PEARSON science

S.B.

7

AUSTRALIAN CURRICULUM

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2 Properties of substances

3 Earth resources

4 Mixtures

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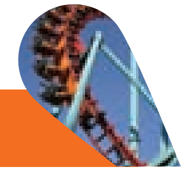
5 Habitats and interactions

6 Classification

7 Forces



8 Machines

9 Earth in space

PEARSON science

Student Book

Written specifically to meet the requirements of the Australian Curriculum, the student book acts as a guide for both student and teacher.

- Written specifically for the Australian Curriculum Science course
- Utilises an inquiry approach throughout
- Offers content and activities that enhance the development of Achievement Standards. The content is presented in a range of contexts within the three interrelated strands of Science Inquiry Skills, Science as a Human Endeavour and Science Understanding.

Activity Book

The activity book is a write-in resource designed to enrich students' skills by providing a variety of activities and questions to reinforce learning outcomes.

- Supports and extends the student book
- Caters for a range of learning styles.

Teacher Companion

The teacher companion makes lesson preparation easy by combining full-colour textbook pages with teaching strategies, ideas for class activities and fully worked solutions.

- Ties the entire **Pearson Science** package together
- Includes all answers to the student and activity book.

AUSTRALIAN CURRICULUM

ALWAYS LEARNING

Pearson Reader

Much more than an e-book, **Pearson Reader** is an interactive online version of your student book linked to rich media resources. Not only does it support you with activities and teaching tools, it allows you to personalise your class version of the student book by adding your own links and content. **Pearson Reader** also enables you to harness the collective intelligence of education professionals by connecting you to other **Pearson Reader** users, building a powerful and continually evolving web book for your students.

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We believe in learning.
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delivered in a personal style.
Because wherever learning flourishes, so do people.

PEARSON

How to use this book

PEARSON science 7 Student Book

PEARSON science 7 has been designed for the Australian Curriculum: Science course. It includes content and activities that enhance the development of the Year 7 Achievement Standards within the three interrelated strands of Science Inquiry Skills, Science as a Human Endeavour, and Science Understanding. The content is presented through a range of contexts to engage students and assist them to make connections between science and their lives.

The Cross-curriculum priorities and General Capabilities are addressed throughout the series.

PEARSON science 7 is designed for an inquiry approach to science learning. Its engaging design, unambiguous features and clear easy-to-understand language make this a valuable resource for students of all interests and abilities.

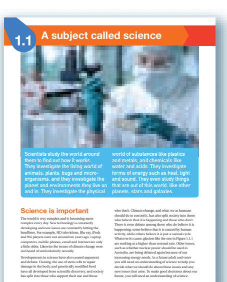
Chapter opening page

The chapter opener engages students through questions that get them thinking about the content and concepts to come.

The key ideas reflect the elaborations and standards relevant to the chapter.

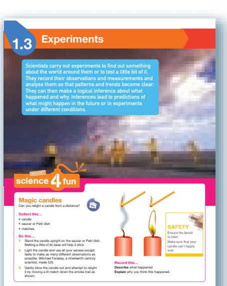
Look who is using science

Careers pages spread throughout the book look at careers that involve and use science.



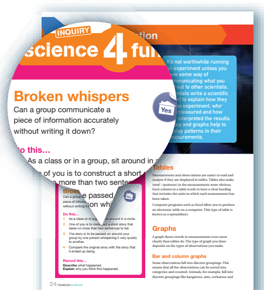
Unit opening

Each chapter is divided into self-contained units. The unit opener includes an introduction that places the material to come in a meaningful context.



Photos and illustrations

Stunning and relevant photos and illustrations are clearly referenced from within the text to assist students to understand the idea being developed.

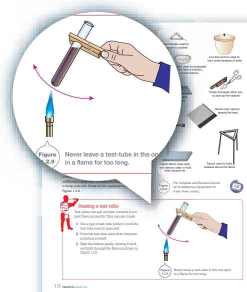


science 4 fun

Inquiry-based activities using everyday materials assist students to understand key concepts under development.

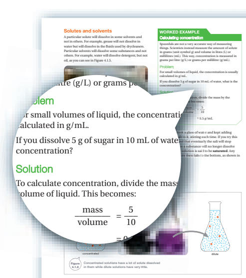
These can be used as a focus or context for the unit.

Icons indicate whether an activity is suitable to be done at home or requires teacher supervision.



Skill builder

Key skills are outlined in clear steps to support science learning.

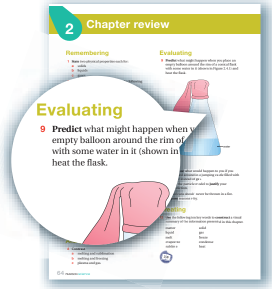


Worked example

Worked examples of problems and techniques assist students to master and apply key skills.

SciFile

SciFiles include quirky information to engage students.



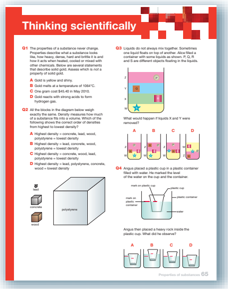
Chapter review

Each chapter finishes with a set of questions and activities organised under the headings of Bloom's Taxonomy of Cognitive Processes.

Unit review

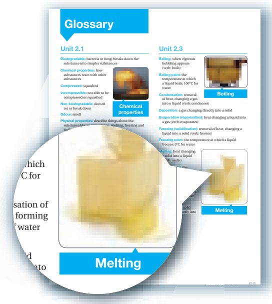
Each unit finishes with a set of questions and activities organised under the headings of Bloom's Taxonomy of Cognitive Processes. To further students' understanding of the intent of a question and level of explanation expected, bolded verbs are used throughout. A list of all verbs and their meanings can be found on page xii.

The final heading is 'Inquiring'. These questions challenge students to use their inquiry skills to go further with the unit content.



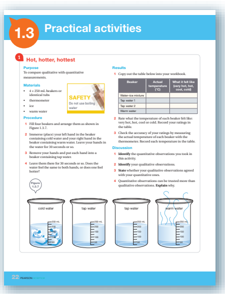
Thinking scientifically

Following the Chapter review are Thinking scientifically style questions relevant to that chapter. These test students' science and interpretive skills.



Glossary

Every chapter concludes with an illustrated glossary that engages students and provides a ready reference for the key terms of the chapter.



Practical activities

Practical activities are placed at the end of each unit. Practical activity icons appear throughout the units to indicate suggested times for practical work.

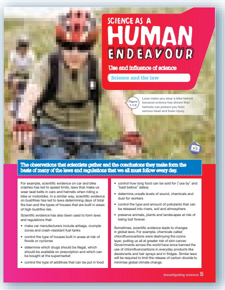
A Student-design investigation icon indicates that an activity includes student design.

Safety boxes highlight significant hazards.

A safety glasses icon reminds students when appropriate to wear safety glasses.

Activity Book icon

This icon indicates a related Activity Book worksheet that enhances or extends this area.



Science as a human endeavour

The Science as a Human Endeavour strand is addressed throughout the units and in Science as a Human Endeavour spreads. Many of these are developed and extended in the Activity Book.

The PEARSON science 7 package

Don't forget the other PEARSON science 7 package components that will help engage and excite students in science:

PEARSON science 7 Activity Book

PEARSON science 7 Teacher Companion

PEARSON science 7 Pearson Reader

Verbs

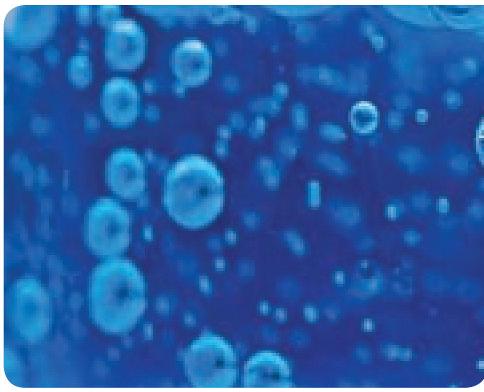
The verbs below, based on Bloom's Taxonomy, appear in **bold** text throughout this book. The verbs help students know the level of response required for a question and provide a common language and consistent meaning in the Australian Curriculum documents.

Remembering	
enter	Place data into a computer program by key strokes or copying from a digital source, e.g. CD, DVD, USB storage device
label	Add annotations to a diagram or drawing
list	Write down phrases or items only without further explanation
name	Present remembered ideas, facts or experiences
present	Provide information for consideration
recall	Present remembered ideas, facts or experiences
record	Store information and observations for later
specify	State in detail
state	Provide information without further explanation
Understanding	
account	Account for—state reasons for, report on. Give an account of—narrate a series of events or transactions
calculate	Ascertain/determine from given facts, figures or information (simply repeating calculations that are set out in the text)
clarify	Make clear or plain
construct	Prepare or devise something, such as a key or diagram
define	State meaning and identify essential qualities
describe	Provide characteristics and features
determine	Find out the size or extent, either by using an equation, counting, estimating, or similar method
discuss	Identify issues and provide points for and/or against
draw	Use a pencil to produce a likeness onto a page, or sketch to provide a representation or view
explain	Provide a sequence to make the relationships between things evident; provide why and/or how
extract	Choose relevant and/or appropriate details
gather	Collect items from different sources
modify	Change in form or amount in some way
outline	Sketch in general terms; indicate the main features
predict	Suggest what may happen based on available information
produce	Provide
propose	Put forward for consideration or action
rank	Place in order of size, age, or as instructed
recount	Retell a series of events
summarise	Express, concisely, the relevant details
write	Compose or construct a sentence that explains a feature
Applying	
apply	Use, utilise, employ in a particular situation
calculate	Ascertain/determine from given facts, figures or information
demonstrate	Show by example
examine	Inquire into
identify	Recognise and name
use	Employ for some purpose

Analysing	
analyse	Identify components and the relationship between them; draw out and relate implications
calculate	Ascertain/determine from given facts, figures or information (requiring more manipulation than simply applying the maths)
classify	Arrange or include in classes/categories
compare	Show how things are similar or different
contrast	Show how things are different or opposite
critically (analyse/ evaluate)	Add a degree or level of accuracy, depth, knowledge and understanding, logic, questioning, reflection and quality to (analyse/evaluate)
discuss	Identify issues and provide points for and/or against
distinguish	Recognise or note/indicate as being distinct or different from; to note differences between
infer	Recognise and explain patterns and meaning and relationships
interpret	Draw meaning from
research	Investigate through literature or practical investigation
Evaluating	
appreciate	Make a judgement about the value of
assess	Make a judgement of value, quality, outcomes, results or size
conclude	Come to a judgement or result based on the reasoning or arguments that you present
critically (analyse/ evaluate)	Add a degree or level of accuracy, depth, knowledge and understanding, logic, questioning, reflection and quality to (analyse/evaluate)
deduce	Draw conclusions
evaluate	Make a judgement based on criteria; determine the value of
extrapolate	Infer from what is known
justify	Support using an argument or conclusion
propose	Put forward (for example a point of view, idea, argument, suggestion) for consideration or action
recommend	Provide reasons in favour
select	Choose one or more items, features, objects
Creating	
construct	Make; build; put together items or arguments
design	Provide step for an experiment or procedure
investigate	Plan, inquire into and draw conclusions about
synthesise	Put together various elements to make a whole

SCIENCE TAKES YOU PLACES

Look who is using science



SCIENCE TEACHER

My name is Sarah Peng and I am a science teacher at a state secondary school.

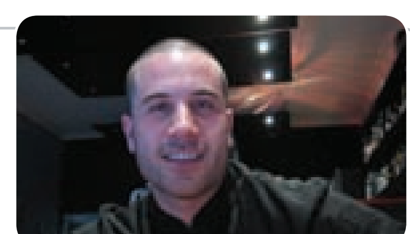
Like many scientists, I have always been curious about how the things around me work. It was natural, then, that I moved into the sciences. At university I specialised in biology and chemistry, and I soon discovered that the best way to share my passion and enthusiasm was to become a science teacher. So, here I am today!

In my role as a teacher I help my students develop a better understanding of the world around them, and show them the skills that enable them to investigate it safely and explore it scientifically. Teaching always brings its challenges and rewards, but overall I really enjoy seeing my students get excited about science and become confident in their skills and their understanding of the subject.

PERSONAL TRAINER

My name is Rebecca O'Sullivan and I'm a gym instructor at one of the gyms run by the YMCA.

In health consultations and re-assessments, I take measurements to determine a person's fitness. I take their blood pressure and heart rate to see the health of their cardiovascular system and measure their height and weight to determine if a member is at an ideal weight for their height. I also measure the thickness of their arms, chest, waist, hips and thighs so that I can compare their size at the next re-assessment. The member is also taken through an aerobic fitness test to determine the volume of oxygen pumped to the muscles during exercise. All these measurements then allow me to write up a suitable exercise program for the member. In my own way, I am a scientist who tests the fitness of people. My laboratory is the health consultation room.



CHEF

My name is Joe Spataro and I'm the head chef and owner of a restaurant.

As a chef I invent new dishes, but as head chef I'm also responsible for the efficient running of the kitchen. This includes looking after the safety of everyone who works in the kitchen. Like laboratories, kitchens can be extremely dangerous places. We work with knives, hot stoves and ovens, and pots of boiling water and oils that can scald or burn. I also need to ensure that the kitchen is kept clean and tidy and that foodstuffs are stored at the right temperatures and away from cleaning chemicals. In this way, a kitchen is like a laboratory. It is where I experiment but it also has risks.

1 Investigating science

HAVE YOU EVER WONDERED…

- why science is taught in schools?
- why scientists run experiments?
- why laboratories have rules?

After completing this chapter students should be able to:

- apply correct scientific terms
- identify where science has been used to make claims about products
- apply specific skills and safety rules
- assess situations and develop safety rules that should apply
- construct tables and graphs to display data
- identify the correct units for a measurement
- identify controlled, dependent and independent variables
- work as a team to investigate a problem.

1.1 A subject called science

Scientists study the world around them to find out how it works. They investigate the living world of animals, plants, bugs and micro-organisms, and they investigate the planet and environments they live on and in. They investigate the physical world of substances like plastics and metals, and chemicals like water and acids. They investigate forms of energy such as heat, light and sound. They even study things that are out of this world, like other planets, stars and galaxies.

Science is important

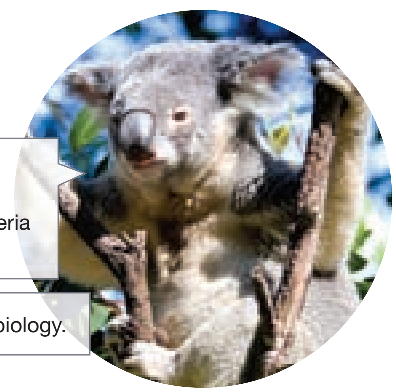
The world is very complex and is becoming more complex every day. New technology is constantly developing and new issues are constantly hitting the headlines. For example, HD televisions, Blu-ray, iPods and Wii players were not around ten years ago. Laptop computers, mobile phones, email and internet are only a little older. Likewise the issues of climate change were not heard of until relatively recently.

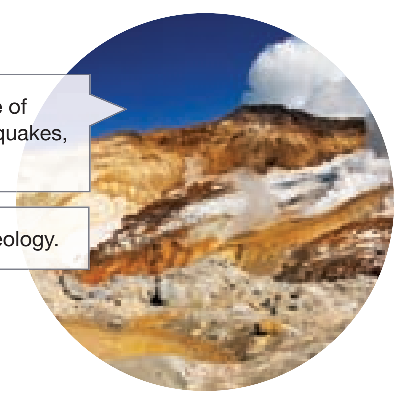
Developments in science have also caused argument and debate. Cloning, the use of stem cells to repair damage in the body, and genetically modified food have all developed from scientific discovery, and society has split into those who support their use and those who don't. Climate change, and what we as humans should do to control it, has also split society into those who believe that it is happening and those who don't. There is even debate among those who do believe it is happening: some believe that it is caused by human activity, while others believe it is just a natural cycle. Whatever its cause, glaciers like the one in Figure 1.1.1 are melting at a higher-than-normal rate. Older issues, such as whether nuclear power should be used in Australia, are being debated again because of our increasing energy needs. As a future adult and voter you will need an understanding of science to help you decide what we should do about these issues and any new issues that arise. To make good decisions about our future, you will need an understanding of science.

The branches of science

The subject of science covers many different areas, ranging from acids to aardvarks, electricity to emus, rats to rocks, Venus to viruses, and much, much more. Science covers so many different areas that it must be split into different **branches** as shown in Figure 1.1.2. Scientists tend to work in one particular branch of science. This allows them to explore it in detail and develop a deep understanding of it without being distracted by what is going on in the other branches.

Figure 1.1.1 Climate change: do we believe the evidence that temperatures are rising because of human activity or do we reject it based on other evidence?





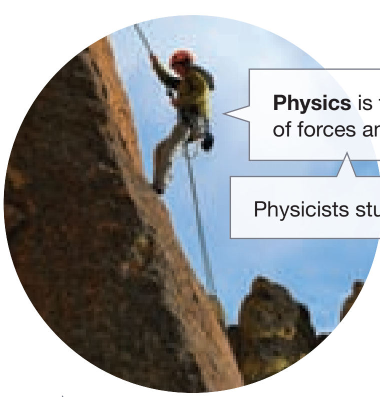


Figure 1.1.2 The main branches of science

Sub-branches of science

The branches of science are so broad that they are split into smaller sub-branches. Geology, for example, covers so much material that a geologist would find it impossible to study it all. Instead geologists tend to specialise by working in a sub-branch like petrology (the study of rocks), palaeontology (fossils), vulcanology (volcanoes) or seismology (earthquakes).

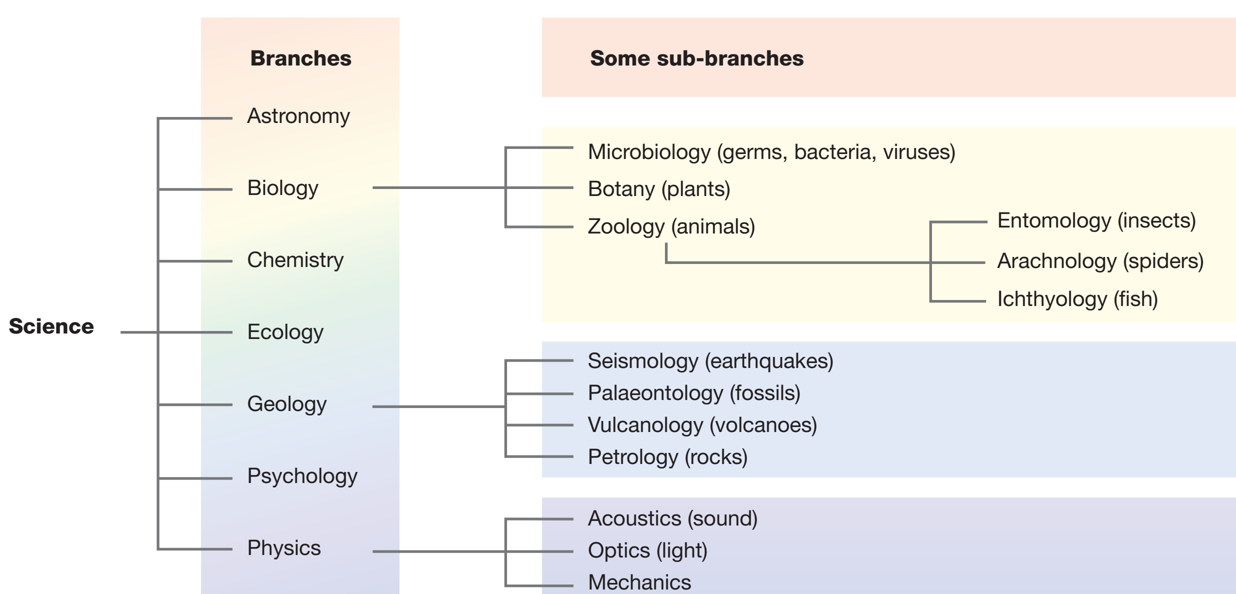
Likewise, there are so many types of living things that biologists specialise in the study of only one type of living thing, for example, animals (zoologists study zoology), plants (botanists study botany) or germs (microbiologists study microbiology). Even sub-branches are sometimes too big: for example, zoology covers so many different types of animals that it is split into smaller sub-branches such as insects (entomologists study entomology), spiders (arachnologists study arachnology) and fish (ichthyologists study ichthyology), as shown in Figure 1.1.3.

SciFile

The science of poo

There are lots of other very specific sub-branches of science. Some are teuthology (the study of the octopus), mycology (the study of fungi), carpology (the study of fruits and seeds) and oology (the study of eggs). Even the scientific study of poo has its own sub-branch: scatology!

Figure 1.1.3 The branches of science are split into smaller sub-branches. Some of these are then split into even smaller sub-branches.



Some common tasks

There are many different branches and sub-branches of science but they are all similar in the basic tasks that their scientists need to carry out. All scientists:

- make observations and measurements
- classify objects into groups of similar things
- make inferences and predictions about what is happening and what might happen in the future
- analyse their measurements, plotting graphs, making calculations and looking for patterns
- make models to help them understand what is happening.

You will learn more about all these tasks later in the book. Most importantly, scientists work as part of a team. You will do this too, especially during practical activities. Teamwork is what's happening in Figure 1.1.4.

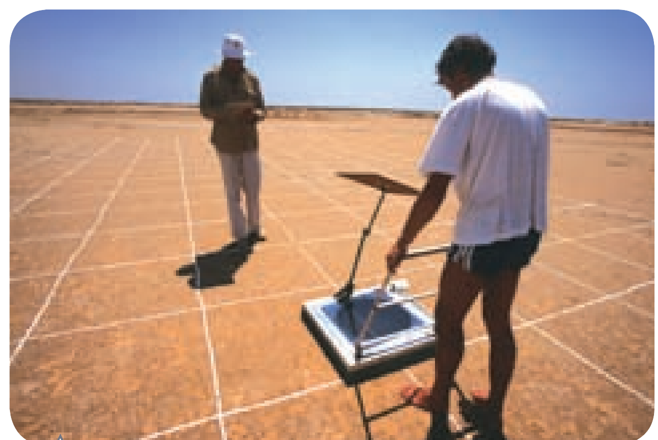


Figure 1.1.4 Everyone is good at something and not so good at something else. By working as part of a team, scientists can share their skills.

SCIENCE AS A HUMAN ENDEAVOUR

Use and influence of science

Science and the law

Laws make you wear a bike helmet because science has shown that helmets can protect you from serious head and brain injury.

Figure 1.1.5

1.1

The observations that scientists gather and the conclusions they make form the basis of many of the laws and regulations that we all must follow every day.

For example, scientific evidence on car and bike crashes has led to speed limits, and laws that make us wear seat belts in cars and helmets when riding a bike or motorbike. In a similar way, scientific evidence on bushfires has led to laws determining days of total fire ban and the types of houses that are built in areas of high bushfire risk.

Scientific evidence has also been used to form laws and regulations that:

- make car manufacturers include airbags, crumple zones and crash-resistant fuel tanks
- control the type of houses built in areas at risk of floods or cyclones
- determine which drugs should be illegal, which should be available on prescription and which can be bought at the supermarket
- control the type of additives that can be put in food
- control how long food can be sold for ('use by' and 'best before' dates)
- determine unsafe levels of sound, chemicals and dust for workers
- control the type and amount of pollutants that can be released into rivers, soil and atmosphere
- preserve animals, plants and landscapes at risk of being lost forever.

Sometimes, scientific evidence leads to changes in global laws. For example, chemicals called chlorofluorocarbons were destroying the ozone layer, putting us all at greater risk of skin cancer. Governments across the world have since banned the use of chlorofluorocarbons in everyday products like deodorants and hair sprays and in fridges. Similar laws will be required to limit the release of carbon dioxide to minimise global climate change.

1.1 Unit review

Remembering

1 **Name**:
  a devices that have only been around in the last ten years
  b a scientific issue that has arisen in the last ten years.

2 **List** seven important branches of science.

3 **List** four sub-branches for each of:
  a biology
  b geology
  c physics.

Understanding

4 **Explain** why everyone needs to have an understanding of science.

5 A biologist usually specialises in one sub-branch of biology. **Explain** why.

Applying

6 **Identify** the branches of science that are being studied below.
  a Amanda is measuring the amount of pollution in a lake.
  b Sarah is making a video of a volcano erupting.
  c Brian is studying the movement of the planets.
  d Yang is measuring the speed of sound.
  e Joe is testing what an acid does to metal.

7 For each of the following investigations, **identify** the branch and sub-branch that is being studied.
  a Abdul is counting how many eggs a cockroach has laid.
  b Hon is studying the crystals embedded in a rock.
  c Travis is investigating how light bends as it passes through glass.
  d Lisa is photographing the bones of a dinosaur.
  e Francesca is measuring the growth of a seedling.

Analysing

8 **Compare** the similarities and differences between the types of work done by a detective and a scientist.

9 Refer to the contents pages (pages v–vii) and **classify** each of the chapters as biology, chemistry, physics, geology or astronomy (space).

Evaluating

10 Some branches of science cover two or more other branches. **Propose** what two branches of science are studied in biochemistry.

Inquiring

1 Search available resources such as textbooks, encyclopedias and the internet, to construct a short biography of the life and scientific achievements of the Australian scientist David Unaipon (Figure 1.1.6).

Figure 1.1.6 David Unaipon was an Australian scientist and inventor. He is shown on the $50 bill.

2 Go to the website for *The New Inventors* and watch a video of this week's inventions.

3 Advertising frequently uses scientific 'evidence' that the product works or that it is better than its competitors. The ad might present scientific evidence on the action of a new additive to a shampoo, deodorant or detergent or discuss which grains are better for your health. Ads for home gym equipment frequently display infrared images showing which muscles are working hard, while some car ads show images of crash-test dummies and anti-skid brake systems.

Find an advertisement on TV, on a billboard, on the internet or in a magazine or newspaper that uses science to help sell the product.
  a Describe how science is used to make the product appear attractive and worth buying.
  b Assess whether the science used is relevant to the product or not.

1.2 The laboratory

The laboratory is where scientists carry out experiments and make observations and measurements. The type of laboratory used by different scientists depends on what they are studying. For many, the laboratory is outdoors. For others, it is a room specially fitted for their experiments. Whatever laboratory and whatever branch of science they work in, scientists use equipment and follow strict rules regarding safety. As a beginning scientist, so will you.

Different laboratories for different scientists

A scientist works in a **laboratory**. Laboratories are where scientists run most of their experiments and make most of their observations, measurements and discoveries. Your idea of a laboratory is probably a large room equipped with Bunsen burners, sinks, glassware, balances and chemicals and occupied by people in white coats and safety glasses. This is the type of laboratory that chemists tend to work in and the type of laboratory that you will eventually work in at school. It might look something like Figure 1.2.1.

Figure 1.2.1 To most of us, the laboratory is a place full of Bunsen burners, glassware and white coats.

Different scientists have very different ideas about what a laboratory is. For marine biologists, the laboratory could be a coral reef. The laboratory of a zoologist might be a rainforest, and a laptop computer and video camera could be their most important equipment. The laboratory of an astronomer will be wherever their telescope is mounted. Figure 1.2.2 shows a palaeontologist at work in his laboratory. Scientists like him will usually have another laboratory in which they can test the samples they collected outdoors. An ecologist, for example, might collect samples of polluted water from a creek but then analyse them back in their other laboratory.

Figure 1.2.2 For palaeontologists, the laboratory could be the site at which a dinosaur skeleton has been found. Their equipment is likely to be a spade and brushes to clear the soil away from around the bones. Sturdy boots, a sunhat and overalls will be far more important to them than white coats.

Equipment

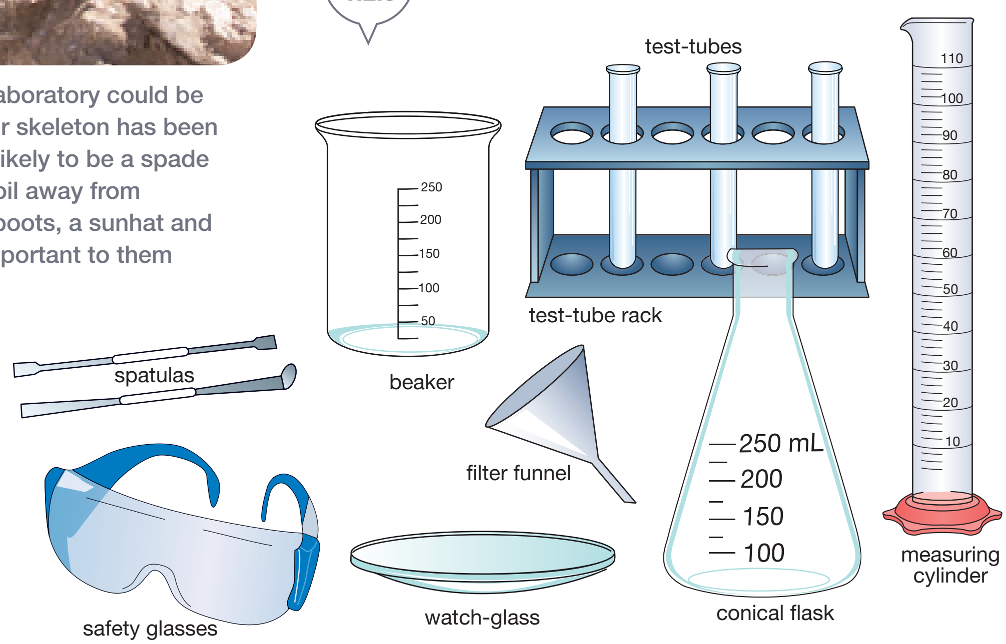
Tools and **equipment** are a necessary part of most jobs. A builder uses power drills and saws, nail guns and measuring tapes, while a chef uses ovens, pots and pans, sieves and measuring spoons. Scientists use equipment too, to help them carry out experiments and to help them describe what they observe more accurately. Each branch of science uses its own specific tools and equipment. An astronomer will not see much without a telescope, and a microbiologist needs a microscope to see bacteria that are invisible to the naked eye. Physicists need ammeters and voltmeters to measure electrical current, and ecologists need pH meters to determine how acidic creek water is. There is, however, a set of equipment common to most laboratories, including the ones at school.

Glassware

Glassware such as beakers, conical flasks, test-tubes and watch-glasses allows you to mix and heat chemicals. Most glassware in the laboratory is made of Pyrex, a special type of glass that is less likely than normal glass to crack when it is heated or cooled. Some common items of glassware are shown in Figure 1.2.3.

Beakers and conical flasks usually have markings up their sides, but the markings only indicate rough volumes. You would use a measuring cylinder to measure more accurate volumes. Volume is normally measured in the laboratory in millilitres (unit symbol mL). Larger volumes are measured in litres (unit symbol L).

Figure 1.2.3 Equipment commonly used in the laboratory



Eating a Vulcano

SciFile

Sometimes laboratories go wrong! In 2009, a Swiss laboratory accidentally discovered how to make chocolate that won't melt on a hot day or in your pocket. It's code-named Vulcano.

SKILL BUILDER

Reading a meniscus

A **meniscus** is the curved shape formed by the surface of a liquid where it contacts another surface. The meniscus is easy to see when the liquid is in a tube such as a measuring cylinder. Sometimes the meniscus curves upwards and sometimes it curves downwards. This could make measuring volumes a little difficult. Figure 1.2.4 shows how scientists measure the volume when a meniscus is present.

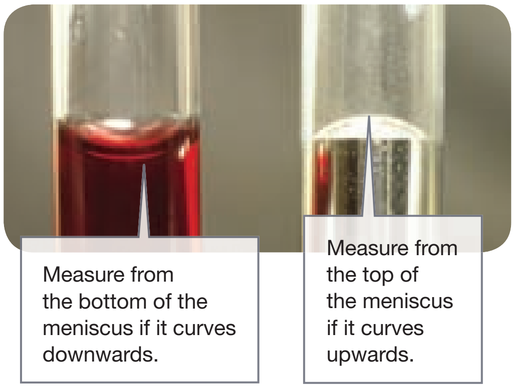


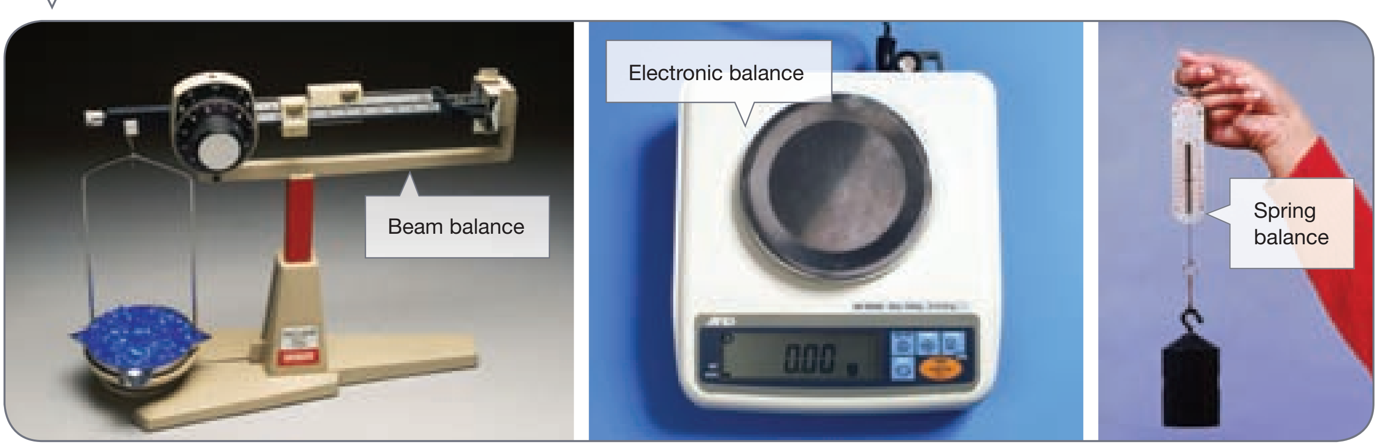
Figure 1.2.4 The surface of a liquid in a measuring cylinder forms a curve called a meniscus.

Balances

The beam balances, electronic balances and spring balances shown in Figure 1.2.5 can all be used to measure the **mass** of an object. Mass is a measure of how much matter there is in an object.

In the laboratory, mass is usually measured in grams (unit symbol g) or kilograms (kg).

Figure 1.2.5 Different balances can be used to measure the mass of an object. Mass is sometimes incorrectly called weight.



Heating equipment

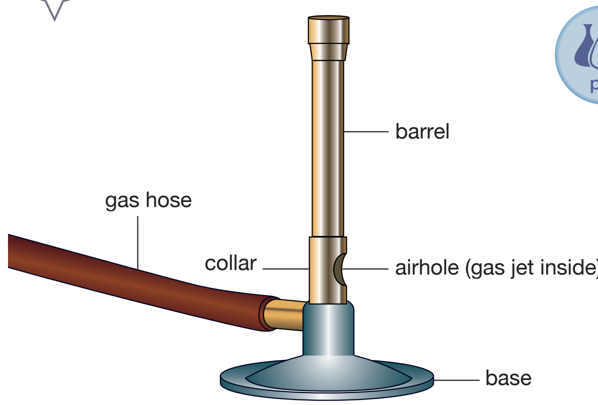
Hotplates and **Bunsen burners** are some of the most important and dangerous pieces of equipment that you will use in the school laboratory. Both get extremely hot and so can burn you seriously if you treat them incorrectly.

Parts of the Bunsen burner

Figure 1.2.6 shows the parts of the Bunsen burner. The collar controls the amount of air that enters the burner and controls the heat and colour of the flame. If you *shut* the airhole, very little air is able to mix with the gas. The gas does not burn well and it produces a pale yellow flame that is easily visible and relatively cool. This is shown in Figure 1.2.7 on page 10. For these reasons, the yellow flame is called the **safety flame**. It is also a dirty flame, because it leaves a layer of black carbon soot on anything that is heated in it.

Figure 1.2.6 The Bunsen burner

1 p14
2 p15



If you *open* the airhole, then a lot of air will enter. The gas will burn efficiently with no smoke, and will be extremely hot (about 1500°C). This flame is noisy. It has a blue colour and is sometimes difficult to see. At the very base of the flame, there is a small cone of unburnt gas. As Figure 1.2.7 on page 10 shows, the hottest part of the flame is just above this cone.

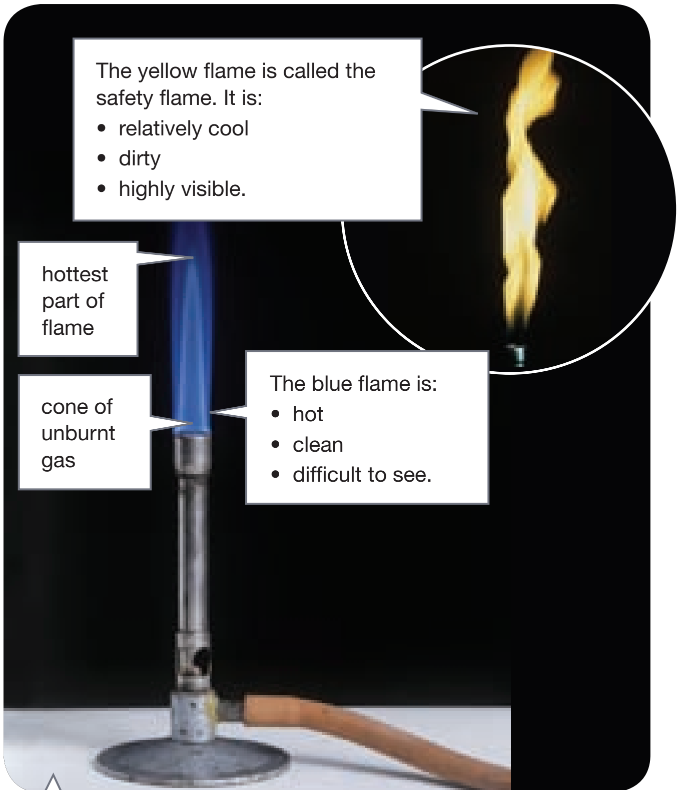


Figure 1.2.7 The yellow flame is easy to see and relatively cool. The blue flame is much hotter and almost invisible. This makes it much more dangerous.

Other equipment used for heating

A kitchen stove isn't very useful unless you have frying pans, saucepans, tongs and stirring spoons to help you cook the food safely. A Bunsen burner also needs additional equipment to help you heat objects and to keep you safe. Some of this equipment is shown in Figure 1.2.8.

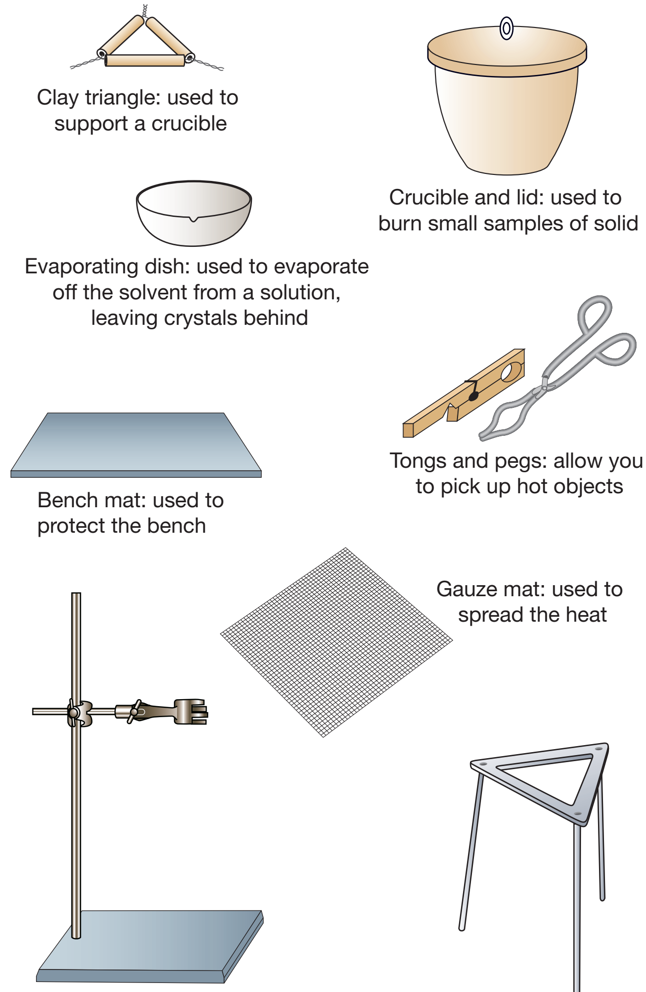


Figure 1.2.8 The hotplate and Bunsen burner need additional equipment to make them useful.

SKILL BUILDER

Heating a test-tube

Test-tubes can spit out their contents if you heat them incorrectly. They can also break.

1. Use a peg or test-tube holder to hold the test-tube near its open end.
2. Point the test-tube away from everyone, including yourself.
3. Heat the bottom gently, moving it back and forth through the flame as shown in Figure 1.2.9.

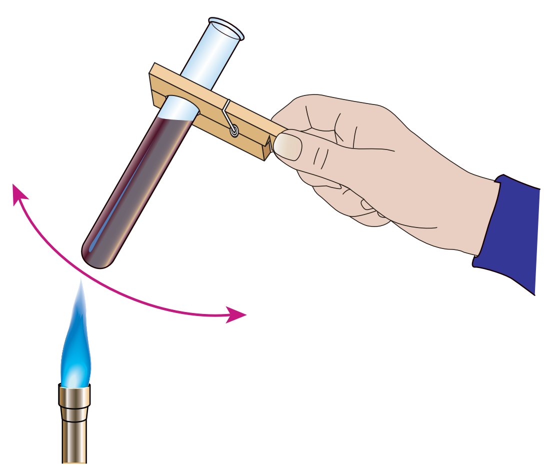


Figure 1.2.9 Never leave a test-tube in the one spot in a flame for too long.

Drawing equipment

Scientists do not draw equipment realistically but as simple two-dimensional (2D) line-drawings, 'splitting' the equipment down the middle to show its **cross-section**.

Figure 1.2.10 shows how scientists draw some of the most common equipment used in the laboratory.

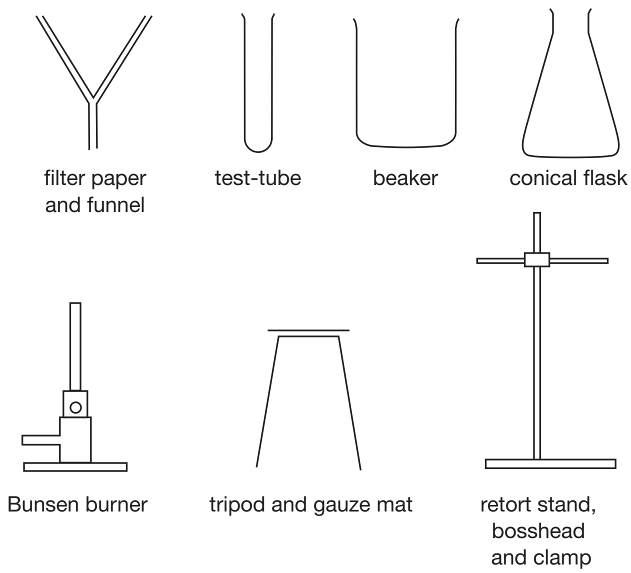


Figure 1.2.10 Scientists draw scientific equipment as simple, two-dimensional cross-sections.

Safety

Science can be fun. Experiments are part of that fun, but they can also be very dangerous. Hotplates and Bunsen burners can burn, and Bunsen flames can set clothes or hair on fire. Acids are corrosive and can burn badly, especially if splashed into your eyes. Many other chemicals are **toxic** and are poisonous if you sniff or taste them. Broken glassware can cut, and small fragments can easily enter your eyes.

Safety rules

The laboratory can be dangerous, but can be safe if we all follow some simple rules. Although each school, each laboratory and each teacher will have their own set of rules that you must follow, some rules are common to all laboratories:

- Always follow instructions from your teacher or laboratory technician.
- Move about the lab in a safe way. Do not run, push or shove.
- Always wear safety glasses when using chemicals.
- Unless instructed to do so by your teacher or lab technician, do not eat, taste, drink or sniff anything in the lab.
- Always tell your teacher if you break something or if you are unsure about what to do.
- Turn on the tap before placing any glassware under it. Otherwise the water might crack the glass of whatever you are holding.

Your teacher and school will give you a list of any other rules that you need to follow in your laboratory.

Other rules apply when you are heating something:

- Always tie back long hair; otherwise it's a fire risk.
- If you need to leave a Bunsen burner on, turn it to a visible yellow safety flame.
- Only use matches to light Bunsen burners.
- Always use tongs to pick up objects that have been heated.
- When you are heating a test-tube, ensure that it is pointed away from everyone (including you).
- Hotplates and Bunsen burners, tripods and gauze mats remain hot for a long time. Allow them to cool before you pack them away.

Safety in the laboratory is really just common sense. If something has the potential to hurt someone then *don't do it!*

Your local experts

If you are confused about equipment, safety, or what you are supposed to do in a laboratory, then there are usually two experts who you can turn to:

- Your science teacher is trained in science and has probably specialised in one particular branch of science, such as biology, chemistry or physics.
- Your laboratory technician (lab tech) will usually be found working behind the scenes in a science department. He or she may come into your laboratory to help your science teacher out, especially if an experiment is particularly dangerous. Your lab tech is trained in safety, the laboratory, its equipment and chemicals.

1.2 Unit review

Remembering

1 **Name** an essential piece of equipment for:
- **a** a microbiologist
- **b** an astronomer.

2 **Name** the special type of glass from which most laboratory glassware is made.

3 **Specify** the temperature that a Bunsen burner flame can reach.

4 **List** four dangers that you will meet in the laboratory.

5 Find the **names** of the two experts you can turn to in the laboratory.

Understanding

6 **Define** the term *cross-section*.

7 **a** The markings on beakers and conical flasks cannot be used to measure out volumes accurately. **Explain** why.
- **b** **Name** the piece of equipment used to measure volumes accurately.

8 All laboratories are different. **Explain** how.

9 A yellow flame will burn you if you are careless, but it is called the safety flame. **Explain** why.

Applying

10 **Identify** the volumes indicated in Figure 1.2.11.

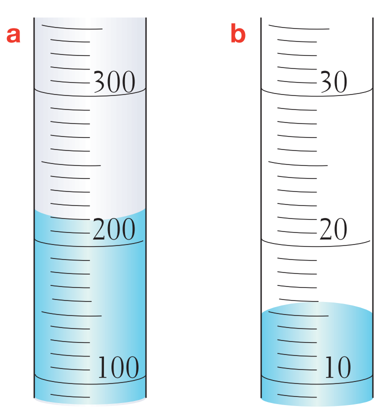


Figure 1.2.11

11 **Identify** whether the following observations would be made of a yellow Bunsen burner flame or a blue Bunsen burner flame:
- **a** dirty
- **b** noisy
- **c** almost invisible
- **d** extremely hot
- **e** closed airhole.

12 **Identify** what the students in Figure 1.2.12 are doing right or are doing wrong.

Figure 1.2.12

Analysing

13 **Assess** what the following safety signs are saying.

a

b

c

d

e

14 **Compare** a beaker with a conical flask.

Evaluating

15 In the laboratory, **propose** a way you could:

- **a** protect your eyes
- **b** avoid slipping while moving around.

16 **Propose** reasons why:

- **a** you should light a match before you turn on the gas to the Bunsen burner
- **b** long hair should be tied back when you are using the Bunsen burner
- **c** eating and drinking is banned in the laboratory
- **d** you should turn a Bunsen burner to a yellow flame if you need to leave it.

Creating

17 You are using a Bunsen burner to heat water in a beaker. **Construct** a scientific diagram to show how your equipment looks.

18 **Create** a sign that warns people that Bunsen burners are hot. Your sign must be in two colours only and use no words.

Inquiring

1 Investigate what an eyewash is and how to use it.

2 Find out what first aid should be applied if you come across someone who has burnt themselves.

3 Find out what a fire blanket is, what it is made of, and how to use it.

4 Research who Bunsen was and what he had to do with the burner named after him.

INQUIRY science 4 fun

Fake wounds

Can you fake an injury?

No

Collect this …

- small ball of coloured dough from your teacher
- small amount of bright red food dye
- spatula or bamboo skewer
- small twigs, cotton wool and bandages

Do this …

1. Pat your lump of dough until it is flat.
2. Pat it onto your skin and blend it in to your skin by squashing its edges down with your fingers.
3. Use the edge of a spatula or skewer to make a fake ‘cut’ in the surface of the dough.
4. Make the wound look more realistic by inserting a small twig into the ‘cut’ and by dribbling some red food dye into it.
5. Use paper towelling, cotton wool or bandages to disguise the edges of the dough.

Record this …

Describe what the cut looked like. Did it look realistic?

Explain what you should do if someone really cuts themselves in the laboratory.

1.2 Practical activities

1 The Bunsen burner

Purpose

To light a Bunsen burner and produce a yellow and blue flame.

Materials

- Bunsen burner, bench mat and matches
- pin

Procedure

Part A: Lighting the Bunsen burner

1 Follow the instructions in the skill builder to light a Bunsen burner.

2 Turn the collar to open and shut the airhole. Observe what colour flames are produced.

3 Turn off the Bunsen burner and allow it to cool.

SAFETY

Tie long hair back.

Turn Bunsen flame to yellow if you need to leave the burner at any time.

Allow all equipment to cool before packing it away.

Part B: Unburnt gas

4 Push a pin through the wood near the top of an unlit match. Balance the match on the top of the Bunsen burner so that the match head is in the centre of its barrel.

5 Light the Bunsen burner as usual and quickly turn it to a blue flame. Figure 1.2.13 shows the correct set-up.

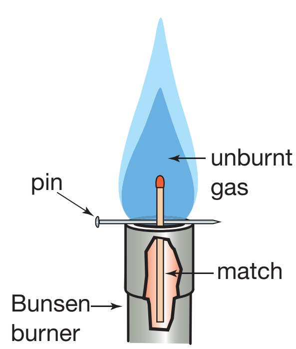


Figure 1.2.13

Results

Record all your observations in a table like the one shown below.

Airhole	Was the flame noisy or quiet?	Flame colour	Other observations
Closed			
Half-closed			
Open			

Discussion

1 **Propose** a reason why the airhole should be closed when you light a Bunsen burner.

2 **Describe** what happened to the match in the barrel of the Bunsen burner.

3 **Explain** your observations.

SKILL BUILDER

Lighting the Bunsen burner

1 Place the Bunsen burner on a heatproof bench mat and connect it to the gas jet.

2 Turn the collar of the Bunsen burner so that the airhole is completely closed.

3 Light a match.

4 Turn on the gas at the gas tap.

5 Hold the lit match about 1 cm over the top of the barrel.

6 If the match blows out then immediately turn the gas off and start again.

7 When lit, the Bunsen burner should produce a bright yellow flame.

8 To obtain a blue flame, turn the collar so that the airhole is opened.

9 This sometimes causes the flame to blow out. If it does, turn off the Bunsen burner and follow the steps above to light it again. Then, to obtain a blue flame, adjust the airhole so that it is not completely open.

2 Investigating the flame

Purpose

To determine which flame is hot, which is cool, which is dirty and which is clean.

Materials

- Bunsen burner, bench mat and matches
- old, 'bald' gauze mat
- small piece of broken white porcelain
- tongs

Procdevice

SAFETY

Tie long hair back.

Turn Bunsen flame to yellow if you need to leave the burner at any time.

Allow all equipment to cool before packing it away.

Part A: Hot or cool?

1 Set up and light the Bunsen burner.

2 Set it to a yellow flame.

3 With tongs, hold the gauze mat vertically in the flame so that it touches the top of the burner as shown in Figure 1.2.14.

4 Set the flame to blue and repeat step 3.

5 Carefully draw diagrams of any heat markings that you see.

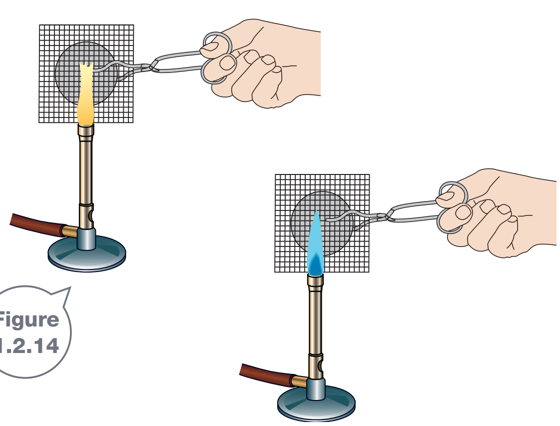


Figure 1.2.14

Part B: Clean or dirty?

6 With tongs, hold the small piece of porcelain in a blue flame and record your observations.

7 Set the flame to yellow and repeat step 6.

Discussion

Part A

1 The wire of the gauze mat will glow red if it is really hot. **Identify** which flame (yellow or blue) made the wire glow red.

2 **Describe** the markings caused by the blue flame.

3 **State** where the flame was the hottest and where it was the 'coolest'.

Part B

4 **Compare** what happened to the porcelain in the yellow flame and the blue flame.

5 **Identify** which flame could be called 'dirty'.

6 **State** whether this was the hot flame or the cool flame.

1.3 Experiments

Scientists carry out experiments to find out something about the world around them or to test a little bit of it. They record their observations and measurements and analyse them so that patterns and trends become clear. They can then make a logical inference about what happened and why. Inferences lead to predictions of what might happen in the future or in experiments under different conditions.

INQUIRY science 4 fun

Magic candles

Can you relight a candle from a distance?

Yes

Collect this ...

- candle
- saucer or Petri dish
- matches

Do this ...

1. Stand the candle upright on the saucer or Petri dish. Melting a little of its base will help it stick.
2. Light the candle and use all your senses except taste to make as many different observations as possible. (Michael Faraday, a nineteenth century scientist, made 53!)
3. Gently blow the candle out and attempt to relight it by moving a lit match down the smoke trail as shown.

SAFETY

Ensure the bench is clear.

Make sure that your candle can't topple over.

Record this ...

Describe what happened.

Explain why you think this happened.

Practical activities

An **experiment** or **practical activity** is a test on a small part of the world around us. It might test the temperatures at which different metals melt, or it might test how Bogong moths know when to migrate to the alpine regions of New South Wales and Victoria. It might test the intelligence of dolphins, how to make building materials fireproof, why some people are allergic to peanuts, why solar eclipses occur, or how chocolate can be made even tastier.

Scientists either design their own experiments or follow the instructions of other scientists who have performed them already. You will be doing this too. You will be given instructions for most practical activities, but some will require you and your group to plan and carry out your own investigations.

Observations and measurements

Although scientists use all of their five senses to make **observations**, sight is probably the sense that gives them the most information. This is the sense being used in Figure 1.3.1. Scientists make either qualitative or quantitative observations.

Figure 1.3.1 The main sense a scientist uses is sight. They will also use hearing, smell, taste and touch, although often it will be far too dangerous to use some of these.

Qualitative observations

Qualitative observations are descriptive. They are recorded as diagrams or written down in words. Qualitative observations would be made about the noise a bird makes, the colour of its feathers, what it eats, and how it acts throughout the day. The appearance of shaving foam and the shape of a crab are qualitative observations too, as is the taste of the food in Figure 1.3.2.

Figure 1.3.2 The look, smell and taste of food are qualitative observations.

Quantitative observations

Describing a day as hot (a qualitative observation) doesn't really give an idea of how hot it is. There is no uncertainty about how hot the day is if you specify the temperature it reached: 43°C is hot in anyone's language! Measurements like this are **quantitative observations**. They are written as numbers and allow scientists to be more detailed and accurate in their observations. Distance, mass, time, temperature and volume are quantitative observations, since all can be written as numbers. For example, chips come in 200 gram bags, cans of soft drink hold 375 mL, water boils at 100°C, and it takes 60 minutes to fly from Melbourne to Sydney, a distance of 881 km.

Sometimes an optical illusion like the one shown in Figure 1.3.3 on page 18 will trick your senses into making qualitative observations that are incorrect. Measurement will usually indicate whether your senses were correct or not.

Figure 1.3.3 An optical illusion makes the floors (orange) of this building in Melbourne's Docklands look as if they are at sloping at different angles. Measurement of the distance between the floors proves that they are all horizontal.

SciFile

Moonface!

The Moon often looks huge as it rises in the east but it is really just the same size as when it is somewhere else in the sky. Check this out by holding your hand out and using your fingers to measure its width as it moves across the sky. The illusion is shown in Figure 1.3.4.

Figure 1.3.4 An optical illusion causes the Moon to look huge when it rises.

Units

Measurements are useless unless the units of measurement are included. Scientists use units from the metric system for their measurements.

- Distances, lengths and heights are measured in millimetres (mm), centimetres (cm), metres (m) or kilometres (km).
- Small masses are measured in grams (unit symbol g). Heavier masses are measured in kilograms (kg) or tonnes (t).
- Volume is measured in millilitres (mL) or litres (L).

Other non-metric units are used as well. For example:

- time is measured in seconds (s), minutes (min) or hours (h)
- temperature is measured in degrees Celsius (°C).

The above units together form a system of units called *Système Internationale* (otherwise known as SI units). Each unit has its own symbol and there is a correct way of writing each symbol. For example, the symbol for millilitres is mL and not ML (which means a million litres). Likewise, the symbol for kilograms is kg, not Kg, KG or kgs.

Taking accurate measurements

Measurements are only worthwhile if they are accurate. So that your measurements are as accurate as possible, make sure that:

- everyone in your laboratory team takes their own measurement. You can then calculate the average of everyone's values
- you keep your eye level with the measurement (like in Figure 1.3.5)
- the measuring device starts at zero.

Mistakes are often made when measurements are recorded but you can avoid this if you take enough care. Reduce the chance of recording measurements wrongly by:

- writing down measurements (with their units) as soon as you take them. Do not try to remember measurements
- avoiding fractions like $\frac{1}{2}$ or $\frac{1}{4}$ in measurements. Use decimals instead. 9.5 kg is fine, $9\frac{1}{2}$ kg is not
- making sure that everyone in the group has a copy of the results before you leave the laboratory.

2 p23

Figure 1.3.5 Keep your eyes level with your measurement.

Inferring and predicting

From your observations and measurements, you can sometimes make an **inference**, or logical explanation, about what happened and why it happened. You may then be able to predict how it could work in the future or if the experiment was run in a different way. A **prediction** must be logical and must be based on the observations you made in your experiments. Every day you make observations, inferences and predictions, probably without even knowing it!

Observation:	Everyone is packing up.
Inference:	It must be nearing the end of the lesson.
Prediction:	The bell will ring soon.

In science, you might start with an observation from an experiment:

Observation:	Cubes of sugar dissolve in tea faster when they are broken into smaller pieces.
Inference:	Smaller pieces mix better with the water than larger lumps, making them dissolve faster.
Prediction:	If the sugar is crushed even finer, then it will dissolve even faster.

INQUIRY science 4 fun

The eyes have it

What is the most accurate way of making observations?

Yes

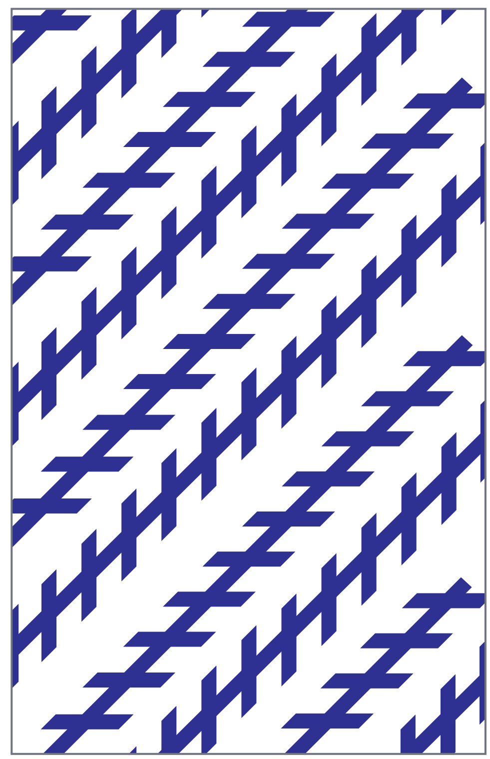
Collect this ...

- a ruler

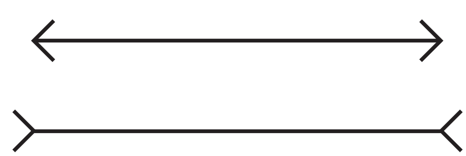
Do this ...

1 Look at the following diagrams and describe them.

a



b



2 Now measure the distance between the lines in diagram a.

3 Measure the length of the lines in diagram b.

Record this ...

Describe the observation that was most accurate.

Explain why you think this happened.

1.3 Unit review

Remembering

1 **List** your five senses.

2 **List** three observations about each of the following:
- a a candle
- b molten (melted) candle wax
- c a candle flame
- d the smoke from a candle that has been blown out.

3 **State** the measurements shown in each of the measuring devices in Figure 1.3.6.

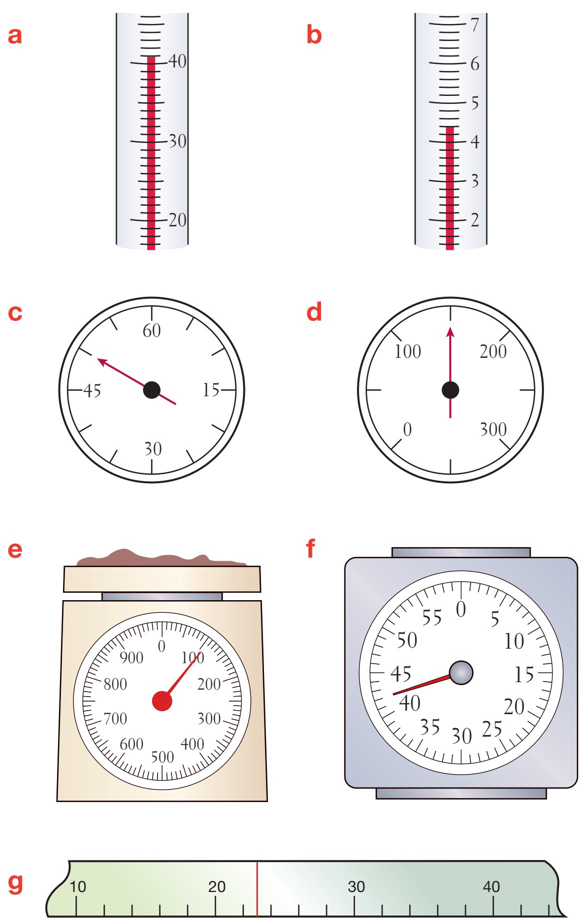


Figure 1.3.6

4 **State** which of the abbreviations below are correct for these units:
- a gram
  - A gm B gms
  - C G D g
- b kilogram
  - A kilo B kg
  - C Kg D KG
- c millimetre
  - A mms B mm
  - C Mm D mL
- d litre
  - A lt B mL
  - C lit D L
- e minutes
  - A min B m
  - C mins D ms

Understanding

5 **Explain** what advantages quantitative observations have over qualitative observations.

6 Give an example to **explain** how optical illusions can lead you to make faulty observations.

Applying

7 **Identify** the best metric unit to use to measure the length of:
- a a bull-ant
- b the length of a cricket field
- c the distance between Brisbane and Cairns.

8 **Identify** the best SI unit to measure the:
- a mass of a mouse
- b time it takes to sneeze
- c temperature of a sick dog
- d mass of a person
- e volume of a swimming pool.

9 **Identify** what is wrong with the way these measurements have been recorded.
- a The mass of a mouse = $150\frac{1}{4}$ g.
- b The car was travelling at 100.
- c A full bottle of soft drink contained 1.25 mL.

10 Sometimes it is too dangerous to use some of our senses. **Identify** which senses you would and would not use in the following experiments.

Activity	Senses that would be safe to use	The sense that would give you the most information	Senses that would be unsafe to use
Testing a new rat poison			
Testing whether minced steak is OK to eat or is 'off'			
Testing the lava flowing from a volcano			
Testing how dangerous an acid is			
Testing whether tomatoes are ripe			

11 In each part of this question there is an observation, an inference and a prediction. **Identify** which is which.
- a i Dinner is being cooked.
  - ii Food smells are coming from the kitchen.
  - iii Dinner will be in half an hour.
- b i The colours of a felt-tip pen ran when they got wet.
  - ii Washing should get the stain of a felt-tip pen out of my shirt.
  - iii The inks used in a felt-tip pen can dissolve in water.
- c i The soup is hot.
  - ii Steam is rising from the soup.
  - iii I'll need to wait a while before I can start.

Analysing

12 **Contrast** qualitative with quantitative observations.

13 **Classify** the following observations as qualitative or quantitative.
- a The night was dark.
- b There were 68 people in the hall.
- c It took 15 minutes to walk to school.

14 The following are statements about the gas you breathe out. **Classify** each statement as an observation, an inference or a prediction.
- a It's hot, moist, colourless and clear.
- b It's carbon dioxide.
- c It's a gas.
- d It's one of the chemicals produced by chemical reactions in your body.
- e If gas stops coming out, then you will soon be dead.

Creating

15 **Design** a way of measuring the:
- a mass of a Smartie or an M&M without using any weighing device
- b thickness of a piece of A4 paper with a normal ruler
- c average number of your heartbeats in a minute.

Inquiring

1 Search the internet for images and video of optical illusions such as the Zolner illusion.

2 Write a short history of the metric system.

3 Find the years in which Australia adopted the metric system.

4 Some chemicals used in a laboratory are thrown in the bin, some are washed down the sink and others have very special requirements for their disposal. It all depends on how dangerous they are. Find out what happens to different chemicals used in the laboratory after an experiment.

1.3 Practical activities

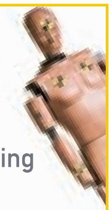
1 Hot, hotter, hottest

Purpose

To compare qualitative with quantitative measurements.

Materials

- 4 × 250 mL beakers or identical tubs
- thermometer
- ice
- warm water



SAFETY
Do not use boiling water

Procedure

1. Fill four beakers and arrange them as shown in Figure 1.3.7.
2. Immerse (place) your left hand in the beaker containing cold water and your right hand in the beaker containing warm water. Leave your hands in the water for 30 seconds or so.
3. Remove your hands and put each hand into a beaker containing tap water.
4. Leave them there for 30 seconds or so. Does the water feel the same to both hands, or does one feel hotter?

Results

1. Copy out the table below into your workbook.

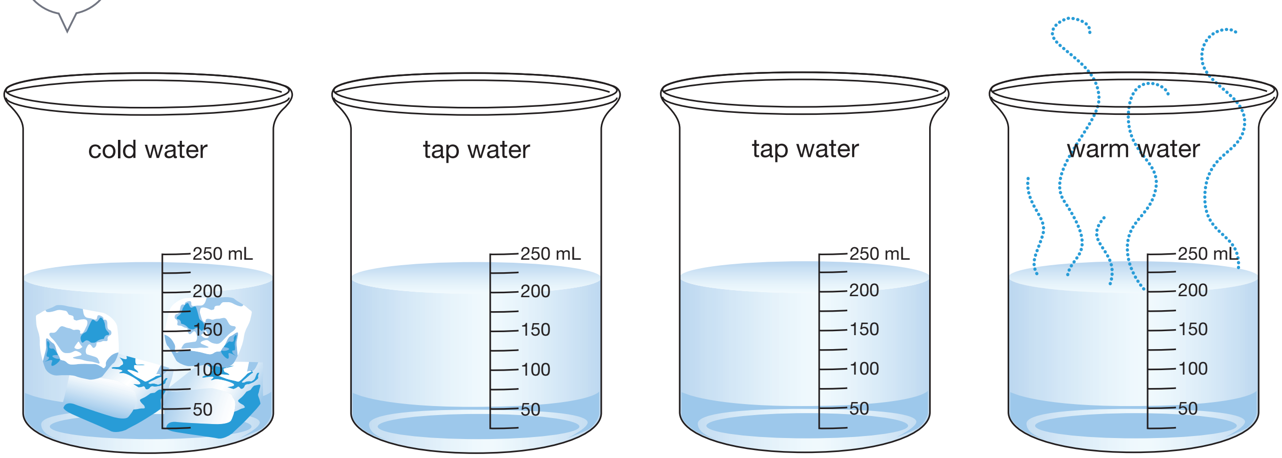
Beaker	Actual temperature (°C)	What it felt like (very hot, hot, cool, cold)
Water–ice mixture		
Tap water 1		
Tap water 2		
Warm water		

2. Rate what the temperature of each beaker felt like: very hot, hot, cool or cold. Record your ratings in the table.
3. Check the accuracy of your ratings by measuring the actual temperature of each beaker with the thermometer. Record each temperature in the table.

Discussion

1. **Identify** the quantitative observations you took in this activity.
2. **Identify** your qualitative observations.
3. **State** whether your qualitative observations agreed with your quantitative ones.
4. Quantitative observations can be trusted more than qualitative observations. **Explain** why.

Figure 1.3.7



2 Taking measurements

Purpose

To observe that not everyone takes the same measurement.

Materials

- access to a range of equipment that shows different quantities (such as a 250 mL beaker, 100 mL conical flask or a 100 mL measuring cylinder containing different quantities of water, a beam or electronic balance with a mass on it, a sheet of paper with a ruler to measure its length)
- A4 sheet of paper next to each piece of equipment

Procedure

Move around the laboratory and read the measurement for each piece of equipment.

Results

1 Construct a table similar to the one below in your workbook.

Name of equipment	Measurement	Units

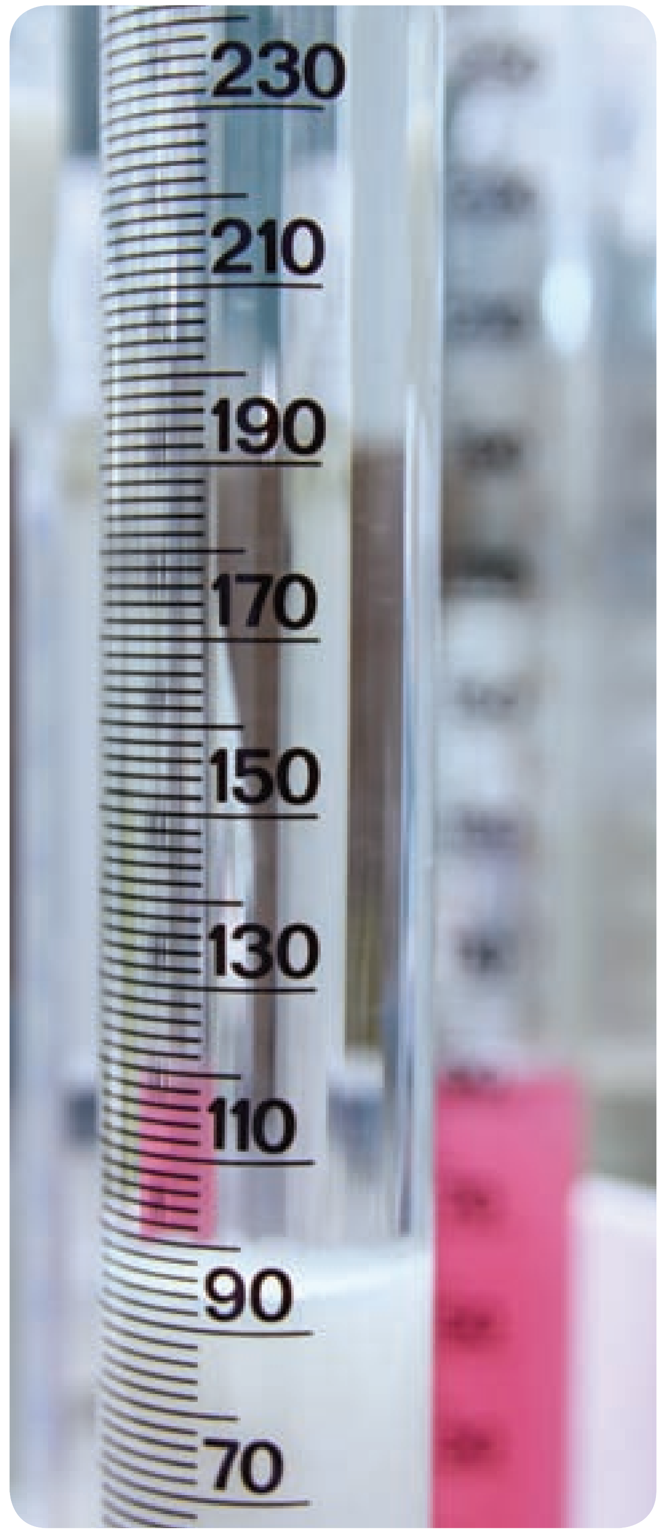
2 Record your measurement in the table and on the paper next to each piece of equipment.

3 After you finish, check all the measurements written on the pieces of paper and determine if they are all exactly the same.

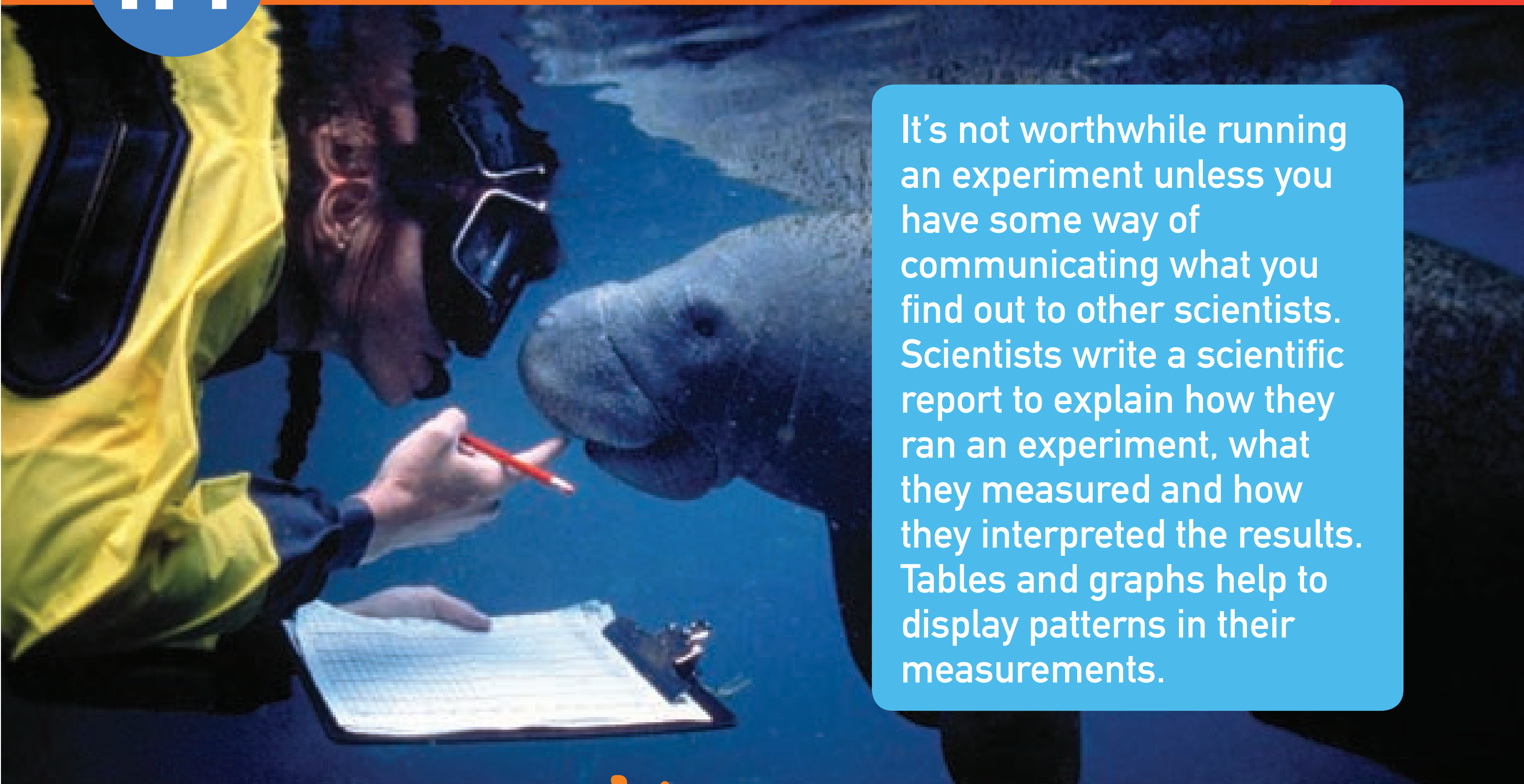
Discussion

1 Everyone in a team will take slightly different measurements, even when measuring exactly the same thing. **Propose** reasons why.

2 **Describe** a way of using all the results on the paper to obtain an even better result.



1.4 Communication



It's not worthwhile running an experiment unless you have some way of communicating what you find out to other scientists. Scientists write a scientific report to explain how they ran an experiment, what they measured and how they interpreted the results. Tables and graphs help to display patterns in their measurements.

INQUIRY science 4 fun

Broken whispers

Yes

Can a group communicate a piece of information accurately without writing it down?

Do this …

1. As a class or in a group, sit around in a circle.
2. One of you is to construct a short story that takes no more than two sentences to tell.
3. The story is to be passed on around your group by one person whispering it very quietly to another.
4. Compare the original story with the story that it ended up being.

Record this …

Describe what happened.
Explain why you think this happened.

Tables

Measurements and observations are easier to read and analyse if they are displayed in tables. Tables also make trends (patterns) in the measurements more obvious. Each column in a table needs to have a clear heading that includes the units in which each measurement has been taken.

Computer programs such as Excel allow you to produce an electronic table on a computer. This type of table is known as a spreadsheet.

Graphs

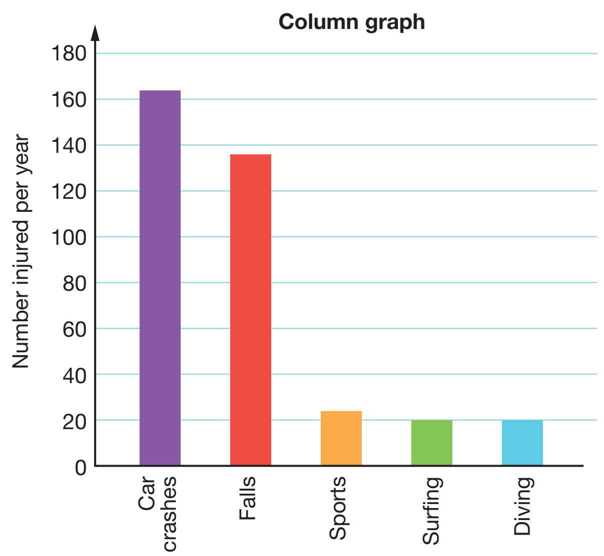
A graph shows trends in measurements even more clearly than tables do. The type of graph you draw depends on the types of observations you make.

Bar and column graphs

Some observations fall into discrete groupings. This means that all the observations can be sorted into categories and counted. Animals, for example, fall into discrete groupings like kangaroos, ants, cockatoos and sharks. Other observations that have discrete values are makes of cars (such as Holden, Toyota, Ford, Mazda), sports (netball, football, golf, tennis), building materials (timber, brick, concrete, glass) and the sex of people (male or female).

Bar and **column graphs** are used when you have a set of observations that are discrete. These discrete values are displayed on one of the axes of the graph while numbers are displayed on the other axis, as shown in Figure 1.4.1. Axes are the horizontal and vertical lines 'framing' the graph.

Cause of spinal injury	Average number injured per year
Car crashes	164
Falls	136
Sports	24
Surfing	20
Diving	20



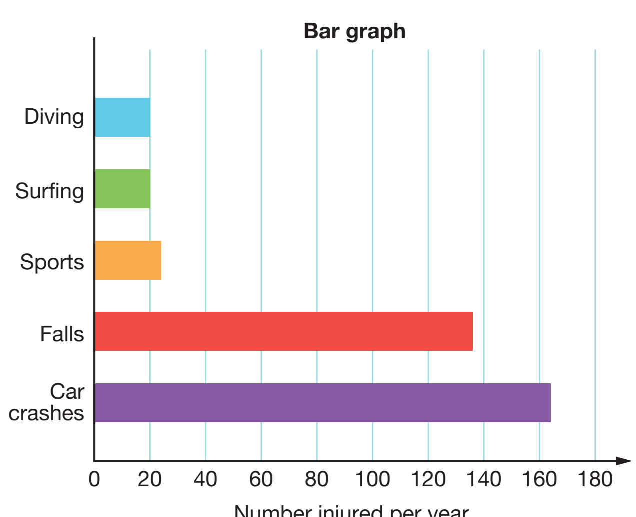


Figure 1.4.1 There are five main causes of injuries to the spine. These two graphs indicate how many Australians are injured on average per year.

Pie graphs

Discrete groupings are also used to construct **pie graphs** or pie charts. A pie graph shows the proportions of each grouping within a total. In a pie graph, the whole pie represents 100%, half the pie represents 50% and a quarter-pie represents 25%. As an example, Figure 1.4.2 shows the percentages of different animals living in a nature reserve.

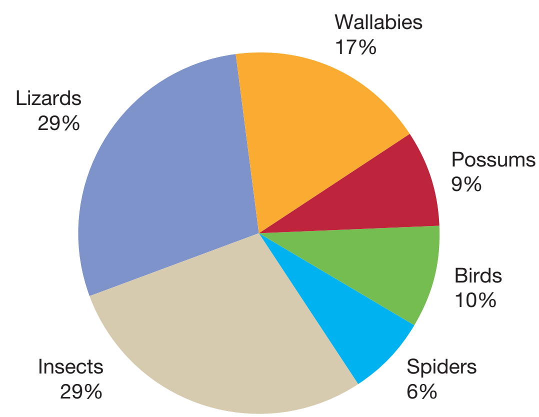


Figure 1.4.2 This pie graph shows the proportions of each animal in a nature reserve and not their real numbers.

Line graphs

Measurements involve numbers that are not discrete but *continuous*. This means that if you choose two numbers, then you can always find other numbers in between them. For example, between 10 and 20 you will find the numbers 11, 12, 13, 14 and so on. Between them are even more numbers such as 11.4, 12.7 and 13.576362. Measurements therefore vary continuously. Continuous variation is shown in the height of humans. Imagine measuring the height of every student and teacher in your school. There would be a spread of heights from short to tall with most heights represented in between. Length, mass, time, volume and temperature measurements are continuous.

Line graphs require two sets of measurements, that show continuous variation. This is shown in Figure 1.4.3 on page 26.

1 p29

Once you have plotted all the points on a line graph, do not connect up the points dot-to-dot. Instead, draw a straight line or a smooth curve roughly through the centre of the points you have plotted. A straight line like this is called a line of best fit while the curve is called a curve of best fit. These 'best fits' clearly show patterns that might exist in the measurements you took in the experiment. These patterns can be described as shown in Figure 1.4.4 on page 26.

2 p30

Age of mouse (days)	Mass (g)
0	5
2	15
4	22
6	25
8	27
10	28

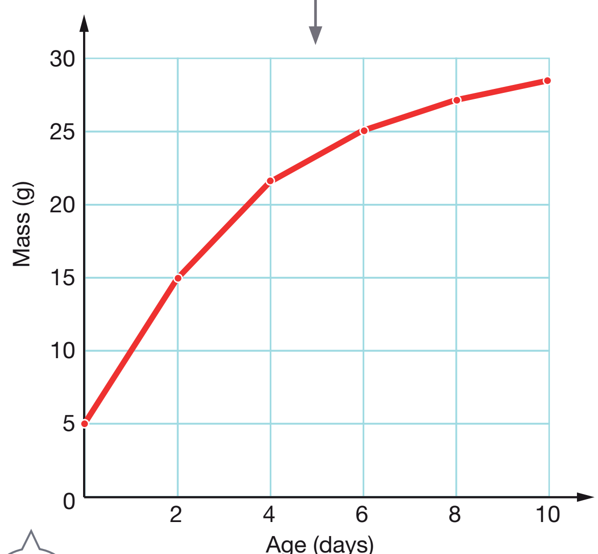


Figure 1.4.3 Line graphs need two sets of numbers to plot.

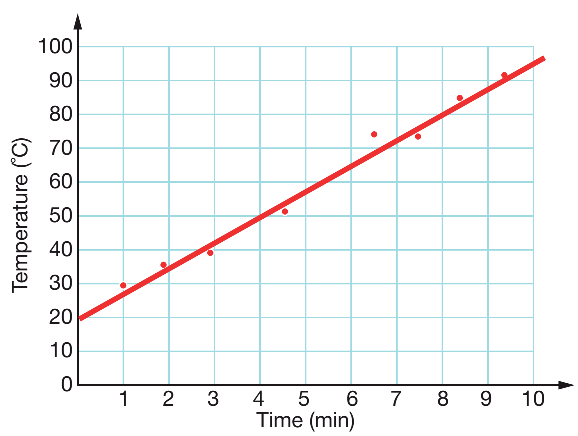


Figure 1.4.4 A line of best fit is drawn roughly through the middle of all the points. In this way, the line of best fit shows the trend or pattern in the graph.

Scientific reports

Scientific reports are used by scientists to communicate to other scientists how they performed an experiment and what they found out in it. If you set out your report clearly and logically, then it allows other scientists to repeat your experiment.

Aim or purpose

The **aim** or **purpose** is what you wanted to do in an experiment or practical activity, what you wanted to show or wanted to prove.

Hypothesis (optional)

You probably have some idea of what might happen in an experiment even before you start it. This 'educated guess' is called your **hypothesis**. A hypothesis is an inference based on what you already know. A hypothesis is not always included in a scientific report.

Materials

This is a list of all the *important* equipment, chemicals and materials that you used. If equipment comes in different sizes, then make sure you include the size you used (for example, 250 mL beaker).

Method or procedure

The **method** or **procedure** is a detailed list of what you did in the experiment. You must include what quantities were used (for example, 5 g, 2 spatula loads or 10 mL), and the exact order in which the steps of the experiment were performed. A diagram of the experiment is a useful way of showing what you did.

Results

Results include all your observations and all your measurements, preferably displayed in a table.

Discussion or analysis

Include in your **discussion** or **analysis**:

- answers to any questions asked in the activity
- any graphs you plotted
- an explanation about what you think your results showed about the experiment
- what you have found about the experiment from other sources such as textbooks, the internet or encyclopedias
- a description of any problems you had with the experiment and what you did to overcome them.

Conclusion

Your **conclusion** needs to summarise what you have found out in the experiment. The conclusion should be short and must relate to the purpose.

1.8

1.4 Unit review

Remembering

1 **Recall** the main sections of a scientific report by matching the following:

Purpose	instructions
Hypothesis	the end
Materials	aim
Procedure	analysis
Discussion	equipment
Conclusion	educated guess

2 **List** the things that should be included in the following sections of a scientific report:

a materials
b procedure
c discussion.

Understanding

3 **Explain** why scientists would want to read what others have found out in experiments.

Applying

4 Adrian ran an experiment in which he tested how much sugar would dissolve in a hot cup of tea.
Identify the best conclusion for his experiment.

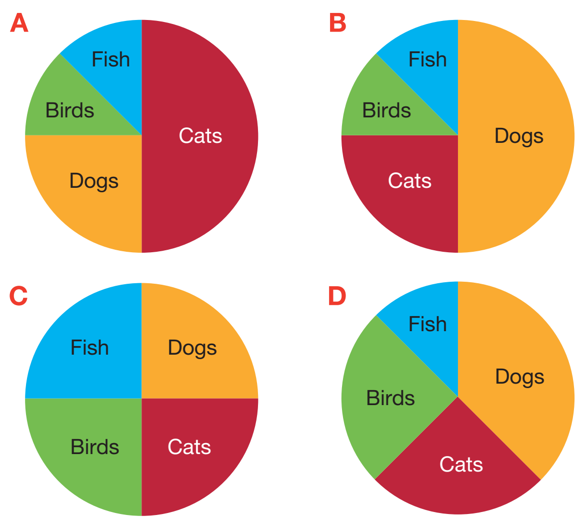
A The experiment was fun.
B I learnt a lot from the experiment about sugar dissolving in hot tea.
C 3 teaspoons of sugar were able to be dissolved in a hot cup of tea.
D Tea tastes better when there is sugar dissolved in it.

5 **Identify** whether a column/bar, pie or line graph would best show the following results.

a The top speeds of different makes of cars
b The temperature of a room throughout a winter's day
c The types of animal with different numbers of legs
d The percentages of your classmates who were born in Australia and overseas
e Your height as you get older

6 **Identify** which of the graphs A–D best represents the results in the table.

Type of pets	Percentage (%)
Dogs	50
Cats	25
Fish	13
Birds	12



7 Use the key below to **identify** the term that best describes the trend shown in each of the line graphs in Figure 1.4.5.

A constant **B** increasing
C decreasing **D** no trend shown.

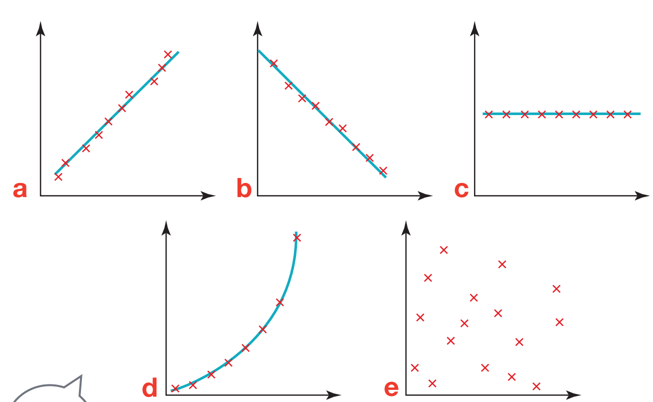


Figure 1.4.5

1.4 Unit review

Analysing

8 Draw simple sketches to **contrast** a column graph with a:

- **a** bar graph
- **b** pie chart
- **c** line graph.

Evaluating

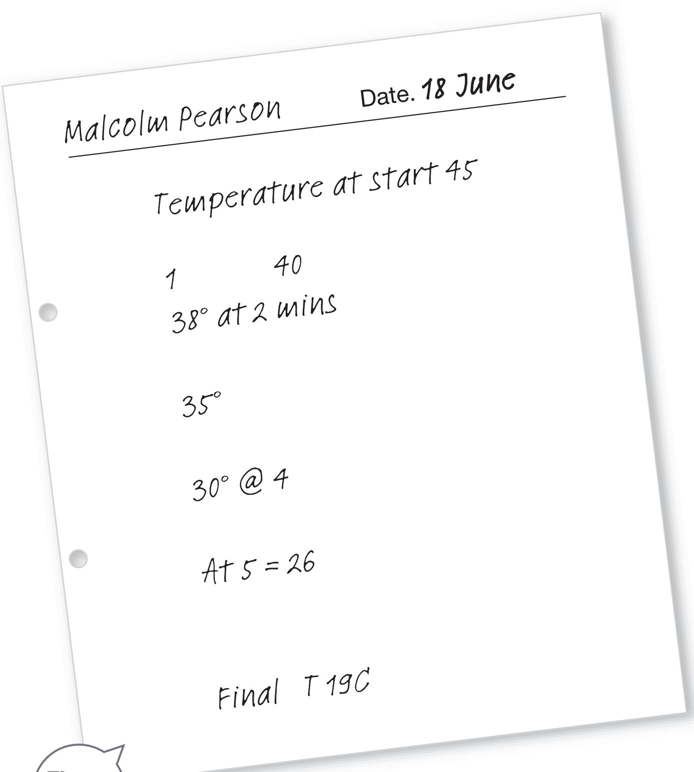
9 **Propose** reasons why a message sent around a room via whispers often ends up very wrong.

Creating

10 **Construct** an appropriate conclusion for the following aims.

- **a** To test if fishing line is stronger than string
- **b** To prove that water boils at 100°C
- **c** To determine how much water a sponge can hold

11 **Construct** a table for the poorly recorded results shown in Figure 1.4.6.



Malcolm Pearson Date. 18 June

Temperature at start 45

1 40

38° at 2 mins

35°

30° @ 4

At 5 = 26

Final T 19C

Figure 1.4.6

12 Bridie noted the speedometer reading every 5 seconds as her mum's car accelerated. At the start, the speed was 0 km/h. The speed was 20 km/h after 5 seconds, then 30, 50, 60 and 80 every 5 seconds after.

- **a** **Construct** a table to display her results.
- **b** **Construct** a line graph to show her results.

Inquiring

Find out about the Mars Polar Lander (Figure 1.4.7), the spacecraft that crashed into Mars as a result of poor communication between different groups of scientists.

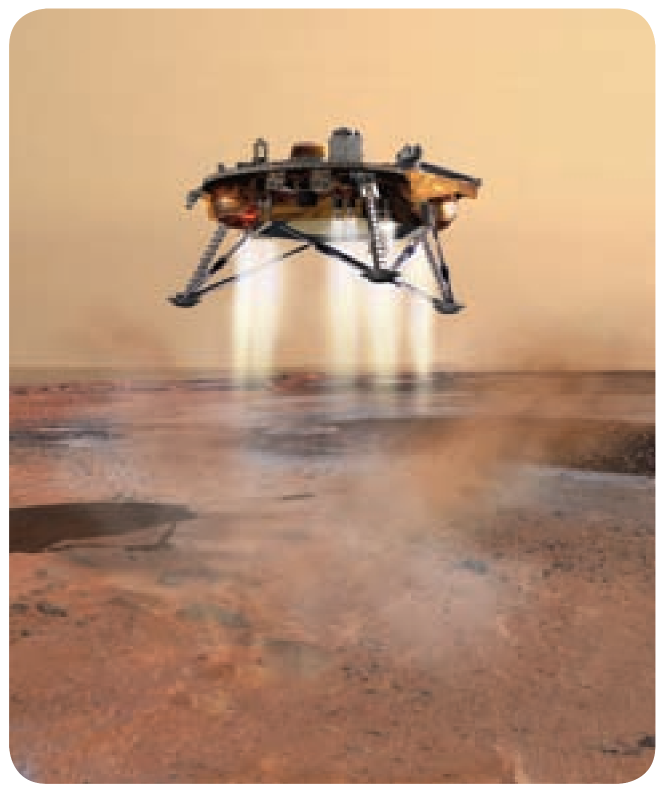


Figure 1.4.7 An artist's impression of what the landing of the Mars Polar Lander *should* have looked like.

1.4 Practical activities

1 Hot drinks cooling

Purpose

To compare the rates at which different cups of hot drink cool.

Materials

- beakers, cups and mugs
- hot water (from an urn or heated over the Bunsen burner or hotplate)
- one or more of tea, coffee, drinking chocolate
- milk and sugar
- teaspoon or stirring stick
- thermometer
- stopwatch, clock or watch

SAFETY

Do not boil the water that you are heating. It needs to be hot but not boiling.

Do not pick up any beaker with hot water with your bare hands. Use special tongs made for beakers or use insulated gloves.

Wear safety glasses at all times.

Procedure

1. You are going to measure the temperatures of two cups, mugs or beakers of tea, coffee or drinking chocolate as they cool.
2. Prepare at least two cups, beakers or mugs of tea, coffee and/or drinking chocolate, adding sugar and milk as desired.
3. Measure the temperature of each drink every 1 minute for at least 10 minutes.

Results

1. Record all your temperatures in a results table similar to the one below.

Time (min)	Cup of tea	Beaker of coffee	Mug of drinking chocolate
0 (at the start)			
1			
2			
3			
4			

2. Plot the results of each drink as a line graph on a similar grid to that shown in Figure 1.4.8.

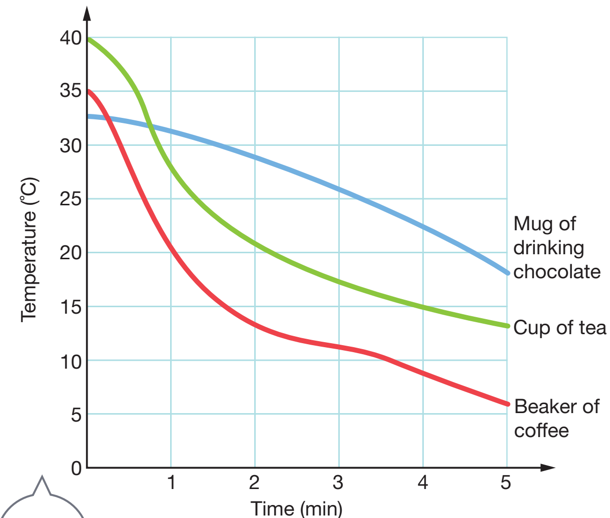


Figure 1.4.8

Discussion

1. **Describe** the trend or pattern that each graph showed. Was it increasing, decreasing, constant, unpredictable?
2. **Identify** which drink cooled the:
   a. fastest
   b. slowest.
3. **List** as many factors as you can to **explain** why the drinks cooled at different rates.
4. **Propose** improvements that could be made to your experiment.

2 Spaghetti predictions

Purpose

To use a graph to predict unknown measurements.

Materials

- 4 lengths of spaghetti
- beam balance or electronic balance
- 30 cm ruler (with 1 mm markings)

Procedure

1. Break three lengths of spaghetti into three pieces each so that you end up with nine different lengths.
2. Measure the length and mass of each piece of spaghetti.

Results

1. Record the lengths and masses you measure in a table like that shown below.

Length (mm)	Mass (g)

2. Use this information to plot a line graph. Draw a straight line so that it passes roughly through the centre of your points. An example of a line of best fit is shown in Figure 1.4.9.

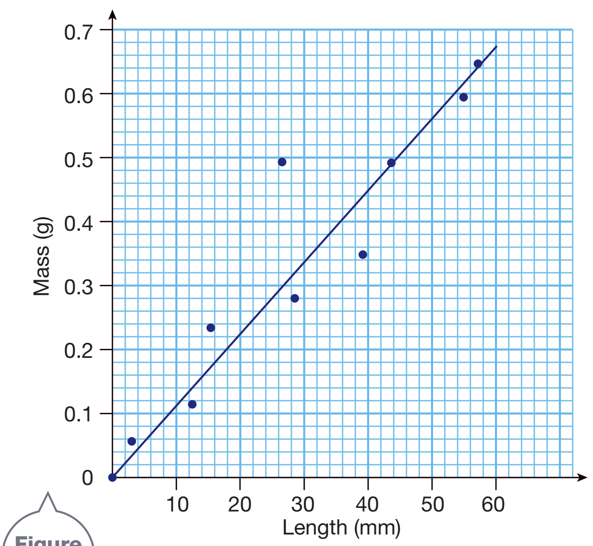


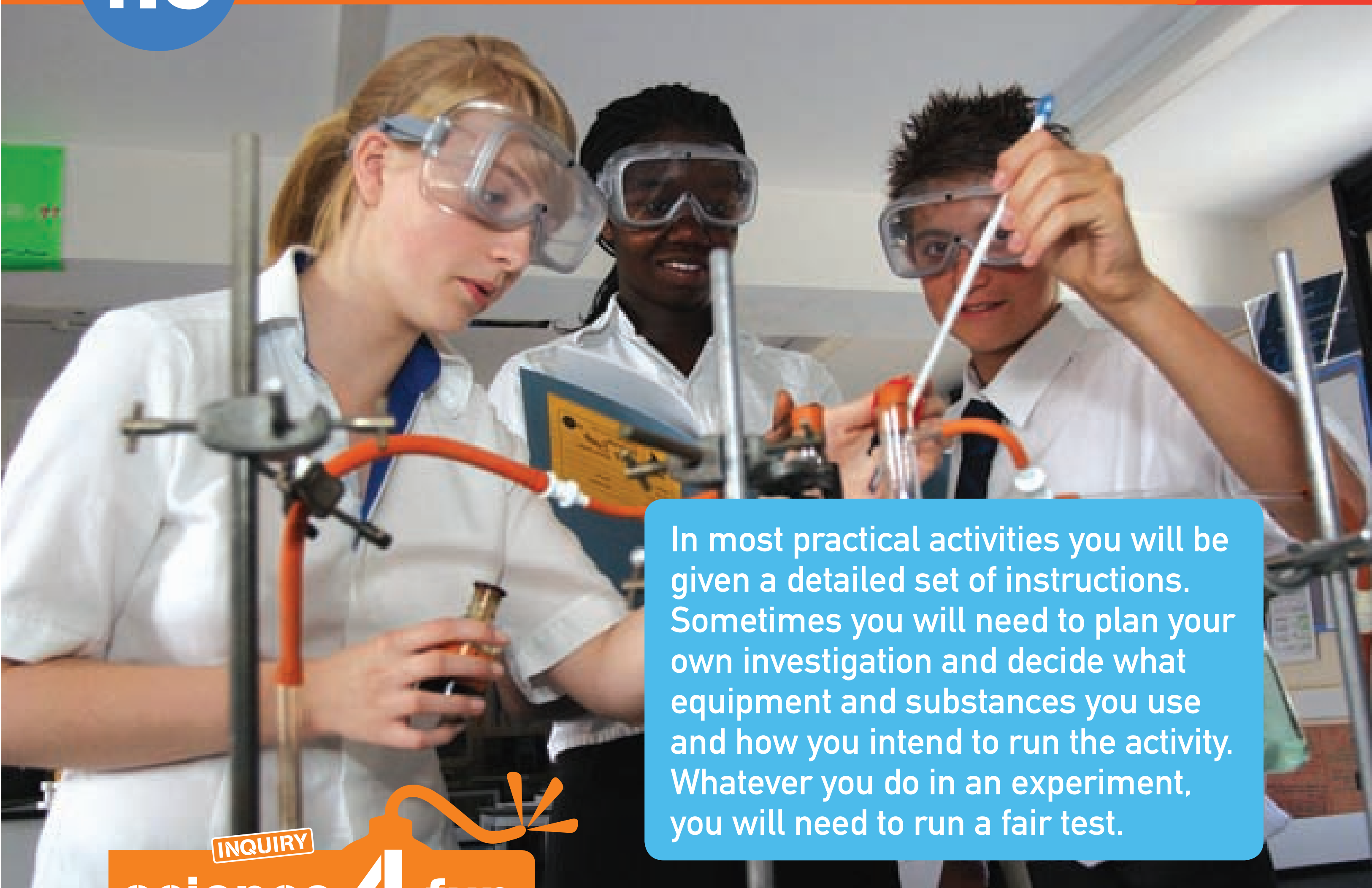
Figure 1.4.9

3. You only had nine lengths of spaghetti and there were lots of other lengths that you could not measure. Mark on your graph a length that you did not measure.
4. Use the graph to estimate the mass of this length.
5. Snap your final length of spaghetti at the length you chose in step 3 and measure its mass.
6. Compare its mass with your prediction in step 4.

Discussion

1. **Explain** why a line of best fit is better than joining points dot-to-dot.
2. **Construct** a conclusion about the link between mass and length of spaghetti.

1.5 Designing your own investigation



In most practical activities you will be given a detailed set of instructions. Sometimes you will need to plan your own investigation and decide what equipment and substances you use and how you intend to run the activity. Whatever you do in an experiment, you will need to run a fair test.

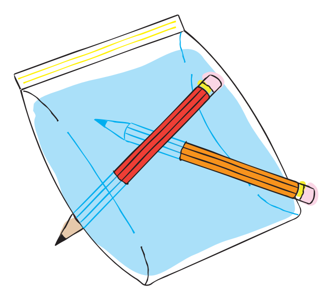
INQUIRY

science 4 fun

No-leak bags

What happens when you stab a plastic bag full of water?

Yes



Collect this ...

- 1 zip-lock plastic bag
- pencils
- pencil sharpener
- water
- access to a sink or bucket

Do this ...

1 Sharpen the pencils so that their tips form a very sharp point.

2 Three-quarters fill the plastic bag with water, and zip it shut.

3 Hold the plastic bag above a sink or bucket (or work outside).

4 Stab the bag fast with a pencil so that the tip comes out the other side.

5 Repeat with the other pencils.

Record this ...

Describe what happened.
Explain why you think this happened.

Identifying variables

Many different factors influence what happens in an experiment. In science, these factors are known as **variables**. Think of the time it takes someone to run 100 metres. The time taken will depend on many variables, such as the age, weight and fitness of the runner, the shoes being worn, the direction of the wind and whether the surface was grass, concrete or sand.

Any experiment that you carry out must be a **fair test**. To be fair, you should change only one variable at a time. Otherwise you won't be able to work out what variable caused any change. All the other variables must be controlled, being kept exactly the same.

In any experiment you should be able to identify the:

- **dependent variable**: this is what you are trying to measure. It depends on all the other variables. For the 100-metre run, the dependent variable is the time taken.
- **independent variable**: this is the variable that you want to test and is what the dependent variable depends on. Change this and what you are trying to measure will probably change too. For the 100-metre run, you might choose to test the surface run on, and so this would be the independent variable.
- **controlled variables**: these are all the other variables that you don't want to test right now. These are kept constant. In the 100-metre run, you are testing the surface, so every other variable needs to be kept the same. The age, fitness and weight of the runner, the type of shoes they are wearing and the wind direction would all need to be kept constant.

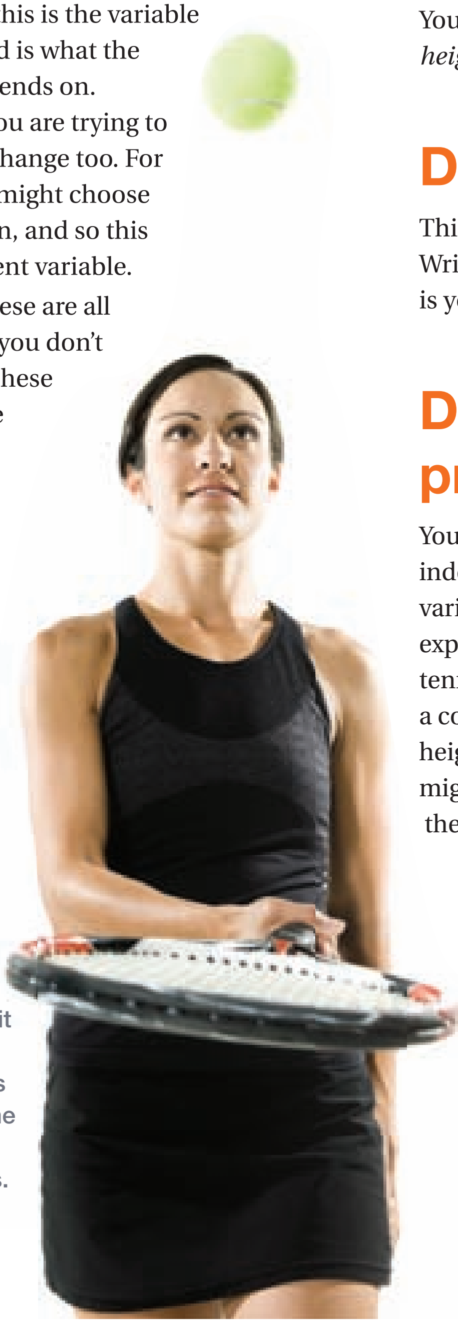


Figure 1.5.1 The type of ball and the surface it is dropped onto are two variables that will affect the height to which the ball bounces.

Figure 1.5.1 shows a ball bouncing on a racquet. When a ball is dropped onto a surface such as a racquet, many variables influence the height the ball bounces back to. The height of a bounce (bounce height) is the dependent variable because it depends on other (independent) variables. Just a few of these are the:

- type of ball that is being bounced
- type of surface it is being bounced on
- height the ball drops from (drop height).

Let's say you decide to test how the drop height of a ball affects the bounce height. Your variables are therefore:

- dependent variable: bounce height. This is what you are measuring and will be the basis of your aim.
- independent variable: drop height. This is what you are changing.
- controlled variables: the type of ball and surface. These must be kept the same throughout the experiment.

Your purpose therefore would be: *To test how drop height affects bounce height.*

Developing a hypothesis

Think about what is likely to happen in the experiment. Write down what you think might logically happen. This is your hypothesis.

Developing your procedure

Your procedure must test the effect of only the independent variable you chose earlier. All other variables must be kept the same. In this ball-bounce experiment, you need to test one type of ball (such as a tennis ball) and one type of surface (for example, onto a concrete path). The only thing you can change is the height you drop the ball from. Figure 1.5.2 shows how this might be done. If you want to change another variable, then you need to run a new and separate experiment.

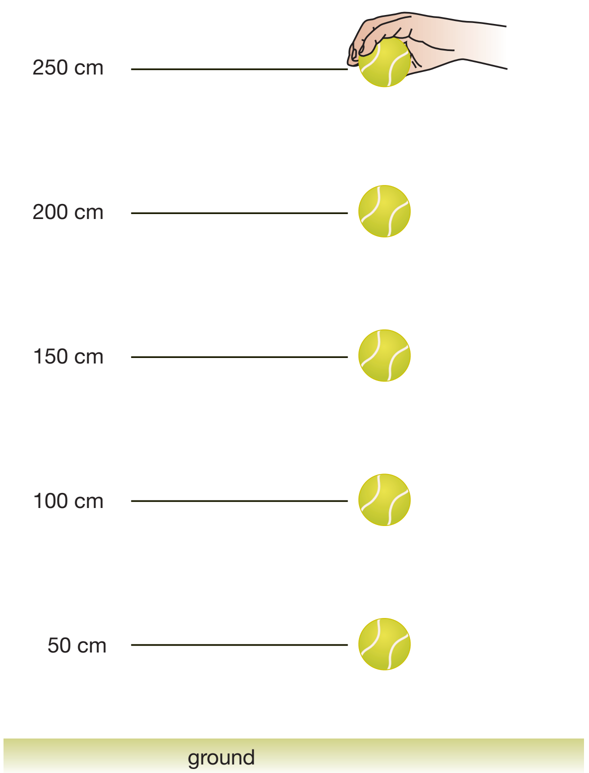


Figure 1.5.2 Try to test five or more different heights and make sure they are not too close to each other. Anything less than five measurements and measurements that are too close make patterns difficult to see.

Putting your results in a table

Before you start, think about the heights you might drop the ball from and the results you might obtain. Here you are measuring drop height and bounce height. An appropriate results table would look like the one shown in Table 1.5.1.

Table 1.5.1 Results table

Drop height cm	Bounce height (cm)
0	0
50	30
100	62
150	95
200	120
250	148

Plotting a graph

When plotting a graph, you first need to decide which type of graph you are to plot. Line graphs like that shown in Figure 1.5.3 are used when you have two sets of continuous measurements.

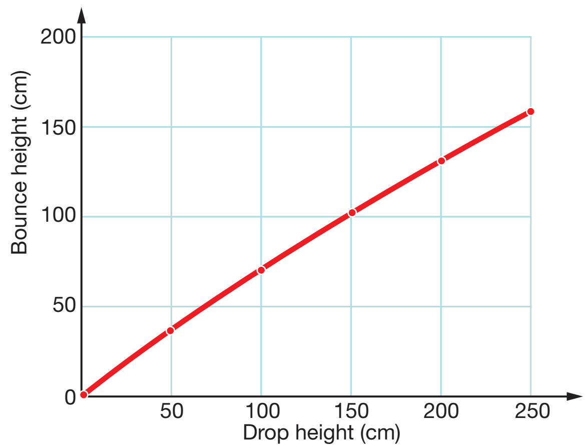


Figure 1.5.3 Two sets of measurements require a line graph.

The results in Figure 1.5.3 have two sets of numbers and so a line graph is the most appropriate graph to plot. In this example, a column, bar or pie graph would make no sense.

Bar graphs are used when one set of results is discrete. For example, bar graphs would be a good way of showing the way bounce height changed when the type of ball or type of surface was changed.

Your conclusion

Your conclusion must answer the purpose or aim of your experiment. Depending on what you tested, appropriate aims and conclusions would be:

Purpose: To test what increasing drop height does to bounce height.

Conclusion: Increasing drop height causes bounce height to increase.

1.5 Unit review

Remembering

1 **Recall** variables by matching the different terms with their definitions.

Dependent variable	Kept the same
Independent variable	Changed during the experiment
Controlled variable	What you are measuring

2 In the science4fun activity on page 31, sharp pencils were stabbed into a plastic bag full of water. For this activity, **state**:

- **a** an aim
- **b** a logical hypothesis.

3 **List** variables that are likely to affect the:

- **a** amount of sugar that will dissolve in a cup of tea
- **b** number of visitors to a swimming pool
- **c** growth of a plant
- **d** time taken to cook a potato
- **e** number of times you go to the toilet in a day.

Understanding

4 **Explain** why only one variable should be changed in any single experiment.

5 **Explain** why you should try to collect five or more results in an experiment.

6 Georgie heard an old tale that if you want an avocado to ripen quickly, then it should be placed in a brown paper bag with a banana. She thought this sounded weird and wanted to see if it was true. **Describe** in detail how she could test if the tale was true or not.

Applying

7 **Identify** which of the following sets of drop heights would give the best idea of what happens when drop height is increased.

- **A** 10 mm, 20 mm, 30 mm, 40 mm, 50 mm
- **B** 5 cm, 10 cm, 15 cm, 20 cm, 25 cm
- **C** 50 cm, 100 cm, 150 cm, 200 cm, 250 cm
- **D** 10 m, 20 m, 30 m, 40 m, 50 m

8 **Identify** likely aims that would have led to these conclusions.

- **a** Tennis balls bounced the best on concrete. They did not bounce as well on short grass and bounced poorly on long grass.
- **b** Superballs bounced best, followed in order by tennis balls and volleyballs. Squash balls were the worst bouncers.

9 **Identify** the variables that are likely to affect the amount of detergent froth produced when washing the dishes.

Evaluating

10 Bob ran an experiment on bouncing balls and recorded the following results.

Ball	Surface	Drop height (cm)	Bounce height (cm)
Tennis	Sand	30	1
Squash	Concrete	300	30
Golf	Gravel	100	5
Volleyball	Grass	50	10

On the basis of his results, he claimed that squash balls bounced better than tennis balls.

- **a** **State** the dependent variable that Bob tested.
- **b** **Identify** how many variables Bob changed during the experiment.
- **c** **Assess** whether the experiment was a fair test.
- **d** Do you agree with Bob's conclusion? **Justify** your answer.

Creating

11 For the experiment in Question 9 or 10, **construct** a method that would test a single variable.

Inquiring

Scientific investigations are regularly reported in the newspaper, on websites and in scientific magazines such as *Cosmos* and *Scientific American*. Find an article that discusses a scientific investigation and:

- give the names of the scientists involved
- summarise what they found out.

1.5 Practical activities

1 Designing your own investigation

Purpose

To design and run an experiment that tests a single variable.

Materials

Choose your own, depending on your choice of topic.

Procedure

Design your own experiment that will test a variable that is likely to affect:

1 the bounce height of a ball

2 the amount of sugar that can be dissolved in a cup of tea

3 the adhesive strength of sticky tape

4 the stretch of an elastic band or other elastic material such as stockings

5 the strength of paper.

Discussion

1 **Construct** a scientific report describing what you did in your prac. In it, you should include a:
   a table of results
   b graph.

2 **Identify** other variables that would affect your experiment.

1 Chapter review

Remembering

1 **Name** the branch of science that studies:
- **a** living things
- **b** chemicals
- **c** forces and energy
- **d** the mind
- **e** the Earth
- **f** space
- **g** the environment.

2 **State** two metric units commonly used for:
- **a** distance
- **b** volume
- **c** mass.

3 **State** which abbreviation is correct for these units.
- **a** degrees Celsius
  - **A** deg C **B** deg
  - **C** °C **D** C
- **b** hour
  - **A** hr **B** h
  - **C** Hr **D** H
- **c** seconds
  - **A** sec **B** secs
  - **C** S **D** s

4 **State** one qualitative and one quantitative observation for each of:
- **a** a can of soft drink
- **b** yourself.

Understanding

5 **Define** the following terms.
- **a** meniscus
- **b** cross-section
- **c** hypothesis
- **d** variable

6 **Describe** the features of a safety flame.

7 **Explain** why the senses of taste and smell are rarely used in science.

Applying

8 **Identify** the equipment in these jumbled words.
- **a** kaeber
- **b** aluspat
- **c** burccile

9 **Identify** the best SI unit to measure the:
- **a** time to run the 100 m sprint
- **b** mass of a car
- **c** volume of water in a sink.

10 **Identify** which of the following statements are observations, which are inferences and which are predictions.
- **a** **i** One Olympian is bigger than the other.
  - **ii** The bigger Olympian will win the event.
  - **iii** One will lift a heavier weight than the other will.
- **b** **i** I'll need to buy a new plant.
  - **ii** The plant is dying.
  - **iii** Leaves are curling up and turning brown.

11 **Identify** the best type of graph (bar, column, pie or line) from the clues below.
- **a** It shows percentages.
- **b** It has two sets of measurements.
- **c** It has discrete groups along its bottom, horizontal axis.
- **d** It has discrete groups along its vertical axis.

Analysing

12 **Classify** the following observations as qualitative or quantitative.
- **a** The cow went 'moo'.
- **b** The car was travelling at 60 km/h.
- **c** The Saints won by 25 points.
- **d** The Sea Eagles won by a lot.

Evaluating

13 **Propose** reasons why the Bunsen burner gas must be turned on after the match is lit.

Creating

14 **Use** the following ten key words to **construct** a visual summary of the information presented in this chapter.

laboratory	equipment
experiment	safety
observations	measurements
units	quantitative
variables	qualitative

1.10

Thinking scientifically

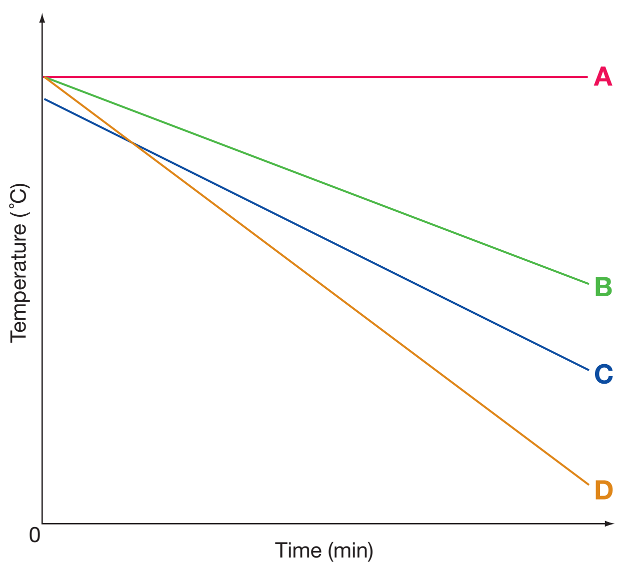
The Three Bears returned home and found someone had been eating their porridge. Being scientific bears, they were interested in how fast different-sized bowls cooled. They filled them with hot porridge and measured the temperature every minute. Their results are shown in the table.

Time (min)	Temperature of Papa Bear's porridge (°C)	Temperature of Mama Bear's porridge (°C)	Temperature of Baby Bear's porridge (°C)
0	60	58	61
1	55	48	50
2		39	48
3	45	31	30
4	40		20
5	35	18	10

Q1 Identify which bowl cooled the fastest.

A Papa Bear's
B Mama Bear's
C Baby Bear's
D Not enough information to decide

Mama Bear then sketched line graphs to show what was happening. These are shown below.



Q2 Identify which graph most likely represents:

a Papa Bear's bowl
b Mama Bear's bowl
c Baby Bear's bowl.

Q3 Identify which of the following variables are *unlikely* to have much effect on the cooling of the porridge.

A size of bowl
B amount of porridge
C amount of sugar in porridge
D starting temperature of porridge

Q4 Baby Bear misread his thermometer once. Identify which of his readings is probably wrong.

A 50°C
B 48°C
C 30°C
D 20°C

Q5 Papa Bear forgot to read his thermometer once. Identify the most likely missing temperature.

A 31°C
B 53°C
C 50°C
D 18°C

Q6 Mama Bear also forgot to read her thermometer. Identify the most likely missing temperature.

A 30°C
B 24°C
C 20°C
D 18°C

Glossary

Unit 1.1

Astronomy: the study of space

Biology: the study of living things

Branches: sub-groups of science

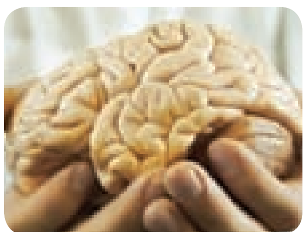
Chemistry: the study of chemicals and their reactions

Ecology: the study of the environment

Geology: the study of Earth

Physics: the study of forces and energy

Psychology: the study of behaviour



Psychology

Unit 1.2

Bunsen burner: used in the laboratory to provide heat

Cross-section: split down the middle

Equipment: tools of the laboratory

Hotplate: heating device

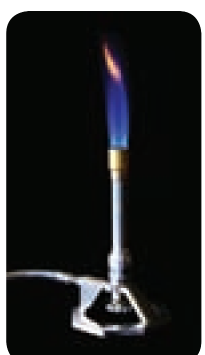
Laboratory: where a scientist works

Mass: amount of matter

Meniscus: curved surface of liquids in narrow tubes

Safety flame: yellow flame

Toxic: poisonous



Bunsen burner

Unit 1.3

Experiment: a scientific test

Inference: logical explanation

Observation: what is seen, heard, smelt, felt, tasted

Practical activity: experiment

Prediction: what might happen

Qualitative observations: observations in words only

Quantitative observations: measurements including numbers

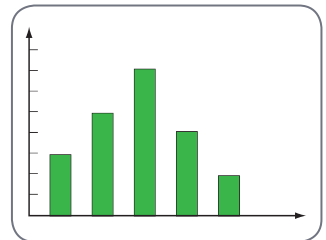
Unit 1.4

Aim: what you are trying to do

Analysis: looking for trends in the results

Bar graph: used when one set of observations is discrete. Bars are horizontal

Column graph: used when one set of observations is discrete. Columns are vertical



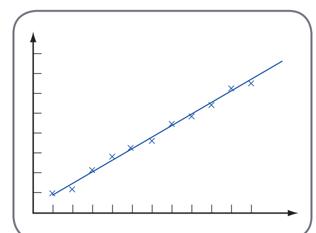
Column graph

Conclusion: what you have found out

Discussion: analysis

Hypothesis: educated guess

Line graph: used when there are two sets of continuous measurements



Line graph

Method: tells how you did the experiment

Pie graph: used to show proportions

Procedure: tells how you did the experiment

Purpose: aim

Results: the measurements and observations made in an experiment

Unit 1.5

Controlled variables: held constant throughout an experiment

Dependent variable: will change naturally as you change the other variables

Fair test: changing only one variable at a time

Independent variable: what you change in an experiment

Variables: factors that influence an experiment

2 Properties of substances

HAVE YOU EVER WONDERED ...

- why icebergs float?
- why clothes dry even when it's not hot?
- why you breathe out fog on a cold morning?
- how cold it can get?

After completing this chapter students should be able to:

- identify properties as physical or chemical
- explain how properties affect how a substance is used or not used
- compare properties of different substances
- assess the biodegradability of different substances
- explain the properties of solids, liquids and gases
- explain changes of state, particularly of water.

2.1 Physical and chemical properties

There are millions of different substances in the world. Each can be identified by its properties. Properties describe a substance and how it acts. They include its appearance, what it does when heated or cooled, and how it reacts with other substances.

Physical properties

You can probably tell which objects and substances around you are solid, liquid or gas by the way they look and act. What you see are **physical properties**. Testing a substance for its physical properties doesn't destroy the substance, or change it into anything new.

Some of the most useful physical properties of a substance are:

- whether it's a solid, liquid or gas at room temperature (normally taken as 25°C)
- the temperatures at which the substance freezes or boils (known as its freezing point and boiling point)
- its appearance (such as its colour and texture, the shape of any crystals within it or whether it is shiny or dull)
- its density (how heavy it is compared to other substances of the same size)
- how hard or brittle the substance is (whether it is easily scratched or whether it crumbles)
- whether the substance dissolves in different liquids (such as water or turpentine)
- its ability to let heat or electricity pass through it (known as its thermal and electrical conductivity).

Solids, liquids and gases

Substances exist in either solid, liquid or gaseous form. These forms are known as the **states** (or phases) of **matter**.

Solids, liquids and gases have very different physical properties. Think of the van in Figure 2.1.1. Cars and vans only change shape when they are in an accident or when they are broken up to be recycled. Also solids cannot be **compressed** (squashed to make them smaller). Try to compress a sugar cube and it might crumble, but the amount of sugar is exactly the same as it was before. The fact that solids do not change shape or size allows them to be used to build structures.

Liquids are similar to solids in that they don't change their size and are **incompressible** (unable to be compressed or squashed). They differ from solids in that they can flow and change shape. Think of orange juice: it splashes about and can be poured from one container into another, taking on a new shape as shown in Figure 2.1.2. The ability of liquids to squeeze along pipes and hoses without changing volume allows them to be used in hydraulic (powered by liquid) systems such as car brakes.

Solids:

- have a fixed shape
- have fixed size and volume
- cannot be compressed (pushed in to make it smaller)
- will usually sink when placed in liquids of the same material.

Figure 2.1.1 Cars and vans are solid. They don't change shape or size unless they are in an accident or they are crushed to be recycled.

Liquids:

- have fixed size and volume
- are able to flow
- take the shape of the bottom of the container they are in
- are incompressible (not able to be compressed).

Figure 2.1.2 Liquids always flow to take up the shape of their container.

Gases are often invisible and many have no **odour** (smell). Water vapour is a gas that is invisible because it is colourless and its particles are spread too far apart for the gas to be seen. However, you can feel water vapour since it gives air its humidity. There is a lot of water vapour in the air on a humid day, making you feel sweaty and sticky. Figure 2.1.3 on page 42 shows a mixture of gases that does have a smell.

Gases differ from solids and liquids in that they can be compressed. This property allows gases to be squeezed into small volumes such as barbecue gas cylinders. It also makes them useful in the gas struts or shock absorbers found in the suspension of bikes and cars. A bump compresses the gas in the struts, softening the impact of the bump. The gas then expands once more, pushing the strut back to its original shape.

SciFile

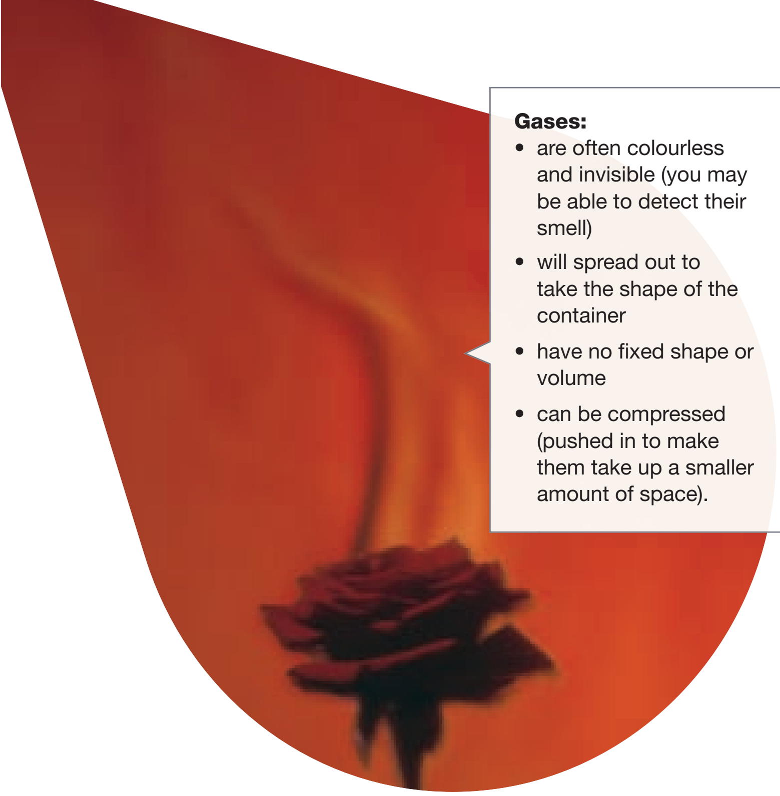
No teardrops!

The shapes of raindrops change as they change size. None of them looks like the teardrops shown in the weather report!

Diameter (mm)	Less than 1	1 to 2	2 to 4.5	Bigger than 4.5
Shape				

p47

2.1 2.2



Gases:

- are often colourless and invisible (you may be able to detect their smell)
- will spread out to take the shape of the container
- have no fixed shape or volume
- can be compressed (pushed in to make them take up a smaller amount of space).

Figure 2.1.3 Perfume, smells, vapours and fumes are all gases. This image shows the gaseous perfume rising from a rose.

Figure 2.1.4 There is a fourth state of matter but it is very rare on Earth. **Plasma** is a gas-like state that only exists at temperatures above 6000°C, making it common on stars but not here. On Earth, plasma is found wherever high-voltage sparks are generated, such as lightning bolts or in this plasma sphere.

Chemical properties

Chemical properties describe how a substance reacts with other substances. A new substance is formed in the process, often with very different properties. For example, iron rusts because it combines with oxygen and water. Iron is grey, hard and often shiny, while the rust it forms is red-orange, flaky and brittle. Likewise, paper burns and dynamite explodes, leaving behind ash and smoke.

Chemical properties that are worthwhile knowing about are whether a substance:

- burns or explodes in oxygen (this is known as combustion)
- rusts or corrodes (known as corrosion) or is corrosion-resistant
- is an acid like vinegar or a base like bicarbonate of soda or neither (this is measured by its pH)
- reacts quickly or slowly with other chemicals (this is known as the rate of reaction). Explosions like the one in Figure 2.1.5 have a fast rate of reaction.

Figure 2.1.5 The chemical properties of LPG and petrol cause them to explode when there is plenty of oxygen and a flame or spark.

2.3

Choosing the right substance

The different properties of substances affect how they are used. For example, the frame of a skyscraper needs to be solid and strong and so is commonly made out of steel. Shopping bags are made of plastic, paper or fabric because they need to be cheap, light, strong and flexible. Likewise, takeaway food containers are often made of polystyrene because it's light and keeps the heat in.

Sometimes liquids or gases will be a better choice than solids. For example, car brakes only work because liquid is pumped through tubes to activate them, while a gas (air) is used to keep a jumping castle in shape. Imagine if the jumping castle shown in Figure 2.1.6 was filled with lead!

Figure 2.1.6 The walls and floor of a jumping castle need to be solid and strong but also smooth and flexible. Inside is a gas (air) that can compress when you jump on it but which will expand as soon as you jump to another spot.

INQUIRY science 4 fun

Property competition

Who is best at identifying physical properties?

Collect this …

- any object from your pencil case
- 2 sheets of lined paper
- 2 pens or pencils

Do this …

1. Team up with another person.
2. Each person needs to number the first ten lines 1, 2, 3 and so on to 10.
3. Choose any object from your pencil case.
4. On the word 'Go' each person starts writing as many physical properties about the object as they can. Put a new property on each new line.
5. The first person to list ten properties is the winner.
6. Compare the two lists then choose another object and start again.

Record this …

Describe what type of physical properties each person listed.

Explain why you could only list physical properties.

SCIENCE AS A HUMAN ENDEAVOUR

Nature and development of science

Biodegradability

Figure 2.1.7 Rotting and mould are signs that a substance is biodegradable.

Leave a sandwich in your schoolbag and a few days later you'll be left with a mess of rotting, smelly goo.

This happens because microscopic bacteria cause chemical reactions that break down substances in the sandwich into simpler substances like sugar, water and carbon dioxide. However, the cling wrap or plastic container that the sandwich was in is unlikely to have changed. The chemical properties of the bread, lettuce and tomato caused them to rot, while the chemical properties of the cling wrap or plastic gave them rot-resistance.

Biodegradable

Substances are classified as being **biodegradable** if bacteria or fungi break them down. Fruit, vegetables, flowers, wood, twigs and leaves are biodegradable since they all break down quickly. This is why they are put into composts: they break down, forming simple substances that can then be used to fertilise other plants. The mould on the strawberry in Figure 2.1.7 shows that it is biodegradable. Animals are biodegradable because bacteria quickly break them down into simpler substances once they die.

Anything made of natural, living substances (or from substances that once lived) is usually biodegradable too. Some examples shown in Figure 2.1.8 are:

- paper and cardboard (made from wood)
- cotton, hessian, linen fabrics (made from plants)
- woollen fabrics (the 'hair' of animals like sheep and goats)
- soaps (made from natural fats and oils).

Non-biodegradable

Non-biodegradable substances eventually break down but often take hundreds of years to do so. Non-biodegradable substances have structures that bacteria and fungi cannot pull apart. Even though most plastics are made from a long-dead natural substance (crude oil), their structures are too different from the structures of living substances for them to be biodegradable. Other non-biodegradable substances are:

- cling wrap (used to wrap sandwiches)
- most plastic shopping bags
- wrappers (used for lollies, chocolate bars and ice-creams)
- polystyrene (used for takeaway food)
- house paints
- glass (used for soft drink and sauce bottles)
- metal cans (used for soft drinks and canned spaghetti).

Anything made from these substances therefore remains in the environment as rubbish and pollution for many, many years. They might crush, break or rip into smaller pieces, but their chemicals are still there polluting the environment.

Figure 2.1.8 Biodegradable sustances like soap, wool, cardboard and vegetable scraps all break down quickly.

Figure 2.1.9 Most plastic bags are not biodegradable and so they don't rot away. If they get washed into rivers and the ocean, wildlife like this bird can get caught up in them and can die.

What can we do?

Most non-biodegradable substances can be burnt but they release toxic (poisonous) fumes and smoke unless the fire happens in special incinerators at extremely high temperatures. Some (like glass bottles and plastics like PET) are able to be recycled. However, most non-biodegradable substances are simply thrown out. To minimise the impact of non-biodegradable substances on the environment, we all need to:

- use biodegradable packaging whenever possible, buying food with no packaging or wrapped in paper or cardboard
- dispose of non-biodegradable packaging in bins, so that it will not end up on the street, rivers and oceans where it may catch and tangle fish, dolphins and birds like the one in Figure 2.1.9
- recycle glass and PET bottles and other plastics wherever possible
- re-use plastic shopping bags or use paper or re-useable cloth bags instead.

Scientists have developed biodegradable plastics from plant-based substances but these plastics are more expensive than similar oil-based plastics. They can't be recycled and cannot be used for long-term packaging. For these reasons, their use is not yet widespread.

2.4
2 p48

2.1 Unit review

Remembering

1 **List** the three states of matter commonly found on Earth.

2 **State** whether the following are solids, liquids or gases.
- **a** a sugar cube
- **b** ink
- **c** air

3 **List** the different states in which different substances exist in the following mixtures.
- **a** soft drink
- **b** chicken curry
- **c** mud

4 **List** two physical properties and one chemical property of a sheet of paper.

5 **List** four biodegradable and four non-biodegradable substances.

Understanding

6 **a** **Explain** why plasma is usually found in stars but rarely on Earth.
- **b** **Describe** the conditions on Earth that allow plasma to form.

7 **Define** the terms:
- **a** compress
- **b** incompressible
- **c** biodegradable.

8 **Explain** how the compressibility of gases makes them ideal for using in shock absorbers in the suspension of cars and bikes.

9 **a** **State** what causes humidity.
- **b** **Describe** what a humid day feels like.

10 **Describe** evidence that tells you that the following are biodegradable.
- **a** a banana
- **b** a sausage

Applying

11 **Identify** an appropriate substance from which to make the walls of a compost bin.

12 A log in the forest grows mushroom-like fungi on it.
- **a** **Use** this information to **state** whether the log is biodegradable or not.
- **b** **Describe** what will be left of the log after 10 years.

Analysing

13 Each of the following substances displays properties of both liquids and solids. **Analyse** the properties of each and use them to **classify** each as solid or liquid.
- **a** sand
- **b** toothpaste
- **c** hair gel

14 **Classify** faeces as biodegradable or non-biodegradable.

Inquiring

1 People are becoming more aware of the effect that plastics like PVC and polystyrene have on the environment. Research how their use has changed because of this awareness.

2 Investigate the guidelines of your local council regarding what can be recycled and what cannot.

3 Design a way of comparing two different substances that can be used for the same purpose (such as the strength and biodegradability of paper and plastic bags, the frothing and cleaning abilities of soap and detergent, or the strength, flammability and biodegradability of natural and synthetic fabrics). Show your plan to your teacher. Once you have approval, test your substances.

4 Oobleck is an easy-to-make slimy goo with such strange properties that it is classified as a 'non-Newtonian' liquid. Basically this means that it is a liquid that doesn't act normally. Search the internet to find recipes or videos showing how to make oobleck. Then make some!

2.1 Practical activities

1 Slime

Purpose

To make slime and observe its properties.

Materials

Note: PVA tends to change consistency depending on the brand chosen and its age. The quantities of PVA and borax shown below may need to be altered slightly depending on the brand of PVA used.

- 4–6% borax solution
- PVA glue
- food dye
- eye dropper/Pasteur pipette
- disposable medicine measuring cup
- 10 mL measuring cylinder
- 2 disposable plastic cups
- icy-pole stick

SAFETY

Wear safety glasses at all times.

Borax can stain, so wash your hands thoroughly after the practical activity.

Procedure

1. Use the measuring cylinder to measure out 10 mL of borax solution.
2. Use the disposable medicine measuring cup to measure out 25 mL of PVA glue.
3. Pour the PVA into a disposable plastic cup, using the icy-pole stick to scrape the last bits out.
4. Add a few drops of food dye to the PVA.
5. Pour the borax solution, all at once, into the cup containing the PVA and food dye.
6. Empty out the slime and rinse it gently under a slow-running tap.

Results

Investigate the properties of slime and record your results in a table like that shown below.

Discussion

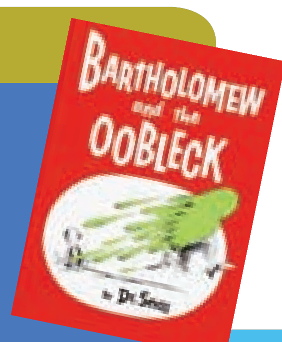
1. **List** the physical properties of your slime.
2. **Use** the physical properties of solids and liquids to **classify** your slime as solid or liquid.
3. **Justify** your choice.

Investigation	Observation	Is this property more like that of a solid or a liquid?
Can slime be rolled into a ball?		
What happens when slime is stretched?		
Does slime flow to take the shape of its container?		
What happens when a ball of slime is dropped?		

SciFile

The Oobleck of Dr Seuss

In the book *Bartholomew and the Oobleck* by Dr Seuss, a king is so bored with ordinary weather that he instructs his wizard to create something new. A green goo called oobleck soon falls from the sky, gumming up the whole kingdom!



2.1 Practical activities

2 What's biodegradable and what's not?

Purpose

To assess how biodegradable different substances are.

Materials

- 4 samples each of different substances or packaging materials such as polystyrene takeaway containers, plastic bags, paper bags, reuseable cotton bags (or any cotton sample), newspaper, PET plastic drink bottles, waxed cardboard juice containers, plastic netting (used for oranges)
- wooden pegs or camp pegs
- access to different environments in which samples can be left undisturbed for at least 3 months. Suggestions are:
  - open, exposed area in sunlight
  - compost bin or pile of grass clippings and leaves
  - sandpit or similar
  - garden bed
- rubber gloves

SAFETY

Wear rubber gloves at all times when handling sand, dirt, compost and samples.

Procedure

1. Use the wooden stakes or camp pegs to spread and peg out one sample of each substance in the sunlight.
2. Bury one sample of each substance in the compost bin, another in a sandpit and another in a garden bed.
3. Wet each sample thoroughly in each different environment.
4. Leave for a month and record what the samples left in the sunlight look like. Look for signs of breakage, mould and discolouration.
5. Carefully dig out the other samples and again record your observations. Re-bury the samples.
6. Observe again after another month and then at the end of a third month.
7. At the end of three months, throw any samples that have not decomposed into the bin or recycle bin. (Check whether they have a triangle with a number in it. If they do, then they are usually recyclable.)

Results

In your workbook, construct a table like that below. Use it to record your observations over the 3 months.

Discussion

1. **Classify** each of the substances as biodegradable or non-biodegradable.
2. **Assess** whether 3 months is really long enough to test whether a material is biodegradable or not.
3. Discolouration is a sign that the sample is beginning to rot. **Propose** what might be causing the change of colour.

Substance	Observation Month 1	Observation Month 2	Observation Month 3
Polystyrene			
Plastic bag			
Paper bag			
Newspaper			
PET plastic bottle			
Waxed cardboard			
Plastic netting			

2.2 Solids, liquids and gases

Each of the states of matter has its own characteristic properties that can be explained using a simple model called the particle model.

INQUIRY science 4 fun

The weight of a gas

Does gas have weight?

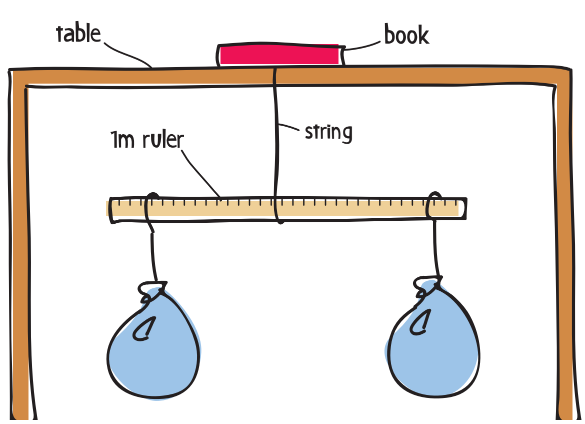
Yes

Collect this …

- 2 balloons
- 3 lengths of string (each about 30 cm long)
- 1 m ruler
- needle (sharp enough to burst a balloon)

Do this …

1. Inflate both balloons until they are roughly the same size.
2. Tie their ends and tie a piece of string to the top of each balloon.
3. Tie one balloon to one end of the ruler and the other balloon to the other end as shown in the diagram. Use the ruler markings to make sure that the strings are the same distance from the ends of the ruler.
4. Tie the third string to the middle of the ruler and hang the ruler from the edge of a table.



5. Balance the ruler so that it hangs parallel to the floor. Do this by sliding the middle string along the ruler until you find the balance point.
6. Puncture ***one*** of the balloons with the needle and observe what happens.

Record this …

Describe what happened.

Explain why you think this happened.

Particles and atoms

Scientists have long wondered what makes up substances. The ancient Greeks thought that all substances were built up from incredibly tiny building blocks known as particles. They even gave these particles a name: *atomos*. We now call these particles **atoms**. Atoms are the particles all matter is made from. Atoms are far too small to be seen with your eyes or even with a normal microscope, but they can sometimes be seen with a powerful type of microscope called a scanning tunnelling microscope (STM). An example is in Figure 2.2.1. STMs are incredibly powerful and expensive and so only a few universities and research laboratories in Australia and around the world have them.

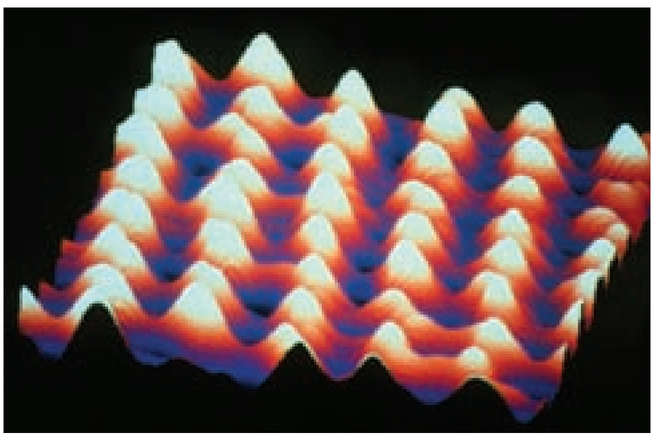


Figure 2.2.1 Each bump in this STM image represents an atom.

Models in science

The physical properties of solids, liquids and gases can be described by the way the particles or atoms that make them up are arranged. Atoms are invisible to all but an STM, however, and this makes an explanation of the properties of solids, liquids and gases extremely difficult. To get over this difficulty, scientists have developed a model called the **particle model** to explain what is happening. Models are often used in science to test or explain something that is difficult to understand. One type of scientific model is shown in Figure 2.2.2.

Figure 2.2.2 Models allow scientists to test ideas and explain what is happening in the world around them. This is a model of a robotic explorer to be used on Mars.

The particle model

In the particle model, atoms are thought of as incredibly small, hard, spherical balls. Each ball has energy and moves according to how much energy it has. If a particle has lots of energy, then it will move about a lot. If the particle has very little energy, then it will be sluggish and move about slowly. You add energy to **matter** whenever you heat it. This causes the particles to move about more, and faster. If you cool a substance, then the reverse happens: the particles move about less and move more slowly.

The particle model assumes the following:

- All substances are made up of tiny, hard particles that are too small to see.
- The particles always have energy and are moving.
- The particles move about more and move faster as temperature is increased.
- Particles are attracted (drawn) to each other. The closer the particles are to one another, the stronger the attraction between them.

Explaining solids

In solids the particles are closely packed in fixed positions. Forces between neighbouring particles form **bonds** that hold all the particles in the solid closely together. The particles in a solid have energy and jiggle about as shown in Figure 2.2.3. The particles don't break out of position but just **vibrate** about on the spot. If you increase the temperature, the particles have more and more energy and so they vibrate about more and more.

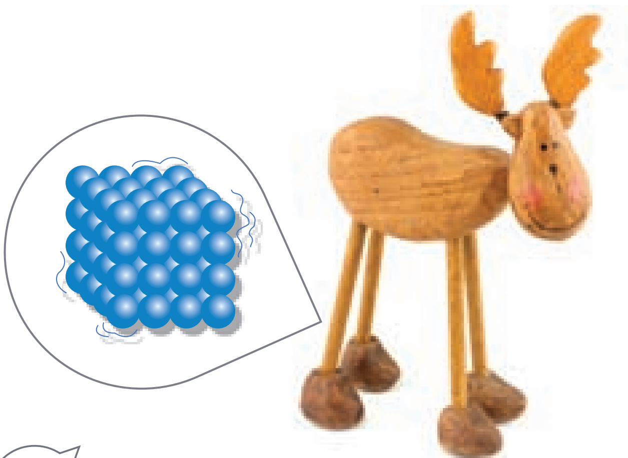


Figure 2.2.3 The particles in a solid are closely packed together and just jiggle about on the spot.

Table 2.2.1 How the particle model explains the physical properties of solids

Property of solids	How the particle model explains it
Solids have a defined shape (they do not flow).	The particles in solids are strongly bonded to their neighbours, fixing their positions.
Solids are incompressible.	The particles in a solid cannot be pushed closer to each other because they are so closely packed that there is almost no space between them.
Solids expand when heated and contract when cooled.	Heating causes the particles in a solid to vibrate faster, making them spread further apart and causing the solid to expand. Cooling slows down vibrations and the opposite happens.

Explaining liquids

In a liquid, the particles are still packed closely together but they are far more loosely bonded (joined) to their neighbours than the particles are in a solid. This is shown in Figure 2.2.4. The loose bonding allows the particles to move about and over each other, allowing the liquid to flow, drip and fill the bottom of whatever container it is in. As the liquid is heated, this movement gets faster.

Figure 2.2.4 The particles in a liquid are packed closely together but are able to move about and over one another. This gives the particles the ability to flow.

Table 2.2.2 How the particle model explains the physical properties of liquids

Property of liquids	How the particle model explains it
Liquids flow to take the shape of the bottom of their container.	Bonds are strong but loose enough to allow the particles in liquids to slip over one another.
Liquids are incompressible.	The particles in a liquid cannot be pushed closer to each other because they are so closely packed that there is almost no space between them.
Liquids expand when heated and contract when cooled.	Heating causes the particles in a liquid to move over each other faster, making them spread further apart and causing the liquid to expand. Cooling slows down this movement and the opposite happens.

Explaining gases

Gases have nothing holding their particles together. This lack of bonds allows the gas particles to travel randomly in straight lines until they hit something, either other gas particles or the walls of the container they are in. This is shown in Figure 2.2.5.

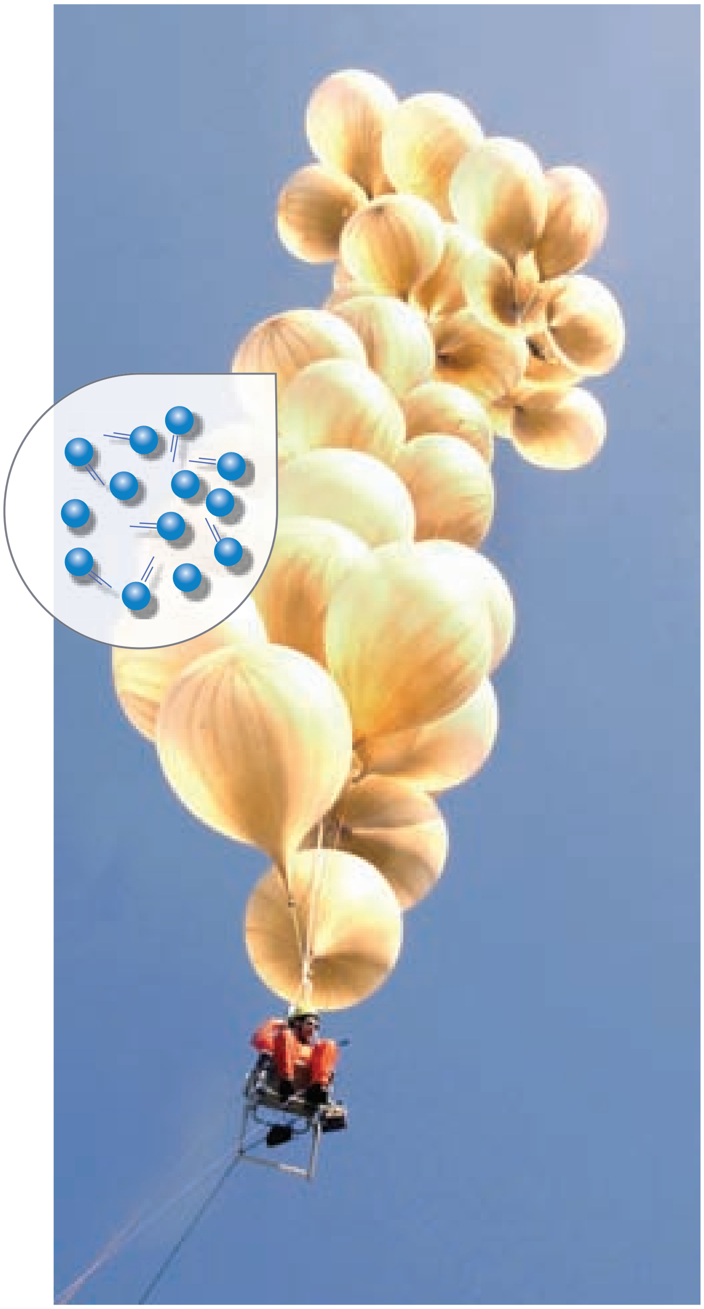


Figure 2.2.5 The particles in a gas are a long way apart and move fast and in straight lines. They only change direction when they hit the walls of their container or each other.

Table 2.2.3 How the particle model explains the physical properties of gases

Property of gases	How the particle model explains it
Gases are often invisible.	Particles in a gas are spread so far apart that you cannot see the gas.
Gases can be compressed.	Particles in a gas are spread so far that there is plenty of vacant space between them. This space allows them to be pushed closer together.
Gases spread to fill their container.	There are no bonds between gas particles and so they are able to move unrestricted by other particles. They travel until they hit the walls of the container.
Gases expand when heated and contract when cooled.	Heating causes the particles in a gas to move faster, making them spread further apart and causing the gas to expand. Cooling slows down this movement and the opposite happens.

SciFile

Colder than cold

As a solid is cooled, energy is removed from its particles, making them vibrate less and less. Eventually they have no energy at all and all vibrations stop. This happens at a temperature of **absolute zero** (–273°C). The particles can't move any slower and so absolute zero is the lowest temperature that is possible.

SCIENCE AS A

HUMAN ENDEAVOUR

Nature and development of science

Robert Brown

Figure 2.2.6 Pollen grains are incredibly light and can be jostled about by water particles. This jostling became known as Brownian motion.

Scientists had an extremely good idea about the particles that made up matter well before the invention of the scanning tunnelling microscope (STM).

This is because you don't always need to see something to know that it exists. Observations indicated that, although they are 'invisible', atoms do exist. These types of observations are known as indirect evidence. You use indirect evidence every day: you know what you are having for dinner from smells coming from the kitchen, and you can often guess what's in a package by its weight and shape and the sounds it makes.

Some of the most convincing indirect evidence for particles came from the work of the Scottish botanist Robert Brown. In 1827, Brown was using his microscope to study tiny pollen grains like those on the bee in Figure 2.2.6 that were floating on some water. He expected the pollen grains to be still but they were moving about, as if being jostled about by something invisible in the water. His sketches of their motion are shown in Figure 2.2.7. Brown could not explain what was happening and it was 1905 before Albert Einstein explained it: 'invisible' particles in the water were constantly moving about, colliding with the pollen grains and pushing them around as they did so.

Brown was not the first to notice this type of motion. In 1785, Jan Ingenhousz had observed similar movement in coal dust suspended in alcohol, and the ancient Roman Lucretius wrote in around 60 BCE of dust particles jiggling about in a beam of sunlight. You may have already noticed something similar. This jiggling eventually became known as **Brownian motion**.

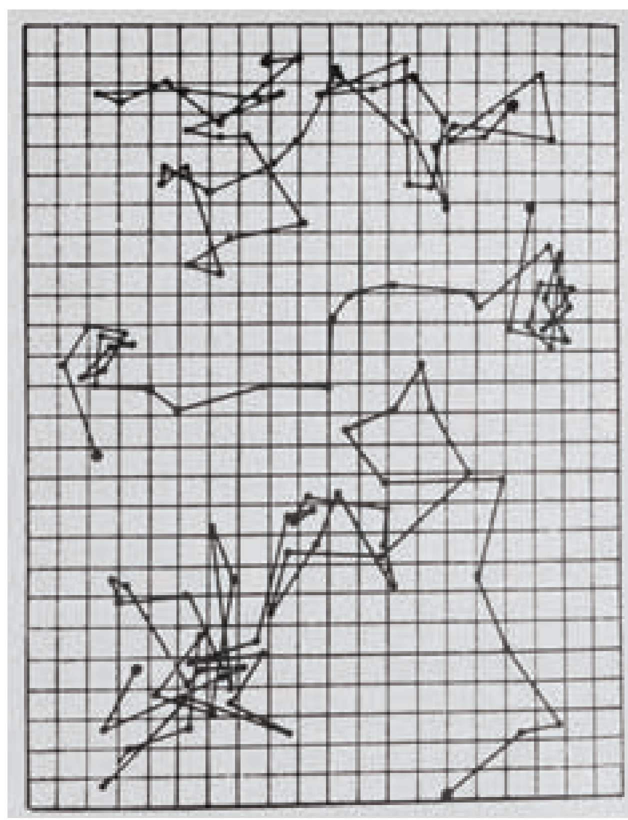


Figure 2.2.7 Robert Brown's original notes marking the positions of pollen grains every 30 seconds.

2 p55

2.2 Unit review

Remembering

1 **State** what causes atoms to move constantly.

2 **State** what temperature is absolute zero.

Understanding

3 Match the state of matter with the movement its particles that **describes** it best.

Solid	Particles move very fast in straight lines.
Liquid	Particles vibrate on the spot.
Gas	Particles vibrate but can also move over one another.

4 **Explain** what happens to the particles in a substance when it is:
- a heated
- b cooled.

5 **Describe** the arrangement of the particles in a:
- a solid
- b liquid
- c gas.

6 **Define** the following terms.
- a vibrate
- b bonds

Applying

7 **Use** the particle model to **explain** why:
- a solids keep their shape
- b a gas can be compressed
- c liquids take the shape of the container they are poured into
- d a solid cannot be compressed.

8 The idea of Brownian motion came from scientific observation. **Identify** the observations Robert Brown made.

Evaluating

9 Barbecue gas cylinders are usually weighed as they are being filled. **Propose** a reason why.

10 Inspect the apparatus shown in the science4fun activity on page 49. Two balloons full of air are balancing on a metre ruler.
- a **Predict** what will happen when one of the balloons is burst.
- b **Justify** your prediction.

Creating

11 **Construct** a Venn diagram showing which properties are shared between solids, liquids and gases and which properties belong to only one state. Follow these instructions.
- a Copy Figure 2.2.8 into your workbook.

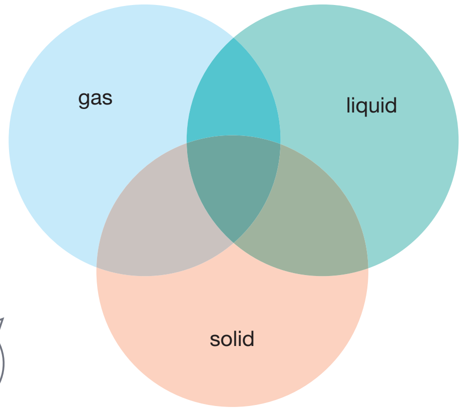


Figure 2.2.8

- b **Identify** which of the following properties is shared by all three states and write it in the overlap of all three circles.

  has energy, fixed shape, changing shape, fixed volume, changing volume, can be compressed, incompressible, closely packed, loosely packed
- c **Identify** the properties shared by two states (for example, solid and gas) and list them in the relevant overlaps.
- d **Identify** the properties displayed by only one state and list these in the appropriate spaces.

Inquiring

1 Search the internet for animations showing how Brownian motion occurs.

2 Construct a biography for Robert Brown in which you outline his achievements.

2.2 Practical activities

1 Compressing liquids and gases

Purpose

To determine whether liquids and gases can be compressed.

Materials

- plastic syringe (without needle)
- 250 mL beaker
- water

SAFETY

Do not use the syringe to squirt water at other people.

Procedure

1 You are about to use a syringe to try to compress water and then try to compress air.

Predict what will happen. Will you be able to compress either of them? If so, which do you think you will able to compress?

2 Fill the beaker with water and use the syringe to suck up water until it is full.

3 Push the nozzle of the syringe against your finger as shown in Figure 2.2.9.

4 Push the plunger down and observe what happens. Can you compress the water?

5 Take the syringe apart, empty it of its water and re-assemble it.

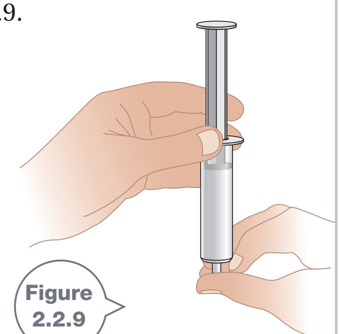


Figure 2.2.9

6 The syringe is now full of air (with a little water that will help seal it). Once again, push the nozzle against your finger and attempt to push the plunger down. Observe what happens. Can you compress the air?

Discussion

1 **Explain** your observations in terms of the spacing of particles in liquids and gases.

2 **Construct** a conclusion about what materials can and cannot be compressed.

2 Indirect evidence

Purpose

To show that you don't always need to see something to know what it is.

Materials

- at least 1 matchbox
- assortment of 'secret' small objects, each one able to fit in the matchbox (for example, an eraser, paperclip, stone, cork, match, pen top)

Procedure

1 Pair up with a classmate. One of you is to place a 'secret' object in the matchbox.

2 The other of the pair is to predict what is in the box without opening it.

3 After a few attempts, swap roles.

Discussion

1 **State** how accurate this method was in determining what is in the matchbox.

2 **Assess** whether you actually need to see something to know that it's there and what it is.

2.3 Changing state

Liquid water freezes to form frost on cold mornings. When it's really cold water can form ice and snow. As the temperature increases during the day, the frost, ice and snow begin to melt to form pools of liquid water. Water can be changed from one state into another by adding energy to it or by removing energy from it. This is done by heating it up or cooling it down.

Adding heat

A solid, liquid or gas might just increase its temperature when heated. If you add enough heat, however, then the substance will change its state. Given enough heat, solids will change into liquids and liquids will change into a gas, as shown in Figure 2.3.1.

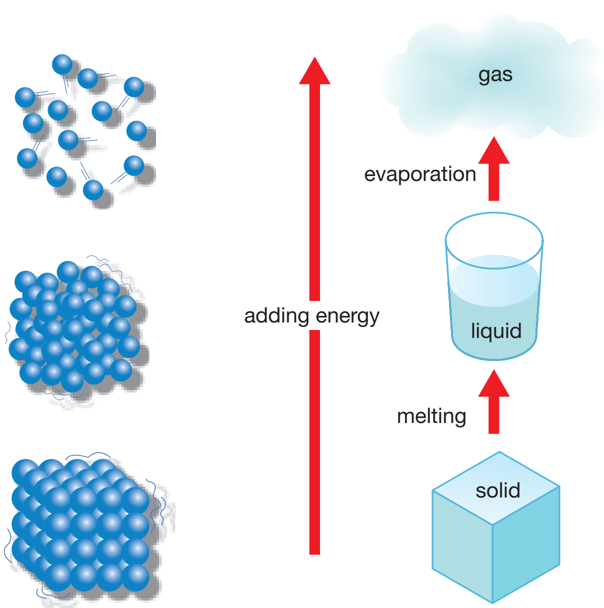


Figure 2.3.1 Adding heat to a solid or liquid causes its particles to move about more, and faster. If enough heat is added, particles break free from each other and the substance changes state: it may melt, evaporate or sublime.

Melting

Melting is the process in which heat causes a solid to change into a liquid. Although the physical properties of the substance change, the substance itself is exactly the same as it was before. Ice (solid water) is exactly the same substance as the liquid water it melts into when it is heated. Likewise, the solid wax that makes up a candle is exactly the same substance as the clear, molten drips of wax that slide down its side.

Heat adds energy to the particles in a solid, making them vibrate faster. If you add enough heat, then the particles at the edges of the solid will be vibrating so violently that they will break free, allowing them to melt away from the others in the solid. You can see this in the melting butter in Figure 2.3.2.

Melting point

The temperature at which a solid melts is known as its **melting point**. A substance is solid below its melting point and is molten (a melted liquid) above it. Water, for example, has a melting point of 0°C.

Different substances have different melting points, as shown in Table 2.3.1.

Figure 2.3.2 Melting starts at the edges of the solid becasue these particles are the first to receive heat from outside. This is why butter and ice cubes melt from the outside towards the centre.

Table 2.3.1 The boiling, melting and freezing points of various substances

Substance	Boiling point (°C)	Melting point (°C)	Freezing point (°C)
Ethanol (alcohol)	78	114	114
Water	100	0	0
Mercury	357	39	39
Silver	2193	961	961

Evaporation

Evaporation is the process in which heat causes a liquid to change into a gas. Evaporation is sometimes also known as **vaporisation**. Heat, for example, causes liquid water to evaporate (or vaporise), turning it into the gas known as water vapour. Wet clothes eventually dry out because the liquid water in them has evaporated to become water vapour. This water vapour then escapes from the clothes and joins the other gases of the air. Figure 2.3.3 shows this process being used.

The bonds between the particles in a liquid are just strong enough to hold them all together to form a fixed volume of liquid. These bonds are too weak to stop the particles from moving about within the liquid, slipping and sliding over one another. Adding energy to a liquid causes its particles to move faster and loosens their bonds even more. If sufficient energy is added, then the particles at the liquid surface move so fast that they can break away completely from the rest of the particles in the liquid. They are now particles of gas, and escape into the atmosphere.

Figure 2.3.3 Evaporation always occurs at all temperatures because there will always be some particles moving fast enough to break free from the liquid. This explains why clothes on the line will eventually dry, even on cold days.

Boiling

Boiling is a special case of evaporation. Evaporation occurs at any temperature, but boiling only happens at a temperature known as the **boiling point**. Boiling is obvious because bubbles appear throughout the liquid. These bubbles are formed by the evaporation of pockets of liquid deep inside the liquid. These pockets change into gas, which expands to form a bubble. The bubble then rises and escapes into the atmosphere when it reaches the surface of the liquid.

Boiling point

The boiling point of a substance is the temperature at which it changes from a liquid into a gas. Water has a boiling point of 100°C. This represents the highest temperature that liquid water can be, and the lowest temperature at which water vapour can be.

Sublimation

Most substances change from solid to gas in two stages: first they melt, and then they evaporate. A few substances change from solid into a gas directly, without going through a liquid stage. **Sublimation** is the process in which heat causes a solid to change directly into a gas.

Two substances that sublime are iodine and solid carbon dioxide (dry ice). Figure 2.3.4 on page 58 shows iodine crystals subliming.

Figure 2.3.4 Iodine doesn't melt. Instead, the black crystals sublime to produce a purple vapour (gas).

SKILL BUILDER

Identifying boiling

Although boiling is accompanied by the release of bubbles from deep within a liquid, it is not the only time bubbles are released when a liquid is heated. Most liquids contain some dissolved gases, such as the oxygen that fish use to breathe. These gases form small bubbles soon after heating begins and can trick you into believing that boiling is happening. However, the bubbles appear at temperatures well below the boiling point and are generally much smaller than big bubbles seen at boiling, shown in Figure 2.3.5. After a short time, these small bubbles stop being released and no more bubbles appear until the liquid itself is boiling.

Figure 2.3.5 Continuous bubbling is a sign of boiling.

Removing heat

The temperature of a substance drops when heat is removed from it. A substance might change state if sufficient heat is removed from it, as seen in Figure 2.3.6.

1 p61

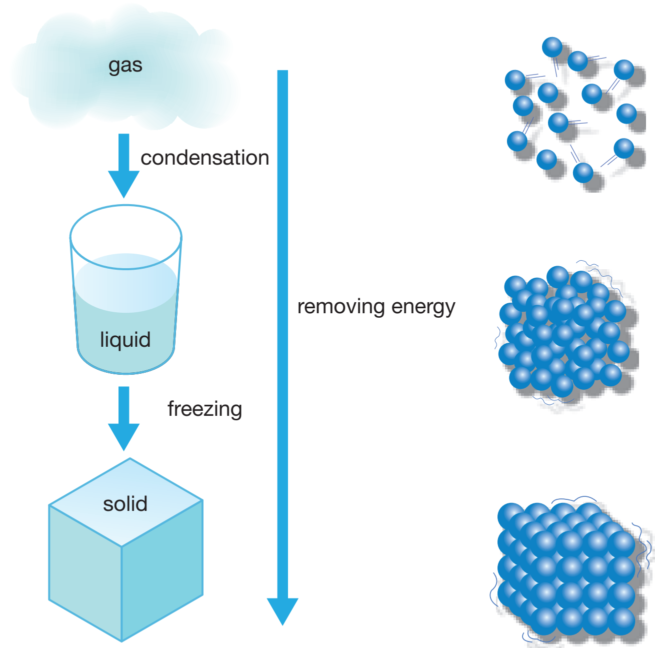


Figure 2.3.6 Substances will condense, freeze or deposit if enough heat is removed from them.

Freezing

Freezing (also known as **solidification**) occurs when heat is lost and a liquid changes into a solid. An example of freezing is shown in Figure 2.3.7. These snowflakes show some of the amazing shapes that can form.

Figure 2.3.7 Snow is a form of ice. It is caused by liquid water freezing around a speck of dust high in the atmosphere to form fantastically shaped snowflakes. Likewise, frost is dew (liquid water) that has frozen overnight.

As a liquid cools, energy is lost from its particles and the particles move more slowly than before. If you remove enough energy, the particles will end up just vibrating on the spot. Bonds form between the particles, locking them into their position to form a solid of definite shape and size.

Freezing point

The **freezing point** is the temperature at which a liquid changes into a solid. Freezing is the opposite process to melting, and so freezing and melting occur at exactly the same temperature. For water, the freezing point is the same as its melting point: 0°C.

INQUIRY **science 4 fun**

Role play

No

Collect this ...

- masking tape
- a clear space of floor (a carpeted area is ideal)

Do this ...

1. Use the masking tape to mark out a closed rectangle on the floor or on a grassed area.
2. Stand within the marked-out area with all the other students in the class.
3. Imagine you are all particles within a solid and that the masking tape represents solid walls. Move about to model what the particles would be doing when:
   - very cold
   - the solid is being heated
   - the solid is starting to melt
   - the liquid formed is being heated
   - the liquid is starting to evaporate
   - the gas formed is being heated.

Record this ...

Describe what happened.

Explain why you think this happened.

Condensation

Condensation is when a substance loses heat and changes from a gas into a liquid. Your lungs are full of water vapour (gaseous water) that will condense into tiny droplets of liquid water when you breathe out onto something cold, like a window or mirror. Likewise, water vapour in the air will condense on a cold night to form droplets of liquid dew that will make the lawn and spider webs wet. This is shown in Figure 2.3.8.

Figure 2.3.8 The dew on this spider web is caused by water vapour condensing overnight.

As a gas is cooled, its particles slow down. When they have slowed enough, the individual particles begin to attract each other and form bonds that will tie their movement to the other particles in the substance. They now act as a group, forming droplets of liquid.

Steam is water vapour that has condensed to form a cloud of tiny but visible liquid water droplets in the air. Water vapour emerges as a gas from a kettle or from a boiling pot on the stove but quickly cools to form a visible fog of tiny liquid water droplets.

Deposition

Some gases change directly into solids without ever passing through a liquid state. This process is known as **deposition**.

2 p63 2.6 2.7

2.3 Unit review

Remembering

1 **State** the temperature at which liquid water:
   a boils b freezes.

2 **Name** two substances that sublime.

3 **State** alternative words for:
   a evaporation b freezing.

4 **Recall** the various changes of state by copying and completing Figure 2.3.9.

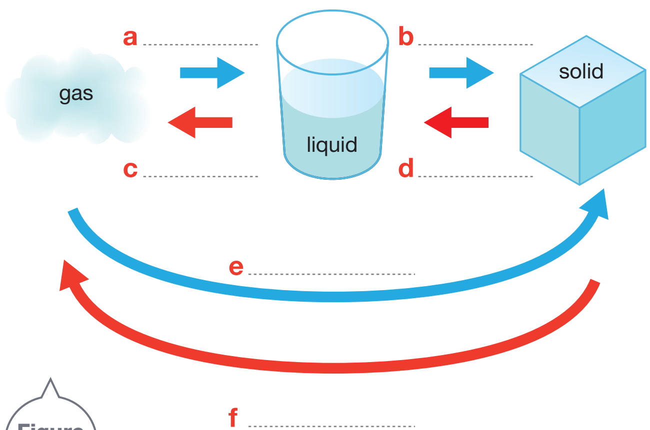


Figure 2.3.9

Understanding

5 **Explain** why the melting point and freezing points of a substance are at exactly the same temperature.

6 **Explain** where all the heat energy is going when a substance is boiling.

7 You peg some wet clothes on a clothes line. **Explain** why the water in the clothes evaporates despite the temperature never getting near the boiling point of water.

8 **Explain** how:
   a snow forms
   b dew forms
   c frost forms.

Applying

9 **Identify** two substances that:
   a melt at relatively low temperatures
   b evaporate at relatively low temperatures.

10 **Identify** the change of state that happens when:
   a ice-cream starts to drip
   b jelly sets
   c the bathroom mirror gets foggy.

11 **Use** the information from Table 2.3.1 to **predict** what state ethanol, water, mercury and silver would be in at the following temperatures.
   a –50°C b –20°C
   c 50°C d 200°C
   e 500°C f 1000°C

12 Sunglasses often fog up when you walk outside from an air conditioned building on a humid summer day. **Use** the idea of condensation to **explain** why.

13 The addition of impurities such as salt to water does two things to the water: it lowers its freezing point, and it increases its boiling point. **Use** this information to **explain** the following.
   a Salt is spread on the roads in northern United States and Canada to help keep the roads clear of ice.
   b Additives can stop a car radiator boiling over.
   c Ice-cream makers are cooled with a mixture of salt and ice and not just pure ice.

Analysing

14 **Contrast**:
   a evaporation and boiling
   b melting and sublimation
   c steam and water vapour.

Inquiring

1 Find out how additives like antifreeze stop car radiators from freezing.

2 Find out if it is safe to eat snow or drink its melt.

3 Research the differences between techniques for freezing food, such as snap freezing and freeze-drying.

4 Search the internet to download images of the different shapes of snowflakes.

5 Search the internet to find videos of substances that sublime.

2.3 Practical activities

1 Temperature graphs

Purpose

To determine what effect salt has on the melting and boiling points of water.

Materials

- 250 mL beaker
- thermometer
- stirring rod
- spatula or spoon
- stopwatch, watch or clock
- Bunsen burner, bench mat, tripod and gauze mat
- retort stand and clamp
- crushed ice or ice cubes
- water
- salt
- graph paper
- ruler
- grey-lead pencil

SAFETY!

Wear safety glasses at all times.

Turn the Bunsen burner flame to yellow when it is not being used.

Allow the Bunsen burner and other equipment to cool before putting it away.

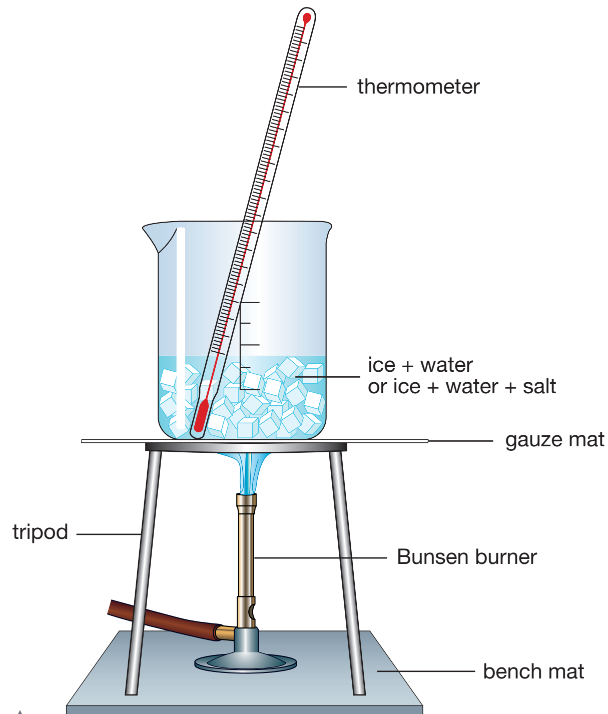


Figure 2.3.10

Procedure

1. Your teacher will tell you which of the following two groups you and your lab partners will be part of:
   - The tap water group: this group will heat a mixture of tap water and ice
   - The salty group: this group will heat a mixture of salt, pure water and ice.
2. Both groups need to add crushed ice or ice cubes to their beaker so that they come up to about the 100 mL mark.
3. Add water to the ice cubes so that it surrounds the ice and also comes up to about the 100 mL mark.
4. The salty group also needs to add salt (a couple of spatula loads or spoonfuls) to their ice/water mixture.
5. Set up the apparatus as shown in Figure 2.3.10.
6. Measure and record the starting temperature of the ice/water or ice/water/salt mixture.
7. Light the Bunsen burner and turn the collar so that the airhole is open and the flame is blue. Start timing immediately.
8. Measure and record the temperature every minute. Use the stirring rod to stir the mixture gently before measuring the temperature.
9. Continue measuring and recording the temperature until the water has been boiling for 2 or 3 minutes. Once it is boiling, you may need to turn the collar on the Bunsen burner to partly close the airhole.

Temperature graphs continued on next page

Temperature graphs continued

10 Copy the graph template shown in Figure 2.3.11 onto graph paper. Ensure that your scale uses equal intervals. Plot your data on the graph and **create** a line graph by joining the points with straight lines.

11 Your graph probably has two parts that are reasonably flat with little or no increase in temperature. Identify those sections of your graph by highlighting them.

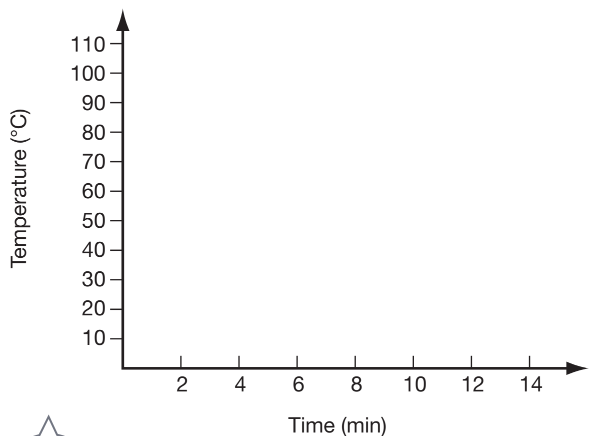


Figure 2.3.11

Discussion

1 **Use** your graph to:

a **identify** the melting point and boiling point

b **state** the water temperature 5 minutes after you started heating

c **state** the time that your sample reached 80°C

d **predict** the temperature of your sample 10 minutes after it started to boil.

2 **Compare** your graph with those of other groups and use the graphs to **compare** the melting and boiling points of salt water with those of tap water.

SKILL BUILDER

Graphing changes of state

A substance changes state because heat causes bonds between its particles to break. Temperature will not change while this is happening, so a graph of temperature versus time will be flat, as shown in Figure 2.3.12.

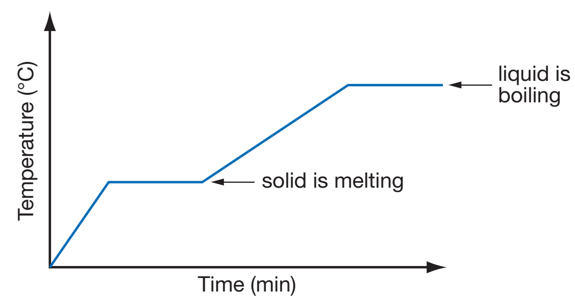


Figure 2.3.12

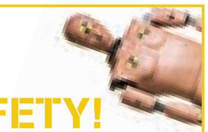
2 Custard shockwaves

Purpose

To use the increased volume of a gas to create a shockwave.

Materials

- large empty coffee can with lid
- rubber or plastic tubing
- plasticine or Blu Tack
- tea-light candle
- long barbecue matches
- custard powder



SAFETY!

Wear safety glasses at all times.

Make sure everyone stands clear and behind a safety screen.

Can be done as a Teacher Demonstration if preferred.

Procedure

1. Make a hole near the base of the coffee can about the same diameter as that of your tubing.
2. Insert the rubber tubing into the hole and use plasticine or Blu Tack to ensure a good seal.
3. Pour a small amount of custard power into the can so that it covers the end of the rubber tube.
4. Place the tea-light candle opposite the tubing/custard powder as shown in Figure 2.3.13.
5. Use the long barbecue matches to light the candle and immediately secure the lid back on the can.
6. As soon as you can, blow a small puff of air through the tubing.

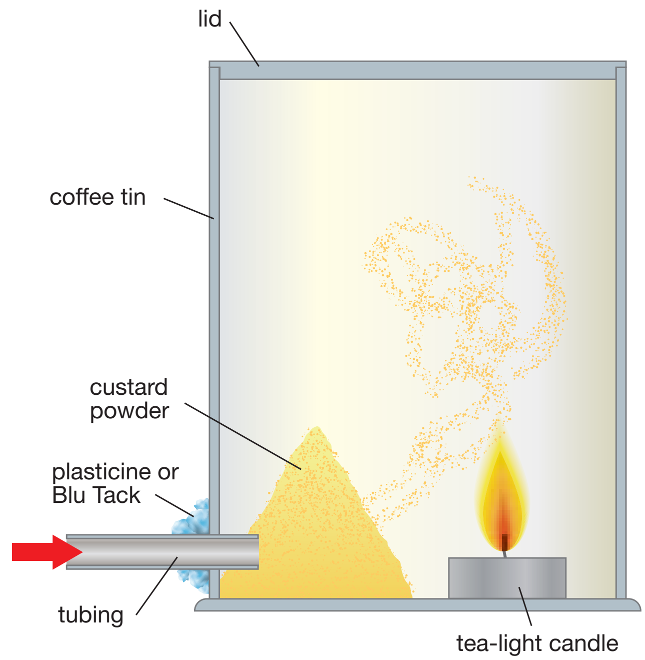


Figure 2.3.13

Results

Describe what happened.

Discussion

1. The flame caused the custard powder to react and burn. **Explain** how you know gases were produced in this experiment.
2. Gases take up far more space than liquids or solids. **Use** this idea to **explain** what happened.
3. A similar sort of explosion happens when gunpowder is ignited in a gun. **Outline** how it could get a bullet moving.

2 Chapter review

Remembering

1 **State** two physical properties each for:
  a solids
  b liquids
  c gases.

2 **State** what happens to particles in the following states when they are heated:
  a solid
  b liquid
  c gas.

3 **Name** the opposite processes to:
  a melting
  b evaporation
  c sublimation.

Understanding

4 Density measures how much of a substance is packed into a certain space. Gases are less dense than liquids or solids of the same material. **Explain** why.

5 **Describe** the property that makes gases ideal for filling jumping castles.

6 **Predict** which of the following is most likely to be the melting point of butter:

A –20°C	B 0°C
C 30°C	D 100°C

Applying

7 When you dive into a swimming pool, the water parts around you as you enter it. **Use** the particle model to **explain**:
  a what happens to the water particles as you dive in
  b why the swimming pool water gives you a 'punch' in the stomach when you do a 'bellywhacker' and not a clean dive.

Analysing

8 **Contrast**:
  a melting and sublimation
  b melting and freezing
  c plasma and gas.

Evaluating

9 **Predict** what might happen when you place an empty balloon around the rim of a conical flask with some water in it (shown in Figure 2.4.1) and heat the flask.

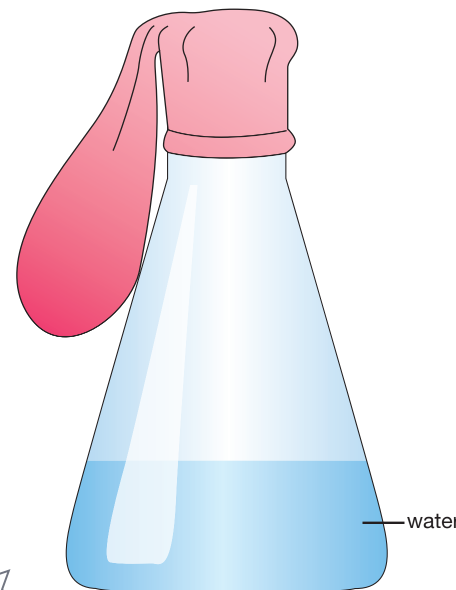


Figure 2.4.1

10 a **Propose** what would happen to you if you jumped around in a jumping castle filled with water instead of gas.
  b Refer to the particle model to **justify** your prediction.

11 Aerosol cans should never be thrown in a fire. **Propose** reasons why.

Creating

12 **Use** the following ten key words to **construct** a visual summary of the information presented in this chapter.

matter	solid
liquid	gas
melt	freeze
evaporate	condense
sublime	heat

2.8

Thinking scientifically

Q1 The properties of a substance never change. Properties describe what a substance looks like, how heavy, dense, hard and brittle it is and how it acts when heated, cooled or mixed with other chemicals. Below are several statements that describe solid gold. Assess which is *not* a property of solid gold.

A Gold is yellow and shiny.

B Gold melts at a temperature of 1064°C.

C One gram cost $45.40 in May 2010.

D Gold reacts with strong acids to form hydrogen gas.

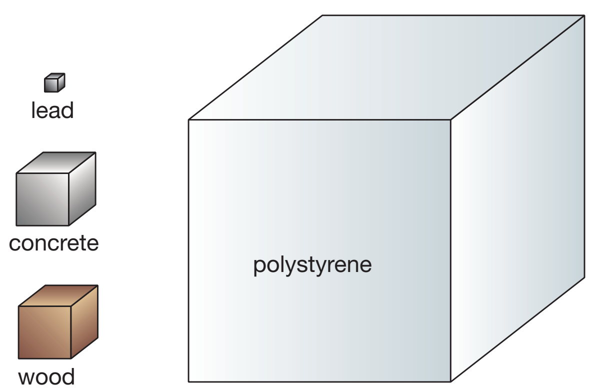
Q2 All the blocks in the diagram below weigh exactly the same. Density measures how much of a substance fits into a volume. Which of the following shows the correct order of densities from highest to lowest density?

A Highest density = concrete, lead, wood, polystyrene = lowest density

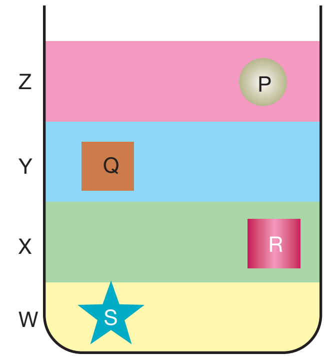
B Highest density = lead, concrete, wood, polystyrene = lowest density

C Highest density = concrete, wood, lead, polystyrene = lowest density

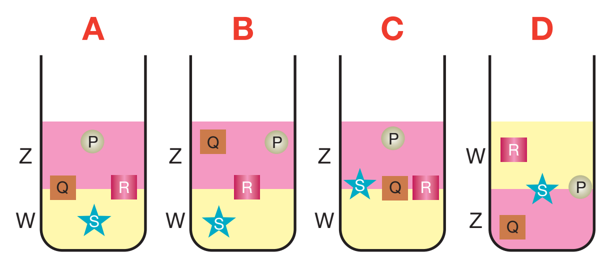
D Highest density = lead, polystyrene, concrete, wood = lowest density



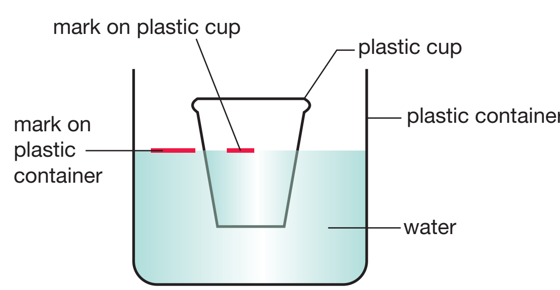
Q3 Liquids do not always mix together. Sometimes one liquid floats on top of another. Alice filled a container with some liquids as shown. P, Q, R and S are different objects floating in the liquids.



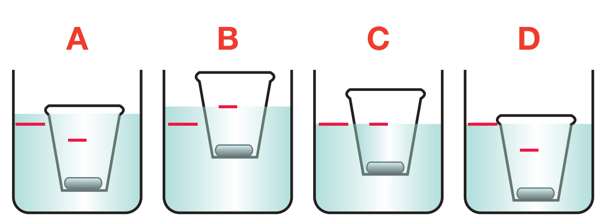
What would happen if liquids X and Y were removed?



Q4 Angus placed a plastic cup in a plastic container filled with water. He marked the level of the water on the cup and the container.



Angus then placed a heavy rock inside the plastic cup. What did he observe?



Glossary

Unit 2.1

Biodegradable: bacteria or fungi breaks down the substance into simpler substances

Chemical properties: how substances react with other substances

Chemical properties

Compressed: squashed

Incompressible: not able to be compressed or squashed

Non-biodegradable: doesn't rot or break down

Odour: smell

Physical properties: describe things about the substance like its appearance, melting, freezing and boiling points and its hardness

Plasma: the fourth state of matter; found in sparks, lightning bolts and in stars

States (phases): solid, liquid, gas (also plasma at temperatures over 6000˚C)

Unit 2.2

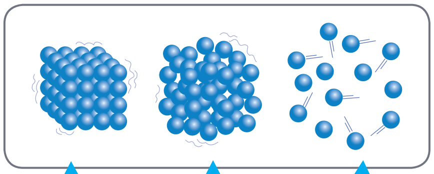
Atoms: the incredibly tiny particles that make up all matter

Bonding: forces of attraction that hold particles together (verb: bonds)

Brownian motion: random motion of particles caused by being bumped and jostled by other particles

Matter: the particles that make up everything

Particle model: the model used to help describe and explain the behaviour of particles in solids, liquids and gases



Particle model

Vibration: jiggling about on the spot (verb: vibrates)

Unit 2.3

Boiling: when vigorous bubbling appears (verb: boils)

Boiling

Boiling point: the temperature at which a liquid boils; 100°C for water

Condensation: removal of heat, changing a gas into a liquid (verb: condenses)

Deposition: a gas changing directly into a solid

Evaporation (vaporisation): heat changing a liquid into a gas (verb: evaporates)

Freezing (solidification): removal of heat, changing a liquid into a solid (verb: freezes)

Freezing point: the temperature at which a liquid freezes; 0°C for water

Melting: heat changing a solid into a liquid (verb: melts)

Melting

Melting point: the temperature at which a solid melts; 0°C for ice

Steam: condensation of water vapour, forming a visible fog of water droplets

Sublimation: a solid changing directly into a gas

3 Earth resources

HAVE YOU EVER WONDERED...

- if humans could run out of resources like coal or oil?
- why you should save energy?
- how clouds form?
- why people should care about what they put in the air or soil?

After completing this chapter students should be able to:

- describe the Earth's major resources, such as soils, air, rocks, water, living things and sunlight
- explain what is meant by a 'renewable' resource
- discuss timescales for the regeneration of resources
- classify energy sources as either renewable or non-renewable
- compare renewable and non-renewable energy sources
- describe how renewable and non-renewable energy sources are used in Australia and the world
- describe the changes of state that occur in the water cycle
- investigate factors affecting the water cycle in nature
- explore ways that humans manage water and affect the water cycle.

3.1 Major Earth resources

Humans need many things to stay alive, like food, air, water and shelter. Other living things have similar needs. These needs are met by the natural resources on Earth. It is the responsibility of everyone to protect these vital resources.

INQUIRY science 4 fun

Rocks

What is in a rock?

No

Collect this …

- stereomicroscope or hand lens
- samples of different rocks

Do this …

1. Carefully study one of the rock samples with the microscope at about ×40 magnification or with a hand lens. Is the material in the rock all the same or is the rock made of different materials?
2. Study the other rocks to see if they have the same materials in them.

Record this …

Describe what you saw.

Explain how these rocks could be used by humans.

Natural resources

A **resource** is anything supplied by the Earth to satisfy a particular need of humans or other living things. Most natural resources are substances, such as rocks or water. However, sunlight is a vital resource that is not a substance. Sunlight is a form of energy and is needed by almost all living things on Earth. Though it enters the Earth from space and is not a substance, it can be considered to be an Earth resource.

The major natural resources of Earth are its:

- rocks
- minerals and fossil fuels (like coal and oil) found in rocks
- soil
- air
- water
- living things
- sunlight.

Some of these resources are shown in Figure 3.1.1.

Figure 3.1.1 Birds, animals, trees, soil, rocks, water, air and sunlight are resources.

These resources are not just used by humans to make things with or to supply us with energy. Almost all life depends on these resources. Many of these resources need to be protected by humans to assist in the survival of all living things, including ourselves.

Renewable and non-renewable resources

The time taken for a resource to be replaced determines whether it is classified as renewable or non-renewable.

A **renewable resource** is a resource that is replaced by natural processes that occur in a timescale shorter than an average human life. This means that renewable resources take less than eighty or so years to be replaced. For example, most trees can be regarded as renewable resources because they grow to maturity in less than eighty years. The major renewable resources are air, water, sunlight and living things.

Some resources like coal and oil take millions of years to be replaced naturally. So to a human these resources would seem like they are not being replaced. As such, they are considered to be **non-renewable resources**. Rocks and soils are also considered to be non-renewable resources because they take so long to be replaced.

Living things as a resource

Living things are a resource for humans and other organisms. For instance, animals eat plants and other animals. Sometimes living things even use other organisms as places to live. For example, tapeworms live in the gut of other animals. Plants use waste materials from animals and other plants as nutrients. Some plants rely on animals as a way of pollinating flowers, such as in Figure 3.1.2. Humans use plants and animals for food, shelter, building materials, clothing, medicines, fertilisers, fuel and many other purposes.

Figure 3.1.2 This plant relies on the hummingbird to pollinate its flowers. To attract the hummingbird the plant produces a sugary substance called nectar.

Living things also depend on their surroundings to supply other resources that they need. Water, rocks, air and soil supply the materials needed for all life. Sunlight is also essential for plants to make their own food and to keep the Earth warm enough for life to exist.

Living things: a renewable resource

Living things are a renewable resource because they reproduce. A forest that has been cut down can regrow. Animals like the cows in Figure 3.1.3 on page 70 are replaced through reproduction. Replacing some forests may take just a few decades. Others forests take longer. Plantations (where humans deliberately plant trees for timber) can be replaced faster than a natural forest. Replacing animals on farms may take a year or so.

Figure 3.1.3 Animals are a renewable resource because they reproduce.

Air as a resource

Air is a mixture of gases and suspended particles such as dust, smoke and water droplets. The main gases in air and their importance to life on Earth can be seen in Table 3.1.1.

Table 3.1.1 Gases in the air

Gas	Percentage in air	Importance to life
Nitrogen	78	Provides nutrients for plants to make proteins and other chemicals, which humans and other animals can use as food.
Oxygen	21	Essential for most living things, to release energy from food that their bodies can then use.
Carbon dioxide	0.03	Essential for plants to make their own food by photosynthesis.
Other gases such as ozone, water vapour and argon	0.97	Many uses depending on the gas. Ozone shields humans from ultraviolet rays (reducing our risk of skin cancers). Water vapour is part of the water cycle that carries water around the planet. Argon is used in light globes.

Air: a renewable resource

About 21% of the air (by volume) is oxygen gas. Oxygen is constantly being used by animals and plants, but is also constantly being replaced by plants. This allows the oxygen level of the atmosphere to stay about the same. Scientists describe the movement of materials from one place to another and then back again as a 'cycle'. Oxygen cycles through Earth and its atmosphere.

All of the oxygen on Earth is thought to have originally been produced by microscopic plant-like organisms and green plants. Green plants like the one in Figure 3.1.4 use the energy from sunlight, carbon dioxide and water to make their own food. The process is called **photosynthesis**. As well as producing the plant's food, photosynthesis also produces oxygen.

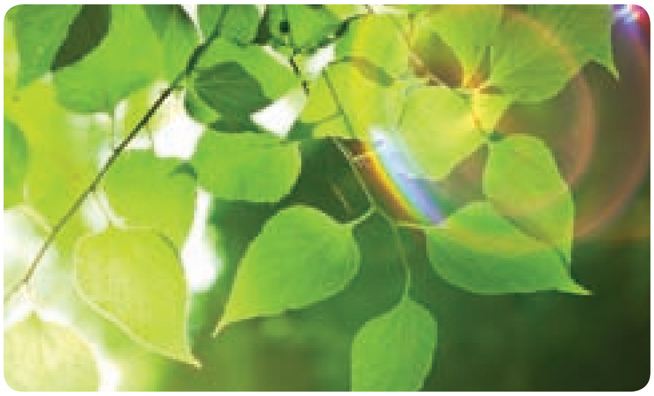


Figure 3.1.4 Green plants use carbon dioxide, water and energy from sunlight to make their food by the process of photosynthesis.

SciFile

Earth's fragile atmosphere

The atmosphere is the very thin layer of air around the Earth's surface. The first astronauts who ventured into space were amazed at how thin and fragile the atmosphere looked from space. Many said it made them think very deeply about the damage humans are doing to the atmosphere.

Only about 0.03% of air is carbon dioxide. This is enough to supply the carbon dioxide needed in photosynthesis. Animals breathe out carbon dioxide because it is a waste product of the processes that release energy in their bodies. So carbon dioxide is also being replaced in the air. It is part of a cycle, where it goes from the atmosphere to plants, and then back again from animals to the air. This cycle of oxygen and carbon dioxide is shown in Figure 3.1.5.

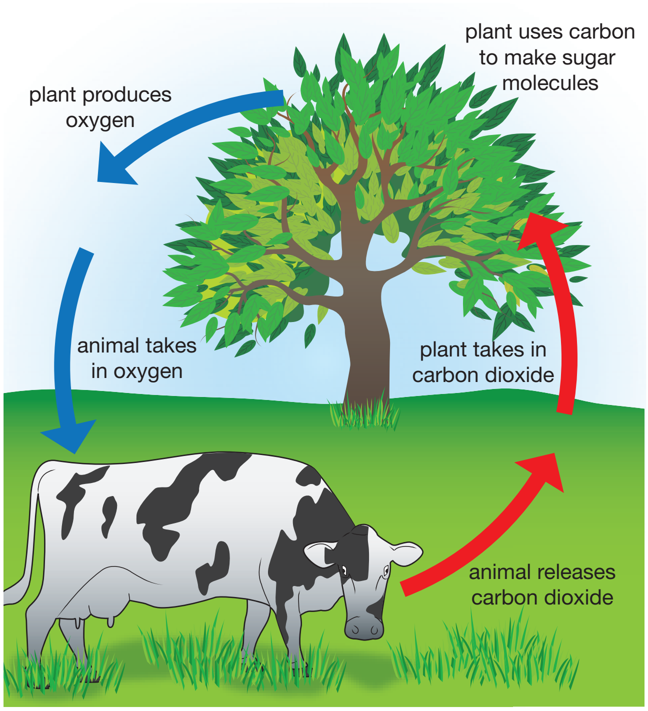


Figure 3.1.5 The exchange of oxygen and carbon dioxide between plants and animals renews these gases in the atmosphere.

Nitrogen gas also has its own cycle as it is absorbed by some organisms and released by others. Gases such as oxygen, carbon dioxide and nitrogen can also move to areas of low concentration where one of them is being used up.

1 p77

Sunlight as a resource

Sunlight has an essential role in supporting life on Earth.

- Plants use sunlight to produce food.
- Sunlight warms the Earth's atmosphere, land and water, keeping it warm enough for most water to stay liquid. If the Earth cooled too much, then all water would freeze and turn to ice. Living organisms contain a lot of water and so they would also freeze.

Sunlight: a renewable resource

Sunlight is a renewable resource and will be for as long as the Sun keeps shining. The Sun is a star, and will continue to shine for billions of years.

Water as a resource

Water covers most of the Earth's surface and all living things (like the bird in Figure 3.1.6) need it. No organism can live without water for long. For this reason, water is the Earth's most important resource.

Figure 3.1.6 Water is a very important resource on Earth because no living thing can survive without water.

SciFile

Living on other planets

Life cannot exist without water. For this reason, scientists searching for signs of life in space are only looking at planets and moons where water can be detected.

Water: a renewable resource

Water is a renewable resource because it can move from place to place and replenish an area. It has a cycle. However, only a tiny fraction of the water on Earth is made new each day. Some water is made when:

- living things like trees burn
- fossil fuels like petrol and coal burn
- living things release energy in their bodies.

The total amount of water on Earth is thought not to have changed much since the planet formed.

Water will be covered in detail in Unit 3.3 and in Chapter 4.

2 p78

Rocks as a resource

Rocks provide two different resources:

- the rocks themselves
- materials found in rocks.

There are many different types of rock. Some rocks are hard and can be used without altering them or removing any materials from them. These solid rocks are used mainly for roads and buildings, like the one shown in Figure 3.1.7. Other rocks are soft, like limestone and sandstone. These rocks are easy to cut, so they are used in paving and walls. Many of the founding buildings of cities are often built from the local bedrock.

Figure 3.1.7

Stone buildings are built from rocks.

Rocks are made from substances called **minerals**. Minerals differ in their physical properties such as colour and hardness. You can see how minerals appear in a magnified view of a rock in Figure 3.1.8. Many minerals are important resources for humans. A variety of minerals and their uses are shown in Table 3.1.2.

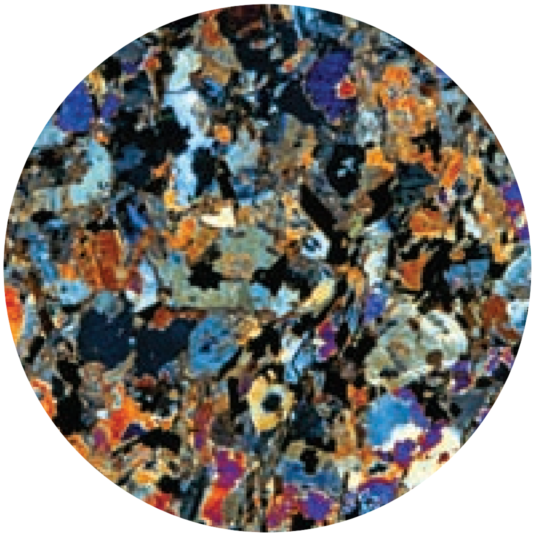


Figure 3.1.8

This is a magnified view of a rock showing that it is composed of different minerals. Each different colour is a different mineral.

Table 3.1.2 Minerals and their uses

Mineral	Main use
Bauxite	Contains aluminium. Aluminium is used for making aircraft, drink cans and high voltage powerlines.
Haematite	Contains iron. Iron is used to make steel, which is used in car bodies, nails, ships and bridges.
Malachite	Contains copper. Copper is used in electrical wiring.
Halite	Contains sodium chloride (table salt). Sodium chloride is used in food preparation and medical applications.

Rocks contain some of the minerals that are needed by living things. As the rocks gradually break down, they release minerals which end up in the water of oceans and lakes, and in the soil. From the water and soil, the minerals are taken up by plants and animals, providing them with necessary trace elements.

Rocks also contain resources that are not minerals. Water is often found in rocks. The fossil fuels oil, natural gas and coal are energy sources that are found in or between layers of rock deep below the ground.

Rocks: a non-renewable resource

Most of the rocks of the Earth were formed millions of years ago. However, in a few places, rocks are still forming today. Some rocks form when hot liquid from inside the Earth cools either below or above the ground. This type of rock is called **igneous rock**. Volcanoes (like the one in Figure 3.1.9) are places where igneous rocks form. The igneous rocks that form below ground can take thousands to millions of years to form. Igneous rocks form on the surface in a day or so because the liquid rock (lava) cools quickly in the air.

Figure 3.1.9

Although new rocks form in and around volcanoes every day, they cannot be considered a renewable resource because the overall process takes so long.

Other types of rocks form when sediments stick together and harden to become rock. This type of rock is called **sedimentary rock**. Most sedimentary rocks form over many thousands or millions of years.

Only a tiny fraction of the Earth's rocks is being replaced each year. The replacement takes so long that rocks are not considered to be renewable resources. Therefore the minerals in the rocks are non-renewable resources. Oil and coal are materials that are found in or between rock layers, and are also non-renewable resources. Oil and coal were formed from dead plants and animals that lived many millions of years ago and are not being formed today.

Soil as a resource

Rock can be worn away by the processes of weathering and erosion. These natural processes have been wearing away rocks throughout the Earth's history.

Weathering

Weathering is the process of breaking rocks down into smaller pieces. Weathering happens in the following ways:

- Changes in temperature between day and night or because of weather and the seasons, can split rocks.
- Water settles in cracks in rocks. As water freezes into ice it expands (gets larger), widening the crack even more.
- Running water and waves can gradually wear away rocks.
- Strong winds blast rocks with small rock particles that wear the rocks away.
- Natural chemicals in the air, soil and water attack substances in the rock. The rock then crumbles and may form a cave like the one shown in Figure 3.1.10.

Figure 3.1.10 This limestone cave was formed by the action of rainwater containing acid that attacked the limestone rocks over a long time.

Erosion and deposition

Rocks are broken down into **sediments** by the process of weathering. Sediments can build up around the parent rock or can be carried away by water, wind and ice in a process called **erosion**. Water, wind and ice are referred to as **agents of erosion**.

The sediments that are carried away from weathered rock by water, wind or ice are eventually dropped somewhere. You can see this in Figure 3.1.11 on page 74. The process where sediments drop out of a moving stream of water, wind or ice is called **deposition**.

SciFile

Sink holes

Sink holes can appear suddenly in areas where limestone is the common type of rock. Sink holes are formed when the limestone below the surface is weathered by chemical action and caves form and then collapse. This sink hole appeared in 2010, in Guatemala, South America, right next to someone's home!

Figure 3.1.11 This sandstorm approaching the Saudi Arabian capital Riyadh shows how much erosion and deposition the wind can cause.

The deposited sediments are added to any soil they fall on, making new soil in the process. Soils are composed of:

- fine rock particles (sediments)
- living organisms (such as worms and moss)
- **humus** (decaying wastes and dead organisms)
- water
- dissolved minerals and gases.

You can see these in Figure 3.1.12.

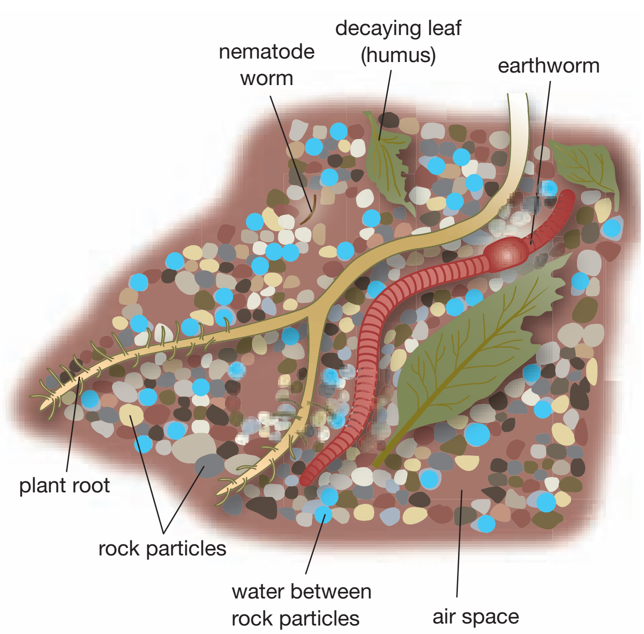


Figure 3.1.12 Soil consists of many components which can support the growth of plants and animals.

INQUIRY science 4 fun

In the dirt

What is in soil?

No

Collect this …

- stereomicroscope or hand lens
- samples of different soils

SAFETY
Wear gloves and do not inhale dust.

Do this …

1 Study one of the soil samples with a stereomicroscope at about ×40 magnification or with a hand lens. Is the material in the soil all the same or is it made of different materials? Try to work out what things are in this soil.

2 Study the other soils to see if they have the same materials in them.

Record this …

Describe what you saw.

Explain why some samples were similar while others were different.

Soil profiles

When you dig down into the soil you can often see different layers (as shown in Figure 3.1.13). These layers are called **horizons** and together the horizons make up the soil profile. The top layer (A horizon) is often a dark brown or black colour due to the high humus content from the organic matter it contains. Most plant roots are found in this top layer of soil. This horizon provides nutrients needed for plant growth. The next layer (B horizon) is called the subsoil. The subsoil is usually more compacted, contains less air and less humus and is therefore lighter in colour. The third layer (C horizon) is broken bedrock. At the bottom is unaltered rock. Horizons B and C usually have little impact on plant growth.

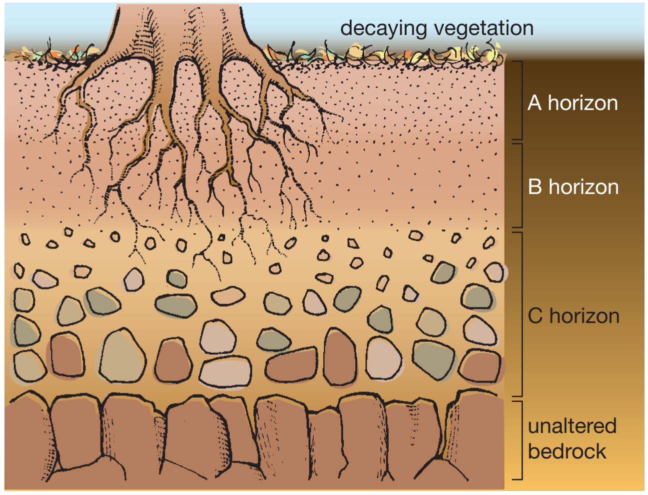


Figure 3.1.13 A soil profile shows that soil has clear layers which are revealed as you dig down.

Fertilisers

Fertilisers are materials that supply mineral nutrients to plants. They contain substances like phosphorus and nitrogen, which plants need to live. Farmers often add them to the soil to improve crop growth.

Common fertilisers are:

- untreated animal droppings such as manure from sheep or chickens
- 'blood and bone'. This is the dried and cooked remains of meat and bone from abattoirs
- chemical fertilisers. Many are manufactured from animal droppings. For example, bird droppings can be processed into a fertiliser called superphosphate.

There is evidence that excessive use of chemical fertilisers is damaging soils and streams and rivers. For this reason, some farmers are reducing their use and are using natural fertilisers instead.

Soil: a non-renewable resource

In some places the rock particles carried by water, wind and ice can build up quickly. An example is where many rivers carrying sediments meet in one place called a river flood plain. In this way the soil is continually added to. Soil can also be enriched by humans in home gardens or on farms. Adding fertilisers or mulch (rotting leaves, bark and twigs) adds nutrients to the soil.

However, in most places on Earth, soils are not being renewed. If a farmer's soil blows away in the wind (or a tornado like the one in Figure 3.1.14) or is washed away in floods, then it is not likely to be replaced in the farmer's lifetime. Some soils form in places where the rocks on the Earth's surface are weathered. However, this process takes hundreds or thousands of years to form soil only a few centimetres thick. Therefore most soils are not considered to be a renewable resource.

Figure 3.1.14 A tornado is a rapidly spinning column of air that forms during certain weather conditions. Tornadoes can strip topsoil from the ground and make it very difficult for any crops to grow.

3 p79 3.1 3.2

3.1 Unit review

Remembering

1 **List** the major resources of the Earth.

2 **List** the main causes of weathering.

3 **List** the ways rock particles can be carried away by erosion.

4 **List** the components of soil.

5 **Recall** what is produced by green plants in photosynthesis.

Understanding

6 **Define** the term *resource*.

7 **Explain** why living things can be considered a renewable resource.

8 **Explain** why minerals in rocks are not considered a renewable resource.

9 **Explain** why soil is such an important resource.

10 **Explain** how rocks are a resource for humans.

Applying

11 **Identify** the major resource on Earth that sustains all life.

12 **Identify** the major Earth resources that are:

- a renewable
- b non-renewable.

Analysing

13 **Classify** the following as renewable or non-renewable:

- a gum trees
- b water
- c sand
- d cows.

14 **Compare**:

- a renewable resources with non-renewable resources
- b erosion and weathering
- c erosion and deposition.

Evaluating

15 **Justify** the following statements:

- a Forests are renewable resources.
- b Soils are non-renewable resources.

Creating

16 **Construct** a table summarising the major resources of the Earth, including how they are a resource for humans and whether the resources are renewable or not.

Inquiring

1 Research the methods used to reduce the effects of soil erosion at the beach or on farms.

2 Research the benefits of adding compost to soils.

3 Forests are renewable. However, to replace them so that they reach the condition called *old growth forest* can take a long time (up to 250 years). Research old growth forests and why scientists consider them important.

4 Research the evidence that Aboriginal people in Australia have used fire to manage the land for thousands of years. In your answer discuss the benefits of the use of fire, particularly the recent discoveries of the effect of smoke on germination of seeds.

3.1 Practical activities

1 Renewing air

Purpose

To investigate whether a green plant produces oxygen.

Materials

- 3 × 250 mL conical flasks labelled A, B and C
- 3 small test-tubes
- 3 one-hole stoppers each with a filter funnel
- aluminium foil to cover one conical flask
- pieces of a leafy green plant such as geranium
- straw
- 3 test-tube stoppers
- test-tube rack
- wooden splint
- matches

Procedure

1. Place a number of pieces of the plant in each conical flask and fill the flasks to the brim with water.
2. Using the straw, blow bubbles through the water in flasks A and C for one minute. This adds carbon dioxide to the flasks.
3. Place a stopper with the filter funnel into each flask. Make sure some water enters the stem of the funnel.
4. Wrap flask C with foil so no light can enter.
5. Carefully add water to three-quarter fill each filter funnel. Then fill each test-tube with water and carefully turn the test-tubes upside down and place them in the filter funnels as shown in Figure 3.1.15.
6. Place the conical flasks outside in direct sunlight for the day if possible. Otherwise use a strong light in the laboratory and leave it on until the next day.
7. The next day, carefully lift the test-tube out of flask A, place a stopper in the top of the test-tube and place it in a test-tube rack.
8. Light the wooden splint and hold it near the test-tube in the rack. Quickly blow out the wooden splint, remove the test-tube stopper and hold the glowing splint in the test tube.

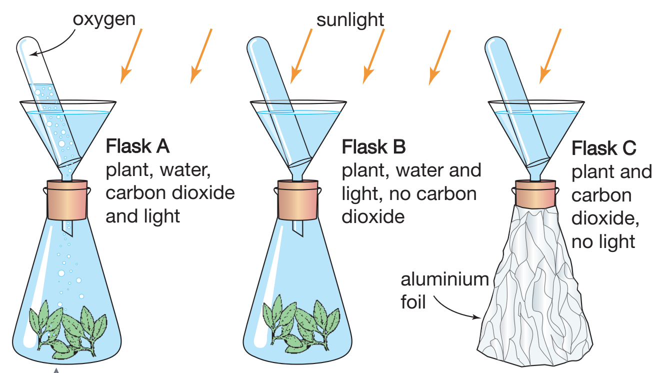


Figure 3.1.15

9. Repeat steps 7 and 8 with the other test-tubes and record what happens.

Results

Record your results in a table like the one below.

What happened to splint		
Test-tube A	Test-tube B	Test-tube C

Discussion

1. **Describe** the results for each test-tube.
2. Oxygen gas has the ability to make a glowing splint of wood catch fire again. **Deduce** whether any of the test-tubes contained oxygen.
3. **Propose** what happened in the three conical flasks.
4. **Explain** how this experiment is relevant to the importance of air as a resource.

3.1 Practical activities

2 Water-holding capacity

Purpose

To compare the water-holding capacity of different soils.

Materials

- 3 plastic filter funnels
- retort stand and 3 clamps, or filter stand
- 3 × 100 mL beakers
- 50 mL measuring cylinder
- cotton wool
- dry soil samples such as clay, loam, sand

SAFETY

Care must be taken not to inhale any soil particles. Wash your hands after completing the practical.

Procedure

1 Set up the equipment as shown in Figure 3.1.16, with a cotton wool plug in the neck of each funnel.

2 Half fill each funnel with a different type of soil.

3 Pour 20 mL of water into each funnel and collect any water that comes through. If no water comes through a particular soil, add another 20 mL water to that soil until some water runs through it.

Results

Record in a table how much water you added to each soil and how much water collected in the beaker.

Discussion

1 a **Identify** the soil with the largest water-holding capacity and the soil with the smallest capacity.

b **Justify** your decision.

2 **Outline** some possible reasons why the soils had different water-holding capacities.

3 Soils described as 'well drained' allow much of the water that enters them to pass through them. Labels on plants at a plant nursery sometimes say that the plant likes well-drained soils. **Propose** the characteristics of soils that make them well drained.

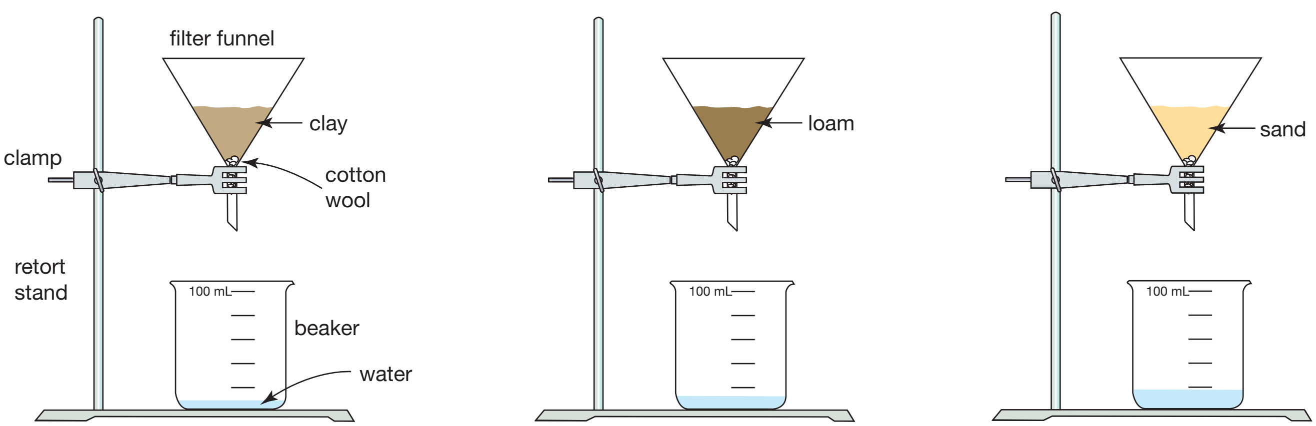


Figure 3.1.16

3 Erosion on a slope

Purpose

To design and conduct an investigation to test if the amount of soil erosion caused by water depends on the slope of the land over which the water runs.

Materials

- plastic gutter
- loam soil
- sandy soil
- bucket
- tap
- hand lens or microscope
- protractor
- wooden blocks or bricks

SAFETY

Care must be taken not to inhale any soil particles. Wash your hands after completing the practical.

Procedure

1. In your design you can use any equipment your teacher has provided or agreed to supply to you.
2. Decide in your group how you will proceed. Draw a diagram of the equipment you need and the procedure you will use to conduct your investigation. Construct a list of the materials you will need.
3. Show your teacher your procedure, and if they agree, collect your materials and conduct your investigation.
4. Record your results.

Discussion

Construct a prac report for your investigation.

Figure 3.1.17 Does the slope of the land affect the amount of soil erosion caused by water?

3.2 Energy sources

In Australia, the burning of coal generates most of our electricity. Fossil fuels produce vast amounts of the greenhouse gas carbon dioxide. This gives Australia one of the highest rates of greenhouse gas emissions per person in the world. Renewable resources such as wind, solar, tidal, hydroelectricity and biomass provide a sustainable and clean alternative.

Energy demand

Early humans had basic energy needs. Without electricity and fossil fuels, their energy needs were met from sunlight and from burning fuels like wood and dried animal manure. Energy demands have risen dramatically in recent times. This can be seen in Figure 3.2.1. Appliances and gadgets such as televisions, iPods, home entertainment units, gaming consoles and computers require a lot of energy to manufacture. They also require ongoing energy to use. Climate-controlled living rooms and the convenience of car and air travel come at an energy cost too. Table 3.2.1 shows that, relative to many parts of the world, Australia and other Western societies such as the United States and Europe consume large amounts of energy.

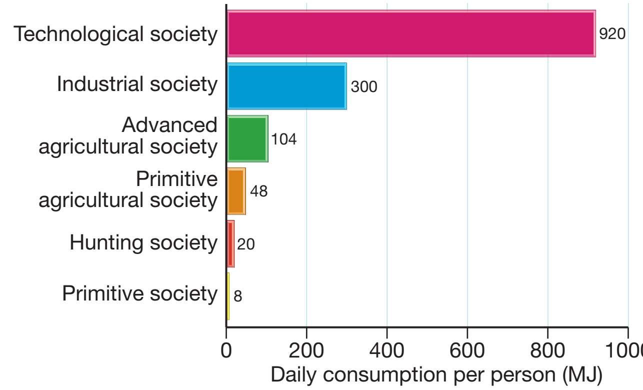


Figure 3.2.1 Comparing the energy needs of primitive cave dwellers with the energy used in today's society highlights the massive increase in energy consumption of recent times.

Table 3.2.1 Energy use per person (GJ) in various countries

Country	Yearly energy use per person (GJ) [1 GJ = 1000 million J]
Australia	240
Canada	348
China	48
Egypt	32
El Salvador	29
Ethiopia	12
Greece	113
Italy	131
Pakistan	19
United Kingdom	164
United States	327

Non-renewable energy sources

Oil, coal, gas and nuclear are energy sources that cannot be replaced. Energy sources such as these are called **non-renewable** energy sources. Oil, coal, gas and their products (such as petrol and diesel) are called **fossil fuels**.

Some 300 million years ago, the dead remains of prehistoric animals and plants were covered by layers of mud, sand and dirt. Pressure and heat below the Earth's surface gradually transformed these remains into the different fossil fuels than can be found today. The original source of energy for these fuels was the sunlight absorbed by the prehistoric plants, and stored in their remains or in the remains of the animals that ate the plants. When burnt, fossil fuels release large amounts of energy but also large amounts of the **greenhouse gas** carbon dioxide. This increased concentration of carbon dioxide in the atmosphere is thought to contribute to climate change.

Nuclear fuels, such as uranium and plutonium, are other non-renewable sources of energy that are used to generate electricity. Small amounts of these fuels can produce large amounts of energy in a chain reaction in a process called nuclear fission. This chain reaction is carefully controlled in a nuclear power plant. The heat created is used to generate electricity. Nuclear power plants do not produce greenhouse gas emissions and are used as the main power source in many countries. However, the process of nuclear fission used in the plants produces wastes that remain radioactive for thousands of years. Safe storage of these wastes remains a problem.

Figure 3.2.2 shows that more than 80% of the world's energy supply is obtained from oil, coal and gas. These are all non-renewable fossil fuels. Australia has plentiful supplies of coal and it is relatively cheap. Major energy sources used in Australia include:

- black and brown coal, to produce steam used to generate most of our electricity
- petrol to power most of our cars, with some using LPG (liquefied petroleum gas, another fossil fuel)
- diesel to power most trucks and some trains
- natural gas for much of our cooking, central heating and hot water services.

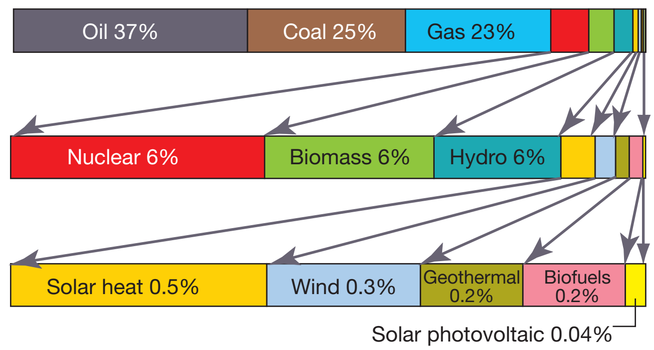


Figure 3.2.2 This chart shows where the world's energy comes from. The second and third rows show detail that cannot be seen in the eight smallest bands of the original (top) graphic.

SciFile

Brown isn't green

Brown coal releases a third more carbon dioxide than the same amount of black coal for only half the heat. Trials are being conducted to develop 'clean coal' technologies to capture and store carbon dioxide emissions from power plants such as Loy Yang. Loy Yang power station, in the Latrobe Valley in Victoria, consumes up to 60 000 tonnes of brown coal per day to supply about one-third of Victoria's energy. Most environmentalists argue that it should be shut down.

Renewable energy sources

Renewable sources of energy can be used over and over again. To build an energy supply for the future and to limit greenhouse gas emissions there is a need to switch from fossil fuels to renewable sources. Power companies offer households the option to buy all their electricity or some of it from an accredited green power provider. This means that by paying slightly more you can buy electricity that has been sourced from renewable energy. Key sources of renewable energy are:

- moving water
- Sun
- wind
- heat within the Earth
- oceans and rivers
- biomass.

Hydroelectricity

Gravity causes things to fall, including water. Water falling from a higher to a lower level (such as from the dam shown in Figure 3.2.3) can be used to turn turbines and generate electricity. This form of electricity is called **hydroelectricity**. The Snowy Mountains hydroelectric scheme is the largest hydroelectric power scheme in Australia. It consists of 16 dams, 7 power stations and over 145 km of tunnels. Hydroelectric schemes are a renewable energy resource. However, large-scale projects change the way rivers flow and alter the environment.

Figure 3.2.3 The energy of falling water is used to turn turbines that generate electricity in a hydroelectric power station.

Biomass

Biomass describes energy that is obtained from materials such as dead plants, plant matter, or animals and their wastes. These materials contain stored energy captured from the Sun. This energy can be released for use in many different ways:

- Heat energy is released when products such as wood or dried manure are burnt.
- When organic wastes such as fruit peelings and grass clippings are put into landfill, they decompose, producing methane and carbon dioxide gases. This gas mixture, called **biogas**, can be collected from landfill sites and the methane gas then used as a fuel.
- Biogas can be produced from human sewage and animal wastes. Production is conducted within tanks fitted with digesters that encourage breakdown of the waste.
- Agricultural crops such as corn (shown in Figure 3.2.4) and sugarcane can be fermented to produce ethanol, which is used as a liquid fuel. Agricultural wastes such as rice husks can also be used to produce ethanol.
- Vegetable oils from plant seeds such as oil palm, sunflower, canola, soybean, sesame and linseed can be converted into biodiesel fuel.
- Algae are harvested to produce biodiesel fuel.

SciFile

A sugar rush

Brazil produces vast crops of sugarcane and uses some to produce ethanol. Most new cars are designed to run on ethanol. This change has lessened Brazil's dependence on oil – its cars are essentially solar powered!

Figure 3.2.4 Corn ethanol is produced in this processing plant in Iowa, USA. The corn grain shown here is a waste product of the process and is sold as animal feed.

Solar energy

Light from the Sun is a valuable renewable resource. It can be used in many ways to provide energy.

- The direction a house faces (its orientation) can help to reduce the need for additional heating and cooling. Using interior materials that absorb sunlight through the day and then release heat at night also helps.
- Sunlight can be used to heat rooftop solar panels to provide households with hot water.
- **Solar cells** (such as that shown in Figure 3.2.5) use materials called semiconductors to convert sunlight directly into electricity. Rooftop solar cells can provide household electricity, and any extra electricity generated can be fed back into the electricity grid. Solar cells are expensive to produce, but their generating capacity is increasing each year. This is reducing the cost of producing electricity using solar cells.
- A solar pond consists of a large volume of water to which salt is added. The pond is lined with black plastic. Sunlight heats water at the base of the pond, and the heat can be used to generate electricity.
- Large-scale solar energy systems, such as that shown in Figure 3.2.6 on page 84, rely upon vast arrays of mirrors to concentrate sunlight. These devices can be used to generate electricity with no greenhouse gas emissions.

Figure 3.2.5 Solar cells are useful for providing energy to small-scale devices such as calculators or garden lighting and for providing electricity in remote areas. The solar cell in this picture is on top of the phone booth.

INQUIRY science 4 fun

Using the Sun

What energy changes occur with a solar cell?

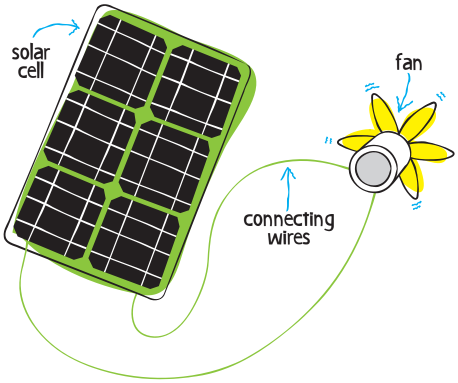
No

Collect this ...

- solar cell
- connecting wires
- electric motor with a fan

Do this ...

1. Use the connecting wires to connect the solar cell to the electric motor.
2. Stand outside (preferably on a sunny day) with the solar cell facing the Sun.



Record this ...

Describe what happened.

Explain why you think this happened.

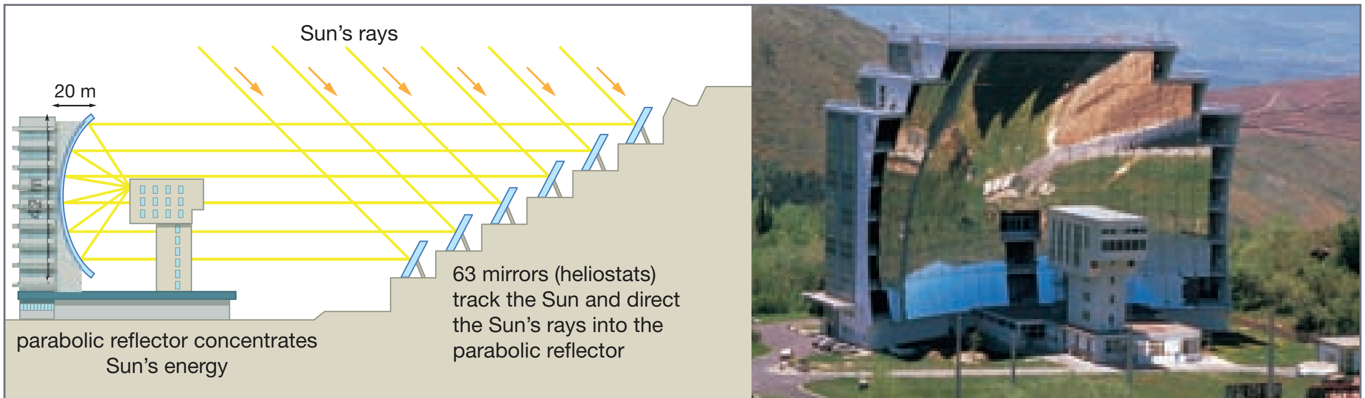


Figure 3.2.6 A solar furnace can produce temperatures up to 3800°C. Solar furnaces can be used to generate electricity or to conduct experiments on materials at extreme temperatures.

Wind energy

Wind energy has been used for centuries and windmills have long been used in Australia to pump water. Wind turbines are like large windmills but are used to generate electricity. Wind farms are located in windy places. You can see a wind farm in Figure 3.2.7.

2 p91

Figure 3.2.7 Wind energy generates no greenhouse gas emissions. Nearby residents may object to wind farms because they do produce noise and occasionally birds may be injured by the turbines as they spin.

Energy from the ocean

There are a number of different techniques that harness energy from the ocean. Although these techniques are generally expensive to establish, they offer a clean energy source once they are operating. An **oscillating wave column** (shown in Figure 3.2.8) and a **tidal barrage** (shown in Figure 3.2.9) are two examples.

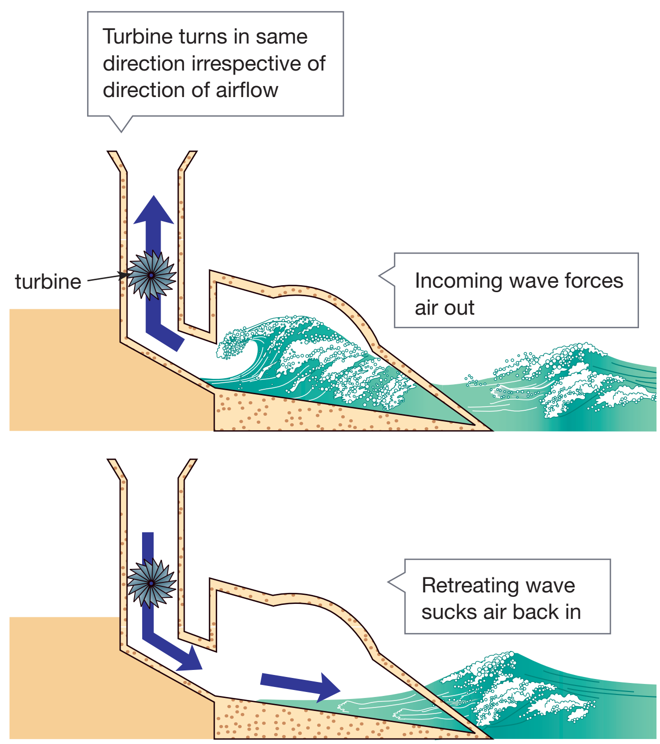


Figure 3.2.8 The oscillating wave column relies on the pressure of the waves to suck air in and out around a turbine to generate electricity.

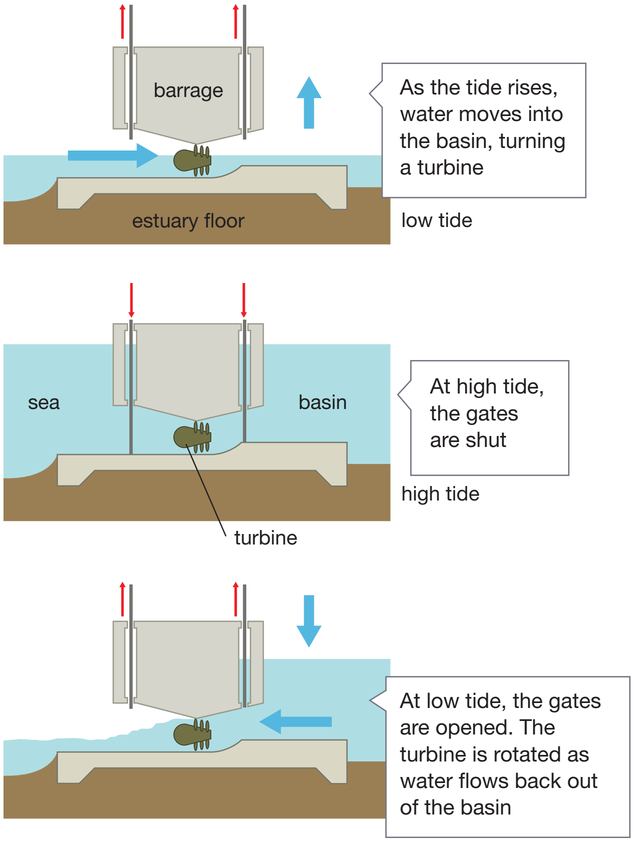


Figure 3.2.9 At low tide, the gates of the tidal barrage open to allow water to fill a basin. These gates are shut at high tide. When the tide is low, the gates are reopened and the pressure of water rushing out is used to generate electricity.

Geothermal energy

Beneath the Earth's crust lies molten magma (melted rock). In Iceland, Japan and New Zealand, this heat lies fairly close to the surface and heated water may burst from the surface as a natural hot spring or geyser like the one shown in Figure 3.2.10. This heated water can be used directly to generate electricity. Another way to use **geothermal energy** is to pump water underground through drilled channels and circulate it through the hot rock. The water is heated by the rock and is used to generate electricity when it returns to the surface. This is shown in Figure 3.2.11. A geothermal power plant has been built at Birdsville, in Queensland, and plants are being developed in South Australia. Geothermal power plants tap into a plentiful natural energy source. However, they are limited to specific areas and can result in pollutant gases escaping from below the Earth's surface.

Figure 3.2.10 This steam is produced by geothermally heated water in Iceland.

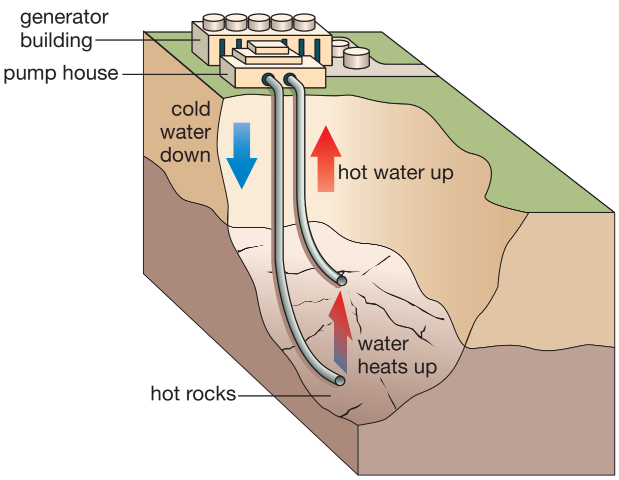
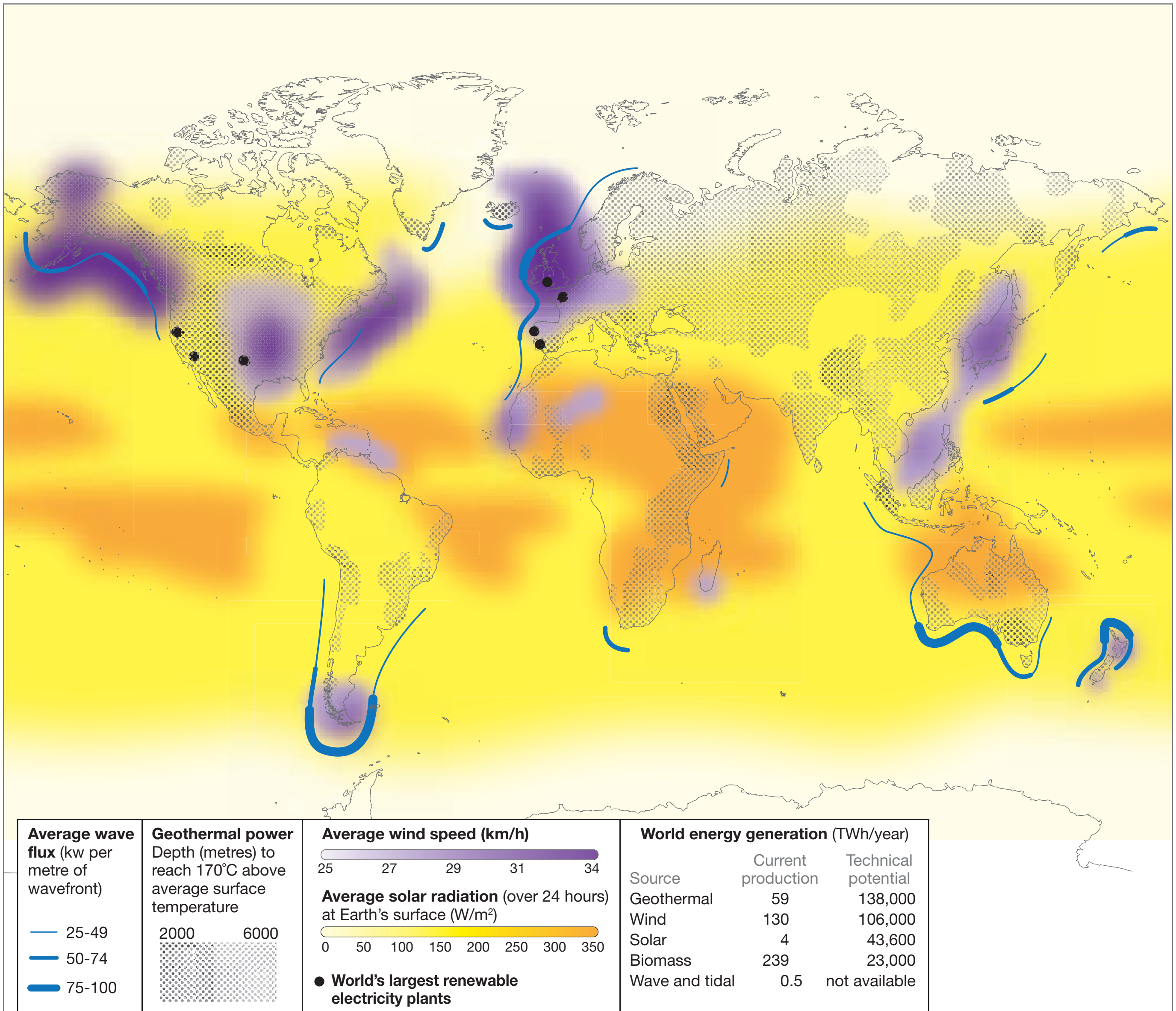


Figure 3.2.11 A geothermal power plant relies upon cold water being pumped below the surface where it is naturally heated over hot rocks and then returns to the surface.

The big picture

A major problem associated with many renewable energy sources is that their output is not continuous. Wind turbines, solar systems and wave generators rely upon the wind blowing, sunlight being present and waves crashing. Better methods need to be developed to store energy when demand is low so it can be used when demand rises. Figure 3.2.2 on page 81 shows that solar energy, geothermal energy and wind energy provide a small fraction of the world energy supply at present. A better approach is to utilise a number of renewable sources of energy. Figure 3.2.12 on page 86 illustrates the enormous potential of renewable energy sources worldwide and highlights the regions best suited to each type.



World energy generation (TWh/year)

Source	Current production	Technical potential
Geothermal	59	138,000
Wind	130	106,000
Solar	4	43,600
Biomass	239	23,000
Wave and tidal	0.5	not available

Figure 3.2.12 The depth of yellow shading indicates the average solar radiation reaching the surface of the Earth. The purple zones indicate regions of high wind speed. The blue lines indicate high tidal activity.

Energy conservation

Reducing the energy we use will ease demands on resources and will minimise greenhouse gas emissions. Here are some ways you can make a difference:

1. Switch off TVs and computers when they are not needed.
2. Walk, ride a bike or catch public transport instead of driving.
3. Use blinds and fans in summer instead of airconditioners.
4. Insulate yourself in winter by wearing a jumper and using blankets or thicker doonas.
5. Drink tap water rather than bottled water.
6. Use cloth bags or a backpack for shopping. Avoid purchasing products with lots of packaging.
7. Reduce the amount you buy, reuse what you have before throwing it away, and recycle goods you no longer need.

SCIENCE AS A HUMAN ENDEAVOUR

Use and influence of science

Umeme Kwa Wote—Energy for all

Figure 3.2.13 In 2008, an experimental program was launched in Kenya that enabled people to recharge a solar-powered lamp such as this one in an energy hub.

About one quarter of the world's population do not have access to an electricity supply.

For many generations, fishermen living by the shores of Lake Victoria, in Eastern Africa, have relied upon kerosene lamps to light their homes and catch fish at night. Kerosene is readily available in remote areas and easy to buy in small quantities. However, it is expensive and highly flammable, and at times kerosene leaks into the lake, adding to its pollution. It is estimated that the burning of kerosene in lamps around the lake produces about 50 000 tonnes of carbon dioxide gas every year.

In April 2008, a lighting company built the first 'energy hub', on the banks of Lake Victoria. Its name is *Umeme Kwa Wote*, Swahili for *energy for all*. It is an energy station consisting of 42 solar panels installed on its roof. These panels convert the tropical sunlight into a clean supply of electricity. Three hubs have been built in Kenya and one in Uganda, with hopes to build another 100 energy hubs in Africa and 20 in Asia.

For a small fee, locals can use this electricity to recharge energy-efficient fluorescent lamps for use on their boats and in their homes. They can also take a rechargeable battery from the energy hub to power fishing lamps. A typical lamp is shown in Figure 3.2.14. It relies on an 11 W globe and is watertight and dust resistant. Costs are much lower than the equivalent costs for kerosene, the light from the lamps is brighter, it carries no health risks, and no greenhouse gases are produced in the process.

The battery can also be used to charge small appliances such as mobile phones and radios. When the batteries are flat, they are brought back to the hub for recharging and are swapped for a charged battery.

The woman shown in Figure 3.2.13 is carrying a lantern with an internal rechargeable battery. This lantern operates for 8 hours, or even longer when switched to a lower power LED light designed to provide enough light to read a book at night.

Figure 3.2.14 These fishermen are dragging their net into the waters of Lake Victoria. They hope to catch sardines attracted by the light source.

3.4

3.2 Unit review

Remembering

1 a **State** one key advantage associated with the use of fossil fuels.
  b **State** two key disadvantages associated with fossil fuel use.

2 **State** one advantage and one disadvantage associated with the use of nuclear fuel.

3 **List** the three sources of energy that supply the majority of the world's needs.

4 **List** five types of seeds that can be used to produce biodiesel fuel.

5 **Recall** another name for a solar cell.

6 **State** the fraction of the world's population that has no access to electricity.

Understanding

7 **Explain** the difference between renewable and non-renewable sources of energy, giving an example of each type.

8 **Outline** how fossil fuels are formed.

9 **Define** the term *biomass*.

10 **Describe** five different ways sunlight can be used as an energy source.

Applying

11 a **State** the average energy use in gigajoules (GJ) of an Australian over a year.
  b **Calculate** this value in joules (J).

12 Each situation below describes different energy changes. **Use** the options in the box below to **identify** which type of energy is being used in each case.

hydroelectricity
oscillating wave column
biomass
fossil fuel
tidal barrage
solar energy
geothermal energy
wind energy

  a Wood is burnt in a camp oven to boil a kettle.
  b Natural gas is used to heat a saucepan of pasta on a stove.
  c Falling water turns turbines that generate electricity.
  d Sunlight falling on a photovoltaic cell is directly converted into electricity.
  e Turbines rotate as air flows through them and this is used to generate electricity.
  f A turbine rotates in one direction and then the other as moving water sucks air past its blades.
  g Water flows rapidly over a turbine, which is used to generate electricity.
  h Water pumped below the surface of the Earth is heated and used to generate electricity.

13 Refer to Figure 3.2.12 to answer the following questions.
  a **State** the current production of electricity from solar sources (in TWh/yr).
  b **State** how much electricity could potentially be produced from solar sources (in TWh/yr).
  c **Propose** three regions of the world that would be best suited to utilising:
    i solar energy
    ii wind energy
    iii ocean energy
    iv geothermal energy.
  d Looking at Australia on this illustration, **propose** which renewable resource you think would be best suited to development in the state or territory that you live in.

14 **Use** Figure 3.2.2 on page 81 to **state** the percentage of world energy consumption supplied by:
  a oil
  b solar photovoltaic energy
  c nuclear energy.

Analysing

15 **Compare** the key advantages and disadvantages between two renewable energy sources, such as solar, wind, tidal, geothermal or hydroelectric energy production.

Evaluating

16 a **Assess** whether nuclear energy is a renewable or non-renewable energy source.

b **Justify** your answer.

17 **Propose** why it is recommended that you switch off appliances at the power source.

18 **Propose** what is meant by the term *green energy*.

19 Consider the suggestions to help households conserve energy use.
   a **Identify** one of these that you could easily act on this week.
   b **Propose** your own personal list of 10 ways that you could save energy.

Creating

20 Australia has plenty of brown and black coal. It is relatively easily mined and relatively cheap.
   a **Construct** an argument for or against the use of coal as an energy resource.
   b **Use** the arguments of the class to run a debate on whether coal should continue to be used as a major source of electrical energy in Australia.

Inquiring

1 Find articles in the newspaper, magazines, on TV current affairs shows or on the internet regarding energy use and energy resources. Assess the arguments presented in each article and use your knowledge of renewable and non-renewable resources to summarise the claims made in them.

2 a Summarise the major sources of energy used in the state or territory in which you live. Survey a number of people about the energy that they use and compare whether this is in agreement with your research.
   b Investigate the energy sources used by two countries other than Australia. Compare their energy sources with those used in Australia.
   c Research and report upon an aspect of renewable energy technology that is being developed by Australian scientists. For example, investigate the work currently being conducted at the National Solar Energy Centre.
   d Some people are concerned that harvesting food crops for biofuel production will result in food shortages. Research and report on whether these are valid concerns and recommend strategies to avoid this happening.
   e Research the developments being made in 'clean coal' technology. List arguments for using coal-fired power plants in the future, with clean coal technologies. Also list arguments that could be made against the use of such power plants with or without the new technology.
   f Some unusual devices are being tested to generate electricity from waves, with names such as 'the Oyster' and 'the Anaconda'. Summarise the development of one type of device designed to harness wave power and construct a model to explain how it works.

3 Research and report on how the solar energy complex shown in Figure 3.2.15 is used to generate electricity.

Figure 3.2.15 This solar energy complex located in the Mojave Desert in California, USA, is an example of a parabolic trough power plant.

3.2 Practical activities

1 Energy from food

The stored chemical energy in food can be used to produce biofuels. Food is also used as your chemical energy.

Purpose

To burn a sample of food and calculate its energy content.

Materials

- food samples such as: Cheezels, crusty bread, Marie biscuit
- cork
- aluminium foil
- paper clip
- retort stand and clamp
- thermometer
- test-tube
- electronic balance
- small measuring cylinder

SAFETY

Do not use peanuts or any nut product.

Watch the burning food sample at all times.

Ensure that the room is well ventilated or complete this experiment inside a fume cupboard.

Procedure

1. Using the measuring cylinder, carefully measure 10 mL of water. Pour it into the test-tube.
2. Cover the cork with aluminium foil. Shape the paper clip like a hook and poke it into the cork.
3. Cut a small piece of your first food sample. Record its mass in your table.
4. Set up the equipment as shown in Figure 3.2.16 so that the food sample will sit about 2 cm below the test-tube.
5. Measure and record the initial temperature of the water.
6. Use the Bunsen burner to set the food sample alight, and then carefully place the burning sample under the test-tube.
7. When the sample stops burning, measure the final temperature of the water and record this result.
8. Repeat the activity using two other food samples.

Results

1. Copy the results table below into your workbook.
2. **Calculate** the change in water temperature by subtracting the initial temperature from the final temperature.
3. For each sample, divide the change in water temperature by the mass of the sample.

Discussion

Compare the different samples and list them in order from the one that contains the most energy per gram to the one that has the least energy per gram.

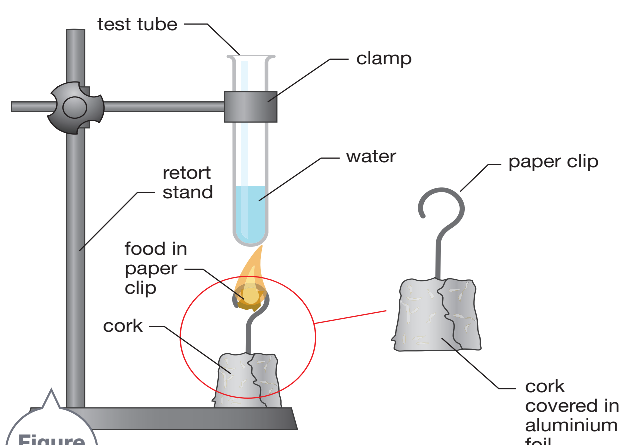


Figure 3.2.16

Food sample	Mass of sample (g)	Initial temperature of water (°C)	Final temperature of water (°C)	Change in water temperature (°C)	Change in water temperature ÷ mass of sample (°C/g)
1					
2					
3					

2 Harnessing the wind

Purpose

To investigate the effect that wind direction has on wind power.

Materials

- fan or a hairdryer
- pinwheel made from a sheet of cardboard (Please go to Pearson Places for a template.)
- nail
- bamboo skewer
- protractor (optional)
- masking tape
- cardboard cylinder
- length of string
- paper clip

Procedure

1. Produce a cardboard pinwheel using the instructions from Pearson Places and tape it securely to a bamboo skewer.
2. Support the pinwheel by inserting it through two holes in a cardboard cylinder as shown in Figure 3.2.17. The pinwheel and skewer should be able to spin freely.
3. Tape a length of string to the skewer where it extends from the cylinder.
4. Tie a paper clip or small sinker to the end of the string.
5. Investigate how the rate of spinning of the pinwheel (as indicated by the height the paper clip rises) is affected by the angle that the wind source (fan or hairdryer) makes with the front of the pinwheel. You could try different angles including 'straight on'.

Results

Present your data in a results table.

Discussion

1. **Describe** any patterns found in your results.
2. **Propose** any improvements that could be made to the design of your prac.

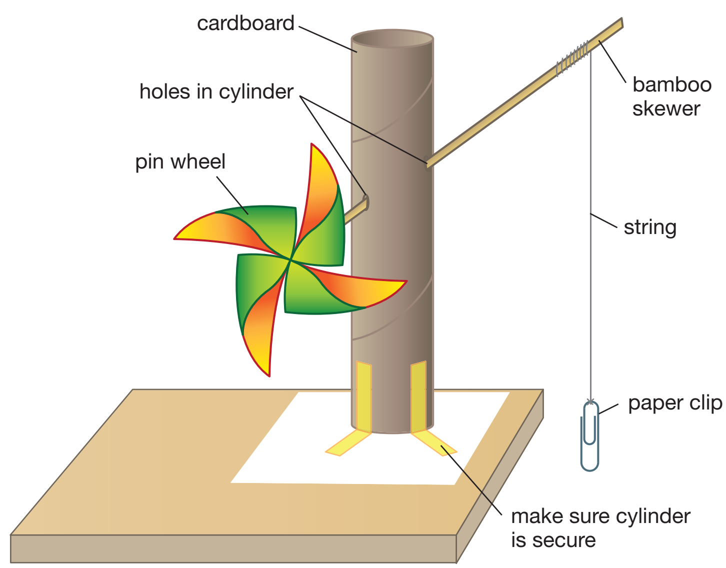
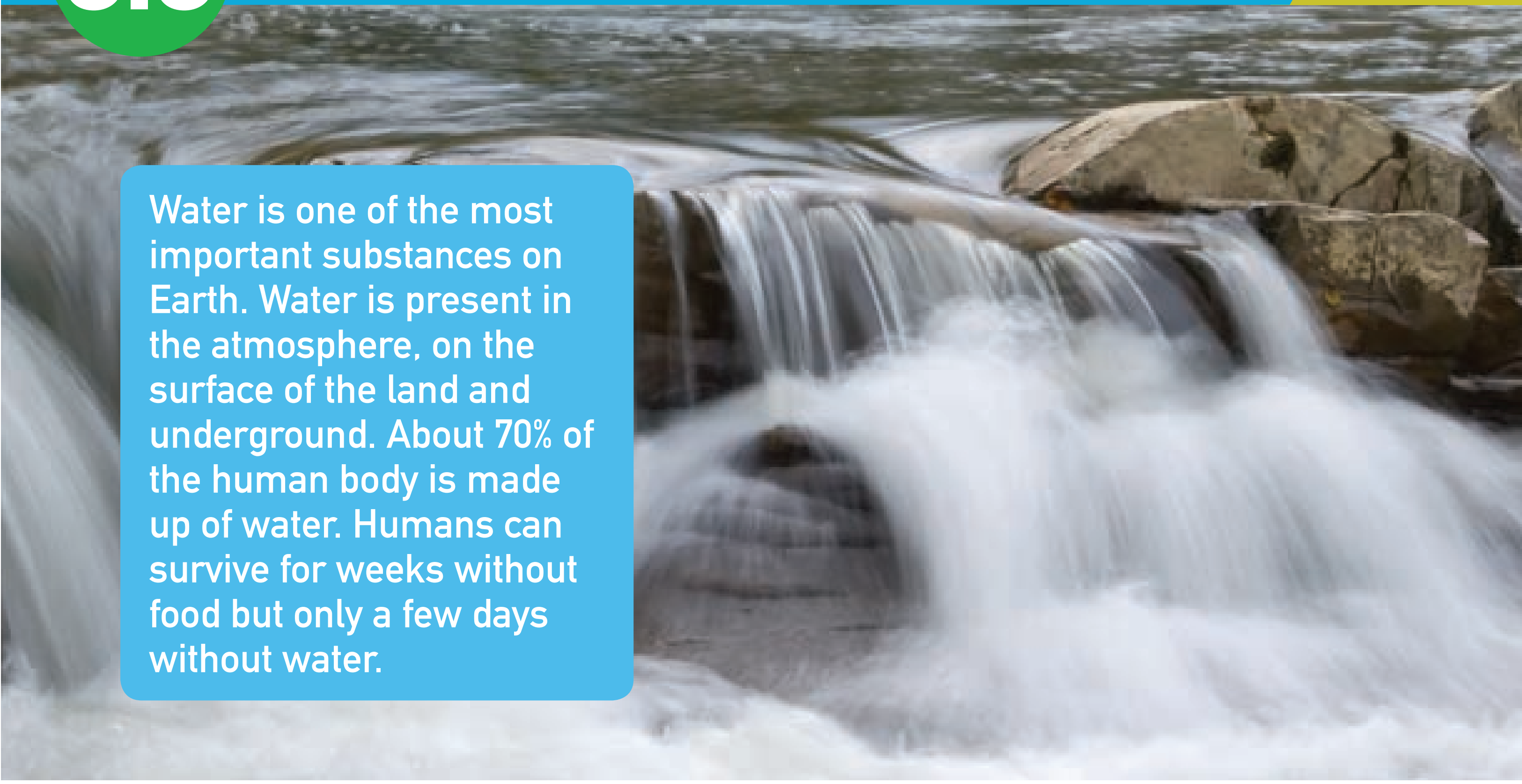


Figure 3.2.17 If the cylinder is unstable, tape it to a thick cardboard base so it is sturdy when standing upright.

3.3 The water cycle



Water is one of the most important substances on Earth. Water is present in the atmosphere, on the surface of the land and underground. About 70% of the human body is made up of water. Humans can survive for weeks without food but only a few days without water.

Water on Earth

Look at the map of the Earth in Figure 3.3.1. It shows that there is far more water than land. About 70% of the Earth's surface is covered by water.

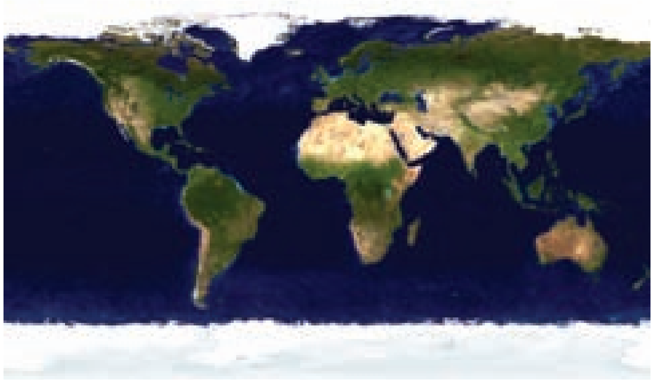


Figure 3.3.1 Seventy per cent of the Earth's surface is covered by water.

However, almost all of the water that covers the Earth's surface (97.5%) is in the oceans and salt water lakes. This makes it unsuitable for drinking and most other uses. The other 2.5% is fresh water, but almost all of that cannot be used because it is either trapped under ground or frozen in glaciers and in the ice caps of the north and south poles. Only about 0.01% of all water on Earth is renewable fresh water and is available for use. The tiny dark blue square in Figure 3.3.2 shows the very small proportion of water on Earth that is available for use by humans and other living things.

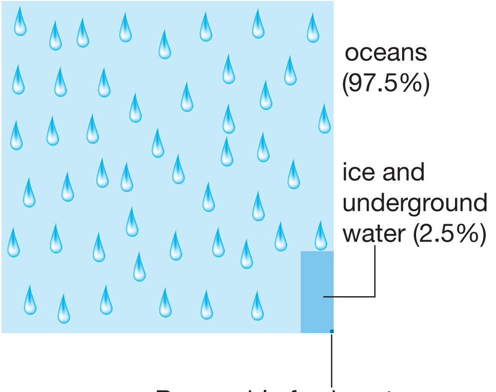


Figure 3.3.2 Comparison of the total amount of water on Earth and the amount we can use

INQUIRY

science 4 fun

Dripping glass

Where did the water on the outside of the glass come from?

Yes

Collect this …

- glass
- cold water from the fridge
- sticky tape or marker pen (optional)
- paper towel

Do this …

1. Half fill the glass with cold water.
2. Dry the outside of the glass with the paper towel.
3. Mark the level of the water with the sticky tape or marker pen.
4. Place the glass on a piece of paper towel on a bench and leave for 5 to 10 minutes.

Record this …

Describe what happened.

Explain why you think this happened.

The water cycle

The amount of water on Earth is **finite**. This means that new water cannot be made. The water on Earth has been recycled over and over again since the Earth was formed.

The natural process of recycling water is known as the **water cycle**. As water moves through the cycle it changes **state**. Figure 3.3.3 shows that energy from the Sun causes water to evaporate from bodies of water such as the ocean, rivers and lakes. Liquid water in the ocean becomes water vapour in the atmosphere.

As the water vapour rises, it cools. At a certain point the air cannot hold any more water vapour and the air is said to be **saturated**. Any further cooling causes water vapour in the air to condense, changing into tiny drops of liquid water. These tiny droplets form clouds, like the one in Figure 3.3.4.

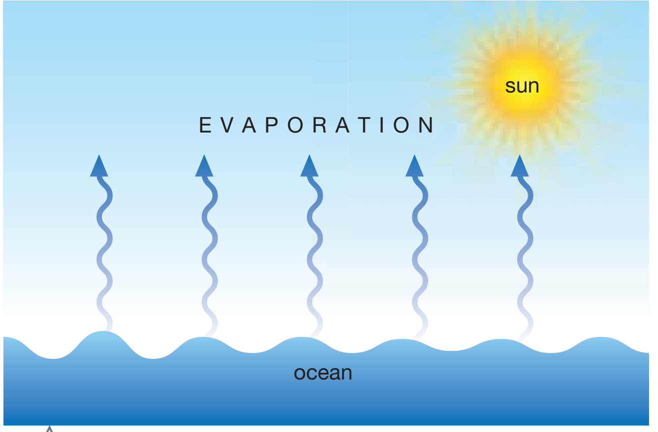


Figure 3.3.3 Evaporation moves water from oceans, rivers and lakes into the atmosphere. About 86% of the evaporation in the water cycle is from the oceans because they are the largest bodies of water.

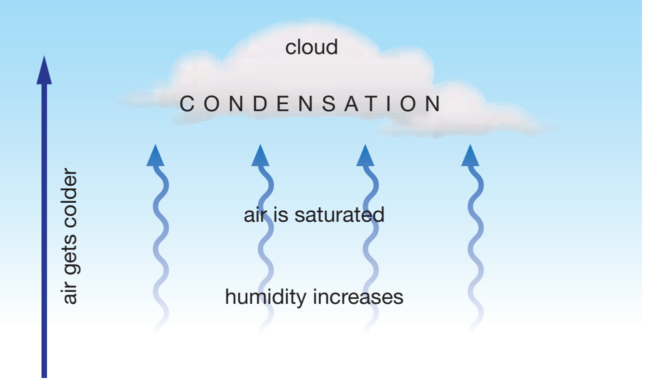


Figure 3.3.4 Cool air holds less water vapour than warm air. In cool air, water vapour condenses and forms clouds.

When the air cools further, the droplets of water combine to become larger and heavier droplets, which then fall back to Earth as **precipitation**. The precipitation may be in the form of liquid rain or it may be frozen, falling to Earth as snow or hail.

Figure 3.3.5 When the temperature in the atmosphere is very low, the water droplets in the clouds freeze. Precipitation then happens as snow or hail.

Two things may happen to the precipitation that falls on land. These are shown in Figure 3.3.6.

- It may flow over the surface as **run-off** moving back into rivers, lakes and streams and eventually flow back to the oceans.
- It may soak down into the soil in a process called **percolation**.

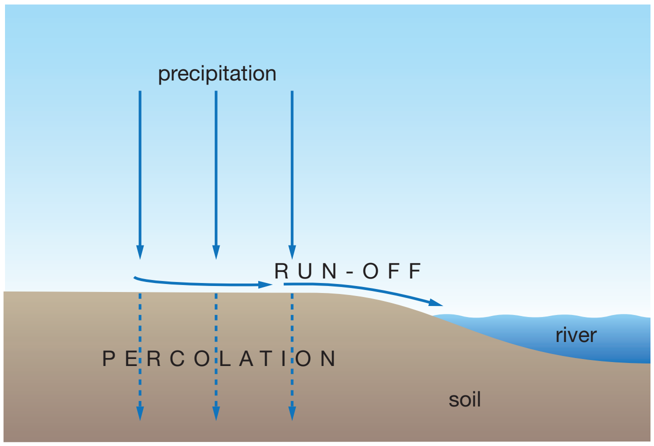


Figure 3.3.6 Once precipitation has landed on Earth it may flow over the surface or percolate into the soil and rocks beneath.

Some of the water that percolates through the soil is taken up by the roots of plants. This water then moves up through the plant. The heat of the Sun causes some of this water to evaporate from the stems, flowers and leaves of plants. The process of the evaporation of water from plants is called **transpiration**. It is shown in Figure 3.3.7. About 10% of the water vapour entering the Earth's atmosphere comes from transpiration.

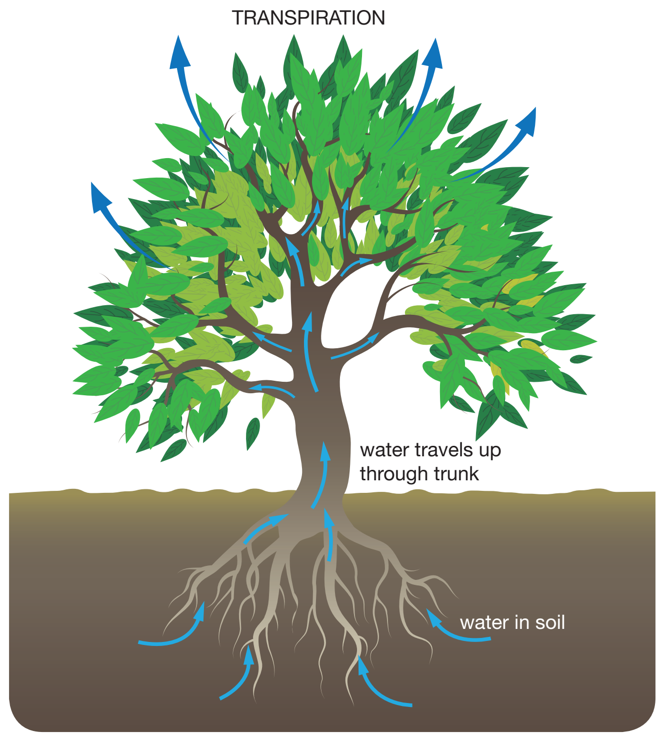
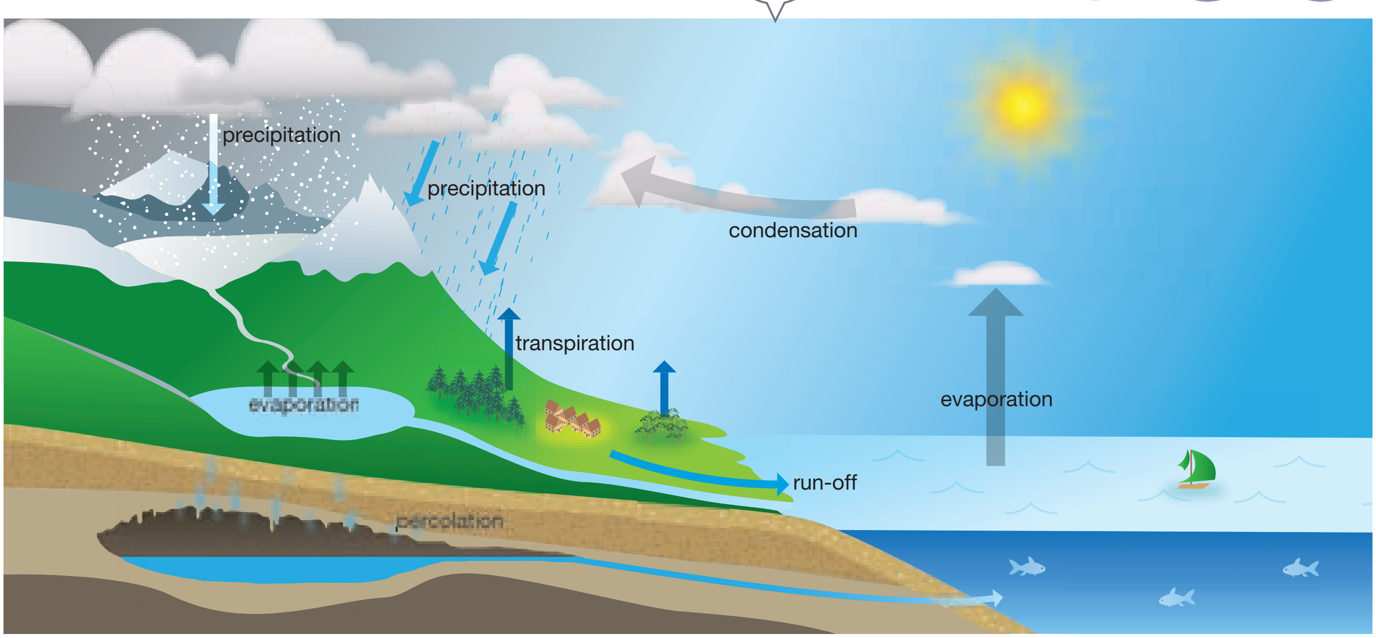


Figure 3.3.7 Transpiration is the evaporation of water from leaves and other parts of a plant. Through transpiration, water is carried from the soil and returned to the atmosphere.

Animals drink fresh water from rivers and lakes. This water is returned to the atmosphere as it evaporates from their bodies, or returned to the ground when it is excreted as urine.

Putting all these processes together creates the water cycle, as shown in Figure 3.3.8.

Figure 3.3.8 The water cycle



Groundwater

Rainwater, rivers and dams are major sources of water for Australia. However, groundwater provides more than 20% of the water used in Australia each year. **Groundwater** is water that exists underground. Most groundwater is not in underground lakes or rivers. Instead this water is trapped in the tiny spaces between grains of sand or within pervious rocks. **Pervious rocks** are rocks that allow water to soak into them. Figure 3.3.9 shows how this works.

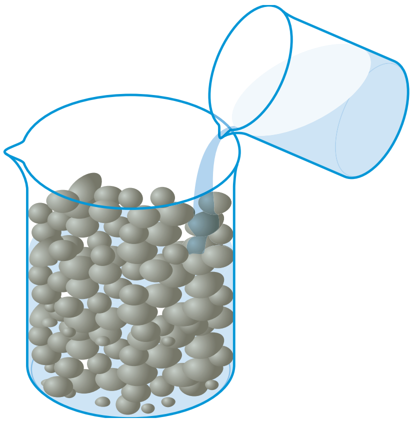


Figure 3.3.9 The effect of pervious rocks is like pouring water into a jar of pebbles or sand. The water does not sit on top. Instead, the water moves down, filling up the spaces between the sand or pebbles.

When the water within the pervious rocks can be extracted using a bore or well, then the layer of rock is known as an **aquifer**. Perth in Western Australia gets about 60% of its water from an aquifer.

The Great Artesian Basin

The Great Artesian Basin is one of the largest groundwater basins in the world. About one-fifth of Australia is sitting on top of it. Many millions of years ago there was an inland sea in Australia. Under this sea, rocks formed in alternating layers of pervious rock and impervious rock. **Impervious rock** does not allow water to soak into it. Movement of the land has exposed areas of the pervious rock. Water can soak into the pervious rock and flow underground. The impervious rock prevents the water from escaping. The result is a very large store of groundwater—the Great Artesian Basin.

It takes a very long time for the water to soak through the rock and into the aquifers. Some of the water in the Great Artesian Basin has been there for millions of years. The structure is shown in Figure 3.3.10.

Factors affecting the water cycle

Many natural factors influence the rate at which water moves through the water cycle. It can take an individual particle of water from a few days to thousands of years to complete the water cycle from ocean to atmosphere to land and back to ocean again. In that time the water slowly seeped through the rocks and was then trapped underground. It is still part of the cycle but will not move onto a different stage until the water is carried up to the surface through a bore or well.

States of water

The water that is trapped as ice at the north and south poles, in glaciers and on the top of high mountains is also part of the water cycle. The water in the ice shown in Figure 3.3.11 on page 96 cannot move on to the next stage until the ice melts.

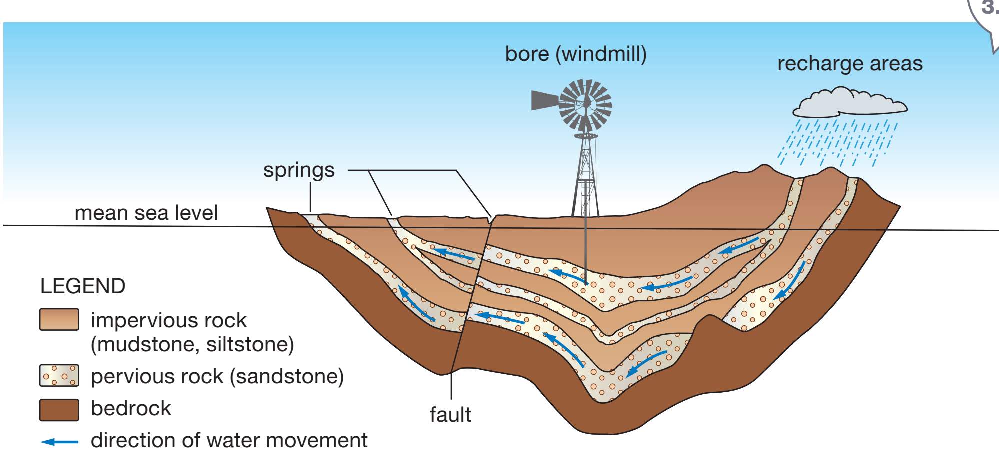


Figure 3.3.10 The Great Artesian Basin is made up of alternating layers of pervious and impervious rocks. Water is extracted from the pervious rocks using aquifers. These aquifers supply water to large areas of inland Australia.

Figure 3.3.11 The water in ice is still part of the water cycle. However, it may be hundreds or thousands of years before the water is able to move onto the next stage of the cycle.

Ice cannot be taken up by plants. Many trees living in areas where water in the soil is frozen for part of the year are deciduous. Deciduous trees lose all their leaves in winter. When they do not have leaves there is very little transpiration.

Martian water

Ice is found at the polar ice caps of the planet Mars. Some scientists think there may be liquid water on Mars. In 2005 NASA photographs revealed new soil deposits suggesting that water had carried sediment through two small valleys sometime during the past seven years.

SciFile

Air temperature

Changes in air temperature affect the rate of evaporation from bodies of water and soil. Changes in temperature also affect the rate of transpiration. As the air temperature increases, the rate of evaporation and transpiration both increase. Plants can slow transpiration down if they are losing water more quickly than they can take it in through their roots. Plants have special openings through which the water evaporates. Plants are able to close these openings if they are losing too much water. In this way plants are able to reduce the rate of transpiration and slow down the movement of water through the water cycle.

Humidity

Humidity is the amount of water vapour in the air. Water vapour can be added to the air until the air becomes **saturated**. When this happens, the air cannot hold any more water vapour. As the air above a surface reaches saturation point the rate of evaporation (and transpiration) slows down and stops. This can be seen in Figure 3.3.12.

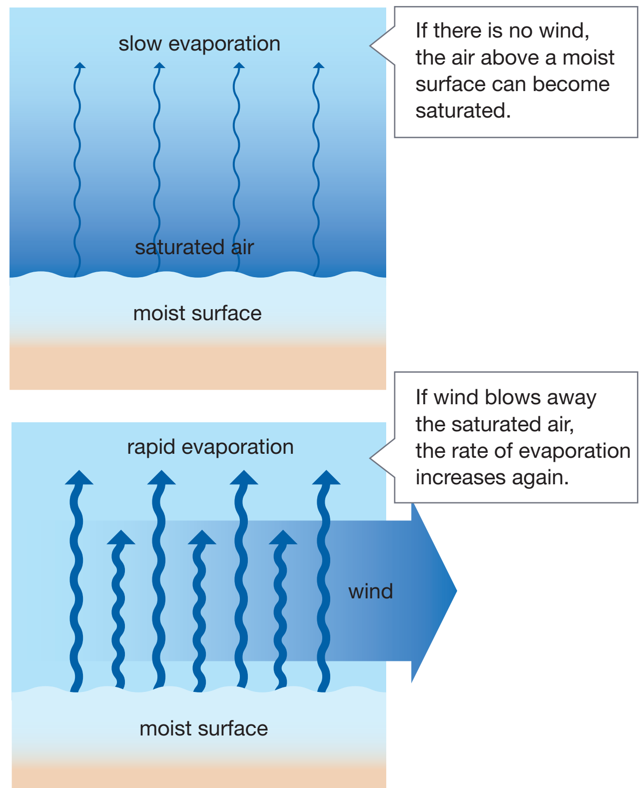


Figure 3.3.12 If there is no wind (top picture), the air above a moist surface becomes saturated and evaporation is slow. Wind blows away the moist air (bottom picture) and evaporation increases.

You may have experienced the effect of saturated air. When you sweat on a hot day with low humidity, the sweat dries (evaporates) off your skin quickly. However, if the air is very humid (as it often is in northern Australia during the summer months) then the sweat remains on your skin and you feel hot and sticky. Turning on a fan may help you feel more comfortable because it starts your sweat evaporating again.

Air movement

Air moving across a wet surface increases the rate of evaporation. Moving air carries away the layer of saturated air that is found on the wet surface. Evaporation and transpiration can then continue to take place.

2 p101

Landscape

The landscape affects run-off and percolation. Rain falling on smooth rock and steep slopes (such as the one in Figure 3.3.13) will quickly run over the surface and into streams and rivers. These streams and rivers will move the water quickly back into the ocean.

Figure 3.3.13 Water moves very quickly downhill when there is no vegetation to slow it down.

Where there are broken rock surfaces and areas of dense vegetation, run-off will be slower. Slower run-off allows more time for percolation to take place. Some soils like sand have many large spaces between the particles. Water can easily percolate into these soils and there is very little run-off. Other soils have small particles that are closely packed together. It takes a long time for water to percolate through these soils and more of the water will flow over the surface as run-off.

Hills and mountains experience more precipitation than low-lying areas. As air moves towards hills and mountains it rises to get over them. The rising air cools and the water vapour it holds condenses, resulting in precipitation. Often clouds are seen over mountains when there are otherwise few clouds around. The clouds in Figure 3.3.14 are evidence of the cooling effect on humid air.

Figure 3.3.14 The clouds on high mountains spoil the view of the top. However, they are evidence of the water cycle at work.

3.7

SciFile

Boiling water

At sea level water boils at 100°C. At the top of Mt Everest there is less pressure and water boils at just 68°C. Deep in the ocean pressure increases. Water near deep geothermal vents remains liquid at temperatures much higher than 100°C.

Vegetation

The type of environment a plant is growing in will affect the rate of transpiration. Some plants such as cacti and many Australian native plants have characteristics that help them conserve water so that they can survive in dry climates. They transpire less than plants without these characteristics.

Amount of sunshine

In nature the energy needed to evaporate water comes from the Sun. In parts of the world where there is a lot of sunshine there is more evaporation than in areas with little sunshine and heavy cloud.

3.3 Unit review

Remembering

1 **State** how much of the Earth's surface is covered in water.

2 **State** how much of Earth's water:
  a is salt water
  b is fresh.

3 **State** the word that describes rain, hail and snow.

4 **List** three natural factors that influence the water cycle.

Understanding

5 **Explain** why it is important that water is recycled in nature.

6 **Explain** why water is considered to be a resource that is in short supply when there is so much of it on Earth.

7 **Describe** what could happen to the rain that falls onto a field of grass.

8 **Describe** the role that animals such as cows or kangaroos play in the water cycle.

9 **Explain** what is meant by the phrase: *the air is saturated*.

Applying

10 **Identify** the process that moves water from:
  a rivers to the atmosphere
  b oceans to the ice cap at the south pole
  c the atmosphere to freshwater lakes
  d surface water to aquifers
  e surface water to rivers.

11 **Use** diagrams to **demonstrate** how water droplets in a cloud develop into rain.

12 Sketch a simple version of Figure 3.3.15 and **use** it to **demonstrate** what would happen to water that fell on the piece of ground represented by the diagram.

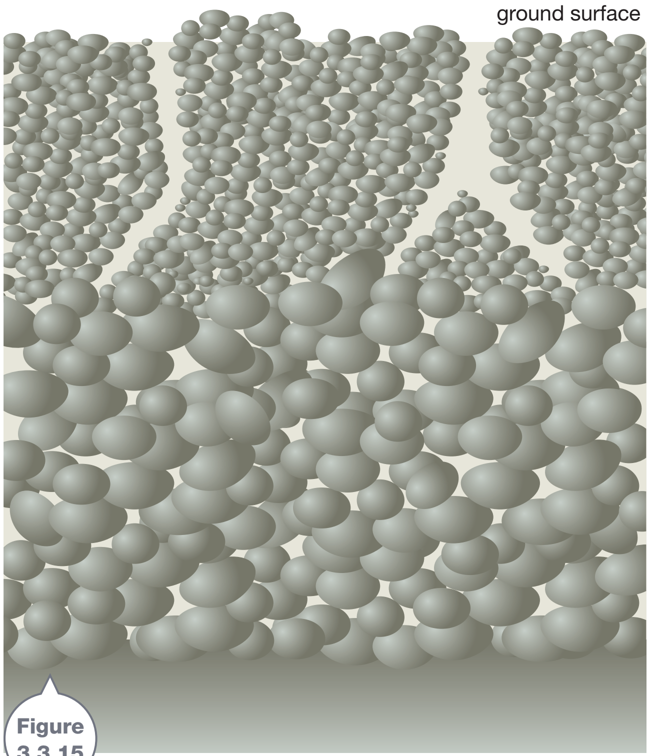


Figure 3.3.15

Analysing

13 **Compare**:
  a evaporation and transpiration
  b pervious and impervious rocks
  c percolation and run-off.

14 **Use** the table below to answer the questions that follow.

Water source	Percentage of total water
Oceans	97.24
Rivers and freshwater lakes	0.01
Inland seas	0.008
Ice caps and glaciers	2.14
Soil moisture	0.005
Ground water	0.61
Atmosphere	0.001

a Oceans are the largest source of water on Earth. **Identify** the next largest source of water.

b **Identify** which holds more water, the soil or the atmosphere.

c **Compare** the amount of water in inland seas, and in freshwater lakes and rivers.

15 **Compare** the amount and rate of percolation of water through the two soil samples shown in Figure 3.3.16.

Evaluating

16 a **Deduce** which of the soils in Figure 3.3.16 would have the greatest amount of run-off in a heavy rainstorm.

b **Justify** your answer.

17 a **Propose** how you would respond to someone who says that all the water you use is recycled water.

b **Explain** your response.

Creating

18 **Construct** a diagram that demonstrates how the cloud on top of the mountain in Figure 3.3.14 on page 97 could have formed.

19 **Construct** a bar or column graph to accurately show the information in the table in question 14.

Inquiring

1 Humans cannot drink sea water. Research and find out why.

2 Research what happens to fish and other living things when the water in ponds and lakes freezes.

3 Find out how hailstones form.

Figure 3.3.16

3.3 Practical activities

1 Water cycle

Purpose
To construct a model of the water cycle.

Materials
- 500 mL beaker
- clear plastic film
- crushed ice
- small plastic bag
- tape (optional)
- water at room temperature

Procedure
1 Set up the equipment as shown in Figure 3.3.17.

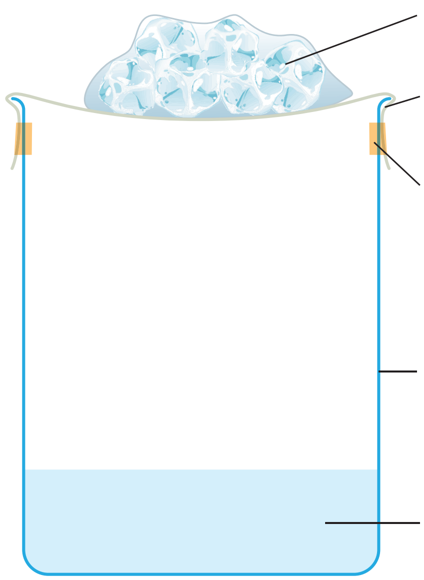


Figure 3.3.17 Model of the water cycle

2 Observe your model of the water cycle for about 20 minutes.

Results
1 Look at the underside of the plastic film (where the air in the beaker is in contact with the plastic). Describe the changes you observed:
  a in the first minute of your investigation
  b after about 5 minutes
  c after about 10 minutes.

2 Use diagrams and written description to record changes you observe.

Discussion
1 **Identify** the part of the water cycle represented by the water in the beaker.

2 a **Explain** what was happening to the water in the beaker.
  b **Identify** the process in the water cycle that this represents.

3 a **Explain** what was happening to the air in the beaker when it was in contact with the plastic film.
  b **Identify** the process in the water cycle that this represents.

4 **Explain** how precipitation was represented in the model.

2 Measuring evaporation

Purpose

To test the effect of sunshine on the rate of evaporation.

Materials

- 2 shallow containers of the same size, material and depth, such as rectangular takeaway food containers
- ruler
- electronic balance (or kitchen scales that measure in 1 g intervals)
- marker pen
- water

Procedure

1. Label one container *sun* and the other container *shade*.
2. Place the sun container on the electronic balance.
3. Add water to the container until it is about 2 cm below the top of the container.
4. Find the mass of the water and the container.
5. Record the mass of the water and the container in a table similar to the one shown above.
6. Repeat steps 2 to 5 using the shade container.
7. Place the sun container where it will be in full sun all day and will be protected from wind.
8. Place the shade container in a shaded area also protected from the wind.
9. Leave the containers undisturbed for at least 24 hours. You can leave them for longer.
10. Carefully find the masses of the containers again. Record the new masses in your table.

	Mass (g)			Amount of water lost (mL)
	Start	Finish	Difference	
Sun container				
Shade container				

Results

Calculate the amount of water lost. Each gram that is lost represents the loss of one millilitre (mL) of water.

Discussion

1. **Compare** the amount of water lost from the different containers.
2. **Compare** your results with the results from other groups.
3. **Identify** any factors that you were not able to control that might have affected your results.
4. **Draw** conclusions about the effect of sun and shade on the rate of evaporation.

3.4 Water management

In nature plants and animals get water from rain, rivers and natural stores such as lakes. Indigenous Australians are able to find underground stores of water by using their observations of plants, birds and other animals. In modern society, water is needed for cities, industry and agriculture. To meet the needs of modern society, water resources have to be managed differently. This management changes the movement of water through the water cycle.

INQUIRY science 4 fun

Ants and water

Can ants help locate a water source?

Yes

Collect this …

shallow container for water

Do this …

1. Fill the container with water.
2. Place it on a path or on the grass in a partially shaded part of the garden.
3. Leave the container undisturbed for about an hour.

Record this …

Describe any change in the behaviour of ants in the area.

Explain why this happened.

Traditional water use

Indigenous Australians are able to live in some of the driest parts of Australia because they can find and manage water resources. One technique to find water is to observe the vegetation. In the middle of a dry area, Ghost Gum trees (such as the one in Figure 3.4.1) indicate where there is underground water. Ant trails also lead to underground water and dingo tracks lead to rock pools and waterholes.

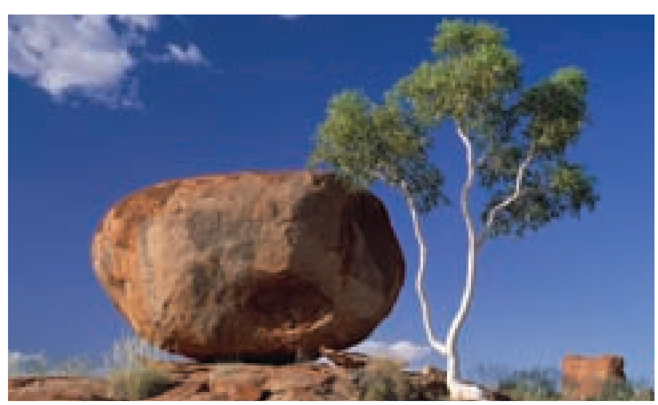


Figure 3.4.1 A mature Ghost Gum has a thick trunk that is covered in very white bark, giving it its name. It grows to about 20 m in height.

Traditional methods used by Indigenous Australians to obtain water include creating shallow wells and digging tunnels to reach water deeper underground. The mouth of the well or tunnel is covered to reduce evaporation and to prevent animals from drinking the water and polluting it.

In the past, the location of water sources determined the routes Indigenous Australians used to travel around the country. In this way they were sure to have reliable sources of water.

There are many **springs** where water from the Great Artesian Basin comes to the surface. One is shown in Figure 3.4.2. These springs are a major source of water for Indigenous Australians and for native plants and animals. Some European explorers and early settlers learned how to find water from the Indigenous people and so they too could get their water from springs.

Figure 3.4.2 Springs from the aquifers of the Great Artesian Basin were used by native animals and later as watering points for cattle.

1 p111

Storing water in dams

Australia is the driest permanently inhabited continent. The rain that does fall is not distributed evenly over the country. Dams are built to capture and store the rain.

Most farms in Australia have dams. The water collected is used for cattle to drink and may be used to irrigate crops. There are also many much larger dams such as Wivenhoe Dam near Brisbane. You can see this in Figure 3.4.3. These large dams collect and store water to be used by industry and households in the cities.

Figure 3.4.3 Large dams like the Wivenhoe Dam are needed to collect enough water for the needs of cities.

SciFile

All ice, no water!

Australia might be dry but the continent of Antarctica is even drier! This is because all of its water exists as ice. The constant freezing temperatures never allow the ice to melt.

All dams interrupt the water cycle because water stored in them does not flow down the river and into the ocean. Water from the surface of the dam evaporates and is returned to the water cycle. However, in a very deep dam some water may not be available for evaporation for a very long time.

SciFile

That's big!

The tallest dam in the world is the Nurek in Tajikistan in the Himalayan Mountains. The dam wall is 300 metres high. In 2014 when the Jinping-I Dam in China is completed it will be taller at 305 metres. Compare this with Wivenhoe Dam on the Brisbane River (Figure 3.4.3). It is just 50 metres high!

Irrigation

Most of the farm crops grown in Australia have been introduced here from other parts of the world. This means that they do not have characteristics that allow them to grow with only small amounts of water. These crops need continuous supplies of water and farmers provide this water through irrigation. **Irrigation** is a practice used in agriculture that provides water to crops using pipes and ditches.

There are two ways farmers irrigate their land:

- spray irrigation
- flood irrigation.

Spray irrigation

You can see spray irrigation in Figure 3.4.4. In **spray irrigation** a pump forces small droplets of water into the air. The water falls on the soil and percolates down to the roots of plants. The water then moves up through the plant and is eventually lost back to the atmosphere through transpiration.

Figure 3.4.4 Spray irrigation is like having rain fall on the crop whenever it is needed.

There are some differences between spray irrigation and rain. When it rains there are usually clouds in the sky and the air is very humid. These factors reduce the rate of evaporation. Spray irrigators may be used on hot days when there is bright sunshine. The tiny droplets of water produced by the spraying equipment evaporate quickly in hot, dry air. Water landing on the leaves also evaporates more quickly than in a natural rain storm. Therefore a significant amount of water that would normally percolate into the soil evaporates into the atmosphere.

Flood irrigation

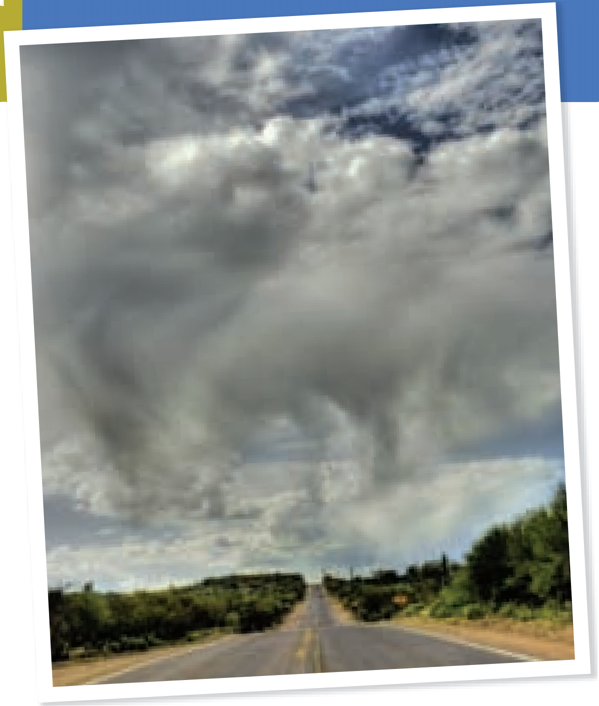
In **flood irrigation**, water is released into channels between the crop plants. This is shown in Figure 3.4.5. The water percolates into the soil to the plant roots. However, the water will evaporate quickly if the soil and irrigation channels are not shaded.

Figure 3.4.5 With flood irrigation the water reaches the roots. However, if there is not a good cover of vegetation much of the water will evaporate.

SciFile

Raining or not?

Not all precipitation reaches the ground. Virga is rain or snow that evaporates somewhere between the clouds and the Earth. It appears as a torn curtain hanging half way to the ground under the clouds.



Moving water around

Dams and pipes can be used to move water from an area where there is plenty of water to areas where there is not enough. The Snowy Mountain Scheme was a very ambitious project that began in 1949 and was completed in 1974. Figure 3.4.6 shows part of the scheme's dam and pipelines. Most of the scheme is underground. The Snowy River in New South Wales is fed from melting snow and rain in the Snowy Mountains. Its position can be seen in Figure 3.4.7. The dams and pipes divert the water from the Snowy River. Only 1% of the water that once flowed in the Snowy River now flows down it and out to sea.

Figure 3.4.6 The Snowy Mountain scheme is one of the largest irrigation projects in the world, with about 225 km of tunnels and pipelines.

Now a large proportion of the water from the Snowy River is diverted through tunnels and dams. It is used to irrigate large farming areas in the Murrumbidgee Irrigation Area, shown in Figure 3.4.8. Irrigation has enabled this area to become one of the main wine and food producing parts of Australia. Water that once flowed very quickly into the ocean is spread across land that is naturally dry.

Figure 3.4.7 Map showing the positions of the Snowy Mountain Scheme and the Murrumbidgee Irrigation Area.

Figure 3.4.8 The main use of the water from the Snowy Mountain Scheme is to generate electricity. It is also a major source of water for the Murrumbidgee Irrigation Area.

The water used for irrigation is returned to the atmosphere through transpiration and evaporation from soil. Irrigation water also percolates through the soil into the ground water. Eventually the excess water flows via the Murray River into the ocean on Australia's southern coast.

Cities

Building cities replaces pervious soil with impervious concrete and bitumen surfaces. Water that lands on soil percolates about 15 mm into the ground before there is any run-off. Water that falls on roofs, roads and footpaths runs off immediately. The water flows into stormwater drains (like the one in Figure 3.4.9) and out to the ocean.

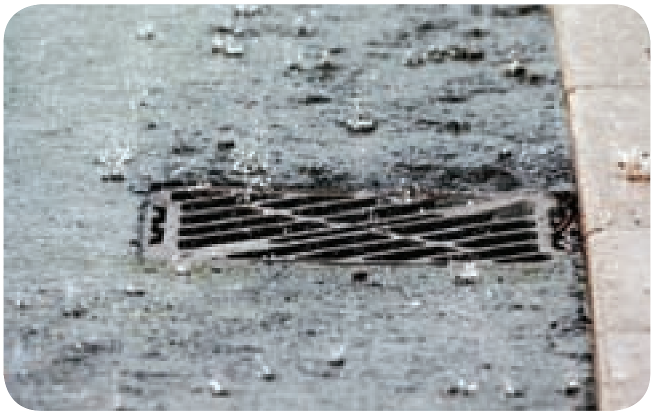


Figure 3.4.9 Water flowing off roofs, streets and other impervious city surfaces goes straight into stormwater drains. From there it goes directly to rivers and the ocean.

In many parts of Australia, attempts are being made to use stormwater. In some Sydney suburbs, stormwater is being collected in tanks and pits. Harmful substances are removed from the water and then it is used to irrigate parkland and sports fields and to water trees in the city.

In the city of Orange in New South Wales some of the water that flows into Blackman's Swamp Creek during storms is captured and then transferred to a nearby dam. Figure 3.4.10 shows how much water flows out during such a storm. All this stormwater is now collected, increasing the water supply for the city.

2 p112

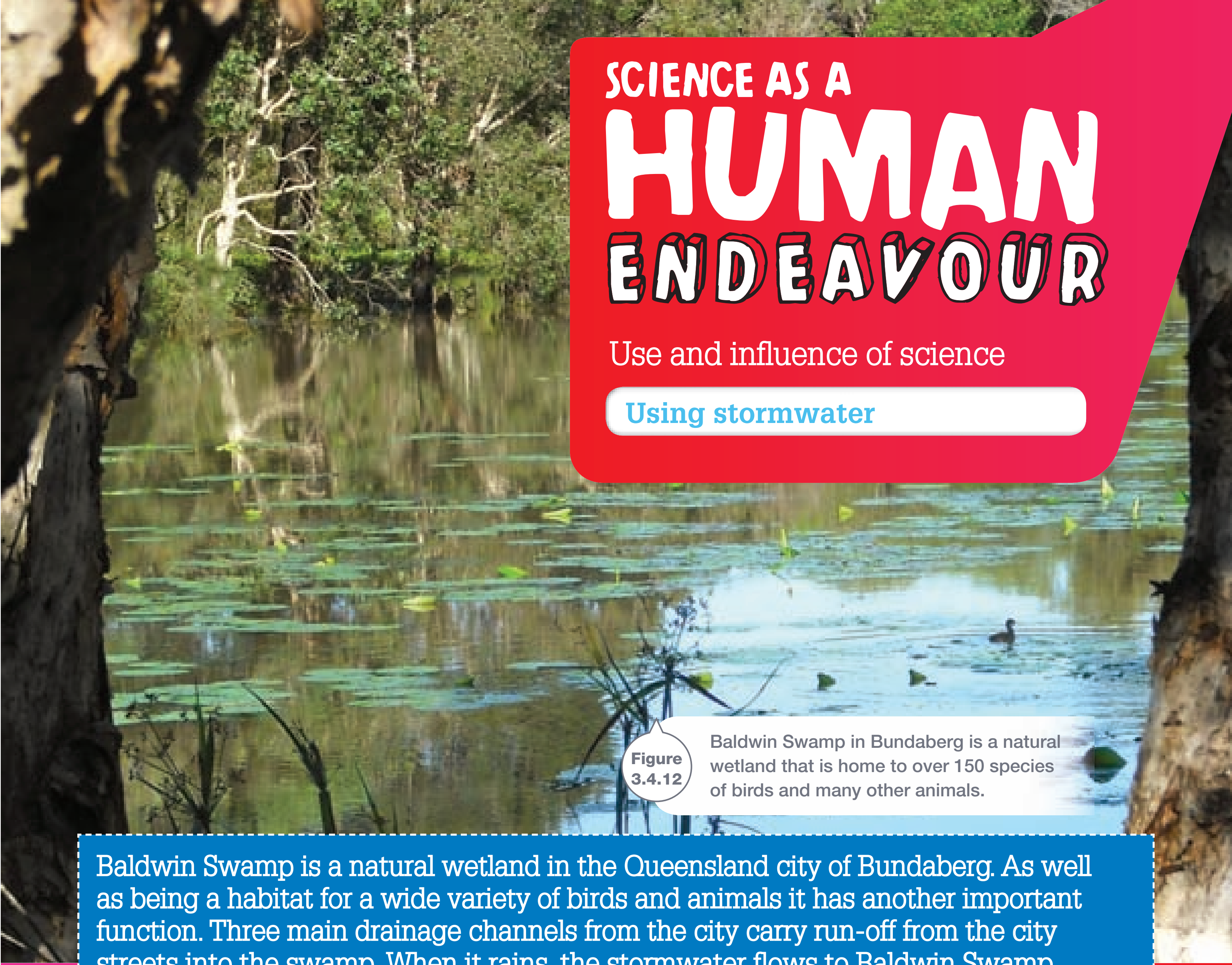
Figure 3.4.10 A large amount of water flows along Blackman's Swamp Creek during a storm.

Changing vegetation

When trees are cut down and replaced with grass or bare soil, the movement of water over the land surface is changed. Trees, shrubs and long grass slow the rate at which water can flow over the ground. This means that there is more time for the water to soak into the soil.

In the absence of vegetation, water moves quickly over bare ground and often carries large amounts of soil with it as it flows into streams and rivers. Figure 3.4.11 shows the effect of this fast-moving water.

Figure 3.4.11 These channels in the soil (known as **rills**) have been created by fast-flowing water.



SCIENCE AS A HUMAN ENDEAVOUR

Use and influence of science

Using stormwater

Figure 3.4.12 Baldwin Swamp in Bundaberg is a natural wetland that is home to over 150 species of birds and many other animals.

Baldwin Swamp is a natural wetland in the Queensland city of Bundaberg. As well as being a habitat for a wide variety of birds and animals it has another important function. Three main drainage channels from the city carry run-off from the city streets into the swamp. When it rains, the stormwater flows to Baldwin Swamp, carrying with it rubbish and pollutants. The rubbish has to be collected by City Council workers. Natural processes in the wetland absorb pollutants from water and improve the quality of the water before it flows out into the river and ocean.

The ability of wetlands to clean water has been used by city councils and land developers in a variety of ways.

On a big scale

Albert Park Lake in Melbourne (shown in Figure 3.4.13 on page 108) is visited by over 6 million people each year and is popular for sailing and rowing. In dry periods water levels in the lake decrease and people cannot sail or row on it. Up until 2005 water from the City of Melbourne's drinking water supplies was used to top up the level of the lake. This used up to 200 million litres of drinking water each year.

In 2005 the Victorian Government established a system that used stormwater to replenish the lake. Because stormwater is a major source of pollution for rivers and lakes, pollution control ponds had to be built as part of the system. This system has allowed the lake to continue to be used for sailing, and for model yacht and rowing clubs.

Rain gardens

Rain gardens are a much smaller scale way of dealing with stormwater. Figure 3.4.14 on page 108 shows how rain gardens slow down the rate of flow and clean pollution from the stormwater before it enters creeks and rivers.

ENDEAVOUR

Figure 3.4.13 Albert Park Lake is a popular place to go sailing and rowing.

Stormwater is channelled into the rain garden bed. In the garden bed is a layer of sand that filters the water. The filtered water is similar in quality to the water in undisturbed streams. It is not drinking quality but it is suitable for irrigation.

Rain gardens can be landscaped into suburban gardens as well as city parks, school yards and large nature strips that divide freeways. Figure 3.4.15 shows a rain garden in action.

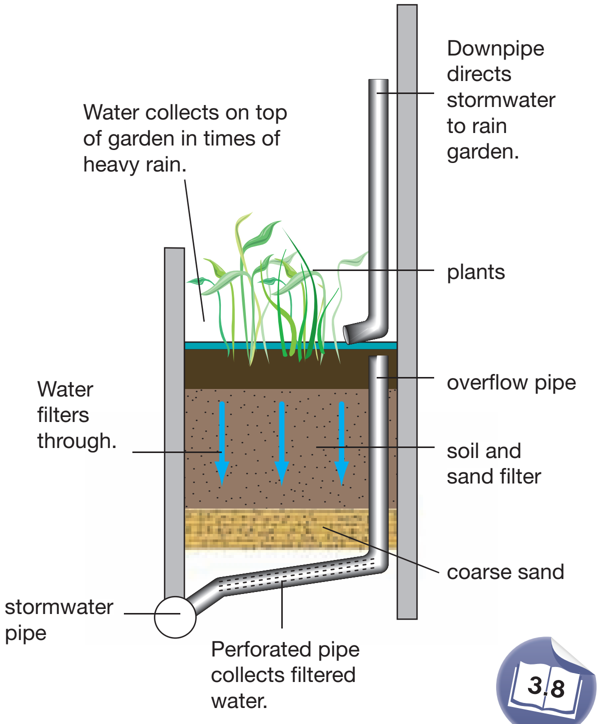


Figure 3.4.14 A rain garden cleans stormwater before it enters creeks and rivers.

Figure 3.4.15 Rain gardens are attractive to look at and they also serve a very useful function.

Rain gardens are currently being built at a new housing estate near Caloundra on Queensland's Sunshine Coast. Here the rain gardens are called biopods. The stormwater in this estate is channelled towards a network of biopods, in which the water is collected. Small trees and other smaller plants growing in the biopods filter the water. The water does not flow out of the biopods to a river or creek but is stored and used later to water gardens. In the newest parts of the housing estate there is a biopod on each street corner.

3.4 Unit review

Remembering

1 **Recall** two observations Indigenous Australians use to help them find water sources.

2 **List** three ways that human actions change the water cycle.

3 **Name** two types of irrigation.

Understanding

4 **Explain** why dams are built near large cities.

5 **Explain** how a dam interrupts the water cycle.

6 At the end of winter the snow in the Snowy Mountains melts and the water flows into streams and rivers.
- a **Describe** what would have happened to that water before the Snowy River Scheme was built.
- b **Describe** what happens to the water from the Snowy Mountains now.
- c **Describe** the benefits that have resulted from the Snowy River Scheme.
- d **Describe** any disadvantages the scheme may have brought to the environment.

7 **Describe** two ways that run-off from cities is being reduced.

Applying

8 Figure 3.4.16 represents an area where part of a forest has been cut down. **Apply** your understanding of the water cycle to **explain**:
- a how and why the humidity of the air at points A and B would be different
- b how and why the rate of flow of water over the surface at points C and D would be different.

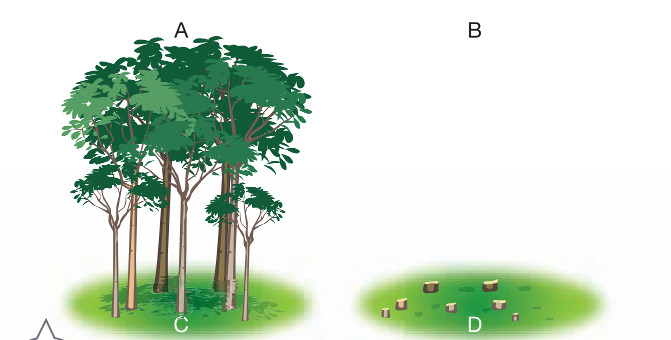


Figure 3.4.16

Analysing

9 **Compare** spray irrigation and flood irrigation by focusing on the effect they have on the water cycle.

10 **Compare** spray irrigation and a natural shower of rain.

Evaluating

11 A severe storm passes over Darwin.
- a **Explain** what happens to the rain that falls on the city.
- b **Deduce** what would have happened to the rain before the city was built.

12 Figure 3.4.17 shows a valley that has been flooded by the construction of a dam. **Deduce** the major change that the presence of the dam will have on the water cycle in that area.

Figure 3.4.17

Creating

13 Imagine a city block in the middle of a large city such as Sydney or Melbourne. **Construct** a diagram of the water cycle for that city block.

14 **Design** a project that would reduce the run-off from your school grounds and would make better use of stormwater.

Inquiring

1 Research the Aboriginal Dreamtime story of the Rainbow Serpent and find out how it relates to the current scientific understanding of the Great Artesian Basin.

2 Research any projects in your area that are designed to reduce the amount of stormwater flowing directly to rivers and oceans.

3 The construction of the Snowy River Scheme reduced the flow of water in the Snowy River by 99%. Research the effects the loss of water had on the environment of the river. Find out if there are any plans to address these effects.

4 The Aswan High Dam (shown in Figure 3.4.18) was built on the river Nile in Egypt between 1960 and 1970. Research the dam and answer the following questions.
  a Identify the reasons for the dam being built.
  b Compare the flow of the river before and after the dam was built.
  c Describe the effect that any changes have had on the environment downstream of the dam.

Figure 3.4.18 Aswan High Dam, Egypt

3.4 Practical activities

1 Water from leaves

Purpose

To investigate water loss from leaves.

Materials

- plastic bag approximately the size of an A4 piece of paper
- string
- access to trees with low branches
- marker pen
- 100 mL measuring cylinder

Procedure

1. Write your name on the plastic bag.
2. Select a twig on your tree that has healthy-looking leaves.
3. Carefully place your bag over the twig so that a number of leaves are enclosed as in Figure 3.4.19. The twig should still be attached to the tree.

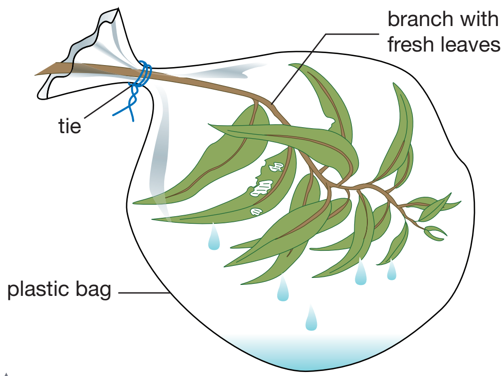


Figure 3.4.19

4. Use the string to tie the bag on tightly.
5. Leave the bag in place for 24 hours.

Results

1. After 24 hours remove the bag from the twig. Be careful not to lose any of the water.
2. Carefully pour the water into the measuring cylinder.
3. Record the amount of water collected.

Discussion

1. **Explain** how the water got into the bag.
2. **Deduce** how the humidity inside the bag would have changed during the 24 hours of the experiment.
3. **Propose** how this change in humidity could have affected the amount of water collected.
4. **Demonstrate** how the information you have collected relates to the water cycle.

3.4 Practical activities

2 Run off or soak in?

Purpose

To observe the percolation of water through different surfaces.

Materials

- 3 × 250 mL beakers or other transparent containers
- quantity of very fine gravel to half fill the beaker
- quantity of sand to half fill the beaker
- quantity of clay soil to half fill the beaker
- 100 mL measuring cylinder
- water
- marker pen

Procedure

1. Label the three beakers: *gravel*, *sand* and *clay*.
2. Fill the gravel beaker with gravel until it is half full. Gently tap the side of the beaker to settle the contents. Add more gravel if necessary.
3. Fill the sand beaker with sand in the same way.
4. Add some clay soil to the clay beaker and push it down firmly. Add more clay soil and push it down again. Repeat this process until the beaker is half full.
5. Measure 100 mL of water and pour it onto the top of the gravel beaker. Pour it over the whole surface, not just in one place. Observe what happens for five minutes.
6. Repeat Step 5 for the other two beakers.

Results

1. Record your observations of the way the water percolates through the three different materials.
2. Record whether any of the materials had water lying on the top after five minutes.

Discussion

1. **Propose** why it was necessary to push the clay soil down firmly instead of just tapping the side of the beaker.
2. **Identify** the material through which percolation occurred most quickly.
3. **Identify** the material through which percolation occurred most slowly.
4. **Explain** why the different rates of percolation occurred.
5. a **Identify** the material from which run-off was most likely to occur.
   b **Justify** your response.

3 Chapter review

Remembering

1 **Name** the following:
  a the term for water, wind and ice that transports sediments away from the site of weathering
  b the process of breaking rocks down into smaller pieces.

2 **List** four devices that may be found in your home that use energy but did not exist 50 years ago.

3 **List** the three changes of state that water passes through in the water cycle.

Understanding

4 **Modify** the following definitions to make them correct.
  a A natural resource is a substance supplied by the Earth for humans to make products they need.
  b A renewable natural resource is one that is replaced by natural processes that occur on Earth on a timescale much longer than a human life.
  c Deposition is the process where sediments are carried away by a moving stream of water, air or ice.

5 Renewable energy researchers are working to develop better ways to store energy. **Explain** why this technology is important.

6 **Describe** the effect that the ice sheets at the north and south poles have on the movement of water through the water cycle.

7 a **Describe** how the rate of evaporation changes on a windy day compared with a calm day.
  b **Explain** why this change happens.

8 Figure 3.5.1 is a simplified diagram of the water cycle.
  a Copy the diagram into your workbook.
  b **Modify** the diagram by adding the names of the changes of state that are taking place.
  c **Predict** places where water could stay for a long time before moving on.
  d **Predict** places where the movement to the next part of the cycle could be fast.

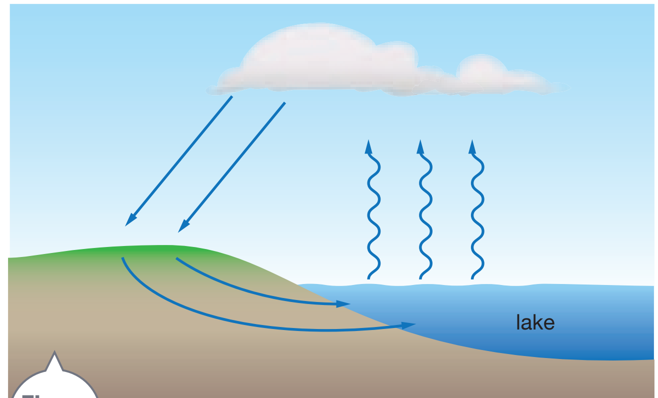


Figure 3.5.1

9 When settlers first brought cattle to the Australian inland, their cattle drank from the natural springs in the area. **Propose** the effect this would have on the water sources used by Indigenous Australians.

Applying

10 **Demonstrate** your understanding of erosion using observations at the beach, in your garden or travelling by car.

11 **Identify** the original source of the energy in fossil fuels.

12 **Identify** the source of heat in water springing from a geyser.

13 **Identify** the part of the water cycle that is represented in Figure 3.5.2.

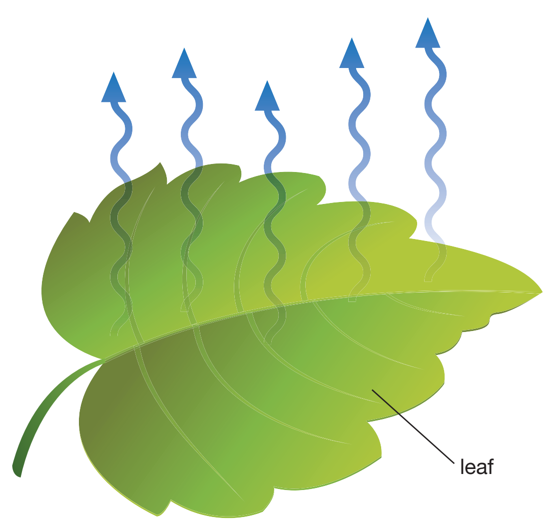


Figure 3.5.2

3 Chapter review

Analysing

14 **Compare** how long it takes to renew soils with how long it takes to replace water in the soil.

15 **Compare** how long it takes to replace rocks with how long it takes to renew gases such as oxygen in the air.

16 **Classify** these energy sources as either renewable or non-renewable:

- solar energy
- oil
- coal
- wind energy
- wave energy
- tidal energy
- LPG gas
- geothermal energy
- wood
- paper
- uranium.

17 **Compare** the amount of water lost from a field of bean plants when it is irrigated using spray irrigation and when it is not irrigated at all.

Evaluating

18 Tides are local temporary currents caused by the gravity of the Moon. **Propose** how a tide may affect soil erosion.

19 Considering the impact of greenhouse gases on global warming, it could be argued that the world should immediately stop using non-renewable forms of energy such as oil, coal and gas. **Evaluate** this argument.

20 Algae can grow in poor-quality soil and do not require the fresh water needed for many other biodiesel crops. **Propose** why algae could potentially offer a good source of biofuel.

21 **Deduce** why some clouds pass overhead without producing any rain.

22 Flexible solar cells are currently being developed. **Propose** three ways that flexible solar cells may be used in the future.

23 **a** **List** the major sources of energy used in Australia to power appliances and for transportation.

b **Propose** what Australia's major energy sources might be in 50 years time.

Creating

24 When storing water is it more efficient to have one large dam or a number of smaller dams? **Design** an experiment that could be used to answer this question.

25 **Use** the following key terms to **construct** a visual summary of the information presented in this chapter:

renewable resource, non-renewable resource, renewable energy source, solar energy, fossil fuels, water cycle, change of state, transpiration, precipitation, human impacts

3.9

Thinking scientifically

Q1 A renewable natural resource is one that is replaced by natural processes that occur in a timescale less than an average human lifetime. Some students were asked to classify some of Earth's resources into renewable resources and non-renewable resources. Their answer is shown in the following table.

Renewable resources	Non-renewable resources
1 rocks	7 wind
2 water	8 air
3 sunlight	9 coal
4 soil	10 petroleum
5 waves	11 natural gas
6 hydro-electric	12 nuclear

Which resources (using the number) did the students classify incorrectly?

A 1, 4, 7, 8
B 2, 3, 9, 10
C 5, 6, 11, 12
D 9, 10, 11, 12

Q2 A non-renewable energy source cannot be replaced. Identify which list below contains only non-renewable energy resources.

A coal, oil, sunlight, wind
B natural gas, sunlight, wind, tidal energy
C oil, uranium, sunlight, tidal energy
D natural gas, coal, oil, uranium

Q3 The change of state from GAS → LIQUID represents:

A the changes taking place in a cloud leading to rain
B the change that takes place in saturated air as it cools
C the change that takes place in leaves of trees with the Sun shining on them
D the change of state necessary for water to be able to percolate through soil

Q4 If the air temperature increased throughout the world, the rate at which water moves through the water cycle would:

A stay the same
B decrease
C increase
D increase in some areas and decrease in others

Q5 As water goes through the water cycle again and again, the amount of water on Earth:

A increases
B decreases
C stays the same
D varies from time to time

Glossary

Unit 3.1

Agents of erosion: water, wind and ice. All three of these agents transport sediments away from the site of weathering

Atmosphere: layer of gases above the Earth's surface

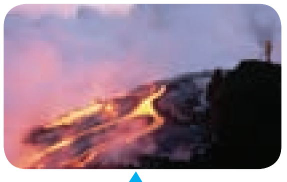
Deposition: the process where sediments drop out of a moving stream of water, air or ice

Erosion: the removal of sediments away from the place of their formation or deposition

Erosion

Humus: decaying plants and animals and their wastes

Igneous rock: rock formed by the cooling of molten rock, for example basalt



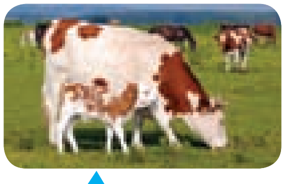
Igneous rock

Minerals: substances found in rocks

Non-renewable resource: a resource that takes longer than the average human lifespan to be replaced

Photosynthesis: the process by which plants use carbon dioxide, water and sunlight to make food

Renewable resource: a resource that is always being replaced naturally



Renewable resource

Resource: something that satisfies a particular purpose or need

Sediment: material such as silt and sand that is transported and deposited by water, ice and wind and forms layers on the Earth's surface. In time it can become compacted to form sedimentary rock

Sedimentary rock: rock formed by compacting and sticking together of sediments, for example sandstone

Weathering: the process of breaking rocks down into smaller pieces

Unit 3.2

Biogas: a gas produced from the fermentation of organic waste, such as waste from sugarcane, and used as fuel

Biomass: all plant and animal matter found on Earth

Fossil fuels: fuels such as coal, oil and natural gas, formed from the remains of living things buried millions of years ago

Geothermal energy: energy sources from heat below the Earth's crust

Hydroelectricity: the process of using water falling from a height to turn turbines and generate electricity

Non-renewable energy source

Non-renewable energy source: a source of energy that cannot be replaced after it is used, such as oil or coal

Nuclear fuel: using uranium or plutonium

Oscillating wave column: a chamber containing a turbine that is fixed in the ocean. As water flows into and out of the chamber, air pushes the turbine back and forth. This rotation is used to generate electricity

Renewable energy source

Renewable energy source: a source of energy that can be replaced after it is used, such as solar or wind energy

Solar cell: a device that absorbs solar energy and converts it directly into electrical energy

Solar cell

Tidal barrage: a construction in which water fills a basin as a tide comes in, rotating a turbine as it flows. The water is stored until low tide, when it is released and again turns the turbine. This rotation is used to generate electricity

Wind energy: harnessing energy from the movement of air using wind turbines

Unit 3.3

Aquifer: a layer of pervious rock from which water can be extracted using a bore or well

Finite: non-renewable or has limited availability, i.e. will run out

Groundwater: water that exists underground

Humidity: the amount of water vapour in the air

Impervious rock: rock that does not allow water to soak into it

Percolation: the process of water soaking into the soil

Pervious rock: rock that allows water to soak into it

Precipitation: any water falling from the sky

Run-off: rainwater not absorbed by the soil

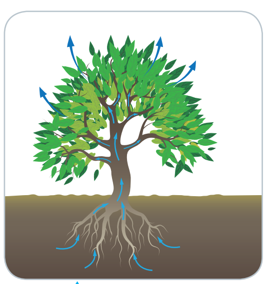
Saturated: not able to hold any more water vapour

States: solid, liquid and gas (another state called plasma exists at temperatures over 60 000°C)

Transpiration: the evaporation of water from plants

Water cycle: the natural process of recycling water


Precipitation


Transpiration

Unit 3.4

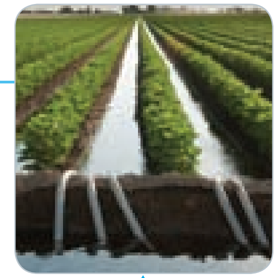
Flood irrigation: a type of irrigation where water is released in between crops in channels

Irrigation: a practice used in agriculture that provides water to crops using pipes and ditches

Rills: channels in bare soil created by fast-flowing water

Spray irrigation: a type of irrigation where a pump sprays water droplets into the air, which fall onto crops like rain

Springs: places where underground water comes to the surface


Flood irrigation


Rills

4 Mixtures

HAVE YOU EVER WONDERED ...

- if red texta is really red?
- what is in ice-cream?
- where the bubbles in a soft drink come from?
- how dishwashing liquid works?

After completing this chapter students should be able to:

- identify pure substances and mixtures such as solutions
- identify the solvents and solutes in different solutions
- use a range of separating techniques
- compare separation methods
- describe everyday applications of separation techniques
- outline how water use and management involves technology
- describe how science has been applied to the treatment of water.

4.1 Types of mixtures

Some substances are pure, having nothing else mixed with them. However, most of the substances that you deal with every day are not pure substances but mixtures. The air you breathe is a mixture, as are an artist's paints and the water from your tap.

INQUIRY science 4 fun

Mixing oil and water

Do oil and water mix?

Yes

Collect this ...

- 2 small thin containers with lids (such as pill bottles)
- cooking oil
- detergent

Do this ...

1. Pour about 5 cm of water into each container.
2. Add about 5 drops of detergent to one container. Mark the container so that you remember that it contains detergent.
3. Pour about half a centimetre of oil into each container.
4. Put a lid on each container and shake each for about 20 seconds.

Record this ...

Describe what happened.

Explain why you think this happened.

What is a mixture?

Paints, drinks, foods, seawater and air are not pure substances but are mixtures. In science a **mixture** is a substance made from two or more pure substances or pure chemicals that have been stirred together. For it to be called a mixture, you must be able to separate them again.

Solutions

Watch carefully as sugar is being stirred into water and you should see the solid sugar seem to disappear! The sugar has dissolved. The sugar solid broke up into very tiny particles that are too small to see. These small particles of sugar spread into the water and, although they cannot be seen, the sweetness of the liquid tells you the sugar particles are still there. This is what is meant when something **dissolves**. A substance that dissolves like this is said to be **soluble**. A substance that does not dissolve is said to be **insoluble**.

When things mix really well like this, the mixture is known as a **solution**. When you stir sugar into water, you make a sugar solution. The substance that dissolves is known as the **solute**. In this example, the sugar is the solute. The substance that dissolves the other one is the **solvent**. So in this case the water is the solvent. You can see this in Figure 4.1.1 on page 120.

Figure 4.1.1 A solution is made by mixing a solute in a solvent. In this case, the solute is sugar and the solvent is water.

Light passes easily through a solution, allowing you to see through it. This is one way of telling whether a mixture is a solution or not. Solutions are transparent (see-through). You can describe solutions like this as 'clear', meaning you can see through them. Look at Figure 4.1.2 and think about which liquid (the milk or the salt water) is the solution.

Figure 4.1.2 Milk being poured into salt water. Which one is the solution?

Solutions can be coloured or colourless. For example, blue copper sulfate solid dissolves in water to form a blue-coloured solution. You know that a solution has been formed because you can see straight through it.

Colourless and clear are not the same. Clear means you that can see though it. Colourless means it is not coloured. Figure 4.1.3 helps explain these different meanings.

Table 4.1.1 lists some different types of solution.

Figure 4.1.3 In this test-tube the top liquid is colourless (and clear), the middle layer is a blue solid (not clear) and the lower layer is coloured and clear.

Table 4.1.1 Common types of solution

Type of solution	Examples
Solid dissolved in a liquid	Grease dissolved in petrol, sugar dissolved in water
Liquid dissolved in another liquid	Liquid detergent dissolved in water, oil dissolved in petrol
Gas dissolved in a liquid	Oxygen gas dissolved in water, oxygen gas dissolved in blood
Gas dissolved in another gas	Oxygen gas, carbon dioxide gas and water vapour dissolved in the other gases of the air

Figure 4.1.4 Soft drinks have liquid water as their solvent. Dissolved in this water are flavourings, sugars and preservatives that give the soft drink its sweetness, colour and taste. Carbon dioxide gas is dissolved too. This gas bubbles to the surface when you release the pressure in the bottle by removing the lid.

Solutes and solvents

A particular solute will dissolve in some solvents and not in others. For example, grease will not dissolve in water but will dissolve in the fluids used by drycleaners. Particular solvents will dissolve some substances and not others. For example, water will dissolve detergent, but not oil, as you can see in Figure 4.1.5.

Figure 4.1.5 Oil will not dissolve in water but detergent will.

1 p126

Concentration

Concentration is a measure of the amount of solute dissolved in a known amount of solvent. If there is a lot of solute dissolved in the solvent, it is said to be a **concentrated** solution. If there is only a little solute in the solution, then it is a **dilute** solution. Four spoonfuls of sugar dissolved in a swimming pool will produce a dilute solution. In contrast, four spoonfuls of sugar in a cup of tea will make it concentrated. A concentrated solution and a dilute solution are shown in Figure 4.1.6.

WORKED EXAMPLE
Calculating concentration

Spoonfuls are not a very accurate way of measuring things. Scientists instead measure the amount of solute in grams (unit symbol g), and volume in litres (L) or millilitres (mL). This way, concentration is measured in grams per litre (g/L) or grams per millilitre (g/mL).

Problem

For small volumes of liquid, the concentration is usually calculated in g/mL.

If you dissolve 5 g of sugar in 10 mL of water, what is the concentration?

Solution

To calculate concentration, divide the mass by the volume of liquid. This becomes:

$$\frac{\text{mass}}{\text{volume}} = \frac{5}{10}$$

$$= 0.5 \text{ g/mL}$$

Imagine you took a glass of water and kept adding spoonfuls of salt to it, stirring each time. If you try this then you will find that eventually the salt will stop dissolving. When a substance will no longer dissolve in a solvent, the solution is said to be **saturated**. Any undissolved solute then falls to the bottom, as shown in Figure 4.1.7 on page 122.

SciFile
Shake your bottle

Many medicines need to be shaken up before you take them. If you don't, one of the important ingredients in the medicine might remain as a sediment on the bottom of the bottle and so you would receive an incorrect dose. That is why you are told to 'shake the bottle before using'.

Figure 4.1.6 Concentrated solutions have a lot of solute dissolved in them while dilute solutions have very little.

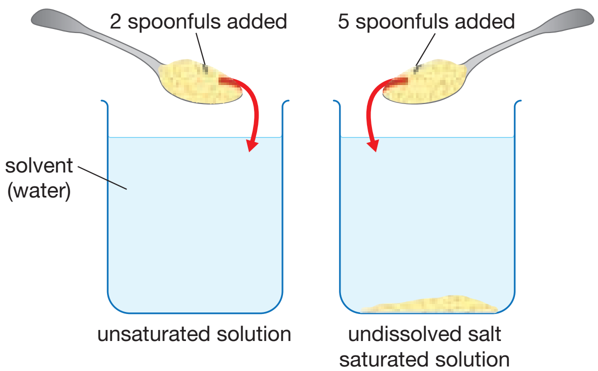


Figure 4.1.7 The solution that is saturated with salt has the higher concentration—so high that no more salt will dissolve.

In the natural world, solutions sometimes become saturated. This can cause solid salt to be deposited around the edges of salt lakes when the salt reaches a high concentration. The solution becomes saturated because of the water evaporating and also because of high levels of salt entering the lake. Figure 4.1.8 shows Lake Gairdner, a salt lake in South Australia.

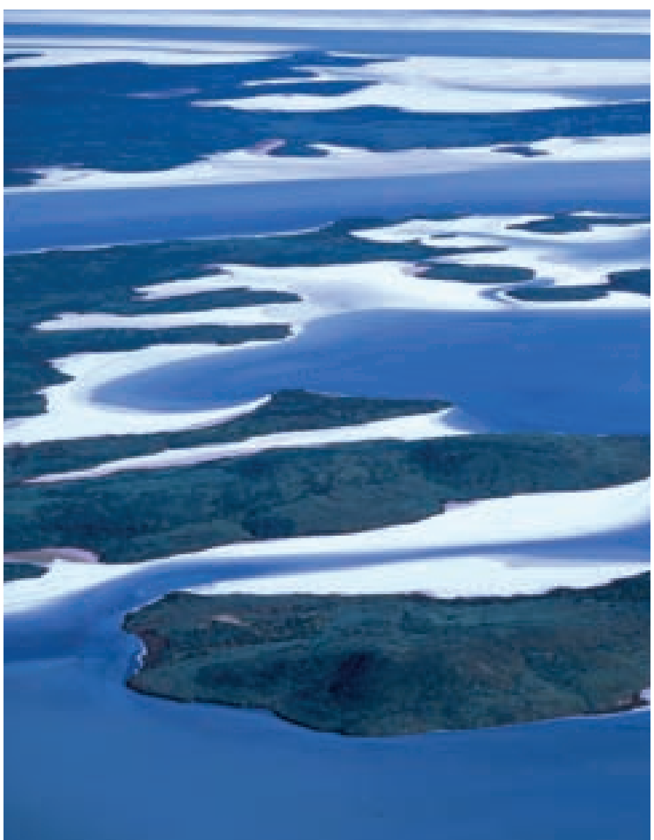


Figure 4.1.8 Salt crystals often form around the edges of salt lakes.

2 p127
3 p128
4.1

Suspensions

Sand does not dissolve when it is mixed into water. Instead it settles quickly to the bottom. Before the sand settles out, the mixture is an example of a **suspension**. In a suspension, one substance does not dissolve in another. The one that does not dissolve separates out when the mixture is left to stand. When the suspended part is still mixed and spread out, it is said to be dispersed.

Table 4.1.2 lists some different types of suspension.

Table 4.1.2 Types of suspension

Type of suspension	Examples
Solid suspended in a liquid	Most suspensions are made of large solid particles that stay mixed with a liquid for a short time, before settling out. Sand in water is an example.
Solids suspended in a gas	Sand carried by the wind drops out of the air it is suspended in as soon as the wind stops. Dust in the air is another example as you can see in Figure 4.1.9.
Liquids suspended in another liquid	Many medicines are suspensions of liquids within another liquid. Oil paints are generally suspensions of one liquid in another.

Figure 4.1.9 Dust floating in the air forms a suspension of a solid (dust) in a gas (air). Eventually, all that dust will settle onto the furniture.

Colloids

Acrylic paints (often called plastic paints) belong to a group of mixtures called colloids. A **colloid** is a mixture made of particles smaller than those found in a suspension but bigger than those of a solute in a solution. The particles are spread out in a substance known as the dispersion medium. In acrylic paints the dispersion medium is water. Zinc oxide, for example, is dispersed in water to give paint a brilliant white colour.

A quick way of determining whether a mixture is a colloid is to try to shine a light through it. To do this, the colloid is usually diluted first. When you shine a light into the diluted colloid, the beam of light can be seen spreading through the liquid. This is because the light is deflected and scattered by the small particles. In a solution, you do not see the beam of light. You can see this test in Figure 4.1.10.

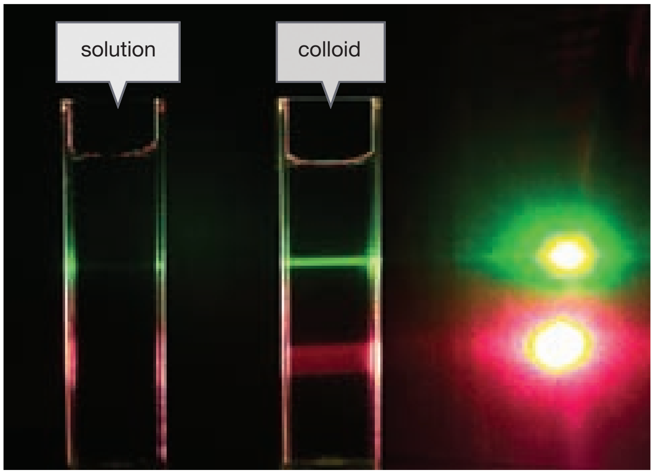


Figure 4.1.10 The light beam can be seen in the colloid but not in the solution.

One common type of colloid is called an emulsion. An **emulsion** is a mixture of a liquid in a liquid where one liquid will not dissolve in the other. Milk is an emulsion composed of tiny particles of fat spread through water. This fat is a liquid, not solid. The milk fat does not dissolve into the water dispersion medium, but stays as small droplets spread throughout the liquid.

Some milk has special chemicals called emulsifiers added to it. An emulsifier is a chemical that breaks up fats and oils into small droplets and disperses it through the liquid. A common emulsifier is the detergent you use for washing dishes. However, the emulsifiers in milk are different from those in your washing-up detergent. You can see how an emulsifier works in Figure 4.1.11.

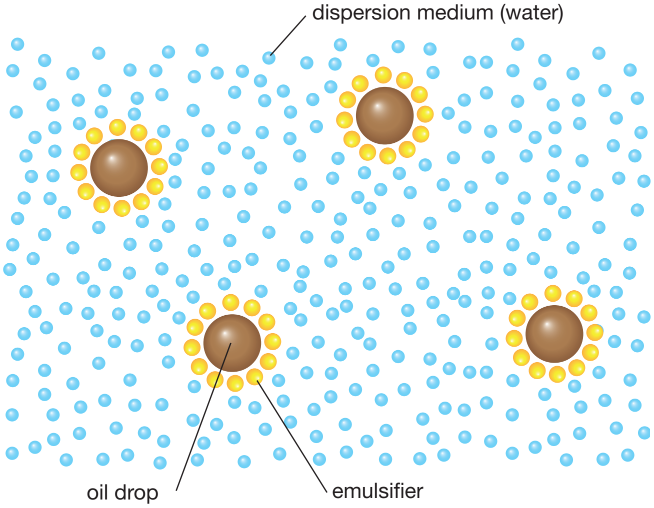


Figure 4.1.11 An emulsifier surrounds the oil droplets and spreads them through the dispersion medium.

Three other types of colloid are gels, foams and sols. These colloids are summarised in Table 4.1.3.

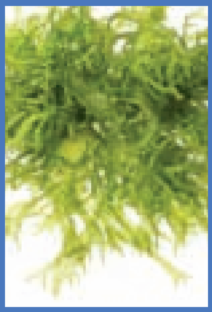
Table 4.1.3 Types of colloid

Type of colloid	What is it like?
Emulsion	A liquid dispersed in a liquid. Milk is a familiar example.
Foam	A gas dispersed in a liquid or a solid. Shaving cream is an example, as is foam 'rubber' used in furniture.
Gel	A liquid dispersed in a solid. Jelly is an example.
Sol	A solid dispersed in a liquid. A good example is blood.

4.2

SciFile

Seaweed in ice-cream



Yuk, seaweed in ice-cream! Well, no lumps of seaweed are in the ice-cream, but a special 'gum' extracted from it is. This gum holds strongly onto water, making the ice-cream thick and smooth instead of thin and runny. It also stops ice forming in the ice-cream when it sits in your freezer.

4.1 Unit review

Remembering

1 **List** two examples each of a solute, a solvent and a solution.

2 **List** four types of solution and give an example of each.

3 **List** three types of suspension and give an example of each.

4 **List** four types of colloid and give an example of each.

5 **Recall** the different types of mixtures by matching each type below with its correct description A, B or C.

- **a** solution
- **b** suspension
- **c** colloid

- **A** A type of mixture in which one substance does not dissolve in another but quickly separates out to form a sediment
- **B** A mixture made of particles smaller than a suspension but bigger than those of a solute in a solution
- **C** A clear mixture in which a substance dissolves in another

Understanding

6 **Outline** a method you could use at home to quickly test whether a mixture was a colloid or not.

7 Mylanta is an antacid liquid used to relieve heartburn. The label tells you to shake the bottle well before use. **Explain** why.

8 **Explain** the meaning of the term *concentrated solution.*

Applying

9 **Identify** what is wrong in the following statements and re-write them accurately.

- **a** A solvent is defined as a substance that dissolves a solid to form a solution.
- **b** An emulsion can be the solution formed when liquids disperse through water.
- **c** To form a suspension, a solid has to be fine enough to stay dispersed in a medium.
- **d** Colloids are composed of particles larger than those in a solution or a suspension.
- **e** An emulsifier can be used to make a solution.
- **f** All solutions are mixtures, but a suspension is not a mixture.

10 Substance X forms a saturated solution in alcohol when 25 grams is dissolved in 100 mL of alcohol. **Calculate** how much to add to 50 mL of alcohol to have an unsaturated solution.

11 A student adds 80 grams of solid X to 100 mL of pure water, but only 10 grams of X dissolves.

- **a** **Calculate** the concentration of substance X.
- **b** **Calculate** how much X would settle on the bottom of the container.

12 How could you **demonstrate** that a sugar solution is just saturated?

Analysing

13 **Compare** a concentrated sugar solution with a dilute sugar solution.

14 **Compare** a sugar solution with a suspension of sand in water.

15 Melting is the change of state in which a solid changes into a liquid. Refer to this information to **compare** dissolving and melting.

16 **Classify** each of the following as solution, suspension or colloid.

- **a** cordial in water
- **b** carbon dioxide gas in lemonade
- **c** clouds
- **d** food colouring in water
- **e** oil in salad dressing
- **f** egg white in a pavlova
- **g** dust in air
- **h** smoke from a car exhaust

17 **Compare** a solution, a suspension and a colloid.

Evaluating

18 A student found that her tea tasted just as sweet whether she mixed 5 teaspoons or 10 teaspoons of sugar into the liquid. **Propose** an explanation for this.

Creating

19 Think of a common mixture and write down what is in it, but don't tell your partner what it is. Your partner does the same. Now **construct** a series of questions you could ask your partner to work out the secret identity of their mixture. Write down your questions, again keeping them secret. Your task is to identify your partner's mixture. Toss a coin to decide who goes first. The winner is the person who needs the smallest number of questions to identify the mixture.

20 **Design** an experiment to test the effectiveness of three different brands of dishwashing liquid detergent (for hand-washing dishes in a sink, not dishwashing machines). If your design is a good one, your teacher may let you conduct the experiment. Your teacher will supply the detergent. You have to choose the test material and equipment to use in your classroom.

Inquiring

Design an experiment to test each of the following ideas. Show your methods to your teacher and ask if you can try them.

1 That sugar and copper sulfate can both be dissolved in the same container of water.

2 That saturating water with sugar will stop copper sulfate dissolving in the saturated sugar solution.

3 That sugar and salt have different solubilities in water. You will need to try some measurements here.

4.1 Practical activities

1 Soluble and insoluble substances

Purpose

To investigate what substances will dissolve in water and kerosene.

Materials

- 6 medium-sized test-tubes with stoppers to fit
- test-tube rack
- copper sulfate ($CuSO_4$)
- copper carbonate ($CaCO_3$)
- table salt (NaCl)
- cooking oil in dropper bottles
- kerosene
- marking pen or sticky labels
- teaspoon

SAFETY!

Kerosene is flammable so keep it away from naked flame. Avoid skin contact and inhaling fumes.

Wear safety glasses at all times.

Procedure

1. Place the test-tubes in the rack. Use the marking pen or sticky labels to number them 1 to 6.
2. Add about 5 cm of tap water to test-tubes 1 to 4. Pour 3 cm of kerosene into test-tubes 5 and 6.
3. Add different solutes to the different test-tubes as shown in Figure 4.1.12.
4. Place a stopper in each test-tube. Shake each of the test-tubes for about 1 minute.
5. Do not tip anything down the sink. Return all test-tubes and liquid to your teacher.

Results

1. Copy the following table into your workbook.

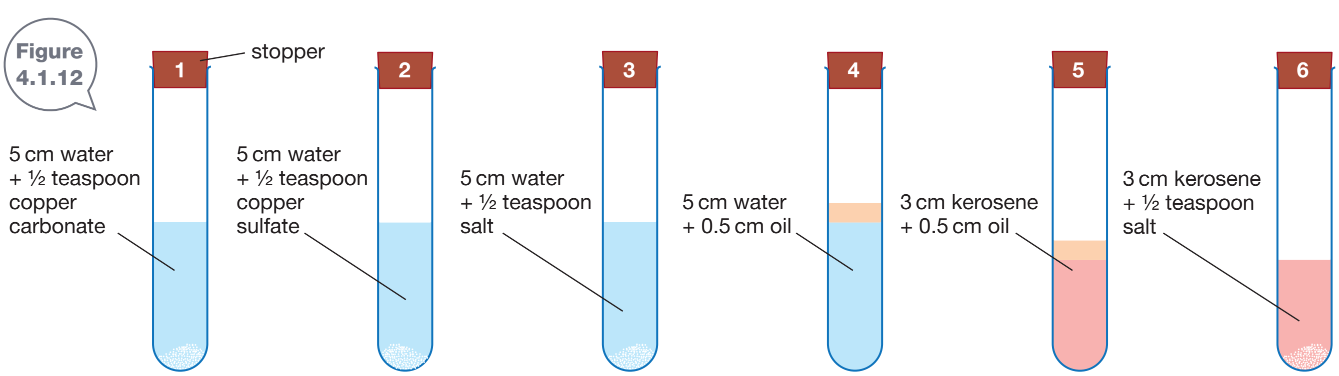
Test-tube number	Dissolving medium (solvent)	Trying to dissolve (solute)	Observation
1	water	copper carbonate	
2	water	copper sulfate	
3	water	salt	
4	water	oil	
5	kerosene	oil	
6	kerosene	salt	

2. Record your observations in the table.

Discussion

1. **Describe** an easy way of telling whether a solution has been formed or not.
2. **Identify** the test-tubes in which a solution formed.
3. **Name** the substances that were insoluble in water.
4. **Name** the substances that were insoluble in kerosene.
5. **Name** the substance that is a solvent of salt but not of oil.
6. **Name** the substance that is a solvent of copper sulfate but not of copper carbonate.

Figure 4.1.12



2 Dissolving and surface area

Purpose

To test whether breaking up a solute into smaller particles can change how fast it dissolves.

Materials

- 2 test-tubes and stoppers
- 2 Sugarine® tablets
- spatula
- teaspoon
- sheet of newspaper
- marking pen or sticky labels

Procedure

1. Place one Sugarine® tablet on the paper and use the back of the spoon to crush it into a powder.
2. Place the test-tubes in the rack and number them 1 and 2.
3. Pour about 5 cm of tap water into each test-tube.
4. This next step must be done at the same time, so two students in your group will have to do one task each.
   - Student 1: Pick up the powdered tablet with the paper and carefully tip the powder into test-tube 1. Place the stopper in the test-tube.
   - *At the same time*, Student 2: Drop a Sugarine® tablet into test-tube 2. Place the stopper in the test-tube.

   The set-up is shown in Figure 4.1.13.

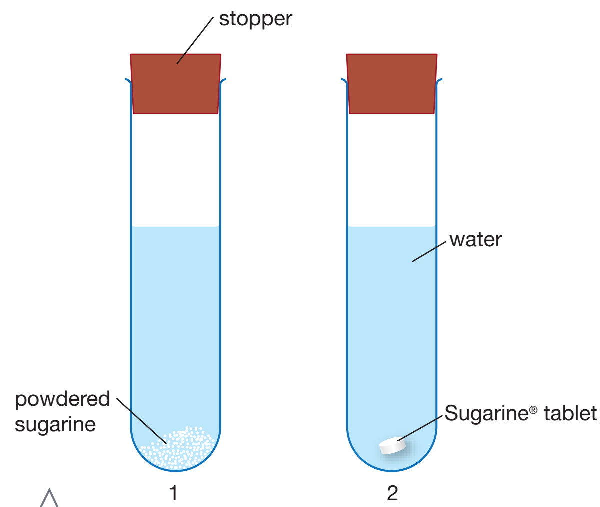


Figure 4.1.13

5. Shake both test-tubes at the same time and in the same way for 10 seconds, then place them in the rack.
6. When you have finished shaking the test-tubes, record your observation in your notes.

Discussion

1. The sugarine tablet in test-tube 1 was crushed into tiny pieces. More of the tablet is in contact with the water than for the solid tablet in test-tube 2. We describe this as having a larger surface area, or a greater amount of subdivision.
   a. **Identify** which has the greater surface area in contact with the water.
   b. **Describe** a difference between the results in test-tubes 1 and 2.
   c. **Explain** why a difference can be expected between test-tubes 1 and 2.
2. **Construct** a conclusion about the effect of a bigger surface area on how fast a substance dissolves.

3 Dissolving and temperature

Purpose

To test whether temperature affects how much of a substance will dissolve.

SAFETY!

Wear safety glasses at all times.

Tie long hair back.

Turn the Bunsen burner flame to yellow when it is not being used.

Allow equipment to cool before packing it away.

Materials

- test-tube and stopper
- test-tube holder
- test-tube rack
- Bunsen burner and bench mat
- copper sulfate ($CuSO_4$)
- spatula

Procedure

Figure 4.1.14 illustrates the procedure for this activity.

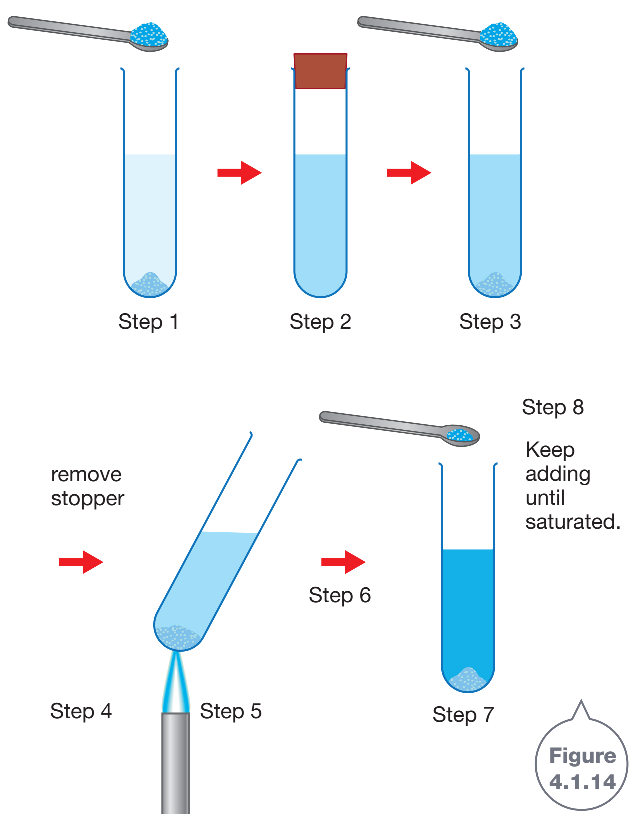


Figure 4.1.14

1. Add about 5 cm of water to the test-tube. Use the spatula to add to the test-tube about as much copper sulfate as you imagine would fit on your little fingernail (but don't put it on your fingernail).
2. Stopper the test-tube and shake it until the solid dissolves.
3. Add another fingernail-size lot of the copper sulfate to the test-tube and again shake it to dissolve the solid. Keep repeating this step until you find that not all the solid dissolves.
4. Remove the stopper from the test-tube.
5. Using a test-tube holder, gently heat the test-tube over a Bunsen burner flame (airhole about one quarter open) for about 20 seconds. Remember to point the mouth of the test-tube away from people while you are heating it. Do not boil the liquid. Watch carefully that you do not bring the flame near the test-tube holder.
6. Place the test-tube in the rack, leaving the test-tube holder attached to it.
7. Carefully add about a match-head-sized amount of copper sulfate to the test-tube.
8. Holding it by the test-tube holder, lift the test-tube and gently swirl it around to try to dissolve the extra copper sulfate solid you added. Be careful not to drop the test-tube or splash the liquid out of the test-tube.
9. Repeat steps 7 and 8 until some solid remains undissolved. Then leave the test-tube in the rack to cool, observing what happens.

Results

Write down your observations of what happened to the contents of the test-tube as it cooled.

Discussion

1. **Compare** the amount of solute that dissolved in cold and hot water.
2. **Describe** what happens to the contents of your test tube as it cools at the completion of steps 7 and 8.

4.2 Separating insoluble substances

Being able to separate insoluble substances from each other is important to many organisms including humans. Grey whales scoop up sand from the sea floor and filter out their food through structures called baleen.

INQUIRY science 4 fun

Panning for gold

Could you find gold?

Yes

Collect this ...

- metal bowl or old cereal bowl (shallow with gently sloping sides)
- fairly clean sand or loam soil
- small metal weights such as nails or washers
- bucket of water or hose

Do this ...

1. The small metal weights are your 'gold'. Mix them up with the soil and put the mixture in the bowl.
2. Half-fill the bowl with water.
3. Hold the bowl with a hand on each side. Move the bowl around in a circular motion to swirl the water through the soil. The soil should start lifting up into the water.
4. Let the water wash over the sides of the bowl as you move it around. The aim is to wash some of the soil out of the bowl with the water.
5. Keep adding water and swirling the soil around so it is gradually removed from the bowl. You should see the 'gold' collecting on the bottom of the bowl.
6. See how pure you can get the 'gold'. You may have to practise to improve your technique.

Record this ...

Describe what happened.

Explain why you think this happened.

Gravity separation

Gold panning (shown in Figure 4.2.1) uses a method called gravity separation. **Gravity separation** uses gravity to separate heavier substances from a suspension. The heavier particles sink to the bottom of the container.

Figure 4.2.1 Panning for gold uses gravity separation.

Decantation is a type of gravity separation that lets suspensions of solids or liquids separate naturally. The top layer can then be poured or scraped off. The top layer could be a:

- liquid, such as oil
- solid, such as plant material like leaves and twigs in soil
- liquid, if a heavy solid has settled to the bottom.

Decanting is used in a kitchen to pour off cooking water from vegetables in a saucepan. Sometimes sediment will collect at the bottom of a bottle of wine that has been left to stand. Pouring the bottle into a glass container (a decanter) leaves the sediment in the bottle. Decanting is used in many industries. Figure 4.2.2 shows the method being used in a science laboratory.

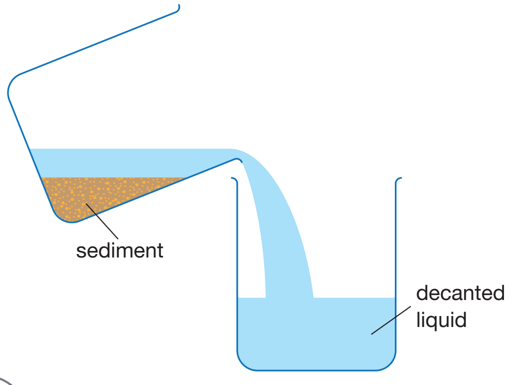


Figure 4.2.2 Decanting a liquid from a solid pours off the liquid to leave the solids behind.

Sieving

A sieve is a barrier with holes in it. Small solid particles can get through, but large ones cannot. The process is called sieving. A colander is a sieve that is used in the kitchen to strain water from food. Likewise, large lumps in flour can be removed before baking by sifting the flour through a strainer, or flour sifter. A fishing net as shown in Figure 4.2.3 is also a sieve.

Figure 4.2.3 A fishing net is a kind of sieve. The small fish and water go through while the larger fish get stuck in the net.

Sieves are graded to a specific size for the job they do. They are used in mining to ensure that only rocks of the correct size enter a rock crusher. They are used in gardening and in soil studies to grade the soil into its different-sized particles to classify the soil being studied.

Filtration

Filtration, also known as filtering, is a widely used method of separating:

- solids from gases
- solids from liquids
- liquids from gases
- liquids from other liquids.

Filtration uses a **filter**. This acts like a sieve to separate insoluble substances. A filter is a barrier with many, many small holes (often microscopic in size) in it. These holes are smaller than the particles being separated and so these particles get caught in the filter. However, smaller particles will pass straight through. Many filters are a mesh of fine fibres like cotton wool, while others are like rock with fine pores in it.

Filters are used to separate coffee grounds from filter coffee. Likewise, tea bags are a type of filter that allows water to move through them while keeping the tea leaves in the bag. Face masks as shown in Figure 4.2.4 are filters that separate dust from air. A similar filter is used in most vacuum cleaners. The filtered, clean air is then blown back into the room. A filter from a vacuum cleaner can be seen in Figure 4.2.5. Filters can also be found in air conditioners, washing machines, dryers, swimming pools and car engines, fuel systems and air cleaners.

Filters are also used in the laboratory. Several different methods are used, but the most common uses filter paper.

Figure 4.2.4 People working in dirty or dusty environments can protect their airways by wearing face masks.

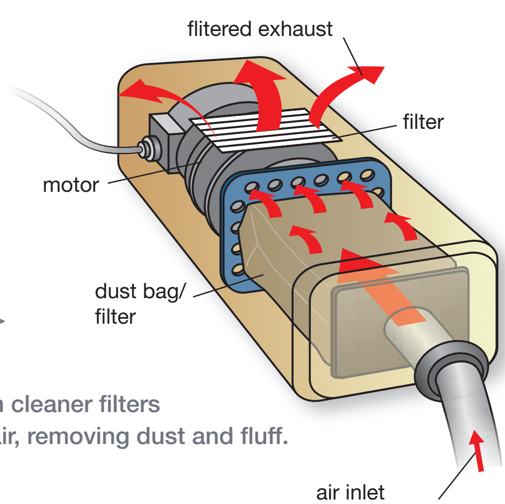


Figure 4.2.5 A vacuum cleaner filters exhaust air, removing dust and fluff.

Human filters

SciFile

Your kidneys filter your blood and produce urine. Your whole blood supply passes through your kidneys in about 1 hour. This means your blood has passed through your kidneys about 24 times in a day. From this you make about 1 litre of urine.

4.3

SKILL BUILDER

Folding a filter paper

There are two methods to fold filter paper. The method you choose depends on the material you are filtering. The conical fold is shown in Figure 4.2.6.

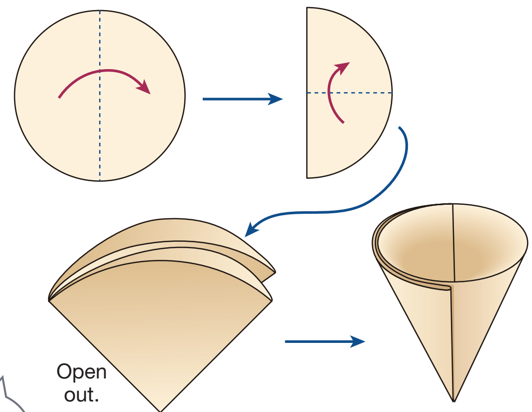


Figure 4.2.6 How to make a conical fold for filter paper

The other method of folding is called fluting. This is shown in Figure 4.2.7.

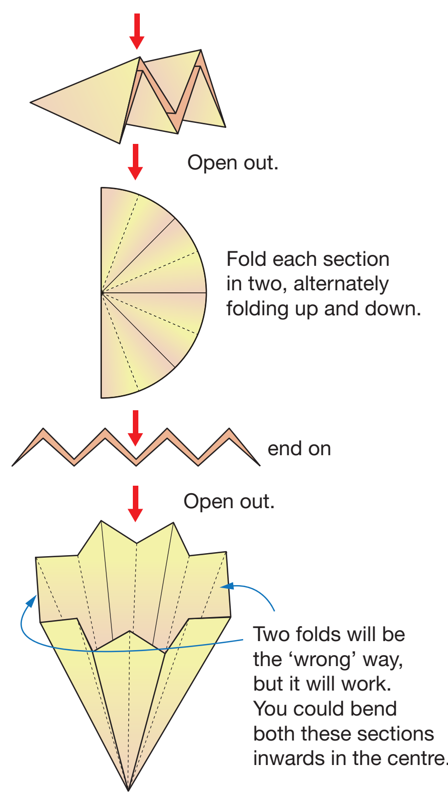


Figure 4.2.7 How to fold a fluted filter paper

Fluting will increase the amount of surface in contact with the liquid and will increase the filtration rate. It is useful for very fine suspensions that can block many of the holes in the paper.

SKILL BUILDER

How to filter

To filter, set up the equipment as shown in Figure 4.2.8.

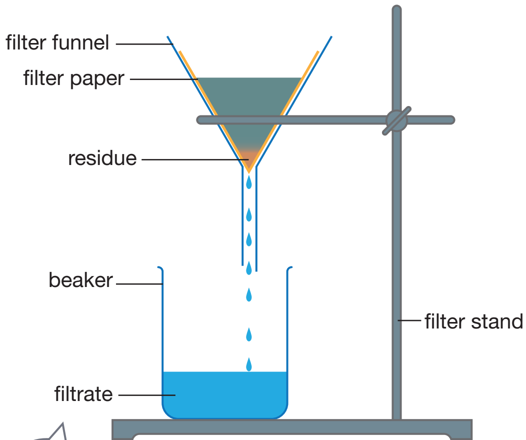


Figure 4.2.8 Filtering set-up

Some rules to follow when filtering are:

1. Do not let the liquid in the filter go over the top of the paper, or solids will enter the filtrate.
2. Do not touch the filter while filtering—it will break and solids will enter the filtrate.

When filtering you may want to keep the filtrate, the solid, or both. This is known as recovering the substance. The table describes the procedure to follow.

What do you want to recover?	What should you do to the beaker containing the mixture?
Only the liquid (filtrate)	Let the solid settle before decanting the liquid into the filter.
Only the solid	Stir the material in the beaker to suspend as much of the solid in the liquid as possible, then pour the suspension into the filter. Use distilled water to wash any remaining solid out of the beaker into the filter paper.
Both liquid and solid	Follow the same procedure as for recovering the solid.

1 p137

Magnetic separation

Iron, nickel and cobalt are the only three pure metals that are always attracted to a magnet. An alloy is a metal mixed with other elements such as carbon. Steel is an alloy of iron and it is magnetic too. Magnetic separation allows iron and steel to be removed from piles of non-magnetic materials.

Magnetic separation is widely used in the mining industry, in the scrap metal business and in recycling. One way of recycling scrap is to feed it into a magnetic rotating drum. The magnetic materials are attracted to the drum and are removed from the flow of rubbish, which passes straight through, as shown in Figure 4.2.9. The collected metals can then be recycled.

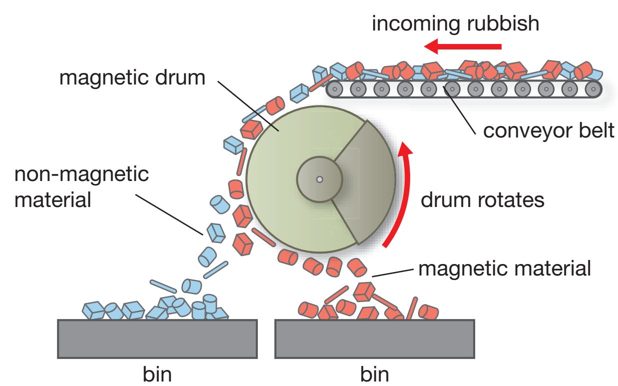


Figure 4.2.9 A rotating drum used to separate magnetic materials from municipal rubbish.

Non-magnetic metals can be made temporarily magnetic if they are good conductors of electricity. A strong magnet nearby can make a temporary electric current flow through them. The current is called an eddy current. A magnetic field exists wherever an electric current flows. So the metal is magnetic while the current flows. A nearby magnet can pull the non-magnetic metals, such as aluminium cans and bottle tops, out of a stream of rubbish. This method is called eddy current separation.

2 p138

Centrifuging

A simple **centrifuge** is shown in Figure 4.2.10. It has chambers that are spun very fast around a shaft. Any tiny particles suspended in the liquid are forced to the sides and then the bottom of each chamber.

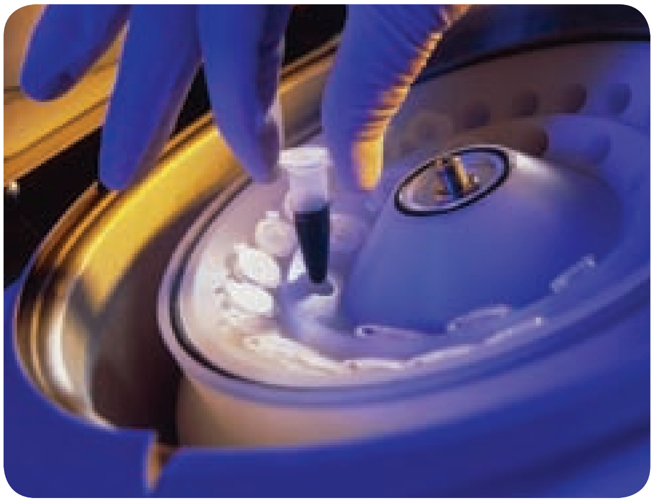


Figure 4.2.10 A simple centrifuge is used to separate substances in the laboratory.

A common use of a centrifuge is in the spin cycle on a washing machine, in which the clothes are spun very fast in the bowl. Figure 4.2.11 shows how this works. Water is forced out of the clothes and through the holes in the bowl. It then drains away and is pumped out of the machine. In a similar way, salad spinners are used in the kitchen to dry washed lettuce.

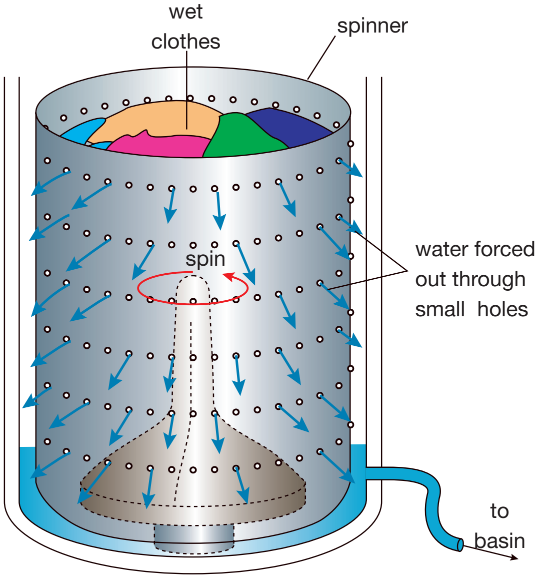


Figure 4.2.11 A washing machine spin cycle acts as a simple centrifuge.

There are many other designs for centrifuges. Some very complicated ones are used in mining. Centrifuging is also widely used in laboratories. Blood bank centrifuges separate samples of blood. Blood is spun to separate it into its red and white cells and liquid plasma.

Electrostatic separation

Electrostatic separation involves giving particles an electric charge and then passing them between electrically charged plates. This is shown in Figure 4.2.12. The negatively charged smoke particles are attracted to the positively charged plates. This process removes the smoke particles from the air.

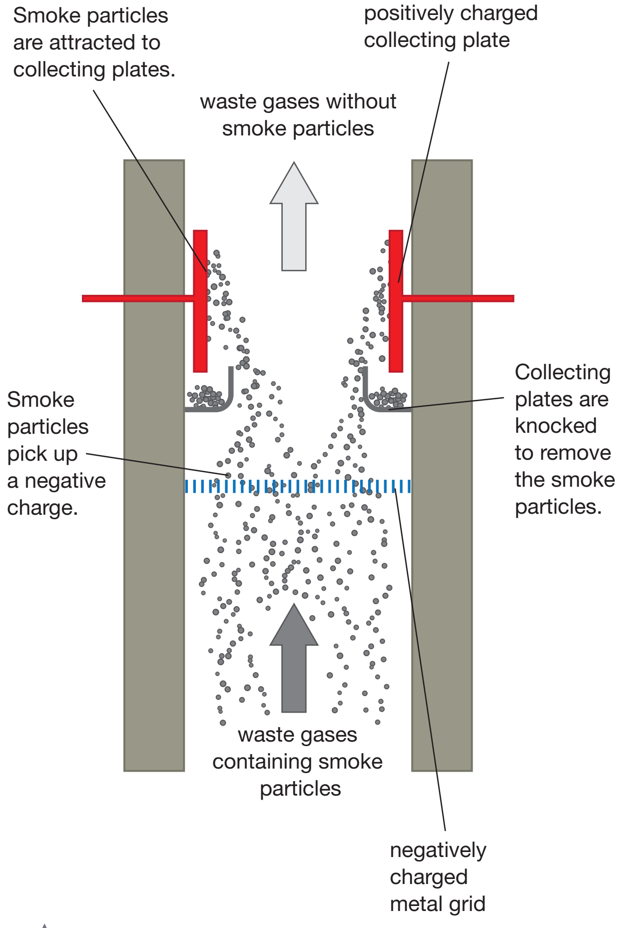


Figure 4.2.12 Electrostatic separation of smoke and air takes place in industrial chimneys.

Electrostatic separation is used to remove many of the smoke particles from industrial chimneys. It is also used in industries such as mining to separate the useful minerals from the not-so-useful ones.

SCIENCE AS A
HUMAN ENDEAVOUR

Use and influence of science

Cyclonic separation

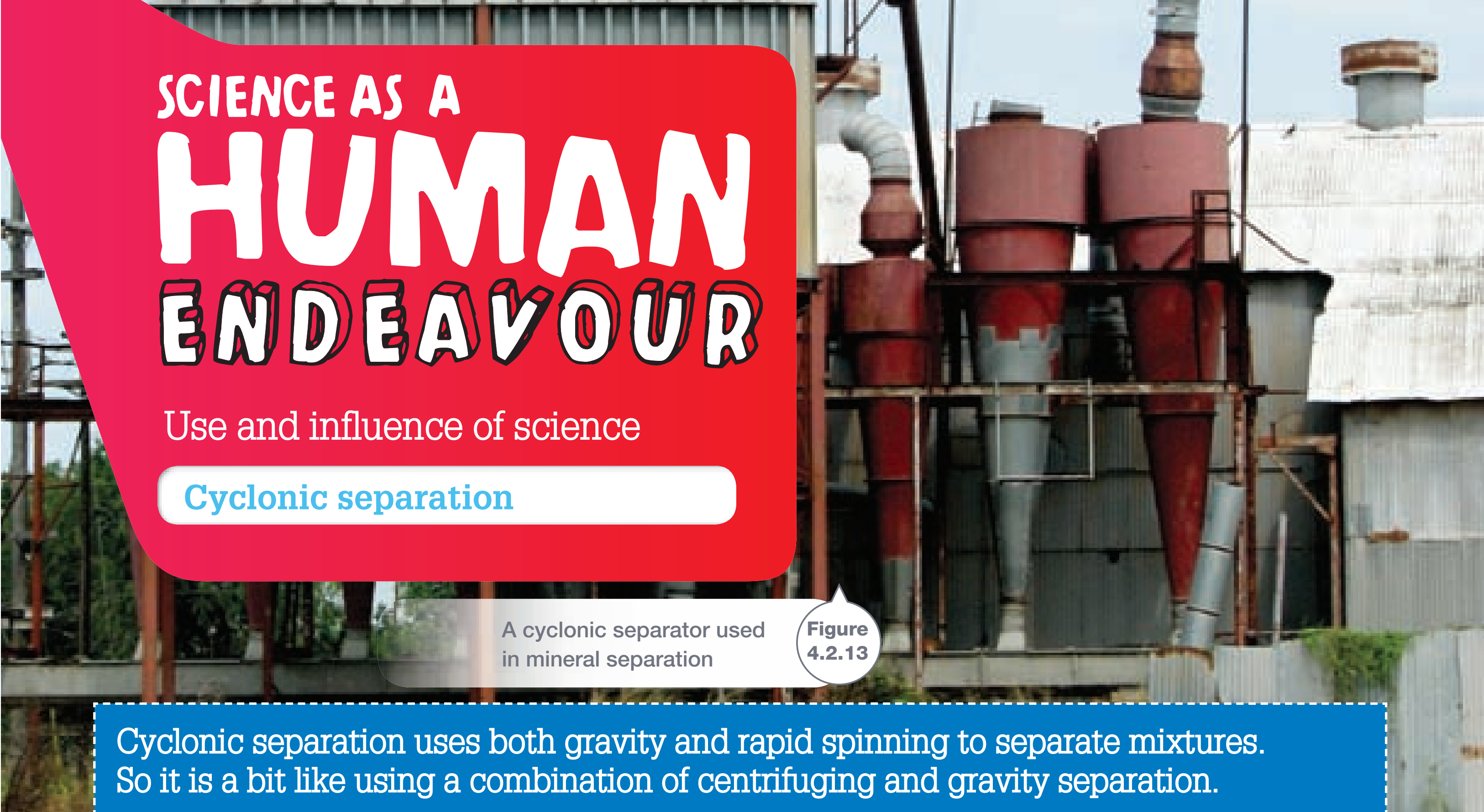


Figure 4.2.13 A cyclonic separator used in mineral separation

Cyclonic separation uses both gravity and rapid spinning to separate mixtures. So it is a bit like using a combination of centrifuging and gravity separation.

Cyclonic separation has become important in mining, and is being used more and more in many other industries. For example, it is used in air-cleaning systems in factories, to clean water in irrigation, and to separate minerals in mining. In the early 1990s it was adapted to make a vacuum cleaner.

Cyclonic separation can be used to clean gases and liquids by removing solid particles in them. For example, Figure 4.2.14 shows how a hydrocyclone cleans dirty water. The water carrying solid particles is pushed into the cyclone chamber at an angle. The water spins around in a spiral, like water going down the sink. Heavier particles are thrown into the wall of the chamber, just like in a centrifuge. The solids then slide down the sides by gravity to the bottom of the separator. There they can be removed. The cleaned water is pushed up the centre of the chamber and out a pipe at the top.

A similar cyclone is used to remove solids from a gas. The gas is allowed in at an angle into a large chamber. There the gas spins around and solid particles are thrown to the sides. The solids sink to the bottom and the clean air escapes at the top. The cyclonic vacuum cleaner uses this method.

Oil can be separated from water using a cyclone. Car washes use these systems to enable them to reuse water that has had oil removed. The water is heavier than the oil and is thrown to the outside of the separator, collecting at the bottom. The oil escapes at the top.

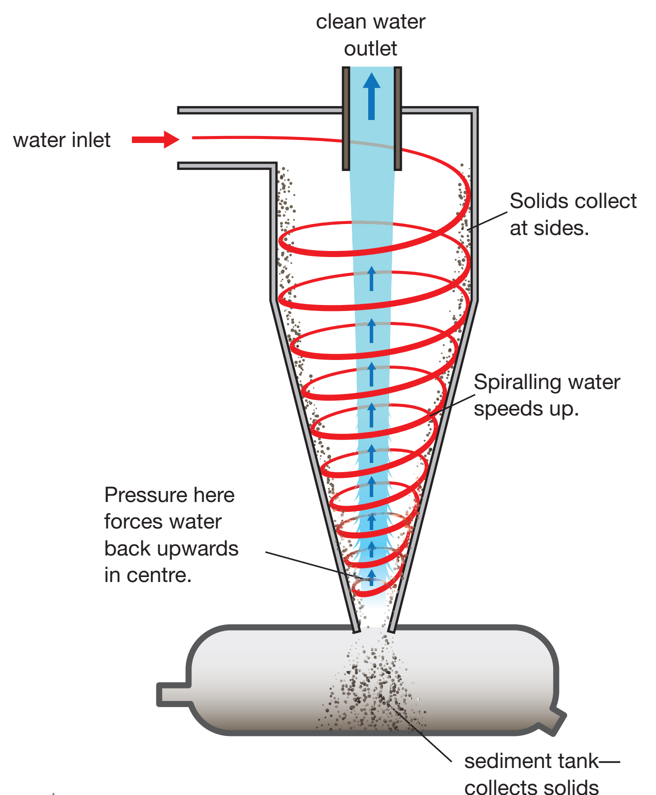


Figure 4.2.14 Cyclonic separation uses gravity and spin to separate mixtures.

4.4

4.2 Unit review

Remembering

1 **List** examples of sieving and filtering around your home.

2 **Name** an example of centrifuging that is used at home.

3 **State** at least two methods of separation that can be used to separate a:
  a solid from another solid
  b solid from a liquid
  c solid from a gas
  d liquid from another liquid.

Understanding

4 a **Describe** what a paper filter would look like if you could magnify it enough.
  b **Explain** how it works to filter out larger particles.

5 **Explain** why filtration cannot separate sugar from water.

6 **Describe** how magnetic separation can be used to separate magnetic and non-magnetic metals from household rubbish.

Applying

7 **Identify** a method of separation that could be used for the following situations.
  a You want some fine clean sand without any sticks or stones from the soil in your garden.
  b You drop some nails into the sand in your back yard.
  c You drop some hundreds-and-thousands into the flour your mum is using for a cake.
  d The gravel border along the driveway at home has become covered by bark, and leaves and fine sticks are mixed with the gravel.
  e Your tea bag breaks in your cup of tea.

Analysing

8 **Compare** the use of conical and fluted filter paper in filtering.

9 **Compare** cyclonic, gravity and centrifuging methods of separation by listing their similarities and differences.

10 **Compare** filtering and sieving.

11 Car air cleaners are structured as shown in Figure 4.2.15.

Figure 4.2.15

  a **Compare** the structure of the air cleaner with a fluted filter paper.
  b **Describe** how this design is effective as an air cleaner.

Evaluating

12 In the laboratory, you are given a mixture of sand and salt. **Propose** a way of separating these two substances.

13 When car tyres are replaced, the installer attaches small weights to the wheel rim to check that the wheel is balanced, with an even mass distribution all around. This is because anything that spins fast and is unbalanced can put an enormous stress on the shaft it is attached to. **Propose** how this could apply to a centrifuge if it was not used properly and was unbalanced.

14 **Propose** a reason why vehicle air, fuel and oil filters need to be changed regularly.

15 You are fixing your skateboard and accidentally drop a steel wheel nut into a drain that is too deep to put your arm in. **Propose** a method of recovering the nut from the drain.

16 Some washing machines do some test spins before starting the spin-dry cycle. After doing this, the machine may not spin the clothes but instead agitate them back and forth for a while, before trying another test spin. **Propose** a reason why the machine has been designed to do this.

Creating

17 **Construct** a table in which you:
- a **list** each of the seven methods of separation in this unit
- b **describe** how each method works
- c **specify** an example where it may be used.

18 **Design** a working model of a magnetic device for separating iron filings or ball bearings from sand. The mixture of sand and metal has to move along a conveyor belt, and a magnet has to separate the mixture into two containers. You could use Lego or laboratory equipment. The conveyor belt can be hand-operated or connected to an electric motor. Your design should detail all the parts and how they work, but you do not have to actually build the model.

Inquiring

1 Search available resources such as textbooks, encyclopaedias and the internet to research the use of cyclones in five different industries, such as mining and agriculture, specifying the purpose of the cyclone.

2 Search the internet for a video that shows eddy current effects on aluminium cans or aluminium metal strips. Describe the video and how it applies to eddy current separation of non-magnetic metals in rubbish recycling.

3 Research two separation methods used in 'blood banks' and in the wine industry.

4 Research four different devices such as hydrocyclones and skimmers that are being used to separate oil and water when cleaning up oil spills in the ocean. Explain how each device works.

5 Research six different methods, including sorbents, separating devices, dispersants and skimming, that can be used to clean up oil spills in the ocean. Figure 4.2.16 shows one method. Give a brief outline of what is done and how each method works. You can choose only one device.

Figure 4.2.16 Cleaning up ocean oil spills can be achieved by several methods. This string of polystyrene floats (called a boom) has trapped oil floating on the ocean's surface.

3 p138

4.2 Practical activities

1 Comparing filters

Purpose

To compare conical and fluted filter papers.

Materials

- 2 funnels
- 4 filter papers
- 2 × 100 mL beakers
- 2 × 250 mL conical flasks
- 2 stirring rods
- copper carbonate ($CuCO_3$)
- sand, water
- 2 timers

Procedure

You need four students in your group to conduct this experiment.

1. Place a funnel in each conical flask.
2. Fold one filter paper into a conical shape and the other into the fluted shape (as shown in Figure 4.2.17). Place each filter in a funnel.
3. Collect one spoonful of sand and place it in 40 mL of water in a beaker. Repeat for the other beaker.
4. Read all of step 4 here before you pour into the filter paper. Two students must do the pouring into the filter papers, and two must do the timing.

   Now pour the contents of one beaker into the conical filter paper. Start the timer as soon as the first water goes into the conical filter paper. *At the same time* pour the same amount of water from the other beaker into the fluted paper. Start the second timer as soon as the water goes into the fluted filter.
5. Add more of the sand and water mixture to each filter paper until all of the liquid has been filtered. Stop the timer when the filter stops filtering. Leave any remaining sand in the beaker. Note the time taken for each filter, and how clear the filtrate is.
6. Repeat steps 1–5 with new filter papers, but this time use copper carbonate instead of sand.

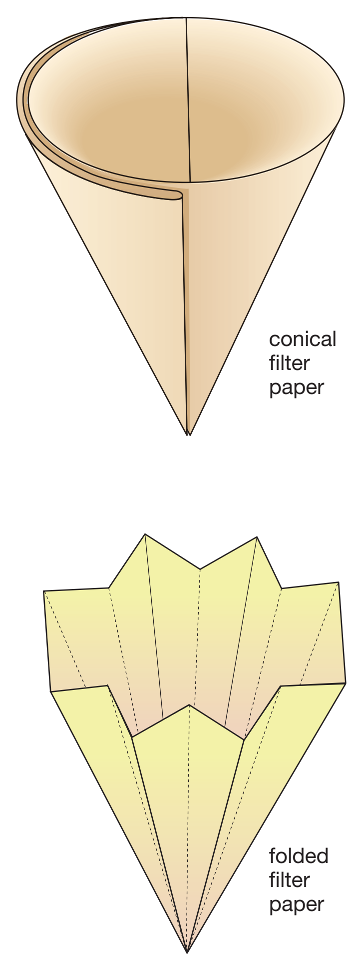
Results

1. Record the appearance of the filtrate, for both the sand and the copper carbonate.
2. Record the time it took for all of the liquid to pass through each filter.

Discussion

1. **Compare** the rate at which the two differently folded filter papers filtered each of the mixtures.
2. **Identify** which was the better method of folding the filter paper.
3. **Explain** why one folding method was better than the other.

Figure 4.2.17



4.2 Practical activities

2 Separating solids

Purpose

To separate a mixture of sand, salt and iron filings.

Materials

Select from:

- filter stand
- filter funnel
- filter paper
- 2 × 100 mL beakers
- stirring rod
- sand
- salt
- iron filings
- magnet (wrapped in plastic)
- teaspoons

Procedure

1. Using different spoons, place one spoonful each of sand, iron filings and salt into a beaker. Mix the solids up well with your spoon or stirring rod.
2. The task for your group is to design a method to separate these three solids from each other, and then use your method to separate them. You can use any equipment your teacher has provided or any that your teacher agrees to supply to you.
3. Decide in your group how you will proceed. Draw a diagram of the equipment you need and the steps you will use to achieve your goal. Construct a list of the equipment you will need.
4. If your teacher agrees, collect your equipment and carry out your experiment.

Results

Record your results.

Discussion

Write a report on your experiment, using the format outlined in Unit 1.3.

3 Oil spills

Purpose

To design a procedure to investigate sorbents as ways to clean up oil spills in the ocean.

Materials

- 50 mL cooking oil
- equal masses of sorbents: cotton balls, paper towel, kitchen sponge
- 3 plastic cups
- detergent
- 2 wide mouth jars
- balance
- tweezers
- timer

Procedure

1. Sorbents are materials that can soak up substances. Your aim is to decide how good the sorbents above are at cleaning up an oil spill in the ocean.
2. Read through the materials above and the results table below. Then, in your team, discuss what procedure you should use. Remember to test sorbents with water.

Results

Your results table may look something like this.

Sorbent	Mass cup (g)	Mass sorbent (g)	Mass cup + sorbent + oil (g)	Mass oil (g)
Sponge				
Paper				
Cotton				

Discussion

Write a report on your experiment using the format outlined in Unit 1.3.

4.3 Separating soluble substances

Soluble substances can be separated using a range of different methods. These methods are used in forensic investigations, food and drink manufacture, supplying fresh drinking water, producing pharmaceutical drugs, and making perfumes.

INQUIRY science 4 fun

Separating colours

Are textas and food colours made of just one pure substance?

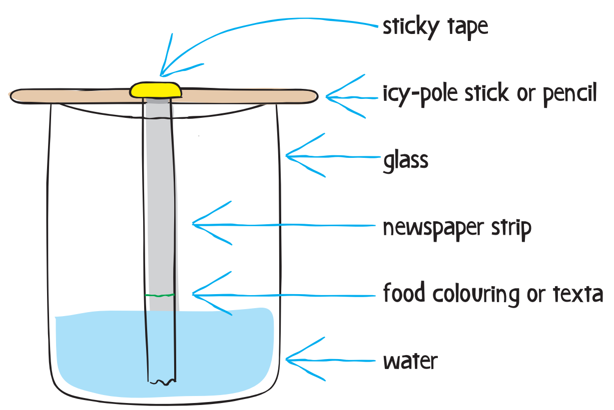
Yes

Collect this …

- sheet of newspaper
- pair of scissors
- 4 narrow drinking glasses
- food colouring (green is good)
- brown felt-tip pen
- sticky tape or Blu Tack
- four pencils (hexagonal cross-section is better than round)
- icy-pole stick

Do this …

1. Cut four blank strips of paper. Each strip should be a few centimetres taller than your glass.
2. Across two of the paper strips, make a line with the felt-tip pen 3 cm from the end. Repeat this for the other two strips using food colouring.



3. Set up the paper as shown. It is best to put the water in first. The water level must be below the coloured line on the paper.
4. When the water has almost reached the top of each strip, take the strips out and let them dry.

Record this …

Describe what happened.
Explain why you think this happened.

Chromatography

Chromatography is a process that can separate a mixture by making it move through another substance like a paper strip, as shown in Figure 4.3.1. Water is a solvent, dissolving the dyes from ink or foods, and carrying the colours with it as it moves up the paper.

Chromatography works because all the chemicals in the mixture you are trying to separate are attracted to the paper by different amounts. Substances that are strongly attracted to the paper are harder for the solvent to move along than substances that are weakly attracted. You can see this in Figure 4.3.1.

Chromatography is very important in industry. It is used to find out what is in oil and gas, and to identify pollutants.

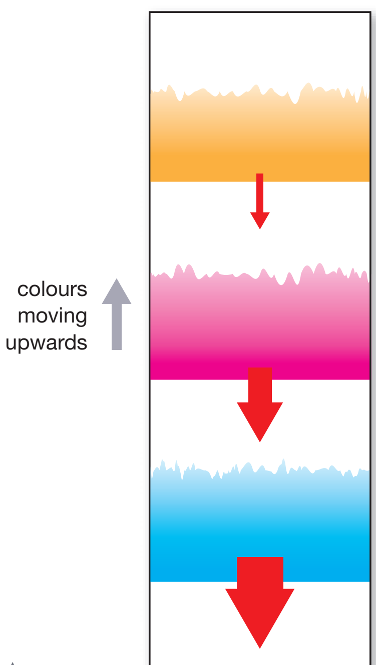


Figure 4.3.1 Paper chromatography separates mixtures.

Lawbreakers beware!

Chromatography can help catch drug cheats in sports by identifying banned drugs in urine. If you write a letter with a particular pen, then chromatography can be used to identify the ink you used and match it to your pen.

SciFile

INQUIRY science 4 fun

Candy crystals

Can you grow the biggest candy crystals?

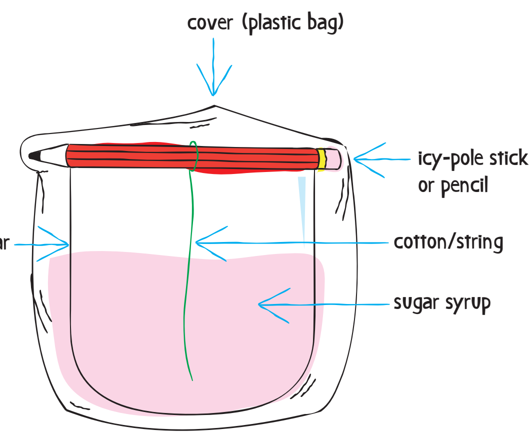
Yes

Collect this ...

- sugar (sucrose)
- water
- clean glass jar
- clean cotton or string
- pencil or icy-pole stick
- food colouring (optional)
- flavouring (optional)
- metal saucepan
- stove

Do this ...

1. Pour 3 cups of sugar and 1 cup of water into the saucepan.
2. Heat, stirring constantly, until all the sugar has dissolved. Try not to boil the solution. A few drops of food colouring and ½ teaspoon of flavouring can be added, but this may slow your crystal formation.
3. Cool the sugar syrup in the refrigerator until it is about room temperature.
4. Soak the string in the syrup and then hang it to dry in the air.
5. Set up your equipment as shown in the diagram.



6. You can eat the candy after the week. Don't eat the string.

Record this ...

Describe what happened.
Explain why you think this happened.

Evaporation

After swimming in the sea, the water on your skin evaporates, leaving tiny crystals of salt behind. **Evaporation** is the process in which heat causes a liquid to change into a gas. This leaves behind any solutes that were dissolved in the liquid. Salt is a solute in sea water, and is left behind after the water evaporates.

Evaporation is a natural process that dries up pools of water on the road and clothes on a line. Evaporation is also used in the laboratory to separate a solvent from its solute. However, the solvent is lost to the atmosphere. This means that you only collect the solute. The solute often forms crystals in a process called **crystallisation**. In Figure 4.3.2 you can see some crystals of caffeine, a chemical in coffee and tea.

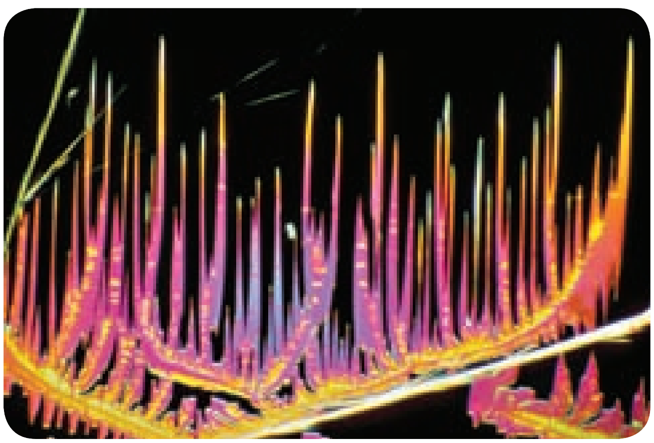


Figure 4.3.2 When the solvent evaporates, the solute can form crystals. These crystals are caffeine.

Evaporation is also used in industry. Salt producers make salt by using the heat from the Sun to evaporate water from pools of salt water. This leaves crystals of salt behind to be collected. Evaporation is used in cooking to concentrate the flavours in sauces.

Liquids do not have to boil to evaporate. This is because liquids evaporate at all temperatures above their freezing point. For example, although water boils at 100°C, it evaporates at all temperatures above 0°C. In the science laboratory, evaporation can be sped up by heating the mixture over a Bunsen burner or hotplate. The solvent will evaporate more slowly if left in the air and the heat of the room.

1 p145

Distillation

Evaporation is the process in which a liquid turns into a gas. Condensation is the opposite: a gas cools to form a liquid. **Distillation** uses both evaporation and condensation to separate substances.

Evaporation loses the liquid solvent to the atmosphere, but sometimes you need to keep the liquid as well. In distillation, the gas is condensed back into a liquid so that it can be collected. If the solvent is water, distillation first evaporates off the water. It then cools the water vapour so that it condenses back into liquid water. The apparatus that converts the gas back to the liquid is called the condenser. Figure 4.3.3 shows a special apparatus called a Liebig condenser that is often used in the laboratory.

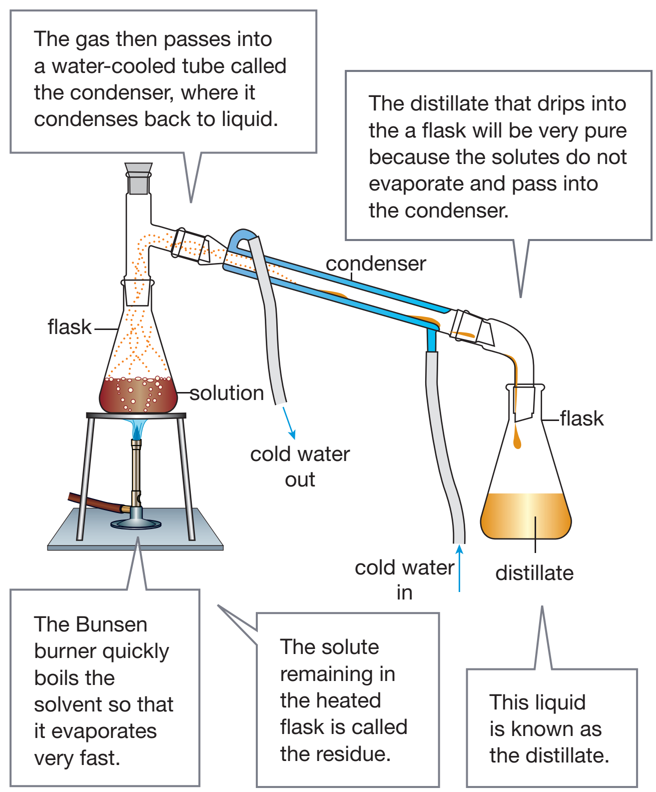


Figure 4.3.3 Distillation using a Liebig condenser is often carried out in the laboratory.

Distillation is able to separate several liquids from each other if they have different boiling points. For example, alcohol has a boiling point of 78°C while water boils at 100°C. These two liquids can therefore be separated by distillation. All the alcohol will evaporate off from the mixture first (at 78°C), leaving the water behind. The water will then evaporate off at 100°C, leaving behind whatever solute was dissolved in it.

As well as separating solutions in laboratories, distillation is used in:

- producing alcoholic drinks such as vodka and bourbon
- separating crude oil into petrol, diesel, lubricating oils and other components
- removing impurities from drinking water
- separating oxygen, nitrogen and argon from air for industrial use.

2 p146

4.5

Adsorption

Adsorption uses substances such as carbon to separate chemicals from water and air.

In adsorption, the chemicals being removed stick to the outside surface of another substance. If this substance has a huge surface area, it means a large amount of material can be adsorbed. Activated carbon has many small spaces in it and so has a huge surface area.

Adsorption is used to purify air and water. It is used where there are dangerous gases around, such as in fires, mine shafts and industrial spills. The workers wear protective masks with filters that can adsorb the gases. Figure 4.3.4 shows a filter from a mask that uses this idea.

Adsorption is sometimes used in human and veterinary medicine when poisonous chemicals have been swallowed. Carbon tablets (like the ones shown in Figure 4.3.5) can be swallowed to adsorb certain poisons—the tablet passes out in the faeces, taking the poison with it.

Figure 4.3.5 Carbon tablets can be used for adsorption of certain poisons.

SciFile
No more smelly farts

If your dog has smelly farts, then your vet might suggest you could use carbon tablets to adsorb the odour. The tablet adsorbs the smelly gases in the dog's intestines, and passes out in the faeces because it is not digested. Humans can take similar tablets to try to control 'traveller's diarrhoea'.

Figure 4.3.4 This face mask has a carbon filter for adsorbing gases.

4.6

4.3 Unit review

Remembering

1 **Recall** methods of separating mixtures by matching each method with its correct description. Choose from A, B, C or D.

- a chromatography
- b adsorption
- c evaporation
- d distillation
- A A method that uses substances with a large surface area to remove chemicals from water and air
- B A process using evaporation and condensation to separate and recover both solute and solvent
- C A process that can separate a mixture by making it move through another substance like a paper strip
- D A process in which heat changes a liquid into a gas, allowing recovery of a solute but not the solvent

2 From the examples in this unit, **name** the separation process used to:

- a separate different coloured substances from food colouring or ink
- b collect salt crystals from seawater
- c make alcoholic drinks like bourbon and whisky
- d remove poisonous substances from the stomach contents of a dog.

Understanding

3 **Explain** the process by which chromatography can separate substances.

4 **Explain** the process by which distillation can separate a solute and a solvent and allow you to recover both substances.

5 You are making copper sulfate crystals in the laboratory by evaporating water from a solution of copper sulfate. **Describe** how you could:

- a make the crystals rapidly
- b form bigger crystals by evaporating the water slowly.

6 **Explain** how a face mask can protect workers in a mineshaft by removing dangerous gases from the air.

Applying

7 **Identify** a separation method that could be used for each of the following purposes.

- a To test whether a particular ink is a mixture of colours
- b To purify water from a washing machine enough to drink it
- c To recover the sugar from a bag that you accidentally dropped into a saucepan of water while you were cooking
- d To remove smells from the air inside a car using the air-conditioning system

Analysing

8 If you are lost in the bush and have no drinking water, you can make a 'bush still' to try to collect some.

- a **Compare** the 'bush still' shown in Figure 4.3.6 with a distillation apparatus.
- b **Explain** how it can be considered an example of distillation.

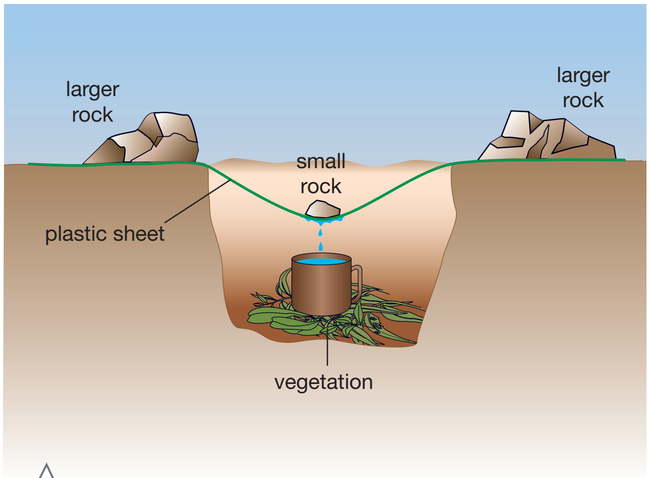


Figure 4.3.6

9 **Compare** evaporation of water and boiling of water.

4.3 Unit review

Evaluating

10 A whisky maker wants to reduce the amount of water in a mixture to give a higher concentration of alcohol. **Justify** the choice of distillation rather than evaporation as a separation method. Note that alcohol boils at 78°C and water boils at 100°C.

11 You can buy inserts for your shoes to get rid of the smell from your feet. **Propose** a way in which they may work, including a likely substance that may be used in the insert.

12 When your dry your bathers after swimming in the sea, they are crisp with salt. However, if you rinse them in fresh water first, they dry clean and salt-free. **Propose** why the two methods of drying produce such different results.

Creating

13 **Construct** a card game of ten cards in which each card describes a different method of separation.

- Use no more than five lines.
- Do not use diagrams.
- Do not use the name of the method of separation or similar words.
- Write the separation method on the back so that someone else can check later what it was.

Inquiring

1 Design an investigation to determine which colours in Smarties or M&Ms are composed of only one coloured substance. Show your design to your teacher and ask if you can carry out your experiment.

2 Research and construct a flow diagram showing the process in:

- **a** collecting salt from commercial salt pans
- **b** making whisky or some other spirit
- **c** the cracking of crude oil in fractional distillation.

3 There is a cave in Chihuahua, Mexico, known as the Giant Cave of Crystals. It contains crystals 11 metres long, the largest crystals ever found. Research and identify the substance that formed the crystals, their shape, and the conditions that allowed such huge crystals to form.

4 Use chromatography to create a coloured butterfly from circular filter paper. You must end up with at least three colours in the butterfly's wings from only two colours added to the paper. Use a piece of filter paper, felt-tip pen or food colours, a Petri dish and water. Collect your equipment and carry out your experiment.

Figure 4.3.7 A forensic scientist inspects the pigments used in different black industrial dyes. Chromatography can produce rings like this or straight streaks of different pigments.

4.3 Practical activities

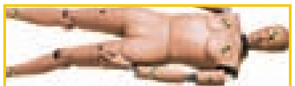
1 Fast and slow evaporation

Purpose

To grow copper sulfate crystals and compare their sizes when formed by fast and slow evaporation.

Materials

- two evaporating basins
- Bunsen burner, bench mat, tripod and gauze mat
- copper sulfate solution ($CuSO_4$)
- 100 mL beaker
- watch-glass



SAFETY!

Wear safety glasses at all times.

Tie long hair back.

Turn the Bunsen burner flame to yellow when it is not being used.

Allow equipment to cool before packing it away.

Procedure

1 Collect about 50 mL of copper sulfate solution in your beaker, and set up the equipment as shown in Figure 4.3.8. Do not turn on the Bunsen burner yet.

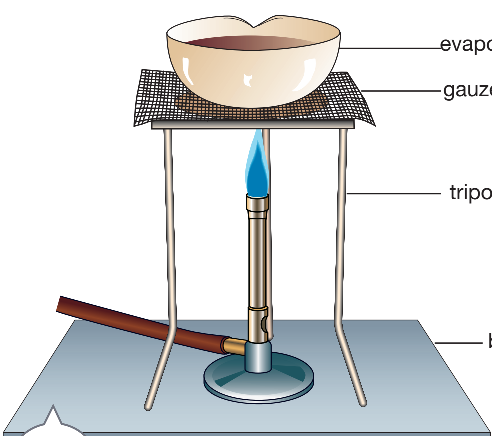


Figure 4.3.8

2 Pour copper sulfate solution into your evaporating basin until it is about half full.

3 Heat the solution with a hot flame with the Bunsen burner airhole about half open, watching carefully that material does not 'spit' out of the basin. If it does spit, close the collar on the Bunsen burner a little, or use the gas hose to move the Bunsen burner carefully in and out of the tripod.

4 When only a small pool of the liquid is left, turn the Bunsen burner off. The rest of the liquid will evaporate with the heat left in the basin.

5 Allow the basin to cool for several minutes.

6 While you are waiting, pour some copper sulfate into the watch-glass until it is about one-quarter full. Set it aside somewhere in the room where it will not be disturbed. Observe what happens over the next day or so.

Discussion

1 **Describe** the crystals formed by fast and slow evaporation.

2 **Use** the results from this prac to **explain** the formation of salt crystals around the edge of salt lakes.

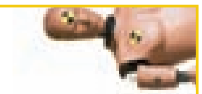
2 Distillation

Purpose

To use distillation to recover both copper sulfate and water from a solution.

Materials

- Bunsen burner, bench mat, tripod and gauze mat
- copper sulfate solution ($CuSO_4$)
- 100 mL beaker
- watch-glass
- test-tube holder
- 250 mL conical flask
- boiling beads
- 2 atomiser bottles



SAFETY!

Wear safety glasses at all times.

Tie long hair back.

Turn the Bunsen burner flame to yellow when it is not being used.

Allow equipment to cool before packing it away.

Procedure

1. Set up your equipment as shown in Figure 4.3.9. Add about 100 mL of copper sulfate solution to the conical flask. Heat the flask with the collar on the Bunsen burner three-quarters open.

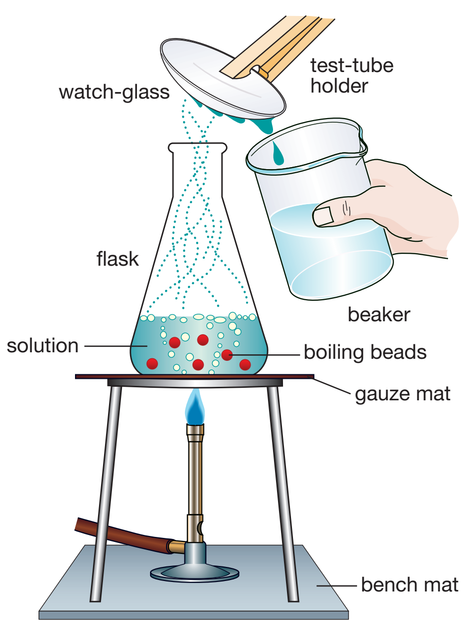


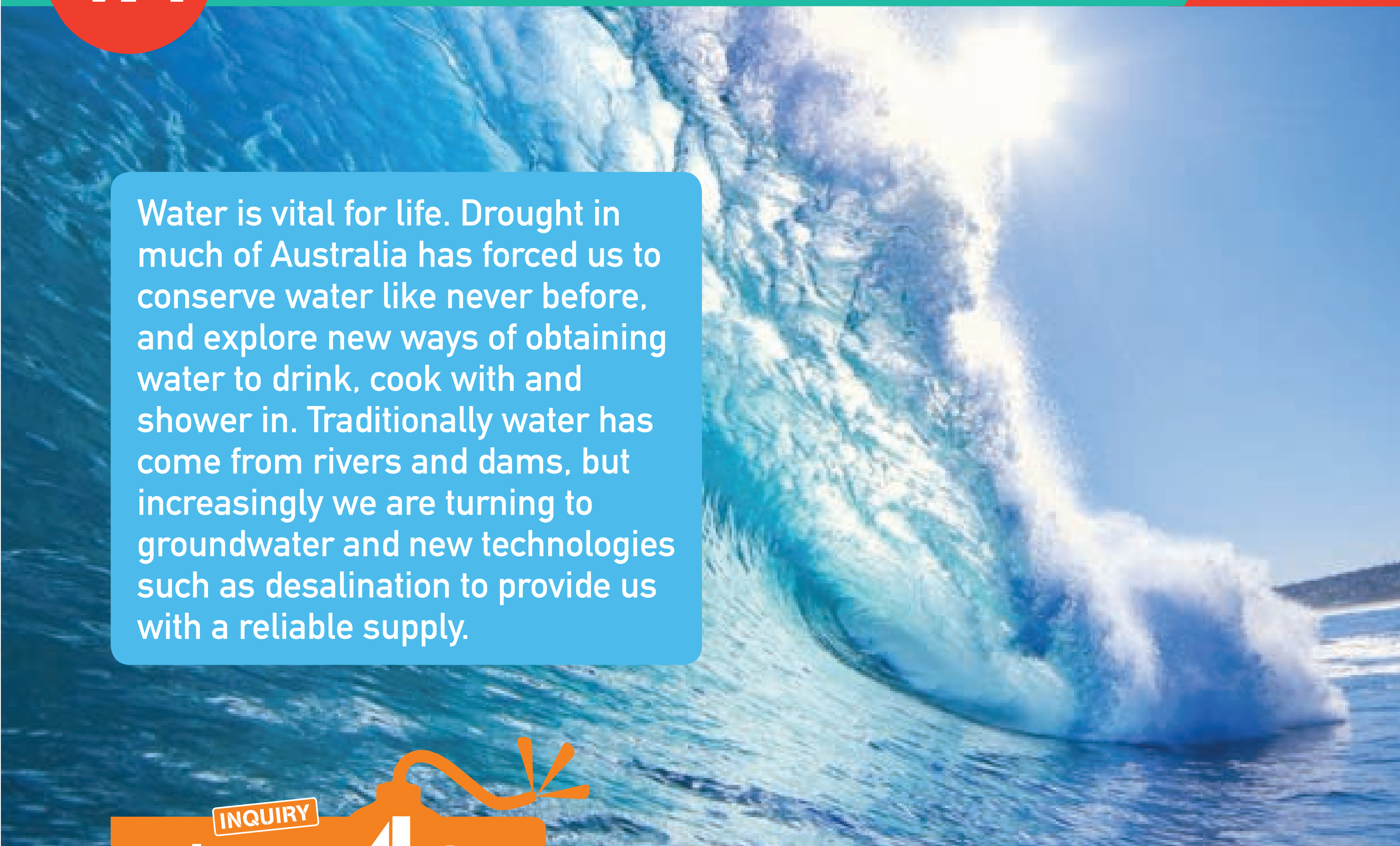
Figure 4.3.9

2. Using the test-tube holder, hold the watch-glass about 2–3 cm from the mouth of the flask. Hold the beaker below the edge of the watch-glass to collect the water that condenses on the watch-glass.
3. Stop heating when you have about 50 mL of liquid left in your conical flask (about half the original amount). You are not going to try to crystallise the copper sulfate.
4. Pour some unheated copper sulfate solution (not the mixture you heated because it will be hot) into an atomiser bottle. When the distillate is cool, pour it into another atomiser bottle.
5. Squirt a little of the copper sulfate solution from the atomiser bottle into the flame of a Bunsen burner. Note the colour of the flame. If there is any copper in the liquid, you should see a greenish flame colour.
6. Squirt a little of the distillate in the atomiser bottle into the flame. Note the colour of the flame.

Discussion

1. **Describe** the amount and appearance of the distillate you collected in the beaker.
2. **Explain** what the flame colour showed when you squirted some of the contents of the atomiser bottles into the flame.
3. **Explain** how this experiment demonstrates that pure water can be collected by distillation.

4.4 Purifying water



Water is vital for life. Drought in much of Australia has forced us to conserve water like never before, and explore new ways of obtaining water to drink, cook with and shower in. Traditionally water has come from rivers and dams, but increasingly we are turning to groundwater and new technologies such as desalination to provide us with a reliable supply.

INQUIRY science 4 fun

Cleaning water

Can dirt clean water?

Yes

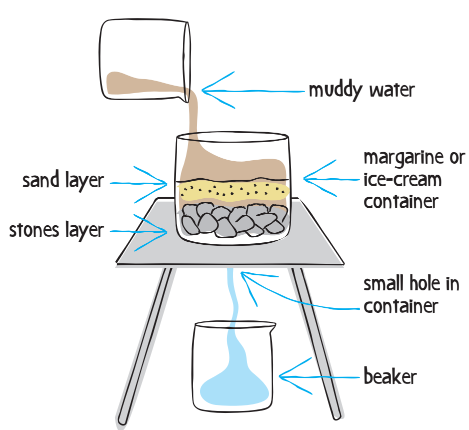
Collect this …

- ice-cream or margarine container
- large plastic bottle or similar container that you can cut a hole in the bottom of
- some fairly clean sand
- some small stones like blue metal or road gravel
- bucket of muddy water
- some bricks or rocks for a stand
- container to catch liquid

Do this …

1 Set up your equipment as shown.

2 Pour some muddy water in and let it pass through into the container at the bottom. Put this sample aside.



3 Repeat pouring the muddy water through until the sample you collect at the bottom has little suspended mud in it.

Record this …

Describe what happened.

Explain why you think this happened.

Is water pure or a mixture?

The term *water* means different things to different people. To scientists, water is a pure chemical with the chemical formula H_2O. However, to the rest of the community, water is what comes out of a tap and is what is found in rivers, lakes, swimming pools and the sea.

Most water is not pure but is a mixture of H_2O and other chemicals. For example, seawater is H_2O but also has dissolved salt (forming a salt solution), sand floating around in it (forming a suspension), and organisms from microscopic bacteria to seaweed and fish. Seawater also has dissolved oxygen in it, which is used by all the organisms that live there.

Water in rivers and lakes has dissolved oxygen, fish, yabbies and bacteria and possibly particles of dirt (forming a muddy suspension). Swimming pools contain dissolved chlorine or other treatment chemicals.

Tap water is a mixture of many substances. Some of these enter the water naturally through contact with soil and rock. Others are added deliberately by water authorities to protect public health. So what is in your water depends on the source of the water, and how it was treated. Water filters like the one shown in Figure 4.4.1 can be used to remove impurities in areas where this is a problem.

Figure 4.4.1 Some people use filters to clean their water of impurities.

SciFile

Water world

98% of the world's water is salt water in the oceans. 77% of all fresh water is ice in Antarctica.

Water sources

Many of the major water sources for Australia's towns are lakes, rivers (such as the one shown in Figure 4.4.2) and water from below the ground.

Figure 4.4.2 The Murray–Darling is Australia's largest river system, with a combined length of about 3700 km. Most of its water is used for irrigation. Adelaide uses some of the remainder for drinking water.

Dams and lakes

Water from a dam, lake or river may contain many substances. Most of these come from the rocks and soil that the rivers pass over and that form the base of the dam or lake. These include:

- metals such as magnesium, calcium, iron, copper and zinc
- chemicals such as chloride, fluoride, carbonate and nitrate
- solid soil particles such as clay, minerals and sand
- living organisms such as microscopic bacteria and algae, and larger water snails, crustaceans such as yabbies, and fish
- rubbish washed down gutters
- toxic chemicals and pollutants from factories and drains.

Groundwater

Water from below the ground is known as groundwater. This comes from rainfall that has soaked into the ground and built up deep in the soil. It can also build up in some types of rocks that allow water to soak into them. These rock layers are known as aquifers. Other rock layers act like a raincoat, preventing water entering them. The 'waterproof' rocks are known as impervious rocks. Aquifers can be deep underground, between layers of impervious rock. The water they contain is then known as artesian water.

The top layer of water in the soil is called the **water table**. Where the water table reaches the surface it becomes a lake or river.

Groundwater is reached by drilling a bore, as shown in Figure 4.4.3.

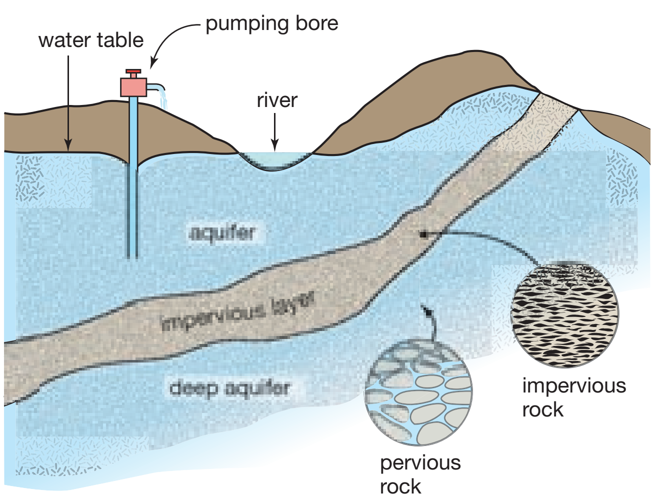


Figure 4.4.3 Aquifers have rock layers containing water.

Groundwater often has a fairly high salt content. The salt is mainly sodium chloride, the kind of salt put onto food, but there are other salts such as magnesium chloride. There may be high levels of metals and many other substances. There may also be fine rock particles like clay.

All these substances need to be removed to make the water suitable to drink or to use in cooking. Corrosion and rusting of washing machines and hot water systems is increased by high levels of dissolved substances in water, often causing them to burst. Clay and other sediments can also block pipes and clog motors.

Desalination

Natural water sources such as dams and groundwater may not be able to supply all of Australia's needs in the future. This is because the water in them comes from rainfall, and rainfall is declining in many parts of the country. Another source of drinking water is salt water, such as seawater or water from salt lakes or salty rivers. Before we can drink this, the salt must be removed. Desalination is the process of removing salts such as sodium chloride from the water.

Desalination can be achieved by distillation, but this process is expensive and so is rarely used on a large scale. A newer method is reverse osmosis, a process using filtration. Salt water is placed under high pressure, which forces it through a very fine membrane. The membrane has microscopically small holes that only the water particles pass through. The salt is left behind. In this way the salt is separated from the water. Reverse osmosis is shown in Figure 4.4.4. Membranes in use are shown in Figure 4.4.5.

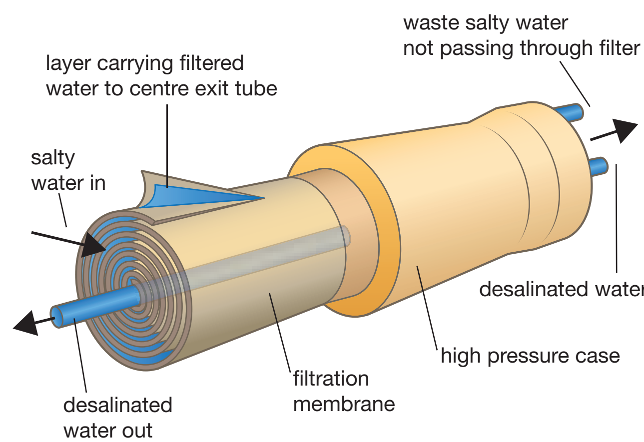


Figure 4.4.4 Reverse osmosis uses a very fine membrane as a filter.

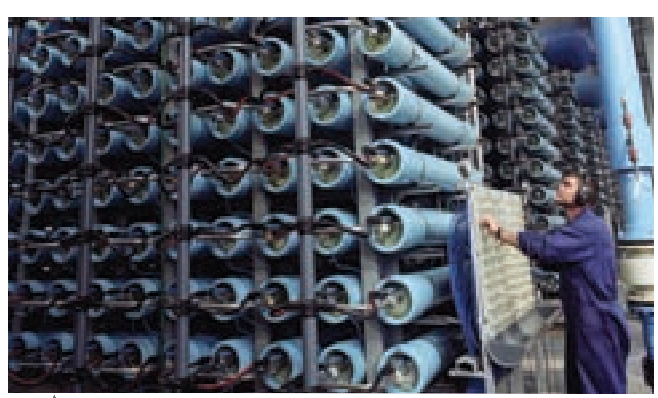


Figure 4.4.5 A membrane array similar to this is used in the desalination plant at Kwinana, Western Australia.

Water treatment

Water fit to drink is called **potable water**, while water unfit to drink is known as non-potable. Water from dams and groundwater goes to a treatment plant before it is supplied as potable water to homes and businesses.

The stages of water treatment are:

- flocculation to separate the fine solid particles like clay out of the water. Chemicals called flocculants are added to make the tiny clay particles clump together. These clumps either float and are skimmed off, or sink to the bottom so the water can be drained off
- filtration—the water is pumped through filters to remove any remaining particles
- sterilisation by adding chlorine to kill micro-organisms like bacteria
- balancing pH—pH level is a measure of acidity, and is adjusted so the water is not acid or alkaline
- fluoridation—fluoride is added to reduce the chance of tooth decay.

1 p156

Sewage and recycled water

Recycling means using something again. Our main source of recycled water is **sewage**, which is wastewater from places like kitchens, bathrooms, toilets and laundries. The recycled water in Australia is not used for drinking, but can be used for watering crops and gardens.

Australian cities are mostly connected to the deep **sewerage** system. This system is a series of underground pipes that carry the sewage away to a waste treatment plant. The treatment plants are to make the water safe to use in irrigation of crops and gardens, and also safe to pump into the ocean or ground. A typical sewage treatment plant connected to deep sewerage is shown in Figure 4.4.6.

The steps in treating sewage are:

- screening—passing the sewage through a sieve to remove large solids
- aeration—air is pumped through the sewage, which helps bacteria in the tank break down some of the smaller solid material
- settling—the liquid flows into a settling tank, where smaller particles like sand sink to the bottom to form a thick liquid with suspended solids called sludge
- filtration—the sludge is removed, and the remaining liquid is placed into tanks containing coarse rocks which act as a filter to remove the fine solids
- sterilisation—the bacteria in the liquid are killed by chemicals or ultraviolet light
- output—liquid is pumped out into the ocean or used on irrigation in agriculture.

Water treatment for potable water appears to be similar to this wastewater treatment. The main difference is water from dams for potable use is cleaned to a higher level of purity.

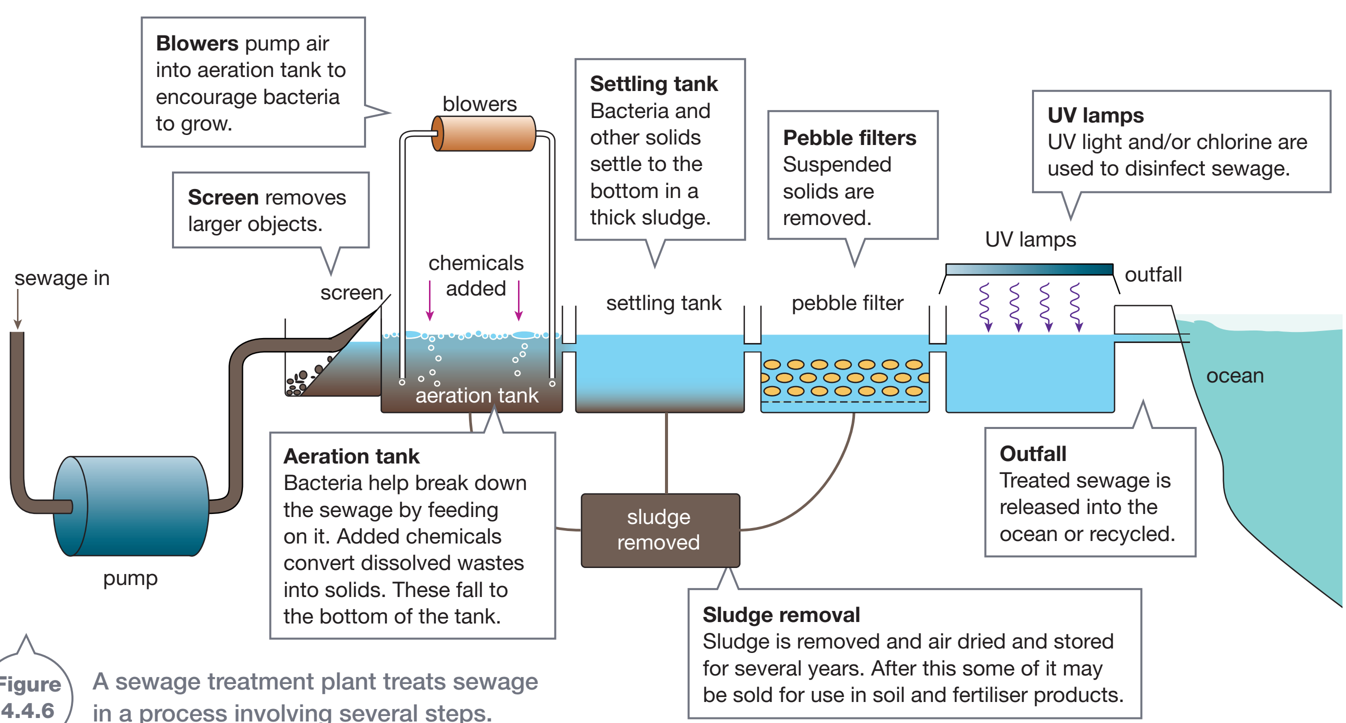


Figure 4.4.6 A sewage treatment plant treats sewage in a process involving several steps.

An alternative sewage treatment system, mainly for individual homes and buildings, uses septic tanks. These are like big concrete wells, and are usually underground in the back yard. They let the solids decompose and make the water safe to seep away into the groundwater or water table.

Septic tanks have a structure like that shown in Figure 4.4.7. The tanks are a sealed concrete unit, but the leach drains or soak wells have an open bottom. The soak wells also have open sides. The solids remain in the tanks, where they are decomposed slowly by bacteria living in the tank. The water (effluent) runs out of the tank into the leach drains or soak wells. Then it passes slowly through soil, where micro-organisms decompose impurities in the water and the sand filters out smaller particles. The water slowly soaks through to the water table and is carried away. Occasionally septic tanks have to be pumped out because the solids have built up and completely fill the tanks.

2 p156

SciFile

In the poo

Septic tanks have to be emptied out from time to time when the solids build up too much. Trucks with long hoses and pumps are used. The hose is pushed into an inspection hole at the top of the tank. However, occasionally the worker has to take the lid off the tank to clear blockages. You need a strong stomach and an ability to cope with bad smells in that job.

Protecting our water

All of us can do a lot to reduce the burden on water treatment plants and on our environment. Reducing how much water we use will obviously help. But another way to help is to avoid putting the wrong things into a toilet or sink. For example:

- Don't throw solids or liquids such as medicines or cotton buds down the sink. Put these in the bin.
- Reduce how much oil, fats or food scraps are washed down the sink. One way is to wipe pots and pans with a paper towel first, before washing up. The paper can be put it in the bin, along with the food scraps.
- Use less detergent. Most people use much more than the manufacturer recommends. Choose detergents that are phosphate-free and nitrate-free, as these substances contribute to algal blooms, which can produce toxic chemicals.
- Don't put paints and pesticides in the drains. They can damage your pipes and damage the environment. Water-based paints cause less damage than oil-based paints. Wipe paint brushes on newspaper and throw the paper in the bin.

Heavy rain will wash any rubbish that you drop on the streets into the gutters and eventually into the rivers, lakes and bays.

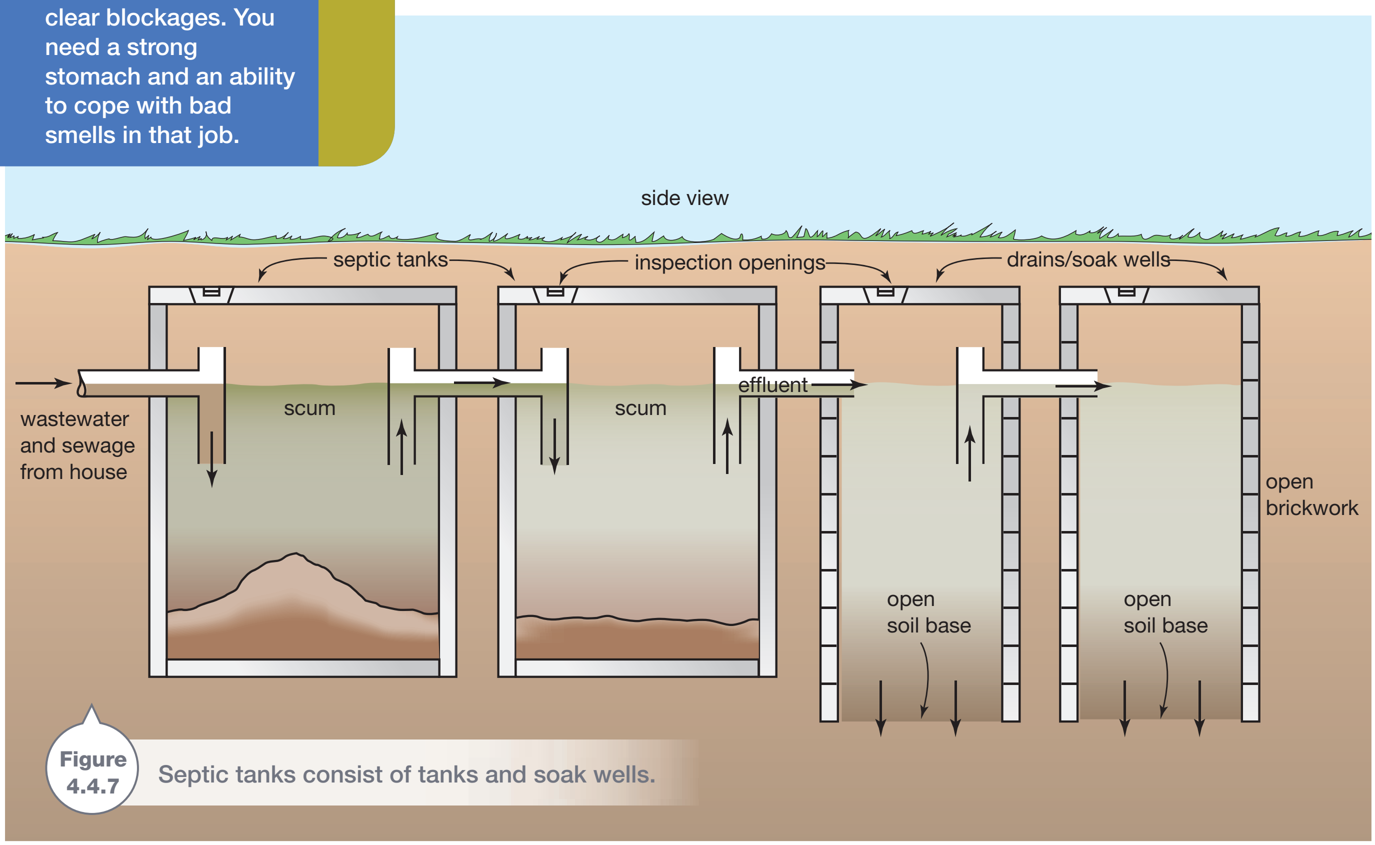


Figure 4.4.7 Septic tanks consist of tanks and soak wells.

SCIENCE AS A HUMAN ENDEAVOUR

Use and influence of science

Drinking recycled sewage

Tasting a bottle of recycled water

Figure 4.4.8

ENDEAVOUR

At present in Australia, recycled sewage water is only used for irrigation of crops and public parks. However, the Australian government has stated that it is almost certain that we will soon use recycled sewage for drinking water.

Why is it being considered?

Australia is the driest inhabited continent. With regular droughts and an increasing population we simply do not have enough water readily available to meet the demand. This is why water authorities are trying to find alternative water supplies and looking for ways to reduce water usage. At present water usage is increasing rather than decreasing.

Figure 4.4.9

Parts of Australia are very dry. Recycling sewage is a possible solution to our shortage of water.

Should we use it?

The proposals have caused a lot of debate. For example, Toowoomba residents in south-east Queensland rejected the proposal to recycle their wastewater. One reason against using it is the 'yuk factor'. This means people don't like the thought of drinking water that came out of someone else's toilet bowl. However, tests have shown that people cannot taste the difference between tap water, bottled water and recycled water.

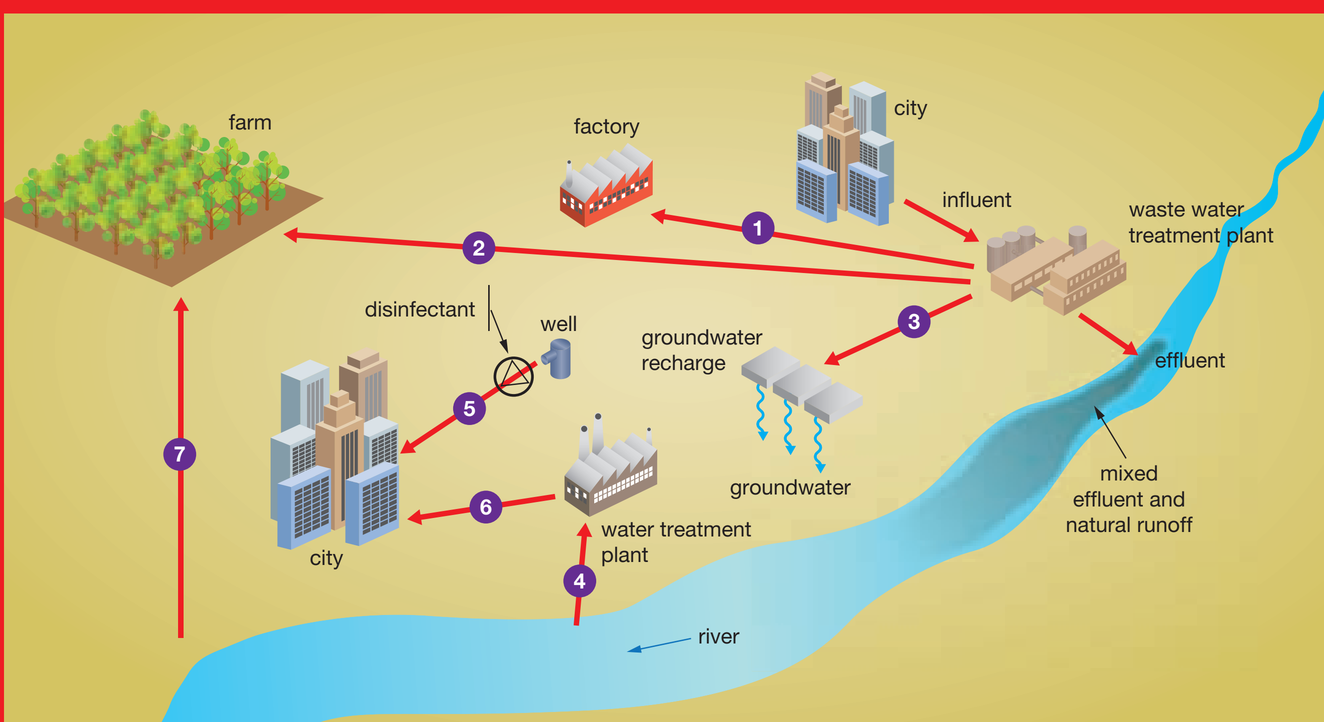
Water authorities in Australia believe that there is no scientific or health reason against recycling wastewater for drinking. This is based on the conclusions of much scientific research. Recycled wastewater is successfully used to top up drinking water supplies in the United States, Singapore and Namibia.

How would it be done?

Some methods of recycling wastewater are shown in Figure 4.4.10. The main proposal at present is that Australia should adopt indirect potable re-use. This means first sending wastewater to a water treatment plant. There it is highly treated to make it safe. The highly treated water is then pumped back into an existing drinking water source such as a reservoir, river or aquifer. The reservoir or aquifer helps treat the water by natural processes going on there, such as filtration by soil particles and decomposition by bacteria. Then, when the water is needed, it is pumped out of the reservoir to another water treatment plant just as at present.

Reverse osmosis is one of the processes that can be used for recycling sewage. In Toowoomba, for example, the wastewater would have been treated using filtration, reverse osmosis, ultraviolet disinfection and oxidation processes to destroy micro-organisms. Reverse osmosis is already used around the world to provide water for industry, as well as drinking water on ships, and there are plans to use it on spaceships.

4.7



1 Direct industrial reuse
2 Direct agricultural reuse
3 Groundwater recharge
4 Indirect potable reuse from river
5 Indirect potable reuse from well
6 Potable water supply system
7 Indirect agricultural reuseable reuse from river

Figure 4.4.10 Some possible methods of recycling wastewater

4.4 Unit review

Remembering

1 **List** some of the substances that are found in:
  a seawater
  b water from dams, lakes and rivers before it is treated.

2 **State** the origin of groundwater.

3 **List** the steps in water treatment before it can be used for potable water.

4 **List** the steps in sewage treatment before supplying water for irrigation.

Understanding

5 **Define** these terms.
  a potable
  b non-potable
  c flocculant
  d desalination

6 **Discuss** why use of groundwater has increased steadily in many areas of Australia in the last decade or so.

7 If the store of water in dams is decreasing, **explain** why we do not just use more groundwater to supply potable water.

8 **Describe** a desalination process that does not involve heating the water.

9 **Describe** how rubbish that you drop in the street eventually ends up in the ocean.

Applying

10 Consider Figure 4.4.6 on page 150 again, showing a sewage treatment plant. **Identify** all the separation methods used in this process.

Analysing

11 **Compare** the treatment of water from dams for potable water with that of wastewater for recycling and use in irrigation.

Evaluating

12 **Propose** a reason why camping and fishing are prohibited in areas near dams.

13 Your sinks at home have an 'S' bend in the water pipes below the drain hole, as shown in Figure 4.4.11. The bend keeps some water trapped in it. When you flush the sink the trapped water is pushed out and replaced by new water. You have a similar water trap in your toilet. **Propose** some reasons why a water trap is needed in sinks.

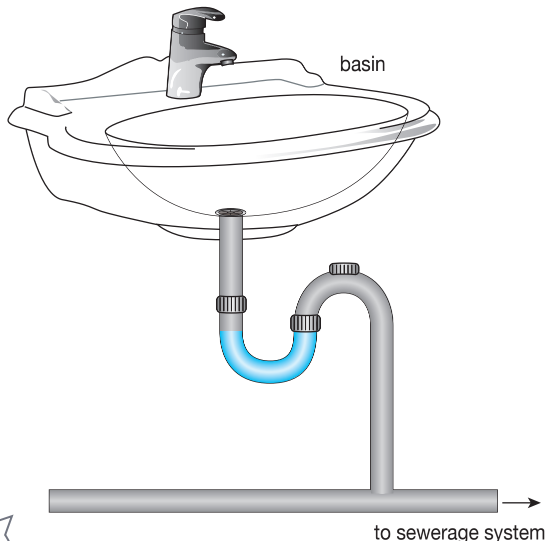


Figure 4.4.11

14 a **Propose** reasons why it's not recommended to put disinfectants or bleach down the sink if you have a septic tank.
  b **Propose** reasons why septic tank owners should not tip paint down the sink.
  c **Propose** reasons why septic tank owners should not put plastic materials down the sink.

Creating

15 **Design** a water purifier for a house using soil filtration. This device should enable you to recycle your washing machine water ('grey water') for use in the toilet. The water will be pumped from the soil filter to a tank that is then connected to your bathroom taps by pipes.

Figure 4.4.12 This reservoir supplying Melbourne with water shows how low levels can become.

Inquiring

1 Find the water authority website from your nearest major city and find the latest data on the water levels in the dams.
   - a Report on whether the water storage is better this year than last year, and what the trend has been like for the last five years.
   - b Is the water corporation concerned about the levels in the dams this year?

2 Research how a typical flushing toilet works (no need to discuss how the mechanism in the cistern works), and compare it with a composting toilet. A diagram of each will improve your presentation. What is the environmental advantage of a composting toilet, and why do you think they are not more popular in Australian cities?

3 A scientist noticed that where muddy water from a river met the ocean, it became clear fairly quickly. One possible reason why it became clear is that the sediment settled because the river slowed down when it met the sea. The particles were then too heavy to stay suspended in the slow-moving water. However, experiments with muddy river water showed that the mud particles stayed suspended in the test-tube when the water was left to settle. An alternative explanation for the the muddy water becoming clear could be flocculation. Research why flocculation could explain what happens when muddy river water meets sea water.

4.8

4.4 Practical activities

1 Flocculation

Purpose

To compare different chemicals as possible flocculating agents.

Materials

- muddy water
- 2 × 100 mL beakers
- filter funnel
- filter paper
- filter stand
- 7 small test-tubes in rack
- test flocculants in dropper bottles:
  - potassium aluminium sulfate (alum)
  - aluminium sulfate
  - sodium carbonate
  - sodium hydrogen carbonate
  - sodium chloride
  - iron(II) sulfate
  - calcium chloride

Procedure

1. Filter the muddy water to remove large particles.
2. Use the filtrate to half-fill the seven test-tubes. Label each tube with a code so you know which flocculant you will add to it.
3. Add five drops of your first test flocculant to the first test-tube, the second to the second test-tube, and so on. Record your observation on each test-tube in a table.
4. Filter one of the clearest test-tubes and observe the filtrate and residue.

Discussion

1. **Identify** the test materials that appeared to be flocculants.
2. **Assess** whether there is any way of telling from this test which substance was the best flocculant.
3. **Explain** how this experiment is relevant to our lives.

2 Sewage treatment

Purpose

To design and build a model of a sewage treatment plant.

Your design should work in the laboratory to produce the cleanest possible water from a mixture of water, vegetable oil, mud, sand, gravel and paper.

Materials

- You will be supplied with a bucket containing the water, vegetable oil, mud, sand, gravel and paper.
- You must supply a list of the equipment you need to your teacher.

Procedure

1. Decide in your group what the essential features of a sewage treatment plant are.
2. Design a model of a sewage treatment plant. The method of separation should model the processes used at a real sewage treatment plant.
3. Show your design to your teacher and ask if you can try it.

Discussion

1. **Compare** your model with a real sewage treatment plant.
2. **Evaluate** the performance of your design.
3. **Discuss** the relevance of this practical activity to everyday life.

4 Chapter review

Remembering

1 **State** an example where each of the following devices may be used.

- a centrifuge
- b hydrocyclone
- c electrostatic separator
- d carbon filter
- e reverse osmosis plant
- f paper chromatography
- g Liebig condenser
- h eddy current separator
- i septic tank

Understanding

2 **Explain** how you could separate oil and water.

3 A student adds 10 grams of solid X to 100 mL of pure water, but only 1 gram dissolves.

- a Give some terms we could use to **describe** this solution.
- b **Calculate** the concentration of substance X.
- c **Calculate** how much X would settle on the bottom of the container.

4 a **Describe** the process of decantation.

- b **State** when you would use it.

5 You are given a mixture of salt and sand. **Explain** the separation methods you would use to recover both.

6 Imagine you were given a mixture containing salt, sand, iron filings and water. **Outline** a sequence of separation methods you would use to separate and recover all the substances.

7 Imagine you need to know if two coloured liquids are the same substance.

- a **Describe** a method you could use at home to try to find out.
- b **Explain** how you would decide if the two liquids are different.

Applying

8 You are analysing a solution containing a blue dye. You filter some of the solution through filter paper. There is no residue in the filter paper and the filtrate is blue. If you filter some of the solution through a fine carbon filter, the filtrate is colourless. If you then take this carbon filter and shake it in methylated spirits, the liquid turns blue. **Apply** your knowledge of separation techniques to **explain** what is probably happening.

Analysing

9 **Compare** solutions, suspensions and colloids.

Evaluating

10 The physical properties of a mixture influence the type of separation method used. Using examples, **justify** this statement.

11 If you add 20 grams of substance Z to 50 mL of water, only 5 grams dissolves.

- a **Calculate** how much of the solid Z on the bottom would dissolve if you added 50 mL more water to the container.
- b **Predict** what would happen to the amount of Z on the bottom if you heated the solution.

12 Which of the following would be the best way to dispose of 500 mL of cooking oil? **Justify** your answer.

- A Pour it down the sink.
- B Flush it down the toilet.
- C Mix it with detergent and put it in the sink.
- D Bury it in the garden.
- E Soak it into paper and put it in the bin.

13 If you whisk an egg white, after a while it starts to turn from a pale yellowish liquid into a light, fluffy white solid. This can be used in making meringue for a lemon meringue pie. **Explain** what type of mixture has probably been made.

Creating

14 **Design** an experiment that can determine the amount of dissolved solids in cool drink.

15 Refer to the following ten key terms to **construct** a visual summary of the information presented in this chapter.

mixture	solution	insoluble
filtration	gravity	distillation
evaporation	sewage	water treatment
water recycling		

4.9

Thinking scientifically

Q1 A mixture of salt, sand and iron filings is to be separated.

Salt can be dissolved in water but sand and iron filings cannot.

Iron filings are attracted to a magnet but salt and sand are not.

Joe used the following steps to separate the substances.

Step W Add water to dissolve the salt.

Step X Filter the mixture to remove the solids.

Step Y Evaporate the water away from the solution.

Step Z Use a magnet to remove the iron filings.

Which of the following shows the order in which Joe should carry out the steps to separate the salt, sand and iron filings successfully?

A W then X then Y then Z
B X then Y then Z then W
C Y then Z then W then X
D Z then W then X then Y

Q2 Jan tested how well certain substances dissolved in cold and hot water. Her results table is shown below.

Substance	Colour of substance	Did it dissolve in	
		Cold water?	Hot water?
E	white	no	no
F	yellow	no	no
G	white	no	yes
H	white	yes	yes
I	brown	yes	yes

Identify which pair of substances could be separated from each other by dissolving one of them in hot water and then filtering the one that didn't dissolve.

A H and I
B E and G
C G and I
D E and F

Q3 The following table shows four types of solutions and two possible examples of each. Only one pair of examples is correct. Which pair of examples is correct?

	Type of solution	Example 1	Example 2
A	Solid dissolved in a liquid	Grease dissolved in petrol	Oxygen dissolved in water
B	Liquid dissolved in another liquid	Oil dissolved in petrol	Sugar dissolved in water
C	Gas dissolved in a liquid	Oxygen gas dissolved in blood	Detergent dissolved in water
D	Gas dissolved in another gas	Oxygen gas dissolved in nitrogen gas	Water vapour dissolved in the air

Q4 Sand is a mixture of small rock fragments, minerals and remains of living things. The following table shows some of the substances in a sample of sand and their characteristics.

	Magnetic	Weight	Fragment size
Silica	No	Not heavy	Large
Coral and shell fragments	No	Not heavy	Large
Feldspar	No	Not heavy	Small
Magnetite	Yes	Very heavy	Small
Rutile	No	Very heavy	Small

Select the correct techniques and the order that would allow rutile to be separated from all other substances.

A Sieving then gravity separation
B Gravity separation then magnetic separation
C Gravity separation then sieving
D Sieving then magnetic separation

Glossary

Unit 4.1

Concentrated

Concentrated: there is a lot of solute in the solvent

Concentration: amount of solute dissolved in a solvent

Colloid: small particles dispersed in a liquid or gas

Dilute: when there is little solute in the solution

Dissolve

Dissolve: break up into tiny particles that are smaller than the eye can see

Emulsion: a mixture of small particles of one substance dispersed in another, but not dissolved in it

Insoluble: substance that does not dissolve in a particular solvent

Mixture: a substance made from two or more pure substances that have been stirred together and that can be separated to recover the original chemicals

Saturated: as much substance as possible is dissolved in a solvent

Soluble: able to be dissolved

Solute: a substance that dissolves to make a solution when we mix it into another substance

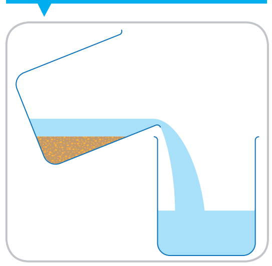
Solution: when a substance dissolves in another, forming a clear mixture

Solvent: a substance that dissolves another

Suspension: mixture in which a substance will not dissolve in another and quickly separates out if left to stand

Unit 4.2

Decantation

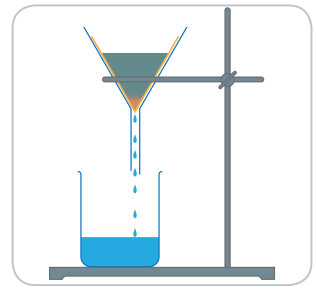


Centrifuge: device that spins very fast to separate solids from liquids, or liquids from other liquids

Decantation: separation by pouring liquid off the top of a mixture of solid in liquid, or liquid in liquid

Filter: screen or membrane used in filtration

Filtration



Filtration: separation of solids or liquids from a liquid or gas by using a barrier with holes smaller than particles being separated

Gravity separation: a method of separating two components from a suspension by using the force of gravity to separate heavier particles to the bottom

Unit 4.3

Adsorption: a method of separation where particles of liquid, solid or gas stick to the outside surface of a solid

Chromatography: a method of separating a mixture by making it move over or through another substance that stays still

Chromatography

Crystallisation: formation of crystals as a dissolved substance solidifies

Distillation: a process that uses evaporation and condensation to separate solids from liquids or liquids from liquids, enabling the recovery of both

Evaporation: a process that uses heat to make a liquid solvent change state to a gas, and leave behind the solute it had dissolved

Unit 4.4

Potable water: drinkable water

Sewage: wastewater from toilets, bathrooms, kitchens and laundries that may contain human waste and other organic chemicals or harmful chemicals

Sewerage: system of pipes underground that collects wastewater from homes and businesses and takes it to treatment plants

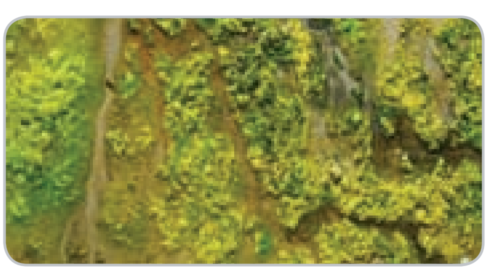
Water table: top layer of waste in the soil

Look who is using science

ENVIRONMENTAL SCIENTIST

My name is Adeline Morrissey and I am an environmental scientist working in the mining industry.

In my job I help mining companies to look after the environment. One of my jobs is to do water sampling to check whether the mine site is contaminating the groundwater. I study how well a company has restored the areas where they have mined. This involves studying the soil and plants. I assist with surveys of animals before companies mine areas to see what animals are present, such as rare species. I am regularly back in the city for report writing and data analysis after I do the field work. The sciences I studied at school and university that I use in my everyday job include chemistry, biology, soil science, plant science and animal sciences.



TAXONOMIST

My name is Dr Will White and I am a fish taxonomist with the CSIRO Marine and Atmospheric Research laboratories.

I work on applied taxonomy and biogeography of Indo-Pacific fishes, mostly sharks and rays. A large proportion of my work has involved field trips to Indonesia to look at the fisheries over there and I have discovered a large number of new species of sharks and rays during this work. I have been involved in the description of almost 50 new species of sharks and rays. I always had an interest in sharks and rays and have always enjoyed diving and underwater photography. Science has been a great way not only to learn new things but also to lead a varied work life with a large amount of travel.

SEWAGE QUALITY ENGINEER

My name is Brett Maurer and I am a sewage quality engineer working for City West Water.

Trade waste (waste released into the sewers from industry) can potentially contaminate and damage pipes and sewage treatment plants. It can also put our sewer workers at risk, particularly if it is releasing dangerous gases. I take samples of sewage and test them to determine what contaminants they contain and whether they meet the regulations for discharging into the sewer. I also collect samples from the space in the pipe above the flowing sewage to determine what gases are there. The information obtained also helps our business identify ways of treating and recycling industrial water and using biosolids—the nutrient-rich sludge that is generated from the treatment plant process. Water is essential for living and my work helps to ensure that supply meets the increasing demand of our increasing population.

Habitats and interactions

5

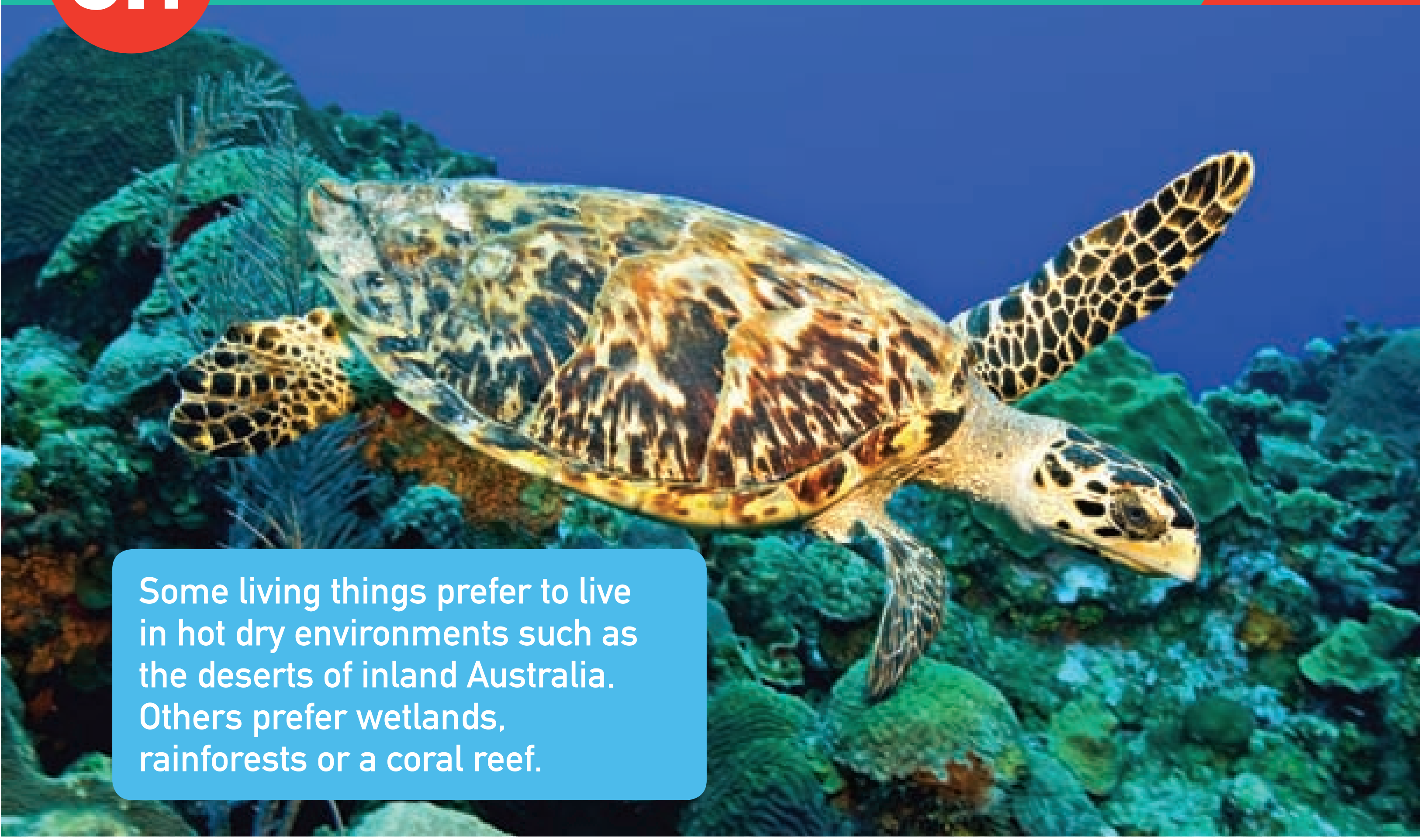
HAVE YOU EVER WONDERED . . .

- why there are different types of plants and animals?
- why different organisms live in different places?
- how human actions affect other living things?

After completing this chapter students should be able to:

- identify the living and non-living things that influence survival in ecosystems
- relate the characteristics of an organism to its survival in its natural habitat
- construct and interpret food chains and food webs to demonstrate relationships in an environment
- classify organisms of an environment according to their position in the food chain
- describe the role of microorganisms within food chains and food webs
- investigate the effect of human activity on local habitats
- explore how living things can cause changes to their environment and impact other living things
- research specific examples of human activity.

5.1 Living places


Some living things prefer to live in hot dry environments such as the deserts of inland Australia. Others prefer wetlands, rainforests or a coral reef.

Habitats

All living things (**organisms**) have a place where they live. This is called their **habitat**. The habitat of an organism is its address. For example, your habitat includes your home, school and perhaps your sporting club.

Habitats are very varied. Figure 5.1.1 shows a wetland—one example of a natural habitat.

Figure 5.1.1 The place where an organism lives is its habitat.

Every living thing has particular needs, and will live only where these needs are met by the resources available in the habitat. Some of the resources a habitat must provide for an organism to survive and reproduce include:

- food
- water
- shelter and living space
- a suitable temperature
- mating partners for reproduction
- gases such as oxygen.

For example, all the needs of the crocodile in Figure 5.1.2 are met by the resources in the river and the surrounding river banks.

Figure 5.1.2 The Australian freshwater crocodile is found in freshwater creeks and rivers of northern Australia, where it can find the birds, frogs and fish that it uses as food. The females need sandy riverbanks in which to dig nests and lay their eggs.

The needs of living things can be divided into two types:

- **biotic factors**. These are living factors that include partners for mating, organisms to eat, and organisms they may compete with for food and shelter.
- **abiotic factors**. These are non-living factors that include light, wind, soil and temperature.

The number of organisms of the same type, living in the same habitat, will vary over time depending on the availability of food, water, living space and mating partners.

1 p170

5.1

Adaptations

To survive in their habitat, organisms have adaptations. **Adaptations** are characteristics that assist organisms to survive and reproduce. Adaptations help organisms to get food and water, protect themselves, build homes and reproduce.

The position of the eyes and nostrils of the crocodile in Figure 5.1.2 are adaptations. They allow the crocodile to breathe air and look for prey when it is almost totally submerged in the water.

The spotted-tailed quoll shown in Figure 5.1.3 is a marsupial that lives in the wet and dry forests of eastern Australia, from Queensland to Tasmania. The quoll's colouring means that it is well camouflaged and can sleep in hollow trees and rock crevices without being seen by other animals that would hunt it for food. A quoll uses its sharp claws and teeth to catch rats, birds and reptiles but will also eat dead remains. Quolls are **nocturnal**, which means they are active and hunt at night. A quoll can see in dim light.

Figure 5.1.3 The spotted-tailed quoll is the largest meat-eating marsupial on Australia's mainland. It was one of the first Australian animals to be encountered by Europeans.

Native trees growing in some parts of Australia need to survive frequent fires. Some trees have buds buried deep within the trunk where they are protected from the heat of the fire. Normally these buds do not sprout. However, if a fire destroys most of the leaves on the tree, these buds grow and quickly cover the tree with new leaves, as shown in Figure 5.1.4.

Figure 5.1.4 After fire destroyed the leaves of this tree, buds hidden deep in the trunk grew and produced new leaves.

All plants need light if they are to survive. Plants use the energy from sunlight to help them make their food. Plants growing in dense rainforests often have adaptations such as hooks on stems and leaves, or long, thin threads called tendrils to help them climb over other plants to reach the sunlight. *Smilax* (shown in Figure 5.1.5) is a common plant in Australian forests. It sends out tendrils that coil around neighbouring branches.

Figure 5.1.5 Tendrils are adaptations that enable *Smilax* to climb over other plants to reach the light.

5.2

Adaptations enable animals to:

- protect themselves from predators (camouflage)
- survive hot and cold temperatures, and wet and dry seasons
- move from place to place (flippers, legs and wings)
- catch and eat food
- take in oxygen
- reproduce.

Adaptations enable plants to:

- protect themselves from grazing animals (spines and thorns)
- take in oxygen and carbon dioxide
- take in water (very long roots)
- capture light (large leaves)
- reproduce.

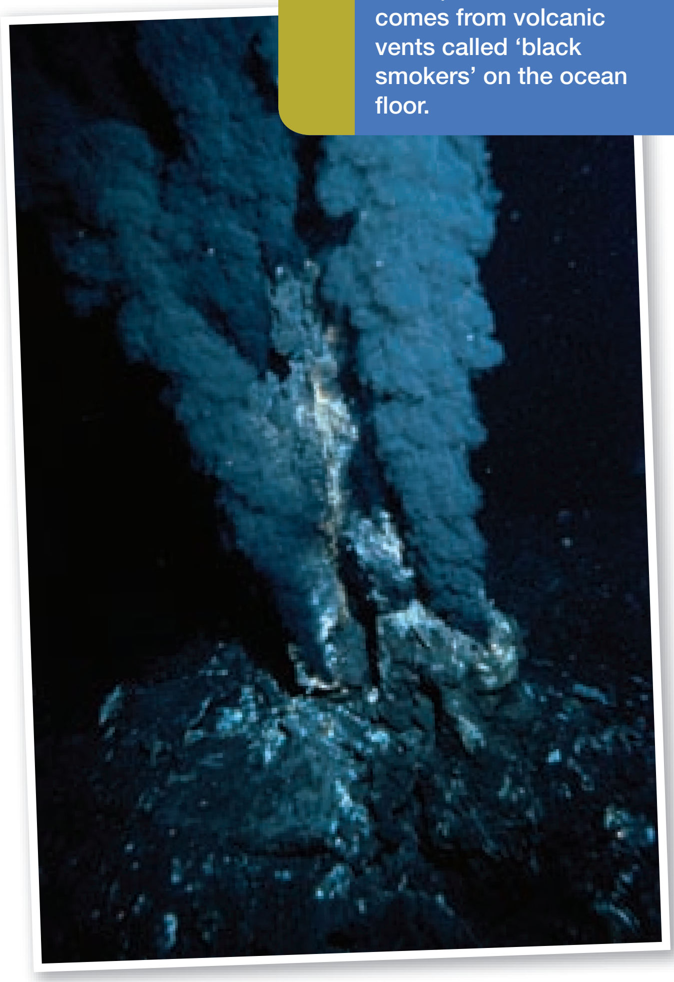
2 p171

5.3

SciFile

It's hot!

Living things can be found in even the harshest environments. A variety of bacteria have been found in superheated (up to 300°C) water that comes from volcanic vents called 'black smokers' on the ocean floor.



Where organisms live

Some organisms can live almost anywhere. They are able to find suitable habitats in a wide range of areas. For example, the red kangaroo shown in Figure 5.1.6 can be found in arid and semi-arid regions from the extreme north of the east coast, to the south-west of mainland Australia.

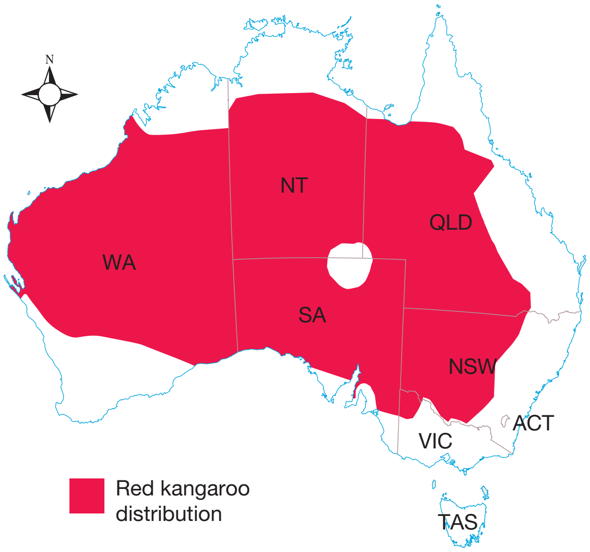


Figure 5.1.6 The red kangaroo lives in grassland, wooded areas and desert. Red kangaroos prefer open grassland with scattered trees that provide shade and shelter.

Other organisms live in very restricted areas. The mountain pygmy possum is a threatened Australian marsupial. It is adapted to habitats found only in mountains at a height of over 1400 metres. Figure 5.1.7 shows the extent of the habitat in which the mountain pygmy possum is found.

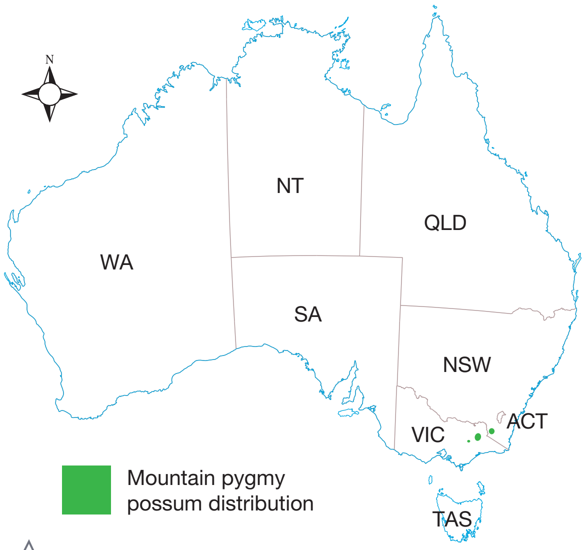


Figure 5.1.7 Spring and summer in the high mountains are short. During this time the mountain pygmy possum feeds on seeds and moths that are rich in fat. In winter the pygmy possum hibernates under the snow.

SciFile

Strong poison

Although poison-arrow frogs are very small (about two centimetres long) they produce a very powerful poison—less than a grain of salt can kill a human. Native hunters in South America use this poison on the tips of their arrows, which is how the frog got its name.

Environmental conditions

How well an organism survives depends on how well it is adapted to the environmental conditions in the area. The term **environment** is used to describe all the things that affect a plant or an animal in its habitat. Many factors may shape and change an environment, including:

- the temperature
- whether it is wet or dry
- whether it is windy
- the quality of the air
- the water quality
- the type of soil
- the plants, animals, bacteria and fungi that live there.

The study of the interactions between living things and their environment is called ecology. **Ecologists** are scientists who study these interactions.

Living together

The **biosphere** is the place where all life as we know it exists. The biosphere consists of the surface of the Earth and its atmosphere. The biosphere is made up of many ecosystems such as forests, wetlands or the coral reef shown in Figure 5.1.8.

Figure 5.1.8 A coral reef is a complex ecosystem with many different types of animals living together.

An **ecosystem** is a system formed by organisms interacting with each other and their non-living surroundings in a balanced way. In an ecosystem there are many habitats. The relationship between the biosphere, ecosystems and habitats is demonstrated in Figure 5.1.9.

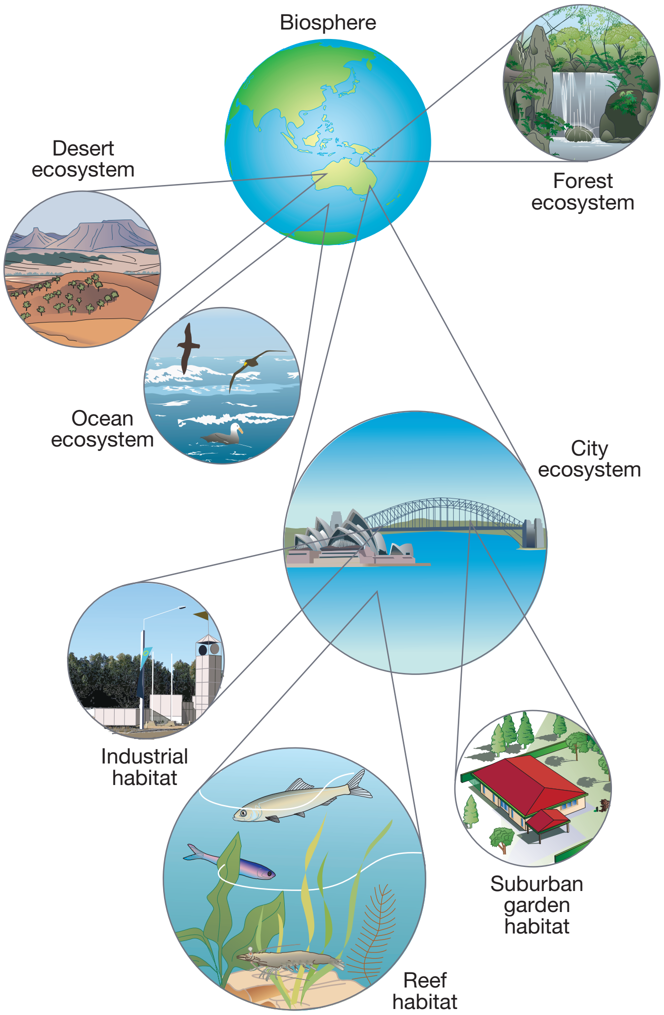


Figure 5.1.9 The relationship between the biosphere, ecosystems and habitats. In the biosphere there are many ecosystems. In an ecosystem there are many habitats.

SciFile

Epiphytes

Epiphytes are plants that grow on other plants. Epiphytes use host plants for support, but take nothing else from them. The epiphyte and the host plant are both able to make their own food; therefore an epiphyte is not a parasite. Some common epiphytes you may have heard of are bird's nest ferns and staghorn ferns, as well as some types of orchids.

The organisms in an ecosystem are interdependent. **Interdependent** organisms depend on each other for survival. There are three main types of interdependence or **symbiosis**.

1 **Commensalism:** This is an interaction between two organisms where only one of them benefits, but the other one is not affected. For example, on the Great Barrier Reef there are small colourful fish called clown fish, seen in Figure 5.1.10. They are not affected by stings from sea anemones. The clown fish lives in the tentacles of the sea anemone and is protected from predators. The clown fish also gets bits of food not eaten by the anemone.

Figure 5.1.10 A clown fish in the tentacles of a sea anemone

2 **Mutualism:** This is an interaction where both the organisms benefit from the relationship and neither is harmed. In many cases, neither organism can exist without the other. Figure 5.1.11 shows lichen growing on a rock. Lichen consists of a fungus and algae growing together. The algae makes its own food using energy from sunlight and the fungus uses this food. The fungus provides the algae with a protected place to live.

5.4

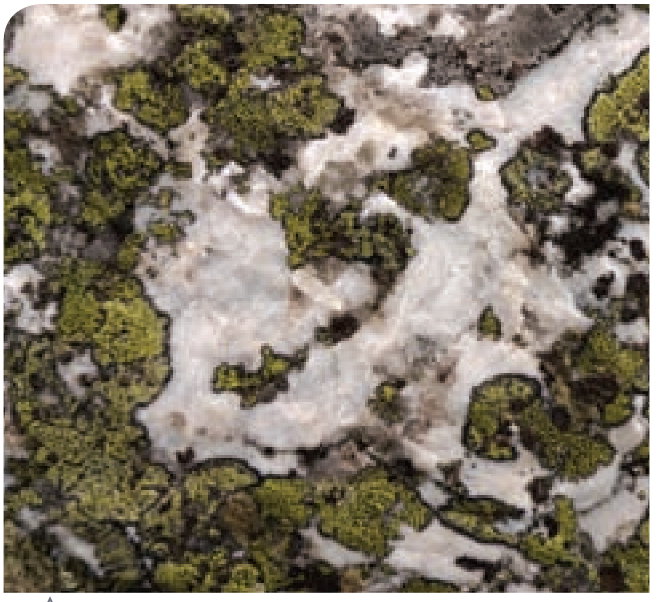


Figure 5.1.11 Lichen growing on a rock

3 **Parasitism:** This is an interaction where one type of organism (the **parasite**) lives on or in another type of organism (the **host**). The parasite obtains food and shelter from its host, but often harms or may even kill the host in return. Heartworm is a parasite that lives in the hearts of dogs. The worms breed rapidly and when present in large numbers can clog up the dog's heart. The worm uses the dog for shelter and food, but in the end the dog often dies. Figure 5.1.12 shows a dog's heart with a major infection of heartworm.

Figure 5.1.12 Heartworms infecting the heart of a dog

SCIENCE AS A HUMAN ENDEAVOUR

Use and influence of science

Tiny vampires

Figure 5.1.13 Leeches can take in several times their own weight in blood in one meal. They digest their meal slowly and may not need to feed again for many months.

After a walk in a damp forest, you may find that you have some small slugs on your legs. These small slugs are probably leeches, and they are sucking your blood. Leeches are parasites. Don't panic. They won't kill you and they are easily removed.

Leeches are common in wet areas along the east coast of Australia. Leeches can detect the warmth of your body and the vibrations caused by your movement. This is how leeches are able to find you. The head of the leech has suckers, which the leech uses for moving along and for sucking. Behind the suckers are jaws that act like little saws to pierce the skin. Australian leeches have only two jaws, but leeches in the rest of the world have three!

When people see a leech attached to their body they want to remove it as soon as possible. Dropping salt, salt water, vinegar or tea tree oil on the leech will cause it to drop off your skin. However, if you wait until the leech has finished feeding, it will drop off by itself—but this can take over half an hour. During this time the leech will expand to many times its original size.

You can prevent attack by leeches if you rub insect repellent over your legs, or wear long trousers tucked into thick socks, and high boots.

In the nineteenth century, bloodletting or bleeding was believed to be a cure for many illnesses. Leeches were commonly used to take blood from the patient. A wound from a leech bite will continue to bleed for up to 10 hours. The leech's saliva contains a chemical that prevents blood from clotting as quickly as normal. When the leech bites, this chemical passes into the body.

As medical science advanced, bloodletting or 'leeching' declined. However, doctors are now using leeches again. The leeches in Figure 5.1.14 are used to reduce swelling after surgery.

Leeches are used after microsurgery to reattach fingers, hands, toes, ears or noses that have been damaged in accidents. The tiny blood vessels in the damaged body part often become blocked as blood clots form within them. The chemical in the leech's saliva keeps the blood flowing through these tiny blood vessels. Leeches are also used during plastic surgery to prevent bruising. A chemical from their saliva is used in treating heart disease where blood clots are a problem. Researchers are continuing to investigate medicinal uses of other chemicals found in leech saliva.

Figure 5.1.14 Medical use of leeches

5.5

5.1 Unit review

Remembering

1 **Recall** an alternative name for a *living thing*.

2 **State** the meaning of the term *habitat*.

3 **List** the important things a habitat must provide so that organisms will be able to live there.

4 **Recall** the name for a scientist who studies the environment.

Understanding

5 **Explain** what an adaptation is.

6 **Explain** why some organisms are found over a very wide area, whereas others live in very restricted areas.

7 **Describe** possible causes of a change in the number and type of organisms living in an area.

8 **Outline** what scientists mean when they say that organisms are 'interdependent'.

Applying

9 **Use** examples to **describe** two types of symbiosis.

10 **Use** your understanding of adaptations to suggest why a particular type of organism cannot just move to another area if its habitat is destroyed.

Analysing

11 **Contrast** biotic and abiotic factors.

12 **Compare** the biosphere and an ecosystem.

13 **Classify** the following as commensalism, mutualism or parasitism. Give reasons for your answers that include a description of the benefit or harm to each of the organisms.
- a a leech sucking on the blood of humans and other mammals
- b a baby kangaroo attached to its mother's nipple
- c cleaner fish taking the parasites off the gills of large carnivorous fish
- d bees carrying pollen from one flower to another as they collect nectar
- e rainforest vines using hooks and tendrils to climb up large trees to reach the light

Evaluating

14 Complete the following table by **proposing** adaptations that an animal or a plant would need to live in each environment.

Environment that is very hot	Environment that is very cold	Environment that contains a large number of predators

15 In a tropical rainforest, very little light reaches the ground because of the dense canopy formed by the trees. Imagine that one very large tree falls down.
- a **Deduce** the changes in abiotic factors that would occur in the area of the forest where the tree fell.
- b **Propose** ways in which the changes would affect the plants and animals living in the immediate area.

Creating

16 Think about a koala living in the Australian bush. **Create** a concept map of the biotic and abiotic factors that would be in the koala's environment. Include any adaptations that the koala would need to survive in its environment.

17 **Create** a poster or electronic presentation outlining the features of commensalism, mutualism and parasitism. Include at least two new examples of each.

18 Work in a small group to **design** a coastal rockpool ecosystem. Attach a concept map showing how the organisms in the rockpool interact.

Inquiring

1 Parasites can affect the health of humans.
- a Identify a human parasite.
- b Describe how humans become infected with the parasite.
- c Describe the symptoms the parasite causes and the long-term effects on health.

5.1 Practical activities

1 What lives in your schoolyard?

Purpose

To investigate the small organisms that are living in various habitats of the school grounds.

Materials

- small paintbrush
- protective gloves
- magnifying glass
- sweep net
- 4 m of string
- 4 weights (stones will do)
- field guide
- large resealable plastic bags
- map of school grounds

SAFETY

Some stinging insects may be captured, so gloves should be worn by the person who has to hold the net and shake the animals into the plastic bag. If there are any animals still caught in the net, avoid contact. Use a paintbrush to remove them.

Procedure

1. Choose the location for your experiment. If possible, each group should choose a location with a different type of ground cover. Draw a sketch of your location, noting the types of plants and the ground conditions. Take photographs if you can.
2. At your location, measure a square area that has sides of one metre. Mark the area using the string and weights. This is the area that will be swept.
3. Practise making a 'figure 8' swing in such a way that the opening of the net is always first to sweep the area.
4. At your test site, go back and forward over the area using the 'figure 8' motion until you have swept the entire square metre area.
5. Hold the bag halfway up to make sure that the organisms do not escape.
6. While another student holds the resealable bag, place the net over it, loosen your hold and turn it inside out into the bag. Carefully shake and remove the net from the bag, being sure to seal it so that the organisms do not escape.
7. Observe the organisms through the resealable bag and try to identify them using your field guide. Count the numbers of each type of organism.
8. Release any organisms that you have found.

Results

1. Record the time and date of your experiment and describe the area in which you made your observations.
2. Construct a table showing the appearance and number of each type of organism at your site.
3. Record your results along with those of other members of your class on your map of the school grounds.
4. As a class, prepare a poster of what lives in the school grounds.

Discussion

1. **Compare** the numbers and different types of organisms caught at the various sites.
2. **Identify** the site that was the most successful in terms of the:
   a. number of organisms caught
   b. variety of organisms caught.
3. **Discuss** the differences between the sites that could cause these variations.
4. **Identify** any other factors that could have led to this result.
5. **Classify** the organisms into groups according to the environmental conditions each preferred. Examples include: dry or moist; long grass or short grass; sun or shade.
6. a. **Discuss** whether or not you would expect the same organisms in your sweep if you conducted this experiment at:
      i. different times of day
      ii. other times during the year.
   b. **Propose** reasons for any variation.
   c. **Describe** a way of testing your predictions.

2 Looking at earthworms

Purpose

To investigate how worms behave in their habitat.

Materials

- trowel
- gloves
- containers
- stereomicroscope or magnifying glass
- sheet of white paper or a white tile

SAFETY

Make sure that you are wearing gloves and that you don't directly inhale any dust. It is important that the worms are treated with care and are not harmed during your investigation. Take care to look after them and then return them to where you collected them, once you have finished.

Procedure

1. Dig for worms in the garden. Choose a place where the soil is moist.
2. Place the worms in a container with some loose soil. Keep the worms moist at all times and make sure they don't escape.
3. In the classroom, gently place one of the worms on the white paper.
4. Look at the earthworm through a stereomicroscope. Make notes about its appearance. Sketch what you see.
5. Observe the way the worm moves.
6. Use the stereomicroscope or magnifying glass to look carefully at the underside of the worm close to its head.
7. Run your finger very gently from the back to the front of the worm's underside.
8. When you have finished, return the earthworm to a natural habitat under some leaves in a moist, shady location.

Discussion

1. **Describe** the shape of the worm and how this helps it move through the soil.
2. a **Describe** how the shape of the worm changed as it moved.
   b **Explain** how the change in shape helps the worm move forward.
   c **Propose** what was happening inside the worm to cause these changes in shape.
3. a **Describe** what you felt and/or saw on the underside of the worm.
   b **Propose** how this feature could help the worm move.
   c **Deduce** why it is difficult to pull a worm from its burrow.
4. Worms are well adapted to living underground. **Identify** the adaptations you observed.

5.2 Food chains and food webs

Healthy ecosystems usually contain many different habitats and a variety of organisms. The organisms living there interact in different ways. Food is one of the most important needs of all living things. Therefore one of the relationships between organisms is a feeding relationship. Some organisms do the eating. Other organisms are the food.

INQUIRY science 4 fun

Predators in the garden

Can I see predators at work in the garden?

Yes

Collect this ...

A magnifying glass could be useful but is not essential.

Do this ...

1. Sit quietly in the garden or in an area of parkland where there are flowers, bushes and trees.
2. Observe the insects, birds and other animals such as lizards that are moving around.
3. Use your magnifying glass to observe insects moving around on the plants.

Record this ...

Describe any situations where an animal was feeding.

Explain which organism was the predator and which was being eaten.

Predators and prey

For an organism to live in a particular habitat, that habitat must provide adequate food or nutrients. Plants make their own food. Animals must consume other animals or plants to get their food. Animals that eat other animals are called **predators**. For example, a dingo will hunt a hopping mouse. The dingo is a predator of the hopping mouse. The animal that is eaten is the **prey**. The hopping mouse in Figure 5.2.1 is the prey of the dingo.

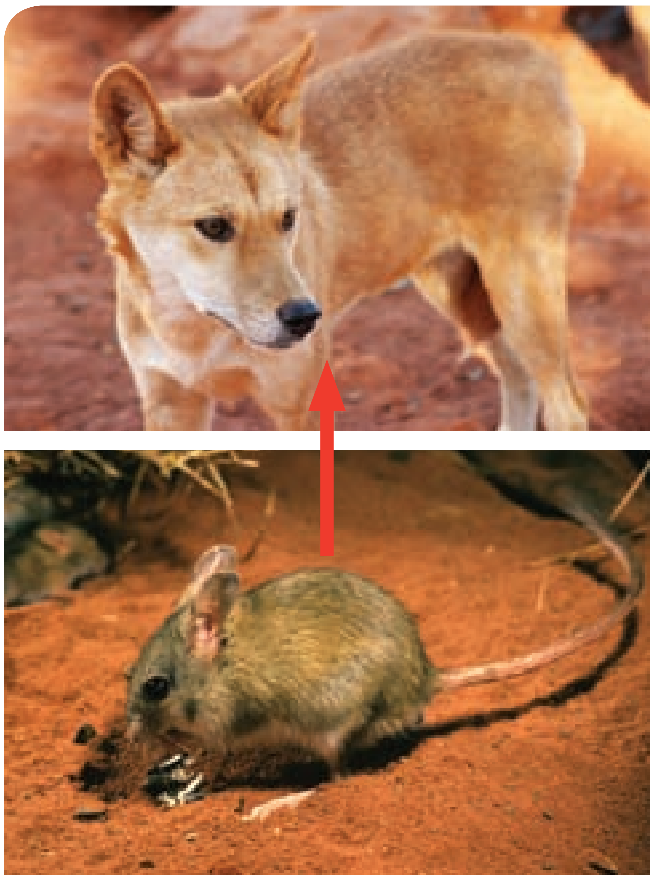


Figure 5.2.1 The dingo is the predator. It preys upon the hopping mouse as a food source.

If two animals eat the same sort of food and they live in the same habitat, they must compete for their food; they are **competitors**. Rabbits (Figure 5.2.2) were introduced into Australia during the 1830s and they compete with many Australian animals for food, living space, water and shelter.

Figure 5.2.2 Wombats and rabbits compete for food, shelter, living space and water.

Food chains

Plants and animals use energy in growing and in day-to-day activity. This energy must come from somewhere. Plants get their energy from sunlight, and animals get their energy from the food they eat. For example, grass uses the energy from sunlight to make the food it needs to be able to grow. A grasshopper may eat the grass to get the energy it needs and a kookaburra might eat several grasshoppers to get the energy it needs. When the kookaburra dies, bacteria will help to decompose its body. The bacteria get the energy they need. The nutrients stored in the body of the kookaburra are returned to the soil and help more grass to grow.

Figure 5.2.3 All food chains start with the Sun, and usually end with bacteria or fungi.

This flow of energy from organism to organism is called a **food chain**. An example of a food chain is shown in Figure 5.2.3.

A food chain is usually drawn as a simple flow chart like this:

Sun → grass → grasshopper → kookaburra → bacteria

The direction of the flow of energy is shown by the arrows.

Producers, consumers and decomposers

Food chains start with the Sun. The Sun gives out light energy. Plants trap the Sun's energy in their leaves using a chemical called **chlorophyll**. Chlorophyll gives plants their green colour. Plants then use the energy they have trapped, with water and carbon dioxide, to make the carbohydrate called glucose. Glucose is a simple sugar. Oxygen is also produced. This process is called photosynthesis. **Photosynthesis** is often written as a chemical equation:

$$\text{carbon dioxide} + \text{water} \xrightarrow[\text{chlorophyll}]{\text{sunlight}} \text{glucose} + \text{oxygen}$$

Plants can produce their own food and so they are called producer organisms or **producers**.

Animals cannot make their own food and must consume (eat) plants or other animals to get the energy and nutrients they need. Animals are therefore called **consumers**. Consumers such as grasshoppers, kangaroos or koalas that eat only plants are known as **herbivores** (Figure 5.2.4). Consumers such as lions, dingoes or kookaburras that eat only other animals are called **carnivores**. **Omnivores** are consumers that eat plants and animals. Humans and some bears are examples of omnivores.

Figure 5.2.4 Koalas are herbivores. They only eat leaves from eucalyptus trees.

If a plant or animal dies without being eaten, its body is broken down by decomposers. **Decomposers** are organisms such as bacteria and fungi that are able to get the energy they need as they break down dead matter and waste products. You can see a type of fungus in Figure 5.2.5.

Figure 5.2.5 The fungi on the tree stump are decomposer organisms. Fungi break down the materials that the tree is made from, returning these materials to the soil. Through this process fungi get the nutrients they need to live and grow.

In this food chain:

Sun → grass → grasshopper → kookaburra → bacteria

the grass is the producer, the grasshopper is a **first-order consumer** and the kookaburra is a **second-order consumer**.

In another food chain, a lizard could eat the grasshopper. The lizard could then be eaten by the kookaburra. The new food chain would look like this:

Sun → grass → grasshopper → lizard → kookaburra → bacteria

The lizard is the second-order consumer and the kookaburra is a **third-order consumer**.

Food webs

In the pond ecosystem shown in Figure 5.2.6, small fish live in constant danger of being eaten. If they go too close to the surface, birds might catch them. If they move away from the protection of the pond weeds, large fish will catch and eat them. The edge of the pond is also dangerous, because frogs and birds are always alert for an easy meal.

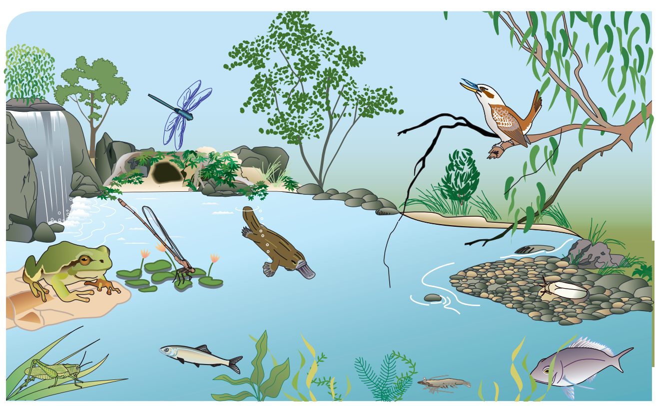


Figure 5.2.6 A pond ecosystem is home to a variety of organisms.

If you drew food chains for every predator in and around the pond, the small fish would be included in most of them. This situation is common in many ecosystems. Each animal consumes a variety of foods but is also the prey of a number of different predators.

Following are four possible food chains for the pond ecosystem.

Sun → pond weed → small fish → kookaburra → decomposer

Sun → pond weed → insect larvae → platypus → decomposer

Sun → pond weed → insect larvae → small fish → kookaburra → decomposer

Sun → pond weed → small fish → large fish → kookaburra → decomposer

Joining a number of food chains together produces a **food web**, such as the one shown in Figure 5.2.7.

Changes often occur in food webs as the populations of different organisms increase, decrease or disappear altogether. Some animals or plants might be in the pond for only a short time each year; for example, tadpoles might be an abundant food source for fish one week, but if they become frogs the next week they will no longer be available to the fish but instead could be a food source for the kookaburra.

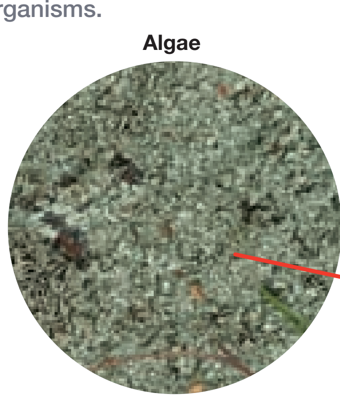
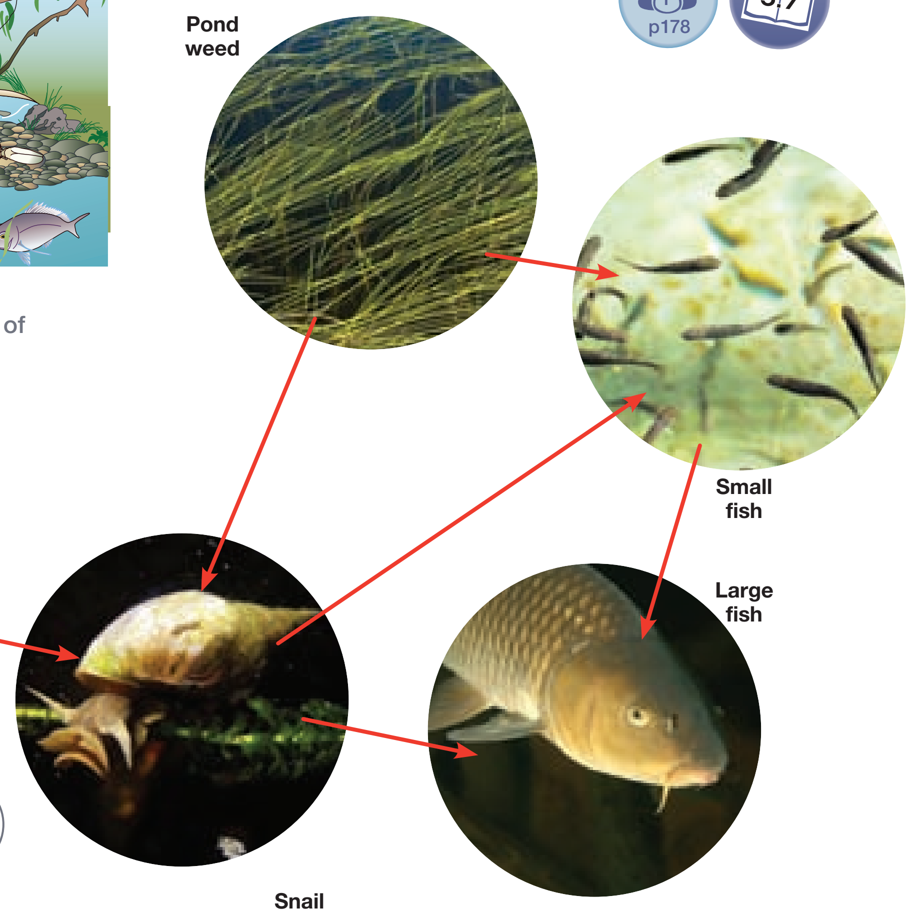



Figure 5.2.7 A food web clearly identifies who eats whom in the whole ecosystem. There are at least three different food chains represented in the food web.

5.2 Unit review

Remembering

1 **State** what the arrows in a food chain indicate.

2 **Name** the process that plants use to make their food.

3 **State** where the energy in a plant's food comes from.

Understanding

4 **Define** the following terms:
  a producer
  c consumer
  d decomposer.

5 **Explain** why all food chains begin with the Sun.

6 **Explain** why a producer is the first living thing in a food chain.

7 **Describe** an example of each of the following:
  a competition between two carnivores
  b competition between two herbivores
  c a predator and its prey.

Applying

8 a Using the food web shown in Figure 5.2.8, **identify** the:
    i producers
    ii consumers.
  b **Identify** and record three food chains that are contained within the web.

Analysing

9 **Compare** a food chain and a food web.

10 **Compare** carnivores, herbivores and omnivores.

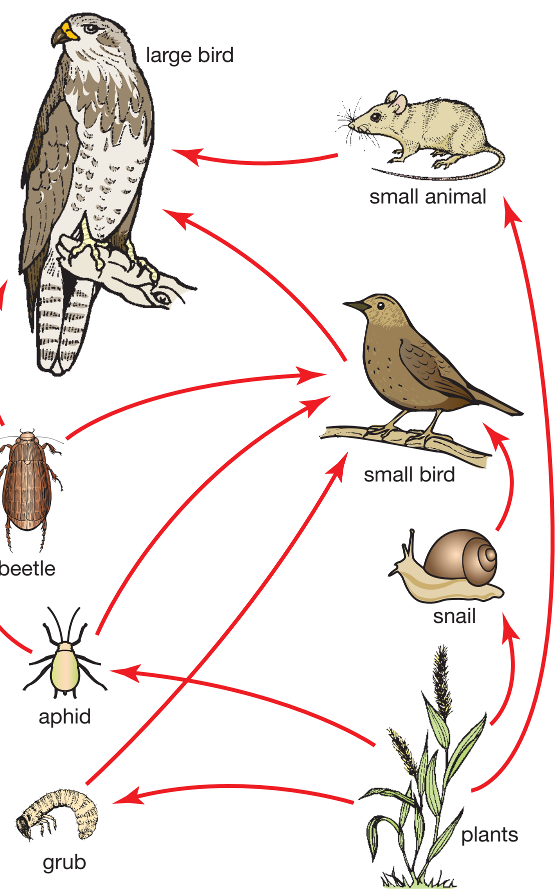


Figure 5.2.8 A large food web

Evaluating

11 a Figure 5.2.9 shows a venus flytrap. This plant catches insects and uses them as a source of nutrients. **Propose** whether a carnivorous plant like a venus flytrap should be known as a producer or a consumer.

b **Justify** your response.

Figure 5.2.9 Venus fly trap

12 **Propose** what could happen in the food web shown in Figure 5.2.8 if the number of:

a small birds decreased

b large birds increased

c plants decreased.

Creating

13 **Use** the following information to **construct** a food web:

- algae (a producer)
- snail (eats algae)
- small fish (eats algae and snails)
- water beetle (eats small fish)
- frog (eats beetles)
- snake (eats beetles and frogs)
- decomposers.

14 Using a set of six cards, write your own name on one card. On the other cards write the names of five plants and animals that you could eat.

a Use these cards to **construct** a food chain in which you are:

i a first-order consumer

ii a second-order consumer

iii the consumer at the end of the food chain.

b **Discuss** how easy was it to make the food chains, and whether you had to make other cards.

15 Ecosystems rely on producers, consumers and decomposers. **Create** a role-play for each of the following situations.

a All the consumers in an ecosystem are removed.

b All the producers in an ecosystem are removed.

c All the decomposers in an ecosystem are removed.

Inquiring

1 Select a habitat in which you are interested or that is relevant to your local area.

a Create a list of plants and animals that live there.

b Construct a food web for the habitat.

2 Research the food eaten by a koala, a great white shark, an emu and a Tasmanian devil. Deduce which of these animals would be most affected if one of their food sources disappeared.

5.2 Practical activities

1 Woolly web

Note: This is a whole-class activity.

Purpose

To create a food web using students connected by pieces of wool.

Materials

- information about feeding relationships in a particular habitat
- small balls of wool or string (start with five for each student)
- card to make labels
- marker pen
- paper clips (one per student)

Procedure

1. Each student selects an organism from the list of organisms found in the habitat.
2. Using the card and marker pen, create a name label so that you can be identified. Attach it using a paper clip.
3. Using the information about feeding relationships, identify the organisms that you will use as a source of food.
4. Start with the producer organisms. Connect the producers to the herbivores that eat them, extending the wool from the producer's right hand to the herbivore's left hand. The producer organisms and the herbivore hold opposite ends of a piece of wool. The wool represents an arrow in the food web.
5. The carnivores then connect to the herbivores they eat, by holding opposite ends of a piece of wool (wool from the right hand of the herbivore should extend to the left hand of the carnivore).
6. Any carnivores that eat other carnivores are then connected until all the feeding relationships are created by pieces of wool. The wool always goes from the right hand of the organism being eaten to the left hand of the predator.
7. Identify one organism that will be eaten—the prey. The student representing that organism gently pulls on one piece of wool so that the energy moves along the food chain from the prey to the predator. The predator then pulls on all of his/her strings so that the energy moves to the next level. Continue in this way until the energy reaches the consumers at the ends of all the food chains.
8. Repeat the exercise, starting with organisms at different levels in the food web.

Results

Observe the effect on other parts of the food web, of the changes you have made.

Discussion

1. **Describe** the effect of a change on the levels of a food web above it.
2. **Describe** the effect of a change on the levels of a food web below it.
3. **Propose** what could happen at higher levels in the food web if an organism disappeared from the habitat.
4. **Identify** any effect the organism's disappearance had on lower levels of the food web.
5. **Explain** why it is an advantage for organisms to have a variety of food sources.
6. **Identify** any of the higher-order consumers that would be left with no food source if one of the first-order consumers in your food web was to disappear from the area.
7. **Deduce** what will happen to your food web if a producer organism is removed from the area.

5.3 Impacts on ecosystems

Environmental conditions in ecosystems change constantly. These changes can be short term such as waves crashing on a rocky shore, or long term such as the seasons. Not all changes are natural changes. Human activity can change ecosystems.

Sustainable ecosystems

Ecosystems that are diverse and are able to provide the needs of the organisms living there over a long period of time are **sustainable ecosystems**.

In sustainable ecosystems (like the one in Figure 5.3.1) there are a wide variety of species. The term **species** is used to describe different types of organisms. There are many different habitats for these species. Each species has a variety of food sources, so if one food source is in short supply they can use another.

Natural ecosystems are sustainable ecosystems. Human activities can change ecosystems. This can result in sustainable or unsustainable environments. Humans can influence ecosystems so that species leave the ecosystem because their needs are no longer met. If the species cannot find a suitable place to live then it is in danger of becoming extinct.

Figure 5.3.1 Sustainable ecosystems provide habitats for a variety of species. The needs of those species are met by the resources of the ecosystem.

Traditional use of fire

Fire causes rapid changes in ecosystems. Fire has been an important part of Australian ecosystems since before humans lived on the continent. In large areas of Australia the plants are adapted to fire. For example, some plants need fire to release seeds from woody seed pods. Others plants recover quickly after fire has destroyed their leaves.

When Aboriginal people came to Australia they used fire as a tool for hunting. Kangaroos and wallabies escaping from the fire would be captured by hunters. Traditional burning patterns used frequent cool fires, such as the fire in Figure 5.3.2. Forests were replaced by open woodlands and grasslands. There was an increase in grazing animals, such as the kangaroos the Aboriginal people used for food. Plants used as food also flourished.

Figure 5.3.2 Traditional Aboriginal burning practices used cool fires that burned the grass and low shrubs without destroying the leaves at the tops of the tallest trees.

Different areas were burned at different times, leaving a mosaic pattern which provided a variety of habitats for different plants and animals. In turn this provided a variety of foods for the Aboriginal people.

When Europeans arrived in Australia, traditional Aboriginal burning practices gradually stopped. Many of the ecosystems they had created disappeared.

Floods

Floods change ecosystems. The usual image of Lake Eyre is a dry bed of salt surrounded by desert, as shown in Figure 5.3.3. When water reaches the lake, a completely different ecosystem is established. After remaining in the sand for years, the seeds of wildflowers germinate, producing large areas of colour. Fish and other aquatic animals flow into the lake with the flood waters. Thousands of water birds such as pelicans, cormorants and ducks fly in and start nesting and breeding. The young birds are an abundant food source for predators such as dingoes and kites. A desert ecosystem returns when the flood waters dry up.

Figure 5.3.3 When water reaches Lake Eyre, the ecosystem is changed from dry desert to an area with many different organisms.

Floods can destroy ecosystems. As Figure 5.3.4 shows, flood waters can carry large amounts of soil from the land, down rivers and into lakes and the ocean. The soil settles out of the water, covering coral reefs, sea grasses and other aquatic habitats. This covering, known as sediment, prevents light from reaching the plants and smothers small animals such as corals. Many of the organisms living in these ecosystems die and the system is permanently changed.

Figure 5.3.4 Dark brown sediments moving from the river into the ocean. The sediments cover plants and animals on the ocean floor.

INQUIRY **science 4 fun**

No food!

How would things change if all the supermarkets closed down?

Collect this ...

No equipment is needed.

Do this ...

Imagine how life in your area would change if all the supermarkets were closed down.

Record this ...

1. **Describe** what you think would happen in the short term of two weeks and in six months.
2. **Explain** how this relates to the destruction of a natural environment and the effect on the organisms that lived there.

Human activities

Agriculture

In Australia, a large proportion of the total land area has been cleared of native vegetation (the plants that usually grow there). The land is now used to graze animals or to grow crops such as the wheat seen in Figure 5.3.5. These agricultural areas provide very different habitats from the native vegetation. Fertilisers and pesticides used on the crops may wash into rivers from the farmland, causing changes in river and wetland ecosystems.

Figure 5.3.5 Vast fields of wheat cannot provide the same habitats as those provided by native vegetation.

Logging

Trees growing in Australia's forests are a valuable source of timber. Timber is used in construction, furniture making and as wood pulp for the production of paper. Figure 5.3.6 shows how the forests, and the habitats the forests contained, are destroyed when the trees are removed.


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Figure 5.3.6 Large trees provide food and shelter for a variety of organisms. These organisms all lose their homes when old trees are cut down.

Mining

In some forms of mining, the surface of the Earth is scraped away to access the resource underneath (Figure 5.3.7). All the habitats that were there are destroyed. There have also been situations where poisonous chemicals from the mines pollute waterways, causing damage to these habitats and the organisms that live in them. Loose soil also washes into rivers and creeks and destroys the habitat of water plants, which cannot grow in muddy water.

Figure 5.3.7 Open-cut mines remove all the vegetation from the surface. The soil and vegetation have to be replaced when mining is finished, but that is too late for the animals that have lost their habitat.

Urbanisation

Towns and cities are built on land that was once a natural ecosystem. The native vegetation is replaced with houses, shops, offices, industries, roads, and new parks and gardens. The animals that once lived there no longer have their habitat and have to move away. However, there are some animals that live quite happily in urban areas and appear to thrive there. Possums such as the brushtail possum in Figure 5.3.8 are a common sight in cities.

Figure 5.3.8 Possums thrive in cities. They live in the space between the ceiling and roof of houses and use vegetable gardens and fruit trees as a source of food. They are often seen travelling from place to place along electricity and telephone wires.

Introduced species

Many species of plants and animals have been introduced into Australia. Most of the animals and plants we use as food are introduced. Pet animals, such as cats, dogs and rabbits, are also introduced.

The wool, cotton and leather used to make clothes and furnishings come from introduced species. The majority of the introduced species have benefited humans. The same is not true for other introduced species such as the fox (Figure 5.3.9), the rabbit and the cane toad.

Figure 5.3.9 The fox was introduced into Australia from Europe in the 1860s to provide sport for hunters.

SciFile

Garbage dump

Mount Everest, the world's highest mountain, could be called the 'World's Highest Garbage Dump'. There are nearly 110 tonnes of litter on Mt Everest. The waste includes high-tech climbing equipment, plastic, tins, oxygen tanks, aluminium cans, clothes, glass and tents.

Loss of species diversity

Human actions have caused many native species to become **extinct**. A species is said to be extinct when nobody has seen it in the wild for over 50 years and the last known individual has died. In the past 200 years more than 125 species of Australian native plants and animals have become extinct. Hunting, changes to the environment, and habitat loss have caused many more species to become threatened.

Threatened organisms can be classified into one of three groups, depending on how great the threat to their survival appears to be.

- **Endangered species** are close to extinction and very small numbers remain. Examples are the helmeted honeyeater, the blue whale, the beaked gecko and the Leadbeater's possum (Figure 5.3.10).
- **Vulnerable species** are experiencing a rapid population decline and are in danger of becoming extinct if the drop in numbers continues. Examples of vulnerable animals are the mountain pygmy possum, the Gippsland giant earthworm, the Mallee fowl, the bilby and the diamond python (Figure 5.3.10).
- **Rare species** have low numbers and are often spread out over a large area. Although the populations may be small, they are not decreasing. Rare organisms include the eastern wallaroo, the leafy sea dragon (Figure 5.3.10), the powerful owl and the alpine tree frog.

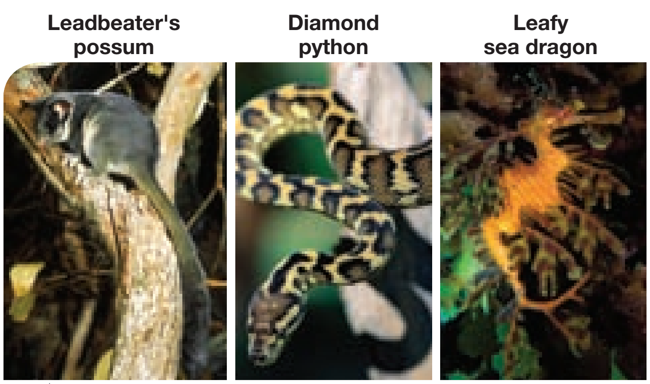

Figure 5.3.10 Threatened species of Australia

Effect of an industry

Sumatra is one of the islands of Indonesia. Its position is shown in Figure 5.3.11. It has a huge range of plant and animal species, some of which are found only on this island.

Figure 5.3.11 Sumatra is one of many islands that make up the country of Indonesia.

The Sumatran elephant, Sumatran tiger (Figure 5.3.12), Sumatran rhino and Sumatran orang-utan are four species that are critically endangered because their habitat is disappearing. These species live in the rainforests of Sumatra. However, Sumatra has lost almost 50% of its tropical rainforests in the past 35 years.

Figure 5.3.12 Sumatra is the only place where this tiger is found. It is the smallest of the tigers and there are fewer than 400 individuals left in the wild.

The rainforests of Sumatra are logged and burned, and then oil palm plantations (such as the one shown in Figure 5.3.13) are established. Indonesia is the world's largest producer of palm oil and the industry brings money into the country and provides employment for many people.

Figure 5.3.13 Oil palm plantations such as this one are replacing rainforest on the island of Sumatra. This is not a suitable habitat for the Sumatran tigers, orang-utan, rhinos and elephants.

5.9
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SCIENCE AS A

HUMAN ENDEAVOUR

ENDEAVOUR

Use and influence of science

Biological control

Figure 5.3.14 *Cactoblastis* moth caterpillars

One method of controlling unwanted pests is to introduce a predator of the pest or a type of organism that will compete with the pest for food or shelter. Using one type of organism to control the numbers of another type of organism is called **biological control**. This includes introducing a disease-causing organism that will kill the pest but not other species.

The following are three examples of biological controls that have been tried in Australia.

The *Cactoblastis* moth (Figure 5.3.15) was introduced into Australia in 1925 in an attempt to control the spread of the prickly pear cactus (Figure 5.3.16). The moths feed only on the cactus, and so they died out when they had eaten all the food. This was a big success and the problem of the cactus was solved within a few years.

Figure 5.3.15 The *Cactoblastis* moth. The caterpillars (larvae) of this moth eat the prickly pear cactus.

The prickly pear cactus was brought to Australia by Captain Phillip on the First Fleet because it was a food source for a beetle that provided the red dye used for soldiers' uniforms. Later it was grown as cattle feed and as a pot plant in gardens. The cactus spread very rapidly and at one stage covered an area the size of the state of Victoria.

Figure 5.3.16

Figure 5.3.17 Plagues of rabbits can quickly destroy the land. Scientists tried to control the spread of rabbits in Australia with poisons and viruses.

Sometimes biological controls do not work as planned. An example of this is the biological control introduced to control rabbits in Australia (Figure 5.3.17). Rabbits eat out crops and grazing lands, as well as burrowing through the soil until it can't be used for anything. In 1995 a virus, the calicivirus, was being researched as a possible method of control. It was accidentally released into the wild ahead of schedule. In the first few weeks, millions of rabbits died. Grazing land regenerated quickly. The results looked promising until it was realised that the foxes that relied on the rabbits for food were now eating small native mammals instead.

The most famous Australian biological control story is the cane toad (seen in Figure 5.3.18). Cane toads are native to South America and were first introduced in Australia in 1935 to control cane beetles. Cane beetles were accidentally introduced with imported sugar cane. As a control agent cane toads were a failure. They did not eat the cane beetle; instead the cane toads found many other things they preferred to eat. A cane toad eats anything it can swallow, including insects, mice, small snakes, lizards and even young cane toads. Poison from glands on its back kills many potential predators such as snakes and even crocodiles.

Figure 5.3.18 Cane toads can weigh up to 1.25 kg, live for up to 15 years and produce 40 000 eggs per year. Cane toad numbers are increasing rapidly and they are spreading across northern Australia. This cane toad is eating a frog.

5.3 Unit review

Remembering

1 **List** three ways in which humans can affect ecosystems.

2 **Name** the method of controlling pests that uses natural predators.

3 **Name** two species that are:

a endangered

b vulnerable.

Understanding

4 **Describe** changes in ecosystems caused by the traditional burning practices used by Indigenous Australians.

5 a **Explain** how a mosaic pattern was created in the vegetation.

b **Explain** the benefits of having the mosaic pattern.

6 **Explain** why the cane toad:

a was introduced into Australia

b is now considered a pest that needs to be controlled.

Applying

7 In an area of the Flinders Ranges in South Australia, foxes were preying on the yellow-footed rock wallaby. Foxes were excluded from an area and for the next ten years the number of wallabies in the area was counted. The results are show in Figure 5.1.19. **Use** the information in the graph to **describe** the effect on the wallaby population of removing the foxes.

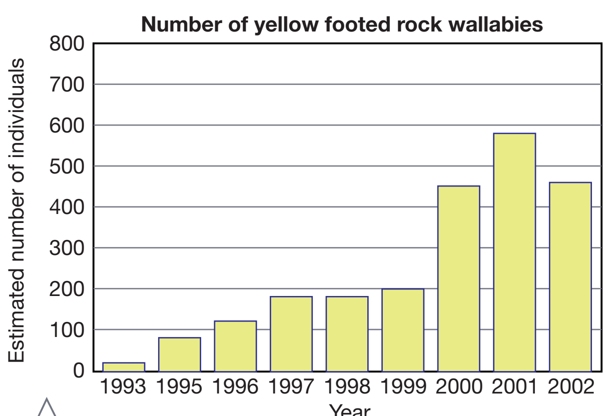


Figure 5.3.19

Analysing

8 **Compare** a sustainable and an unsustainable ecosystem.

9 **Compare** two effects of floods on natural ecosystems.

10 **Compare** the three groups of threatened species.

Evaluating

11 A wheat field is not a natural habitat. However, the wheat field provides a habitat for organisms. **Deduce** the types of organisms that would thrive in this habitat.

12 In some forests only the largest trees are taken out by loggers. **Propose** changes that removing only the largest trees would have on the other organisms living in the forest.

13 Are all introduced species pests? **Justify** your answer.

14 a **Propose** ways in which construction of the buildings shown in Figure 5.3.20 has already affected natural ecosystems.

b **Predict** what could happen to organisms living in a creek downhill from the building site after a heavy rainstorm.

Figure 5.3.20

Creating

15 A wildlife corridor is a strip of native vegetation that links patches of bushland. In many cases the patches of bushland are no longer big enough to provide for all the needs of organisms living in this habitat. Linking the patches of bushland allows animals to reach their food sources, shelter and breeding grounds.

In Figure 5.3.21, there are several isolated patches of bushland. Your task is to modify this area to include wildlife corridors. **Design** this area to include wildlife corridors so that the animals can move between the various areas. You may need to consider how to form links across roads. Present your design in a format of your choice.

farm boundaries

present bushland

swampy areas – unproductive farmland

Conditions

- Farmers don't own land along the river. It is public land 15 m either side of the river's edge
- Farmers have the right to use water for stock
- Farms A, C and G unlikely to cooperate in the wildlife corridor project

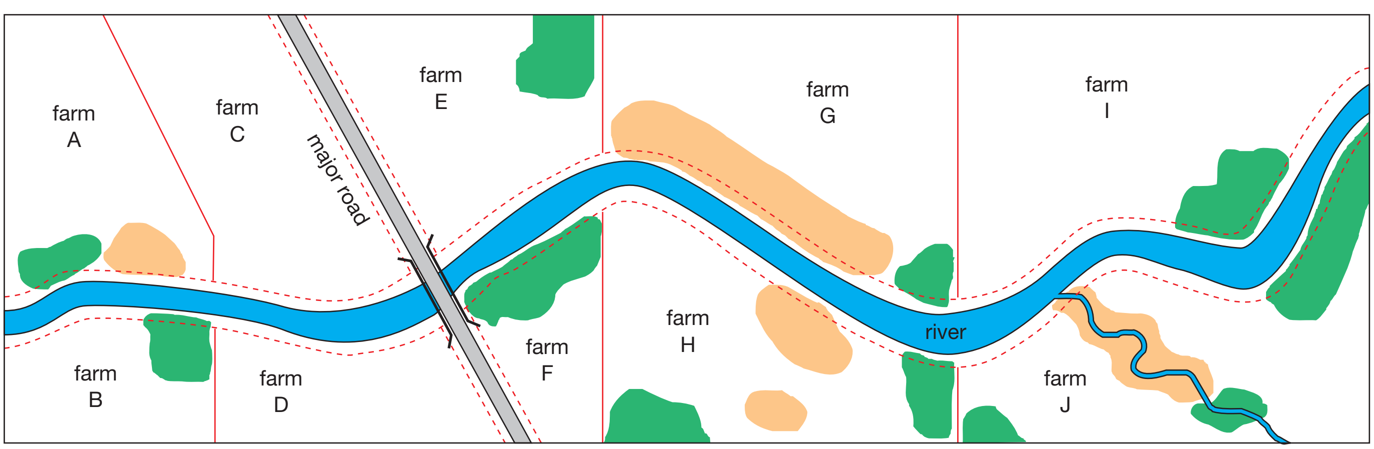


Figure 5.3.21

Inquiring

1 Research the different scientific responses to the rabbit plagues in Australian agricultural areas.

2 The cane toad has become established in many areas of northern Australia.

- **a** Research the effect that the cane toad has had on other living things in these areas.
- **b** Investigate strategies that have been used to control the spread of the cane toad.

3 Identify Australian scientists who are studying the impacts of humans on environments.

- **a** Outline the research these scientists are involved in.
- **b** Describe the human impacts they have identified.
- **c** Describe the changes in human behaviour that the scientists suggest have to be made.

4 Research a local environmental management project.

- **a** Outline the project.
- **b** Describe the reasons the project was set up and the expected benefits to the community.
- **c** Identify the types of scientists involved in the project and the role that each scientist has.

5.3 Practical activities

1 Taking control of plants

Purpose

To design an experiment to investigate the effect of changes in light on the growth of plants.

Materials

- a cardboard box
- black paper
- digital camera
- a range of plants, such as grass, alfalfa, cress
- different-coloured cellophane (blue, green, red, clear)
- measuring tools (rulers, balances, measuring cylinders)
- a light source

Procedure

1. Decide whether you want to study the effect of the direction from which the light is coming, or the effect of the quality of light that is reaching the plant. This will be the controlled variable.
2. Use the above materials to design a way of controlling the amount or quality of light that is reaching the plants.
3. Think about ways in which all the other variables can be kept the same.
4. Decide how you are going to measure or record the response of the plant. The digital camera could be useful for this purpose.
5. Check that the experiment you have designed is a fair test.
6. Record the procedure for your experiment.

Results

Present your results in a way that identifies patterns.

Discussion

1. **Compare** the reaction of different plant species to the variable you studied.
2. **Identify** situations where plants in a natural environment could be exposed to changes in the direction or quality of light.
3. **Discuss** your results in relation to how changes in the environment can affect plants.
4. **Deduce** whether your procedure could be used by ecologists to investigate plant behaviour.
5. **Discuss** the things that worked well and those that didn't in this experiment.
6. **Decide** how the experiment could be improved.

2 Threatened organisms

Purpose

To research the causes of organisms becoming threatened.

Materials

Research tools: access to the internet, encyclopaedias and textbooks

Procedure

1. Research the names of species living in your state or territory that are classified as threatened. The humpback whale (shown in Figure 5.3.22) is an example.
2. Select one of the organisms from the list.
3. Find out:
   a. its normal habitat
   b. the changes occurring that are causing the numbers of this organism to decrease
   c. the influence of human activity on these changes.
4. Propose actions that could be taken to conserve this organism.

Results

Present your research in the form of an electronic presentation or poster.

Figure 5.3.22 The humpback whale is considered to be an endangered species in most countries. A typical humpback whale is about the size of a bus and can live to 95 years.

5 Chapter review

Remembering

1 **State** why a producer organism is normally part of every food chain.

2 **Recall** the original source of energy for food chains.

3 **List** these in order from largest to smallest: habitat, biosphere, ecosystem.

4 **List** these groups of organisms from the ones that are most threatened to the ones that are least threatened:
rare, vulnerable, endangered.

Understanding

5 **Explain** why the habitat of an organism is sometimes referred to as its address.

6 **Modify** these scrambled sentences and rewrite with the words in the correct order.
- a ecosystem are All things an living in interdependent.
- b may feeds A is off organism parasite that kill its an host and it.
- c and sensitive Plants to environment animals changes are their in.

7 Figure 5.4.1 shows a food web where an eagle is the consumer at the top of the food chains.
- a **Predict** what would happen to the number of eagles in the area if foxes were introduced. (Note: foxes would eat koalas, birds and kangaroos.)
- b Redraw the food web and **modify** it to include the foxes.

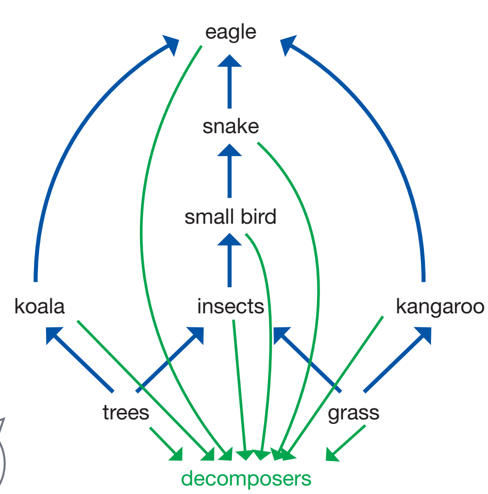


Figure 5.4.1

Analysing

8 **Compare** the role of prey and predator in a habitat.

9 **Classify** the organisms in the following list as either producers or consumers:
cat, magpie, rose, eucalypt, sparrow, worm, ant, grass, daisy.

10 Construct two lists by **classifying** the following items as biotic or abiotic environmental factors in a wetland ecosystem:
water birds, water temperature, crocodile, rate of water flow, amount of salt in the water, water plants, frogs, fish.

Evaluating

11 *Lantana* is a large flowering shrub that is native to Central and South America. It was introduced to Australia in 1841 as an ornamental garden plant that could be cut into a hedge. In the wild it grows rapidly along creek banks. It forms very dense bushes that prevent light from reaching the ground. *Lantana* grows in areas that are difficult to access and is not easy to remove. *Lantana* has a prickly stem and the leaves are poisonous to livestock if eaten. Its seeds are contained in a cluster of fleshy black berries that birds love to eat.

Use the information about *Lantana* to:
- a **propose** ways in which *Lantana* could affect the growth of native plants
- b **propose** ways in which *Lantana* could affect the number and species of native animals living in an area
- c **propose** actions that could be taken to prevent the spread of this plant.

12 Figure 5.4.2 shows the changes in the numbers of different animals found in an area for a period of 40 years. You are asked to interpret the information in this graph.
- a **Identify** the general trend in the population of the native animals (red-necked wallaby and eastern grey kangaroo).
- b **Identify** the general trend in the population of the rabbit—an introduced species.
- c **Compare** the changes in the rabbit population and the changes in the population of the eastern grey kangaroo.

d **Deduce** what may have caused the drop in grey kangaroo numbers in 1885.

e **Identify** the animals that are competing with the eastern grey kangaroo for food.

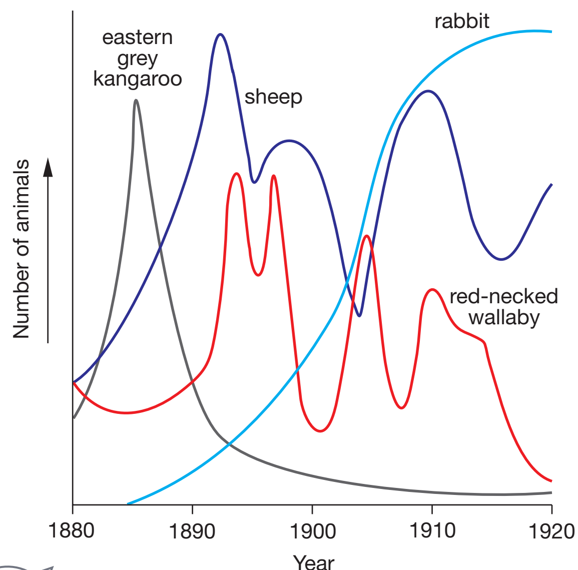


Figure 5.4.2

13 Use the information in Figure 5.4.3 to answer the following questions.

a **Identify** the organisms that compete with each other for food.

b **Deduce** which organism would be affected most by the use of insecticides (chemicals that kill insects).

c **Propose** the consequences for the remaining organisms in the food web if bandicoots became extinct in the area.

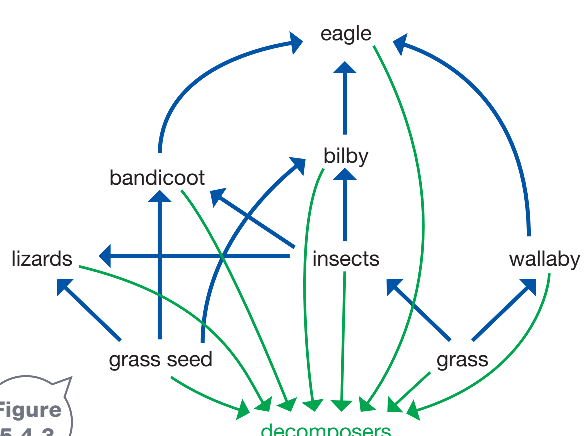


Figure 5.4.3

14 **Propose** reasons why humans are able to live in so many environments.

15 a Use information from the chapter to **identify** ways that human activity affects ecosystems.

b **Classify** the effects as positive or negative.

c **Propose** how the negative influences would make the ecosystem unsustainable.

d **Propose** how the positive influences increase the sustainability of the ecosystem.

16 In northern Australia there is a distinct wet season and dry season. The wet season may last for three months and during this time there may be floods. In the dry season there may not be any rain at all.

a **Propose** the effect on farmers managing a cattle property in this area.

b **Recommend** strategies these farmers could use to overcome any difficulties you identified.

Creating

17 a **Use** the following lists of organisms to **construct** food chains. Under the name of each organism, label it as a producer or a consumer.

b **State** whether it is a first-order, second-order or third-order consumer.

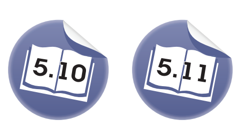
i grass, snake, frog, grasshopper

ii eucalypt, kookaburra, caterpillar

iii shark, large fish, small fish, snail, water plants

18 **Use** the following ten key terms to **construct** a visual summary of the information presented in this chapter:

environment, biotic factors, abiotic factors, habitat, food chain, producer, consumer, photosynthesis, endangered species, adaptation.



Thinking scientifically

Q1 Environmental factors may be biotic (living) or abiotic (non-living). **Identify** the list that has these sorted correctly.

A *biotic:* soil, predators, living space, bacteria, parasites
abiotic: water, prey, light, wind, rock

B *biotic:* prey, living space, parasites, predators, wind
abiotic: soil, water, bacteria, light, rock

C *biotic:* soil, predators, rock, bacteria, light
abiotic: water, parasites prey, wind, living space

D *biotic:* predators, prey, bacteria, parasites
abiotic: water, living space, light, wind, rock, soil

Q2 The fish shown in Figure 5.5.1 is adapted to its habitat; it has characteristics that assist it to survive in its environment. Which characteristic will help it swim through the water?

A the dark colour of its tail and fins
B the long spines in its back fin
C its streamlined shape
D its gaping mouth and small teeth

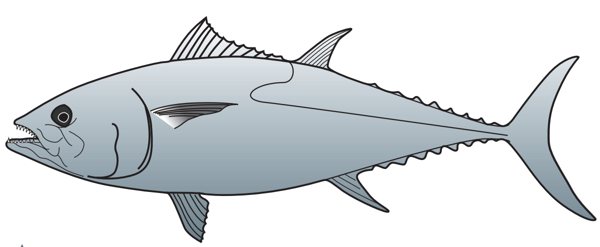


Figure 5.5.1

Q3 First-order consumers feed directly on producers. A producer can manufacture its own food from energy in sunlight. From the food web in Figure 5.5.2, **identify** the group of organisms that are all first-order consumers.

A tadpole, water beetle, snail
B water beetle, frog, small fish
C kingfisher, snail and algae
D snail, tadpole, algae

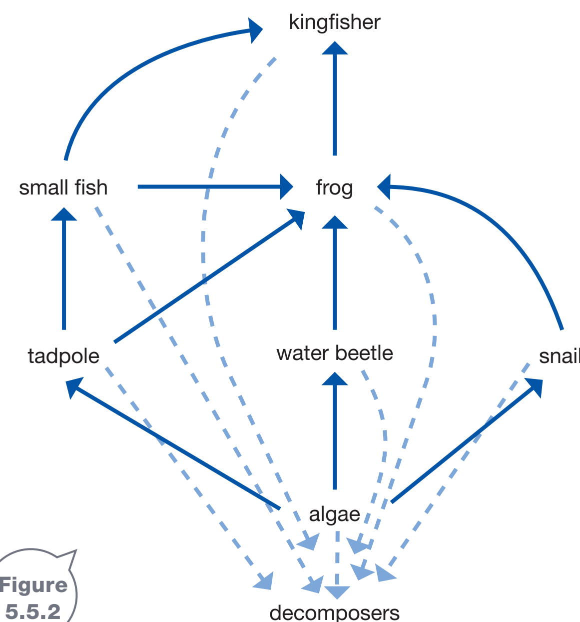


Figure 5.5.2

Q4 From the food web in Figure 5.5.2, **identify** the organism that is both a second-order and a third-order consumer.

A small fish
B kingfisher
C frog
D snail

Q5 **Identify** the plant in Figure 5.5.3 that would be adapted to get the most water from its environment.

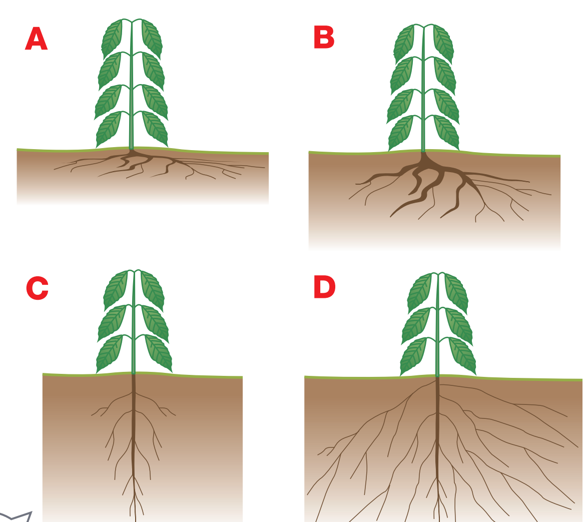


Figure 5.5.3

Glossary

Unit 5.1

Abiotic factors: non-living factors in the environment

Adaptations: characteristics that help an organism to survive in its environment

Biosphere: the place where all life exists; consists of Earth and its atmosphere

Biotic factors: living factors in the environment

Commensalism: an interaction between two organisms where one of them benefits but the other one is not affected

Ecologists: scientists who study the interactions between living things and their environment

Ecosystem: a system formed by organisms interacting with each other and their non-living surroundings in a balanced way

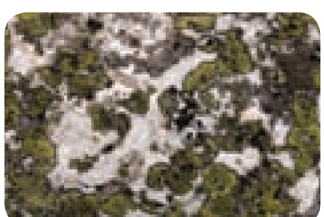
Environment: the term used to describe all the conditions that affect a plant or animal in its habitat

Habitat: the place where an organism lives

Host: an organism in or on which a parasite lives

Interdependent: depending on each other for survival

Mutualism: an interaction between organisms where both the organisms benefit from the relationship and neither is harmed



Mutualism

Nocturnal: active or hunting at night

Parasite: an organism that lives on or in a host, taking food or shelter from the host. The host gets nothing in return and may be harmed

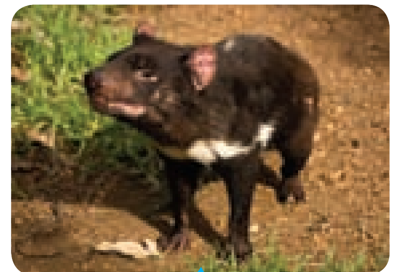
Parasitism: an interaction where one type of organism (the parasite) lives on or in another type of organism (the host); the host is usually harmed or even killed

Parasitism

Symbiosis: another name for interdependence

Unit 5.2

Carnivore: a consumer that eats only other animals



Carnivore

Chlorophyll: the chemical in plants that traps energy from the Sun and gives plants their green colour

Competitors: organisms that have the same food source and live in the same habitat

Consumers: organisms that must eat other organisms to get the energy and nutrients they need; animals are consumer organisms

Decomposers: organisms that get the energy they need by breaking down dead matter and waste products

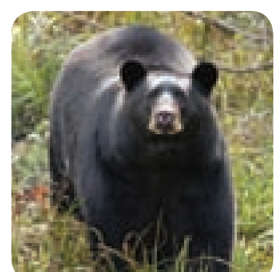
First-order consumer: a consumer that eats a producer

Food chain: the flow of energy from organism to organism in a series of feeding relationships

Food web: a number of food chains combined

Herbivore: an animal that eats only plants

Omnivore: an animal that eats both plants and animals



Omnivore

Photosynthesis: the process used by plants to make their own food

Predator: an animal that eats other animals

Prey: an animal that is eaten by a predator

Producer: an organism able to manufacture its own food; plants are producer organisms

Second-order consumer: a consumer that eats a first-order consumer

Third-order consumer: a consumer that eats a second-order consumer

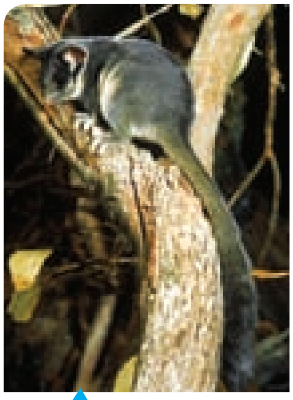
Unit 5.3

Biological control: a method of controlling unwanted pests by using a natural predator or disease

Endangered species: species that are close to extinction and very small numbers remain

Extinct: term used to describe a species that has not been seen in the wild for over 50 years, and of which the last known individual has died

Rare species: species that has low numbers, often spread out over a large area; the population is not decreasing

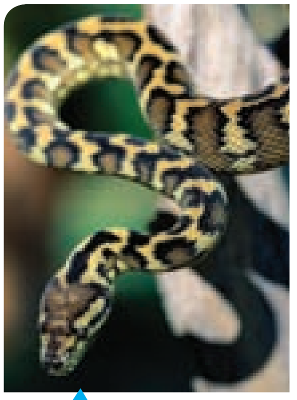


Endangered species

Species: the term used to describe different types of living things

Sustainable ecosystem: an ecosystem that is diverse and able to provide for the needs of the organisms living there over a long period of time

Vulnerable species: species that is experiencing a rapid population decline and is in danger of becoming extinct if the drop in numbers continues



Vulnerable species

Classification

6

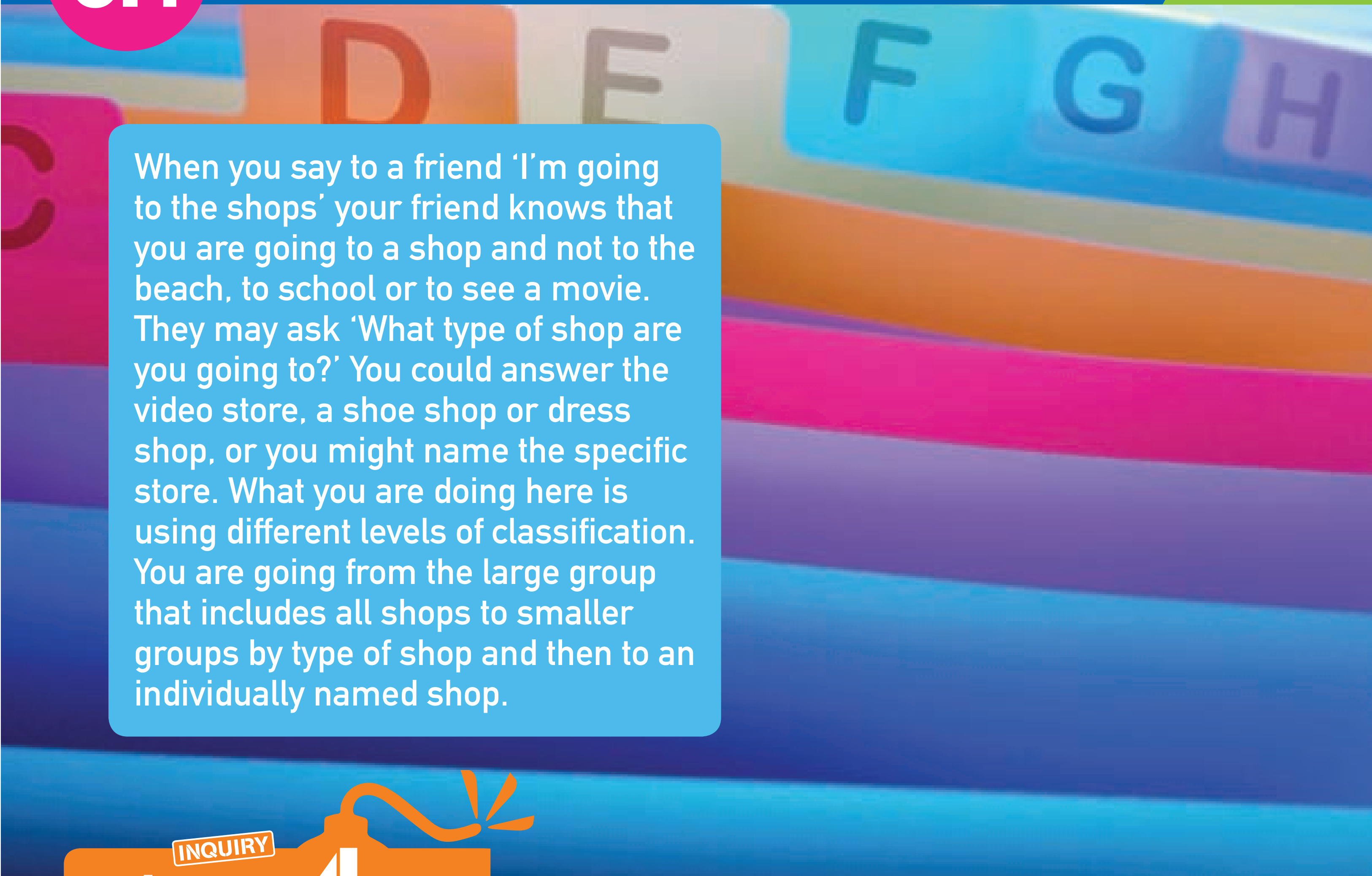
HAVE YOU EVER WONDERED…

- why living things are put into groups?
- how scientists make sense of millions of living things?
- why some plants and animals have a number of different names?

After completing this chapter students should be able to:

- present different reasons for classifying, such as identification and communication
- demonstrate different ways of presenting keys
- use provided keys to identify organisms
- classify using hierarchical systems such as kingdom, phylum, class, order, family, genus and species
- group a variety of organisms on the basis of similarities and differences in particular features
- use scientific conventions for naming species
- describe how biological classifications have changed over time.

6.1 What is classification?



When you say to a friend 'I'm going to the shops' your friend knows that you are going to a shop and not to the beach, to school or to see a movie. They may ask 'What type of shop are you going to?' You could answer the video store, a shoe shop or dress shop, or you might name the specific store. What you are doing here is using different levels of classification. You are going from the large group that includes all shops to smaller groups by type of shop and then to an individually named shop.

INQUIRY science 4 fun

Your pencil case

How could the things in your pencil case be classified?

Collect this …

- the contents of your pencil case

Do this …

1. Tip the contents of your pencil case out on the table.
2. Sort the contents into groups and give names to each group.
3. List the items included in each group under the group name.
4. Re-sort the contents into different groups, and again list the items included in each group.

Record this …

Describe how you decided what to include in the groups.
Explain which of the groupings was most useful.

You use it every day

Classification is the process of putting things into groups. It is a skill needed in many areas of life, not only in science.

Next time you walk round a supermarket, think about the way products are grouped. Biscuits are all in the same aisle, with the savoury biscuits separated from sweet and chocolate biscuits. Canned items are usually together, but the canned fruit is separated from the baked beans and soups, and fresh fruit is organised as in Figure 6.1.1.

Figure 6.1.1 Fruit and vegetables in the supermarket are sorted into groups. This makes it easier to find the type of vegetable you need or the variety of orange you prefer to buy.

Music you download onto your iPod is classified in a variety of ways. This allows you to find the music by searching via artist, album, composer or genre (such as rock, pop and dance).

In a library, the fiction and non-fiction books are in different areas. The non-fiction books are then placed in smaller groups according to their subject, and the fiction books are sorted in alphabetical order of the author's surname.

Sorting things in this way makes it easier to find a particular item. Imagine what shopping day would be like if the hundreds of supermarket items were placed on the shelves at random! Similarly it would be nearly impossible to find a song by your favourite band or a book by your favourite author if there was no organisation to the way the songs were ordered and books were placed.

Which group?

As an individual you are classified in many different ways for different purposes. You are classified as male or female, according to your year at school (such as Year 7 or 8), as part of a particular family (for example the Robinsons or the Singhs), as living in a particular suburb (for example Brunswick, Indooroopilly or Glenelg) or city (such as Bundaberg, Canberra or Whyalla) or state (Western Australia, Tasmania or New South Wales). The group you are placed in depends on the reason you and others are being grouped. You are part of all these groups at different times.

1 p204

SciFile

Just a moment

Time is classified with years being divided into 12 months, which are divided into days, hours, minutes and seconds. But what is a moment? According to an old English system of classifying time, a *moment* is one and a half minutes.

Groups change

Plants and animals are often grouped in different ways too. For example, the grass making up a garden's lawn is looked after and encouraged to grow. However, if the grass escapes from the lawn area and into the flower beds, the grass is now considered to be a pest and is dug out or even poisoned. The plant that is wanted in one place is a **weed** in another place. *Weed* is not a name given to a special group of plants, but is a classification for any plant growing where it is not wanted (like the one in Figure 6.1.2). To one person a plant may be wanted; to another it is a weed. A plant may be wanted in one situation and be a weed in another situation.

Many plants have been introduced into Australia from overseas. Some introductions were intentional and they have been beneficial. Many food crops, such as wheat, potatoes, tomatoes and apples, were introduced by early European settlers and are still cultivated and controlled.

Figure 6.1.2 A weed is just a plant growing where it is not wanted.

Other introduced plants have created problems. Lantana (*Lantana camara*) has a pretty flower and was introduced to Australia in the 1840s. You can see it in Figure 6.1.3. It now grows out of control in New South Wales and Queensland and has already invaded over 4 million hectares of farmland, woodlands and forests. This is an area about two-thirds the size of Tasmania! Scientists believe that, if not controlled, lantana could invade an area of 35 million hectares across New South Wales, Queensland, Western Australia and Northern Territory. Lantana spreads rapidly and is toxic to livestock that try to eat it. For these reasons, lantana is classified as a Weed of National Significance.

Figure 6.1.4 The red fox (*Vulpes vulpes*) is a pest but it does help to control another pest species—the rabbit.

Animals have also been introduced to Australia for food (for example cattle and sheep), transport (for example horses and camels), hunting (such as foxes, shown in Figure 6.1.4, and rabbits) and to control other pests (the cane toad was introduced to control a beetle ruining sugar cane crops). Some of these animals have become a major problem for Australian wildlife. Foxes eat wildlife, rabbits eat vegetation normally eaten by wildlife, while poisonous cane toads will kill any snakes, crocodiles and birds that eat them. These 'animal weeds' are known as **pest species**.

Figure 6.1.3 Lantana (*Lantana camara*) is a weed species introduced from South America.

Scientists classify

Classification is an important skill used in all branches of science. Scientists observe ways in which objects are similar and group them together. Chemists classify substances such as those in Figure 6.1.5 and group them

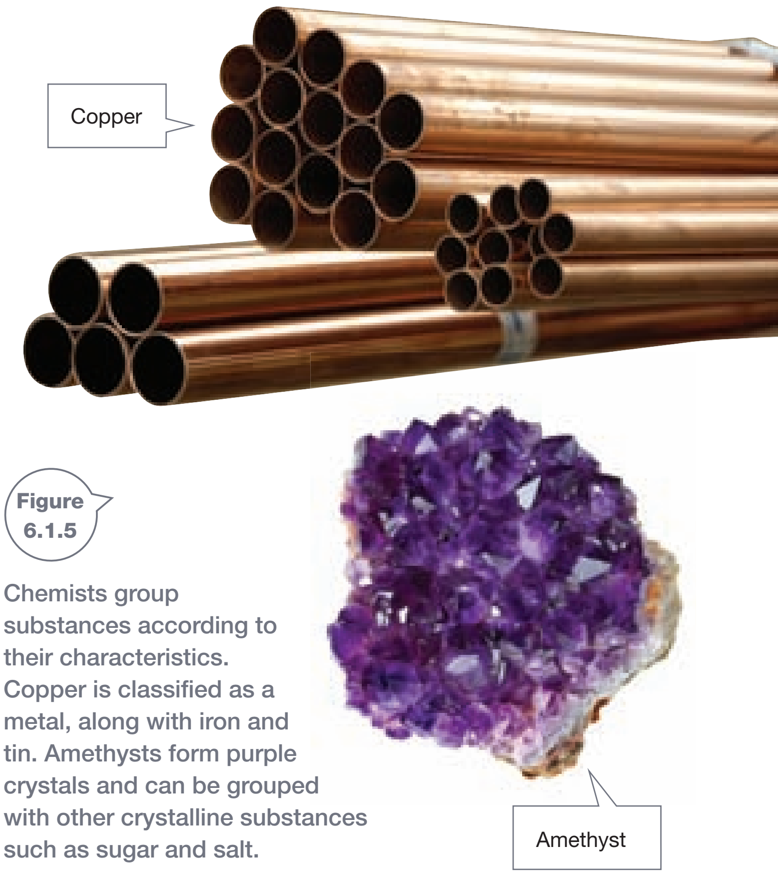


Figure 6.1.5 Chemists group substances according to their characteristics. Copper is classified as a metal, along with iron and tin. Amethysts form purple crystals and can be grouped with other crystalline substances such as sugar and salt.

using names such as metal or non-metal, and acid or base. Geologists classify rocks as sedimentary, igneous or metamorphic (Figure 6.1.6), and astronomers classify heavenly bodies into groups such as stars and planets.

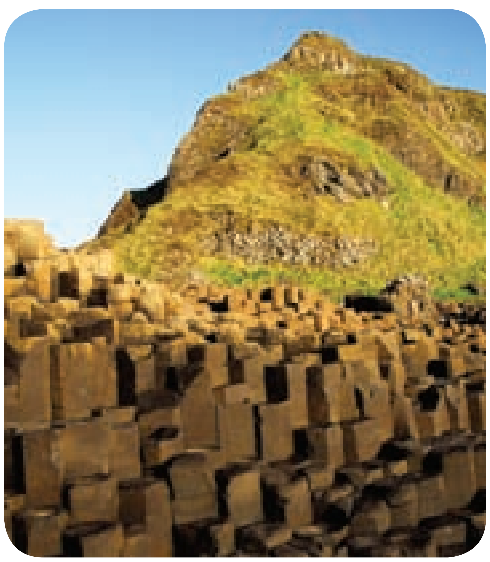


Figure 6.1.6 Geologists classify rocks using characteristics such as how hard they are, their colour, and how they were formed. Sedimentary rocks (top) are laid down in layers. Basalt (bottom) is a dark rock formed in the Earth's surface following a volcanic eruption.

Introducing keys

Biologists classify living things. Scientists who specialise in grouping and naming living things are known as **taxonomists**, and the science of grouping and naming things is called **taxonomy**. Once the characteristics of organisms have been described this information can be used to develop a key. The key is a tool that can then be used to identify unknown organisms.

The simplest type of key is a dichotomous key. The word *dichotomous* means *cut in two*. A **dichotomous key** is a series of choices that leads to the identification of an object. At each stage of using a dichotomous key you are given two choices. Each choice leads to another two choices and so on, until there are no more choices and the object is identified.

Keys work best if the features used to make the choices are easy to observe, with everyone knowing exactly what they mean. Take height as an example. A person's height is easy to observe, but words such as tall or short can be interpreted in different ways. You would probably describe someone taller than you as 'tall'. That same person might be described as short by an even taller person as shown in Figure 6.1.7. Tallness therefore is not a good and reliable feature for a key. Descriptions of height such as 'greater than 1.5 metres in height' are more reliable.

Figure 6.1.7 Descriptions such as tall or short are subjective, with different interpretations, but a measurement is not.

Two ways of writing keys are as flow charts or tables. The buttons shown in Figure 6.1.8 have been used to construct the two keys shown in Figures 6.1.9 and 6.1.10.

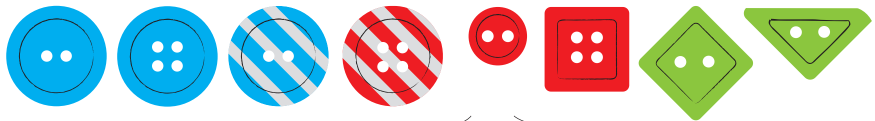


Figure 6.1.8 These buttons can be classified using keys as shown in Figures 6.1.9 and 6.1.10.

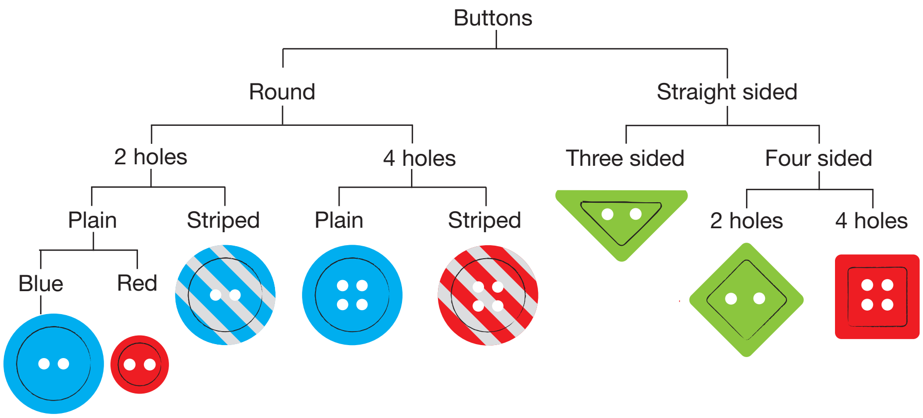


Figure 6.1.9 One possible flow chart key for the eight types of buttons

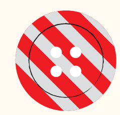
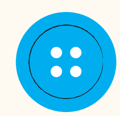
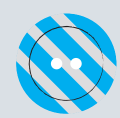
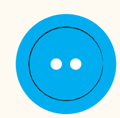
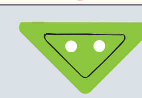
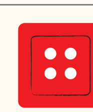
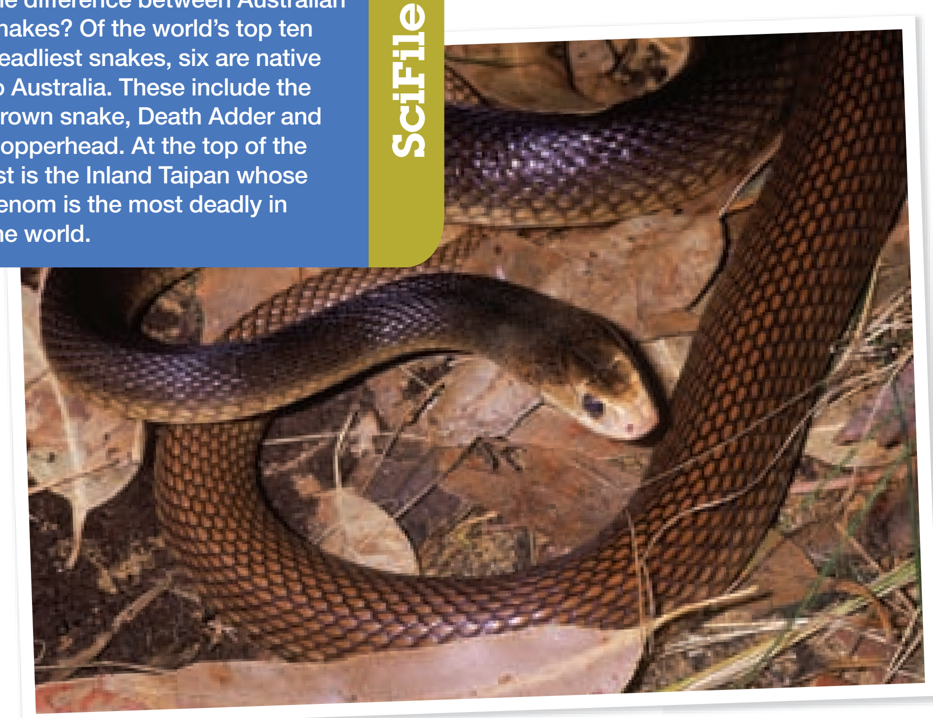
1a	Has a round shape	Go to 2
b	Has straight sides	Go to 6
2a	Has 4 holes	Go to 3
b	Has 2 holes	Go to 4
3a	Striped	
b	Plain coloured	
4a	Striped	
b	Plain colours	Go to 5
5a	Blue	
b	Red	
6a	Three-sided	
b	Four-sided	Go to 7
7a	Two holes	
b	Four holes	

Figure 6.1.10 A table key for the same buttons

Harmless or deadly?

SciFile

Is it important to be able to tell the difference between Australian snakes? Of the world's top ten deadliest snakes, six are native to Australia. These include the Brown snake, Death Adder and Copperhead. At the top of the list is the Inland Taipan whose venom is the most deadly in the world.



6.1 6.2

Strong keys

Some features or characteristics are better to use in a key than others. Size, colour and shape can change as an organism grows and develops, or may vary within the same kind of organism. Structural features make a much stronger key that can be used at any time, regardless of age of the organism. It is easy to construct a strong key for something like the buttons because they do not change. People and other living things do change with time, and if a key is to be used both now and at some time in the future then it has to use features that will not change.

Look at the two faces in Figure 6.1.11. There are two easily observed differences between these two girls. Only one has a pony tail, and therefore long hair. The other has short hair and no pony tail. One has blue eyes and the other brown eyes. You could use any of these differences to separate them in a key; however, only one of the differences would give you a strong key. The girl with the pony tail and long hair could wear her hair down or cut her hair short. The other girl could grow her hair longer. One difference will always be the same—the difference in eye colour. It is the difference in eye colour that will give you a strong key.

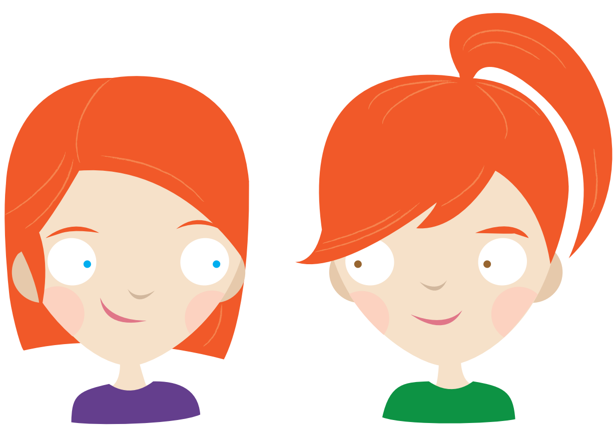


Figure 6.1.11 Characteristics for a strong key should be easy to observe and not change over time. Consider the differences you can observe between these two girls.

6.3

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WORKED EXAMPLE

Creating a dichotomous key

Problem

Use the four shapes in Figure 6.1.12 to create a dichotomous key.

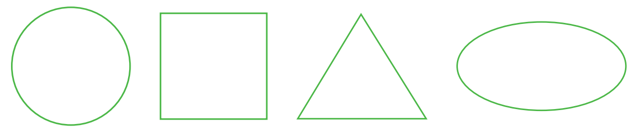


Figure 6.1.12

Solution

Both a table key (Figure 6.1.13) and a flow chart key (Figure 6.1.14) can be constructed using these shapes.

1a	Has straight sides	Go to 2
b	No straight sides	Go to 3
2a	Has four sides	Square
b	Has three sides	Triangle
3a	All diameters are equal	Circle
b	Diameters are not all equal	Oval

Figure 6.1.13 Table key

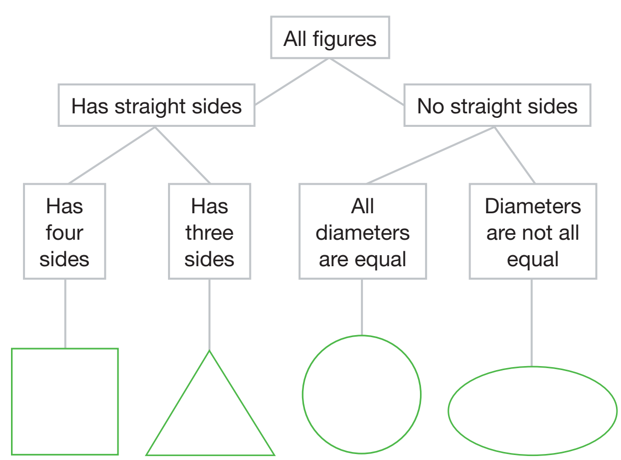


Figure 6.1.14 Flow chart key

6.1 Unit review

Remembering

1 **State** why we need to group things together.

2 **Name** the type of key where there are two choices at each step.

3 **Name** the type of scientist who names and classifies living things.

Understanding

4 **Explain** how classification makes shopping at the supermarket easier.

5 **Explain** what is meant by a *strong key*.

6 **Predict** what could happen if a key used features that were not obvious or reliable.

7 a Some plants are called *weeds* while others are not. **Describe** how you could decide whether something is a weed or not.

b Would *weed* or *not a weed* be a good alternative to use in a key? **Explain** your answer.

Applying

8 a **Use** the key shown in Figure 6.1.15 for 'Forms of transport' to **describe**:

i a motorbike

ii rollerblades.

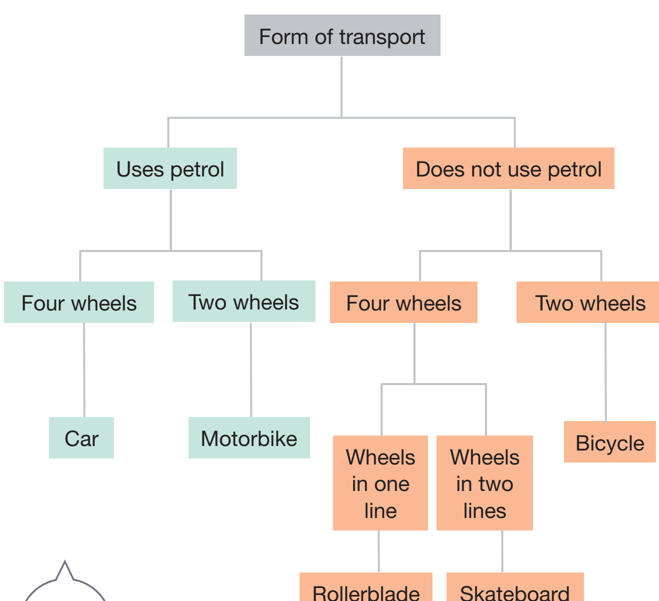


Figure 6.1.15

b **Modify** the key so that it would include a tricycle.

9 The shapes in Figure 6.1.16 could be grouped in more than one way. **Apply** your understanding of classification to suggest the best way of grouping the shapes.

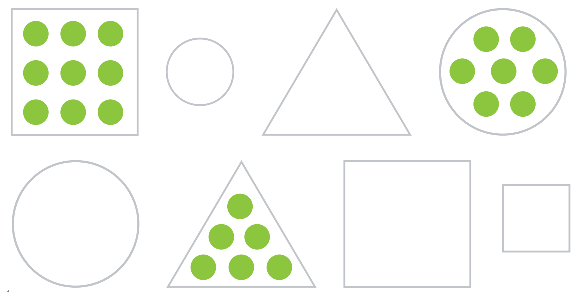


Figure 6.1.16

Analysing

10 **Classify** the following objects into three groups.

pencil	boot
book	chalk
comic	shoe
crayon	sandal

11 a **Classify** the five objects shown in Figure 6.1.17 into two groups in at least three different ways.

Figure 6.1.17

b For each grouping, **describe** the features you used for the grouping.

c **Discuss** the usefulness of each feature you chose.

12 **Compare** how easy it is to use table keys and flow charts.

13 **Analyse** the cars in a car park and list characteristics that could be used to classify them.

Evaluating

14 In the property section of some newspapers, houses are listed under their suburbs.

a **Explain** how this makes it easier for people to buy a house.

b **Propose** other ways houses could be listed.

15 a In the key shown in Figure 6.1.18, **identify** which features make it a strong key and which are not useful.

b **Justify** your decisions.

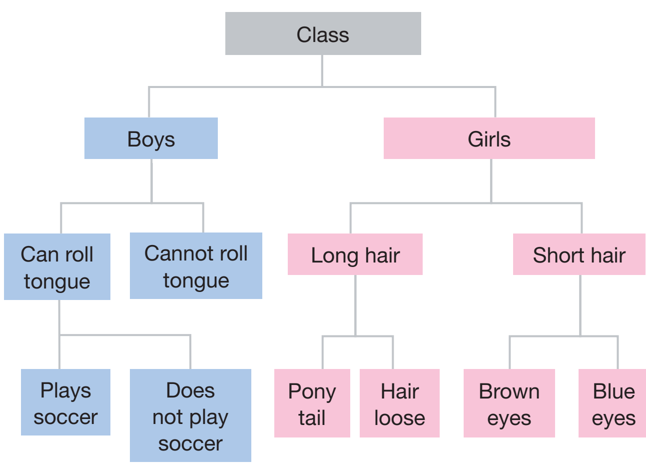


Figure 6.1.18

16 a **Identify** which of the following characteristics would be useful when constructing a key to identify varieties of dog:

- loud bark/quiet bark
- pink tongue/black and pink tongue
- short hair/long hair
- large ears/small ears
- wags tail/does not wag tail
- black/brown
- straight hair/curly hair
- hair hangs over eyes/hair not over eyes.

b **Justify** your choices.

Creating

17 **Construct** a key using these terms:

cricket	playing field
soccer	tennis racquet
chess	netball
tennis	hockey stick
squash court	

18 a **Construct** a key that could be used to identify the objects from Figure 6.1.17.

b Share your key with other members of the class. **Compare** the choices that were used.

Inquiring

1 In most newspapers there is a section for advertisements called 'Classifieds'. Find out why this is an appropriate heading.

2 Visit two or more supermarkets to research the way:

a the meat is classified

b frozen foods are classified.

6.1 Practical activities

1 Sorting leaves

Purpose

To use a variety of characteristics to sort leaves into groups.

Materials

- leaves from a variety of plants
- butcher's paper
- glue

SAFETY

Avoid collecting leaves from any plants for which you have a known allergy and from plants with stinging hairs.

Procedure

1. Collect a variety of leaves from around home or around school. Gather them from a number of different types of plants.
2. Number each leaf.
3. Sort the leaves into groups. Start with two groups, then re-sort them into three groups and then again into four groups.

Results

1. Each time you sort the leaves, describe the characteristics you used to separate the groups.
2. Decide which of the groupings best classified your leaves. Paste the leaves onto a sheet of butcher's paper or poster paper to construct a flow chart or dichotomous key showing their classification.

Discussion

1. **Explain** your reasons for choosing those characteristics.
2. a **Compare** the groupings you made and state which is the most useful grouping.
   b **Explain** your decision.

2 Class key

Purpose

To construct a dichotomous key to identify each member of the class.

Materials

- class members

Procedure

1. Brainstorm and list differences that could be used to distinguish between class members.
2. Decide if these differences would make a strong key.
3. When you have decided on the first choice, the members of the class should form the two groups.
4. For one of these groups, decide on the next choices that will allow each student to be identified.
5. Repeat for the other group.
6. Record the choice used at each step.
7. Construct the key showing this classification.
8. Some less obvious characteristics that could be used to classify the class are:
   - ability to roll tongue
   - ear lobes attached or free
   - length of second toe compared to big toe
   - dimples in cheek
   - dimple in chin
   - widow's peak.
9. Now use these characteristics to organise the class first into two groups, then four, then eight and so on.

Discussion

1. **Explain** why a class member who is absent on the day the key was created could not be identified using the class key.
2. **Predict** what would happen if you tried using the key to identify that class member.

6.2 Classifying living things

About 1.7 million different types of living things or organisms that live on Earth have been identified and described. It is easier to find products in a supermarket when they are grouped, and in a similar way it's easier to describe and talk about all the living things on Earth if they are sorted into groups. Taxonomists classify organisms into groups by using the characteristics they have in common.

INQUIRY

science 4 fun

Pasta pasta

How different are the varieties of pasta?

Yes

Collect this ...

- 6 different types of pasta

Do this ...

1 Describe each of the types of pasta, making a note of the similarities and differences.

2 Use the differences between the pastas to sort them into groups.

3 Create a dichotomous key for the pasta.

Record this ...

Describe any difficulties you had in sorting the types of pasta.

Explain why you selected the characteristics you used to create the key.

Levels of classification

The first level of classification sorts living things into a small number of groups. Each group has a very large number of organisms in it, and each organism shares important characteristics with others in their group. Although similar in many ways, the organisms in each group still have many, many differences. **Kingdom** is the name given to the group at this first level of classification.

The kingdoms are divided into smaller groups in which the organisms are more similar, as Figure 6.2.1 shows. The second level of classification is into **phyla** (singular **phylum**). In the Plant kingdom the phyla are often called **divisions**.

- Phyla and divisions are then divided into **classes**.
- Classes are divided into **orders**.
- Orders are divided into **families**.
- Families are divided into **genera** (singular **genus**).
- Genera are divided into **species**.

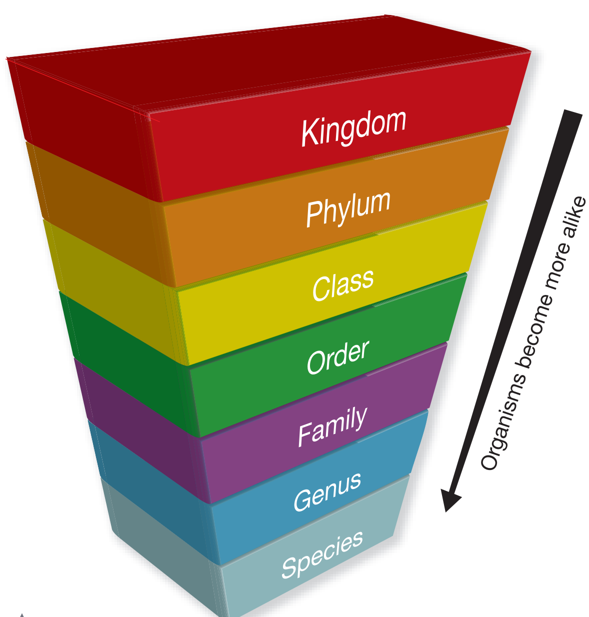


Figure 6.2.1 Organisms are classified first into broad groups—kingdoms. At each level of classification below the level of kingdom, the groups contain fewer types of organisms and the organisms become more similar.

Moving down through the levels in the classification system, the groups become smaller in that they have fewer types of living things in them. Figure 6.2.2 shows how organisms become more similar as you move through the levels of classification.

Organisms of the same species are most similar, but they are not identical. Look around at the people in your classroom or in the street. All the individuals in Figure 6.2.3 belong to the same species (*Homo sapiens*), but you can easily see that they are not all identical.

WORKED EXAMPLE

Creating a mnemonic

A mnemonic is a way of helping you remember things. One way of trying to remember a list is to make a sentence with each word starting with the first letters of the list words. For example, you could use a mnemonic to remember the order of the groups in biological classification.

Keep	Placing	Cake	Orders	For	Good	Students
Kingdom	Phylum	Class	Order	Family	Genus	Species

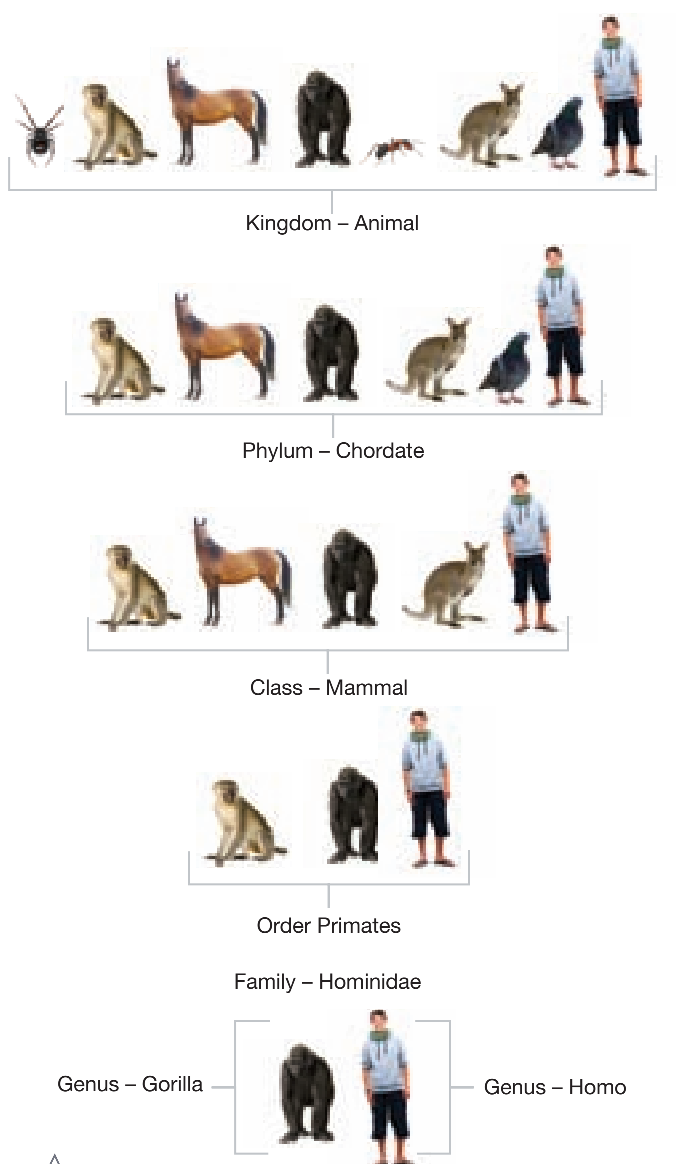


Figure 6.2.2 Gorillas and humans are the two animals in this group that have most characteristics in common.

Figure 6.2.3 All humans belong to the one species but they are not all identical.

Kingdoms

Some of the kingdoms contain organisms that are familiar to you. Some are shown in Figures 6.2.4–6.2.6. You could probably produce a long list of animals, ranging from kangaroos to rosellas and snakes. You are also probably familiar with plants as a group, although you may not know as many of their names.

It is likely that you will have seen fungi in the form of the mushrooms you eat, mould that grows on old bread, and the bracket fungi sometimes seen on rotting wood.

You are less likely to be familiar with the other two kingdoms—Monerans and Protists—because they contain organisms that can only be seen using a microscope.

You should have no difficulty placing cows in the animal kingdom and recognising grass as a plant. However, some organisms have unusual sets of characteristics or are very tiny. These organisms cannot be classified as easily. For this reason scientists look at the basic units of life—the cells—to find features that allow them to sort organisms into groups.

Figure 6.2.4 The boy and his dog are both members of the Animal kingdom, as are the frog and the bee sitting on its head.

Figure 6.2.5 The tall trees and the ferns growing under them are members of the Plant kingdom. So is the Sturt's Desert Pea, pictured right, the state flower of South Australia.

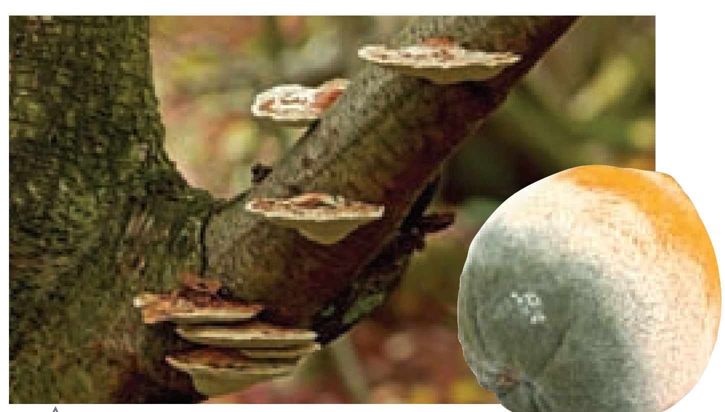


Figure 6.2.6 You may have seen fungi such as these bracket fungi on the trunks of dead trees. The blue-green mould growing on this orange is also a fungus.

Cells are the building blocks of all living things. Most cells are microscopic. This means they are so small that they can only be seen using a microscope. When they are magnified you can see that cells from different living things are organised differently. The characteristics that are used to place organisms into the five kingdoms are listed in Table 6.2.1.

Fungi

Some fungi can be seen without a microscope, while others (such as the yeast in Figure 6.2.7) are unicellular microscopic organisms, being made of just one cell.

Figure 6.2.7 Yeast is a unicellular fungus used in the manufacture of beer and to make bread rise. The photograph here shows the cells magnified ×2260.

Fungi cannot make their own food, and therefore they must feed on other organisms. Fungi are the main cause of decay (or rotting) in fruit and vegetables. Fungi are **decomposers** responsible for breaking down wastes like faeces and dead organisms and returning the nutrients they contain to the environment.

Fungi are the source of some medicines. For example the antibiotic penicillin is prepared from *Penicillium*, a blue-green mould. Penicillin is used to fight bacterial diseases.

Protists

Most organisms in the Protist kingdom live in water. One type is shown in Figure 6.2.8. The protists are more diverse than any other kingdom, and they are grouped together because they do not fit any other kingdom.

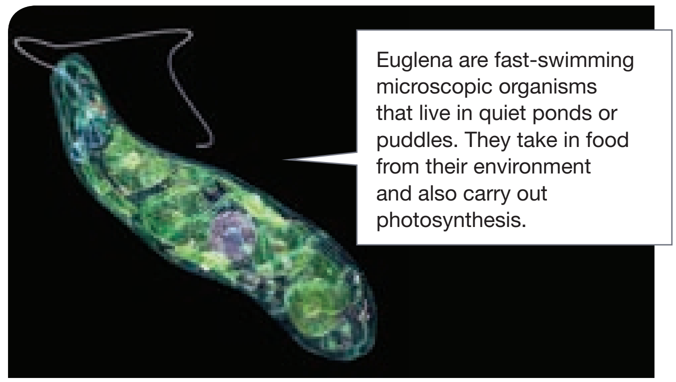
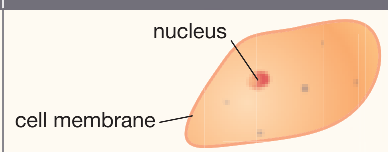
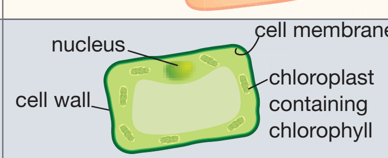
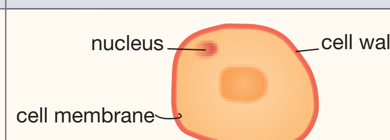
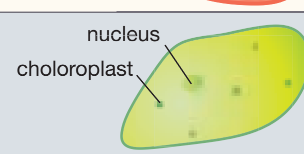
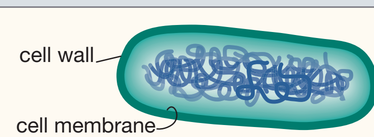


Figure 6.2.8 At their front end Euglena have a single whip-like tail known as a flagellum that pulls the cell through the water, like a propeller pulling an aeroplane through the air.

Table 6.2.1 Characteristics of the five kingdoms

Kingdom	Characteristics		Examples
Animal	Get their energy by feeding on other living things. Made up of many cells.		Pelican, human, frog, spider, jellyfish
Plant	Make their food by photosynthesis using sunlight, water and carbon dioxide. Made up of many cells.		Grass, daisy, gum tree, moss
Fungi	Feed mostly on dead material from other living things. Can be made up of many cells, or a single cell.		Moulds, toadstools, mushrooms, yeast
Protist	Plant-like and animal-like single-celled organisms.		Protozoa, algae
Monera	Very simple and small microscopic single-celled organisms.		Bacteria and cyanobacteria

Protists vary in the way they move, the way they feed, and how they live. Some contain the green pigment chlorophyll and can make their own food. Others catch and eat food from the water around them. Protists in turn become an important source of food for many aquatic organisms. Most protists are not harmful to humans, but some cause disease. These diseases tend to be more common in tropical climates. For example, amoebic dysentery, which causes severe pain and diarrhoea, is caused by drinking water contaminated with protists.

Some protists such as Volvox (Figure 6.2.9) form colonies. Algae are protists made up of many cells. They are different from Volvox, as many of their cells have special jobs to do associated with tasks such as reproduction and attaching the algae to rocks. Algae (like the one in Figure 6.2.10) are placed in the protist kingdom only because they do not fit in any of the other kingdoms.

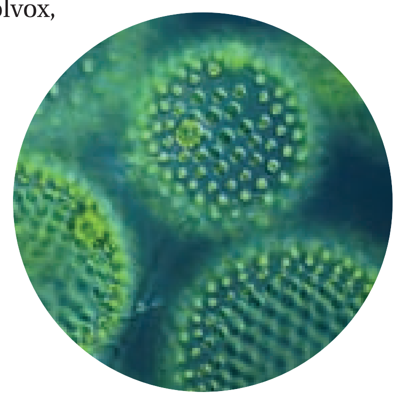


Figure 6.2.9 Some protists such as this Volvox live in colonies. Each individual has flagella and chloroplasts and can make its own food. The cells are held together by a jelly-like substance, and they all swim around together using their flagella in a coordinated way.

Figure 6.2.10 Seaweeds such as this giant kelp (*Macrocystis pyrifera*), an alga, are protists are made of many cells.

Monera

The kingdom Monera includes all the organisms known as bacteria. You can see some bacteria in Figure 6.2.11. Monera is so diverse that some taxonomists believe it should be divided into two kingdoms or even into three major groups.

Many people associate bacteria with disease and infections, but most bacteria are harmless and some are actually good for you. *Lactobacilli* are bacteria that occur naturally in dairy products. Bacteria also live in your intestines where they help your digestion. Along with fungi, bacteria are decomposers responsible for breaking down wastes and returning the nutrients they contain to the environment.

Figure 6.2.11 Bacteria belong to the kingdom Monera. The bacteria here have been magnified and the photo coloured so that they can be seen clearly.

Most bacteria rely on other organisms for their food. Examples are the decomposers and the bacteria that live inside your body. However, bacteria such as cyanobacteria or sulfur bacteria make their own food.

Bacteria live in many different places, ranging in temperature from hot springs (Figure 6.2.12) where the temperature reaches 300°C, to the ice fields of Antarctica.

1 p215
2 p215

Figure 6.2.12 The water in this bubbling geyser is very hot. Bacteria able to live in temperatures between 50° and 60°C form a brown scum at the edge of the water.

Naming species

People have always given names to the organisms that are important to them. People living in different areas often had different names for the same organism.This leads to confusion when trying to communicate their knowledge of plants and animals to others outside their local area.

For example, the introduced European plant with the common name 'purple bugloss' (Figure 6.2.13) has become a major weed in many parts of Australia, especially New South Wales, Western Australia and Victoria. As it spread it has become known under different names. It is still known as purple bugloss but other common names now include riverina bluebell, Salvation Jane, Paterson's curse, blueweed, blue echium, Lady Campbell weed, plantain-leaf, viper's bugloss, and purple peril. Scientists avoid confusion by using only one scientific name for the plant—*Echium plantagineum*.

Figure 6.2.13 *Echium plantagineum* has many common names but only one scientific name.

Scientific naming

When scientists discover a new organism they observe it carefully, describe it, look for ways that it is similar to species they know, and then decide which group it belongs to. Once this has been decided they give it a name. The name will be used by all scientists throughout the world. It does not matter which country they come from or which language they speak. Scientists all use the same biological name to describe a particular organism.

The name given to a newly described organism is not random. Taxonomists use a naming system that gives every species a unique two-part name. The first part of the species name tells you the genus to which the organism belongs, and always starts with a capital letter. The second part tells you the species within that genus. This part of the name always starts with a lower case letter. When the names are typed, italics are used. When names are written, they are underlined.

For example, *Panthera leo*, *Panthera onca*, *Panthera pardus* and *Panthera tigris* (Figure 6.2.14) all belong to the same genus. They all have the same first part to their name. If they are in the same genus they must be fairly similar to each other. However, they are not all the same species. You can tell that because the second part of their name (their species name) is different. You are more likely to recognise the animals by their common names: lion, jaguar, leopard, and tiger.

6.4

Figure 6.2.14 All these species belong to the same genus, *Panthera*.

SCIENCE AS A HUMAN ENDEAVOUR

Nature and development of science

Naming living things

Figure 6.2.15 Linnaeus renamed the carnation so that it had only two names: *Dianthus caryophyllus L.*

Carle von Linné was born in Sweden in 1707. He made changes to the way living things were classified and named. Three hundred years later taxonomists still use his ideas.

Figure 6.2.16 Carolus Linnaeus developed the binomial system for naming living things.

From a very early age Carle von Linné loved studying the living things in his garden and in the fields around his home. Like all educated people in Europe at that time, he wrote all his scientific work in Latin. He loved the Latin language so much that he even changed the spelling of his name to the Latin form Carolus Linnaeus, and it is by this version of his name that he is remembered. He is pictured in Figure 6.2.16.

As a young man Linnaeus travelled throughout Lapland, collecting, describing and naming species. He collected over one hundred dried and pressed specimens that were new to science.

The method that Linnaeus and other scientists of his time used to name these new species used a genus name followed by a description. As more and more types of organisms were discovered, it became increasingly difficult to come up with a unique description for them. For example, *Canis* is the genus name for a dog (a canine). If a new species of dog was found in the woods, then it could be the 'canine' that 'lives in woods'. If another canine was found living in the woods it would have to be described differently.

It could be the 'canine' that 'lives in woods; dark coat in winter; found only in the north'—and so the names expanded.

As an example, a carnation needed nine words to describe it: *Dianthus floribus solitaris, squamis calycinus subovatus brevissimis.* It literally means the dianthus (or carnation) with a single flower within a scaly, short calyx which is below the ovary.

Linnaeus thought that there must be a better system. He organised the classification of organisms into a hierarchy, with kingdom at the top and species as the lowest level. The name given to an organism would be the name of the genus to which that organism belonged, followed by one descriptive name for the species—each living thing would only have two names. With this, binomial naming (also known as binomial nomenclature) was born. Instead of the carnation having nine names, it now has two. It is known as *Dianthus caryophyllus L*. The L. after the name tells us that the species was named by Linnaeus.

Latin was used as the language for naming because it was a language then understood by all well educated people throughout Europe. Also, it was not a spoken language, and therefore the meanings of the words did not change. Words develop slightly different meanings and spellings over time when a language is spoken. This does not happen in Latin.

Binomial nomenclature is now used internationally regardless of the language spoken in the country the organism or scientist comes from. The system has been used for plants since 1753, for animals since 1758, and for bacteria since 1980.

Linnaeus never stopped working and eventually named 4235 species of plants and about 6000 species of animals. He also wrote letters to others interested in studying plants. For example, Linnaeus corresponded with the botanist Joseph Banks, who sailed to Australia with Captain Cook on the *Endeavour* (Figure 6.2.17) in 1768.

Figure 6.2.17 Banks and Solander sailed to Australia on the *Endeavour* with Captain Cook.

Also on board was Daniel Solander, one of Linnaeus's students. Between them Banks and Solander collected more than 1000 species of plants new to science.

6.5

SciFile

Revenge!

After an argument with the French scientist Georges Louis de Buffon, Linnaeus named a stinky weed after him! He gave it the genus name *Buffonia*.

6.2 Unit review

Remembering

1 **State** the number of kingdoms in the system of classification used in this book.

2 **List** the names of the kingdoms.

3 **Name** the building block of all living things.

4 **Name** the level of classification in which organisms are most similar.

5 **List** the levels of classification in order from the one that has the largest number of types of organism to the one that has fewest.

6 **Name** the system used by scientists to name species of organisms.

Understanding

7 The two animals in Figure 6.2.18 look very different. Refer to Table 6.2.1 to **explain** why they are both classified as animals.

Figure 6.2.18

8 a **Describe** the characteristics that cause plants and animals to be placed in separate kingdoms.
  b **Describe** the characteristic that plants and fungi have in common.
  c **Explain** why plants and fungi are in different kingdoms.

9 **Describe** some of the difficulties that could arise if only common names were used for plants and animals.

10 **Describe** the features of the organism shown in Figure 6.2.19 that you could use to classify it.

Figure 6.2.19

11 **Describe** one problem and one benefit that fungi can bring.

12 a **Explain** what the words *binomial nomenclature* actually mean.
  b **Explain** why it is an appropriate description for the system scientists use to name living things.

Applying

13 Below are the names of four organisms:

- *Acacia gunnii*
- *Tristania conferta*
- *Eucalyptus gunnii*
- *Acacia conferta.*

Although you probably do not know what the organisms look like, **identify** which ones are most closely related.

14 **Demonstrate** how biological names should be written by rewriting these names correctly. In each example, the genus and species are in the correct order.
  a *Pan Troglodytes*
  b homo sapiens
  c *banksia Robur*

15 One organism was described as macroscopic. Another organism was described as microscopic. **Identify** the main difference between them.

Analysing

16 Explorers in a previously unknown area have found some very strange organisms. These are some descriptions from one of their notebooks. **Classify** these organisms into their correct kingdom.

- **a** The organism was very small, about the size of a pin head. When I looked at it under a microscope, I could see that it was made of many cells that did not appear to have any walls.
- **b** The organism was shaped like a semicircle with a radius of about 8 cm. It was found on the side of a tree. Looking through the microscope, I could see many cells that all looked very much alike. There was a distinct cell wall. The cells were colourless.
- **c** The organism was seen when I looked at some water under a microscope. It was still very small when I had the microscope on the highest power. I could see that the organism was unicellular but I could not see a distinct nucleus.

17 **Compare** the two kingdoms Protists and Monerans.

Evaluating

18 Four organisms A, B, C and D all belong to the same kingdom.

A and D belong to the same class.

A and C belong to the same genus.

B and C belong to the same order.

- **a** **Deduce** which two organisms are most alike.
- **b** Use this information to answer the question 'Do organisms A and B belong to the same order?' **Justify** your decision.

Creating

19 **Construct** a concept map showing the characteristics of the five kingdoms.

Inquiring

1 Research the history of the species *Echium plantagineum* in Australia and find out why it has the common names of Salvation Jane and Paterson's Curse.

2 *Giardia* is a protozoan with two nuclei and is an intestinal parasite. *Euglena*, also a protozoan, moves by using a flagellum but also contains chloroplasts and manufactures its own food by photosynthesis. Slime moulds, such as *Physarum polycephalum*, behave like amoebas, can be seen without using a microscope and have many nuclei. Scientists include these organisms and many others in the Protist kingdom. Research these and other unusual protists, then debate approaches to their classification.

3 Questions 13 and 14 give the biological names of some organisms. Use your research skills to find out what types of organisms they are. For example, the *Acacia* shown in Figure 6.2.20 is also known as wattle.

Figure 6.2.20 *Acacia* is a genus that is commonly called wattle.

6.2 Practical activities

1 All kingdoms are useful

Purpose

To use research and presentation skills to gather information about the kingdoms.

Materials

- library and internet resources

Procedure

1. Choose one of the five kingdoms.
2. Use your research skills to find out:
   a. ways in which representatives of that kingdom are useful to humans
   b. ways in which they cause problems for or are harmful to humans.
3. Use your information to suggest what could happen to the world if all the organisms in that kingdom were to suddenly become extinct.
4. Create a poster or PowerPoint presentation of your ideas.

Discussion

1. Select and **describe** the most interesting thing that you found out about the kingdom you researched.
2. Select and **describe** the most surprising thing you discovered.
3. **Propose** ideas about whether or not we could survive in our world without these kingdoms.
   a. Monera
   b. Protist
   c. Fungi
   d. Plant

2 Pictorial key

Purpose

To create a picture wall that represents the kingdoms.

Materials

- digital camera or mobile phone with inbuilt camera
- sticky-tape or Blu Tack
- cardboard
- marker pen

Procedure

1. Brainstorm where it would be possible to find representatives of the five kingdoms.
2. Decide which kingdoms you will be able to photograph for yourselves.
3. Make a name card for each of the kingdoms and attach it to the wall.
4. Organise people in the class to take photographs around school or at home.
5. Take photographs of different representatives of each kingdom and attach them to the wall under the name card. Try to get at least three or four photographs for each kingdom.
6. Try to sort the photos within the plant and animal kingdoms into smaller groups. You could also add information about the classification of the organism to the back or underneath the photograph.

Discussion

1. **Compare** the number of photographs you have for each kingdom.
   a. **State** which kingdom was most difficult to photograph. **Explain** why this was so.
   b. **State** whether there was a kingdom that you could not photograph for yourselves. **Explain** why you couldn't.
   c. **State** which kingdom was the easiest one to photograph. **Explain** why this was so.
2. **Describe** the photograph you find most interesting. **Explain** why it interests you.
3. **Discuss** whether your photographs truly represent the variety of organisms in that kingdom.

6.3 Animals and plants

Plants and animals are the organisms that you are probably most familiar with. Think about the animals such as fish, starfish, sea anemones or coral you have seen in rock pools, or the trees, possums and birds in the suburbs. These familiar organisms are only a small part of the 1.25 million animals and 400 000 plants that scientists have described.

INQUIRY science 4 fun

Evidence of animals

Yes

Can you tell if animals are around even if you cannot see them?

Possums made all these scratch marks as they climbed the tree.

Collect this ...

- a magnifying glass (optional)
- notepad and pen or digital camera.

Do this ...

1. Make careful observations as you walk to and from school, wander round the school grounds, go to a park, beach or for a walk in the bush.
2. Record evidence that animals have been there. The evidence could include: holes in leaves where they have been eaten, footprints, soil and gravel thrown up by ants making a nest, scratches on bark where claws have been used to climb trees, and shells or crab sand balls on the beach.

Record this ...

Describe the place or places where you saw most evidence of animal activity.

Explain why the animals were likely to have been there.

Animal phyla

Animals are often described as **vertebrates** (animals with backbones) or **invertebrates** (animals without backbones). Although this difference is very important, these terms are not always used in the scientific classification of animals. Scientists have made a large number of observations of living things. The presence or absence of a backbone is only one of the observations. Using the similarities and differences these observations reveal, scientists have grouped all the known members of the animal kingdom into the nine phyla shown in Figure 6.3.1.

Animals
- Poriferans
- Cnidarians
- Echinoderms
- Nemotodes
- Platyhelminths
- Molluscs
- Arthropods
- Chordates

Figure 6.3.1 Eight of the animal phyla in this key do not have backbones. The phylum Chordates includes all the animals with backbones.

Poriferans

Poriferans live in the water and most are found in marine environments. They are commonly called sponges because they are full of holes (pores) through which water passes, carrying their food. They filter the food out of the water, and for this reason they are known as filter feeders. The wastes along with water are pushed out through an opening at the top of the sponge. A typical sponge is shown in Figure 6.3.2.

Figure 6.3.2 This yellow tube sponge grows to about 80 cm tall. It pushes so much water through its body as it feeds that divers can feel a current of water if they place their hands near the top of the sponge's tube.

Cnidarians

Cnidarians have radial symmetry. Jellyfish, sea anemones and coral polyps belong to this phylum. They have only one body opening. Food goes into the body through this opening and waste comes out of the same opening. Cnidarians all have stinging cells, which they use to catch their food. Cnidarians are not interested in using humans for food, but the poison from their stinging cells will cause you intense pain (and in some cases could kill you) if you get tangled in their tentacles. Figure 6.3.3 shows one particularly deadly species of cnidarian.

Figure 6.3.3 The venom produced by the stinging cells of the box jellyfish (*Chironex fleckeri*) is one of the most poisonous in the animal kingdom. The poison causes the animals that tangle in the tentacles to have a heart attack. This can happen to humans too. The box jellyfish is responsible for 100 human deaths per year.

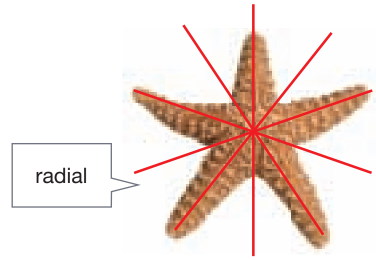
SKILL BUILDER

Symmetry in organisms

Organisms are often described as having radial symmetry or bilateral symmetry.

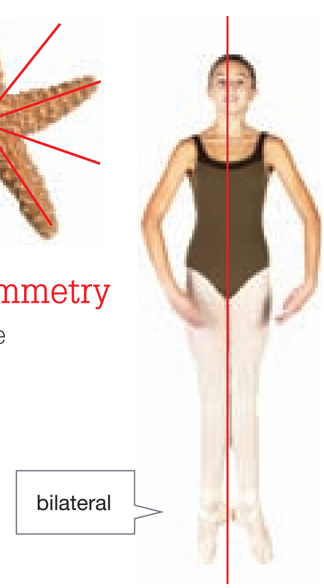
Radial symmetry

A cut in any direction through the middle will result in identical halves.



Bilateral symmetry

There is only one position where a cut produces identical halves.



Echinoderms

Echinoderms also live in the ocean, often near the coast. Starfish, brittlestars, sea urchins and sea cucumbers belong to this phylum. Starfish, brittlestars and sea urchins have a spiny skin, which you can see in Figure 6.3.4, but the skin of sea cucumbers is leathery. One thing common to all Echinoderms is that they have radial symmetry.

Figure 6.3.4 There are over 6000 species of echinoderm. This picture shows two species: an orange starfish, and the black spines of a sea urchin. All echinoderms have a chalky layer under their skin, which forms a protective armour.

Annelids

Annelids are found in water and in damp places on land. The most familiar annelid is the earthworm, shown in Figure 6.3.5. Look closely and you will see rings along the length of its body. These rings are segments or divisions within the body, and give the group their common name of 'segmented worms'. These animals have bilateral symmetry. Other annelids are leeches and ragworms (often used as bait for fishing).

Figure 6.3.5 Annelids have two body openings—one at the front where food enters and one at the back from which wastes leave.

Nematodes

Nematodes are also called worms, but they do not have segments. They are 'round worms'. They have bilateral symmetry like annelids, with long tapered bodies that are pointed at each end. They are commonly found in damp soil, in water, and as parasites in the bodies of other organisms. **Parasites** are organisms that live on or in another organism, called a host. They get their food from the host, but the host gets nothing in return and may be harmed. Heart worm, a common disease of dogs, is caused by a nematode. Even humans can be hosts to parasitic nematodes, like the one shown in Figure 6.3.6.

Figure 6.3.6 *Ascaris lumbricoides* is a parasitic nematode that inhabits the human intestine. They can grow up to 35 cm in length. You would know if you were infected with them because they cause stomach pain, vomiting and diarrhoea.

Platyhelminths

Platyhelminths also have worm as part of their common name—they are flat worms. They have bilateral symmetry with the body flattened top to bottom (Figure 6.3.7). They live in water or very moist places.

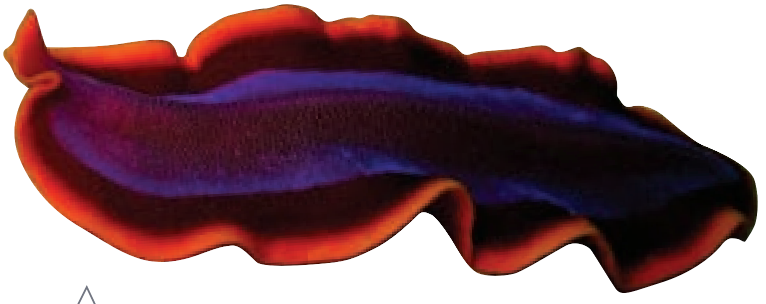


Figure 6.3.7 There are over 12 000 species of platyhelminths. Some are scavengers, cleaning up the wastes in the oceans and waterways, some eat microscopic animals, but many are parasites.

Molluscs

Molluscs are members of the second largest phylum in the animal kingdom. All of them live in water or in very moist places. Snails, slugs and oysters belong to this group. They come in a wide variety of shapes and sizes, but all have bilateral symmetry, have well developed internal organs, and have a muscular foot which they can use to move along. Some molluscs have a shell for protection like that in Figure 6.3.8.

Figure 6.3.8 The protective shell of the snail is clearly visible. What cannot be seen is the rough tongue-like structure the snail uses to rip apart the leaves on which it feeds.

Arthropods

Arthropods are found everywhere—on land, in the air and in water. They are the largest animal phylum, with over one million species described. Arthropods are able to survive on dry land because they have a waterproof **exoskeleton**—a skeleton on the outside of the body. The skeleton does not bend, so the limbs of arthropods (legs and antennae) are jointed to allow the animals to move. Inside, the body is divided into segments. These are sometimes visible as lines across the exoskeleton. The spider in Figure 6.3.9 is an example of an arthropod.

6.6

Figure 6.3.9 Flies and spiders, crabs, prawns and millipedes are all arthropods.

Chordates

Most of the larger animals you see around you can be described as vertebrates. Dogs, cows, birds, fish and humans are all vertebrates. All vertebrates belong to the same phylum, the **chordates**.

Chordates have a nerve cord running down their backs, which gives this group its name. Most chordates have skeletons inside their body (an **endoskeleton**), and most of the chordates have a series of small bones protecting the nerve cord. The small bones are called **vertebrae**, and together they are called the **vertebral column** or backbone. The group of chordates that has a backbone is commonly called the vertebrates. The bird shown in Figure 6.3.10 is an example of a chordate.

Figure 6.3.10 Birds are examples of chordates. They have a spine and spinal cord.

SciFile

Spineless?

All chordates have a nerve cord but not all have a backbone to protect it. Some have a rod of cells known as a notochord lying below the nerve cord. Adult sea squirts look just like a bag of jelly. They filter food from the water and then squirt out the water when they are finished with it.

All chordates have bilateral symmetry. They are divided into classes based on a range of characteristics that includes the way they breathe, their skin covering, body temperature, and how they reproduce. The seven classes of chordates are shown in Figure 6.3.11.

Chordates
- Chordates without backbones
- Agnatha
- Chondrichthyes
- Osteichthyes
- Amphibians
- Reptiles
- Aves
- Mammals

Figure 6.3.11 Classes of chordates

There are three classes of chordates that are commonly called fish: Agnatha, Chondrichthyes and Osteichthyes. They all live in water and breathe using gills. They are **ectothermic**, which means that their body temperature varies with the temperature of the water they live in.

Agnatha

The **agnatha** are jawless fish. There are many fossils of jawless fish, but the only living representatives are hagfish and lampreys like the one in Figure 6.3.12. They have an internal skeleton made of **cartilage**. This is more flexible than bone—it is cartilage in the wobbly bit at the end of your nose. Agnatha have a fin along their backs. Their mouth is a round sucker, lined with horny teeth as shown in Figure 6.3.12, which they use to attach themselves to other fish. All agnatha are parasites.

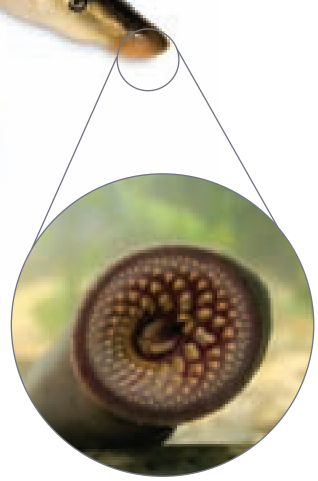


Figure 6.3.12 Lampreys are shaped like an eel. Their mouth (shown right) is like a suction cup that attaches the parasite to its host. The horny teeth inside the sucker scrape the skin away so that the lamprey can suck blood.

Chondrichthyes

Sharks and rays belong to the class of chordates called **Chondrichthyes**. Their skeleton is also made of cartilage, which gives them their common name of cartilaginous fish. Unlike the jawless fish, they have proper jaws and teeth. Sharks and rays have fins on the side of their bodies as well as along their backs as shown in Figure 6.3.13, and this helps them to be agile swimmers.

Figure 6.3.13 Rays are members of the class Chondrichthyes. Their side fins are extended to resemble wings.

Osteichthyes

The **osteichthyes** are also fish. They have fins on the back and sides of their body and have proper jaws and teeth. What makes them different is their skeleton. It is made of bone, and they are known as the bony fish. Tuna, goldfish, eels, sea horses and lungfish all belong to this group. Figure 6.3.14 shows a barramundi, an example of a bony fish.

Figure 6.3.14 The barramundi (*Lates calcarifer*) is found in river estuaries and in the ocean around the north of Australia, from Fraser Island in the east around to Shark Bay in the west.

Amphibians

Amphibians are chordates that live both in and out of water. Their eggs are laid in water, and the larvae or tadpoles must live in water because they breathe through gills. The body then changes shape in a process called metamorphosis, allowing the adult to live on land, breathing air using lungs. Their lungs are not very effective, and amphibians also take oxygen in through their skin. To be able to do this the skin must remain moist. Frogs like the one shown in Figure 6.3.15, toads, newts and salamanders are all amphibians.

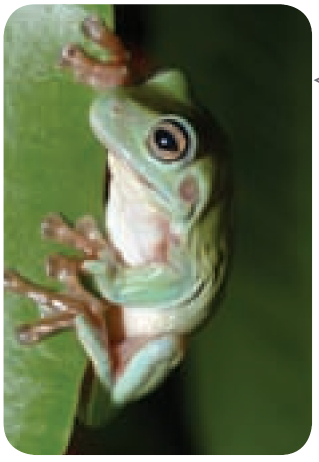


Figure 6.3.15

Amphibians must keep their skin moist, and usually live near water or in very moist places. They are all ectothermic, and therefore they are not found in very cold areas.

Reptiles

Reptiles such as snakes, crocodiles and lizards are ectothermic, and have a dry, scaly skin. They breathe using only their lungs. Generally they lay eggs with a leathery shell on land. While most spend their whole life cycle on land, there are exceptions. Sea snakes like the one shown in Figure 6.3.16 spend all their lives in water, and some cannot move on land at all. Sea snakes do not lay eggs; instead they give birth to live young. Some land snakes and lizards also do this.

Figure 6.3.16

The olive sea snake (*Aipysurus laevis*) is a very poisonous organism found in the ocean off northern Australia from Brisbane (Queensland) to Shark Bay (Western Australia).

Aves

Aves is the biological name for birds. Birds are different from other groups because they have feathers covering their body and lay hard-shelled eggs. All birds have wings, including those that can't fly, like the penguins in Figure 6.3.17. Bats are the only other chordates with wings. Birds are **endothermic**, meaning that they generate their own heat and are able to control their body temperature. This allows them to remain warm in cold environments.

Figure 6.3.17

Most birds can fly, even birds as big as flamingos (*Phoenicopterus roseus*). Although penguins, such as this Humboldt penguin (*Spheniscus humboldtii*), cannot fly on land, they move their wings to swim in the same way as other birds move their wings to fly. Penguins are, in effect, flying underwater.

Mammals

The class **Mammals** includes all the animals that have a body covering of hair, and feed their babies on milk produced by the mother. Like birds, mammals are endothermic. Mammals are divided into three subclasses based on the way they reproduce. All three of these subclasses are represented by animals found in Australia.

- **Placentals** are mammals in which the baby is nourished inside the mother's body by a placenta and the baby is born at a more mature stage. Placental mammals include seals, dingos, horses and humans, as well as the flying fox and humpback whale shown in Figure 6.3.18.
- **Monotremes** lay eggs; this subclass consists of two species of echidna (an example is shown in Figure 6.3.19) and the platypus.
- **Marsupials** such as the wombat in Figure 6.3.20 give birth to a tiny undeveloped young that climbs into the pouch where it is fed on milk. The young marsupial grows and completes its development in the pouch.

1 p229

Figure 6.3.19 A short-beaked echidna (*Tachyglossus aculeatus*) is a mammal that lays eggs—a monotreme. Monotremes are found only in Australia and New Guinea.

Figure 6.3.20 The hairy-nosed wombat (*Lasiorhinus krefftii*) is one of the 140 species of Australian marsupials. Most of the world's species of marsupials are Australian.

Figure 6.3.18 The grey-headed flying fox (*Pteropus poliocephalus*) and the humpback whale (*Megaptera novoaeangliae*) are placental mammals found in Australia or in

SciFile

Big whales

In a list of the largest mammals in the world, whales occupy the top spots. The largest of these is the blue whale. It can have a mass of 190 000 kg! The heaviest land animal is the African elephant, at a mere 5000 kg.

SCIENCE AS A HUMAN ENDEAVOUR

Nature and development of science

Is this a real animal?

Figure 6.2.21 When explorers first described a platypus it caused problems for taxonomists.

Leading up to the seventeenth century, naturalists in Europe had described, named and classified many living things. They were confident that they understood the animal kingdom and that their classification system would be able to include any new species that were discovered. Explorers to Africa and America tested these ideas by bringing back creatures never seen before, such as giraffes, hippopotamuses, armadillos and opossums. A bigger stir was yet to come!

Figure 6.3.22 Animals such as the armadillo (*Dasypus novemcinctus*) and the hippopotamus (*Hippopotamus amphibius*) tested European scientists' systems of classification.

In 1798 the Governor of New South Wales, John Hunter, watched an Aboriginal hunter spear a small amphibious creature in the Hawkesbury River, near Sydney. Hunter sent the skin to England, where scientists described this strange creature as having characteristics of a fish, bird and quadruped (four-footed animal). It was about the size of a cat, had a bill like a duck, four short legs, and webbed feet. They had not seen anything like it before and it did not fit into their classification system.

Figure 6.3.23 Using dried skins like this one, European scientists tried to imagine what a platypus looked like and how it lived. It is not surprising that they were confused at first.

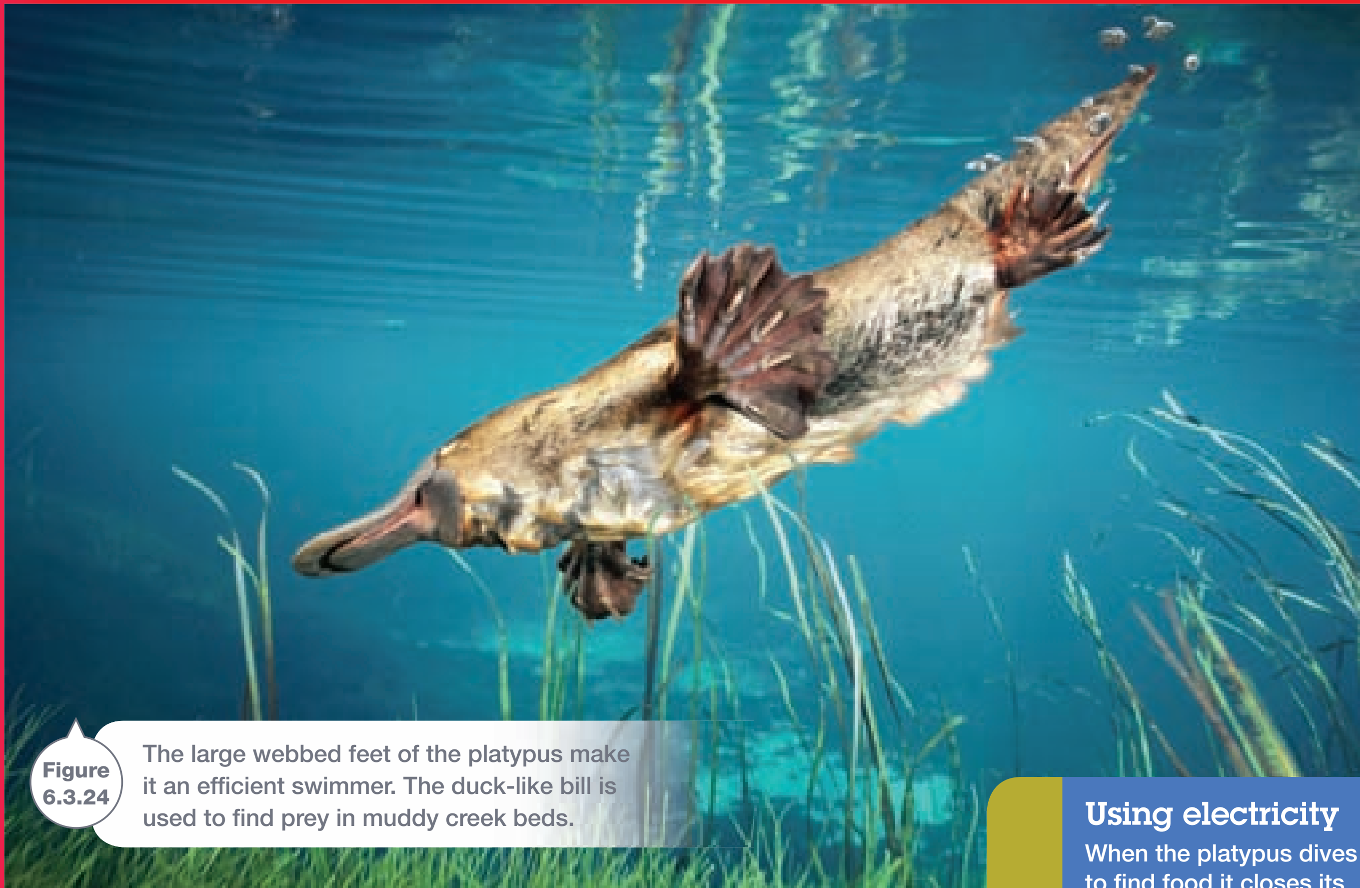


Figure 6.3.24 The large webbed feet of the platypus make it an efficient swimmer. The duck-like bill is used to find prey in muddy creek beds.

Other specimens of skins and skeletons arrived and were examined by Dr George Shaw, an experienced naturalist. He wondered if the animal was a hoax or trick. At that time, Chinese sailors had a reputation for their skill in stitching together parts of different animals to create a non-existent animal that they then sold to European sailors. Despite very close examination, George Shaw could not find any evidence of this being a hoax. There were no cut marks or stitched parts.

When complete, preserved specimens arrived in 1800, accompanied by descriptions from people who had observed the animal, Shaw was able to confirm that the animal was no hoax and no freak of nature. It was a new type of animal, a new genus. The question then became whether it was a mammal. The animal:

- had fur like a mammal
- was warm-blooded (endothermic) like a mammal and a bird
- had a beak like a bird
- lived in water like an amphibian.

At this stage the scientists did not know that the platypus laid eggs (like a bird or reptile) and produced milk for its young (characteristic of a mammal). It was many years before scientists were able to gather all the information they needed to describe this new animal in detail and decide how to classify it. A new group of mammals was created—the monotremes. This includes the platypus and echidna.

The animal that we now know as the platypus has had a variety of names:

- different Aboriginal nations called it *boondaburra*, *mallingong* or *tambreet*
- early European settlers called it the water mole
- George Shaw described it as *Platypus anatinus* (meaning flat-footed and duck-like)
- Johann Blumenbach, a German naturalist, described the platypus at a similar time to George Shaw but named it *Ornithorhynchus paradoxus* (meaning a puzzle with a bird-like nose).

An organism can only have one scientific name, so one of the scientific names had to go. 'Platypus' had been used as the name of a genus of beetle, which meant it could not be used again. The names were combined and so the animal is now known as *Ornithorhynchus anatinus*. It is shown in Figure 6.3.24.

SciFile

Using electricity

When the platypus dives to find food it closes its eyes and nostrils. It cannot see, nor can it smell its prey. The platypus searches for food using its electro-sensitive beak. The beak is so sensitive it can detect tiny electrical signals from the muscles of small arthropods and worms as they move around.

Plant divisions

The plant kingdom has three divisions, characterised by the way they reproduce and whether or not they have organised systems for transporting materials through the plant. Figure 6.3.25 shows these divisions and the plant classes.

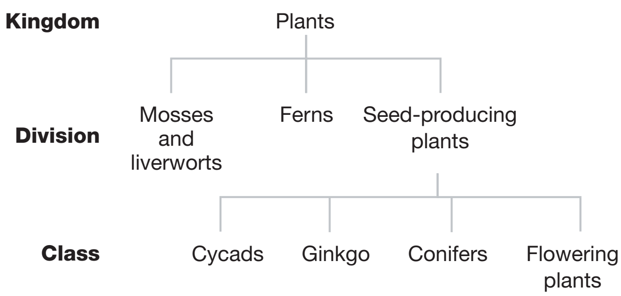


Figure 6.3.25 Key to the plant kingdom

Mosses and **liverworts** (such as those shown in Figure 6.3.26) are usually very small because they do not have any tissue containing veins to transport water or nutrients through the plant. They absorb water from the atmosphere through their leaves. Therefore, they must live in damp places where they are not in danger of drying out. They reproduce using **spores**, which are single cells that grow into a new moss plant.

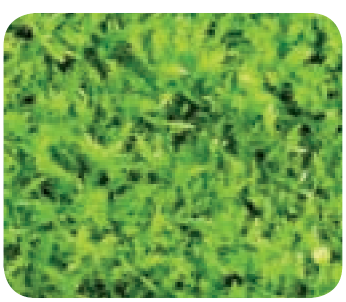


Figure 6.3.26 Mosses are low-growing plants forming a mat on a rock, tree or soil surface.

Ferns have a *vascular system* for transporting food and water throughout the plant. They also reproduce using spores produced in structures known as sporangia, like those in Figure 6.3.27.

Seed-producing plants reproduce using seeds. Seeds are more complex than spores. They contain one cell that becomes the new plant. There are also many other cells in the seed. These provide food for the developing plant until the leaves are formed. The division of seed-producing plants has four classes: **cycads** (Figure 6.3.28), **ginkgo** (Figure 6.3.29, on page 226), **conifers** (Figure 6.3.30, on page 226) and **flowering plants**.

Figure 6.3.27 The spores are produced in the dark spots (sporangia) on the back of the fern leaf.

Figure 6.3.28 Cycads have separate male and female plants. The male plant produces pollen in cones. The female cone produces the seed and provides some protection for the seed as it develops.

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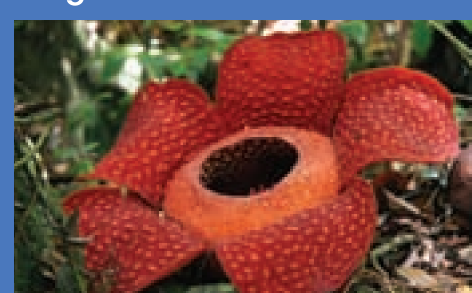
Largest flower



The largest flower in the world is found in South-East Asia. It can be up to one metre in diameter and weighs 11 kg. Its name is *Rafflesia arnoldii*. Its smell is like rotting meat.

Figure 6.3.29 *Ginkgo biloba* is sometimes called the maidenhair fern tree. It is the only living member of this class.

Ginkgos have separate male and female trees. Male trees produce pollen in cones, and female trees produce seeds in fruit with a fleshy, smelly coat.

Conifers produce the male (pollen-bearing) and female (seed-bearing) cones on the same tree. Cypress, fir and pine belong to this class. Australian conifers include the hoop pine (*Araucaria cunninghamii*), Huon pine (*Lagarastrobos franklinii*) and Wollemi pine (*Wollemia nobilis*).

Flowering plants produce seeds fully protected inside the female part of the flower, which is known as the ovary. Many of the flowers produced by flowering plants are used to attract pollinators such as bees, flies, moths, birds or bats. Grasses, with less showy flowers, are pollinated by wind.

6.7
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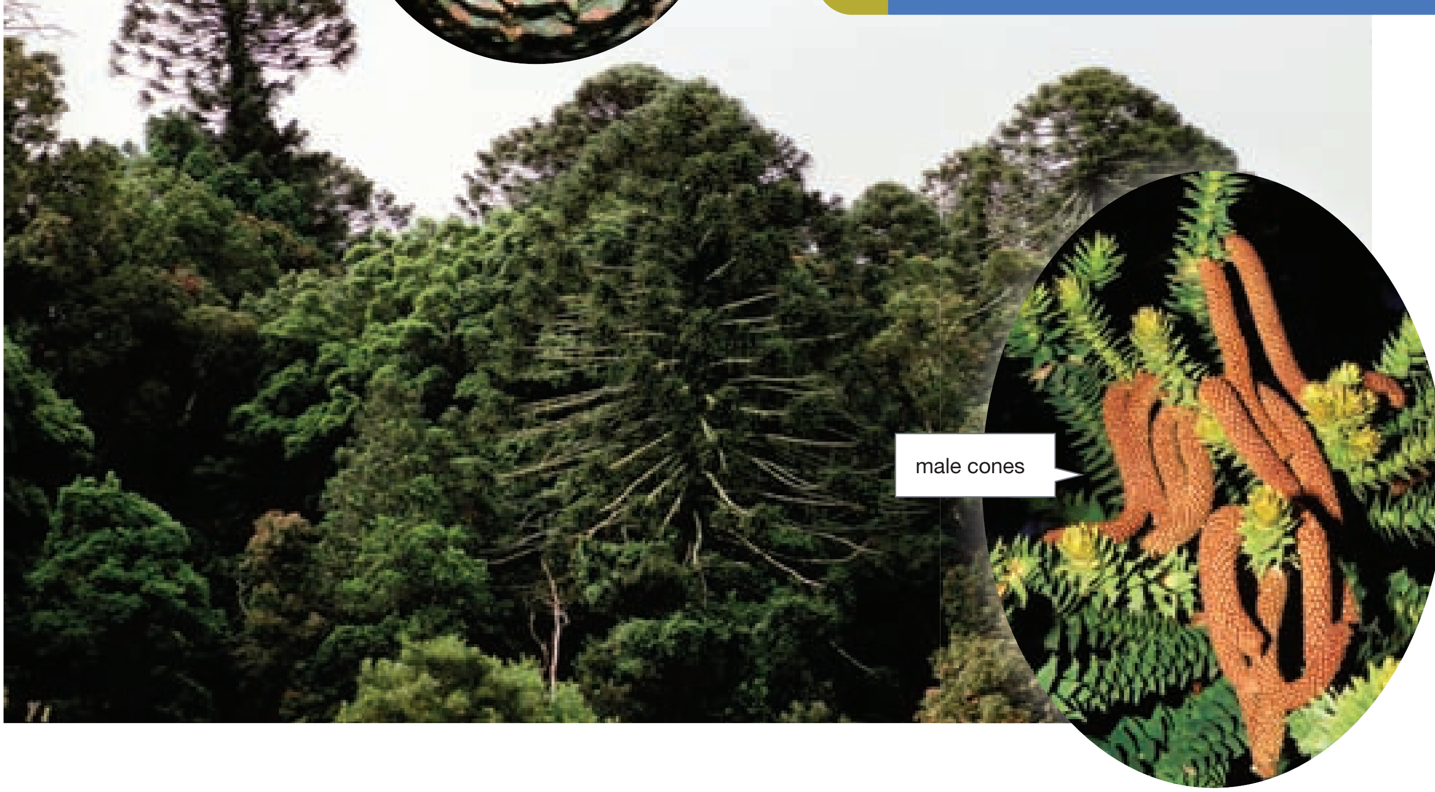
Figure 6.3.30 The Bunya pine (*Araucaria bidwillii*) stands taller than the other trees in the forest. Like all conifers it produces male and female cones on the same tree.



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Tiny flowers

Although this daisy looks like one flower, it is in fact hundreds of florets (small flowers) of two different types. Ray florets make up the parts that look like petals. Disc florets make up the central part.

6.3 Unit review

Remembering

1 **List** the nine phyla of animals.

2 **Name** the phylum that describes the largest number of types of animals.

3 **Name** the classes of seed-bearing plants.

Understanding

4 **Describe** the relationship between a division in the classification of plants and a phylum in the classification of animals.

5 a **Describe** the difference between an exoskeleton and an endoskeleton.
  b **Name** a group of animals that has an exoskeleton.
  c **Name** a group of animals with an endoskeleton.

6 **Explain** why frogs need to live in damp places but lizards can survive in dry areas.

Applying

7 a Copy Figure 6.3.31 into your workbook, then **identify** their lines of symmetry.
  b For each diagram **state** whether the diagram represents radial or bilateral symmetry.

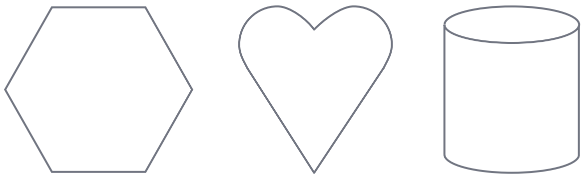


Figure 6.3.31

8 An African elephant can have a mass of 5000 kg and the mass of a blue whale can reach 190 000 kg. **Calculate** the number of times heavier a blue whale is than an elephant.

Analysing

9 **Compare** annelids with nematodes by listing their similarities and differences.

10 **Contrast** an endothermic animal with one that is ectothermic.

11 **Compare** the characteristics used to classify:
  a a shark and a barramundi
  b a frog and a lizard
  c a kangaroo and a platypus
  d a moss and a fern.

12 **Contrast** platyhelminths and nematodes.

13 **Use** the following descriptions to **classify** the organisms.
  a It is less than one centimetre tall and when the leaves were examined under the microscope no veins could be seen.
  b This organism was collected from the ocean. It has a soft body with long tentacles. After I touched the tentacles my hand was stinging.
  c A tree over 20 m tall with needle-like leaves and seeds produced in cones on its branches.

Evaluating

14 Examine the animals drawn in Figure 6.3.32.
  a **Classify** each into a phylum.
  b **Justify** your decisions.

Figure 6.3.32

6.3 Unit review

15 **Propose** reasons why animals without a skeleton often live in water.

16 **Select** information from the pages on animal classification to complete the table.

Phylum	Where it lives	Symmetry	Number of body openings	Type of skeleton	Other features

Creating

17 **Construct** a key to **classify** the following organisms. Start with kingdom level.
- a sponge
- b moss
- c fern
- d spider
- e snake
- f kangaroo
- g gum tree

18 Make a large copy of Figure 6.3.33 in your workbook and use it to **create** a Venn diagram to **compare** the three chordate classes commonly called fish.

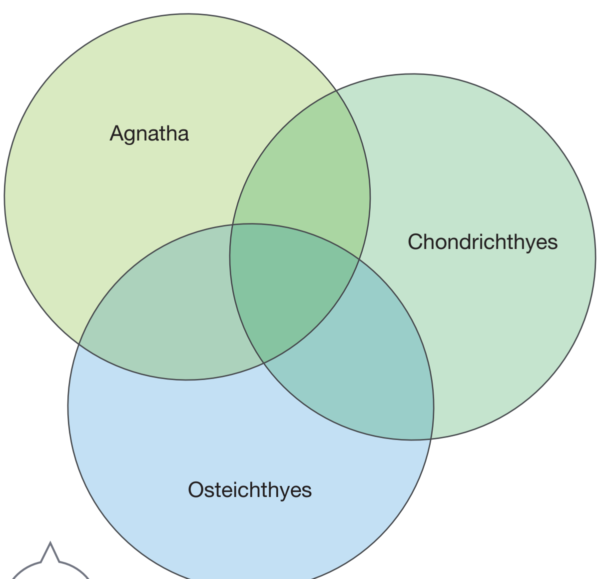


Figure 6.3.33

19 **Create** mnemonics to help you remember the:
- a names of the kingdoms
- b animal phyla
- c divisions of the plant kingdom.

Inquiring

1 Research the platypus and find answers to the following questions:
Where does it nest and have its young?
Does it incubate the eggs like a bird?
How does it feed the young?
What does it feed on?

Add some more of your own questions to the list and summarise what you find.

2 Find how the stings on the tentacles of jellyfish work. Use labelled diagrams to present your answer.

3 Research the phylum Arthropoda.
- a List the classes within the phylum.
- b Describe each class in words and pictures.
- c Identify the characteristics used by scientists to separate the classes.
- d Create a dichotomous key for the phylum.

6.3 Practical activities

1 The importance of animals

Purpose

To find out more about the different animal groups.

Materials

- research resources such as library and internet

Procedure

1. Choose one of the animal phyla.
2. Research the names of some of the animals in that group. When you have found one that interests you, prepare a poster, information leaflet or PowerPoint presentation about that animal.

   In the presentation include:
   - the biological classification of the animal
   - where it lives
   - how it feeds and what it feeds on
   - ways it is important to humans.
3. List at least five other animals in this phylum. For each animal, compare it with the animals you researched to show why they are classified together in the phylum and to identify differences between them. Include any other interesting information you find.
4. Make a presentation to the class.

Discussion

Propose what would happen if all the animals in the group you selected were to disappear.

2 Classifying plants

Purpose

To construct a classification key for plants found in your local area.

Materials

- a description of and samples from plants found at home or in the school grounds
- photographs of the plants if samples cannot be collected or to help with your description
- paper and pencil for drawing up the key

  Note: If you took photographs of all your samples you could use the plants from all the groups in the class and create a more comprehensive key.

Procedure

1. Sort your plants into two groups, according to one characteristic that each plant either has or doesn't have. Write down the characteristic you used to divide up your plants.
2. Using a different characteristic each time, repeat this process, splitting each group of plants again and again until you have each plant on its own in a separate group. You will need a large area to separate them each time. Then you can name them, or give them a letter. Make sure you write down the characteristic you used to divide up your plants each time.
3. Use each of your identified characteristics in Steps 1 and 2 to design a key for other students to use to identify your plants.
4. Hide the names or letters at the end of your key, then give your samples and key to a student who did not work on the key with you. Ask them to try to identify each plant from your key.

Discussion

1. **Assess** how easy your key was to use in identifying the plants.
2. **Identify** if some features were easier to use than others for identifying plants.
3. **Use** the information gathered to improve your key, and then ask another classmate to use it for you. **Assess** whether your key is more effective this time.
4. **Explain** why you did or did not find it easy to construct the key.
5. **Suggest** other information that would have been of benefit to you.

6.4 Other classification systems

Indigenous people all over the world have complex and sophisticated classifications of plants and animals, but they do not look like the system used by Western science. Classification is a tool used to help people to communicate. Indigenous classifications help the people of a tribe or local area to communicate about the plants and animals that are important to them. The classification used in one area will not necessarily be the same as the classification used in other areas.

Indigenous Australia

The Indigenous people of Australia have sophisticated classification systems that suit the way they live in their environments. The classifications take into account relationships the Indigenous people recognise between the living and non-living parts of the environment, and group together things that are used in similar ways.

Figure 6.4.1 These bush fruits and mussels would not be grouped together by Western science. However, they can all be classified as bush tucker.

The classification system used by the Yolngu of Arnhem Land (Northern Territory) begins by creating two groups —things that have life, and things that do not. Things that have life are further divided into three groups:

1. Things that move themselves, such as the Sun and planets, or the water and fire shown in Figure 6.4.2.
2. Things that breathe and reproduce. This group includes all plants and animals except humans.
3. Humans.

Figure 6.4.2 The Yolngu people of Arnhem Land classify fire as 'something that could move itself'.

Things that breathe and reproduce

Things that breathe and reproduce are then subdivided into nine different sets. For example:

- *guya* is the name for a group that includes all fish
- *dharpa* is all plants with woody stems
- *warrakan* includes all land or freshwater mammals, birds and reptiles, with the exception of snakes. Figure 6.4.3 shows some warrakan.
- *bäpi* is the group to which snakes, legless lizards and worms belong.

Some of the nine groups are further subdivided. For example:

- *warrakan* are grouped according to whether they fly, walk, crawl or slide
- *guya* are subdivided according to where they live: near the surface of the water, near the bottom, in rivers, in fresh water, or among reefs and rocks.

Figure 6.4.3 The Yolngu group animals according to how they move. Birds and bats are in the same group—the *warrakan butthunamirr*—because they can both fly. Biological classification uses differences between birds and bats to place them in separate groups right down to the genus level. Galahs are named *Eolophus roseicapillus* and the lesser long-eared bat is named *Nyctophilus geoffroyi*.

Comparing classifications

The hierarchy of classification used by the Yolngu is similar to but much simpler than the biological classification. The classification of three finches found in Arnhem Land could be used as an example.

The scientific classification is shown in Figure 6.4.4.

Kingdom	Animalia (Animals)
Phylum	Chordata (Chordates)
Class	Aves (Birds)
Order	Passeriformes (Perching birds)
Family	Frigillidae (Finches)
Genus	*Poephila*
Species	*Poephila personata* Masked finch; *Poephila acuticauda* Long-tailed finch; *Poephila bichenovii* Double-barred finch

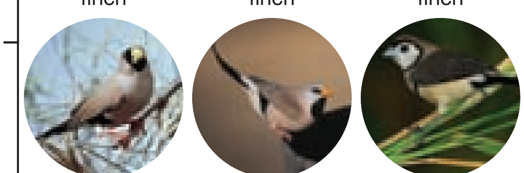


Figure 6.4.4 Finch classification

The classification of the Yolngu is shown in Figure 6.4.5. It is a lot simpler.

There are no specific names for the different finches: they are all *lidjildji*. They only give specific names to things that are of special use or significance.

Thing that has life

Thing that breathes and reproduces

Warrakan

Lidjildji (finches)
(All finches have the same name)

Figure 6.4.5 The Yolngu have a simple classification of the finches of Northern Australia.

Same word, different meaning

For the Yolngu, words can also have different meanings at different stages of a person's life. Children up to the age of 10 years (like the one in Figure 6.4.6) have two words for bird. They use *warrakan* to mean large bird and *djikay* means a small bird. From the age of 11 to 18 years, *warrakan* means both large and small birds. From 19 to 30 years, *warrakan* mainly refers to large edible birds, and for people over 30 years the same word refers to large land animals such as birds, reptiles, bats and echidnas.

Figure 6.4.6 Indigenous children hunt small birds and lizards for food.

The change in use of the words relates to the place in society of the person and their stage of life. Children will notice small birds and may have fun looking for them in the bushes or grass. As they get older and start hunting birds for food, it does not really matter whether it is large or small, so only one word is used. Gradually the word becomes used more generally to mean a variety of food animals.

North America

The Innu are the indigenous inhabitants of an area near Quebec in Canada.

Like the Australian Aborigines, the Innu have a detailed knowledge of the plants and animals that are important in their lives. They classify animals by where the animals live. Although the binomial system might consider two animals to be the same animal species, the Innu call them different names depending on their sex and age.

In their traditional way of life the Innu survived mainly by hunting and trapping caribou, deer, small game and moose like the one shown in Figure 6.4.7. Therefore it is not surprising that they have a large number of different words to describe the way an animal moves and for parts of its anatomy.

Like all traditional societies, the Innu had a very detailed knowledge of the feeding habits of the animals they hunted, and knew about the diseases that the animals could suffer. This knowledge was important for the health of their community.

1 p236

SciFile

Always forwards

Emus and kangaroos cannot walk backwards. This is why they were the indigenous animals selected for the Australian coat of arms.

Figure 6.4.7 The Innu people had a very good knowledge of how moose behaved. This helped when they hunted moose for food.

SciFile

Indigenous names

When Captain Cook's ship *Endeavour* was being repaired in North Queensland, Joseph Banks started recording local Aboriginal names for plants and animals. One name he recorded was *gangurru* for a local type of kangaroo. This local name has become the English word for all kangaroos.

INQUIRY

science 4 fun

Observing

Yes

Collect this …

- a pet animal, or a place where you can observe an animal closely
- paper and pencil
- digital camera (optional)

Do this …

1. Imagine that your life could depend on knowing as much as you can about this animal. Observe the animal very closely. No observation is too small. Remember that observing uses more senses than just sight.
2. Record as many observations as you can of the animal.

Record this …

Describe any new things you learnt about the animal.

Explain how much time and care it would take to learn all there was to know about the habits of an animal in the wild.

Language

People in traditional societies had extensive knowledge of things that affected their daily lives, and this is often reflected in their language.

As hunters it was important that the Innu people could communicate with each other about the movement of the animals they were tracking.

For most Australians, snow is not an important part of the weather. Hail, snow, sleet and frost are common in Britain, where the English language originated.Therefore there are English words related to snowy weather. Snow is part of the life of the people of Lapland in northern Finland for many months of the year, and in their language there are over 50 words to describe snow. They have their equivalent of our words, plus specific words for things such as a snowstorm, freshly fallen powdery snow, a reindeer path in the snow, and ice with snow on top. Figure 6.4.8 shows two different types of snow.

2 p236

Figure 6.4.8 Laplanders use different words to describe the snow they could ride snowmobiles on and the snow on top of the frozen waterfall. Surprisingly, they do not have a verb in their language that means ‘to snow’.

6.4 Unit review

Remembering

1 **Specify** what sorts of animals are included in the following terms.
   a *guya*
   b *warrakan*

2 **State** the Yolngu name for:
   a plants with woody stems
   b snakes and lizards.

Understanding

3 **Explain** why the Yolngu people do not have names for all the different birds.

4 **Explain** why the word Yolngu word *warrakan* refers to different things at different times.

5 Would you expect Indigenous Australian languages to have many words for 'snow'? **Explain** your response.

Applying

6 **Identify** issues that could arise if Indigenous Australians from one area were discussing hunting for food with a tribe from a different area.

7 **Predict** some situations for which Indigenous Australians would have more relevant words in their languages than would Laplanders.

Analysing

8 **Discuss** the suggestion that Indigenous Australians would benefit from having one classification system for the whole country.

Evaluating

9 a **Propose** whether the five kingdom classification of living things would be of use to Indigenous Australians or to the Innu of North America.
   b **Justify** your answer.

10 **Deduce** reasons for there being many different Indigenous classification systems for living things in Australia.

11 The Yolngu people classified *warrakan* according to whether they moved by flying, walking, crawling or sliding. **Propose** why this classification was useful to them.

12 The Innu people of North America have a very good understanding of moose because they hunt it for food. **Propose** a list of Australian animals of which Indigenous populations would have a similar understanding.

13 a This Unit has looked at ways that Indigenous Australians from one area classified living things. **List** other things in their environment they might classify.
   b For one of the items on your list, **propose** a possible classification.

14 The Dharawal people of New South Wales lived in the area around Sydney. Following is a list of words from their language, with the English translation.

Dharawal	English
wungawunga	wonga pigeon
gura	wind
wumbat	wombat
garaguru	cloud
wularu	wallaroo
gurbuny	fog
bubuk	boobook owl
guwing	sun
wulaba	rock wallaby
danagal	ice
dingu	dingo
mungi	lightning
yanada	moon

Some Dharawal words have been adopted into English, but others have not. Examples of this are shown in Figure 6.4.9.

   a **Classify** the words that have been adopted. **Discuss** possible reasons for their adoption.
   b **Classify** the words that have not been adopted. **Discuss** possible reasons for them not being adopted.

15 **Propose** an explanation for Laplanders not having a word in their language for 'to snow' when they have so many words to describe snow on the ground.

Figure 6.4.9 The Dharawal people's names for some common Australian animals

Inquiring

1 A classification system for plants used by Indigenous Australians was into 'plants used for medicine' and 'plants used for food'. Use library and internet resources to discover more about the use of plants for medicine and discuss the idea that other cultures in other places and at other times would have used a similar classification.

2 a Make contact with an Indigenous community in your area and arrange a meeting.

b Devise questions to ask the community to enable you to gather first-hand information about:

i how they classify living things

ii ways that information is gathered and passed on

iii ways in which plants and animals are important to the community apart from as food.

c Create a poster or an electronic presentation to share the information with other groups in the school. Include in your presentation the most surprising thing that you learned about the way that the local Indigenous community classified living things.

3 Talk to people from the Indigenous population in your local area to learn some of their stories that describe the special relationship that the Indigenous people have with the land and the native plants and animals.

6.4 Practical activities

1 The names I know

Purpose

To explore ways in which classification systems could have evolved.

Materials

- paper
- pencil

Procedure

1. Make a list of the living things that are regularly part of your life.
2. If you know the name, use it—for example *dog*, or *apple*. If you do not know specific names, use group names such as *tree* or *bug*.
3. Share your list with a partner and combine the two lists.
4. Share your combined list with another pair and make one list for the group.
5. Think up ways that you could group the things you have on your list. For example, you could have *pets* or *food*.
6. If you have a very long list in some groups, subdivide it into smaller groups by making a second level of classification.
7. Create a key for the items in your lists. Go only as far as you think is useful. You do not have to separate out each item.

Discussion

1. **Identify** which type of classification your key most resembled—biological classification, or one more like that from Yolngu people. **Explain** why this was the case.
2. **Compare** the items for which you had specific names and those that had group names. **State** which of these would be more important to you in terms of survival.
3. **Compare** the list you started with and the final list used for the classification. **Estimate** how much of your list was the same as the lists from the others in your group.
4. **Identify** the groups where there was the greatest amount of overlap. **Explain** why there was so much overlap.
5. **Identify** the groups where there was most difference. **Explain** why there was so much difference.

2 Classifying weather

Purpose

To compare calendars.

Materials

- pen
- paper

Procedure

Part A

1. Analyse the information presented in calendars from two Indigenous groups: the Wardaman people of Northern Territory (Figure 6.4.10) and the Brambuk people of Victoria (Figure 6.4.11).
2. Compare the calendars with the temperature and rainfall statistics from the Australian Bureau of Meteorology for Katherine (Figure 6.4.12) near where the Wardaman people live, and Ararat (Figure 6.4.13) near where the Brambuk people live.

Part B

3. Create a personal calendar by drawing a circle at least 10 cm in diameter. Divide it into 12 equal segments. Label the segments with a month of the year.
4. Into the calendar place the events that are important to you and that occur at the same time each year. Consider events such as sports seasons, birthdays, family holidays, school terms, and seasons of the year.

Wardaman People

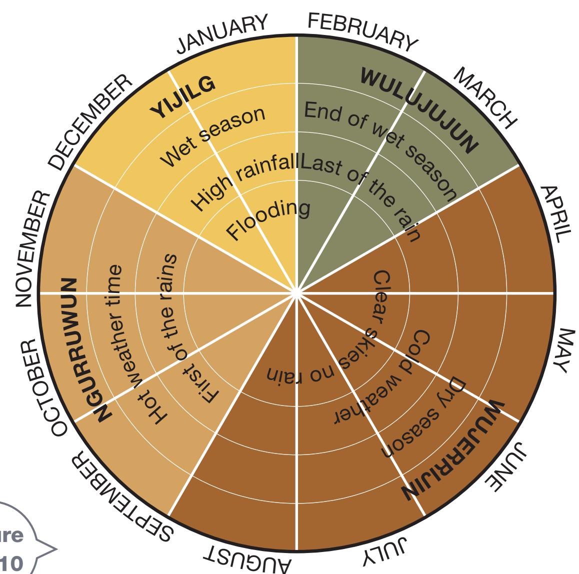


Figure 6.4.10

Brambuk People

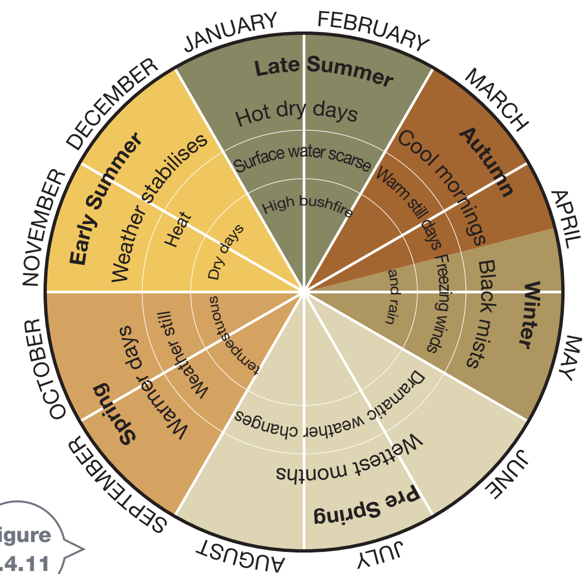


Figure 6.4.11

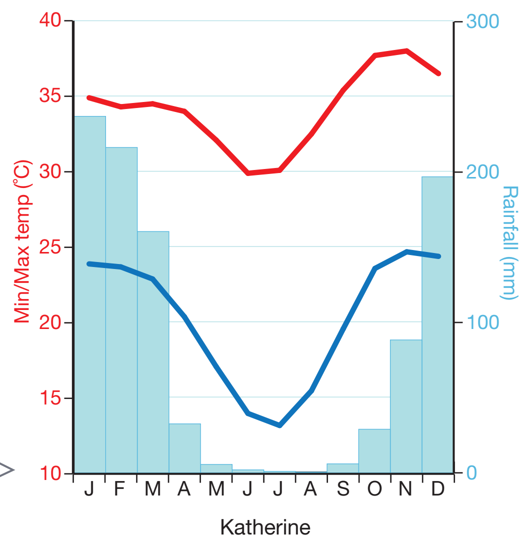


Figure 6.4.12

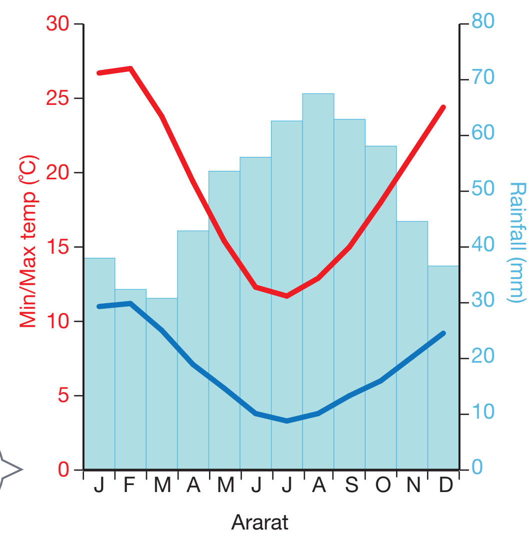


Figure 6.4.13

Discussion

Part A

1 **Explain** what information is classified in the calendars and graphs.

2 **Compare** the information included in the two Indigenous calendars. **Propose** reasons for any differences.

3 **Propose** ways the information used to construct the calendars was collected.

4 **Explain** how the Bureau of Meteorology collects temperature and rainfall statistics.

5 **Compare** the calendar of the Wardaman people with the statistics for Katherine, and the calendar of the Brambuk people with the statistics for Ararat. **Assess** the accuracy of the information gathered by the Indigenous people.

6 **Discuss** the uses made of the calendars in Indigenous society and the uses made of the information from the Bureau of Meteorology in society today.

Part B

7 **Compare** the information included in your calendar and the Indigenous calendars.

8 **Propose** reasons for any differences.

6 Chapter review

Remembering

1 **Name** the type of scientist who places things in groups.

2 **State** the meaning of the term *classification*.

3 **List** examples of classification you experience most days.

4 **List** the kingdoms with single-celled organisms.

5 **Name** the kingdom in which you will find all the organisms without a distinct nucleus.

6 **List** the three classes of animals that are often grouped together as fish.

7 **Name** the classes of seed-bearing plants.

8 **Name** the scientist who devised binomial naming.

9 **Recall** each phylum of animals described as follows.
  a Has stinging cells
  b Has an exoskeleton
  c Has a single muscular foot
  d Has a nerve cord

Understanding

10 **Explain** why the products in supermarkets are not arranged in alphabetical order.

11 **Explain** how classification is used in:
  a clothing shops
  b shops selling music DVDs.

12 **Explain** why characteristics such as hair length or style, or the presence of facial hair, would not make a strong key.

13 **Describe** the plant kingdom, highlighting the features that make it different from the other kingdoms.

14 **Gather** information from Unit 6.2 about the protists and **explain** why this kingdom could be called the 'kingdom of misfits'.

Applying

15 Use Figure 6.5.1 to **identify** characteristics that could be used in a key to identify these creatures.

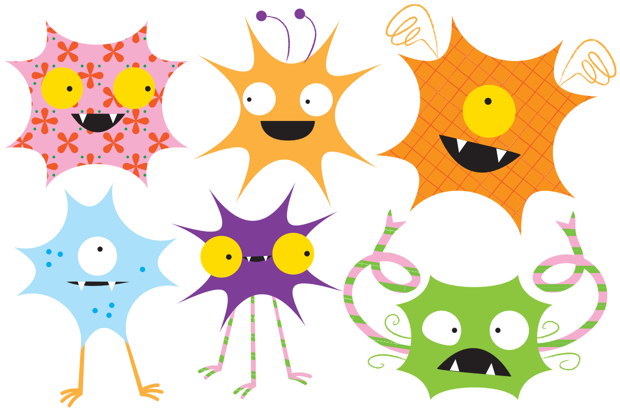


Figure 6.5.1

16 **Identify** the kingdom and phylum to which the organisms shown in Figure 6.5.2 belong.

a

b

Figure 6.5.2

Analysing

17 **Compare** scientific classification with the classification developed by the Yolngu people.

18 **Contrast** the following kingdoms:
- **a** plant and animal
- **b** moneran and protist
- **c** plant and fungi.

19 As people explore new environments they find new organism that have to be described and named. **Discuss** the advantages of having the binomial system of classification compared to the system before Linnaeus.

20 Use the following information to **classify** each of these organisms into a kingdom and, if possible, phylum/division.
- **a** Found when pond water was examined under a microscope. It is green and appears to be a number of cells grouped together within a thin 'skin'. Flagella are visible attached to each cell. A nucleus is visible within each cell.
- **b** Large organism standing about two metres tall. A soft brown hair covers its body. It had a pouch-like structure on the front of the body. At times a small head appeared out of the pouch.
- **c** Small green leaves are arranged like a spiral around something that looks like a stem but it has no vascular tissue. This organism is about one centimetre tall. It was found in the shade behind a rock.

21 **Analyse** the key in Figure 6.5.3 to **identify** its strengths and weaknesses.

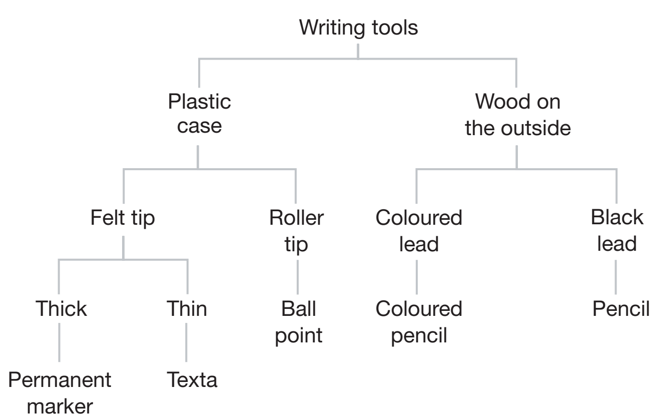


Figure 6.5.3

Evaluating

22 Refer to the following plant names.

Eucalyptus robusta
Grevillea banksii
Metrosideros robusta
Grevillea ericifolia
Eucalyptus banksii

- **a** **i** **Identify** which of the listed organisms would be most closely related to *Grevillea robusta*.
  - **ii** **Justify** your response.
- **b** **i** **Select** other species in the list that are related to each other.
  - **ii** **Explain** your selection.
- **c** **i** **State** how many species are represented in the list.
  - **ii** **Justify** your response.
- **d** **i** **State** how many different genera (plural of genus) are represented in the list.
  - **ii** **Justify** your response.

Creating

23 **Apply** your knowledge of keys to **construct** a strong key for the creatures shown in Figure 6.5.1.

24 **Use** the following ten key words to **construct** a visual summary of the information in this chapter.

kingdom
species
classification
taxonomy
dichotomous key
plants
animals
protists
monera
fungi

6.8

Thinking scientifically

Two students were given this information about some animals and asked to put them into groups.

Animal	Number of legs	Number of pairs of wings	Number of body parts	Other characteristic
spider	8	0	2	poisonous
fly	6	2	3	feeds on nectar
tick	8	0	2	feeds on blood
scorpion	8	0	2	poisonous
mosquito	6	2	3	feeds on blood

Jo's groups
spider scorpion
fly tick mosquito

Kai's groups
spider scorpion tick
fly mosquito

Q1 Which characteristic did Jo use to create the groups?

A Number of legs
B Number of pairs of wings
C Number of body parts
D Other characteristic

Q2 Which characteristic did Kai use to create the groups?

A Number of legs
B Number of pairs of wings
C Number of body parts
D Other characteristic

Q3 Students created this key for their group.

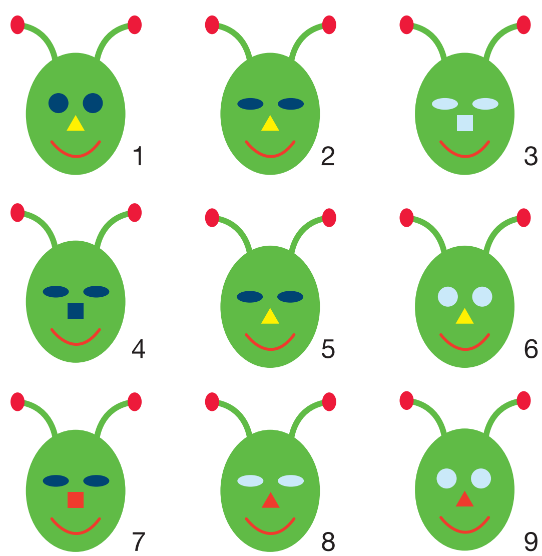
1	a	Male	Go to 2
	b	Female	Go to 5
2	a	Straight hair	Go to 3
	b	Curly hair	Go to 4
3	a	Can roll tongue	Mark
	b	Cannot roll tongue	Yasu
4	a	Brown eyes	Hans
	b	Grey eyes	Jack
5	a	Straight hair	Jane
	b	Curly hair	Mai

How many people in the group have straight hair?

A 1
B 2
C 3
D 4

Q4 The aliens below belong to three different family groups. Which two aliens belong to the same family?

A 1 and 5
B 2 and 3
C 4 and 6
D 5 and 8



Q5 Which alien belongs to the same family as alien 9?

A 8
B 6
C 7
D 3

Glossary

Unit 6.1

Classification: the process of putting things into groups

Dichotomous key: a key with two choices at each stage

Pest species: an animal species that causes problems and is not wanted in an area

Taxonomist: a scientist who specialises in grouping and naming things

Taxonomy: the science of grouping and naming things

Weed: a group name for any plant growing where it is not wanted

Unit 6.2

Animal: one of the five kingdoms of living things; multicellular organisms with a membrane as the outer layer and a distinct nucleus

Cells: the building blocks of all living things

Class: the division under phylum in the classification of living things

Decomposers: bacteria and fungi responsible for the natural breakdown of wastes

Division: the level below kingdom in the classification of plants

Family: the division in the classification system below order and above genus

Flagellum (plural **flagella**)**:** whip-like tail of single-celled organisms

Fungi

Fungi (singular **Fungus**)**:** one of the five kingdoms of living things; multicellular or unicellular organisms with a cell wall as the outer covering and a distinct nucleus

Genus (plural **genera**)**:** the division in the classification system below family and above species

Kingdom: the first level of classification

Macroscopic: able to be seen without the help of a microscope

Microscopic: cannot be seen without the help of a microscope

Monera: one of the five kingdoms of living things; single-celled organisms without a distinct nucleus

Multicellular: made of many cells

Order: the division in the classification system below class and above family

Phylum (plural **phyla**)**:** the second level of classification of living things, below kingdom and above class

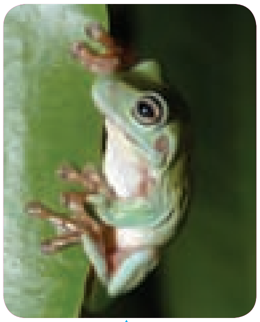
Plant: one of the five kingdoms of living things; multicellular organism with a cellulose cell wall as the outer layer and a distinct nucleus

Protist: one of the five kingdoms of living things, consisting of single-celled organisms with a distinct nucleus

Species: the last level of classification of living things

Unicellular: made of only one cell

Unit 6.3



Amphibians

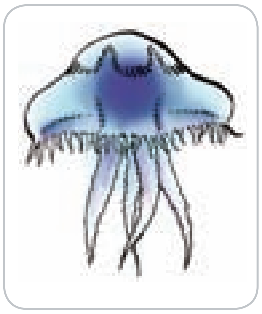
Agnatha: jawless fish with an internal skeleton made of cartilage; examples hagfish and lampreys

Amphibians: chordates that live both in and out of water

Annelids: phylum of the Animal kingdom consisting of the segmented worms; example earthworm

Arthropods: animals with an exoskeleton and jointed limbs; example crabs and insects

Aves: animals with feathers covering their body; lay hard-shelled eggs and are endothermic



Cnidarians

Cartilage: flexible material from which the skeletons of Agnatha and Chondrichthyes are made

Chondrichthyes: fish with proper jaws and teeth, a skeleton made of cartilage and fins on the sides of their bodies as well as along their backs; example sharks and rays

Chordates: animals with a nerve cord running down their backs, and an endoskeleton

Glossary

Cnidarians: animals with radial symmetry, one body opening and stinging cells; example jellyfish, sea anemones and coral polyps

Conifers: plants that bear their seeds on cones and have male and female cones on the same tree; example cypress, fir and hoop pine

Cycads: plants that bear their seeds in cones and have male and female cones on separate plants

Echinoderms: radially symmetrical animals, most of which have spiny skin; example starfish, brittlestars, sea urchins and sea cucumbers

Echinoderms

Ectothermic: describes animals with a body temperature that varies with the temperature of their surroundings

Endoskeleton: a skeleton inside the body

Endothermic: describes animals with a body temperature controlled internally

Exoskeleton: a skeleton on the outside the body

Ferns: plants that reproduce using spores and have a vascular system for transporting food and water throughout the plant

Ferns

Flowering plants: plants that produce seeds fully protected inside an ovary

Ginkgos: trees with separate male and female plants. Pollen is produced in cones. The female tree produces fleshy-coated seeds. *Ginkgo biloba* is the only living member of this class

Invertebrates: animals without backbones

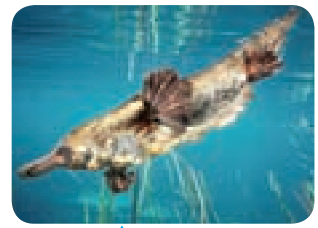
Liverworts: plants with no vascular tissue that reproduce using spores

Mammals: a class that includes all the animals that have a body covering of hair and feed their babies on milk produced by the mother

Marsupials: a subclass of mammals that give birth to immature young that are suckled in a pouch; example koala, kangaroo and wombat

Molluscs: phylum of animals that are bilaterally symmetrical, have well developed internal organs, and have a muscular foot which they use to move along

Monotremes: a subclass of mammals that lays eggs; examples echidna and platypus



Monotremes

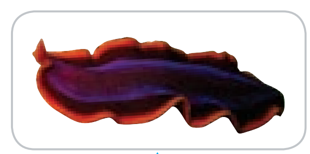
Mosses: plants with no vascular tissue that reproduce using spores

Nematodes: phylum of the animal kingdom consisting of the roundworms

Osteichthyes: the bony fish; examples tuna, barramundi, eels, sea horses and lungfish

Parasite: organism that live on or in another organism called a host; they get their food from the host, but the host gets nothing in return and may be harmed

Placentals: a subclass of mammals that nourish the baby inside the mother's body by a placenta, and in which the baby is born at a more mature stage; example dingo, horse and human

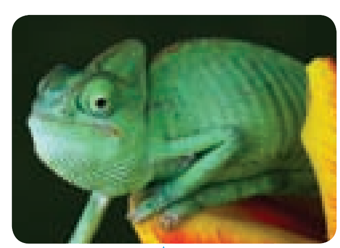


Platyhelminths

Platyhelminths: phylum of the animal kingdom consisting of the flatworms

Poriferans: phylum of the animal kingdom consisting of the sponges

Reptiles: animals with scales covering their body; ectotherms, most of which lay eggs with leathery shells



Reptiles

Seed-producing plants: plants that reproduce using seeds

Spores: single cells that grow into a new moss plant, fern or fungus

Vertebrae: the individual bones of the vertebral column

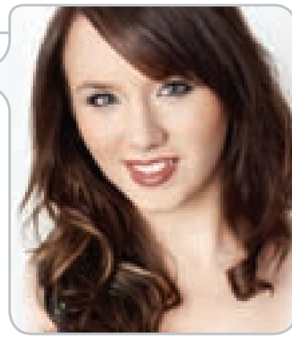
Vertebral column: the series of small bones protecting the nerve cord found in most chordates

Vertebrates: animals with backbones

SCIENCE TAKES YOU PLACES

Look who is using science

PROFESSIONAL DANCER



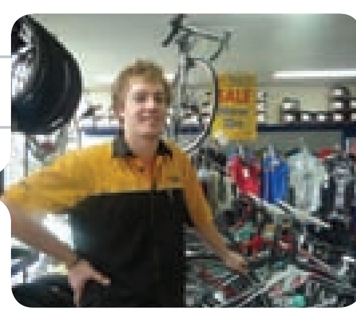
My name is Brianna Lees and I am a professional dancer.

As a dancer I need to understand how to keep my balance during rapid changes of motion and energy transfer. I began to learn how to do this at a young age, when I had lessons in several dance styles, and learnt more about forces when I completed a two-year Diploma of Dance and Performance.

A lot of my time is spent auditioning for parts in musicals, shows, corporate events and children's entertainment. My work involves choreography, costume fittings, rehearsals and usually eight performances a week.

Most aspiring dancers have a part-time job to support themselves in case they are unsuccessful in an audition. I teach dance technique in schools part-time. The industry is very competitive, but being a dancer is rewarding. You work hard, and the moments performing on stage make the physical training and auditions worthwhile. It is satisfying to make an impact on an audience and have your efforts appreciated.

BIKE MECHANIC



My name is Scott Jones and I work at a bicycle store.

My day at work is taken up with servicing bikes, serving customers, checking stock and assembling new bikes to place them on the floor.

When servicing bikes, I lubricate and degrease the gears first, and check that everything is running smoothly. Bike riding is a very social activity. Most mornings I meet up with a riding group and about 30 of us do a road ride, usually around the beach. On my days off, I enjoy mountain biking around beach areas or in the hills. Different types of bikes are better suited to road riding and mountain biking, and over the years I have collected a shed full. I'll always keep a connection with this job because I get great rates on buying new bikes and I like working with people who have similar interests to my own.

TRUCK DRIVER

My name is Trevor Worland. I own a transport logistics company and manage the storage and distribution of products to clients.

When I am organising my deliveries, it is important that I don't exceed the maximum weight my truck can carry. The truck won't accelerate or stop as quickly when it is carrying a heavier load, and I need to take corners more slowly. The weight of the load needs to be evenly distributed, otherwise goods can be damaged and the performance of the truck is affected. I check my tyres to keep them at their maximum pressure because this makes a big difference in the way the truck handles and it also saves fuel. I enjoy my work because I am my own boss and can work flexible hours. I meet lots of people in my job, see many sights, have endless opportunities, and never have two days the same.

7 Forces

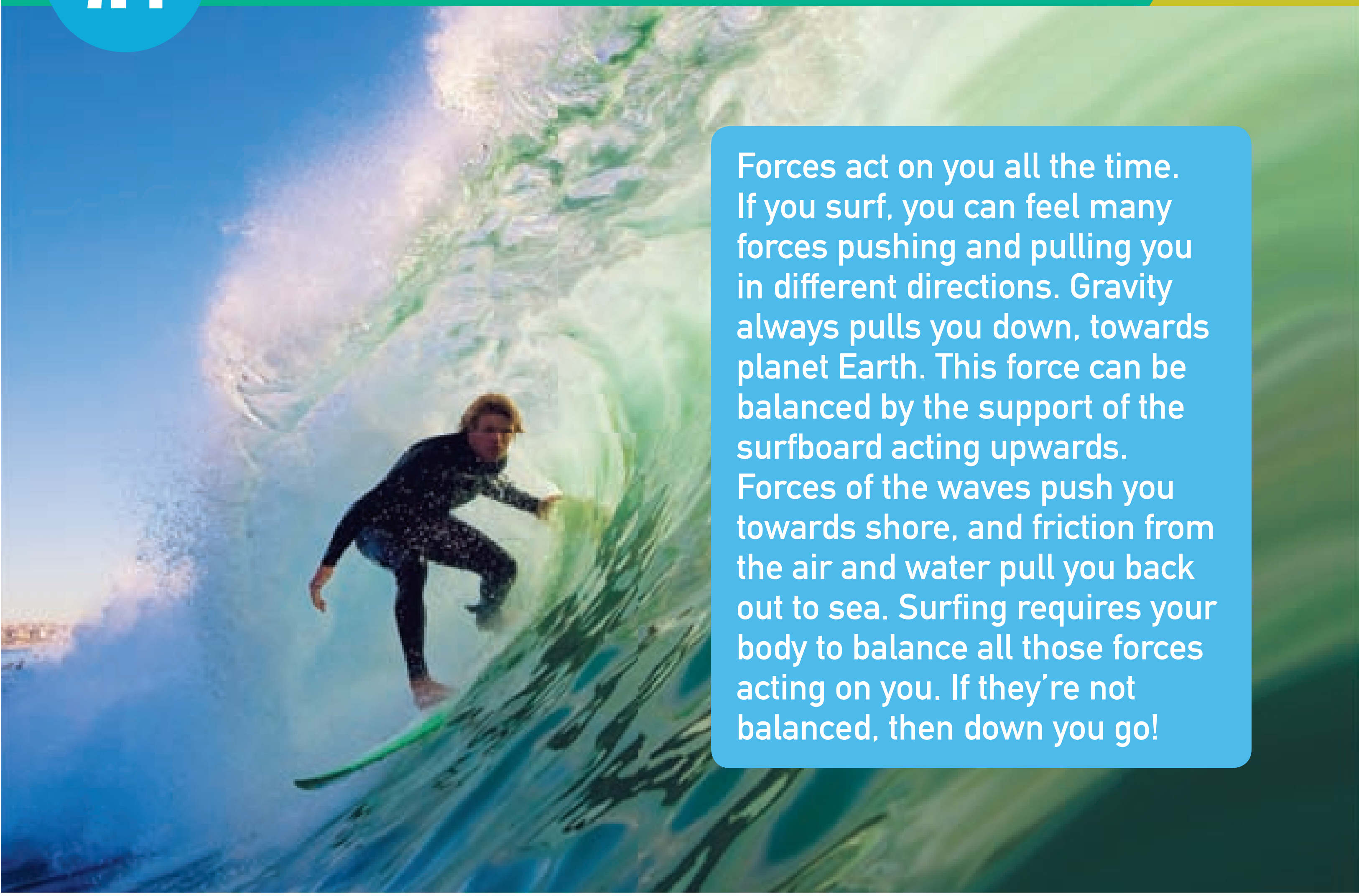
HAVE YOU EVER WONDERED...

- why your stomach feels funny on a rollercoaster?
- why you lean sideways when turning a sharp corner in a bus?
- why a feather falls more slowly than a stone?

After completing this chapter students should be able to:

- identify whether forces acting upon an object are balanced or unbalanced
- recall that change to an object's motion is caused by unbalanced forces acting on the object
- investigate the effects of applying different forces to familiar objects
- investigate common situations where forces are balanced, such as stationary objects and unbalanced, such as falling objects
- identify how wearing a seatbelt offers protection to a person in a car accident
- explain how sports scientists apply knowledge of forces in order to improve performance
- discuss beneficial and unwanted effects of friction
- recall that the Earth's gravity pulls objects towards the centre of the Earth
- discuss how gravity explains the motion of the planets and why objects fall
- recall that a magnet will attract certain materials within a magnetic field
- explain how an object becomes charged and describe the effects of electrostatic forces.

7.1 What are forces?



Forces act on you all the time. If you surf, you can feel many forces pushing and pulling you in different directions. Gravity always pulls you down, towards planet Earth. This force can be balanced by the support of the surfboard acting upwards. Forces of the waves push you towards shore, and friction from the air and water pull you back out to sea. Surfing requires your body to balance all those forces acting on you. If they're not balanced, then down you go!

What is a force?

A **force** is a push, a pull or a twist. This is shown in Figure 7.1.1.

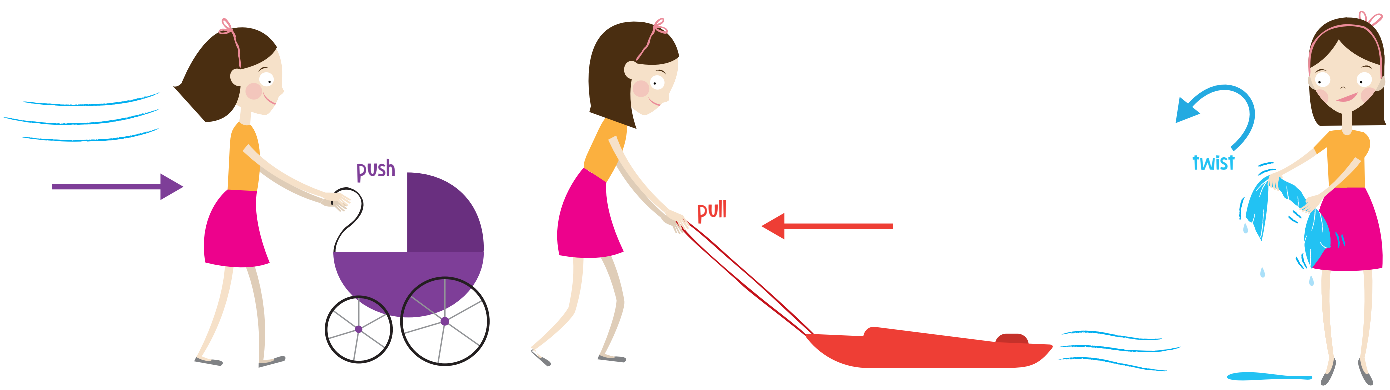


Figure 7.1.1 A force is applied when something is pushed, pulled or twisted.

What can forces do?

All around you, things move, or are in motion. Whenever there is a change in motion, a force has acted. Some examples are shown in Figure 7.1.2.

p253

Figure 7.1.2 Forces are needed to cause a change in the motion of an object. Here are examples of the ways motion can change around you.

Measuring forces

A spring balance can be used to measure a force. The larger the pulling force, the more the spring is stretched and the higher the reading on the scale. The spring balance shown in Figure 7.1.3 operates in this way. Bathroom scales use a spring that is squashed or compressed to measure force.

Force is measured using a unit called the **newton** (symbol **N**). This is named after the 17th-century English scientist, Sir Isaac Newton. It takes a force of about 1 N to lift an apple.

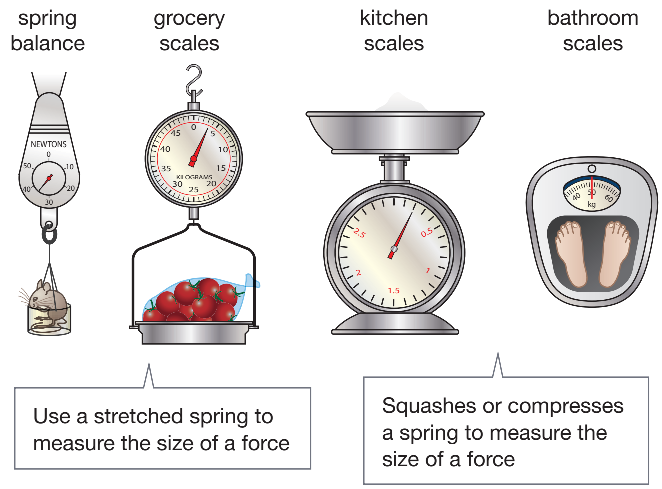


Figure 7.1.3 The ability of springs to stretch and squash allow a weight force to be measured.

SKILL BUILDER

Drawing forces

Many forces can act on an object at the same time. You can show these forces in a diagram such as Figure 7.1.4 by representing each as an arrow.

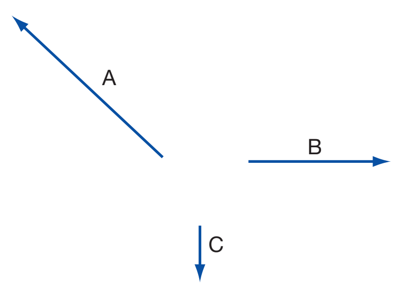


Figure 7.1.4 Forces are represented by arrows that show the direction in which the force acts. The size of the arrow represents the size of the force, so the bigger the arrow, the bigger the force. Force **A** is the largest of these three forces and force **C** is the smallest.

Balanced forces

The forces acting on an object can be balanced or unbalanced. When sitting on a chair, the force of gravity pulls you downwards, towards Earth. A support force from your chair acts upwards and balances the downwards force of gravity. This balancing act is shown in Figure 7.1.5.

Figure 7.1.5

The downwards force of gravity is balanced by the upwards support force from the chair. The forces acting on this person are balanced.

Balanced forces don't always mean that the object is stopped: it might be travelling at the same speed without changing directions. Consider Nishika, about to ride her bike. To take off, Nishika must accelerate, pedalling fast and hard to produce a force large enough to push her forwards. She needs to overcome the friction caused by the roughness of the road and by the air that she pushes through. To speed up, Nishika keeps accelerating. Her pedalling needs to provide a driving force that is bigger than the force of friction acting in the opposite direction. As Nishika continues her journey, she may travel at a constant speed without slowing down or speeding up. When this happens, the forwards force from her pedalling is cancelled out by the friction forces pushing her backwards. At this stage, her motion is constant and all of the forces acting on her are balanced, as shown in Figure 7.1.6.

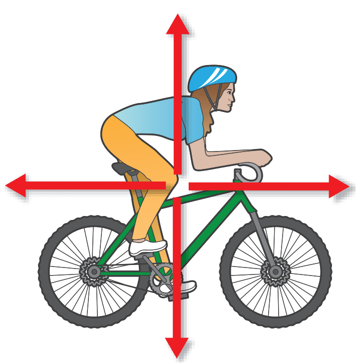


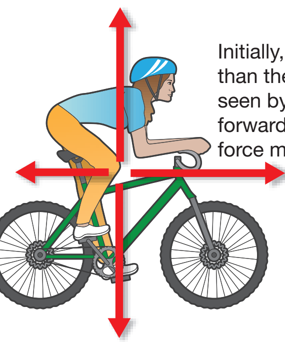
Figure 7.1.6

At this stage of the ride, Nishika travels at a constant or even speed. All of the forces acting on her are balanced. This is indicated by the red arrows being the same length in each direction.

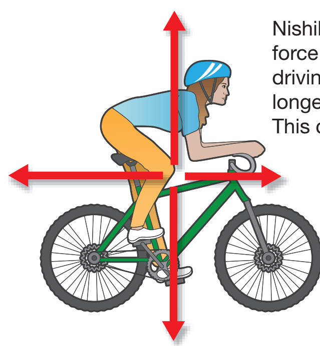
Unbalanced forces

Whenever the forces acting on Nishika are unbalanced, her motion will change. Motion always changes in the direction of the unbalanced force, as can be seen in Figure 7.1.7. This means that the forces are unbalanced when Nishika:

- starts moving (by pedalling fast and hard)
- speeds up (by pedalling faster and harder)
- slows down (by using the brakes)
- comes to a stop (by using the brakes)
- changes direction (by turning the handlebars).



Initially, the forwards force is greater than the force of friction. This can be seen by the longer red arrow in the forwards direction. This unbalanced force makes Nishika speed up.



Nishika is applying the brakes and the force of friction is greater than the driving force. This can be seen by the longer red arrow pointed backwards. This causes her to slow down.

Figure 7.1.7

Nishika's motion will change whenever the forces acting are not balanced.

7.1

Inertia

If you put your schoolbag down in your bedroom, it will stay there until something happens to it. Someone could lift it, push it or pull it to make it move; but if left alone, your schoolbag will stay as you left it. This ability of the schoolbag to remain unchanged is called its **inertia**. Everything and everyone possesses inertia. Inertia can be described as the tendency to resist any change in motion.

INQUIRY science 4 fun

Marble motion

Can you design and build a device that will apply different forces to a marble?

Yes

Collect this ...

- an arrangement of objects, such as elastic bands, wooden ramps, springs, balloons, cardboard boxes, cardboard tubes, funnels, icy pole sticks
- a marble

Do this ...

1. Design a device so that once a marble is dropped onto or into your device, it will speed up, slow down, change direction and finally come to a stop.
2. Build your device and test it out.

Record this ...

Describe what happened to the marble's motion after it was dropped.

Explain why you think this happened.

Figure 7.1.8 In a front-on collision, although the car has stopped, the motion of its passengers continues due to the effects of inertia.

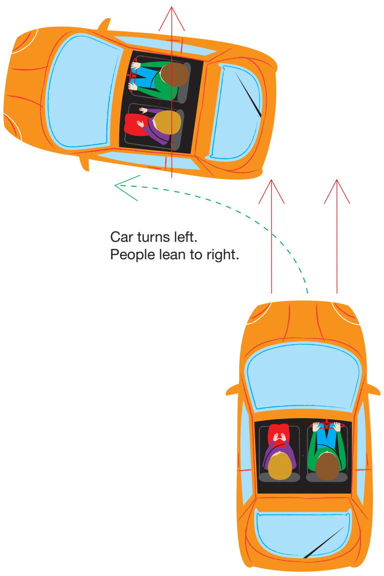


Figure 7.1.9 When travelling forwards in a car that suddenly turns left, you may lean to the right. Although the steering force changes the direction of the car, you continue to move straight ahead.

Sir Isaac Newton proposed some statements to explain the way things move. These are called laws of motion. Newton's first law of motion states that:

- anything that is not moving will stay that way unless a force makes it move
- anything that is moving will keep moving at the same speed and in the same direction unless a force makes it change.

This law explains why Nishika needed to apply an unbalanced force in order to change her motion. Figure 7.1.8 shows what happens to crash-test dummies the instant after a car hits a wall at 56 km/h. The motion of its passengers continues until something else stops them. Similarly, when travelling in a car or bus turning a corner, your body continues to travel in a straight line. As a result, you lean to one side as the vehicle turns, as shown in Figure 7.1.9.

Wearing seatbelts while travelling in a car and wearing a helment while riding a bike help to protect you from the effects of inertia.

The effect of mass

The more massive something is, the greater its inertia. This means it takes greater force to change its motion. It takes a far smaller force to stop a pebble rolling down a hill than to stop a massive rock. Similarly, it takes a smaller force to get the pebble moving in the first place.

SciFile

Pumpkin helmets

Operators of the many motorcycle taxis used as cheap transport in Nigeria were unhappy about a new law forcing them to wear helmets. Complaining that the helmets were expensive and were often stolen, many riders protested against the law by wearing helmets made from pots, pans, plastic or even dried pumpkin shells. Authorities were not pleased and their motorbikes were confiscated.

Figure 7.1.10 A crash test in motion.

SCIENCE AS A HUMAN ENDEAVOUR

Use and influence of science

Car safety features

An average 1.2 million people around the world die in road deaths each year, with another 50 million suffering related injuries.

ANCAP (Australasian New Car Assessment Program) provides information to consumers about the level of protection afforded by all new cars on the market. A system of star ratings, from 1 to a maximum of 5 stars, is used to indicate how safe a car will be in an accident.

If a car stops suddenly, its passengers continue to move forward until they hit something that stops them. If they stop by hitting the windscreen, dashboard or steering column at this speed, they can be seriously injured or killed. Crash testing helps develop safer cars and inform consumers of the safety rating of new cars on the market.

INQUIRY science 4 fun

Starting and stopping

What happens to your body as a car starts and stops?

Yes

Collect this …

- a skateboard or toy truck
- a petri dish or jar lid
- masking tape
- a marble

Do this …

1 Tape the petri dish to the skateboard or toy truck.
2 Put a marble or ball bearing in the dish.
3 Observe what happens to the marble when you push the skateboard/truck forward, stop it, or push it around a corner.

Record this …

Describe what happened to the marble in each case.
Explain why you think this happened.

Figure 7.1.11 illustrates some of the active and passive safety features found in many new cars. Active safety features are designed to reduce the chance of an accident. They include:

- good quality tyres inflated to correct pressure
- functioning headlights
- an effective braking system
- reversing cameras
- reversing sensors
- ABS (anti-lock brakes)
- traction control
- ESC (electronic stability control)
- night vision
- brake assist.

Passive safety features lessen the possible damage to the occupants of a car in an accident. They include:

- correctly adjusted three-point seatbelts and seatbelt reminder lights
- front and side airbags
- crumple zones (shown in Figure 7.1.12)
- side impact protection systems
- no sharp features protruding from the dashboard of the car.

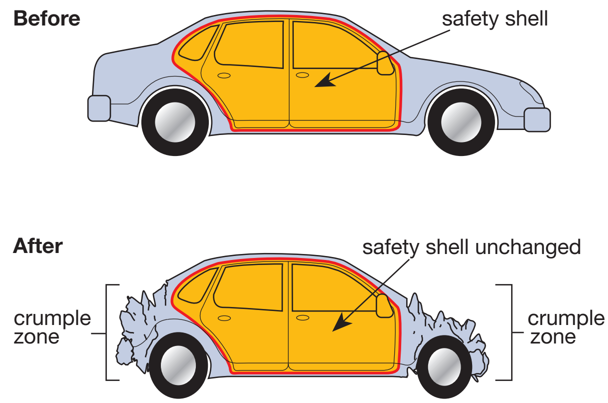


Figure 7.1.12 The passenger shell of a car is usually made from steel to protect its passengers. The engine compartment and the boot, however, are designed to collapse in a collision. This increases the time the car takes to come to a stop, which reduces the force of the impact.

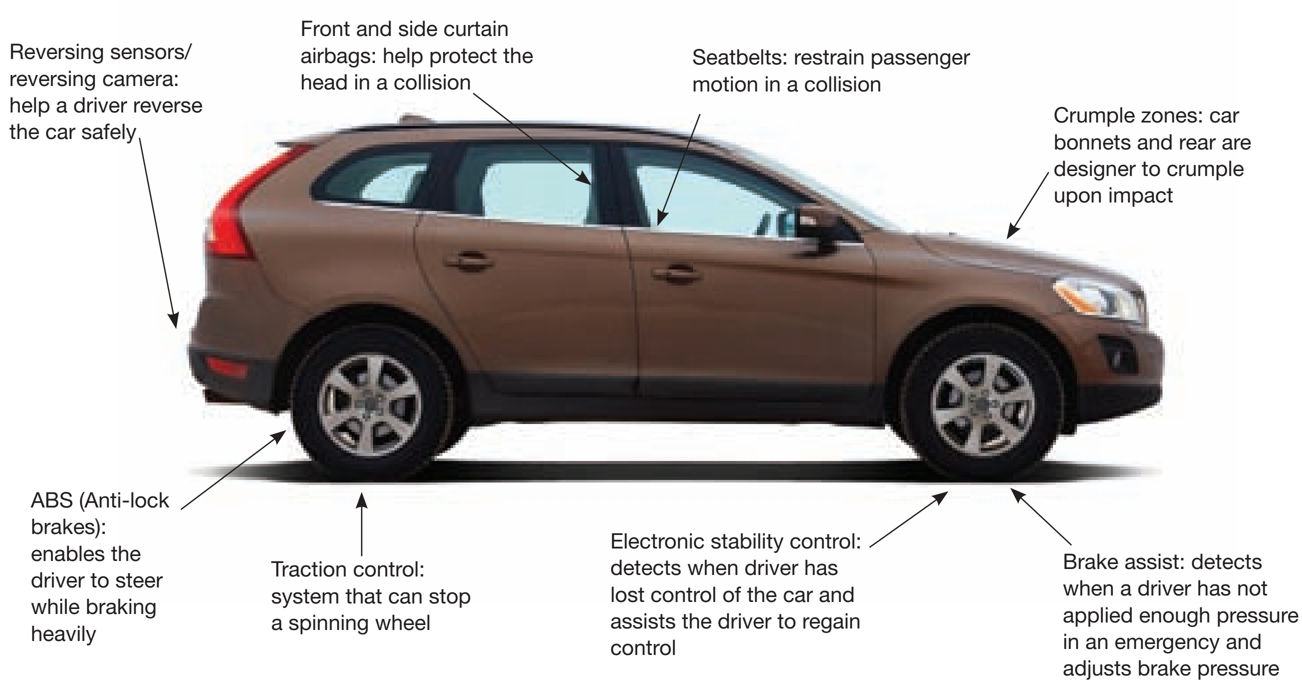


Figure 7.1.11 These are some of the active and passive safety features that can be found in a car.

2 p254

7.2

7.1 Unit review

Remembering

1 **State** which word from the list below correctly completes each statement.

push motion newton force spring

a All around us, things move or are in ____.
b Whenever there is a change in motion, a ____ has acted.
c A force can be a ____, a pull or a twist.
d A force can be measured using a ____ balance.
e The unit used to measure force is called the ____.

2 **List** five ways a force can change motion.

3 **State** whether the following are true or false.
a If the forces acting on an object are balanced, then it is not moving.
b You supply a force when you squeeze a tube of toothpaste.
c Inertia describes the tendency of an object to change its motion.
d The less mass an object has, the greater its inertia.

Understanding

4 **Describe** an example of a force that:
a speeds up an object's motion
b changes an object's direction.

5 **Explain** how a spring balance is used to measure force.

6 The grocery and bathroom scales shown in Figure 7.1.3 on page 246 both use a spring to measure the size of a force. **Outline** how the spring is used in each case.

7 Refer to Figure 7.1.6 on page 247.
a **Name** the forces acting on Nishika when she travels at a constant speed.
b **Explain** why the arrows on this force diagram are shown to be equal in size.

8 **Describe** the role of each of the following safety features in protecting passengers of a car in an accident: airbags, anti-lock brakes, reversing sensors, electronic stability control and seatbelts.

9 **Explain** why cars are designed with crumple zones.

Applying

10 **Identify** the direction of movement of objects acted upon by these forces:

Force to left (N)	Force to right (N)	Force upwards (N)	Force downwards (N)	Direction of movement
10	10	10	0	
20	30	0	0	
25	5	15	15	
30	30	10	50	
40	40	100	100	

11 Figure 7.1.13 shows forces acting upon four boxes, labelled A, B, C and D.

Use an arrow to **demonstrate** the size and direction of the overall force acting on boxes A, B, C and D.

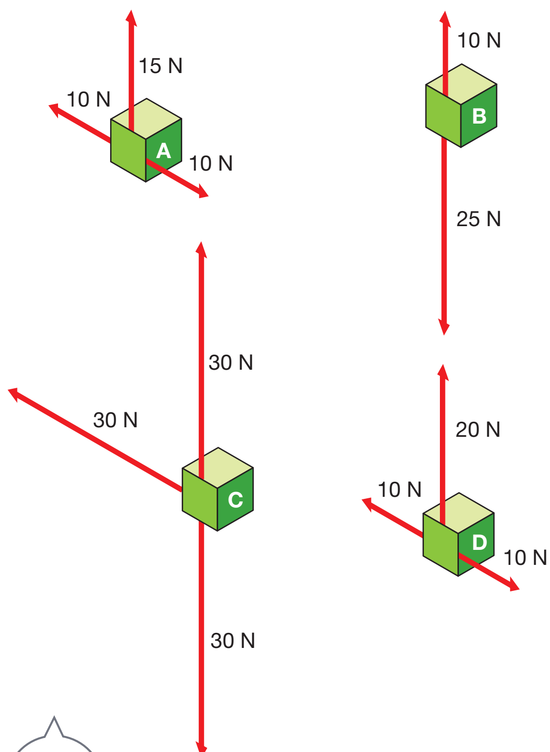


Figure 7.1.13

7.1 Unit review

12 **Use** your understanding of inertia to **explain** the following situations.

- **a** Mien is rollerblading along the footpath. Upon hitting a small stone, he falls forward, grazing the palms of his hands and his knees.
- **b** Madeline brakes suddenly when driving to work because she failed to notice that the driver in front was slowing. Some china plates resting on the back seat fall forward and some break.
- **c** Carl loses his balance and falls backwards while standing in a train as it leaves a station.

Analysing

13 **Classify** each of these actions as a push, pull or twist force.

- **a** Sweeping the floor
- **b** Dragging a heavy sports bag along the floor
- **c** Throwing a cricket ball
- **d** Hitting a golf ball
- **e** Tightening wheel nuts on a car
- **f** Closing your front door from the inside of the house
- **g** Closing your front door from outside your house

14 Forces can be represented by arrows.

- **a** **Compare** the forces shown in Figure 7.1.14 by stating which:
  - **i** force is the largest
  - **ii** two forces are the same size
  - **iii** two forces act in the same direction.

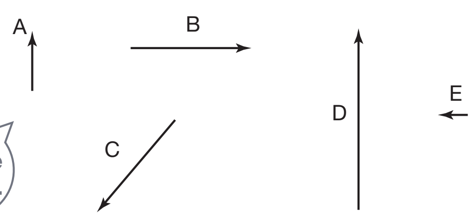


Figure 7.1.14

- **b** If forces B and E acted on an object, **predict** which direction the object would move.

Creating

15 Bob uses an old yo-yo for a trick called 'around the world'. Unfortunately, the string breaks as the yo-yo reaches point X (Figure 7.1.15).

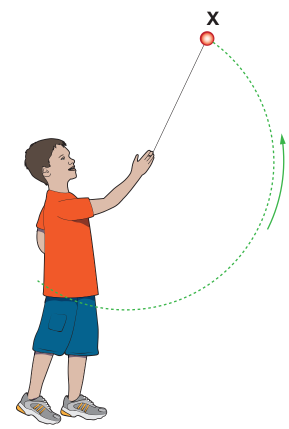


Figure 7.1.15

- **a** **Construct** a diagram to show the path you think the yo-yo will take immediately afterwards.
- **b** **Justify** your answer in terms of its inertia.

Inquiring

1 Sir Isaac Newton (1642–1727) used mathematics to develop theories to help us understand the world better. Research his life and work. Construct an illustrated timeline in which you outline major events and discoveries in his life.

2 Compare the:

- number of airbags installed
- features of the airbag system

for three different models of cars.

Recommend which of the three cars would provide greatest protection in an accident.

3 Design and construct a device that can measure the size of a force. Explain how your scale works and describe how this measurement can be converted into newtons.

4 Design and conduct an experiment to examine the effects of inertia on a moving object. For example, you could study what happens as you swing a bucket of water in a vertical loop. You could use a mobile phone or video camera to record and analyse changes in the object's motion.

7.1 Practical activities

1 Looking at forces

Forces act all around us, all of the time. Whenever the shape or motion of an object changes, we know that an unbalanced force has acted.

Purpose

To observe a range of forces in action.

Materials

- textbook
- table tennis ball
- balloon
- woollen fabric
- magnet
- paper clip
- plastic straw
- plasticine
- tennis ball
- plastic cup
- pencil case
- ruler
- bucket

Procedure

Complete each of the tasks in the table, recording your observations as you go.

Results

1 Copy the table into your workbook.

2 Record all your observations in the appropriate columns.

Discussion

1 A force was acting in each task. **Explain** how you knew.

2 **List** any objects that changed shape as a result of the force.

3 **State** whether any of these changes in shape were permanent.

4 **State** whether the tennis ball changed its shape at any stage of its journey.

5 **Discuss** whether a table tennis ball could remain stationary even when two people blow air on it from two straws.

Task		Changes observed in the motion or shape	What produced the force?
a	Prop up one end of a textbook to make a ramp. Roll a tennis ball down it.		
b	Rub woollen fabric against an inflated balloon, and bring the balloon towards someone's hair.		
c	Point an end of a bar magnet towards a paper clip.		
d	Drop a tennis ball and try to catch it when it bounces.		
e	Blow a table tennis ball across a bench using a plastic straw.		
f	Use a straw to blow bubbles in water in a cup. (Do not drink it.)		
g	Push your pencil case across the bench using a ruler.		
h	Squash a lump of plasticine.		
i	Push an inflated balloon into a bucket of water and then let the balloon go.		

2 Crash test dummies

Purpose

To model crash-test dummies and describe their motion in different types of collisions.

Materials

- trolley
- about 50 g of plasticine
- toothpicks
- talcum powder
- block of wood
- ruler or measuring tape
- ramp
- some books or bricks to make ramp and a barrier
- video camera or mobile phone

Procedure

Part 1: Collision with a barrier

1. Construct a model crash-test dummy of a person from plasticine and toothpicks.
2. Set up a ramp to a height of about 50 cm. Place a brick 30 cm in front of the ramp as shown in Figure 7.1.16.
3. Place crash dummy A on a trolley. Lightly powder the dummy with talcum powder to prevent it sticking to the trolley.
4. Release the trolley from the top of the ramp, and watch the motion of dummy A carefully (or record its motion) as it hits the brick.
5. Repeat the test three times and record your observations.

Part 2: Collision between two vehicles

6. Join with another group. Remove the brick and place one trolley and dummy B in its place.
7. Release dummy A from the top of the ramp and record what happens to dummies A and B when the trolleys collide.
8. Repeat this test three times.

Discussion

1. Part 1: Collision with a barrier
   a. **Describe** changes in the motion of dummy A on impact.
   b. **Explain** these changes in terms of inertia.
   c. **List** any safety features that would protect dummy A in this impact.
2. Part 2: Collision between two vehicles
   a. **Describe** changes in the motion of dummy A on impact.
   b. **Explain** these changes in terms of inertia.
   c. **List** any safety features that would protect dummy B in this impact.

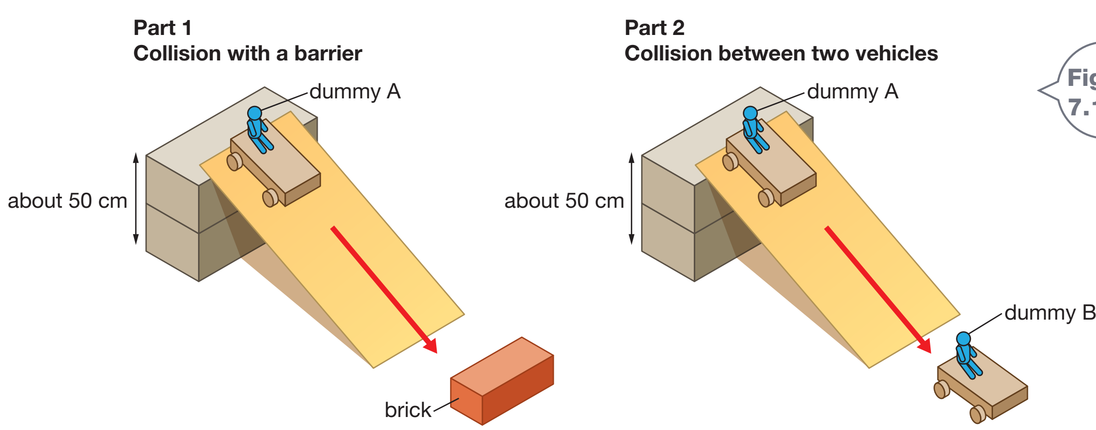


Figure 7.1.16

7.2 Friction—a contact force

According to Newton's first law, things that are moving will continue to do so unless a force makes them stop. The force that makes most moving objects stop is friction. Friction exists whenever two surfaces are in contact. Friction is the force that provides the grip needed by cars, bikes, trucks and your shoes to get moving, change direction and slow down. Friction can be a problem. It causes machines with moving parts to heat up, which wastes energy.

INQUIRY science 4 fun

Warming up

Yes

Collect this ...

- block of wood
- piece of sandpaper

Do this ...

1 Rub your hands together as quickly as you can for a minute. How do they feel?

2 Now rub a piece of sandpaper back and forth over a piece of wood for a couple of minutes. Feel the surface of the wood.

Record this ...

Describe what happened in each case.

Explain why you think these observations happened.

What is friction?

If you roll a soccer ball along a patch of open grass, then it will slow down and eventually stop. The force that slows it down is **friction**. Friction occurs whenever one object tries to move over another. Because it occurs between surfaces in contact, friction is called a **contact force**. Friction acts in an opposite direction to motion, as shown in Figure 7.2.1.

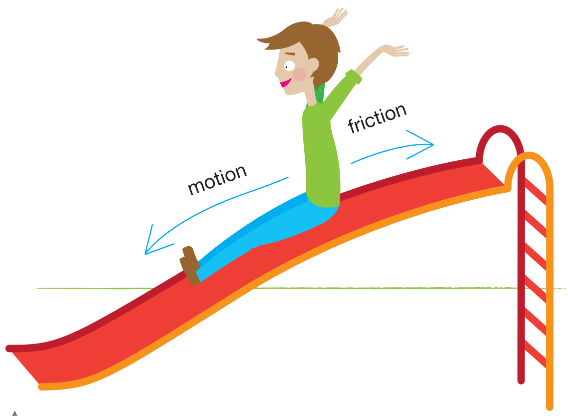


Figure 7.2.1 Friction always acts in the opposite direction to motion.

Two sheets of sandpaper will appear to 'stick' when you try to slide them over each other. This is because the grit on one sheet grabs and catches bumps on the other. This causes friction, and collisions between these bumps create heat.

All surfaces have bumps on them, even 'smooth' materials such as glass or steel. Figure 7.2.2 shows the microscopic bumps on the 'smooth' surfaces of a contact lens. An ice sheet is a very smooth surface (Figure 7.2.3). Try to walk on ice and you will slip because the friction is so low. You may have already worked this out and suffered a few bruises as a result!

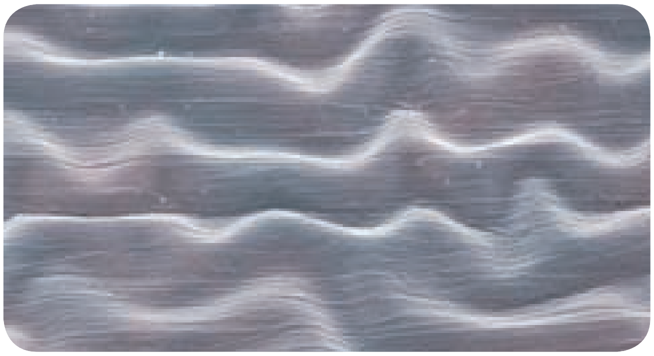


Figure 7.2.2 These ridges are microscopic bumps on the surface of a plastic contact lens, viewed with an electron microscope.

Figure 7.2.3 The puck used in ice hockey will travel long and fast along the ice unless it is blocked. This is because of the low friction between the ice and the puck.

What affects friction?

Friction depends on:

- how rough the surfaces in contact are
- how hard the surfaces are pushed together.

The greater the weight of a sliding object, the greater the force of friction, as shown in Figure 7.2.4.

7.3

1 p261

Figure 7.2.4 Greater friction exists between the heavier box and the floor than between the lighter box and the floor. This makes the heavier box harder to move.

Useful friction

When you walk, you push your foot backwards against the ground. The force of friction acts in the opposite direction to push you forward. For this to happen, there must be enough traction, or grip between your feet and the ground, or else you slip. This is shown in Figure 7.2.5. Without friction, you could not pick things up, walk, run, ride a bike or travel in a car.

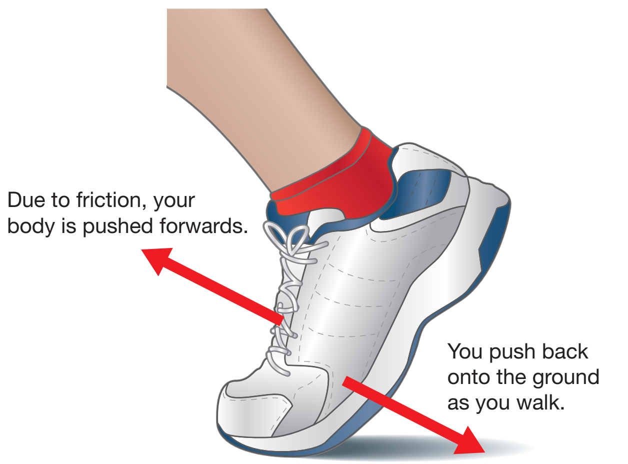


Figure 7.2.5 Friction enables us to walk.

Figure 7.2.6 The ridges and grooves seen in your fingerprints increase the friction between your fingers and the objects you grasp.

Unwanted friction

You rely on friction in your daily life, but it also has some unwanted effects. Moving parts, such as those in a machine, are gradually made thinner, or worn away, by friction. Friction also produces heat. Much of the energy put into a machine, such as a car, aircraft, a mixer or an electric knife, is converted into heat. This makes the machine less efficient and wastes energy, because it is not being converted into the useful forms of energy required. A car radiator absorbs heat produced by the friction of moving parts in a car engine.

Friction between an object and the air around it slows its motion. This type friction is called **air resistance**, or drag. A wind tunnel, such as that shown in Figure 7.2.7, can test how well an object cuts through the air.

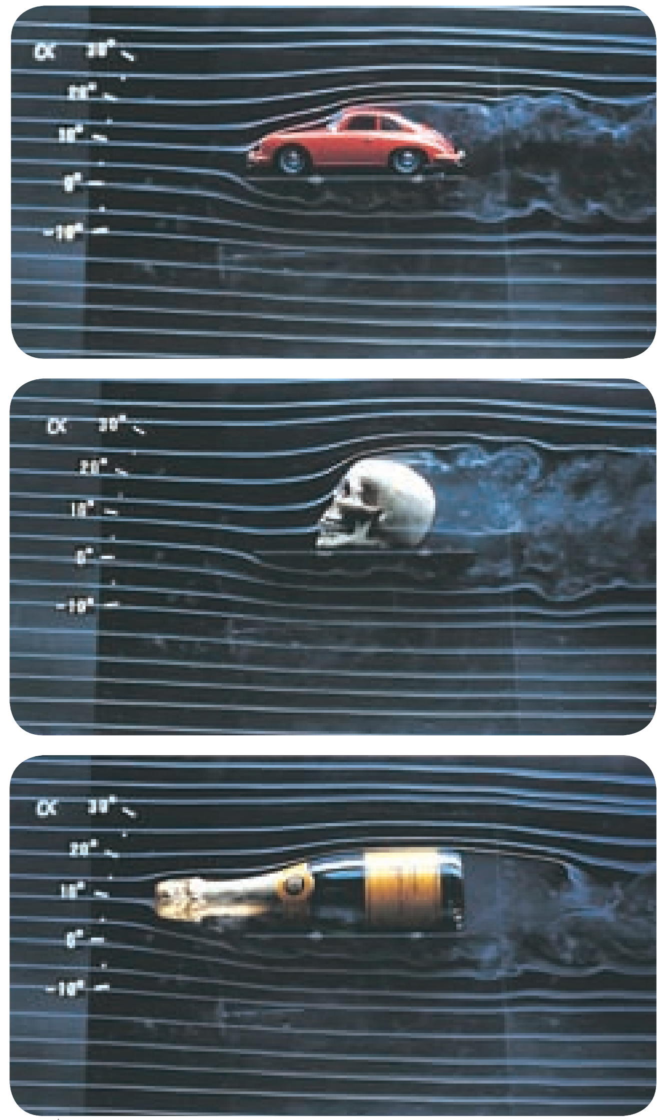


Figure 7.2.7 Studying the air flow over these objects reveals that drag occurs at the front of an object where air bunches up as it moves forward, and also behind it, where there is a space needing to be filled.

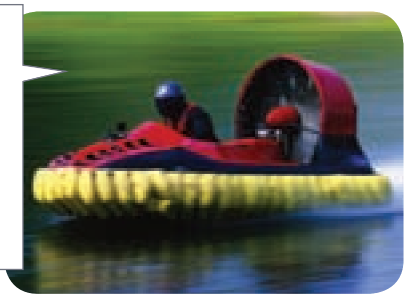
Reducing friction

Reducing friction makes machines more efficient, cheaper to run and longer lasting. Friction can be reduced by a number of different methods (see Figure 7.2.8).

2 p262

Removalists use trolleys to shift refrigerators because rolling surfaces produce less friction than sliding surfaces. Skateboards and rollerblades have ball bearings inserted into the hub of their wheels, allowing them roll more freely over the axle.

An effective way to reduce friction is to stop moving parts being in contact with each other. A hovercraft travels on a blanket of air with very little friction.



You may have slipped on spilt grease or oil at home. These substances are called **lubricants**. By adding grease to ball bearings, or putting oil into a car, we reduce the friction between moving parts. Polishing a surfboard helps to make its surface smoother and will reduce friction.

Vehicles such as cars and aircraft are all designed to have a streamlined shape. These shapes allow air to flow over and around them more freely, and reduce drag.

Figure 7.2.8 There are a number of ways friction can be reduced.

SciFile

Low-drag shark

These are shark scales. Each is made from dentine, is coated in dental enamel and measures about a half a millimetre. The base of each scale is made from bone and attaches the scale to the shark's skin. The shark's scales reduce churning of the water as the shark moves, and allow it to glide more smoothly as it seeks its prey.

SciFile

Swimsuit friction

Swimmers have always tried to reduce their friction with the water. Men shave their heads, legs and chests and swimmers often wear full-body swimsuits. In 2009, swimmers competing in the World Titles in Rome were allowed to wear hi-tech polyurethane swimsuits, resulting in 43 new world records. These suits are now banned in competition.

7.4

7.2 Unit review

Remembering

1 **State** three everyday activities you couldn't do without friction.

2 **Name** which surfaces are in contact when friction acts:
- **a** when you kick a football
- **b** when you swim at the beach
- **c** as you walk down the street
- **d** as two people push a broken-down car.

3 **State** whether the following are true or false.
- **a** Friction acts in the same direction as an object's motion.
- **b** The greater the weight of the sliding object, the less the force of friction it experiences.
- **c** Friction makes a machine more efficient.

Understanding

4 In your own words, **explain** why friction exists.

5 Without friction, you could not pick up an apple. **Explain** why.

6 **Explain** why a car needs a radiator to operate effectively.

7 **Explain** why it is easier to push a toy chest along the floor when it is empty than when it is full.

8 **Explain** why ball bearings are used within the hubs of skateboard wheels.

9 Your grandmother has asked you to shift her refrigerator to the other side of the kitchen. **Describe** three ways you could reduce friction to make the task easier.

10 A mountain bike is designed to be considerably heavier than a road bike. **Explain** why this is the case, considering the typical surfaces each is used on.

Analysing

11 Figure 7.2.9 shows an ice-skater performing a routine on ice.
- **a** **Compare** the level of friction that would be present on the ice and on a footpath.
- **b** **Discuss** how this difference allows the ice-skater to move differently on the ice.
- **c** The base of an ice skate is a narrow blade. **Explain** how this shape helps to lessen friction.

Figure 7.2.9

12 **Analyse** the following and rate them in order from those that would experience the most friction to those that would experience the least.
- A couch being dragged across carpet
- A waxed pair of skis travelling on snow
- An ice-hockey puck hit across the ice
- A child's tricycle being pulled along the footpath

Evaluating

13 A minibus is travelling along a flat road. **Use** Figure 7.2.10 to answer the questions below.

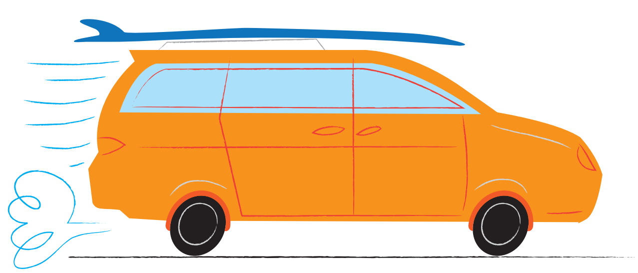


Figure 7.2.10

- **a** **Name** two sources of friction that are acting on the vehicle.
- **b** **State** the direction in which these forces act.
- **c** **Describe** what the driver should do to maintain the speed of the minibus.

d The surfboard is now removed from the roof-rack.

i **Explain** whether the friction acting on the car would increase or decrease.

ii **Justify** your answer.

e **Predict** what would happen if the tyres on the minibus were not properly inflated. Use friction to **justify** your answer.

14 The blades of an electric mixer are hot after beating some cream. **Justify** why this had happened in terms of friction.

15 Weighlifters rub chalk onto their hands before attempting a lift. The chalk absorbs any sweat on the weightlifter's palms.

a **Propose** why weightlifters use this chalk.

b **Predict** what could happen if they use too much chalk on their hands.

Creating

16 Imagine that you wake up one morning and the force of friction no longer exists. **Create** a role-play or a story or **construct** a flowchart in which you **describe** what happens when you attempt five everyday tasks, such as getting dressed, brushing your teeth, cooking and eating your breakfast, getting to school, and sitting in class.

Inquiring

1 Describe how disc and drum brakes use friction to slow and stop a car. Present your findings as a labelled poster.

2 Investigate the friction that exists within three objects in your home. For example, you could investigate a doorhandle, a suitcase on rollers or the mechanism of a sliding door or drawer.

- Describe how the mechanism works and state where friction is experienced.
- Propose how this friction can be reduced.

3 Using a cardboard box, an electric fan, streamers or wool and some sticky tape, construct a wind tunnel to test the aerodynamics of at least five objects. Describe which shapes you find to be the most aerodynamic.

4 Identify and describe the way the body coverings of three different animals assist them by reducing friction as the animals move.

5 Identify the structure of a polar bear's foot, shown in Figure 7.2.11. Explain how this increases friction between the bear's foot and the ice.

Figure 7.2.11 The underside of a polar bear's foot

7.2 Practical activities

1 Friction and mass

Purpose

To investigate how increasing mass affects the size of friction.

Materials

- wooden block with hook
- spring balance or force sensor
- 200 g masses

Procedure

1. Place the wooden block on a bench top.
2. Attach the spring balance to the block of wood as shown in Figure 7.2.12.

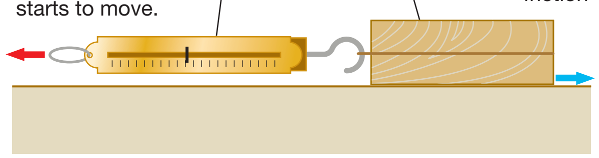


Figure 7.2.12

3. Measure the size of the force needed to keep the block moving at a constant speed. This is equal to the force of friction. Record this in your results table.
4. Repeat step 3 twice and record the results.
5. Add a 200 g mass on top of the block of wood. Measure the friction between the block and the bench top three times and add these results to the table.
6. Repeat the friction measurements for 400, 600, 800 and 1000 g (1 kg) masses on the block, recording three results for each test.

Results

1. Copy the table below into your workbook.
2. Calculate the average of your results in the table. (Add the three forces and divide by three.)
3. Construct a line graph showing your results. Place mass added to the block on the horizontal axis (0, 200, 400, 600, 800, 1000 g) and the friction force on the vertical axis (in newtons).

Discussion

1. **Describe** what happened to the size of the force of friction as the mass on the wooden block increased.
2. **Discuss** a situation in which you have noticed this link between friction and mass.
3. **Propose** any improvements that could be made to the design of this experiment.

Object moving	Friction force measured (N)			Average friction (N)
	Trial 1	Trial 2	Trial 3	
Wooden block				
Wooden block + 200 g				
Wooden block + 400 g				
Wooden block + 600 g				
Wooden block + 800 g				
Wooden block + 1000 g				

2 Reducing friction

Purpose

To reduce the force of friction between a block of wood and a wooden ramp.

Materials

- wooden block
- wooden ramp
- various materials to place on the ramp, such as:
  - linoleum square
  - carpet square
  - sandpaper
  - waxed paper
  - other materials as approved by your teacher
- protractor
- 3 pieces of dowel

Procedure

1. In your results table, enter the details of each surface you are testing in the second column. With permission, you may also test the block on 2 tablespoons of cooking oil.
2. Predict in which experiment there will be the most friction between the block and the ramp, and in which there will be the least.
3. Place the wooden block on a marked position near the end of a plank of wood.
4. Slowly lift the end of the plank that the block is on, holding the other end of the plank on the bench top as shown in Figure 7.2.13.

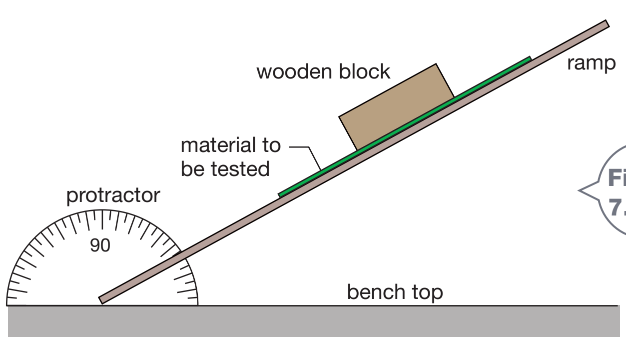


Figure 7.2.13

5. Use the protractor to measure the angle at which the block first starts to slide down the plank.
6. Repeat the test using the wooden dowels as rollers, and then test each surface you have available.

Results

1. Copy the following table into your workbook.

Experiment number	Set-up of equipment	Angle at which block starts to slide down ramp
1	Wooden block on ramp	
2	Wooden block placed on dowel rollers on ramp	

2. **Construct** a bar or column graph that compares the angle at which the block started to slide for each surface.

Discussion

1. The larger the angle at which the block started to move, the larger the friction between the block and the ramp. **Assess** whether you were correct in predicting which block experienced the most friction.
2. **Assess** whether you were correct in predicting which had least friction.
3. **Construct** a diagram on which you label the direction of friction acting on the block.
4. **Identify** two examples where lubricants, rollers or waxing are used to reduce the force of friction.

7.3 Gravity—a non-contact force

On the Giant Drop on the Gold Coast, passengers fall 120 metres (39 storeys) in 5 seconds, reaching speeds up to 135 km/h! A magnetic braking system stops them just before they hit the ground. In everyday life, you don't experience gravity quite as dramatically as these passengers, but you do feel its effects every minute.

What is gravity?

All objects attract each other. There is a force of attraction between you and your schoolbag, as there is between you and everything around you. **Gravity** is this force of attraction. The more mass a pair of objects have, the stronger the pulling force of gravity between them. As a result, you are pulled strongly towards the Earth (just like the skydiver in Figure 7.3.1) and the Earth is pulled strongly towards you. The Earth has much more mass than you, so the pull you exert on it is barely noticeable, but you can feel its pull. In comparison, you and your schoolbag have a much smaller mass, so the force between you and your bag is very small.

Figure 7.3.1 A force of attraction called gravity pulls the skydiver towards Earth.

Gravitational fields

If you throw a ball into the air, you know it will fall back to Earth. If an object lies within a region called the Earth's **gravitational field**, then a gravitational force will act upon it. This region is called a **force field**. Gravity acts through a force field, without direct contact. It can be described as a **non-contact force**. Figure 7.3.2 on page 264 shows the direction of the Earth's gravitational field.

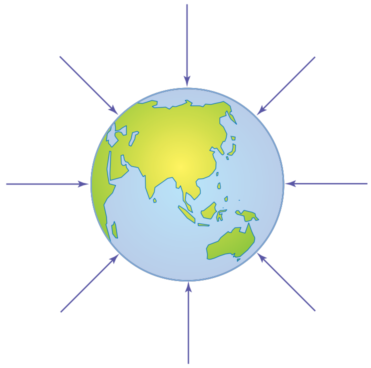


Figure 7.3.2 These field lines show the direction of a gravitational field. An object inside this field will experience gravitational force acting in this direction. The strength of the gravitational force field reduces as distance from the Earth increases.

Planets of our solar system lie within the Sun's gravitational field. As a result, these planets, including Earth, are pulled towards the Sun by a gravitational force. This force is not strong enough to pull Earth or another planet onto the Sun, but it is strong enough to keep it from escaping into deep space. Planets orbit the Sun in elliptical paths as shown in Figure 7.3.3. Similarly, our Moon and various artificial satellites are pulled into an orbit of the Earth because they lie within the Earth's gravitational field.

Comparing mass and weight

In everyday language, mass and weight mean the same. However, to scientists they are very different quantities.

What is mass?

Mass is the amount of matter in an object. Your mass would remain the same if you travelled to other planets, because the matter you are made from remains the same. Mass is measured in kilograms (kg). Smaller masses, such as the ingredients of a cake, are measured in grams (g). The mass of a large object, such as a car or truck, is measured in tonnes (t).

What is weight?

Weight is the name given to the pulling force of gravity on an object. Because it is a force, weight is measured in newtons (N). Your weight depends not only on your mass, but also on the strength of the gravitational field of the planet or moon that you are on. For this reason your weight on the Moon (Figure 7.3.4) is only one-sixth that on Earth.

7.5

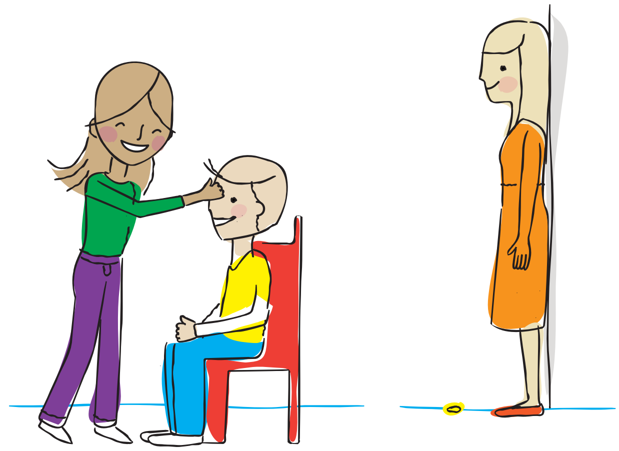
Figure 7.3.3 Gravitational attraction keeps moons in orbit around massive planets, and planets in orbit around more massive stars like our Sun.

Figure 7.3.4 This photo of astronaut Eugene Cernan, the last person to stand on the Moon, was taken in 1972. The Moon has less mass than the Earth, and so it has a weaker gravitational field. Although an astronaut's mass is unchanged, their weight is less on the Moon than on Earth.

INQUIRY science 4 fun

Centre of mass

Yes



The centre of mass or centre of gravity is a point where you can imagine all of an object's weight is concentrated. This point can be inside or, surprisingly, outside the object. Where is your centre of mass when you sit and when you bend down?

Collect this ...

- chair
- wall
- coin

Do this ...

Part A

1 Place the back of the chair against a wall.
2 Your partner is to sit on the chair, with their feet flat on the floor in front of the chair.
3 Put your thumb on their forehead.
4 Ask your partner to stand up.

Part B

1 Stand with your back to a wall.
2 Your partner is to put a coin on the floor, near your feet.
3 Try to pick up the coin.

Record this ...

Describe what happened.
Explain why you think this happened.

Stability

When you drive over a bridge, you can usually see heavy columns, stretched cables, arches or other supports designed to give it strength (Figure 7.3.5). All structures must be designed so that they can withstand the many types of forces that can act upon them. People and equipment in an office building push down on its supports. Cars and trucks travelling across a bridge push down on its foundations. Materials expand when temperatures rise, and contract when temperatures fall. These changes can squash, stretch or twist structures, as can strong winds, rain and hail. In addition, large structures need to be able to support the force of their own weight pushing downwards, and the force of the ground below that pushes upwards with an equal force.

Figure 7.3.5 Compare the design structures that support each of these bridges.

Falling

If you drop an autumn leaf and a stone from the same height, you'd be fairly sure that the stone would hit the ground first. For many centuries, this caused people to believe that heavier things fell faster than lighter ones. Galilei Galileo (1564–1642) performed experiments with falling objects. He realised that the reason some things fell faster was not because they weighed more, but because they had a smaller surface area than other things. Air is pushed out of the way as an object falls. A leaf has a greater surface area than a stone of the same mass. It experiences a greater force of friction (air resistance), slowing its motion and causing it to flutter as it falls (Figure 7.3.6).

1 p271

2 p272

Figure 7.3.6 A leaf flutters as it falls, because it has a relatively large surface area and experiences more air resistance than other more compact objects.

Light as a feather?

SciFile

In 1971, Apollo astronaut David Scott dropped a feather and a hammer from the same height at the same time while on the Moon's surface. They hit the ground at exactly the same time. Go to Pearson Reader to see a video of his demonstration.

Terminal velocity

As an object's speed increases, its air resistance also increases. This means that the air resistance on a falling object increases as it falls. Eventually, the air resistance acting on the object equals its weight force. When this happens, the forces acting on the object are balanced and the object then falls at a constant speed. This speed is called **terminal velocity**. This situation is shown in Figure 7.3.7.

The terminal velocity of a skydiver without a parachute is far too great to survive a landing on Earth. Opening a parachute provides a much larger surface area, which greatly increases the force of air resistance. This slows the skydiver down and soon after a safe terminal velocity is reached.

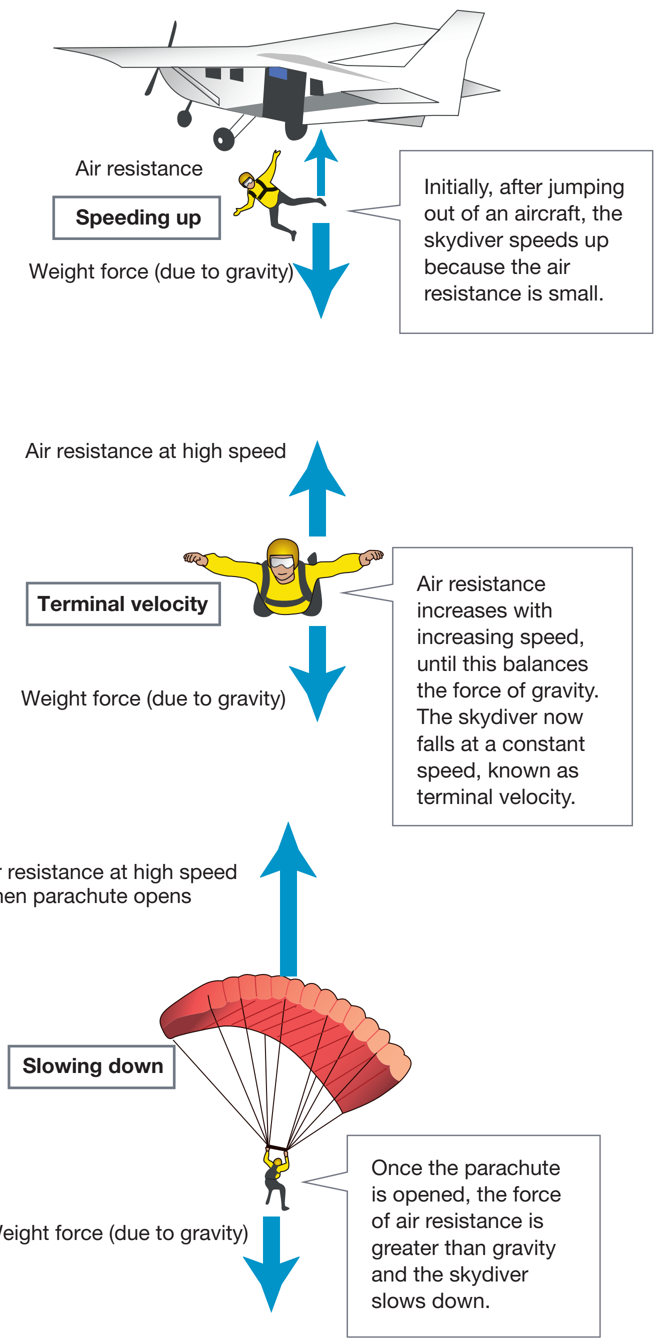


Figure 7.3.7 The motion of a skydiver depends upon the relative sizes of the forces of air resistance and weight.

7.6

INQUIRY

science 4 fun

Flying paper

Yes

An aircraft is able to fly because of the shape of its wings. How can these produce lift?

Collect this ...

- sheet of paper
- scissors

Do this ...

1. Cut a strip of paper, 5 cm wide and about 20 cm long
2. Hold the narrow end just below your lips.
3. Blow over the strip.

Record this ...

Describe whether the paper moved up or down.
Explain why you think this happened.

Flight

People have always wanted to fly. With modern aircraft, you can. There are four key forces at work on any aircraft (Figure 7.3.8). Thrust is the force pushing the aircraft forwards. This is needed to overcome the friction, or drag force, that is produced as the aircraft moves through the air. A large lift force is produced when air streams over the wings of the aircraft. These wings have a shape called an aerofoil to create this force, as shown in Figure 7.3.9. The wing is shaped so that it is longer over the top than it is from below. As a result, air flows more quickly over the wing than it flows beneath it. This produces higher air pressure below the wing than above, which pushes the wing upwards with the lift force. The lift force of course must overcome the massive weight of the aircraft, or else it's not leaving the ground!

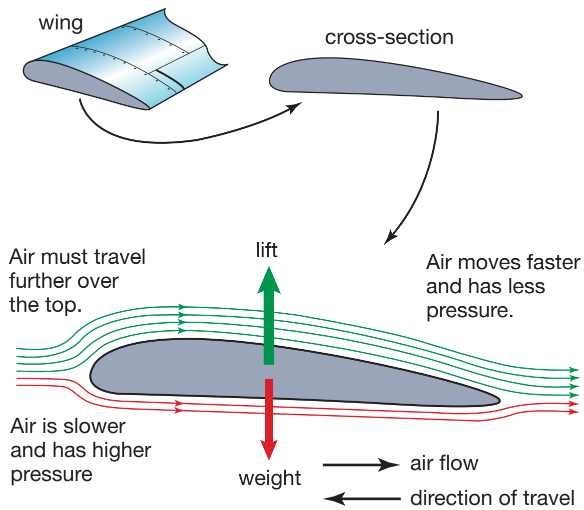


Figure 7.3.9 The way in which a wing creates lift is called the Bernoulli effect, and was discovered by Dutch–Swiss mathematician Daniel Bernoulli in 1738.

SciFile

Price of fame

Daniel Bernoulli (1700–82) became famous for applying mathematics to mechanical situations. His father, Johann, was head of mathematics at Gronigen University in the Netherlands. However, after Daniel and his father both entered and tied for first place in a scientific contest at the University of Paris, Johann banned Daniel from entering his house, because he did not want to be compared to his son.

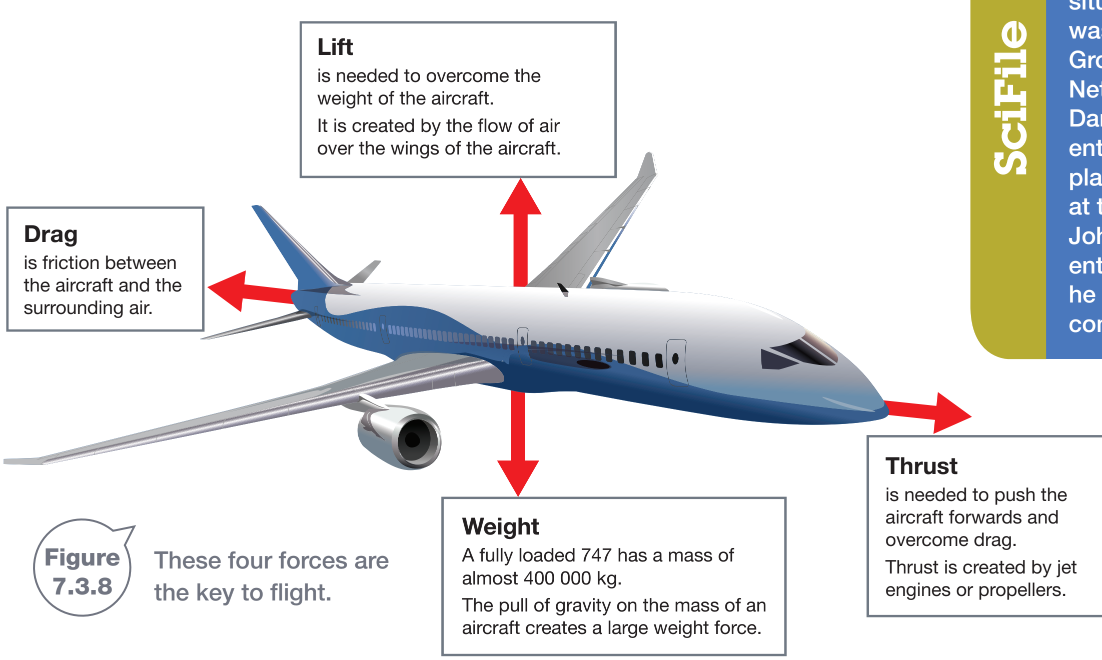


Figure 7.3.8 These four forces are the key to flight.

SCIENCE AS A HUMAN ENDEAVOUR

Use and influence of science

Science and sport

Figure 7.3.10 Wearing a streamlined helmet and using disc wheels rather than wheels with spokes reduces friction while cycling.

In any sporting competition, a slight advantage of one athlete over another can mean the difference between winning and losing. Sports scientists apply scientific ideas and techniques to improve an athlete's performance.

To prepare an athlete for an event, a sports scientist may use heart monitors and GPS (global positioning) devices to track the intensity of their training. The diet of the athlete is carefully planned and the athlete follows a tailored exercise program.

Technology can be used that may give an athlete an advantage. For example, when competing in a race, your body pushes forwards against the drag force of the friction of the air or water that surrounds you. If you can reduce this friction, you will travel slightly faster. That's why helmets like the one in Figure 7.3.10 are streamlined.

Using a pole vault made from a glass-fibre composite (as shown in Figure 7.3.11) benefits the performance of a pole vaulter. Other ways in which technology can make a difference to performance include:

- using running shoes that absorb force
- using swimwear that reduces drag
- using or football boots that provide sufficient friction
- having dimples on a golf ball to reduce drag
- using bicycles of light weight and streamlined design.

Understanding how forces affect motion can help a sportsperson to:

- throw baseballs or cricket balls with the curve or spin desired
- control their use of the wind while sailing
- keep their centre of gravity as low as possible to keep their balance when performing gymnastics, pole vaulting or high jumping
- dive into a pool without splashing
- swim with an efficient stroke in the water
- adjust the strings on a tennis racquet.

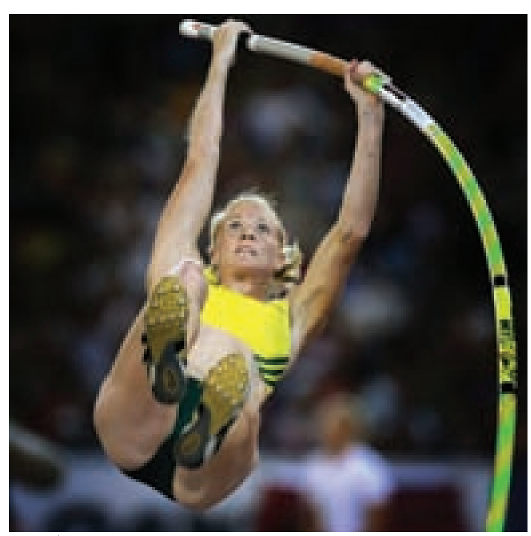


Figure 7.3.11 Replacing bamboo with a glass-fibre composite has resulted in huge increases in the record height for pole vaulting.

7.3 Unit review

Remembering

1 **Recall** gravity by selecting the correct term to complete the following sentences.
   a Gravity is a contact/non-contact force.
   b Gravity pulls/pushes objects towards the Earth.
   c All objects naturally attract/repel each other.
   d Objects fall at different speeds due to their weight/surface area.

2 **State** the unit used to measure mass.

3 **State** the unit used to measure weight.

4 **Name** the force that slows an object down as it falls.

5 a **State** whether air flows more quickly over the top or bottom surface of an aircraft wing.
   b **Name** the force that is created by this flow of air.

Understanding

6 The lines in Figure 7.3.12 represent the Earth's gravitational field.

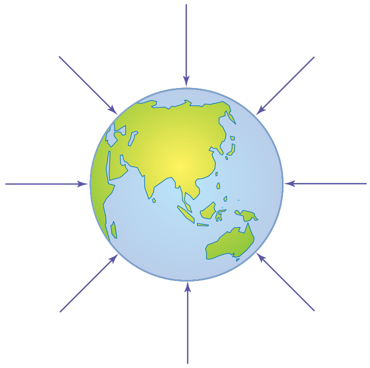


Figure 7.3.12

   a **Describe** what happens to an object that is located in the region of this field.
   b **Describe** what happens to the strength of this gravitational field as an object moves further away from Earth.
   c **Explain** why gravity is called a non-contact force.

7 **Describe** the effect of the force of gravity in three sporting events.

8 **Describe** three ways that knowledge of forces can be used to improve an athlete's performance.

9 **Describe** the role of a sports scientist.

10 Two forces act on a skydiver falling towards Earth.
   a **Name** these two forces.
   b Using a force diagram to help, **explain** at what stage of the fall the skydiver is accelerating, or speeding up, as they travel towards Earth.
   c Eventually the two forces are balanced. **Explain** how this affects the skydiver and **state** what this motion is called.

Applying

11 **Identify** whether the forces of thrust and drag on an aircraft are balanced in the following cases. If they are not balanced, **state** which is greater.
   a The aircraft speeds up.
   b The aircraft slows down.
   c The aircraft cruises at constant speed.

Analysing

12 **Compare** mass and weight by listing their similarities and differences.

13 A tennis ball, a cricket ball and a shot put are dropped at the same time. The path of the tennis ball as it falls is shown in Figure 7.3.13.

Analyse where the other two balls would be at the same time as the tennis ball (ignore air resistance).

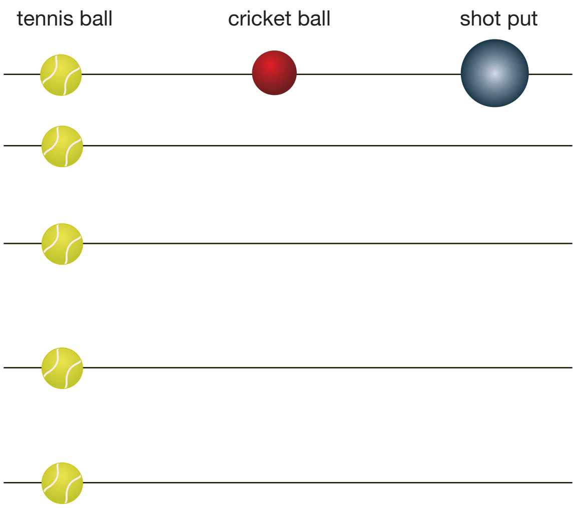


Figure 7.3.13

7.3 Unit review

Evaluating

14 Is there gravity on the Moon? **Justify** your answer.

15 **a** **Propose** three different ways that a person's mass could change throughout their life.

b **Propose** how a person's mass could remain the same, but their weight changes.

16 Min-Jee drops a leaf and a small rock from the top of a playground slide.

a **Predict** which will hit the ground first.

b **Assess** whether gravity acts differently on objects because of their different mass.

c **Predict** what Min-Jee would observe if her experiment was repeated on the Moon.

17 **a** **Predict** what would happen as an aircraft tried to take off, if its wings had been attached upside down.

b **Justify** your response.

Creating

18 According to the ancient Greek philosopher Aristotle, heavy objects contain more gravity than light objects, so they fall faster. **Construct** a response to Aristotle in which you disagree with his viewpoint.

19 Imagine what would happen if instead of being an attractive force, gravity was a repulsive force that pushed objects away.

Construct three diagrams showing what could happen to things around you if this was the case.

Inquiring

1 Search the internet to gather and view:

a video footage of some extreme gravity situations, such as a vertical drop theme-park ride, bungee jumping or skydiving

b video footage of astronauts in motion on the Moon

c images showing the streamlined shape of different models of aircraft.

2 Use the internet to investigate how the strength of the Earth's gravitational field decreases the further an object gets from Earth. Construct a labelled illustration or create a multimedia display to present your findings.

3 **a** Explain what is meant by the term 'zero gravity'.

b Investigate how astronauts train to be able to tolerate zero gravity conditions.

4 Research different types of parachute design. Discuss key features involved in the design and explain how these assist the parachutist.

5 Can you build a strong bridge? Design at least three different types of bridges that span a length of 30 cm. Construct your bridges from the same material (for example wood, cardboard or straws). Investigate the load that each can support and write a report about your conclusions.

6 Design and build a capsule capable of protecting a precious egg as it falls from a height at your school. The capsule needs to be constructed using a sheet of newspaper, 80 cm of sticky tape, and 80 cm of string.

SAFETY

Mark off the drop zone to ensure that no one is below the capsule when it is dropped.

Investigate how well your capsule protected the egg.

Compare the designs of your classmates and describe the design features that helped to protect the egg on impact. If you could repeat the task using an unlimited supply of newspaper, sticky tape and string, outline what you would do and explain why.

7.3 Practical activities

1 Look out below!

Purpose

To investigate if heavier objects fall faster than lighter ones.

Materials

- metre ruler
- Blu Tack
- foam or rubber
- a number of unbreakable objects of different size
- sheet of butcher's paper
- 50 g mass
- electronic balance

SAFETY

Be careful not to drop objects where they could fall on someone.

Note: If possible, use a motion sensor or light gates to complete this experiment more accurately.

Procedure

1. Measure the mass of each object and record the masses in your results table (shown below).
2. Predict what will happen when each object falls. Record your predictions in the table.
3. Mark a height of 2 metres on a wall with a piece of Blu Tack. Place some foam or rubber at its base. This is your 'drop zone' to test how fast each object falls.
4. Drop the 50 g mass and another item from the marked height on the wall as shown in Figure 7.3.14.

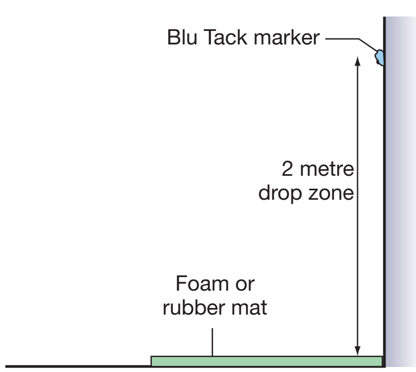


Figure 7.3.14

5. Record whether the object landed at about the same time, slower or faster than the 50 g mass. Repeat the test if you are unsure.
6. Repeat, using the 50 g mass and every object to be tested, and record your results.
7. Drop the 50 g mass and the sheet of A4 paper (held horizontally) and record your result.
8. Crumple the sheet of paper into a loose ball and repeat the test.
9. Finally, scrunch the loose ball into the tightest ball you can and do the test again.

Results

Copy the table below into your workbook and record all your masses, predictions and measurements in it.

Discussion

1. **Assess** how accurate your predictions were.
2. **State** whether most objects fell at the same rate as the 50 g mass, or faster, or slower.
3. a **State** which object fell the slowest.
   b **Propose** a reason why this was the slowest.
4. a **Name** the objects that fell faster than the 50 g mass.
   b **Propose** reasons why.
5. **Propose** a reason why the 50 g mass was used in every experiment.
6. a **Summarise** how the shape of the sheet of paper changes how it fell.
   b **Explain** why.
7. **Draw** a conclusion for this activity.

Falling object	Mass (g)	My predictions	Landed		
		Will fall the same/faster/slower than the 50 g mass	about the same time as 50 g mass	before the 50 g mass	after the 50 g mass

2 Robocopter investigation

A robocopter is a paper construction that spins as it falls when it is dropped from a height. Your task is to make a robocopter and then **investigate** how changing one variable or factor affects the time that it takes to fall. The design of a robocopter is shown in Figure 7.3.15. To build your robocopter, cut a copy of the template shown in Figure 7.3.16 onto a piece of paper or cardboard. Cut along solid lines and fold along dotted lines, as shown by the arrow. Place a paper clip at the base as shown in Figure 7.3.15 and you are ready for a spin!

You could test:

- changing the length of its blades
- adding more paper clips to its base
- making different-sized robocopters
- making robocopters from different thicknesses of paper or cardboard.

Write a purpose for your investigation, list the materials needed and the procedure you follow. State the variable (factor) you are testing and which variables (factors) you will keep constant. Record your results in a table and show these in a graph. Make sure you write about what you observed in your experiment and any problems that you found, and add a conclusion that summarises your findings.

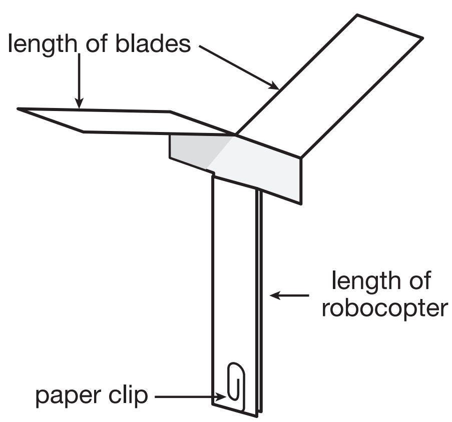


Figure 7.3.15 A completed robocopter

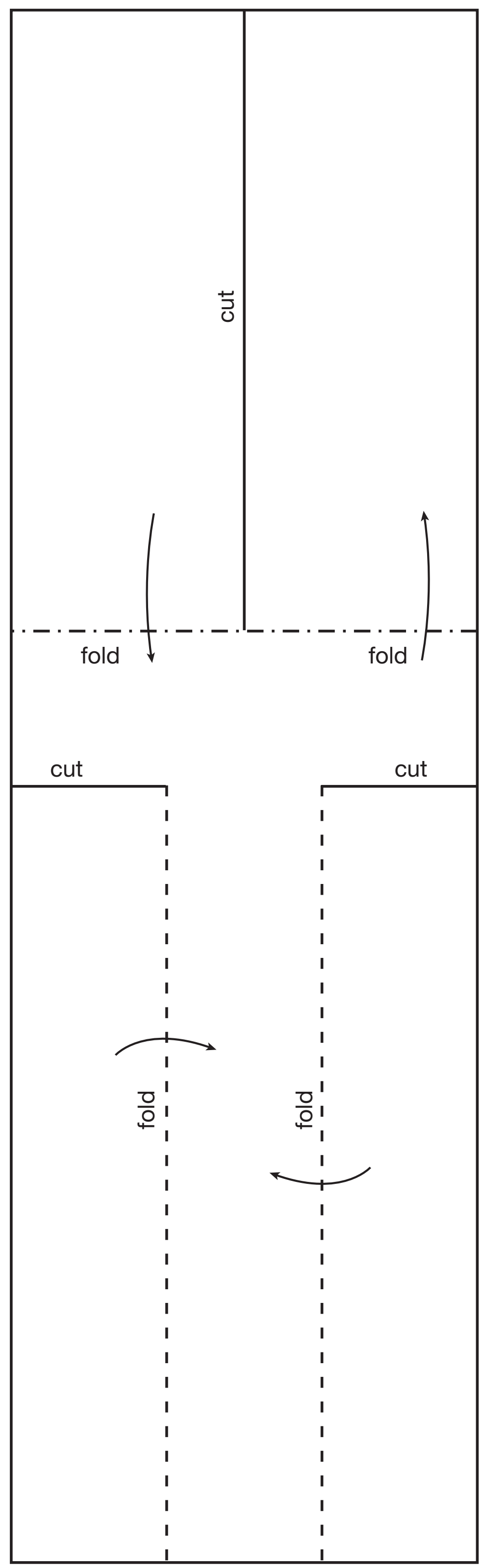
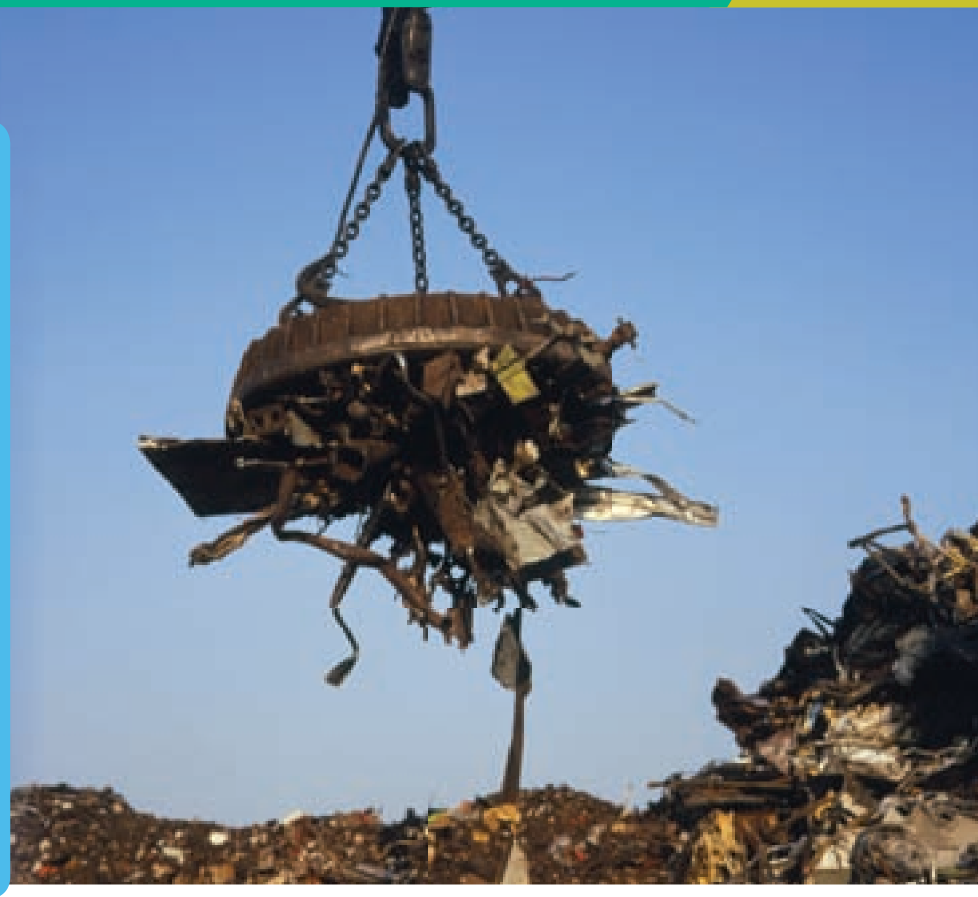


Figure 7.3.16

7.4 Magnetic and electric fields



A non-contact force acts through a region of space called a force field. If you drop an object, it is pulled towards the Earth due to the Earth's gravitational force field. A balloon can be charged and attract a thin stream of water that lies within its electric field. A magnet can attract a tub of nails if they lie within its magnetic field. Powerful electromagnets can lift heavy steel.

INQUIRY science 4 fun

What do magnets attract?

Can you guess which materials around you are attracted by a magnet?

Collect this …

- bar magnet or fridge magnets
- selection of objects such as paper clips, thumb tacks, nails, plastic spoons, cans, coins, chalk, marbles, safety pins, pens, toothpicks

Do this …

1 Draw up a table with three columns, as shown above.

Object tested	My prediction (will attract/ won't attract)	What happened

2 **Predict** which items you think will be attracted by the magnet.

3 Test to see which objects are attracted and complete the table.

Record this …

Describe whether most of your predictions were correct.

Explain which types of substances are more likely to be attracted to a magnet.

Magnetic fields

A magnet pulls, or attracts, materials containing the metals iron, cobalt or nickel. Steel is made from iron, and so steel is also attracted to a magnet. The horseshoe magnet shown in Figure 7.4.1 attracts the steel filings from a distance away. This happens because the steel filings were positioned within its magnetic field. A **magnetic field** is the space around a magnet where a magnetic force is experienced. The steel filings were pulled by a magnetic force in the direction of the magnetic field.

Figure 7.4.1 This horseshoe magnet is placed near a mixture of steel and copper filings. Only the steel filings are attracted to the magnet, with the copper remaining in the pile below. Magnets can be used to separate magnetic metals from a mixture of substances.

The ends of a magnet are called **poles**. If a magnet floats in water, then one end spins to face the Earth's north pole. This end is the north pole of the magnet. The opposite pole of the magnet is the south pole. If a magnet is cut in half, it still has a north and a south pole. The magnetic field is strongest at the poles of a magnet.

A magnetic field is normally invisible to us. Its shape and strength can be determined either by passing a compass around a magnet, or by examining a sprinkling of iron filings around a magnet. Figure 7.4.2 shows that magnetic field lines point from the north to the south pole.

INQUIRY science 4 fun

Seeing magnetic field lines

No

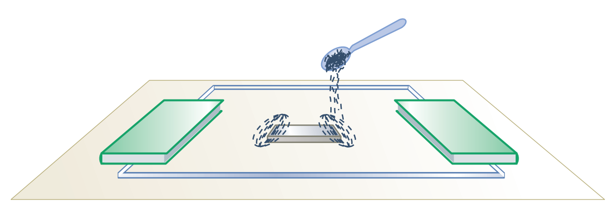
Can you see a magnetic field?

Collect this …

- collection of magnets
- thin books
- stiff, transparent plastic
- white paper
- iron filings

Do this …

1. Place a bar magnet on a sheet of paper.
2. Put the plastic sheet over this and flatten its edges with some books.
3. Sprinkle about a teaspoon of iron filings onto the plastic sheet.
4. Lightly tap the sheet to spread these. What pattern can you see?
5. Gather up all the iron filings and then test a different magnet.



Record this …

Describe each pattern you saw.
Explain why you think these formed.

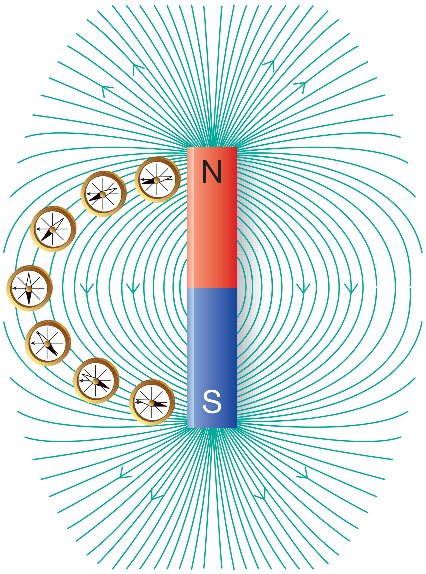


Figure 7.4.2

Magnetic field lines do not cross, and always run from the north to the south pole of a magnet.

Magnetic field lines:

- show the direction that a compass would point
- always run from the north pole to the south pole
- do not cross
- represent a strong magnetic field when they are bunched closely together
- represent a weak magnetic field when they are spaced further apart.

The Earth's magnetic field

The Earth itself has a magnetic field. It behaves as though it has a huge bar magnet in its centre like that shown in Figure 7.4.3. Scientists believe the Earth's magnetic field is generated by moving molten rock inside the Earth's core.

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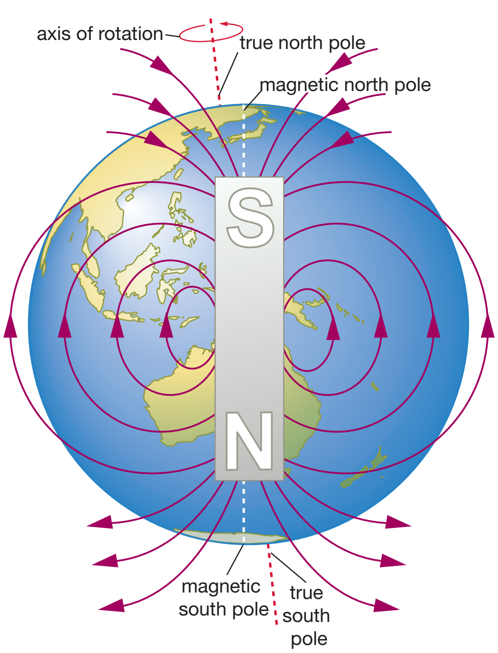

Figure 7.4.3

The Earth is surrounded by a magnetic field. The poles of the imaginary bar magnet inside the Earth lie about 3000 km from the geographical north and south poles.

The Earth's magnetic field does more than direct our compasses. The Sun produces solar wind. These are high-energy particles that can damage living things. The Earth's magnetic field and the atmosphere slows these charged particles down as they travel towards Earth. It directs their path towards the magnetic poles. Collisions between these particles and those in the upper atmosphere can produce spectacular light shows called auroras, as seen in Figure 7.4.4.

Figure 7.4.4

The first stunning light display shown here was photographed in Alaska. It shows the Aurora Borealis, or Northern Lights. The Southern Lights, or Aurora Australis, can be seen in the lower image. It appears in the southern hemisphere at times during the Antarctic winter.

SciFile

In-built navigation

Over 800 years ago, Chinese sailors used lodestone as a compass. Lodestone is a naturally occurring magnetic material. Many animals, such as honeybees, dolphins, tuna, whales and pigeons, contain tiny crystals of magnetite (which makes up lodestone) in their brains or stomachs. These act as tiny internal compasses, preventing the animal from getting lost and helping them find their homes.

Attraction and repulsion of poles

Magnetic poles may be attracted to each other, or repelled by a magnetic force. Poles that are the same are called like poles. Like poles will push away, or repel each other. Poles that are different are called unlike poles. Unlike poles pull together, or attract each other. These situations are shown in Figure 7.4.5.

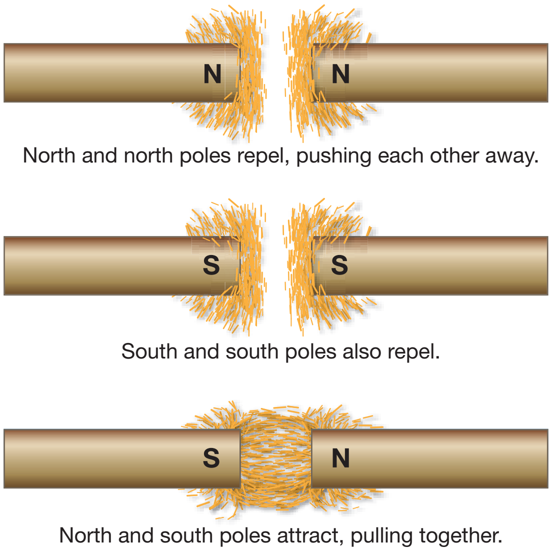

Figure 7.4.5 Magnetic poles that are like (NN or SS) will repel, whereas magnetic poles that are unlike (NS) will attract. We can then say that unlike poles attract while like poles repel each other.

Floating on air

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The repulsion of magnetic poles can make things float. This is called magnetic levitation. Maglev trains float about 10 cm above their track. They can reach speeds of 500 km/h because they operate with very little friction. Magnetic bearings used in machinery can support moving parts without touching them. They are complex to build, but offer great potential in reducing friction in a machine.

Magnetic domains

The metals iron, nickel and cobalt are attracted to magnets, while all other substances are not. Scientists believe that inside each of these metals are tiny magnetic particles called **domains**. Each of these acts like a mini-magnet, and has a north and a south pole. In a piece of magnetised iron, the domains all point in the same direction. This makes the domain act like a magnet. The domains in a piece of unmagnetised iron point in random directions, as shown in Figure 7.4.6.

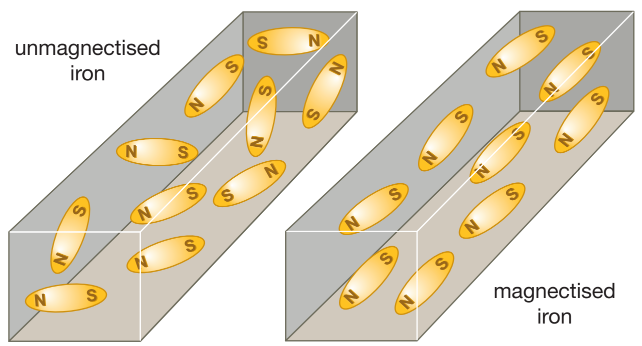

Figure 7.4.6 Domains are like mini-magnets. When they line up, they form a magnet with a north and a south pole. When they point in random directions, the metal has no magnetic properties.

Types of magnets

Temporary and permanent magnets

If you stroke an iron nail many times in the same direction with a bar magnet, then the nail begins to act like a magnet itself. This happens because you have pulled all of its domains into line. After a while, the effect wears off and the domains point in random directions once again. In this case, the nail is called a **temporary magnet** because it only acts like a magnet for a short period of time. **Permanent magnets** can be made by hitting or heating the metal to make the domains stay in this arrangement.

Magnets made from soft iron lose their magnetism more easily than magnets made from cast iron. Data stored on the magnetic strip on a credit card can be lost when placed near a strong magnetic field. If a magnet is heated or dropped, its domains may be knocked out of alignment, destroying its magnetism.

Electromagnets

In 1820, the Danish scientist Hans Oersted made an unexpected discovery. While explaining to his students that he did not believe there was any link between magnetism and electricity, he placed a compass near a wire through which an electric current was flowing. To his surprise, he saw the compass needle move. Oersted realised that electricity flowing through a wire creates a magnetic field around it. If the wire is wound into a coil, it produces a much stronger magnetic field. Inserting a piece of iron inside the coil increases its strength even further. Such a device is called an electromagnet and is shown in Figure 7.4.7. It acts like a bar magnet.

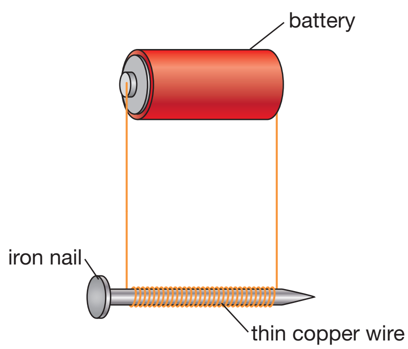

Figure 7.4.7 An electric current in the wire creates a magnetic field. This field can be turned on and off with the current. Coiling the wire and adding an iron insert increases the strength of the electromagnet.

An electromagnet is a temporary magnet, because when the electricity in the wire is switched off, the magnetic field is also switched off. Electromagnets are used within the speakers of our radios, TVs and sound systems. Household appliances such as hairdryers and power tools use electromagnets inside electric motors.

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7.7

Electric fields

Force fields also exist around electric charges. To understand **electric fields**, you first need an understanding of the atom and its internal structure.

What is an atom?

Everything around us is made up of tiny particles called **atoms**. Atoms themselves are made up of even smaller particles, called protons, neutrons and electrons. Neutrons are found deep within an atom in a region called the nucleus. They have no charge. Protons are also found in the nucleus and have a positive charge (+). Electrons move in the space around the nucleus as shown in Figure 7.4.8. They have a negative charge (–).

Usually an object has equal numbers of protons and electrons. It has no overall charge and is said to be neutral.

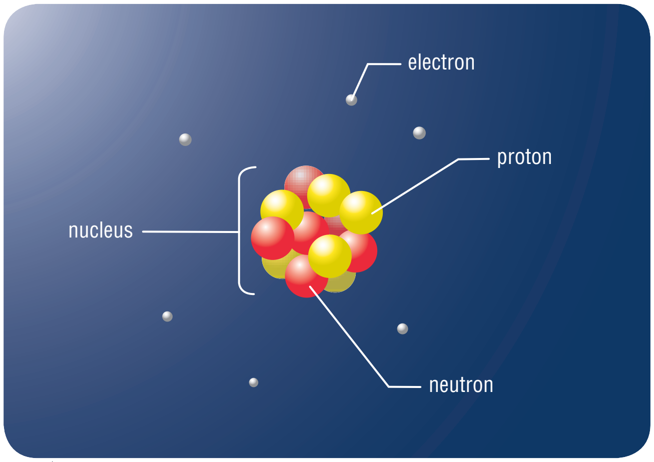

Figure 7.4.8 An atom consists of three types of smaller (subatomic) particles, called protons, neutrons and electrons.

SciFile

Splitting hairs

The atoms that make up everything around you are so small that you would need to line up about one million of them to stretch the width of a human hair.

Charging up

If one material is rubbed against another, electrons may move from one substance onto the other. If this happens, the number of protons and electrons in each is no longer balanced. Some materials, such as plastic, rubber and wood, will build up charge when rubbed with another substance. Such materials are called electrical **insulators**. Electrons cannot flow freely through them. The reason electrical wires are covered with plastic is because plastic is an effective electrical insulator. Metallic objects do not build up a static charge, because electrons can flow through them. These materials, such as a copper electrical wire, are called electrical **conductors**.

Figure 7.4.9 on page 278 shows that when a glass rod is rubbed with a silk cloth, electrons move from the glass rod onto the silk cloth. The glass rod has lost electrons and is now **positively charged**, because it has more protons than electrons. The silk cloth has gained electrons and is **negatively charged**, having more electrons than protons. When an object becomes charged (has unequal numbers of protons and electrons), we say that it has **static electricity**.

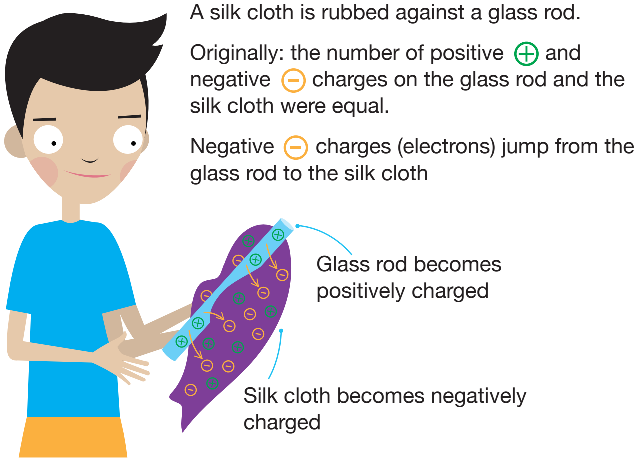

Figure 7.4.9 Electrons are rubbed from the glass rod and jump onto the silk cloth. As a result, the glass rod becomes positively charged and the silk cloth is negatively charged.

A force field called an electric field exists around any object that is charged. Any charged object positioned within this field will experience a force, called an **electrostatic force** (or an electric force). If we rub a balloon with a silk cloth, electrons rub off the silk and onto the balloon. Both the silk cloth and the balloon are now charged, and are surrounded by an electric field. Figure 7.4.10 shows what happens when these charged objects are placed next to each other. If placed inside an electric field, two objects with different types of charge will attract each other, while those with the same type of charge will repel. Note that a charged object may also attract a neutral object.

A machine called a Van de Graaff generator separates charge by friction between a moving rubber belt and a plastic pulley. Negative charges are released to flow through to the ground, while positive charges are transferred onto the dome of the generator. The girl touching the generator in Figure 7.4.11 becomes positively charged. Her hair stands up because each strand of hair is repelling the hair around it!

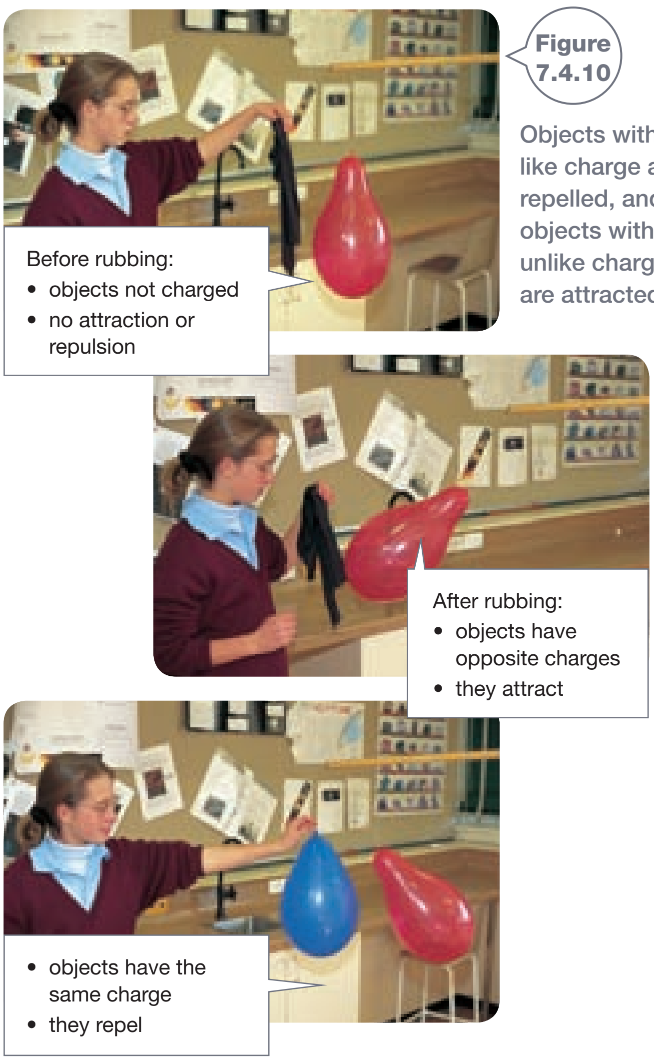

Figure 7.4.10 Objects with like charge are repelled, and objects with unlike charge are attracted.

Figure 7.4.11 Each strand of this girl's hair is positively charged and is repelling all of the hair around it.

How is electric charge discharged?

Static electricity describes a build-up of charge. If you walk across carpet on a dry day and touch a metal door handle, you could get a shock. Friction between your feet and the carpet rub electrons from the carpet onto you, making you and the carpet both charged. Normally, this charge gradually leaks back out of your shoes to the ground, or into the air, and you become neutral once more. If there is a big build-up of charge, or if you wear rubber-soled shoes that stop the charge from escaping, extra electrons can jump from you to the metal door handle as a spark. You feel this as a small electric shock. If you were to touch another person while charged, electrons would jump onto this person and you would both feel a static shock.

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Dazzling fashion

The Sp4rkl3 skirt is a piece of clothing with a difference: it really shines! Designed by a team at the Massachusetts Institute of Technology, the skirt contains circuitry and layers of Teflon and nylon. As the wearer moves around, these layers generate static electricity which can be discharged to power rows of LEDs that are studded into the fabric.

Much larger and more dangerous electric shocks can be received if you are struck by lightning. Lightning itself is a giant spark that is the result of charge build-up within a thundercloud.

The movement of water droplets in storm clouds can cause charges to separate within a cloud. The top becomes strongly positive as it loses electrons, and the bottom becomes strongly negative due to a build up of electrons. If enough static electricity builds up, electrons can jump to another region of the cloud, to another cloud or to the ground. This process is shown in Figure 7.4.12.

7.8

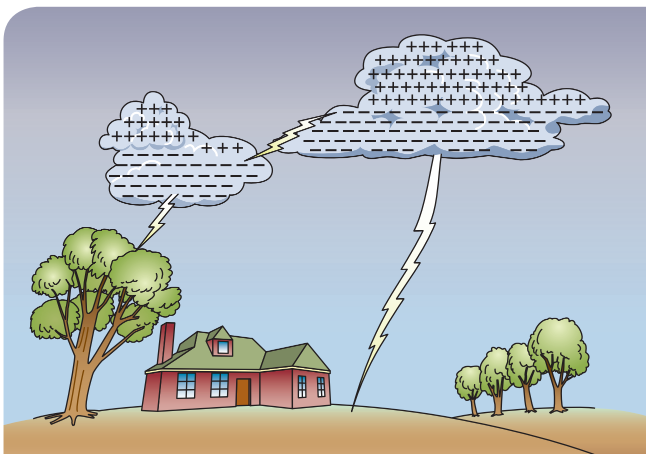


Figure 7.4.12 This flow of electrons is lightning. The heat produced by lightning makes the surrounding air expand rapidly, which we hear as thunder.

SciFile

When lightning strikes

Lightning hits the tallest objects around, so never shelter under a big tree if you are caught outside during a thunderstorm. Seek shelter inside a house or in an enclosed car. The electrical current of a lightning flash can travel through house wiring or plumbing, so keep your distance from electrical appliances, sinks and showers during a thunderstorm.

7.4 Unit review

Remembering

1 Copy each statement, and **state** which term in italics correctly completes each sentence.

- **a** A magnetic force is a *contact/non-contact* force.
- **b** As you get closer to a magnet, the size of the magnetic force *increases/decreases*.
- **c** A north pole of one magnet is attracted to the *north/south* pole of another magnet.
- **d** A magnet is *strongest/weakest* at its poles.

2 **List** five places you could find a magnet in your home.

3 Atoms consist of two types of charged particles.

- **a** **State** the name of a positively charged particle.
- **b** **State** the name of a negatively charged particle.

4 If a plastic ruler loses electrons when it is rubbed on a piece of woollen fabric, **state** whether it has become positively or negatively charged.

Understanding

5 **Explain** how Oersted realised that an electric current could create a magnetic field.

6 **Explain** why a steel ball bearing is attracted to a magnet.

Applying

7 **Identify** whether the magnets in Figure 7.4.13 will attract or repel in each case.

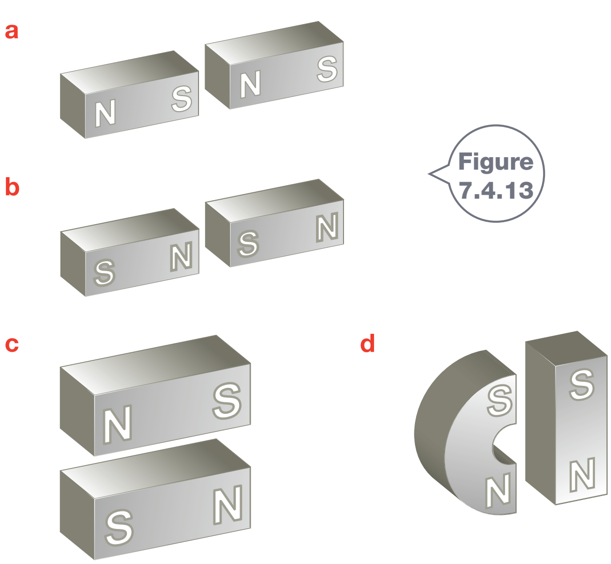


Figure 7.4.13

8 **Use** the magnetic field shown in Figure 7.4.14 for the following questions.

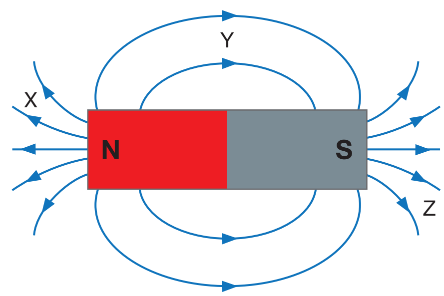


Figure 7.4.14

- **a** Would a compass placed at X point to the left or right?
- **b** In which position, X, Y or Z, would an iron nail be attracted to the magnet with the most force?
  - **i** In which of these positions is the magnetic field strongest?
  - **ii** How do you know this from the diagram?

9 In Figure 7.4.15, **identify** a:

- **a** positively charged object
- **b** negatively charged object
- **c** neutral object.

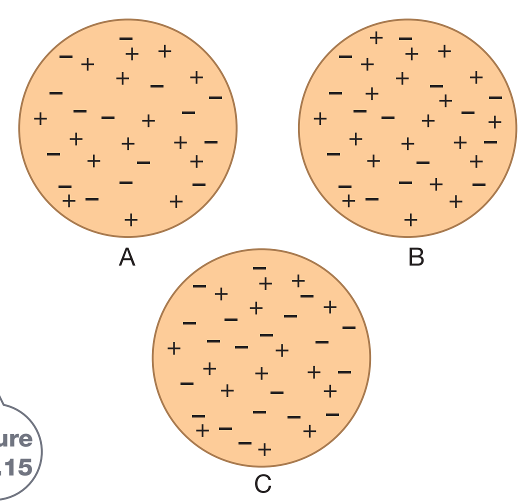


Figure 7.4.15

10 In each situation, **identify** which two surfaces are rubbing together to produce static electricity.

- **a** Hundreds-and-thousands stick to the walls of the plastic bottle in which they are stored.
- **b** After driving to a shop, you get a shock as you close the car door.
- **c** Your clothes crackle as you lift them out of the clothes dryer.

Analysing

11 The bar magnet and the horseshoe magnet shown in Figure 7.4.16 are attracted to each other.

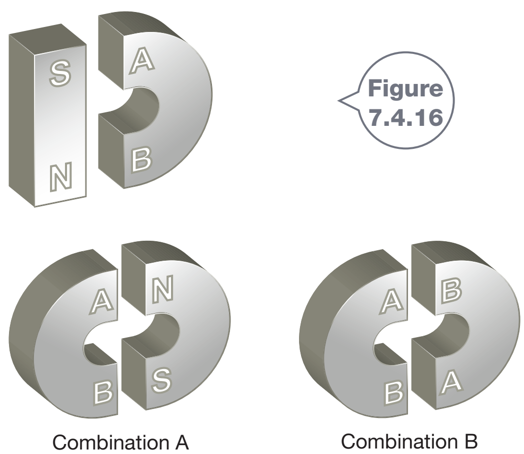


Figure 7.4.16

Analyse this diagram to:

- **a** **identify** whether each of the combinations A and B will attract or repel
- **b** **explain** whether you have been able to answer for combination B without any other information.

12 **Classify** each of the following materials as an electrical conductor or an electrical insulator.

- **a** aluminium foil
- **b** polystyrene cup
- **c** plastic ruler
- **d** glass rod
- **e** copper pipe
- **f** rubber hose

Evaluating

13 Sometimes you can hear a crackle when pulling on a nylon jumper. **Propose** what makes this sound.

14 **Propose** why you are asked to turn off mobile phones while putting petrol in a car.

15 Ralph and Julia are walking along the red carpet to an Academy Awards ceremony. Upon touching a gold banister, Julia receives a nasty static shock.

- **a** **Analyse** why Julia got a shock.
- **b** **Propose** how she could prevent this from happening again.

Creating

16 Lying on a bench in front of you is nail A, which is not magnetised, and nail B, which has been treated to become a temporary magnet.

- **a** **Construct** a diagram to show how the domains inside nails A and B could be aligned at the moment.
- **b** **Construct** another diagram to show how you would expect the domains of nails A and B to look tomorrow.

Inquiring

1 Naturally occurring magnetic materials have been used for centuries to guide sailors. Magnets have many other applications in the world today. Research and describe one aspect of modern use, such as that within:

- metal detectors
- magnetic strips on credit cards
- magnetic separators
- loudspeakers
- electric bells.

2 An MRI (magnetic resonance imaging) machine uses very strong magnetic fields to glimpse inside the body. Describe:

- **a** what it is commonly used for
- **b** any precautions associated with its use.

3 An induction cooktop uses electricity to focus a magnetic field where the food is to cook. Assess the advantages and disadvantages of this method of cooking.

4 Design and conduct an experiment in which you magnetise a nail by stroking it (in one direction) with a bar magnet. You could investigate one of the following.

- Whether the number of paper clips attracted vary depending on how many times the nail was stroked
- If the time the nail remains magnetic varies for the number of strokes made

7.4 Practical activities

1 Magnetic shielding

Purpose

To test which materials a magnetic field can pass through and which materials will block a magnetic field.

Materials

- 50 g mass
- paper clips
- cotton thread
- Blu Tack
- bar magnet
- retort stand and clamp
- sheets of different materials such as cardboard, plastic, aluminium foil, iron, steel, tin, wood, glass, copper

Procedure

1 Set up the equipment as shown in Figure 7.4.17.

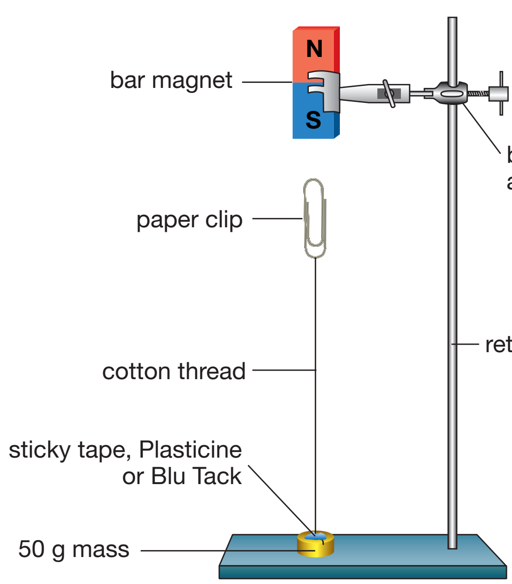


Figure 7.4.17

2 Find the maximum distance that can be left between the paper clip and the magnet before the paper clip falls.

3 Insert each different sheet between the paper clip and the magnet and record what happens in your results table.

Results

In your workbook, construct a table like that shown below to record your observations.

Material	Paper clip stayed/dropped

Discussion

1 In terms of the strength of a magnetic field, **explain** why the paper clip fell when it was moved further from the bar magnet.

2 **List** the materials that allowed a magnetic field to pass through them.

3 **List** which materials acted as a magnetic shield.

4 Magnetic fields can damage sensitive electronic equipment. **Propose** a use for materials that act as magnetic shields.

2 Making an electromagnet

Purpose

To make an electromagnet and test how its strength can be increased.

SAFETY

Take care when connecting your circuits.

Materials

- 6V lantern battery or a power pack
- large nail or bolt (at least 7 cm long)
- compass
- paper clips
- switch
- 2 insulated wires (one long) with alligator clips

Procedure

1 Test to see if the nail on its own will pick up any paper clips.

2 Connect the shorter wire from the battery/power pack to the switch.

3 Carefully wind the long wire 10 times around the nail as neatly as you can.

4 Connect one end to the switch and the other to the power supply as shown in Figure 7.4.18.

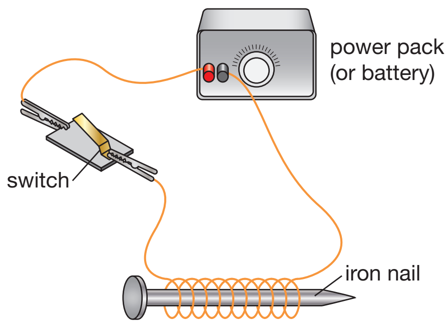


Figure 7.4.18 Setting up your circuit with the electromagnet

Results

1 Copy the table below into your workbook.

2 Set the power pack to 6 volts DC.

3 Press the switch down and record the number of paper clips raised for each number of turns of the wire.

4 Test which end of the nail is the north and south pole using a compass.

5 Reverse the connections to the power supply and repeat step 4.

Number of turns on wire	Number of paper clips picked up
0	
10	
20	
30	
40	
50	

Discussion

1 **State** the effect of the number of turns of the wire on the number of paper clips picked up.

2 **Describe** what happened to the poles of the electromagnet when the connections were reversed.

3 Investigating static electricity

Purpose

To explore static electricity.

Materials

- plastic comb
- sheet of paper
- woollen material
- balloons
- string
- retort stand and clamp

Procedure

1 Rub the plastic comb vigorously on the woollen material. Bring it close to some tiny pieces of paper. Write down what happens.

2 Turn a water tap on and carefully turn it down to get the finest stream that you can of steadily flowing water. Rub the comb with the woollen material and hold it close to the stream of water. Draw a diagram to show what you observe.

3 Blow up a balloon and rub it with the woollen material. See if you can make the balloon ‘stick’ to the wall.

4 Blow up a second balloon. Attach a piece of string to each of the balloons and then tie these to a retort stand. Rub both balloons with the woollen material. Draw a diagram to show what happened.

Discussion

1 **Explain** why you could pick up the pieces of paper with the comb.

2 **Describe** what happened to the stream of water when the charged comb was brought near to it.

3 **Explain** why the water behaved in this way.

4 **Propose** an explanation for your observations in the two balloon activities.

7 Chapter review

Remembering

1 **State** whether the following are true or false.
- **a** An elephant has greater inertia than a mouse.
- **b** A person inside a bus that is turning left will lean to their left side.
- **c** Gravity is a contact force.
- **d** Weight is measured in kilograms.
- **e** The north pole of a magnet will attract the north pole of another magnet.
- **f** The magnetic field of a magnet is strongest at its poles.
- **g** A proton has a negative charge.
- **h** An electric field exists around a charged particle.

2 **List** four examples of a pushing force.

3 **Name** a surface that has little friction.

4 **Name** the three metals that are attracted to magnets.

5 **State** whether an electromagnet is a temporary or a permanent magnet.

Understanding

6 **Explain** the difference between a contact force and a non-contact force. Give an example of each type.

7 Su-Lin washes some lettuce and spins it in a salad spinner. When she opens the spinner, she finds the lettuce is almost dry in the meshed insert, but the outside container contains droplets of water. In terms of inertia, **explain** how the salad spinner dries the lettuce.

8 **Describe** what the Bernoulli effect refers to and give an example.

9 **Explain** how dropping a magnet could destroy its magnetism.

10 If a comb pulled through your hair becomes negatively charged, then **predict** the charge of your hair.

11 If you rub a CD with a cloth to clean it, you may notice dust drifting towards it and landing on its surface. **Describe** why this happens.

Applying

12 **Use** the diagrams in Figure 7.5.1 to **identify** which direction (not at all, up, down, left or right) each object shown will move when acted upon by the forces shown.

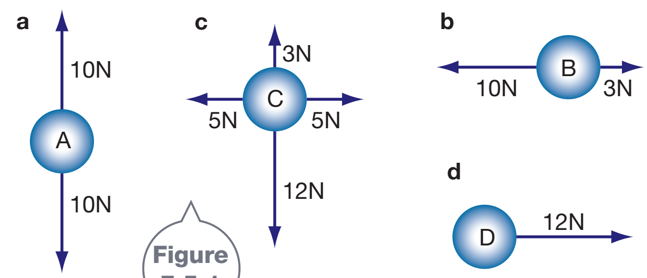


Figure 7.5.1

13 Figure 7.5.2 shows a graph that compares the braking distances of new and old tyres for different road surfaces and weather conditions. **Use** it to answer the questions that follow.

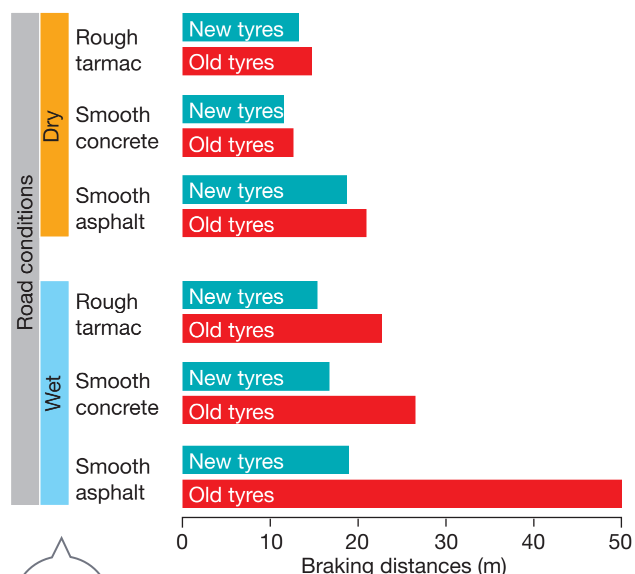


Figure 7.5.2

- **a** **State** which combination of factors produces the longest braking distance.
- **b** **State** reasons for the result in terms of forces.
- **c** **Describe** the weather conditions under which tyre performance varies the most.
- **d** **State** whether new or old tyres vary the most in performance.
- **e** **Explain** why old tyres are not as effective in stopping a car as new tyres.

Analysing

14 **Analyse** the force diagram in Figure 7.5.3.

a **State** in which direction the boat is moving.

b **Predict** what will happen to the speed of the boat when many fish have been caught in the net.

c If the boat is travelling at a constant speed, **compare** the size of the thrust and drag forces acting on the boat.

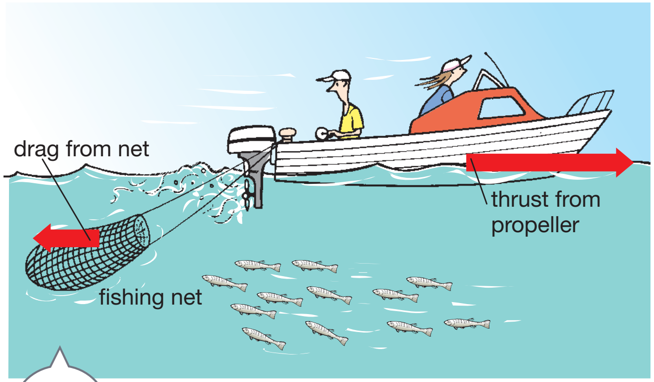


Figure 7.5.3

Evaluating

15 Mariah flicks a coin across the stone benchtop in her kitchen. Later that day, she tries to flick the same coin across sand at the beach.

a **Predict** which coin would travel the greater distance.

b **Justify** your prediction.

16 Figure 7.5.4 shows three blocks of wood resting on different surfaces. If you were to pull each by its hook, **propose** which block would move with the least friction and which block would move with the most friction.

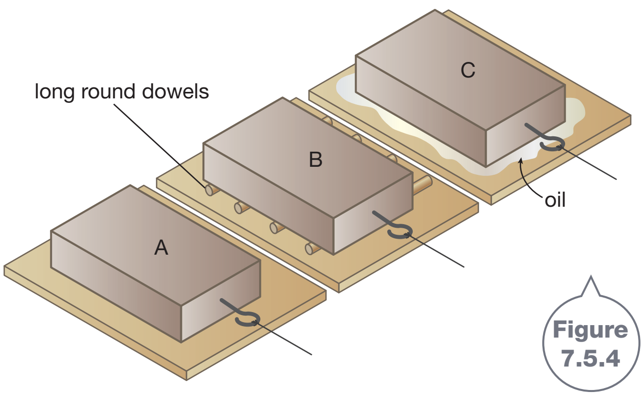


Figure 7.5.4

17 A length of wire is used to make coils A, B and C shown in Figure 7.5.5. An iron nail is inserted into Coil C.

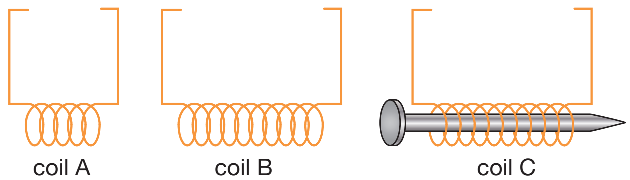


Figure 7.5.5

a **Propose** which of the three would produce the strongest electromagnet when connected to a power supply.

b **Justify** your response.

Creating

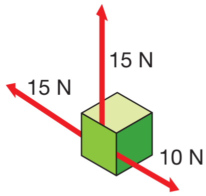
18 **Use** the following ten key terms to **construct** a visual chapter summary of the information presented in this chapter.

gravity	mass
weight	friction
inertia	force
force field	motion
magnetic field	electric field

7.9

Thinking scientifically

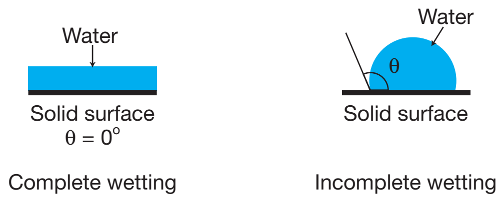
Q1 The total force acting on an object can be found by comparing the overall horizontal and overall vertical forces. A box is acted upon by three forces as shown below.



Which way will the box move as a result of these forces?

A Upwards and to the left
B Upwards and to the right
C Downwards and to the left
D Downwards and to the right

Q2 Water on a solid surface may form a droplet on the surface (with a particular angle of contact, θ), or completely wet the surface. This is shown in the diagram below.



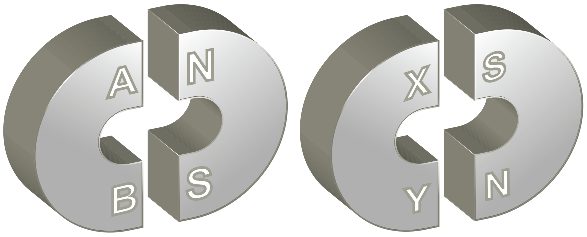
The table lists typical values of the contact angle measured between water and various surfaces.

Solid surface	Contact angle, θ (°)
Tooth enamel	36
Paraffin wax	110
Skin	80
Glass	0
Hair	90

The order in which water wets these surfaces, from the least to the greatest amount, is:

A glass, paraffin wax, hair, skin, tooth enamel
B paraffin wax, tooth enamel, glass, hair, skin
C glass, tooth enamel, skin, hair, paraffin wax
D paraffin wax, hair, skin, tooth enamel, glass

Q3 Siobhan finds two horseshoe magnets in her school laboratory that do not have their poles marked correctly. One has poles labelled A and B, while the other has poles labelled X and Y. She tests each using a third horseshoe magnet and finds the following combinations attract.



Knowing that opposite poles attract, select which of the following pairs of poles will attract.

A X and B; Y and A
B X and A; X and B
C Y and A; Y and B
D X and A; Y and B

Glossary

Unit 7.1

Acceleration: increase in speed (verb: accelerate)

Deceleration: decrease in speed (verb: decelerate)

Force: a push, pull or a twist that can change an object's motion

Inertia: the tendency of an object to resist any change in its motion

Newton (N): unit used to measure force

Force

Unit 7.2

Air resistance: or drag: friction that acts on an object moving through the air

Contact force: force that acts between two objects that touch, or are in contact; for example friction

Friction: force that acts against an object's motion

Lubricants: fluid, such as oil, used to reduce friction between moving parts

Friction

Unit 7.3

Force field: region of space in which an object will experience a non-contact force

Gravitational field: region of space in which an object will experience a force due to gravity

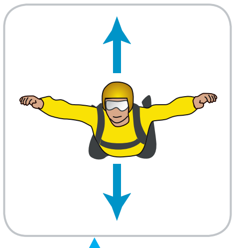
Gravity: force of attraction between any two objects, for example the Earth and a person

Mass: the amount of matter in a substance (measured in kilograms)

Non-contact force: force that acts on an object from a distance

Terminal velocity: the point at which a falling body ceases to accelerate, but falls at constant speed, because its weight is balanced by air resistance

Weight: the force of gravity pulling on an object, measured in newtons



Terminal velocity

Unit 7.4

Atoms: tiny particles that make up all matter

Conductor: substance through which electrons can flow, such as metal

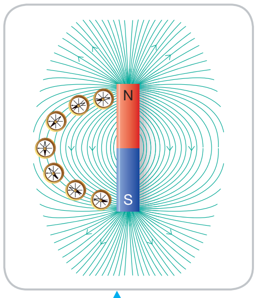
Domains: small regions inside a magnet that each behave as a mini-magnet, with a north and south pole

Electric field: region around a charged object in which another will experience a force

Electrostatic force: force experienced inside an electric field (also called electric force)

Insulator: substance through which electrons do not flow, such as plastic

Magnetic field: region around a magnet in which a magnetic force is experienced

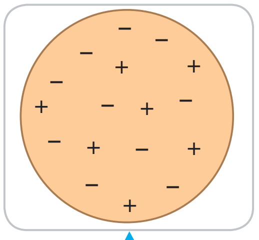


Magnetic field

Negatively charged: having more negative charges (electrons) than positive charges (protons)

Permanent magnet: a material that remains magnetic for a long period of time

Poles: ends of a magnet, may be a north or a south pole

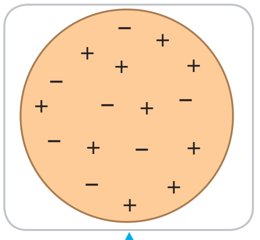


Negatively charged

Positively charged: having more positive charges (protons) than negative charges (electrons)

Temporary magnet: a material that keeps its magnetism for a short period of time

Static electricity: a build-up of electric charge



Positively charged

8 Machines

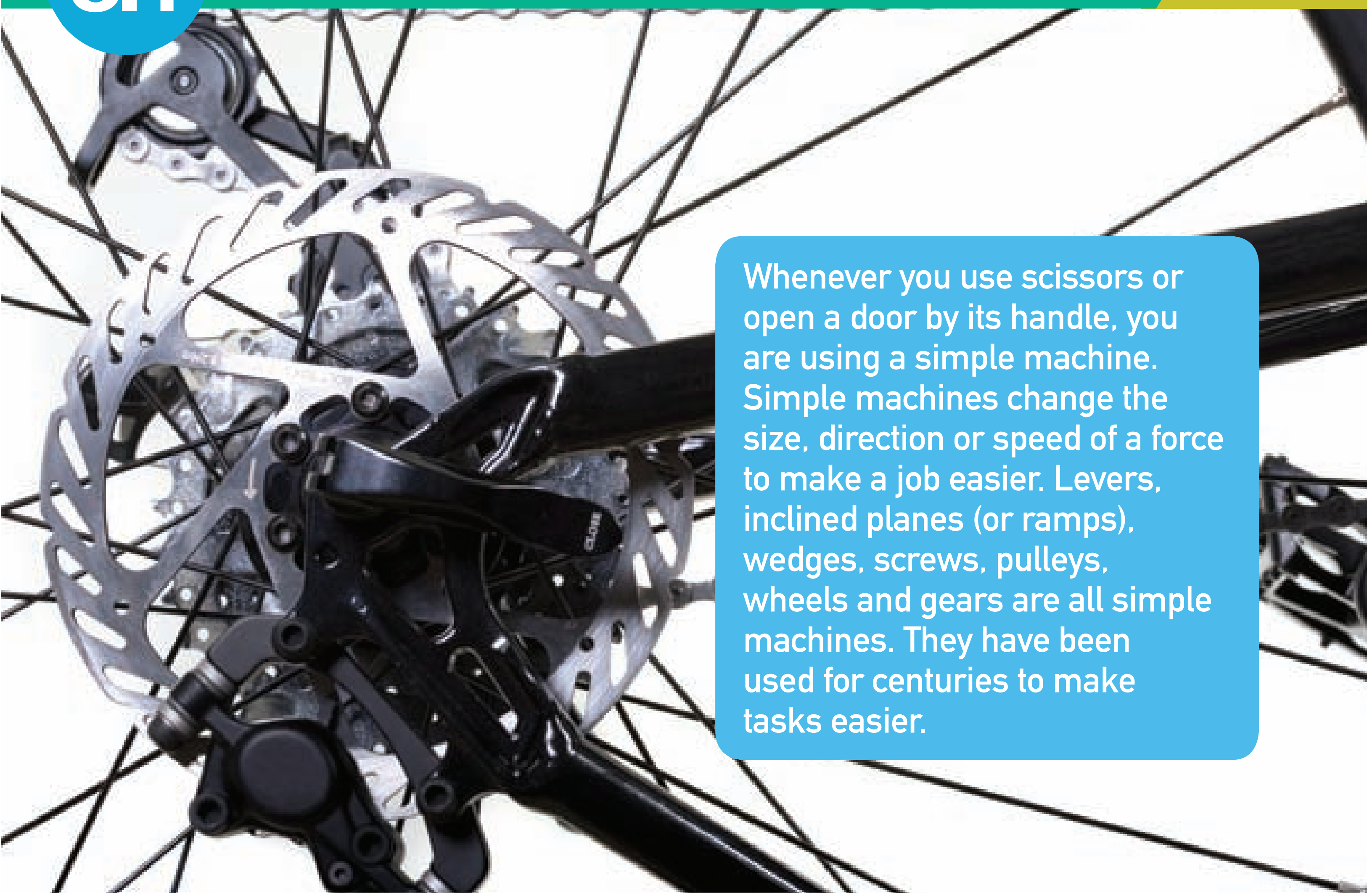
HAVE YOU EVER WONDERED…

- why an axe splits wood but a hammer doesn't?
- how gears work on a bicycle?
- why door have handles?
- how a zip works?

After completing this chapter students should be able to:

- recall that a machine can change the size of a force, the direction a force is applied, or change the speed of an object
- recall that a machine is something that makes life easier
- identify simple machines, such as levers, inclined planes, screws, pulleys, wheels and gears
- investigate a simple machine such as a lever or pulley system
- identify how a force or speed/distance advantage is gained from the use of levers, ramps, pulley systems and gears
- discuss how Indigenous Australians have designed and use a range of weapons and tools
- identify three classes of levers and, given sufficient information, calculate the mechanical advantage they provide
- identify that ramps, wedges, zippers and screws are all examples of inclined planes.

8.1 Machines around us



Whenever you use scissors or open a door by its handle, you are using a simple machine. Simple machines change the size, direction or speed of a force to make a job easier. Levers, inclined planes (or ramps), wedges, screws, pulleys, wheels and gears are all simple machines. They have been used for centuries to make tasks easier.

What can machines do?

To get a job done, you apply a force called an **effort**. The **load** is the force actually required to do the job. A **simple machine** can make a task easier in three different ways. It can:

- change the size of a force
- make things speed up
- change the direction of a force.

Changing the size of a force

Lifting a car to change a tyre would require a huge effort force applied over a small distance. For most of us, this task would be impossible. However, using a jack makes the task easier and the effort required smaller. You apply a small force to the handle of the jack, but wind it over a very long distance. This is shown in Figure 8.1.1. In the same way, a crowbar can be used to shift a rock that would otherwise be too heavy to move. Machines used in this way magnify the force you apply to do a job. These machines are known as **force multipliers**.

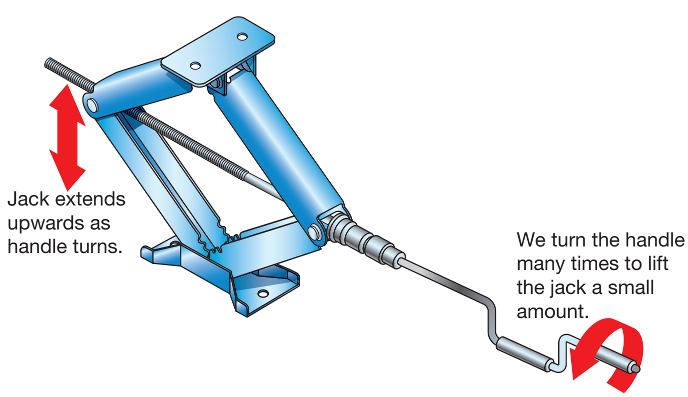


Figure 8.1.1 You use a small force to turn the handle of a jack handle through a very large distance, in order to lift a car.

Making things speed up

A machine can also make something move faster than otherwise possible. For example, when you use an eggbeater like that in Figure 8.1.2 to whip cream, the blades move much faster than the handle. Similarly, when riding a bike, different gear combinations can make the wheels spin much faster than the pedals are moving. You need to apply greater force to these types of machines but the machines speed things up. For this reason, they are known as **speed multipliers**.

Figure 8.1.2 A machine can increase the speed of moving parts.

Changing the direction of a force

A machine can also change the direction in which a force acts. It would be very awkward if you needed to lift the cables of a set of blinds to pull them up. Instead, you pull the cable down and a pulley changes the direction of the force on the blinds to lift them up. Figure 8.1.3 shows how pulleys can be used to move a giant puppet.

Figure 8.1.3 Pulling downwards on a series of pulleys allows the puppeteers from a French marionette street theatre company to move the puppet's limbs upwards.

SciFile

Australia's Leonardo: David Unaipon (1872–1967)

Born in South Australia, David Unaipon was a preacher, Indigenous rights activist, inventor and the first published Aboriginal writer. He developed an improved handpiece for shearing sheep and patented another nine applications for inventions. Uniapon predicted helicopter flight from observing the flight of the boomerang! For many years, he tried to develop a perpetual motion machine—a machine that would keep going forever.

Levers

A **lever** is a simple machine that is made of a long, rigid object (such as a stick or metal rod) and a pivot or **fulcrum** about which it rotates. Most levers, like the crowbar shown in Figure 8.1.4, increase the size of the effort that you can apply or reduce the effort needed to get a job done.

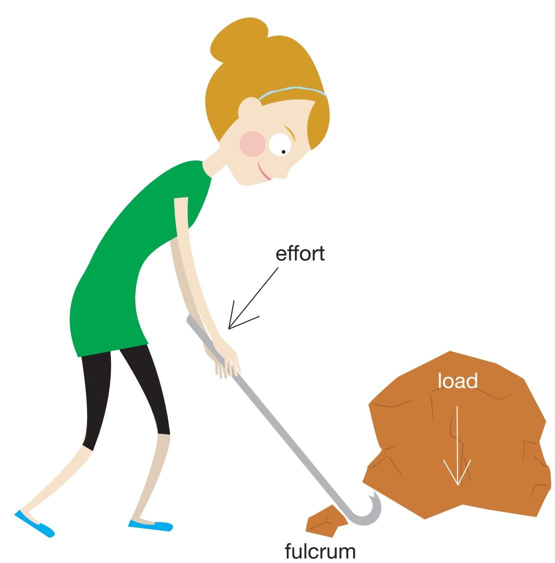


Figure 8.1.4 A crowbar or long stick used like this acts as a lever. The lever increases the force that you can supply.

Figure 8.1.5 Using a hammer as a lever reduces the size of the effort needed to pull a nail from a piece of wood. This makes the task much easier.

Figure 8.1.5 shows how the claw of a hammer can be used as a lever to pull a nail (the load) out of a piece of wood. However, when using just your fingers, the effort required is so high that the task is nearly impossible. Using a teaspoon to remove the lid of a coffee tin multiplies force in the same way. This is shown in Figure 8.1.6.

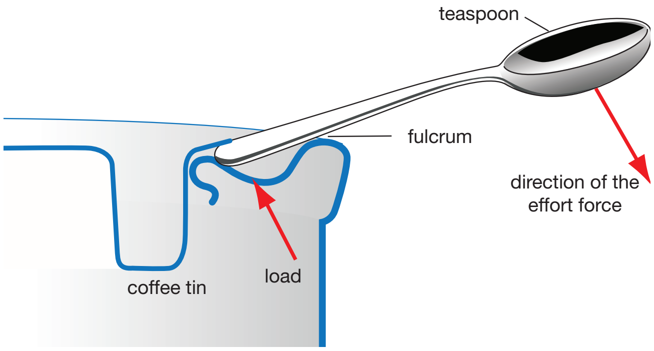


Figure 8.1.6 The load being shifted here is the coffee lid, and the edge of the tin is the fulcrum. The effort is applied as a downwards force on the teaspoon and the lever magnifies this force to open the lid.

INQUIRY science 4 fun

Launching marshmallows

How does a catapult work?

Collect this …

- string
- straws
- icy-pole sticks
- masking tape
- marshmallow
- paper clips
- cardboard squares
- plastic spoon
- 10 rubber bands
- permanent marker
- safety glasses

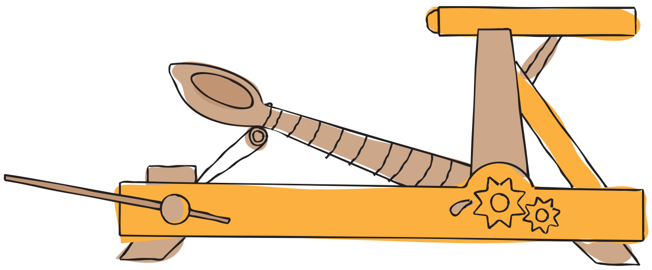
Do this …

1. Use some or all of your equipment to build a catapult.
2. You have a time limit of 30 minutes.
3. Draw an initial or symbol on your marshmallow so you can tell it apart from the others.
4. Line up all of the class catapults and load each with marshmallow ammunition.
5. Fire each catapult.
6. Which marshmallow went the greatest distance?

Record this …

Describe how you built your catapult, using a diagram to assist your description.

Explain how your catapult works.



SKILL BUILDER

Mechanical advantage

A machine makes a task easier. You can measure how much easier a task has become by calculating the mechanical advantage a machine produces. **Mechanical advantage** is equal to the size of the load force divided by the effort:

$$\text{Mechanical advantage} = \frac{\text{load}}{\text{effort}}$$

A machine with a mechanical advantage of 2 indicates that using this machine allows you to:

- lift twice the load that you would normally be able to lift
- use half the force you would have otherwise needed to do a particular job.

For a lever, mechanical advantage can also be calculated using:

$$\text{Mechanical advantage} = \frac{\text{distance from effort to fulcrum}}{\text{distance from load to fulcrum}}$$

This means a lever has a greater mechanical advantage when the distance from the fulcrum to the effort is longer than the distance of the fulcrum to the load. This situation is shown in Figure 8.1.7. This happens because a smaller effort force may be applied over a larger distance. The two statements above for mechanical advantage can be combined into a rule called the *principle of levers*. This states that:

$$\text{Effort} \times \text{distance (of effort to fulcrum)} = \text{load} \times \text{distance (load to fulcrum)}$$

Figure 8.1.8 shows how this applies to opening a tin.

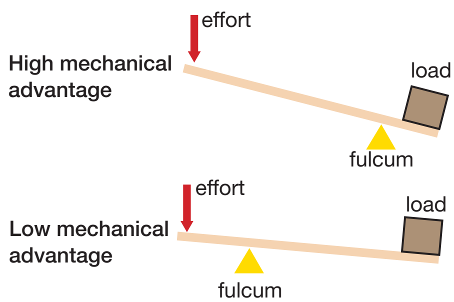


Figure 8.1.7 As the distance between the effort and the fulcrum increases, so too does the mechanical advantage of a lever.

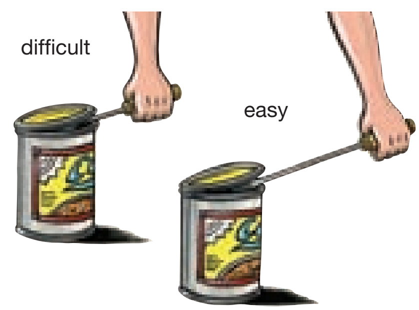


Figure 8.1.8 It is easier to open the tin shown using the longer screwdriver, because it has a greater distance from the fulcrum to the effort.

WORKED EXAMPLE

Mechanical advantage

Problem 1

Jess applies an effort of 150 N to lift a rock of weight 600 N using a long piece of wood as a lever. Calculate the mechanical advantage of the lever.

Solution 1

The load is the weight Jess is trying to lift. This is 600 N.

The effort is the force she exerts of 150 N.

$$\begin{aligned}\text{Mechanical advantage} &= \frac{\text{load}}{\text{effort}}\\ &= \frac{600}{150}\\ &= 4\end{aligned}$$

This means that the lever has made Jess's force four times larger. She only needs to put in one-quarter the effort she would otherwise need to apply to do the job.

Problem 2

Con uses another stick to shift a second rock. The distance from his hand on the stick to the fulcrum is 120 cm, and the distance from the fulcrum to the rock is 40 cm. Calculate the mechanical advantage of this lever system.

Solution 2

$$\begin{aligned}\text{Mechanical advantage} &= \frac{\text{distance from effort to fulcrum}}{\text{distance from load to fulcrum}}\\ &= \frac{120}{40}\\ &= 3\end{aligned}$$

This means Con can shift the rock with three times less force than when using his bare hands. It also means that he could lift a rock three times heavier than he normally could.

Types of levers

In the examples so far, a lever has been used as a force multiplier. A lever can also be used as a speed multiplier. The way a lever operates depends upon the position of the effort, load and fulcrum. There are three different ways we can use levers. Levers can be grouped into three types or classes of levers.

First-class levers

When you use a lever as a crowbar, or as a teaspoon to lift a lid from a tin, you are using a **first-class lever**. Some first-class levers are shown in Figure 8.1.9. First-class levers have the fulcrum positioned between the effort and load forces. The handle of the crowbar shown in Figure 8.1.4 on page 290 moved through a larger distance than the load, but in doing so, the force applied is increased. Other first-class levers are pliers, tin snips, hedge-cutters and scissors.

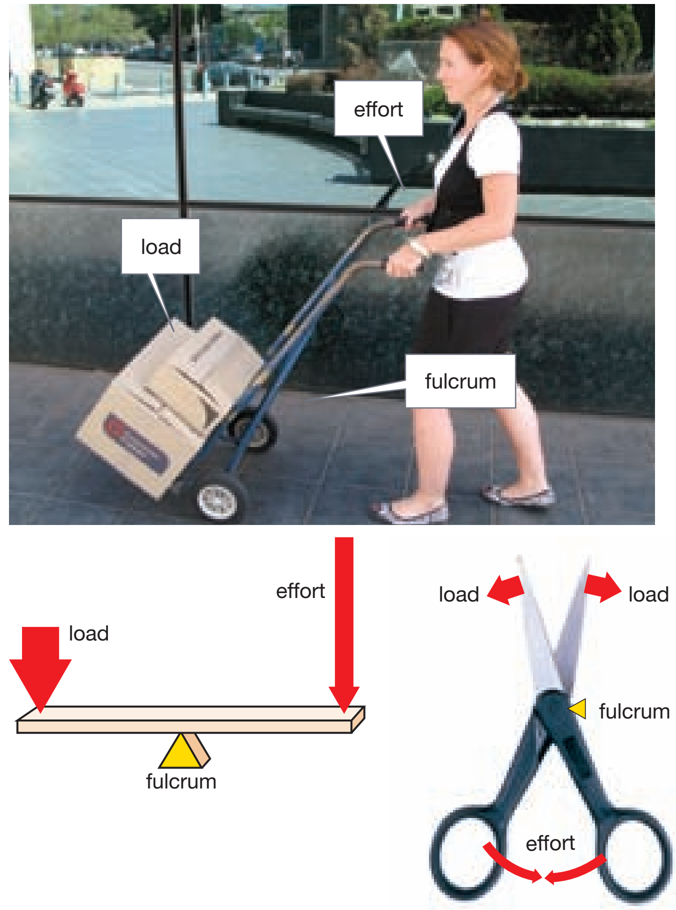


Figure 8.1.9 A first-class lever has its fulcrum positioned between the effort and the load. These levers act as force multipliers. The greater the distance between the fulcrum and the effort, the greater the mechanical advantage of the lever.

SciFile

Levered launch

Legend has it that Greek mathematician Archimedes (287–212 BCE) believed he could move the Earth itself if he had a long enough lever. According to another legend, Archimedes used pulleys and levers to launch a ship that no one could get into the sea.

p298

INQUIRY science 4 fun

Lever lifting

How should a lever be arranged to provide the best mechanical advantage?

Collect this ...

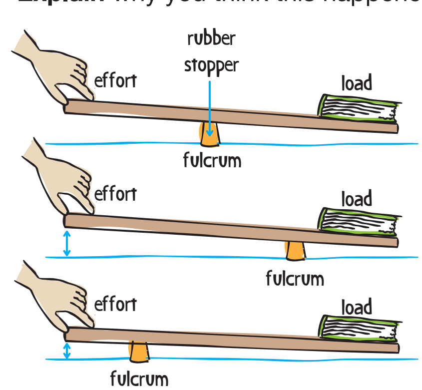
- metre ruler
- rubber stopper
- heavy book

Do this ...

1. Set up the equipment in the three ways shown.
2. Compare how hard or easy it was to lift the book in each case.

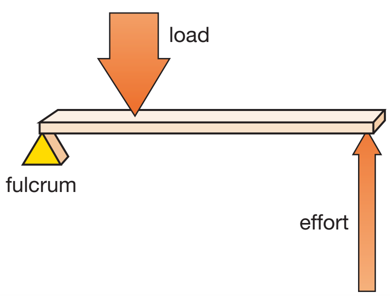
Record this ...

1. **Describe** what happened.
2. **Explain** why you think this happened.



Second-class levers

If the load is positioned between the fulcrum and the effort, then the lever is called a **second-class lever**. This also acts as a force multiplier. A wheelbarrow is an example of such a lever. By lifting the end with the handles a greater distance than the load is lifted, as shown in Figure 8.1.10, the force applied is increased. Other second-class levers include bottle openers, paper guillotines and nutcrackers.



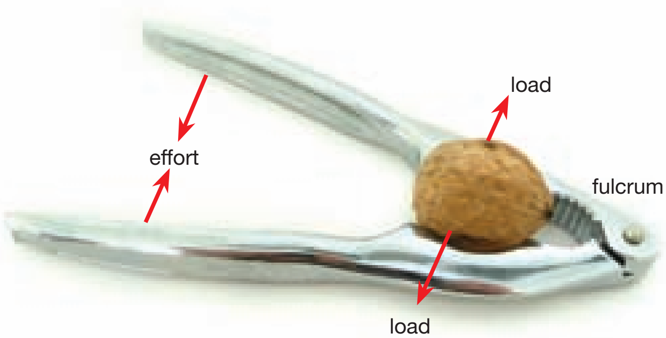


Figure 8.1.10 A second-class lever has its fulcrum positioned at one end of the system and the effort at the other. These levers also act as force multipliers.

Third-class levers

If the effort is positioned between the fulcrum and the load, then the lever is called a **third-class lever**. When using a broom, you apply a large effort force to the handle. The handle moves though a much shorter distance than the end of the broom, which moves much faster, but with less force. The broom acts as a third-class lever. It has traded an increase in force for an increase in speed. Tennis racquets, cricket bats and golf clubs are used in this way, so that they hit balls at high speed. This is shown in Figure 8.1.11. Tweezers and tongs are also third-class levers.

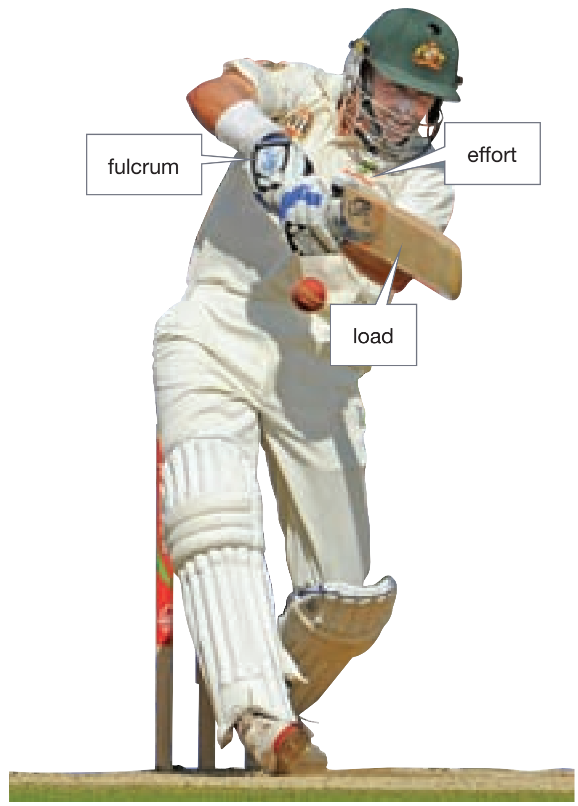
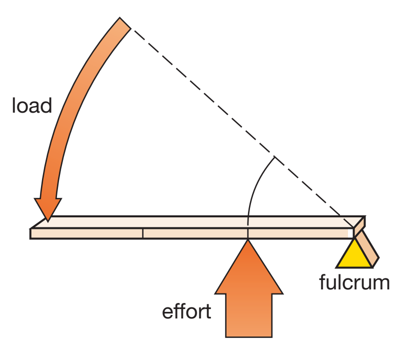


Figure 8.1.11 Tennis racquets, baseball bats, cricket bats and golf clubs are all used as third-class levers. They are speed multipliers.



8.1 8.2 2 p299 3 p300

8.1 Unit review

Remembering

1 **List** three ways a machine can make a task easier.

2 **State** the unit used to measure force.

3 **State** whether each statement below is true or false.

- **a** A lever is a simple machine that can increase the effort supplied to get a job done.
- **b** If using a crowbar to lift a tree stump, then the tree stump is called the effort.
- **c** A crowbar used as a lever rotates about a point called the fulcrum.
- **d** When using the claw of a hammer to pull a nail out of a piece of wood, the hammer acts as a force multiplier.

4 **Recall** which class of lever multiplies speed.

Understanding

5 **Describe** two ways of calculating mechanical advantage for a lever.

6 Most levers used in ball sports are third-class levers.

- **a** **Explain** why this is the case.
- **b** A tennis player serving a ball will toss it into the air and reach upwards to hit the ball. **Explain** how this increases the speed of their serve.

7 The nutcracker illustrated in Figure 8.1.10 is a force multiplier. **Describe** a way the design of this nutcracker could be changed to give it a greater mechanical advantage.

Applying

8 **Identify** whether each of the following machines makes a task easier by increasing the size of a force, speeding something up, or changing the direction of a force.

- **a** axe
- **b** crowbar
- **c** hand drill

9 Ping uses a chisel to lift the lid from a paint tin. **Identify** what acts as the:

- **a** load
- **b** effort
- **c** fulcrum.

10 **Identify** the following as first-, second- or third-class levers.

- **a** Load positioned between the fulcrum and the effort
- **b** Effort positioned between the fulcrum and the load
- **c** Fulcrum positioned between the effort and the load

11 A machine has a mechanical advantage of 10, and is used to lift an outdoor statue weighing 900 newtons.

- **a** **Calculate** the force required to lift the statue using the machine.
- **b** **Use** effort, loads and distances moved to **explain** where this force advantage comes from.

12 **Calculate** the size of the mechanical advantage for each system shown in Figure 8.1.12.

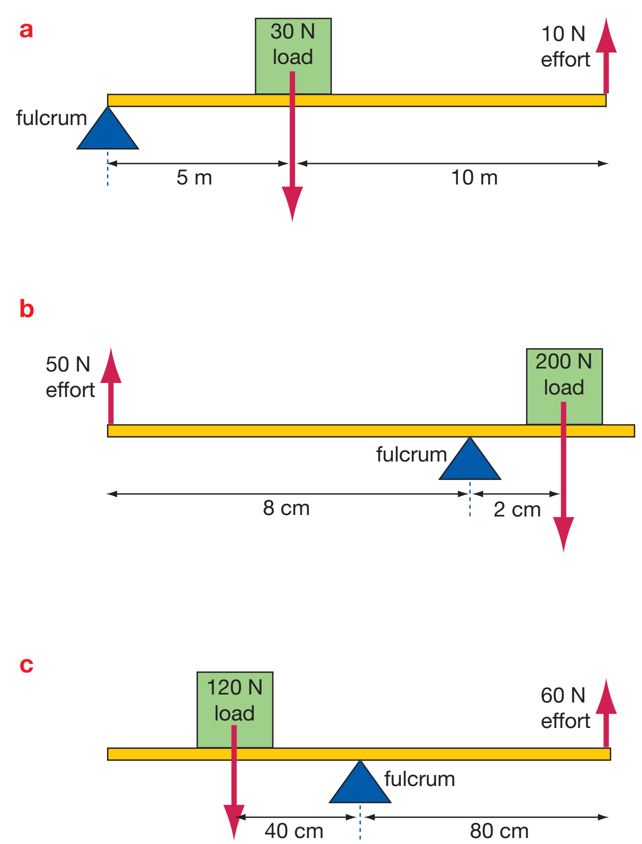


Figure 8.1.12

8.1 Unit review

Analysing

13 **Classify** the objects shown in Figure 8.1.13 as first-, second- or third-class levers.

Figure 8.1.13

14 **a** Copy each diagram in Figure 8.1.14. **Analyse** how each object operates and label the position of the fulcrum (F), load (L) and effort (E) on each diagram.

b **Identify** which class of lever is shown in each diagram.

c **State** whether each is a force multiplier or a speed multiplier.

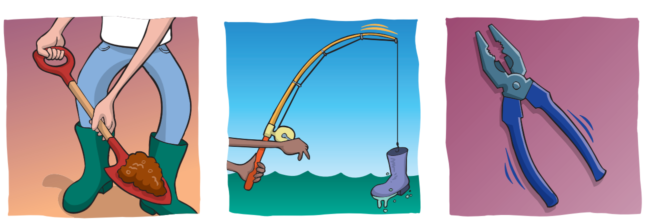


Figure 8.1.14

15 Figure 8.1.15 shows a 600 N load placed on a lever.

a **Calculate** the size of the force that must be supplied at point X to lift the load.

b If the load was now switched to position X, and the effort force applied where the load had been positioned, **calculate** the size of the effort force now required to lift the load.

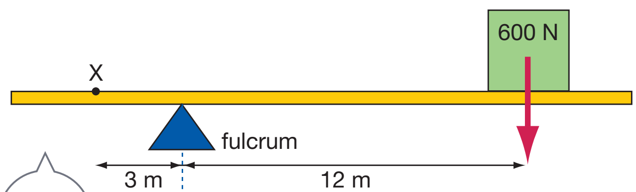


Figure 8.1.15

16 Keung has a mass of 35 kg, while his friend Zuzu has a mass of 50 kg. They'd like to play on a see-saw and have both sides evenly balanced.

a **Explain** which boy should sit closer to the fulcrum of the see-saw and why.

b Zuzu sat 1 metre from the pivot of the see-saw. Use the principle of levers to **calculate** where Charlie would need to sit to maintain balance.

Evaluating

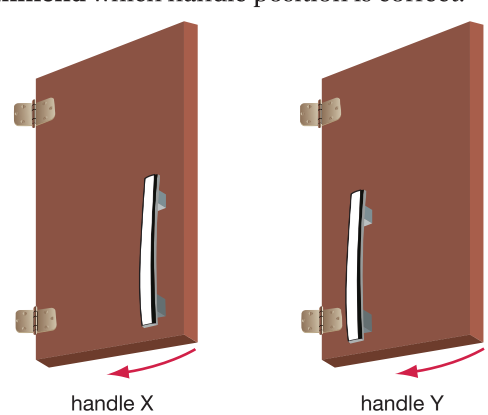
17 A door acts as a lever, with its fulcrum at its hinges. An inexperienced tradesman was unsure where to put the handles on a cupboard door, so he screwed in two sets so that he could compare them to see which worked better.

a **Compare** the distance moved by your hand in opening a door using handle X and handle Y in Figure 8.1.16.

b **Discuss** which handle would be more difficult to use.

c **Recommend** which handle position is correct.

Figure 8.1.16



Inquiring

1. Investigate machines such as the windlass, whip and whim used to pull loads up from mines on the goldfields. Construct a labelled diagram to explain how one operates.
2. Many examples of levers can be found around your home, particularly as kitchen gadgets, sporting equipment or as tools in the garage. Use the internet to gather images of at least 20 different household levers. Organise your images to construct a poster in which each is classified as a force or speed multiplier.
3. Create a poster in which you illustrate how a lever used by our body or in a ball sport works. Label F, E and L (fulcrum, effort and load) and identify which class of lever is operating.
4. The photo in Figure 8.1.17 shows Korean acrobats using a see-saw. Search the internet to gather clips of acrobats such as these in action. Classify the see-saw by grouping it into the correct class of lever.

Figure 8.1.17

5. Investigate a range of household machines—such as a corkscrew, pliers, scissors, chopsticks, stapler, tweezers, eggbeater, hammer, tongs, hand drill, zipper, old clock, knife and apple, old doorknob, bottle opener, fishing rod. Describe how each works and classify these as devices that multiply force and devices that multiply speed.
6. Playground swings, slides, roundabouts, slides, flying foxes and see-saws are made up of many simple machines. Choose one item of playground equipment, either one that exists now or a new type of your own design. Some examples are shown in Figure 8.1.18. Construct a model of the equipment, using simple materials such as icy-pole sticks, straws, string, tin lids, cardboard, paper, split pins, paper clips or pieces of dowel.

Figure 8.1.18

8.1 Practical activities

1 Modelling a see-saw

Purpose

To investigate how the effort force required to balance a load on a see-saw is affected as it is moved closer to the fulcrum.

Materials

- metre ruler
- stiff cardboard square
- 2 plastic cups
- slotted masses
- masking tape
- scissors

Procedure

1 Use the scissors and ruler to score two lines so that the square is divided into thirds. Bend the cardboard to make a triangular prism to use as a fulcrum, as shown in Figure 8.1.19.

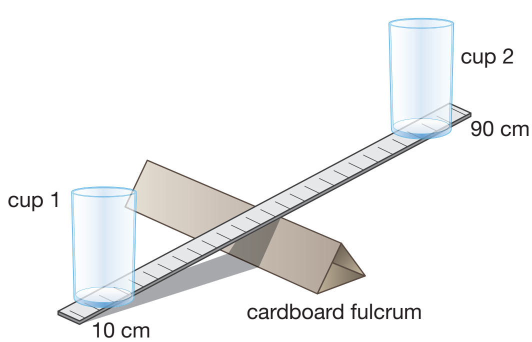


Figure 8.1.19

2 Position the ruler so that the fulcrum is halfway along its length.

3 Tape one of the plastic cups at one end of the ruler, so that its centre sits at the 10 cm mark, and a second cup at the 90 cm mark.

4 Copy the results table below.

5 Put 100 g of masses in the first cup and measure how much mass needs to be added to the second cup to balance this.

6 Repeat this process with the centre of the second cup positioned above the 85, 80, 75, 70, 65 and 60 cm marks along the ruler.

Results

Copy and complete the table below.

Discussion

1 **Describe** whether more or less mass was required to balance the load as the effort force moved closer to the fulcrum of the see-saw.

2 **Discuss** whether you have experienced this yourself on a see-saw.

3 **Calculate** the columns in your table:

Mass in cup 1 × D_1
and
Mass in cup 2 × D_2

4 **State** whether the values calculated above are similar. **Explain** your result.

Mass in cup 1 (g)	D_1 (distance of cup 1 from fulcrum) (cm)	Mass in cup 1 × D_1	Mass in cup 2 (g)	D_2 (distance of cup 2 from fulcrum) (cm)	Mass in cup 2 × D_2
100	40			40	
100	40			35	
100	40			30	
100	40			25	
100	40			20	
100	40			15	
100	40			10	

2 Investigating first-class levers

Purpose

To examine what effect changing the position of the fulcrum has on a first-class lever.

Materials

- retort stand and clamp
- string
- metre ruler (preferably with holes every centimetre)
- slotted masses and hangers
- 3 large paper clips
- spring balance (or a force sensor)

Procedure

1. Use a large paper clip to hang the ruler over the stand and clamp as shown in Figure 8.1.20 so that the fulcrum is at the 20 cm mark of the ruler.

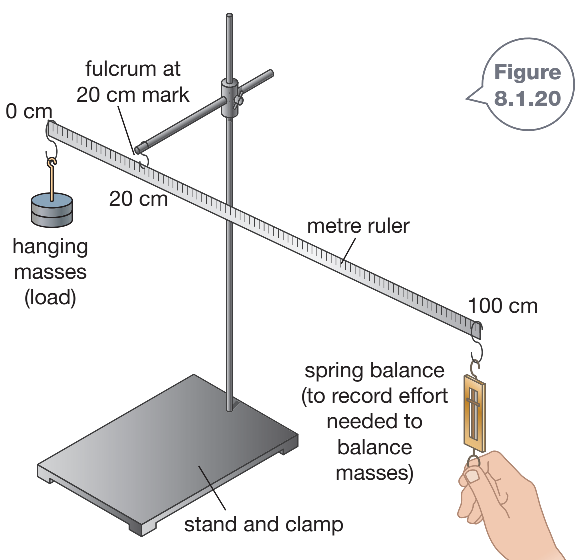


Figure 8.1.20

2. Hang a 100 g mass from the 0 cm mark. This mass exerts a weight force of 1 N downwards and represents the load on the lever.
3. Using a spring balance or force sensor positioned at the 100 cm mark of the ruler, measure and record the effort force needed to balance the load.
4. Continue this process for load masses of 150, 200 and 250 g and enter results into a table as shown below.
5. Now take the ruler off the paperclip and readjust it so that the fulcrum is positioned at the 40 cm mark on the ruler.
6. Repeat steps 3–4 and record your results in a table like the one below.

Results

In your workbook, copy and complete the following table and use it to record all of your measurements.

Discussion

1. **Calculate** the mechanical advantage of the lever with the fulcrum positioned at the 20 cm mark.
2. **Calculate** the mechanical advantage of the lever with the fulcrum positioned at the 40 cm mark.
3. **State** which lever has the greater mechanical advantage.
4. **Explain** how this affected the size of the effort needed to balance the load forces.

Load mass (g)	Load force (N) (load mass/100)	Distance (load to fulcrum) (cm)	Effort force (N) (measured using spring balance)	Distance (effort to fulcrum) (cm)
100	1	20		80
150	1.5	20		80
200	2	20		80
250	2.5	20		80
100	1	40		60
150	1.5	40		60
200	2	40		60
250	2.5	40		60

8.1 Practical activities

3 Levers in action

Purpose

To use and examine levers.

Materials

- three different examples of levers, such as a teaspoon and tin, a pair of pliers and a nut and bolt, a pair of tweezers and grains of rice, pair of scissors and paper, a nutcracker and small spongy ball, a stapler with staples

Procedure

Use each of your lever systems to perform a simple task. For example, use the teaspoon to remove the lid of a tin, undo a bolt using pliers, cut paper with scissors, pick up rice with tweezers, squeeze a spongy ball with a nut cracker, or use a stapler.

Results

Copy and complete the table below for each lever system you examine. Include a labelled diagram and an explanation of how each lever works.

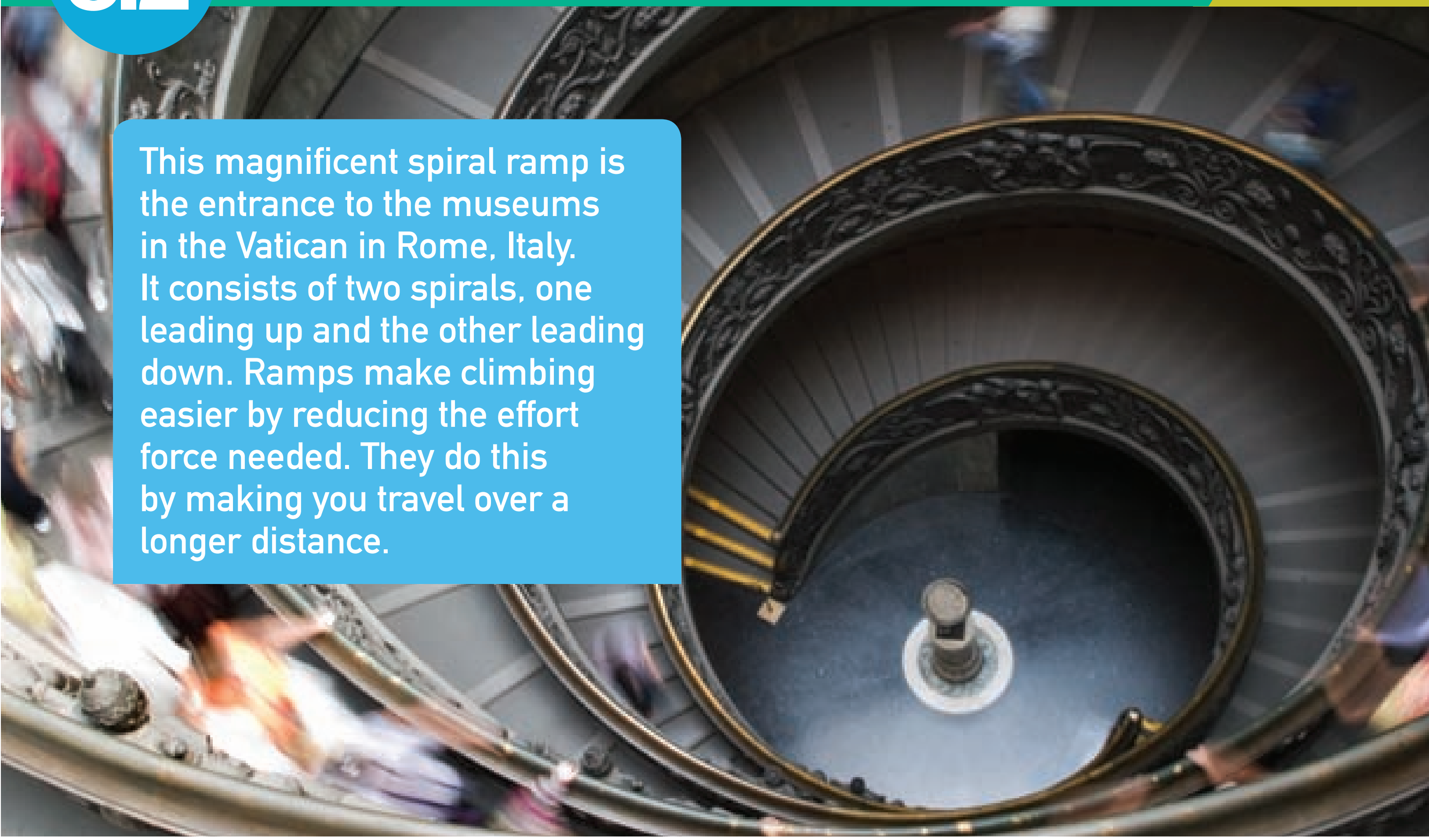
Discussion

1 **Classify** which levers were used to increase force and which were used to increase speed.

2 **Describe** how you would perform each of the tasks you completed without these simple machines, and explain how each task would be more difficult.

Lever system	Labelled diagram showing position of load (L), effort (E) and fulcrum (F)	How you think it works	Type of lever

8.2 Inclined planes



This magnificent spiral ramp is the entrance to the museums in the Vatican in Rome, Italy. It consists of two spirals, one leading up and the other leading down. Ramps make climbing easier by reducing the effort force needed. They do this by making you travel over a longer distance.

Ramps

The roads and tracks through mountain ranges are usually twisted and winding, such as the one shown in Figure 8.2.1. Imagine instead that the road to the top of a mountain went up in a straight line. The distance you would travel would be much shorter, but the road would be steeper, very difficult to travel up and possibly dangerous. By travelling a greater distance over a winding road, you can climb the mountain using less effort force. This makes it easier on the car's engine on the way up and easier on its brakes on the way down.

Moving heavy furniture or packing equipment into a truck would require a very large effort force if it was lifted directly from the ground into the truck. A **ramp**, or **inclined plane**, is a simple machine that makes this task much simpler. In using a ramp like the one in Figure 8.2.2 on page 302, you use a smaller force over a longer distance in loading objects into a truck.

Figure 8.2.1 Winding roads and tracks reduce the slope of an incline in mountain areas, making it easier for cars and bushwalkers.

Figure 8.2.2 Loading and unloading heavy sound equipment such as this would be almost impossible without the use of a ramp.

Wedges

Imagine trying to bite into an apple without your front teeth. Your front teeth, called *incisors*, cut like a knife. These are simple machines called **wedges**. A wedge is a double inclined plane that moves through another object. Wedges are used to split objects because they change the direction of a force by 90° and increase its size. When an axe is pushed downwards, the wedge of the axe head pushes the wood apart, as shown in Figure 8.2.3. Pins, needles, nails and doorstops are all examples of wedges.

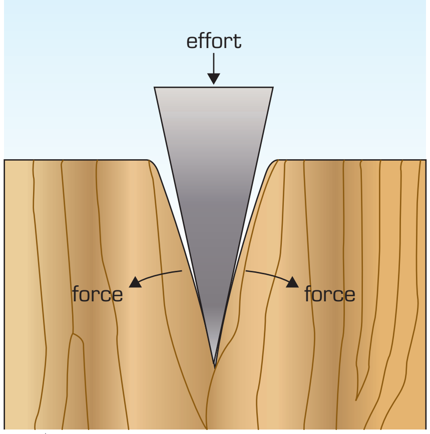


Figure 8.2.3 A wedge changes the direction of a force, enabling an object to be split. The longer the inclined edge of this wedge and the sharper the axe, the easier the wood is to split.

INQUIRY science 4 fun

Getting the point

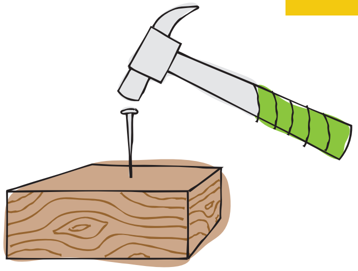
No

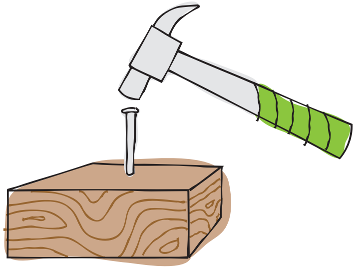
How does a nail enter a block of wood?

Collect this . . .

- 2 nails
- off-cut of wood
- hammer
- metal stud (not pointed)

SAFETY
Take care that you don't hit your fingers when using the hammer.





Do this . . .

1. Try to hammer a nail into a block of wood.
2. Hold a nail upside down on the wood and give it a few light taps with the hammer to blunt its end.
3. Try to hammer the blunt nail into your block of wood.

Record this . . .

Describe what happened.

Explain why you think this happened.

SKILL BUILDER

The mechanical advantage of a ramp

The mechanical advantage of a ramp is given by the mathematical formula:

$$\text{Mechanical advantage} = \frac{\text{length of slope}}{\text{height of slope}}$$

Ramps are widely used in buildings to make it easier to deliver goods to shops and easier for people to enter, particularly the elderly, those in wheelchairs or pushing prams, as shown in Figure 8.2.4.

p308

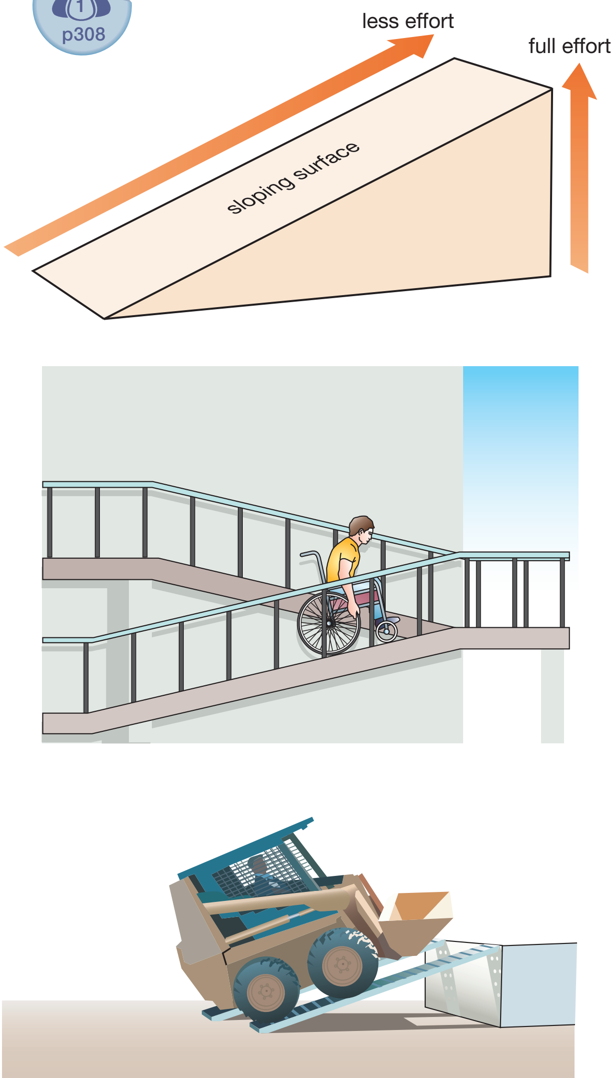


Figure 8.2.4 Although you must travel a greater distance when using a ramp, you can do so with less force. This makes the task easier.

WORKED EXAMPLE
Mechanical advantage of a ramp

Problem 1

A crate of weight 300 N is pushed with an effort force of 60 N up a 10 metre ramp into a doorway as shown in Figure 8.2.5. **Calculate** the mechanical advantage of this ramp.

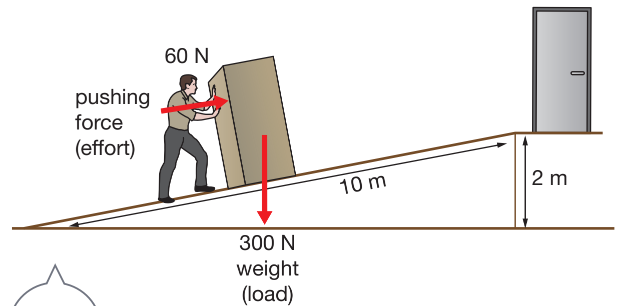


Figure 8.2.5

Solution 1

$$\text{Mechanical advantage} = \frac{\text{length of slope}}{\text{height of slope}} = \frac{10}{2} = 5$$

The ramp provides a mechanical advantage of 5.

Problem 2

Given that the load is the weight of the crate, which is 300 N, **calculate** the size of the effort force required to push the crate up this ramp.

The effort force is one-fifth the load force.

$$\text{effort} = \frac{300}{5} = 60\text{ N}$$

The ramp provides a mechanical advantage of 5. This means that the crate can be pushed up the ramp with 5 times less force. The crate could be moved with a force of 60 N rather than its weight of 300 N using this ramp.

8.3 8.4

Zips

Clothing, purses, wallets, sleeping bags, suitcases, handbags, backpacks and pencil cases are just some examples where zips are found. A zip consists of two sets of interlocking teeth and is very strong when fastened. As shown in Figure 8.2.6, the slide of a zipper uses three wedges to force these teeth together when doing the zip up, and unlatch when undoing it.

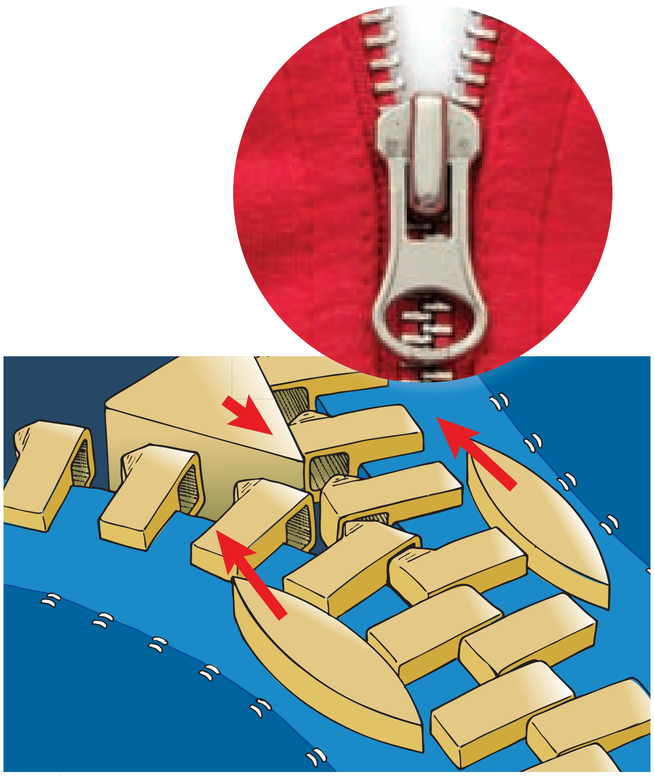


Figure 8.2.6 A zip consists of a zipper track, containing two rows of teeth. The zipper is closed when the hooks in the teeth on one side of the zipper are slotted into hollows of teeth on the other side. The zipper slide is a collection of wedges. A central wedge unlatches the teeth as the zip is undone and side wedges force the teeth together when the zip is done up.

Zip history

SciFile

After their invention in 1913, zips were mainly used on boots and tobacco pouches. Twenty years later they were being used in clothing. Zips were first used in children's clothes to help children get dressed more easily. When used in the manufacturing of adult clothing, there were fears that zips would allow people to take off their clothes too fast!

Screws

A **screw** is a spiral inclined plane (Figure 8.2.7). It is a simple machine that is designed to cut through another substance. Wood screws cut through timber, boat propellers are screws that cut through water and aircraft propellers are screws that cut through the air.

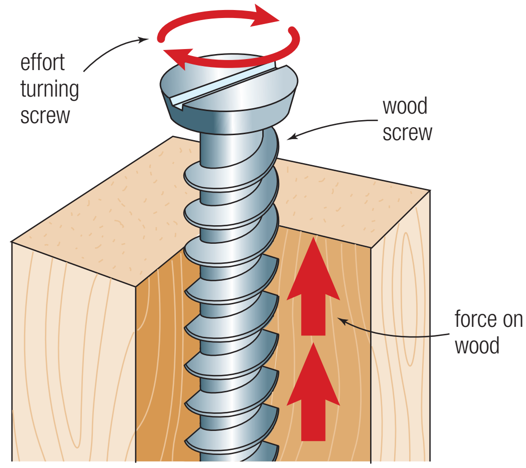


Figure 8.2.7 A screw is an inclined plane that winds around a metal cylinder. It increases the force you apply by moving through a greater distance.

As a screwdriver turns a screw into a piece of wood, the timber moves along the spiral ramp. This enables you to drive the screw into the wood with much less force than would be needed if you hammered it directly. This is because the screw is moved a greater distance through the timber when screwed into place. The spiral inclined plane around a metal screw is called the thread. As Figure 8.2.8 shows, the closer the turns of the thread are the gentler the slope (or **pitch**) of the inclined plane will be, and the greater the force will be magnified.

2 p309

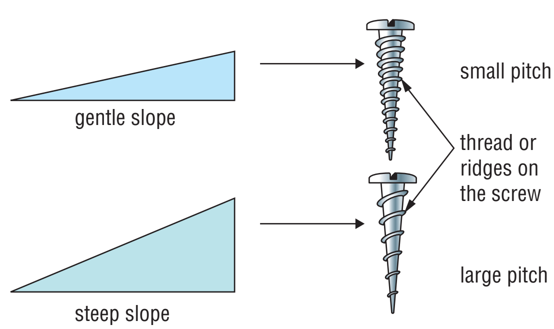


Figure 8.2.8 A screw with a small pitch is easy to screw into a piece of wood, but to do so it must be turned many times by the screwdriver. A screw with a large pitch takes fewer turns of a screwdriver to be inserted into wood, but requires more force than the previous screw.

Figure 8.2.9 A spear thrower is a machine that allows people to hunt better.

SCIENCE AS A HUMAN ENDEAVOUR

Nature and development of science

Indigenous tools and weapons

Indigenous Australians developed and used a range of tools that were designed to perform specific tasks.

Stone tools recently discovered in Western Australia are over 35 000 years old. Stone tools were produced by a process called flaking. In this process, a block of stone (called a core), was struck with a hammer stone (usually a pebble), to chip off a sharp piece of stone, called a flake. These flakes were further flaked, or 'retouched' to be reshaped. Often a hard, volcanic piece of rock was also used to grind a sharp edge. Using these techniques, people could create sharp points of spears, chisels, axes, saws or knives (Figure 8.2.10). The types of stone that were best suited to producing flakes were those rich in silica, such as quartz, quartzite, chert and flint. These stones are hard but brittle. These sharp stone tools could cut more cleanly than a steel blade. Resins were used to attach a cutting stone to a piece of wood as a handle.

Figure 8.2.10 These stone flakes have been chipped off a core rock. They can be reshaped or resharpened as required.

Indigenous Australians developed a number of unique weapons. Spears were used with a various shaped tips. The tip of a spear itself is a simple machine, being a double inclined plane. In addition, a number of designs of spear throwers were used throughout Australia. The device shown in Figure 8.2.11, known as a woomera to tribes in New South Wales, was made from a dense wood, such as that from a wattle. The spear thrower has a peg that hooks into the end of a spear. When used to throw the spear, it acts as an extension of the thrower's arm. This increases the length of time the force is applied to the spear and multiplies the speed with which it is launched. This device makes the mechanics of throwing a spear far more efficient and as a result, the spear travels much further than would otherwise be possible.

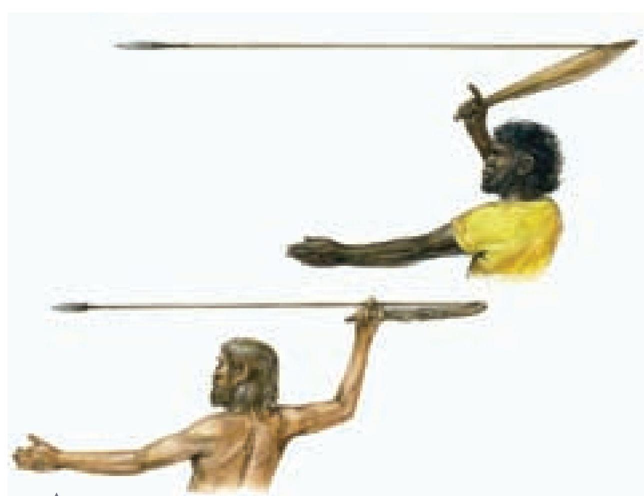


Figure 8.2.11 A spear can be thrown two or three times as far using a spear thrower. In addition, spear throwers were used to carry food and water.

8.2 Unit review

Remembering

1 **List** three places where you have used a ramp.

2 **List** three common examples of a wedge.

3 **State** which simple machine could be called a:
  a double inclined plane
  b spiral inclined plane.

4 **State** whether each of these statements is true or false.
  a The longer the slope of a ramp for a certain height, the greater its mechanical advantage.
  b A screw with a small pitch corresponds to a steep inclined plane.
  c A screw with a small pitch requires fewer turns to be inserted into a piece of wood than a screw with a large pitch.
  d A wedge changes the direction of a force by 90° and increases its size.

5 **State** an example of a type of screw that cuts through a:
  a solid
  b liquid
  c gas.

6 **Recall** five devices that can be produced by flaking.

7 **Recall** one name for a spear thrower.

Understanding

8 The person shown in Figure 8.2.12 needs to get to the top of this dam wall. There are two options: climb straight up or use the stairs on the right.

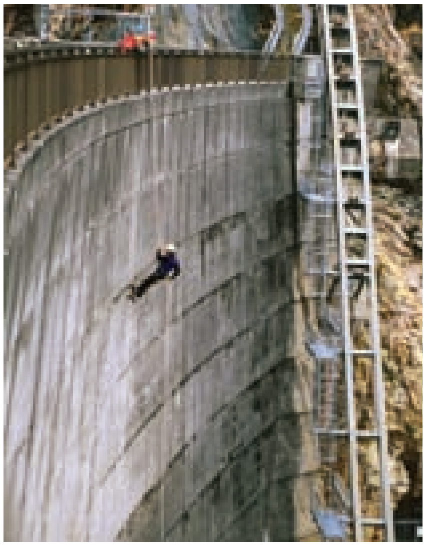


Figure 8.2.12

  a **State** whether the effort force needed to reach the top is the same or different using both methods.
  b **Explain** your answer above.

9 **Explain** how a screw provides a force advantage.

10 **Describe** how a stone is flaked.

11 **Explain** why stone rich in silica is suitable to use in creating stone tools.

12 **Explain** how a spear thrower allows a hunter to throw a spear much further than otherwise possible.

Applying

13 **Identify** which type of simple machine (inclined plane, wedge or screw) is described by these devices.
  a corkscrew
  b axe
  c electric fan
  d car park ramp
  e chisel
  f escalator

14 **Calculate** the mechanical advantage of a ramp in which a load of weight 100 N is lifted by an effort force of 20 N.

15 **Calculate** the mechanical advantage of ramps with the dimensions listed in the table below.

Length of slope (m)	Height of ramp (m)	Mechanical advantage
15	3	
50	25	
12	2	
20	5	
240	30	

16 a **Calculate** the mechanical advantage of the two ramps shown in Figure 8.2.13.

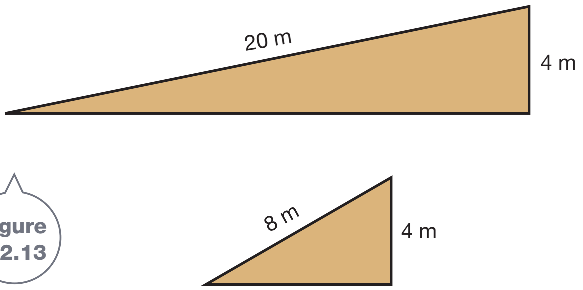


Figure 8.2.13

b A 500 N shipping container must be lifted a height of 4 m from a dock onto a ship. **Calculate** the size of the effort force that would be needed to shift it using each of the ramps shown.

Evaluating

17 Sometimes it is recommended that a blunt nail be used when repairing a wooden object, because it has less chance of causing the wood to split. **Propose** why this is the case.

18 A 10 000 N industrial oven is being moved from a factory to a restaurant. It must be raised a vertical height of 1 m into a truck. The removalists refuse to push it up a ramp with a force greater than 200 N. **Propose** the dimensions of a suitable ramp. The removalists should not need to exceed the force of 200 N. **Justify** your answer.

Inquiring

1 The Archimedes screw is an invention designed by the famous Greek physicist and mathematician Archimedes. Research to describe:
- what its design looks like
- what it was designed to do
- how it works
- where it is used today.

2 Research the history of the invention of the zip. Outline different variations and different inventors who played a role in its development.

3 Investigate a car jack. Count how many times you need to turn the handle in order to make the jack rise by 1 cm. Explain how the jack is able to provide a far greater lifting force than the size of the force we apply to it.

4 Australian building regulations state that ramps must be built:
- with a slope of no more than 1:8 for step or kerb ramps that have a maximum length of 1.52 m (the horizontal distance must be more than eight times its height);
- no steeper than 1:14 for ramps longer than
1.52 m in length (the horizontal distance must be more than 14 times its height).

You can see these dimensions in Figure 8.2.14. Record the location and dimensions of a number of ramps found in your school or your local shopping centre. Calculate whether each ramp complies with the Australian standard and write a report to summarise your findings.

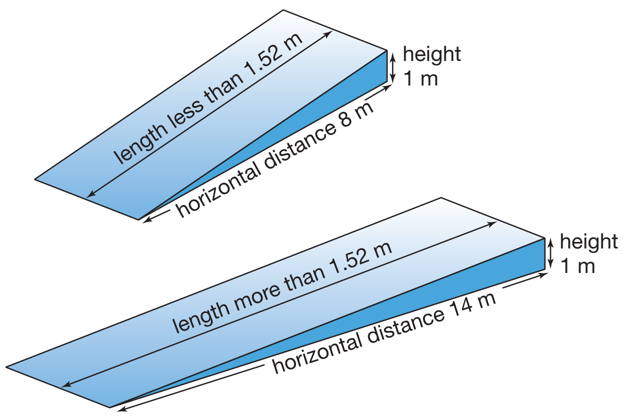


Figure 8.2.14 These are the dimensions of the steepest inclines allowed by law on Australian kerbs and longer ramps built for public use.

8.2 Practical activities

1 Using ramps

Purpose

To measure the force required to lift a cart vertically and to lift it using ramps of differing slope.

Materials

- trolley
- spring balance (or force sensor)
- a number of books or a couple of blocks or bricks to elevate ramp
- wooden ramp
- spring balance
- protractor

Procedure

1 Position a plank of wood on a pile of books (or a brick and some books) to make a ramp that is about 10 cm high, as shown in Figure 8.2.15.

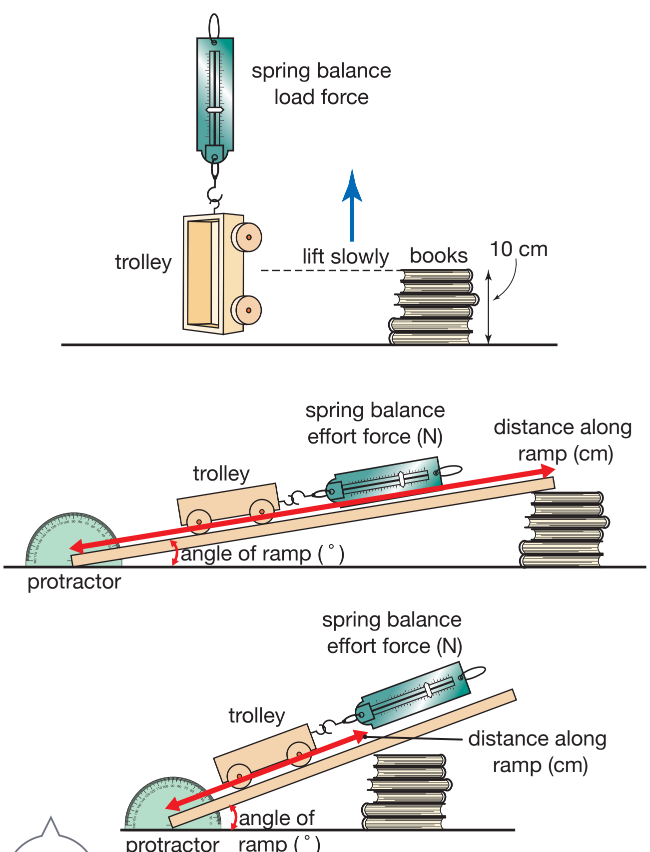


Figure 8.2.15

2 Attach the trolley to a spring balance (or force sensor). Carefully lift it vertically until its rear is level with the height of your ramp. Record this weight as the load force.

3 Measure the angle of elevation of the ramp and its distance from the base to the pile of books. Record these values in the table.

4 Slowly drag the trolley up the ramp to the pile of books. Record the effort force required.

5 Repeat steps 3 and 4 for four different angles of the ramp. Measure the new ramp length and effort force each time.

6 Calculate the mechanical advantage for each angle of ramp tested.

Results

In your workbook, copy the following results table.

Angle of ramp (°)	Distance along ramp (cm)	Effort to pull trolley up ramp (N)	Mechanical advantage of ramp $\left(\frac{\text{load}}{\text{effort}}\right)$

Discussion

1 **State** whether having a large or a smaller angle of ramp increased its mechanical advantage.

2 **Explain** why this occurred, considering how the effective distance of the ramp varied with the changing angle.

3 **List** three situations in which using a ramp at a shopping centre is useful.

2 The turn of a screw

When you drive a screw into a piece of wood, the effort you apply is over a much larger distance than the depth to which you have to sink the screw into the wood.

Purpose

To compare the turn of a screw with the depth it is sunk.

Materials

- A4 piece of paper
- pencil
- ruler
- scissors
- screw
- piece of cotton

Procedure

1. Cut the piece of paper diagonally into two halves. You only need to use one half for this task.
2. Place a pencil along the vertical edge, as shown in Figure 8.2.16a.
3. Mark the top of your pencil on this sheet and rule a horizontal line across. Cut this section from the paper.
4. Measure the length, *T*, of the longest side of triangle 1. If the pencil were a screw, then *T* is the distance you would have to turn to sink it a distance equal to the length of the pencil.
5. Measure the length of the pencil, *L*.
6. Roll the paper around the pencil, as shown in Figure 8.2.16b.
7. Measure the distance between the thread of your paper screw. This is called its pitch, *P*.
8. Taking your triangular sheet of paper, make a cut across from the tip of the pencil to another point A, as shown in Figure 8.2.16c. This forms triangle 2. Wind the pencil up again.
9. Measure the new thread and pitch lengths.
10. Cut a third triangle (triangle 3) by making a cut to point B, and repeat the process.
11. Measure the length of the thread of the real screw by winding a piece of cotton around it.
12. Measure the length of this screw and estimate its pitch.

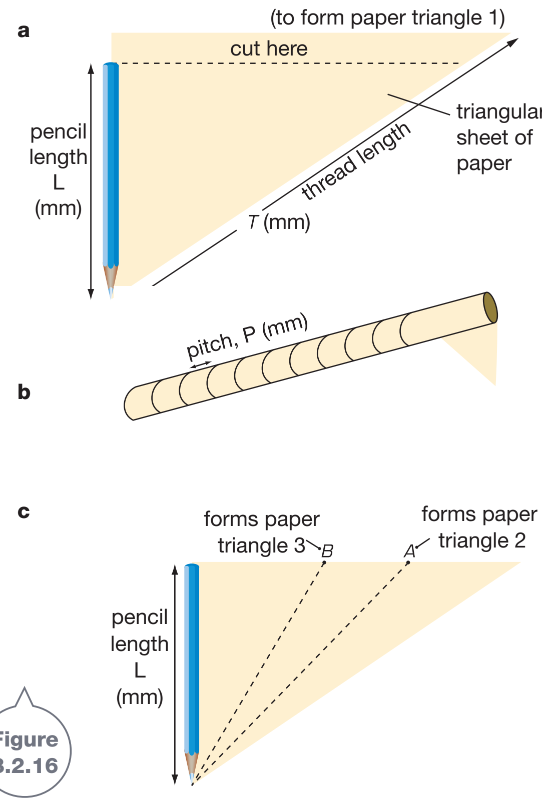


Figure 8.2.16

Results

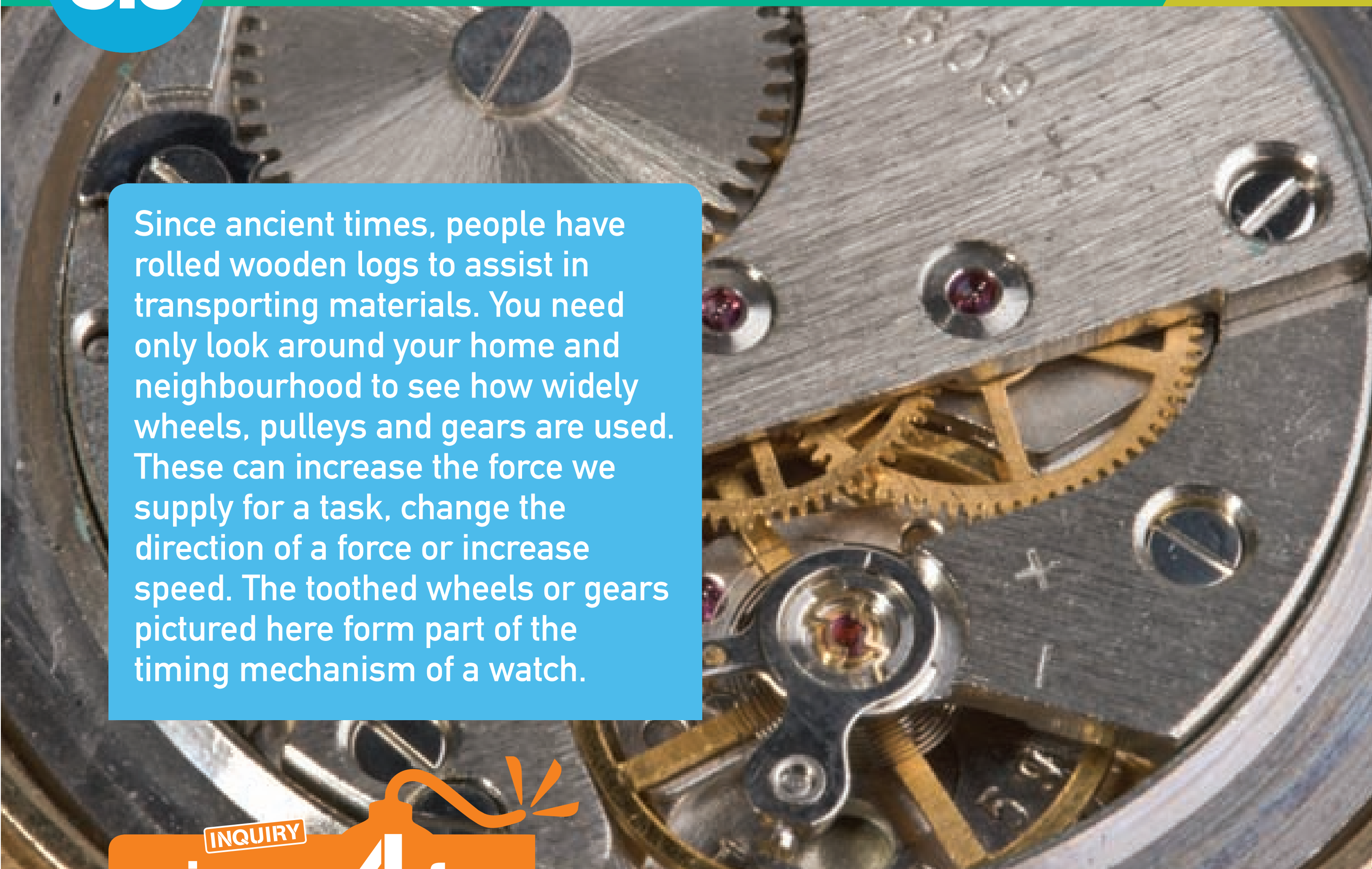
In your workbook, copy and complete the following table.

Paper triangle	Thread length, *T* (mm)	Pencil or screw length, *L* (mm)	Pitch, *P* (mm)
1			
2			
3			
Screw			

Discussion

1. **State** how far you would need to turn the initial paper screw to sink it the distance of the pencil.
2. **Describe** what happens to the pitch of a screw as its thread becomes shorter.
3. **Explain** whether you think a screw would be more effective with a smaller or larger pitch.
4. **Compare** the length of the screw you examined with the length of its thread.

8.3 Wheels, pulleys and gears



Since ancient times, people have rolled wooden logs to assist in transporting materials. You need only look around your home and neighbourhood to see how widely wheels, pulleys and gears are used. These can increase the force we supply for a task, change the direction of a force or increase speed. The toothed wheels or gears pictured here form part of the timing mechanism of a watch.

INQUIRY science 4 fun

Turning on a tap

Yes

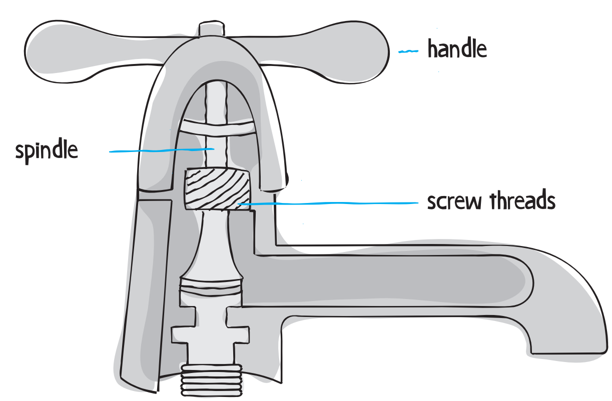
Can you turn on a tap without its handle?

Collect this …

- a tap that can be unscrewed

Do this …

1. Place a plug in the sink to avoid losing any parts down the drain.
2. Carefully unscrew a tap.
3. Place the screw, handle and cap on the basin.
4. The tap should now just be a spindle, or an axle.
5. Try to turn the tap on just using your hands.
6. Offer a challenge to your friends and family. Can it be done?



Record this …

Describe what happened.

Explain why you think this happened.

Wheels

The centre of a **wheel** is called its **axle** and the outside of a wheel is its **rim**. This is shown in Figure 8.3.1. A wheel on an axle is a special type of lever. Each spoke of the wheel is a lever, the axle is the fulcrum and the wheel rim is the outer end of the lever. As a lever can produce a force or a speed advantage so too can a wheel. Figure 8.3.2 shows how a wheel can provide a speed advantage. Figure 8.3.3 shows how a wheel can produce a force advantage. When you apply a force to turn on a tap, the handle acts as a wheel. It increases the force you apply at its centre, allowing the spindle or axle to turn.

1 p319

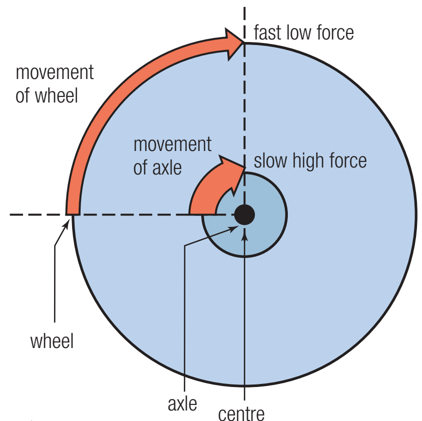


Figure 8.3.1 The rim of the wheel rotates with greater speed than the axle in its centre. As the wheel turns, the force at its centre is larger than the force at its rim.

Figure 8.3.2 The motor of an electric fan turns the central axle relatively slowly. This speed is multiplied through the spinning blades. The longer the blades, the greater the speed multiplied. Aircraft propellers also act as speed multipliers.

Figure 8.3.3 In each of these situations, a wheel is used to produce a force advantage.The force applied to the steering wheel rim, the screwdriver or the winder of the sardine tin is increased at the axle of each wheel. Using a longer lever arm further increases the force produced at its axle. The larger the steering wheel, the easier the axle is to turn.

Pulleys

Sometimes it is necessary to change the direction of a force. To lift a set of Venetian or Roman blinds, it is much easier to apply a downwards force on a cable than to try to lift it upwards from a height. A simple way of doing this is to use a **pulley**. A pulley is a wheel with a groove around it into which a rope or chain can move. To increase the force applied, more than one pulley must be. The single pulley shown in Figure 8.3.4 changes the direction, but not the size of the effort force required to lift a load. Using two pulleys halves the size of the effort force required, providing a mechanical advantage of 2. In this case, the force is applied over a greater distance.

2 p319

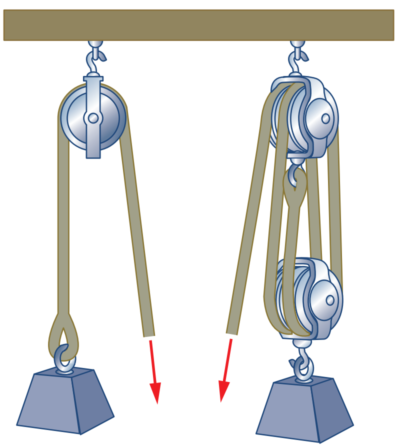


Figure 8.3.4 The block and tackle arrangement shown on the right provides four times the force of the single pulley on the left.

A greater mechanical advantage can be produced using a number of pulleys in an arrangement called a **block and tackle**. Such an arrangement is useful to lift heavy objects and is shown in Figure 8.3.5.

Figure 8.3.5 A multiple pulley system increases the size of the force applied, and is useful for raising heavy objects.

INQUIRY science 4 fun

Playing with pulleys

Can you use a pulley to push two people together?

Collect this …

- 2 broom handles (or wooden handles)
- long piece of rope

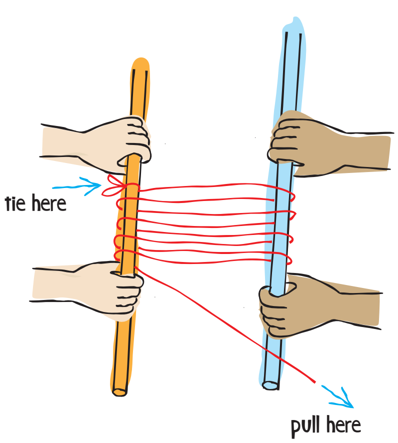
Do this …

1. Give two students a broom handle each to hold horizontally.
2. The students face each other, standing about 50 cm apart.
3. Tie one end of the rope to one handle and then loop the other end over the other handle and back over the first, about six times.
4. Ask the students to try to resist moving together, and pull the free end of the rope so that it tightens around the handles.

Record this …

Describe what happened.

Explain why you think this happened.



Gears

In some older-style machines such as lathes, one wheel is connected to another wheel by a rubber belt. The belt transfers the spinning motion of the first wheel to the second. The difference in speed depends upon the diameter of each wheel. As shown in Figure 8.3.6, the fanbelt in a car operates in this way. One disadvantage with such a system is that the belt can slip. This is avoided when you use gears, or cogs, to transfer spinning motion.

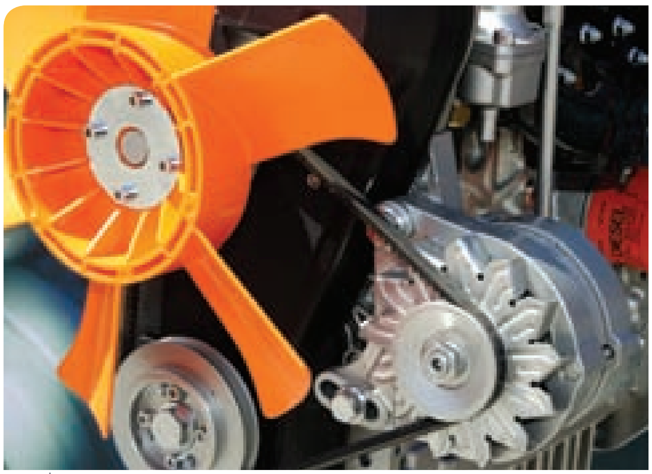


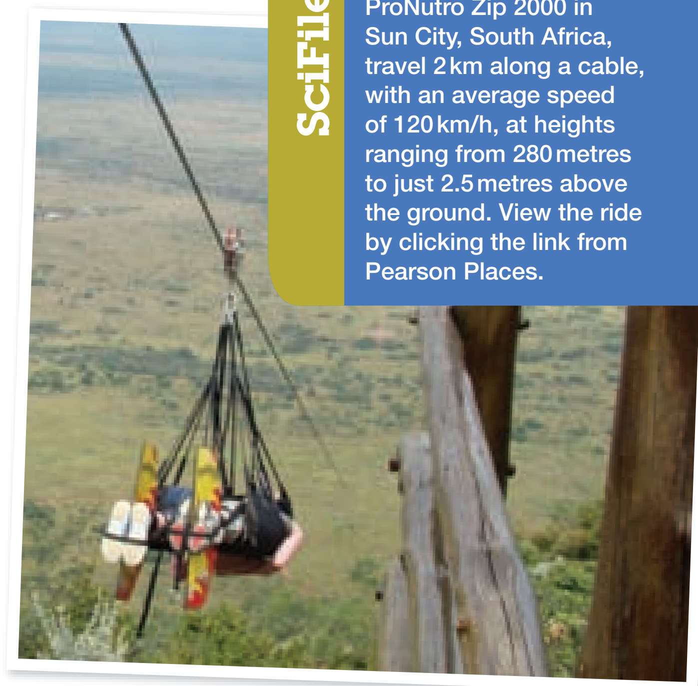
Figure 8.3.6 A fanbelt connects different-sized wheels inside a car engine.

Gears are wheels that have teeth around their rim. The most common type of gears are called spur gears. These are the type shown in Figure 8.3.7 on page 314. Gears can mesh directly together, or be joined by a chain, such as on a bicycle or in the overhead cam shaft in some car engines. A set of gears that are connected is called a **gear train**. When one gear turns, the gear it interlocks with also turns, but in the opposite direction. The gear that supplies the force is called the **driving gear**. The gear that is connected to this gear is called the **driven gear**. Different combinations of gears are selected to increase either the force applied or the speed of turning.

SciFile

Got to fly

What is the longest flying fox you have ever been on? Riders on the ProNutro Zip 2000 in Sun City, South Africa, travel 2 km along a cable, with an average speed of 120 km/h, at heights ranging from 280 metres to just 2.5 metres above the ground. View the ride by clicking the link from Pearson Places.



SciFile

Boneshakers

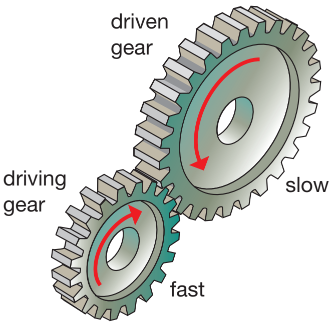
Early bicycles did not use gears and did not have the suspension used today. An early French bike, the velocipede was made of wood, with iron tyres, and was popular around 1864–71. In England, it became known as 'the boneshaker', a good description for what happened to the rider when travelling along cobblestone streets!

Gears as force multipliers

If the driving gear is smaller than the driven gear, then the combination acts as a force multiplier. The larger cog will rotate more slowly in this case, but the force it delivers is much larger. This gear combination is called gearing down and is useful when you need a large force. For example, it would help a car get up a hill or help in using a winch. This is shown in Figure 8.3.7.

Figure 8.3.7

This gear combination results in a driven gear that rotates more slowly than the driving gear, but does so with greater force.

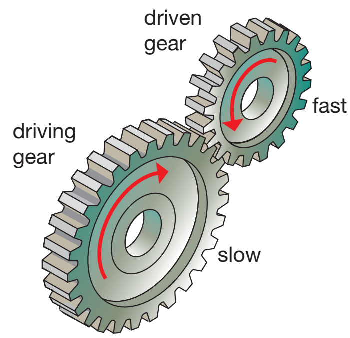


Gears as speed multipliers

If the driving gear is larger than the driven gear then the combination acts as a speed multiplier. This happens because one turn of the large cog will make the smaller cog spin a number of times. This gear combination is called gearing up. It is useful when using an eggbeater, where you require the beaters to spin faster than the handle turns. This is shown in Figure 8.3.8.

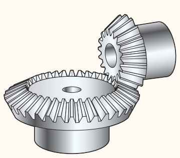
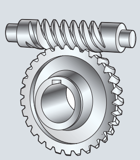
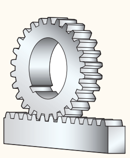
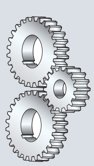
Figure 8.3.8

Using gears as a speed multiplier is useful when using an eggbeater. Applying a greater force to the handle pays off as the beaters spin faster.



There are many different types of gears, each suited to a specific purpose. Some examples are shown in Table 8.3.1.

Table 8.3.1 Different types of gears and their uses

Type of gear	Function	Example
Bevel gear 	Positioned at right angles to each other so that they change the plane of rotation	Hand drills: as the handle is turned in a vertical direction, this is transferred into rotation of the drill bit in a horizontal plane
Worm gear 	Looks like a screw, and is used to drive a gear. Is often used to reduce speed	Used to tune a guitar string
Rack and pinion 	A gear wheel rotates over a row of teeth, called the rack. This converts rotational motion into straight-line (or linear) motion	Used to convert steering wheel rotation into linear motion to the right or the left in order to turn the wheels of the car
Idler gear 	Positioned between a driving and a driven gear to get them rotating in the same direction	Engaging an idler gear between two gears in a car with manual transmission allows the car to reverse

Using gears on a bicycle

Gears used in a bicycle are called **sprockets**. The pedal and crank is attached to a gear sprocket called the chain wheel. This is connected by a chain to the rear sprocket (Figure 8.3.9). A bike with 21 gears gives the rider the choice of 21 different gear combinations. The front chain wheel has three sprockets and the rear wheel has seven.

Figure 8.3.9 The teeth of the sprocket hook into the bicycle chain to transfer motion.

To use first gear, you select the largest rear-wheel sprocket, and the smallest chain wheel sprocket, as shown in Figure 8.3.10. This means that you need to pedal more, but the rear wheel is moved with much greater force. When you select the highest gear, the smallest rear-wheel sprocket and largest chain wheel sprocket are used, as shown in Figure 8.3.11. Using such an arrangement, a greater force is required to turn the chain wheel sprocket, but the rear wheel turns faster.

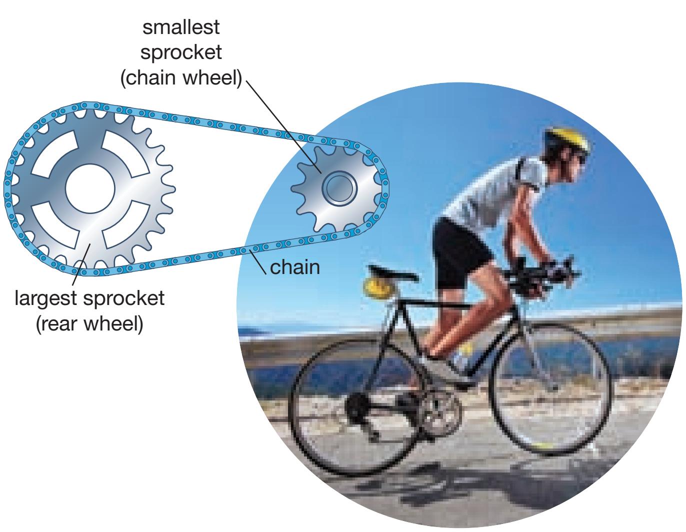


Figure 8.3.10 First gear on a bicycle is useful when you need to start moving or ride up a hill.

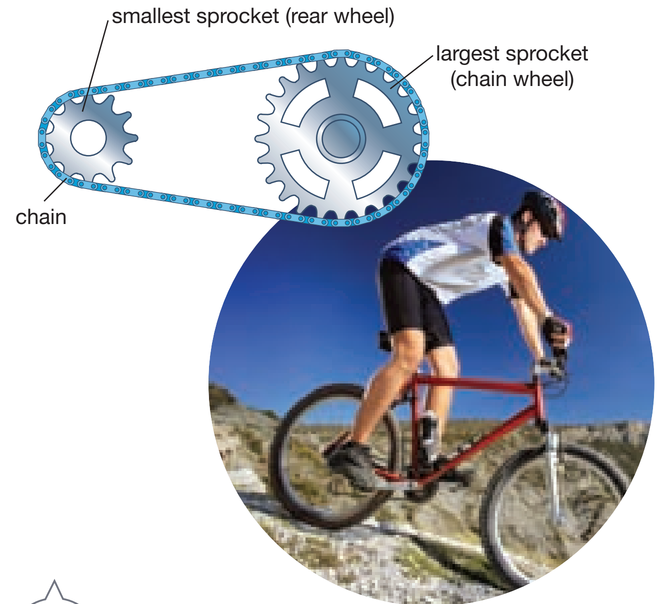


Figure 8.3.11 High gear on a bicycle is useful when cruising along an easy, flat road or going downhill. It enables you to pedal slowly, but still move along quickly.

3 p320 4 p321 8.5

SKILL BUILDER

Calculating the gear ratio

The **gear ratio** of sprockets on a bicycle, or of two gears meshed together on a machine, is calculated by dividing the number of teeth on the driving sprocket (or driving gear) by the number of teeth on the driven sprocket (or driven gear).

The low gear combination shown in Figure 8.3.10 has 12 teeth on the driving sprocket and 24 on the driven sprocket. The gear ratio is $\frac{12}{24} = 0.5$. This means the rear sprocket spins through half a revolution for every turn of the chain wheel.

The high gear combination shown in Figure 8.3.11 has the opposite combination.

Its gear ratio is $\frac{24}{12} = 2$. This means that for each turn of the chain wheel, the rear sprocket turns twice.

SCIENCE AS A HUMAN ENDEAVOUR

Use and influence of science

Robotics

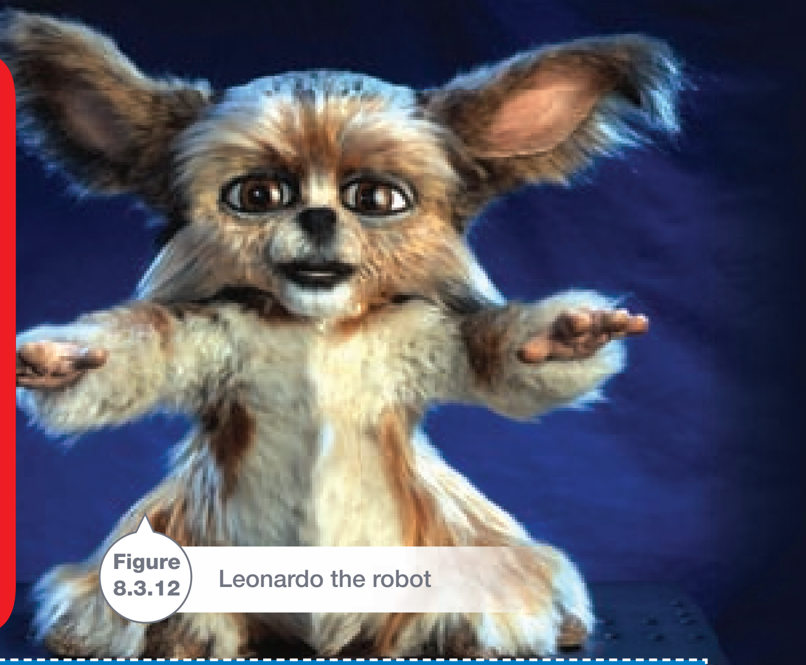


Figure 8.3.12 Leonardo the robot

Leonardo the robot has been developed by the Stan Winston Studio and MIT's Artificial Intelligence Laboratory. Leonardo is designed to be sociable, by observing and responding to the cues of people nearby.

Robots are complex machines. They can be designed to perform many tasks, but have no intelligence of their own. Many robots are operated from a distance by a human controller. These telerobotic systems (*tele* means 'at a distance') extend a human's ability to carry out particular tasks. Some robots, such as those used as vacuum cleaners or lawn mowers, are designed to be autonomous, or control themselves. They do this by incorporating a number of sensors that can detect a particular condition and then react to it in some way. Many developments in robot design have been made by scientists observing the ways that insects or other animals move and sense their surroundings.

Robots are generally used to perform tasks that are very repetitive and those that require great precision. Assembly production lines building cars now commonly use robots to weld panels (Figure 8.3.13). Robot arms are used in the manufacturing industry, to perform tasks such as packing, testing, gluing and precision drilling.

Figure 8.3.13 This time exposure photo shows orange robot arms welding car bodies on an assembly line. The movement of these arms is precise and they never tire, explaining why most cars are now assembled in this way.

Robots are now used in surgery for work too fine to be carried out by a human. The da Vinci system is widely used for keyhole surgery, for gall bladder removal, prostate surgery, heart bypasses and even brain surgery. These procedures are conducted through smaller incisions so patients have a faster recovery rate and suffer fewer complications than with conventional surgery. You can see it in Figure 8.3.14.

Figure 8.3.14 Surgical tools on the end of robot arms are shown here operating on a human heart. These arms are controlled by a surgeon, who looks at a beamed image of the operation site.

Robots are also used to perform tasks that are dangerous to humans. Autonomous robots are being used to explore dangerous environments such as other planets and shipwrecks, for defusing bombs, and for investigating inside a volcano or searching through disaster zones.

8.6

8.3 Unit review

Remembering

1 The wheel in Figure 8.3.15 can be thought of as a lever.
  a **State** whether its fulcrum is located at A, B, C or D.
  b **State** the length of the lever arm.

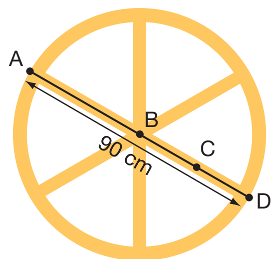


Figure 8.3.15

2 **Specify** which turns faster on a wheel—its centre or its rim.

3 **List** two examples where a wheel is used as a force multiplier.

4 **List** two examples where a wheel is used as a speed multiplier.

5 **Name** one use for:
  a bevel gears
  b worm gears
  c rack and pinion gears.

Understanding

6 Examine Figure 8.3.3 on page 311. **Explain** how each type of wheel shown acts as a force multiplier.

7 a **Explain** what is meant by a *block and tackle*.
  b **Describe** how a block and tackle is used.

8 **Discuss** how a pulley system obtains a force advantage.

Applying

9 a **Identify** three jobs around your home which you would like a robot to perform.
  b **Explain** why you have chosen each job.

10 For Figure 8.3.16:
  a **Calculate** the gear ratio for the combination shown.
  b **Describe** a type of riding situation for which this combination would be useful.

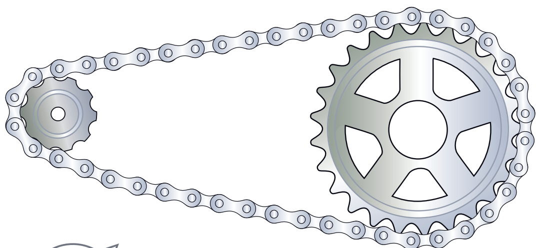


Figure 8.3.16

11 **Use** Figure 8.3.17 to answer the following.
  a **State** how many pulleys are being used by the system.
  b **Calculate** how much easier it will be to lift an object using such an arrangement.

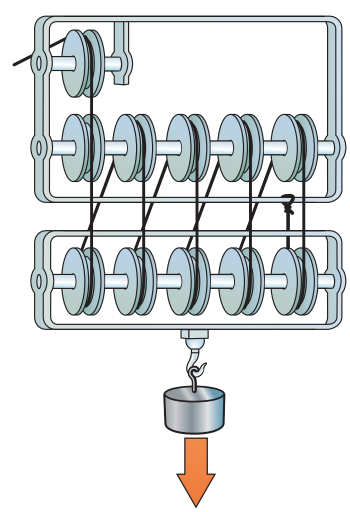


Figure 8.3.17

8.3 Unit review

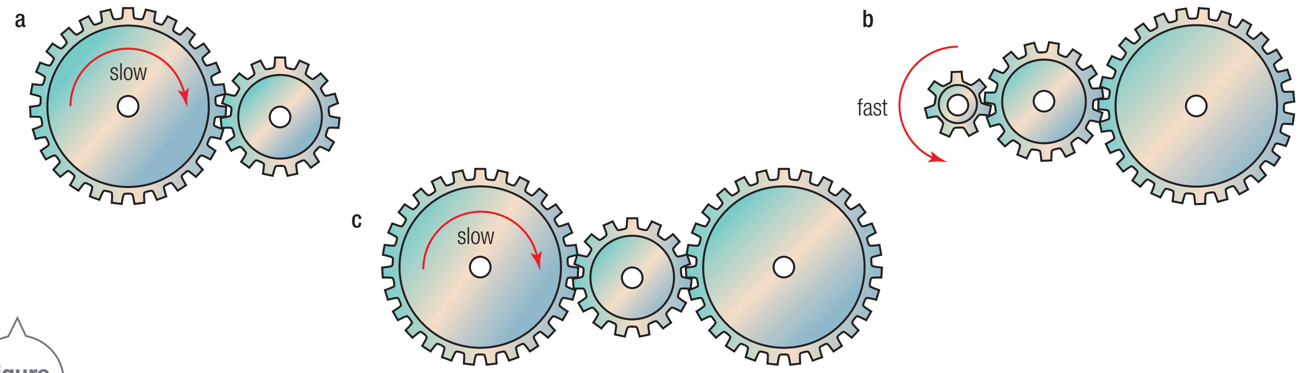


Figure 8.3.18

Analysing

12 Copy the three gear trains from Figure 8.3.18. **Analyse** the direction of rotation and speed of each gear and show these on your diagram.

13 A farmer applies an effort force of 150 N to a pulley system to lift a sack of wool weighing 600 N.

- **a** From this information **calculate** how many pulleys are in the system.
- **b** **Calculate** how much further he needs to pull the rope than when using a single pulley.

Creating

14 **Construct** a diagram to show an arrangement of gears in a gear train to act as a:

- **a** force multiplier
- **b** speed multiplier.

Inquiring

1 Robocup is an international competition, aimed to develop a team of fully autonomous (self-controlled) humanoid robots that can beat the best soccer team in the world by the year 2050. Use the internet to construct a timeline outlining:

- when this competition began
- the year and location of past Robocups.

Illustrate your timeline with images of some of the competing robots from past challenges.

2 Leonardo da Vinci was not only a wonderful painter, he also sketched inventions of many machines that were well before his time. Search available resources such as textbooks, encyclopaedias and the internet to describe some of these fascinating inventions.

3 Design and construct a machine that uses as many of the different types of simple machine studied in this chapter as you can. You can choose to build a:

- machine able to lift a small load
- replica of a medieval machine, such as a trebuchet or drawbridge
- mechanical toy.

4 Use a model building set such as Lego to build a gear train that increases force, and a gear train that increases speed. Calculate the gear ratio between the driving and driven gear in each case.

5 Research Lance Hill and the Hill's Hoist.

8.7 8.8

8.3 Practical activities

1 Using a wheel and an axle

Purpose
To build a simple machine consisting of a wheel and an axle.

Materials
- 250 mL beaker or tin can
- 2 paper clips
- length of stiff wire
- sticky tape
- 100 g mass
- string

Procedure
1 Set up the equipment shown in Figure 8.3.19a. Tape the two paper clips to hold the wire axle in position.

2 Try to lift the 100 g mass by twisting the wire around using your thumb and index finger.

3 Now, remove the paperclips and remove the wire. Bend the end without the masses to form a handle as shown in Figure 8.3.19b.

4 Reassemble the equipment and now try to lift the masses by turning the handle.

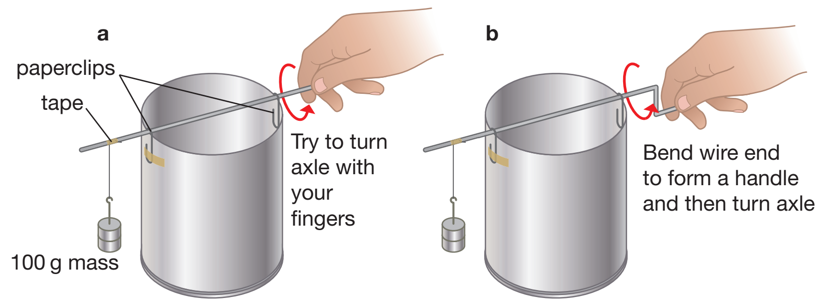


Figure 8.3.19

Discussion
1 **Describe** the difficulty of using the equipment with the straight axle to lift the masses using the straight piece of wire.

2 **Explain** any differences in doing this when using the bent handle.

3 **Propose** a reason this change makes the task easier.

4 This handle is acting as a lever. **Identify** why turning the handle provides the force advantage needed to lift the mass.

5 **Identify** three places you've seen systems similar to this being used to provide a force advantage.

2 Investigating pulleys

Purpose
To compare the advantage of using single-pulley, double-pulley and multiple-pulley arrangements to lift a load a distance.

Materials
- 2 single pulleys
- 2 double pulleys
- 2 m length of cord or rope
- slotted 50 g masses
- spring balance (or force sensor)
- metre ruler
- wooden beam

Procedure
1 Use a spring balance or force sensor to record the weight of 500 g of slotted masses. Record this load force in a table like that shown on the next page.

2 Position the metre ruler or beam of wood across two benches or tables and set up the single pulley arrangement shown in Figure 8.3.20a on page 320.

3 Record the force required to raise the load a height of 20 cm.

4 Repeat steps 3 and 4 with the other two pulley arrangements shown in Figure 8.3.20.

Investigating pulleys continued on next page

Investigating pulleys continued

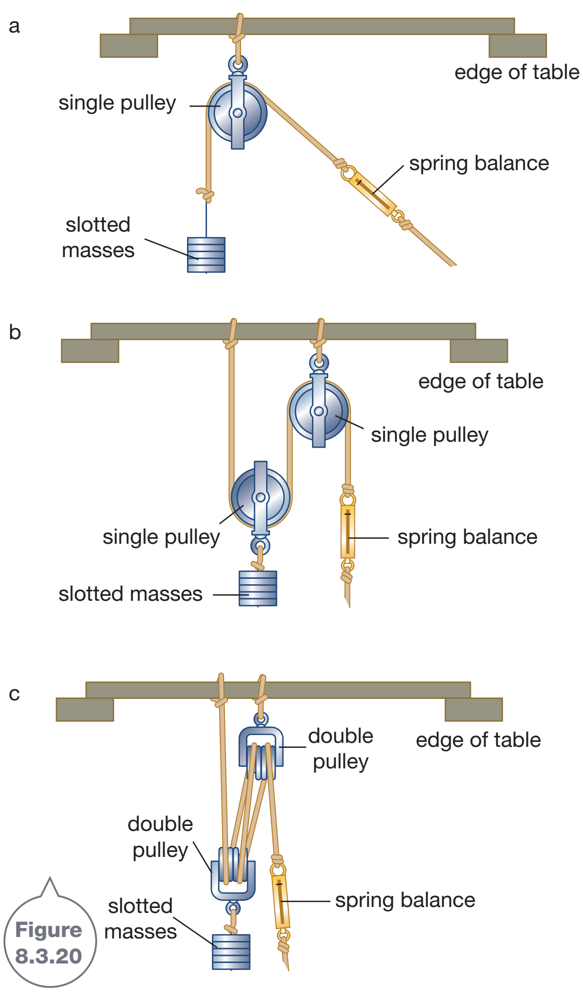


Figure 8.3.20

Results

Copy the results table below and complete this as you work through the experiment.

Arrangement	Number of pulleys used	Load force (N)	Effort force to raise load 20 cm (N)	Mechanical advantage $\left(\frac{\text{load}}{\text{effort}}\right)$
Single pulley	1			
Two single pulleys	2			
Two double pulleys	4			

Discussion

1 **Describe** how the effort required to lift the 500 g mass changed as more pulleys were used.

2 **Compare** the mechanical advantage gained in using four pulleys to that of a single pulley.

3 **Describe** how the lengths of rope pulled through the pulleys varied in each arrangement.

4 **Explain** how a multiple-pulley system can provide a force advantage.

5 **Explain** how friction affects the efficiency of a pulley system.

3 Investigating a geared machine

Purpose

To examine the gear arrangement of a household machine.

Materials

- hand drill
- eggbeater
- corkscrew
- adjustable spanner, flour sifter or any geared machine

Procedure

Examine how your machine operates.

Results

1 Draw a diagram of the machine. Label any examples of rack and pinion gears, bevel gears, worm gears, wheel and axles, screws, levers and wedges.

2 Label the driving gear and a driven gear on your diagram.

3 Show the direction of rotation of each.

4 Compare the number of turns made by the driving gear and the driven gear.

Discussion

1 **Identify** whether the gear combination in your machine is used as a force or a speed multiplier.

2 **Explain** how this occurs, by **comparing** the rotation of the driving and driven gears.

4 Investigating bicycles

Purpose

To examine the gearing combinations of a bicycle.

Materials

- geared bicycle
- broom handle
- piece of chalk

SAFETY

Keep fingers clear of moving spokes on the wheel at all times.

Procedure

1. Copy the table from the Results section.
2. Lift the rear of the bicycle off the ground and support it against two stools or benches as shown in Figure 8.3.21.

Figure 8.3.21

3. Select the first gear, so that the chain wheel is on the smallest sprocket and the rear sprocket is on the largest.
4. Make a mark with chalk on the rear tyre. Slowly turn the pedals one revolution and count how many revolutions the rear wheel makes in this time.
5. Record this data in the first row of your table.
6. Count the number of teeth on the front and rear sprockets and enter this data.
7. Repeat steps 3–6 for another four gear combinations.

Results

Copy and complete the following table.

Combination number	Number of turns of rear wheel for one turn of pedals	Number of teeth on chain wheel sprocket (N_1)	Number of teeth on rear wheel sprocket (N_2)	Gear ratio $\frac{N_1}{N_2}$
1				
2				
3				
4				
5				

Discussion

1. **Identify** which gear combination is best suited to riding uphill. **Justify** your choice.
2. **Identify** which gear combination is best suited to riding along a flat, easy road. **Justify** your choice.

8 Chapter review

Remembering

1 **Name** the simple machine that is a double inclined plane.

2 **State** the formula used to calculate the mechanical advantage of a lever, given the size of the load force and the effort supplied.

3 a **State** the class of lever acting in each situation shown in Figure 8.4.1.

b **Specify** which act as force multipliers, and which act as speed multipliers.

Figure 8.4.1

Understanding

4 Carefully read the following statements and **modify** any that are false to make them true.

a A steeper ramp provides a greater mechanical advantage than a ramp with a gentle slope.

b A pair of tongs acts as a first-class lever.

c Two interconnected gears rotate in the same direction.

d When a driving gear is smaller than the driven gear, the driven gear rotates faster than the driving gear.

5 **Explain** what is meant by the term *mechanical advantage*.

6 **Explain** how it is possible for two people to ride their bikes next to each other, one pedalling much faster than the other, but both travelling at the same speed.

Applying

7 **Use** Figure 8.4.2 to explain how using the handle of a tap increases the size of the force you apply to its spindle.

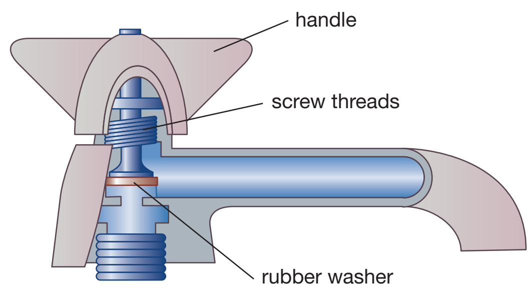


Figure 8.4.2

8 **Calculate** the size of the mechanical advantage of each of the following lever systems.

a A wheelbarrow has an effort arm of length 1.5 m and a load arm of 0.5 m.

b A crowbar used to shift an old fence. The effort arm is 1.2 m and the load arm is 5 cm (0.05 m).

9 While riding a bike, an effort force is applied to a chain-wheel cog with 25 teeth, which is connected to a rear-wheel cog with 75 teeth.

a **Calculate** the gear ratio of this arrangement.

b **Identify** whether this arrangement acts to multiply force or speed.

Analysing

10 **Calculate** where a 25-gram mass should be positioned on each see-saw shown in Figure 8.4.3 so that they will balance.

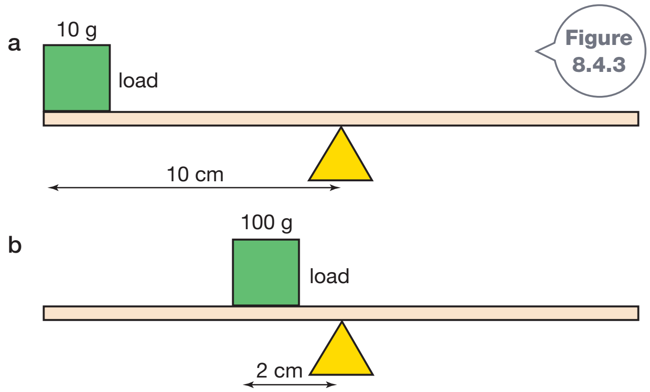


Figure 8.4.3

11 **Analyse** the combination of gears shown in Figure 8.4.4.

- **a** If gear 1 turns in a clockwise direction, then state which direction gears 2, 3 and 4 will turn.
- **b** If axle 2 is rotated, then identify whether gear 1 or gear 3 will turn faster.

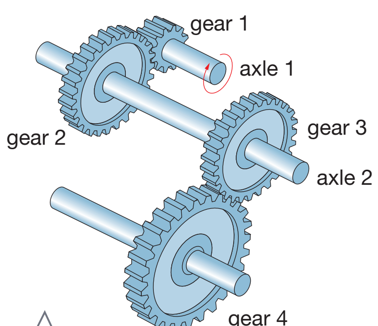


Figure 8.4.4

12 Figure 8.4.5 shows the pulley system of a lathe. The electric motor is driven at a constant rate. The rate of the drive shaft is then determined by changing the selection of the belt onto different pulley wheels. **Analyse** Figure 8.4.5 to answer the following questions.

- **a** When the belt is positioned as shown in the diagram, **state** which will turn faster—the motor or the drive shaft.
- **b** **Explain** what would happen to this turning rate if the belt was moved to the Z and 3 position.

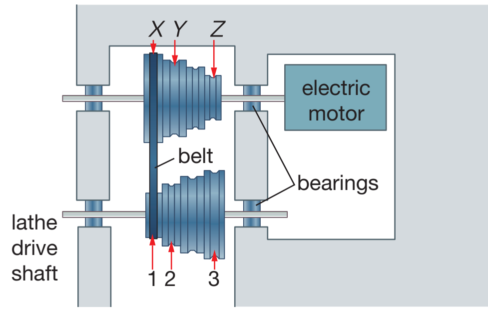


Figure 8.4.5

Evaluating

13 Robots are currently being used in the following situations. **Propose** why they are used in each case.

- **a** To weld car bodies together
- **b** To test suspicious packages at airports.

14 An effort force of 400 N is used to raise a load using a single pulley.

- **a** **Calculate** the effort force that would be required to lift this load using a system of five pulleys.
- **b** If this was performed, the actual effort required will be greater than the amount you have calculated. **Propose** reasons to explain this.

15 Tien pushes a toy helicopter across the floor. As its wheels rotate, a propeller spins faster. **Predict** whether the driving gear is larger or smaller than the driven gear, giving reasons for your answer.

Creating

16 **Use** the following ten key words to **construct** a visual summary of the information presented in this chapter.

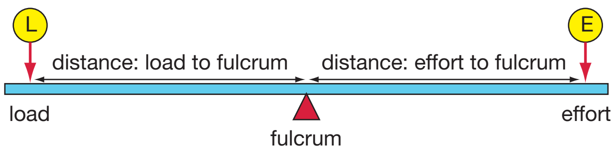
simple machine
load
effort
mechanical advantage
force multiplier
speed multiplier
lever
inclined plane
wheel
gear

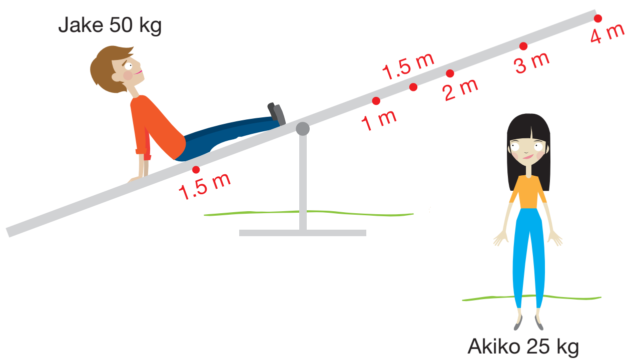
8.9

Thinking scientifically

Q1 A see-saw is a lever that pivots about a central point called the fulcrum. An effort, E, applied some distance from the fulcrum can be used to lift a load, L, positioned on the other side of the fulcrum. The principle of levers is a rule that holds for a see-saw. This states that:

Load × distance from load to fulcrum = effort × distance from effort to fulcrum





Jake has a mass of 50 kg and sits 1.5 m from the fulcrum of a see-saw. Akiko has a mass of 25 kg. To balance the see-saw, she should sit on the opposite side to Jake and:

A 1 m from the fulcrum
B 1.5 m from the fulcrum
C 2 m from the fulcrum
D 3 m from the fulcrum.

Q2 A gear train is a set of interconnected gears.

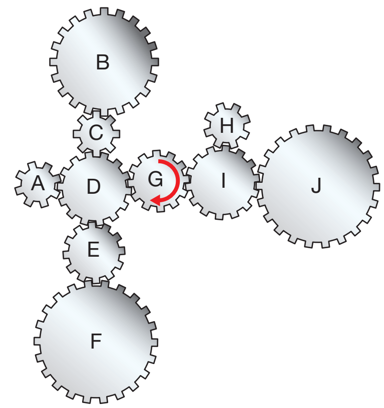
A driving gear supplies a force to turn another gear, called the driven gear.

A driven gear turns in the opposite direction to the driving gear.

If the driven gear is smaller than the driving gear, then it will turn faster than the driving gear.

If the driven gear is larger than the driving gear, then it will turn more slowly than the driving gear.

Study the diagram showing a gear train in a children's play area.

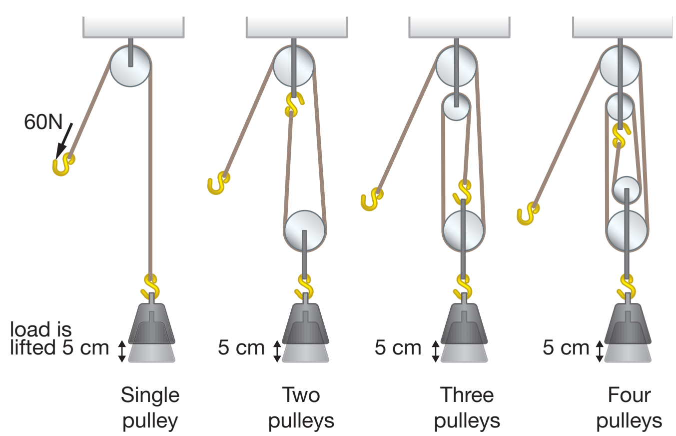


A child turns gear G in a clockwise direction. The gear/s that turn clockwise and more slowly than G are:

A A, C and H
B J
C B, D, F and I
D E

Q3 A pulley can be used to lift a load. Increasing the number of pulleys increases the mechanical advantage, making the load easier to lift. If four pulleys are used to lift a load, then only one-quarter of the force is needed compared to using a single pulley, but the cable must be pulled four times the distance.

A 60 N mass is lifted 5 cm by a single pulley, then by two, three and four pulleys as shown.



The correctly ordered force needed to lift the load and the length of cable that is pulled when using the two-, three- and four-pulley systems are:

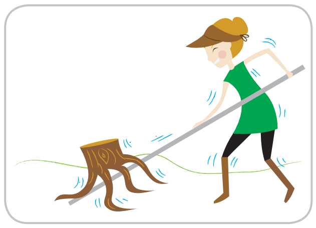
A 15 N, 20 N, 30 N; 10 cm, 15 cm, 20 cm
B 30 N, 20 N, 15 N; 20 cm, 15 cm, 10 cm
C 30 N, 20 N, 15 N; 10 cm, 15 cm, 20 cm
D 15 N, 20 N, 30 N; 20 cm, 15 cm, 10 cm

Glossary

Unit 8.1

Effort: force applied to a lever to overcome the load

First-class lever: lever with effort and loads located at each end, and fulcrum in the centre



First-class lever

Force multiplier: machine that increases the force applied for a task, such as a first-class lever

Fulcrum: point about which a lever pivots

Lever: simple machine consisting of a rigid rod that pivots about a point

Load: force that a lever is used to overcome

Mechanical advantage: ratio of a load force to the effort force used by a machine

Second-class lever: lever with the fulcrum located at one end, the effort at the other and load in the centre

Simple machine: a device that makes work easier by changing the size or direction of a force

Second-class lever

Speed multiplier: machine that requires a small movement of an effort to produce a large movement of a load, such as a third-class lever

Third-class lever: lever with the fulcrum located at one end, with the load at the other and effort in the centre

Third-class lever

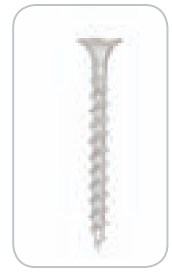
Unit 8.2

Inclined plane: a simple machine that reduces the effort needed to lift a load by increasing the distance it acts

Pitch: distance between adjacent threads on a screw

Ramp: an inclined plane used to help lift an object

Screw: a spiral-shaped inclined plane



Screw

Wedge: a double inclined plane, such as a knife or an axe

Wedge

Unit 8.3

Axle: shaft on which a wheel rotates

Block and tackle: a system of two or more pulleys using rope or cable to lift heavy objects

Driven gear: the gear that receives force from a driving gear

Driving gear: the gear that supplies force to another gear

Gear ratio: ratio of the number of teeth on the driving gear and the number of teeth on a driven gear

Gear train: a system of interconnected gears

Gears: a wheel with teeth used to turn another gear wheel

Pulley: a wheel with a groove over which a rope or cable can slide, used to change the direction of a force

Rim: outer edge of a wheel

Sprocket: a toothed wheel used to link onto a chain on a bicycle

Wheel: type of a lever with an axle acting as its fulcrum

9 Earth in space

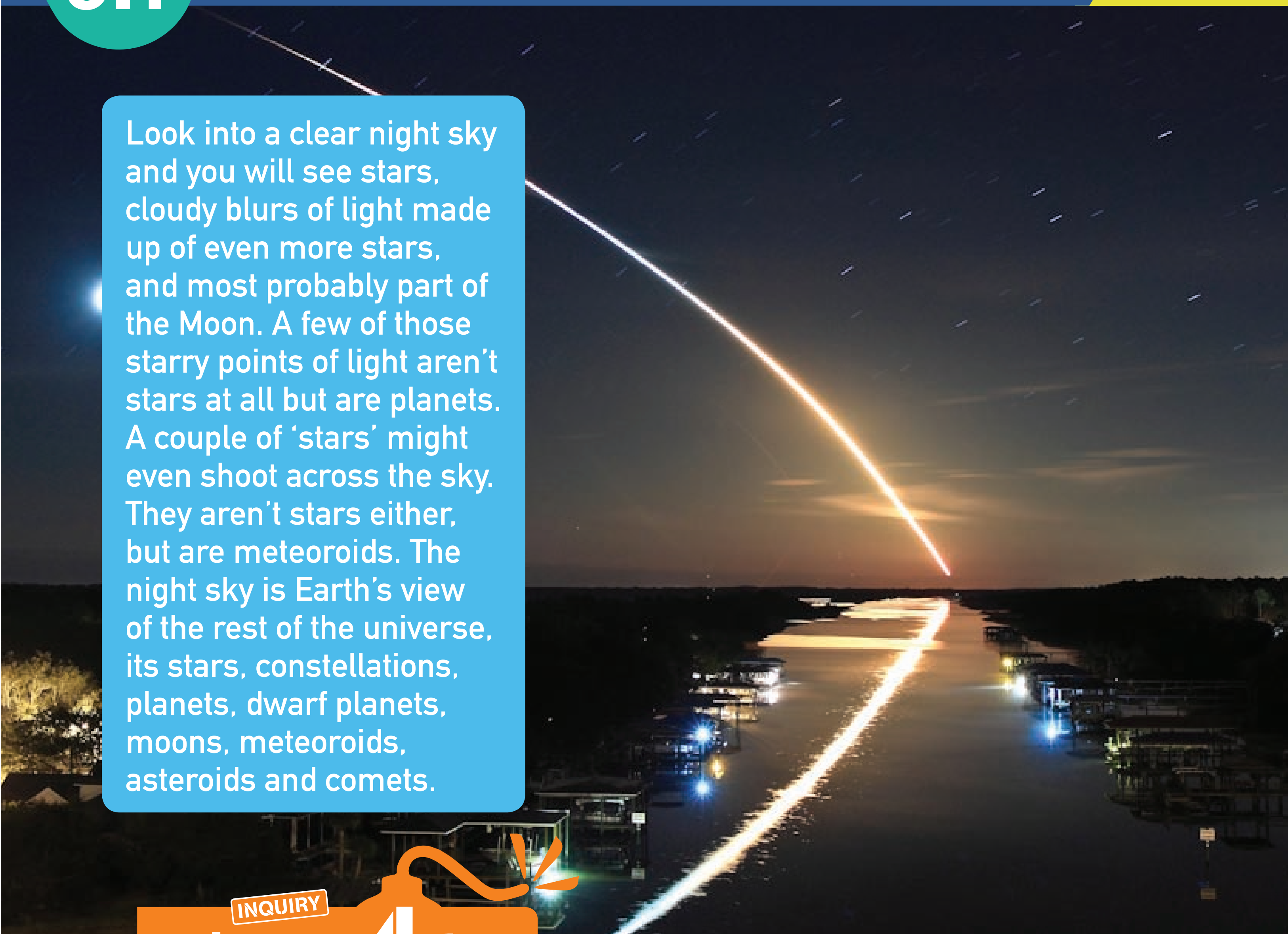
HAVE YOU EVER WONDERED...

- why the Sun rises in the east and sets in the west?
- why we have seasons?
- why sometimes there is a full Moon and other times none at all?

After completing this chapter students should be able to:

- explain lunar and solar eclipses, seasons and phases of the Moon
- compare times for the rotations and orbits of the Earth, Sun and Moon
- model the relative movements of the Earth, Sun and Moon
- explain why different regions of the Earth experience different seasonal conditions
- explain how gravity keeps planets in orbit around the Sun
- outline how advances in telescopes and space probes have provided new evidence about space
- research the development of different models of the solar system
- research developments in the understanding of astronomy.

9.1 The night sky



Look into a clear night sky and you will see stars, cloudy blurs of light made up of even more stars, and most probably part of the Moon. A few of those starry points of light aren't stars at all but are planets. A couple of 'stars' might even shoot across the sky. They aren't stars either, but are meteoroids. The night sky is Earth's view of the rest of the universe, its stars, constellations, planets, dwarf planets, moons, meteoroids, asteroids and comets.

INQUIRY science 4 fun

Skywatch

Yes

Collect this …

- sky map (from Activity Book 9.1 or similar)
- binoculars (if available)

Do this …

1. Wait until the Sun has been down for at least half an hour.
2. Find a spot outside where you can see the sky and where there are as few street and house lights as possible.
3. Face south and try to find the Southern Cross and the pointers. The Cross may be upside down or lying in an unusual orientation.
4. If the Moon is in the sky, observe it (using binoculars if possible).
5. Use a sky map to identify a number of constellations.

Record this …

Describe what you saw.
Explain what you think caused each of the features you saw.

Observing the night sky

Although most people can see about 2000 stars in the night sky with the naked eye, the exact number depends on the weather, how close you are to the bright lights of a city, and whether or not the Moon is in the sky.

Not all those bright points of light are the same: some have different colours, some are much brighter or much dimmer than others and some move at different speeds. If you use a telescope, then some of these differences become even more apparent. These visible differences arise because not every point of light in the night sky is a real star. While most points of light are stars, a handful are planets, and a few might be meteors or comets.

Stars

Stars are massive burning balls of hydrogen gas. Hydrogen is explosive but the light and heat that comes from stars is not from 'normal' hydrogen explosions. It comes from nuclear explosions instead! A nuclear reaction (called a fusion reaction) converts hydrogen into helium, releasing untold amounts of energy as heat, light and radiation as it does so.

The nearest star to Earth is the Sun, being 'only' 150 million kilometres from us. At this distance, the light and heat from those nuclear explosions takes just over 8 minutes to reach us.

The Milky Way

A band of light runs across the night sky from one horizon to the other. In ancient times, people thought that this looked like a road made of milk. That's why it was named the **Milky Way**. You can see it in Figure 9.1.1. Scientists now know that this white band is the light from more than 200 billion stars. Most of these stars are too far away to be seen distinctly or individually from Earth, but their combined glow is one of the most spectacular features of the night sky.

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Starry, starry day

The stars are always there in the sky whether it's night or day. However, you can't see them in daylight because they can't compete with the intense brightness of the Sun.

Of the few thousand stars that can be made out distinctly, only a few are bright or significant enough to have been given their own names. Most stars are named as part of the **constellation** to which they belong.

Figure 9.1.1 The Milky Way. The light pollution caused by city buildings and street lighting means that many Australians have never seen this breathtaking sight in its full glory.

Constellations

A constellation is a group of stars that forms a recognisable pattern when viewed from Earth. The stars in Figure 9.1.2 show the Southern Cross, perhaps Australia's most recognisable constellation.

1 p334

Figure 9.1.2 The Southern Cross is a constellation that can only be seen from the southern hemisphere. It can therefore be seen from Australia, New Zealand and the countries of southern Africa and South America.

Different groups of people in different parts of the world have looked at the same stars and grouped them together in different ways to form patterns and pictures relevant to them and their culture. The most famous set of constellations in Western culture are the signs of the zodiac.

SKILL BUILDER

Finding south

Ancient navigators used the Southern Cross to find which direction is south. You can do this too, using two different methods. Both methods locate the position of the south celestial pole. This is the point in the night sky around which all the stars seem to rotate. Once this is located, a line is dropped to the horizon. Where it hits is directly south from where you are.

Method 1: Locate the south celestial pole by extending the main axis of the Southern Cross four times.

Method 2: Locate the south celestial pole by extending the main axis. Construct another line out from the middle of the pointers as shown in Figure 9.1.3. The south celestial pole is where the two lines meet.

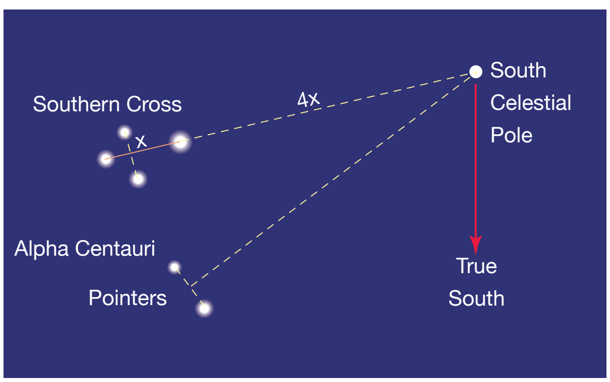

Figure 9.1.3 How to use the Southern Cross to find true south

The zodiac

The twelve constellations that make up the zodiac are considered special by many because they are the only constellations that the Sun appears to move through. These are the famous ‘star signs’ such as Leo, Scorpio and Sagittarius that are referred to in the astrology columns of newspapers or on the internet. Figure 9.1.4 shows the signs of the zodiac with the dates traditionally associated with them. These dates were originally assigned by the ancient astronomer Ptolemy to correspond to the time when the Sun appeared to move through each constellation.

9.1

9.2

20 January–18 February	Aquarius	♒
19 February–20 March	Pisces	♓
21 March–19 April	Aries	♈
20 April–20 May	Taurus	♉
21 May–20 June	Gemini	♊
21 June–22 July	Cancer	♋
23 July–22 August	Leo	♌
23 August–22 September	Virgo	♍
23 September–22 October	Libra	♎
23 October–21 November	Scorpio	♏
22 November–21 December	Sagittarius	♐
22 December–19 January	Capricorn	♑

Figure 9.1.4 The zodiac is made up of the 12 constellations through which the Sun appears to travel.

Astrology is the belief that the positions of the Sun, stars and planets affect a person’s personality and the day-to-day events of their life. There is no scientific or statistical evidence that suggests that is true. In contrast, **astronomy** is the scientific study of stars, planets and other objects seen in the night sky. In astronomy, as in other sciences, theories and models must be supported by evidence. If they are not the theories or models must be changed or discarded. This chapter is concerned with astronomy and not astrology.

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Change to the zodiac

The Sun’s apparent position has changed since Ptolemy invented the zodiac 2000 years ago. This means that the dates given in magazines no longer match the position of the Sun. For example, 29 October is said to fall in Scorpio. However, on that date the Sun is really in Libra!

SCIENCE AS A HUMAN ENDEAVOUR

Use and influence of science

Aboriginal constellations

This group of stars called Orion is easy to identify in the southern sky. Figure 9.1.5

When looking for patterns in the stars, people are naturally reminded of familar everyday objects. It is not surprising that people from different cultures with different lifestyles would identify different constellations. Also, different stars are visible from different parts of the Earth. For example, Polaris cannot be seen in Australia, despite being a very prominent star in the northern hemisphere. Likewise, the Southern Cross can only be seen in the southern hemisphere.

For example, consider the group of stars in Figure 9.1.5. The ancient Greeks called this group of stars Orion after a famous hunter from mythology. It's shown in Figure 9.1.6. The bright stars at the corners represent the hunter's hands and feet, the group of stars across the middle is his belt with a sword sticking out of it. The problem with this image for Australians is that it appears upside down when viewed from the southern hemisphere. Instead, many modern Australians call this constellation 'the saucepan'. Orion's sword is the handle of the saucepan, as shown in Figure 9.1.7. The Yolngu people of the Northern Territory know this group of stars as Djulpan or the canoe, shown in Figure 9.1.8. Here the sword/saucepan handle represents a fishing line trailing behind the canoe in the water.

Orion, the hunter Figure 9.1.6

Figure 9.1.7 The saucepan in Orion

Different cultural perspectives can also produce completely different ways of looking at the sky. The image in Figure 9.1.9 shows the Aboriginal emu-in-the-sky constellation. An unusual thing about this constellation is that it is seen by looking at the dark clouds of dust between the stars rather than at the stars themselves.

Figure 9.1.8 Djulpan, the canoe, in Orion

Figure 9.1.9 The emu-in-the-sky constellation and an engraving of it in Ku-ring-gai Chase National Park near Sydney. The constellation appears directly above the engraving as shown every autumn.

Planets

Planets are very different from stars. There are no nuclear explosions on the planets and so planets do not make their own light. Instead, they reflect light falling on them from the Sun. This allows us to see them in the night sky. They're seen as points of light that look very much like real stars.

As Figure 9.1.10 shows, Mercury, Venus, Earth and Mars are the closest planets to the Sun. These are known as the rocky planets or **terrestrial** (meaning Earth-like) planets. All these planets are rocky with a hard surface. Mercury, Venus and Mars are relatively close to Earth and are often seen in the night sky as a bright or coloured point of light. Mercury and Venus are usually visible before dawn as morning 'stars' or just after sunset as evening 'stars'. At these times, Venus is the brightest 'star' in the sky. Mars appears as a red-coloured 'star'.

The outer planets of Jupiter, Saturn, Uranus and Neptune are huge balls of gas with a small and rocky core. For this reason, they are commonly known as the **gas giants**. While Jupiter and Saturn can be seen as 'stars' with the naked eye, Neptune and Uranus can only be seen from Earth using a telescope.

Dwarf planets

Pluto was classified as a planet when discovered in 1930. However, it was an extremely odd one: it is very small, has a moon nearly the same size, and it travels around the Sun with an orbit that is in a different plane to the orbits of all the other planets.

In 2006, the International Astronomical Union (IAU) created a new category of dwarf planets. Like planets, **dwarf planets** are roughly spherical and travel around the Sun. Unlike 'normal' planets, dwarf planets don't have enough mass and have insufficient gravity to clear their neighbourhood of dust and rocks. For this reason, Pluto is now classified as a dwarf planet. Astronomers have since found a number of other dwarf planets (Haumea, Eris and Makemake). You can see them in Figure 9.1.11. They are located a little beyond Pluto in a region of icy rock fragments called the **Kuiper Belt**. Another dwarf planet is the asteroid Ceres, located between Mars and Jupiter.

2 p334

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Seeing stars?

Sometimes you will see a 'star' that is moving slowly across the sky. It's not a star or a planet—it is a large piece of space junk or a satellite reflecting sunlight. It may even be the International Space Station.

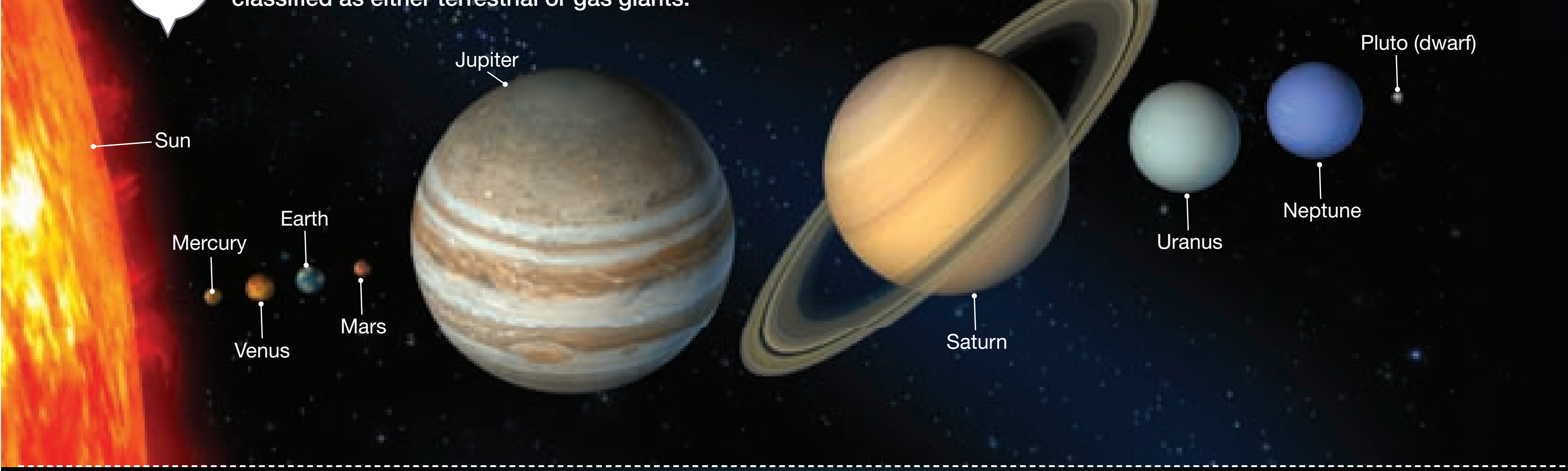


Figure 9.1.10 The eight planets of the solar system can be classified as either terrestrial or gas giants.

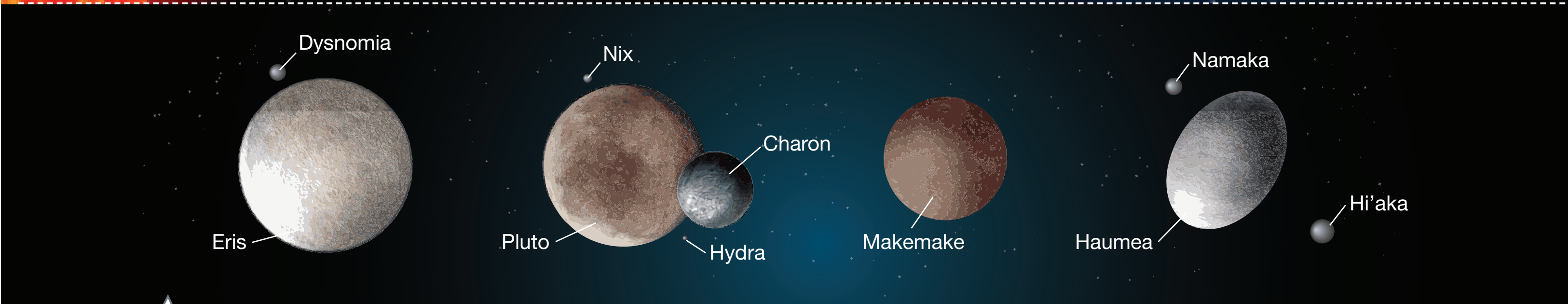


Figure 9.1.11 The Kuiper Belt contains a number of dwarf planets and similar-sized objects.

9.1 Unit review

Remembering

1 **Name** the type of nuclear reaction that powers stars.

2 a **Name** the nearest star to Earth.
b **State** how long it takes its light to reach Earth.

3 **Name** the bright band of light that can be seen in the night sky.

4 a **State** how many stars are visible to the naked eye.
b **List** factors that affect the number of stars able to be seen.

5 **Name** a star or constellation that can only be seen in:
a the southern hemisphere
b the northern hemisphere.

6 **List**:
a the rocky planets
b the gas giants
c the dwarf planets.

7 You see many bright points of light in the night sky. **List** the different types of things they could be, from most likely to least likely.

Understanding

8 **Explain** why planets are sometimes mistaken for stars.

9 **Explain** why Pluto is no longer considered a planet.

Analysing

10 **Contrast**:
a a planet with a star
b astronomy with astrology.

Evaluating

11 Three constellations based on the same group of stars are shown in Figures 9.1.6, 9.1.7 and 9.1.8 on pages 330 and 331.
a **Assess** which best fits the pattern of stars.
b **Justify** your answer.

12 It would be easy for astronauts to move about on the surface of Mars but it would be impossible for them on Jupiter. **Propose** reasons why.

Creating

13 **Construct** a diagram showing how true south can be located using the Southern Cross.

14 **Construct** a letter or email to the editor of your newspaper in which you propose some ways in which people living in your nearest capital city can reduce light pollution to create better conditions for amateur astronomy.

15 **Construct** and **name** a new constellation that would fit the star pattern shown in Figure 9.1.12.

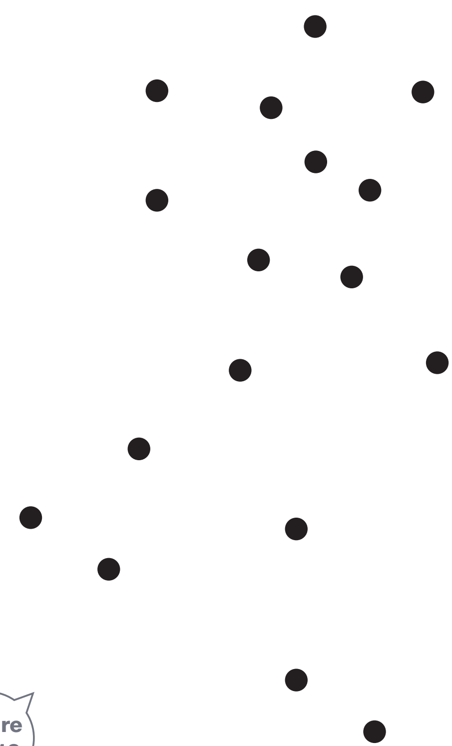


Figure 9.1.12

Inquiring

Research the constellations recognised by different cultural groups living in your local area.

9.1 Practical activities

1 Seeing constellations

Purpose

To use simulation software to observe constellations.

Materials

- computer
- a planetarium program such as SkyGlobe, Stellarium, Celestia or WorldWide Telescope. These can usually be downloaded as freeware or accessed online.

Procedure

1. Set the program to show the sky as it will appear at 8 pm tonight from your home town.
2. Most programs will have a function that superimposes constellations over the pattern of stars. Switch this on.
3. Choose a constellation. Sketch it.
4. Switch the constellation function off. Sketch the stars that make up the constellation. Use different-sized dots to represent the relative brightness of the stars.
5. Repeat steps 2–4 for another three constellations.
6. Tonight, try to find these constellations in the night sky.

Discussion

1. **Describe** how difficult it was to find the real constellations in the night sky.
2. **List** the factors that make it difficult for you to see constellations in the sky clearly.

2 Visiting dwarf planets

Purpose

To use simulation software to observe a number of dwarf planets.

Materials

- computer
- a planetarium program such as SkyGlobe, Celestia or WorldWide Telescope

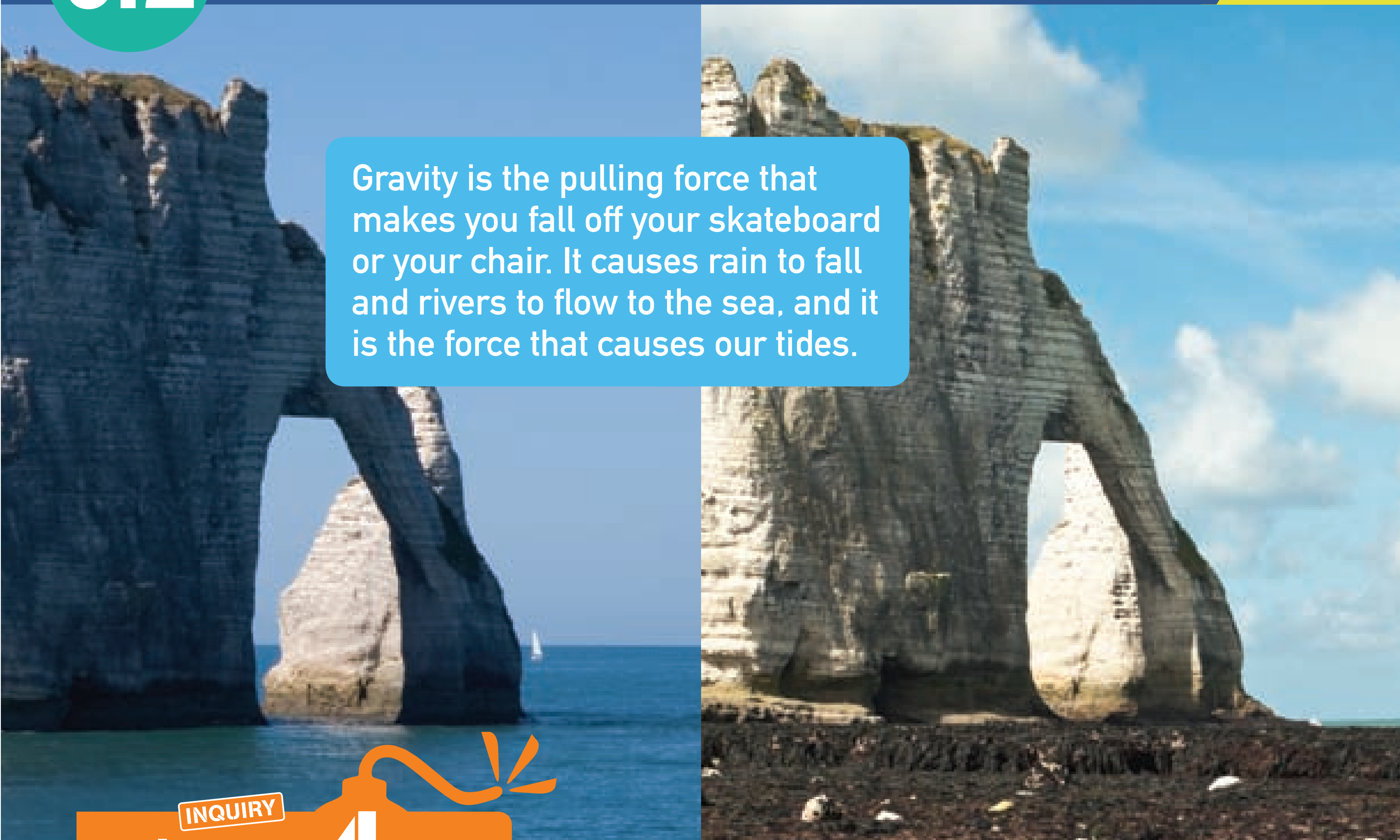
Procedure

1. Set the program to show the sky as it will appear at 8 pm tonight from your home town.
2. Search for Ceres.
3. Zoom in until the image of the dwarf planet fills the screen. Sketch it.
4. Zoom out to identify and sketch any moons orbiting the dwarf planet.
5. Repeat steps 2–4 for other dwarf planets, such as Pluto, Eris, Makemake, Haumea.

Discussion

1. **List** the three characteristics of a planet.
2. Dwarf planets lack one of those characteristics. **Describe** the feature that most lack.

9.2 Gravity, tides and orbits



Gravity is the pulling force that makes you fall off your skateboard or your chair. It causes rain to fall and rivers to flow to the sea, and it is the force that causes our tides.

INQUIRY

science 4 fun

Drawing ellipses

Can you draw an accurate ellipse?

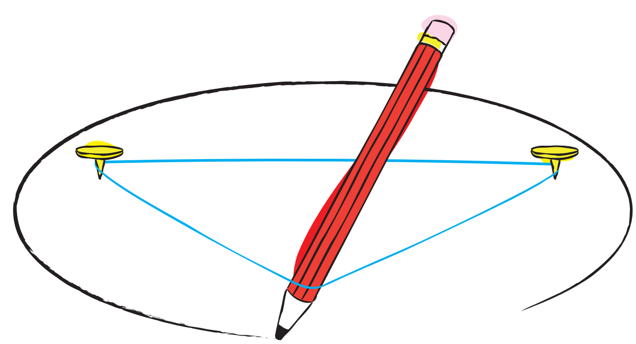
Yes

Collect this …

- 2 pins
- sheet of cardboard or thick pad of papers (such as your workbook)
- length of string or cotton
- pencil or felt-tip pen

Do this …

1. Stick the pins well apart into the cardboard or pad of papers.
2. Tie the string or cotton into a loop so that it fits loosely over the two pins.
3. Use the pencil or felt-tip pen to stretch the loop out.
4. Keeping the loop tight, ‘orbit’ the pins with the pencil or pen, drawing as you go.



Record this …

Describe what happened.
Explain how this relates to the shape of orbits.

Gravity

While some forces make contact with the objects that they push or pull around, other forces act without touching. These **non-contact forces** act instead through **force fields**. As Figure 9.2.1 shows, magnets have magnetic force fields around them that attract objects containing iron and create pushes and pulls around other magnets.

Figure 9.2.1 Iron filings align (line up) with the field lines around a magnet, showing the direction and strength of its magnetic field.

Gravitational fields

Around every mass is a **gravitational force field** that attracts other masses. This attractive force is **gravity**, and it attempts to pull masses together. Matter is the stuff that everything is made up of, and matter has **mass**. You have mass, as does the person who is sitting next to you, the chair you are sitting on, and the pen you are writing with. They all have their own gravitational fields, and all of them are attracting each other. This force of gravity and its attraction is most obvious when you fall off your chair! The force of gravity between you and Earth is commonly called weight.

The effect of mass

Gravity is a force caused by mass. The bigger the mass, the stronger its gravitational field and the more it attracts other masses nearby. However, gravity is a very weak force, and a lot of mass is required before any attraction is noticeable: people, pens, chairs, and even cars, buildings and ships, are not massive enough to have much effect on other masses. This is why you don't get pulled towards the person sitting next to you or even a large skyscraper that you are walking past. Gravity is only noticeable when one of the objects is really massive, such as a planet, moon or star. These objects have strong gravitational fields around them that attract anything else that is nearby, including you. Earth has a gravitational field like that shown in Figure 9.2.2.

Figure 9.2.2 Fields lines are used to show the direction of a gravitational field around an object. Masses 'fall' in the direction of these field lines, which point towards the centre of the moon, star or planet.

1 p344

The effect of distance

The gravitational fields around planets, moons or stars rapidly get weaker as you move away from them. For example, Earth's gravitational field is a little weaker on the top of Mt Everest, its highest mountain, than at sea level. However, the difference is too small for you to notice and can only be detected by extremely sensitive instruments. By the time you get to the Moon, Earth's pull is weak and far lower than at Earth's surface.

Tides

The Moon is the closest big mass to Earth. Its gravitational pull drags all the water in the oceans and seas towards it, causing a bulge on the side of Earth that faces the Moon. As Earth rotates this bulge moves, so that it stays pointing towards the Moon. Another smaller bulge forms on the opposite side of Earth. The Sun also draws water towards it and changes the size of this bulge as it moves across Earth's surface. These moving bulges cause two high **tides** and two low tides per day as shown in Figure 9.2.3.

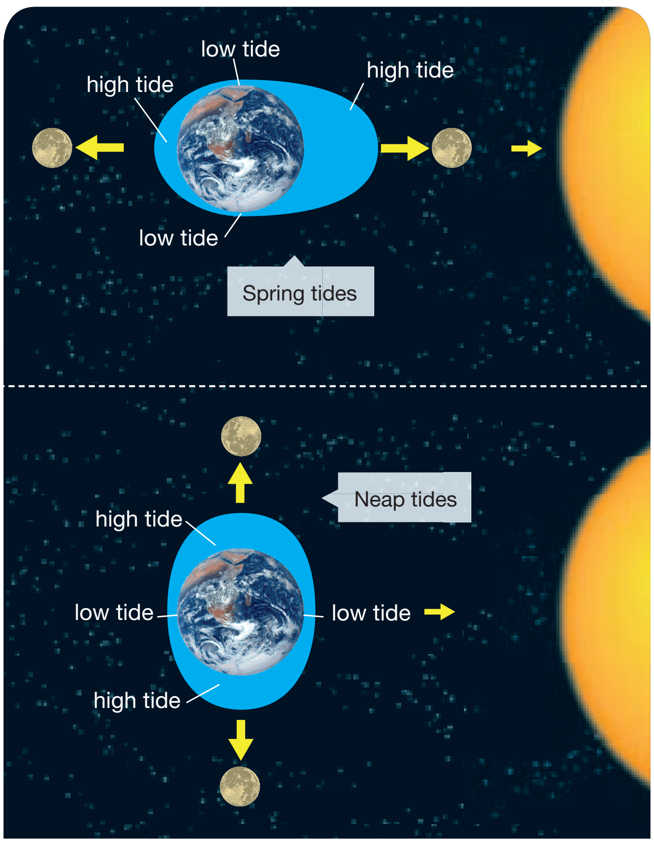


Figure 9.2.3 Spring tides are large because the gravitational pull of both the Moon and the Sun are in the same direction and the bulges from each add up. Neap tides are smaller because the Moon and Sun are pulling in different directions.

Orbits

The gravitational fields around planets, moons and stars are often strong enough to 'trap' other masses so that they travel continuously around them in a path known as an **orbit**. For example, Earth and the other planets of the solar system are 'trapped' by the gravitational field of the Sun and so they orbit it. Likewise, the Moon keeps orbiting Earth. This is shown in Figure 9.2.4. At least 63 moons orbit Jupiter, and millions of rock fragments, ice and dust form rings that orbit Saturn. You can see Saturn's rings in Figure 9.2.5.

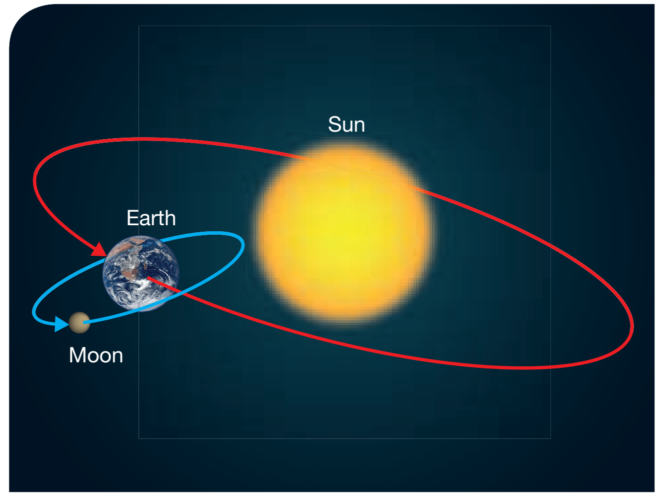


Figure 9.2.4 Earth orbits the Sun, and the Moon orbits Earth.

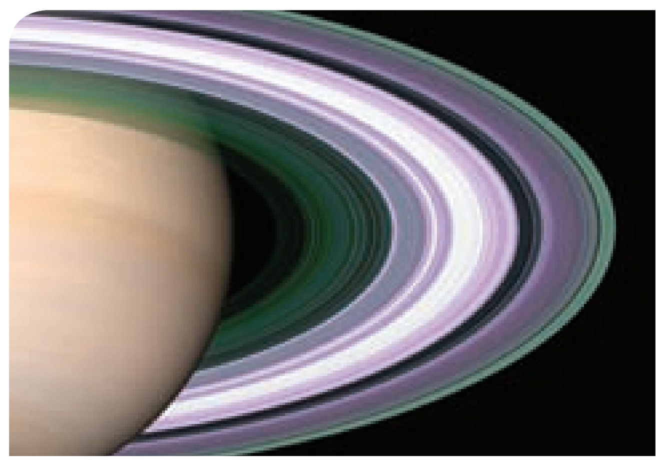


Figure 9.2.5 Fragments of rock, dust and ice orbit Saturn, forming a spectacular series of rings around the planet.

Objects that are in orbits like this are known as **satellites**. The planets of the solar system are **natural satellites** of the Sun, and the Moon is a natural satellite of Earth. Earth also has many **artificial satellites** orbiting it. Some are used to transmit information such as telephone and the internet, while others scan the Earth for everything from erosion and bushfires to espionage (spying). The largest artificial satellite in orbit around Earth is the **International Space Station** (ISS), shown in Figure 9.2.6 on page 338.

Figure 9.2.6 The International Space Station (ISS) is an artificial satellite orbiting Earth. It has a crew of six on board at all times.

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SciFile

Unstable orbits

If a satellite is travelling too slowly then it will slowly spiral in. This is what most artificial satellites eventually do. Likewise, if a satellite is travelling too fast then it will slowly spiral outwards. The Moon is doing this: it strays a tiny 3.8 cm away from Earth each year!

Orbit shapes

Orbits are elliptical in shape. **Ellipses** are oval-shaped closed loops, but some are almost circular. The orbit of the Moon around Earth, for example, is nearly circular, as are the orbits of Mercury, Venus, Earth and Mars around the Sun. Jupiter, Saturn, Uranus, Neptune and the dwarf planet Pluto have more oval-shaped ellipses as their orbits. Comets from deep space are sometimes trapped by the gravitational field of the Sun and sweep around it on long and thin elliptical orbits. Comets often orbit in a plane very different from that of the planets. A typical orbit of a comet is shown in Figure 9.2.7.

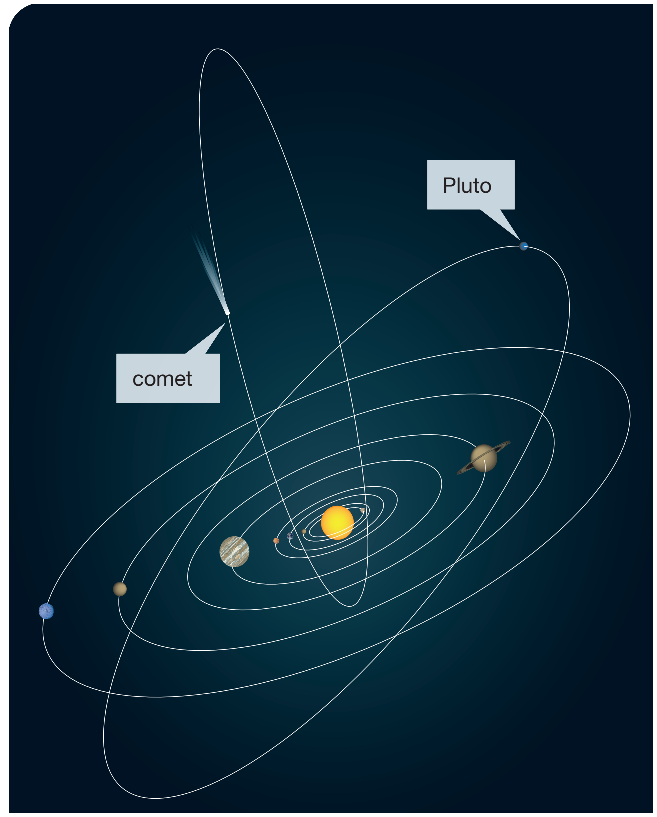


Figure 9.2.7 The dwarf planet Pluto orbits in a different plane to the rest of the solar system. Its long, thin elliptical orbit sometimes places Pluto closer to the Sun than Neptune. Comets usually orbit the Sun in a different plane too.

Explaining orbits

Imagine you are on the top of a tall mountain with a handful of tennis balls. Drop one and it will fall to your feet because gravity pulls it downwards. If you throw the ball horizontally, it still falls but it takes a curved path to the ground, landing at a distance away from you. Now imagine that you could throw the ball so fast that it kept on falling, never hitting the Earth. If you could do this then the ball would be in orbit. The ball will then keep 'falling' around Earth forever, needing no extra push or power to keep it orbiting. Figure 9.2.8 shows how. An orbit like this can only happen outside Earth's atmosphere because there is no air resistance and therefore nothing to slow the satellite down.

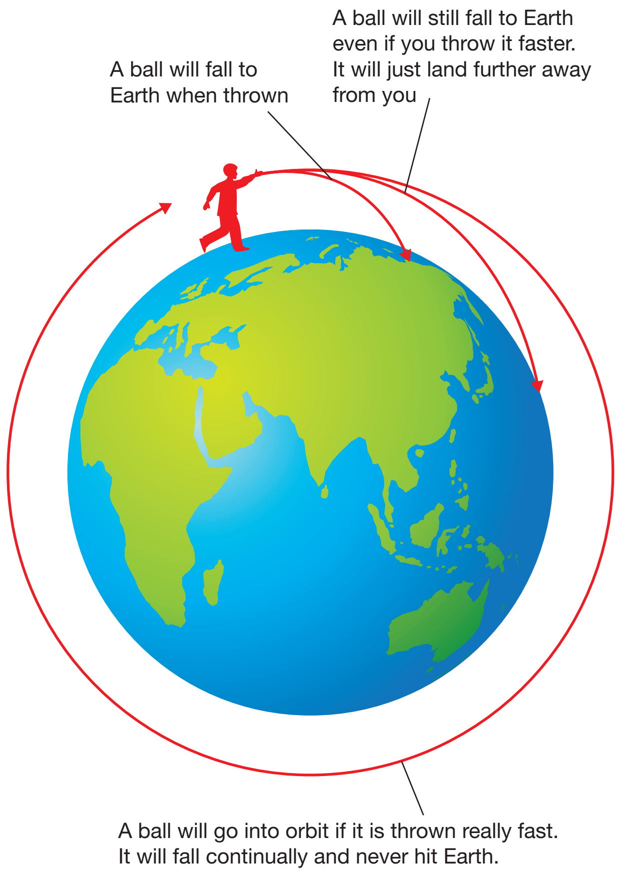


Figure 9.2.8 Throw an object slowly and it will land back on Earth. However, if you throw it from a high point and really fast, then it will continue to fall and keep missing the planet. The object will then be in orbit around Earth.

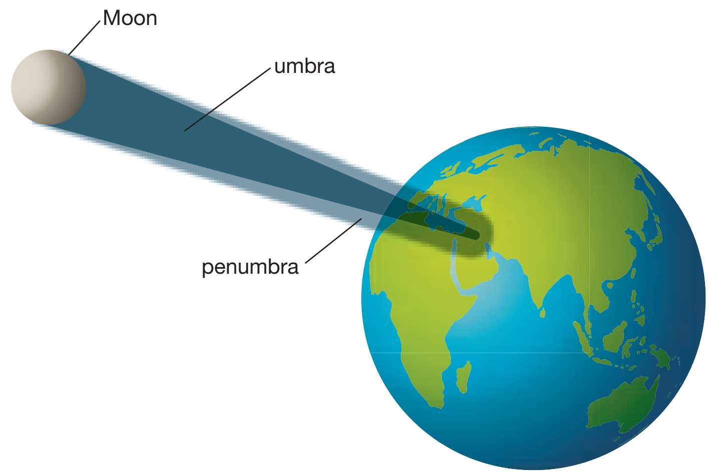


Figure 9.2.9 The Moon is too small to block light from the Sun over the entire Earth, and so its shadow falls on only part of Earth's surface. Only these parts experience a solar eclipse.

Eclipses

Sometimes the orbits of the Moon around Earth and Earth around the Sun cause all three bodies to align so that the Moon blocks sunlight from reaching Earth, or the Earth blocks sunlight from reaching the Moon. When this happens, as **eclipse** occurs.

Solar eclipses

A **solar eclipse** occurs whenever light from the Sun is blocked by the Moon, casting a shadow onto Earth like that shown in Figure 9.2.9. Whatever part of Earth's surface is in shadow is plunged into darkness until the Moon moves out of the way again. Figure 9.2.10 shows the view from Earth when it happens. Solar eclipses can be complete (in the **umbra**, where the shadow is full and dark) or partial (in the **penumbra**, where the shadow is less dense).

Figure 9.2.10 Astronomers use solar eclipses to view the corona or very outer layer of the Sun, and the solar flares that burst from it.

SciFile

A dragon ate the Moon!

The ancient Chinese and Vikings both thought that a lunar eclipse happened because the Moon was eaten: the Chinese thought a dragon did it, while the Vikings thought that a wolf ate it. Some American Indian tribes instead thought a bear was wandering throught the sky, fighting the Moon whenever it blocked the path.

Lunar eclipses

During a **lunar eclipse**, the Earth blocks light from reaching the Moon. As the Moon passes along its orbit, it first passes through the penumbra, causing a partial lunar eclipse. It then moves through the umbra, forming a total lunar eclipse, before moving back into the penumbra and then back into the sunlight. Figure 9.2.11 shows how this happens. You can see what the Moon looks like during a lunar eclipse in Figure 9.2.12.

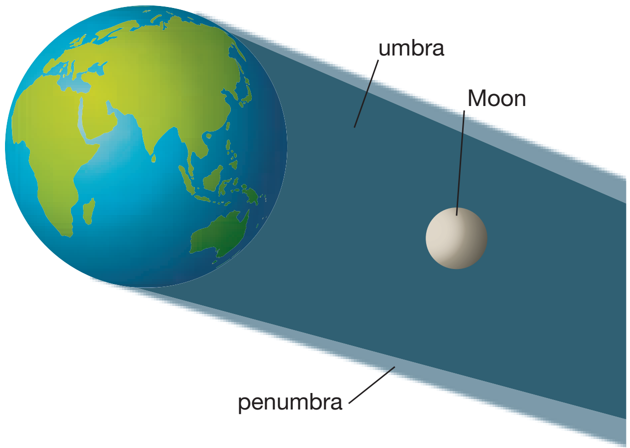


Figure 9.2.11 A lunar eclipse passes through different stages depending on what part of the Earth's shadow it is passing through.

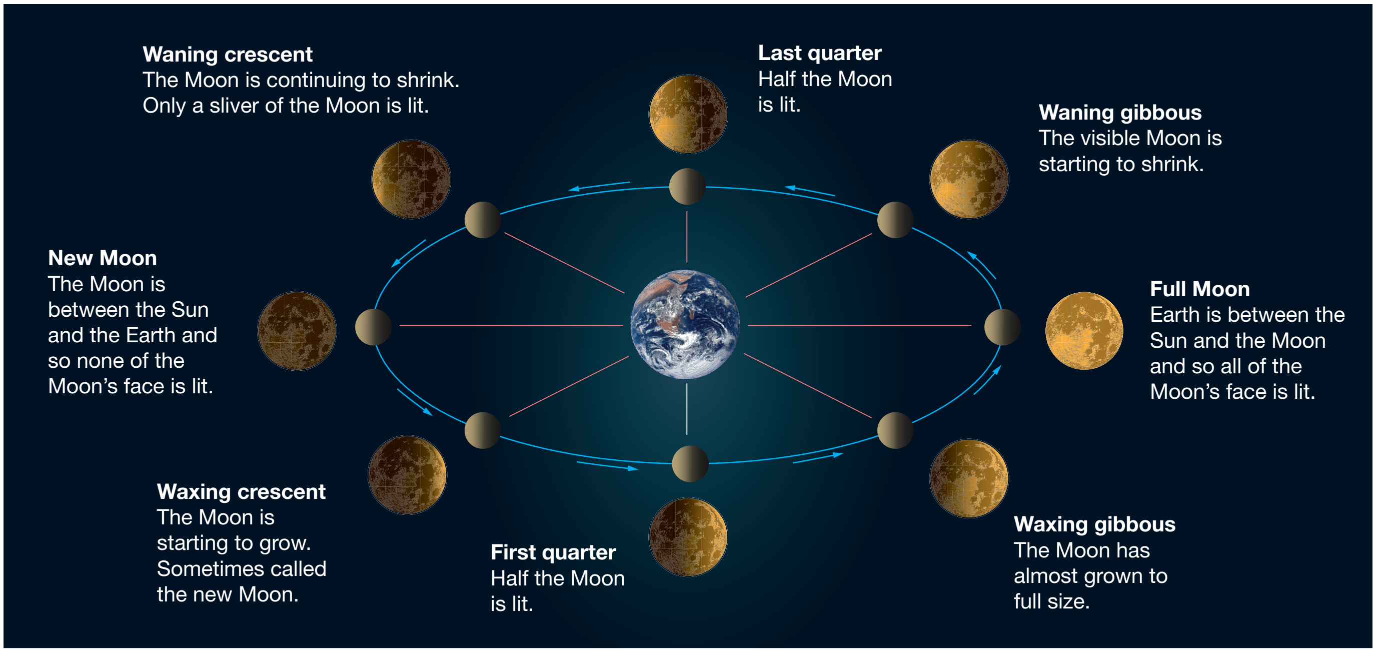
Figure 9.2.12 Five images of the Moon during a total lunar eclipse. The Moon does not disapper completely while it is in the umbra because it is lit by a little sunlight bent by Earth's atmosphere.

Phases of the Moon

Half of the Moon faces the Sun and is always bathed in sunlight (except during lunar eclipses). On Earth, however, we do not always see its full face. As Figure 9.2.13 shows, what we see depends on where the Moon is in its orbit and how much of the face is receiving light. The different shapes that we see are known as **phases** of the Moon.

9.5

Figure 9.2.13 The phases of the Moon depend on where it is in its orbit around Earth.



SCIENCE AS A HUMAN ENDEAVOUR

Nature and development of science

Changing ideas

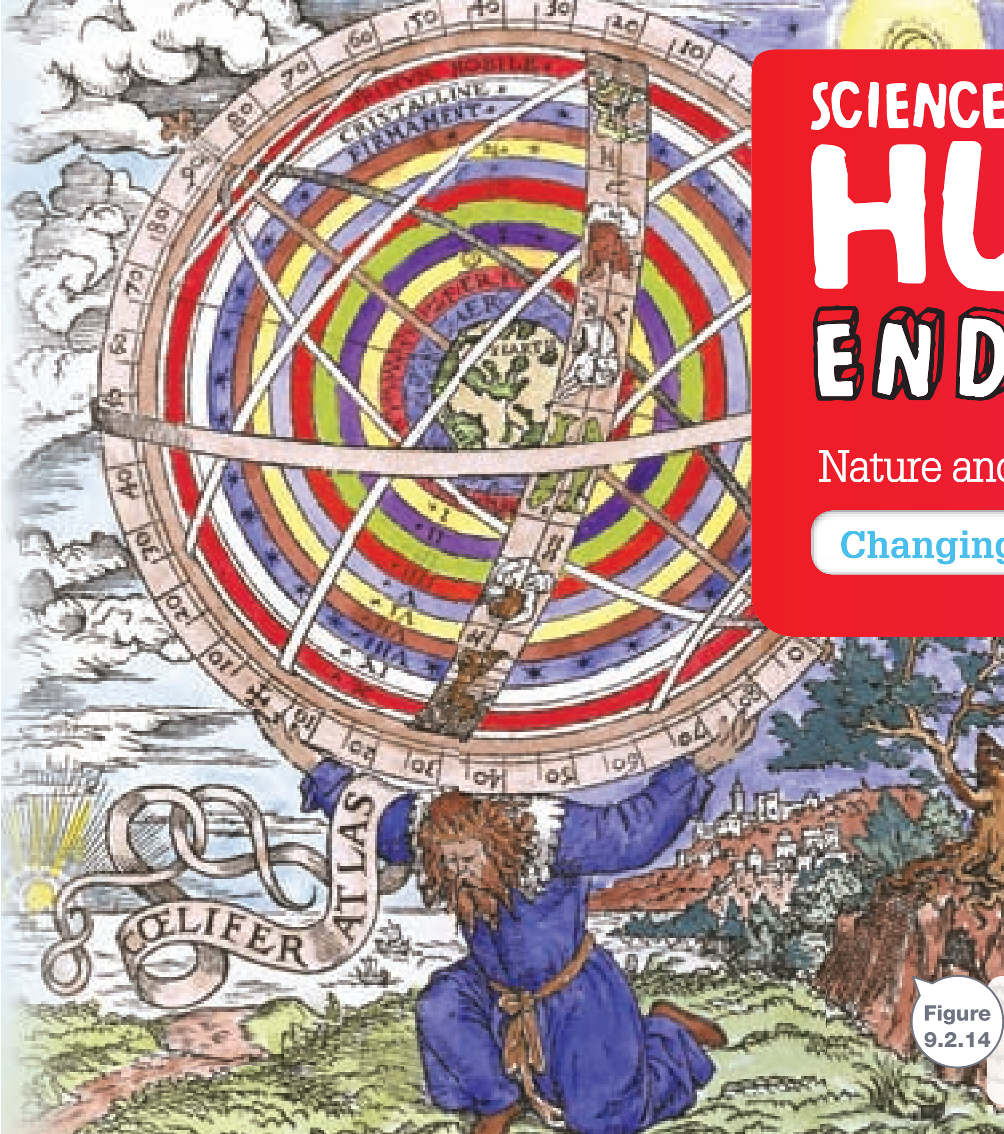


Figure 9.2.14 According to the ancient Greeks, Atlas was the god who carried the universe on his back.

The Sun rises in the east and sets in the west. Some ancient cultures thought that a new Sun was being 'born' each day, only to 'die' at sunset. Another explanation had the Sun moving around Earth. This suggested that Earth was the centre of the universe, with everything revolving around it.

The geocentric model

If Earth was the centre of the universe, then it was logical that everything else must travel around it in orbits. This way of thinking is known as the **geocentric model**, pictured in Figure 9.2.15. This model obeyed two of the most important characteristics of any scientific model or theory:

- it was simple
- it explained all the evidence available at the time.

Although the geocentric model made sense to the ancients, they observed that the planets sometimes seemed to turn around and move backwards! This strange looped motion is shown in Figure 9.2.16 on page 342 and is known as **retrograde motion**. The geocentric model could explain retrograde motion, but only if complex changes were made to it.

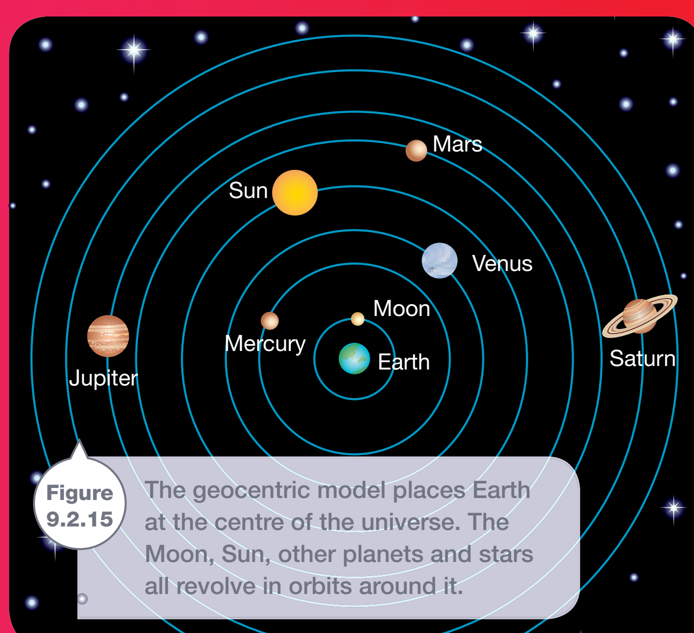


Figure 9.2.15 The geocentric model places Earth at the centre of the universe. The Moon, Sun, other planets and stars all revolve in orbits around it.

Heliocentric model

An alternative model was able to explain all available evidence more simply. This model has the Sun at the centre of the solar system and is known as the **heliocentric model**. The model is shown in Figure 9.2.17. The heliocentric model explained retrograde motion easily: although all the planets are revolving in the same direction, the planets all move at different speeds. This changes their relative positions in space and sometimes makes planets appear to move backwards!

Figure 9.2.16 When viewed over a couple of months, the motion of Mars seems to loop back on itself: it shows retrograde motion. Without complex changes, the geocentric model cannot explain this motion.

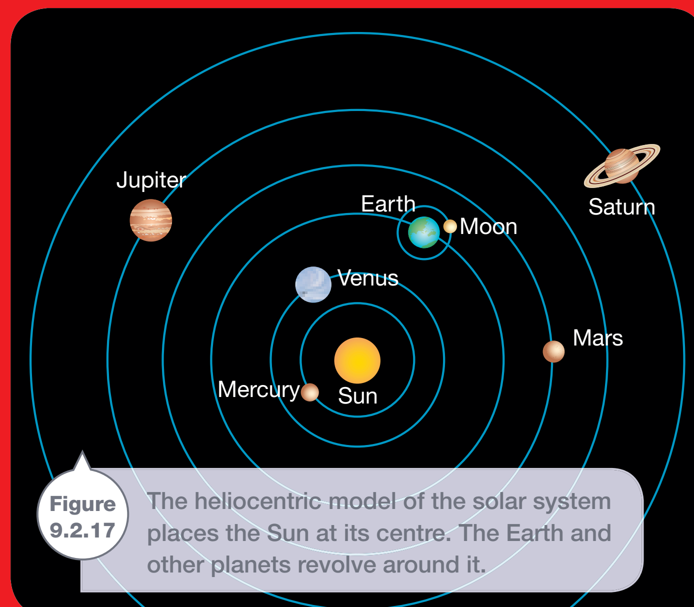


Figure 9.2.17 The heliocentric model of the solar system places the Sun at its centre. The Earth and other planets revolve around it.

Figure 9.2.18 An illustration from 1660 showing the heliocentric model with the Sun at its centre

9.2 Unit review

Remembering

1 **List** five things around you that are pulling you with a weak gravitational force.

2 **Name** one thing that is currently pulling you with a strong gravitational force.

3 **Name** one:
- a natural satellite of the Sun
- b natural satellite of Earth
- c artificial satellite of Earth.

4 **Recall** how gravity changes with distance by ranking the following from the place which would have the highest gravity to the place with the lowest gravity.
- A On top of Mt Kosciuszko (New South Wales), the tallest mountain in Australia (2228 m).
- B At the top of Q1 tower (Queensland), the tallest building in Australia (323 m)
- C On Bells Beach (Victoria) (sea level)
- D On the edge of the Lake Eyre (South Australia) (15 m below sea level).

5 **State** how many high tides and how many low tides will be experienced every day at the docks in Fremantle, Western Australia.

6 **Name** the model of the solar system that places at its centre:
- a the Sun
- b the Earth.

7 **List** the two most important characteristics of any scientific model.

Understanding

8 Give reasons to **explain** why you aren't pulled towards a wall despite there being a gravitational attraction between you and it.

9 The times for high and low tides differ around Australia. **Explain** why.

10 **Explain** what is different about the orbits of Pluto and comets around the Sun.

11 **Explain** why a satellite does not need to be powered to keep it in orbit.

12 **Explain** why the geocentric model was abandoned in favour of the heliocentric model.

Applying

13 **Identify** whether a neap or a spring tide produces greater changes in sea levels. Use a diagram to explain your answer.

14 **Use** a diagram to **explain** what retrograde motion is.

15 The painting on page 341 dates from 1160. It shows the ancient Greek god Atlas carrying the solar system on his back. **Identify** whether it shows the solar system as heliocentric or geocentric.

Analysing

16 **Contrast** a natural satellite and an artificial satellite.

Evaluating

17 Imagine that you shoot a gun horizontally off a tall mountain, the bullet going so fast that it goes into orbit around Earth. It could be extremely dangerous if you stay on top of the mountain. **Propose** why.

18 When half the Moon is visible, its phase is not called a half-moon but a quarter moon. **Propose** reasons why.

Inquiring

1 Research the following astronomers, classifying them as supporters of the geocentric model or the heliocentric model of the solar system:
- a Johannes Kepler
- b Heracleides
- c Pythagoras
- d Claudius Ptolemy
- e Nicolaus Copernicus
- f Galileo Galilei
- g Isaac Newton
- h Khayyan.

2 Search the internet to find and view:
- a simulations showing the orbits of the planets of the solar system
- b simulations showing the orbits of the Moon around Earth and Earth around the Sun
- c live vision on NASA TV from the International Space Station in orbit around Earth
- d animations showing how the heliocentric model explains retrograde motion.

9.2 Practical activities

1 Go jump!

Each planet in the solar system has a different mass and so gravity changes depending on which planet you are on. This means that you can jump different heights on different planets. This assumes that the surface is solid!

Purpose

To calculate how high you could jump on another planet.

Materials

- metre ruler or tape measure
- calculator

Procedure

1. Choose a safe and clear space, perhaps outside.
2. One of your laboratory partners needs to hold the metre ruler vertically, with the 'zero end' touching the ground.
3. Another needs to be crouched down, with their eyes level with the ruler.
4. Stand next to the ruler and jump as high as you can.
5. Your lab partner needs to measure the height your feet got to in the jump.
6. Repeat two more times and record your jump heights.

Results

1. Record all your jump heights in a table like the one shown above.
2. Calculate your average jump height by:
   - adding: Jump 1 + Jump 2 + Jump 3
   - dividing: by 3.
3. Calculate the height you could jump on the Moon and other planets by:
   - dividing: your average jump ÷ gravity.

Planet or moon	Gravity compared to Earth's (Earth = 1)	Predicted jump height (cm)
Earth	1	
Moon	0.16	
Mercury	0.38	
Venus	0.91	
Mars	0.38	
Jupiter	2.36	
Saturn	0.92	
Uranus	0.89	
Neptune	1.1	

Discussion

1. **Identify** the celestial body/bodies on which you could jump:
   a. the highest
   b. the lowest
   c. about the same as on Earth.
2. Astronauts on the Moon were able to jump higher than on Earth but not as high as you calculated above. **Propose** reasons why.
3. Find the world records for various athletics such as high jump and pole vault and **calculate** what they would be on the other planets.

2 Planetary orbits

Purpose

To construct a model of an orbit and to determine the effect of changing gravity.

Materials

- plastic casing of ball-point pen or short length of plastic or metal tubing
- string or strong cotton thread
- rubber bung with hole
- washers
- large open area

SAFETY

Make sure you have plenty of room.

Wear safety glasses at all times.

Procedure

1. Tie the string or cotton thread securely to the rubber bung by passing it through the hole a number of times and then knotting it tightly.
2. Pass the string or thread through the tubing and tie a couple of washers on the other end, as shown in Figure 9.2.19.
3. Find a place where there is plenty of room and swing the rubber bung horizontally around your head.
4. Swing it at a speed that keeps the washers away at a constant level below the tubing.
5. Add more washers and repeat.
6. Carefully observe what happens to the speed and radius of the 'orbit' as more washers are added.

Discussion

1. **Identify** which part of this model represents:
   a. a satellite in orbit
   b. the force of gravity
   c. the planet around which the satellite orbits.
2. **Describe** what happened to the speed and radius of the orbit when the gravitational pull of the planet was increased.

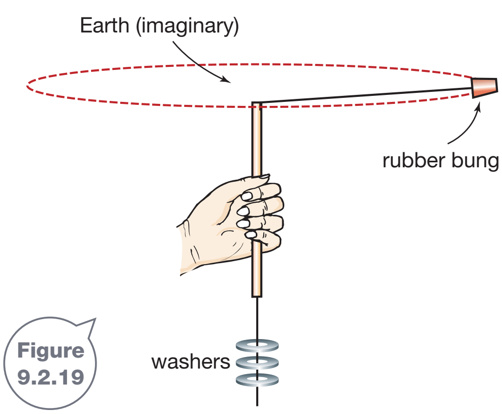
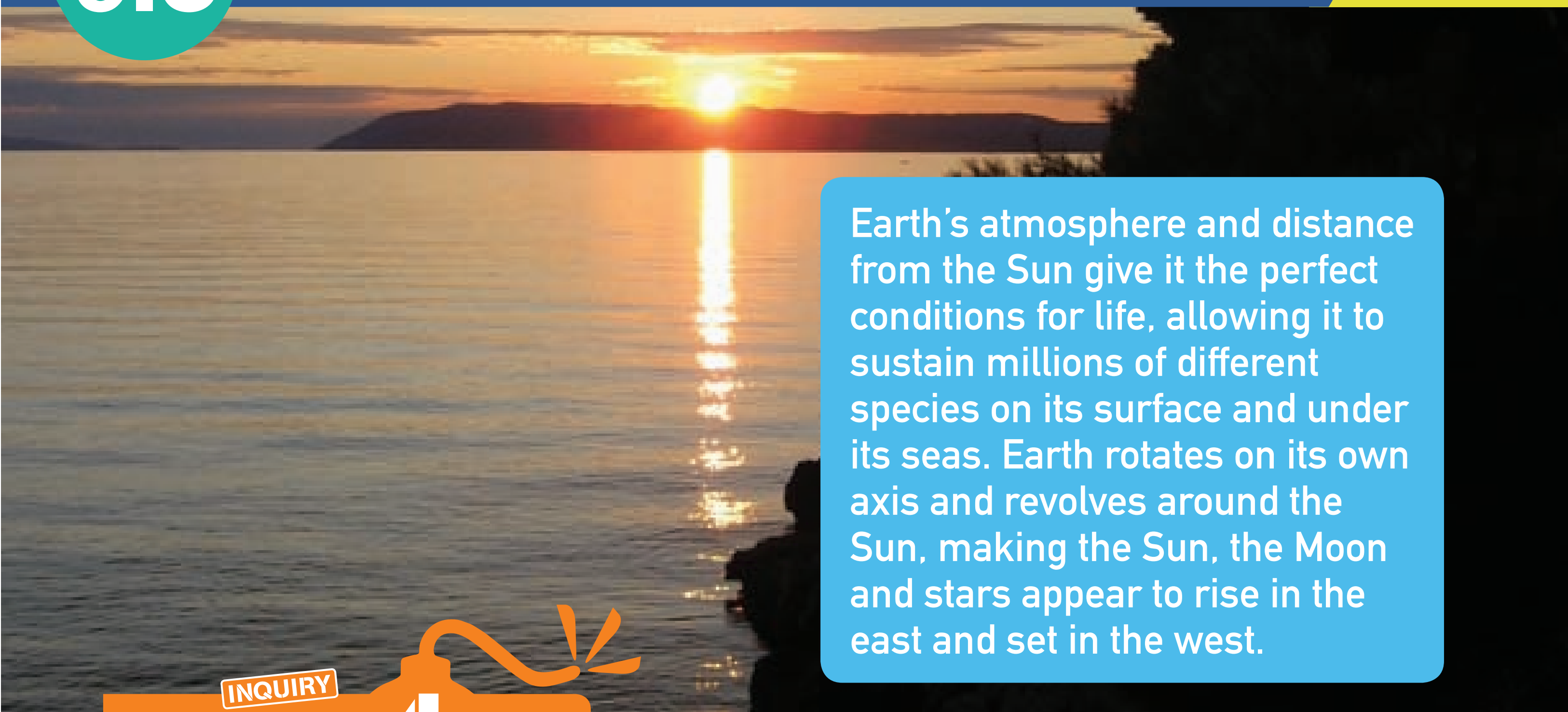


Figure 9.2.19

9.3 Earth



Earth's atmosphere and distance from the Sun give it the perfect conditions for life, allowing it to sustain millions of different species on its surface and under its seas. Earth rotates on its own axis and revolves around the Sun, making the Sun, the Moon and stars appear to rise in the east and set in the west.

INQUIRY science 4 fun

Make a sundial

Can a sundial tell the time accurately?

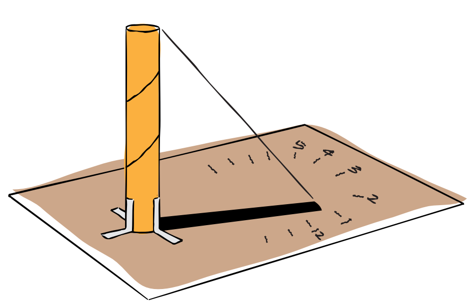
Yes

Collect this ...

- sturdy sheet of cardboard or scrap timber
- sheet of A4 scrap paper
- sticky-tape
- felt-tip pen
- watch or clock
- compass (optional)

Do this ...

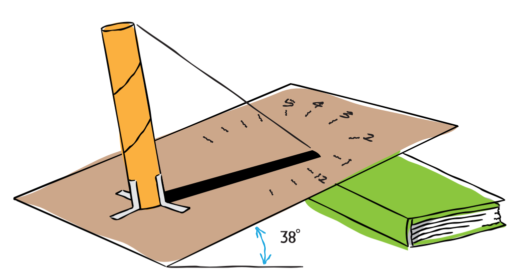
1. Roll up the A4 sheet of paper lengthwise to form a cylinder.
2. Secure it to the sheet of cardboard with strips of sticky-tape so that it stands upright.



3. Place your sundial in a spot where it gets sunlight most of the day.
4. Every hour, use the felt-tip pen to mark where the shadow falls on the cardboard or timber sheet. Write the time next to its mark.

To make your sundial more accurate:

5. Use a compass to find exactly where north is.
6. Use an atlas or search the internet for the latitude of where you live. Melbourne, for example, is 38°S. Use a protractor to measure out this angle and tilt the base so that it slopes away from north at this angle.



Record this ...

Describe what happened.
Explain how you could use your sundial to tell the time.

The Earth in space

Every day the Sun appears to rise in the east and set in the west, as do the Moon and stars. The Sun doesn't really move this way. Neither do the Moon or the stars. Instead, the Earth itself is spinning from west to east, making it appear that the Sun, Moon and stars move the other way. This can be seen in Figure 9.3.1.

Figure 9.3.1 Every five minutes another photograph was taken to produce this image of the Sun setting in the west.

Day and night

An imaginary line called the **axis** runs through the Earth from the north pole to the south pole. Earth rotates (spins) about this line, from west to east. The time taken for any planet to rotate about its axis is referred to as its **day**. Earth takes 24 hours to complete one rotation, and so one day on Earth is 24 hours. During this day, the Sun rises once in the east and sets once in the west.

As Figure 9.3.2 shows, at any time half of planet Earth is bathed in sunlight. This half experiences daylight. The other half is in the dark and so experiences night. As Earth rotates, some countries move into the light and others move out of it.

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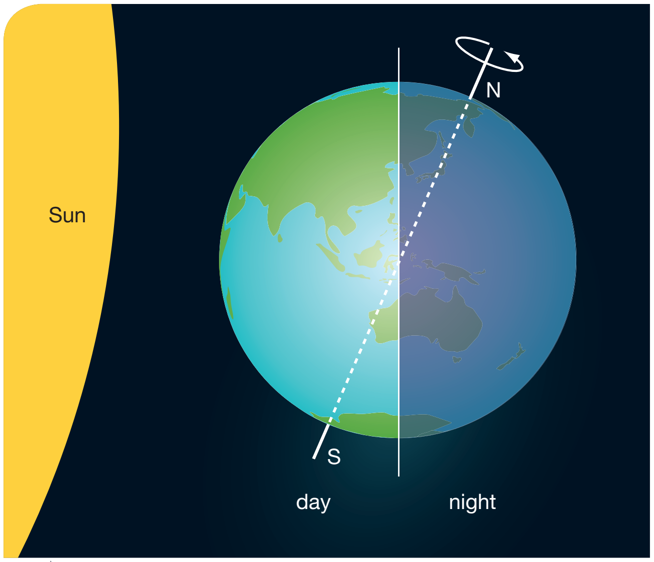


Figure 9.3.2 A day is the time it takes for Earth to spin around on its axis once completely. As Earth spins, only half is bathed in sunlight at any one time. This half experiences daylight. The dark half experiences night.

The year

Like all the other planets in the solar system, Earth orbits the Sun. It travels at an average speed of 108 000 km/h and takes $365\frac{1}{4}$ days to complete one **revolution** (one complete orbit). A complete orbit is shown in Figure 9.3.3. The time taken by a planet to revolve around the Sun is referred to as its **year**. For Earth, a year is $365\frac{1}{4}$ days. The quarter day makes setting up a calendar very difficult and so a calendar year is taken normally as 365 days. Every four years, however, the calendar needs to 'up' and an extra day (29 February) is added to make a **leap year** of 366 days.

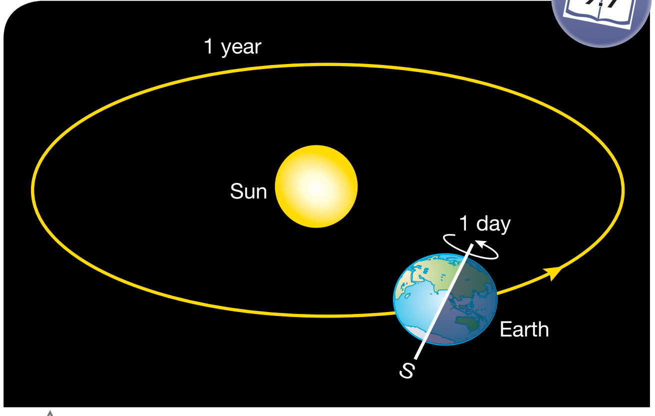


Figure 9.3.3 A year is the time it takes for Earth to completely revolve or orbit around the Sun. A day is the time it takes to rotate completely on its own axis.

Leap years

SKILL BUILDER

Every fourth year is not always a leap year. Use the following key to calculate whether a year is a leap year or not.

Can the year divided by 400?	If yes, then go to 2.
If not, can the year be divided by 100?	If yes, then go to 1.
If not, can the year be divided by 4?	If yes, then go to 2.
1	It's a normal year.
2	It's a leap year.

WORKED EXAMPLE

Identifying leap years

Problem

Is 2012 a leap year?

Solution

2012 ÷ 400 = 5.03 (cannot be divided by 400)

2012 ÷ 100 = 20.12 (cannot be divided by 100)

2012 ÷ 4 = 503

This is a whole number and so 2012 is a leap year.

Climate

The regions around the equator always point towards the Sun, and the sunlight that falls on them is bright and its heat is concentrated. This makes it hot all the time with very little variation between the seasons.

The north and south poles are always the coldest part of the planet. As Figure 9.3.4 shows, any sunlight that falls on them is almost parallel to the Earth's surface, spreading it over a large area. In their winters, the poles are pointed so far away from the Sun that it doesn't appear at all through the day. In contrast, there is day-long sunlight in the summer.

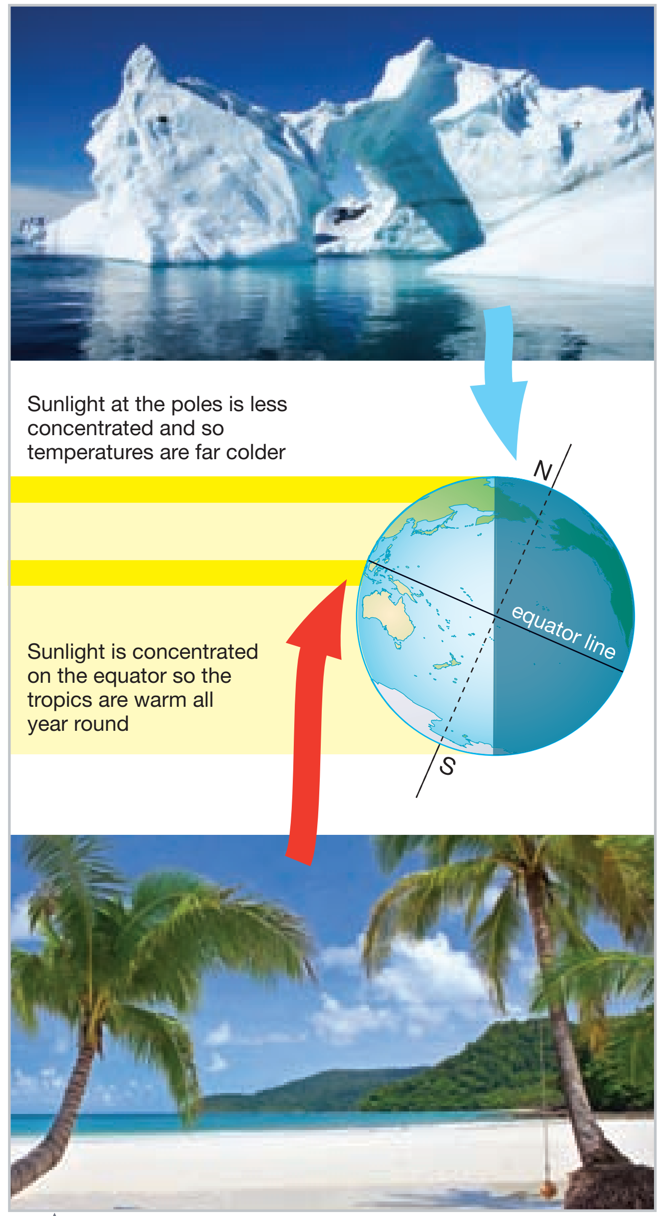


Figure 9.3.4 The Earth is spherical and so sunlight hits its different regions at different angles.

Australia is a huge continent that spreads from near the equator to the Southern Ocean. As a result, the country has a wide range of climates: far north Queensland, the Northern Territory and the Kimberley region of Western Australia are always hot, while Tasmania and southern Victoria are usually much cooler.

2 p353

Seasons

As Earth revolves around the Sun, its axis is not 'vertical' but is tilted at an angle of 23.5°. This tilt gives us our **seasons**. As Figure 9.3.5 shows, some parts of Earth point towards the Sun, exposing them more so the sunlight falling on them is more concentrated. These parts experience summer. Other parts of Earth are pointed away from the Sun. In these regions the sunlight is spread over a larger area. This results in lower temperatures and winter.

Earth exposes different parts of its surface to the Sun as it moves along its orbit. Australia experiences summer from December through to March because this is when the southern hemisphere is pointed towards the Sun. Meanwhile, the northern hemisphere is pointing away from the Sun and is experiencing winter. The situation reverses six months later.

In summer, Earth's tilt causes the Sun to be more vertical in the sky at noon than in winter. This causes:

- more hours of sunlight in summer than in winter
- the position on the horizon where the Sun rises and sets to change slightly each day
- short shadows in summer and long shadows at exactly the same time of day in winter. Architects and builders use this fact to control the amount of sunlight that enters a house. Eaves, verandas and pergolas block the vertical summer sun, keeping the house cool. However, the more angled winter sun can get underneath them and enter the house to keep it warm.

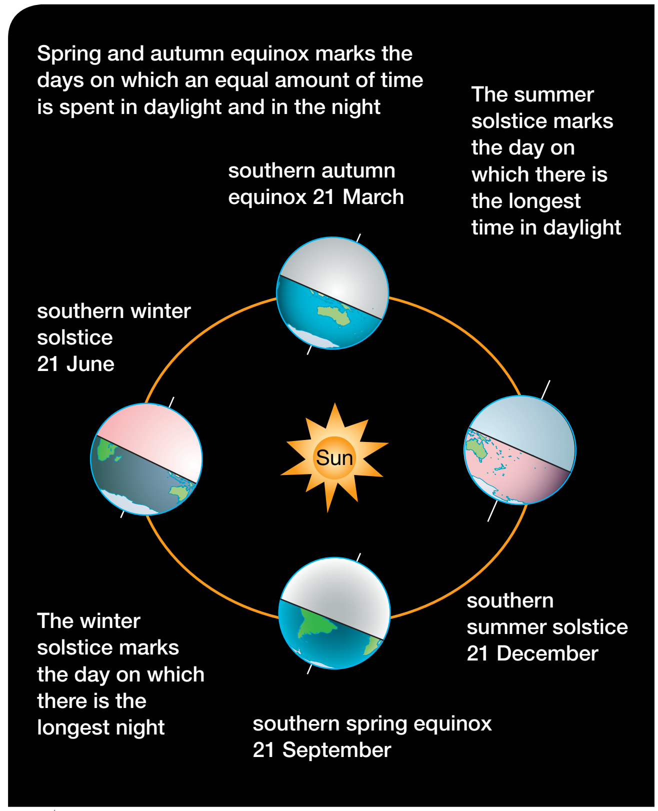


Figure 9.3.5 Earth's tilted axis causes sunlight to be more concentrated on some parts of Earth than others at different times of the year. This causes the seasons.

INQUIRY science 4 fun

Same but different

What happens when sunlight falls on Earth at an angle?

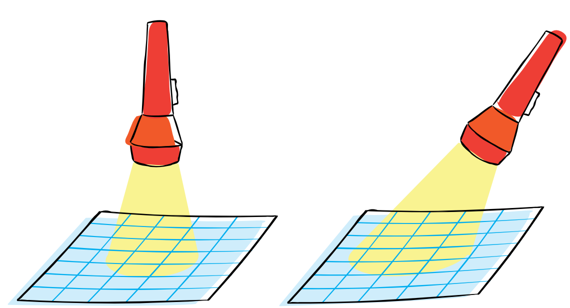
Yes

Collect this…

- torch
- sheet of paper (preferably graph paper or with a grid)
- 30 cm ruler

Do this…

1. Place the sheet of paper on the floor or on a desk or table.
2. Hold the torch 30 cm from the paper and shine its light directly onto the paper.
3. Trace around the 'pool'of light.
4. Repeat, but this time direct the torch so that its light falls on the paper at an angle.
5. Once again, trace around the 'pool' of light.



Record this…

Describe what happened.
Explain why you think this happened.

9.3 Unit review

Remembering

1 **State** which of the following is correct. Earth spins from:

A north to south
B east to west
C south to north
D west to east

2 **Recall** the following terms by matching each with the correct number of days:

A year	365
A 'normal' calendar year	366
A leap year	365.25 or $365\frac{1}{4}$

Understanding

3 **Define** the following terms:
a 1 day
b 1 year
c 1 revolution.

4 **Describe** the problems that would be caused if our calendar year was taken as $365\frac{1}{4}$ and not 365 and 366 days.

5 **Explain** why tropical countries are located around the equator.

6 The equinox marks the time in the year that the length of day and night are exactly the same. **Predict**:
a how many equinoxes occur each year
b the seasons they occur in.

Applying

7 **Use** a sketch to help **define** the following terms:
a Earth's axis
b the equator
c the poles.

8 Some people only have a birthday every four years. **Identify** the date on which they were born.

9 The surface of Earth is moving at incredible speeds due to its spin. **Identify** the part(s) on Earth's surface that are:
a moving the fastest
b just turning on the spot.

10 **Calculate** whether the following years are/were leap years or not.
a 1896
b 1900
c 2225
d 2400.

11 **Use** the labels on the diagram shown in Figure 9.3.6 to **identify** the part(s) of Earth (A, B, C or D) experiencing:
a summer
b winter
c a day in which the Sun is always in the sky
d a day in which the Sun never appears.

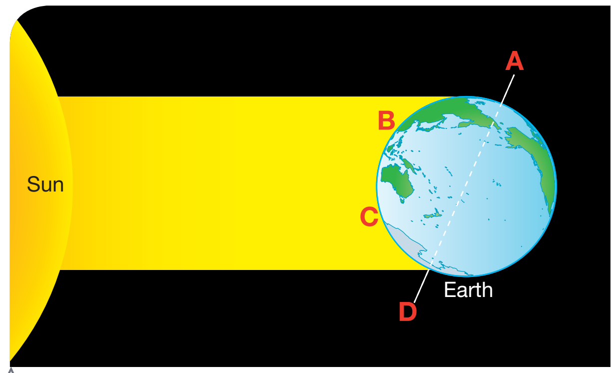


Figure 9.3.6

12 a **Use** Figure 9.3.5 to help to **predict** the season that Australia experienced on the following dates:
A 21 March
B 30 June
C New Year's Day, 1 January
D Anzac Day, 25 April

b **Identify** what season the northern hemisphere would be experiencing on the same dates.

13 We can only celebrate New Year's Eve at 12 midnight because our calendar years are rounded off at either 365 or 366 days. If we used $365\frac{1}{4}$ days for our calendar year, then New Year's celebrations would have to be celebrated at different times each year.
a **Calculate** how many hours there are in one quarter of a day.
b New Year's Eve was at 12 am this year. If the calendar year was $365\frac{1}{4}$ days long, then **calculate** the time it would occur:
i next year
ii the year after that.
c **Calculate** how many years would pass before New Year's Eve returned to 12 am.
d **Use** this example to **explain** why the length of a calendar year is rounded to 365 or 366 days.

Evaluating

14 China has no time zones, despite being a country as large as Australia. **Compare** what a day would be like in its east and in its west.

15 Russia has 11 time zones. **Propose** a reason why. (A map will help.)

16 **Predict** from the list below the set of results most likely obtained in the science4fun activity on page 349.

- **A** Direct torch: 48 squares; angled torch: 64 squares
- **B** Direct torch: 64 squares; angled torch: 48 squares
- **C** Direct torch: 64 squares; angled torch: 64 squares
- **B** Direct torch: 48 squares; angled torch: 48 squares

17 Not every 'turn-of-century' year is a leap year.

- **a** **Calculate** whether the 'turn-of-century' years 1500, 1600, 1700 through to 2500 were/will be leap years or not.
- **b** **Propose** a reason why most 'turn-of-century' years are not leap years.

18 **Propose** what would happen to the seasons if Earth's tilt suddenly changed to:

- **a** 0° (no tilt at all)
- **b** 45° (more than now)
- **c** 10° (less than now).

Creating

19 Science fiction and horror authors have long been fascinated by the idea of endless days and endless nights. Imagine a planet that doesn't spin. On it, forms of life have evolved very differently from those found on Earth. Think of what may live on the dark side and light side of the planet. Just as important, think of the forms of life that couldn't possibly exist. **Create** a short story or a plotline for a blockbuster movie about:

- **a** a creature from one side travelling into the other (light to dark or dark to light)
- **b** a human landing on the planet and exploring both sides.

Inquiring

1 Design a model to show why day and night occur and how the seasons happen. A search of the internet might help you come up with ideas.

2 Not everyone experiences summer, autumn, winter and spring. For example, people in the far north of Australia instead talk about the wet and dry seasons. Research the seasons and calendars used by the Aboriginal and Torres Strait Islander peoples.

3 Search available resources such as textbooks, encyclopaedias and the internet to research:

- **a** the times of sunrise and sunset over a week. Summarise what you find in a table
- **b** the starting and finishing dates for the different seasons in different countries
- **c** what UTC is and how all the world's clocks are based on it
- **d** what the International Date Line is, where it is, and why it's needed
- **e** how long a day and a year is on the other planets of the solar system
- **f** whether other planets in the solar system experience seasons.

4 Find and compare the times for the rotation and orbits of the Earth, Sun and Moon.

5 Research how Al Battani calculated the length of the year in the tenth century.

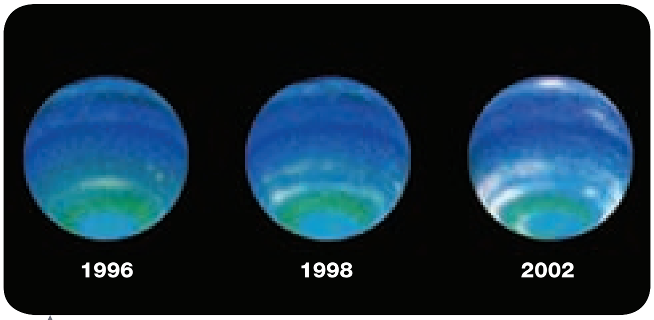


Figure 9.3.7 Neptune's axis tilts at 29° and should show seasons like Earth. However, Neptune's year is the same as 165 Earth years, so each season would be about 40 years long! The increasing white bands in these images are thought to mark the start of spring.

9.3 Practical activities

1 Day and night

Purpose

To model day and night on Earth.

Materials

- balloon
- string or cotton
- felt-tip pen
- access to a globe
- access to a bright light (such as a projector, spotlight, data projector or similar)

Procedure

1. Blow up your balloon and tie it off so that no gas can escape. This is your Earth, and its tied-off end represents the north pole.
2. Tie a length of string or cotton to the north pole.
3. Use the felt-tip pen to draw on the balloon the position of the equator, south pole and International Date Line.
4. Use the globe to check the shape and position of the major continents and copy them onto the balloon. Make sure you include Australia.
5. On Australia, write a large E on the east coast and a large W on the west coast.
6. Hang the balloon by the string in front of the bright light and slowly turn it from the 'west' (W) to 'east' (E) as shown in Figure 9.3.8.

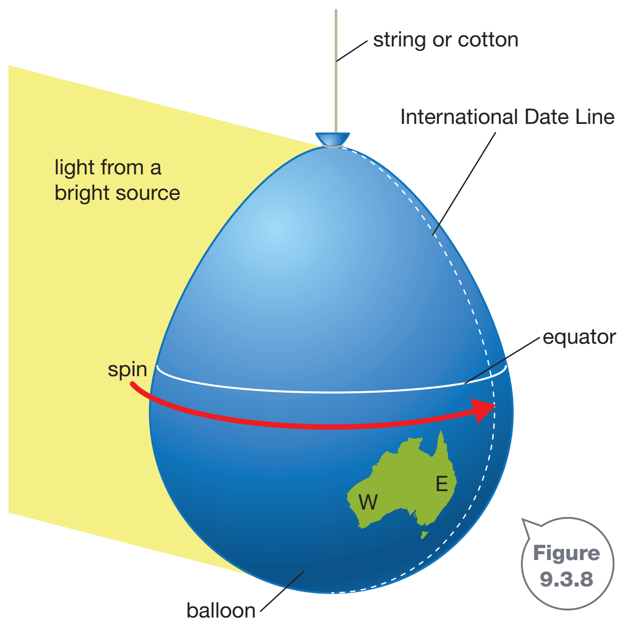


Figure 9.3.8

Discussion

1. The Sun rises in the east and sets in the west, but you rotated your 'Earth' in the opposite direction. **Explain** why there is a difference.
2. **Identify** which coast of Australia:
   a. first came into 'daylight'
   b. was the last to move into 'night'.
3. Perth is on a different time zone from Melbourne, Sydney and Brisbane, being two hours 'behind' them. **Use** your model to **explain** why different time zones are needed in Australia.
4. **Assess** how accurate this model is in showing Earth, its spin, and its day.

2 Angles make a difference

Purpose

To test whether the angle of sunlight affects the surface temperature on Earth.

Materials

- lamp (such as a microscope lamp)
- 2 thermometers
- 2 blocks of wood
- black plastic
- sticky-tape

Procedure

1. Cut out two small identically sized sheets of black plastic and tape them onto wooden blocks so that they make pockets.
2. Secure a thermometer in each pocket, ensuring that it is touching the plastic sheet. Tape the thermometer to the board to secure it.
3. Place the two blocks the same distance from the lamp. Figure 9.3.9 shows the set-up.
   - Block A: Lay one block flat on the desk so that the light from the lamp falls on it at an angle.
   - Block B: Use some books to chock up the other block so that it is at an angle to the desk and the light falls directly on it.
4. Turn on the lamp.

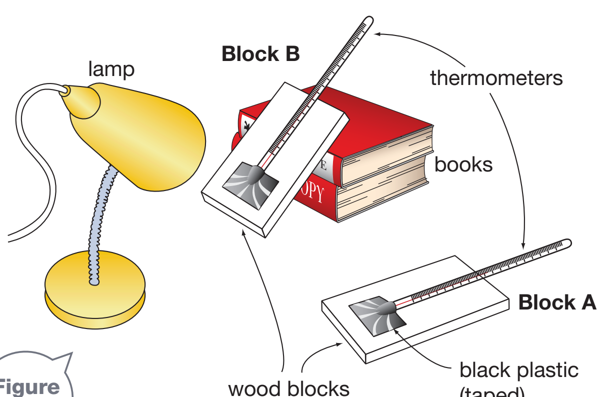


Figure 9.3.9

Results

1. Record the temperature of each thermometer every minute for at least five minutes.
2. Place your results in a table like the one shown below.

Time (min)	Block A	Block B
1		
2		
3		
4		
5		

Discussion

1. **Identify** which block (A or B) showed the greatest increase in temperature.
2. **Identify** which block (A or B) modelled the surface of the Earth in:
   a. far north Queensland
   b. southern Tasmania.
3. **Use** your results to **explain** why:
   a. the tropics are found near the equator
   b. icebergs are only found near the poles.

9.4 Small solar system bodies

Planets, dwarf planets, stars and constellations aren't the only things in the sky. There are thousands of chunks of rock and ice out there too. These chunks are commonly known as asteroids and comets. In 2006, the IAU (International Astronomical Union) grouped these chunks together and gave them the name small solar system body (or SSSB).

INQUIRY science 4 fun

Liquid craters

Yes

Meteor strikes have marked the Moon with many craters. Many have peaks in their centre. What forms them?

Collect this ...

- glass or 250 mL beaker
- drinking straw
- water

Do this ...

1. Put a small amount of water in the glass or beaker.
2. Place one end of the straw in the water and then block the other end with your finger.
3. Keep your finger on the straw while you remove it. It should be holding some of the water.
4. Release the pressure of your finger so that a couple of drops fall back into the glass or beaker.
5. Carefully observe what happens to the surface of the water as the drop falls in, particularly at its centre.

Figure 9.4.1 The energy of some meteorites is sometimes so high that it melts the Moon's rock, causing it to slosh around and to form a small peak in the centre of the crater. Droplets form a similar peak when they hit liquid water.

Record this ...

Describe what happened.
Explain why you think this happened.

Comets

Comets are among the most spectacular sights in the sky. Figure 9.4.2 shows the image of a comet as recorded by a German artist in 1664. Some have been so bright that they could be easily seen with the naked eye, even during the day. From the earliest times, superstitious people have seen the appearance of a comet as an omen of disaster or history-making events.

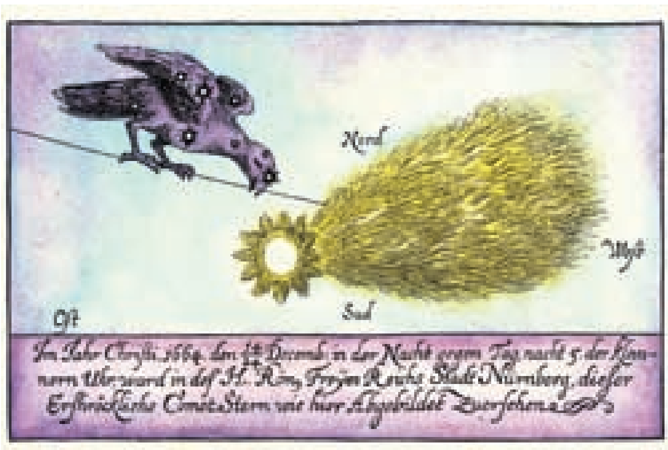


Figure 9.4.2 This German painting records the appearance of a comet for 10 days in December 1664.

When viewed from Earth, comets:

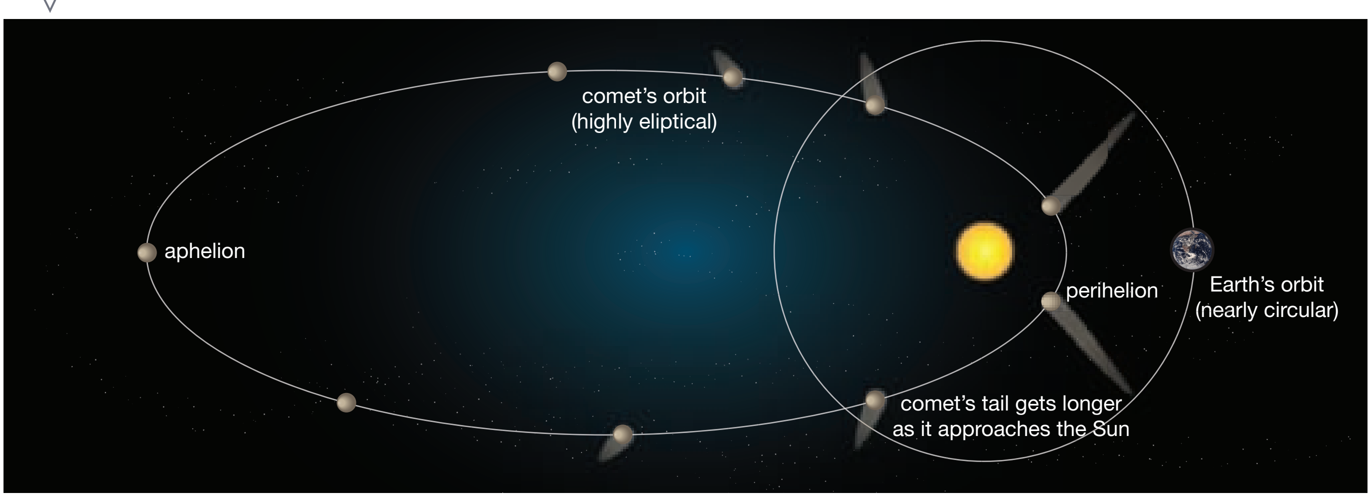
- gradually get brighter and then fade over a period of weeks
- have a distinctive **coma** (or fuzzy atmosphere) at their head and often a trailing 'tail'
- reappear periodically.

Comets are commonly referred to as 'dirty snowballs' since they are made primarily of ice mixed with frozen carbon dioxide and other carbon-based molecules. As Figure 9.4.3 shows, comets have highly elliptical orbits, with the **aphelion** (its point of furthest distance from the Sun) of many comets being beyond Pluto in a distant region of space known as the Oort cloud. As a comet approaches its **perihelion** (its point of closest approach to the Sun), it encounters both radiation from Sun and the solar wind. The **solar wind** is a stream of high-energy particles that is emitted from the Sun in all directions. The radiation causes the comet's surface to vaporise and form a thin atmosphere or coma. The solar wind also blasts heavier dust particles from the surface of the comet and pushes these, and molecules from the coma, into a 'tail'. Since the tail is created by the solar wind, it always points away from the Sun, regardless of whether the comet is moving towards the Sun or away from it.

Halley's Comet

Halley's Comet was the first comet to be recognised as periodic, returning to the inner solar system at regular intervals. The eighteenth century English astronomer Edmund Halley recognised that descriptions of a comet that appeared in 1682 were almost exactly the same as the description of a comet observed earlier in 1531 and another seen in 1607. Halley proposed that these three observations were all describing a single comet that returned to the inner solar system approximately every 76 years. Halley died in 1742 and so was not able to witness the confirmation of his theory when the comet reappeared in 1758. Science historians have been able to identify sightings of Halley's Comet as far back as 240 BCE. Its most recent appearance was in 1986.

Figure 9.4.3 A comet's orbit is highly elliptical. Its tail always points away from the Sun.



Comet Shoemaker-Levy 9

A comet discovered by Carolyn and Eugene Shoemaker and David Levy in 1993 came to international attention when it broke up and crashed into Jupiter in July 1994. Telescopes around the world turned to Jupiter to observe the impacts, which provided scientists with a wealth of information about the upper atmosphere of the gas giant. The impact scars from the collision lasted for many months. They can be seen as dark patches in Figure 9.4.4.

Figure 9.4.4 The dark patches are impact scars from Shoemaker-Levy 9's crash into Jupiter.

Asteroids

An **asteroid** is an irregular rocky object left over from the formation of the solar system. Most known asteroids orbit the Sun in a band known as the **asteroid belt** that lies between the orbits of Mars and Jupiter. Scientists believe that competing gravitational effects of Mars and Jupiter prevented these objects ever forming into a planet.

Over half of the mass of the entire asteroid belt is contained in its four largest asteroids. Ceres is the biggest of the asteroids. It is large and round enough to be classified as a dwarf planet. The relative sizes of Earth, the Moon and Ceres can be seen in Figure 9.4.5. An irregularly shaped asteroid called Ida is another large asteroid. With a length of 56 kilometres, Ida's gravity is high enough to have trapped another, smaller asteroid called Dactyl as a moon! Most asteroids are much smaller than Ceres and Ida.

The asteroid belt is a possible source of mineral resources for space settlements. One of the great challenges associated with building large structures in space is the enormous cost of sending the building materials up from Earth by rocket. It may be much cheaper to capture an asteroid and mine it.

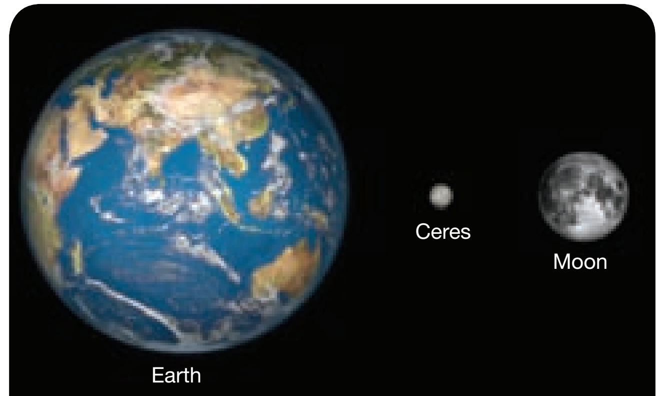


Figure 9.4.5 This artist's impression compares the size of Earth, the Moon and Ceres. Although it is classed as a dwarf planet, Ceres is much smaller than the Moon.

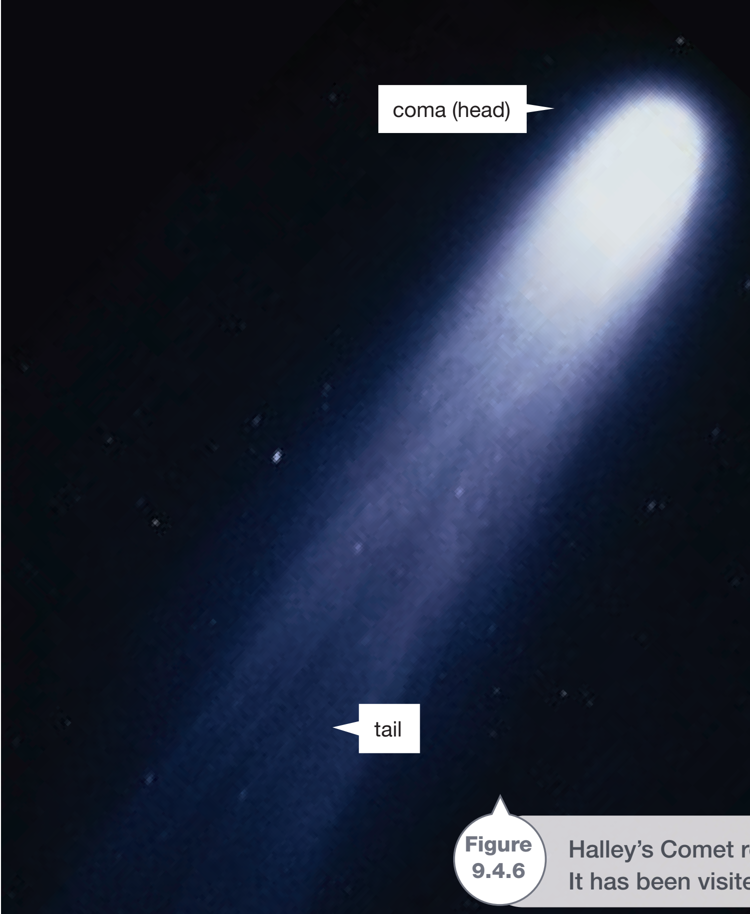
Meteoroids

Occasionally, the path of an asteroid will bring it close enough to the Earth for it to be captured by the Earth's gravitational field. As this lump of space rock falls through the Earth's atmosphere, friction between it and the air generates enormous amounts of heat. This turns the asteroid into a blazing fireball known as a **meteoroid**, or more popularly a 'shooting star'. These can be among the most exciting sights in the night sky, particularly when a group of meteoroids enter the same part of the atmosphere at the same time, producing a **meteor shower**. Meteor showers often occur when the Earth passes through the tail of a comet.

Fortunately, most meteoroids are so small that they burn up completely in the atmosphere, in which case they are known as **meteors**. If a meteoroid is very large, then a part of it might reach the ground before it has completely burnt up. The part that reaches the ground is called a **meteorite**. Most meteorites are tiny, but on very rare occasions Earth is struck by a large meteorite. When this happens, the results can be devastating. Meteorites usually travel at very high speeds and the impact can create a massive crater (such as the one shown in Figure 9.4.8 on page 359) and cause widespread destruction. There is strong evidence to suggest that a major meteorite impact caused the extinction of the dinosaurs 65 million years ago. In 1908 a meteor about 50 metres across exploded above Tunguska in Siberia, flattening about 2000 square kilometres of forest.

Meteorite impacts can also be very useful. By studying impact craters on the Moon and rocky planets such as Mercury and Mars, scientists can learn much about the history of these bodies.

1 p360
2 p361



SCIENCE AS A HUMAN ENDEAVOUR

Use and influence of science

Exploring comets and asteroids

Figure 9.4.6 Halley's Comet returns every 76 years. It has been visited by four space probes.

Comets and asteroids can tell astronomers a lot about what the solar system was like before it condensed into the star and planets we have today. Scientists have sent numerous spacecraft to fly by, photograph and land on various small solar system bodies. Table 9.4.1 gives a summary of some of these important missions.

Table 9.4.1 Missions to explore comets and asteroids

Year	Spacecraft	Target	Type of mission	Notes	Fate of spacecraft
1985	*ICE*	Comet Giacobini-Zinner Halley's Comet	Fly by	*ICE* stands for International Cometary Explorer (it was originally International Sun-Earth Explorer 3)	Shut down in 1997. Will return to vicinity of Earth in 2014
1986	*Vega 1* and *Vega 2*	Halley's Comet	Fly by	Both Vega spacecraft dropped landers onto Venus before flying by Halley's Comet	*Vega 1* headed out into deep space *Vega 2* put into a heliocentric orbit
1986	*Giotto*	Halley's Comet	Fly by	Also flew by Comet Grigg-Skjellerup	Put into hibernation in 1992
1986	*Suisei* and *Sakigake*	Halley's Comet	Fly by	Twin Japanese probes	*Suisei* was shut down in 1998 *Sakigake* lost contact with Earth in 1995
1991 and 1993	*Galileo*	Asteroid Gaspra (1991) Asteroid Ida (1993)	Fly by	Gaspra was the first asteroid ever to be closely approached by a spacecraft. It was discovered that Ida has a small moon, which was named Dactyl	Deliberately crashed into Jupiter in 1994

ENDEAVOUR

1994	*Clementine*	Asteroid Geographos	Fly by	Mission failed due to instrument malfunction—thrusters misfired leaving the craft tumbling uncontrollably	Mission terminated in 1994 with craft in heliocentric orbit
1997 and 2001	*NEAR—Shoemaker* (**N**ear **E**arth **A**steroid **R**endezvous)	Asteroid Mathilde (1997) Asteroid Eros (2001)	Fly by (Mathilde) Fly by and landing (Eros)	After its launch, the probe was renamed in honour of the astronomer Eugene Shoemaker. This was the first spacecraft to land safely on an asteroid. It transmitted experimental data from the surface of Eros for over 2 weeks	Still on Eros. Efforts to contact it in 2002 were unsuccessful
1999 and 2001	*Deep Space 1*	Asteroid Braille (1999) Comet Borrelly (2001)	Fly by	Fly by was only partially successful due to camera malfunctions	Shut down in December 2001
2002	*CONTOUR* (**CO**met **N**ucleus **TOUR**)	Comet Encke, Schwassmann-Wachmann 3 Comet d'Arrest	Fly by	Intended to investigate the nuclei of several comets	Broke apart shortly after launch
2004	*Stardust*	Comet Wild 2	Fly by	Collected dust samples from the comet's coma and returned them to Earth	Extended mission: Stardust will fly by Comet Tempel 1 in 2011
2005	*Hayabusa*	Asteroid Itokawa	Sample return	Contact with *Hayabusa* was lost in December 2005 and then regained in 2006	Returned to Earth in June 2010, landing in South Australia
2005	*Deep Impact*	Comet Tempel	Fly by and impact	First mission to eject material from a comet's surface. Provided important information about composition of comets	Mission continues. Flew past Comet Hartley 2 in 2010
Launched in 2004	*Rosetta*	Asteroid Steins (2008) Asteroid Lutetia (2010) Comet Churyumov-Gerasimenko (2014)	Fly by, orbit and land	Will release a lander called Philae on to the surface of the comet to record changes as it approaches the Sun	Mission ongoing
Launched in 2007	*Dawn*	Asteroid Vesta (2011) Dwarf planet Ceres (2015)	Fly by	Will be first spacecraft to orbit two objects in the asteroid belt	Mission ongoing

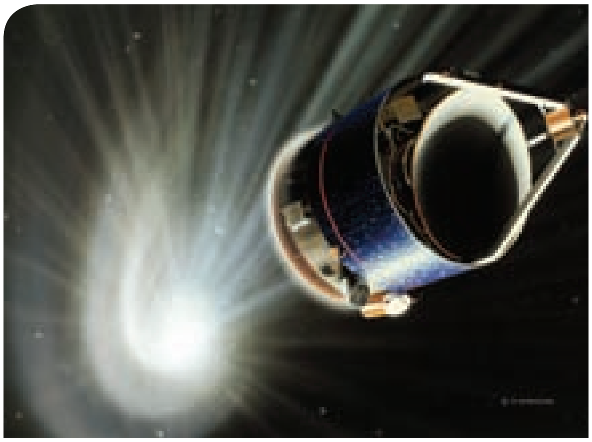


Figure 9.4.7 Artist's impression of *Giotto* and Halley's Comet. *Giotto* was Europe's first deep space mission.

9.4 Unit review

Remembering

1 **State** what the acronym SSSB stands for.

2 **List** the distinguishing features of a comet.

Understanding

3 **Use** a diagram to **define** the terms 'aphelion' and 'perihelion'.

4 **Explain** why a comet's tail always points away from the Sun.

5 **Explain** why comets and meteor showers are often observed together.

6 **Outline** why the term 'shooting star' is not an appropriate name for a meteor.

Applying

7 Encke's Comet was the second comet (after Halley's) to be identified as periodic. It was last seen in April 2007 and is expected again in early August 2010. **Calculate** its orbital period, the time the comet takes to complete one complete orbit.

8 Halley's Comet last appeared in 1986. Given that it has an orbital period of 76 years, **calculate** the years in which the next three sightings should occur.

Analysing

9 **Compare** the composition of an asteroid with the composition of a comet.

10 Unlike comets, asteroids and meteors do not have a 'coma'. **Discuss** why.

Evaluating

11 Some historians have suggested that Halley's Comet may have been the 'Star in the East' seen by the three wise men in the story of the birth of Jesus. Halley's Comet was observed by Chinese astronomers in 240 BCE and has an orbital period of 76 years.

a **Use** this information to **calculate** the years Halley's Comet would have appeared between 100 BCE and 100 CE.

b **Evaluate** the likelihood of Halley's Comet appearing in the year of Jesus' birth, which most historians think was either 4 or 6 BCE.

12 Some scientists estimate that in the next 100 years there is a 10% chance of Earth being hit by something large from space, such as a meteor, asteroid or comet.

a **Identify** arguments for and against research that uses telescopes to search for large objects in space that are heading our way.

b **Assess** whether the risk justifies this research.

Figure 9.4.8 Meteorite impact crater in Arizona, USA. The crater is 275 m deep and 1.26 km in diameter. The meteoroid that caused it was around 60 m in diameter and has a mass of more than 10 000 tonnes.

Creating

13 **Construct** a poster that explains the difference between the terms 'meteor', 'meteoroid' and 'meteorite' and gives a realistic assessment of the dangers associated with a meteorite impact.

Inquiring

1 Research other famous comets such as Comet Hale-Bopp and the Great January Comet of 1910. In particular, find out how different people reacted to the appearance of these comets.

2 Research the documented sightings of Halley's Comet throughout history. Are these all exactly 76 years apart?

3 Research more information about spacecraft that have visited asteroids or comets. Find out which of these spacecraft are still operating.

4 Research the meanings of the terms 'minor planet' and 'planetoid'.

9.4 Practical activities

1 Simulating impact craters

Purpose
To determine what information about meteorite impacts can be determined from impact craters.

Materials
- 4 cups of damp sand or flour
- small plastic box or tray (such as a lunch box or take-away food container)
- several marbles or ball bearings (of various sizes if possible)
- tweezers
- piece of tissue paper or cloth
- large sheet of plastic (to clean up mess)

Procedure
1. Lay out the tray on the large sheet of plastic or set up outside.
2. Fill the tray with flour or sand to a depth of 2–3 cm. Keep at least one cup aside for later.
3. Drop a marble or ball bearing into the flour or sand to make an impact crater.
4. Using tweezers, carefully remove the marble or ball bearing. Avoid changing the shape of the crater.
5. Repeat steps 3 and 4 with marbles of different sizes from different heights until a pattern of overlapping craters has been formed.
6. Sketch or photograph the crater pattern.
7. Simulate volcanic activity by sprinkling the remaining flour or sand over a section of the crater pattern. Sketch or photograph this section.
8. Simulate erosion by lightly dragging the tissue or cloth over a section of the tray.
9. Sketch or photograph the crater pattern.
10. Simulate earthquakes by lightly tapping the side of the tray.
11. Drop several more marbles or ball bearings.
12. Sketch or photograph the crater pattern.

Results
Can you tell from the crater patterns you made which craters were formed earlier and which were formed later? If so, **explain** how.

Discussion
1. **Propose** what effect each of the following would have on the pattern of impact craters:
   a. volcanic activity
   b. erosion
   c. earthquakes.
2. It is possible to identify which impact craters were formed after volcanic activity, erosion and earthquakes. **Propose** what the landscape would look like if a crater was formed after each type of activity.
3. Use information gained from this activity to **predict** what astronomers could learn from the pattern of impact craters on a moon or a planet.

2 Toilet paper solar system

Purpose

To construct two scaled models of the solar system that show the distance between the planets, the Kuiper Belt and the Oort Cloud.

Materials

- 300-sheet roll of toilet paper
- pen or pencil (not a felt-tipped pen)

Procedure

Part A: The planets

1 Unroll a little of the toilet roll. At the very start of the first sheet, draw and label the SUN.

2 Unroll the toilet roll a little further. At the end of the fourth sheet, draw a small planet. Label it MERCURY.

3 The table below shows where you need to draw and label the other planets of the solar system. The scale being used here is 1 sheet = 15 million kilometres or 1 : 15 000 000. Using this scale, Uranus should be drawn at the edge of the final sheet on the roll.

Planet	Distance (millions of km)	Toilet sheets
Mercury	58	4
Venus	108	6.5
Earth	150	10
Mars	228	15.5
Jupiter	778	52
Saturn	1427	95.5
Neptune	2871	193.5
Uranus	4498	300

Part B: The Kuiper Belt and Oort Cloud

4 Turn the roll over and again draw a dot to represent the SUN at the very start of the first sheet.

5 As before, mark the following features of the solar system as shown in the instructions below. This table uses the scale 1 sheet = 26 billion kilometres (the distance light travels in one day).

Planet	Distance (km)	Instructions
Earth	150 million	Draw a dot 0.5 mm from the Sun on the 1st sheet
Pluto	5906 million	Draw a dot about $\frac{1}{4}$ of the way into the 1st sheet
Kuiper Belt	5000 million to 40 billion	Draw a belt from Pluto to the middle of the 2nd sheet
Oort Cloud	30 trillion	Draw a cloud on the 285th sheet

Discussion

1 **List**:
 a the four terrestrial planets
 b the four gas giants
 c three dwarf planets.

2 **State** which of the following 'space rocks' come from the Oort Cloud.
 A asteroids
 B comets
 C meteoroids
 D dwarf planets

3 Despite its great distance, the Oort Cloud is still being influenced by the Sun's gravitational pull. **Describe** the evidence that supports this claim.

9 Chapter review

Remembering

1 **State** whether the following statements are true or false:
- a Only large masses like planets, stars and moons have a gravitational field.
- b The further you go out from a planet, the weaker its gravity becomes.
- c A day on Earth is the time it takes for Earth to revolve once around the Sun.
- d Earth has four seasons because of its tilted axis.
- e On Earth, we only see one side of the Moon.
- f Pluto is a planet.

2 **List** the four planets that are known as:
- a terrestrial planets
- b gas giants.

3 **Name** the two celestial bodies that affect the location and size of the tides on Earth.

Understanding

4 **Explain** why constellations vary from one culture to another.

5 **Describe** the shape of an ellipse.

6 The Moon can still be seen during a lunar eclipse. **Explain** why.

7 **Explain** why Earth experiences four seasons each year.

8 **Describe** how the day and year are related to Earth's movement.

9 **Predict** what the world would be like if there were no time zones and the globe was all at exactly the same time.

10 Copy and complete the table below to **summarise** some of the information from this chapter.

Type of object	Definition	Example
Planet	Orbits the Sun	Earth
Dwarf planet		Pluto
Comet		
Asteroid		
Meteor		
Meteorite		

Applying

11 You are about to fly between Perth and Brisbane. **Identify** where in your flight gravity will be:
- a the least
- b the greatest.

12 Sanjay is a Year 7 student. He roughly sketched the diagram of the solar system shown in Figure 9.5.1, but forgot to add labels and didn't draw every orbit. **Identify** which of the orbits he drew most likely represents that of:
- a Earth (an inner planet)
- b the Moon
- c Neptune (an outer planet)
- d Pluto
- e Halley's comet.

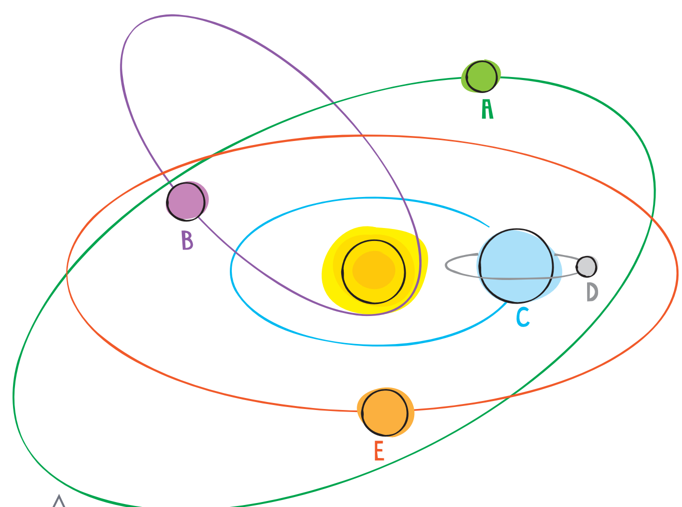


Figure 9.5.1

13 Everything around you has its own gravitational field.
- a **Identify** what mass affects you the most.
- b **Explain** why other things like the wall or the person sitting next to you don't influence you much.

14 **Use** a diagram to **clarify** the terms *aphelion* and *perihelion*.

Analysing

15 **Calculate** whether you were born in a leap year or not.

16 **Contrast**
- a a comet with a meteor
- b the geocentric and helicentric models of the solar system
- c an eclipse with an ellipse.

Evaluating

17 Gravity always pulls you down. **Assess** whether this statement is true, false, or a bit of both.

18 Geology is the study of the Earth, and the geocentric model has Earth at its centre. **Use** this information to **propose** a meaning for the prefix geo-.

19 How should Australians prepare for the possibility of a major meteorite impact? **Propose** a set of measures for individuals and for the Federal Government.

20 Below is a list of areas of astronomical research.
- a **Assess** which is most important.
- b **Justify** your answer.

- Search for extraterrestrial life
- Search for asteroids/comets that could collide with Earth
- Robot missions to the moons of Jupiter and Saturn
- A crewed mission to Mars

21 The International Space Station (ISS) orbits Earth 340 km above its surface. On board, astronauts float around in 'weightless' conditions. Two Year 7 students are arguing about what this means. Joe says this proves there is no gravity at the height of the ISS. Sarah disagrees, saying that there must be gravity at that height.
- a Use the evidence given above to **draw** your own conclusion.
- b **Justify** your response.

Creating

22 A mnemonic is a way of remembering the order of something. **Create** your own mnemonic to help you remember the order of the planets of the solar system.

23 **Construct** a diagram showing a comet at various points of its orbit. Clearly label the direction of motion of the comet and the size and direction of its tail.

24 The ancients reacted to solar and lunar eclipses with amazement and fear because they did not know why they happened. Imagine you are one of the ancients seeing a solar eclipse for the first time. **Create** a short news item for your local newspaper *Neanderthal News* or a short news item for the current affairs show *Neolithic Nightly*. Your item must describe what you saw and how people around you reacted.

25 **Use** the following ten key words to **construct** a visual summary of the information presented in this chapter:

stars, constellation, gravity, orbit, ellipse, Sun, Earth, Moon, tides, comet

9.8

Thinking scientifically

The Bayer system is used to name stars within a constellation. It uses the Greek alphabet to name them, with alpha (α) being the brightest star. Beta (β) is used for the next brightest, gamma (γ) for the next and so on.

The two pointers of the Southern Cross are α-Centauri and β-Centauri. In another constellation are Alpha-Cygni and Beta-Cygni.

Q1 Use this information to state which of the following stars would be the brightest.

- **A** α-Centauri
- **B** β-Centauri
- **C** Alpha-Cygni
- **D** Beta-Cygni
- **E** α-Centauri AND Alpha Cygni
- **F** β-Centauri AND Beta Cygni
- **G** α-Centauri is brighter than β-Centauri and Alpha-Cygni is brighter than Beta-Cygni but there is not enough information to tell whether α-Centauri is brighter than Alpha-Cygni or whether β-Centauri is brighter than Beta-Cygni.

The first six letters of the Greek alphabet are α (alpha), β (beta), γ (gamma), δ (delta), ε (epsilon) and ζ (zeta).

Q2 Use this information to identify which of the following lists its stars in the correct order from brightest to least bright.

- **A** α-Crucis, δ-Crucis, Gamma-Crucis, Zeta-Crucis
- **B** β-Geminorum, Beta-Crucis, β-Cygnis, Beta-Orionis
- **C** δ-Geminorum, δ-Centauri, δ-Cygni, δ-Crucis
- **D** β-Geminorum, Gamma-Geminorum, Delta-Geminorum, ε-Geminorum

Density determines whether an object sinks or floats. Basalt rock has a density of around 3.0 g/cm^3 while the density of pure water is 1.0 g/cm^3. These densities suggest that a lump of basalt will sink when placed in water. The average density of a human is 1.01 g/cm^3. We are slightly denser than water and so will sink very slowly into it.

The table below shows the density of the eight planets of the solar system.

Planet	Density (g/cm^3)
Mercury	5.427
Venus	5.204
Earth	5.515
Mars	3.934
Jupiter	1.326
Saturn	0.687
Uranus	1.27
Neptune	1.638

Use the following key to answer questions 3 to 6.

- **A** Mercury, Venus, Earth, Mars
- **B** Mercury, Venus, Earth
- **C** Jupiter, Saturn, Uranus, Neptune
- **D** Saturn

Q3 Identify the planet(s) that are most likely to be rocky.

Q4 Identify the planet(s) you would most likely sink into.

Q5 Identify the planet(s) on which a lump of basalt would sink.

Q6 Identify which of the planet(s) would float on water.

Glossary

Unit 9.1

Astrology: the belief that the position of various celestial objects can directly affect the events of a person's life

Astronomy: the scientific study of stars, planets and other celestial objects

Constellation: a group of stars that forms a recognisable pattern in the night sky

Gas giants: the large planets of the outer solar system: Jupiter, Saturn, Uranus, Neptune

Milky Way: the galaxy in which the solar system is located

Terrestrial: Earth-like, rocky. The terrestrial planets are Mercury, Venus, Earth and Mars

Milky Way

Unit 9.2

Artificial satellites: satellites placed into orbit by humans

Ellipses: oval shape

Geocentric model: a model of the universe in which Earth is at the centre

Gravitational force field: invisible field that causes masses to be attracted to each other

Gravity: force of attraction between masses

Heliocentric model: model of the solar system in which the Sun is at the centre

Lunar eclipse: when the Earth blocks sunlight from reaching the Moon

Mass: matter

Orbit: path a planet takes around a star, or a moon or satellite takes around a planet

Phases: different shapes of the Moon as seen from Earth

Retrograde motion: apparent loop-like motion of the planets as seen from Earth

Satellite: a mass in orbit around another mass

Solar eclipse: when the Moon blocks sunlight from reaching the Earth

Tides: bulges in the ocean caused by the combined gravitational pull of the Moon and Sun

Unit 9.3

Axis: the line connecting the north pole with the south pole. The Earth rotates around this axis

Day: the time a planet takes to rotate once completely on its own axis

Leap year: 366 days

Revolution: one complete orbit around the Sun

Seasons: caused by the tilt of a planet's axis

Year: the time a planet takes to revolve once around the Sun

Day

Unit 9.4

Aphelion: point at which an object orbiting the Sun in an elliptical orbit is closest to the Sun

Asteroid: an irregular rocky object left over from the formation of the solar system; most are found orbiting the Sun between Mars and Jupiter

Asteroid belt: a group of asteroids orbiting between the orbits of Mars and Jupiter

Comet: a ball of ice, dust and rock that orbits the Sun in a highly elliptical orbit

Meteor: a meteoroid that burns up in the Earth's atmosphere

Meteorite: a meteoroid big enough to reach the surface of the Earth without burning up in the Earth's atmosphere

Comet

Meteoroid: a small piece of space rock that enters the Earth's atmosphere

Perihelion: point at which an object orbiting the Sun in an elliptical orbit is furthest from the Sun

Solar wind: stream of high-energy particles emitted from the Sun

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