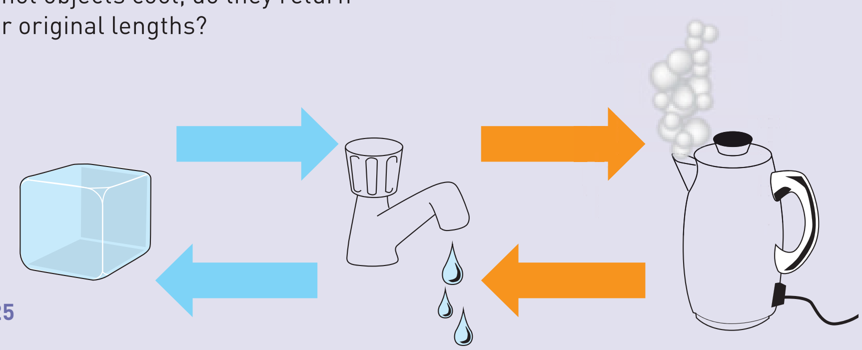

Figure 4.25

EXPERIMENT 4.6A: CLASSIFYING ELEMENTS
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4.6 Atoms and elements make up matter

The kinetic theory of matter helps us understand not just physical properties, but also chemical properties. This theory states that all particles have kinetic energy. A closer look at the particles shows us that they are made up of atoms. An **element** is a pure substance made of only one type of atom. All the atoms in the element are identical.

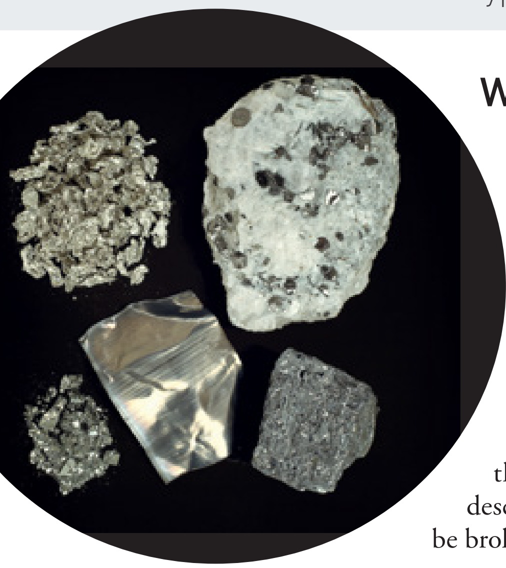

Figure 4.28 Not all metals are the same.

What are atoms?

In Unit 4.2 you learned about the ideas of Democritus and the Ancient Greeks. They used the word *atomos* to describe those particles that could not be divided up any further. The concept of the atom was also referred to in ancient Indian texts. John Dalton and other chemists from the 17th century onwards further developed the idea, using the term 'atom' to describe those particles that couldn't be broken down any further by chemical means.

The smallest atom in terms of mass is the hydrogen atom. Next is helium. Heavier atoms include those of lead and uranium.

What are elements?

An element is a pure substance made of only one type of atom. All the atoms in the element are identical. There are 90 different elements that are found naturally on Earth. Each element is made of a different type of atom. Another 20 or so atoms have been made artificially, but these are highly radioactive and break down within a second. These artificially made atoms are too large to be stable and they disintegrate almost as soon as they are made.

Elements cannot be broken down into other substances because they are already the simplest substances. They can be thought of as being 'elementary', which is the origin of the name element.

Figure 4.29 Aluminium foil is made of the element aluminium and each strip contains billions of aluminium atoms.

The element is the substance that can be observed and has properties that can be measured. Atoms are far too small to be observed and are incredibly difficult to measure.

In the solid state, atoms of metals are held in a lattice. Most other elements, which are not metals, are called non-metals. Most non-metals are gases at normal temperatures. Some gases, such as neon and helium, are **monatomic**. This means that each gas particle is a single atom (mono = one). However, the atoms in other gases, such as oxygen, hydrogen and nitrogen, are **diatomic**. The atoms of these elements join together in pairs (di = two).

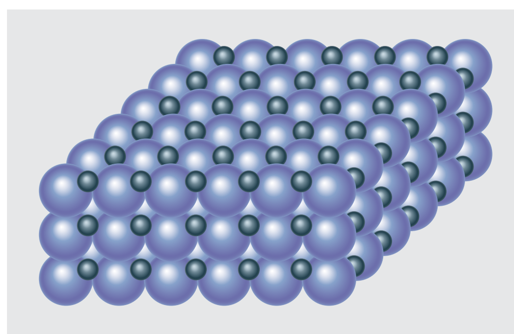

Figure 4.30 A metallic lattice.

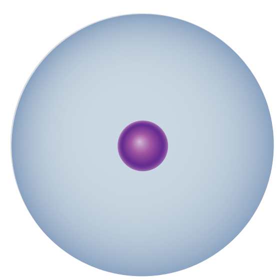

Figure 4.31 Helium is monatomic.

CHALLENGE 4.6B: IDENTIFYING THE ELEMENTS IN THE PERIODIC TABLE
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EXPERIMENT 4.6: PROPERTIES OF THE ELEMENTS
GO TO PAGE 187.

Key: 6 C 12.01 Carbon — Atomic number, Chemical symbol, Atomic mass, Name of element

Group 1–2: Metals; 3–12: Transition metals; 13–17: Non-metals (to the right of the zigzag line)

Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H 1.01 Hydrogen																	2 He 4.00 Helium
2	3 Li 6.94 Lithium	4 Be 9.01 Beryllium											5 B 10.81 Boron	6 C 12.01 Carbon	7 N 14.01 Nitrogen	8 O 16.00 Oxygen	9 F 19.00 Fluorine	10 Ne 20.18 Neon
3	11 Na 22.99 Sodium	12 Mg 24.31 Magnesium											13 Al 26.98 Aluminium	14 Si 28.09 Silicon	15 P 30.97 Phosphorus	16 S 32.07 Sulfur	17 Cl 35.45 Chlorine	18 Ar 39.95 Argon
4	19 K 39.10 Potassium	20 Ca 40.08 Calcium	21 Sc 44.95 Scandium	22 Ti 47.88 Titanium	23 V 50.94 Vanadium	24 Cr 52.00 Chromium	25 Mn 54.95 Manganese	26 Fe 55.85 Iron	27 Co 58.93 Cobalt	28 Ni 58.70 Nickel	29 Cu 63.55 Copper	30 Zn 65.39 Zinc	31 Ga 69.72 Gallium	32 Ge 72.61 Germanium	33 As 74.92 Arsenic	34 Se 78.96 Selenium	35 Br 79.90 Bromine	36 Kr 83.80 Krypton
5	37 Rb 85.47 Rubidium	38 Sr 87.62 Strontium	39 Y 88.91 Yttrium	40 Zr 91.22 Zirconium	41 Nb 92.91 Niobium	42 Mo 95.94 Molybdenum	43 Tc (98) Technetium	44 Ru 101.07 Ruthenium	45 Rh 102.91 Rhodium	46 Pd 106.4 Palladium	47 Ag 107.87 Silver	48 Cd 112.41 Cadmium	49 In 114.82 Indium	50 Sn 118.71 Tin	51 Sb 121.74 Antimony	52 Te 127.60 Tellurium	53 I 126.90 Iodine	54 Xe 131.29 Xenon
6	55 Cs 132.91 Cesium	56 Ba 137.33 Barium	57 to 71	72 Hf 178.49 Hafnium	73 Ta 180.95 Tantalum	74 W 183.85 Tungsten	75 Re 186.21 Rhenium	76 Os 190.23 Osmium	77 Ir 192.22 Iridium	78 Pt 195.08 Platinum	79 Au 196.97 Gold	80 Hg 200.59 Mercury	81 Tl 204.38 Thallium	82 Pb 207.2 Lead	83 Bi 208.98 Bismuth	84 Po (209) Polonium	85 At (210) Astatine	86 Rn (222) Radon
7	87 Fr (223) Francium	88 Ra 226.03 Radium	89 to 103	104 Rf (205) Rutherfordium	105 Db 105 Dubnium	106 Sg (271) Seaborgium	107 Bh (272) Bohrium	108 Hs (277) Hassium	109 Mt (276) Meitnerium	110 Ds (281) Darmstadium	111 Rg (280) Roentgenium	112 Cn (285) Copernicium						

Atomic masses in parentheses are from the most stable of common isotopes.

Rare earth elements Lanthanoid series

57 La 138.91 Lanthanum	58 Ce 140.12 Cerium	59 Pr 140.91 Praseodymium	60 Nd 144.24 Neodymium	61 Pm (145) Promethium	62 Sm 150.4 Samarium	63 Eu 151.97 Europium	64 Gd 157.25 Gadolinium	65 Tb 158.93 Terbium	66 Dy 162.50 Dysprosium	67 Ho 164.93 Holmium	68 Er 167.26 Erbium	69 Tm 168.93 Thulium	70 Yb 173.04 Ytterbium	71 Lu 174.97 Lutetium

Actinoid series

89 Ac 227.03 Actinium	90 Th 232.04 Thorium	91 Pa 231.04 Protactinium	92 U 238.03 Uranium	93 Np 237.05 Neptunium	94 Pu (244) Plutonium	95 Am (243) Americium	96 Cm (247) Curium	97 Bk (247) Berkelium	98 Cf (251) Californium	99 Es (252) Einsteinium	100 Fm (257) Fermium	101 Md (258) Mendelevium	102 No (259) Nobelium	103 Lr (260) Lawrencium

Figure 4.32 The periodic table.

Elements and the periodic table

The **periodic table** arranges all the elements in order of the size of their atoms. It also groups together elements with similar properties. The horizontal rows in the table are called periods. The vertical columns are called groups. The elements in a group often have similar properties, such as the way they look or how they behave. Metals are found to the left of the zigzag line in the table and non-metals are found to the right.

On the periodic table, you will notice that elements are represented by their symbols, which consist of one or two letters: hydrogen has the symbol H; helium has the symbol He. Other symbols are oxygen (O), carbon (C), nitrogen (N), sulfur (S), gold (Au) and silver (Ag).

Elements can also be classified on the basis of their chemical properties. These include how they react with other substances, such as acids and the oxygen in the air. You will be learning more about the chemical reactions of elements in Chapter 5.

Check your learning 4.6

Remember and understand

1. What is the connection between atoms and elements?
2. What are the two main types of elements?
3. What are the rows of a periodic table called?
4. What are the names of the first five elements on the periodic table? What are their symbols?
5. Which element is in period 3, group 2?
6. What two letters are not represented in the elemental symbols of the periodic table?
7. How many words can you make up using the elemental symbols of the periodic table?

4.7 Atoms bond together to make molecules and compounds

Molecules are groups of two or more atoms that are bonded together. They can be the same element or different. When the atoms are different elements they can also be called **compounds**. Compounds are different from mixtures because the atoms are chemically joined or **bonded**. The properties of molecules and compounds can be explained using the kinetic theory of matter.

Figure 4.33 Most tablets and capsules are compounds of the active ingredients mixed with substances to help the active ingredients absorb into the blood and reach their desired target.

What are molecules?

Molecular substances can be elements (made of the same type of atoms), such as oxygen (O_2), or compounds (made of two or more different types of atoms bonded together), such as water (H_2O) and carbon dioxide (CO_2). We use a chemical formula to show the types and numbers of atoms that make up molecules.

Oxygen is an example of a **molecular element**. An oxygen molecule consists of two oxygen atoms joined together. Oxygen gas is a substance made of oxygen molecules. Pure oxygen gas consists of millions and millions of oxygen molecules, all exactly alike.

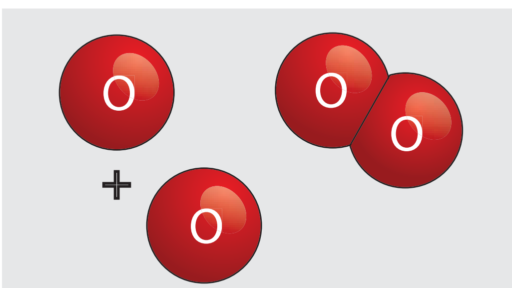

Figure 4.34 An oxygen molecule (O_2) is formed by two oxygen atoms.

This means that the word 'oxygen' can be used in two different ways: it can be used to describe the element or it can be used as the name of the molecule. When you see the names of chemicals being used, check the way in which the name is being used.

Molecules of a compound contain atoms of two or more different elements. Carbon dioxide is a **molecular compound**. Its molecules contain carbon and oxygen atoms. Pure carbon dioxide gas (the substance) consists of millions and millions of carbon dioxide molecules.

Water is another molecular compound. A water molecule consists of one atom of oxygen joined to two atoms of hydrogen. Pure water consists of many millions of water molecules. The water molecules are all identical.

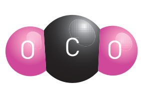

Figure 4.35 A carbon dioxide molecule (CO_2) is a compound made up of one carbon atom and two oxygen atoms.

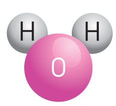

Figure 4.36 A water molecule (H_2O) is a compound made up of two hydrogen atoms and one oxygen atom.

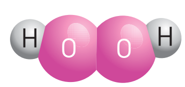

Figure 4.37 A hydrogen peroxide molecule (H_2O_2) is a compound made up of two hydrogen atoms and two oxygen atoms.

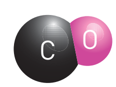

Figure 4.38 A carbon monoxide molecule (CO) is a compound made up of one carbon atom and one oxygen atom.

EXPERIMENT 4.7: DECOMPOSING COPPER CARBONATE
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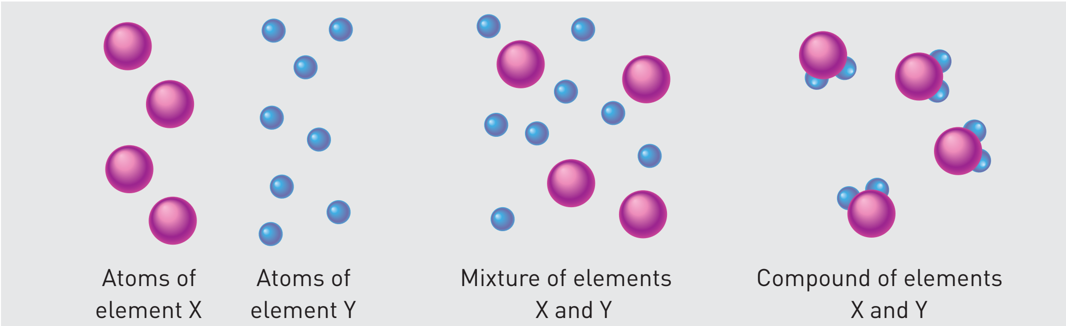


Figure 4.39 Mixtures are different from compounds.

Compounds and mixtures

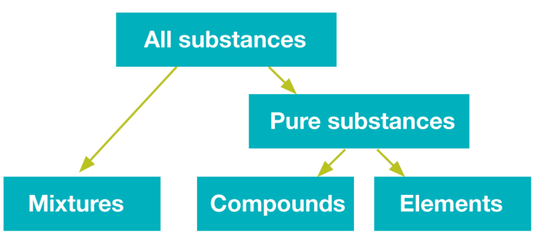
You have seen that elements contain only one type of atom. However, you will know that there are far more substances than just the 90 naturally occurring elements.

Most of the substances we use are compounds. By altering the numbers and types of atoms, chemists can alter the properties of these substances. Many of the substances that are important to our society are used because of their important properties. These compounds are made in factories or obtained from natural products. Some important compounds are pharmaceuticals, fertilisers and polymers.

Some compounds are molecular, such as water and carbon dioxide. Other compounds are called **polymers**. The molecules in polymers are made of groups of atoms that repeat over and over – like the beads on a necklace. Plastics are examples of polymers. Other polymers include chemicals found in plants and animals, such as starch and proteins.

Other compounds do not contain molecules but exist in a lattice arrangement, with atoms held together in three-dimensional networks.

Elements and compounds are pure substances. The particles within one pure substance, whether they are atoms or molecules, are all the same. The following chart shows the different types of substances.



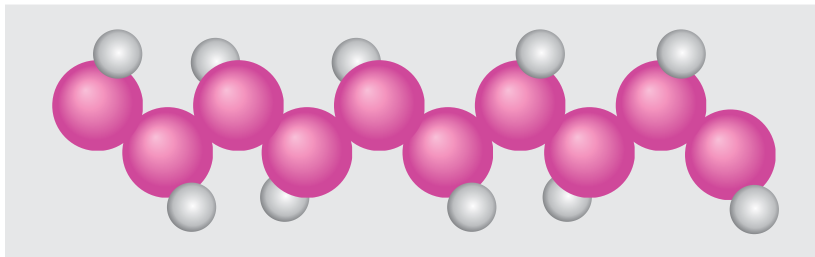
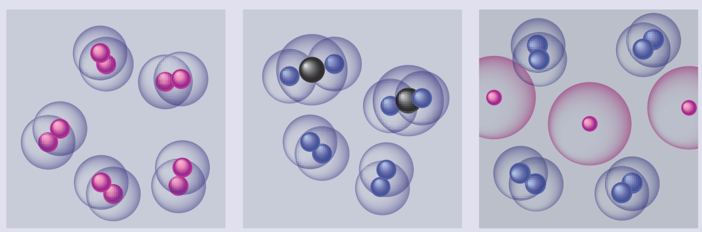


Figure 4.40 A polyethylene molecule is made up of thousands of carbon atoms joined in a chain, with hydrogen atoms attached to the carbon chain.

Check your learning 4.7

Remember and understand

1 Look at the diagrams below, which show (i) a mixture of an element and a compound, (ii) a mixture of two elements, and (iii) a pure element.



State which description matches which diagram, explaining your reasoning for each type of substance.

2 What are some elements that exist as molecules rather than single atoms?

3 How are molecules and compounds related? Explain your answer.

4 What is the difference in meaning between the following groups of words?

a atoms and molecules

b elements and compounds

c diatomic and monatomic

d molecule, polymer and lattice.

5 Ammonia is a gas that contains molecules with the formula NH_3. What elements are present in ammonia and how many of each atom is there in each ammonia molecule?

* REVIEW

4

Remember and understand

1 What are the three common states of matter?

2 Select one word to replace each phrase.

a The spreading out of a substance, such as a dye or smell.

b The ability of one substance to scratch another substance.

c The ratio of the mass divided by the volume.

3 In which of the three major states of matter do the particles have the most energy? Explain your reasoning.

4 What is the difference between the physical and chemical properties of a substance?

5 What is the difference between mass and matter?

6 What is the correct word or words for the following descriptions?

a A group of atoms chemically bonded together.

b A three-dimensional arrangement of particles in rows, columns and layers.

c Where energy breaks apart a compound into simpler substances or elements.

d A feature of a substance that you can observe and measure without destroying or changing the substance.

Apply and analyse

7 When you are boiling water, the volume the water is reduced as it evaporates. Does this mean that the density of water changes?

8 Use the kinetic theory of matter to explain why the pressure inside car tyres will increase on a hot day.

9 If you heated a newly discovered substance and it decomposed into two new substances, was the original substance an element or a compound? Give reasons for your answer.

10 When you breathe out on a cold morning, your breath appears white and foggy. This only occurs when it is very cold. What is the white fog that you see?

Evaluate and create

11 Many people have ideas they think will explain observations and events in science. For an idea to become a theory, it must be able to explain a range of observations. The

Figure 4.41 Exhaling clouds!

idea must also be supported by evidence and/or observations.

a Can you suggest what evidence would have been required to support the idea that all substances are made of atoms?

b It is found that a substance cannot be broken down into a more simple substance. How could you use the kinetic theory of matter to explain this observation?

12 Elements only contain one type of atom, whereas compounds contain a combination of different atoms. This difference in structure can explain some of the behaviours of elements and compounds. By referring to the arrangement of atoms, explain the following statements.

a When an electric current is passed through water, it is possible to produce hydrogen gas and oxygen gas.

b Early chemists, called alchemists, tried to turn lead and other metals into gold, but none of them succeeded.

c When limestone, which is made of the compound calcium carbonate ($CaCO_3$), is heated strongly, carbon dioxide gas is produced. However, when iron is heated, no new substance is created.

13 You should now realise that the structure and properties of a substance can be explained by the particles that make up the substance. Explain the following observations by referring to the arrangement and/or the movement of the particles within the substance. You can use labelled diagrams to improve your answers.

a Water left in an open bottle will gradually evaporate and, if the temperature of the water increases, the water will evaporate more quickly.

b Mercury is a unique substance because it is the only metal that is liquid at room temperature, and it even gives off a vapour (which makes it very dangerous because this vapour can be breathed into our lungs).

c Polythene can be produced in two different forms, high-density polythene (HDPE) or low-density polythene (LDPE). If the particles in both HDPE and LDPE are the same, suggest how the structure of the two substances would be different.

d When you heat a piece of polythene it will melt. While it is liquid, it can be formed into a different shape and when it cools the polythene will stay in this new shape.

e We can see steam, but we cannot see water vapour.

Research

14 Choose one of the following topics for a research project. A few guiding questions have been provided for you, but you should add more questions that you want to investigate. Present your research in a format of your own choosing, giving careful consideration to the information you are presenting.

a **State of the matter**

The changes between the states of matter have many uses. Research some of these uses and their impact on our society. Some ideas are how refrigeration and air conditioning work; making moulds and casts, such as chocolate, iron and aluminium castings; obtaining medical-grade oxygen and nitrogen from the air; how the energy changes that occur during evaporation of water and the subsequent condensation of water vapour into rain affect thunderstorms and cyclones.

b **People matter**

The discovery of air pressure is a long and interesting story. Research the background of Evangelista Torricelli, Blaise Pascal and Otto von Guericke. For example, Otto von Guericke built a large water thermometer in the front of his house and made the Magdeburg hemispheres. Two opposing teams of eight horses, working like a tug-of-war, could not pull the hemispheres apart.

4

* KEY WORDS

atom
smallest particle of matter that cannot be created, destroyed or broken down (indivisible)

boiling point
the temperature at which a liquid becomes a gas

bonded
when two objects (atoms) remain attracted to each other

chemical property
how a substance behaves in a chemical reaction, e.g. how it reacts with acid

chemistry
branch of science that deals with matter and changes that take place within it

compound
substance made up of two or more different types of atoms bonded together, e.g. water

compressibility
ability of a substance to be compressed (squashed); gases can be compressed but solids and liquids cannot

diatomic
a molecule that contains only two atoms

diffusion
spontaneous spreading out of a substance through a liquid or gas, e.g. the diffusion of perfume in air

element
pure substance made up of only one type of atom, e.g. oxygen, carbon

hardness
how easily a mineral can be scratched; measured on the Mohs hardness scale

incompressible
when a substance cannot be compressed; solids and liquids are incompressible

kinetic energy
energy of motion or moving objects

mass
amount of matter in a substance, usually measured in kilograms

matter
anything that has mass and volume

melting point
the temperature at which a solid becomes a liquid

molecular compound
a molecule that contains two or more different atoms bonded together

molecular element
a molecule that contains two or more of the same atoms bonded together

molecule
group of two or more atoms that are bonded together, e.g. a water molecule

monatomic
a single atom

particle model of matter
theory that all matter is made up of very tiny particles

periodic table
the arrangement of elements into a table according to their chemical properties

physical property
can be measured or observed without changing a substance into something else, e.g. colour, boiling point

polymer
long chain molecule made up of many simpler repeating units

tensile strength
a measure of the flexibility of the links or bonds between the particles in a substance

theory
explanation of a small part of the natural world that is supported by a large body of evidence

viscosity
a measure of how slowly a liquid changes its shape; the thickness of a liquid

volume
how much space an object takes up, usually measured in litres

PHYSICAL AND CHEMICAL CHANGE

5

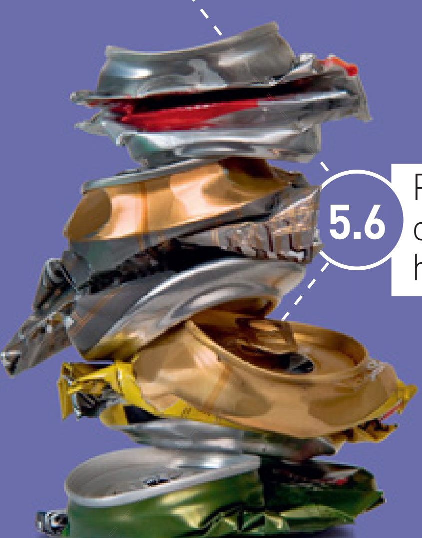
5.1 Physical change is a change in shape or appearance

5.2 Chemical change produces new substances

5.3 Chemical reactions can break bonds and re-form new bonds

5.4 Heat can speed up a reaction

5.5 Many substances exist because of the work of scientists



5.6 Physical and chemical changes are used to recycle household waste

What if?

Dissolving tablets

What you need:

effervescent antacid tablets, beaker, water, timer, Vaseline

What to do:

1 Place 100 mL of water in a beaker.

2 Place the effervescent antacid tablet in the water and time how long it takes to dissolve.

What if?

» What if warm water were used?

» What if cold water were used?

» What if the tablet were broken up?

» What if more than 100 mL of water were used?

» What if the tablet were covered in Vaseline?

5.1 Physical change is a change in shape or appearance

One way that substances can change is through a physical change. The substance still consists of the same particles, but it looks different. A cut diamond is made of the same material as an uncut diamond. Chocolate that has melted and solidified into a mould is the same as the original block of chocolate. Physical changes can happen when a force is applied, when substances break down into smaller pieces and when substances change state between solid, liquid and gas.

Figure 5.1 Ice melting to water is an example of a physical change.

Physical changes are reversible

Most physical changes are reversible, which means the change can be undone and the substance goes back to how it was. When you put water in the freezer, it turns to solid ice. When you take the ice out of the freezer, it changes back into water. In this way we can deduce that a physical change has taken place because the water is still water and no new substances have been created.

For each of these substances the particle itself has not changed. The molecule of water that contains two hydrogen atoms and one oxygen atom (H_2O) is exactly the same when it is a solid, liquid or a gas. The main difference is how closely packed all the water molecules are and how much kinetic energy they have.

In ice, all the water molecules are in a regular arrangement (rows, columns and layers).

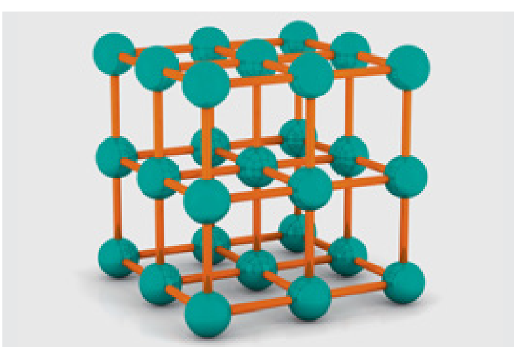


Figure 5.2 Particles in a solid may be arranged in a lattice.

A three-dimensional arrangement of particles in a regular pattern is called a **lattice**. The water molecules in ice are constantly vibrating. This ice lattice is unique. The solid takes up more space than the liquid water.

When heat energy is added, the water molecules vibrate faster. However, the molecules are still held in place in the lattice by other water molecules around them. As the ice warms up, the water molecules gain more energy and vibrate faster. Eventually they have so much energy that the water molecules break free of the others around them. The solid ice has melted to become liquid water.

Changing state

Substances can change between the three states. You are familiar with seeing water change state (when ice blocks melt), but other substances may only ever be seen in one state. Theoretically, all substances can be changed into different states if the temperature is hot (or cold) enough. Even gases, such as nitrogen, can be turned into a liquid at very low temperatures. 'Dry ice' is actually solidified carbon dioxide.

Vaporisation and condensation

When a liquid evaporates to become a gas, we say it has **vaporised**. A **vapour** is the gaseous form of a substance that is normally a solid or

EXPERIMENT 5.1: MELTING CHOCOLATE
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CHALLENGE 5.1: EXPLORING PHYSICAL
CHANGES GO TO PAGE 190.

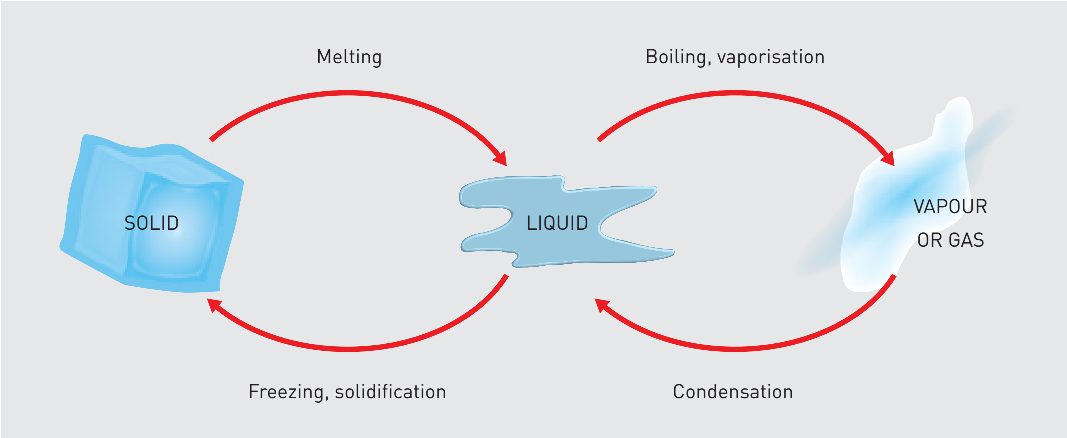


Figure 5.3 Changing states.

Figure 5.4 Dry ice is frozen carbon dioxide gas.

liquid at room temperature. For example, when water is turned into a gas, it is referred to as water vapour. Vapours that are smelly are often called **fumes**. However, remember that vapours and fumes are still gases and will behave like gases.

Volatile substances, such as petrol, vaporise easily. Cooking oil does not vaporise if left at normal room temperatures. Cooking oil is not a volatile liquid.

Boiling occurs when we heat a liquid to change it into a gas. The boiling point of pure water is 100°C. At this temperature, water changes its state to become water vapour. Water left in the open at normal room temperature will gradually evaporate. If the water is heated to its boiling point, the water molecules will quickly gain kinetic energy and evaporate faster.

When a gas changes state to become a liquid, normally by cooling, we say it **condenses**. The most common condensation that you can observe is when water vapour in the air (or your breath) condenses on a cold surface. The kinetic energy of the water particle passes to the surface as heat energy. The water particle slows its movement and becomes liquid water.

Melting and solidification

When a solid is heated and changes state to become a liquid, we say it has **melted**. When the liquid loses heat and becomes a solid, it is called solidification. When solidification happens to water, it is sometimes called freezing.

Sublimation

Some substances don't ever exist as liquids. They just change state from a solid to a gas or from a gas to a solid. This process is called **sublimation**. Dry ice changes directly from a solid into a gas. Dry ice is often used to produce smoke effects on stage at concerts. However, the 'smoke' you see is not carbon dioxide, but clouds of water. When dry ice sublimes to form carbon dioxide gas, it cools the air quickly, which causes water vapour in the air to condense and form clouds of water.

Diamond is the hardest known substance on Earth. It also sublimes, but only at extremely high temperatures (above 3500°C).

Figure 5.5 Water vapour in the air has condensed on this cold window.

Check your learning 5.1

Remember and understand

1 Describe what the following words mean:
   a lattice
   b sublimation
   c condenses
   d volatile.

Apply and analyse

2 A student claimed that the bubbles in boiling water were oxygen. Are they correct? Explain your answer.
3 Explain why all perfumes are volatile liquids.

Evaluate and create

4 Draw a diagram with the three major states of water. Name the physical changes the water goes through to form ice and water vapour.

Figure 5.6 Dry ice does not form a liquid. Instead the particles sublimate.

5.2 Chemical change produces new substances

When substances interact, they may change. The changes can be noticed in many ways, such as by a change in colour, the formation of bubbles, a change in temperature or the formation of solids. In both pure elements and pure compounds, the smallest particles in the substance are all identical to each other, whether they are individual atoms or molecules made up from a particular combination of atoms. When a chemical change occurs, the original (reactant) particles are rearranged to form new substances (products) with new properties.

Chemical changes

In a chemical change, a new chemical is made. This means that the atoms have been moved around into new arrangements. In some chemical changes, atoms can be separated to make new chemicals. Sometimes atoms and molecules join together to make new chemical substances with larger molecules. New substances have new particles and new properties. Both the physical and chemical properties of the new substance (the product) will be different from those of the original substance (the reactant).

In every chemical reaction, one or more substances are changed into new, different substances with different physical and chemical properties. Chemical changes are usually not reversible – you cannot un-burn toast!

Whether a change is physical or chemical depends on the substances, the temperature and how you mix them.

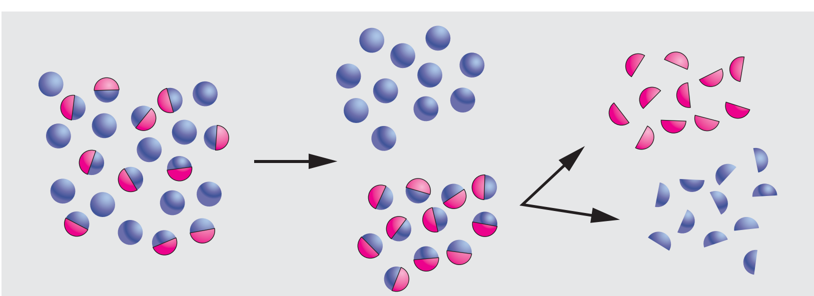


Figure 5.7 In a physical change, only the appearance of the substance changes because the particles have been rearranged. In a chemical change, new chemicals are made.

Physical change or chemical change?

When solid chocolate is heated gradually, it melts and changes shape; when cooled, it goes back to the solid state. It may have a different shape, but it is still chocolate. In this situation, a physical change has taken place because the chocolate is still the same substance: it is still made up of the same particles.

However, if you heat chocolate at too high a temperature, it burns. When it cools, it no longer tastes of chocolate, but of burnt chocolate. This is a chemical change, because a new substance is formed that is different from chocolate – you can tell by the taste and smell! This is why most chocolate recipes suggest heating chocolate over boiling water rather than over a hot plate, so that the chocolate does not get too hot and a chemical change does not take place.

When you bake a cake, mixing the ingredients together produces a physical change. Baking the cake involves a chemical change.

Cooking often turns food brown. This is due to the sugar in the food caramelising – turning into brown caramel. The change forms a new substance and is not reversible. It is a chemical change.

We can usually identify a chemical change if one of the following occurs (see Figures 5.8 to 5.11).

CHALLENGE 5.2: MAKING CARAMEL
GO TO PAGE 190.

EXPERIMENT 5.2: OBSERVING CHEMICAL
REACTIONS GO TO PAGE 191.

Figure 5.8 A gas is produced, which we either see as bubbles or fizz.

Figure 5.9 A colour change occurs that is non-reversible. Heating an iron nail to red hot is a physical change because the red colour will disappear as the nail cools down; however, if the iron in the nail reacts with air and becomes rusty, it is a chemical change.

Figure 5.12 Heating chocolate slowly causes it to melt – a physical change. If it is heated quickly and at a higher temperature, the chocolate will burn – a chemical change.

Figure 5.10 Light or heat is absorbed or produced in chemical reactions. When the atoms in sodium metal and water rearrange themselves, the extra energy is released as light and heat.

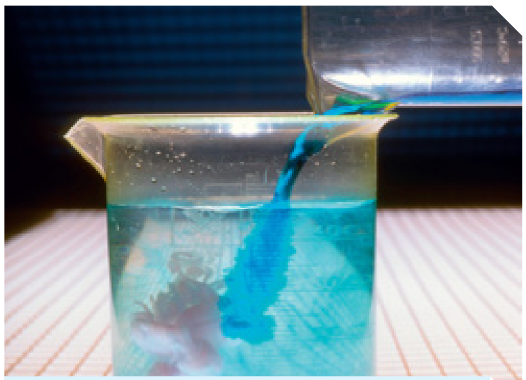


Figure 5.11 A precipitate (insoluble solid substance) forms that does not go away.

Check your learning 5.2

Remember and understand

1 When melted chocolate is put in the fridge, it cools quickly producing small crystals that were not present before. This changes the taste of the chocolate. Is this a chemical or physical change?

2 What is the evidence for a chemical change?

3 Identify the following as physical or chemical changes.
   a Melting cooking chocolate into animal shapes.
   b Burning magnesium ribbon to form a white ash.
   c Boiling water and condensing the vapour.
   d Dissolving magnesium in acid to produce hydrogen gas.
   e Separating leaves from woodchips using a garden blower.

Apply and analyse

4 Why is caramelisation a chemical reaction?

5 What is the evidence that baking a cake from egg, flour and butter is a chemical reaction?

5.3 Chemical reactions can break bonds and re-form new bonds

A chemical change can also be described as a **chemical reaction**. In chemical changes or reactions in substances, the atoms can separate from each other and bond together in new combinations to form new substances.

Figure 5.13 Bacteria can cause chemical changes in dairy foods.

Chemical reactions

The substances that you start with are called **reactants**. They react or change to produce new substances. The substances that you finish with are called **products**. They are produced in a chemical change. There may be more than one reactant and product for each chemical change.

Chemical reactions are all around us. They not only occur in factories – they take place in our homes and in our bodies. Every process in your body requires chemical changes. Cooking food changes it chemically so it is more edible and easier to digest.

Reactions in cooking

Preparing and cooking food involves many physical and chemical changes to the food. There are other similarities between chemistry and cooking – some of the techniques, such as heating, mixing and filtering, used in cooking are similar to the tasks of a chemist.

There are many chemical reactions in the kitchen. Baked vegetables and meat turn brown as the sugars are caramelised. Usually the sugar comes from the breakdown of the starch granules into starch molecules, followed by a chemical change into a sugar. Other chemical changes involve the breakdown of proteins in meat. A few vitamins may be destroyed by some cooking methods.

Some chemical changes are caused by microorganisms. Sour milk forms when a bacterium converts milk sugar (lactose) into an acid (lactic acid). The taste of sour milk is unpalatable and the large numbers of bacteria in the milk may make you sick. Cheese is made by fungi that consume the sugars in milk and cause the protein to thicken. In making yoghurt, the bacteria act as a culture (a colony of microorganisms) that is transferred to the new medium (milk).

Other chemicals are added to our food, including emulsifiers, flavourings, colourings, antioxidants and preservatives. These help keep the food stable, improve its appearance

Figure 5.14 How would a chemist use these cooking techniques?

EXPERIMENT 5.3: COMPARING REACTANTS AND PRODUCTS
GO TO PAGE 192.

and increase its shelf life. Processed foods usually have a list of these additives on the packet.

More chemical reactions

Burning is a chemical reaction. The correct scientific word for burning is 'combustion'.

Magnesium is a metal that can burn fairly easily, giving off a lot of heat and bright, white light. Before any reaction starts, we know we have magnesium in the ribbon. When the magnesium interacts with the oxygen in the air, the reactants are magnesium and oxygen. The chemical reaction takes place when we see the magnesium ribbon burn. After the ribbon has burned, we are left with a white powder, magnesium oxide, as the product of the reaction.

New products

Many substances that we now take for granted, such as medicines, chemicals used in agriculture and construction, and plastics such as PVC and polythene, are made from chemical reactions with crude oil.

These products are hard to make in the laboratory because they require high temperatures and some specialised conditions. A substance that you can make in the laboratory is nylon – a compound consisting of long molecules (called polymers).

Chemical equations

Scientists use a shorthand technique to describe what happens to reactants and products in chemical reactions. This is called a chemical equation. The reactants are written on the left-hand side and the products are written on the right-hand side. An arrow represents the chemical change.

reactants → products

For magnesium ribbon burning in air, the chemical reaction could be represented by the following chemical word equation and chemical symbol equation:

magnesium + oxygen → magnesium oxide
(in air) (white powdered form)

$$2\ Mg + O_2 \rightarrow 2\ MgO$$

Figure 5.15 Some processed foods have artificial chemicals added to them.

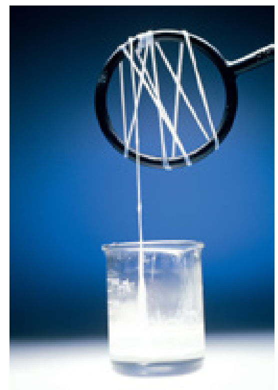


Figure 5.16 Nylon thread is made by mixing two solutions.

Check your learning 5.3

Remember and understand

1 Complete the following table. In the final column, include details about the substance's properties near a flame.

SUBSTANCE	FORMULA FOR SUBSTANCE	COLOUR	STATE AT ROOM TEMPERATURE	CHEMICAL PROPERTIES
Hydrogen				
Oxygen				
Water				

2 How different are reactants and products in chemical reactions?

3 What does the arrow represent in a chemical equation?

4 Why is it unnecessary to write an equation for a physical change?

Apply and analyse

5 Compared with a word equation, what extra information does a symbol equation contain?

6 Name the reactant and the product in the following chemical reactions.

a Iron ore is made into a steel ship.

b Bread is made from flour.

c Freezer bags made from polythene are manufactured from ethene.

d Nitrogen fertilisers are made from nitrogen gas and hydrogen gas.

e Carbon dioxide is produced when petrol is burnt in a car engine.

5.4 Heat can speed up a reaction

The rate of a reaction can be sped up or slowed down. A number of factors affect the rate of a reaction. These include the particle size, temperature and concentration of substances and the presence of catalysts. The particle model helps us understand this more clearly.

The effect of particle size

The size of a particle in a substance affects the rate of a reaction. The smaller the size of the particles, the faster the rate of the reaction. This is because the smaller particles have a greater total surface area, which means that the particles have a greater chance of interacting with each other.

The effect of temperature

If we know that the size of particles has an effect on the rate of a chemical reaction, how does temperature affect particles of the same size?

For substances to react, their particles must come into contact with each other, or collide. This is known as the **collision theory**. In the collision theory, the more collisions that happen between the particles, the more likely it is that they will react.

One way to increase the number of collisions between the particles is to increase the temperature. When heat energy is added to the substance, the particles gain kinetic energy and therefore move quicker. To slow down a reaction, the temperature can be reduced so that the particles have less kinetic energy and have less chance of colliding.

The effect of concentration

In addition to changing the rate of chemical reactions through particle size and temperature,
the number of particles trapped in a small area, the **concentration**, also has an effect. More concentrated substances will react more easily, again due to the collision theory. A more concentrated substance has more particles available to collide with particles from another substance. For instance, to

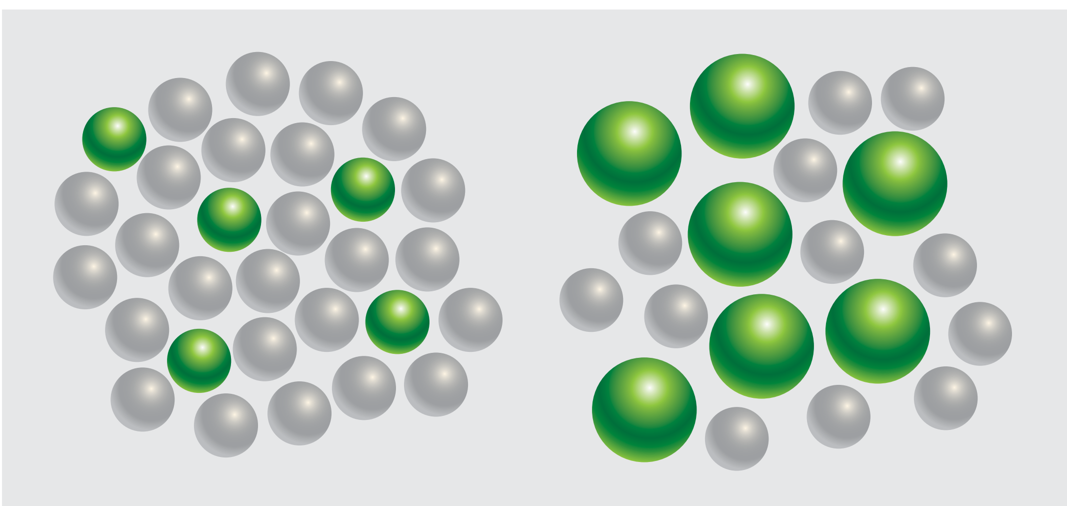


Figure 5.17 More reactants can interact when the particles are small (left). Large particles have less total surface area, compared to the small particles, to make contact with other reactants (right).

EXPERIMENT 5.4A: EFFECT OF PARTICLE SIZE ON REACTION RATES
GO TO PAGE 193.

EXPERIMENT 5.4B: SPEEDING UP REACTIONS WITH ENZYMES
GO TO PAGE 194.

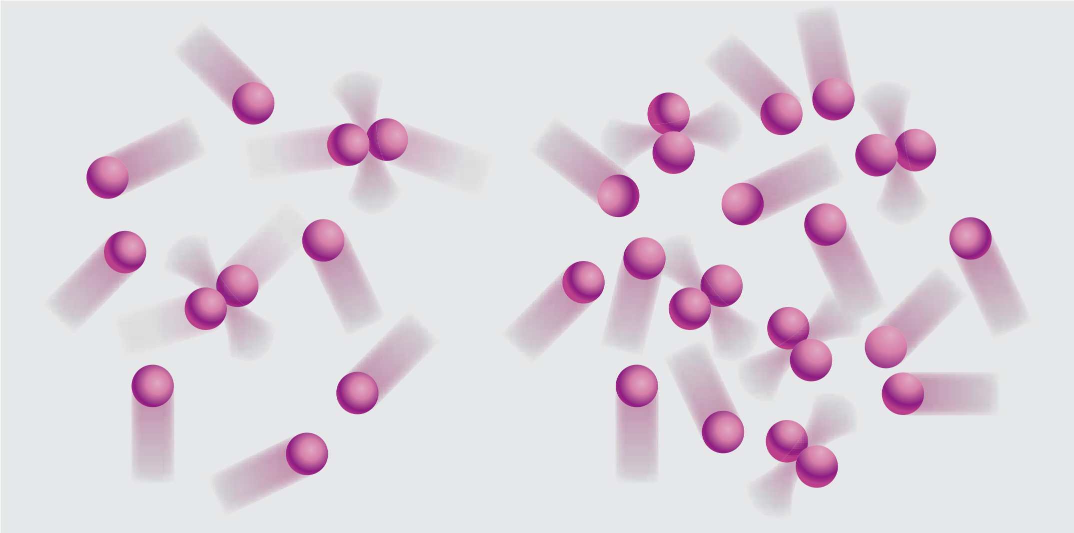


Figure 5.18 At low concentrations there are few collisions between particles (left). At high concentrations, the number of collisions between particles is increased (right).

increase the rate of a reaction between a solid substance and one in solution, increasing the concentration of the solution will mean that there are more particles in the solution to collide with the particles in the solid.

The effect of catalysts

Adding another substance or materials may also affect the rate of the chemical reaction. Substances that increase the rate of a reaction without becoming used up by it are known as **catalysts**.

Enzymes are types of catalysts that help speed up reactions in living things. We have many enzymes in our bodies that help speed up chemical reactions. For example, enzymes found in the digestive system help break down food. Enzymes are very 'fussy' and only work with one type of reactant and so will only catalyse one reaction each. They act like landing strips for reactants, allowing the chemicals to collide with each other more easily.

Enzymes are responsible for the ripening of fruit. When a piece of fruit is cut and left exposed to the air, enzymes help the oxygen react with the fruit and make it turn brown. This enzyme can be blocked by adding vitamin C.

Check your learning 5.4

Remember and understand

1. How does the particle model of matter help explain the rate of reactions?
2. What is the collision theory?
3. How does particle size affect the rate of a reaction?
4. What effect do enzymes have on the rate of a reaction?
5. Describe what happens to the number of particles when you increase the concentration of a substance.
6. How does increasing the concentration of reactants increase the rate of a reaction?

Apply and analyse

7. Does increasing the rate of a reaction change the amount of product produced? Explain your reasoning.

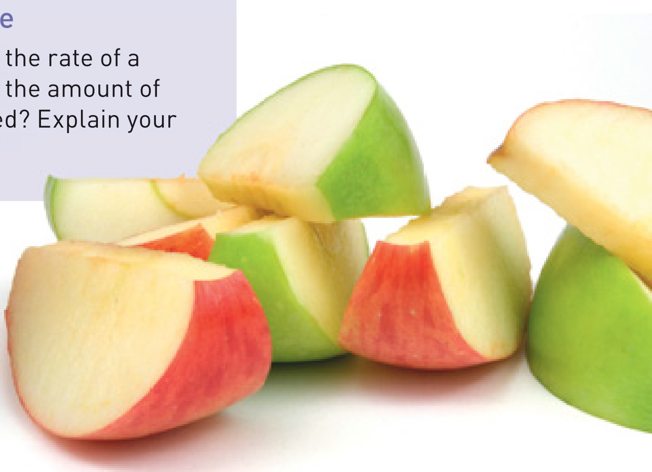


Figure 5.19 Adding lemon juice to cut apples stops them from going brown. Lemons contain vitamin C.

//SCIENCE AS
A HUMAN ENDEAVOUR//

5.5 Many substances exist because of the work of scientists

It is easy to forget just how much we rely on manufactured products in our life. Increasingly, many substances and materials are processed (i.e. changed) or manufactured before they are used. These substances, such as medicines, electronic components, composite materials in aircraft and polymers, only exist because of the work of scientists changing them from their original state to one that you can use.

Figure 5.20 All these products come from petroleum.

Pharmaceuticals

Pharmacies (sometimes also called 'chemist shops') are where medicines are prepared and dispensed. A pharmacist (sometimes also called a 'chemist') has studied chemistry, but has specialised in the study of medicines and their effect on the body (called 'pharmacology').

Oil refinery

Petroleum, or crude oil, is an important product in our society. Oil is pumped from the ground and is carried in pipelines or tankers to refineries, where it is separated into its components. The low-value parts of the crude oil mixture are converted into high-value products, such as petrol, diesel and materials used to produce plastics. 'Plastic' is the common name for a range of polymers used in items such as freezer bags, CD cases, shoes, furniture and clothing.

Figure 5.22 Pharmacists are chemists with a specialisation.

Glues and adhesives

Glue was used in ancient Babylon 3500 years ago when King Nebuchadnezzar used bitumen (also called 'asphalt') to hold building stones together. Later, plant gums, egg white and animal products (such as gelatin) were used for gluing paper and wood. The paints used by the old masters were made using egg white, which helped to hold the parts of the paint mixture together.

Figure 5.21 Many everyday items are the result of carefully considered chemistry.

EXPERIMENT 5.5: MAKING CASEIN GLUE
GO TO PAGE 195.

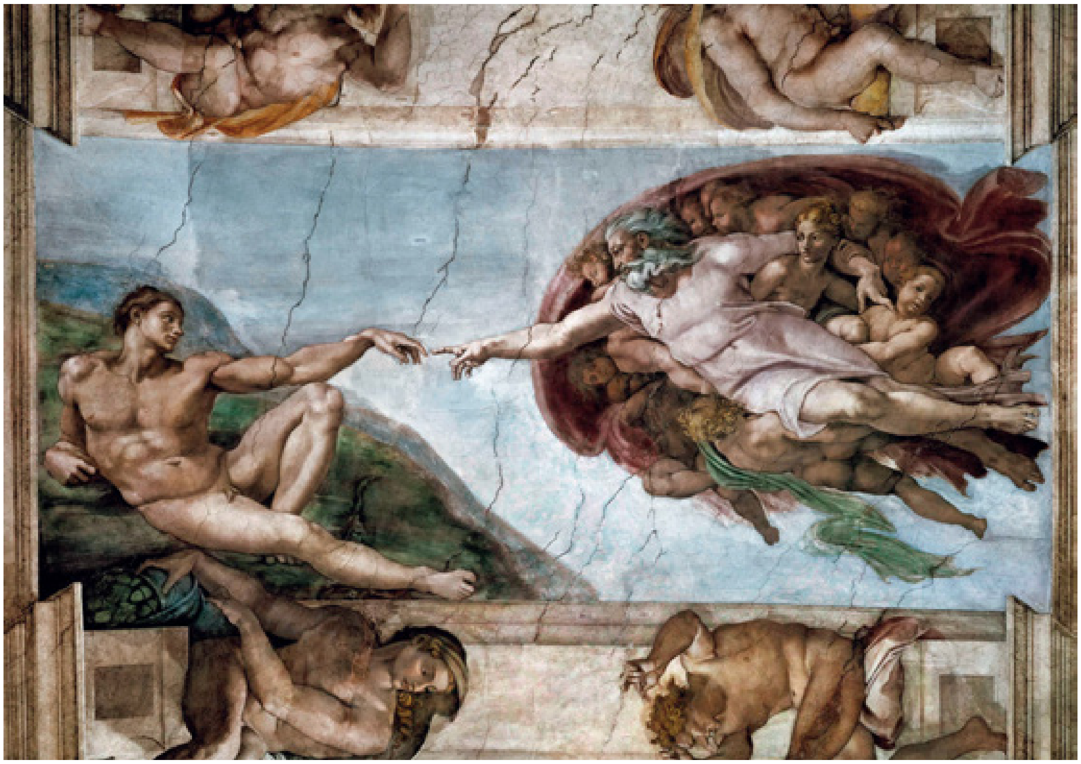


Figure 5.23 Older paints contained egg white to help hold the paint together.

Figure 5.24 A glue is any substance that sticks things together.

In World War I, aircraft were made of wood. The wood was glued with casein glue (casein is a protein in milk) and albumin (a protein in egg white).

Nowadays, many synthetic glues are used. Once, shoes were made of layers of leather nailed and sewn together; now these layers are mostly glued. Glue is used to hold many things together, including the chips in chipboard and the layers in MDF board, plywood and in a lot of furniture. Even the brake linings in cars are glued (bonded).

Dyes

Before the use of dyes, all clothes had the same colour – the off-white colour of natural fibres, raw cotton, silk and wool.

The first dye was obtained from murex whelk shells, a type of sea snail. It took 9000 shells to make enough dye for one Roman emperor's toga! Only the emperor had dyed clothes, and these were always purple. In fact, the whelk almost became extinct as a result of being hunted for its dye.

The soldiers in the British Army used to be known as 'redcoats'. Their uniform consisted of a red coat, which was dyed using the liquid extracted from scale insects. This red dye, cochineal, is available today in supermarkets, but it is now made synthetically.

The first synthetic (or artificial) dye was discovered accidentally by William Perkin in 1878. He named his dye after its colour, mauve. Soon many other coloured dyes had been discovered and were being manufactured.

Computer printers use dyes when they print photographs. Modern inks do not fade, so the photographs last longer than photographs printed many years ago.

Extend your understanding

1. What is the role of chemistry in purifying crude oil in an oil refinery?
2. Describe how chemists have improved on natural glues and adhesives.
3. What colour were the first natural dye and the first synthetic dye?
4. List five materials that are made by chemists.

Figure 5.25 Dyes originally came from living organisms. Today they are mostly synthetic.

//SCIENCE AS
A HUMAN ENDEAVOUR//

5.6 Physical and chemical changes are used to recycle household waste

Understanding the difference between physical and chemical reactions can help us understand which objects can be recycled. Objects that can undergo physical reactions can be easily recycled because the reactions are reversible and new shapes can be formed. Chemical reactions can be used to create new materials that can be used again.

Types of plastic

As you discovered in 5.5, plastics are made from a chemical reaction with crude oil. This is hard to recycle and as most plastic products are only designed to be used for one year, they often end up in landfill. Recycling the chemicals in the plastic is often cheaper than the oil needed to create new products.

All recycled plastic belongs in seven groups. (See Figures 5.26 to 5.32).

Mechanical/physical recycling of plastics

This is broken into several steps.

1 Cutting the large pieces of plastic using shears or saws.
2 Shredding the plastic into small flakes.
3 Separating the contaminants in cyclone (centrifuge) separators.
4 Floating off the plastics according to their density.
5 Extruding the plastic by heating it to a melting state and forcing it into long strands.
6 Cooling the strands and cutting it into small pellets so that it can be reused for new products.

Chemical recycling of plastics

Chemical recycling involves creating a chemical reaction that causes the long polymer molecules that make up the plastic to break into smaller molecules called monomers. This requires a lot of energy because it is trying to reverse the initial chemical change that created the plastic. As the initial reactants (crude oil) become more expensive, the chemical recycling of plastics will become a more attractive option.

Recycling of metals

Metals such as iron can be easily recycled using physical reactions. This means the metal can be heated until it melts, and then reshaped in its new form. One of the problems with recycling metals, such as iron, is that they easily rust. You will have seen rust on cars, food tins, tools, fences, roofs and bridges.

Rust is the most common type of corrosion. **Corrosion** is a chemical reaction between a substance and its environment. Rusting refers to the corrosion of iron and steel objects when they are exposed to air. These materials tend to

Figure 5.26 Polyethylene terephthalate (PET or PETE) is the plastic found in soft drink bottles or oven ready meal trays.

Figure 5.27 High density polyethylene (HDPE) is used to make milk and juice bottles, some washing-up bottles, toys and grocery bags.

Figure 5.28 Polyvinyl chloride (PVC) is used to make clear food packaging, shampoo and medication bottles, and food trays.

Figure 5.29 Low density polyethylene (LDPE) is used to make grocery bags, bin liners, bread bags and frozen food bags.

Figure 5.30 Polypropylene (PP) is used to make microwave meal trays, sauce bottles, yoghurt containers and medicine bottles.

Figure 5.31 Polystyrene (PS) is used to make foam meat or fish trays, coffee cups, plastic cutlery and sandwich boxes.

Figure 5.32 Group 7 contains all other plastics, including nylon and fibreglass, that cannot be recycled.

rust very easily and, once the reaction starts, it is difficult to slow or stop. The rust is a reddish brown molecule of iron oxide that forms from the reaction of iron with oxygen, as shown in the word equation below.

iron + oxygen → iron oxide

The chemical reaction of rusting is very difficult to reverse, and this prevents metal being reused. Rust can be prevented in a number of ways. Most ways involve preventing the iron from coming into contact with the oxygen in air, such as coating the iron with paint or oil, or preventing the reaction from taking place.

Extend your understanding

1 Examine your rubbish and write a list of the plastics that can be recycled.
2 Draw a picture of what happens at each stage of the mechanical recycling process.
3 Why is the chemical recycling of plastics expensive?
4 What is corrosion?
5 What happens when iron rusts?

Remember and understand

1 Use the particle model to explain:
   a melting
   b freezing
   c sublimation
   d condensation.

2 What is a reactant in a chemical reaction?

3 What changes might be observed during a chemical change?

4 What is the difference between a physical change and a chemical change?

5 Using your knowledge of particles, explain why most physical changes can be reversed.

6 Name four ways to speed up a chemical reaction. Use the particle model to explain why each method works.

7 Describe three uses of chemicals in the home.

8 Why is nylon described as a synthetic material?

9 Name an object that is made from PVC.

Apply and analyse

10 Chemists would never write a chemical equation for the melting of chocolate. Why is this?

11 In one experiment, you observed the reaction between copper sulfate solution and iron to make copper and iron sulfate solution.
   a Complete the following table to summarise the changes observed in this reaction.

NAME OF REACTANTS	DESCRIPTION	NAME OF PRODUCTS	DESCRIPTION

   b Use the information in the table to explain why this is an example of a chemical change.

12 Dyes can be synthetic or natural in origin.
   a Describe one advantage and one disadvantage of using natural dyes.
   b Describe one advantage and one disadvantage of using synthetic dyes.

13 The use of chemistry to produce new materials has affected people's lives in a range of ways.
   a Describe how new materials have changed the type of clothes that people wear.
   b Describe how new materials have changed the type of food that people eat.

14 Describe a chemical change that may be harmful to the environment if it is allowed to occur in an uncontrolled way.

15 The following are descriptions of interactions that occur around us in our daily lives. Describe what the products of these interactions might be and explain whether you think the changes described are useful or harmful.

a A bike is left out in the rain so that parts of the bike that are made of steel are in contact with water for a few hours.

b A barbecue fuelled by propane gas is turned on.

c A hairdresser applies bleach to someone's hair.

d Sugar dissolves in a cup of tea.

16 Some of the chemical changes that occur with food are described as biochemical reactions. Why do you think that is?

Evaluate and create

17 Think about what you do on a daily basis, including eating, washing, travelling, working and playing. Describe how these activities would be different if you were only able to use natural materials.

18 An environmental action group wanted to ban the use of chemicals in your school.

Either:

a Write a letter to your school principal explaining why you think this would be a good idea;

or:

b Write a letter to the leader of the environmental group explaining why you think this is a bad idea.

19 Substances can change when they interact with each other. In each of the following situations, a change is described. For each change, describe the interactions that have caused the change to occur. The first one has been done for you.

a Glue makes a bond between two pieces of wood. *Possible answer: The glue interacts with the oxygen in the air, which causes it to set hard, which joins the two pieces of wood together.*

b Sugar turns into caramel.

c Charcoal burns in air to form the gas carbon dioxide.

d Starch is digested in our stomach to form simple sugars, such as glucose.

e A loaf of bread rises in an oven as carbon dioxide gas is produced.

Research

20 Choose one of the following topics for a research project. A few guiding questions have been provided for you, but you should add more questions that you want to investigate. Present your research in a format of your own choosing, giving careful consideration to the information you are presenting.

a **Magic or chemistry?**

Magicians use a range of tricks to deceive the audience into thinking magic is real. Some of these tricks use chemical reactions. What sort of chemical reactions could be used by magicians? What sort of physical changes could be used in tricks performed by magicians? How does the 'magic' happen?

b **Explosives**

The history of the development of explosives is fascinating. Who discovered them? When were explosives first used and how do they work? What are the main chemicals used and what types are there? What part did Alfred Nobel play?

c **Respiration**

Respiration is a chemical process that occurs in our body and is essential for our survival. What are the reactants used in respiration? What are the products? Where in our bodies does respiration occur? Why is respiration such an important process?

d **Barbecue fuels**

Most home barbecues burn liquefied petroleum gas (LPG) as the fuel. This is the gas that can be bought at hardware and camping stores in cylinders. What chemicals are present in LPG? What are the advantages of gas barbecues over solid fuel barbecues? What safety precautions must be followed when storing LPG cylinders?

* *KEY WORDS*

5

boil
to change state from a liquid to a gas

catalyst
a substance that increases the rate of a chemical reaction without undergoing any permanent chemical change

chemical reaction
procedure that produces new chemicals; same as chemical change

collision theory
when substances react, their particles must come into contact or collide with each other

concentration
the amount of a substance in a set volume

condense
when a gas becomes a liquid

corrosion
the damage caused to metal by its environment

enzyme
chemical that helps make chemical reactions happen; a type of catalyst

fume
a gas or vapour that has a strong smell or is dangerous to breathe in

lattice
three-dimensional arrangement of particles in a regular pattern

melt
to change state from a solid to a liquid

product
substance obtained at the end of a chemical reaction; written on the right side of a chemical equation

reactant
substance used at the beginning of a chemical reaction; written on the left side of a chemical equation

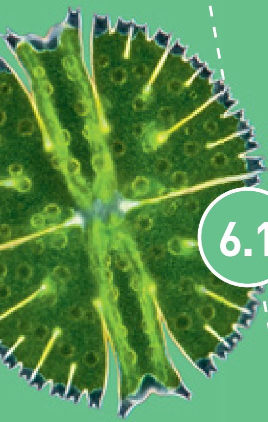
sublimation
change of state straight from a solid to a gas or from a gas to a solid

vaporise
to change state from a liquid to a gas; same as evaporate

vapour
gaseous form of a substance that is normally a solid or liquid, e.g. water vapour

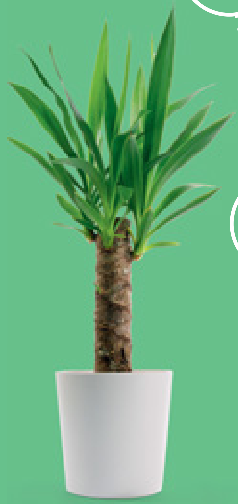
volatile
a substance that easily becomes a gas

CELLS 6



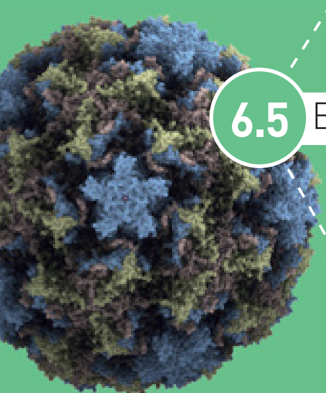
6.1 All living things are made up of cells

6.2 Microscopes are used to study cells



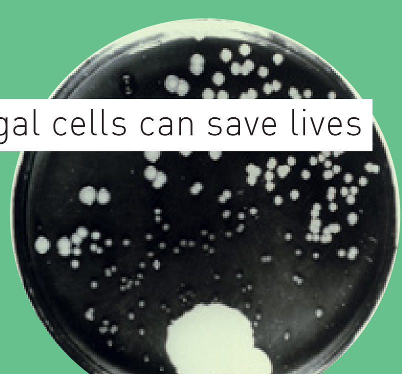
6.3 Plant and animal cells have organelles

6.4 All organisms have cells that specialise



6.5 Bacteria are single-celled organisms

6.6 Eukaryotic cells undergo mitosis



6.7 Fungal cells can save lives

What if?

Building blocks

What you need:

building blocks (for example, Lego blocks)

What to do:

1 Use the blocks to make a cube.
2 Rearrange the blocks to make a pyramid shape.
3 Rearrange the blocks a third time to make a rough circle.

What if?

» What if you wanted to make your shapes bigger?
» What if you just had one large block? How many shapes could you make?
» What if you had different shaped blocks? How many shapes could you make?

6.1 All living things are made up of cells

Scientists have not always known that living things are made up of cells. It was the invention of the microscope in the mid-17th century that allowed us to see the building blocks of life – the tiny units that form every living thing. Microscopes showed that each and every living thing is made up of **cells**.

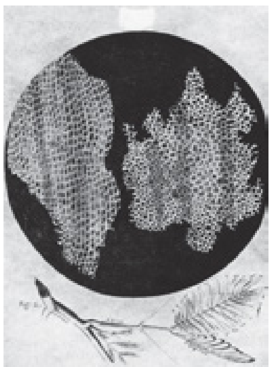


Figure 6.1 Robert Hooke's drawing of cork.

Discovering cells

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

Hooke's most famous achievement was his diagram of very thin slices of cork (Figure 6.1). He was surprised to see that, under the microscope, the cork looked like a piece of honeycomb. He described the 'holes' and their boundaries in the 'honeycomb' as cells because they reminded him of the small rooms in a monastery, which were also called cells. Hooke had discovered plant cells.

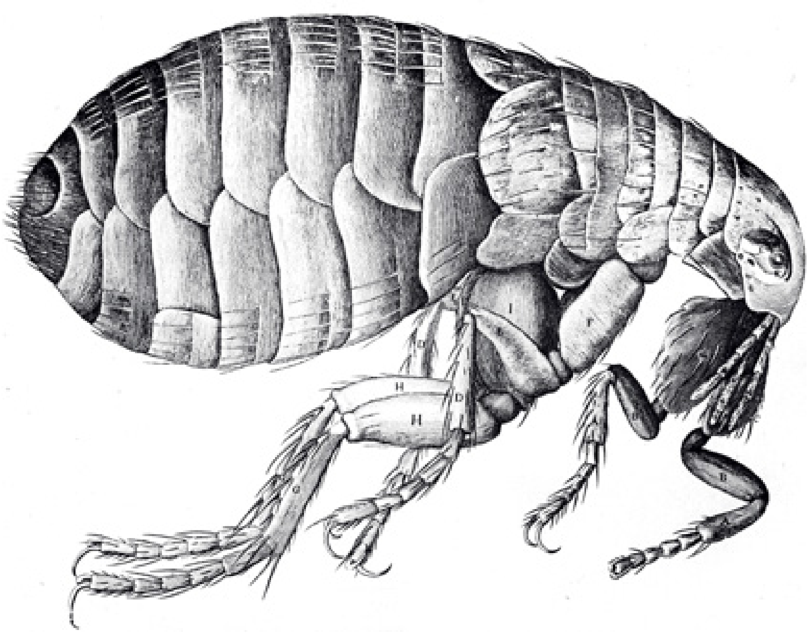


Figure 6.2 Robert Hooke's detailed drawing of a flea.

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

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

Cell theory

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

> All organisms are composed of one or more cells.
> Cells are the basic unit of life and structure.
> New cells are created from existing cells.

Any living thing that has more than one cell is referred to as **multicellular**, but there are many living things, such as bacteria, that consist of only one cell. These are called **single-celled** or **unicellular** organisms. **Microorganisms**, which are also often referred to as **microbes**, are organisms that can only be seen under the microscope – they can be single-celled or multicellular.

SKILLS LAB 6.1: DRAWING CELLS
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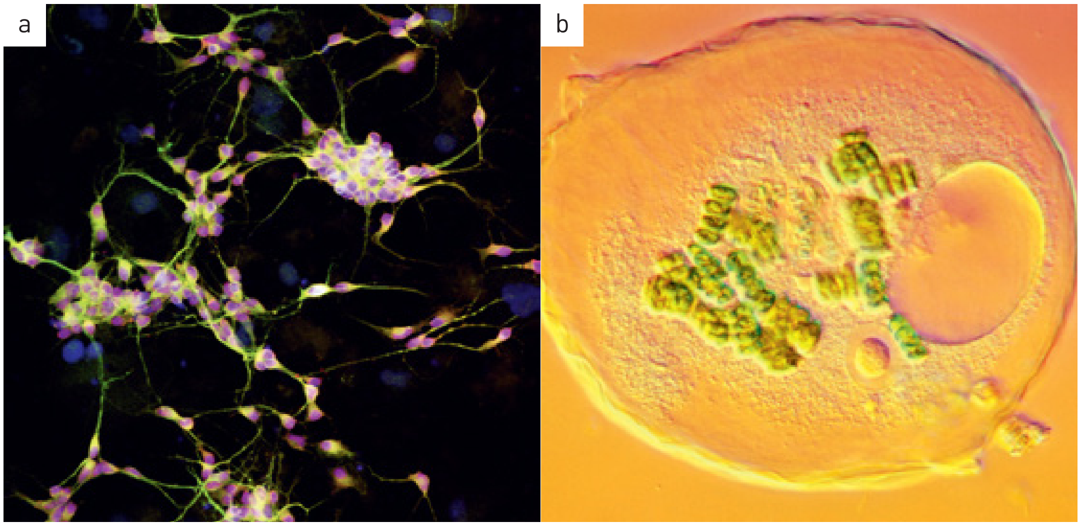

Figure 6.3 (a) Human nerve cells are part of multicellular humans, but (b) the amoeba is a unicellular organism.

Why are cells so small?

The surface of a cell is called the **cell membrane**. Some substances can move across this membrane; **nutrients** enter the cell and wastes exit the cell. In order to survive, cells benefit from the relatively large surface area of the cell membrane to maximise the ability to take in nutrients and remove wastes.

The total space inside the cell is referred to as the cell's volume. As a cell increases in size, both its volume and its surface area increase. The problem is, the volume increases much more than the surface area. Eventually the volume becomes so big that it becomes difficult for nutrients to get into the centre of the cell and for wastes to get out. We compare the relationship between the amount of surface area and the volume of a cell through a fraction – the **surface area to volume ratio**. Small cells have a large surface area compared to their volume (a large surface area to volume ratio) and are therefore better able to survive.

This explains why single-celled organisms are so small. A single cell must do all the same things that a larger organism does. The cell membrane is particularly important because it provides a barrier between the inside of the cell and the external environment. All the nutrients needed to keep the cells alive, and the waste products made by the cell, are transported across the cell membrane. It is essential that the cell membrane provides a large surface area for the transport of so many molecules into and out of the cell.

Figure 6.4 The irregular shape of this unicellular organism (called a desmid) maximises the surface area to volume ratio.

Check your learning 6.1

Remember and understand

1 Who invented the first microscope?
2 Why are cells called 'cells'?
3 What does 'multicellular' mean?
4 Name five multicellular organisms.
5 What do all unicellular organisms have in common?
6 What are the three principles of the combined cell theory?

Apply and analyse

7 The common house dust mite is a microorganism. Could you see this animal without a microscope? Explain how you came to your answer.
8 Would a cell with a bigger surface area to volume ratio be able to meet its requirements for nutrients more effectively? Why or why not?
9 Why are unicellular organisms always very small?

6.2 Microscopes are used to study cells

In the same way that eyeglasses have a glass or plastic lens for vision correction, a **microscope** is an instrument that use lenses to magnify the size of the object placed under it. The science of investigating small objects using a microscope is called **microscopy**.

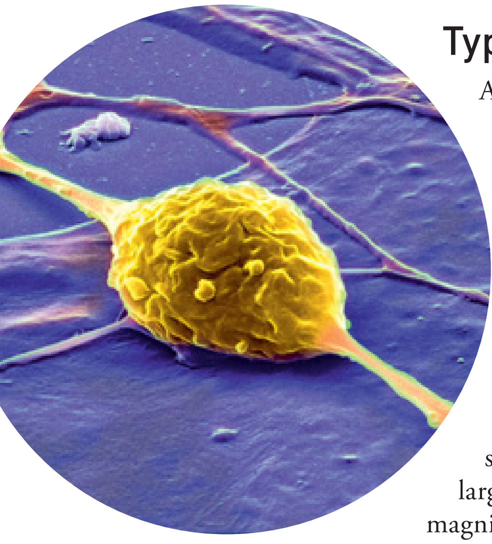

Figure 6.5 SEM image of a nerve cell.

Types of microscopes

As a science student, you will probably use a light microscope in your laboratory. You may also work with images produced by different types of **electron microscopes.**

Light microscopes

There are two common types of light microscope – the **stereomicroscope** and the **compound light microscope**. The stereomicroscope is used for viewing larger objects, such as insects. It can magnify up to 200 times and shows a three-dimensional view.

The compound light microscope is used to observe thin slices of specimens. It can magnify up to 1500 times. Its view is two-dimensional. The specimen must be thin enough to allow light to pass through it.

The stereomicroscope has two **eyepieces** to look through, whereas the compound light microscope can have one or two eyepieces. The word **monocular** is used to describe a microscope with one eyepiece (mono = one). Microscopes with two lenses are called **binocular** (bi = two). The compound light microscope uses the effect of two lenses (one in the eyepieces and one further down the column, called the **objective lens**) combined with light to give a greater magnification. Most cells are clear in colour so a **stain**, such as iodine, is used to help make them more visible by providing contrast.

Electron microscopes

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

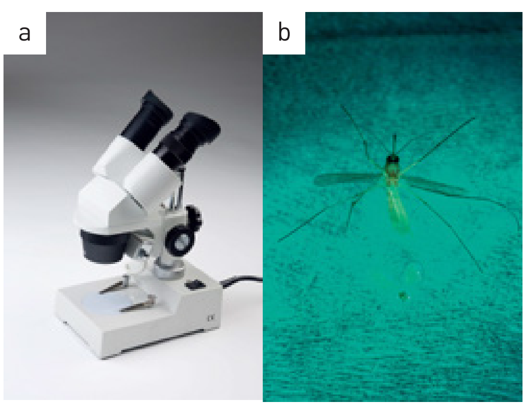

Figure 6.6 (a) A stereomicroscope. (b) An insect, as seen under a stereomicroscope.

Figure 6.7 (a) A compound light microscope. (b) A flea, as seen under a compound light microscope.

SKILLS LAB 6.2: GETTING TO KNOW YOUR MICROSCOPE
GO TO PAGE 197.

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

Getting to know your compound light microscope

Figure 6.8 shows the parts of a monocular compound light microscope. Microscopes are fragile instruments that must be treated with care.

> Always use two hands to carry a microscope – one hand around the main part of the instrument and the other underneath it.
> Some microscopes have a built-in lamp. Others have separate lamps that need to be set up so they shine onto the mirror. Adjust the mirror to project the light through the stage onto the specimen. Do not allow sunlight to shine directly up the column.
> Place the slide on the stage then select the objective lens with the lowest magnification.
> Look from the side and adjust the coarse focus knob so that the objective lens is *just above – and not touching* – the slide. Check which way you must turn the knob to move the objective lens away from the slide.

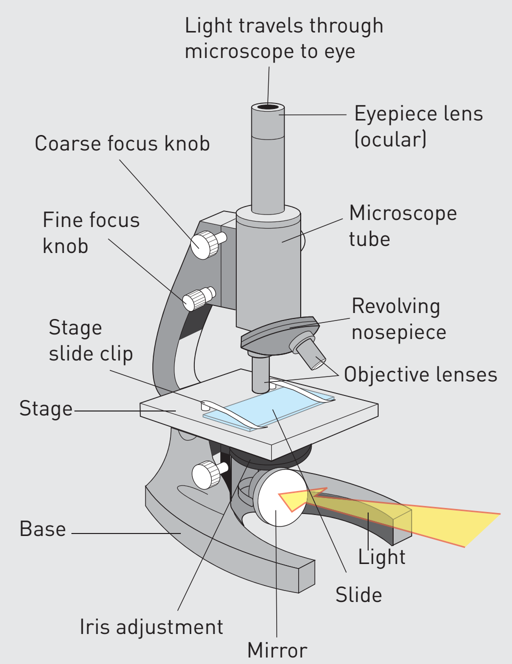

Figure 6.8 Parts of a compound light microscope.

> Use the coarse focus knob to bring the specimen into view. Use the fine focus knob to help you see it more clearly.
> If you want a higher magnification, rotate the objective lens to a higher magnification.
> Draw what you see (as a record) using a pencil.
> Work out the total magnification.
> Write the magnification next to your sketch.
> Label and date the sketch.

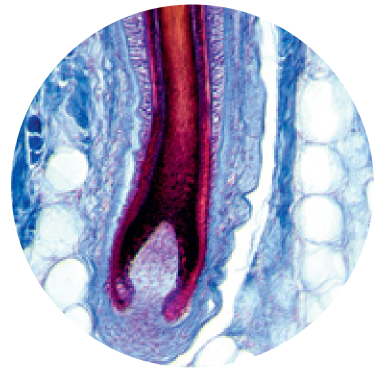

Figure 6.9 Human hair root that is stained for contrast.

Magnification calculations

Using different combinations of lenses means you can magnify your object by different amounts. To calculate the total magnification of a compound light microscope, multiply the magnification of the eyepiece lens by the magnification of the objective lens. These figures are marked on each lens.

Table 6.1 The total magnification of a microscope can be determined by multiplying the magnifications of the eyepiece and the objective lens.

EYEPIECE MAGNIFICATION	OBJECTIVE LENS MAGNIFICATION	TOTAL MAGNIFICATION
× 5	× 10	× 50
× 10	× 20	× 200

Check your learning 6.2

Remember and understand

1 What type or types of microscopes are in your science laboratory?
2 Why do you look from the side when you adjust the coarse focus knob?
3 Why must very thin samples be used under a light microscope?
4 What is 'microscopy'?

Apply and analyse

5 Explain why it is important to label and date your specimen drawings. Give three different reasons.
6 Complete the following magnification table for a compound light microscope by working out the missing values.

EYEPIECE MAGNIFICATION	OBJECTIVE LENS MAGNIFICATION	TOTAL MAGNIFICATION
× 5		× 100
	× 20	× 300
× 10	× 50	

6.3 Plant and animal cells have organelles

A cell is the basic unit of life. It is called this because it is the smallest unit of an organism that is considered living. But, just as the basic unit of length – the metre – can be broken down into smaller parts (e.g. centimetres and millimetres), the cell is made up of smaller parts, too. Cells are made up of **organelles** (mini-organs), cytoplasm, DNA, nutrients, wastes and other substances.

Cell structures

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

> **Cell membrane** – this acts like the 'skin' of a cell, forming a barrier around the cell. It controls the entry and exit of things into and out of the cell.

> **Cytoplasm** – this is the jelly-like fluid inside the cell membrane that surrounds everything inside the cell. It helps provide structure to the cell and contains many dissolved nutrients and waste products.

> **DNA** (deoxyribonucleic acid) – this contains the instructions for every job your cells need to do and is passed from one generation to the next. The code for half your DNA came from your mother, and the other half came from your father. The same complete set of DNA is found in every one of your cells.

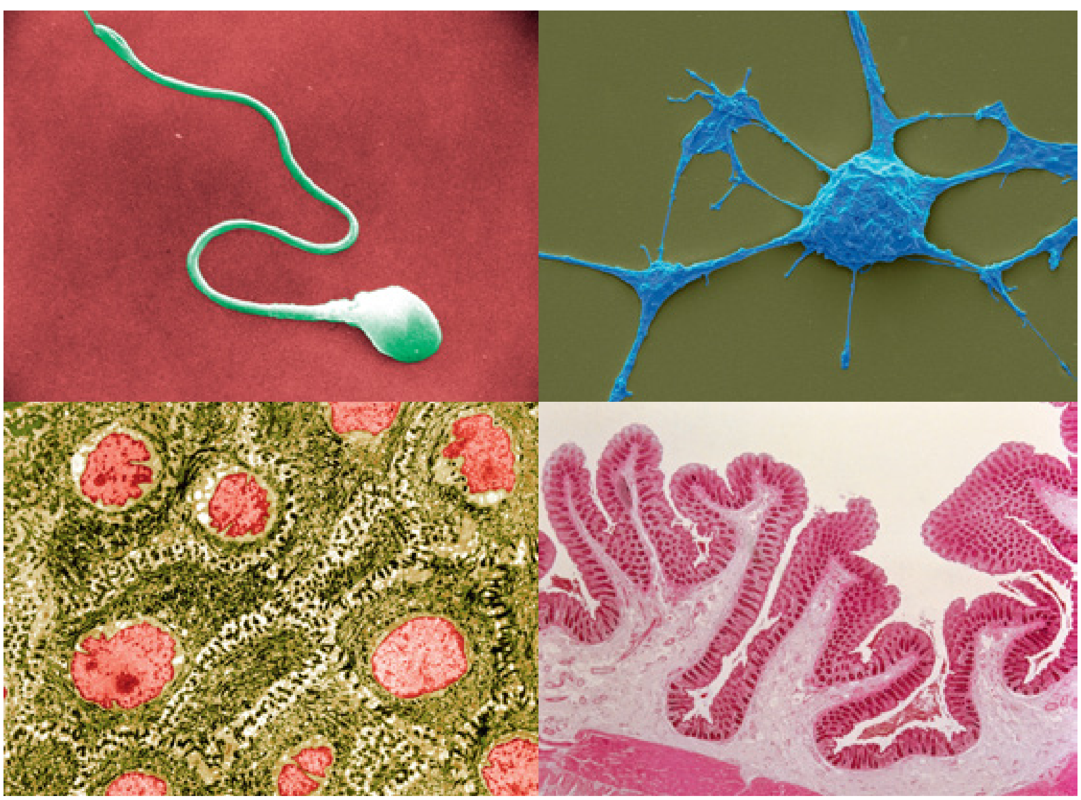

Figure 6.10 Cells can be different shapes and sizes: (a) sperm cell, (b) nerve cell, (c) skin cell and (d) intestinal cell.

CHALLENGE 6.3: COMPARING THE SIZE OF CELLS AND THEIR PARTS
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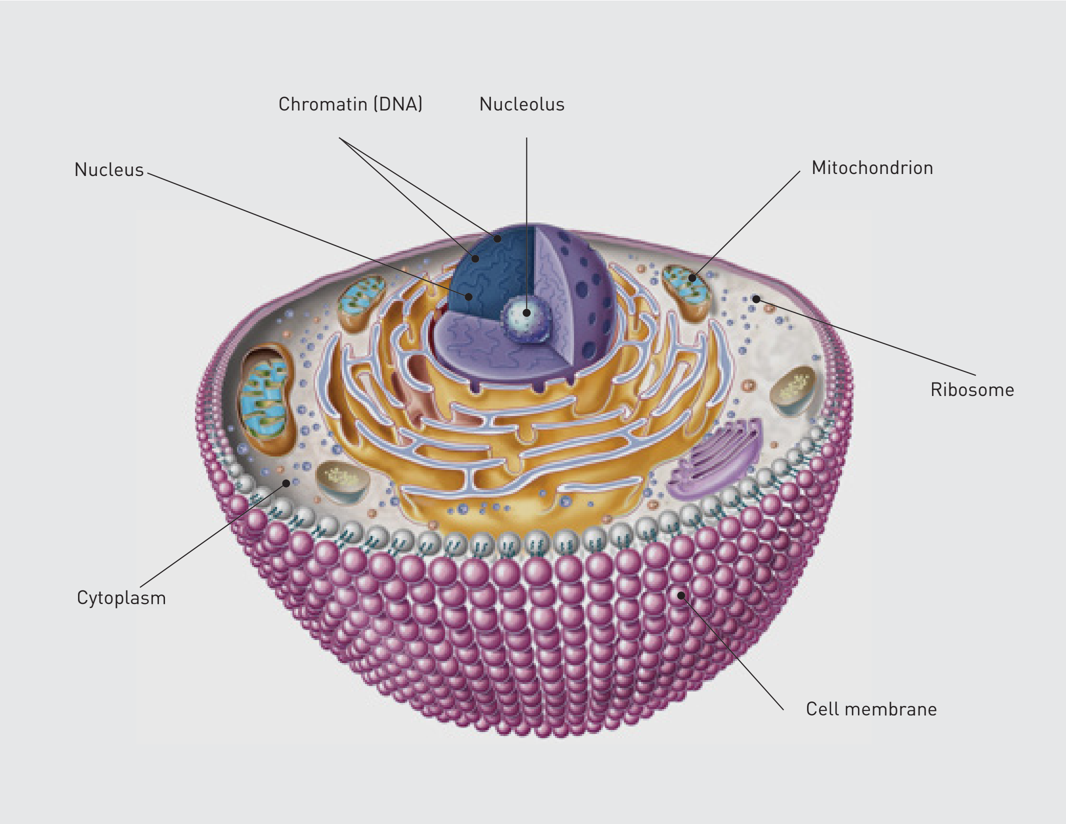

Figure 6.11 Some key parts (organelles) of an animal cell.

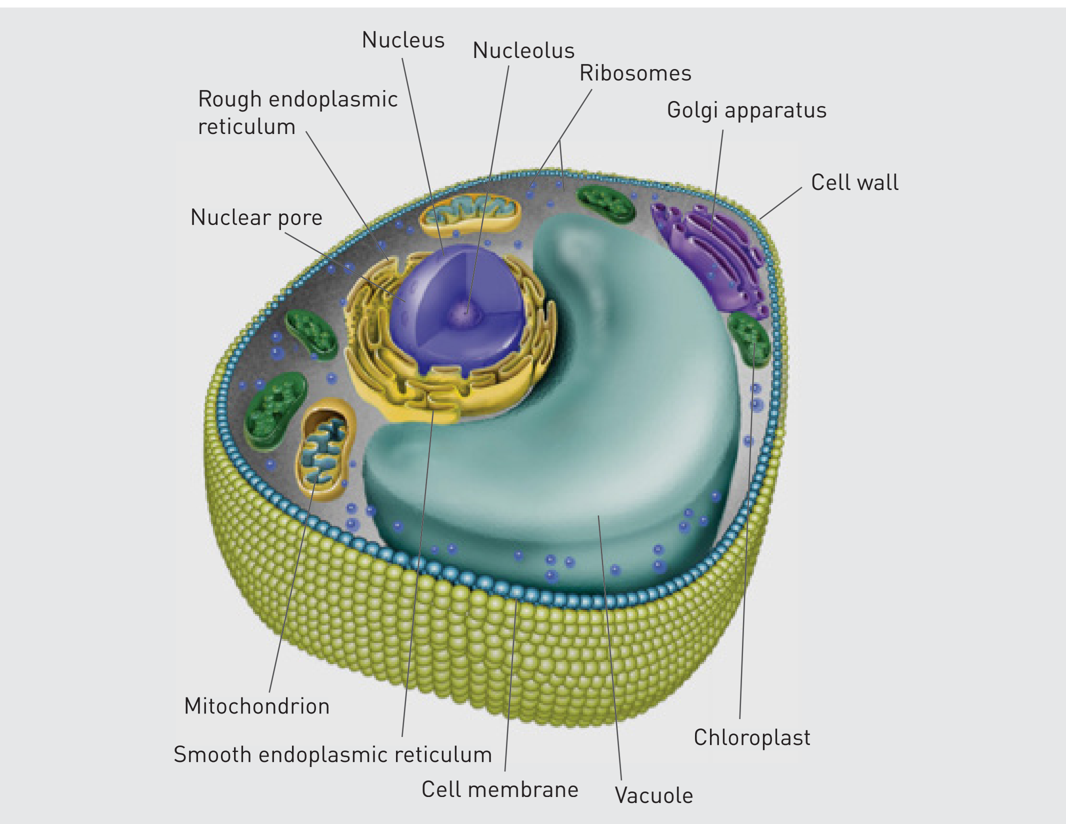

Figure 6.12 Some key parts (organelles) of an plant cell.

A closer look at organelles

The different organelles in cells all have specific functions. These functions are necessary for the cell to survive. Some organelles, such as ribosomes, are part of the cytoplasm, whereas other organelles are separated from the cytoplasm by a membrane, much like the cell membrane. These organelles, such as the nucleus and chloroplasts, are called membrane-bound organelles.

Let’s take a closer look at four very important membrane-bound organelles in the cell – the mitochondria, ribosomes, chloroplasts and vesicles.

Mitochondria

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

Mitochondria are rod-shaped organelles with an inner and an outer membrane. The inner membrane is folded to increase the surface area of the membrane. A chemical reaction called cellular respiration occurs inside the mitochondria. This reaction involves the rearrangement of the atoms in glucose (from the food we eat) and oxygen to produce water, carbon dioxide and energy. This energy is used by our bodies to help us move and grow.

Ribosomes

Ribosomes are where protein is made in the cell. Proteins are small molecules with different roles. There are many different types of proteins. For example, proteins make up hair and nails, or help transport oxygen through the bloodstream.

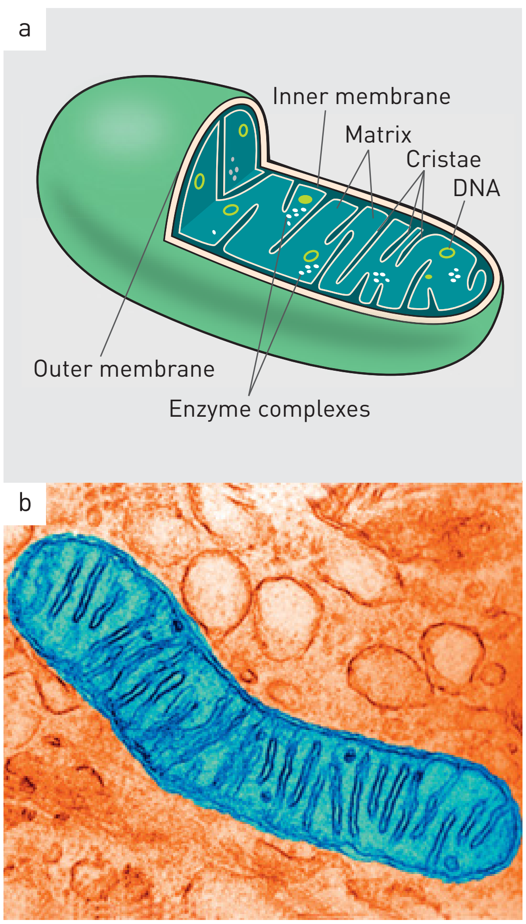

Figure 6.13 (a) Schematic diagram showing the structure of a mitochondrion. (b) Electron micrograph of a mitochondrion.

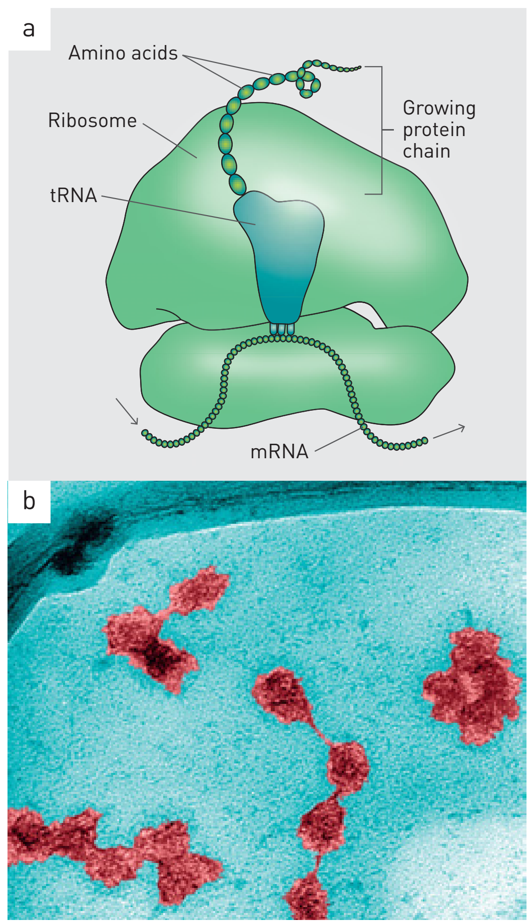

Figure 6.14 (a) Schematic diagram showing the structure of a ribosome (b) Electron micrograph of ribosomes.

EXPERIMENT 6.3A: LOOKING AT ORGANELLES
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EXPERIMENT 6.3B: MEASURING CELLS
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Chloroplasts

Chloroplasts are only found in plant cells and some unicellular organisms. These organelles are like microscopic solar panels that transform solar energy into chemical energy.

Chloroplasts are usually green because of a molecule called **chlorophyll**. Chlorophyll uses the Sun's light energy to rearrange molecules of carbon dioxide and water into glucose (a sugar) and oxygen. This chemical reaction is called **photosynthesis**.

Vesicles

Vesicles are organelles that are used by plant and animal cells to store water, nutrients and waste products. A membrane surrounds the vesicle, separating the substances from the rest of the cell. Plant cells usually have one large vesicle called a vacuole (see Figure 6.12). Animals cells may have many small vesicles.

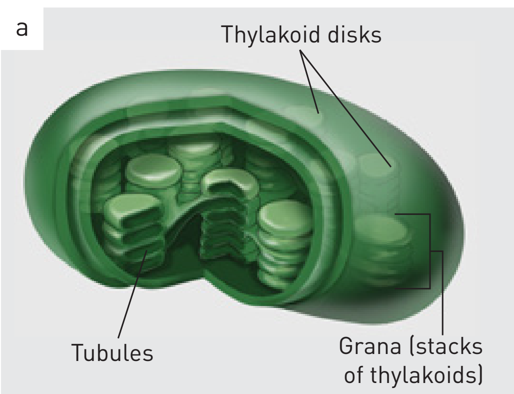

Figure 6.15 (a) Schematic diagram showing the structure of a chloroplast. (b) Electron micrograph of a chloroplast.

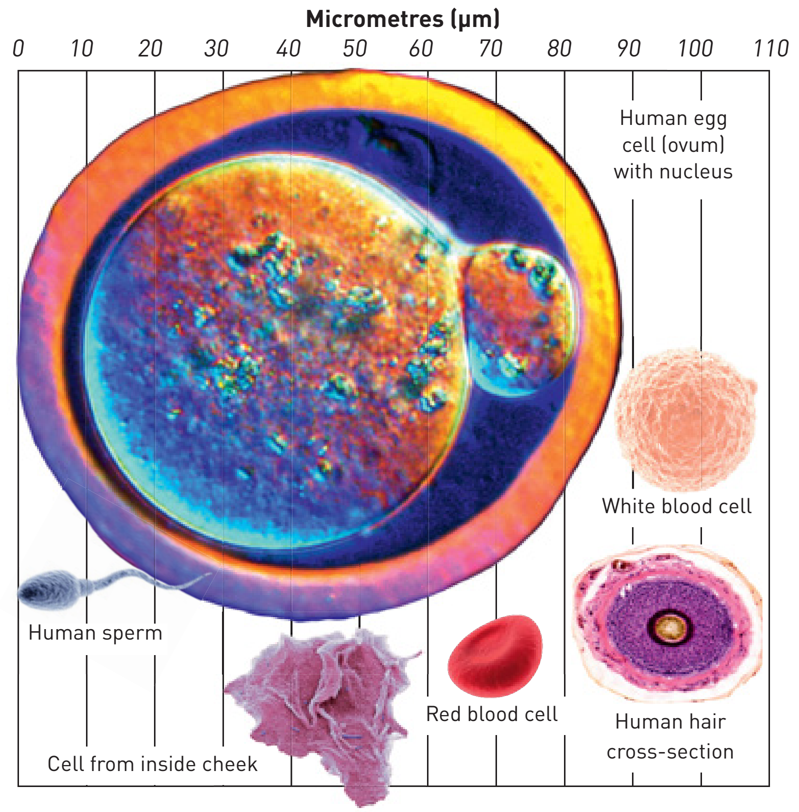

Figure 6.16 Different types of cells are different sizes and are measured in micrometres (μm). One micrometre is equivalent to one-thousandth of 1 millimetre.

Check your learning 6.3

Remember and understand

1 Name three organelles that are surrounded by a membrane.
2 What is the function of the cell membrane? In other words, why does a cell need a membrane?
3 What are some of the roles of proteins in organisms?
4 In which organelle does cellular respiration occur?
5 What is stored in a vacuole?
6 What is photosynthesis?

Apply and analyse

7 What features of cells mean they are classified as living things? Remember MRNGREWW from Year 7?
8 Where would you be more likely to find large numbers of mitochondria, in a muscle cell or a bone cell? Explain your reasoning.

6.4 All organisms have cells that specialise

A giraffe, a worm and a mushroom are all classified as living organisms, yet they have many differences. Although they all share cells as their basic building blocks, the structure and function of these cells are different. Because cells are the basic building blocks of life, understanding the structure of cells enables us to better understand how organisms function.

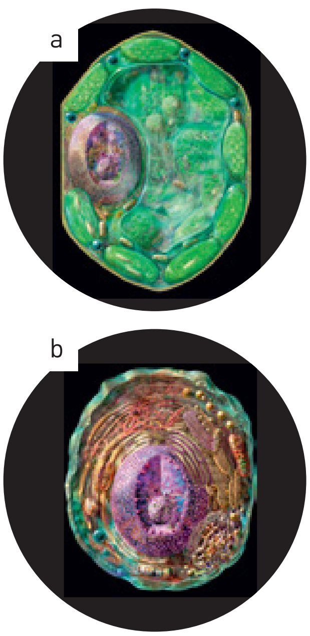

Figure 6.17 Typical (a) plant and (b) animal cells.

Prokaryotes and eukaryotes

An organism's cell type can be used to classify it. Cells are classified into two main groups – prokaryotic cells and eukaryotic cells. **Prokaryotic cells** belong in the kingdom Monera. They are the most primitive cellular forms on Earth and are unicellular. They are much simpler than eukaryotic cells and do not have many of the organelles described in the previous section. For example, they have no nucleus and their genetic material is found free in the cytoplasm. Prokaryotes include the diverse range of bacteria.

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

Plant cells

By looking at different characteristics of plants and animals, it's fairly easy to see that they are different types of organisms. However, once microscopes started to become more powerful, suddenly scientists could see that there were differences between plant and animal cells (Figure 6.17). Plant cells use their chloroplasts to photosynthesise and need cell walls to provide structure. Many plant cells also store their nutrients in large vacuoles (large spaces surrounded by a membrane).

Fungal cells

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

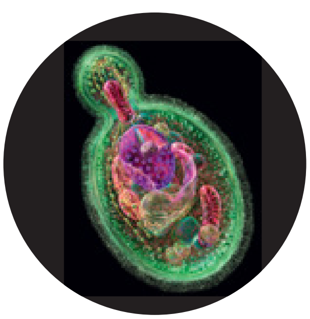

Figure 6.18 Cells in kingdom Fungi have cell walls and nuclei, but no chloroplasts.

Table 6.2 Characteristics of eukaryotic and prokaryotic cells.

CHARACTERISTIC	KINGDOM				
	EUKARYOTES				PROKARYOTES
	ANIMALS	PLANTS	FUNGI	PROTISTA	MONERA
Number of cells	Multicellular	Multicellular	Multicellular, some unicellular (e.g. yeasts)	Multicellular or unicellular	Unicellular
Cell wall	Absent	Present	Present	Present in some	Present
Genetic material	Present	Present	Present	Present	Present
Nucleus	Present	Present	Present	Present	Absent
Mitochondria	Present	Present	Present	Present	Absent
Chloroplasts	Absent	Present	Absent	Present in some	Absent
Large vacuoles	Absent	Present	Absent	Present in some	Absent
Ribosomes	Present	Present	Present	Present	Present

CHALLENGE 6.4: CLASSIFYING USING CELLS
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EXPERIMENT 6.4: PLANT AND ANIMAL CELLS
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Protists

Protists are a diverse group of organisms that are mostly unicellular. Many live in water, some are photosynthetic (i.e. make their own food, like plants), some eat other organisms and some causes diseases. Depending on where it lives and its food sources, a protist's shape or structure will have evolved to suit. The protists in Figures 6.19 to 6.22 have structures particular to their lifestyles.

Animal cells

Single-celled or unicellular organisms, such as bacteria, are made of one cell only. Multicellular organisms, like us, are made of more than one cell and often many billions of cells. The different cells in a multicellular organism communicate and work together to produce a functioning organism. Their different roles in the body mean they have different sizes and shapes.

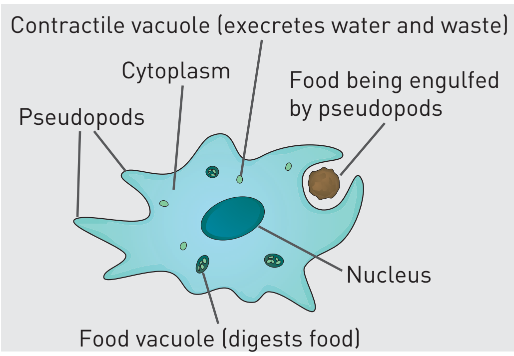

Figure 6.19 An amoeba can change the shape of its blobby body, creating foot shapes for movement and mouth shapes for swallowing food.

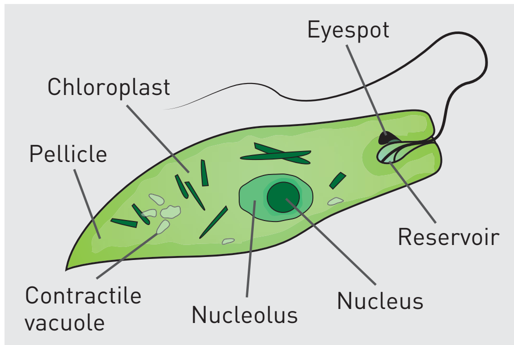

Figure 6.21 Euglena moves really quickly when it needs to, with a bullet-shaped body and a long tail called a flagellum to whip it into action.

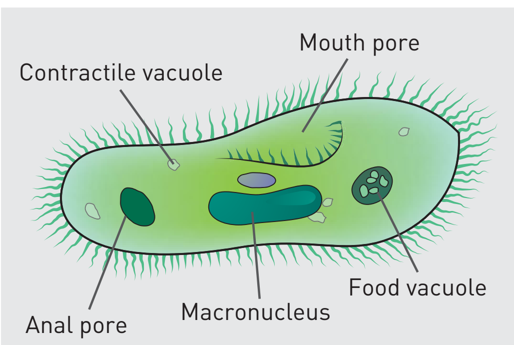

Figure 6.20 The paramecium plods along slowly with lots of tiny hairs called cilia that act like miniature oars.

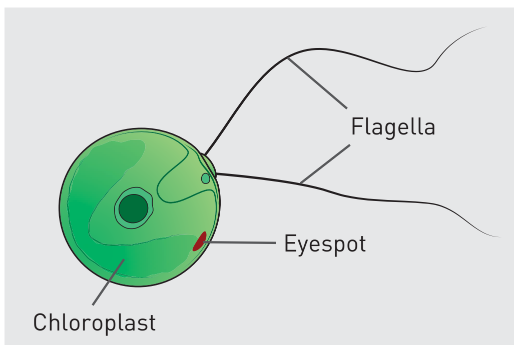

Figure 6.22 Chlamydomonas has an eyespot that can detect light for photosynthesis and two flagella that help it swim along in a breaststroke-like motion.

Check your learning 6.4

Remember and understand

1. Give an example of a unicellular organism and a multicellular organism.
2. Describe the two main differences between eukaryotic and prokaryotic organisms.
3. Where is the genetic material found in a prokaryotic cell?
4. Table 6.2 shows that plant cells contain chloroplasts. Although a typical plant cell contains chloroplasts, chloroplasts are not found in all plant cells.
   a. Suggest why some cells in a plant root may lack chloroplasts.
   b. In which part of a plant would you expect cells to contain many chloroplasts?
5. Look back at Table 6.2, then suggest which kingdom is often referred to as 'the rest'.

6.5 Bacteria are single-celled organisms

Unicellular organisms, such as bacteria, are living in and around us all the time. The average adult human has 1 kilogram of non-human life inside their large intestine alone. Some bacteria and microbes are essential for keeping our body healthy and working correctly. Others can be deadly.

Natural flora

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

Microbes causing disease

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

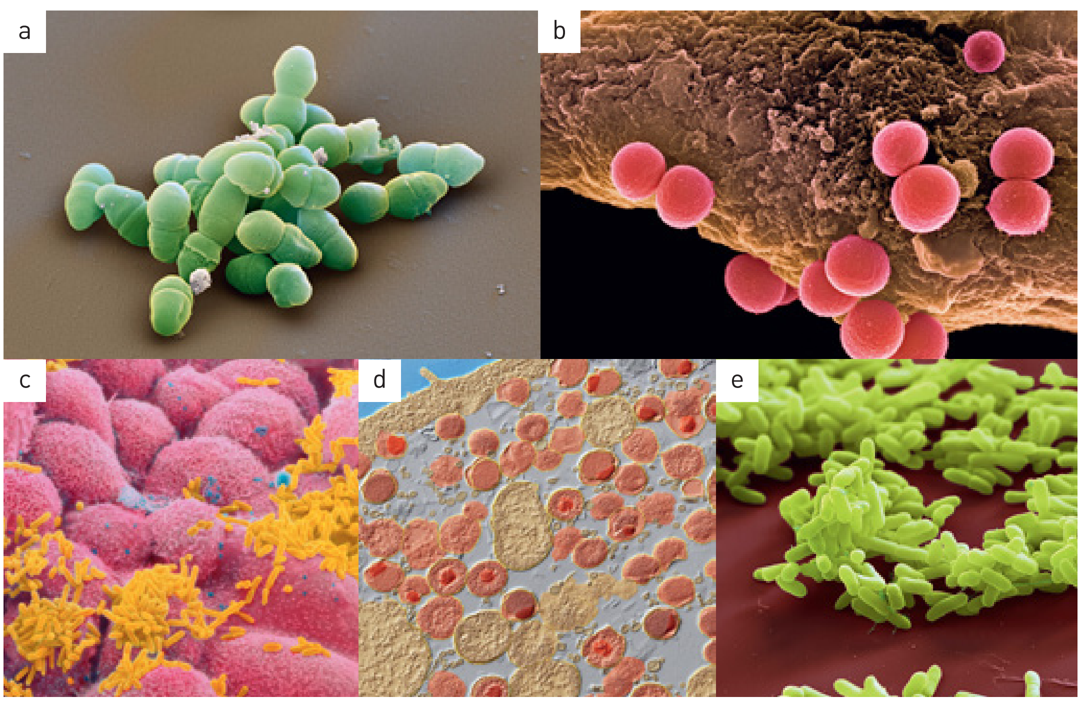

Figure 6.23 (a) *Staphylococcus epidermis*, (b) *Staphylococcus aureus* in the hair, (c) *Haemophilus influenza* in the nose, (d) *Chlamydia trachamates* in the eye, (e) *Esherichia coli* in the intestines.

EXPERIMENT 6.5: MICROBES ALL AROUND
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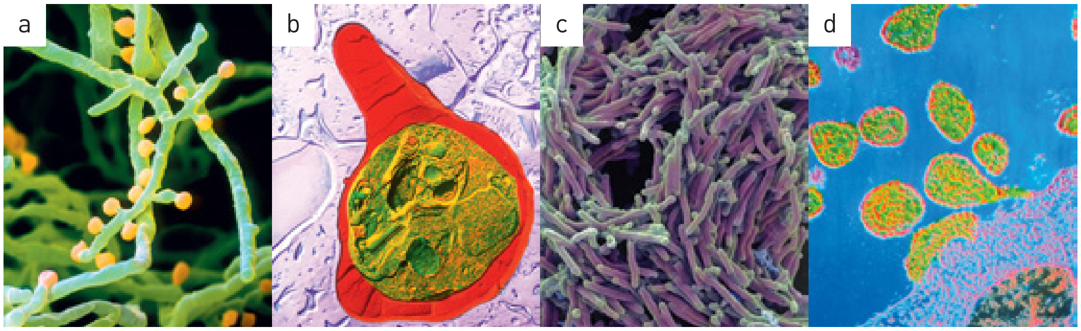

Figure 6.24 (a) *Trichophyton mentagrophtes*, cause of ringworm and tinea; (b) a red blood cell infected with malarial parasites; (c) tuberculosis bacteria; (d) Rubella virus.

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

Viruses

Viruses are actually considered by most scientists to be non-living pathogens. Viruses cannot survive and reproduce outside a host cell.

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

Bacterial growth

Bacteria reproduce using a process called **binary fission** (binary = two; fission = split). As the name suggests, a bacteria cell grows slightly larger and then splits in two. This is a very quick process, sometimes taking as little as 20 minutes. This can be represented on a graph such as the one in Figure 6.25.

Most bacterial growth is stopped at temperatures below 4°C and above 60°C. For this reason, your fridge should be below 4°C and cooked food waiting to be served should be stored above 60°C.

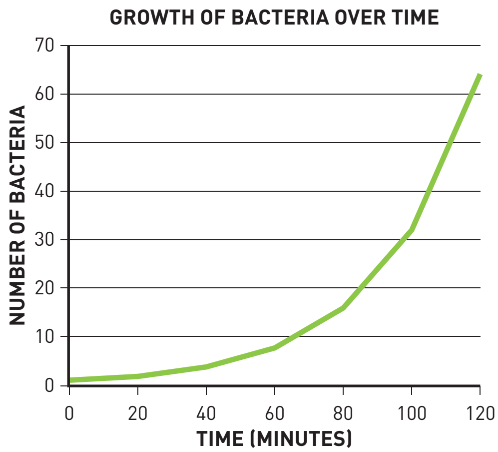

Figure 6.25 The number of bacteria cells can double every 20 minutes.

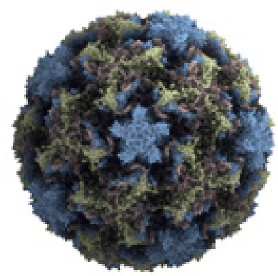

Figure 6.26 Human rhinovirus, responsible for the common cold. Viruses are much smaller than cells.

Check your learning 6.5

Remember and understand

1 What type of microorganism does our digestive system rely on? What does this organism do?
2 What is natural flora?
3 Can natural flora ever be harmful to our bodies?
4 What is a pathogen? What are the four main groups of pathogens?
5 Why is a virus not considered to be living?

Apply and analyse

6 It is not recommended that food be left out of the fridge for more than 3 hours. Use binary fission to explain why.

6.6 Eukaryotic cells undergo mitosis

Cells, like organisms, need to carry out many functions for survival. They need to process many substances, harness energy and, ultimately, reproduce. When your cells grow and repair, they undergo **mitosis**. When a cell is no longer needed it is destroyed (**apoptosis**). When mitosis gets out of control, a tumour can grow.

Making more cells

The instructions for all these jobs are in the form of DNA – lengths of codes that can be 'read' when required to make sure jobs are done correctly. The DNA is stored in the **nucleus**, which is often referred to as the control centre or 'brain' of the cell.

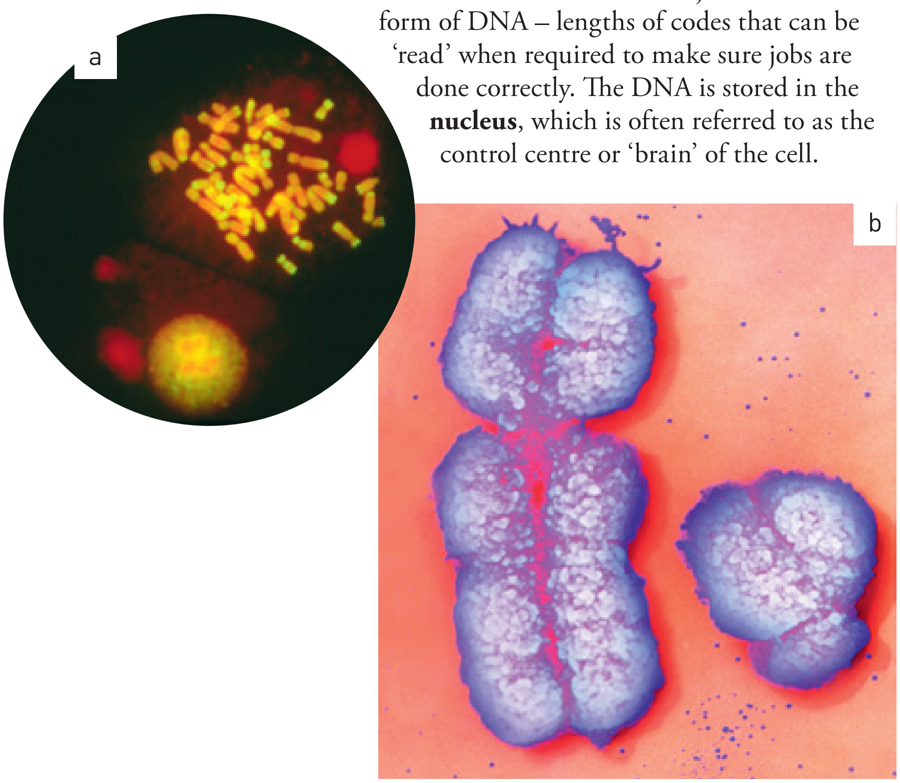

Figure 6.27 (a) Light microscope and (b) electron microscope images of human chromosomes.

When cells are ready to reproduce they simply split in half, but each new cell needs its own copy of the full set of instructional DNA. Before the **parent cell** can split, a completely new set of DNA needs to be made. The DNA also needs to organise itself so that each new **daughter cell** has nothing missing. Each new cell needs one full set of DNA instructions.

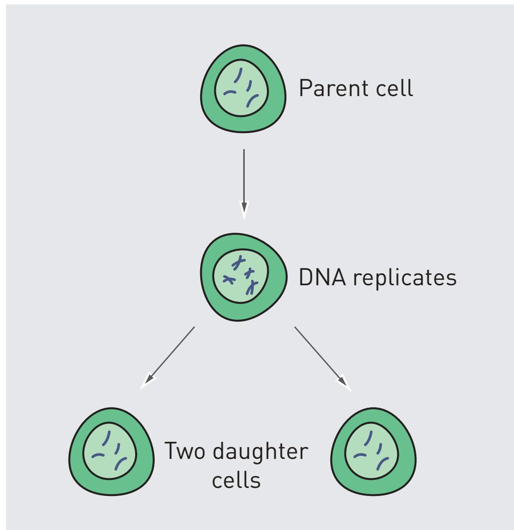

Figure 6.28 The process of mitosis.

The organelles are also roughly split into two groups. This process of organised cell division is called mitosis.

We need new cells every day to replace old or damaged cells. Every scratch on your skin needs new cells to fix it. Some of your red blood cells need to be replaced every time you bleed. You need to grow taller. All these things need mitosis to make the new cells.

Cancer: mitosis out of control

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

The term **cancer** describes a group of diseases that result from uncontrolled cell division. A cancer can form in any part of the body. Cancer affects humans and other animals. As an

CHALLENGE 6.6: MODELLING MITOSIS
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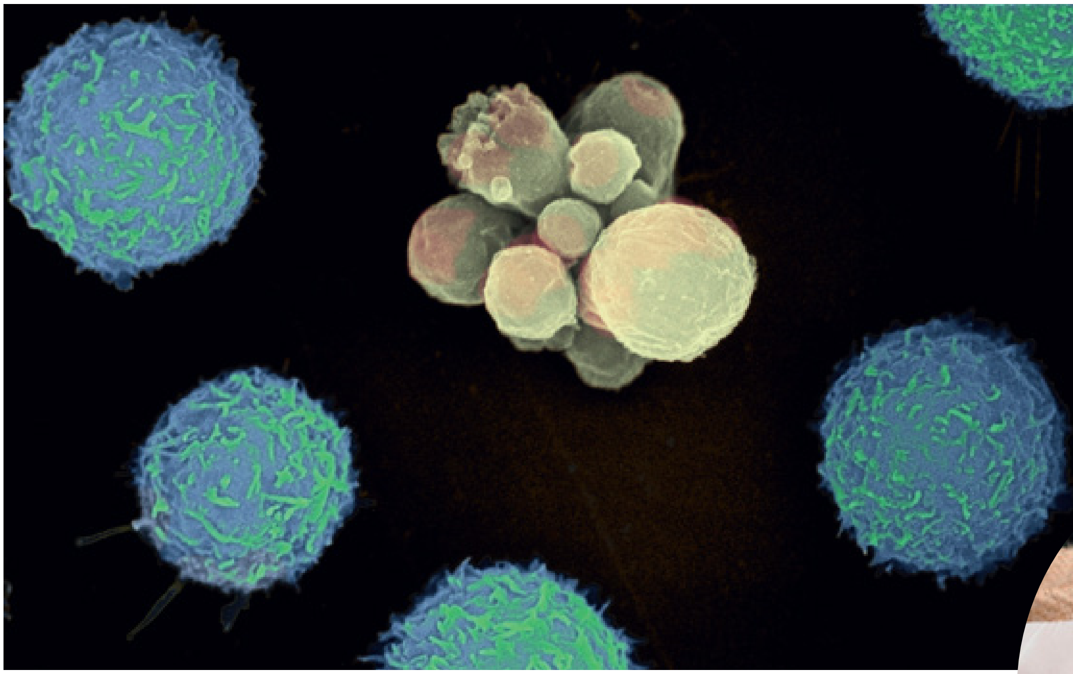


Figure 6.29 The yellow cells are undergoing apoptosis, or programmed cell death.

organism grows, cells reproduce to replace cells that are old or those that have died through injury. The process of a cell dying is a very normal and important part of the development and functioning of an organism. Programmed cell death is known as apoptosis. In fact, it was only through the programmed death of cells around your hands and feet that your fingers and toes formed during your early development.

Sometimes the DNA of a cell becomes damaged. This may be caused by a number of things, such as radiation, viruses or chemicals, called **mutagens**. Cancer-causing chemicals are also called **carcinogens**. The change to the DNA results in a change in the instructions for the cell.

Damage to the genetic material may prevent a cell from self-destructing. When a damaged cell starts dividing uncontrollably it is called a growth or **tumour**. The tumour is the cancer. The tumour may split off and spread throughout the body, causing secondary cancers. The secondary cancers can damage or destroy other organs.

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

Figure 6.30 Tasmanian devil facial tumour is a malignant tumour.

Figure 6.31 The hazard symbol for a carcinogen.

Check your learning 6.6

Remember and understand

1 List three reasons why new cells need to be made.
2 On a sheet of paper, draw diagrams to describe the steps involved in mitosis. Label the parent cells and daughter cells.
3 What is the name of the substance that provides instructions for the cell and where is it found?
4 What is apoptosis? When does it occur?
5 Where is DNA found in your skin cells?
6 Red blood cells do not have a nucleus. Explain why this makes it impossible to for them to undergo mitosis.

Apply and analyse

7 Cigarette smoke is considered a carcinogen. What does this mean?
8 Explain why a single cancer drug cannot destroy all types of cancer.

//SCIENCE AS A HUMAN ENDEAVOUR//

6.7 Fungal cells can save lives

Have you ever scratched yourself on a rose bush, or pricked yourself with a needle? Before the discovery of antibiotics, such a simple break in the skin would have been enough to kill you.

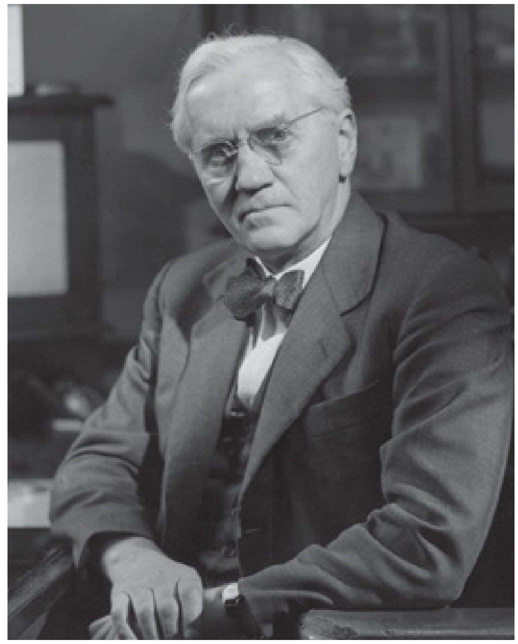


Figure 6.32 Alexander Fleming.

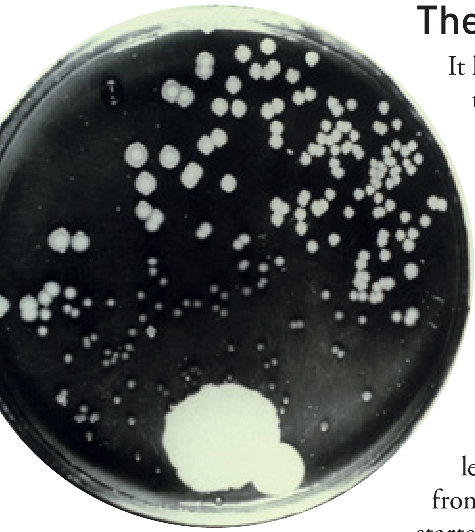


Figure 6.33 Some moulds are able to prevent bacterial growth.

The discovery of penicillin

It has been accepted for over 3000 years that some moulds could kill infection. The discovery in 1928 of the chemical that was responsible for this is attributed to Alexander Fleming.

Fleming was trying to grow bacteria on special agar plates as part of his research. Bacteria usually grow very well across the top of agar plates. However, this day Fleming failed to clean up after his experiment and left an agar plate open on his bench before leaving for a holiday. When he returned from his break, a small spot of mould had started growing in the centre of the plate. All around the mould was a clear circle where the bacteria was unable to grow. Fleming concluded that the mould (*Penicillium*) was producing a molecule that prevented the bacteria from growing. The molecule, which was named penicillin, had the ability to stop bacterial growth by preventing the bacteria repairing or making a new cell wall.

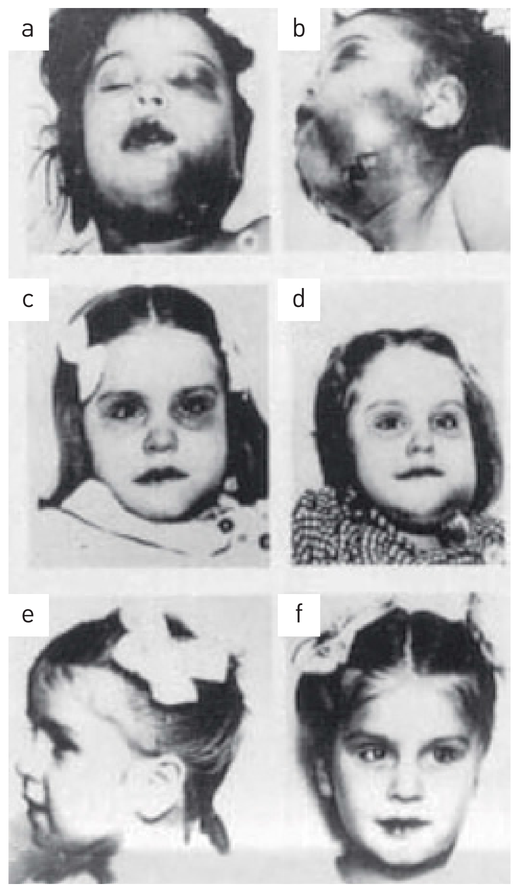


Figure 6.35 These photos from 1942 show the improvement of a child after penicillin treatment for a bacterial infection. (a, b) Before treatment. (c) Four days after treatment. (d) Nine days after treatment. (e, f) Fully recovered.

Producing penicillin

It took ten more years and the work of Howard Florey (an Australian) and Ernst Chain to develop a method of isolating penicillin and producing it on a large scale. They were part of a team of specialists brought together to grow up the mould, extract the penicillin, purify it and trial its treatment on patients.

Their most important experiment occurred in May 1940. Eight mice were infected with streptococcal bacteria, and four of the mice were treated with the newly extracted penicillin. These four mice survived while the mice without the penicillin died.

Figure 6.34 Howard Florey.

This led the researchers to trial the penicillin on their first patient. Albert Alexander's whole face was swollen after being scratched by a rose thorn. One eye had been removed while the other had been lanced to drain the pus. Within one day of being given penicillin, he started to improve. Unfortunately Fleming's group did not have enough penicillin to finish the treatment and the patient suffered a relapse and died. As a result the researchers tried treating children, as smaller doses could be used and the treatment could last longer. Eventually their purification methods and resulting treatment were successful. They were awarded a Nobel Prize in 1945 for their work.

The use of penicillin as an antibiotic revolutionised health care and the lives of many people who, without such treatment, would have died from bacterial infection.

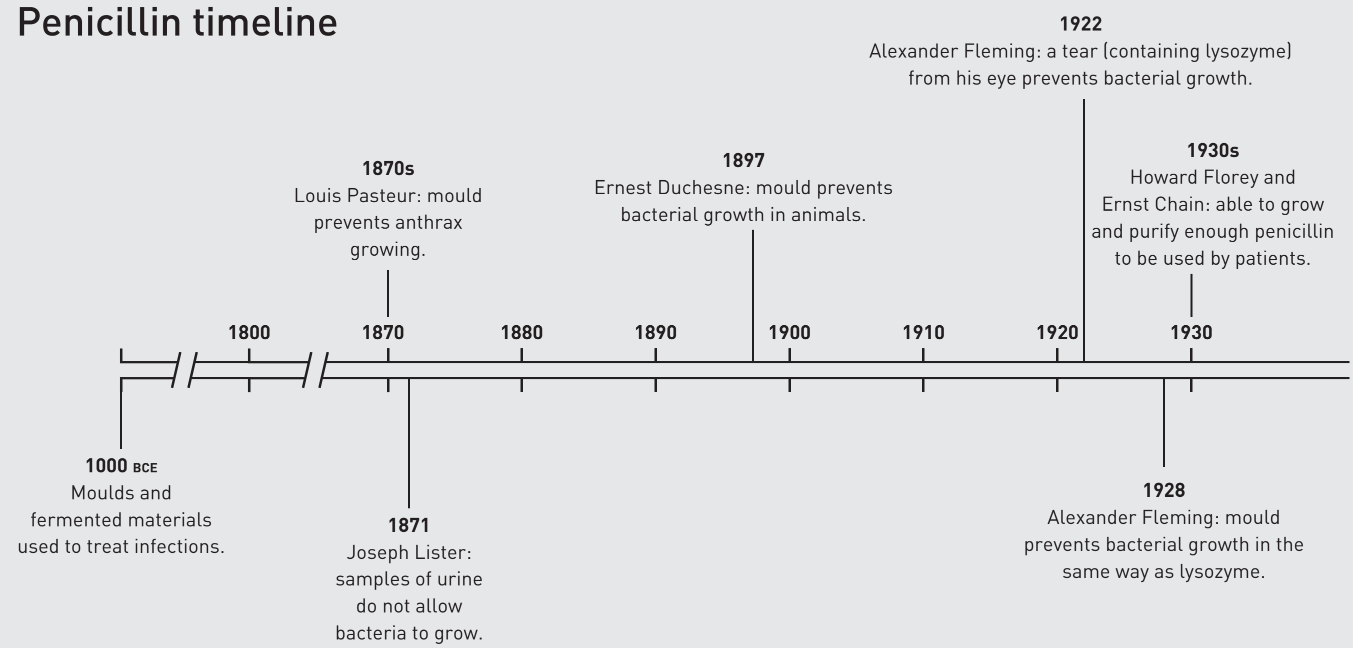
Overuse of antibiotics

There are now many more different antibiotics available, most of which are extracted from fungi. The overuse of antibiotics is a cause for concern. Due to the rapid rate at which bacteria reproduce, some strains of bacteria are becoming 'resistant' to treatment. That is, they are not affected by antibiotics. Scientists are continually searching for new types of natural and artificial antibiotics to treat these new 'superbugs' that are resistant to all known antibiotics.

A dose of antibiotics destroys not only the harmful bacteria, but also the good bacteria in your body, so they should only be used to treat bacterial infections when absolutely necessary.

Figure 6.36 Ernst Chain.

Penicillin timeline



Extend your understanding

1. What is the difference between fungi and bacteria?
2. Fungi usually grow best at 22°C. How did leaving the agar plate on the bench accidentally help Fleming make his discovery?
3. Why did Florey and his group of scientists not give penicillin to four of their mice?
4. Many of our medicines today originate from the molecules made in nature. How does the purity of penicillin prepared in a laboratory compare with the fermented materials used in 1000 BCE?
5. 'The most exciting phrase to hear in science, the one that heralds discoveries, is not "Eureka" but "that's funny ..."' Use Fleming's discovery to explain this quote from Isaac Asimov.

* REVIEW

6

Remember and understand

1 Who was the first person to describe cells? What cells did they draw?

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

3 Explain two key ideas presented in the cell theory.

4 Explain why programmed cell death is necessary.

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

6 What is the cell theory?

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

8 How are fungal cells different from bacterial cells?

9 Define the following words:

   a mitosis

   b cancer

   c mutagen

   d binary fission

   e pathogen.

Apply and analyse

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

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

12 Ribosomes are found in every cell on Earth. What function do ribosomes perform in cells? Why is it so important?

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

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

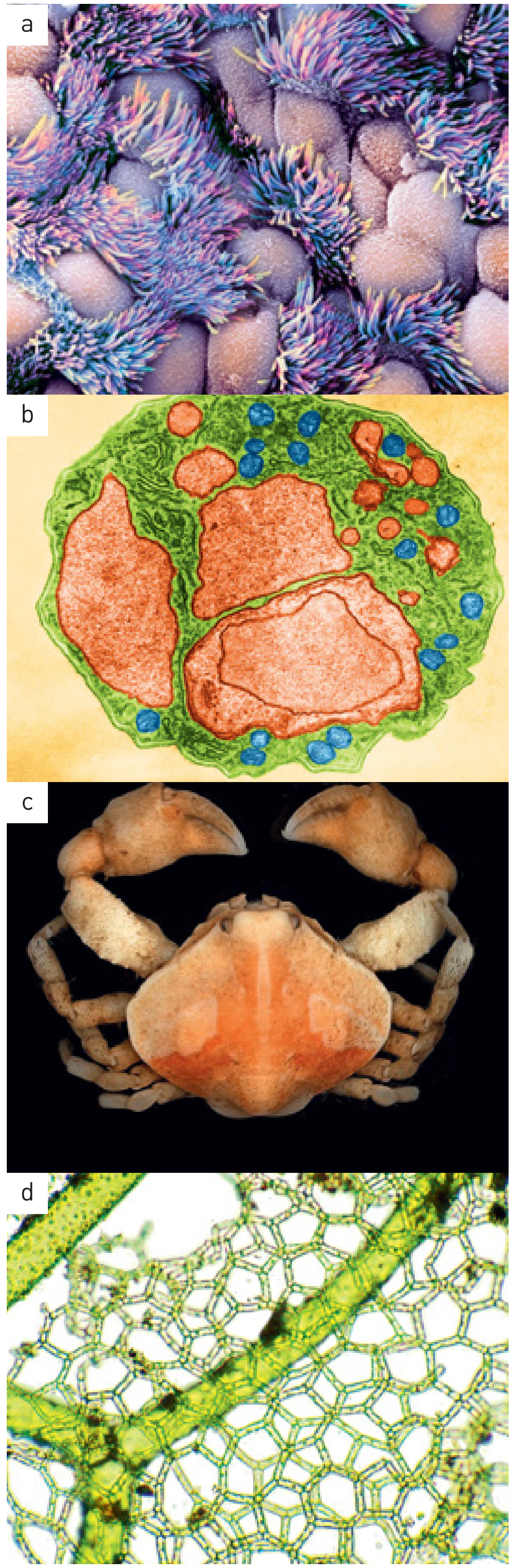


Figure 6.37

15 Identify the microscope most likely to have created the images in Figure 6.37.

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

   a Suggest why James identified many chloroplasts within each cell when they appeared to be absent from the cells viewed by Emily.

   b Emily commented that she could identify a nucleus in most cells. If a nucleus is not visible in a particular cell, does this mean that the cell does not contain a nucleus?

Evaluate and create

17 Similes are often used in creative writing to compare two things using the words 'like' or 'as'. Explain the similarities that allow these similes to be used.

   a Cells are like building blocks.

   b The nucleus is like a control centre.

   c The mitochondrion is like a power station.

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

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

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

Research

21 Choose one of the following topics for a research project. A few guiding questions have been provided for you, but you should add more questions that you want to investigate. Present your research in a format of your own choosing, giving careful consideration to the information you are presenting.

   a **Linking big concepts**

   In this chapter six big concepts about cells were discussed. Think of a creative way to represent these concepts and make links between them, using as many of the key words in the chapter as you can. You might use a concept map or mind map with each of the questions as major bubbles. You could choose to use diagrams only or draw a picture that shows all the aspects of the particles of life. The method of presentation that you select must enable you to share your ideas with others.

   b **Stem cells**

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

   c **Discovery of penicillin**

   The discovery of penicillin was considered an important factor behind the outcome of World War II. Soldiers who were injured on the battlefield could be mended, given a shot of penicillin, and returned to the battlefield again instead of having limbs amputated. Write a newspaper article describing the importance of this major discovery.

   d **Plant cells**

   Plants do not have lungs to breathe. Instead they have small pores called stomata, which allow air to pass in and out of the plant. These stomata are made up of two guard cells that can change their shape. Find out how stomata open and close in response to changing environmental conditions. Under what type of conditions are the stomata likely to open? What are the triggers for the stomata to close? How does the shape of the guard cells assist the opening and closing of the pore?

6

KEY WORDS

apoptosis
programmed cell death

binary fission
a form of asexual reproduction used by bacteria; the splitting of a parent cell into two equal daughter cells

binocular
using two eyes; a type of microscope

cell
(in biology) the building block of living things

chlorophyll
green pigment found inside chloroplasts that absorbs solar energy and uses it in photosynthesis

chloroplast
organelle found in plant cells that transforms solar energy into chemical energy

compound light microscope
a microscope with two or more lenses

daughter cell
a cell that results from parent cell division

electron microscope
a microscope that uses electrons (tiny negatively charged particles) to create images

eukaryotic cell
complex cell that contains a nucleus and membrane-bound organelles

infectious disease
disease caused by the passing of a pathogen from one organism to another; also known as contagious disease

microbe
a living thing that can only be seen with the use of a microscope; a microorganism

microbiology
the science involving the study of microscopic organisms

microorganism
a living thing that can only be seen with the use of a microscope

microscopy
the study of living things that can only be seen with the use of a microscope

mitochondrion
powerhouse organelle of a cell; the site of energy production; (plural mitochondria)

mitosis
process of cell division to provide growth or repair

monocular
using one eye; a type of microscope

multicellular
an organism that has two or more cells

mutagen
a substance that may damage a cell's genetic material (DNA)

natural flora
microbes that live happily in our bodies

nucleus
(in biology) control centre of a cell that contains all the genetic material (DNA) for that cell

objective lens
lens in the column of a compound light microscope

organelle
smaller part of a cell, each one having a different function

parent cell
the original cell before it undergoes cell division

pathogen
microbe that can potentially cause a disease

photosynthesis
chemical process plants use to make glucose and oxygen from carbon dioxide and water

prokaryotic cell
primitive single-celled organism that has no nucleus

ribosome
cell organelle where protein production takes place

single-celled
an organism that consists of one cell

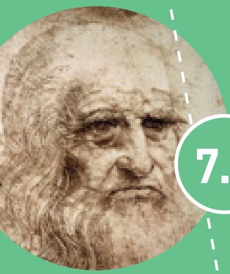
stain
substance, such as iodine, used to make cells more visible under a microscope

stereomicroscope
a microscope with two eyepieces that uses low magnification

surface area to volume ratio
the relationship between the area around the outside of a cell and its volume, as a fraction

unicellular
an organism that exists as a single cell

SURVIVING 7



7.1 The human body is divided into systems

7.2 The digestive system is made up of organs

7.3 The digestive system varies between animals

7.4 Things sometimes go wrong in the digestive system

7.5 The respiratory system exchanges gases

7.6 Things sometimes go wrong in the respiratory system

7.7 The circulatory system carries substances around the body

7.8 Things sometimes go wrong in the circulatory system

7.9 The excretory system removes waste

7.10 Plants have tissues and organs

What if?

Heartbeats

What you need:

a stopwatch

What to do:

1. Sit down for 2 minutes.
2. Measure the number of times you breathe in every minute.
3. Measure the number of times your heart beats every minute.
4. Record your measurements in a table.

What if?

» What if you ran around the oval for 5 minutes? How would your heart rate and breathing rate change?

» What if you listened to music with a slow beat for 5 minutes?

» What if you listened to music with a fast beat for 5 minutes?

7.1 The human body is divided into systems

Like all living things, we are made of different types of cells. Groups of cells that do a similar task are called **tissues**. Groups of tissues that work together are called **organs**. The liver, heart, eyes, brain and intestines are all examples of organs. When groups of different organs work together, they are called a **body system**.

Figure 7.1 The process of mummification required organs to be removed. They were sealed in 'canopic' jars.

How did the first scientists learn about the body?

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

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

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

Leonardo da Vinci

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

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

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

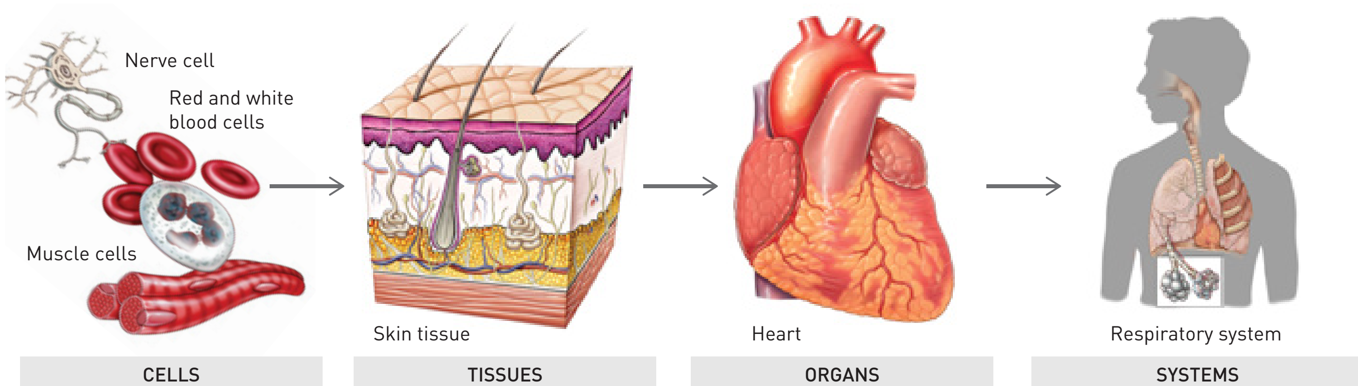


Figure 7.2 The different levels of organisation in the body.

CHALLENGE 7.1: BROWN PAPER BODY BRAINSTORM
GO TO PAGE 203.

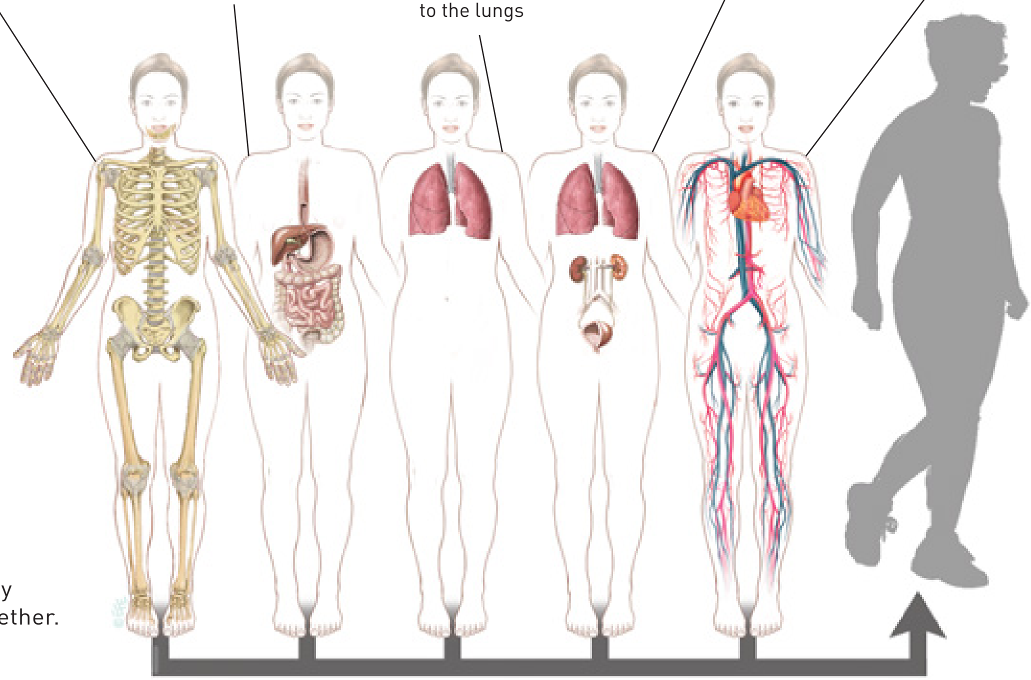


Figure 7.3 Our body systems work together.

The body snatchers

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

Anatomists paid gangs to steal bodies from graveyards. Body snatchers were known as 'the Resurrectionists' – giving new life to dead bodies.

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

Check your learning 7.1

Remember and understand

1. What is the difference between cells, tissues and organs?
2. Why did the Egyptian *shamans* study how the body worked?
3. Why is Leonardo da Vinci (Figure 7.4) so famous?
4. What is, or was, a body snatcher?
5. Why do surgeons need a thorough understanding of anatomy?

Apply and analyse

6. Draw a timeline of when and how the early anatomists studied the body. Use an internet search to help you complete this question.

Figure 7.4 Leonardo da Vinci.

7.2 The digestive system is made up of organs

Digestion is the process by which food (and drink) are broken down and absorbed into your blood for transport to your cells. The food we eat provides us with the energy to stay alive and the building materials for growth and repair.

Digestion

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

Physical digestion

Your teeth are responsible for the physical breakdown of your food. There are three main types of teeth in your mouth that do this process. The front ones are called incisors, the pointy teeth next to the incisors are called canines and the rest of your teeth, which are flatter, are called molars. You also have a large muscular organ called a tongue that can push upwards, sideways and backwards. When you swallow your food, the muscles behind the food squeeze tight, and the muscles in front of the food relax. This forces the food to move in a process called **peristalsis**.

Chemical digestion

The mouth is also where saliva is found. Saliva is mostly water, but also contains different types of enzymes. Enzymes are chemicals that can speed up a reaction. In the digestive system, enzymes encourage the lumps of food to break up into nutrients that are small enough to be absorbed by the body.

The stomach contains a mixture of gastric juices to help digest the food you have eaten.

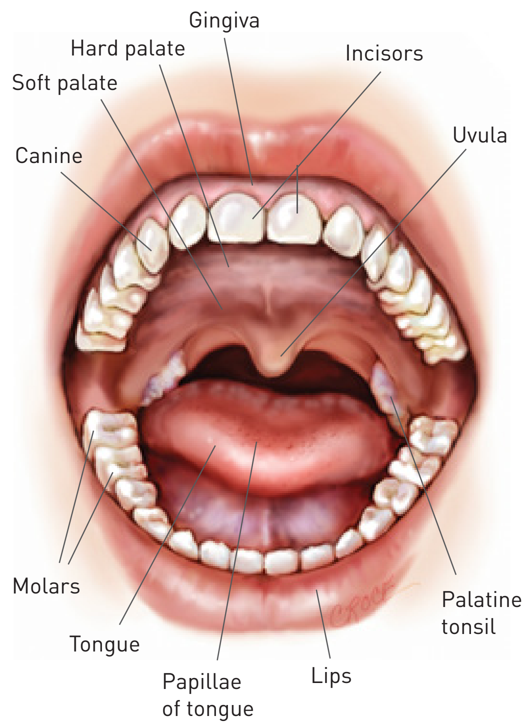


Figure 7.5 The teeth and mouth physically break down food.

These juices include acid that kills any bacteria that may be in the food, and an enzyme that digests the protein (found in meat) in your meal. The cells lining the inside of the stomach produce mucus to stop the acid burning the stomach walls. The resulting mixture of acid, enzymes and digested food is called **chyme**.

Absorbing nutrients

Most nutrients are absorbed in the small intestine. The inside of the small intestine is full of ridges called **villi**. These ridges increase the surface area that the nutrients pass over. This allows more time for all the nutrients to be absorbed from the chyme.

EXPERIMENT 7.2A: DIGESTING PROTEIN
GO TO PAGE 204.

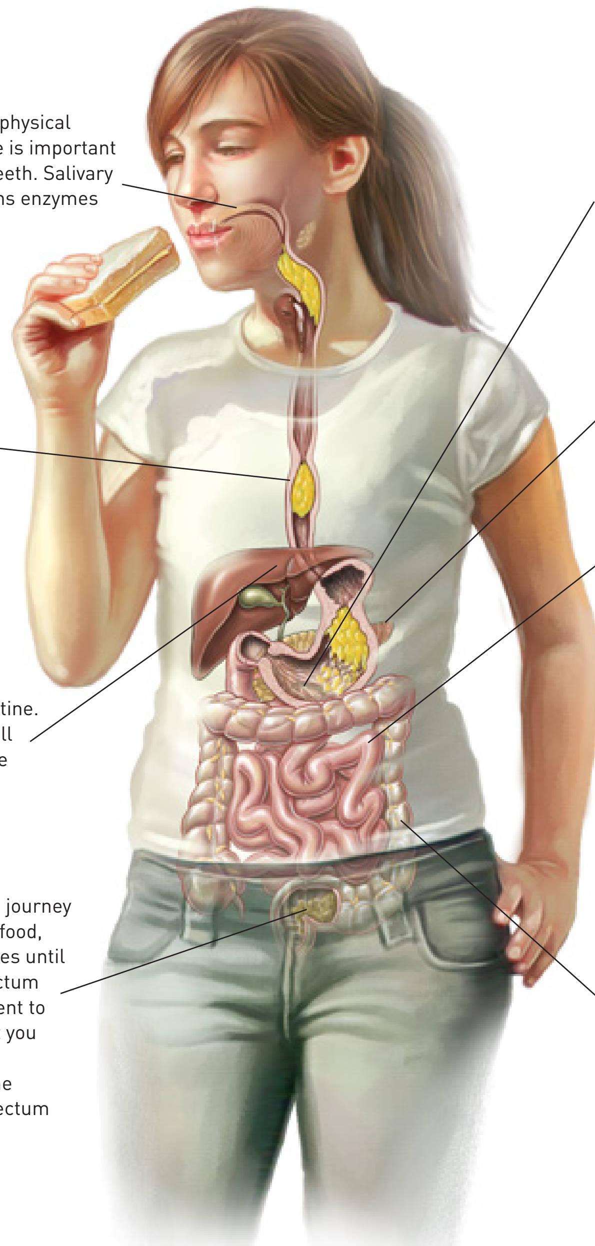
EXPERIMENT 7.2B: WHAT IF AN ENZYME WAS BOILED?
GO TO PAGE 205.

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

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

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

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



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

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

Small intestine
The small intestine is called 'small' because it is quite narrow. If you laid a small intestine out in a straight line, it would be approximately 5 m long. The intestines are really important because they absorb the nutrients that all the cells of the body require. The ability to absorb nutrients is increased by projections, called villi, along the inner wall of the intestine that increase the surface area for absorption. Bacteria in the small intestine also help with digestion. Chyme takes about 5 or 6 hours to pass through the small intestine.

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

Figure 7.6 The structure of the digestive system is shown here with key parts labelled.

Check your learning 7.2

Remember and understand

1 List, in order, the organs of the digestive system that food moves through, from the mouth to the anus.
2 How does saliva make it easier to eat dry biscuits?
3 What is the difference between mechanical and chemical digestion? Which occurs in the stomach?
4 What is the difference between the digestive system and the digestive tract?
5 Which organs are involved in digestion but do not have food pass through them?

Apply and analyse

6 Teeth would look very nice if they were all the same size and shape. What is the advantage of having different types of teeth in your mouth?
7 Can you think of any tools that may work the same way as incisors, canines or molars?
8 What are villi? What is their function?

7.3 The digestive system varies between animals

There are a large number of different types of animals in the world that have a varied diet. Herbivores eat plants. Carnivores eat meat. Omnivores, including us, eat a variety of foods. Although we all need the same basic nutrients, how we obtain those nutrients from our food varies.

Figure 7.7 The teeth on this dinosaur show it was a carnivore.

Teeth tell a story

Before the invention of knives and forks, we used to tear our food apart with our fingers and teeth. Each type of tooth has a specialised function. Incisors have a sharp knifelike structure, and animals such as rats and mice use their incisors to cut their way through food. Canine teeth are pointed and are useful in ripping lumps of meat apart. This is why many meat eaters (carnivores) have large canine teeth. Molars are flatter and are especially good at grinding the plant food of herbivores into small pieces so that it can be digested more effectively by enzymes.

Palaeontologists are scientists who study fossils, including the skulls and teeth of extinct animals. Palaeontologists use the teeth to predict what the animal ate when it was alive.

Herbivore hindgut

Some plants, such as sugar cane, have a ready supply of the sugar that we need for energy. Other plants, such as potatoes, contain starch that our enzymes can break up for nutrients. Not all plants make it this easy to obtain the nutrients that herbivores need. The outside of a plant cell is surrounded by a cell wall made of cellulose. Few animals have the enzyme (cellulase) that can break up this solid nutrient. Instead they rely on bacteria to break it up for them. These bacteria live in the **caecum**, a dead-end pouch where food is stored until the bacteria can digest it. In many animals the caecum is found between the small intestine

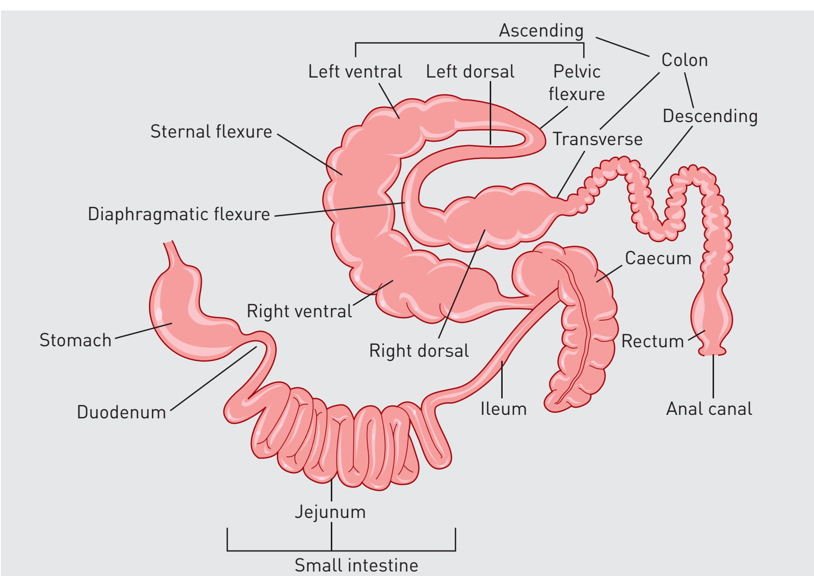


Figure 7.8 The caecum of a horse is found between the small intestine and the large intestine.

Figure 7.9 This fossil has a lot of molars and a few incisors. This suggests that it belonged to a herbivore.

and the large intestine. This is a problem for the animal as it means the plant matter is digested after it passes through the place where the nutrients can be absorbed, in the small intestine. This means some animals, such as possums, rabbits, rodents and termites, eat their own faeces to get the extra nutrients that may have been missed the first time through.

Ruminants

Ruminants are animals with hooves that have four chambers in their stomachs. A cow is an example of a ruminant. When the cow first swallows its food, the grass goes to the first stomach, which is called the **rumen**. This allows the grass to mix with different types of bacteria that can break up the cellulose in the plant's cell wall. The cow regurgitates the grass and chews it over and over again to help the bacteria break down the nutrients. The second stomach (**reticulum**) is involved in trapping any unwanted things the cow might have swallowed, such as rocks or wire. The third stomach, the **omasum**, has many leaf-like folds that filter the fine particles and water into the **abomasum** (the fourth stomach). It is this last section that contains the acid and enzymes just like a human stomach.

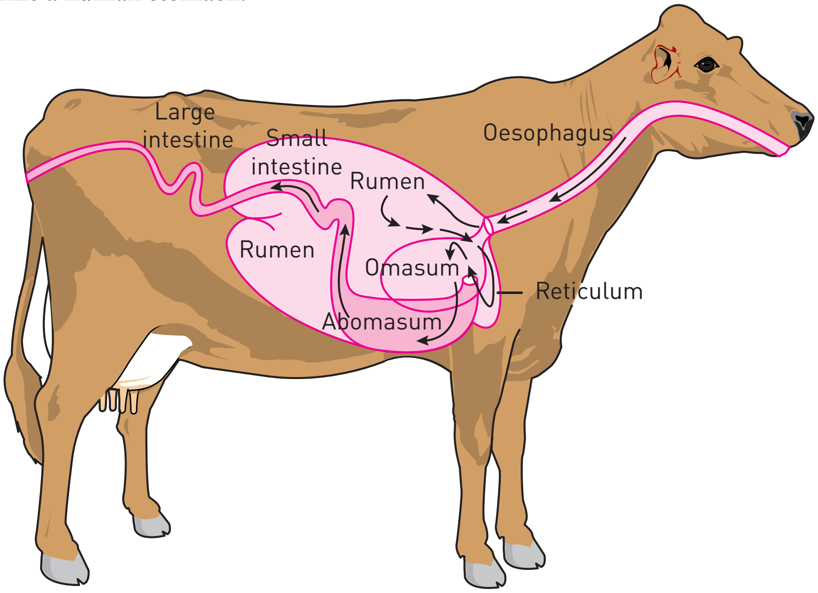


Figure 7.10 The four stomachs of a cow allow it to digest grass.

Check your learning 7.3

Remember and understand

1. How many stomachs does a cow have?
2. Are digestive systems the same in all animals? Explain.

Apply and analyse

3. Examine the images in Figure 7.11 of the digestive systems of a carnivore, a herbivore and an omnivore. Correctly label each digestive system according to the animal's diet. Provide evidence from the diagrams to support each of your answers.
4. Identify the possible diet of the fossils in Figure 7.12. Provide evidence from the photographs to support each of your answers.

Evaluate and create

5. Research the digestive system of an animal of your choice. In what way is it similar, and different, to the digestive system of humans? How does the structure of your animal's digestive system relate to the food it eats?

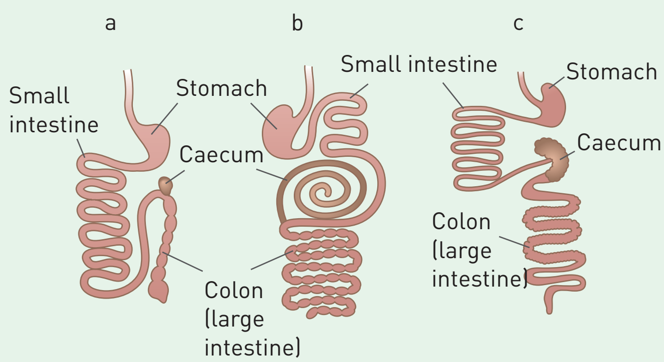


Figure 7.11

Figure 7.12

7.4 Things sometimes go wrong in the digestive system

The digestive system is just like a production line in a factory. Each organ relies on the previous section working effectively. This does not always occur. The stomach can get **ulcers**. Gall bladders can get **gallstones**. The small intestine may not be able to absorb a nutrient such as gluten and cause **gluten intolerance**. The large intestine may become blocked causing **constipation**.

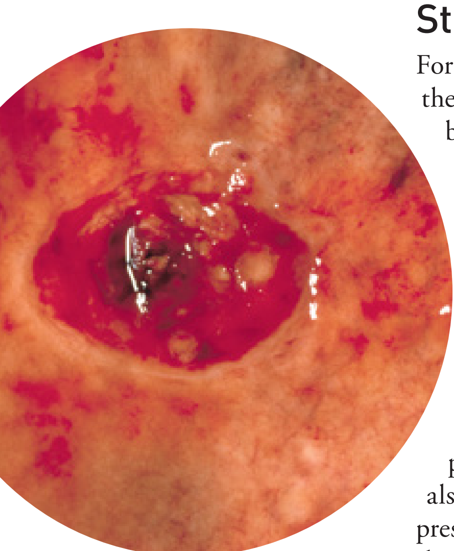


Figure 7.13 A stomach ulcer.

Stomach ulcers

For many years ulcers (small open sores) in the stomach lining were thought to be caused by too much rich, spicy food and stress. Patients would come to hospital in a lot of pain from the stomach acid burning the other tissues around the ulcer. Because it was thought no bacteria could survive in the stomach's acid environment, no one considered that a bacteria could be the cause of the ulcers. Two Australian scientists, Barry Marshall and Robin Warren, noticed that every patient who presented with symptoms of a stomach ulcer also had the bacterium *Helicobacter pylori* present in their stomach. In the early 1980s they did a series of experiments to show that the spiral-shaped bacteria caused damage to the cells lining the stomach, forming an ulcer. These bacteria can be killed by antibiotics. In 2005, Marshall and Warren were awarded the Nobel Prize for medicine (the highest prize in science).

Gallstones

The gall bladder is a small pouch-like structure that stores the bile from the liver. Bile contains many things, including a detergent-like substance that helps to physically break up the fat that leaves the stomach in the chyme. Occasionally, parts of the bile harden into a small stone that stops the bile leaving the gall bladder. The amount of bile in the pouch increases, causing the gall bladder to swell up. This causes severe stomach pains. If the

Figure 7.14 Robin Warren (left) and Barry Marshall (right).

stone cannot be shattered by **ultrasound**, or removed by surgery, the gall bladder may have to be removed. This means the person will have difficulty digesting fatty foods because of the lack of bile to break up the fats.

Gluten intolerance

Gluten is a small molecule found in many cereals and grains. Our body uses enzymes to chemically digest the gluten so that we can use the nutrients it contains. Some people do not have this enzyme. This means they cannot digest the gluten and that they are gluten intolerant. It can cause a range of different symptoms, from blockages of the intestines to **diarrhoea** (watery faeces). Gluten intolerance is different to gluten allergies. If a person is allergic to gluten, their body's immune system fights against the gluten. This can affect their whole body, not just their faeces.

Figure 7.15 Gallstones.

Figure 7.16 A number of grains contain gluten.

Constipation

Sometimes the large intestine becomes blocked. This can be caused by a poor diet (not enough fruit and vegetables), or by an infection. It usually starts with a small blockage, but as more food moves down the digestive system, it gets caught behind the blockage and gradually fills the large intestine. This causes pain and discomfort. Sometimes medication is needed to help the large intestine move the blockage. If it is not treated, the person may die.

Figure 7.17 Constipation may cause pain and discomfort.

Extend your understanding

1. What causes stomach ulcers?
2. What role does bile play in the digestive system?
3. What is the difference between gluten intolerance and gluten allergy?
4. Why does a person with constipation experience pain?
5. Research the extreme measures that Barry Marshall took to show his colleagues that the spiral bacteria caused stomach ulcers.

7.5 The respiratory system exchanges gases

The respiratory system is the body system responsible for breathing – getting oxygen from the air we inhale down the **trachea**, the **bronchi** and the bronchioles into the alveolar sacs and eventually into our blood. We need oxygen to produce the energy for staying alive. As a result, our cells produce carbon dioxide. Our **lungs** breathe out to help us remove the carbon dioxide from our blood.

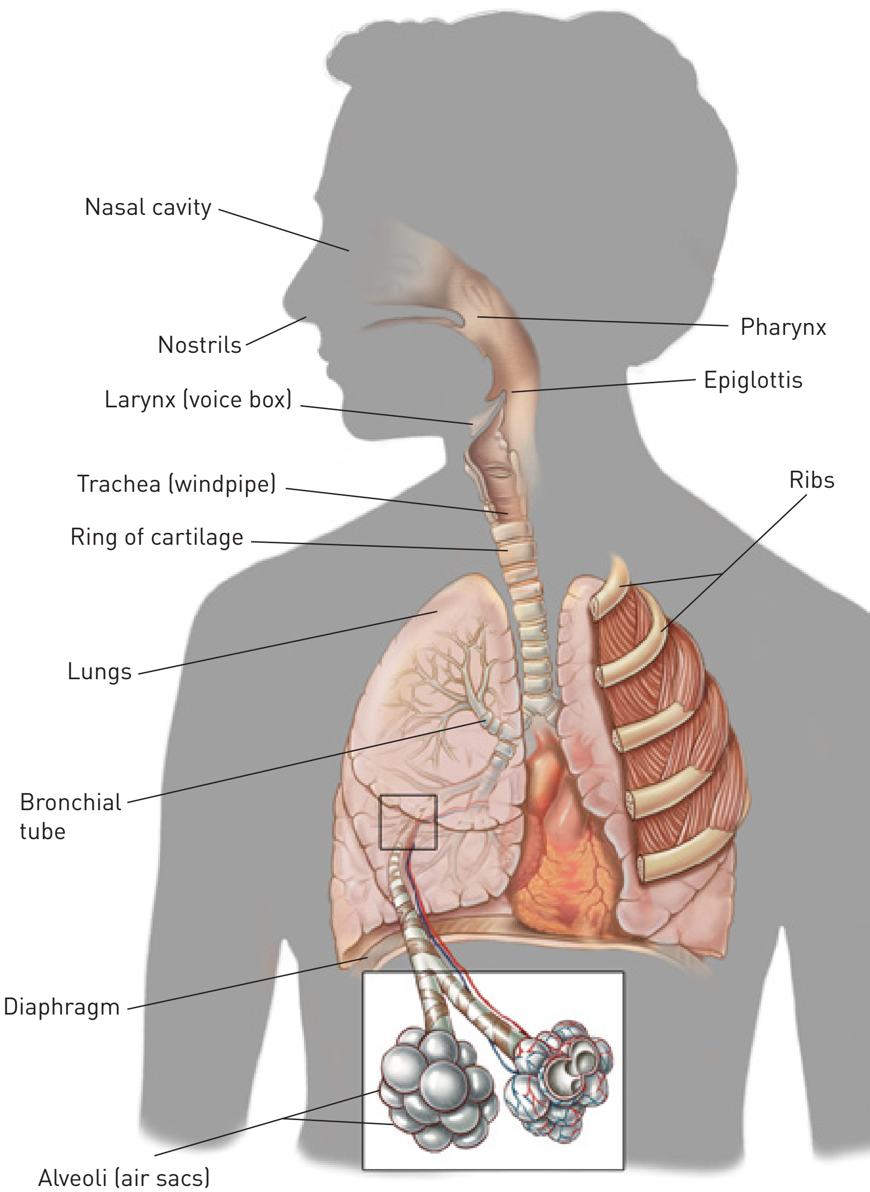


Figure 7.18 The structure of the respiratory system.

Why do we need oxygen?

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

Where does the air go?

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

The lungs

There are *two* lungs in our chest, changing in size every time we take a breath and they fill with air. The trachea branches into two to carry air into

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each lung. These branches are called bronchi. The lungs feel spongy to touch because they are home to millions of tiny air sacs called **alveoli**. If these air sacs were unravelled and flattened, they would have a surface area of approximately half the size of a tennis court. Each tiny alveolus is covered by a mesh of even smaller blood vessels called capillaries. The lungs are structured to have as many air sacs as close to as many blood vessels as possible.

Oxygen moves into the blood, whereas carbon dioxide (the waste product of cellular respiration) moves out of the blood.

The diaphragm

The **diaphragm** is a dome-shaped muscle that is attached to your ribs and moves up and down beneath your lungs. The muscle contracts down and relaxes up. The diaphragm also separates the heart and lungs from the stomach and digestive system. The lungs have no muscle tissue, so they can't move on their own. Every time you breathe in, the muscles in the diaphragm and between the ribs work together to expand your chest. This creates suction that opens the lungs, pulling air in. Then the muscles relax, allowing the air to move out again.

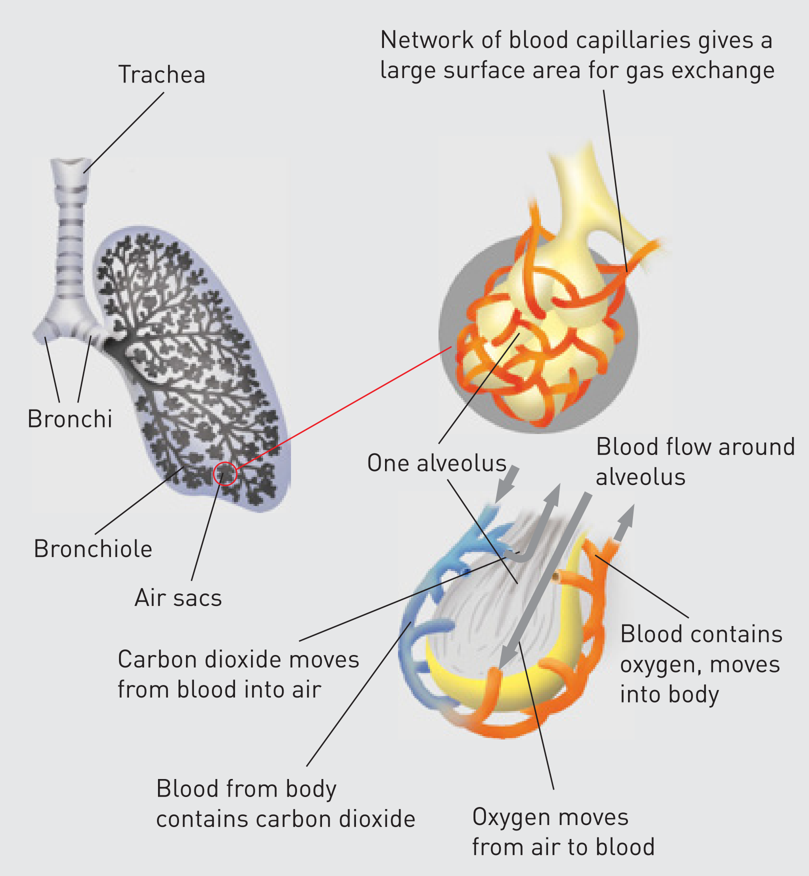

Figure 7.19 Gas exchange takes place in the alveoli.

Check your learning 7.5

Remember and understand

1. Draw a simple diagram showing how air travels down from the mouth and nose to the alveoli at the end of the branches of the bronchioles.
2. Explain the term 'gas exchange'.
3. At the same time that oxygen is passing into the blood, what gas is passing out of the blood back into the lungs?
4. Write the sequence of steps in breathing in and breathing out.
5. What role does the epiglottis play?
6. What advantage does the large surface area of the alveoli give in allowing oxygen to pass into the blood?

Apply and analyse

7. In your own words, explain why we need to breathe.

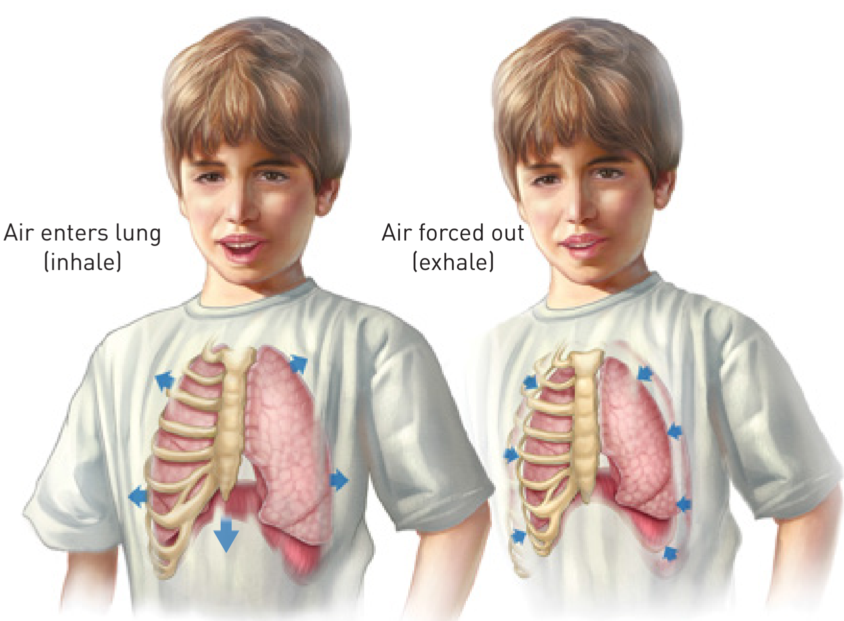

Figure 7.20 Breathing consists of inhalation and exhalation.

//SCIENCE AS A HUMAN ENDEAVOUR//

7.6 Things sometimes go wrong in the respiratory system

Our respiratory system is responsible for supplying the oxygen we need for energy. When things go wrong, our body struggles to survive. Small irritations make us cough. **Asthma** causes the airways to become smaller. **Emphysema** prevents the oxygen from entering our blood. **Pneumonia** is an infection that fills our lungs with fluid.

Coughing and sneezing

Every time you breathe in, you also take in small particles of dust, pollen and other particles. These particles are trapped by the cells lining our upper airways. Small **cilia** (hair-like structures) on the surface of the cells trap these particles and push them back to the top of the throat where they are swallowed. Larger particles trigger the diaphragm to contract quickly, making us cough. This pushes up the large particle before it enters the bronchioles.

Sometimes the particles get trapped by the hairs in our nose. This causes a message to go to our brain, which coordinates the muscles in the eyes, chest, stomach and diaphragm, making us sneeze. Some sneezes have been recorded at over 120 kilometres per hour.

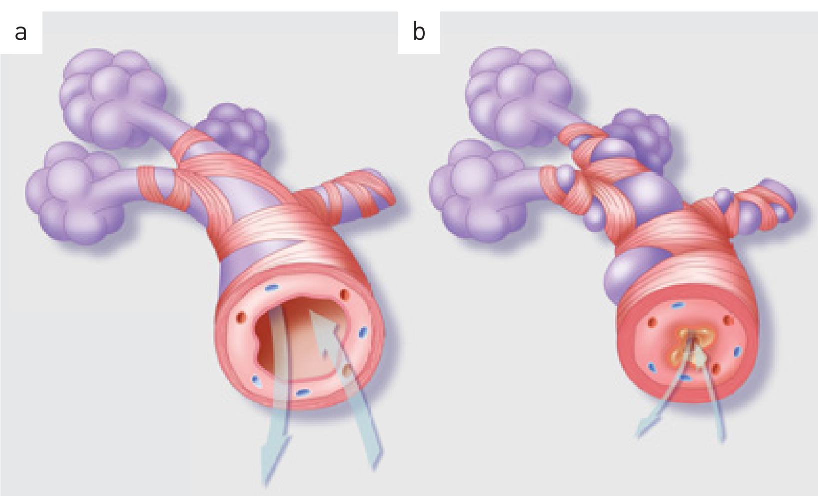

Figure 7.22 Asthma causes the bronchioles to become narrow: (a) normal airway and (b) asthmatic airway.

Figure 7.21 We cough or sneeze to clear small particles from our airways.

Asthma

Asthma is quite common in our population, affecting more than one in ten Australians. Asthma usually starts when something in the environment irritates the airways. This causes the bronchi and bronchioles to narrow, making it harder for air to move into the lungs. This makes it hard to breathe. Asthma attacks can be reversed by drugs, such as Ventolin, that relax the airways.

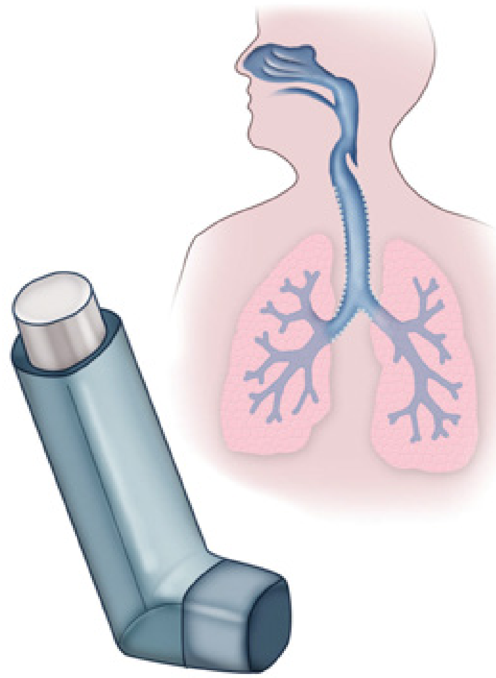

Figure 7.23 Ventolin is commonly used to control asthma attacks.

Emphysema

Smoking involves breathing toxic chemicals and tar into your lungs. The tar is like honey, covering the inside of the alveoli and stopping oxygen from moving into the blood. The toxic chemicals in the smoke kill the cells, destroying the alveolar sacs, and travel through the blood to cause trouble all over your body. Emphysema is a disease that is caused by the inability of the collapsed alveoli to move air in and out. A person with emphysema struggles to breathe in enough oxygen to walk even 20 metres.

Pneumonia

Pneumonia is caused by a bacterial or viral infection in the lungs. The alveoli in the lungs fill up with bacteria, pus and fluid. This prevents air moving into the lungs. Anyone can contract pneumonia, but it tends to be most common in young children and the elderly. A short course of antibiotics (special drugs that kill bacteria) can clear the lungs again.

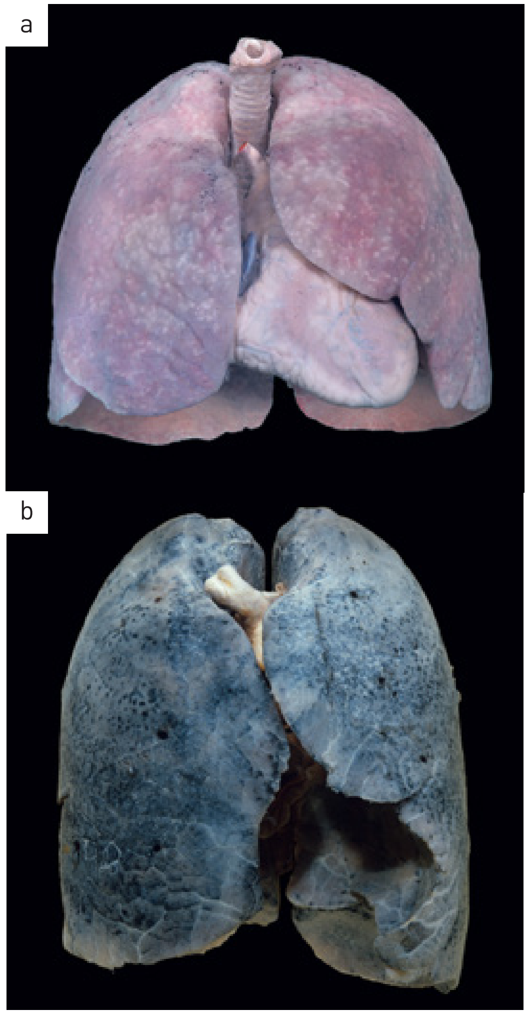

Figure 7.24 (a) Healthy lungs. (b) A smoker's lungs.

Extend your understanding

1. What causes each of the following?
   a. a cough
   b. a sneeze.
2. What is asthma?
3. Why do people with pneumonia feel tired all the time?
4. It is physically impossible to keep your eyes open during a sneeze. Can you explain why?
5. Describe some health risks people take with their lungs. What can be done to avoid these risks?

7.7 The circulatory system carries substances around the body

The circulatory system is the body system responsible for moving blood around your body. Many different substances, including nutrients and wastes, are transported in the blood, picked up from and dropped off at different locations.

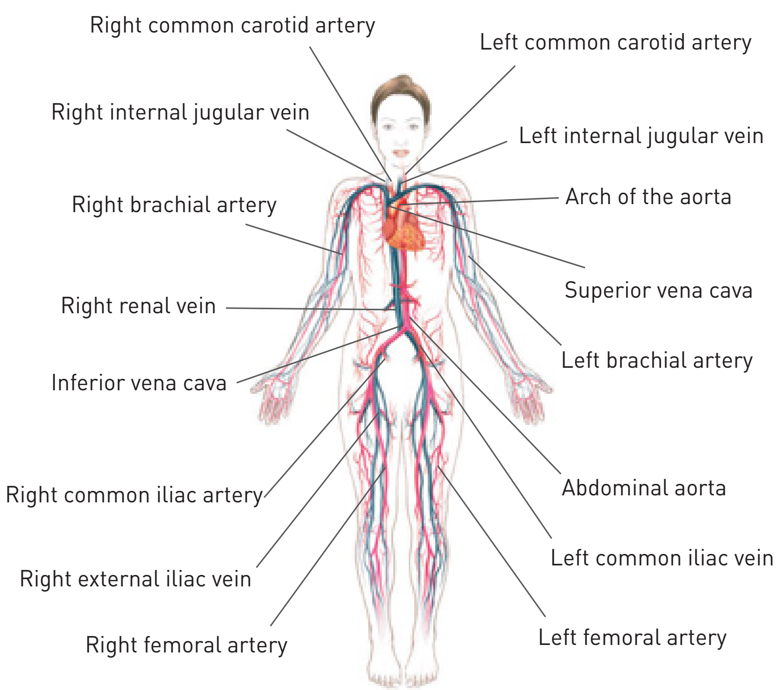

Figure 7.25 The structure of the circulatory system with key parts labelled.

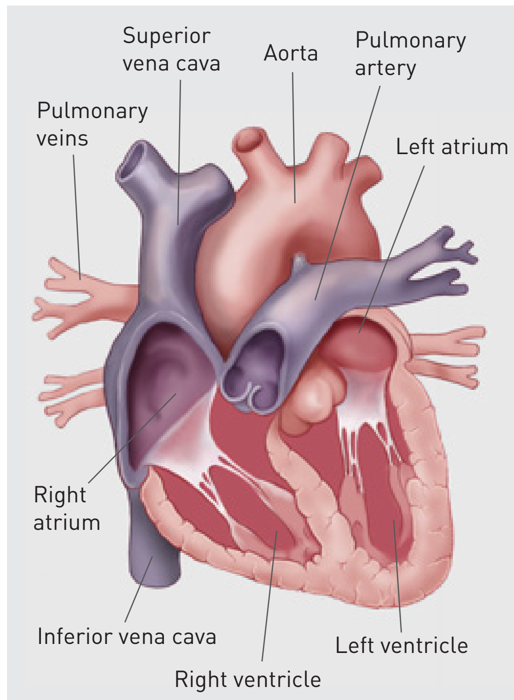

Figure 7.26 This diagram shows your heart, as well as some of the major blood vessels that travel to and from the heart. The diagram uses a common convention that shows the arteries in red and the veins in blue.

The heart

The heart is a large two-part pump about the size of your fist. It is made of four chambers: two **atria** at the top and two **ventricles** at the bottom. The ventricle on the right side of the heart pumps blood to the lungs to 'drop off' carbon dioxide and 'pick up' oxygen. This oxygenated blood moves back to the left atrium and on to the left ventricle. The more muscular left ventricle pumps blood out through the **aorta** at the top of the heart and around the body. Valves keep the blood moving in the right direction until it gets back to the right atrium of the heart.

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

> Oxygen is carried by the **red blood cells** from the lungs to all the cells of the body. Carbon dioxide is dissolved in the **plasma** (the straw-coloured liquid at the top of centrifuged blood).

> Nutrients and wastes are also dissolved in the plasma for transport to and from cells.

EXPERIMENT 7.7: HEART DISSECTION
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- **White blood cells** use the blood to travel to places where bacterial cells that cause infection are growing. The white blood cells then kill the bacterial cells.
- **Platelets** are cell fragments that burst when exposed to breaks in the blood vessels. They fill the hole and glue the edges together.

Blood vessels

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

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

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

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

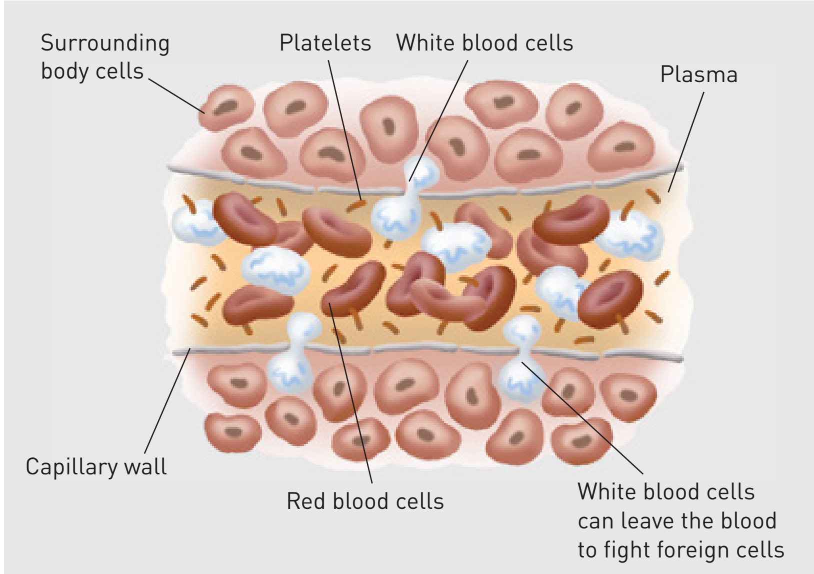

Figure 7.27 A cross-section of a blood vessel.

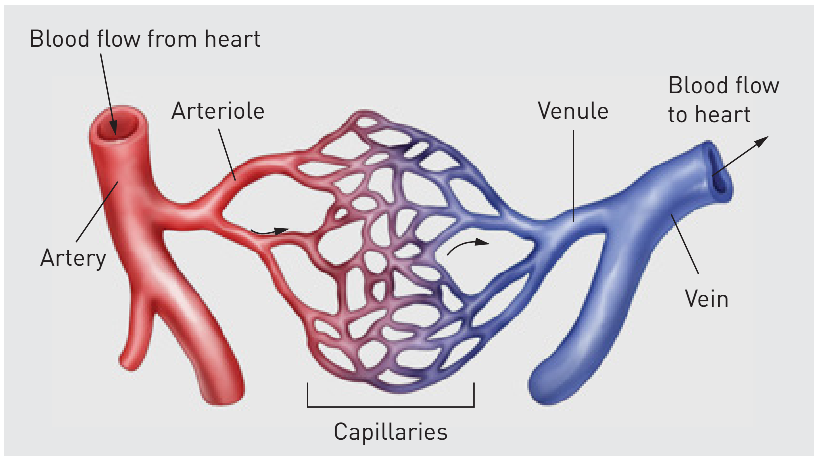

Figure 7.28 Capillary bed, showing the relationship between arteries, veins and capillaries.

Check your learning 7.7

Remember and understand

1. Copy and complete: The circulatory system is the transport system for the body, delivering ________ and other ________ to the cells and carrying wastes away for removal. ________ blood cells are responsible for carrying oxygen, ________ blood cells fight germs, ________ block cuts and ________ is the liquid carrying them all.
2. Explain how the three blood vessel types differ in their structure, jobs and locations. Use diagrams in your answer.
3. How many chambers are there in your heart? Name them.
4. Use Figure 7.26 showing the structure of the heart to complete the following for the path of blood through the chambers of the heart:
   body → ________ → ________ → lungs → ________ → ________ → body.
5. Rewrite your answer to question 4, adding the names of the veins and the arteries involved.
6. From which body system does the circulatory system absorb nutrients?
7. Why would muscles need the heart to pump faster during exercise? What chemical reaction does this include?
8. Instead of the blood travelling directly from the lungs to the rest of the body, the blood returns to the heart first. What is the advantage of doing this?

//SCIENCE AS A HUMAN ENDEAVOUR//

7.8 Things sometimes go wrong in the circulatory system

Blood vessels carry oxygen and nutrients around the body. When something goes wrong, the body is unable to make the energy it needs to survive. Valves in the heart can leak (valve disease), the vessels can narrow (atherosclerosis) and the cells in the heart can die in a heart attack. Healthy eating and regular exercise all help to keep your heart healthy.

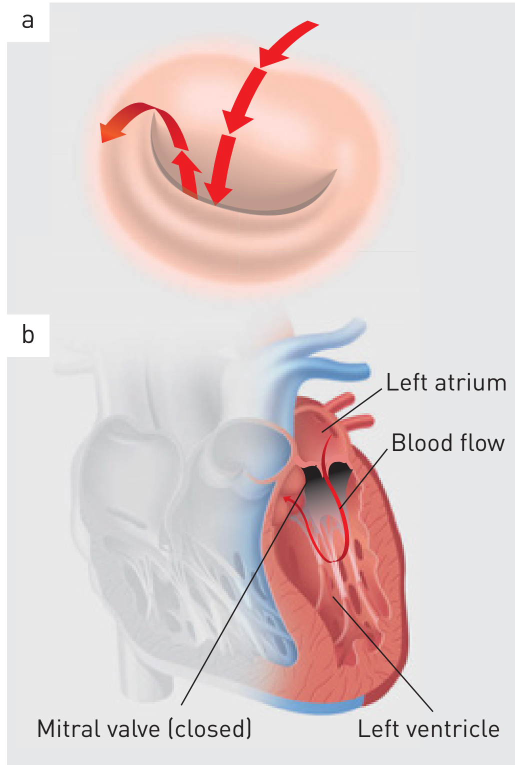

Figure 7.29 (a) The heart valve opens to allow blood to flow from the atrium to the ventricle. (b) Closing of the valve prevents the backflow of blood so that it can be pumped effectively around the body.

Valve disease

The heart has a series of valves that prevent the blood flowing backwards. This means when the ventricle fills with blood from the atrium, the valve between the atrium and ventricle closes (lub), forcing the blood to flow out of the heart when the ventricle contracts. The valve between the ventricle and the aorta then closes (dub) allowing the ventricle to fill once again. This is what creates the lub-dub sound you hear when you listen to your heart.

Sometimes these valves become damaged. They may become narrowed from scarring (stenosis), they may leak (regurgitation or insufficiency) or not close properly (prolapse). This prevents the blood from flowing properly around the body. As a result, less oxygen and nutrients get carried to the cells. This makes the person very tired all the time.

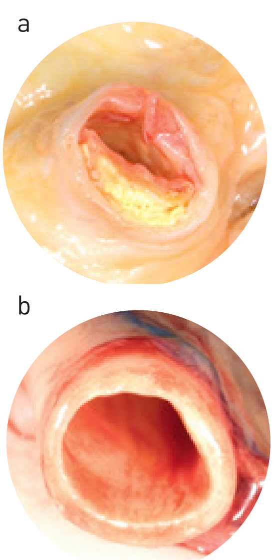

Figure 7.30 (a) A blocked artery and (b) an unblocked artery.

Atherosclerosis

Atherosclerosis is a disease that results from the narrowing of the blood vessels. This narrowing is caused by a build-up of plaque on the inside of the arteries and veins. Plaque consists of fat, cholesterol and other substances normally found in the blood. Layers of plaque are laid down over time, eventually

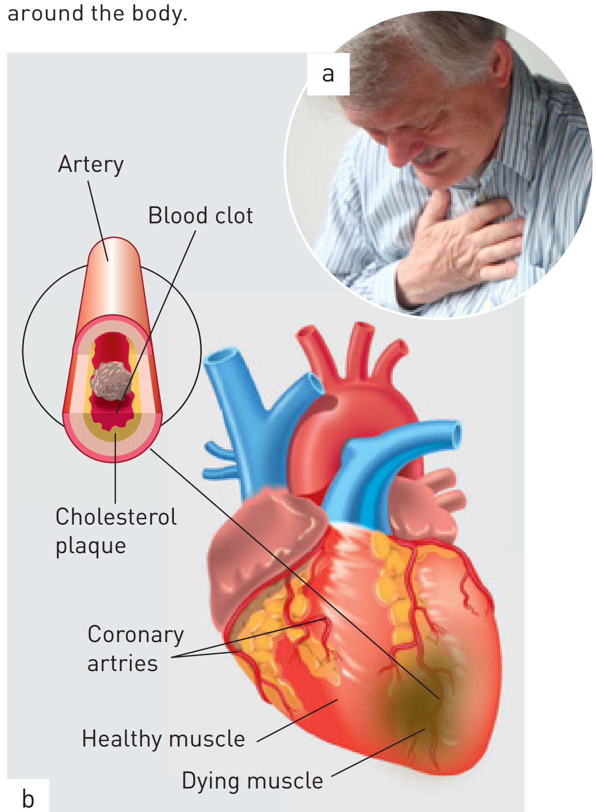

Figure 7.31 (a) Chest pain is often caused by a (b) blockage in the heart's own blood vessels.

CHALLENGE 7.8: MODELLING BLOOD FLOW
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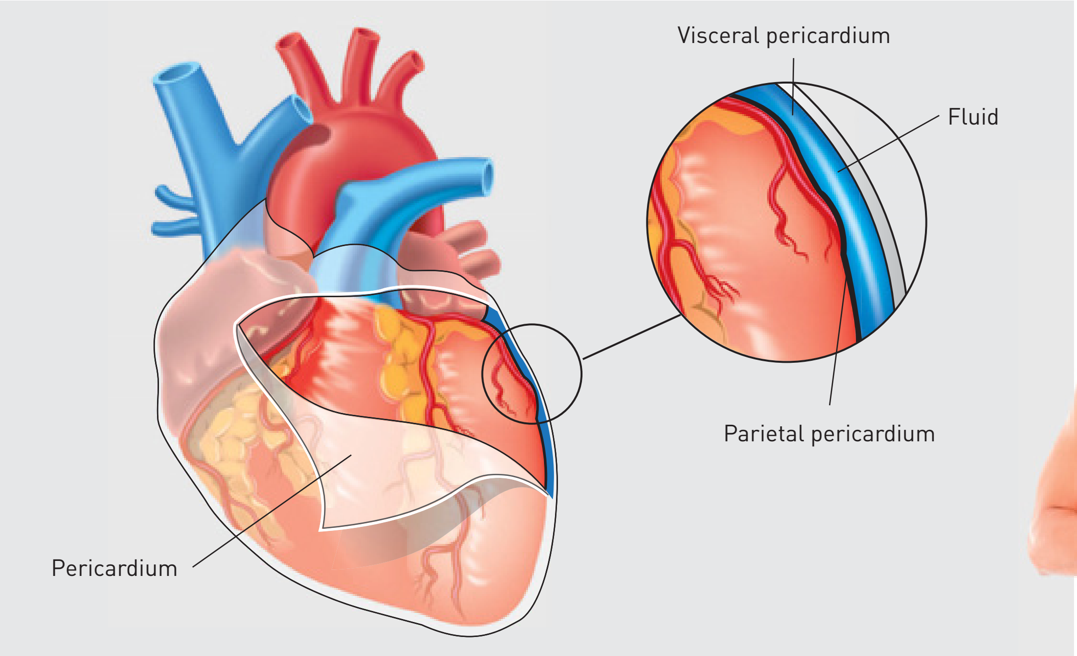

Figure 7.32 The pericardium reduces friction in a beating heart.

hardening and restricting the blood flow. The symptoms depend on the part of the body affected by the narrowed blood vessel. If the blood vessel is in the heart, then a heart attack will follow.

Coronary heart disease

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

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

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

Pericarditis

The pericardium is the thin sac that surrounds the heart and helps it move easily when it beats. It reduces the friction when the heart beats. Sometimes this thin layer of cells can become infected by bacteria, causing the sac to fill with fluid– a condition known as pericarditis. As a result the heart cannot beat properly. This restricts the heart from filling properly with blood. Antibiotics are needed to help kill the bacteria.

Extend your understanding

1 What causes the lub-dub sound you hear when you listen to your heart?
2 What is the cause of the following valve conditions?
   a stenosis
   b regurgitation or insufficiency
   c prolapse.
3 What is the purpose of the heart having a pericardium?
4 What is the link between atherosclerosis and cardiovascular disease?
5 What things could you do to ensure your circulatory system stays healthy?
6 How does the heart muscle become damaged during a heart attack?
7 How does the function of the pericardium become affected when it fills with fluid during an infection?

7.9 The excretory system removes waste

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

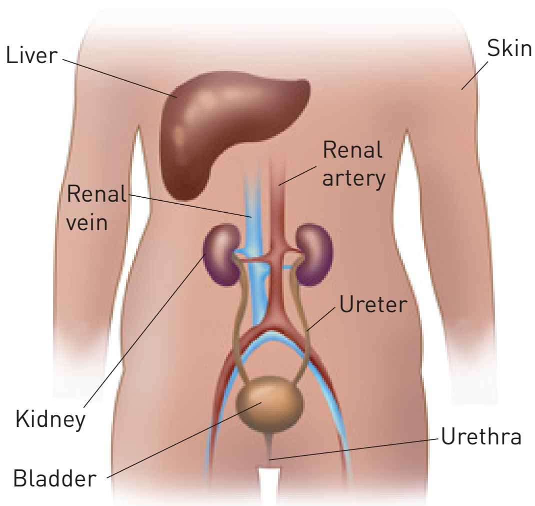

Figure 7.33 The structure of the excretory system with key parts labelled.

What is waste?

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

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

Figure 7.34 The salt that you eat helps substances move in and out of cells. However, if there is too much salt in your body, things get out of balance. Your body gets rid of the excess salt by filtering it out through the kidneys.

The kidneys

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

Figure 7.35 Ammonia is a strong cleaning solution. Liquid ammonia can dissolve some metals, so you can imagine why it's not a good thing to have too much of it in your body.

EXPERIMENT 7.9: KIDNEY DISSECTION
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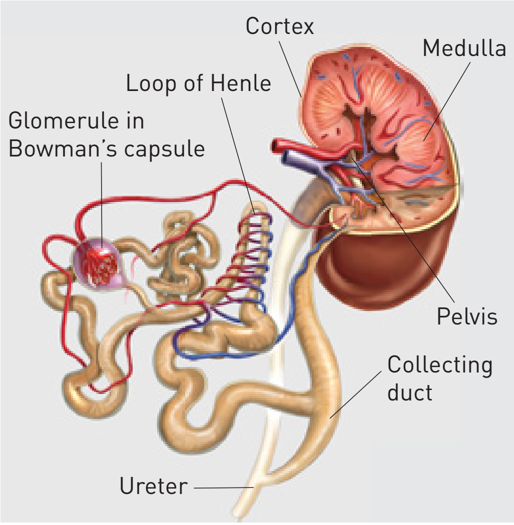

Figure 7.36 The structure of the kidneys. The nephron, shown in greater detail on the left, is the filtering unit of the kidney.

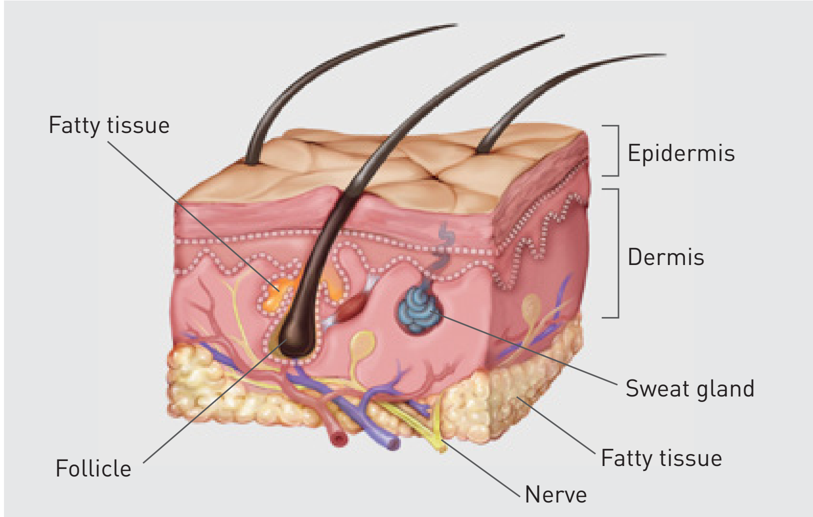

Figure 7.37 The structure of skin.

The skin

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

The liver

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

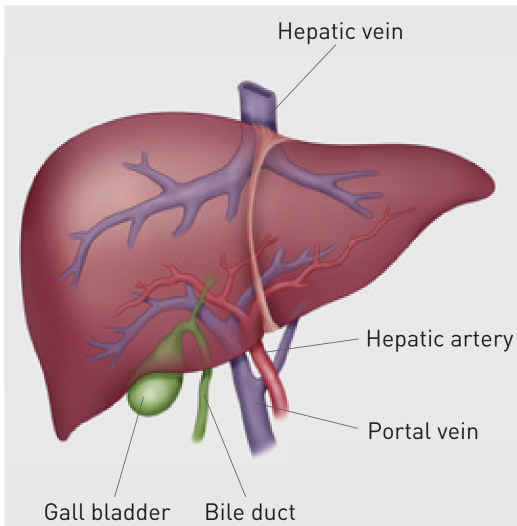

Figure 7.38 The structure of the liver with key parts labelled.

Figure 7.39 Protein digestion produces toxic ammonia.

Check your learning 7.9

Remember and understand

1 What does the word 'excretion' mean?
2 Can you think of any similarities between your excretory system and your respiratory system?
3 What are four organs involved in excretion?
4 Why does urine tend to be more concentrated in hot weather?
5 How does your body get rid of the following wastes?
   a salt
   b water
   c urea.

Apply and analyse

6 What effect would running a marathon have on the quantity and concentration of the urine?
7 If someone passes blood in their urine, it is a likely sign of kidney damage. Can you think of why?

CHALLENGE 7.10A: LOCATING THE STOMATA OF A LEAF
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CHALLENGE 7.10B: LOCATING THE XYLEM AND PHLOEM IN A STEM
GO TO PAGE 209.

7.10 Plants have tissues and organs

Plants are multicellular organisms that have specialised organs to help move water and nutrients around the body. **Roots** use **osmosis** to absorb water from the soil. **Stems** transport the water and nutrients around the plant. **Leaves** exchange gases and produce the sugars needed for energy.

Roots

Roots help anchor a plant to the soil and help it absorb nutrients and water. Most root cells have a series of small hairs to increase the amount of surface area that can take in the water. First the roots take mineral salts from the soil and store them in their cells. This makes the inside of the roots more 'salty' than the soil. Water molecules are attracted to the mineral salts in the root cells. As a result, water moves through the root cell membrane and into the plant. This process is called osmosis.

Stem

The stem of a plant is the organ responsible for the transport of water and nutrients between the leaves and roots. There are two main structures in the **vascular bundle** of the stem.

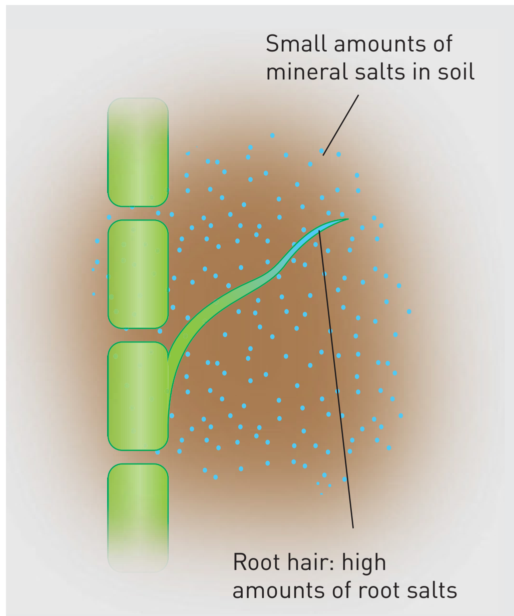

Figure 7.40 Osmosis into a root hair.

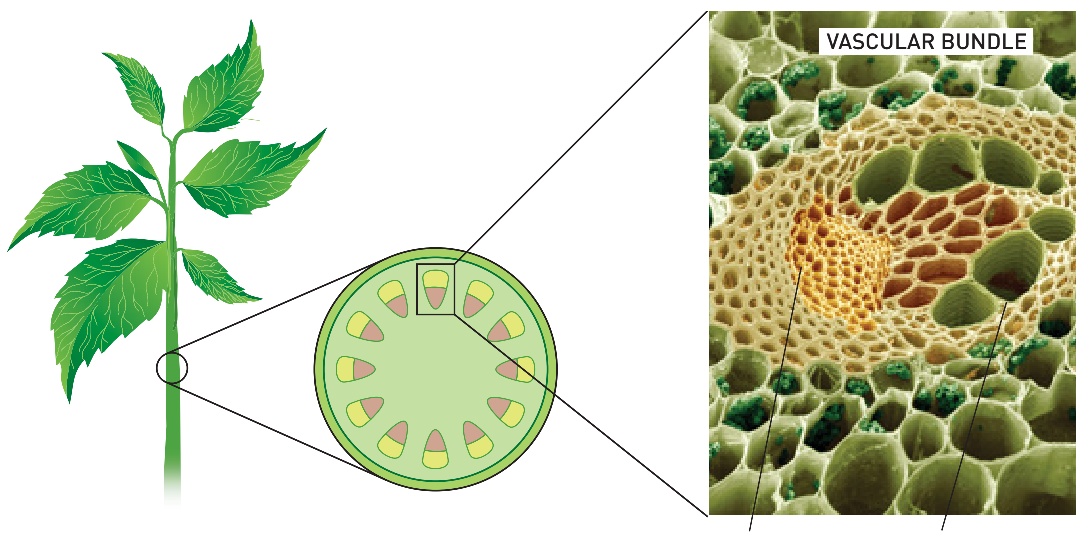

Figure 7.41 The structure of the stem of a plant.

CHALLENGE 7.10C: MODELLING ROOT CELLS
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EXPERIMENT 7.10: FACTORS THAT AFFECT TRANSPIRATION
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The **xylem** (*zi-lem*) is a straw-like structure that moves the water from the roots to the top of the plant. Water molecules like to stick together; you can see this in the way a drop of water forms a spherical shape. When water evaporates from the leaves at the top of a plant (**transpiration**), other water molecules move up to replace it. This can pull water molecules from the roots to the top of a 10 metre tree.

The **phloem** (*flo-em*) is another network of cells in the plant stem that transport the glucose produced in the leaves to other parts of the plant. These sugars are needed for all cells in the plant to produce the energy they need to stay alive.

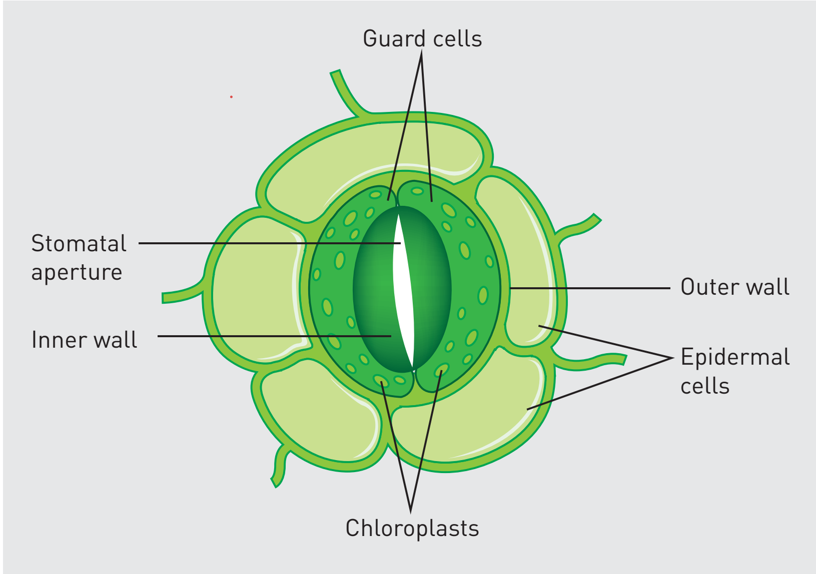


Figure 7.42 The structure of a plant stoma.

Leaves

The leaves of a plant are involved in exchanging gases. In sunlight, a plant needs carbon dioxide to produce the sugars it needs for energy. The carbon dioxide moves in and out of cells through a small opening called a stoma (plural stomata). A plant stoma has two specialised guard cells that can grow longer, forcing a hole to appear between them. This allows air to move in and out. When it is too hot, the plant loses more water than the roots can replace. This causes the guard cells to become smaller, closing the pores in the plant's stomata.

When the sun is shining, the leaves convert the water from the roots and the carbon dioxide from the stomata into glucose (sugar) and oxygen in a process called photosynthesis. Photosynthesis cannot happen without the help of **chlorophyll**. This is the reason most leaves are green.

During autumn, some leave lose their green chlorophyll. This allows the other colours present in the leaves (reds, oranges and yellows) to appear.

Figure 7.43 Autumn leaves come in a range of colours.

Check your learning 7.10

Remember and understand

1 Name three organs found in most plants and describe their function (what they do).
2 What is osmosis?
3 What is the difference between xylem and phloem?
4 Why do leaves become red and yellow in autumn?
5 What system in humans provides the same function as a plant stem?

Apply and analyse

6 Some florists sell blue orchids that are artificially coloured. Use your knowledge of plant systems to explain how these orchids may have become blue.

Figure 7.44 Artificially coloured orchids.

Remember and understand

1 What was Leonardo da Vinci famous for?
2 What do you think motivated the earliest studies of the human body?
3 Name four things that the circulatory system transports around your body.
4 What is the gaseous waste product removed by the lungs?
5 Describe how the respiratory system and circulatory system work together.
6 What is the difference between respiration and breathing?

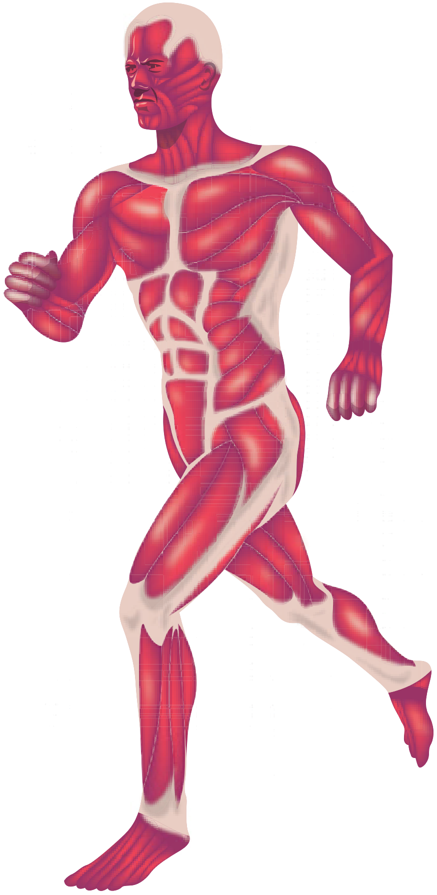


Figure 7.45 The respiratory system and circulatory system must work together to supply oxygen to the muscles.

7 Where does chemical digestion occur in the body?
8 Where does peristalsis occur in the body? Explain how it causes food to move.
9 Plants do not have a digestive system. What organ helps the plant supply all its energy needs?

Apply and analyse

10 How does the human digestive system 'feed' all the other systems?
11 Why would muscles need more blood during exercise?

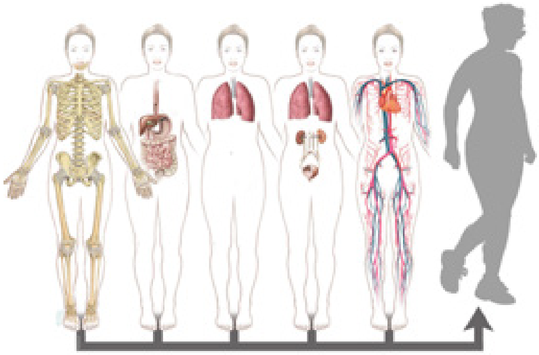


Figure 7.46 Each system in the human body is made up of organs that must work together.

12 Would you expect to find chloroplasts in the roots of a plant? Why or why not?
13 Sweating is often considered to be a bad thing. What is your perspective? Put forward an argument for your point of view. What do you think would happen if you didn't sweat?
14 Imagine it is your job to construct a 'user's manual' for one of the systems covered in this chapter. Write a list of ten 'Frequently Asked Questions' (FAQ) to go at the front of the manual. Write an answer to as many of your questions as you can. If you don't know the answer, write down where you could find the answer or who you could ask.
15 Some people have had the valves in their heart replaced with prosthetic valves, either made from synthetic materials or transplanted directly from a pig or cow heart. Why is it so important that the valves in a heart are functioning properly?
16 Mangrove trees get rid of excess salt through their leaves. This salt is often seen as white crystals on the underside of the leaves. Which system does this represent for the plant? How is this similar to humans? Which organ(s) is responsible for this in humans?

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

Evaluate and create

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

Figure 7.47 There are many different systems in your body that must work together to keep you alive.

19 Revisit Challenge 7.1, the brown paper body brainstorm that you did at the start of this unit. Look at the body you and your group created. Evaluate your own work by writing a short paragraph about how your knowledge of your major body systems has changed after completing this unit. Give yourself a score out of 5 for *then* and a score out of 5 for *now*.

Ethical understanding

20 There are many diseases that affect the different organs in the body. Sometimes the only treatment available is an organ transplant. Replacement hearts and lungs can only be obtained from critically injured patients who have been certified brain dead. Discuss the advantages and disadvantages of organ donation with a partner. Would you want your organs donated if you were brain dead? Explain the reasoning behind your decision.

Research

21 Choose one of the following topics for a research project. A few guiding questions have been provided for you, but you should add more questions that you want to investigate. Present your research in a format of your own choosing, giving careful consideration to the information you are presenting.

a **Smoking bans**

Many smoking bans, such as bans in workplaces, are related to the issue of secondhand smoke. This refers to how smoke affects people standing near a person who is smoking. Find out some facts about the impacts of secondhand smoke. Do you think the rules are required? Argue your position on whether smoking bans should be extended, removed or are fine as they are now.

b **Getting rid of nitrogen**

Animals need to get rid of nitrogen. Some animals produce ammonia, some produce uric acid, some produce urea and others produce guanine. Find out which types of animals produce these different substances to remove nitrogen. In which environments do animals that produce ammonia live? In which environments do animals that produce urea live? What are the advantages for animals of producing the different forms of nitrogenous wastes?

c **Omega-3 fatty acids**

What are omega-3 fatty acids? What foods should be eaten to include them in your diet? How do omega-3 fatty acids help reduce heart disease? What other diseases are helped by omega-3 fatty acids? Why is this sort of fat good for you to eat?

d **Rh factor**

What is the Rh factor? How is the Rh factor written with blood groups? What percentage of the population is Rh negative and what percentage is Rh positive? What affect does the Rh factor have in pregnancy?

* KEY WORDS

7

abomasum
the fourth stomach of a cow

alveoli
tiny air sacs in the lungs where gas exchange occurs

aorta
the major artery that carries oxygenated blood from the heart and divides into smaller arteries around the body

arterioles
smaller arteries

artery
thick, muscular-walled blood vessel that carries blood away from the heart under pressure

atria
the smaller upper chambers of the heart

bronchi
the air passages that carry air in and out of the lungs; airways

caecum
a small dead-end pouch that connects the small and large intestines

capillary
blood vessel with a wall only one cell thick, allowing substances to easily pass into and out of the blood

diaphragm
the dome-shaped muscle that is attached to ribs and moves up and down beneath the lungs

epiglottis
a flap of skin that controls the passage of food and air

excretory system
a group of organs that are involved in excretion

lungs
organs found in the ribcage that are part of the respiratory system

nephron
tiny structure in the kidneys that filters the blood

omasum
the third stomach of a cow

osmosis
the movement of water through a selective membrane from an area of low 'salt' concentration to an area of high 'salt' concentration; occurs in root cells

peristalsis
when muscles behind the food squeeze tight, and the muscles in front of the food relax, causing the food to move along the throat or intestines

pharynx
the throat; connects the mouth to the oesophagus

phloem
the vascular tissue found in plant stems that carries the sugars around the plant

plasma
the straw-colour fluid that forms part of the blood

platelets
small disc-like cells found in blood that are involved with forming clots

red blood cells
cells found in the blood that carry oxygen around the body

reticulum
the second stomach of a cow

rumen
the first stomach of a cow

trachea
the large tube that connects the throat to the bronchi; carries air in and out of the body

transpiration
the process of water evaporation from plant leaves that causes water to move up from the roots

vascular bundle
groups of tubes found in plant stems that carry water and nutrients around the plant

vein
thin-walled blood vessel that carries blood back to the heart

ventricles
the large lower chambers of the heart

villi
small ridges found in the small intestine that absorb nutrients from the digestive system

white blood cells
cells found in the blood that help fight infections

xylem
the tissue in plants that carries water from the roots to the rest of the plant

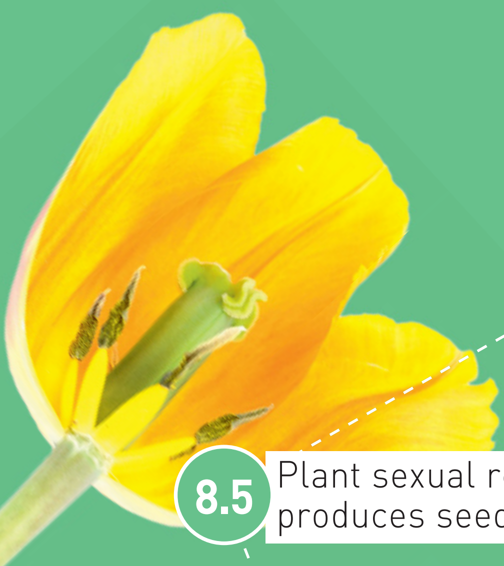
REPRODUCING 8

8.1 There are different ways of reproducing

8.2 The female reproductive system produces eggs in the ovaries

8.3 The male reproductive system produces sperm in the testes

8.4 Things sometimes go wrong in reproduction



8.5 Plant sexual reproduction produces seeds

8.6 Reproduction techniques have an impact in agriculture

What if?

Dogs and roses

What you need:

A3 paper, pens

What to do:

1. Divide into small groups.
2. Divide the piece of paper in two equal sections.
3. On one half, write down everything you know about how show dogs are bred.
4. On the other half, write down everything you know about how prize roses are grown.

What if?

» What if a show dog were unable to breed? What would happen to it?

» What if all rose bushes could grow identical flowers? What other factors could influence how the rose flower appeared?

8.1 There are different ways of reproducing

All living things reproduce, leaving new organisms to carry on when others die. **Asexual reproduction** involves a single organism making an exact genetic copy of itself. **Sexual reproduction** involves a combining of the genetic material from two organisms to produce a new organism.

Figure 8.1 The queen bee likes parthenogenesis because her unfertilised eggs always become male bees, which means no competition for her crown!

Figure 8.2 The mouth-brooding frog doesn't eat at all while protecting the eggs it holds in its mouth.

Asexual reproduction

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

In asexual reproduction, the offspring have exactly the same genetic material (known as DNA) as the parent. If an organism is really suited to an environment, the lack of variation can contribute to further success. However, if the environment changes in any way that becomes unsuitable for the organism, the entire species risks extinction. The simplest version of asexual reproduction is an organism splitting in half to form two new organisms. This is known as **binary fission**.

An amazing asexual reproductive strategy known as **parthenogenesis** involves unfertilised eggs hatching into new organisms. A reticulated python in a zoo, which had been kept isolated from other snakes, managed to lay eggs that produced six daughters. The zoo keepers tested the genetic material (DNA) of the baby snakes and found that it was identical to the mother's genetic material. Other animals, such as the crown of thorns starfish, are able to form new individuals when they are split in two. This is called **fragmentation**.

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

Vegetative structures include plantlets, stolons and rhizomes.

Figure 8.3 **Plantlets:** tiny plants that grow on either the parent stem, leaf or root.

Figure 8.4 **Stolons (runners):** stems running along the ground.

Figure 8.5 **Rhizomes:** underground stems.

EXPERIMENT 8.1: VEGETATIVE PROPAGATION
GO TO PAGE 211.

Sexual reproduction

The two cells that joined to make you were called sex cells or **gametes** – an egg from your mum and sperm from your dad. Many organisms rely on gametes fusing to make new organisms and this process is referred to as sexual reproduction.

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

Figure 8.8 Even though nudibranchs are hermaphrodites, they tend to find a partner to mate with. Whichever is fastest at injecting a chemical into the other will get to be the boy!

Figure 8.6 When garden snails mate, both snails give and receive sperm, so both get pregnant.

Figure 8.7 When the dominant male in a population of wrasse dies, a female can become a male to replace him.

Figure 8.9 Identical twins are only identical according to their DNA.

Hermaphrodites

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

Nature or nurture?

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

Check your learning 8.1

Remember and understand

1. What does 'reproduction' mean?
2. How does sexual reproduction differ from asexual reproduction?
3. What substance is responsible for family resemblances?

Apply and analyse

4. Is variation within a species essential? Explain.
5. What circumstances might make it difficult for an organism to reproduce sexually?
6. When would parthenogenesis be useful for organisms that usually reproduce sexually?

Evaluate and create

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

8.2 The female reproductive system produces eggs in the ovaries

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

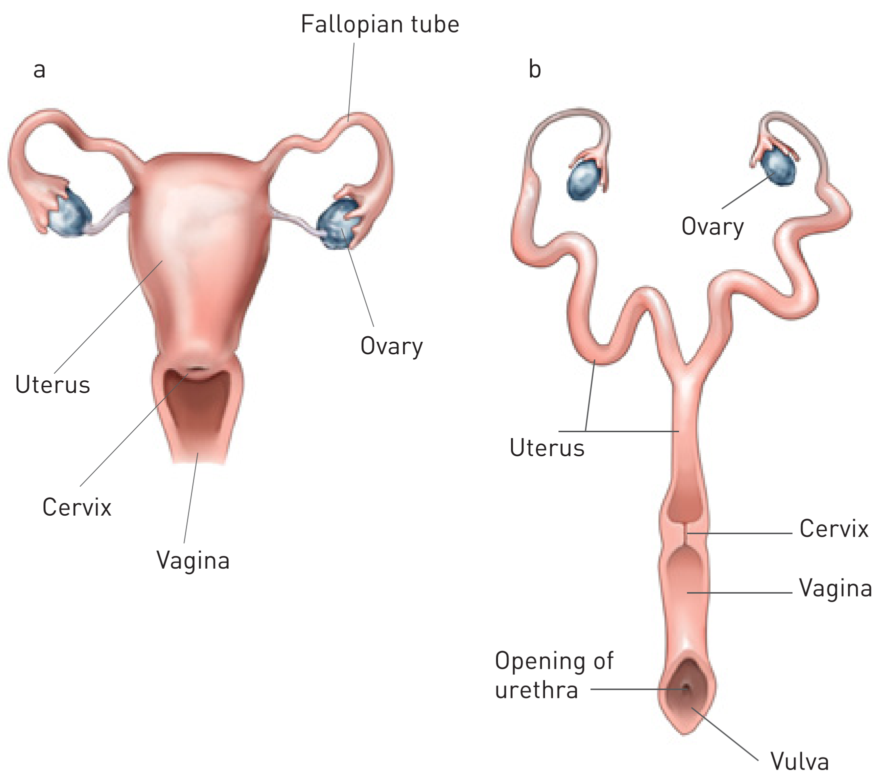


Figure 8.11 The female reproductive system varies between vertebrates. (a) Human and (b) rabbit reproductive systems.

Human reproduction

In humans, girls are born with hundreds of thousands of eggs or **ova** (singular ovum) partially formed in their **ovaries**. Every month a chemical messenger from the brain (**oestrogen**) causes one egg to mature and be released. This process is called **ovulation**. The egg travels down the **fallopian tubes** to the **uterus**. If sperm are present in the fallopian tubes, then the egg may become fertilised. In the 3–5 days it takes for the egg to travel the fallopian tubes, the lining of the uterus (the **endometrium**) becomes thicker. This is to provide a safe place for the fertilised egg, or **zygote**, to grow into a **foetus**.

If the egg is not fertilised, then the endometrial lining will break down and, 2 weeks after ovulation, will pass through the **cervix** and **vagina** as a period. This monthly cycle is called **menstruation**.

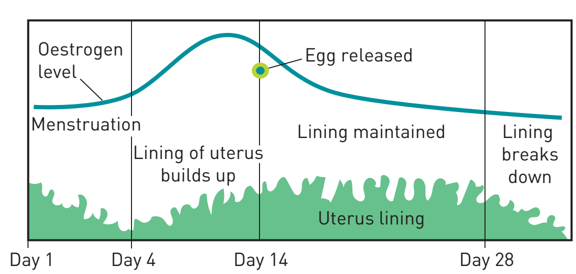


Figure 8.10 During the average 28 day menstrual cycle, ovulation occurs at day 14.

Menstruation usually first occurs in females between 11 and 15 years of age, but it can start before 10 years for some girls, and as late as 16 for others. It can take up to 2 years for menstruation to become a regular cycle. The average length of the cycle is 28 days, but it can vary from 23 to 35 days.

If the egg is fertilised and develops into a zygote, then it attaches to the thick endometrial layer. A special organ called the **placenta** forms between the foetus and the uterus. The placenta allows oxygen and nutrients to pass from the mother to the developing foetus. The length of time between fertilisation and birth is called **gestation** (or pregnancy). In humans this takes 9 months.

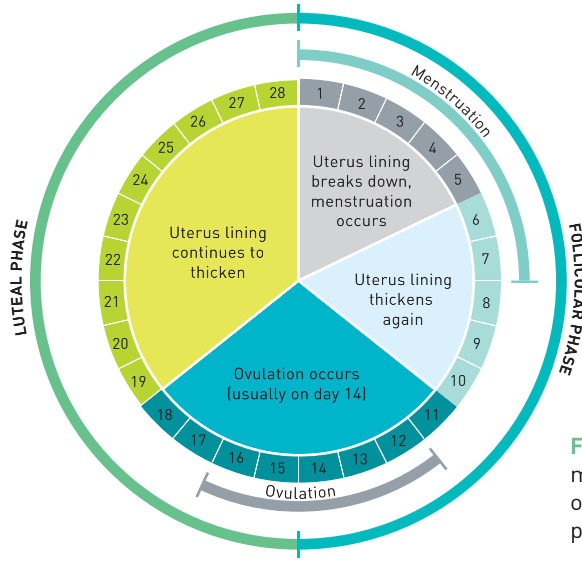


Figure 8.12 The menstrual cycle begins on the first day of a period.

Giving birth

Human mothers go through three stages when giving birth. The first stage involves the muscular walls of the uterus contracting, gently squeezing the baby down against the cervix. This causes the cervix to flatten and start dilating (opening). The cervix must open 10 cm before the baby's head can move through the vagina. This is the second stage of birth. When born, the baby is still attached to the placenta, which is inside the mother, via the umbilical cord. When the umbilical cord is cut, it will form the belly button on the baby. The third and final stage of birth is the delivery of the placenta. This is important to prevent infections from developing in the uterus.

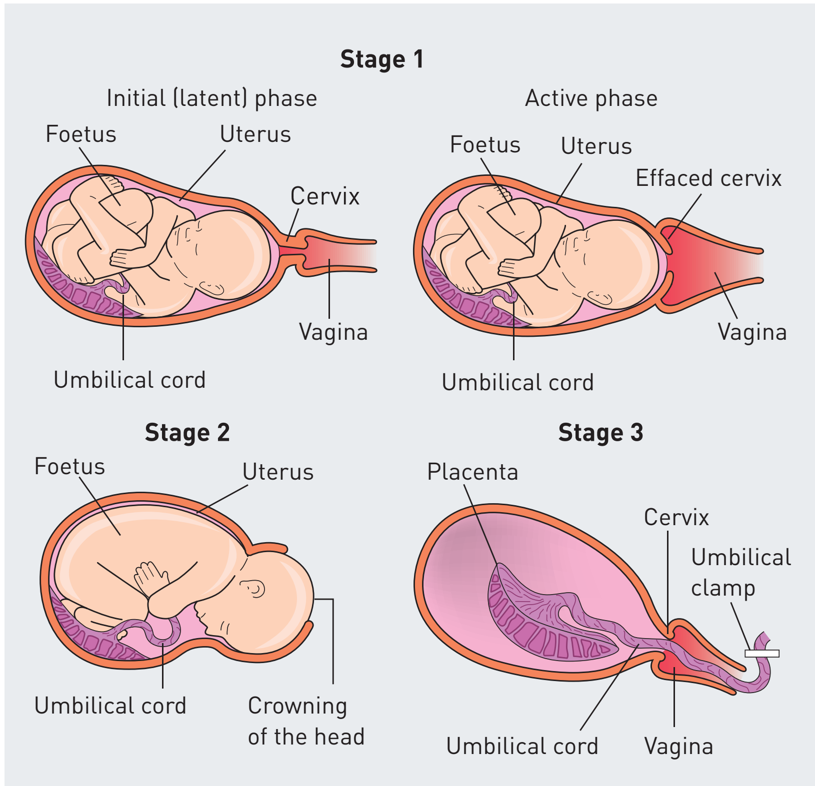


Figure 8.13 The three stages of childbirth.

Check your learning 8.2

Remember and understand

1 List a chemical messenger in human females.
2 Where does the ovum become fertilised in humans?
3 What is menstruation?
4 How often does menstruation occur?
5 What are the three stages of giving birth?
6 On what day in the average cycle does ovulation occur?

Apply and analyse

7 A student said that a baby girl already had all her eggs intact when she was born. Are they correct? Explain your reasoning.

8.3 The male reproductive system produces sperm in the testes

The vast majority of animals reproduce sexually. They are also **sexually dimorphic**, which means that the males look physically different from the females. For baby animals to be born there needs to be **fertilisation** of an egg by a sperm. This could happen inside the female or male (**internal fertilisation**) or out in the open (**external fertilisation**).

Male reproductive organs

In fertilisation, a gamete from the father (sperm) must meet the gamete from the mother (egg or ovum). The sperm is produced in special organs called the **testes**. The testes are also responsible for producing a male chemical messenger called **testosterone**. In most animals, the two testes are kept outside the body in a sack called the **scrotum**. This is to keep the sperm cooler than the 37°C of the rest of the body. If sperm get too hot then they will not be able to fertilise an egg properly.

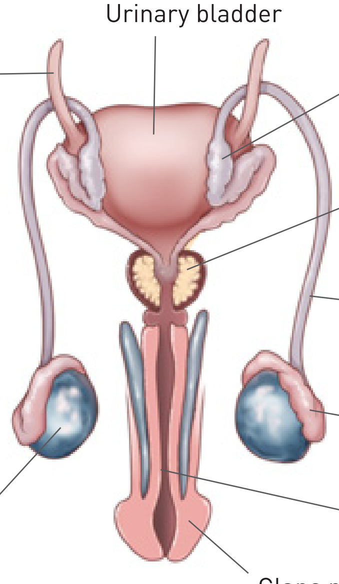


Figure 8.14 Human male reproductive system.

Once sperm are produced in the testes, they move to the **epididymis** to mature. When necessary, the epididymis contracts (squeezes tight), and the sperm is moved into the **vas deferens**. The sperm need energy to be activated. **Seminal vesicles** are small pouch-like structures that provide a sugary fluid that is needed for the sperms' journey along the vas deferens tube to the **prostate gland**. The prostate gland is a walnut-sized structure that blocks the flow of urine so that the sperm can move along the urethra and be ejaculated out through the penis. The function of the penis is to help the sperm reach the eggs.

Fertilisation

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

Monotremes, a very rare group of mammals that consists of the platypus and the echidna, lay leathery eggs.

All mammals suckle their young with highly nutritious milk from the mother to give them the best start in life.

Like monotremes, reptiles and birds lay internally fertilised eggs. Reptile eggs are leathery, whereas bird eggs have a hard shell. The eggs contain all the nutrients the foetus needs

Figure 8.15 Marsupial foetuses finish developing in the pouch.

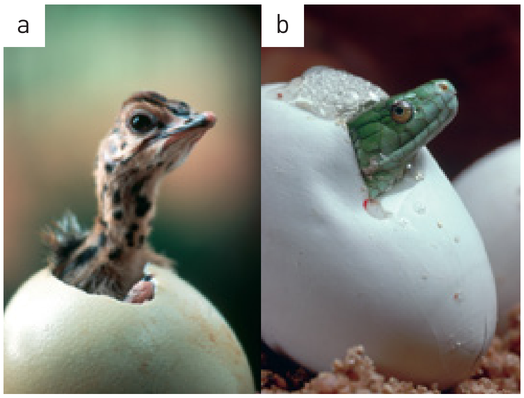


Figure 8.16 (a) Birds' eggs are hard while (b) reptile eggs are leathery.

Figure 8.17 Some fish protect their eggs from predators.

to develop fully, which is really important for reptiles because most reptiles leave their babies to fend for themselves.

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

Invertebrates making babies

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

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

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

Figure 8.18 A female fly lays eggs through her oviduct.

Check your learning 8.3

Remember and understand

1 Explain 'sexual dimorphism' in your own words.
2 Name a chemical messenger in males.

Apply and analyse

3 Why do animals that practise external fertilisation usually lay large numbers of eggs?
4 Which group of mammals has the longest gestation? Explain.
5 Which two vertebrate classes lay leathery eggs?
6 Why would terrestrial invertebrates fertilise their eggs internally?

Evaluate and create

7 Make up a story that describes the journey of Mr Sperm from his home in the testes to meet the love of his life, Ms Ovum.

//SCIENCE AS
A HUMAN ENDEAVOUR//

8.4 Things sometimes go wrong in reproduction

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

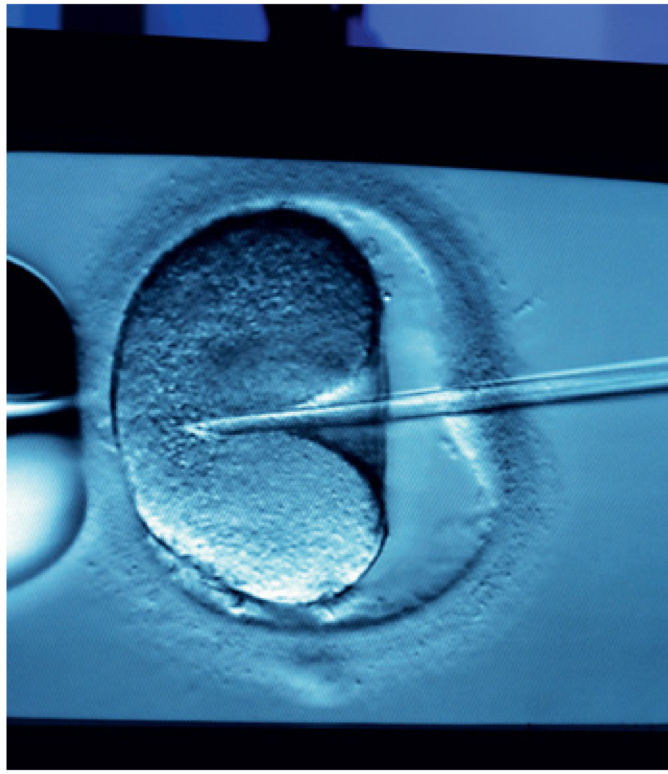


Figure 8.19 In IVF, eggs are injected with sperm for fertilisation.

Endometriosis

Sometimes the lining of the uterus, the endometrium, starts growing outside the uterus. These cells can grow on the outside of the uterus, or spread to other organs such as the ovaries. Each month the endometrial cells grow, and then break down, just as in the menstrual cycle. This can be very painful and the scarring can prevent the eggs from being able to move down the fallopian tubes. This can make it difficult for pregnancy to occur.

Human reproduction

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

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

Preserving biodiversity

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

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

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

CHALLENGE 8.4: WORKING WITH THE RSPCA
GO TO PAGE 211.

Figure 8.21 Captive breeding programs are helping to save the bilby.

Figure 8.22 It's not a very happy life for domestic animals without food or shelter.

Contraception and desexing

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

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

Local councils very commonly require animals that are pets to be desexed. Cats, for example, often wander freely during the day and have many opportunities to breed – but who will look after all the kittens? If everyone's cats were free to breed, the neighbourhood would soon be swarming with kittens.

Figure 8.20 Ultrasounds allow the developing foetus to be seen.

Extend your understanding

1 What does IVF stand for?
2 Why are babies less likely to be born with problems now compared with 50 years ago?
3 What is biodiversity? Why is it so important to preserve biodiversity?
4 Explain, in your own words, why it is necessary for zookeepers to control the reproduction of animals in the zoo.

8.5 Plant sexual reproduction produces seeds

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

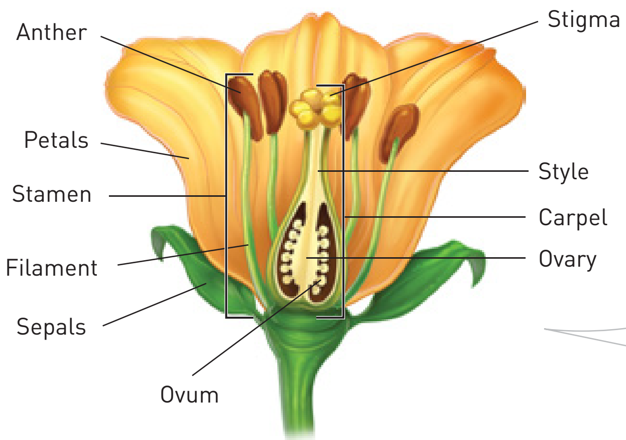


Figure 8.23 Basic structure of a flower.

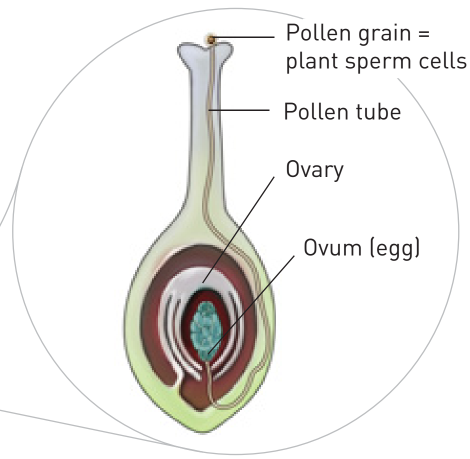


Figure 8.24 Structure of the carpel with key structures labelled.

Pollination

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

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

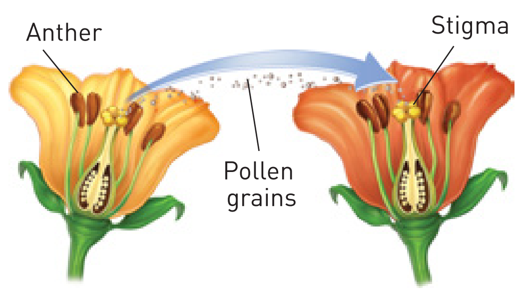


Figure 8.25 Cross-pollination.

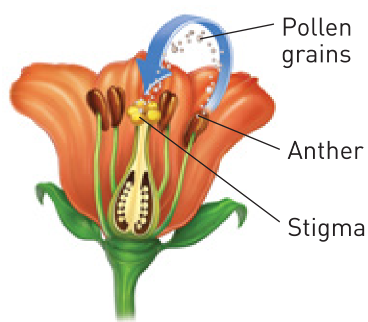


Figure 8.26 Self-pollination.

EXPERIMENT 8.5: FLOWER DISSECTION
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After fertilisation, the ovary takes on a role similar to that of a bird's egg. It swells to become a fruit, which provides nutrition and protection for the zygotes to grow into embryos inside the seeds. The ovary structure is seen in the structure of the seed-bearing area of the fruit.

Not all flowers are the same

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

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

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

Sexual spores

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

Figure 8.30 Fern 'sori' produce spores for reproduction.

Figure 8.27 Rafflesia.

Figure 8.28 Bottlebrush.

Figure 8.29 Daffodil.

Figure 8.31 Mosses produce spores for sexual reproduction.

Check your learning 8.5

Remember and understand

1. What is the name of the structure that holds a plant's sexual reproductive systems?
2. What is the difference between self-pollination and cross-pollination? Which produces more variety?
3. How is fertilisation different from pollination?
4. Draw a circular flow diagram using the following terms: flower, pollen, seed, fruit, pollination, fertilisation, ovum, pollen, ovary and anther.
5. Why are some flowers large and coloured, and others tiny and plain?
6. How is a spore like a seed? How is it different?

Apply and analyse

7. Plants that are successful weeds often use both sexual and asexual reproduction. Mint is common in herb gardens and reproduces with little flowers as well as using vegetative reproduction. Why would it be difficult to get rid of mint once it has spread through a garden bed?

//SCIENCE AS A HUMAN ENDEAVOUR//

8.6 Reproduction techniques have an impact in agriculture

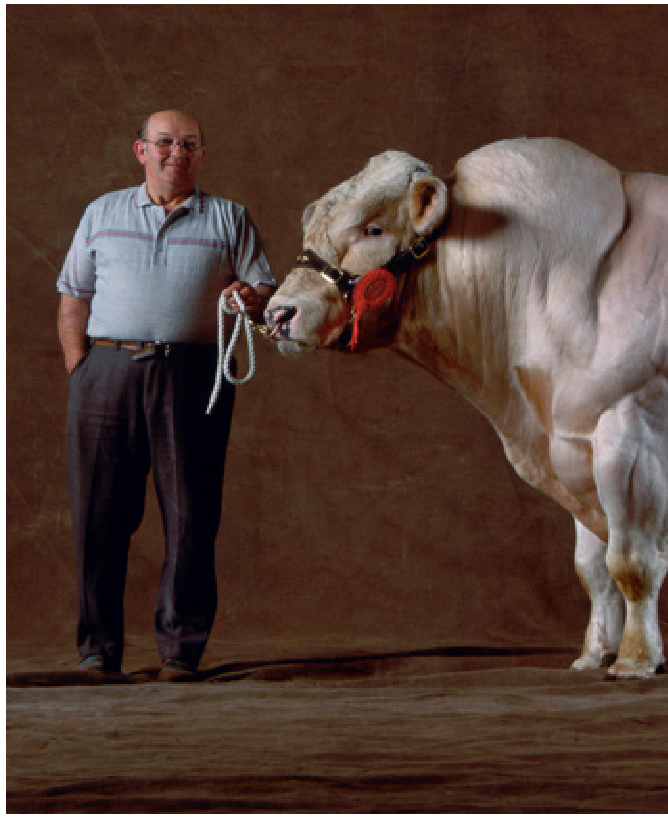


Figure 8.32 Some people get a little carried away with selective breeding.

* Many reproductive technologies are used in agriculture to improve desired characteristics in plants and animals. This has an impact on diversity and risks inbreeding.

Selective breeding

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

Occasionally animals have difficulty in breeding. This may be due to location (the animals may be on opposite sides of the country) or their owners wanting to have greater control over the animals they breed with. As a result, sperm banks for animals have been developed. Desired characteristics, such as speed or 'staying power' in racing horses, or facial shape or coat colour in dogs, are described in a catalogue for owners to examine. The desired frozen sperm can be purchased and sent to the owner of the female animal, where it will be used to create offspring with the desired characteristics.

Selective breeding also applies to plants. A type of wheat that is known to survive frost or disease can be deliberately cross-pollinated with a type of wheat that produces high-quality grains with the aim of producing a grain that combines both features.

Loss of diversity

Diversity in plants and animals refers to the variety of genetic material in a single population or species. When a characteristic, such as milk production in cows, is used for selective breeding, then any cow that does not produce 'enough' milk is not encouraged to breed. This often means the genetic material from that cow is not passed on to the next generation. Instead the next generation of calves will only have genetic material from the few cows that meet the milk production criteria. As a result, there is less variation in the genetic material. Although this does not seem a problem initially, it puts the whole population at risk of disease. If one plant or animal is at risk of a disease, the rest of that population, with the same genetic material, is also vulnerable.

An example of this is the facial tumour in the Tasmanian devil. All Tasmanian devils have very similar genetic material. When one individual devil developed a tumour on its face, it was able to pass it on to another devil that had similar genetics.

Figure 8.34 In the mid-1800s, the population of Ireland relied very heavily on potatoes for food. When a fungus infected the potatoes, the lack of genetic diversity meant that all potato crops were wiped out and about 1 million people died of starvation.

Figure 8.33 The Tasmanian devil facial tumour is caused by the uncontrolled growth of a cancerous cell.

Figure 8.35 Labradors are known to have hip problems as the result of many years of inbreeding.

Inbreeding

Inbreeding results from animals reproducing with animals to which they're closely related. When this happens, rare diseases can show up. For example, some dogs that were chosen to breed because of their particular looks may also have hip problems. Inbreeding has been quite a problem with dog breeds, especially when people don't check an animal's ancestry carefully.

Extend your understanding

1. What is selective breeding? Give examples in your answer.
2. What technology can be used to assist selective breeding?
3. What is inbreeding? Give an example.
4. Why is genetic diversity in a population important?
5. Is selective breeding always a good idea?
6. Research an example of the difficulties faced by breeding flat-faced pug dogs.

Remember and understand

1 What is the scientific term for 'making new organisms'?
2 What is a gamete?
3 What are the common names for the two gametes in animals? In plants?
4 What is the difference between a foetus and a baby?
5 Which produces greater variation: sexual or asexual reproduction?
6 What is the function of a fruit?
7 Why do organisms that fertilise internally tend to produce fewer eggs than those that fertilise externally?
8 Which is better for maintaining biodiversity: self-pollination or cross-pollination? Give reasons for your answer.
9 What is the difference between a spore and a seed?

Apply and analyse

10 Use your understanding of sexual dimorphism to describe three features that differ between a male and a female in humans. Describe three that may differ in birds.
11 A farmer grows two types of corn on the farm. One type is terribly affected by the frosts in winter but produces really large, juicy corn cobs when it is protected. The other copes in winter without a problem but has only average corn cobs. What could the farmer do to improve his crops?
12 A 13-year-old girl was keeping a record of her menstrual cycle. She found her cycle lasted approximately 28 days.

If her last period started on 1 June, determine the following:

a When will she ovulate?

b When will her next period start?

13 Examine the images in Figure 8.37, then give two features that are genetic and two that are environmental.
14 If a hermaphrodite reproduced alone, would it be considered sexual or asexual reproduction? Explain.
15 Skinks drop their tails when threatened, but their tails can grow back. Is this a type of asexual reproduction? Explain.
16 Some reptile eggs are affected by the temperatures they experience while incubating in the nest (see figure 8.38). For example, within a single nest, the temperature may vary enough to produce a mix of both. How might warmer weather as a result of the enhanced greenhouse effect impact green sea turtle populations?

Evaluate and create

17 The life cycles and reproductive strategies of invertebrates are incredibly diverse. Choose an invertebrate to research and present your findings in the form of a poster or webpage to present to the class. Research projects could be shared in a mini-conference format.
18 Humans don't reproduce asexually – ever. What consequences might there be if a human was able to reproduce asexually? What consequences might there be if many humans were able to reproduce asexually?
19 Divide into two groups to debate one of the topics below.

a Selective breeding is essential to maintain food production for humans.

b Reproductive technologies interfere with nature.

c Selective breeding is important in preventing extinction.

d Genetic diversity can be maintained without technology.

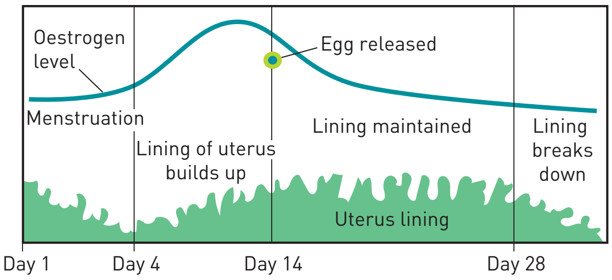


Figure 8.36 The average 28 day menstrual cycle.

Figure 8.37 These dogs are from the same litter.

Figure 8.38 Green sea turtle eggs produce female babies when the eggs are warmer and male babies when the eggs are cooler.

Research

20 Choose one of the following topics for a research project. A few guiding questions have been provided for you, but you should add more questions that you want to investigate. Present your research in a format of your own choosing, giving careful consideration to the information you are presenting.

a **Dog breeding in Australia**

Some breeds of dogs are vulnerable to a series of genetic problems, such as difficulty breathing or displaced hips, as a result of decades of inbreeding. Research a breed of dog that has such difficulties. What features are these pedigree dogs judged on in dog shows? What problems have arisen as a result of the inbreeding? What measures are the RSPCA and the Australian National Kennel Council taking to ensure these problems do not continue?

b **Seed banks**

A seed bank stores a large variety of seeds in case a particular species of plant is placed at risk as a result of natural disaster, outbreaks of disease or war. Research a major seed bank near your school. What type of seeds do they collect? Who collects the seeds for the bank? How are they collected? What conditions are needed for the seeds to remain viable (alive)?

c **Chorionic villi sampling (CVS)**

Chorionic villi sampling is a procedure that some mothers undergo to test for genetic problems in the foetus. How is this procedure performed? When can this test be taken? What type of abnormalities can be detected with this test? What is genetic counselling?

d **Contraception**

Contraception is the term used for the range of methods or devices that are used to prevent pregnancy. Birth control methods have been used for thousands of years. What is the difference between barrier, surgical and chemical methods of contraception? Research two methods of contraception that can be used by humans. Do males or females use them? How effective are they at preventing pregnancy?

8 * KEY WORDS

anther
part of the stamen (male plant) that contains pollen

asexual reproduction
type of reproduction not involving the fusing of gametes; where an organism can create offspring without a partner

carpel
the female reproductive organ of a flower; includes the stigma, style and ovary

cervix
the narrow neck connecting the uterus and the vagina

endometrium
the lining of the uterus

epididymis
the coiled tube behind the testes that carries sperm to the vas deferens

fallopian tubes
the tubes that connect the ovaries to the uterus in a female

fertilisation
stage of sexual reproduction involving the joining of a sperm and an egg

foetus
stage in the development of a human baby taken from when the baby acquires human features (normally after 8 weeks of development)

gamete
sex cell; in humans, the sperm and egg cells

hermaphrodite
organism that has both male and female reproductive systems

menstruation
also know as a period; the process of the endometrial lining of the uterus breaking down and leaving the vagina

oestrogen
a reproductive hormone found in females

ovary
the female organ that produces eggs

oviduct
the tube through which eggs travel from the ovary

ovulation
the part of the menstrual cycle when an egg is released from the ovary

ovum
the reproductive egg

placenta
the organ the connects the developing foetus to its mother

prostate gland
the walnut-sized structure surrounding the neck of the male bladder that blocks the flow of urine so that the sperm can move along the urethra

scrotum
the sac-like structure that contains the testes

seminal vesicle
small pouch-like structures that provide a sugary fluid that is needed for the sperms' journey along the vas deferens tube

sexual reproduction
type of reproduction involving the fusing of gametes

sexually dimorphic
those species in which the male and female organisms look structurally different

spore
tiny reproductive structure that, unlike a gamete, does not need to fuse with another cell to form a new organism

stigma
the male part of a plant, which consists of a filament supporting an anther

testis
the male organ of the reproductive system that produces sperm; plural testes

testosterone
a male hormone involved in the reproductive system

uterus
an organ in the female reproductive system; where the foetus develops

vagina
an organ that is part of the female reproductive system; a muscular tube connecting the outside of the female body to the cervix

vas deferens
the tube through which sperm travels from the epididymis to the prostate

vegetative reproduction
type of asexual reproduction where part of a plant breaks off, forming a new organism with no need for seeds or spores; similar to fragmentation

zygote
a fertilised egg

EXPERIMENTS 9

Learning and working in a laboratory

*

Working in a science laboratory requires you to use a variety of special skills. Many of these you may not use anywhere else. You must know how to identify, prepare and clean up equipment safely to prevent chemicals contaminating future experiments, or harming yourself or someone else.

Wearing lab coats and safety glasses, having hair tied back

Figure 9.1 Wearing a lab coat and safety glasses is an essential part of completing any experiment.

How to clean equipment

Figure 9.2 Place warm water in the equipment (e.g. beaker).

Figure 9.3 Add a small amount of detergent.

Figure 9.4 Use a brush or cloth to wipe around the equipment.

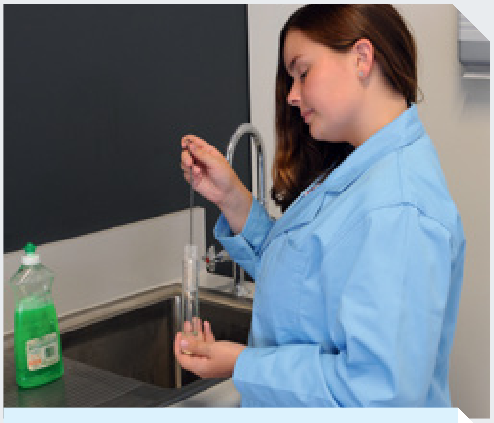


Figure 9.5 Clean test tubes using a small bottle brush.

Figure 9.6 Tip out water and rinse the equipment with fresh water to prevent contamination for the next experiment.

Figure 9.7 Place the equipment upside down to drain.

What to do with broken glass

Figure 9.8 Place the glass in a special glass bin. Alternatively, wrap the glass in newspaper and dispose of it in the normal rubbish.

DO NOT USE YOUR HANDS TO PICK UP THE GLASS!

How to clean up common spills

Figure 9.9 If it is safe, wipe the spill up with paper towel and dispose of it in the normal rubbish.

TELL YOUR TEACHER FIRST.

Figure 9.10 If it is not safe, follow your teacher's directions. Some schools have a special spill kit you can use.

Safely smelling chemicals

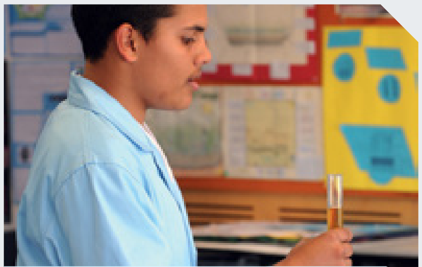


Figure 9.11 Hold the chemical slightly away from your face.

Figure 9.12 Use your hand to gently waft a small amount of air above the container towards your face.

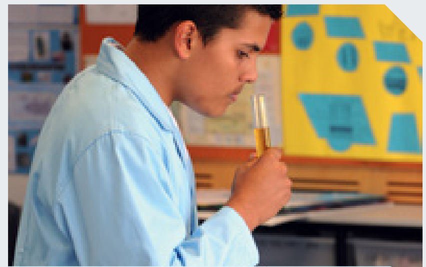


Figure 9.13 Take a small breath through your nose.

CHECK WITH YOUR TEACHER IF IT IS SAFE TO SMELL THE CHEMICAL, AND ONLY PROCEED IF IT IS.

How to light a Bunsen burner

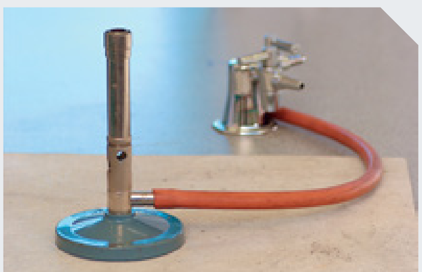


Figure 9.14 Place the Bunsen burner on a heating mat.

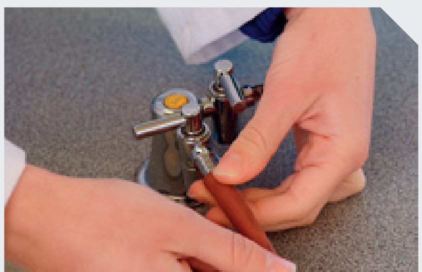


Figure 9.15 Connect the rubber hose firmly to the gas tap.

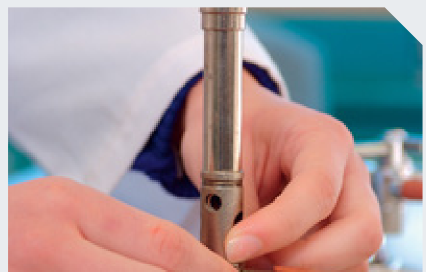


Figure 9.16 Close the air hole by turning the collar.

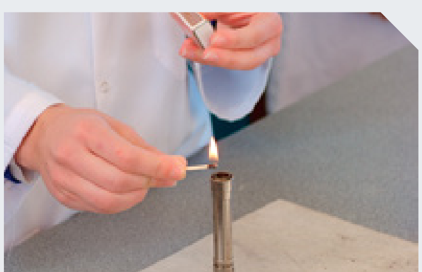


Figure 9.17 Light a match and place it above the barrel, with your hand below the flame..

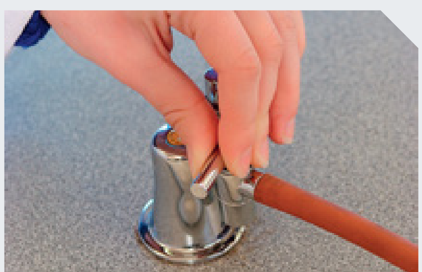


Figure 9.18 Open the gas tap fully.

Figure 9.19 The Bunsen burner will now have a yellow (safety) flame.

REMEMBER TO KEEP YOUR HAND BELOW THE FLAME.

1.4
EXPERIMENT

Aim

To determine the relationship between the distance elastic is pulled back and the distance a marshmallow moves after it is released.

Materials

- Rubber bands
- Plastic ring or pipe cleaners
- Marshmallows
- Chair

Marshmallow slingshots

Method

1. Make a chain of rubber bands by threading the end of one band through and over the end of the second band, then pulling tight.
2. Place a plastic ring in the centre of the rubber band chain.
3. Secure the rubber bands to the legs of an upside down chair as shown.
4. Insert a marshmallow into the ring.
5. Pull back the marshmallow the measured amount ensuring the elastic is horizontal to the ground.
6. Wait until everyone is out of the flight path, release the elastic bands.
7. Measure the distance the marshmallow travelled.

Inquiry: Choose one of the following questions to investigate.

- What if the elastic bands were not horizontal?
- What if the rubber bands were tied tighter?
- What if a smaller marshmallow was used?

Answer the following questions in relation to your inquiry.

- Write a hypothesis for your question.
- What (independent) variable will you change from the first method?
- What (dependent) variable will you measure/observe?
- Name three variables you will keep the same/control.
- Record your method, observations and results in your logbook.

Results

Record your results and observations in a table.

Discussion

1. What was your independent variable? What was your dependent variable?
2. What variables were difficult to control? Explain how you overcame this difficulty.
3. Was your hypothesis supported? Use evidence from your results to support your answer.

Conclusion

What is the relationship between the distance elastic is pulled back and the distance a marshmallow moves?

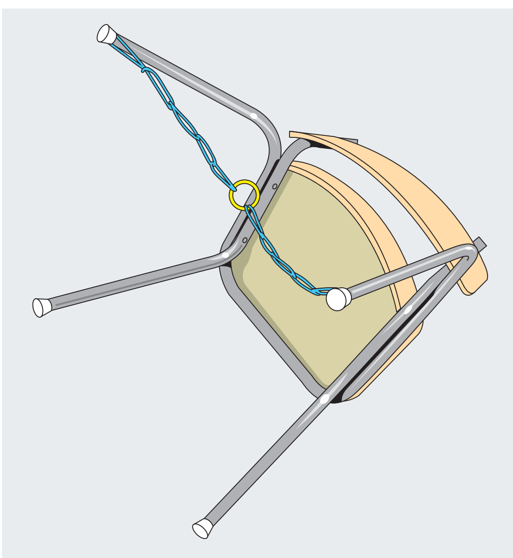


Figure 9.20 Secure the chain to the legs of a chair.

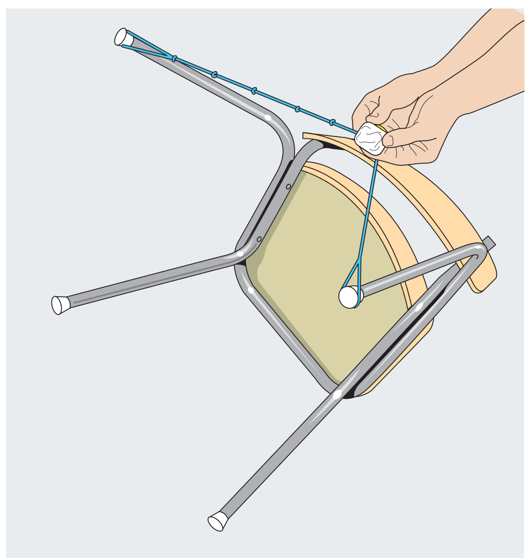


Figure 9.21 Pull back the marshmallow the measured amount.

2.1 SKILLS LAB

What you need

- Rock samples (unnamed, perhaps labelled A, B, C, D etc.)
- Hand lens
- Table 9.1

Identifying rocks

What to do

1 Examine each rock sample with the hand lens and use the key in Table 9.1 to identify it. Be aware of the following.
   - Crystals in rocks have straight edges and flat, shiny surfaces.
   - Grains are not shiny, they are jagged or rounded and more like grains of sand.
   - Coarse grains are about the size of a grain of rice, medium grains are smaller but still visible to the naked eye and small grains are only visible with a hand lens or magnifier.

2 Display your results in a table that identifies the rock sample (e.g. sample A), lists its main properties and gives its name.

Questions

1 How difficult was it to identify your rock samples?

2 Were there any samples you could not identify?

3 Compare your results with those of another group. Were there any differences between your results?

4 Ask your teacher for the names of your rock samples and see which ones you got right (hopefully all of them).

Table 9.1 Key for common types of rocks.

1	Does the rock have layers? (Use a magnifying glass to check)	Yes – Go to 3; No – Go to 2
2	Can you see cracks in the rock?	Yes – Go to 4; No – Go to 5
3	Can sand be rubbed off the rock?	Yes – **Sandstone**; No – Go to 8
4	Is the rock a light colour (i.e. mostly white)?	Yes – **Marble**; No – Go to 10
5	Does the rock look like glass?	Yes – **Obsidian**; No – Go to 6
6	Does the rock have a lot of holes that make it light to hold?	Yes – **Pumice**; No – Go to 7
7	Is the rock grey to black?	Yes – **Basalt**; No – **Limestone**
8	Can you see crystals in the rock?	Yes – **Gneiss**; No – Go to 9
9	Can you easily split the rock into thin, flat pieces?	Yes – **Slate**; No – **Shale**
10	Does the rock have a lot of holes that make it light to hold?	Yes – **Pumice**; No – **Granite**

2.2 SKILLS LAB

What you need

- 5 cm long iron nail for scratching tool
- Samples of:
  - glass microscope slide
  - disposable plastic Petri dish
  - 2 cm × 5 cm piece of copper sheet
  - half a stick of chalk

Testing the hardness of common substances

What to do

1 Scratch the objects against each other and rank them from softest to hardest. When testing the hardness, scratch only a small part of the mineral or object. A 5 cm long scratch is all that is needed.
   Which sample is the hardest?
   Which sample is the softest?

2 Collect some mineral samples. Arrange them in order of hardness. Minerals such as feldspar, quartz and calcite are listed in Table 2.2.

Questions

1 Did your results match the results of other groups? Use examples as evidence to support your answer.

2 Explain the phrase, ‘Hardness of a rock is a relative measurement’.

2.3 EXPERIMENT

Aim

To determine which brands of toothpaste, and which minerals, are most effective in removing a stain from porcelain tiles.

Materials

- 3 porcelain tiles
- Toothbrush
- Water
- Permanent marker
- Toothpaste (at least three brands)

Testing the minerals in toothpaste

Method

1 Record the list of ingredients in the toothpaste.

2 Use the permanent marker to mark a cross in the centre of each porcelain tile.

3 Put a pea-sized amount of toothpaste on the toothbrush. Brush one of the marked tiles 50 times in one direction. Try to use the same force with each stroke.

4 Record how many strokes it took to remove the mark from the tile.

5 Use the water to rinse off the toothbrush thoroughly.

6 Repeat this measurement three times.

Inquiry: What if another toothpaste, with different minerals, was used to remove a stain?

- Write a hypothesis for your question.
- What (independent) variable will you change from the first method?
- What (dependent) variable will you measure/observe?
- Name three variables you will keep the same/control.
- Use the method you followed previously to test the various toothpastes.
- Record your measurements in a table.

Results

Copy and complete Table 9.2 to show the number of strokes required to clean the tile.

Discussion

1 Why did you repeat each measurement three times?

2 Which brand of toothpaste was most effective in cleaning the mark off the tiles?

3 Many false teeth are made of porcelain. What recommendations would you make to a person with teeth of this type?

4 What role does fluoride play in toothpaste?

5 Excess fluoride ingestion causes fluorosis – a condition in which developing teeth become discoloured. Describe how young children may be vulnerable to this condition.

Conclusion

Describe the role of each of the following minerals in toothpaste.

- Fluorite
- Mica
- Sand/silica
- Sodium carbonate

Table 9.2

TOOTHPASTE BRAND	MINERALS PRESENT	NUMBER OF STROKES REQUIRED				OBSERVATIONS
		ATTEMPT 1	ATTEMPT 2	ATTEMPT 3	AVERAGE	

2.4

EXPERIMENT

Aim

To grow crystals and determine what affects their size.

Materials

- Alum solution
- Bunsen burner
- Matches
- Heatproof mat
- Tripod
- Gauze mat
- 2 Petri dishes
- Evaporating dish
- Safety glasses
- 250 mL beaker
- Tablespoon

What affects crystal size?

Method

1. Prepare a solution of alum by mixing 2½ tablespoons of alum with ½ cup of hot water. Stir until the alum is dissolved.
2. Pour roughly equal amounts of alum solution into the evaporating dish and the two Petri dishes.
3. Put one of the Petri dishes in the refrigerator.
4. Put the other Petri dish on a window sill.
5. Place the evaporating dish on the gauze mat.
6. While wearing safety glasses, gently heat the evaporating dish containing the alum solution over a yellow (safety) flame. The yellow flame is cooler and will allow for gentle boiling.
7. Continue heating the solution until nearly all the water has evaporated.
8. Observe the size of the crystals formed in the evaporating dish.
9. After 2 days, observe the size of the crystals formed in the two Petri dishes.
10. Observe the crystals formed in the refrigerator again after 4 or 5 days.

Results

Draw a labelled diagram of the crystals formed in the evaporating dish and in the two Petri dishes. Your diagram needs to show the different sizes of the crystals in the different dishes.

Discussion

1. What was the independent variable for this experiment?
2. What was the dependent variable?
3. Name three variables you needed to control.
4. Each of these crystals grew over a different time span. How does the time allowed for the crystal to form affect the size of the crystals?

Conclusion

What do you know about the factors affecting crystal size?

2.5
EXPERIMENT

Making sedimentary rocks

Aim

To make small samples of sedimentary rocks and compare them against real samples.

Materials

> Dry clay
> Dry sand
> Plaster of Paris
> Small, smooth pebbles
> Samples of sedimentary rocks
> Water
> Mortar and pestle
> Teaspoon
> Four empty matchboxes
> White tile

Method

1 Grind a lump of dry clay with a mortar and pestle until it is fine and powdery.

2 Using the teaspoon, mix the dry ingredients for each rock sample on a white tile according to the recipes in Table 9.3, but don't add the water just yet. You will need to prepare two shale samples to use in Experiment 2.6

3 Pile up your ingredients into a little hill and make a small dip in the centre for the water.

4 Slowly add the water and stir until the ingredients are uniformly mixed. Be careful not to make the mixture too wet.

5 Press your mixture into an empty matchbox, label it with the rock type and your name and leave it to dry for 2 days.

6 When your 'rock' is dry, peel off the matchbox and examine your sample. Take digital photos of your samples and photos of the 'real' rocks for comparison. Keep your two shale samples for Experiment 2.6.

Results

Include images of your rocks here, along with any statements about the process or products.

Discussion

1 In what ways were your rocks similar to real sedimentary rocks?

2 What were the differences between your samples and the real rocks?

Conclusion

What have you discovered about sedimentary rocks?

Table 9.3

ROCK	NUMBER OF TEASPOONS				
	DRY CLAY	SAND	PLASTER OF PARIS	PEBBLES	WATER
Sandstone	½	4	½	0	2
Shale	5	1/2	0	0	2
Conglomerate	½	1	½	4	2

2.6
EXPERIMENT

Aim

To make a sample of a metamorphic rock.

Materials

- 2 shale rock samples from Experiment 2.5
- Bunsen burner
- Tripod
- Pipe clay triangle
- Gauze mat
- Evaporating dish
- Tongs
- 2 × 250 mL beakers

Making a metamorphic rock

Method

1. Allow your shale samples to dry for approximately 1 week.
2. Place one of the shale samples on a pipe clay triangle on top of a gauze mat and heat strongly over a blue Bunsen burner flame for about half an hour. You could place an evaporating dish upside down over the shale to retain more heat.
3. After about 30 minutes of heating, allow the sample to cool for 10 minutes. Then, use the tongs to carefully pick up the shale sample and drop it into a beaker of water.
4. Drop the second, unheated shale sample into another beaker of water and observe what happens to the two rock samples.

Results

Record your observations in a table.

Discussion

1. What differences do you notice about the two rock samples when they are dropped into the water?
2. Can strong heat change the properties of rocks over time?
3. How different was your new metamorphic rock sample from the original shale sample? Was the method successful?

Conclusion

What do you know about the formation of metamorphic rocks?

2.7
SKILLS LAB

Modelling the rock cycle

What you need

- Crayons
- Sharpener
- 2 sheets of aluminium foil
- 2 wooden blocks
- Beaker
- Bunsen burner
- Large clamp
- Tripod
- Gauze mat
- Stirring rod
- Matches

What to do

1 Remove the paper from the crayons.
2 Shave the crayons into small piles. Keep each colour in a separate pile.
3 Cover one wooden block with aluminium foil.
4 Sprinkle a layer of crayon shavings over the aluminium foil to form the first layer.
5 Repeat step 4 for the remaining colours of crayons.
6 Cover the layers of crayons with another sheet of aluminium foil.
7 Place the second wooden block on top of the foil and press down with as much pressure as possible.
8 Remove the top block and aluminium foil and examine the compacted shavings.
9 Place the shavings between the aluminium foil and wooden blocks again.
10 Apply the large clamp around the wooden blocks and shavings. Tighten the clamp as much as possible.
11 Remove the clamp and examine the compacted crayon shavings.
12 Place the compacted crayon shavings into the beaker.
13 Heat the compacted crayon shavings over the Bunsen burner, stirring occasionally.
14 Allow the crayon mixture to cool.
15 Examine the resulting crayon sample.

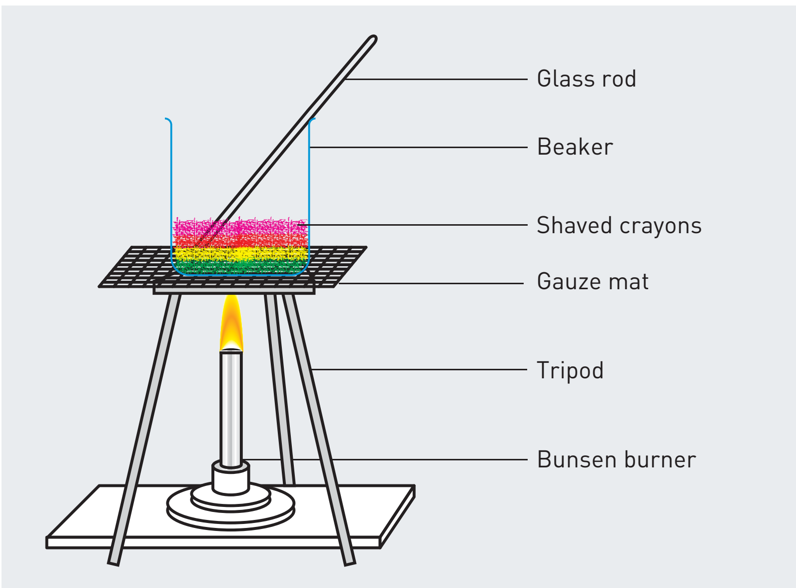


Figure 9.22 Experimental setup.

Questions

1 What type of weathering (mechanical or chemical) took place at step 2?
2 What term is used to describe the movement of the sediment pile of crayon shavings onto the aluminium foil at step 4?
3 What type of rock did you form in step 8?
4 What type of rock did you form in step 11?
5 What type of rock did you form in step 15?
6 What are the similarities and differences between the three forms of rock you created?

2.8
CHALLENGE

Preventing soil erosion

Design brief

Design a way to prevent a 5 cm layer of soil in a large foil lasagne dish from being eroded when water is poured from a watering can. The lasagne dish should be set at an angle.

Criteria restrictions

- Pebbles can be no larger than 1.5 cm in diameter.
- Sticks must be less than 5 cm long.
- Artificial materials must not be toxic to the environment.
- No more than 1 cup of material may be added.
- A maximum amount of soil must still be available for cultivation.

Questioning and predicting

- How will you prevent the soil from being washed away?
- What materials will you use?
- Where will you position the materials on the lasagne tray?
- Figure 9.23 shows the general setup of the experiment.

Processing, analysing and evaluating

1 What changes did you have to make to your design to ensure that it was stable?
2 What was the most successful feature of your design?
3 What were the limitations of your design?
4 Would it be possible to create a large-scale version of your design? Explain how your materials correlate to materials used in the large-scale version.
5 If you were doing this experiment again, explain how you would modify your design.

Communicating

Present the various stages of your investigation in a formal experimental report.

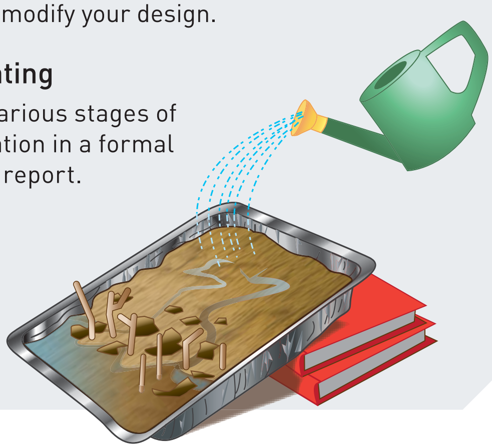


Figure 9.23 Experimental set-up.

2.9A
CHALLENGE

Using evidence to deduce

Scale and measurement

The only evidence of a dinosaur stampede is near Winton in Queensland. A large theropod, which took steps of up to 2 m in length and walked at 9 km/h, approached from the north. After six steps the animal slowed down and, at the tenth step, it turned right. The smaller tracks show that there was then a stampede by 150 smaller ornithopods and coelurosaurs.

1 How would palaeontologists know the species of the dinosaurs involved in the stampede?
2 What information would help palaeontologists work out the weight of the dinosaurs?
3 How could the palaeontologists determine how fast the dinosaurs were travelling?
4 How could the palaeontologists tell that the theropod slowed down?
5 Propose a reason for the stampede.

Figure 9.24 These footprints from near Winton, in Queensland, show a dinosaur stampede.

Reconstructing animals

What you need

> Figure 9.25 for photocopying
> Scissors
> Glue
> Tracing paper

What to do

1. Figure 9.25a shows pieces of a human skeleton, with some bones held together and some separated. Each bone is shown in front view. You'll also find a printable version in your obook. Photocopy and cut out the bones and glue them into your notebook in the shape of a person. (Enlarge the photocopy if you need to.) Then, draw the skin, leaving space for organs and muscles. Use your own body to work out the right and left arms and legs.
2. Figure 9.25b shows the bones of a frog, with some bones held together and some separated. Each bone is shown in top view. Photocopy and cut out the bones and glue them into your notebook in the shape of a frog. (Enlarge the photocopy if you need to.) Then, draw the skin, leaving space for organs and muscles. The arms and legs are the most difficult.
3. Figure 9.25c shows the broken skeleton of an extinct amphibian found as a fossil in Queensland. Each bone is shown in top view. Photocopy and cut out the bones and glue them into your notebook in the shape that you believe this animal may have had in real life. (Enlarge the photocopy if you need to.) Then, draw the skin, allowing for organs and muscles. Colour the animal and draw in some of its habitat.

Discussion

1. What assumptions have you made about the size of the human muscles in Figure 9.25a?
2. How did you decide the positions of the frog bones in Figure 9.25b? Did you refer to a picture of a modern-day frog? Is this a valid method to use?
3. What assumptions have you made about the colours of the amphibian's skin in Figure 9.25c? Explain the reasons for your choices.

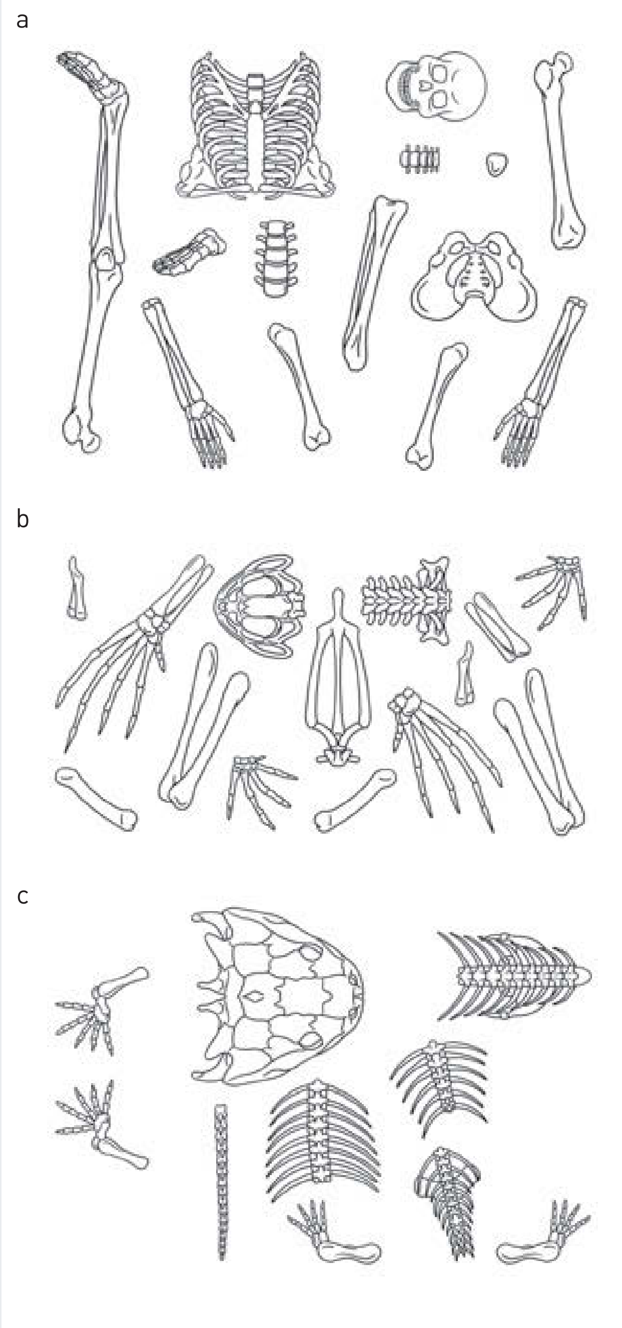


Figure 9.25 Photocopy and cut out these bones.

HINT: TRACING PAPER COULD BE USED FOR EACH 'LAYER' OF DETAIL YOU ADD.

3.1

SKILLS LAB

Draw flow diagrams of energy transfer

What you need

- Station 1: A variety of wind-up toys
- Station 2: Battery, wires, small buzzer
- Station 3: Tuning fork
- Station 4: Plastic cup, water, salt, aluminium strip, copper strip, 2 wires, multimeter
- Station 5: Plastic windmill, kettle
- Station 6: Toy car, ramp, measuring tape

What to do

Spread around the room are stations with different types of energy. Follow the steps below for each station.

STATION 1

1 Wind up the toys and watch them move.

STATION 2

1 Connect the battery to a buzzer.

STATION 3

1 Gently tap the forked end of the tuning fork on the table.

2 What do you notice happens?

STATION 4

1 Fill most of the cup with water.

2 Add 1 tablespoon of salt to the water.

3 Fold a strip of aluminium and a strip of copper over opposite sides of the cup so that one end is in the saltwater and the other end is on the outside of the cup.

4 Attach wires to the outside edges of the metal strips.

5 Connect the multimeter to the wires and check the voltage reading.

6 What energy does the multimeter read at this station?

7 Where did this energy come from?

STATION 5

1 Blow on the plastic windmill.

2 What energy makes the windmill move?

3 Where did this energy come from?

4 Hold the plastic windmill over a boiling kettle while being careful not to burn yourself with the steam.

5 Where is the energy coming from this time?

STATION 6

1 Set up the ramp so that the top end is 10 cm above the ground.

2 Place the car at the top of the ramp.

3 Allow the car to roll down the ramp and along the floor.

4 How far did the car roll?

5 Where did the energy for the car to move come from?

6 How could you increase this energy?

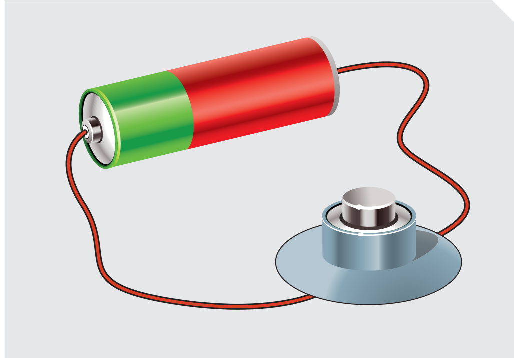
Results

Copy and complete Table 9.4 and identify the object where you first see evidence of the energy, and the object where you last see the energy.

Table 9.4

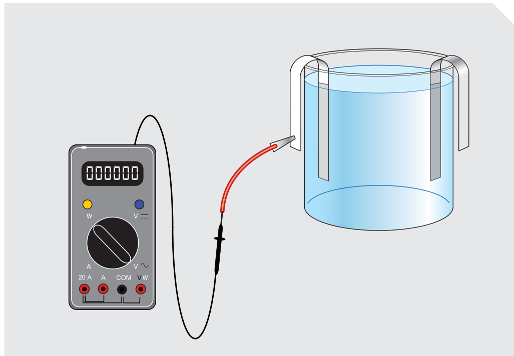
STATION	WHERE DOES THE ENERGY COME FROM?	WHICH OBJECT OR PART OF THE OBJECT HAS THE ENERGY LAST?
1		
2		
3		
4		
5		
6		

Station 1 What path does the energy take as it is transferred through the wind-up toys?



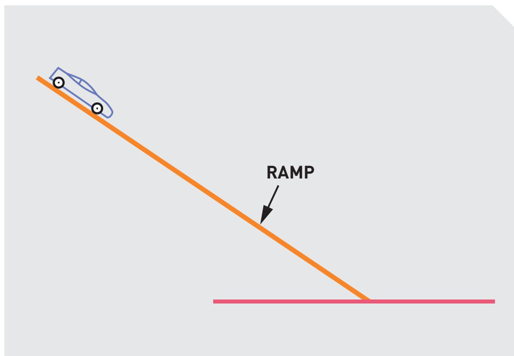
Station 2 Use wires to connect the buzzer to the battery.

Station 3 Where does the sound energy come from or transfer from?



Station 4 Connect the saltwater battery to a multimeter.

Station 5 A toy windmill acts like an electricity-generating turbine.



Station 6 What path does the energy take as the car moves down the ramp?

3.2 EXPERIMENT

Aim

To investigate how elastic potential energy can be used to power a boat.

Materials

- Waxed cardboard (milk cartons work well)
- Scissors
- Rubber band
- Butterfly pins
- Water bath or swimming pool

What if the amount of elastic potential energy was increased?

Method

1. Cut out the waxed cardboard to match the diagram in Figure 9.22.
2. Put the rubber band around the propeller and attach it to the boat using butterfly pins.
3. Wind the propeller anticlockwise (when viewed from the right side of the boat), place the boat in the water and release it.
4. Measure how far the boat travels.

Inquiry: What if more elastic potential energy was stored in the rubber band propeller?

1. Write a hypothesis for your inquiry.
2. What (independent) variable will you change from the first method?
3. What (dependent) variable will you measure/observe?
4. What variables will you need to control to ensure a fair test? How will you control them?

Results

Complete Table 9.5.

Draw a line graph showing the effect of increasing the elastic potential energy of the propeller on the distance the boat travelled.

Discussion

1. Did you collect qualitative or quantitative data for this experiment? Explain.
2. Why did you make three attempts at each propeller rotation to determine the average distance travelled?
3. What type of energy was the elastic potential energy converted to?
4. Your hands provided the energy to wind the propeller. Where did this energy come from?

Conclusion

Describe the relationship between the potential energy given to the propeller and the distance the boat moved.

Table 9.5

NUMBER OF ROTATIONS OF THE PROPELLER	DISTANCE THE BOAT TRAVELLED ATTEMPT 1	DISTANCE THE BOAT TRAVELLED ATTEMPT 2	DISTANCE THE BOAT TRAVELLED ATTEMPT 3	AVERAGE DISTANCE THE BOAT TRAVELLED
1				
2				
3				
4				
5				

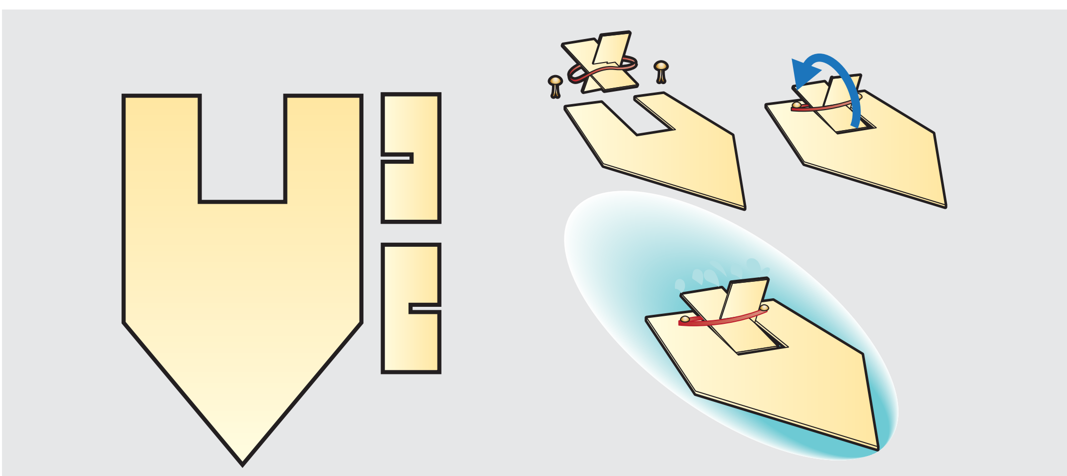


Figure 9.26 The parts and method of assembly for a rubber band boat.

3.3 CHALLENGE

Exploring sound energy

What you need

> Tuning fork
> Wooden table or wooden box
> Electric guitar
> Acoustic guitar

What to do

1 Hit a tuning fork on the sole of your shoe and then listen to the sound it makes.

2 Now repeat that process, and then hold the tuning fork so it is standing upright on a wooden table or wooden box. What difference did the table make to the loudness of the sound?

3 Do it again, but see if you can feel the table or box vibrating this time. Why do you think this may have happened?

4 If possible, compare the sound of an unplugged electric guitar to that of an acoustic guitar. Which is louder? Why do you think this is so?

5 Now place your hand on the body of the acoustic guitar as it is played. Can you feel the vibrations? What about with the electric guitar? Does this help you explain why the acoustic guitar may be louder?

Discussion

1 How do you change the way you play a recorder so that it gives out more sound energy?

2 How does a pianist manage to play some notes softly and others very loudly?

3 When you want to yell or speak louder, how do you make the sound coming from your mouth louder?

4 How do drummers make their drums sound louder?

3.4 CHALLENGE

Energy converters

Consider each device in Table 9.6, the energy it uses to work (the energy input) and the useful energy it produces (the energy output).

Table 9.6 Common devices that convert energy.

DEVICE	ENERGY INPUT	ENERGY OUTPUT
Drum		Sound
Hydroelectricity	Gravitational	
	Electrical	Sound
Light bulb		Light
Battery	Chemical	
Car engine		Kinetic
	Elastic	Kinetic
Gas heater		Heat
	Nuclear	Light
Solar panel	Solar energy	
Phone charger		Electrical

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

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

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

3.5 EXPERIMENT

Aim

To investigate the energy efficiency of a bouncing ball.

Materials

- Tennis ball
- Metre ruler
- A selection of other types of balls

What if you bounced a ball?

Method

1. Hold the tennis ball 1 metre above the ground next to the vertical ruler.
2. Drop the ball (do not throw it) on a hard surface.
3. Use the metre ruler to measure how high the ball bounces back. Be careful to avoid parallel error by ensuring your eye is parallel with the ball.
4. Determine the percentage energy efficiency by using the formula below:

Inquiry: Choose one of the following questions to investigate.

- What if another ball was bounced on the same surface? (Does it have the same efficiency?)
- What if the same ball was bounced on another surface? (Does it have the same efficiency?)

Answer the following questions in relation to your inquiry.

- Write a hypothesis for your inquiry.
- What (independent) variable will you change from the first method?
- What (dependent) variable will you measure/observe?
- Write a list of variables you will need to control to ensure a fair test. Describe how you will control each variable.

Results

1. Complete Table 9.7.
2. Draw a column graph showing how the energy efficiency of the balls changed with your independent variable.

Discussion

1. Describe the results of your experiment.
2. Did your experiment provide evidence that supported your hypothesis?
3. What type of energy did the ball have:
   - before it was dropped?
   - just before it hit the ground?
   - as it touched the ground?
4. Where did the waste energy go?
5. Draw a flow diagram of the energy transformation.
6. Draw a flow diagram of the energy transfer.
7. Describe the evidence that supported or refuted your hypothesis.

Table 9.7

INDEPENDENT VARIABLE (SURFACE/BALL)	HEIGHT OF BOUNCE			AVERAGE HEIGHT OF BOUNCE	EFFICIENCY (PERCENT)
	ATTEMPT 1	ATTEMPT 2	ATTEMPT 3		

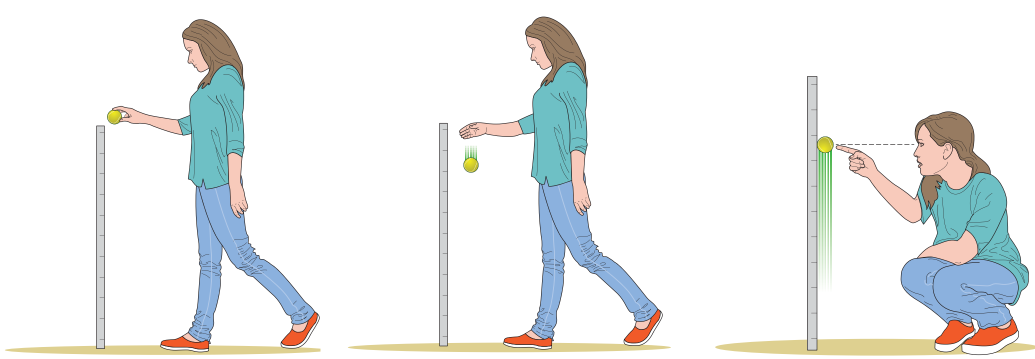


Figure 9.27 Experimental setup.

3.6
CHALLENGE

Design an energy-efficient house

Design brief

Design and build two identical houses out of cardboard or wood. Add a feature to one of the houses that will make it more efficient in staying cool. Test your design feature by exposing both houses to an energy source (a strong light) and determine the rate of temperature increase for each house.

Criteria restrictions

> Only one feature may be added to the second house.
> The feature must represent a design feature that is currently available to home owners.
> The feature must be proportionate in size to the house.

Questioning and predicting

> Which feature will you add?
> What materials will you use?
> Why do you think your added feature will keep the house cool?

Planning and conducting

> How will you measure the temperature of the two houses?
> For how long will you expose the houses to the energy source?

Processing, analysing and evaluating

1 Describe the rate of temperature increase in both houses.

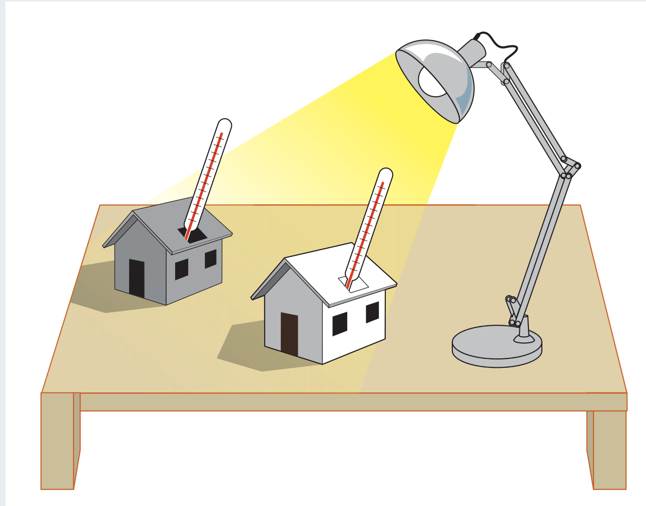


Figure 9.28 General setup of experiment.

2 How efficient was your feature at preventing the transfer of thermal energy?
3 What were the limitations of your design?
4 Would it be possible to create a large-scale version of your design for a real house?
5 If you were doing this experiment again, how would you modify your device? Explain.

Communicating

Present the various stages of your investigation in a formal experimental report.

3.7
CHALLENGE

During what time of the day does the Sun produce the most energy?

What you need

- Solar cell
- Motor with propeller
- Wires
- Sunshine
- Timer

What to do

1. Connect the solar panel to the motor using the wires.
2. Record the weather conditions.
3. Expose the solar panel to sunshine. Count how many times the propeller rotates in 1 minute.
4. Repeat this test at different times of the day, or on different days.
5. Record your data in the following table.

DATE	TIME	REVOLUTIONS OF PROPELLER/ MINUTE	WEATHER CONDITIONS

Discussion

1. At what time of day does the Sun produce the most light energy?
2. Why should you take readings over several days?
3. Why did you record the weather conditions?
4. Draw a flow diagram that shows the energy transformations for your challenge.

3.8

EXPERIMENT

Investigating structures and materials using icy pole sticks

Aim

To investigate the difference in structural capacity (how much weight it can hold) of the icy pole beam based on its orientation.

Materials

- Icy pole sticks (at least six per group)
- 2 small blocks of timber with a 1.5 mm slot cut across them to hold the 'beam'
- A bucket with a handle
- A second bucket full of water
- 100 mL measuring cylinder or jug

This experiment uses icy pole stick beams to investigate elements of structure such as the beams in buildings and bridges.

CAUTION! IT MAY BE WORTH PERFORMING THIS INVESTIGATION OUTSIDE, OR WHERE THE WATER WILL DO THE LEAST AMOUNT OF DAMAGE.

Method

1. Place an icy pole stick across the slots on the two blocks of timber to act as a 'beam' on its side.
2. Hang the empty bucket from the centre of the 'beam'.
3. Add water to the bucket, 100 mL at a time. Record how much water is needed to make the 'beam' break.
4. Draw a picture of the break in the icy pole stick.
5. Repeat this procedure twice more to determine an average breaking weight for the 'beam'.
6. Did the icy pole stick break the same way each time?

Inquiry: What if the 'beam' is placed flat?

- Write a hypothesis for your inquiry.
- What (independent) variable will you change from the first method?
- What (dependent) variable will you measure/observe?
- Write a list of variables you will need to control to ensure a fair test. Describe how you will control each variable.

Results

Draw a table to show your results.

Discussion

1. The 'beams' were both the same size. What comments can you make about the difference between the two ways the 'beams' were tested?
2. Were you surprised by the difference in how much water was needed to make the 'beams' break?
3. Which orientation do you think would be more suitable for construction? Use your investigation to justify your answer.

Conclusion

What do you know about how the structural capacity of the beam is affected by its orientation?

Leakywater Council swimming pool and waterslide

Design brief

The Leakywater Council invites suitably qualified and experienced students to construct a prototype waterslide to supplement the Leakywater Olympic Swimming Pool. The waterslide must engage children of all ages in safe play. All people who use the waterslide should have enough gravitational potential energy to transform into effective kinetic energy (and speed) at the base of the slide.

Criteria restrictions

The prototype (scale model) should comprise all parts of a successful waterslide that engages children of all ages in safe play. Your prototype tower must be built from the list of materials in Table 9.8. You must supply your own materials.

Questioning and predicting

- What features do you think a waterslide should have? How many slides should there be?
- What restrictions do you think the council would put on the design of a waterslide? (Remember that as a body loses height it loses gravitational potential energy and gains kinetic energy (i.e. it speeds up). You don't want people travelling too fast on the slide.)
- How wide does your support tower need to be?
- How high will your model tower be?

Planning and conducting

- What will your waterslide look like?
- Find examples of waterslides that show the types of designs you could use for your support structure.
- How do the examples support the slides?
- How do the examples provide access to the top of the slide?
- Keep safety in mind. You don't want someone falling out of the slide.
- How is the structure going to be held together?
- What parts of the design may be difficult to build?
- Are there ways the model could be improved before you begin building?
- What materials will you use to build your prototype? All materials have a cost. Consider the materials listed in Table 9.8 (and any others you can think of) and choose those that you would use for each component of your waterslide prototype.

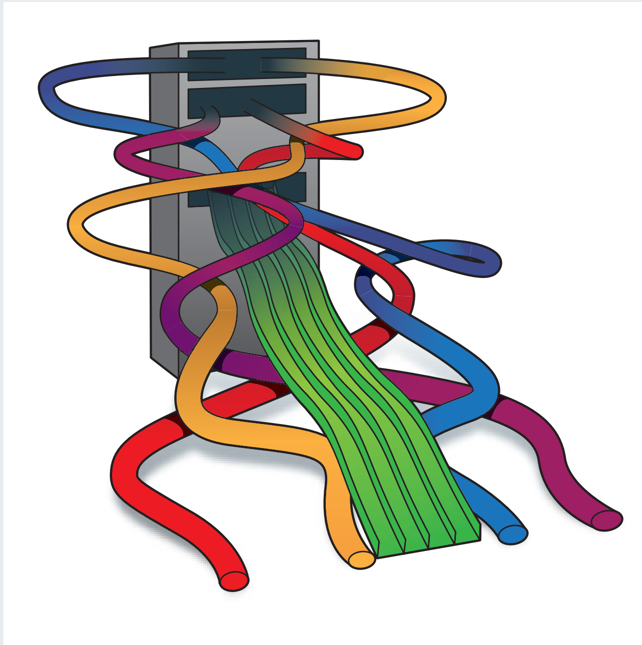


Figure 9.29 Waterslides convert gravitational potential energy to kinetic energy.

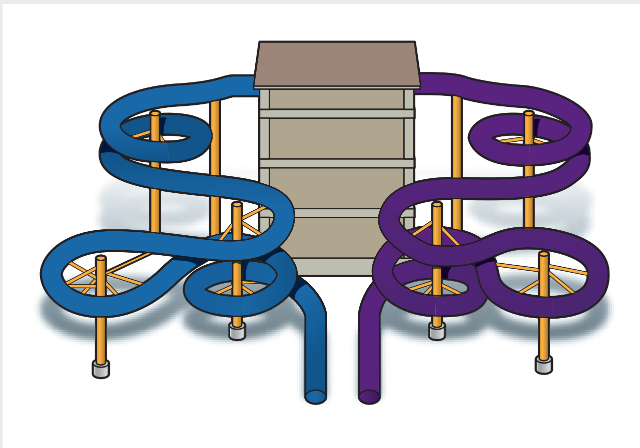


Figure 9.30 Long waterslides have more friction than short waterslides.

Table 9.8 Materials and their approximate costs.

MATERIAL	APPROXIMATE COST	MATERIAL	APPROXIMATE COST
Garden hose	$5 per metre	Pipe cleaners	$2 for 20
Toilet rolls	$0.75 each	Paper clips	$3 for 30
Icy pole sticks	$5 for 20	Cardboard box	$2 each
Toothpicks	$3 for 50	Lunch box	$6 each
Sticky tape	$2.50 per roll	PVC tube	$8 each
Blu Tack	$1 per strip	Plasticine	$4 for 250 grams
Wooden rulers	$2 each	Newspaper	$2 each
Plastic rulers	$3 each	Chopsticks	$1 each
Bubble wrap	$1 per metre	Forks	$1.50 each
Wooden rods	$1 each	Plastic wrap	$4 per roll
Ice cream containers	$4 per container	Plastic bag	$0.10 each

Processing, analysing and evaluating

1 Is the tower freestanding?
2 How much weight does the tower support? Does it need to be stronger?
3 Is there any room for improvement? What other materials could be used to improve the performance of the tower?
4 What is the cost of the prototype? How would this relate to the cost of the full size water slide?

Communicating

Present the various stages of your investigation in a formal experimental report.

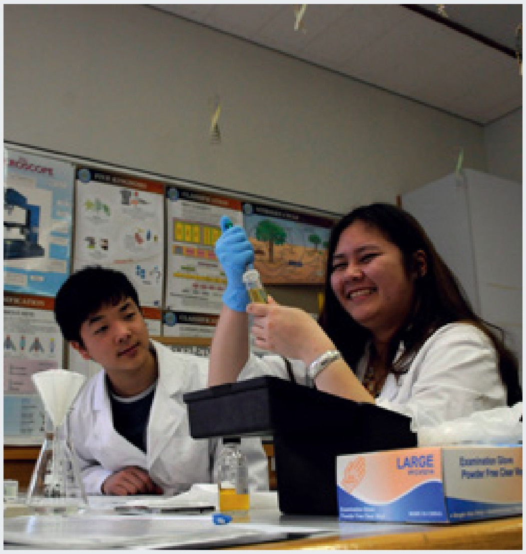


Figure 9.31 You may need to test a variety of materials to determine their suitability for your waterslide.

Figure 9.32 The amount of kinetic energy a person has at the bottom of a waterslide often indicates the success of the design.

4.1 EXPERIMENT

Comparing states of matter

Aim

To investigate the characteristics of solids, liquids and gases.

Materials

- Clamp
- 250 mL beaker
- Water
- Food colouring
- Three different-shaped containers
- Plastic syringe
- Stopper to fit syringe
- 100 mL beaker
- Electronic balance
- Balloon

Method

1. Copy Table 9.9 and complete it as you work through the method.
2. Examine the clamp and record its mass, shape, ability to be compressed and other data in the table.
3. One-third fill the 250 mL beaker with water. Add two drops of food colouring and mix carefully.
4. Pour the coloured water, in turn, into the three other containers. Record what happens to the shape of the water in each of the containers.
5. Half fill the syringe with water and invert it onto the stopper on the bench as shown in Figure 9.33. Make sure that the syringe is well sealed before compressing it. Record whether water can be compressed (i.e. made to take up less volume).
6. Set the empty 100 mL beaker on the electronic balance and press the TARE button. Pour in the water from the syringe and measure the mass of the water.
7. Draw the syringe full of air and invert the syringe onto the stopper. Compress the syringe. Record whether air is compressible and takes the shape of the syringe.
8. Record the mass of the empty balloon and then blow it up. Tie off the end and weigh the balloon again, this time with air in it. Subtract the mass of the empty balloon from that of the blown-up balloon to calculate the mass of the air inside the balloon. Record whether the air takes the shape of the balloon.

Discussion

1. Which substances had a measurable mass?
2. Did each substance take up space? Was there any variation in the shapes each substance was able to take?
3. Which states of matter took on the shape of their containers?
4. Which state of matter can be compressed into a smaller space? Describe what happened.

Results

Complete Table 9.9.

Conclusion

Write a short paragraph to describe what you know about the states of matter.

Table 9.9

MATTER	STATE OF MATTER	MASS (g)	ABLE TO TAKE SHAPE OF CONTAINER?	ABLE TO BE COMPRESSED?	OTHER CHARACTERISTICS OBSERVED
Clamp	Solid				
Water	Liquid				
Air	Gas				

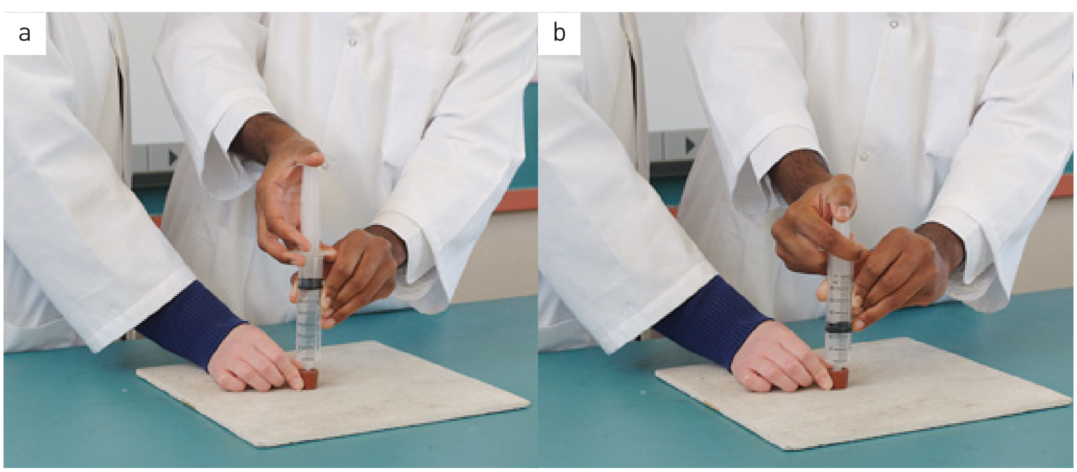


Figure 9.33 Testing the compressibility of air: (a) before and (b) after depressing the plunger on the syringe.

4.3A CHALLENGE

Modelling matter

By now you should have a good idea about how the particle model of matter describes the structure of solids, liquids and gases.

What you need

> Items such as table tennis balls, coins, lollies, marbles and pieces of modelling clay

What to do

Make a model of the three states of matter, using objects to represent the particles. Suitable items include table tennis balls, coins, lollies, marbles and pieces of modelling clay. Alternatively, you can use objects from home.

Discussion

1. How well do your particles represent the characteristics of real particles?
2. How well does your model represent the position and arrangement of real particles?
3. Can your model represent the movement of real particles?
4. How well could your model help explain the properties of real substances, such as the melting of solids?
5. Is there a better material (or different objects) that you could use to represent the particles? How would this improve the model?

4.3B CHALLENGE

Making a cuppa

You can observe diffusion in a simple experiment.

What you need

> Two large beakers
> Hot water
> Cold water
> Two tea bags

What to do

1. Fill one beaker with hot water and the other with cold water.
2. Allow the beakers to sit still for a few minutes so that the movement of the water inside them is reduced.
3. Place a tea bag into each beaker. Brown colour from the tea leaves seeps into the water and then diffuses throughout the beaker of water.
4. Compare the speed of diffusion in hot and cold water.

4.4 EXPERIMENT

Aim

To measure the density of liquid water.

Materials

- 10 mL measuring cylinder
- Electronic balance
- Water
- Calculator
- 50 mL measuring cylinder

The density den

To calculate the density of a substance, you first need to know its mass and volume. The most appropriate units for the substances you will be working with are grams (g) for mass and millilitres (mL) or cubic centimetres (cm^3) for volume. Millilitres tend to be used for the volume of liquids, whereas cubic centimetres are used for solids.

Note that 1 mL is the same as 1 cm^3. Therefore, grams per millilitre (g/mL) is the same as grams per cubic centimetre (g/cm^3).

Three density experiments are set up around the laboratory. In two experiments, you will measure density in grams per millilitre (g/mL) to make it easier to work with liquids.

STATION A

Method

1 Copy Table 9.10 and use it to record your measurements.

2 Measure the mass of the 10 mL measuring cylinder. Record its mass in grams.

3 Remove the measuring cylinder from the balance and add 6.0 mL of water to it.

4 Measure the mass of the cylinder and water. Calculate the mass of the water by subtracting the mass of the cylinder from the combined mass of the cylinder and water.

5 Calculate the density of the water and record your answer. (Don't forget the units!)

6 Repeat the experiment with the 50 mL measuring cylinder and 20 mL of water. Calculate the density of the water.

7 To obtain a third measurement of the density of water, choose one of the two measuring cylinders and any amount of water. Measure the mass of the water and its volume. Calculate the density of the water.

Results

List the three results you obtained for the density of water. Calculate an average value.

Discussion

1 The standard value for the density of water is 1.00 g/mL at 25°C. How does your average value compare with this?

2 What could have caused your results to differ from the standard value of the density of water?

3 When you calculate the density of water, does the amount of water used make any difference? Explain the reasons for your answer.

4 Why do scientists repeat experiments?

Table 9.10

	MASS OF MEASURING CYLINDER (g)	VOLUME OF WATER (mL)	MASS OF MEASURING CYLINDER AND WATER (g)	MASS OF WATER (g)	DENSITY OF WATER = MASS/VOLUME (g/mL)
10 mL measuring cylinder		6			
50 mL measuring cylinder		20			
					Average =

Aim

To measure the density of regular-shaped blocks made from different materials.

Materials

- Several blocks made from different substances (e.g. wood, polystyrene, lead, zinc)
- Ruler
- Electronic balance
- Calculator

STATION B

Method

1. Copy Table 9.11, adding a row for each additional substance, and measure and record the mass of each of the blocks.
2. Calculate the volume of each block. (An example has been done for you in Figure 9.34.)

Results

Rank the blocks in order from least dense to most dense.

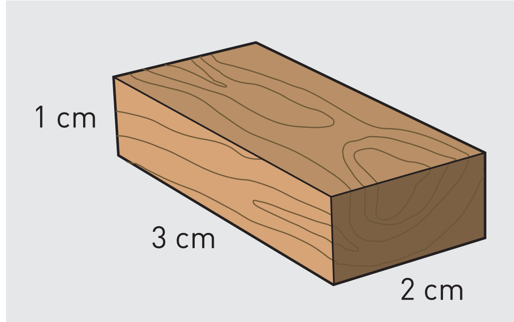


Figure 9.34 Calculating the volume of a regular-shaped block.

Table 9.11

SUBSTANCE	LENGTH (cm)	WIDTH (cm)	HEIGHT (cm)	VOLUME (cm^3)	MASS (g)	DENSITY (g/cm^3)
Wood	3	2	1	$3 \times 2 \times 1 =$ 6 cm^3	3	$3 \div 6 = 0.5$ g/cm^3

Aim

To measure the density of irregularly shaped objects.

Materials

- Four different objects (e.g. spatula, a small rock, a lump of plasticine and an object of your choice) that each fit into the measuring cylinder
- Electronic balance
- 100 mL measuring cylinder

STATION C

Method

1. Complete Table 9.12 with four blank rows.
2. Measure the mass of the first object. Record the mass, in grams, in your table.
3. Use the displacement method to work out the volume of the object. Approximately half fill the measuring cylinder. To calculate the volume of the object, subtract the volume of water in the cylinder before the object was added from the volume after the object was added.
4. Calculate the density of the object.
5. Repeat the experiment with the remaining objects.

Results

Include your table here.

Table 9.12

OBJECT	MASS (g)	VOLUME BEFORE (mL)	VOLUME AFTER (mL)	VOLUME OF OBJECT (AFTER – BEFORE, IN mL)	DENSITY (g/mL)

Discussion

1. What were some of the difficulties you had using the displacement method for calculating density?
2. What were some advantages of using the displacement method for measuring volume?
3. How does the density of water compare with those of the other objects you measured? Use the results from all the experiments to rank the objects from lowest to highest density.
4. How would our world be different if the density of water was five times as much (i.e. 5 g/mL)? How would this affect your mass, your life and the world generally?

Conclusion

What do you know about how density affects the behaviour of objects?

4.5A

EXPERIMENT

Aim

Three activities are set up to determine the effect of heat on solids, liquids and gases.

Effect of heat

CAUTION! WEAR SAFETY GLASSES AND A LAB COAT, AND TIE LONG HAIR BACK, WHEN USING A BUNSEN BURNER.

STATION 1: HEATING A SOLID

Materials

> Ball and ring apparatus
> 2 × 250 mL beakers
> Hot tap water
> Ice

Method

1 Look at your ball and ring. Try passing the ball through the ring before heating and cooling. Record your observations.
2 Half fill a 250 mL beaker with hot tap water. Place your ball in the hot water for 5 minutes. Keep the ring away from the hot water.
3 Try passing the ball through the ring. Record your observations.
4 Half fill the other beaker with cold tap water and add ice. Put the ball in the iced water and leave it for 5 minutes. Keep the ring away from the iced water.
5 Try passing the ball through the ring. Record your observations.

Results

Record your observations.

Discussion

1 What happened to change the size of the metal ball?
2 Use the kinetic theory of matter to explain what was happening to the particles in the solid when heat was applied.
3 Do objects return to their original size when they cool to their original temperature?

STATION 2: HEATING A LIQUID

Materials

> 100 mL conical flask
> Narrow glass tubing
> Rubber stopper to fit tubing
> Food colouring
> Water
> Felt-tipped pen
> Bunsen burner and heating mat
> Gauze mat
> Tripod

Safety

> Make sure the apparatus is not left unattended. The dye and water will spurt out the top of the glass tube if allowed to.
> The flask and its contents may be hot. Allow all equipment time to cool before handling it.

Method

1 Put two drops of food colouring in the flask and fill the flask right to the top with water.
2 Place the stopper fitted with the tube in the flask. Some water will rise up the tube. Using the felt-tipped pen, mark this first level on the tube.
3 Place the flask on the gauze mat on the tripod and heat gently.
4 After a few minutes of heating, turn off the Bunsen burner. Mark the level of the water in the tube again.
5 Watch what happens to the level of the water as it cools.

Results

Record your observations.

Discussion

1 Describe what happened to the water in the tube as the flask was heated.
2 What happened to the level of the water in the tube as the water cooled?
3 Use the kinetic theory of matter to explain why the liquid expanded when heated.

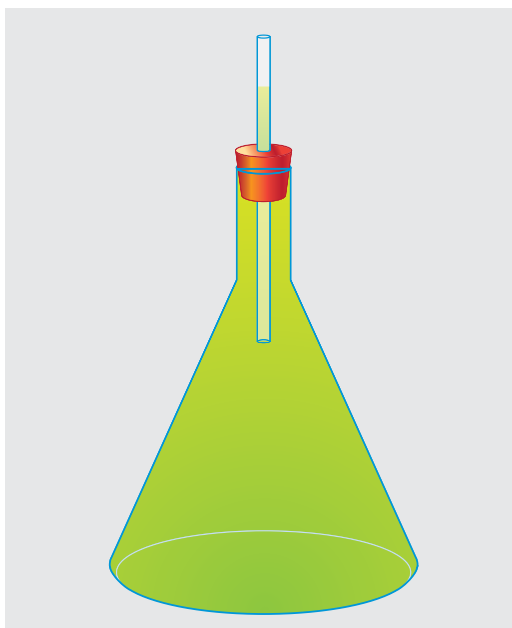


Figure 9.35 Experimental set-up to show the expansion of a liquid on heating.

Materials

- Balloon
- 100 mL conical flask
- String
- Ruler
- 250 mL beaker of hot water
- Ice bath (250 mL beaker of water and ice)

STATION 3: HEATING GASES

Method

1 Blow up the balloon to help stretch the rubber. Let the air out again until it is about the size of an apple.

2 Place the balloon over the neck of the flask.

3 Use the string and ruler to measure the circumference of the balloon at room temperature. Complete the following table and record this measurement.

TEMPERATURE	BALLOON CIRCUMFERENCE (cm)
Room temperature	
Hot water	
Ice bath	

4 Place the flask with the balloon in a beaker of hot water. Wait a few minutes.

5 Measure and record the balloon's circumference.

6 Place the flask with the balloon in an ice bath with a small amount of water. Wait a few minutes and then measure and record the balloon's circumference.

Results

Record your observations, including your table.

Discussion

1 What happened to the size of the balloon as the temperature went from cold to hot?

2 Was any air added to change the size of the balloon?

3 Use the ideas of the particle model of matter to explain how the balloon expanded and contracted with the changes in temperature.

Conclusion

What do you know about the effects of heat on solids, liquids and gases?

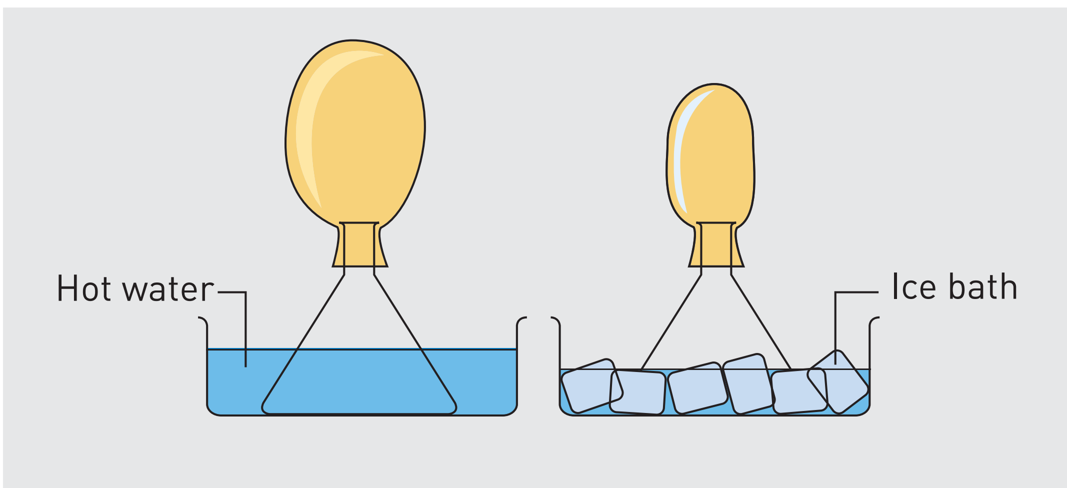


Figure 9.36 Experimental set-up to show the expansion and contraction of a gas after heating and cooling.

4.5B
EXPERIMENT

From ice to steam

Aim

To investigate the melting and boiling points of water.

Materials

- 250 mL beaker
- Crushed ice
- Water
- Tripod stand
- Bunsen burner and heating mat
- Gauze mat
- Stirring rod
- Watch or clock
- Retort stand, clamp and boss head
- Thermometer (0–110°C) or thermistor probe

Safety

- Steam and boiling water can both scald. Take great care when measuring the higher temperatures. If scalded, place the area of skin under cold running water for at least 5 minutes and show your teacher.

WEAR SAFETY GLASSES AND LAB COAT, AND TIE LONG HAIR BACK, WHEN USING A BUNSEN BURNER.

Method

1 Place some ice and water into the beaker.

2 Wait until most of the ice has melted.

3 While you are waiting, prepare a tripod stand, Bunsen burner, heating mat and other equipment so you can heat the water in the beaker. Set up a clamp to hold a thermometer or a thermistor probe that is connected to a data logger.

4 Complete the following table.

TIME (MINUTES)	TEMPERATURE (°C)
0	
1	
2	
3	
4	
5	

5 Place some crushed ice and a small amount of tap water in the beaker. Stir with the stirring rod for approximately 1 minute.

6 Measure and record the temperature of the water and ice mixture. This is the melting point of water. Record the temperature in your table at time 0.

7 Set up the equipment as shown in Figure 9.37, checking to make sure the thermometer is not touching the bottom of the beaker and that it is secure in the clamp. Do not stir with the thermometer.

8 Light the Bunsen burner and start heating the ice and water.

9 Measure and record the temperature of the mixture in the beaker every minute until the water starts to boil and produce steam. This is the boiling point of water.

10 Continue heating for another 4 minutes, unless most of the water has evaporated.

11 Using graph paper, or a suitable computer program, draw an appropriate graph with temperature on the vertical axis and time on the horizontal axis.

Results

Record your observations, including your table and graphs.

Discussion

1 a At what temperature did you measure the melting point of ice?

  b How does your measured melting point of ice compare with the standard measurement of 0°C?

2 a At what temperature did you measure the boiling point of water?

  b How does your measured boiling point of water compare with the standard measurement of 100°C?

3 Were there times when it was difficult to read the thermometer? Why?

4 Compare your results with those of the rest of the class. Suggest why there is a variation in the answers.

Conclusion

What do you know about the melting and boiling points of water?

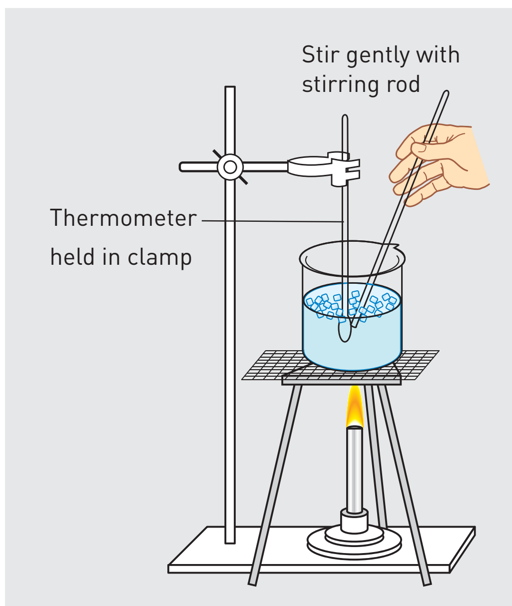


Figure 9.37 Experimental set-up for measuring the melting point of ice.

Classifying elements

What you need

- Cardboard
- Felt-tipped pens
- Scissors

What to do

1. Make up some cards like the ones shown in Figure 9.38 to represent the different elements.
2. Sort the cards into those with a one-letter symbol and those with a two-letter symbol.
   - How many elements have a one-letter symbol?
   - How many have a two-letter symbol?
   - Why is classifying elements according to their symbol a bad idea?
3. Sort the cards according to the colour of the element.
   - How many elements are silver coloured?
   - How many elements have another colour?
   - Why is classifying elements according to their colour a bad idea?
4. Sort the cards according to whether they are solids, liquids or gases.
   - How many elements are solids, liquids and gases?
   - Why is classifying elements according to their state a bad idea?

Cu **Copper** Solid brown, shiny	**Al** **Aluminium** Solid silver, shiny	**Mg** **Magnesium** Solid silver, shiny	**Cl** **Chlorine** Gas yellowish-green	**C** **Carbon** Solid black, dull	**S** **Sulfur** Solid yellow, dull
Fe **Iron** Solid grey, shiny	**P** **Phosphorus** Solid red, dull	**Pb** **Lead** Solid grey, shiny	**K** **Potassium** Solid silver, shiny	**Hg** **Mercury** Liquid silver, shiny	**O** **Oxygen** Gas colourless
H **Hydrogen** Gas colourless	**I** **Iodine** Solid grey, sparkly	**Ca** **Calcium** Solid grey, shiny	**Sn** **Tin** Solid silver, shiny	**Br** **Bromine** Liquid red-brown	**Zn** **Zinc** Solid silver, shiny

Figure 9.38 Example element cards.

Identifying the elements in the periodic table

What you need

- A copy of the periodic table
- Coloured pencils

What to do

1. On your periodic table:
   - Draw a triangle around all the elements that are liquids.
   - Draw a circle around all the gases.
   - Draw a square around all the metalloids.
   - Colour all the transition metals in blue.
2. Choose one element on the table.
   - Colour your element in green.
   - Colour the period that your element belongs to red.
   - Colour the group your element belongs to yellow.
3. Research the following information for your element:
   - name
   - symbol
   - atomic number
   - atomic mass
   - five properties of your element
   - some uses for your element
   - where your element can be found
   - who discovered your element
4. Is your element dangerous? A Material Data Sheet (MDS) is provided for every dangerous substance. It contains information about the risks involved in handling the substance. Research a MDS for your chosen element and record the following information:
   - Risks associated with your element
   - How to handle your element safely

6 C 12.01 Carbon	
6	Atomic number
C	Chemical symbol
12.01	Atomic mass
Carbon	Name of element

Group; Transition metals (groups 3–12); Non-metals (groups 13–17); Metals

Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H 1.01 Hydrogen																	2 He 4.00 Helium
2	3 Li 6.94 Lithium	4 Be 9.01 Beryllium											5 B 10.81 Boron	6 C 12.01 Carbon	7 N 14.01 Nitrogen	8 O 16.00 Oxygen	9 F 19.00 Fluorine	10 Ne 20.18 Neon
3	11 Na 22.99 Sodium	12 Mg 24.31 Magnesium											13 Al 26.98 Aluminium	14 Si 28.09 Silicon	15 P 30.97 Phosphorus	16 S 32.07 Sulfur	17 Cl 35.45 Chlorine	18 Ar 39.95 Argon
4	19 K 39.10 Potassium	20 Ca 40.08 Calcium	21 Sc 44.95 Scandium	22 Ti 47.88 Titanium	23 V 50.94 Vanadium	24 Cr 52.00 Chromium	25 Mn 54.95 Manganese	26 Fe 55.85 Iron	27 Co 58.93 Cobalt	28 Ni 58.70 Nickel	29 Cu 63.55 Copper	30 Zn 65.39 Zinc	31 Ga 69.72 Callium	32 Ge 72.61 Germanium	33 As 74.92 Arsenic	34 Se 78.96 Selenium	35 Br 79.90 Bromine	36 Kr 83.80 Krypton
5	37 Rb 85.47 Rubidium	38 Sr 87.62 Strontium	39 Y 88.91 Yttrium	40 Zr 91.22 Zirconium	41 Nb 92.91 Niobium	42 Mo 95.94 Molybdenum	43 Tc (98) Technetium	44 Ru 101.07 Ruthenium	45 Rh 102.91 Rhodium	46 Pd 106.4 Palladium	47 Ag 107.87 Silver	48 Cd 112.41 Cadmium	49 In 114.82 Indium	50 Sn 118.71 Tin	51 Sb 121.74 Antimony	52 Te 127.60 Tellurium	53 I 126.90 Iodine	54 Xe 131.29 Xenon
6	55 Cs 132.91 Cesium	56 Ba 137.33 Barium	57 to 71	72 Hf 178.49 Hafnium	73 Ta 180.95 Tantalum	74 W 183.85 Tungsten	75 Re 186.21 Rhenium	76 Os 190.23 Osmium	77 Ir 192.22 Iridium	78 Pt 195.08 Platinum	79 Au 196.97 Gold	80 Hg 200.59 Mercury	81 Ti 204.38 Thallium	82 Pb 207.2 Lead	83 Bi 208.98 Bismuth	84 Po (209) Polonium	85 At (210) Astatine	86 Rn (222) Radon
7	87 Fr (223) Francium	88 Ra 226.03 Radium	89 to 103	104 Rf (205) Rutherfordium	105 Db 105 Dubnium	106 Sg (271) Seaborgium	107 Bh (272) Bohrium	108 Hs (277) Hassium	109 Mt (276) Meitnerium	110 Ds (281) Darmstadtium	111 Rg (280) Roentgenium	112 Cn (285) Copernicium						

Atomic masses in parentheses are from the most stable of common isotopes.

Rare earth elements Lanthanoid series														
57 La 138.91 Lanthanum	58 Ce 140.12 Cerium	59 Pr 140.91 Praseodymium	60 Nd 144.24 Neodymium	61 Pm (145) Promethium	62 Sm 150.4 Samarium	63 Eu 151.97 Europium	64 Gd 157.25 Gadolinium	65 Tb 158.93 Terbium	66 Dy 162.50 Dysprosium	67 Ho 164.93 Holmium	68 Er 167.26 Erbium	69 Tm 168.93 Thulium	70 Yb 173.04 Ytterbium	71 Lu 174.97 Lutetium

Actinoid series														
89 Ac 227.03 Actinium	90 Th 232.04 Thorium	91 Pa 231.04 Protactinium	92 U 238.03 Uranium	93 Np 237.05 Neptunium	94 Pu (244) Plutonium	95 Am (243) Americium	96 Cm (247) Curium	97 Bk (247) Berkelium	98 Cf (251) Californium	99 Es (252) Einsteinium	100 Fm (257) Fermium	101 Md (258) Mendelevium	102 No (259) Nobelium	103 Lr (260) Lawrencium

4.6 EXPERIMENT

Properties of the elements

Aim

To observe the differences between different elements of the periodic table.

Materials

- Steel wool
- Aluminium
- Copper
- Magnesium
- Graphite/lead pencil
- Zinc
- Iron nail (non-galvanised)
- Forceps
- Battery
- 3 wires
- Lamp
- 0.5 M hydrochloric acid
- Distilled water
- 6 test tubes
- Test tube holder

Method

1. Use the steel wool to rub a small section of your material. Record the colour and appearance in Table 9.13. Is it shiny or dull?
2. Use the forceps to try to bend each substance. Is it malleable (able to bend)? Is it brittle (breaks when bent)?
3. Set up a circuit with the battery, lamp and wires as shown below. Connect the two loose wires to the material. Does the light glow? Does your material conduct electricity?

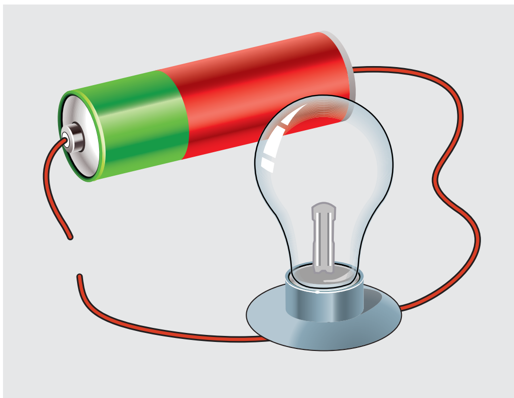


Figure 9.39 This incomplete circuit can measure the conductivity of objects.

4. Replace your sample into the test tube and add 3 cm of hydrochloric acid to the test tube. Do you see any immediate reaction? If possible, leave it overnight to see if there is any change.
5. Repeat your tests with all of your samples and record your observations in the table.

Results

Record your results in Table 9.13.

Discussion

1. What similarities do you observe between the elements you tested?
2. Can you divide all the materials into two groups? What properties do you use to separate the materials?
3. If you discovered a new material that was shiny and that bent when you dropped it, which groups would you put it in? Explain. What other properties might you expect it to have?

Conclusion

Describe what you know about the physical and chemical properties of these materials.

Table 9.13

ELEMENT	IS IT SHINY/DULL	IS IT MALLEABLE/ BRITTLE?	DOES IT CONDUCT ELECTRICITY?	DOES IT REACT WITH ACID?

4.7 EXPERIMENT

Decomposing copper carbonate

Aim

To decompose (break into smaller parts) copper carbonate.

Materials

- Plastic beaker
- Test tube or crucible
- Electronic balance
- Spatula
- Copper carbonate
- Bunsen burner and heating mat
- Tripod stand
- Matches
- Wooden tongs
- Paper towel

Safety

WEAR SAFETY GLASSES AND LAB COAT, AND TIE LONG HAIR BACK, WHEN USING A BUNSEN BURNER.

- Use a yellow (cooler) safety flame for this experiment.
- Hold the test tube or crucible securely with the tongs and always point it away from yourself and others.
- Never place hot objects on the balance.

Method

1. Place a plastic beaker containing the test tube on the balance. Tare the balance so it reads zero.
2. Using a spatula, add approximately 3 grams of copper carbonate into the test tube. Record the mass in grams (this is W1).
3. Set the Bunsen burner up on the heating mat. Light the flame, ensuring the hole is closed and a yellow (safety) flame is burning.
4. Using the wooden tongs to hold the top of the test tube, gently wave the base of the test tube over the flame twice. Record any changes. Continue to do this for 2 minutes, recording any changes. Be very careful to point the open end of the test tube away from others and yourself.
5. Allow the test tube and copper carbonate to cool. Wipe any black powder from the outside of the tube off with paper towel.
6. Place the test tube in the original plastic beaker. Reweigh the test tube and beaker and record the mass in grams (this is W2). Note any change in weight.

Results

Record your results in Table 9.14.

Discussion

1. What happened to the copper carbonate? Consider the colour and any change in mass.
2. What evidence is there that copper carbonate is a compound and not an element?
3. What are the possible sources of error in this experiment?

Conclusion

What happens when copper carbonate decomposes?

Table 9.14

WEIGHT OF COPPER CARBONATE BEFORE HEATING (W1) (g)	WEIGHT OF COPPER CARBONATE AFTER HEATING (W2) (g)	DIFFERENCE W1 – W2 (g)

5.1 EXPERIMENT

Melting chocolate

Aim

To examine the physical change in melting chocolate

Materials

- Milk, dark and white cooking chocolate buttons (approximately ten of each)
- 3 × 100 mL beakers
- Thermometer
- 250 mL beaker (as a water bath)
- Stirring rod
- Bunsen burner and heating mat or hotplate
- Timer

Method

1. Place four to six buttons of milk cooking chocolate in a beaker.
2. Place a thermometer in the beaker.
3. Place the beaker in a hot water bath (or boiling water in a beaker) and heat it to 60°C. Do not stir the chocolate.
4. Time how long it takes to melt. Record your observations.

Inquiry: What if another type of chocolate was melted? Would it melt faster or slower than milk chocolate?

- Write a hypothesis for your question.
- What (independent) variable will you change from the first method?
- How will you determine when the chocolate has melted?
- Name three variables you will keep the same/control.
- Record your observations and measurements in a table.

Results

1. Record your observations, including any diagrams and photographs.
2. Draw a column graph of the time it took for each type of chocolate to melt.

Figure 9.40 Placing the small beaker of chocolate buttons in a beaker of boiling water causes the chocolate to melt.

Discussion

1. Was there any difference in the time it took for each type of chocolate to melt?
2. Did all three types of chocolate melt in the same pattern? (Inside first or outside edges first?)
3. How could a chef apply your observations in the kitchen?
4. Did you burn any of the types of chocolate?
5. Did a new substance form? How can you tell?

Conclusion

What similarities and differences are there between milk, dark and white chocolate?

5.1 CHALLENGE

Exploring physical changes

What you need

- Aluminium drink can
- Elastic/rubber band
- Rock salt
- Ice
- Sugar cube
- Vitamin C tablet
- Slice of bread
- Piece of cloth
- Scissors

What to do

1. For each of the materials provided, find ways to change its physical appearance.
2. Record the method you used and your observations in Table 9.15.

Discussion

1. List three different ways in which a physical change can take place.
2. What did each change have in common?

Table 9.15

MATERIAL	METHOD USED	HAS THE SUBSTANCE CHANGED?	CAN THE CHANGE BE REVERSED/ UNDONE?

5.2 CHALLENGE

Making caramel

What you need

- Sugar
- Test tube
- Test tube holder
- Bunsen burner and heating mat

What to do

1. Place a pea-sized amount of ordinary sugar into a dry test tube.
2. Wearing safety glasses and, with the test tube facing away from you and everyone else, gently heat the sugar by passing it through the top part of a blue flame.
3. If you are careful, the sugar grains will crumble (they lose water in a chemical reaction) and turn into a brown syrup. This brown syrup is caramel. You may see condensation on the inside of the test tube as the water is driven out of the sugar.
4. If you continue heating, or heat too strongly, you will burn the sugar. Charcoal residue is left behind. This is another chemical change.

Figure 9.41 Heated sugar undergoes a chemical change.

5.2
EXPERIMENT

Aim

To observe the reactants and products in chemical reactions.

Materials

- Spatula
- Copper carbonate (solid)
- Bunsen burner and heating mat
- Matches
- Two test tubes and test tube holder
- Baking soda (sodium bicarbonate)
- 5 mL of 1 M hydrochloric acid
- Thermometer
- Wooden splint
- Magnesium ribbon (1 cm length)
- ~0.5 M copper sulfate solution
- 100 mL beaker
- Tongs
- Piece of steel wool, about thumb size when rolled up

Observing chemical reactions

Method

PART A

1 Place a large spatula of copper carbonate in a test tube.
2 Set up the Bunsen burner.
3 Using a test tube holder, gently heat the test tube by passing it over the flame twice. Make sure the test tube is facing away from you and everyone else. Observe any changes and repeat until the powder changes colour.
4 Collect the waste powder in a beaker for disposal.

PART B

1 Place the baking soda in a test tube to a depth of 0.5 cm.
2 Add an equal amount of 1 M hydrochloric acid to the test tube and observe.
3 Conduct a carbon dioxide test by holding a burning wood splint above the tube. If the flame goes out, carbon dioxide is present as one of the products of the chemical reaction.

PART C

1 Pour 5 mL of hydrochloric acid into the bottom of a test tube. Measure its temperature with the thermometer.
2 Add the magnesium ribbon to the test tube. Measure its temperature again.
3 Observe what happens using sight, touch (the outside of the tube only!) and sound.

PART D

1 Pour approximately 30 mL of the copper sulfate solution into a 100 mL beaker.
2 Use the tongs to place the steel wool into the copper sulfate solution.
3 Carefully observe the changes that occur to both the steel wool and the copper sulfate solution.
4 Collect the copper sulfate/steel wool solution in a beaker for safe disposal.

Figure 9.42 When heating a test tube, be sure to point it away from you or anyone else close by.

Results

Include your observations here.

Discussion

1 What happened to the copper carbonate when it was heated?
2 Did it change when taken away from the heat?
3 Is this similar to the melting chocolate experiment? Why or why not?
4 What is produced in the baking soda and acid experiment?
5 Why does the flame on the burning splint go out if carbon dioxide is present?
6 What happened to the magnesium metal?

Conclusion

What did you observe about the reactants and products of chemical reactions?

5.3 EXPERIMENT

Comparing reactants and products

Aim

To examine the physical and chemical properties of reactants and products.

Materials

- Piece of magnesium ribbon (1 cm)
- One pea-sized sample of magnesium oxide powder
- 20 mL of 1 M hydrochloric acid
- Two test tubes and test tube rack

Method

1. Examine each sample by looking and carefully moving the sample in the bottom of a test tube. Record your observations in your table.
2. Add 10 mL of 1 M hydrochloric acid into each test tube in the test tube rack.
3. Observe any reactions. Record your observations in Table 9.16.

Results

Write a short statement describing each sample and how it reacted with acid.

Table 9.16

SUBSTANCE	COLOUR	STATE	SHINY/DULL	REACTION WITH ACID
Magnesium				
Magnesium oxide				

Discussion

1. Do magnesium and magnesium oxide have the same physical properties?
2. Do magnesium and magnesium oxide have the same chemical properties?

Conclusion

What do you know about the physical and chemical properties of reactants and products?

5.4A
EXPERIMENT

Aim

To observe how particle size affects the rate of a reaction.

Materials

- Dried eggshells
- Mortar and pestle
- Electronic balance
- Pieces of filter paper
- Two small beakers
- 10 mL graduated cylinder
- Dilute hydrochloric acid (1 M HCl)
- Stirring rod
- Stopwatch

CAUTION! SOME STUDENTS MAY HAVE EGG ALLERGIES.

Effect of particle size on reaction rates

Method

1. Place a piece of filter paper on the electronic balance and then place a quarter of an eggshell onto the filter paper. Measure and record the combined mass. Remove the filter paper and record the mass of the egg shell.
2. Place the eggshell into a beaker and add 5.0 mL of hydrochloric acid. Record the time.
3. Stir the eggshell and the acid occasionally.
4. Time how long it takes for the reaction to stop.
5. When the reaction stops, filter the remaining solution using the original filter paper.
6. Allow the filter paper to dry overnight and measure the mass.
7. Now grind a quarter of the eggshell into very small pieces using the mortar and pestle.

Figure 9.43 Weighing the eggshells allows you to calculate the mass lost in the reaction.

Figure 9.44 Grinding the eggshells creates smaller particles.

8. Place another piece of filter paper onto the electronic balance and then place the ground-up eggshell onto the filter paper. Measure and record the combined mass. Remove the filter paper and record the mass of the ground-up eggshell.
9. Place the ground-up eggshell into a small beaker and add 5.0 mL of 1 M HCl. Record the time.
10. Stir the eggshell and the acid occasionally.
11. Time how long it takes for the reaction to stop.
12. When the reactions stops, filter the remaining solution using the original filter paper.
13. Allow the filter paper to dry overnight and measure the mass.
14. Calculate the mass lost in the first reaction by subtracting the mass of the filter paper after the reaction from the combined starting mass.
15. Calculate the percentage of calcium carbonate in the quarter of the eggshell using the formula below.

$$\frac{\text{Mass lost in the first reaction}}{\text{Starting mass of egg shell in the first reaction}} \times \frac{100}{1}$$

16. Repeat these calculations for the ground-up eggshell.

Results

Draw an appropriate table for your results.

Discussion

1. Which eggshell dissolved faster?
2. How many times faster was the rate of the reaction for the ground-up eggshell than for the large piece of eggshell?
3. Why do small pieces react faster than one large piece?
4. Why is stirring necessary?
5. Did grinding up the eggshell change the amount of calcium carbonate in it?

Conclusion

What do you know about how particle size affects reaction rate?

5.4B EXPERIMENT

Aim

To investigate the effect of enzymes on breaking down hydrogen peroxide.

Materials

- 1 packet of dried yeast
- 200 mL beaker
- 10 mL hydrogen peroxide (3%)
- 1 splint
- Matches

Speeding up reactions with enzymes

Hydrogen peroxide breaks down into oxygen and water slowly over time. Yeast has a catalyst that speeds up this reaction.

Method

1. Add the yeast into the beaker.
2. Add 10 mL of the hydrogen peroxide into the beaker.
3. Light the splint and then blow it out. Place the glowing splint in the top half of the beaker.
4. Record your observations.

Results

Record your observations in a table.

Discussion

1. Was the breakdown of hydrogen peroxide into oxygen and water noticeable before the yeast was added?
2. What happened to the rate of hydrogen peroxide breakdown when the yeast was added?
3. What effect did the gas produced have on the glowing splint?
4. What gas would cause this reaction?

Conclusion

What do you know about how enzymes affect the rate of a reaction?

5.5 EXPERIMENT

Aim

To improve the manufacture of casein glue.

Materials

- Full cream milk (70 mL for each group of students)
- 250 mL beaker
- Bunsen burner and heating mat
- Tripod stand and gauze mat
- Matches
- Thermometer
- Heatproof glove
- Vinegar (20 mL)
- Stirring rod
- Sieve
- Disposable cleaning cloth
- Ammonia solution (2 drops) (teacher use only)
- Icy pole sticks (for gluing together)

Making casein glue

Casein is a protein in milk. It can be extracted from milk and chemically changed so it has the properties of a glue.

Method

1. Pour 70 mL of milk into the 250 mL beaker.
2. Set up your Bunsen burner and heat the milk to ***no more than 50°C***. Remove the milk from the heat using a heatproof glove.
3. Slowly add 20 mL of vinegar to the milk, with gentle stirring. Do not stir vigorously as you will break up the curd (lumpy bits) being formed. The curd should clump as much as possible.
4. Set up the sieve over the sink or a large beaker. Put a piece of disposable cloth over the sieve.
5. Gently pour the mixture through the cloth and sieve to filter the whey (liquid) from the curds (lumps of mainly protein). Once it has stopped dripping, very gently squeeze the cloth to remove any excess liquid.
6. Return the solids to the original 250 mL beaker and carry it to the fume cupboard for your teacher to add two drops of ammonia.
7. While your sample is in the fume cupboard, stir it well.
8. Take your sample and two icy pole sticks to your bench.
9. Spread your sample between the sticks and press them together. Leave them overnight and then test how well your glue has worked.

Inquiry: Choose one of the questions below to investigate.

- What if skim milk was used?
- What if soy milk was used?
- What if more vinegar was used?
- What if more ammonia was added?

Answer the following questions in relation to your inquiry.

- Write a hypothesis for your question.
- What (independent) variable will you change from the first method?
- How will you determine which glue is stronger?
- Name three variables you will keep the same/control.

Results

Record your observations and measurements in a table.

Discussion

1. Why is it important to wear safety glasses in this experiment?
2. What are the reactants used in this experiment? What are the products?
3. How could you compare the strength of different glues?
4. How do you think someone worked out that you could make glue from milk?

Conclusion

What do you know about making glue?

6.1 SKILLS LAB

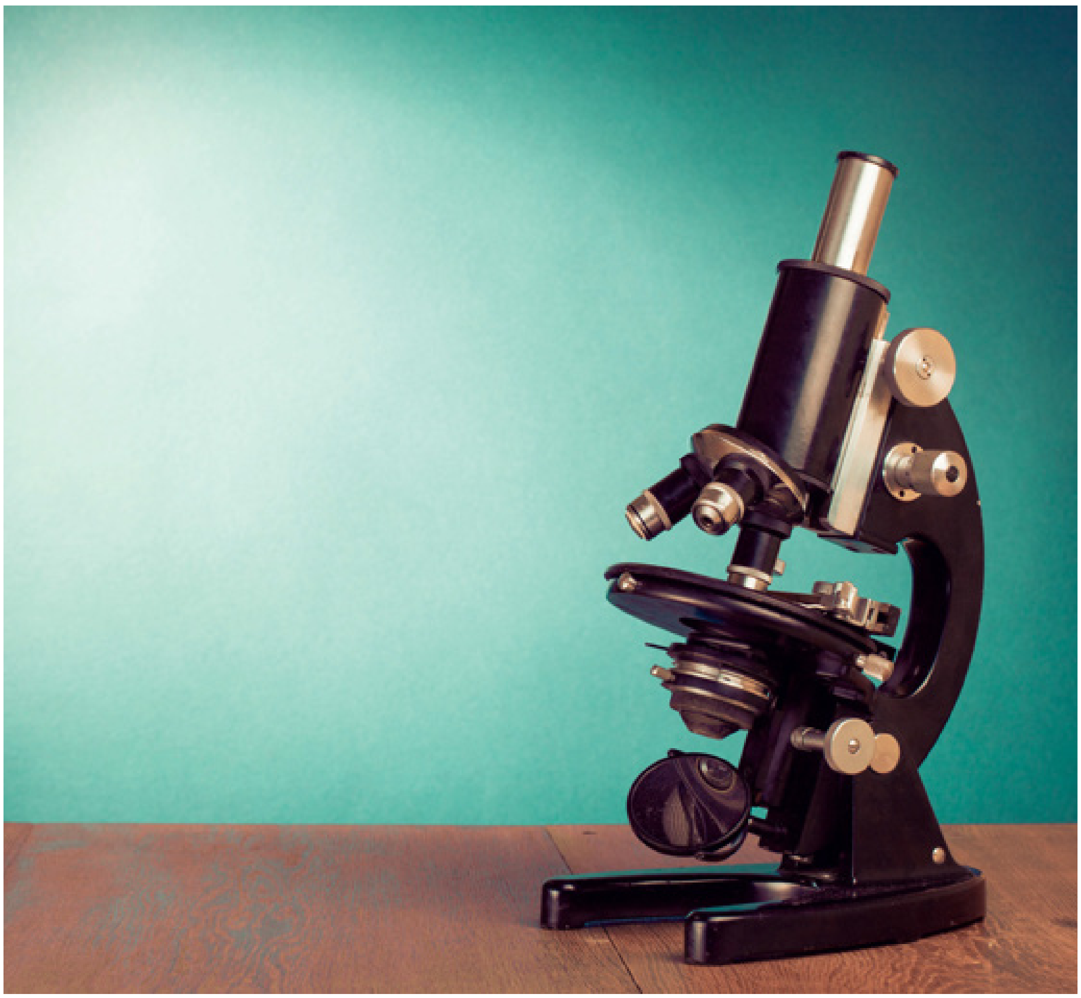
Drawing cells

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

DO NOT ATTEMPT TO ADJUST ANY OF THE MICROSCOPES! ASK YOUR TEACHER OR LABORATORY TECHNICIAN TO ADJUST THE MICROSCOPE IF YOU THINK IT HAS BEEN BUMPED OR HAS GONE OUT OF FOCUS.

What to do

1. Look carefully at each specimen. Write down its name and a sentence that describes what you see.
2. Make a very simple pencil sketch of a single cell that you can see. Draw the outside edge of the cell first, including any bump or unusual shape you notice.
3. Draw two more cells that are close to your original cell. (Do not attempt to draw every cell that you see.)
4. If you can see anything inside the cells (it may only be a dark dot), mark this on your sketch.
5. Label any parts that you can identify.
   > Which cells, in your opinion, were the most unusual?
   > Which cells had very obvious walls around them?
   > Which cells were the smallest?
   > Which cells were the largest?
   > How did your view through the microscope compare with the images of the cells in Figure 6.17?
   > Describe some of the difficulties of drawing cells seen through a microscope.



6.2

SKILLS LAB

Getting to know your microscope

What you need

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

Figure 9.45 Use scissors to cut out words from the newspaper.

Figure 9.46 Gently lower the glass coverslip down until it is flat.

What to do

1. Always use two hands to carry a microscope – one hand should be around the main part of the instrument and the other underneath it.
2. Some microscopes have a built-in lamp. Others have separate lamps that need to be set up so they shine onto the mirror. Adjust the mirror to project the light through the stage onto the specimen. Do not allow sunlight to shine directly up the column.
3. Place the slide on the stage then select the objective lens with the lowest magnification first.
4. Cut out two small words from a piece of newspaper.
5. Place the cut-out newspaper on the microscope slide and add two drops of water to help it 'stick' to the slide. Place a coverslip on top. This is called a wet mount.
6. Look from the side and adjust the coarse focus knob so that the objective lens is *just above – and not touching* – the slide. Check which way you must turn the knob to move the objective lens away from the slide.
7. Use the coarse focus knob to bring the specimen into view. Find one letter from the newsprint to focus on.
8. Move the slide slightly towards your body and observe what happens.
9. Move the slide slightly to the left and observe what happens.
10. Increase the magnification by rotating the objective lens to a higher magnification.
11. Draw a diagram of the newspaper letter (as a record) using a sharp lead pencil. Never colour or shade areas; if absolutely necessary, use dots or lines instead.
12. Work out the total magnification.
13. Write the magnification next to your sketch.
14. Label and date the sketch.
15. Take the newspaper out and prepare another slide using the tissue paper. Make sure a drop of water is added and the coverslip is placed over the top carefully.
16. Sketch what you see.
17. Repeat with sticky tape and then a hair from your head.

Figure 9.47 Carefully adjust the focus of the microscope.

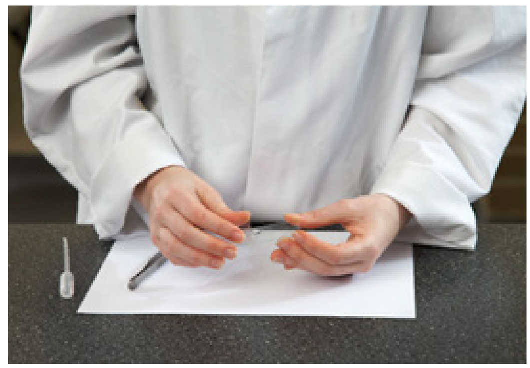


Figure 9.48 Examine a hair under the microscope.

Questions

1. Describe what the newspaper letter looks like through the microscope. What does this mean for all things you see through this type of microscope?
2. What features could you see on the tissue paper and sticky tape that you could not see with the naked eye?
3. Use a series of cause-and-effect graphic organisers, similar to that shown in Table 9.17, to record the results of your experiment when you moved the slide different ways. For example, the cause link may be 'move the slide to the left'. Then write what happened in the effect link.

Table 9.17 Cause-and-effect graphic organiser.

CAUSE	→	EFFECT
What did you do to cause the change you observed?		What effect did it have?

Comparing the size of cells and their parts

What you need

> Sheet of poster paper
> Pencil
> 30 cm ruler
> Eraser

What to do

PART A

1 Using a scale of 1 cm : 1 μm, draw a series of circles to represent the average size of various cells and microbes according to the measurements given in Table 9.18.

Table 9.18 Average diameters of different cell types.

CELL TYPE	AVERAGE DIAMETER (μm)
Human cheek cell	30
Human red blood cell	7
Human white blood cell	25
Epidermal plant cell	50
Staphylococcus bacterium (spherical)	1
Escherichia coli bacterium (rod shaped)	3

2 Rank the cells and microbes from smallest to largest.

PART B

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

1 Use the measurements given in Table 9.19 to add a chloroplast and a mitochondrion (singular) to your set of diagrams.

Table 9.19 Size of cell organelles.

CELL ORGANELLE	AVERAGE SIZE (μm)
Chloroplast	5 μm long × 1.5 μm wide
Mitochondrion	2 μm long × 1 μm wide

2 Which of the cell organelles in Table 9.19 are not visible under the light microscope?

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

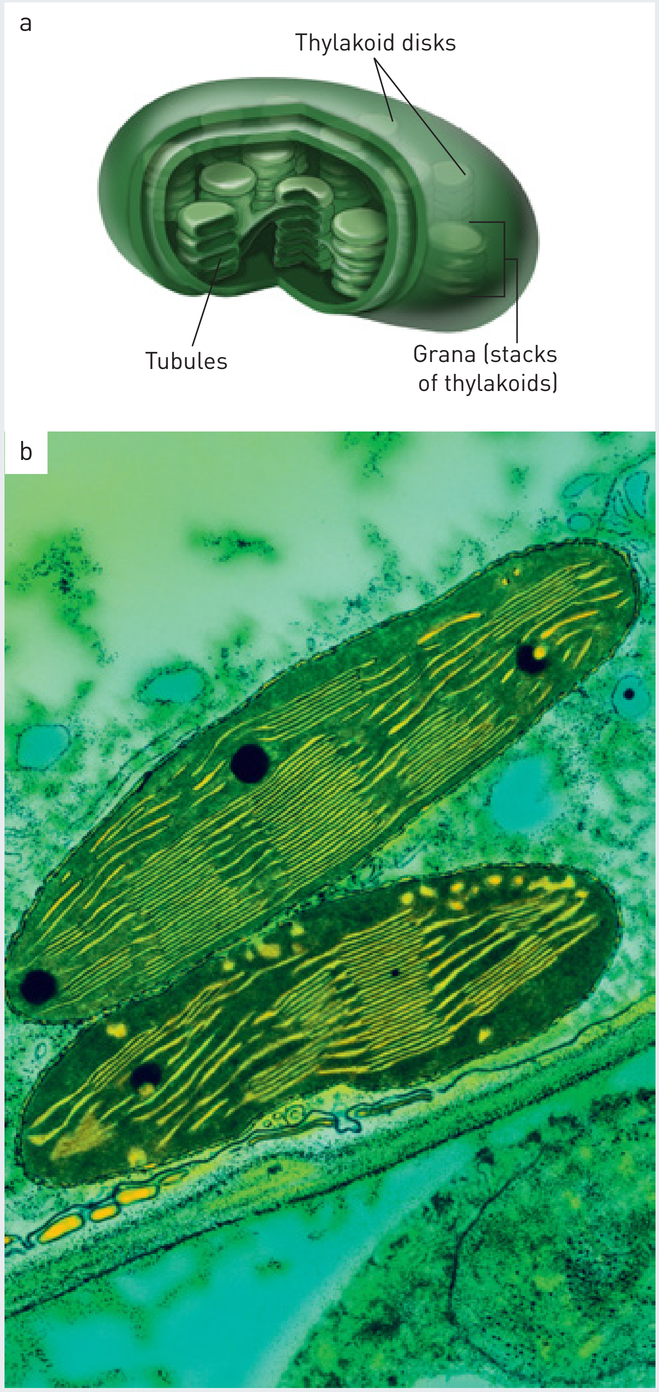


Figure 9.49 (a) Schematic diagram showing the structure of a chloroplast. (b) Electron micrograph of a chloroplast.

6.3A

EXPERIMENT

Looking at organelles

Aim

To prepare slides to view the organelles in the cells of a brown onion and an *Elodea canadensis* plant. You may wish to review Skills lab 6.2 for slide and microscope use.

Materials

- Onion wedge
- Three glass slides
- Three glass coverslips
- Water
- Light microscope
- Methylene blue stain or iodine
- Leaf from an *Elodea canadensis* plant
- Blotting paper

Method

ONION SKIN CELLS – UNSTAINED

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

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

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

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

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

ONION SKIN CELLS – STAINED

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

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

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

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

ELODEA CANADENSIS CELLS

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

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

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

Figure 9.50 Add a drop of water to the slide then add a coverslip.

11 What other organelle is clearly visible in these cells?

Results

Include your labelled diagrams in this section.

Discussion

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

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

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

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

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

Conclusion

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

6.3B EXPERIMENT

Measuring cells

Aim

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

Materials

- Onion cell slide (prepared in Experiment 6.3a)
- Light microscope
- Mini-grid slide or 1 mm graph paper photocopied onto a transparency
- Other various prepared slides, such as human blood, nerve cells, leaf epidermis

Method

1. Focus the onion cells under the light microscope.
2. Once in focus, estimate the average length and width of one cell in relation to the field of view.
3. Gently remove the slide and insert the slide containing the mini-grid.
4. Each box is 1 mm in length. Determine the length of the field of view by counting how many boxes fit across the light field.
5. Use this measurement to calculate the average length of one onion cell by estimating how many cells fit across the light field.
6. Repeat this process for each of the other prepared slides.

Results

Rank the cells viewed in size from smallest to largest.

Discussion

Does your ranking match Table 9.18 from Challenge 6.3?

Conclusion

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

6.4 CHALLENGE

Classifying using cells

What you need

- Light microscope
- Four pre-prepared cells labelled A–D, supplied by your teacher (these may include leaf epidermal cells, yeast cells, protea cells or animal cells)

What to do

1. Look at each slide under the microscope.
2. Using Table 9.18 to help you, classify each slide into one of the five kingdoms.
3. Use a table like the one below to present your results.

SLIDE	AVERAGE DIAMETER (μm)	KINGDOM
A	30	
B	7	
C	25	
D	50	

6.4

Aim

To compare plant and animal cells.

Materials

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

Plant and animal cells

Method

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

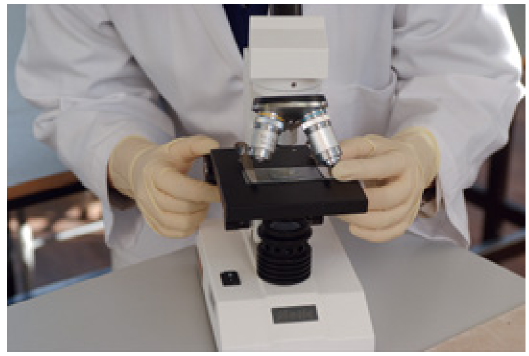
2 Place the skin on the microscope slide and add a tiny drop of iodine. This stains parts of the cells to make them easier to see.

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

4 Place the slide on the stage.

5 Focus the microscope.

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



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

8 Draw the cells you observe.

9 Write down the total magnification and label the diagram.

Results

Include your cell diagrams here.

Discussion

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

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

3 Compare the two sketches you have prepared with the images of plant and animal cells in Figure 6.17. List any differences and similarities.

4 Use the Venn diagram in Figure 9.51 to show how plant and animal cells are similar and how they are different.

Conclusion

What do you know about plant and animal cells?

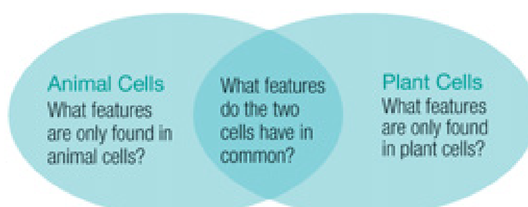


Figure 9.51 What are the similarities and differences between plant and animal cells?

6.5
EXPERIMENT

Microbes all around

Aim

To determine the effectiveness of detergents in killing or restricting bacterial growth.

Materials

- 3 Petri dishes (containing nutrient agar)
- 2 sterilised swabs
- Paraffin wax strips
- Incubator

Figure 9.52 Carefully wipe the swab over the agar plate.

In this activity you will investigate if common detergents can kill the bacteria found in the local environment. Most human pathogenic bacteria and fungi (those that are potentially harmful to humans) grow optimally at 37°C. For this reason, samples should be sealed with paraffin wax or tape prior to incubation and destroyed immediately after analysis.

Method

1 Two agar plates are to be used for growing microbes and the third is the negative control plate. The negative control plate should not be opened at any stage of the activity, but must be incubated alongside the sample plates.
2 Decide on a site around the school to be tested for microbes.
3 Keep the swabs sterile (germ free) until you reach the site.
4 Rub the swab over the site and then gently rub it across the surface of the agar in both directions. Take care not to damage the surface of the agar.
5 Quickly place the lid on the plate, seal it with a wax strip and then incubate it, along with the control plate, at 37°C for 2–3 days.

Inquiry: What if a detergent was spread over the surface of the agar plate?

- Choose a detergent that you would like to test.
- Write a hypothesis for your experiment.
- What (independent) variable will you change from the first method?
- How will you know if the detergent is effective in killing/restricting bacterial growth? (This is your dependent variable.)
- List three variables you will keep the same/control between the three plates.
- Record your observations in a table.
- At the end of the activity, dispose of the agar plates appropriately.

Discussion

1 Describe the growth on your sample plates after the incubation period. A labelled diagram may assist your description. Did you observe the growth of both bacteria and fungi? What were some of the differences between them?
2 If your sample plate showed evidence of bacterial growth, do you think that there was more than one type of bacteria present? Justify your response.
3 Was your detergent effective in controlling bacterial growth?
4 Suggest why there may be some differences between the growth on your plates and those of other students.
5 Explain why it is important that both the swab and the plate are sterile and are only exposed to the environment for a short period while collecting the sample.
6 If the negative control plate was sterilised appropriately prior to the beginning of this activity and then incubated alongside the sample plate, it should have shown no bacterial or fungal growth. Explain the purpose of the negative control plate.

Conclusion

What do your results conclude about the effectiveness of your detergent?

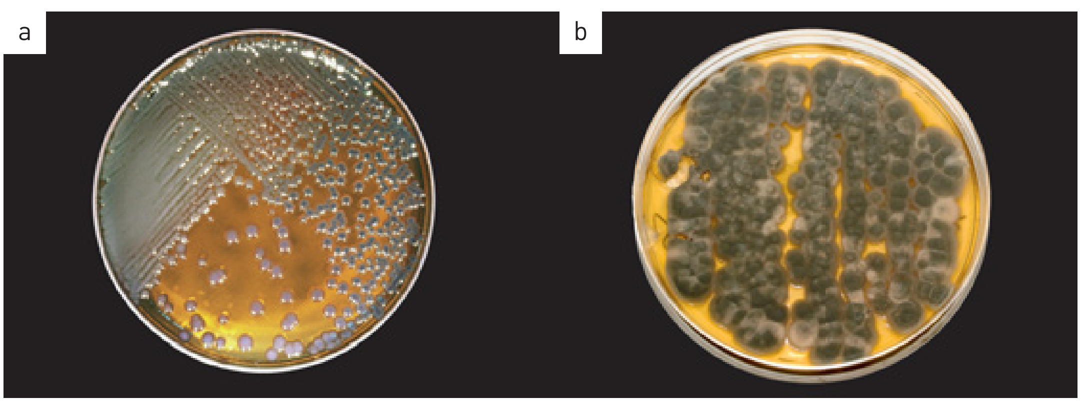


Figure 9.53 (a) Bacterial colonies growing on an agar plate. (b) Fungi tend to have a dusty or fuzzy appearance.

6.6 CHALLENGE

Modelling mitosis

What you need

> 4 long balloons
> Permanent marker

What to do

1 Blow up one balloon and label it 'parent cell'.
2 Blow up the second balloon to represent the parent cell becoming larger in preparation for mitosis.
3 Use the two remaining balloons to represent the two daughter cells that result from cell division. Label each of these cells 'daughter cell'.

Discussion

> How would you represent a cancerous cell?
> How would you represent apoptosis in a balloon cell?

7.1 CHALLENGE

Brown paper body brainstorm

What you need

> Large pieces of butcher's paper
> Several different-coloured felt-tipped pens

What to do

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

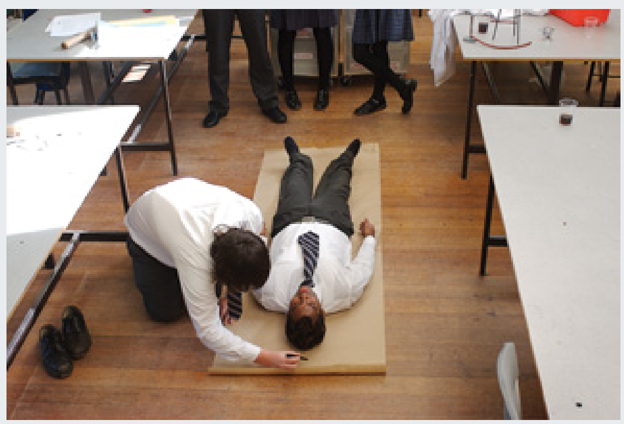


Figure 9.54 Draw a model of the survival systems of your body.

7.2A EXPERIMENT

Digesting protein

Aim

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

Materials

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

Safety

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

CAUTION! SOME STUDENTS MAY HAVE EGG ALLERGIES.

CAUTION! DANGEROUS CHEMICALS ARE INVOLVED – POUR CAREFULLY, CLEAN UP ALL SPILLS IMMEDIATELY AND RINSE YOUR HANDS IF YOU COME INTO CONTACT WITH ANY CHEMICALS.

Method

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

Results

Record the ingredients for each tube with a tick or cross in Table 9.20. Provide very brief statements to describe your observations of the results.

Discussion

1. This experiment is a 'controlled' experiment. What do you understand this term to mean?
2. How can combining the class's data improve the accuracy of the interpretations?
3. Construct a sentence to explain how the comparison of tubes relates to the human stomach for A and B, A and C, and A and D.
4. In which test tube(s) has the protein been almost completely digested? How do you know?
5. Has the pepsin digested the protein? If so, how can you be sure?
6. What are enzymes?
7. Does HCl digest the protein by itself? How do you know?
8. Complete the following word equations to show what has happened in this experiment.
   Tube A: protein + ________________ + ________________ → amino acids
   Tube B: water + ________________ + ________________ → ________________
   Tube C: pepsin + ________________ + ________________ → ________________
   Tube D: pepsin + ________________ + ________________ → ________________
9. Why does the body digest protein? What would happen to the protein after it has been digested?
10. Predict what would happen if this experiment was repeated with carbohydrates instead of protein, leaving the rest of the experiment exactly the same.

Conclusion

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

Table 9.20

TUBE	EGG WHITE	PEPSIN SOLUTION	HCl	NaOH	WATER	RESULTS
A						
B						
C						
D						

7.2B
EXPERIMENT

Aim

To determine what conditions are needed for an enzyme to digest protein.

Materials

- Jelly crystals
- Boiling water to make up jelly
- Large beaker to make up jelly
- 3 × 100 mL beakers
- Fresh pineapple
- Boiled pineapple
- Tinned pineapple

What if an enzyme was boiled?

The gelatine in jelly is a protein that can be broken up by an enzyme found in fresh pineapple or kiwi fruit. For this reason many packets of jelly come with a warning not to add fresh fruit to the jelly.

Method

1. Make up the jelly according to the instructions on the packet.
2. Pour 50 mL of liquid jelly into two beakers.
3. Add a few pieces of the fresh pineapple to one of the beakers.
4. Allow to cool overnight in the fridge.
5. Record your observations in a table.

Inquiry

Choose one of the questions below to investigate.

- What if the pineapple was boiled before being added to the jelly?
- What if tinned pineapple was added to the jelly?

Answer the following questions in relation to your inquiry.

- Write a hypothesis for your question.
- What (independent) variable will you change from the first method?
- What (dependent) variable will you measure/observe?
- Name three variables you will keep the same/control.
- Record your observations in a table.

Results

Draw a table to record your observations.

Discussion

1. Describe the difference between the jelly with the fresh pineapple and the jelly with no pineapple.
2. Use the term 'chemical digestion' to explain your observations.
3. Was your hypothesis supported in your inquiry? Explain your answer.
4. Suggest an alternative reason for the results you obtained in your inquiry.

Conclusion

Explain why you should not add fresh pineapple to jelly.

7.5A CHALLENGE

Measure your lung capacity

What you need

- A large 5 litre container
- Access to a large sink or tub
- 1 metre of tubing

What to do

1. Place 10 cm of water in the bottom of a sink.
2. Fill the container with water.
3. Tip the container upside down in the sink so that the opening is submerged. This will prevent the water leaving the container.
4. Place one end of the tubing under the opening of the container.
5. Take a deep breath and blow as much as your can into the tubing. As you blow air into the container, the water should be pushed out the bottom.
6. Measure how much air you are able to blow out of your lungs into the container.

Discussion

1. Can you repeat the results by performing your experiment two more times?
2. Is there a chance your results could have been affected by something else? For example, do you have a lung infection?
3. Compare your results to others in the class. Can you notice any relationship between height of the person and their lung capacity?

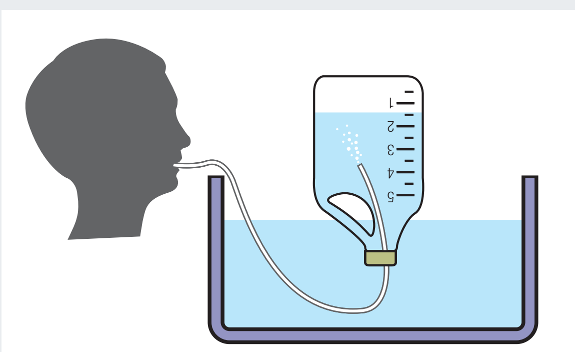


Figure 9.55 Measure the capacity of your lungs.

7.5B CHALLENGE

Fish dissection

What you need

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

SAFETY REFER TO CHAPTER 1 FOR DISSECTION SKILLS AND SAFETY GUIDELINES.

PART A

What to do

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

Discussion

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

PART B

What to do

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

Discussion

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

Figure 9.56 Identify the key organs in the dissected fish.

7.7 EXPERIMENT

Aim

To explore the structure and function of a heart.

Materials

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

Heart dissection

SAFETY REFER TO CHAPTER 1 FOR DISSECTION SKILLS AND SAFETY GUIDELINES.

Method

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

2 Use your fingers to feel the right side of the heart. Compare the thickness of the right and left sides. Feel the muscle in the centre of the heart.

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

4 Push a dissecting probe or your finger out through the artery leading from the right ventricle.

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

6 Push a dissecting probe or your finger out through the artery leading from the left ventricle.

Results

Include labelled diagrams and observations here.

Discussion

1 What is the artery from Method step 4 called?

2 What is the artery from Method step 6 called?

3 How does the thickness of this artery wall compare with the thickness of a vein wall?

4 How does the thickness of ventricle walls compare with that of atrial walls?

5 How can you explain the difference between the left and right ventricle walls?

Conclusion

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

Figure 9.57 Identify the right and left sides of the heart.

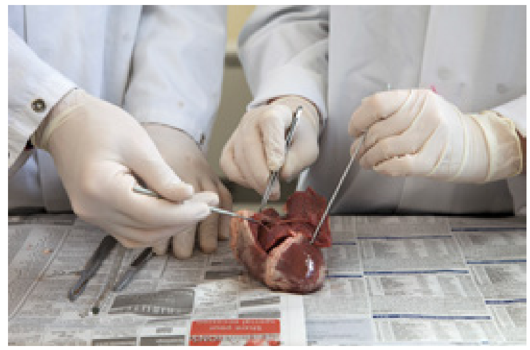


Figure 9.58 Compare the thicknesses of the right and left ventricles.

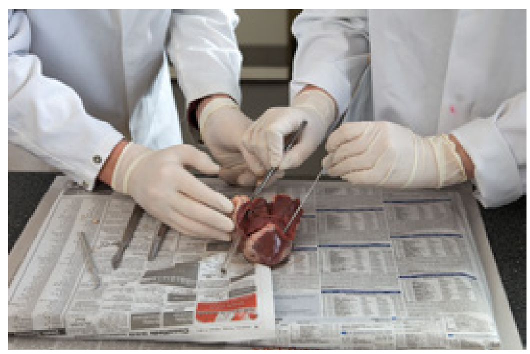


Figure 9.59 Use the dissecting probe to identify the arteries.

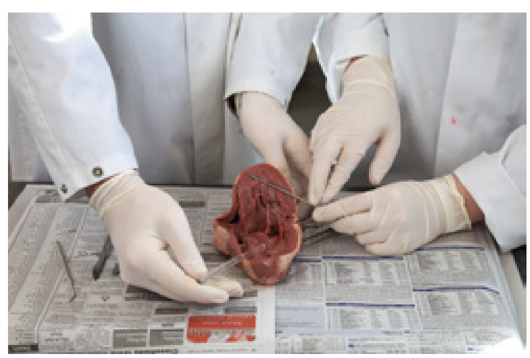


Figure 9.60 Identify the artery leaving the left ventricle.

7.8
CHALLENGE

Modelling blood flow

What you need

- Scissors
- Plastic cups
- 1 thin straw
- Play dough
- 1 thick straw
- Food colouring
- Water
- Large tray
- Timer

What to do

1. Use the scissors to poke a straw-sized hole through the side of the cup.
2. Place the thin straw through the hole of the cup making sure the straw is not being squeezed.
3. Use play dough to seal around the hole so that there are no leaks. Water should only be able to escape through the straw.
4. Cut the straw so that it is 5 cm in length.
5. Repeat this with another cup for the thick straw making sure the straw is placed in approximately the same height from the cup's base.
6. Place the cups in the tray and fill both cups with equal amounts of coloured water.
7. Time how long each cup takes to become empty.

Discussion

1. What effect did narrowing the straws have in the effectiveness of water flow?
2. What complication of the circulatory system does this model reflect?
3. Treatment for this complication involves inserting a small balloon into the blood vessel and allowing it to stretch the vessel so that it becomes wider. How will this help the patient?

7.9
EXPERIMENT

Kidney dissection

Aim

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

Materials

- Sheep's kidney
- Dissecting kit
- Dissecting board

CAUTION! REFER TO CHAPTER 1 FOR DISSECTION SKILLS AND SAFETY GUIDELINES.

Method

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

Results

Include your labelled diagrams here.

Discussion

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

Conclusion

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

7.10A
CHALLENGE

Locating the stomata of a leaf

What you need
> Clear fingernail polish
> Fresh plant leaf
> Clear sticky tape
> Glass slide
> Microscope

What to do
1 Paint a thick patch of clear nail polish in the underside of the leaf and allow to dry.
2 Place a piece of the clear sticky tape over the dried nail polish.
3 Gently peel the sticky tape off the leaf, removing the nail polish patch from the leaf's surface.
4 Tape the peeled section of leaf onto the glass slide.
5 Examine the slide under the microscope and locate a stoma (singlular of stomata).
6 Draw a labelled diagram of the stoma.

Discussion
1 What function do stomata have in a plant?
2 Was the stoma you located open or closed?
3 Refer to the time of day and the location of the plant to explain why the stoma on your plant was open or closed.

7.10B
CHALLENGE

Locating the xylem and phloem in a stem

What you need
> 500 mL beaker
> Water
> Blue or red food colouring
> Fresh stick of celery
> Scalpel and cutting board
> Permanent marker
> Magnifying glass

What to do
1 Add 200 mL of water to the beaker.
2 Add 15 drops of food colouring to the water.
3 Cut the bottom 10 cm off the celery.
4 Place the top half of the celery in the beaker of coloured water.
5 Mark the water level with a permanent marker. Leave for 2–3 days.
6 Remove the celery from the water and use the scalpel to cut a horizontal transverse section of the celery stalk.
7 Locate the pathway by which the coloured water moved through the celery. Draw a labelled diagram of the celery cross-section.

Discussion
1 What did you notice about the amount of water in the beaker after 2–3 days?
2 Use the term 'transpiration' to explain your answer to the previous question.
3 What is the name of the pathway that moved the coloured water through the celery?
4 How is this similar to the circulatory system in humans? How is it different?

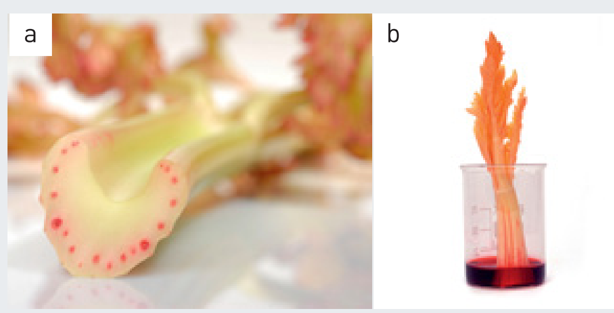


Figure 9.61 (a) The dye marks the path the water takes from the roots. (b) As water evaporates from the leaves, the dye water replaces it.

7.10C
CHALLENGE

Modelling root cells

What you need

- 15 cm dialysis tubing
- Distilled water
- 5 mL of 5% starch solution
- Scales
- 200 mL beaker

What to do

1. Soften the dialysis tubing by running distilled water over the outside of it.
2. Tie a knot in one end of the tubing.
3. Add 5 mL of starch solution to the tubing.
4. Seal the open end by tying a knot.
5. Wash the outside of the tubing with distilled water.
6. Pat the outside of the tubing dry and determine its weight using the scales.
7. Place the tubing in the beaker. Add 100 mL distilled water.
8. Leave overnight.
9. Remove the dialysis tubing from the water and carefully pat dry.
10. Determine the weight of the dialysis tubing.

Discussion

1. What was the difference in weight of the dialysis tube with starch before and after soaking in water?
2. What caused the change in the weight of the tubing?
3. What is osmosis?
4. Use the term 'osmosis' to explain how the dialysis tubing is similar to the cells in a root.

7.10
EXPERIMENT

Factors that affect transpiration

Aim

To determine the factors that affect the transpiration of water from plants.

Materials

- 200 mL measuring cylinders
- Water
- Fresh celery stalks

Method

1. Add 100 mL of water to one of the measuring cylinders.
2. Cut the bottom 10 cm off a celery stalk and trim so that the end of it fits into the measuring cylinder.
3. Place the top half of the celery in the measuring cylinder.
4. Mark the water level with a permanent marker. Leave for 2–3 days at room temperature.
5. Measure how much water has been lost by the celery stick.

Inquiry: Choose one of the questions below to investigate

- What if the celery was placed in sunshine?
- What if the celery was placed in wind? (A fan may be used.)
- What if the celery was placed in a humid environment? (A large clear plastic bag may be placed over the celery.)

Answer the following questions in relation to your inquiry.

- Write a hypothesis for your question.
- What (independent) variable will you change from the first method?
- What (dependent) variable will you measure/observe?
- Name three variables you will keep the same/control.

Results

Record your observations and measurements in a table.

Discussion

1. What is transpiration?
2. What factors would you expect to affect transpiration?
3. Did your results support your hypothesis? Use evidence from your results to support your answer.
4. How could you use your results to support the plants in your garden?

Conclusion

What do you know about the factors that affect transpiration?

8.1
EXPERIMENT

Vegetative propagation

Aim
To produce a new plant using vegetative propagation.

Materials
- 2 x 500 mL beakers
- Distilled water
- Scissors
- Geranium plant
- Flowerpots with potting mix

Method
1 Fill the beakers 3/4 full with distilled water.
2 Use the scissors to cut four healthy stems with 1–2 healthy leaves on each from the same plant.
3 Place the cut ends of the stems into the distilled water.
4 Observe the cut ends of the stems for 2–3 weeks.
5 Transfer the cuttings to the flowerpots.
6 Water the plants regularly and observe their growth.

Results
Record your observations in a logbook. Take photos of any changes in growth.

Discussion
1 Is this form of reproduction sexual or asexual? Provide a reason for your answer.
2 How similar is the genetic material in the parent plant to that of the new (daughter) plants?
3 Will the daughter plants be identical in shape and size to the parent plant?
4 A student claimed that they were making plant clones. What are plant clones? Was the student correct?

Conclusion
What do you know about vegetative propagation?

8.4
CHALLENGE

Working with the RSPCA

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

What to do
Create a mathematical model (or diagram) demonstrating how many cats can be produced from two fertile cats.

This task is exponential, meaning that when the two cats reach 6 months of age they can start to breed and, after 60 days, will have a litter of four kittens, after 6 months these four kittens will also be able to have kittens themselves and so on. Cats can start the breeding cycle almost straight after having kittens, which means, on average, cats can have three litters of kittens a year.

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

Discussion
1 Explain what desexing is and why it is important.
2 Based on your calculations, how many cats were produced after 4 years?
3 How would desexing the first mating pair change your results?
4 Do you think this was a 'fair test'? Explain the reasons for your answer.
5 What other factors could affect the number of cats?
6 Why do you think the RSPCA takes in so many more cats than dogs?Figure 9.67 Some dogs are kept in small dirty kennels so that the owners can sell the puppies.

8.5 EXPERIMENT

Flower dissection

Aim

To examine the main parts of a flower.

Materials

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

Method

1. Place the newspaper on the bench.
2. Cut the flower off the stalk.
3. Observe the flower. Identify the main parts of the flower from Figure 9.62.
4. Draw a labelled diagram of the flower.
5. Gently remove the sepals and petals.
6. Look for the stamens with anthers at the top. The anthers hold the pollen. You should be able to dust some pollen onto your finger.
7. Cut off the male parts at the bottom of the petal.
8. Observe the female part of the flower. It has the stigma at the top and the ovary at the bottom.
9. Cut the ovary lengthwise. In it you will see tiny white scales, which are the ovules. When the ova inside the ovules are fertilised by the pollen, they will grow to become seeds and the ovary will grow to become the fruit.
10. Draw a labelled diagram of the ovary.
11. Clean up your bench by wrapping the flower in the newspaper. Wash your hands.

Results

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

Discussion

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

Conclusion

What do you know about the parts of a flower?Exploring physical changes

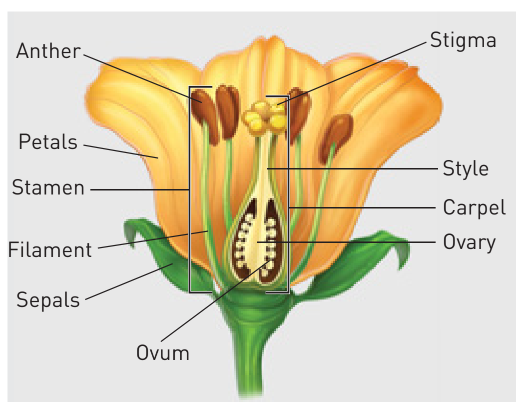


Figure 9.62 The structure of a flower.

GLOSSARY

A

abomasum
the fourth stomach of a cow

alveoli
tiny air sacs in the lungs where gas exchange occurs

amino acid
small molecule that makes up a protein

ammonia
a toxic substance produced by the liver; a cleaning fluid

anatomy
structure of an organism and its component parts; usually refers to human anatomy

anther
part of the stamen (male plant) that contains pollen

aorta
the major artery that carries oxygenated blood from the heart and divides into smaller arteries around the body

apoptosis
programmed cell death

arterioles
smaller arteries

artery
thick, muscular-walled blood vessel that carries blood away from the heart under pressure

asexual reproduction
type of reproduction not involving the fusing of gametes; where an organism can create offspring without a partner

asthma
condition where the bronchi and bronchioles swell, making it harder to breathe; usually triggered by something in the environment

atom
smallest particle of matter that cannot be created, destroyed or broken down (indivisible)

atria
the smaller upper chambers of the heart

B

binary fission
a form of asexual reproduction used by bacteria; the splitting of a parent cell into two equal daughter cells

binocular
using two eyes; a type of microscope

blood
liquid that circulates in the blood vessels and contains a combination of cells, cell fragments, liquid and dissolved substances

blood vessel
tube in the body that carries blood

body system
a collection of organs with a common purpose

boil
to change state from a liquid to a gas

boiling point
the temperature at which a liquid becomes a gas

bonded
when two objects (atoms) remain attracted to each other

bronchi
the air passages that carry air in and out of the lungs; airways

C

caecum
a small dead-end pouch that connects the small and large intestines

cancer
group of diseases that result from uncontrolled cell division

capillary
blood vessel with a wall only one cell thick, allowing substances to easily pass into and out of the blood

carcinogen
cancer-causing substance

carpel
the female reproductive organ of a flower; includes the stigma, style and ovary

catalyst
a substance that increases the rate of a chemical reaction without undergoing any permanent chemical change

cell
(in biology) the building block of living things

cell membrane
barrier around a cell that controls the entry and exit of things into and out of a cell

cell theory
the theory that all organisms are composed of one or more cells, cells are the basic unit of life and structure, and new cells are created from existing cells

cellular respiration
the chemical process where sugars (glucose) and oxygen is converted to carbon dioxide, water and energy

cervix
the narrow neck connecting the uterus and the vagina

chemical potential energy
energy stored in chemicals, e.g. in food, fuel or explosives; also known simply as chemical energy

chemical property
how a substance behaves in a chemical reaction, e.g. how it reacts with acid

chemical reaction
procedure that produces new chemicals; same as chemical change

chemistry
branch of science that deals with matter and changes that take place with it

chlorophyll
green pigment found inside chloroplasts that absorbs solar energy and uses it in photosynthesis

chloroplast
organelle found in plant cells that transforms solar energy into chemical energy

chyme
mixture of acid, enzymes and digested food that leaves the stomach

cilia
small hairs on the surface of a cell involved in movement

cleavage
number of smooth planes a mineral breaks along

collision theory
when substances react, their particles must come into contact or collide with each other

colour
property of rocks and minerals used to identify them

comparative dating
determining the age of rocks by comparing them to rocks of known age

compound
substance made up of two or more different types of atoms bonded together, e.g. water

compound light microscope
a microscope with two or more lenses

compressibility
ability of a substance to be compressed (squashed); gases can be compressed but solids and liquids cannot

concentration
the amount of a substance in a set volume

condense
when a gas becomes a liquid

constipation
a medical condition that results from a blockage in the large intestine

contraception
method used to prevent pregnancy

controlled variables
variables that will remain unchanged through the experiment

corrosion
the damage caused to metal by its environment

corrosive
a substance that is destructive to living tissues, such as skin and eyes, or to some types of metals

cost–benefit analysis
list of the costs compared with the benefits; usually performed to analyse a proposed engineering project

criteria
the important aspects of a project that need to be measured; designed to make sure each project is as good as it can be

cross-pollination
involves pollen from a flower landing on the female part of a flower on a different plant, producing greater variation than self-pollination

crystal
small, organised particle in rocks, which has smooth sides and sharp edges

cytoplasm
the 'jelly-like' fluid inside the cell membrane that contains dissolved nutrients, waste products and organelles

D

daughter cell
a cell that results from parent cell division

dependent variable
variable that may change as a result of the experiment

desexing
a surgical form of contraception used with animals

diaphragm
the dome-shaped muscle that is attached to ribs and moves up and down beneath the lungs

diarrhoea
watery faeces

diatomic
a molecule that contains only two atoms

diffusion
spontaneous spreading out of a substance through a liquid or gas, e.g. the diffusion of perfume in air

digestion
process by which food is broken down and absorbed into the blood for transport to the cells

directly proportional relationship
the dependent variable increases as the independent variable increases

dissection
the process of disassembling and studying the internal structures of plants, animals and humans

DNA (deoxyribonucleic acid)
a molecule that contains all the instructions for every job performed by the cell; this information can be passed from one generation to the next

E

elastic potential energy
energy stored through stretching or squashing, e.g. in a stretched spring or rubber band

electrical energy
energy associated with electric charge, either stationary (static) or moving (current)

electron microscope
a microscope that uses electrons (tiny negatively charged particles) to create images

element
pure substance made up of only one type of atom, e.g. oxygen, carbon

emphysema
disease that results from damage to the alveoli in the lungs; one of the diseases that can be caused by smoking

endometrium
the lining of the uterus

energy efficiency
measure of the amount of useful energy transformed in an energy transformation process; usually expressed as a percentage of the input energy, e.g. 90% efficiency is very good

enzyme
chemical that helps make chemical reactions happen; a type of catalyst

epididymis
the coiled tube behind the testes that carries sperm to the vas deferens

epiglottis
a flap of skin that controls the passage of food and air

erosion
movement of sediment to another area

eukaryotic cell
complex cell that contains a nucleus and membrane-bound organelles

excretion
process of removing wastes from the body

excretory system
a group of organs that are involved in excretion

external fertilisation
when the egg and sperm meet outside the bodies of the parents

extrusive igneous rock
rock formed at the Earth's surface by quickly cooling lava

eyepiece
lens where eye is placed when using a microscope

F

fair testing
experiment where only the independent variable is changed and all other variables are kept constant

fallopian tubes
the tubes that connect the ovaries to the uterus in a female

fertilisation
stage of sexual reproduction involving the joining of a sperm and an egg

foetus
stage in the development of a human baby taken from when the baby acquires human features (normally after 8 weeks of development)

foliation
occurs when rock is subjected to uneven pressure

fossil
remains (or imprint) of an animal or plant preserved in rock

fragmentation
type of asexual reproduction where an organism splits into fragments and each fragment grows into a new organism

frost shattering
process of weathering in which repeated freezing and melting of water expands cracks in rocks so that eventually part of the rock splits off

fume
a gas or vapour that has a strong smell or is dangerous to breathe in

G

gallstone
a hard substance or stone that is produced by the gall bladder

gamete
sex cell; in humans, the sperm and egg cells

geologist
scientist who studies rocks

gestation
the time between fertilisation and birth

gluten intolerance
an inability to digest or break down gluten

grain
small rock particle; grain size can be used to identify rock type

gravitational potential energy
energy stored due to the height of an object, e.g. a child at the top of a slide

H

hardness
how easily a mineral can be scratched; measured on the Mohs hardness scale

hazard
something that has the potential to put your health and safety at risk

hermaphrodite
organism that has both male and female reproductive systems

hypothesis
a statement that describes the expected relationship between the independent variable and the dependent variable

I

igneous rock
rock formed by cooling magma and lava

inbreeding
breeding of animals that are related, increasing the chances of genetic abnormalities appearing

incompressible
when a substance cannot be compressed; solids and liquids are incompressible

independent variable
a variable (factor) that is changed in an experiment

index fossil
fossil found in different rocks, that can be used to determine age of rocks

index mineral
a mineral that only forms under a particular temperature and pressure; used to determine the history of the mineral

infectious disease
disease caused by the passing of a pathogen from one organism to another; also known as contagious disease

inhale
to breathe in

internal fertilisation
when the sperm fertilises the egg inside the body of an organism

intrusive igneous rock
rock formed underground by slowly cooling magma

inversely proportional relationship
the dependent variable increases as the independent variable decreases

K

kinetic energy
energy of motion or moving objects

L

lattice
three-dimensional arrangement of particles in a regular pattern

lava
hot, molten rock that comes to the surface of the Earth in a volcanic eruption

law of conservation of energy
scientific rule that states that the total energy in a system is always constant and cannot be created or destroyed

layer
property of rocks used to identify them

leaf
a plant organ that transforms light energy into chemical energy through photosynthesis

lungs
organs found in the ribcage that are part of the respiratory system

lustre
shininess

M

magma
hot, molten rock inside the Earth

mass
amount of matter in a substance, usually measured in kilograms

matter
anything that has mass and volume

melt
to change the state from a solid to a liquid

melting point
the temperature at which a solid becomes a liquid

menstruation
also know as a period; the process of the endometrial lining of the uterus breaking down and leaving the vagina

metabolism
chemical reactions that occur in the body

metamorphic rock
rock formed from other rock that has experienced intense heat and pressure

microbe
a living thing that can only be seen with the use of a microscope; a microorganism

microbiology
the science involving the study of microscopic organisms

microorganism
a living thing that can only be seen with the use of a microscope

microscope
scientific instrument used to magnify the size of an object

microscopy
the study of living things that can only be seen with the use of a microscope

mineral
naturally occurring solid substance with its own chemical composition, structure and properties

mitochondrion
powerhouse organelle of a cell; the site of energy production; (plural mitochondria)

mitosis
process of cell division to provide growth or repair

molecular compound
a molecule that contains two or more different atoms bonded together

molecular element
a molecule that contains two or more of the same atoms bonded together

molecule
group of two or more atoms that are bonded together, e.g. a water molecule

monatomic
a single atom

monocular
using one eye; a type of microscope

multicellular
an organism that has two or more cells

mutagen
a substance that may damage a cell's genetic material (DNA)

N

natural flora
microbes that live happily in our bodies

nephron
tiny structure in the kidneys that filters the blood

nuclear energy
energy stored in the nucleus of an atom and released in nuclear reactors or explosions of nuclear weapons; much, much larger than the chemical energy released in chemical reactions

nucleus
(in biology) control centre of a cell that contains all the genetic material (DNA) for that cell

nutrient
soluble substance that an organism needs to live and grow; usually taken in from the environment

O

objective lens
lens in the column of a compound light microscope

oestrogen
a reproductive hormone found in females

offspring
an organism's young, or child

omasum
the third stomach of a cow

onion skin weathering
weathering of rock where the outside of the rock peels off

ore
mineral containing a large amount of useful metal

organ
group of tissues that work together, e.g. liver, heart, eyes, brain

organelle
smaller part of a cell, each one having a different function

osmosis
the movement of water through a selective membrane from an area of low 'salt' concentration to an area of high 'salt' concentration; occurs in root cells

ovary
the female organ that produces eggs

oviduct
the tube through which eggs travel from the ovary

ovulation
the part of the menstrual cycle when an egg is released from the ovary

ovum
the reproductive egg

P

palaeontologist
scientist who studies fossils

parent cell
the original cell before it undergoes cell division

parthenogenesis
asexual reproductive strategy where unfertilised eggs hatch into new organisms

particle model of matter
theory that all matter is made up of very tiny particles

pathogen
microbe that can potentially cause a disease

periodic table
the arrangement of elements into a table according to their chemical properties

peristalsis
when muscles behind the food squeeze tight, and the muscles in front of the food relax, causing the food to move along the throat or intestines

pharynx
the throat; connects the mouth to the oesophagus

phloem
the vascular tissue found in plant stems that carries the sugars around the plant

photosynthesis
chemical process plants use to make glucose and oxygen from carbon dioxide and water

photovoltaic cells (PVCs)
an electrical device that converts light energy into electrical energy, *see* solar cells

physical property
can be measured or observed without changing a substance into something else, e.g. colour, boiling point

placenta
the organ the connects the developing foetus to its mother

plasma
the straw-colour fluid that forms part of the blood

platelets
small disc-like cells found in blood that are involved with forming clots

pneumonia
when the alveoli in the lungs fill up with bacteria, pus and fluid as a result of a bacteria or virus infection

pollination
process that occurs in flowering plants when a pollen cell lands on the female part of the flower

polymer
long chain molecule made up of many simpler repeating units

potential energy
energy stored in objects and waiting to be used, e.g. gravitational potential energy

product
substance obtained at the end of a chemical reaction; written on the right of a chemical equation

prokaryotic cell
primitive single-celled organism that has no nucleus

property
(in chemistry) characteristic or behaviours of something that are always the same, e.g. the density of gold

prostate gland
the walnut-sized structure surrounding the neck of the male bladder that blocks the flow of urine so that the sperm can move along the urethra

R

radioactive dating
determining the age of rocks by comparing the amounts of uranium and its decay product lead

reactant
substance used at the beginning of a chemical reaction; written on the left of a chemical equation

red blood cells
cells found in the blood that carry oxygen around the body

remote control
electronic device used for the remote operation (i.e. at a distance) of a machine

reticulum
the second stomach of a cow

ribosome
cell organelle where protein production takes place

rock cycle
process of formation and destruction of different rock types

root
a plant organ involved in absorbing water and minerals

rumen
the first stomach of a cow

S

scrotum
the sac-like structure that contains the testes

sedimentary rock
rock formed from compacted mud, sand or pebbles, or the remains of living things

self-pollination
involves pollen from a flower landing on its own ovum or that of another flower on the same plant

seminal vesicle
small pouch-like structures that provide a sugary fluid that is needed for the sperms' journey along the vas deferens tube

sexual reproduction
type of reproduction involving the fusing of gametes

sexually dimorphic
those species in which the male and female organisms look structurally different

single-celled
an organism that consists of one cell

solar cell
used to transform sunlight directly into electrical energy; usually in the form of a panel; also known as a solar panel

sound energy
type of kinetic energy made when things vibrate

spore
tiny reproductive structure that, unlike a gamete, does not need to fuse with another cell to form a new organism

stain
substance, such as iodine, used to make cells more visible under a microscope

stem
a plant organ involved in transporting sugars, water and nutrients

stereomicroscope
a microscope with two eyepieces that uses low magnification

stigma
the male part of a plant, which consists of a filament supporting an anther

streak
colour of powdered or crushed mineral

sublimation
change of state straight from a solid to a gas or from a gas to a solid

surface area to volume ratio
the relationship between the area around the outside of a cell and its volume, as a fraction

symptom
changes that occur to an individual as a consequence of a disease

T

tensile strength
a measure of the flexibility of the links or bonds between the particles in a substance

testis
the male organ of the reproductive system that produces sperm; plural testes

testosterone
a male hormone involved in the reproductive system

theory
explanation of a small part of the natural world that is supported by a large body of evidence

thermal energy
scientific term for heat energy

tissue
group of cells that do a similar task

tor
round rocks produced by onion skin weathering

trachea
the large tube that connects the throat to the bronchi; carries air in and out of the body

transferred
said of energy that has moved from one object to another

transformed
changed one form of energy into another form of energy

transpiration
the process of water evaporation from plant leaves that causes water to move up from the roots

tumour
growth or lump caused by a cell growing out of control

U

ulcer
an open sore on the inside or the outside of the body

ultrasound
using sound vibrations to shatter stones inside the body; can also be used to develop images of organs inside the body

unicellular
an organism that exists as a single cell

urea
a waste product formed by the body

uterus
an organ in the female reproductive system; where the foetus develops

V

vagina
an organ that is part of the female reproductive system; a muscular tube connecting the outside of the female body to the cervix

vaporise
to change state from a liquid to a gas; same as evaporate

vapour
gaseous form of a substance that is normally a solid or liquid, e.g. water vapour

variable
something that can affect the results of an experiment

vascular bundle
groups of tubes found in plant stems that carry water and nutrients around the plant

vas deferens
the tube through which sperm travels from the epididymis to the prostate

vegetative reproduction
type of asexual reproduction where a part of a plant breaks off, forming a new organism with no need for seeds or spores; similar to fragmentation

vein
thin-walled blood vessel that carries blood back to the heart

ventricles
the large lower chambers of the heart

villi
small ridges found in the small intestine that absorb nutrients from the digestive system

viscosity
a measure of how slowly a liquid changes its shape; the thickness of a liquid

volatile
a substance that easily becomes a gas

volume
how much space an object takes up, usually measured in litres

W

weathering
break down of rocks and minerals by movement of water and animals, and extremes of temperature

weight
property of rocks used to identify them

white blood cells
cells found in the blood that help fight infections

X

xylem
the tissue in plants that carries water from the roots to the rest of the plant

Z

zygote
a fertilised egg

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