# > 5.3 Weather and climate

## In this topic you will:

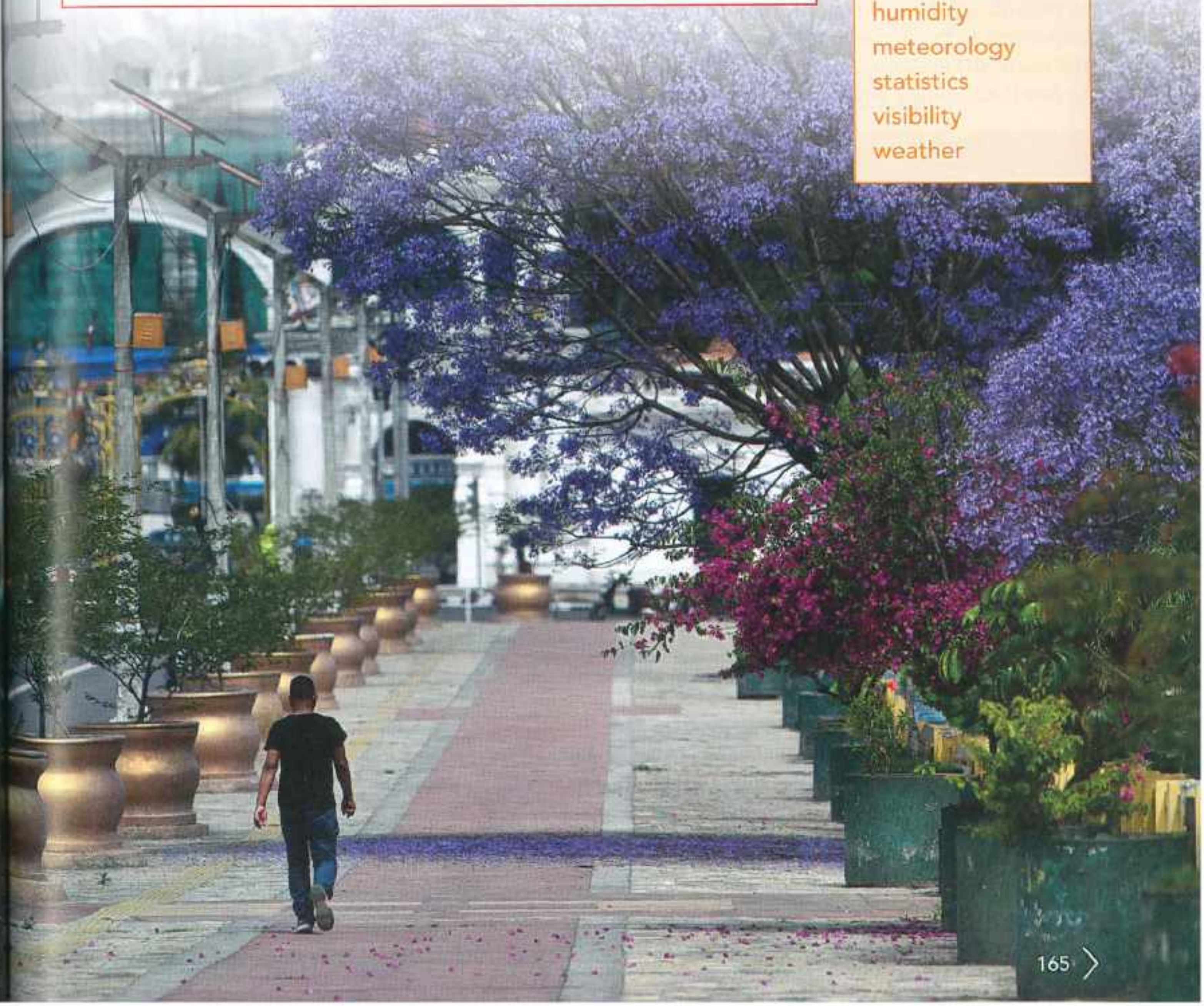
- learn the difference between weather and climate
- make observations of the weather.

## Getting started

With a partner, write down as many words about the weather as you can. Be prepared to share them with the class. You must be ready to explain the meanings of the words you write down.

## Key words

atmosphere
climate
climatology
humidity
meteorology
statistics
visibility
weather



# What is weather?

When you look out of the window, what is the **weather** like?

What people mean by weather is the state of the **atmosphere** and its changes from minute to minute, hour to hour, day to day, or week to week. In some places, the weather is very similar each day, but in others the weather changes frequently.

When people talk about the weather they say things such as, 'What is the weather like today?', 'How hot is it today?' or 'Will it rain tomorrow?' They are thinking in the short term.

People generally think about weather as the combination of temperature, **humidity**, precipitation, cloudiness, **visibility** and wind.

Countries all over the world take careful measurements of the weather to help predict what will happen next, to see patterns in the weather, and to provide information about the weather over time. For example, it is important to be prepared for snowstorms or heat waves as they can affect the transport systems, production of food, how much power people need to run their homes, and even what people want to buy in the shops.

Scotland

Namibia

New Zealand

Canada

Republic of Ireland

Bangladesh

## Questions

1 Describe the weather in each of the photographs. Use as many of the words from the *Getting started* task as you can.

2 Why do scientists take careful measurements of the weather?

## Activity 5.3.1

### Recording the weather

In this activity you will record the details of the weather over a period of at least a week.

#### Method

3 In your group, discuss which weather features you will be able to measure and/or observe. Share these ideas with the class.

4 After the discussion make a list of the weather features that you will measure and/or observe.

5 Decide how your group will collect this information.
What equipment will you need?
You may need to do some research to decide this.
You may need some laboratory equipment.
A camera might also be useful as you could take photographs to record cloud cover.

Remember that you should take readings at the **same time each day**. Record the temperature in the shade, not in full Sun. Make sure the bulb of the thermometer is not touching anything other than the air.

6 Prepare a results table to record your findings.

7 Record your findings each day for at least a week.

### Questions

1 Why should the readings be taken at the same time each day?

2 Why are the temperature readings always taken in the shade?

3 Write a report about the changes in the weather over the week.
In this report you should present your observations in an appropriate way.

4 Plot a line graph to show the changes in temperature during your investigation.

5 Compare your readings with someone else in your class. Are there any differences and, if so, can you give reasons for the differences? Is this comparison a fair comparison?

6 Compare your readings with those that are recorded nationally. You could use the internet to find these. Are yours different? If so, explain why they are different. Is this comparison a fair one?

## Activity 5.3.2

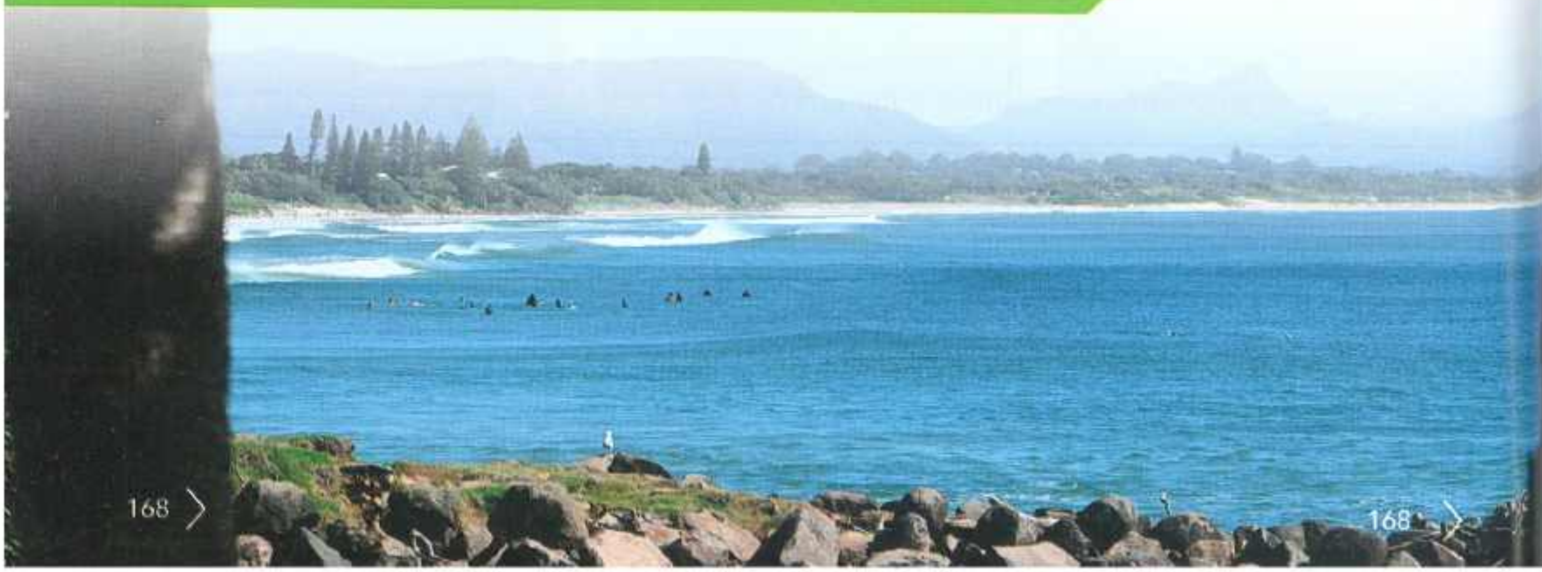
### Finding out about the weather

In this activity you will find and evaluate information about the weather in a particular place.

1. Work with a partner. Choose a place, anywhere in the world. It might be somewhere you would like to go on holiday – a beach, mountains for skiing, or somewhere to sail a boat.
2. Find as much information as you can about the weather in that place. For example: What is the average number of hours of sunshine? How much rain is expected? How windy is it? How much snow will there be?

   Make sure you find information from different sources. You might look at websites for travel agents, the national weather service or local weather watchers. You could also look at past weather records over a few years and compare them.
3. Think about these questions and discuss them with your partner:
   - Is the information you find from all sources exactly the same?
   - Can you suggest why this is?
   - Which source of information do you think is more reliable?
   - Could some sources be biased? Perhaps someone wants to give the best view of the weather to encourage you to go there.
4. Present your findings, as a poster or a talk, and suggest the best time of year to visit your chosen place. Use the suggested questions as a starting point to explain which sources of information you have used and how much you feel able to trust the information.

How can I explain the difference between the weather and the climate where I live?

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## Weather or climate?

What is the difference between weather and **climate**?

When people talk about climate, they mean the weather of a place over a much longer time, usually more than 30 years. Weather can change in a few hours or even in minutes.

Climate is the average weather in an area and takes several years to change. Climate information includes the **statistics** of weather information that tells us about the normal weather as well as the range of extreme weather at that place.

Weather is affected by factors such as temperature, humidity, cloudiness and precipitation.

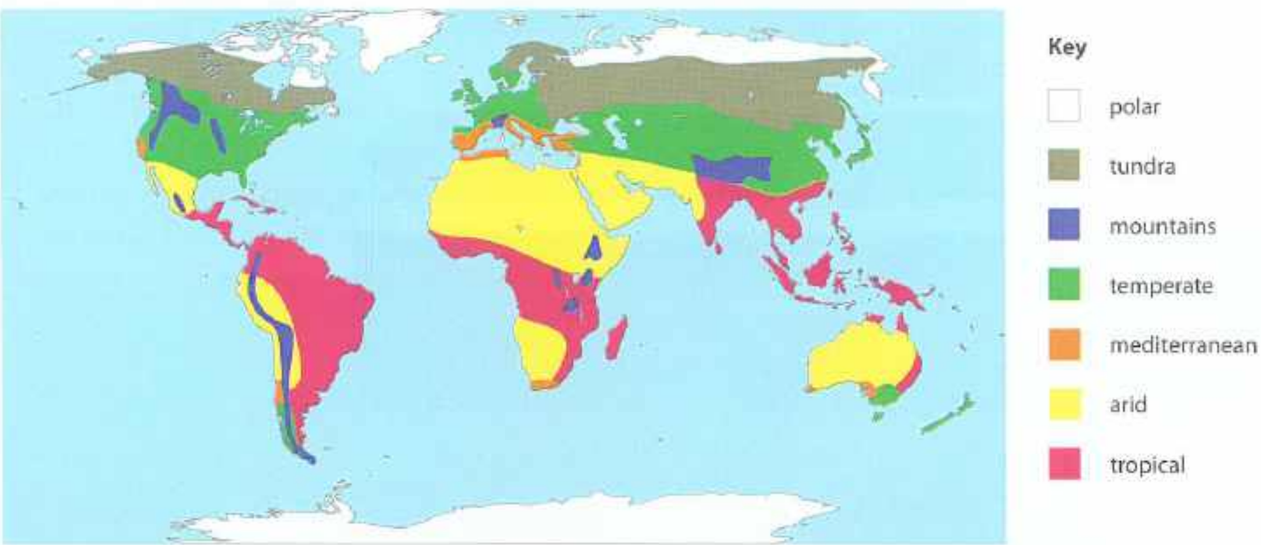
Climate is affected by two key factors: temperature and precipitation.

The study of weather is called **meteorology**.

The study of climate is called **climatology**.

## Climate zones

The map below shows the main climate zones on Earth. The key shows the names of these zones.



Each zone has a characteristic climate.

| Climate zone | Description of climate |
|---|---|
| Polar | very cold and dry all year |
| Temperate | cold winters and mild summers |
| Arid | hot and dry all year |
| Tropical | hot and wet all year |
| Mediterranean | mild winters and hot, dry summers |
| Mountains/tundra/taiga | very cold all year |

## Questions

3 Which climate zone do you live in?

4 Name **two** countries that are in the arid zone. (You may need to use an atlas to help you.)

5 Name **two** countries that have areas with a Mediterranean climate but are not near the Mediterranean Sea.

6 Name **three** countries that are in the tropical zone.

7 What is the difference between the climate in the arid zone and the tropical zone?

8 What are the differences between the climate in the temperate zone and the Mediterranean zone?

What do I notice about how the climate zones are distributed?

### Summary checklist

- [ ] I can explain the difference between weather and climate.
- [ ] I can make observations and take measurements of the weather.

# > 5.4 Climate and ice ages

## In this topic you will:

- learn about how the Earth's climate has changed
- find out about ice ages, glacial periods and interglacial periods
- look at some evidence that the Earth's climate cycles between colder and warmer periods.

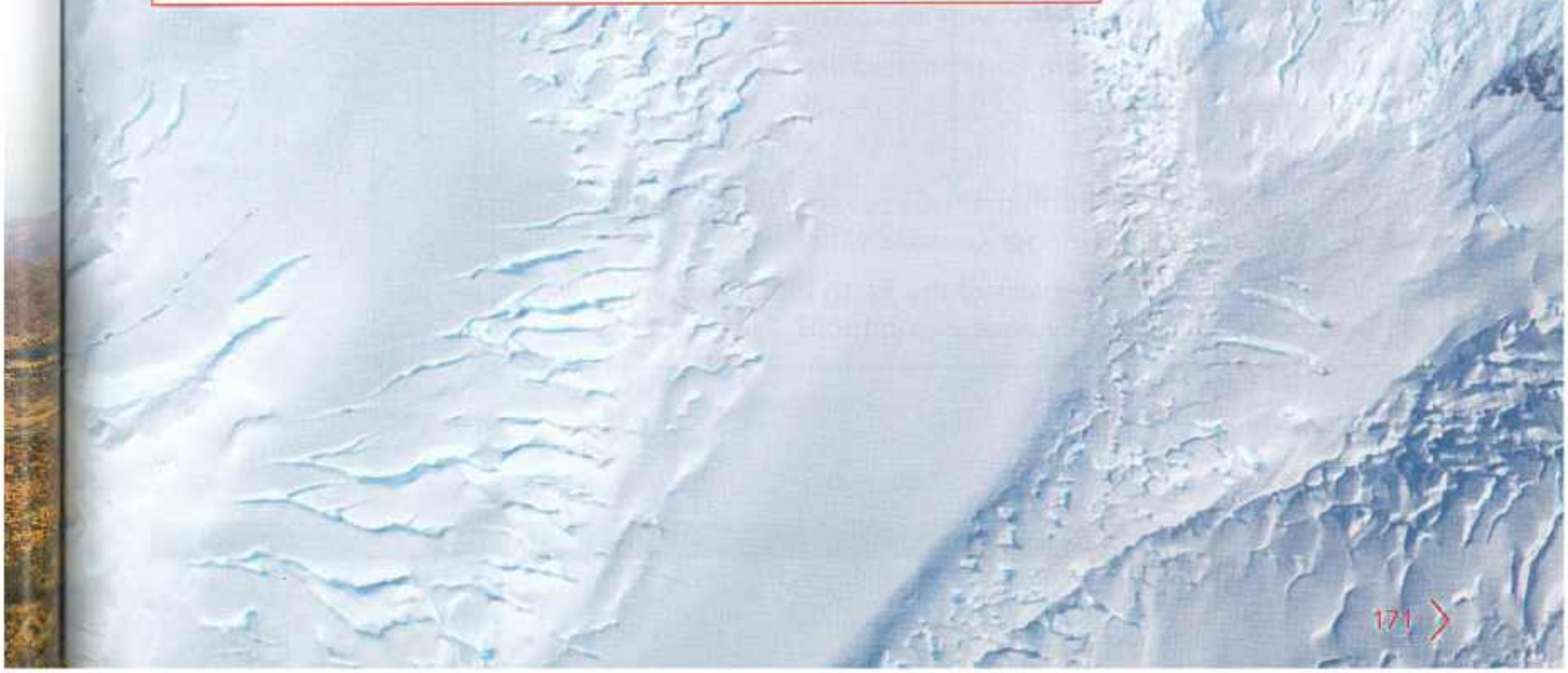
## Getting started

The photgraph shows the body of a baby mammoth, which has been named Yuka. Her frozen body was discovered in 1977 in eastern Siberia. In that part of the world, it is so cold that the lower layers of the soil stay frozen solid all year round. Scientists think that Yuka lived and died about 39 000 years ago, when the temperature was even colder than it is now.

With a partner, discuss why Yuka's body has been preserved for so long. Be ready to share your ideas with the rest of the class.

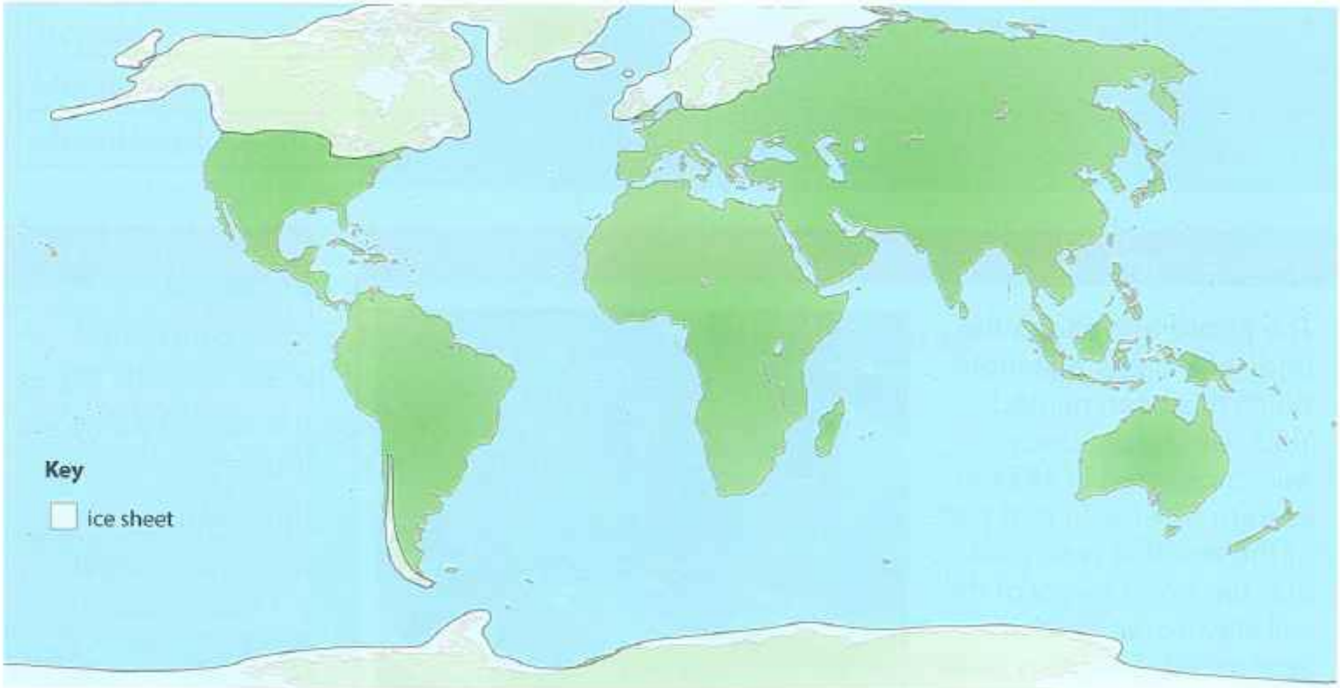
## Key words

boulder
cycle
glacial period
glaciers
ice ages
interglacial period
peat bog



# Ice sheets

Look at the photograph in the *Getting started* section. When Yuka was alive, and for thousands of years afterwards, the Earth was much colder than it is now. The map shows the parts of the world that were covered by ice sheets 25 000 years ago.




## Activity 5.4.1

### Where in the World is there ice?

Working in a group of three or four, use an atlas to find out which parts of the Earth are covered with ice today.

Compare this with what the Earth looked like 25 000 years ago. Be ready to share your ideas.

### Questions

1 Name a part of the Earth that was covered with ice 25 000 years ago, but is no longer covered with ice.

2 When you look at the parts of the Earth that are covered with ice today, what do they have in common?

# Glacial and interglacial periods

The very cold period when Yuka lived lasted until about 10 000 years ago. Because so much of the Earth was frozen, it is called a **glacial period**. 'Glacial' means 'frozen'. Today, the Earth is in an **interglacial period**. 'Inter' means 'between'. Over the last 450 000 years, the Earth's climate has cycled, or swung, between glacial and interglacial periods.

- In an interglacial period, there is permanent ice close to the North and South Poles.
- In a glacial period, the ice spreads much further south from the North Pole and further north from the South Pole.

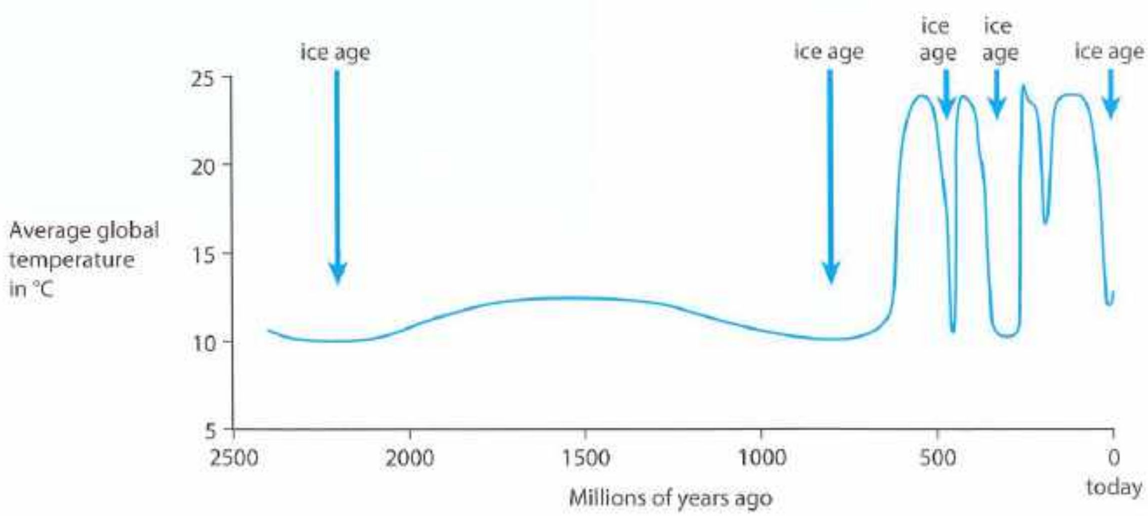
When Yuka was alive, the Earth was in a glacial period; much more of the Earth was frozen than now

## Ice ages

Looking even further back in time, scientists have found that this **cycle** of glacial periods and inter-glacial periods did not always happen. There were long periods of time when Earth was so warm that there was no permanent ice on its surface, not even at the North Pole or South Pole.

In between these warm periods, there were cold periods, with glacials and interglacials. These cold periods are called **ice ages**.

The graph below shows when scientists think the ice ages happened on Earth. They think the second one, which began about 850 million years ago, was the coldest. Some scientists think that the whole Earth was covered with ice and snow then. The Earth was like a giant snowball.



### Questions

1 How many ice ages do scientists think there have been on Earth?

2 Is the Earth in an ice age now? Explain why you think that.

3 Explain the difference between a glacial period and an ice age.

4 Is the Earth in a glacial period now?

## How do scientists know the Earth was colder in the past?

The photograph shows some **boulders** (big rocks) in California, USA. People have often wondered how rocks like this got into their strange positions. The best explanation is that they were carried there by ancient **glaciers**. Glaciers are rivers of ice that move slowly downhill (they are formed from snow that, over many years, becomes compressed into thick masses of ice). The glaciers carry rocks with them. If the glacier melts, the rocks are left behind. Sometimes, scientists can see scratches on the rock surfaces, where the moving ice dragged other rocks across them.

These rocks are in Yosemite National Park, in California; scientists think they were left behind when a glacier melted, thousands of years ago

Boulders like this were the first clue that there were glaciers in parts of the Earth that are much warmer now. Later, other evidence was found that supports this idea. For example, in places that are now quite warm, there are fossils of animals and plants that were adapted to live in very cold places.

A glacier in Iceland

### Questions

5 Use an atlas or the internet to identify and list glaciers nearest to where you live.

6 When rivers run through rock, they wear the rock away. This sometimes creates very deep valleys, such as the Grand Canyon in Arizona. When glaciers moved millions of years ago, they left their mark on the landscape. Find out about and describe the effect that glaciers had on the land.

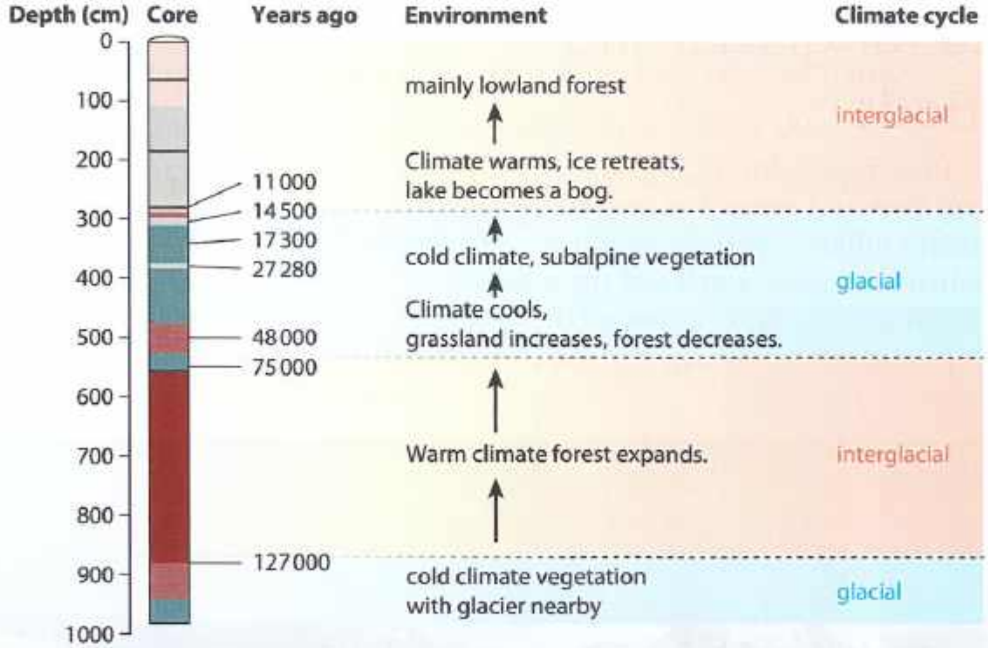
## Pollen evidence for glacial and interglacial periods

When plants die they decay. In some conditions, without oxygen and slightly acid, the decay is very slow and a **peat bog** may be formed. The different layers of peat represent different periods of history: the deeper the peat, the older it is. Scientists can take samples of the peat bog by using an instrument called an auger to remove a core of the peat bog. They must be careful to remove the core and keep it in the correct order so that they know which part is oldest.

This scientist is using an auger to extract a core sample from beneath the ice

A core sample from a peat bog showing different layers

In New Zealand, a scientist extracted a core of soil from a peat bog. The deepest level of the soil in the core was formed 127 000 years ago. The scientist collected pollen from different parts of the core. He identified the plants from which the pollen came. Because he knew the type of climate that each kind of plant can live in, he was able to work out what the climate was like between 127 000 years ago and now.




## Summary checklist

- [ ] I can describe how the Earth's climate has changed in the past.
- [ ] I can explain the difference between ice ages, glacial and interglacial periods.
- [ ] I can give some evidence that the Earth's climate cycles between colder and warmer periods.

# > 5.5 Atmosphere and climate

## In this topic you will:

- learn about the atmosphere of the Earth
- learn how a change in the atmosphere can affect the climate
- learn about renewable resources.

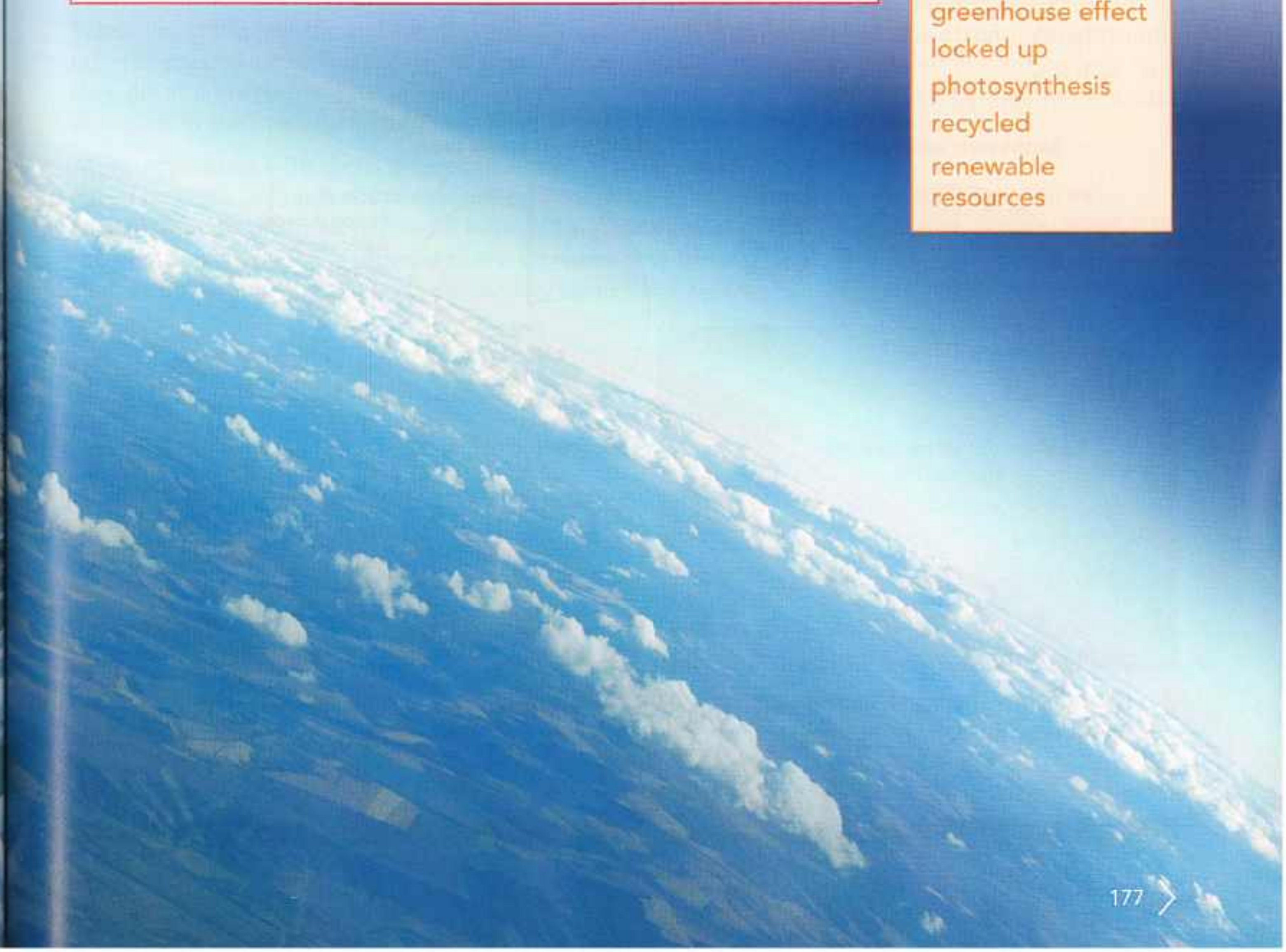
## Getting started

What is an ice age? What evidence is there to show that the Earth's climate was different in the past?

Think about the two questions. Write down your ideas. Then discuss them with a partner. Together, sort your ideas out and be prepared to share them with the class.

## Key words

bioplastics
deforestation
emissions
fossil fuels
global warming
greenhouse effect
locked up
photosynthesis
recycled
renewable resources

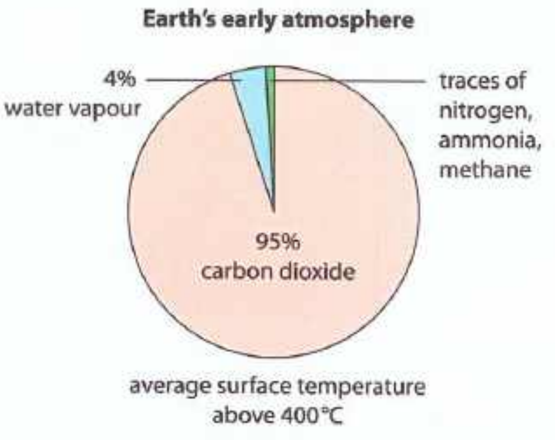


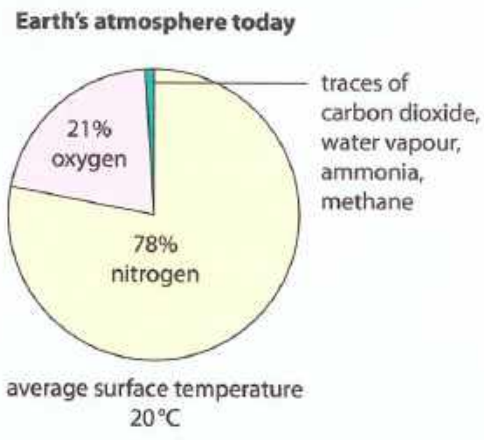
# The atmosphere

The atmosphere is a layer of gas above the Earth's surface. It is very different today from the atmosphere when the Earth formed.

Scientists think that the Earth formed about 4600 million years ago. The Earth was very hot and it was molten for millions of years. Then, as the Earth cooled, a solid crust formed. There was a lot of volcanic activity, much more than there is now. The volcanoes produced gases, which formed the early atmosphere. Water vapour was produced by the volcanoes and, as the Earth cooled, this water vapour condensed into liquid water. The water fell as rain and formed the first lakes and oceans.

About 4000 million years ago, scientists think that the atmosphere contained mainly carbon dioxide, little or no oxygen, small amounts of methane and ammonia gas, and some water vapour. This early atmosphere on Earth was like the atmosphere on Venus is today. The temperature on Venus is very high – on the surface, it is 467 °C which is hot enough to melt lead.




## Questions

1 Where did the early atmosphere on Earth come from?

2 Give **at least two** differences between Earth's early atmosphere and the atmosphere today.

3 Explain why the Earth's early atmosphere was not suitable for humans or any other animals.

# Changes to the atmosphere

About 3500 million years ago, micro-organisms developed on Earth. They lived in the oceans. They used the carbon dioxide in the atmosphere to make food. They produced oxygen as a waste product of this process. As plants developed over millions of years, they began to grow on land. Plants use carbon dioxide to produce food (glucose, a sugar) by the process of **photosynthesis**.

carbon dioxide + water → glucose + oxygen

The levels of oxygen in the atmosphere continued to rise. Scientists know this because there was enough oxygen to combine with iron in the rocks to form iron oxide.

These rocks in Dallo, Ethiopia, have bands of red iron oxide and date from about 2.1 to 2.0 billion years ago

By 200 million years ago there was very little carbon dioxide left in the atmosphere. Most of the carbon had been used to make the chemicals, which are part of all living things.

When the organisms die and rot, the carbon in them is released back into the environment. It is **recycled**. Some organisms do not rot when they die and are turned into **fossil fuels** such as oil or coal. The carbon is **locked up** in the fossil fuels until they are burned.

Many organisms with shells evolved around 600 to 400 million years ago. The shells are made from calcium carbonate, $CaCO_3$. When these shelled animals died and fell to the bottom of the oceans as sediment, the many layers of shells pressing down on each other formed rocks, such as limestone. So, carbon is also locked up in these rocks.

Fern fossil in coal

This limestone is full of fossils of animals with shells

Scientists can find out about the composition of the atmosphere in the past by analysing the pockets of air trapped inside samples of ice cores. The ice cores are taken from deep layers of polar ice that were formed many hundreds of thousands of years ago.

### Questions

4 What are fossil fuels?

5 How did the carbon dioxide in the atmosphere get used up?

6 What evidence is there that the levels of oxygen increased?

7 What two elements are present in carbon dioxide?

8 What three elements are present in calcium carbonate?

9 Limestone is a sedimentary rock. How is it formed?

10 When did carbon first start to be locked up?

## Atmospheric changes today

The amount of carbon dioxide in the atmosphere fell until about 200 years ago. Then the levels of carbon dioxide began to rise. Where is the carbon dioxide coming from? Humans caused this rise because they started to release the carbon that had been locked up in the Earth for millions of years. They burn fossil fuels, such as oil and coal, to keep themselves warm.

carbon + oxygen → carbon dioxide

As humans developed industry and transport, they burned more and more oil and coal. So, there are greater **emissions** of carbon dioxide. Humans use a lot of fossil fuels to generate electricity in power stations.

A container ship burning diesel

Brick factories producing waste gases from fossil fuel

Cars burning petrol

Humans also make the situation worse as they cut down forests of large established trees that use a lot of carbon dioxide in photosynthesis. This **deforestation** is done for many reasons: to use the wood for building or to make things, to get to resources such as minerals which are mined, to produce crops for profit such as palm oil, to grow more food crops or to provide pastures for animals such as cattle. Because there are fewer trees, less of the carbon dioxide is being used up, so the level in the atmosphere increases. Cattle eat the grass and produce carbon dioxide and methane in their intestines. This also changes the atmosphere.

This forest is being cut down to provide wood

Many of the trees in this forest have been cut down to grow palm oil plants

This forest is being cut down to provide more land for agriculture

When limestone, which consists of calcium carbonate, is used to make other products such as building cement, the carbon in the calcium carbonate is released into the atmosphere.

calcium carbonate → calcium oxide + carbon dioxide

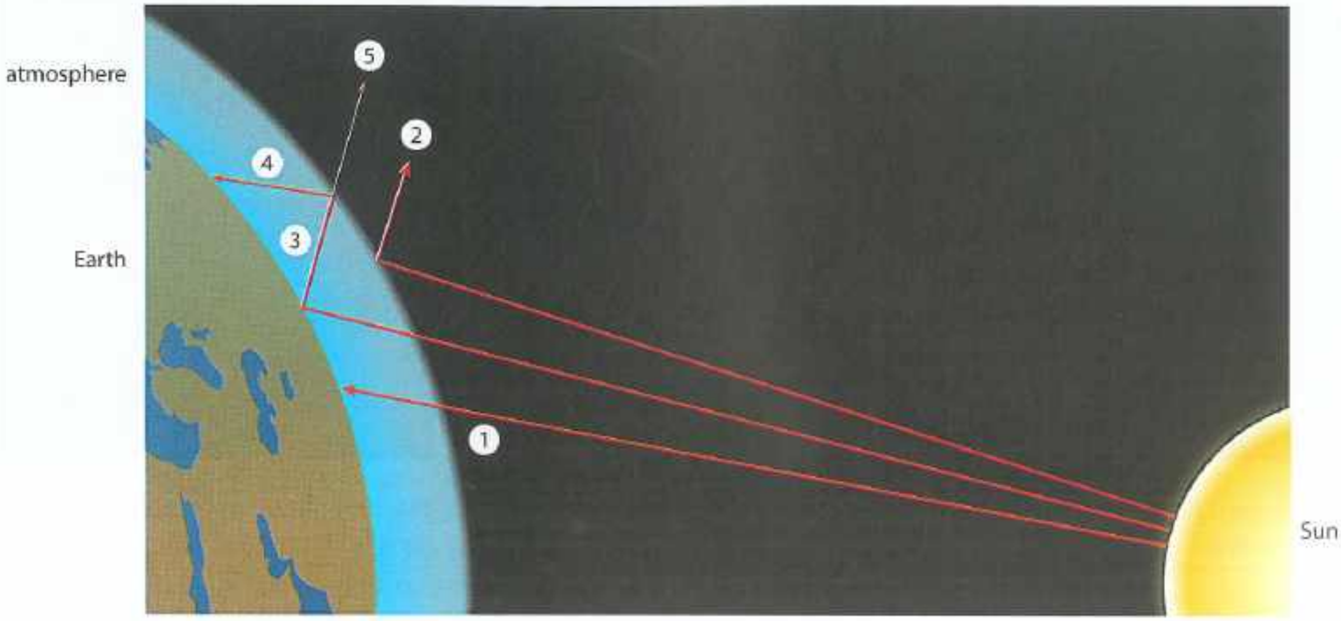
All these things lead to a change in the atmosphere and an increase in carbon dioxide levels.

## Atmospheric changes and climate

There is evidence that the carbon dioxide and other gases, such as methane, act like a blanket around the Earth. This is an analogy. The 'blanket' represents the gases that keep the Earth warm. Another analogy is that the gases are like putting the Earth in a greenhouse. A greenhouse lets in light and heat from the Sun, but heat energy is trapped inside.

Think about how an analogy can help you to understand an idea.

The layers of gases produce the **greenhouse effect**. This is a natural effect; without it, the Earth would be much colder. However, increasing the levels of greenhouse gases, such as carbon dioxide, methane and water vapour, increases the greenhouse effect. So, as the levels of carbon dioxide, methane and water vapour increase, the amount of heat escaping decreases, and so the Earth's climate becomes warmer. This is known as **global warming**.



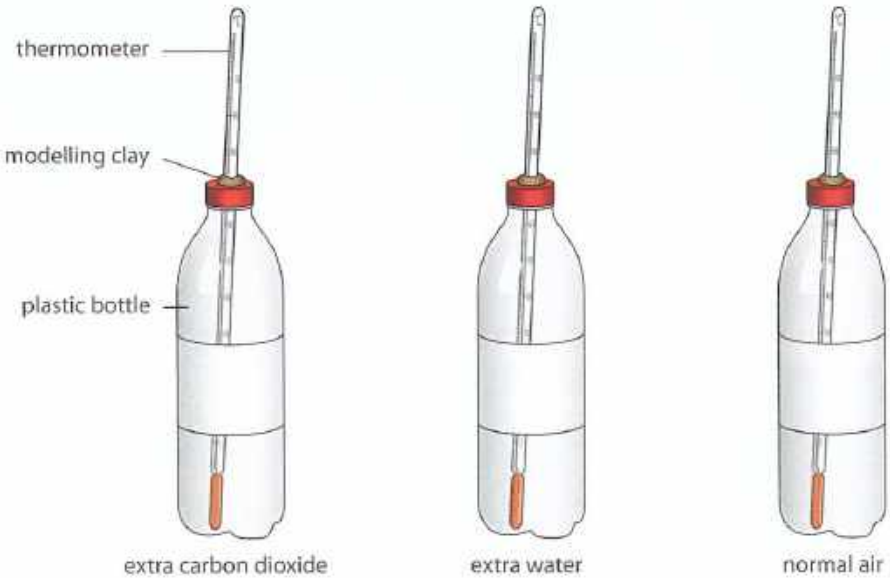

1. Energy from the sun falls on the Earth and warms it up.
2. Some of this energy does not get through the atmosphere and is reflected back into space.
3. Energy leaves the Earth and passes into the atmosphere.
4. Much of this energy is reflected back to Earth by the layer of greenhouse gases such as carbon dioxide, methane and water vapour.
5. Some of this energy from the Earth passes through the atmosphere into space.

## Think like a scientist

### The greenhouse effect

You will need:

- three large plastic bottles, such as 2-litre drinks bottles with lids, with a hole in each lid
- three thermometers
- a means of fixing the thermometers in place, such as modelling clay
- carbon dioxide supply




### Method

1. Place a thermometer in each of the bottles so that the bulb does not touch the bottle in any way.
2. Add some carbon dioxide to one bottle.
3. Add about 5 $cm^3$ of water to another bottle.
4. Leave the third bottle with normal air.
5. Label the bottles.
6. Place the bottles alongside one another outside. If this is not possible, you can leave them in the classroom near the window.
7. Take the temperatures in each bottle at the start.
8. Record the temperatures in the three bottles over the next few days. It is up to you to decide when and how often.

Continued

**Questions**

1 What did you consider when deciding when and how often to take readings?
2 Present your findings in a table.
3 What do your results show?
4 Why did you have one bottle with normal air in it?
5 Can you explain why you got these results?
6 How could you improve the investigation?

# Reducing global warming

You have seen that humans contribute to global warming by burning fossil fuels. One way to reduce this impact is to use **renewable resources**.

A renewable resource is one that does not deplete (run out) or can be replenished within a human's life time. Examples include wind, tidal and solar power.

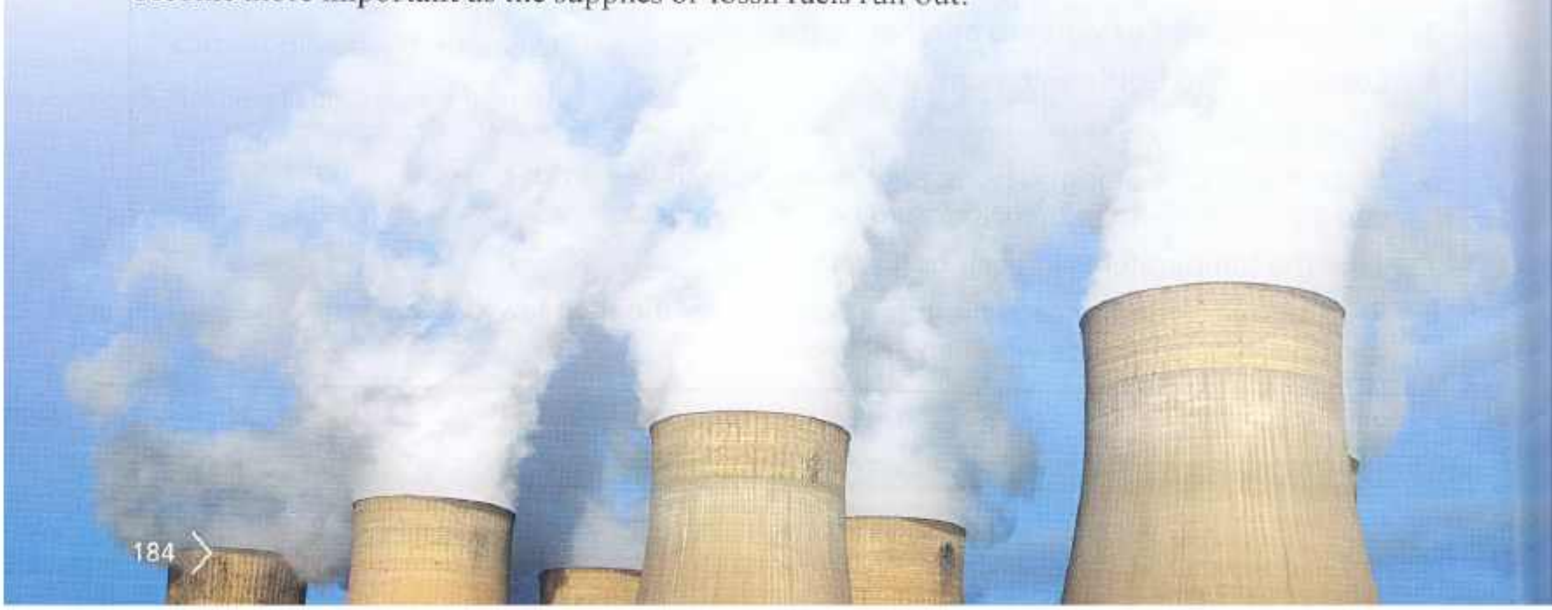
A non-renewable resource is a resource that cannot be replaced after it is used. Examples include coal, petroleum, and natural gas.

## Renewable resources

When fossil fuels are burned to generate electricity, carbon dioxide is produced. This adds to the problem of global warming.

The more electricity is produced, the more carbon dioxide adds to the problem.

To reduce global warming, people need to generate more of their electricity from renewable energy resources. These energy resources will become more important as the supplies of fossil fuels run out.



## Wind

People have been using the power of the wind for hundreds of years. They used windmills to grind wheat into flour and to pump water. Now they use wind turbines to generate electricity. You need a lot of wind turbines to generate as much electricity as a power station so wind turbines are grouped together to form wind farms. No harmful waste product, such as carbon dioxide, is produced when electricity is generated in this way. The problem with wind-generated power is that electricity is only produced when the wind blows.

This windmill in France was used to grind wheat

This wind pump is used to pump water on this farm

This wind farm, made up of many wind turbines, is used to generate electricity in China

## Tidal

Tides make water rise and fall twice every day. This happens as a result of the pull of the Moon's gravity as the Earth spins. It is possible to use this movement to generate electricity. To do this, water in river estuaries is trapped behind a barrier and then released as the tide goes out. When released, the water flows through electricity generator turbines. The problem is that electricity is only generated at certain times each day. Also, the barrier may interfere with wildlife habitats.

A hydroelectric turbine at a tidal farm in Brest, North West France

## Solar

The energy from the Sun can be used to generate electricity. Photovoltaic cells can change solar energy to electrical energy. This can only happen when the Sun is shining.

These photovoltaic cells are part of a large solar energy farm in Mexico

# Bioplastics

The use of plastics has developed over the past hundred years. Plastics are useful materials but they have one big problem: they do not break down easily and cause many problems for wildlife when they are thrown away. The waste builds up on land and in the oceans. Humans produce a lot of plastic waste, especially from plastics that are only used once.

**Bioplastic** is a biodegradable material that comes from renewable sources (biomass, such as vegetable oils, sawdust or food waste). Conventional plastics are made from petroleum.

Plastic waste on a beach

Cutlery made from biodegradable bioplastic

The use of bioplastics from renewable sources will help to reduce the use of fossil fuels and to prevent damage to the environment caused by disposal of single-use plastics.

What can I do to reduce my use of single-use plastics?

## Summary checklist

- [ ] I can describe Earth's atmosphere today and in the past.
- [ ] I can describe how a change in the atmosphere can change the climate
- [ ] I can identify renewable sources of energy.
- [ ] I can explain how the use of renewable energy sources will reduce the greenhouse effect.

## Project: Global warming and climate change debate

### Background

In June 2019, the **average world** temperature was 16.6 °C. It was an increase of 1.1 °C above the average global temperature for the whole of the twentieth century. During this worldwide heat wave there were:

- wildfires in the Arctic with millions of hectares burning in Northern Russia
- severe water shortages in India
- more than 5000 people in Japan taken to hospital for treatment due to heat
- a huge impact on the growth of crops.

July 2019 was the hottest on record in Europe. People died of heat stroke. Overhead power cables expanded in the heat and failed. Crops were damaged so food production was affected.

Scientists say it is the latest sign that the Earth is experiencing a huge increase in global warming. Nearly all scientists think that the rise in carbon dioxide emissions from human activities is altering the temperature. A climate researcher from the European Union's Copernicus Climate Change Service, said in a television interview:

> 'This particular month has been very warm, but to me this is not the main point. All the months of 2019 have been warm in comparison to other years. And that trend is not likely to stop unless we do something about reducing the emission of greenhouse gases.'

However, some people think that the change in temperatures is just part of the Earth's normal cycle and there is no need to reduce the emissions of greenhouse gases as there is no proof it is these gases that cause climate change.

### Your task

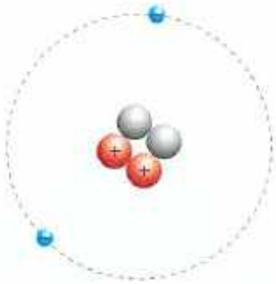
Work in groups of two to four. Create two lists of evidence and give your reasoning: one list in support of the idea that humans are contributing to climate change, and one list that does not support that idea.

Your teacher will select which point of view each group will represent. During the debate your group must stick to the point of view you have been given.

# Check your progress

**5.1 a** Copy the diagram of a helium atom and label it, using these labels.

**proton** **neutron** **electron** **nucleus**



[4]

**b** Name the subatomic particle that:

**i** has a positive charge [1]

**ii** has no charge [1]

**iii** has the least mass [1]

**iv** is made up of protons and neutrons. [1]

**5.2** Gold jewellery is marked to tell you how pure the gold is.
Which is the marking that has the most gold? Write **one** letter. [1]

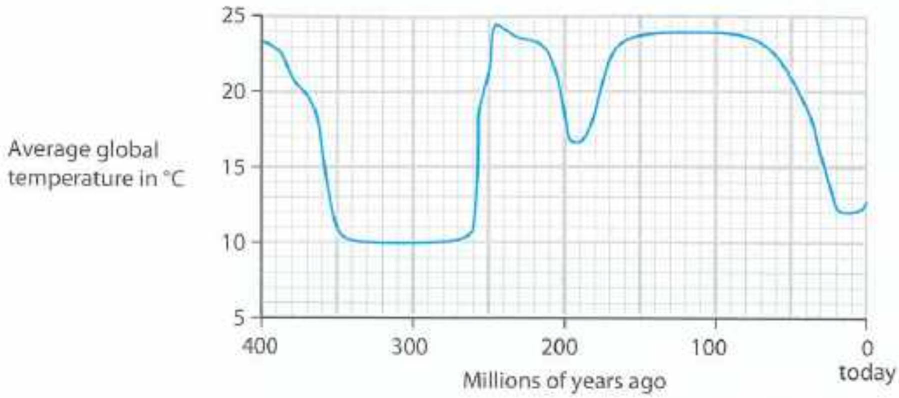
**A** 15 carat gold **B** 9 carat gold **C** 18 carat gold

**5.3** Pure diamond is made up of carbon atoms arranged in a particular way.
How do pure diamonds differ from diamonds that contain other elements? [1]

**5.4** Match the terms, A–E, with the meanings, 1–5. [5]

| | |
|---|---|
| **A** weather | **1** a measure of the amount of water vapour in the atmosphere |
| **B** climatology | **2** the state of the atmosphere in a particular place |
| **C** climate | **3** the study of weather |
| **D** meteorology | **4** the weather conditions prevailing in an area in general and over a long period |
| **E** humidity | **5** the study of climate |

**5.5** The graph shows the average global temperatures over the past 400 million years.




- **a** What was the average global temperature between 330 and 280 million years ago? [1]
- **b** What is this period of time known as? [1]
- **c** What was the average global temperature 100 million years ago? [1]

**5.6** Greenland has been frozen for a long time. Scientists study ice cores from deep in the ice in Greenland. How does this help us to understand how our atmosphere has changed over time? [2]

**5.7** What evidence is there that the Earth is getting warmer? [2]

**5.8** The atmosphere has changed since the Earth formed.
For each of these statements write true or false.

- **a** The atmosphere now has more carbon dioxide than the earlier atmosphere. [1]
- **b** The early atmosphere had little or no oxygen. [1]
- **c** The atmosphere was formed from the gases produced by volcanoes. [1]
- **d** The atmosphere today contains about 50% nitrogen. [1]
- **e** The atmosphere today contains about 0.04% carbon dioxide. [1]

**5.9**
- **a** Much of the electricity you use is generated using fossil fuels.
Name **three** ways electricity can be generated without using these fuels. [1]
- **b** What is meant by the term 'global warming'? [2]
- **c** Explain how using fossil fuels adds to the problems of global warming. [2]

**5.10** What is an analogy? Give an example. [2]

# 6 Light

## 6.1 Reflection

**In this topic you will:**

- describe how light is reflected from a plane surface
- understand the law of reflection
- be able to draw ray diagrams to show reflection of light.

**Getting started**

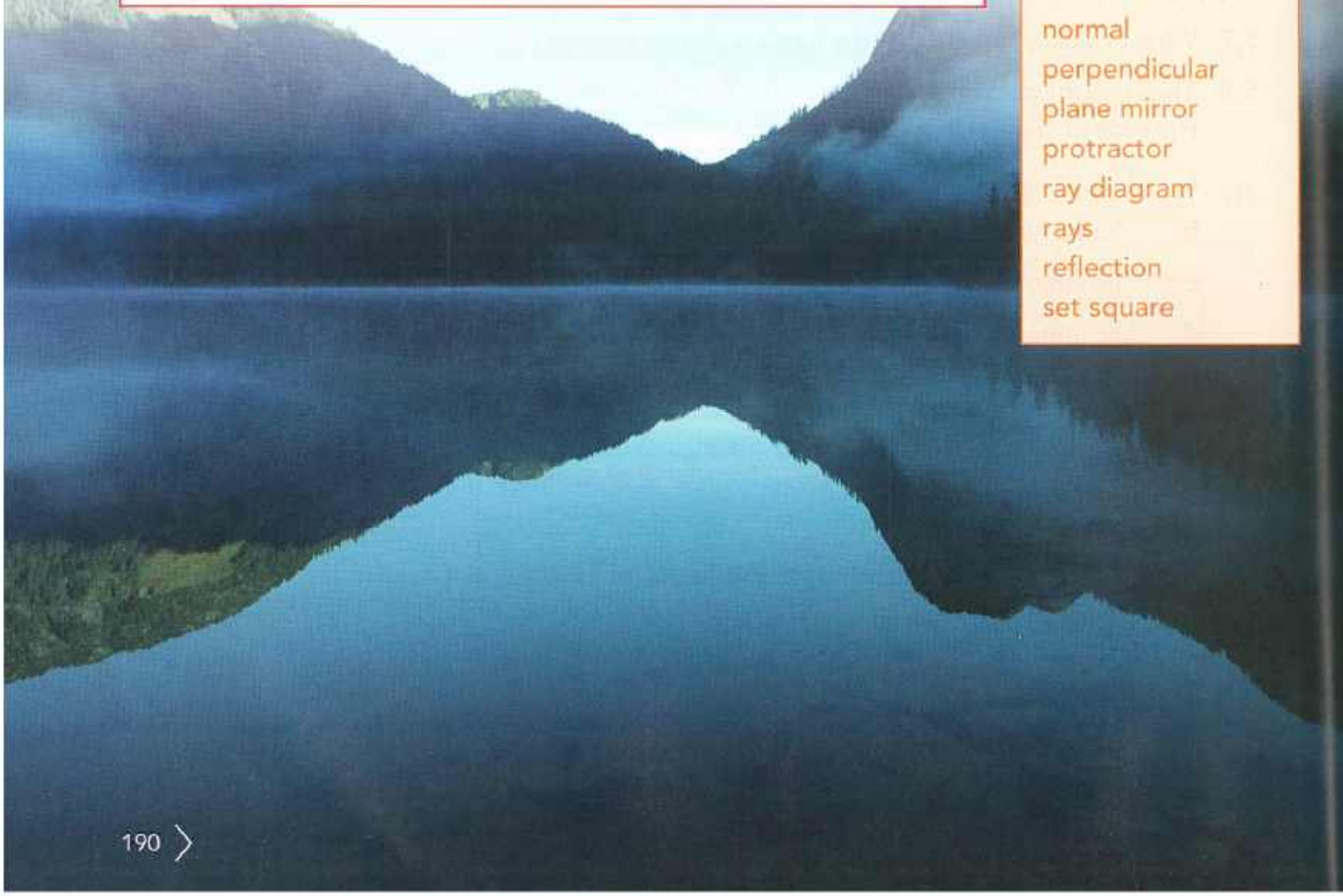
Work in groups to discuss answers to these questions.

1 Does light travel in straight lines or in curved paths?

2 Describe the evidence to support your answer to question 1.

**Key words**

angle of incidence
angle of reflection
incident ray
law of reflection
normal
perpendicular
plane mirror
protractor
ray diagram
rays
reflection
set square



# Reflection

When you think of **reflection** you probably think of using a mirror.

Most of the mirrors you use are **plane mirrors**. Plane means a flat surface.

To see what reflection looks like from a surface that is not plane, you can look at your own reflection from a spoon. The reflection is distorted.

Remember that light travels in straight lines called **rays**.

A light ray arriving at a surface, such as a mirror, is called an **incident ray**. An incident ray is the ray coming onto a surface.

The incident ray makes an angle with the surface of the mirror. Measure this angle from a line perpendicular to the mirror and not from the mirror itself. The line **perpendicular** to the mirror is called the **normal**.

In physics and maths, 'normal' means perpendicular or at right angles to something.

We can use this information to draw **ray diagrams**. They show what happens to the light rays during reflection.

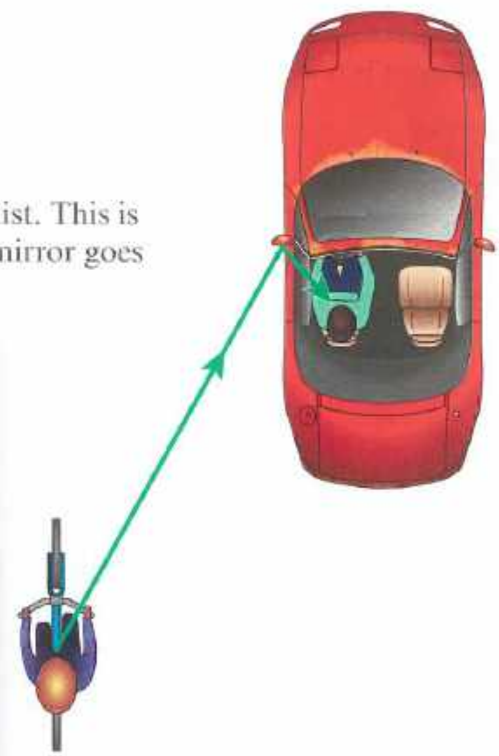
Ray diagrams should obey the **law of reflection**: the angle of reflection is equal to the angle of incidence.

In science, a law is something that always applies.

We can use the law of reflection in everyday situations.

For example, mirrors can be used to see behind us.

In this picture, light from the Sun is reflected from the cyclist. This is the incident ray on the mirror. The reflected ray from the mirror goes to the driver's eye.



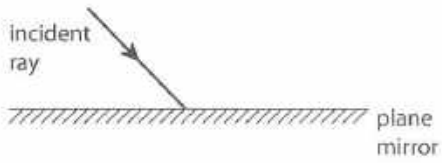
The driver of the car can see the cyclist by using this mirror; the ray diagram shows how this works

# Drawing ray diagrams

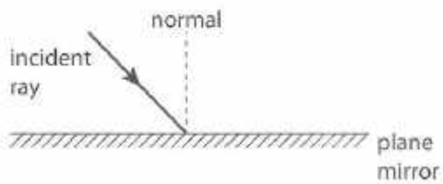
When drawing light rays, always use a ruler and put an arrowhead on the ray to show its direction.

1 Draw the incident ray and the mirror. Sometimes, this is done for you.

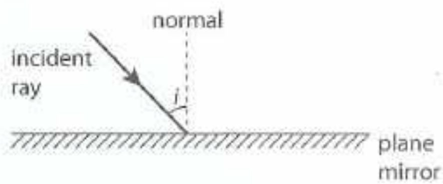

2 Use a ruler to make the incident ray meet the mirror.



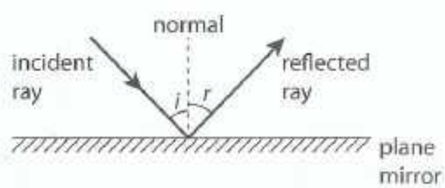

3 Use a **protractor** or **set square** to draw the normal. The normal is perpendicular to the mirror where the incident ray meets the surface. The normal is usually a dashed line so it is not confused with the light ray.




4 Use a protractor to measure the angle between the incident ray and the normal. We call this angle the **angle of incidence** or *i*.



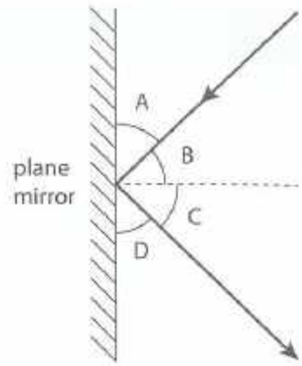

5 Measure an angle equal to the angle of incidence on the other side of the normal. This angle is called the **angle of reflection** or *r*. Draw a reflected light ray coming away from the mirror at this angle. Remember to put an arrowhead on the reflected ray.



## Questions

1 Which of the angles in this diagram is the angle of reflection?

Write the letter.



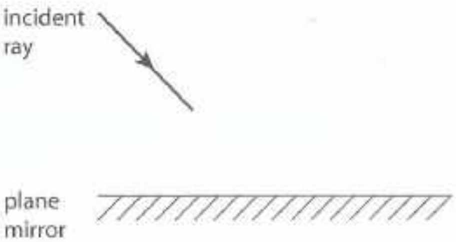

2 Copy this ray diagram. You do **not** have to measure angles for making your copy.

a Extend the incident ray to meet the mirror.

b Draw a normal where the incident ray meets the mirror.

c Measure and write down the angle of incidence.

d Draw a reflected ray in the correct place.



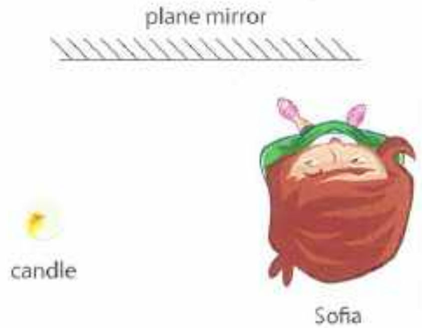

3 Sofia looks at a candle in the mirror.

Copy and complete the diagram to show how light from the candle reflects from the mirror to Sofia.

You do **not** have to measure the angles.

Draw and label:

- the incident ray
- the normal
- the reflected ray
- the angle of incidence
- the angle of reflection.

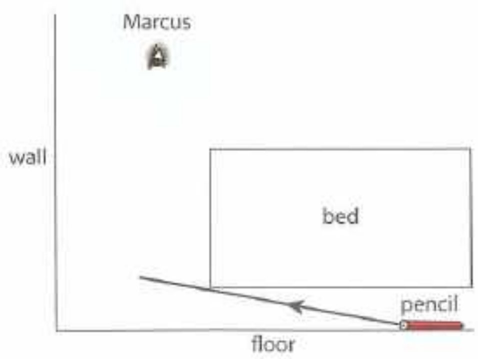



4 Marcus drops a pencil. The pencil rolls under his bed. Marcus cannot see the pencil.

The diagram shows a light ray coming from the pencil.

Marcus can use a mirror to see the pencil.

Copy and complete the diagram by adding a mirror and a reflected light ray to show how Marcus can see the pencil. You do **not** have to measure the angles.



## Activity 6.1.1

### Mirrors and reflections

Work in pairs.

Make a list of places where mirrors are used.

In each of your examples, describe why a mirror is used.

Reflections can also be seen from some surfaces that are **not** mirrors.

Make a list of some of these surfaces.

What do these surfaces have in common?

## Think like a scientist

### Measuring angles of incidence and reflection

In this investigation, you will investigate the law of reflection.

Work in pairs or groups of three.

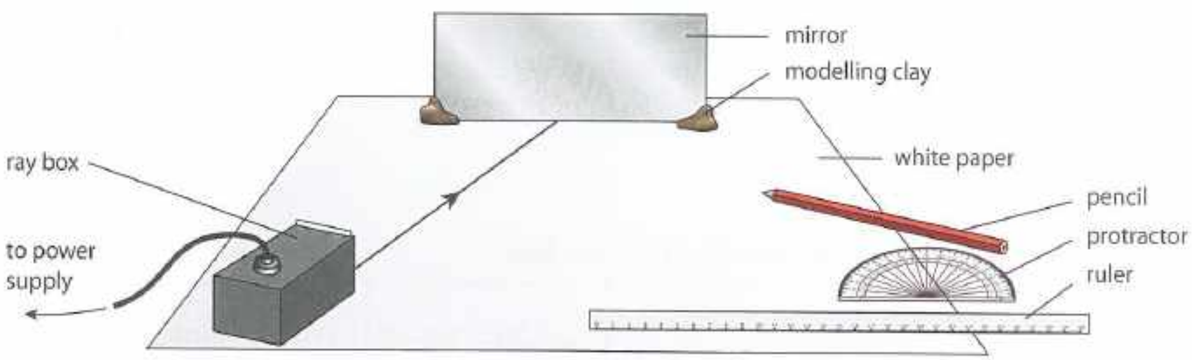
Make the room as dark as possible for this activity.

**You will need:**

- equipment shown in the diagram

### Method

1 Set up the equipment as shown in the diagram.




2 Place the plane mirror vertically at one side of the white paper. Mark the position of the front of the mirror on the paper using a pencil.

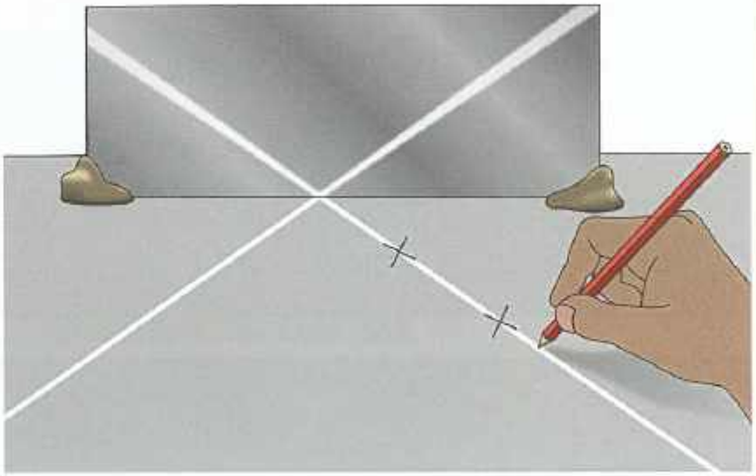
Continued

3 Use the protractor to draw a normal line at the surface of the mirror.

4 Use the ray box to direct a ray of light onto the mirror where the normal meets the mirror surface.

5 Use a pencil to make marks on the paper for the positions of the incident and reflected rays, as shown in the diagram.

6 Turn the ray box off, remove the mirror and use the pencil marks to construct a ray diagram.



7 Measure and record the angle of incidence, *i* and the angle of reflection, *r* from your diagram.

8 Repeat this for at least four more different angles of incidence. Use a new piece of paper or a new area on the same piece of paper each time.

### Questions

1 Record your results in a table with two columns: *angle of incidence* and *angle of reflection*. Remember to include the unit.

2 State:

  a the independent variable

  b the dependent variable

  in this experiment.

3 Draw a graph of your results. Put the independent variable on the horizontal axis. Complete your graph with a straight line of best fit.

4 Describe the pattern in your results.

5 a Describe some of the things that were difficult to do accurately in this experiment.

  b Suggest some ways to improve the accuracy of this experiment.

Continued

**Self-assessment**

For each of these statements, decide on how well you agree.

Give yourself five if you agree very much and one if you do not agree at all.

- I can recall the law of reflection.
- I can draw ray diagrams to show reflection.
- The experiment on reflection helped my understanding.

## Summary checklist

- [ ] I can understand and describe how light is reflected from a plane mirror.
- [ ] I can recall the law of reflection.
- [ ] I can draw ray diagrams to show reflection of light from a plane mirror.

# 6.2 Refraction

## In this topic you will:

- describe how light is refracted at the boundary between air and glass or air and water
- describe how light changes speed when it passes between different substances
- draw ray diagrams to show how light is refracted.

## Getting started

Work in groups to discuss answers to these questions. Be ready to share your ideas with the rest of the class.

1 List as many transparent materials as you can. Try to include solids, liquids and gases.

2 Why do you think you cannot see clearly when looking through a glass of water?

## Key words

angle of refraction

away from the normal

bent

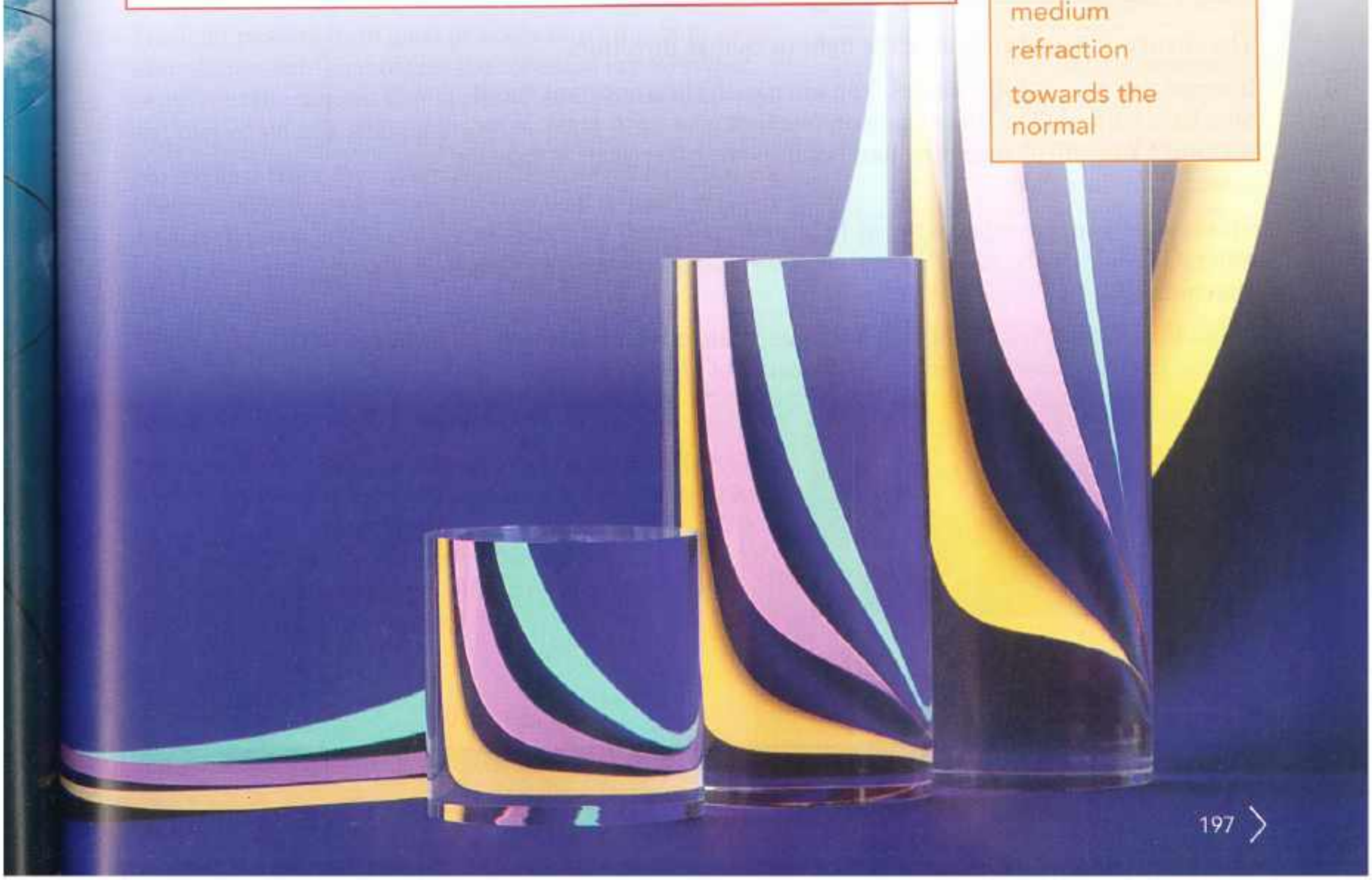
distorted

lenses

medium

refraction

towards the normal



# Refraction

When you look through a glass of water or through a wet window, you cannot see clearly.

Look carefully at the picture, which shows a glass of water on a table. The background, through the glass of water, appears **distorted**. Distorted means changed in some way from the original.

The background appears distorted because of **refraction**.

The material that light passes through is called a **medium**. Air, glass and water are each examples of a medium for light to pass through.

Light travels very fast. The speed of light in air is 300 000 kilometres per second (km/s). When light passes from air into water or glass, the light travels more slowly. The table shows how the speed of light changes according to the medium.

This glass of water is refracting the light passing through it

| Medium | Speed of light in km/s |
|---|---|
| air | 300 000 |
| water | 225 000 |
| glass | 200 000 |

The change of speed can cause the light to change direction.

Imagine you are on roller skates. You are moving at a constant speed on a hard surface. The roller skate on one foot goes onto grass. What happens? You will change direction because one roller skate is moving slower than the other.

This is what happens when a ray of light passes from air into glass or water. One side of the ray of light slows down first, causing it to change direction.

Refraction of light is defined as the change in direction of light on passing from one medium to another because of change in speed.

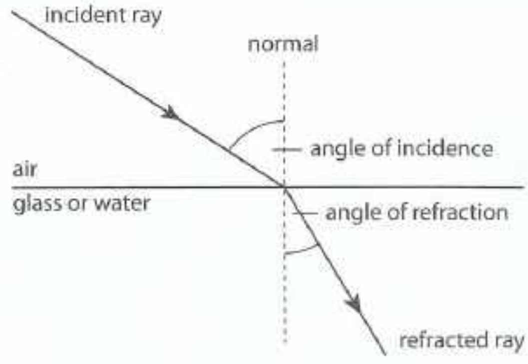
## Light passing from air into water or glass

This ray diagram shows what happens when light passes from air into glass or water.

The light slows down when it passes from air into glass or water. This causes it to change direction.

The light passing from air into glass or water is bent **towards the normal**. That means the refracted ray is closer to the normal than it would be if the incident ray just carried on in a straight line.

Notice also from the ray diagram that, when light passes from air into glass or water, the angle of incidence is greater than the **angle of refraction**. Both of these angles are measured from the normal.




Light passing from air into glass or water is **bent** towards the normal

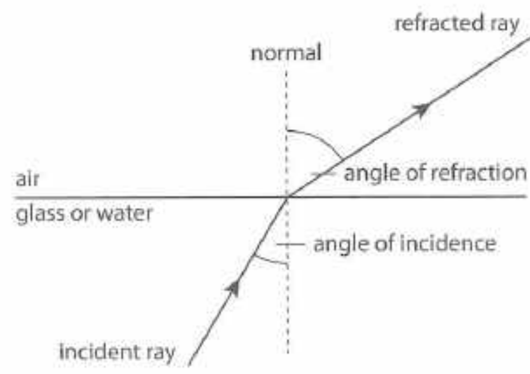
## Light passing from water or glass into air

This ray diagram shows what happens when a ray of light passes from water or glass into air.

The light speeds up when it passes from glass or water into air. This causes it to change direction.

The light passing from glass or water into air is bent **away from the normal**. That means the refracted ray is further away from the normal than it would be if the incident ray just carried on in a straight line.

Notice also from the ray diagram that, when light passes from glass or water into air, the angle of refraction is greater than the angle of incidence.
Both of these angles are measured from the normal.




Light passing from glass or water into air is bent away from the normal

## Refraction in everyday life

Refraction can be a nuisance. It can stop you from seeing clearly through wet windows.

Each individual drop of water on the window refracts light in a different direction, making it very difficult to see. This is why many vehicles have windscreen wipers. The windscreen wipers remove the water drops. It is then easier to see clearly as all the refraction from the glass is in the same direction.

Drops of water on glass make it difficult to see because of refraction

Refraction can also be useful. **Lenses** are used in our eyes, in cameras and in glasses that people wear, to cause refraction of light.

A lens is a curved piece of glass that is designed to refract light in a known way.

This phone has a lens to refract light for a photograph

Different glasses refract light in different ways to help people to see more clearly

## Questions

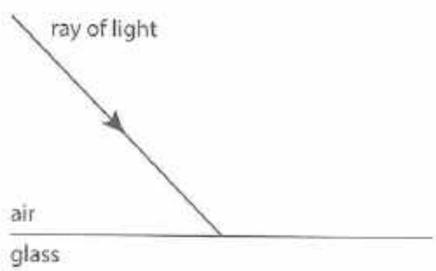
**1** Copy and complete the sentences, using 'faster' or 'slower'.

- **a** Light travels … in water than it does in air.
- **b** Light travels … in air than it does in glass.

**2** Copy and complete the sentence to describe refraction correctly.

Refraction of light happens when light … direction because of a change in … .

**3** This ray diagram shows a ray of light in air.

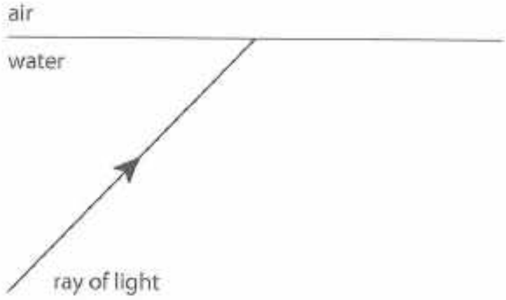



Copy and complete the ray diagram to show what happens when the ray of light enters the glass.

Include on your diagram:

- the normal
- the angle of incidence
- the refracted ray
- the angle of refraction.

**4** This diagram shows a ray of light in water.




Copy and complete the ray diagram to show what happens when the ray of light enters the air.

Include on your diagram:

- the normal
- the angle of incidence
- the refracted ray
- the angle of refraction.

## Activity 6.2.1

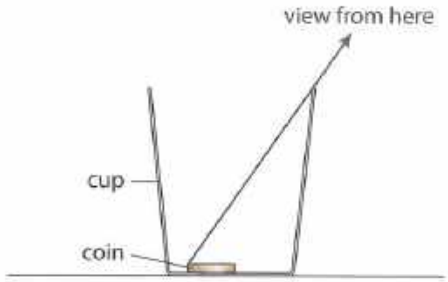
### Refraction effects

This activity shows three effects of refraction.

*Effect 1: The appearing coin*

Place a coin or small piece of metal at the bottom of an opaque container, such as a cup.

Position yourself so that the coin is just out of view behind the edge of the container, as shown in the diagram.




Now pour water into the cup until it is almost full. Pour the water in carefully so the coin does not move. The coin comes into view.

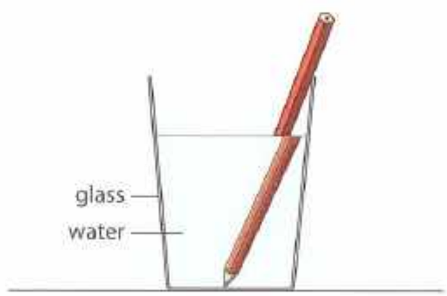
Can you use a ray diagram to explain why? You need to think about how a light ray travels from the coin, up through the water and out into the air.

*Effect 2: Broken pencil in water*

Pour water into a transparent drinking glass until it is about three-quarters full.

Place a pencil into the glass so it is resting at an angle.

View the glass and pencil from the side.




The pencil appears to be broken at the surface of the water.

Can you use a ray diagram to explain why? You need to think about how light travels from the pencil, through the water and out through the side of the glass.

*Effect 3: Broken pencil in water and oil*

Repeat the demonstration in Effect 2, but this time put water into the glass until it is only half full. Now, gently pour cooking oil on top of the water until the glass is about three-quarters full.

View the glass and the pencil from the side again.

How does the pencil appear this time?

What can you conclude about the speed of light in water and in cooking oil?

## Think like a scientist

### Drawing accurate ray diagrams

In this investigation, you will make accurate ray diagrams from rays of light.

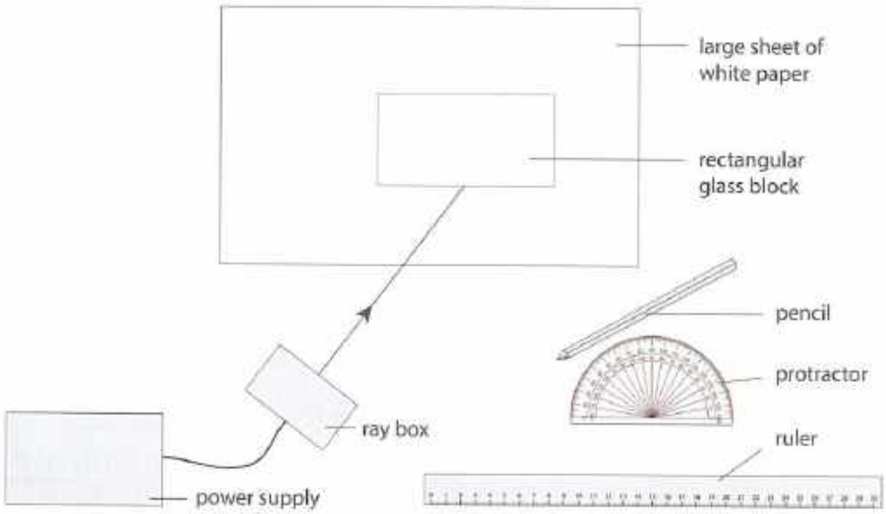
Work in groups of three or four. Make the room as dark as possible for this activity.

**You will need:**

- equipment shown in the diagram

### Method

1 Set up the equipment as shown in the diagram. The diagram shows the equipment viewed from above.




2 Use the pencil to draw around the glass block.

3 Switch on the ray box and position it so the light ray makes an angle with the glass surface.

4 Use the pencil to mark the position of the incident ray in two places: about 5 cm away from the glass block and where it meets the glass block.

5 Do the same for the ray that emerges from the glass block on the other side.

6 Switch off the ray box and lift the glass block off the paper.

7 Use the ruler to join up the light rays.

8 Use the protractor to draw a normal at both surfaces of the glass block.

9 Measure the angle of incidence and angle of reflection at both surfaces.

10 Repeat steps 2–9, using different angles and a new piece of paper each time. Make sure to include an angle of incidence of zero.

Continued

### Questions

1 What did you notice about the pairs of angles at each surface each time?

2 Plot a graph of your results for the glass surface where the light ray goes into the glass.

Put *angle of incidence* on the horizontal axis and *angle of refraction* on the vertical axis.

Join your points with a line that passes through all of the points.

3 Describe the trend shown in the graph.

4 What do you observe when the angle of incidence is zero?

### Self-assessment

- What did you do in your group?
- Did you make sure everyone in your group had a role?
- Would you feel confident to lead a group activity next time?

## Summary checklist

- [ ] I can describe how light changes speed between air and either water or glass.
- [ ] I can recall that a change in speed can make a light ray change direction.
- [ ] I can recall which way light changes direction when it passes from air into glass or water.
- [ ] I can recall which way light changes direction when it passes from glass or water into air.

# > 6.3 Making rainbows

## In this topic you will:

- learn how white light is made from many colours
- discover how dispersion of white light can be done with a prism
- be able to recall the colours of white light in the correct order.

## Getting started

Work in groups to discuss the answer to these questions.

1. Do you ever see a rainbow at night?
2. Does the Sun have to be shining to enable you to see a rainbow?
3. Does there have to be rain or recent rain to enable you to see a rainbow?
4. What colours can you see in a rainbow?

## Key words

dispersion
prism
spectrum
triangular

## Newton's discovery about light

The name Newton is often associated with forces, but Isaac Newton made many important discoveries.

In the year 1666, Newton showed that white light could be split into different colours. The picture shows Newton using light from the Sun, coming through a hole. Newton is using a glass block in the shape of a triangle to split the light into its colours. He is shining the colours onto a screen.

The next picture shows what the colours look like when seen on a screen. These are the colours that make up white light.

## The spectrum

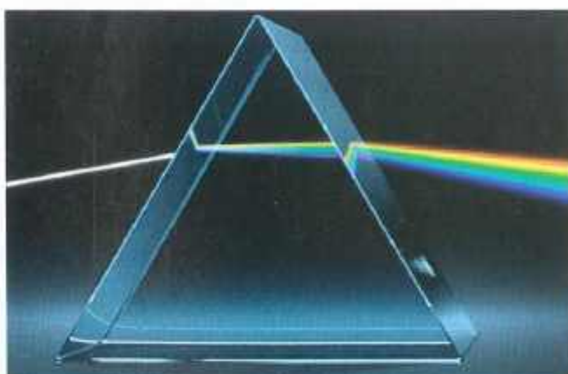
The range of colours that can be seen in white light is called a **spectrum**. In the spectrum, the colours are not separate but they merge from one to another.

Some people think Newton originally saw five or six colours, but most people now agree that there are seven. In the order that they appear in the spectrum, these seven colours are:

red orange yellow green blue indigo violet

You can remember the order of the colours using a made-up person's name: 'ROY G BIV'.

## Dispersion



**Dispersion** means splitting light into different colours. Dispersion happens because light is refracted. Each of the different colours of light that make up white light is refracted through a slightly different angle. This can be shown by using a **triangular prism**. Triangular means in the shape of a triangle. A prism is a solid shape such as the one that Newton used.

When a ray of white light passes through the prism, the ray is refracted. Violet light is refracted through the largest angle and red light is refracted through the smallest angle. You can see this in the picture.

## Rainbows

A rainbow is formed when drops of water in the air cause dispersion of light. The light is also reflected from inside the drops of water. That means that, for you to see a rainbow:

- the Sun must be shining, to provide bright light
- there must be rain or small drops of water in the air, to cause dispersion of light
- the Sun must be behind you, because the water drops reflect the light inside them.

The drops of water from the hosepipe in the photograph are making a rainbow. The Sun is shining and the Sun is behind the camera.

### Questions

1 What name is given to white light being split into different colours?

**refraction** **dispersion** **reflection** **conduction**

2 The diagram shows a glass block used to separate white light.

What name describes this piece of equipment?

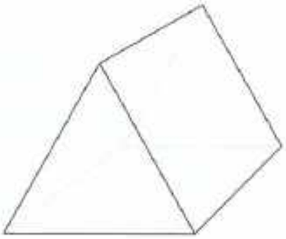
Write **one** letter.

A round glass cylinder

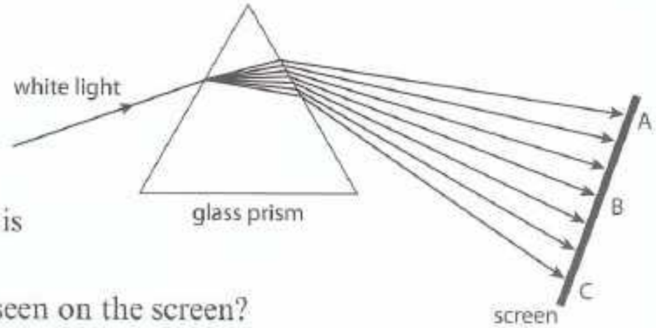
B square glass prism

C triangular glass prism

D hexagonal glass prism



3 The diagram shows white light being separated into different colours. The colours are seen on a white screen.




a Which letter shows the position of red light on the screen?

b Which letter shows the colour of light that is refracted through the **smallest** angle?

c What word describes the range of colours seen on the screen?

**refraction** **reflected** **separated** **spectrum**

4 Explain why drops of water are needed for a rainbow to be seen.

5 When looking at a rainbow, some people see indigo and violet as the **same** colour.

How many colours will these people say they can see in the rainbow?

## Think like a scientist

### Making a rainbow

In this activity, you will change variables and describe how observations change.

Work in groups of two or three.

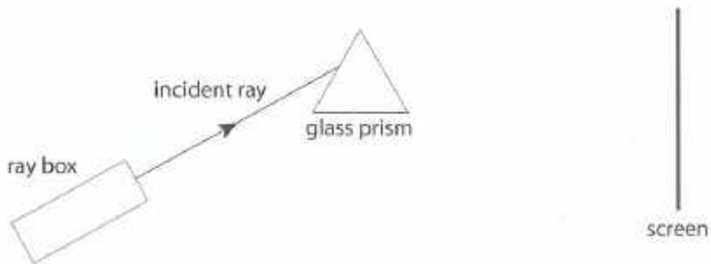
You will need:

- ray box and suitable power supply
- triangular glass prism
- piece of white paper or card to use as a screen

### Safety

Do not put your eye closer to the prism than about one metre. The light will become very bright and could cause damage to your eye.

Make the room as dark as possible for this activity.




Set up the equipment as shown in the diagram.

#### Method: Part 1

1 Adjust the positions of the ray box and the screen until you see the colours of the rainbow on the screen.

2 Move the screen closer to the prism.

3 Move the screen further away from the screen.

### Questions

1 a How many colours can you see on the screen?

b List the colours in order, starting from red.

2 Name the colour that is refracted:

a through the smallest angle

b through the largest angle.

3 Describe **two** things that happened to the colours when:

a the screen was moved closer to the prism

b the screen was moved further away from the prism.

Continued

Method: Part 2

1 Remove the screen and stand about 1 metre from the prism, in the same direction as the screen had been.
2 Move so that you are looking into the refracted rays with one eye. You may find it easier to cover the other eye.
3 Move from side to side so that you can see the different colours.
4 Increase the distance between your eye and the prism to about 2 metres.
5 Again, move from side to side so that you can see the different colours.

### Questions

4 Describe **two** differences in the observations when you moved further away.
5 Describe **one** advantage and **one** disadvantage of Method: Part 1 for observing the colours.
6 This activity is an analogy for how rainbows form. Describe **one** strength and **one** limitation of this analogy.

### Self-assessment

Different people see different numbers of colours in this activity. The numbers of colours usually vary from 5 to 7.

Did you see the same number as everyone else in the class?

Suggest reasons why people see different numbers of colours.

### Summary checklist

- [ ] I can recall that white light is made from different colours of light.
- [ ] I can describe how to use a prism to produce dispersion of white light.
- [ ] I can list the seven colours in order, starting from red.

# 6.4 Colours of light

## In this topic you will:

- discover what happens when colours of light are added
- discover what happens when colours of light are subtracted
- discover why we see different colours.

## Getting started

Work in pairs.

Make a list of all the colours you can see in this picture of flowers.

How many did you get? How does this number compare with other groups?

## Key words

absorbed
coloured filters
cyan
magenta
non-luminous
primary colours
subtraction
transmit

# Primary colours

In Topic 3.3 you learned that there are seven colours in white light. These are the colours that can be seen in the rainbow.

However, there are three colours of light from which all other colours of light can be made. These are called the **primary colours**. The primary colours cannot be made by mixing any other colours of light.

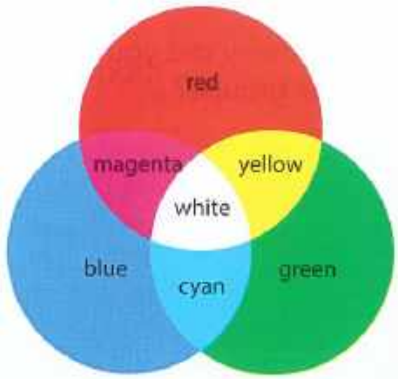
The primary colours of light are:

| Red | Green | Blue |
|---|---|---|

The primary colours of light are different from the primary colours in paints. The colours in light mix differently from the colours in paint.

## Adding colours of light

The diagram shows what happens when three beams of light, each of a different primary colour, overlap.



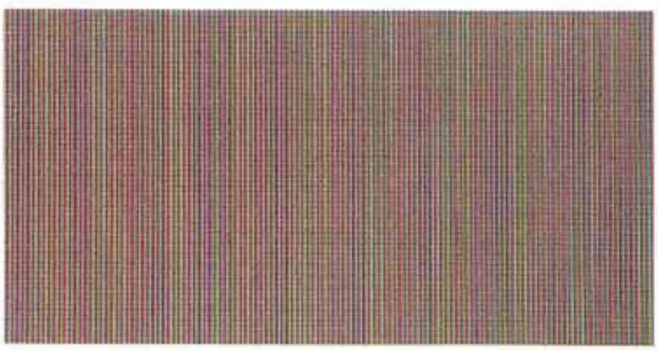

You can see the effect of adding the primary colours:

- red + green = yellow
- red + blue = magenta
- blue + green = cyan
- red + green + blue = white

The different colours that you see on a mobile phone, computer or television are all produced from combinations of the three primary colours of light.

When you look very closely at some types of computer monitor, television or phone screen, you can see the individual sources of red, green and blue light.

The colours on this phone display are made by adding the three primary colours of light



Close-up of a television screen showing the sources of the primary colours of light

When you look at a television or phone screen, you see far more colours than just red, green, blue, **cyan**, **magenta**, yellow and white. Most screens can display 256 different colours. Changing the brightness of the primary colours makes all these different colours. For example, orange is made by adding red and green, but with the red brighter than the green.

Research has shown that 256 is the maximum number of colours that most people can see.

## Subtracting colours of light

You have probably used a filter in your chemistry lessons. Filters are used to remove something from a mixture.

You can also use **coloured filters** to remove colours from light.

If a transparent piece of coloured glass or plastic is placed in front of a white light, then only light of that colour will be **transmitted** (get through). All the other colours will be **absorbed**.

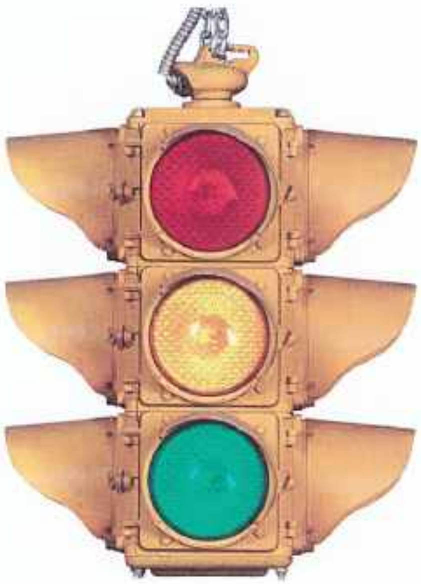
A common example of coloured filters is in traffic lights.

The traffic lights use three identical white lamps. In front of each lamp is a coloured filter for red, yellow or green.

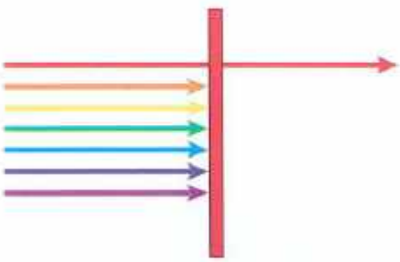
Take the red filter as the example to see how this works.

White light, from the lamp, is made from the seven colours of light: red, orange, yellow, green, blue, indigo and violet.

When these seven colours arrive at the red filter, only red is transmitted. The other six are absorbed. This is shown in the diagram.



These traffic lights use coloured filters



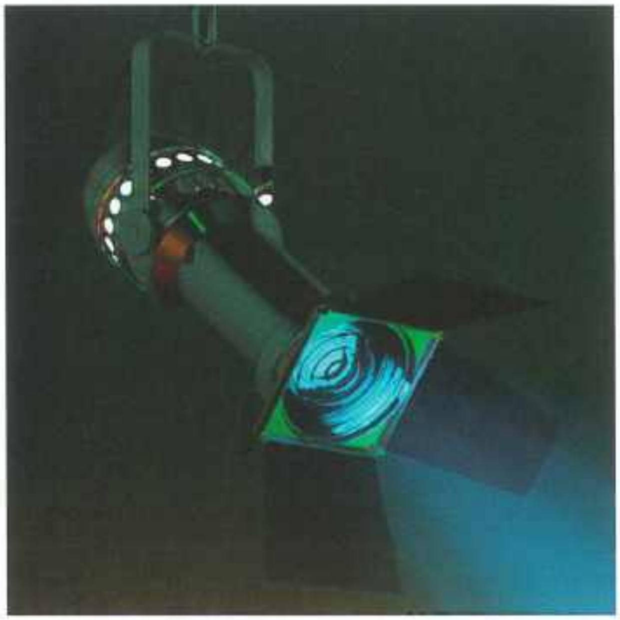
This is an example of **subtraction** of light. White light has had six colours subtracted to leave only red.

In the traffic lights, the yellow and green filters work in exactly the same way. Each of them absorbs six colours and only transmits one colour.

The blue stage light in the picture has a white lamp and a blue filter. If you look carefully, you can see where the white lamp is inside the black case.

The colours of the filters in stage lights can be changed to produce different colours.

Photographers sometimes use coloured filters on a camera to get different effects.



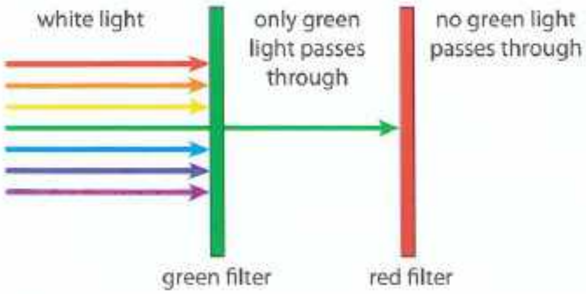
This stage light is using a white lamp and a blue filter

This is the effect of looking through a cyan cellophane filter

As with numbers, it is possible to subtract colours of light until the end result is zero.

For example, if white light shines on a green filter, only green light will get through. The other colours of the white light are absorbed.

If this green light then shines on a red filter, then no light will get through. That is because green is one of the colours that a red filter absorbs.

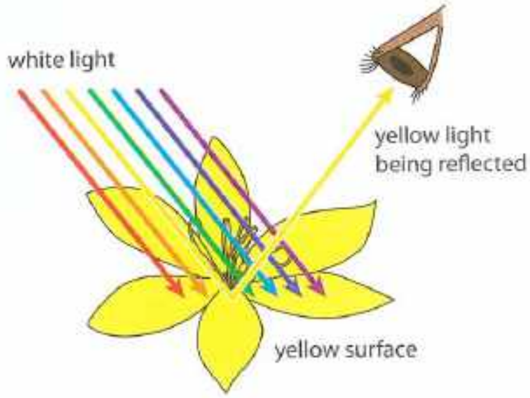



The result of using two different coloured filters

## Seeing colours

When you look at a **non-luminous** object, you see the light that is reflected from the object. Non-luminous means the object does not emit its own light.

Look at the flower in the picture.

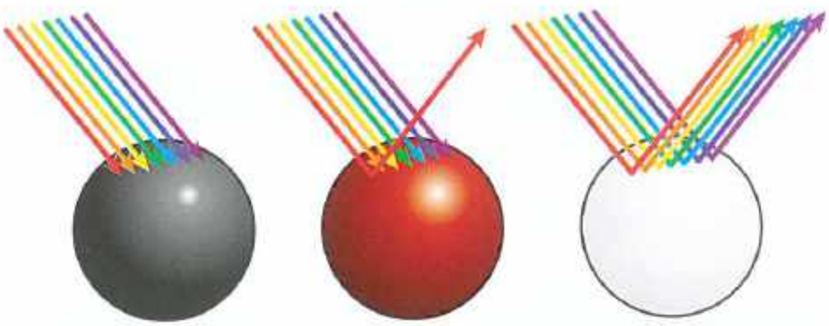



The flower is seen in white light. The flower looks yellow because it reflects only yellow light. The flower absorbs the other six colours in white light. This is shown in the diagram.

A white object reflects all the colours in white light equally.

A black object absorbs all the colours in white light and does not reflect any.

These three balls appear black, red or white, according which colours of light they reflect and which they absorb.



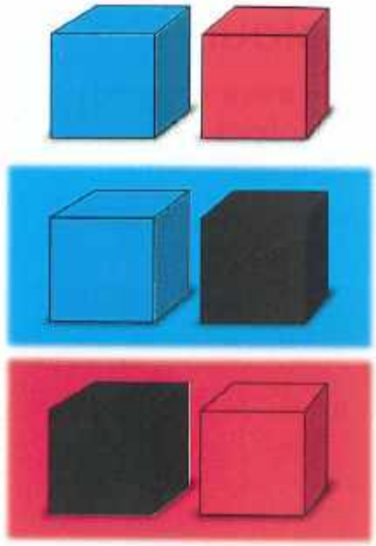
Look at the two cubes in the diagrams.

Red objects only reflect red light, and blue objects only reflect blue light. They absorb all other colours.

So, in white light, the red cube appears red and the blue cube appears blue.

In blue light, the red cube appears black: there is no red light for it to reflect, and the blue light is absorbed.

In red light, the blue cube appears black for the same reason – it absorbs the red light and does not reflect any light.



blue and red cubes seen in white light

blue and red cubes seen in blue light

blue and red cubes seen in red light

## Questions

1. List the three primary colours of light.

2. Name the colour produced when

   a. red light and blue light are added together

   b. red light and green light are added together

   c. red, green and blue lights are added together.

3. A stage light uses a white lamp.
   What colour of light will be seen when:

   a. a yellow filter is used

   b. an orange filter is used.

4. a. A green ball appears green. What **two** colours of light could each be shining on the green ball?

      **blue   green   red   white   magenta**

   b. A blue ball appears black. What **two** colours of light could each be shining on the blue ball?

      **blue   green   red   white**

5. A T-shirt looks red. What could explain this?

   Write **three** letters.

   A. The T-shirt is red and is seen in white light.

   B. The T-shirt is red and is seen in red light.

   C. The T-shirt is blue and is seen in green light.

   D. The T-shirt is white and is seen in red light.

   E. The T-shirt is yellow and is seen in blue light.

## Activity 6.4.1

### Making colours on the screen

Many computer applications, such as those for word-processing and slide-making, have colour options. In the 'more colours' options of these there are RGB tools to customise colours.

The letters RGB stand for 'red', 'green' and 'blue', the primary colours of light. You can adjust these to make whatever colour you want. For example, bright red has:

- R at maximum
- G at zero
- B at zero.

Bright yellow has:

- R at maximum
- G at maximum
- B at zero.


Try making:

- magenta
- cyan
- white
- black.

Now make some other colours of your choice.

In each case, write down the RGB settings for each colour.

## Think like a scientist

### Identify the colour

In this investigation, you will make predictions about colours and light.

Work in groups of two or three.

**You will need:**

- white paper and coloured paper
- coloured pens
- flashlights
- coloured filters
- a room that can be darkened

## Continued

### Method 1

1 Write the names of some colours on a piece of coloured paper. Use different coloured pens to write each word. The colours do not have to match correctly.

For example, on yellow paper, write:

- 'blue' with blue pen
- 'red' with green pen
- 'green' with blue pen.

2 Use the flashlight and a red filter to illuminate the paper.

3 Ask someone from a different group to identify:

- the colour of the paper
- the words that are written in the correct colours
- the colours of pen used to write the other words.

4 Vary the words, the colours of the pens, the colours of the paper and the colours of the filters, and repeat steps **1–3**.

### Questions

1 Which colour combinations were easiest to get correct?

2 Which colour combinations were most difficult to get correct?

### Self-assessment

1 What parts of this topic are easiest to understand?

2 What parts of this topic are most difficult to understand?

3 What part of this topic could you teach to someone else?

## Summary checklist

- [ ] I can recall the three primary colours of light.
- [ ] I can recall the colours that are made when these primary colours are added together.
- [ ] I understand that filters work by subtracting light.
- [ ] I can predict what will happen when light of different colours shines on filters of different colours.
- [ ] I understand why coloured objects appear coloured when seen in white light.
- [ ] I can predict the colours that objects will appear to be, when seen in light of different colours.

# › 6.5 Galaxies

## In this topic you will:

- discover that galaxies contain dust, gas, stars and other solar systems.

## Getting started

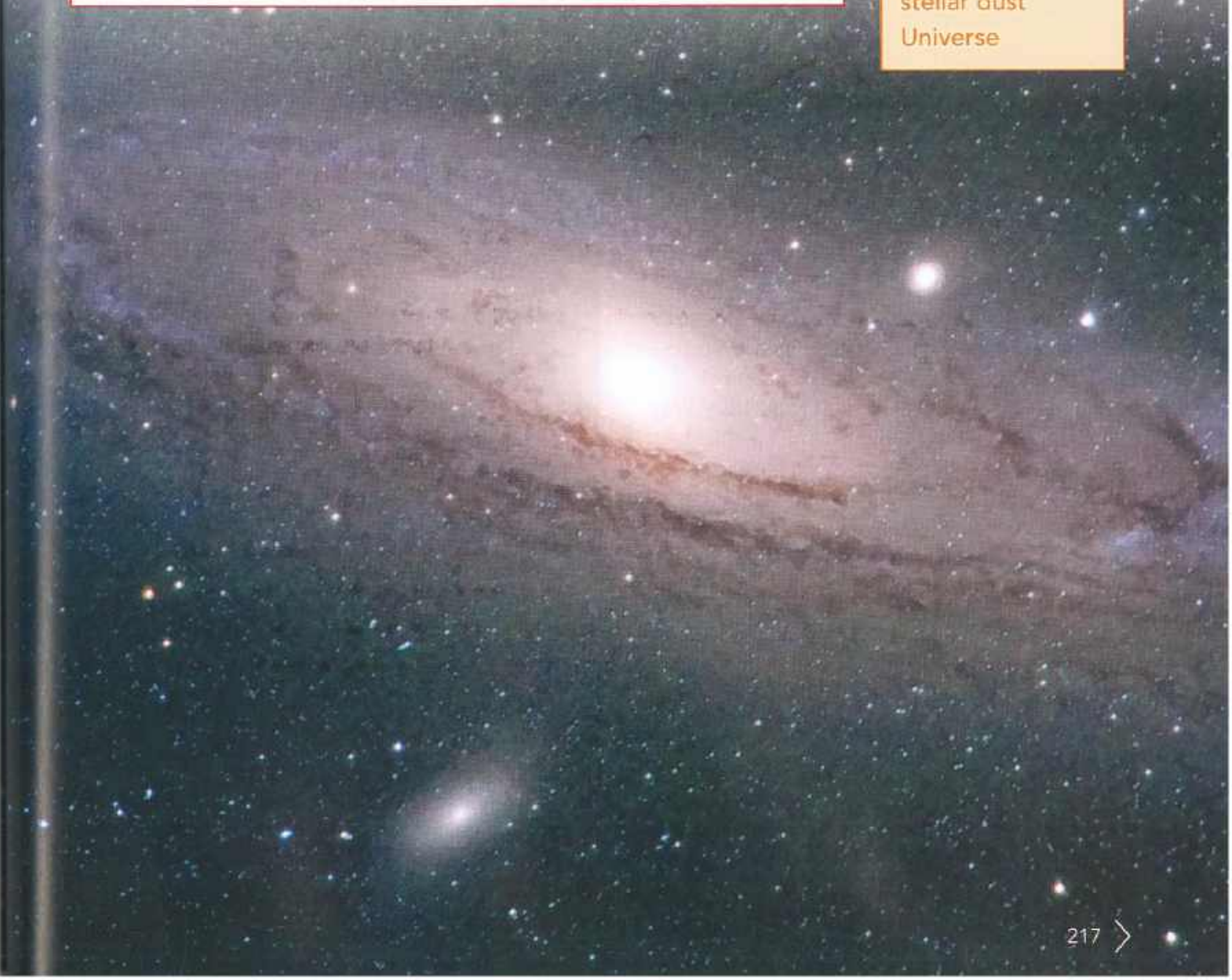
Work in pairs.

Arrange these objects in order, from smallest to largest.

**star**   **solar system**   **planet**   **galaxy**   **moon**

## Key words

elliptical
galaxy
irregular
spiral
stellar dust
Universe



## The Milky Way

If you look at the sky on a clear night, far away from any lights, you can see a milky band across the sky. This milky band is part of the **galaxy** where we live, called the Milky Way. The photograph shows what this looks like through a camera set for very low light conditions.

Part of our own galaxy, the Milky Way

The word 'galaxy' comes from a Greek word for 'milky'.

## Shapes of galaxies

The reason why our own galaxy looks like a band across the sky is because of the shape of the galaxy. The Milky Way is a **spiral** galaxy. If you were to look at the Milky Way from far away, it would appear as a spiral.

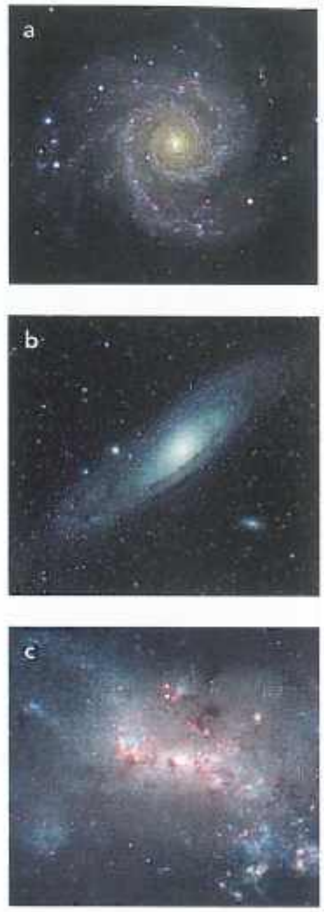
This is what the Milky Way would look like from far away

Because we live in a spiral galaxy, we can only see one 'arm' of the spiral, which is that band across the sky. In fact, most of the stars we see at night are in our own galaxy. There are an estimated 250 000 000 stars in the Milky Way, including our Sun.

There are other galaxies in the **Universe** besides our own. The word Universe is used to describe all of space and everything in it.

These other galaxies have different shapes, and they are classified according to shape. They are called **elliptical** galaxies or **irregular** galaxies.

The closest known galaxy to the Milky Way is called the Canis Major Dwarf Galaxy. It is elliptical in shape and a distance of 240 000 million million km away from us.




The three different shapes of galaxy: **a** Spiral, **b** Elliptical, **c** Irregular

## What are galaxies made of?

Galaxies are made from **stellar dust**, gas, stars and solar systems held together by gravity. Stellar dust is the dust found in space. The Earth is travelling through a cloud of stellar dust that is estimated to contain one dust particle in every one million $m^3$ of space!

The gravity holding a galaxy together is strong because galaxies have very large mass. Even if you could travel at the speed of light (300 000 km/s), it would take you more than 100 000 years to cross from one side of the Milky Way to the other! Scientists estimate the mass of the Milky Way to be 1 500 000 000 000 times the mass of the Sun.

## How many galaxies are there?

Scientists have counted the galaxies in one part of space. The scientists then multiplied this number up to estimate the number of galaxies in the Universe. The answer they got was 100 000 000 000 galaxies!

Estimates such as this may not be accurate. There could be more or fewer galaxies in the part of space that the scientists counted compared with the rest of the Universe. Also, the scientists may not know the total volume of the Universe accurately.

### Questions

1 List the three different shapes of galaxies.

2 Which of these are found in galaxies?

Choose all that are correct from the list.

**planet** **star** **Universe** **stellar gas**

3 Name the force that holds the parts of a galaxy together.

4 Explain why most of the stars we see in the night sky are from our own galaxy and not from other galaxies.

5 Suggest why scientists can only estimate the number of stars in the Milky Way and not know the number accurately.

## Think like a scientist

### Estimating large numbers

In this investigation, you will use an analogy for estimating the number of stars in a galaxy.

Work in groups of two or three.

**You will need:**

• one large cup or other container filled with coarse sand or fine gravel, for the whole class • hand lens (magnifying glass) for each group • piece of white paper for each group • small container for the whole class • access to laboratory equipment for measuring masses and volumes • calculator for each group

Scientists cannot count the number of stars in a galaxy because there are too many. However, scientists can estimate the number of stars in a galaxy.

You are going to estimate the number of grains of sand in your container. There are too many to count them all, so this activity is an analogy for how scientists estimate numbers of stars.

#### Method

1. Put a small quantity of sand from the large container onto the white paper and separate the grains. You should only put out the quantity you can count easily.
2. Count the grains, record the number, and put the grains into the small container.
3. Do the same again: count some grains from the large container and then add them to the small container.
4. Write down the total number of grains your group put in the small container.
5. Decide, as a class, whether you want to work in mass or in volume for the last two steps.
6. Measure the total mass or volume of the grains in the small container. A sensitive balance can be used to measure the mass, or a small syringe without a plunger can be used to measure the volume.
7. Put the grains from the small container back into the large container. Measure the total mass or volume of sand in the large container.

Continued

### Questions

1 What was the total number of grains the class put in the small container? Call this value $G$ for grains.

2 What was the total volume or mass of the grains in the small container? Call this value $S$ for small.

3 What was the total volume or mass of the grains in the large container? Call this value $L$ for large.

4 Calculate the value of $G \times \frac{L}{S}$

5 This number is an estimate of the total number of grains in the large container.

  a Explain the advantage of this method compared to counting all the grains in the large container.

  b Give reasons why the estimate may not be accurate.

  c Suggest some ways that the estimate could be made more accurate.

6 Suggest how working as a whole class is an analogy for how scientists who study the Milky Way work together.

7 Knowing roughly how long it took you to count your grains in step 2, estimate how long it would take you to count all the grains in the large container.

8 Suggest how you could estimate the number of grains of sand on a beach.

### Self-assessment

Decide how confident you are about:

- understanding how this method of estimating works
- whether you could apply this method to estimating some other large quantity.

## Summary checklist

- [ ] I understand what galaxies are.
- [ ] I can recall the three shapes of galaxies.
- [ ] I can recall that galaxies contain stellar dust and gas, stars and solar systems.
- [ ] I understand that gravity holds all the parts of a galaxy together in space.

# 6.6 Rocks in space

## In this topic you will:

- discover that asteroids are rocks that are smaller than planets
- know that scientists believe asteroids to be rocks left over from the formation of the Solar System.

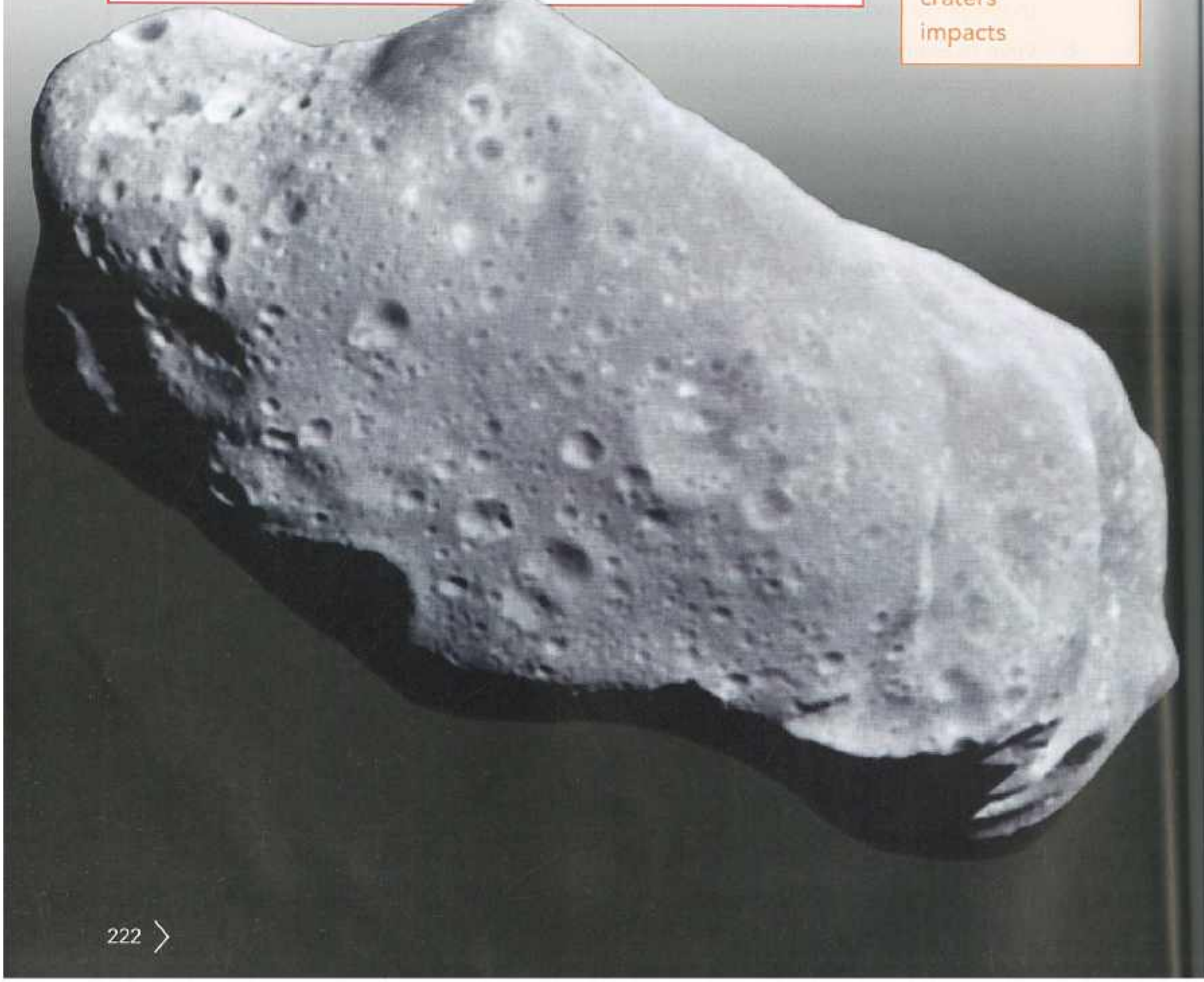
## Getting started

Work in groups.

Make a list of different types of objects in the Solar System.

## Key words

asteroid belt
asteroids
craters
impacts



# Asteroids

**Asteroids** are objects made from rock that orbit the Sun.

Asteroids range in size up to 975 km across. The smallest asteroid that has been studied is 2 m across.

Most asteroids are not regular shapes, just as rocks on Earth are not regular shapes.

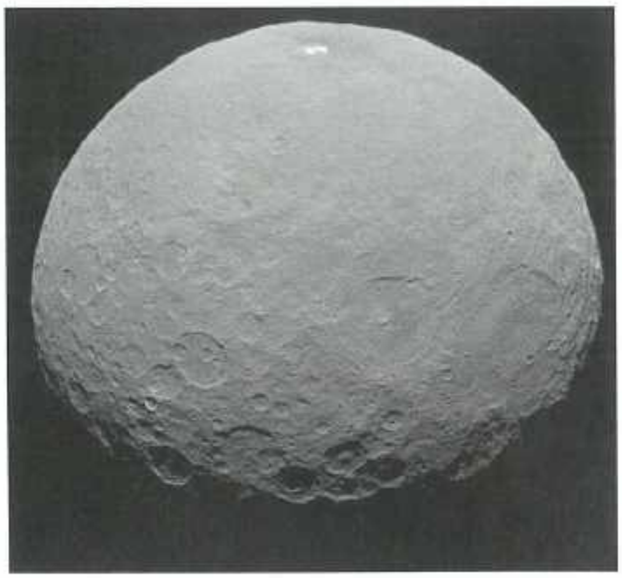
Scientists describe the shape of most asteroids as being similar to the shape of potatoes.

Most of the asteroids in the Solar System orbit the Sun between the orbits of Mars and Jupiter. This part of the Solar System is called the **asteroid belt.**

There are millions of asteroids. Some have been studied and have been given names.

The largest asteroid is called Ceres and was discovered in the year 1801. When Ceres was discovered, scientists thought it was a new planet. As Ceres looked much smaller than a planet, the term asteroid was introduced.

This photograph of Ceres, was taken by a spacecraft in 2015.



Ceres

Ceres looks like a small planet. It is round, with a diameter of 975 km, and covered with **craters**.

Ceres also has a core, a mantle and a crust like some planets.

Scientists think that Ceres would have become a planet if it had continued to grow during the formation of the Solar System.

The asteroid Itokawa is one of the smallest asteroids to be visited by a spacecraft.

Asteroid Itokawa is about 530 m long and about 250 m wide. In the year 2005, a spacecraft collected samples from the surface of Itokawa.

Study of the samples has given scientists more evidence about how the Solar System formed.

Itokawa

Itokawa appears to be made from lumps of rock. These lumps of rock appear to have come from other small planets or moons which have been broken by **impacts**. The force of gravity holding the lumps of rock together is weak because the asteroid is a relatively small object. When an asteroid such as Itokawa passes a large object such as a planet, tidal forces can change the shape of the asteroid.

Some asteroids are made from a single piece of rock. Scientists know this because these asteroids are small and spin quickly. The force of gravity in these asteroids would be too weak to hold separate pieces of rock together.

## Asteroids and Earth

Scientists think that a large asteroid impacts the Earth on average every 130 000 years.

Smaller asteroids impact the Earth very frequently.

This map shows where asteroids impacted Earth between the years 1994 and 2013. Many small asteroids break up in the Earth's atmosphere and never reach the surface.

Asteroid impacts on Earth between 1994 and 2013

There are two reasons why asteroids impact with Earth.

- The Earth exerts a strong force of gravity on passing objects such as asteroids.
- Many asteroids have orbits that pass relatively close to Earth.

## Questions

1 Describe what is meant by the term 'asteroid'.

2 Some asteroids have diameters between 300 and 500 m.

Explain why these asteroids are classed as small objects in the Solar System.

3 The asteroid Ceres is covered with craters.
Suggest how these craters were formed.

4 Describe where the rocks came from to form asteroids.

## Activity 6.6.1

### Making a model asteroid

In this activity, you will make a model of an asteroid.

**You will need:**

- a selection of small rocks
- some coarse sand
- glue suitable for stone
- black acrylic paint (or any paint which can be applied safely to rock)
- white acrylic paint
- trays for mixing paint
- paint brushes

### Method

1 Use the internet or the pictures in this topic to plan what your model will look like.

2 Choose a small rock and, if necessary, attach sand onto the surface with glue to give a rough texture.

3 When the glue has dried, you can paint your asteroid.

4 Mix the black and white paints to achieve the colours of grey that you want.

5 Together with the other models in your class, you could make a model of part of the asteroid belt.

### Questions

1 Describe **one** way that your model shows that asteroids are different from planets.

2 Some large asteroids that your model could represent have a diameter of 200 km. The planet Jupiter has a diameter of 140 000 km. Calculate how many times larger Jupiter is than these asteroids.

3 a Use a ruler to measure the length of your model asteroid.

b Use your answer to question **2** to calculate the size of model you would need to make for the planet Jupiter on the same scale.

## Think like a scientist

### What happened at Tunguska?

In this investigation, you will look at evidence that supports or contradicts hypotheses.

Work in groups of two or three.

#### Method

1 Read these facts.

- Tunguska is in northern Russia, far from any towns or cities. There is forest there, with many trees.
- In the morning of 30 June 1908 there was a very large explosion at Tunguska, between 5 km and 10 km above the ground.
- People living over 800 km away could see and hear the explosion.
- Vibrations from the explosion were recorded almost 5000 km away.
- The explosion flattened trees over an area of 2000 $km^2$.

2 Read these five hypotheses of what caused the explosion.

1. A comet impacting the Earth.
2. A type of volcano erupting.
3. Testing of a new type of bomb.
4. An alien spacecraft crashing.
5. An asteroid impacting the Earth.

3 Consider the evidence.

- All the trees that fell are pointing outwards from a central position.
- People discovered how to make very powerful bombs in 1945.
- No bomb this powerful has ever been made.
- Tunguska is very far from tectonic plate boundaries.
- Most comets break up higher than 10 km in the atmosphere.
- A small part of a comet is made from rock.
- Small rocky fragments have been found that show the signs of falling through the atmosphere at very high speed.
- No metal parts have been found at Tunguska.

Continued

### Questions

1 Use the evidence to decide whether each of the five hypotheses can be supported or contradicted.

You can also use facts given in this topic as evidence.

Write about each hypothesis in turn.

2 Decide, using this evidence:

   a which of the hypotheses are most likely

   b which of the hypotheses are most unlikely.

3 Explain some of the limitations of the conclusions you have made.

### Peer-assessment

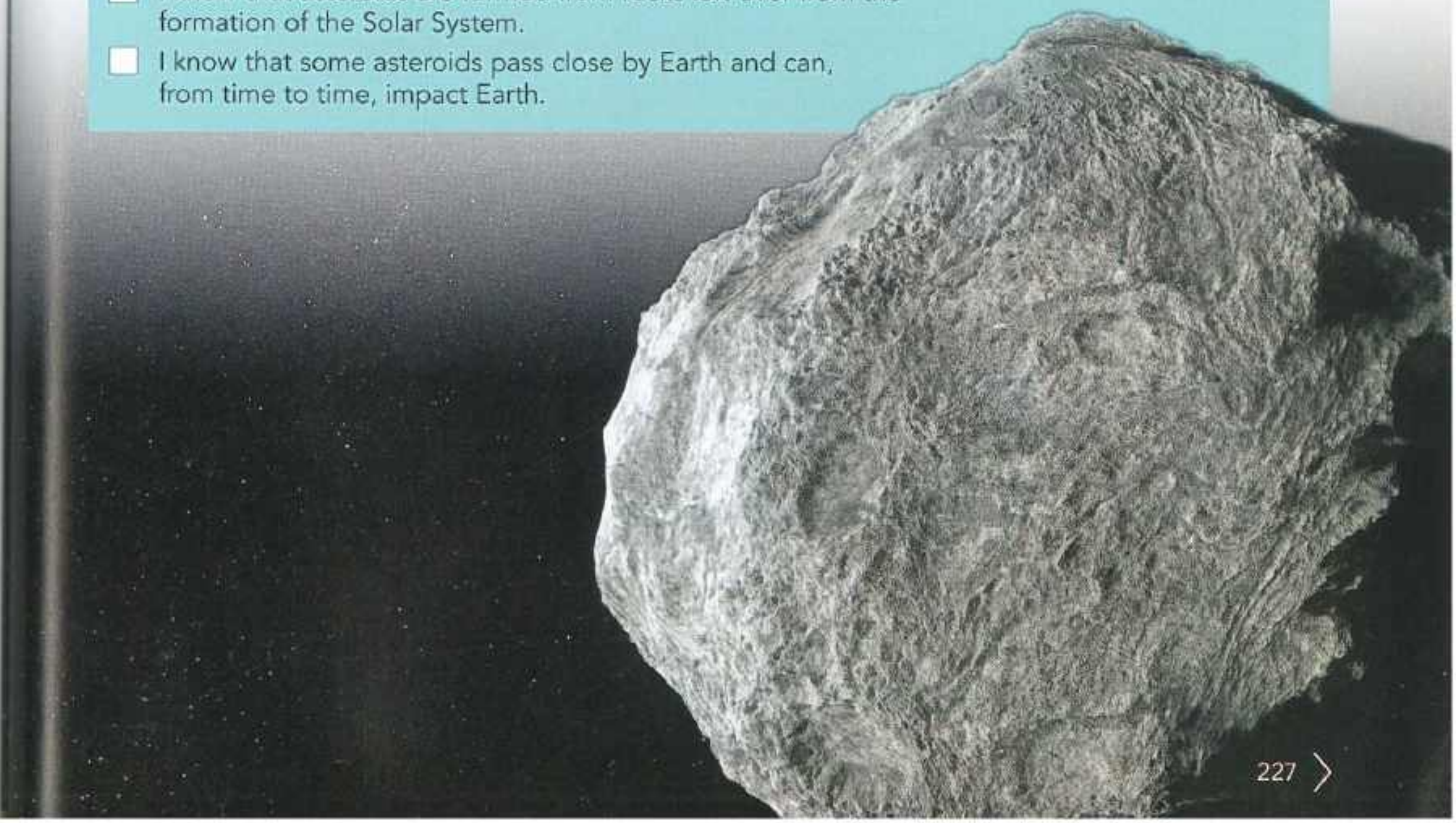
Find another group whose answers to question **2** are different from yours.

1 Are you convinced by their conclusions?

2 If not, can you understand why they made these conclusions?

## Summary checklist

- [ ] I can describe what is meant by the term asteroid.
- [ ] I can recall where most asteroids in the Solar System are found.
- [ ] I know that asteroids are formed from rocks left over from the formation of the Solar System.
- [ ] I know that some asteroids pass close by Earth and can, from time to time, impact Earth.



## Project: Investigating refraction

### Background

Dissolve some white sugar or salt in water. Make sure it is all dissolved so you have a transparent solution.

Now take a transparent container holding some water. Look at the water from the side and slowly pour your sugar or salt solution into the water.

Describe what you see.

How can you see both liquids if they are both transparent? We can see them because of refraction.

### Your task

You will do experiments that will help you explain what you see when you pour the sugar or salt solution into water.

Work in groups.

You can use equipment such as:

- a ray box and power supply
- glass or plastic containers with smooth, flat sides
- water
- other transparent liquids
- sugar and salt to dissolve in water.

### Safety

Remember to keep liquids away from the power supply and the ray box.

Carry out experiments using the method in *Think like a scientist: Drawing accurate ray diagrams* in Topic 6.2.

Investigate how each substance refracts light.

- When you dissolve sugar or salt in water, does it change how the light is refracted?
- Which substance refracts the light through the largest angle?
- Which substance refracts the light through the smallest angle?
- Does the concentration of the sugar or salt affect the refraction?

Record all your results and present them in the most effective way.

Can you now explain what you see when you pour the sugar or salt solution into water?

# Check your progress

**6.1** A plane mirror is a type of mirror.
Write the word from the list that describes the meaning of plane. **[1]**

**flat** **irregular** **round** **smooth**

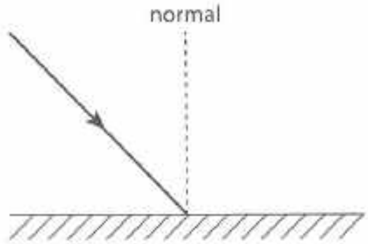
**6.2** Copy and complete the sentence that describes how light is reflected from a plane mirror.

The angle of reflection is … to the angle of … . **[2]**

**6.3** Copy and complete the diagram to show how light is reflected from the plane mirror.

You do **not** have to measure angles.

Label the reflected ray and the angles of incidence and reflection. **[3]**




**6.4** The motorcycle in the picture is fitted with mirrors.

The motorcycle rider can see objects that are behind the motorcycle by using these mirrors.

Draw a ray diagram to show how the rider can see a ray of light that is coming from behind. **[4]**

**6.5** State the name given to light changing direction when the light passes from air into water. **[1]**

**6.6** Copy and complete each of these sentences with either the words 'speeds up' or the words 'slows down'.

- When light passes from air into glass, the light ....
- When light passes from air into water, the light ....
- When light passes from glass into air, the light .... **[1]**

**6.7** Copy these sentences.

Write T or F after each one to show if it is true or false.

- In a ray diagram, the angle of incidence is measured between the light ray and the surface.
- In a ray diagram, the angle of refraction is measured between the light ray and the normal.
- In a ray diagram, the normal is a line at 90° to the surface. **[2]**

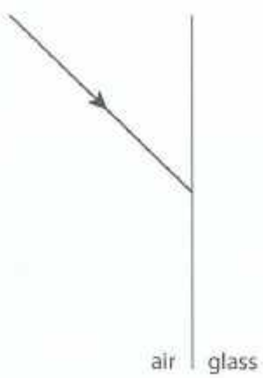
**6.8** Copy these ray diagrams to show what happens to the light rays.

On each diagram, draw and label:

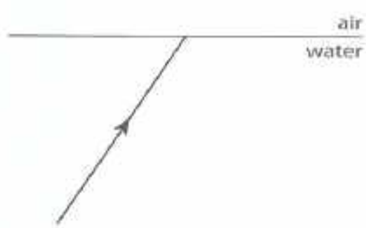
- the normal
- the refracted ray
- the angles of incidence and refraction.

You do **not** have to measure any angles.

a **[4]**




b **[4]**



**6.9** Complete the sentences by using words from the list.

Each word can be used once, more than once or not at all. **[5]**

| | | | |
|---|---|---|---|
| **dispersion** | **prism** | **colours** | **spectrum** |
| **orange** | **violet** | **blue** | **reflection** |

White light can be split into its component ….

This is called … and can be done with a ….

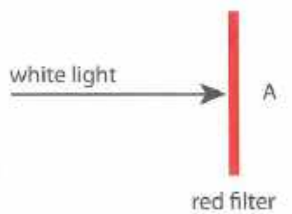
The range of colours is called a ….

The range starts with red and ends with ….

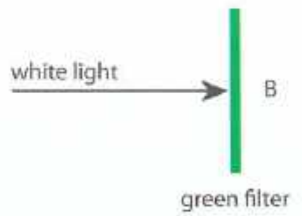
**6.10** Describe the light that will emerge at points A, B and C when white light shines on each of these filters.

- If coloured light will emerge, write the colour.
- If white light will emerge, write 'no change'.
- If no light will emerge, write 'no light'.

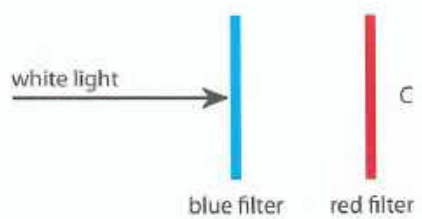
**a** **[1]**




**b** **[1]**




**c** **[1]**

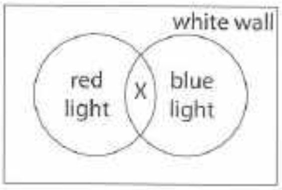


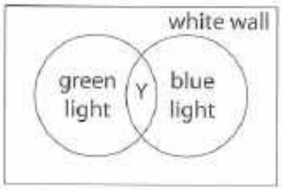
**6.11** A theatre uses coloured lights to make objects appear different. Write the colour that each of these objects will appear.

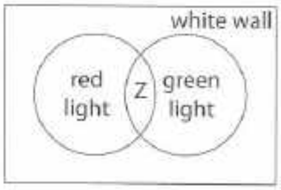
- **a** A red book in white light. [1]
- **b** A green door in green light. [1]
- **c** A white T-shirt in blue light. [1]
- **d** A blue ball in green light. [1]

**6.12** Two different coloured lights of the same brightness shine onto a white wall. The two colours of light overlap.

Write the colours that will be seen at the points X, Y and Z.

**a** 


**b** 


**c** 


[1]

- **d** State the colour that would be seen if red, green and blue lights of the same brightness all overlapped on the white wall. [1]

**6.13** **a** List the **four** things that make up a galaxy. [2]

- **b** Name the galaxy that contains the Earth. [1]

**6.14** Asteroids are different from planets. State **two** features of asteroids that make them different from planets. [2]

# 7 Diet and growth

## 7.1 Nutrients

**In this topic you will:**

- learn about the six types of nutrient that everyone needs to eat
- find out why we need these nutrients
- learn about some good sources of these nutrients.

**Getting started**

Everyone needs energy to stay alive and to do things. They get their energy from the food that they eat.

Think about the answers to these two questions on your own.

Then turn to your partner and discuss your answers.

Be ready to share your ideas with the rest of the class.

- Which kinds of food are best for giving you energy?
- What happens to your food after you have swallowed it, before it gives you energy?

**Key words**

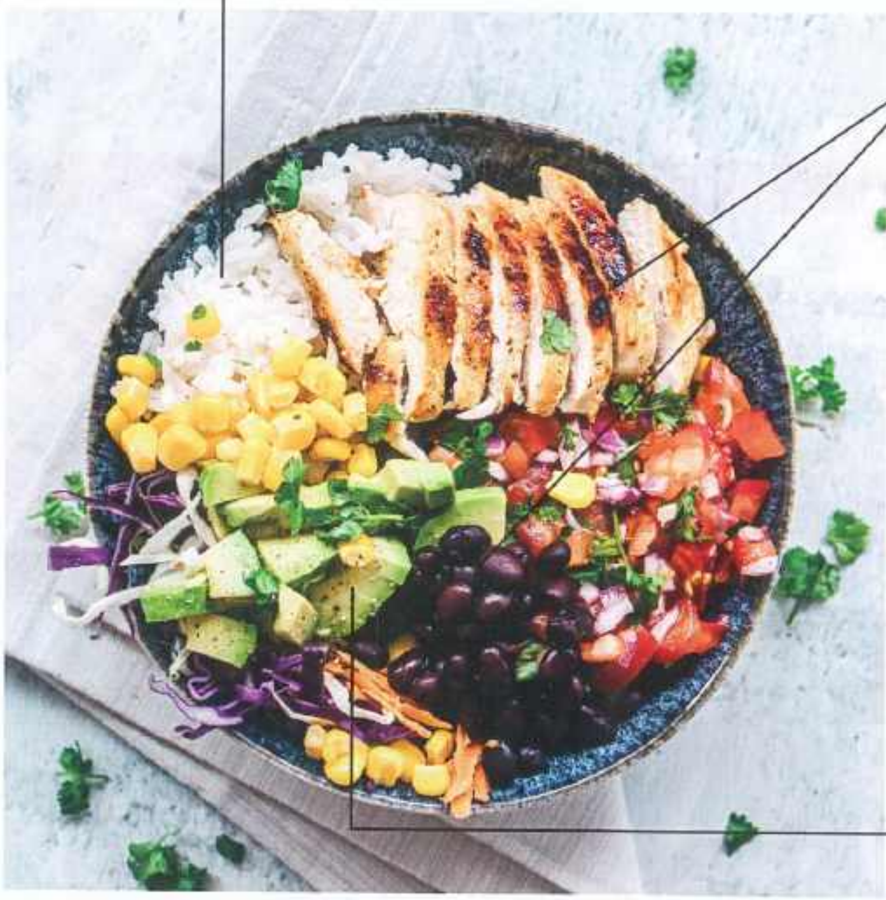
anaemia
carbohydrate
fat
minerals
nutrients
oil
protein
starch
vitamin A
vitamin C
vitamin D
vitamins

# Carbohydrates, fats and proteins

The photograph shows a plate of food.

There are several different kinds of food on the plate. How does each of these foods help the body to stay healthy, and to have energy?

The rice contains a lot of **starch**. Starch is a type of **carbohydrate**. After you have eaten starch, the body breaks it down to make a sugar called glucose. You may remember that glucose is the fuel that your cells use for respiration, to release energy. So, starch, sugar and other carbohydrates are needed to give you energy.



The chicken and beans contain a lot of **protein**. Protein is important for making new cells in the body. So, you need protein to help the body to grow, or to repair itself if it gets damaged. Protein is also needed to make haemoglobin and antibodies.

The avocado contains **fats** and **oils**. Fats and oils are very similar but, at normal temperatures, fats are solid and oils are liquid. Fats and oils give you energy. They are also needed to make cell membranes.

Protein, carbohydrate and fat are **nutrients**. Nutrients are substances found in food, that you need to stay healthy. These three photographs show some of the kinds of food that you can eat to get these nutrients.

These foods are good sources of protein

These foods are good sources of starch (a type of carbohydrate)

These foods contain a lot of fat

## Energy stores

You do not eat all the time, but you need energy all the time. You get almost all of your energy from the carbohydrates and fats that you eat. You can also get energy from protein if you run out of carbohydrates and fats.

You store a little bit of carbohydrate, and quite a lot of fat, in your body. These energy stores provide you with energy whenever you need it.

You store a small amount of carbohydrate in your cells, especially in the liver and muscles. These are short-term energy stores.

For long-term stores, your body stores fat in special cells underneath the skin and around some of the body organs.

Fat stores in the body also provide heat insulation. Animals that live in cold places, like this seal, have a lot of fat stores underneath their skin, to help to stop them losing heat from their body.

## Activity 7.1.1

### Protein and carbohydrate in food

Work with a partner for this activity.

Think about what both of you have eaten so far today. Make a list.

Which foods do you think contain a lot of protein?
In your list, draw a green circle around each one.

Which foods do you think contain a lot of carbohydrate?
In your list, draw a blue circle around each one.

Use the internet or a reference book to see if you are right.
Make changes to your list if you were not correct.

## Think like a scientist

### Testing foods for starch

This is an extension activity.

You are going to try to find out which types of food contain starch.

You can use iodine solution to find out if a food contains starch.

Iodine solution is orange-brown. When it mixes with starch, it becomes very dark blue-black.

**You will need:**

- at least six different kinds of food
- some paper plates or other plates to put the pieces of food on, keeping them separate
- white tile
- bottle of iodine solution with a dropper

### Method

1 Collect six different kinds of food. Try to include some foods that come from plants, and some that come from animals. Make sure you keep them completely separate from one another.

2 Draw a results table like this:

| Food | Colour of iodine solution after adding to the food | Does the food contain starch? |
|---|---|---|
| | | |
| | | |

Continued

3 Take a small piece of the first food. Put it onto a white tile.

4 Add a few drops of iodine solution. Record the colour that you see in your results table.

5 Clean the white tile. Now repeat steps 3 and 4 for the other foods, making sure to clean the tile each time.

6 Complete the last column in your results table.

### Questions

1 Explain why it was important to keep all the foods separate from one another.

2 Suggest why it is a good idea to use a white tile for this experiment.

3 In your results table, which column shows your results? Which column shows your conclusions?

4 Did any of the foods that came from plants contain starch?

5 Did any of the foods that came from animals contain starch?

## Questions

1 Copy and complete this table.

| Nutrient | Examples of foods that contain a lot of this nutrient | Why the body needs this nutrient |
|---|---|---|
| Protein | | |
| Carbohydrate | | |
| Fat | | |

2 Explain the difference between the meanings of the words 'food' and 'nutrient'.

# Vitamins

**Vitamins** are nutrients that are needed in only small amounts, but if you don't eat them you can get ill.

There are lots of different kinds of vitamin. Each kind is given a letter.

## Vitamin A

**Vitamin A** is needed to help your eyes to work well, so that your vision is good. It is particularly important for helping us to see when it is quite dark. People who don't have enough vitamin A in their diet may not be able to see anything at night. It also helps your white blood cells to fight pathogens.

You get vitamin A by eating green vegetables, carrots and squash (such as pumpkin), fruit, foods made from milk (such as cheese) and some kinds of fish.

## Vitamin C

**Vitamin C** helps the skin to stay strong and to heal quickly if it is damaged. It keeps blood vessels and bones healthy. People who don't eat enough vitamin C can get an illness called scurvy. A person with scurvy feels weak and may have swollen, bleeding gums.

You get vitamin C by eating fresh fruit and vegetables. Citrus fruits are particularly rich in vitamin C. Potatoes and colourful berries are also good sources of vitamin C.

In the past, before anyone knew about vitamin C, sailors on long sea voyages often got scurvy. This was because they had no fresh fruit or vegetables to eat.

## Vitamin D

**Vitamin D** is needed for strong bones and teeth. It helps the body to absorb calcium from the food that you eat.

There are not many kinds of food that contain vitamin D. Oily fish is probably the best source. But for most people, most vitamin D does not come from the food that you eat. Instead, vitamin D is made in the skin when sunlight falls onto it.

People who never go outdoors, or who never get any sunlight on their skin, may not get enough vitamin D. This is most likely to happen if you live in a country far from the equator, or where there is not much sunshine.

In children, lack of vitamin D can stop their bones growing normally. This illness is called rickets.

### Activity 7.1.2

**Vitamins poster**

Work in a group of three for this activity.

You will need a big piece of paper, and some coloured pens or pencils.

Divide the sheet of paper into three equal areas labelled Vitamin A, Vitamin C and Vitamin D.

Use the information in this book, the internet and/or the library to find out which foods contain a lot of each vitamin.

Draw pictures of the foods in each space. If you like, you could also cut out some pictures of foods from packaging or magazines, and stick the pictures onto your poster.

# Minerals

There are several different kinds of **mineral** that you need to eat. Two of the most important ones are calcium and iron.

## Calcium

Bones and teeth contain calcium, so you need to eat plenty of calcium to make them strong. Foods made from milk are excellent sources of calcium. Seeds and some types of nut (such as almonds) also contain a lot of calcium.

## Iron

Iron is needed to make haemoglobin. If you don't eat enough iron, you don't make enough haemoglobin, so not enough oxygen is transported around the body. This causes an illness called **anaemia**, which makes a person feel very tired. Good sources of iron include meat (especially red meat), dark green vegetables, many kinds of fish and shellfish and some nuts and seeds.

## Questions

**3** Look back at question **1**. Draw a similar table, but include vitamin A, vitamin C, vitamin D, calcium and iron instead of protein, carbohydrate and fats.

Then complete your table.

**4** Use your knowledge about respiration to explain why a person with anaemia does not have much energy.

**5** These bell peppers are stuffed with lentils and vegetables, and topped with cheese. They contain a lot of iron and calcium.

What other nutrients do you think this meal contains? Explain your answer.

# Water

There is one more nutrient to add to the list of what you need to take into your body each day. This is water.

Water is needed for many different purposes in the body. Cells and blood contain a lot of water. Almost 60% of a person's body weight is made up of water. Water in cells allows all the different chemicals inside them to dissolve, so that they can react together. These reactions keep us alive. Water in blood allows it to flow easily, transporting substances all over the body.

### Summary checklist

- [ ] I can list the six types of nutrient that I need in my diet.
- [ ] I can explain why I need each of these nutrients.
- [ ] I can list some foods that contain each of these nutrients.

# 7.2 A balanced diet

## In this topic you will:

- find out what is meant by a balanced diet
- think about the nutrients you should try to eat each day
- learn why you should try not to eat too much of some nutrients.

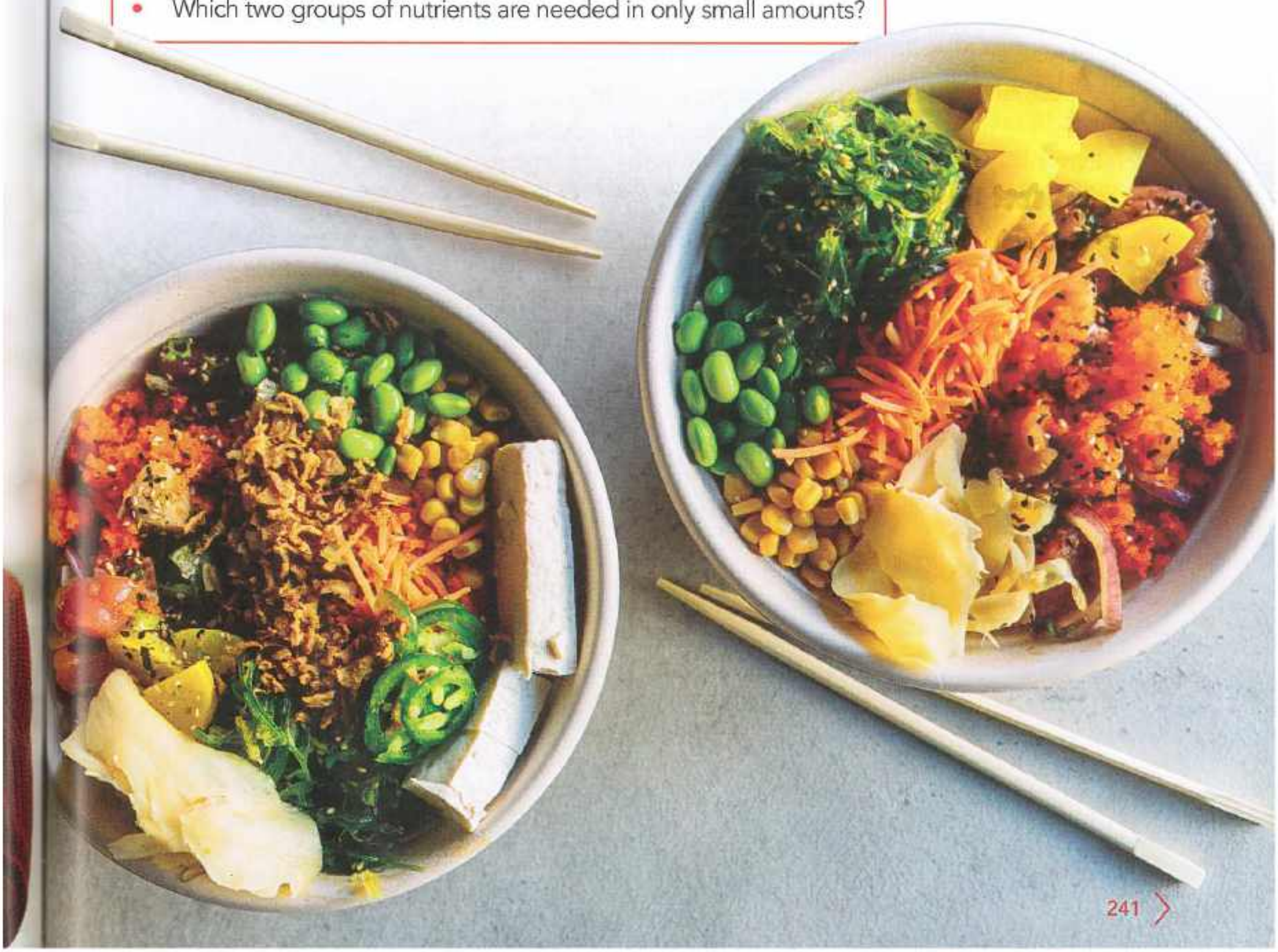
## Getting started

Try to answer these questions on your own.

- Can you name the six nutrients that you need to eat?
- Which three nutrients can give you energy?
- Which two groups of nutrients are needed in only small amounts?

## Key words

balanced diet
constipation
fibre



# Diet

Your diet is the food that you eat each day. Your diet should provide you with some of all the different kinds of nutrients. It should also give you the right amount of energy.

A diet that provides all the different kinds of nutrients, and the right amount of energy, is called a **balanced diet**.

# How much energy?

Each day, the energy in the food you eat should be approximately equal to the energy that you use up. Most of your energy comes from the carbohydrates and fat that you eat.

Different people use different amounts of energy. For example:

- if you do a lot of sport, or walk or run a lot each day, you use more energy
- if you don't move around much, you use less energy
- some people's genes mean that their body uses up energy more quickly than other people doing the same thing
- if you are growing fast, you need extra energy to help your cells to divide
- tall people use more energy to move their body around than small people

# Different diets

Everyone is different. Different people need different diets. Everyone needs plenty of minerals and vitamins, but people vary in how much protein and carbohydrate they need. Here are some examples.

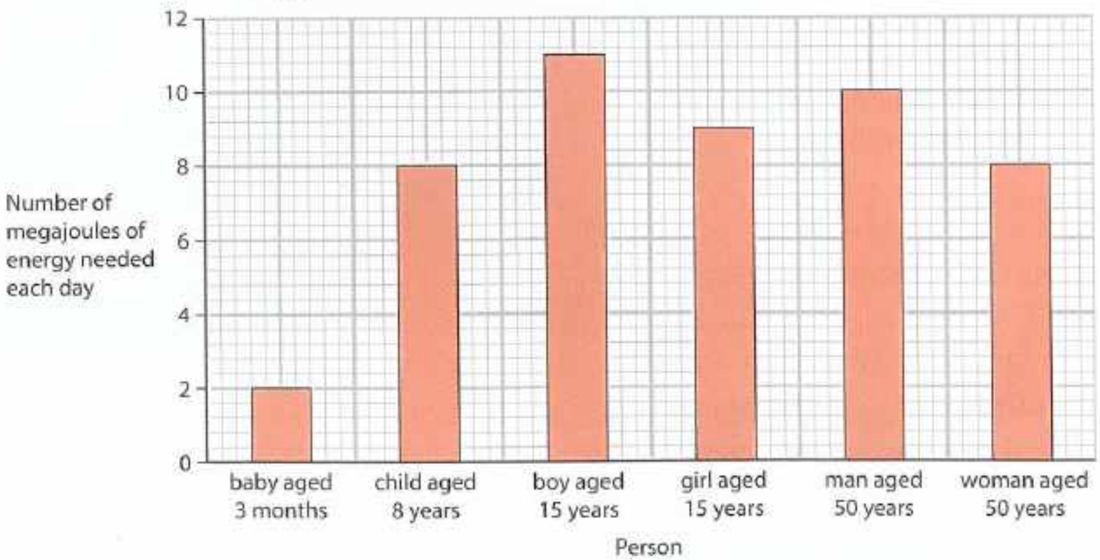
Young people who are still growing need a lot of protein to make new cells. If they use a lot of energy, then they need to eat enough carbohydrate to give them plenty of energy. They need to eat a little bit of fat for energy and making the membranes on the new cells.

People who have to sit down for a lot of the day don't use up as much energy as people who are very active. So they don't need to eat as much carbohydrate or fat as someone who has a job that involves moving around, or who does a lot of sport.

A pregnant woman needs to eat plenty of protein to help to build her growing baby's new cells. She also needs lots of iron in her diet, to make haemoglobin in her own blood and her baby's blood. She should eat plenty of calcium, for building her baby's bones.

## Questions

The bar chart shows some examples of the energy that different people need each day. A megajoule (MJ) is one million joules.



1 How many MJ of energy does an 8-year-old child need, on average?

2 Explain why some 8-year-old children might need more energy than this.

3 Explain why some 8-year-old children might need less energy than this.

4 Suggest why a man aged 50 years needs to take in less energy in his diet than a boy aged 15 years.

5 Suggest why most 15-year-old girls need less energy in their diet than most 15-year-old boys.

## Fibre

As well as the six nutrients you need in your diet, you also need to eat plenty of **fibre**.

Fibre is not actually a nutrient. This is because, when you eat it, you cannot digest it. So it does not go into the blood or to your cells. Instead, it just travels all the way through the digestive system. It leaves the body as faeces.

You might think this means that it is no use to you, but in fact fibre is very important to keep the digestive system healthy. It helps to prevent **constipation**, when the digestive system slows down and faeces collect inside it, instead of being passed out.

Fibre is mostly cellulose. Remember that plant cell walls are made of cellulose, so foods made from plants are a good source of fibre. Cereal grains, seeds and fresh fruit and vegetables are all excellent sources of fibre. And the good thing about this is that these foods usually contain lots of different minerals and vitamins, too.

### Question

6 Copy and complete each of these sentences. Choose the correct words.

   a I need protein for growth / energy.

   b There is a lot of protein in sugar / fish.

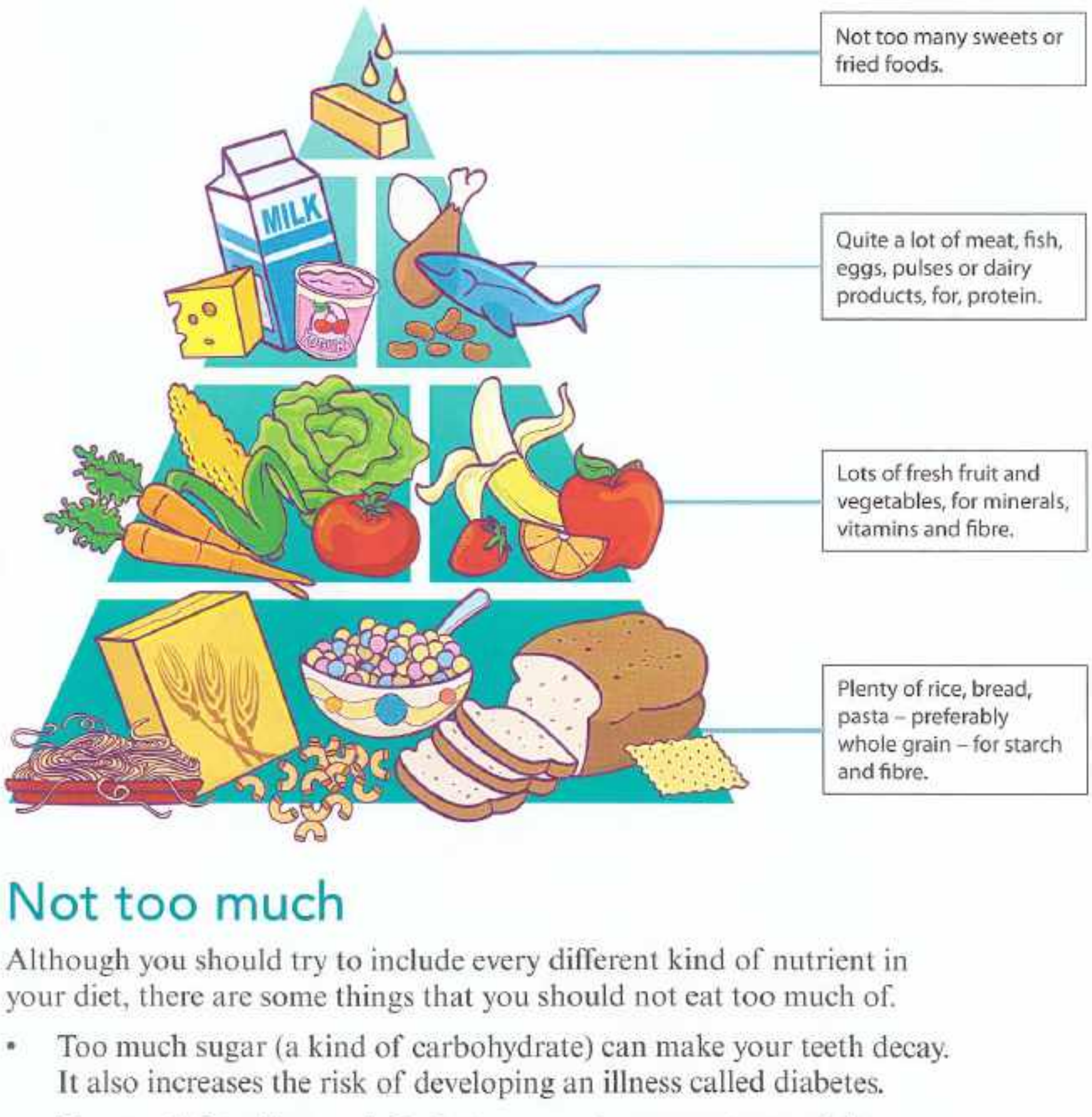
   c Starch and sugar / fat are carbohydrates.

   d I get energy from carbohydrate and calcium / fat.

## Food groups

It can be quite difficult to think about which nutrients are in each kind of food that you eat. To make it easier, it sometimes helps to think about food groups.

The picture shows some different kinds of food arranged in a triangle. The bigger the area in the triangle, the greater the proportion of your diet that kind of food should make up.




## Not too much

Although you should try to include every different kind of nutrient in your diet, there are some things that you should not eat too much of.

- Too much sugar (a kind of carbohydrate) can make your teeth decay. It also increases the risk of developing an illness called diabetes.
- Too much fat, oil or carbohydrate can make you put on weight. This can put a strain on your joints, heart and other body organs.
- Eating too many fats that come from animals can increase the risk of developing heart disease.

## Activity 7.2.1

### Advice on a healthy diet

Work with a partner for this activity.

These five learners are all giving good advice about eating a balanced diet.


Think about what each person is saying.

Match each of the pieces of advice with one of these reasons.

1. This means that you will get some of each kind of nutrient, including all the different vitamins and minerals.
2. These contain fibre and lots of vitamins.
3. This often contains a lot of fat from animals, and very few vitamins or minerals.
4. Not eating enough food will prevent the cells, tissues and organs in your body having enough energy to keep healthy.
5. It can increase the risk of getting heart disease when you get older.

## Questions

**7** Look at the picture of the food triangle.

- **a** Explain why sweets and fried foods are at the top of the triangle.
- **b** Explain why it is better to eat whole-grain bread or brown rice rather than white bread or white rice.
- **c** Suggest how you can make sure you get enough protein in your diet, if you don't like eating meat or fish.

**8** Your little brother's favourite meal is a lamb burger and fries, with a sweet milky drink.

- **a** What nutrients does he get from this meal?
- **b** What else should he include in his diet?
- **c** Explain to him why he should not eat his favourite meal too often.

### Summary checklist

- [ ] I can explain what is meant by a balanced diet.
- [ ] I can explain why different people need different diets.
- [ ] I can explain why no one should eat too much sugar or fat.

# > 7.3 Growth, development and health

## In this topic you will:

- learn how growth takes place
- find out about the difference between growth and development
- think about how your diet and the amount of exercise you take affects your growth, development and health
- learn how smoking affects health.

## Getting started

Most people know that doing plenty of exercise and not smoking help you to stay healthy.

With a partner, think about these questions.

1 How does doing plenty of exercise help to keep you healthy?

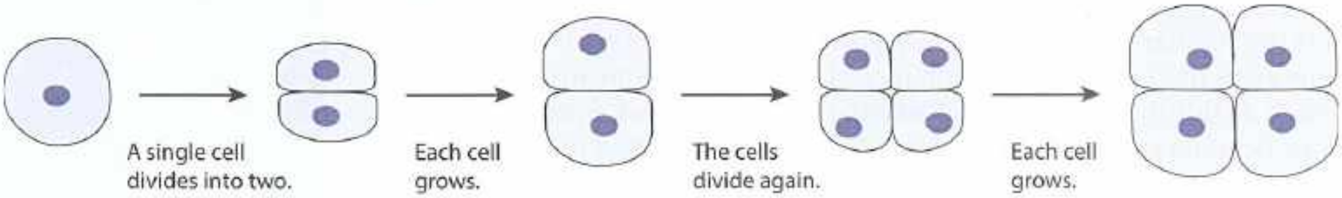
2 How does not smoking help to keep you healthy?

## Key words

carbon monoxide
development
embryo
nicotine
particulates
tar

# Growth

Every person on Earth began their life as a single cell. This cell divided to produce two cells. Each of these cells got bigger, then divided again.




To begin with, the cells are all the same. They produce a little ball of cells called an **embryo**, and eventually a baby.

This all happens inside the mother's body. By the time the baby is born, it is a miniature human being. It continues to grow until it is about 18–20 years old.

Cells contain a lot of protein. Energy is needed to make cells divide. A pregnant woman and a growing child need plenty of protein in their diet, as well as enough energy to help cells to divide.

# Development

The change from a single cell to an adult human involves more than just growth. As the tiny embryo grows into a baby, all its different tissues and organs are formed. As the baby grows into a child, its leg muscles and bones become stronger, so that it can walk and then run. Its brain develops, as it learns to talk and to play with toys.

These changes are called **development**.

Each person is an individual, and everyone grows and develops at different rates, and in slightly different ways. But everyone goes through the same stages in development. These are shown in this chart. Notice that each stage blends gradually into the next one – there are no sharp divisions between them.


## Questions

1 Growth means getting bigger. Explain what happens as a person grows, to make their body get bigger.

2 Some young children do not get enough protein or energy in their diet. Explain why they may not grow very tall.

# Exercise and health

Topic 7.2 described some of the ways in which your diet can affect your health. There are other ways in which the decisions you make about your lifestyles can affect how healthy you are.

Taking regular exercise is a really good thing to do. This uses some of energy in the food you eat each day, stopping you from storing too much as fat. It also makes the heart and muscles work hard, so that they become strong. Exercise can also make people feel more cheerful and positive about life.

# Smoking

Smoking cigarettes damages the smoker's health. It also damages the health of people around them, who accidentally breathe in cigarette smoke.

Tobacco contains many different harmful substances.

## Nicotine

Tobacco smoke contains **nicotine**. Nicotine can help someone to stay alert. Nicotine is addictive. This means that it is difficult to manage without it, once you are used to smoking. This is why smokers find it so difficult to stop smoking.

Nicotine damages the blood vessels in a smoker's body. It makes them get narrower, so it is harder for blood to get through them. Smokers are more likely than non-smokers to develop heart disease.

## Tar

Tobacco smoke contains a mixture of dark, sticky substances called **tar**. Some of the chemicals in tar cause cancer. Cancer happens when cells start dividing out of control and spread to other parts of the body. Smoking increases the risk of getting many different kinds of cancer, including lung cancer.

## Carbon monoxide

**Carbon monoxide** is a poisonous gas. When it gets into the body, it combines with haemoglobin inside red blood cells. This stops haemoglobin doing its normal job, which is to combine with oxygen and transport it to all the body cells that need it. So a smoker's cells don't get enough oxygen. They cannot carry out enough respiration, so don't have enough energy.

## Particulates

Tobacco smoke contains tiny particles of carbon and other materials, called **particulates**. They get trapped inside the smoker's lungs. This makes the walls of the alveoli break down. Instead of having millions of tiny alveoli in the lungs, the smoker has a lot of big spaces. This is makes it difficult for them to get enough oxygen into their blood.

## Activity 7.3.1

### Why do people smoke?

Work in a group of three for this activity, and be ready to share your ideas at the end.

Until the 1960s, no one realised that smoking was bad for your health. Today, everyone knows how harmful it is.

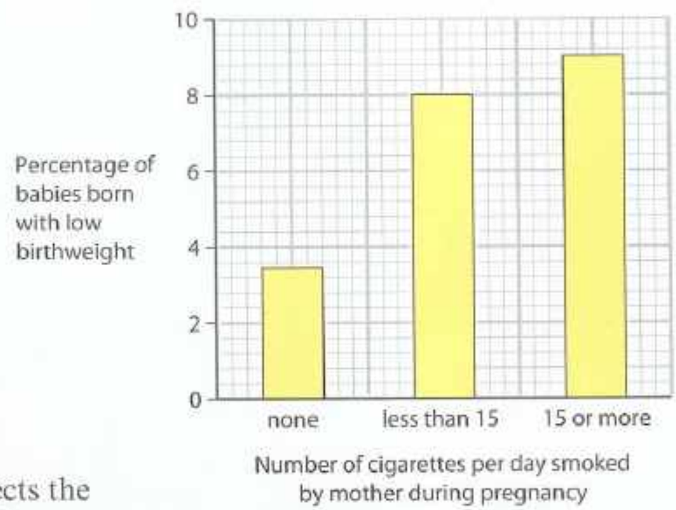
In your group, discuss these questions. You might need to do some research to find the answers to some of them.

- Why do people choose to smoke? Do you think the reasons are different for older people and younger people?
- Why is it difficult to give up smoking, once you have started?
- In the 1940s and 1950s some cigarettes were advertised as being medically approved and good for you. Find some data about smoking from the 1950s. Where did the data come from? Was some of it biased? Why might tobacco companies have tried to hide the dangers? Why did it take so long for people to realise that smoking was harmful?
- Is the government in your country trying to reduce the number of people smoking? If so, what are they doing?

## Questions

This bar chart shows the percentages of babies with a birthweight lower than normal, born to mothers who smoked different numbers of cigarettes per day while they were pregnant.

Use the information in the bar chart to answer these questions.




**3** What percentage of babies born to mothers who do not smoke have a low birthweight?

**4** Calculate the percentage of babies born to non-smoking mothers that do **not** have a low birthweight.

**5** Describe how smoking during pregnancy affects the chance of having a baby with a low birthweight.

## Summary checklist

- [ ] I can describe how organisms grow.
- [ ] I can explain what is meant by development.
- [ ] I can explain why exercise is good for a person's health.
- [ ] I can explain how smoking damages health.

# 7.4 Moving the body

## In this topic you will:

- learn about hinge joints and ball-and-socket joints
- find out how a pair of muscles moves the arm at the elbow.

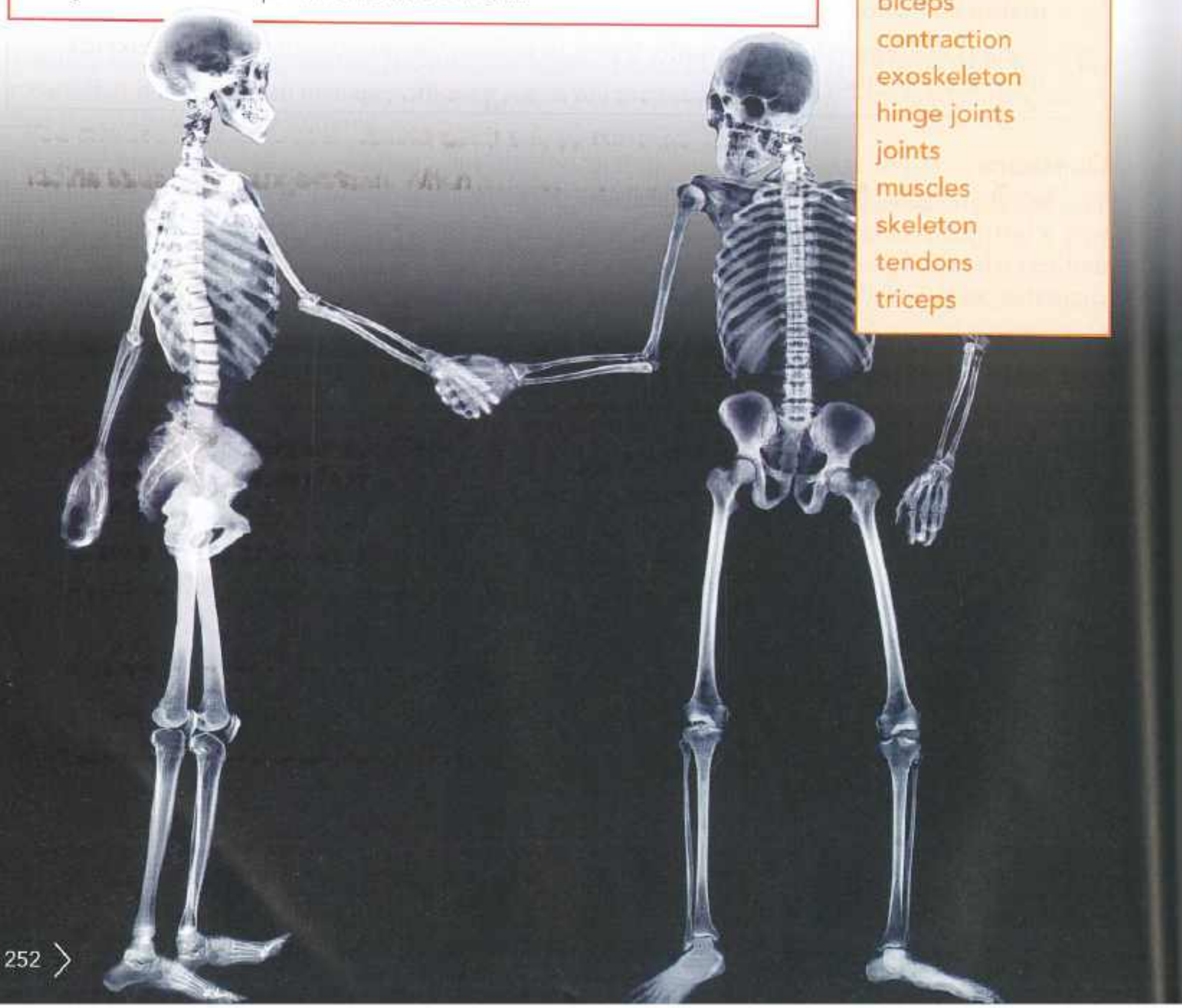
## Getting started

1 Some bones protect parts of the body. Look at the diagram of the skeleton on the next page. Which bones do you think are important for protection? What do they protect?

2 Some bones are important in movement. Which bones do you think are important for movement?

## Key words

antagonistic muscles
ball-and-socket joints
biceps
contraction
exoskeleton
hinge joints
joints
muscles
skeleton
tendons
triceps



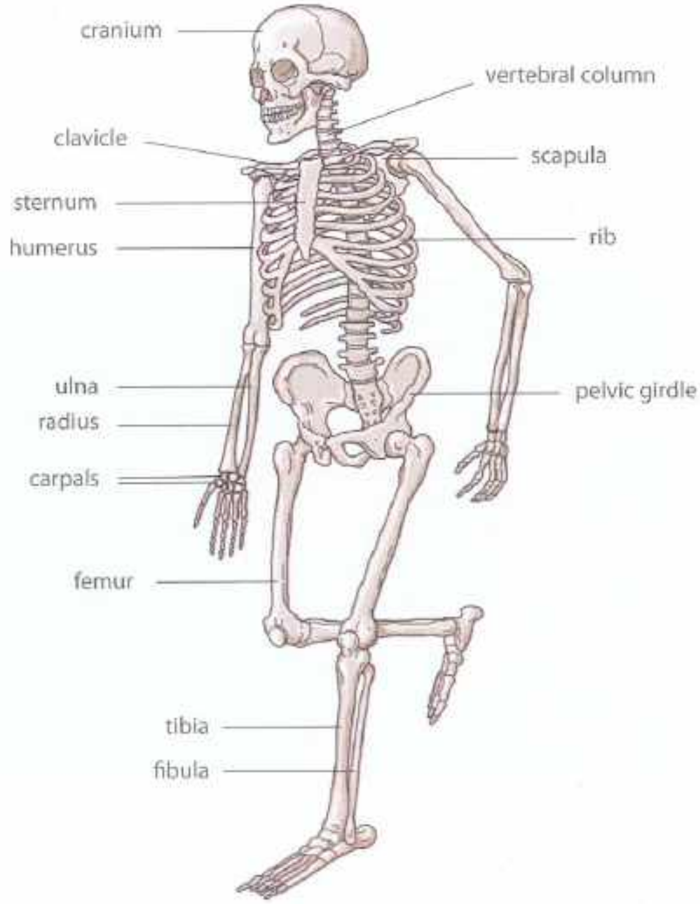
## The skeleton

Animals' bodies are supported by a **skeleton**. Insects and other arthropods have a skeleton on the outside of their body.

This is called an **exoskeleton**.

Your skeleton is inside your body. It is made of bones. You do not need to remember the names of all of these bones, but you may know some of them already.

Bones are hard and strong. They contain a lot of calcium. If you do not have enough calcium in your diet, your bones may not grow properly. Bones contain living cells, so you also need protein in your diet to build strong bones.




The human skeleton

## Joints

Bones cannot bend. Movement in the skeleton can only take place where two bones meet one another. These places are called **joints**.

Some joints work like the hinges on a door. They let the bones move back and forth in one direction, in the same way that a door opens and closes. These are called **hinge joints**.

Some joints let the bones move in a complete circle. At these joints, one of the bones has an end shaped like a ball. The other bone has a cup, or socket, that the ball fits into. These are called **ball-and-socket joints**.

### Activity 7.4.1

#### Identifying different kinds of joint

Work with a partner.

Look at the diagram of the skeleton. If you have a model of a skeleton, you could look at that as well.

Can you find at least **two** different hinge joints on the skeleton? (You may be able to find many more than two.) Try moving your own joints at these places. Which bones meet at the hinge joints?

Now try to find **two** different ball-and-socket joints on the skeleton. Try moving your own joints at these places. Which bones meet at the ball-and-socket joints?

Write down your ideas, and be ready to share them with the rest of the class.

## Questions

1 Explain what a joint is.

2 These pictures show a man hitting a golf shot.

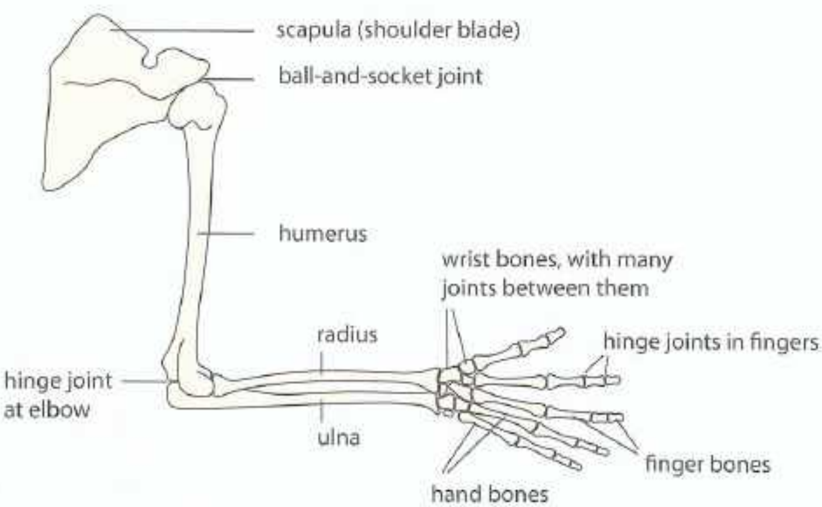
a Which hinge joints is he moving?

b Which ball-and-socket joints is he moving?

# Joints in the arm

You have several different joints in your arms. These include the shoulder joint, the elbow joint, the wrist joint and all the joints in the fingers.

The photo is an X-ray of someone's arm. Can you pick out the humerus, radius and ulna? You should also be able to find the hinge joint at the elbow, and the ball-and-socket joint at the shoulder.



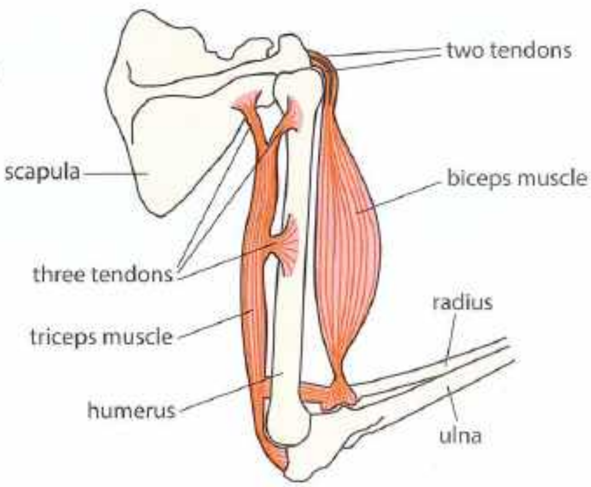

# Muscles

Bones and joints cannot move themselves. You use **muscles** to move bones at joints.

Muscles are made of specialised cells. These cells are able to make themselves shorter. This is called **contraction**.

Muscles use energy to contract. Like all cells, they get this energy from nutrients, especially glucose. The energy is released from glucose by respiration. The more you ask your muscles to contract, the more energy they use, and therefore the more glucose they use.

Muscles can produce a strong pulling force when they contract. Many of your muscles are attached to bones, by tough cords called **tendons**. When the muscle contracts, it pulls on the tendon, which pulls on the bone. This makes the bone move at a joint.




This diagram shows the muscles that move the arm bones at the elbow joint.

First, look at the biggest muscle in the diagram. This is the **biceps**. (Biceps is an unusual word, because it ends in an s even though it is singular. One biceps, two biceps.) 'Bi-' means two. This muscle is called the *bi*ceps because it has *two* tendons that attach it to the scapula.

The longer, thinner muscle in the diagram is the **triceps**.

## Questions

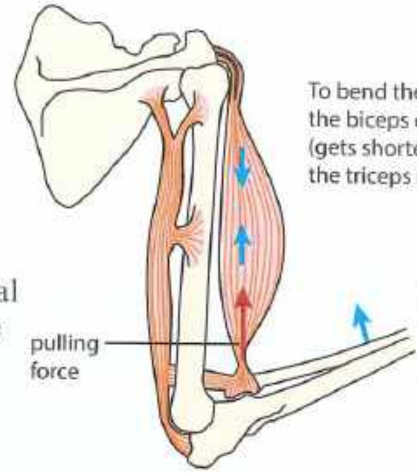
3 The biceps is attached to the scapula at one end. Which bone is the other end attached to?

4 Which bones is the triceps attached to?

5 Tri- means three. Suggest why the triceps has this name.

6 Tendons do not stretch. Suggest why not.

# Bending the elbow joint




Think about what happens when you bend your arm at the elbow.

When you decide to bend your arm, your brain sends an electrical impulse along a neurone, to your biceps muscle.

The cells in the biceps muscle respond to this electrical impulse by contracting. This makes the whole muscle get shorter.

The biceps muscle is firmly fixed to the scapula at one end and the radius at the other end. So, when it gets shorter, these bones are pulled closer together. The elbow bends, as shown in the diagram.

### Activity 7.4.2

#### Feeling your muscles

You can do this activity on your own.

Rest your arm on the table in front of you, keeping it straight.

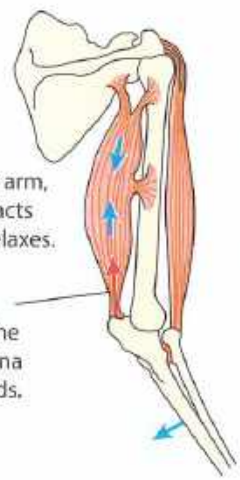
Put the fingers of your other hand on your upper arm, where your biceps muscle is.

Slowly and steadily, bend your arm upwards.
Do this several times.

What can you feel happening in your upper arm, when you do this?

Be ready to share your ideas.

# Straightening the elbow joint




Now think about how you straighten your arm at the elbow joint.

It's important to remember that muscles can only pull. They cannot push. Muscles can generate a force by getting shorter, or contracting. But they cannot generate a force by getting longer.

So, the biceps cannot push the arm straight again. You need another muscle to *pull* the arm straight.

The muscle that does this is the triceps muscle. This diagram shows how it does this.

When a muscle is not contracting, it relaxes. This is all that muscles can do – they can either contract or relax.

# Antagonistic muscles

You can see that the biceps muscle and the triceps muscle work as a team.

- To bend the arm, the biceps contracts and the triceps relaxes.
- To straighten the arm, the triceps contracts and the biceps relaxes.

Two muscles that work together like this are called **antagonistic muscles**. When one of them contracts, it moves the bones at a joint in one direction. When the other muscle contracts, it moves the bones in the other direction.

## Think like a scientist

### Using a model arm to investigate how the biceps muscle works

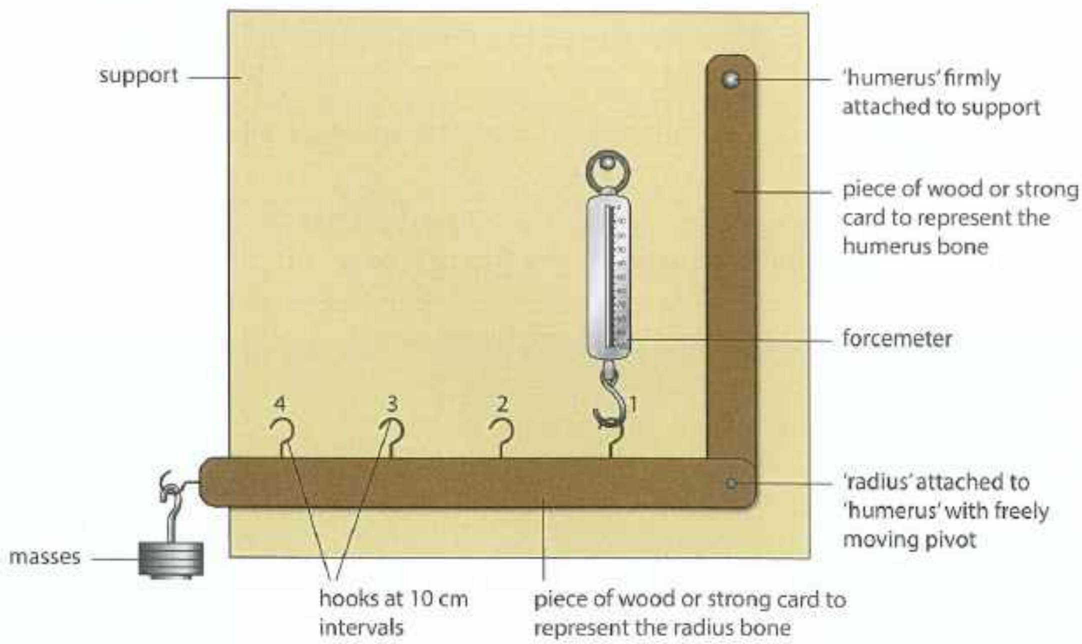
You are going to investigate how the size of the force produced by the biceps muscle differs, if it is attached at different positions on the radius.

You will need:

- model arm, like the one in the diagram
- some masses on a hanger
- forcemeter

Topic 3.4 showed that the arm acts like a lever. In this investigation, you are going to try attaching the 'biceps muscle' at different points along the 'radius', to find out the force needed to lift a weight.

Set up your model arm like this.



## Continued

### Method

1 Read through the instructions given in the method. Then construct a chart to fill in your results.

2 Put some masses on the hanger. Start with just one or two masses. (Make sure you record these masses in your results chart.)

3 Attach the forcemeter to hook 1. Pull gently and steadily vertically upwards until the 'radius' makes a right angle with the 'humerus'. Record the reading on the forcemeter as you keep the radius in this position.

4 Now attach the forcemeter to hook 2, and repeat.

5 Repeat again, with the forcemeter attached to hook 3 and then hook 4.

6 Put some more masses on the hanger. Repeat steps 3 to 5.

### Questions

1 What does the forcemeter represent in this model?

2 What happened to the force needed to keep the radius horizontal, as you moved the forcemeter further away from the elbow joint?

3 Use what you have learnt about turning forces (moments) in your physics lessons to explain your answer to question **2**.

4 What happened to the force needed to move the radius, when you added extra masses to the hanger?

5 Use what you have learnt about turning forces (moments) in your physics lessons to explain your answer to question **4**.

6 Which position – 1, 2, 3 or 4 – matches the position where the real biceps is attached to the real radius?

7 Muscles can produce very strong forces when they contract. But they cannot make themselves very much shorter. Suggest why the real biceps is attached in this position.

## Summary checklist

- [ ] I can name the bones in the arm.
- [ ] I can identify some hinge joints and ball-and-socket joints in the body.
- [ ] I can describe how muscles produce a force when they contract.
- [ ] I can explain how the biceps and triceps work as antagonistic muscles to move the arm at the elbow.

## Project: A diet for Mars explorers

In this project, you will evaluate issues that require scientific understanding.

### Your task

You are going to work with everyone else in your class to produce a display about feeding astronauts as they travel to Mars and back.

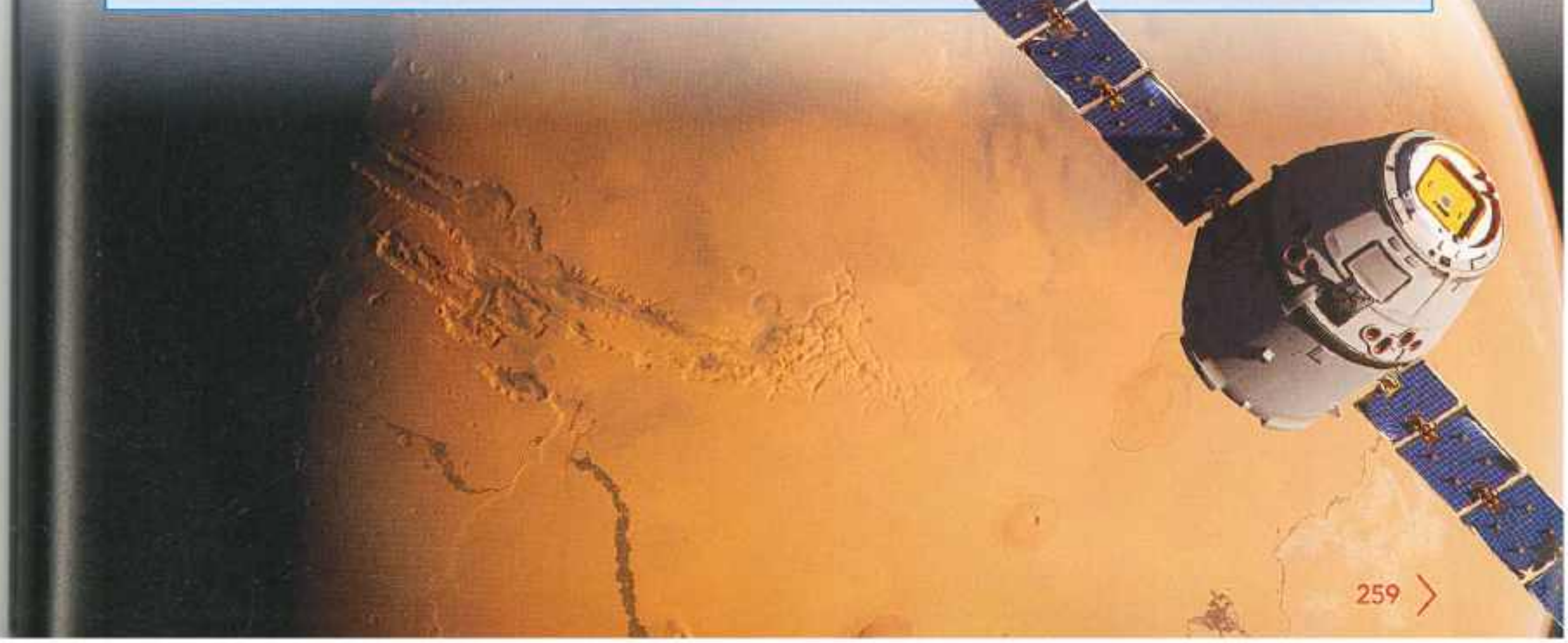
The National Aeronautics and Space Administration (NASA) is hoping to send people to Mars by the 2030s. They have many problems to solve if they are going to achieve this. One problem is how to feed the astronauts so that they stay healthy and strong during the long trip. It would take up to three years to go to Mars and back.

Here are some problems and suggestions that are being discussed by scientists and others.

- NASA could send a spaceship loaded with five years'-worth of food to arrive on Mars before the astronauts arrive. Would that work better than the astronauts taking all their food with them?
- It would take up less space if the food could just be pills, instead of 'real' food. Would that work?
- The bones and muscles of astronauts get smaller and weaker when they are in space for a long time. Are there any kinds of food that might help to reduce this problem?
- To get fresh vitamins, astronauts need to eat fresh plant-based foods. Could they grow plants on their spaceship? Could they grow plants on Mars?

Work in a group of four or five. Choose one or two of these problems – it would be good if different groups choose different ones. Use the internet to find other people's ideas for solving the problems. You might also have your own ideas.

Work with the other groups in your class to produce a display about how to feed the Martian astronauts.



# Check your progress

**7.1** A weightlifter asks their trainer for advice on his diet.
The trainer gives this advice.

- Eat some protein with every meal.
- Eat plenty of starch or other carbohydrates.

**a** Copy and complete the sentences. Choose words from the list.

**constriction contract fat relax glucose respiration**

The weightlifter uses their muscles to lift weights.

The muscles .................... to make the weights move.

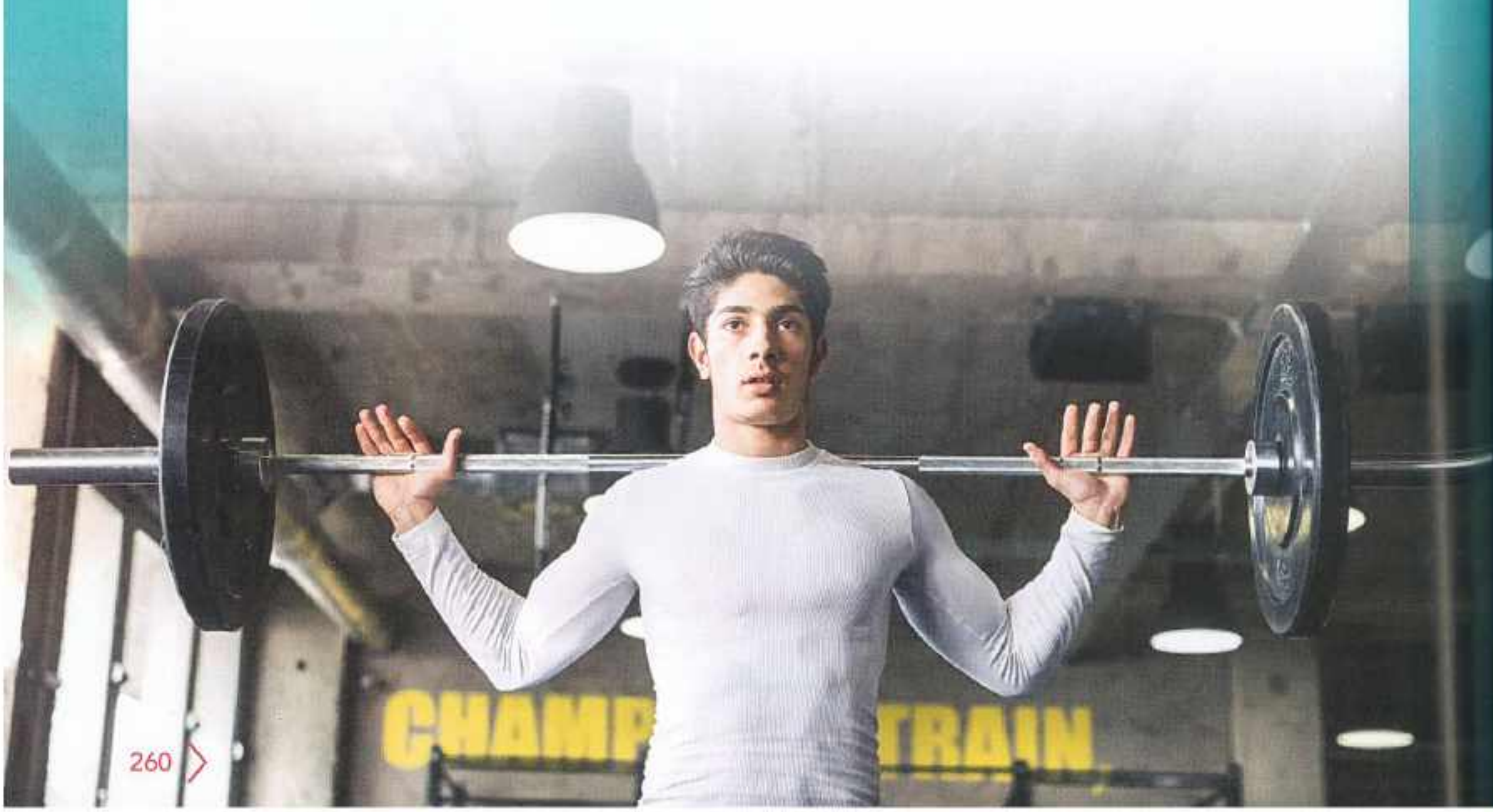
This uses energy.

The muscles get the energy by breaking down .................... in a reaction called .................... . [3]

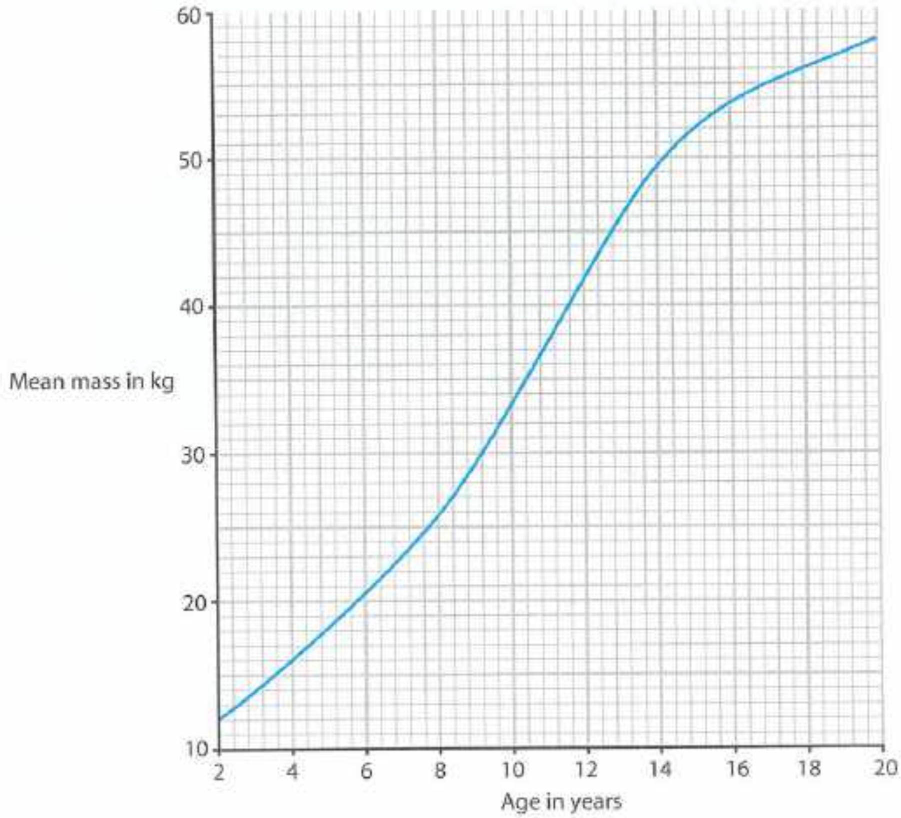
**b** Explain why the weightlifter needs to eat plenty of protein. [2]

**c** Explain why the weightlifter needs to eat plenty of carbohydrate. [2]

**d** List **four** other nutrients the weightlifter should include in their diet as well as protein and carbohydrate. [2]



**7.2** The graph shows the mean mass of girls at different ages.



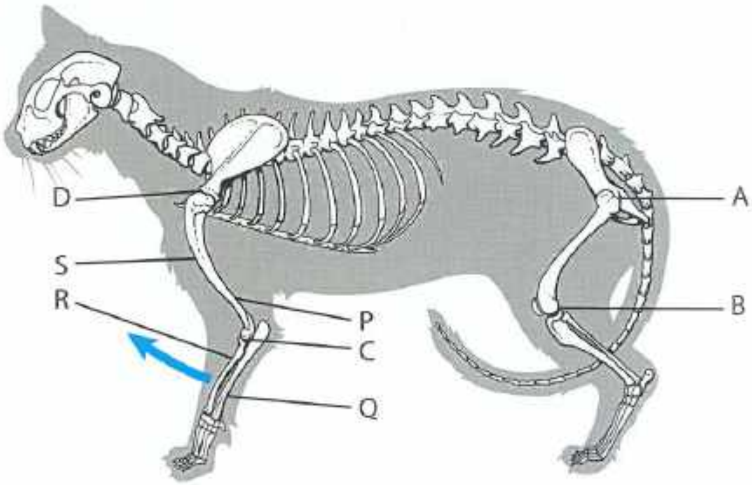

**a** What is the mean mass of girls when they are two years old? [1]

**b** By how much does the mean mass increase between two years and 10 years old? [1]

**c** Between which ages does growth happen most rapidly? [1]

**d** Does the graph show that most girls have stopped growing by the age of 20? Explain your answer. [1]

**7.3** The diagram shows the skeleton of a cat. Cats have the same bones as humans, but their sizes are different.




**a** Which joints, A, B, C or D, are hinge joints and which are ball-and-socket joints? **[1]**

**b** Where should the two ends of a muscle be attached to move the cat's front leg as shown by the arrow?

Choose from P, Q, R and S. **[1]**

**c** Where should the two ends of a muscle be attached to move the cat's front leg back to its original position?

Choose from P, Q, R and S. **[1]**

**d** What name is given to two muscles like the ones you have described in parts **b** and **c**? **[1]**

**e** Explain why two muscles are needed to move a bone in one direction and then back again. **[2]**

**f** Name **one** mineral needed for the cat to form strong bones. **[1]**

**g** Cats are predators. They eat other animals. Suggest where cats get this mineral from, in their diet. **[1]**

# 8 Chemical reactions

## 8.1 Exothermic reactions

### In this topic you will:

- learn about chemical reactions that give out energy
- plan and carry out an investigation.

### Getting started

This word equation shows the reaction between carbon and oxygen that takes place when carbon burns:

carbon + oxygen ⟶ carbon dioxide

Answer these questions and then compare answers with a partner. Be prepared to share your answers with the class.

- Name a reactant.
- Name a product.
- How many atoms make up a particle of carbon dioxide?
- How many of these atoms are carbon?
- How do you know that burning releases energy to the environment?

### Key words

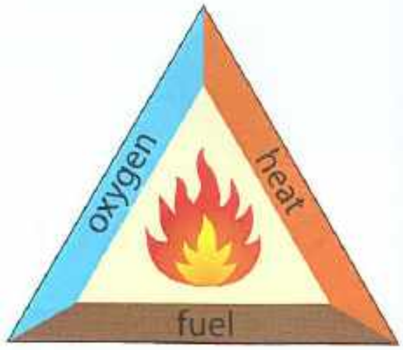
combustion
dissipate
exothermic reaction
fuel
oxidation reaction
preliminary work

# Burning

When something burns, a chemical reaction takes place. Burning is a chemical reaction in which a substance combines with oxygen. In a burning reaction, there are energy changes. The substance that reacts with oxygen is called a **fuel**.

Fuels have a store of chemical energy. Charcoal, wood, coal, natural gas and oil are examples of fuels.

When the fuel burns, the chemical energy is changed to thermal, light and sound energy. The thermal, light and sound energy **dissipate** (spread out) into the surroundings.




Burning requires oxygen, fuel and heat (thermal energy)

**Combustion** is another term for burning.

Look back at the equation in *Getting started*. You can see that, during the reaction, the atoms of carbon and oxygen join together in new ways. When this happens, chemical energy is changed to thermal energy and the temperature rises.

A chemical reaction in which thermal energy is given out is called an **exothermic reaction**.

## Questions

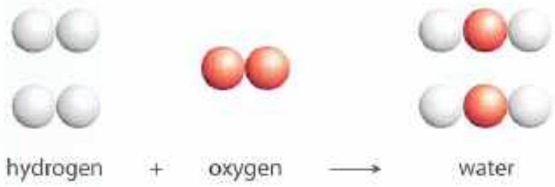
1 What is needed for combustion to take place?

2 What is an exothermic reaction?

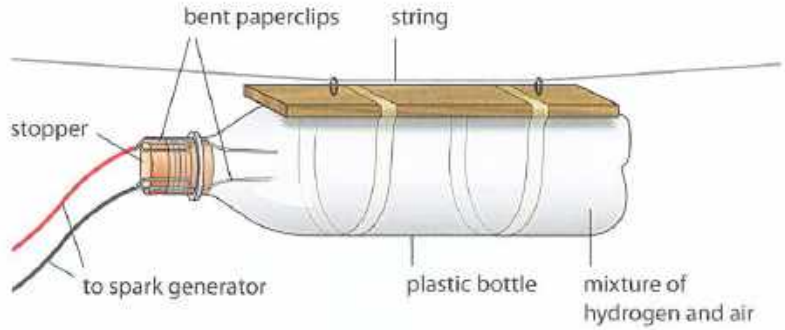
3 How can you tell that burning is an exothermic reaction?

# Burning other substances

Hydrogen can be used as a fuel in a model rocket. The combustion of hydrogen is an exothermic reaction. The hydrogen and the oxygen combine to form water.




When the atoms of hydrogen and oxygen rearrange themselves and combine together, energy is given out. This chemical energy is changed into kinetic, thermal, sound and light energy.



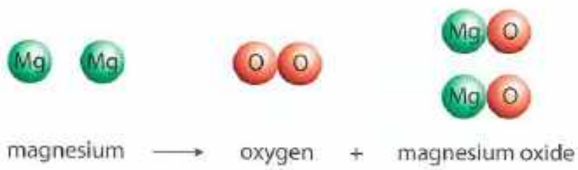

Burning hydrogen can propel a plastic bottle like a rocket

In this experiment, a large plastic soda bottle filled with hydrogen and air is attached to a string across the room. The stopper in the bottle has wires that allow a spark to be generated. The hot spark provides the energy to start the reaction. The hydrogen and oxygen react together.

The reaction gives out a lot of energy and the stopper is pushed out. This energy makes the bottle shoot (move very quickly) along the string.

The reactions of other substances burning in air are also exothermic reactions. An example is burning magnesium, which produces magnesium oxide. Energy is given out as heat and light as the magnesium and oxygen atoms rearrange themselves.

Burning magnesium ribbon

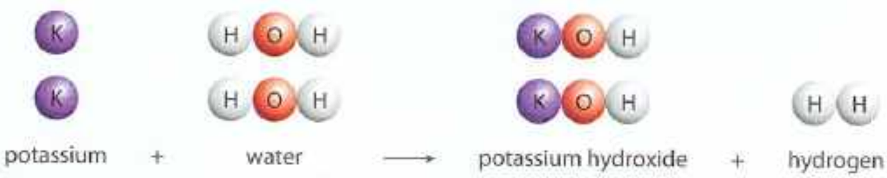



When a substance burns, it combines with oxygen and a new substance called an oxide is formed. Any reaction in which a substance combines with oxygen is an **oxidation reaction**.

# Other exothermic reactions

## With water

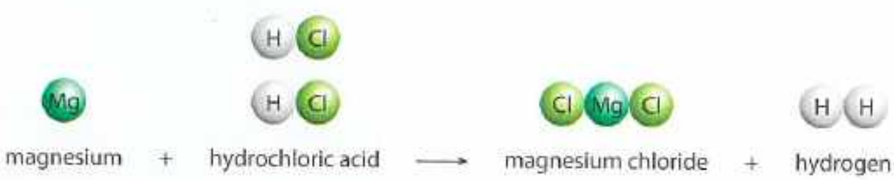
This is the equation for the reaction between potassium and water.




Water is made up of particles containing atoms of hydrogen and oxygen. In the potassium and water reaction, the bonds between the atoms of oxygen and hydrogen in the water break. The atoms rearrange to form the products potassium hydroxide and hydrogen. Stored chemical energy is changed to thermal energy, which dissipates into the environment.

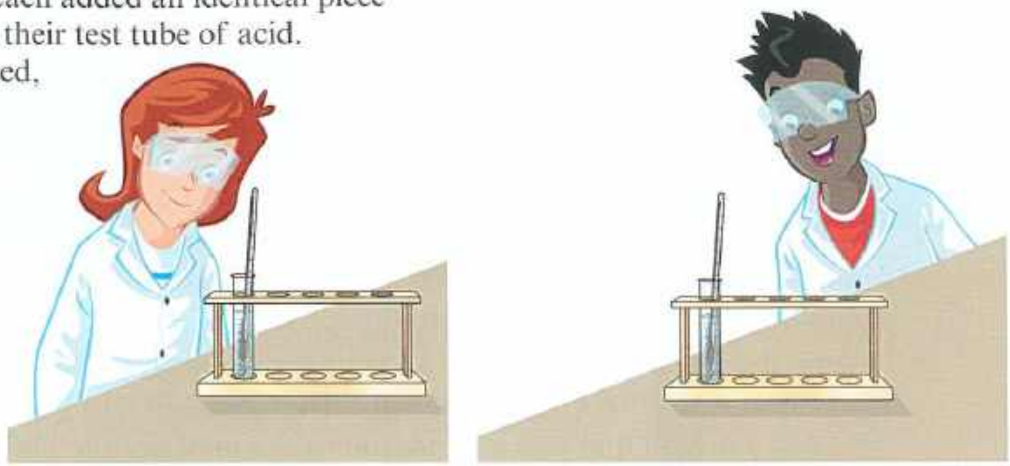
## With acid

If you add magnesium to dilute hydrochloric acid, the test tube gets hot. This reaction is an exothermic one.



# Measuring temperature rise during a reaction

Sofia and Marcus each measured 10 $cm^3$ of dilute hydrochloric acid into a test tube and measured the temperature. Then they each added an identical piece of magnesium ribbon to their test tube of acid. When the reaction stopped, they each measured the temperature again.



Measuring the rise in temperature when magnesium reacts with hydrochloric acid

| Sofia's results | |
|---|---|
| Start temperature in °C | End temperature in °C |
| 18 | 42 |

| Marcus's results | |
|---|---|
| Start temperature in °C | End temperature in °C |
| 21 | 45 |

## Questions

4 What are the products when magnesium and hydrochloric acid react?

5 How did Sofia and Marcus know when the reaction had finished?

6 Marcus thought that more chemical energy had been changed to thermal energy by his reaction because, in his experiment, the end temperature was higher. Sofia thought that both reactions changed the same quantity of chemical energy to thermal energy. Whose idea is correct? Explain why?

7 Explain why it is a good idea to wear safety glasses whilst carrying out this investigation.

8 Sofia and Marcus wondered how they could produce a higher temperature change. Their ideas included adding more magnesium, using a different metal and using a different acid.

Write each of these three ideas as a scientific question to be investigated.

## Think like a scientist

### Planning and carrying out an investigation into the reaction between acid and magnesium

#### Method

1. Choose one of the scientific questions to be investigated from question 8 (or write one of your own) and write a plan for your investigation.
   - Before you write your plan, try out the reaction between magnesium and an acid. In this **preliminary work** you should practise measuring the temperature change.
   - Decide what equipment you will need and make a list.
   - You also need to find out how big a change in the variable (for example, the length of the magnesium ribbon) is needed to make a change in the temperature that you can measure.
   - When the reaction takes place and chemical energy is changed to thermal energy, the thermal energy dissipates (spreads out) into the environment.
     - Are you sure that you are measuring the temperature change accurately?
     - What could you do to reduce this heat loss?
   - Decide how you will record and present your results.
   - Carry out a risk assessment.
2. Ask your teacher to check your plan.
3. Carry out your plan. You may find that you want to make changes to it once you begin doing the investigation. If so, write down the changes that you have made and explain why you made them.

#### Questions

1. What can you conclude from your results?
2. Compare your results with others from the class. Are your results in agreement with others who carried out the same investigation?
3. How could you improve your investigation?

How can preliminary work help me to improve my investigation?

## Summary checklist

- [ ] I can describe what happens in an exothermic reaction.
- [ ] I can plan an investigation.
- [ ] I can carry out an investigation safely.

# 8.2 Endothermic reactions

## In this topic you will:

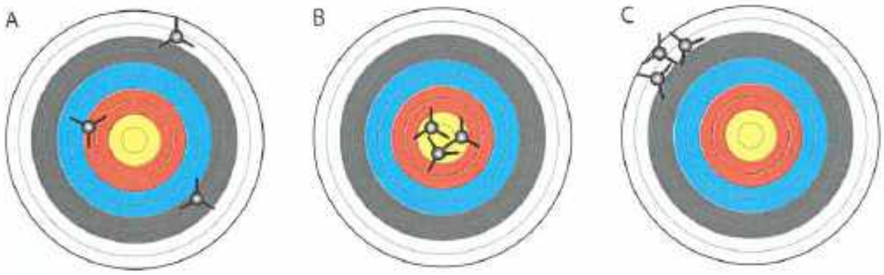
- learn about chemical reactions that absorb energy
- distinguish between exothermic and endothermic reactions and processes
- learn about the use of exothermic and endothermic reactions and processes.

## Getting started

When you make any scientific measurements, you are told that you need to be accurate and precise.

- What do you think this means? Discuss it with your partner.

Look at these three archery targets.



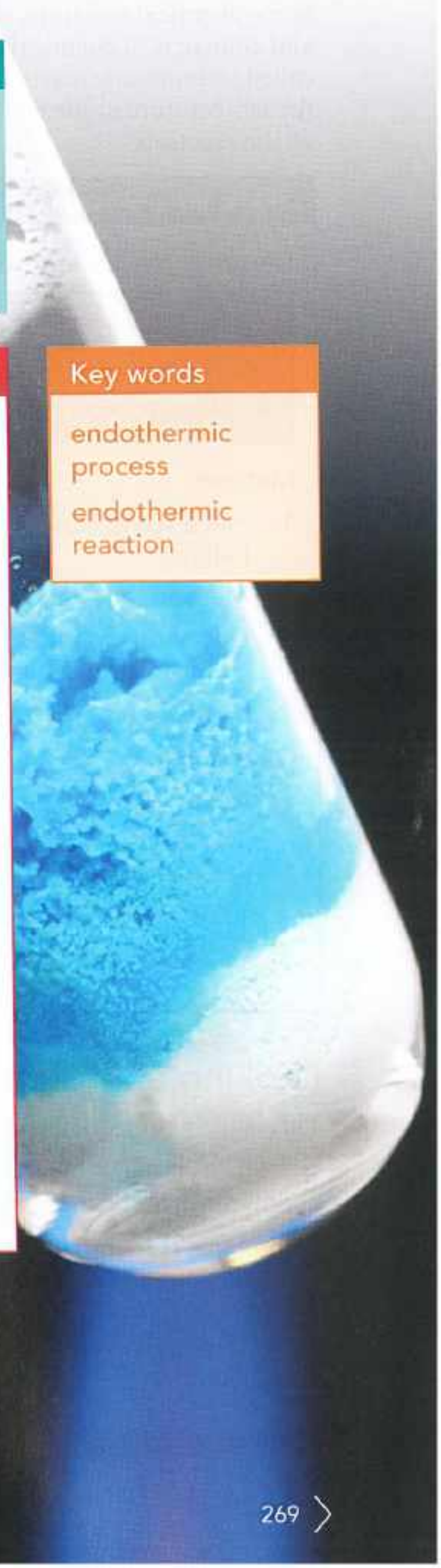

- If you are being accurate, where should your arrows hit the target?
- If you are being precise, should all your arrows be near to one another or spread out?
- Which archer, A, B or C, has been precise but not accurate?
- Which archer, A, B or C, has been neither precise nor accurate?
- Which archer, A, B or C, has been both accurate and precise?

Share your answers and ideas with the class.

## Key words

endothermic process

endothermic reaction



# Endothermic reactions

Some chemical reactions absorb thermal energy from their surroundings and change it to chemical energy stored in the chemical bonds. These are called **endothermic reactions**. When an endothermic reaction takes place, the temperature at the end of the reaction is lower than that at the start of the reaction.

## Think like a scientist

### Carrying out an endothermic reaction

You will need:

- test tube
- test tube rack
- stirring rod
- thermometer
- spatula
- lemon juice or citric acid
- sodium hydrogencarbonate
- safety glasses

Method

1. Place some citric acid or lemon juice in a test tube so that it is about half full.
2. Measure and record the temperature.
3. Add three spatulas of sodium hydrogencarbonate and stir. Do **not** use the thermometer to do this.
4. Measure and record the temperature.

### Questions

1. What was the difference between the temperature at the start and the end of the experiment?
2. Is thermal energy given out to the surroundings or taken in from the surroundings during this reaction?

## Looking at endothermic reactions

This is the word equation for the reaction between sodium hydrogencarbonate and citric acid:

sodium hydrogencarbonate + citric acid ⟶ sodium citrate + water + carbon dioxide

During this reaction, thermal energy is absorbed from the surroundings and stored in the form of chemical bonds. So, if this reaction was carried out in a test tube, the surroundings will have a lower temperature and the test tube will feel cooler.

If you eat sherbet sweets, this reaction takes place in your mouth. The sherbet is a mixture of dry citric acid and sodium hydrogencarbonate. When you eat the sweets, these substances dissolve in your saliva, and react together. This gives a cool, 'fizzy' feeling in your mouth (the surroundings), which is refreshing.

### Questions

1 Look at the word equation again:

sodium hydrogencarbonate + citric acid ⟶ sodium citrate + water + carbon dioxide

  a What are the reactants?

  b Which are the products?

2 What is an endothermic reaction?

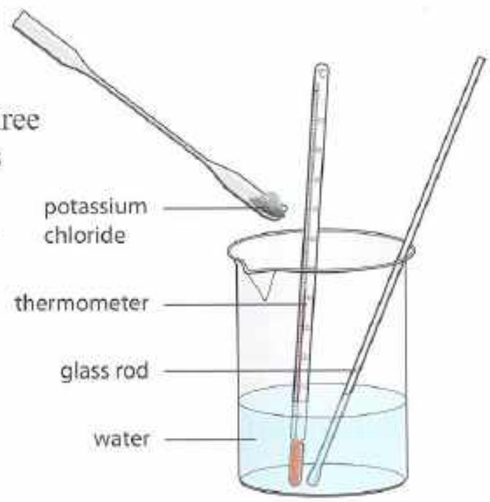
3 Explain why eating sherbet sweets makes your mouth feel cooler.

4 You may also get a 'fizzy' feeling in your mouth when you eat sherbet. Why is this?

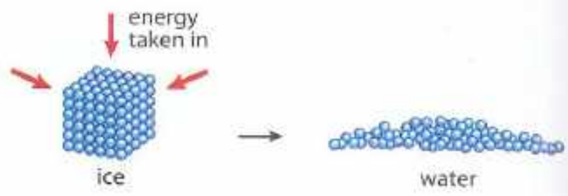
## Endothermic processes

If you place about 25 $cm^3$ of water in a beaker and then stir in three spatulas of potassium chloride, you will find that the beaker gets cold. In this case, no chemical reaction has taken place. No new products are formed. The potassium chloride has just dissolved. A solution of potassium chloride has been formed. Potassium chloride is the solute and water is the solvent.

When potassium chloride dissolves in water, thermal energy is absorbed from the surroundings. This is why the beaker feels cold. This is an **endothermic process**.



Ice melting is another endothermic process. Thermal energy is absorbed from the surroundings as the solid ice changes to liquid water. Think about what happens to the particles when water changes state. The particles in the ice are lined up in rows and can only vibrate about fixed positions – they cannot move around inside the ice. The forces between the particles are strong.




As the particles absorb thermal energy from the surroundings, they vibrate more and more. The ice begins to melt. When the particles have enough energy, they can move and overcome the forces holding them in place. The particles can now slide past one another. The water is now in a liquid state.

## Questions

**5** Why is ice melting called an endothermic *process* and not an endothermic *reaction*?

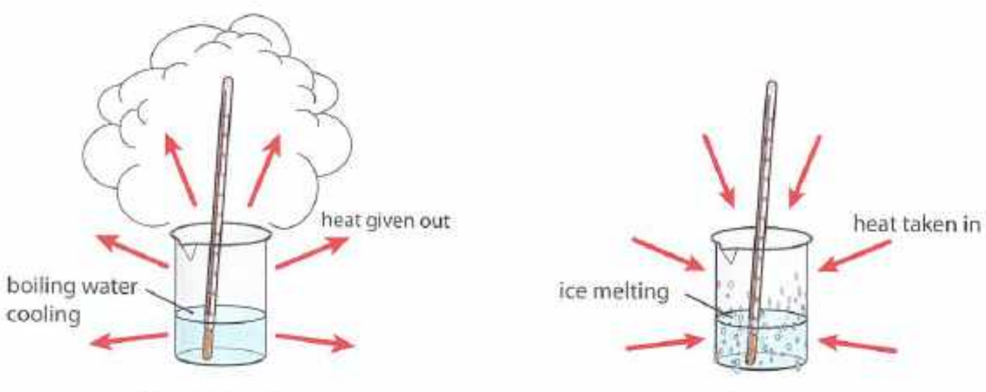
**6** Suggest a change of state, other than ice melting, that is an endothermic process.

**7** When you have been swimming and you come out of the pool, you may feel cold. Use your understanding of endothermic processes to explain why.

**8** Suggest whether water freezing is an endothermic or exothermic process. Can you explain your suggestion?

# Endothermic or exothermic?

In exothermic reactions and processes, thermal energy is given out. In endothermic reactions and processes, thermal energy is taken in.




Exothermic process

Endothermic process

## Think like a scientist

### Endothermic or exothermic?

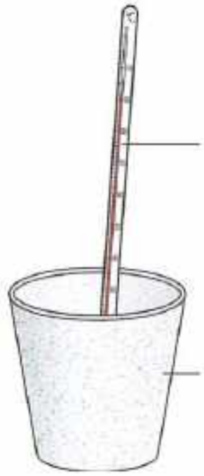
In this series of experiments, you will try some of these reactions and processes and decide if the reaction or process gives out energy to the surroundings or absorbs energy from the surroundings.

**You will need:**

- beakers or polystyrene cups or other insulated containers
- stirring rod
- thermometer (do not use the thermometer for stirring the solutions)
- chemicals as listed below
- safety glasses

Here are some reactions and processes you could try.

- Sodium hydroxide and dilute hydrochloric acid.
- Potassium chloride and water.
- Melting ice cubes.
- Copper sulfate solution and magnesium powder.
- Ammonium nitrate and water.
- Boiling water until steam comes off.
- Steam from a kettle directed at a cold surface.
- Dilute hydrochloric acid and magnesium ribbon.
- Sodium hydrogencarbonate and citric acid.




### Method

Carry out some or all of the reactions or processes suggested. Make sure you do a risk assessment for each test that you do. You will need to adapt this method for processes that do not involve using two substances.

1. Construct a results table.
2. Place one of the solutions in the beaker or polystyrene cup.
3. Measure and record the temperature.
4. Add the other substance. Stir with the stirring rod.
5. Allow the substances to react, dissolve or change.
6. Measure and record the temperature.
7. Clean the thermometer and the stirring rod before using them for the next test.
8. For each test you did, say if it is endothermic or exothermic and if it is a reaction or process.

Continued

### Questions

1. What advantage is there if a polystyrene cup is used rather than a glass beaker?
2. Which reaction gave out the most energy **to** the surroundings?
3. Which reaction absorbed the most energy **from** the surroundings?
4. Did you have difficulty measuring the temperature with any of these reactions or processes? Explain how you could decide if the reaction or process was exothermic or endothermic if you could not measure the temperature.

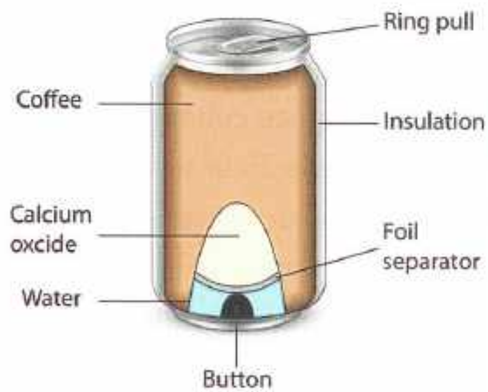
## Using exothermic reactions

Some exothermic reactions are used to produce self-heating cans of food or drink. For example, a can of self-heating coffee contains a small compartment at the bottom. The compartment is in two parts, separated by foil: one contains calcium oxide, the other contains water. Pressing a button breaks the foil seal, and the two parts are mixed.

When the water and calcium oxide are mixed together they react, and heat (thermal energy) is given off. The thermal energy is transferred to the coffee.

calcium oxide + water ⟶ calcium hydroxide

These cans can be useful if you are in a remote area, in an emergency when there is no power, or when you are camping.



A self-heating can

The cans are expensive to produce because the compartments must be sealed from one another and from the food, so that it does not become contaminated. There have also been problems with the food not being heated evenly.

## Using endothermic reactions


A chemical ice pack being used to treat an injury

People sometimes use ice packs when they injure themselves. The ice packs are stored in a fridge or freezer until they are needed. When the ice pack is placed on the injured area, heat is transferred to the ice pack and the ice melts. (This is an endothermic process, not an endothermic reaction as no new substances are formed.) The injured area is cooled which prevents it from swelling. After it has been used, the ice pack can go back into the freezer to be used again.

Some 'ice' packs are made from substances that undergo an endothermic process when they mix together.

These packs can be used even when you don't have fridge or freezer. The pack has two compartments inside, each with a different substance. These are usually ammonium nitrate and water. When you push on the pack and break the compartment containing ammonium nitrate, the water mixes with it and the ammonium nitrate begins to dissolve. This is an endothermic process, so the temperature drops.

### Questions

9 Explain why self-heating cans are very expensive.

10 Explain why a self-heating food container can only be used once.

11 Describe **one** advantage and **one** disadvantage of each of the two types of icepack described above.

What exothermic and endothermic reactions do I use in my everyday life?

### Summary checklist

- [ ] I can list some chemical reactions that are endothermic.
- [ ] I can explain the difference between an endothermic reaction and an endothermic process.
- [ ] I can carry out an investigation to distinguish between exothermic and endothermic reactions and processes.
- [ ] I can describe some uses of exothermic and endothermic reactions and processes.

# 8.3 Reactions of metals with oxygen

## In this topic you will:

- describe the reactions of some metals with oxygen
- carry out an investigation
- compare how reactive some metals are with oxygen.

## Getting started

In one minute, write down all the properties of metals that you can remember. Compare your list with a partner and add any new ones to your list. Then compare your new list with another pair and add any more properties. Be prepared to share your list with the class.

## Key words

collapses
inert
prevent
reactive
rusts

# Metals and oxygen

In Stage 7 you learned about the properties of metals. Now you are going to investigate how different metals react with oxygen.

## Think like a scientist

### Heating metals in air

In this activity, you will heat several different metals in air. Air contains oxygen, and some metals will react with it.

Read though the instructions and decide on the safety precautions you will need to take. Discuss these in your group and then with the class before you carry out your investigation.

**You will need:**

- safety glasses
- Bunsen burner
- heatproof mat
- tongs
- small pieces of metal such as magnesium, zinc, iron and copper

### Method

1. Take a small piece of one of the metals.
2. Place it in the tongs and heat it in a Bunsen flame.
3. Record your observations in a table. Explain what happened.
4. Repeat steps **1–3** for each of the other metals.

### Questions

1. Which was the most reactive metal that you used? What evidence do you have for this?
2. What safety precautions did you take?
3. Suggest why you were not given metals such as sodium or potassium to heat.
4. Suggest why you were not given metals such as gold or silver to heat.

# Looking at the reactions of metals with oxygen

Many metals react with oxygen if they get hot enough. When you look carefully at the reactions of metals with oxygen, it is possible to identify which metals are more **reactive**. For example, magnesium is more reactive than iron because magnesium reacts more quickly than iron. This reaction between metals and oxygen is an oxidation reaction.

Some metals react very quickly with oxygen without even being heated. When pieces of sodium, potassium or calcium are taken from their containers, they appear dull. When the pieces are cut, the surface is shiny. The shiny surface soon becomes dull because the metal reacts with the oxygen in the air. The surface becomes covered with a new substance – the oxide of the metal. These metals are so reactive that they have to be stored under oil to **prevent** them reacting with the water vapour in the air. The layer of metal oxide on the surface prevents any more of the metal from reacting with the air or water vapour.

A scientist cuts a piece of sodium metal with a scalpel

The general word equation for this reaction is:

$$\text{metal} + \text{oxygen} \longrightarrow \text{metal oxide}$$

Some metals, such as gold, do not react with oxygen. They are generally unreactive. They are described as **inert**.

Silver reacts slowly with the air. If a silver object is not cleaned it goes black over time, as silver oxide is formed.

## Questions

1 Which property of sodium and potassium is not typical of a metal?

2 Why is the scientist in the photograph wearing gloves to cut the piece of sodium?

3 Write a word equation for the reaction between sodium and oxygen.

# The reaction between iron and oxygen

When iron is left in damp air it **rusts**. The iron reacts with oxygen to form an orange-brown solid, called iron oxide. This is known as rust.

$$\text{iron} + \text{oxygen} \longrightarrow \text{iron oxide}$$

This is not a very useful reaction because it means that the iron changes and no longer has the same properties. A strong iron girder can become rusted and fall apart. This could mean that a building **collapses**.

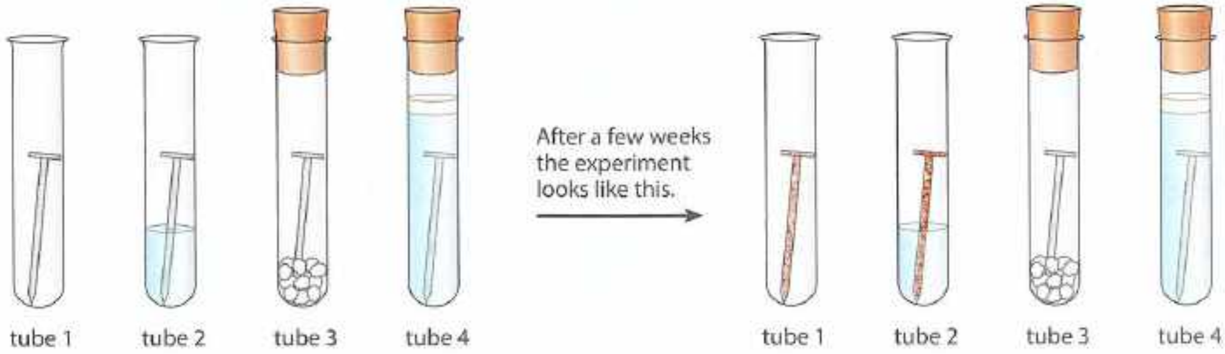
The reaction between iron and oxygen only takes place when both water and oxygen are present. The water is not part of the equation, but it is needed for the reaction to happen. The reaction takes a long time to happen – iron is not very reactive with oxygen.

This new, shiny spanner, nuts, bolts and washers are made mostly of iron

The iron sheets in this old barn have rusted

# What causes iron to rust?

A new iron nail is placed in each of four test tubes, as in the diagram.




Test tube 1 contains nothing, apart from the nail, and is open to the air.

Test tube 2 contains water and the nail is half in the water. The tube is open to the air. So, this tube has air and water.

Test tube 3 has calcium chloride in the bottom. The calcium chloride absorbs water so the air inside the tube is dry. The tube is stoppered.

Test tube 4 has water that has been boiled to remove as much dissolved gas as possible. On top of the boiled water is a layer of oil. This stops any air entering the water. The tube is stoppered.

| Tube number | Contains | Result |
|---|---|---|
| 1 | moist air | nail is rusted |
| 2 | water and air | nail is very rusty |
| 3 | dry air | no rust |
| 4 | boiled water covered with oil, no air | small amount of rust |

## Questions

4 What conditions are needed to **prevent** iron from rusting?

5 Which test tube and which conditions caused the iron to rust most quickly?

6 Why is the same type of nail used in all test tubes?

7 How is the air in test tube 3 dried?

8 How is the air in test tube 4 kept out of contact with the nail?

## How can iron be protected?

There are ways that iron can be protected so that it does not rust.

Iron can be painted; this stops the oxygen in the air reaching the iron


Iron can be galvanised; this means covering the iron with a layer of zinc which prevents the oxygen reaching the iron

Why do we need to reduce the rusting of iron?

### Summary checklist

- [ ] I can describe the reactions of some metals with oxygen.
- [ ] I can carry out an investigation safely.
- [ ] I can compare how reactive some metals are with oxygen.

# 8.4 Reactions of metals with water

## In this topic you will:

- describe the reactions of some metals with water
- carry out an investigation
- compare how reactive some metals are with water.

## Getting started

Think back to the reactions of metals with oxygen that you studied in Topic 8.3. Write down the name of the most reactive metal you learnt about and try to make a list of the other metals in order of how reactive they are. Compare your list with a partner and make one list to share with the class.

### Key words

reactivity

sandpaper

# Metals and water

In Topic 8.3 you learned about the reactions of metals with oxygen. Now you are going to investigate how different metals react with water.

## Think like a scientist

### Reactions of metals with water

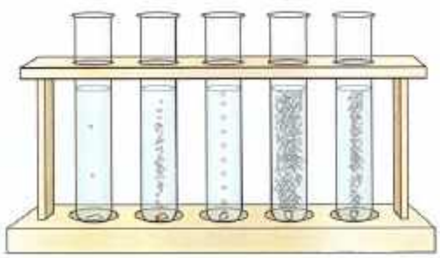
It can be difficult to see how some metals react with water. This is because they may be covered in a surface layer of metal oxide if they have reacted with the oxygen in the air. In the investigations, you may need to use **sandpaper** to clean the surface of the metals so that the metal can come in direct contact with the water.

You will need:

- test tubes
- test tube rack
- sandpaper
- forceps
- small pieces of metals such as magnesium, zinc, iron and copper

#### Method

1. Take a small piece of one of the metals you have been given. Use sandpaper to clean the surface of the metal.
2. Place the metal into a test tube of water.
3. Record your observations in a table and explain what happened. You may need to leave the metal to react for some time. If nothing happens, you could try testing the metal again, this time using hot water.
4. Repeat steps **1–3** for each of the other metals you have been given.



#### Questions

1. Which was the most reactive of the metals you were given? What evidence do you have for this?
2. Use the results of your experiment to arrange the metals in order of their **reactivity**, starting with the most reactive.
3. Suggest why some metals will react with hot water but not with cold water.

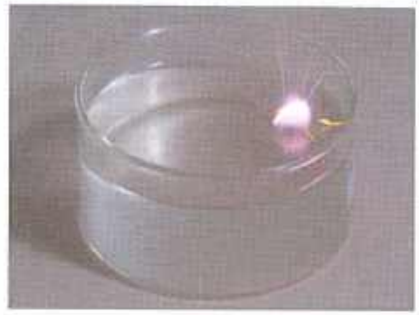
# Reactions of sodium and potassium with water

Some metals are too reactive for you to test in water. Sodium and potassium react very vigorously. They have to be stored under oil to prevent them from reacting with the water vapour in the air.

In these two reactions, the metal reacted with water to produce hydrogen and the metal hydroxide.

metal + water ⟶ metal hydroxide + hydrogen

Sodium reacts vigorously with water



When potassium reacts with water, so much thermal energy is generated that the hydrogen produced catches fire

## Questions

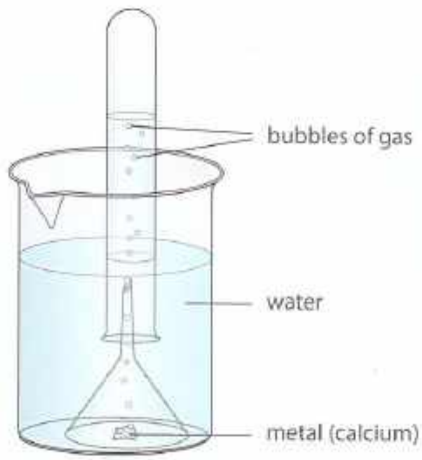
1 Write the word equation for the reaction between sodium and water.

2 What safety precautions must be taken when these reactions take place?

3 Explain why these metals are stored under oil.

# Reactions of other metals with water

Some other metals react less vigorously with water – for example, calcium and magnesium. In the experiment shown in the diagram, a piece of calcium has been placed at the bottom of a beaker and covered with water. A filter funnel has been placed upside down over the metal. The gas given off is collected in a test tube by the displacement of water.




## Questions

4 What is the gas that is given off? How would you test for it?

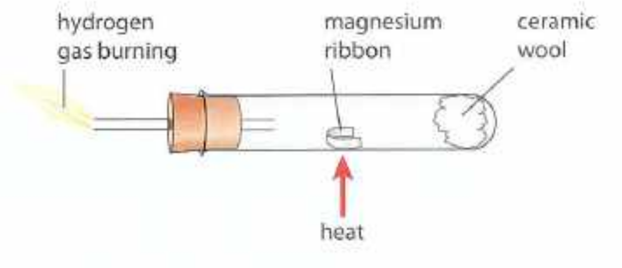
5 How could you tell if calcium or magnesium is more reactive?

6 What factors should you take into account to make this a fair test?

7 Write the word equation for the reaction between calcium and water.

Some of the metals that do not react with water may react with steam. Even magnesium will react more rapidly with steam than with water.

In the reaction shown here, magnesium is heated. From time to time, the heat is directed at the ceramic wool. The ceramic wool has been soaked in water, which when heated produces steam. In this reaction the magnesium reacts with water, which is in the form of a gas. Magnesium oxide and hydrogen are formed. The hydrogen gas that is given off can be burnt.



Heating magnesium

The word equation for this reaction is:

magnesium + water (g) ⟶ magnesium oxide + hydrogen

The (g) after water indicates it is water in the form of a gas, in this case steam. Steam is formed by boiling water and is very hot, whereas water vapour is made up of water particles in the air at lower temperatures. Some metals, such as gold, do not react with water at all.

## Questions

**8** Explain, using particle theory, why the reaction between steam and magnesium is more vigorous than between water and magnesium.

**9** Name **three** metals that do not react with water.

**10** If an element is said to be inert, what does it mean?

### Summary checklist

- [ ] I can describe the reactions of some metals with water.
- [ ] I can carry out an investigation safely.
- [ ] I can compare how reactive some metals are with water.

# 8.5 Reactions of metals with dilute acids

## In this topic you will:

- describe the reactions of some metals with dilute acid
- plan an investigation
- carry out an investigation safely
- compare how reactive some metals are with dilute acid.

## Getting started

You have 2 minutes to write down and complete as many of these word equations as you can.

- oxygen + sodium ⟶
- oxygen + magnesium ⟶
- oxygen + iron ⟶
- water + potassium ⟶
- water + calcium ⟶
- magnesium + steam ⟶

Check your partner's work. Be prepared to share your answers with the class.

## Key words

reagents

salt

# A familiar reaction

You will probably remember the reaction of magnesium with dilute hydrochloric acid. This is the word equation for this reaction:

magnesium + hydrochloric acid ⟶ magnesium chloride + hydrogen

Magnesium chloride is an example of a **salt**. When a metal reacts with an acid, the products are a salt and hydrogen.

The general equation for this reaction is:

metal + acid ⟶ salt + hydrogen

## Questions

1 Write the word equation for the reaction between magnesium and sulfuric acid.

2 What is the salt produced in the reaction in question **1**?

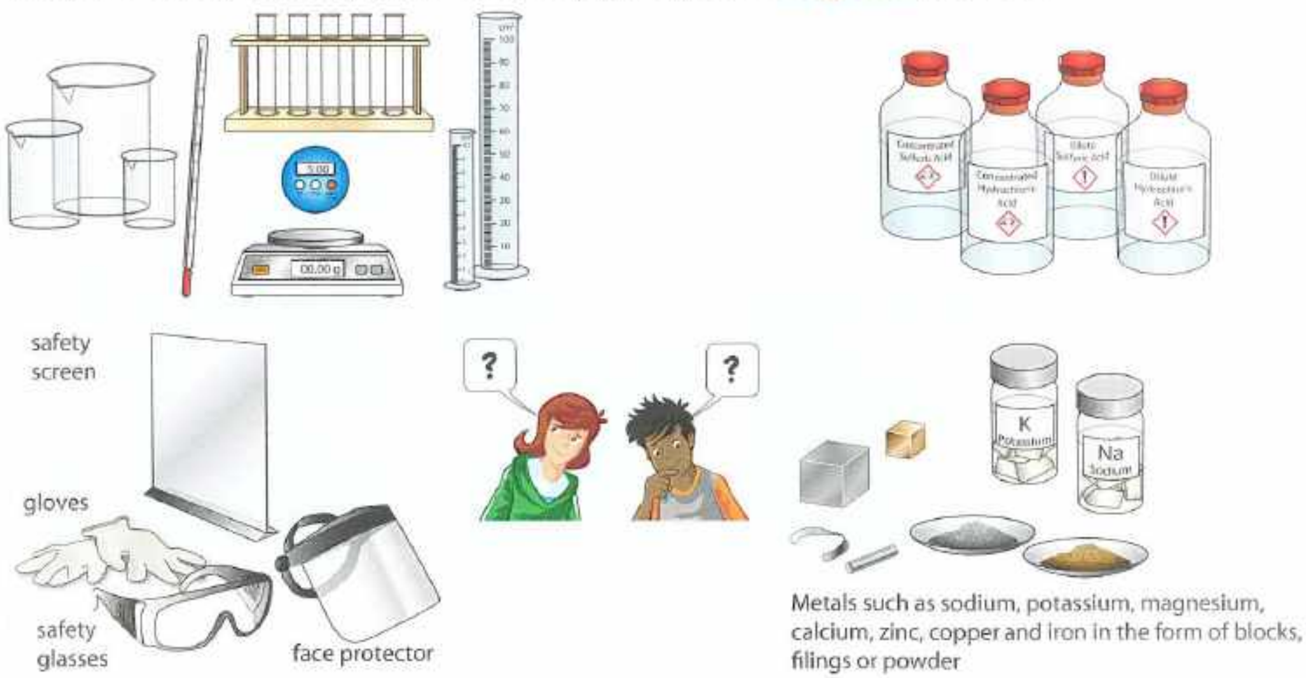
3 Describe what you would observe if this reaction took place in a test tube.

4 Write the word equation for the reaction between zinc and nitric acid.

## Think like a scientist

### An investigation into the reaction of metals in acid

Sofia and Marcus have been asked to investigate the reactivity of metals with acids. They need to decide on which of the equipment and **reagents** they need.




Metals such as sodium, potassium, magnesium, calcium, zinc, copper and iron in the form of blocks, filings or powder

## Continued

*Part 1: Planning the investigation*

Plan the investigation for Sofia and Marcus. Choose which of the items in the diagrams they need to use. Some of the items are not appropriate to use.

Discuss in your small group how you will answer these questions.

- What will they change?
- What will they keep the same?
- How will they measure the reactivity and decide which is the most or least reactive metal?
- How will they keep safe?
- What equipment will they use?

Remember to include a results table and an idea of what they should be looking for in order to identify which are the most reactive metals.

Write your plan and show it to your teacher.

### Questions

1 Which of the metals shown should Sofia and Marcus **not** use? Explain why.

2 Explain which measuring cylinder they should use to measure out enough acid to use in this investigation.

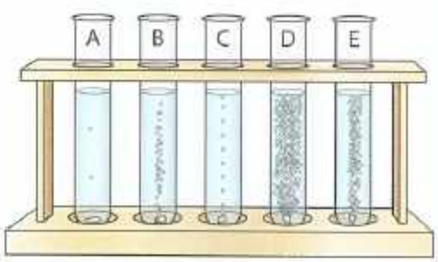
*Part 2: Carrying out the investigation*

Your task is to find the order of reactivity of the metals you are given. Remember to work in a methodical way and keep an accurate record of your results.

Method

1 Follow the plan you have written, once you have had it checked by your teacher.

2 Select the appropriate equipment.




### Questions

3 Which metal was the most reactive in dilute acid?

4 Which metal was the least reactive in dilute acid?

## Activity 8.5.1

### Reactivity order

On seperate sticky notes, write the name of each of the metals you **used** when carrying out the investigation into the reaction of metals in acid.

Stick these on to the table in the order of reactivity, with the most reactive at the top. Use the information from the investigation above.

Compare your order with other groups. Are they the same or similar?

Use the class results to make an order you all agree on.

Does this order match the results from the investigations of the reactions of metals with oxygen and water?

Now write sticky notes for the metals you could not use (sodium, gold, silver, calcium and potassium) and fit those into your list.

When you are happy with your order, make a poster to show your list and illustrate it with diagrams to show the various reactions with oxygen, water and/or dilute acids.

### Questions

1 Which was the most reactive of the metals you used?

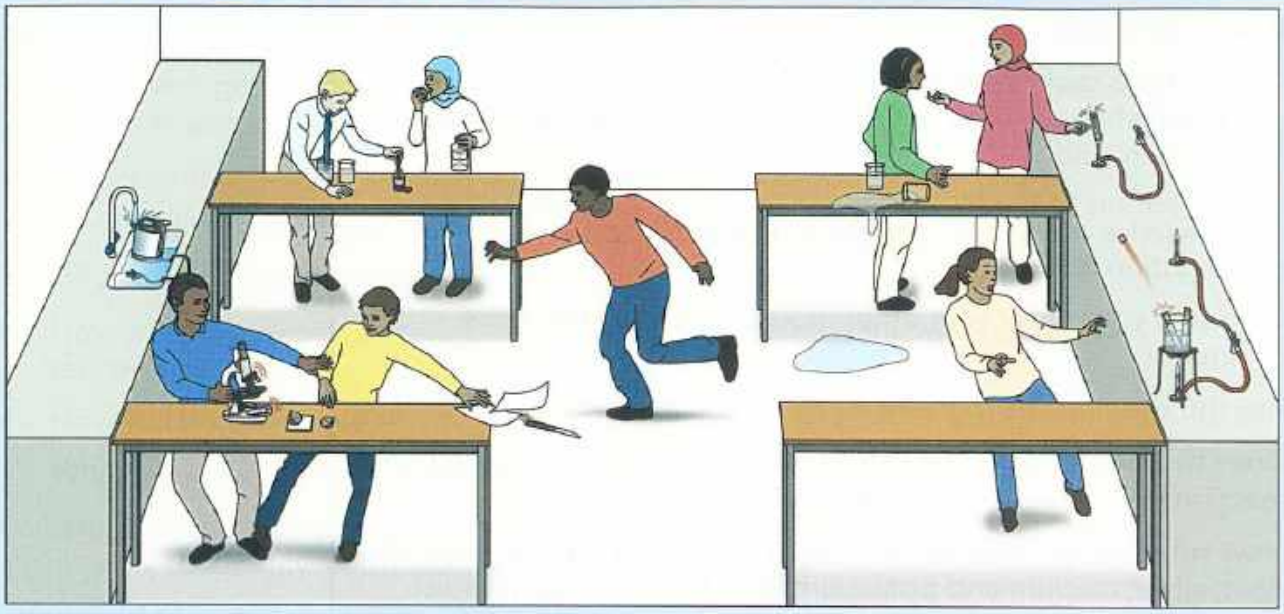
2 How did you decide which of the metals in the list was the least reactive?

How did the three investigations help me to decide in which order to put the metals?

## Summary checklist

- [ ] I can describe the reactions of some metals with dilute acid.
- [ ] I can plan an investigation.
- [ ] I can carry out an investigation safely.
- [ ] I can compare how reactive some metals are with dilute acid.

## Project: Working with chemicals safely



### Background

Each day you make decisions about how to keep safe and minimise the risks that you take. It might be when you cross a street, when you make a hot drink, head a football, cook a meal or use a knife to cut vegetables. You probably don't even realise you are doing it, but you are carrying out a risk assessment for most tasks.

In the laboratory there are a number of hazardous situations. There are rules about how you should behave and what you should do to stay safe. In the picture above there are lots of things happening that are unsafe. People should never behave like that in a laboratory.

### Your task

Work in a group of three or four. Start by looking carefully at the picture and identify as many things that are unsafe as you can. Make a list, with reasons, to explain why each thing is unsafe.

Next, you need to provide guidance to learners starting the secondary science course, to help them keep safe. You could:

- write a poem or a song
- write a guide book
- write and perform a short play
- make a poster.

You should try to come up with some original way of getting the safety message across.

Your work will be shared with the whole class.

# Check your progress

**8.1** Match these words or phrases to the descriptions, **a**, **b**, **c**, **d** and **e**.
Each word or phrase may be used once, more than once or not at all.

**burning decreases endothermic increases exothermic**
**evaporation melting ice magnesium ribbon placed in hydrochloric acid**
**sodium hydrogencarbonate added to citric acid**

- **a** An example of a chemical reaction where thermal energy is given out to the surroundings. [1]
- **b** An example of an endothermic reaction. [1]
- **c** The temperature in an endothermic reaction. [1]
- **d** An example of an endothermic process. [1]
- **e** The type of reaction between calcium and water. [1]

**8.2** Burning is a chemical reaction where thermal energy is given out to the surroundings. Marcus has four fuels to investigate to find out which gives out the most thermal energy to the surroundings. He uses apparatus like this:


- **a** Which variable will Marcus change? [1]
- **b** Name **two** variables Marcus must keep the same. [2]
- **c** Explain what he must do in order to be able to identify which fuel gave out the most thermal energy to the surroundings. [2]
- **d** Name **one** safety precaution he should take whilst carrying out this investigation. [1]

**8.3** Copy and complete the following word equations.

- **a** carbon + … ⟶ carbon dioxide [1]
- **b** sodium hydroxide + … ⟶ sodium chloride + … [2]
- **c** … + oxygen ⟶ magnesium oxide [1]
- **d** potassium + water ⟶ … + … [2]

**8.4** Zara and Arun are carrying out an investigation into the heat given off when they add pieces of calcium to water. They both use 10 cm$^3$ water and add pieces of calcium.

These are Zara's results.

| Mass of calcium added in g | Start temperature in °C | Final temperature in °C | Temperature change in °C |
|---|---|---|---|
| 1 | 19 | 20 | |
| 2 | 19 | 21 | |
| 3 | 19 | 22 | |
| 4 | 19 | 23 | |

These are Arun's results.

| Mass of calcium added in g | Start temperature in °C | Final temperature in °C | Temperature change in °C |
|---|---|---|---|
| 1 | 21 | 22 | |
| 2 | 21 | 22 | |
| 3 | 21 | 24 | |
| 4 | 21 | 25 | |

**a** What trend is shown by both sets of results? **[1]**

**b** Predict what would happen if 5 g of calcium was added. **[1]**

**c** Complete the table for both of the student's results. **[2]**

**d** Construct a summary table to show the mean temperature change for each mass of calcium used. (Your table does not need to show the start and final temperatures). **[2]**

**e** Zara and Arun plot a graph of their results.

- **i** Which variable and unit should they put along the horizontal axis? **[1]**
- **ii** Which variable and unit should they put on the vertical axis? **[1]**

**f** Zara and Arun carried out a third set of experiments, using 20 cm$^3$ water instead of 10 cm$^3$. Could they use these results to add to the first two sets, to calculate the mean temperature change? Explain your answer. **[2]**

# 9 Magnetism

## > 9.1 Magnetic fields

**In this topic you will:**

- describe a magnetic field
- understand that magnetic fields surround magnets
- understand how magnetic fields interact.

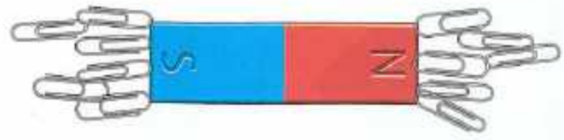
**Getting started**

Work in pairs. Make a list of places where magnets are used.

**Key words**

compass
like poles
magnet
magnetic
magnetic field
magnetic field lines

# The magnetic field




The paperclips are made from steel, which is a magnetic material

A **magnet** is something that will attract **magnetic** materials. Magnetic materials include the metals iron, steel, nickel and cobalt. You will probably have used a magnet to attract paperclips.

Magnets have two poles, north and south. They are shown with the letters N and S on diagrams.

When a paperclip is close to one of the poles of a magnet, the paperclip will be attracted to the magnet. As you move the paperclip further away, it stops being attracted.

The paperclip is attracted to a magnet when it is in the **magnetic field** of that magnet.

A magnetic field is the area around a magnet where the effects of the magnet can be detected.

A magnetic field surrounds all magnets. The magnetic field of a magnet is strongest at the poles.


The paperclip is outside the magnetic field of this magnet, so will not be attracted

You can detect a magnetic field in two ways. You can:

- see whether a magnetic object moves because of attraction
- use a **compass**.

A compass contains a magnetised needle that is free to turn. The needle will turn and point in the direction of a magnetic field. The picture shows a compass. Some mobile devices such as phones have compass apps.

A compass can be used to detect a magnetic field

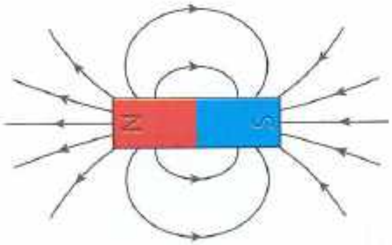
## Magnetic field lines

You can draw **magnetic field lines** around a magnet to represent the magnetic field.

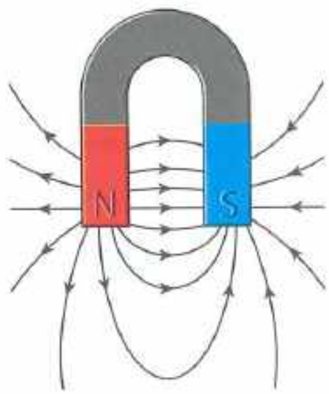
The rules are that magnetic field lines:

- join opposite poles
- have arrows that point N → S
- must not touch each other
- must not cross each other.

Following these rules, the magnetic field lines around a bar magnet look like this:




and the magnetic field lines around a horseshoe magnet look like this:

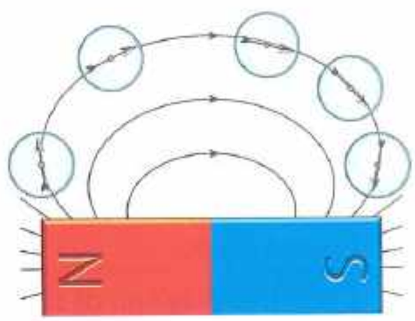



You can tell by looking at magnetic field lines where the magnetic field is strongest. The magnetic field is strongest where the lines are closest together.

If one magnet is stronger than another, the magnetic field of the stronger magnet will be different in two ways.

- All the field lines will be closer together.
- The field lines will extend further away from the magnet.

You can also tell, by looking at magnetic field lines, in what direction a compass will point. When it is in a magnetic field, a compass will point in the direction of the lines.

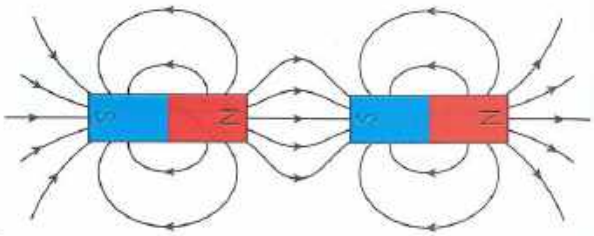



The five small compasses are pointing in the direction of the magnetic field lines

# Magnetic fields interacting

You probably already know about the forces between two magnets.

- Two north poles repel.
- Two south poles repel.
- A north and a south pole attract.

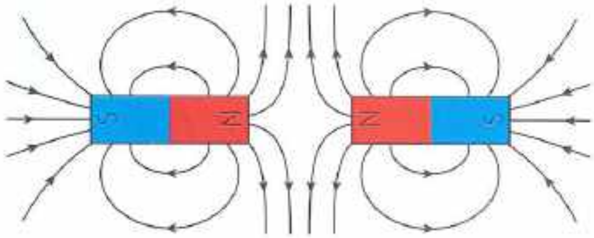



These forces are due to the magnetic fields from each magnet.

Look at the field lines between two magnets when their opposite poles are together.

The magnetic field lines between the two magnets are all pointing in the same direction. This means there will be a force of attraction between the magnets.

Now look at the field lines between two magnets when their **like poles** are together.




The magnetic field lines in the space directly between these two magnets are all pointing in opposite directions. This means the magnets will repel, or try to move away from each other.

## Questions

**1** Describe what is meant by the term 'magnetic field'.

**2** The magnetic field of magnet A extends further than the magnetic field of magnet B.

State what can be concluded about the strengths of these two magnets.

**3** Copy this diagram of a bar magnet.


Draw magnetic field lines around your diagram.

Put arrows on each line.

**4** **a** Draw magnetic field lines to show how a north and a south pole attract.

**b** Draw magnetic field lines to show how two south poles repel.

## Activity 9.1.1

### Showing a magnetic field pattern

Work in pairs.

**You will need:**

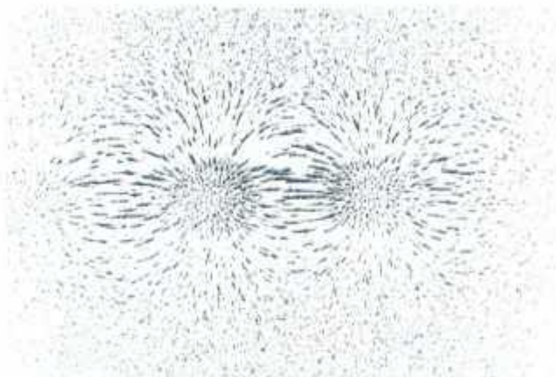
- bar magnet • horseshoe magnet (optional) • piece of A4 size paper
- piece of thick card, not thicker than the thickness of the magnet
- iron filings

### Safety

Be careful not to get the iron filings on your skin. They can be sharp and get stuck in your skin.

Be careful not to get the iron filings on the magnet. They are very difficult to remove and other people will get the iron filings on their skin.

### Method



1 Cut a hole in the middle of the thick card, just large enough to put the bar magnet in.

2 Put the bar magnet into the hole so it lies flat in the card. The card is to support the paper and keep the paper level.

3 Put the paper on top of the card so the magnet is under the middle of the paper.

4 Gently and evenly sprinkle the iron filings over the paper. Tap the paper gently to allow the iron filings to move into position.

You should see a pattern like the one in the picture.

### Questions

1 a Where is the magnetic field strongest?

b How can you tell this from the pattern of iron filings?

2 a Can you tell, by looking at the pattern of iron filings, which is the north or south pole?

b Explain your answer.

3 Look closely at the iron filings that are on top of the poles of the magnet. What do you observe?

When you have finished, carefully lift the paper vertically away from the magnet. Bend the paper to form a slight 'U' shape and use this as a channel to pour the iron filings back into the container.

Continued

### Extension

If you have time, you could use two magnets, first arranged with like poles facing and then with opposite poles facing. In each case, try to explain the pattern of iron filings.

## Think like a scientist

### Detecting a magnetic field

In this investigation, you will investigate ways of detecting a magnetic field.

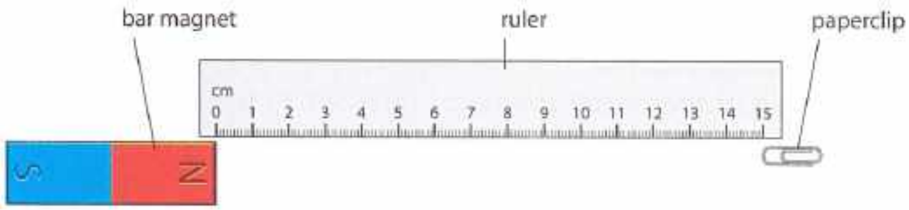
Work in pairs or groups of three.

**You will need:**

See the diagram. You could also choose some other different types of magnets to investigate.

### Method

1 Set the magnet, ruler and paperclip on a smooth surface as shown in the diagram.




2 Record whether the north or south pole of the magnet is facing the paperclip.

3 Slowly move the paperclip toward the pole of the magnet. If your bar magnet is not marked, can you devise a method to tell which pole is which?

4 Record the distance from the pole of the magnet when the paperclip becomes attracted to the magnet. Call this value *d* for distance.

5 Repeat another two times and record all your measurements of *d*.

6 Turn the magnet around so the other pole is facing the paperclip.

7 Repeat steps 3–5 for this pole.

8 If you have time, repeat the investigation with other, different, magnets.

Continued

## Questions

1 Calculate the average of your *d* values for each pole of each magnet you tested.

2 Explain how the value of *d* is related to the strength of the magnetic field.

3 Explain what your results show about the strength of the magnetic field from the north and south poles of the **same** magnet.

4 Explain why:

  a the surface needs to be as smooth as possible

  b the paperclip needs to be as small as possible.

5 Suggest how you could improve this investigation to get more accurate values of *d*.

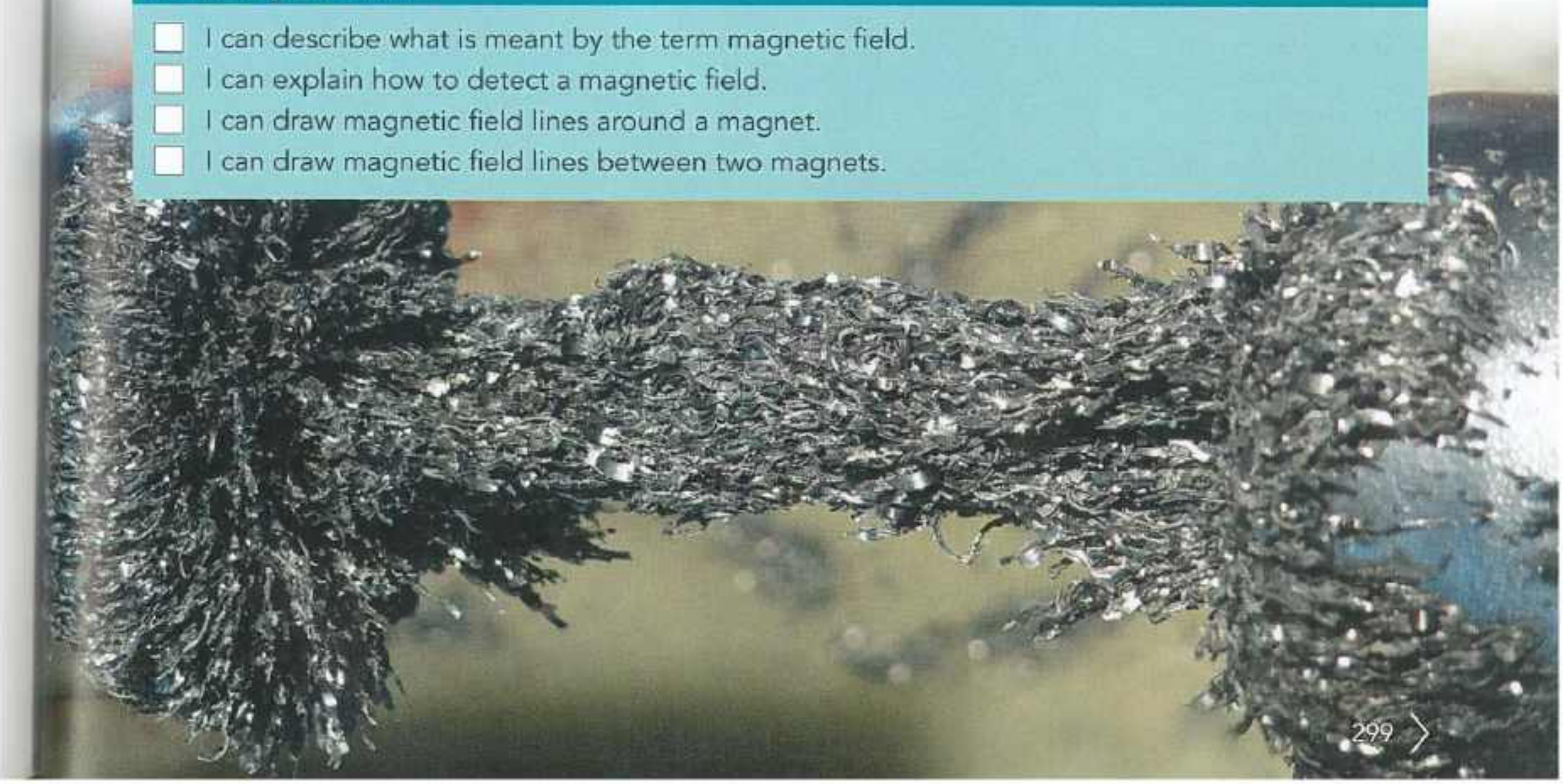
## Self-assessment

Decide how much you agree with each of these statements. Give yourself 5 if you agree very much and 1 if you do not agree at all.

- I understand what is meant by a magnetic field.
- I can draw the magnetic field lines around a bar magnet.
- I can draw the magnetic field lines between two opposite poles of different bar magnets.
- I can draw the magnetic field lines between two like poles of different bar magnets.

## Summary checklist

- [ ] I can describe what is meant by the term magnetic field.
- [ ] I can explain how to detect a magnetic field.
- [ ] I can draw magnetic field lines around a magnet.
- [ ] I can draw magnetic field lines between two magnets.



# 9.2 The Earth as a giant magnet

## In this topic you will:

- discover that the Earth has a magnetic field
- learn that the core of the Earth acts as a magnet.

## Getting started

Work in groups to discuss the answers to these questions.

- The terms 'north pole' and 'south pole' are used when we discuss magnets. Where else are they used?
- What is a magnetic compass used for, apart from science experiments in school?

## Key words

geographic north

magnetic north

naturally occurring

navigate

# The Earth's magnetic field

Around 4000 years ago, a Greek shepherd called Magnes was looking after his sheep. The story of Magnes says that iron nails in his shoes stuck to one particular type of rock. The rock was called lodestone and contained a substance that was later named magnetite, which is a **naturally occurring** magnet. Naturally occurring means it is not made by people.

Both the Greeks and the Chinese started to investigate magnetic properties.

The Chinese discovered that a small needle of lodestone, split off the rock, could be made to float on water. When allowed to float, the needle of lodestone always turned to point in the same direction.

One end of the needle pointed toward the north and the other end pointed toward the south. This was the invention of the magnetic compass.

It was soon discovered that the compass needle pointed to a position close to the Earth's north pole, but not exactly to the **geographic north** pole. This point is now called **magnetic north**. Magnetic north moves very slowly, and is currently in the Arctic Ocean, north of Alaska.

The first compasses, in 200 BCE, looked like this

The invention of the compass was very important because it allowed people to **navigate** in places such as oceans and deserts, with less chance of getting lost. With a compass, you will always know what direction you are facing.

Even today with satellite navigation (satnav), ships and aeroplanes still use magnetic compasses.

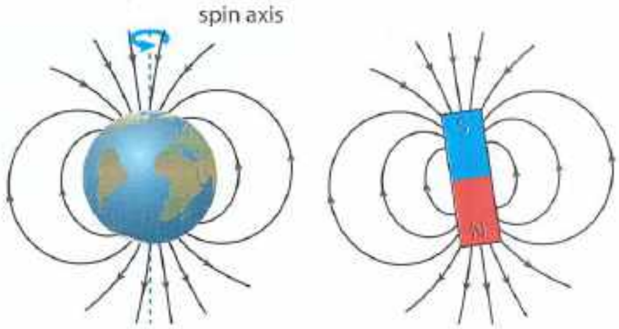
Satnav systems do not use the Earth's magnetic field.

The compass on this modern ship is the bowl-shaped object near the centre of the picture

Some animals use the Earth's magnetic field to navigate over long distances.

The diagram shows what the Earth's magnetic field lines look like compared with a bar magnet.

These birds are using the Earth's magnetic field to navigate




The Earth's magnetic field is similar to that of a bar magnet

Notice, in the diagram, that the magnetic field lines around the Earth point towards the Earth's north pole. You will remember from Topic 9.1 that magnetic field lines point from north to south.

This means that the north pole of Earth is actually a magnetic south pole.

The term magnetic north, when used in context of the Earth and navigation, means the magnetic pole that is close to the geographic north pole.

In the same way, magnetic south is the magnetic pole that is close to the geographic south pole.

The geographic north and south poles are the parts of the Earth through which the spin axis passes. The axis is the imaginary line around which the Earth spins.

The Earth's magnetic field causes the natural appearance of lights visible in the night sky close to the north and south poles. These are caused by particles coming from the Sun arriving into the stronger parts of the Earth's magnetic field.

The needle on this magnetic compass is pointing towards the Earth's magnetic north

This natural light display is caused by the Earth's magnetic field

## Origin of the Earth's magnetic field

People once thought that the Earth was made almost entirely from magnetic rocks. However, it is now known that the high temperatures deep inside the Earth would cause rocks to lose any magnetism that they had.

Scientists also know that the Earth's magnetic field has reversed in the past. The last change was around 500 000 years ago, when north really was north!

It is now known that the Earth's core is the origin of the magnetic field, but scientists have still to discover the exact reason for this. They think the heat generated in the core, which is mostly made from iron, causes it to continually create a magnetic field. The core also contains some nickel, which is another magnetic metal. The movement in the liquid outer core would explain why the magnetic poles move slowly, and have occasionally reversed. Magnetic north moves at a speed of about 60 km per year.


Airport runways are numbered according to their direction from magnetic north (23 is short for 230, which means 230° away from the direction of magnetic north); the numbers sometimes have to be changed due to movement of magnetic north

### Questions

1 Name the piece of equipment that is used for navigation using the Earth's magnetic field.

2 A bar magnet is allowed to rotate freely. Explain which pole of the bar magnet will point towards geographic north.

3 The position of magnetic north on Earth moves at a speed of about 60 km per year. Explain why the position of magnetic north can still be used for navigation on a 12-hour journey.

4 a What part of the Earth's structure causes the Earth's magnetic field?

b Name the magnetic metal that makes up most of this part.

5 a Draw a circle to represent the Earth. With the top of your circle representing geographic north, draw the magnetic field lines around the Earth. Add arrows to show the direction of the field.

b State the relationship between the direction of the magnetic field lines and the direction that a magnetic compass will point.

## Think like a scientist

### Detecting the Earth's magnetic field

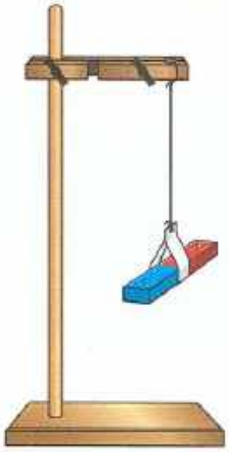
In this activity, you will change variables and describe how observations change.

Work in groups of two or three.

**You will need:**

- needle or thin iron nail
- bar magnet
- light string or thread
- paper and scissors
- adhesive tape
- non-magnetic bowl of water
- wooden clamp stand or non-magnetic support
- piece of cork or polystyrene on which the needle or nail will float

#### Method: Part 1



1 Make a paper support for the bar magnet so that the magnet will hang horizontally, as shown in the diagram.

2 Use the light string to hang the magnet, in the paper support, from the wooden clamp stand as shown in the diagram. Make sure there are no other magnets or large magnetic objects close by.

3 Allow the magnet to come to rest. Record the direction the magnet is pointing.

4 Move the equipment to another part of the room. Again record the direction the magnet is pointing.

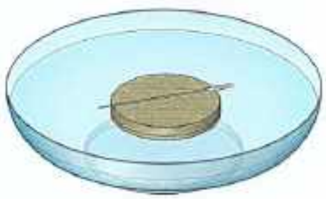
#### Method: Part 2

5 Hold the needle or nail and gently stroke the bar magnet along it several times. as shown in the diagram.

6 Record:

- which pole of the magnet was in contact with the needle
- which direction the magnet moved along the needle.

7 Move the magnet away from where you are working.



8 Cut a disc from the cork or a circle from the polystyrene. Set the needle on the disc and float the disc in the water, in a non-magnetic bowl, as shown.

9 As in *Method: Part 1*, make sure there are no other magnets or large magnetic objects close by.

10 Allow the needle to come to rest and record the direction it is pointing.

11 Carefully move the equipment to another part of the room and record the direction the needle is pointing.

Continued

### Questions

1 In both methods, the investigation is carried out in two different parts of the room. Explain the reason for this.

2 a In Method: Part 1, which pole of the magnet pointed north?

  b Explain what this shows about the poles of the Earth's magnetic field.

3 a In Method: Part 2, state which end of the needle pointed north.

  b Use your answers to question **2** to help you to state which pole of the magnetised needle was pointing north.

4 a Which pole of the magnet was used to stroke the needle or nail?

  b Which end of the needle was the magnet removed from after each stroking action?

  c What is the relationship between your answers to questions **4a** and **4b**?

5 In both methods, you made magnetic compasses. Explain why these compasses would **not** be practical for navigation on a journey.

### Self-assessment

Answer 'yes' or 'no' to each of these questions.

- I understand that the Earth has a magnetic field.
- I can explain why the north pole of a magnetic compass points north, even though like poles repel.
- I can describe an experiment to show that the Earth has a magnetic field.

## Summary checklist

- [ ] I know that the Earth has a magnetic field.
- [ ] I can draw a diagram to show the Earth's magnetic field lines.
- [ ] I can understand why the north pole of a freely rotating magnet points north.
- [ ] I know that the core of the Earth is the origin of the Earth's magnetic field.

# 9.3 Electromagnets

**In this topic you will:**

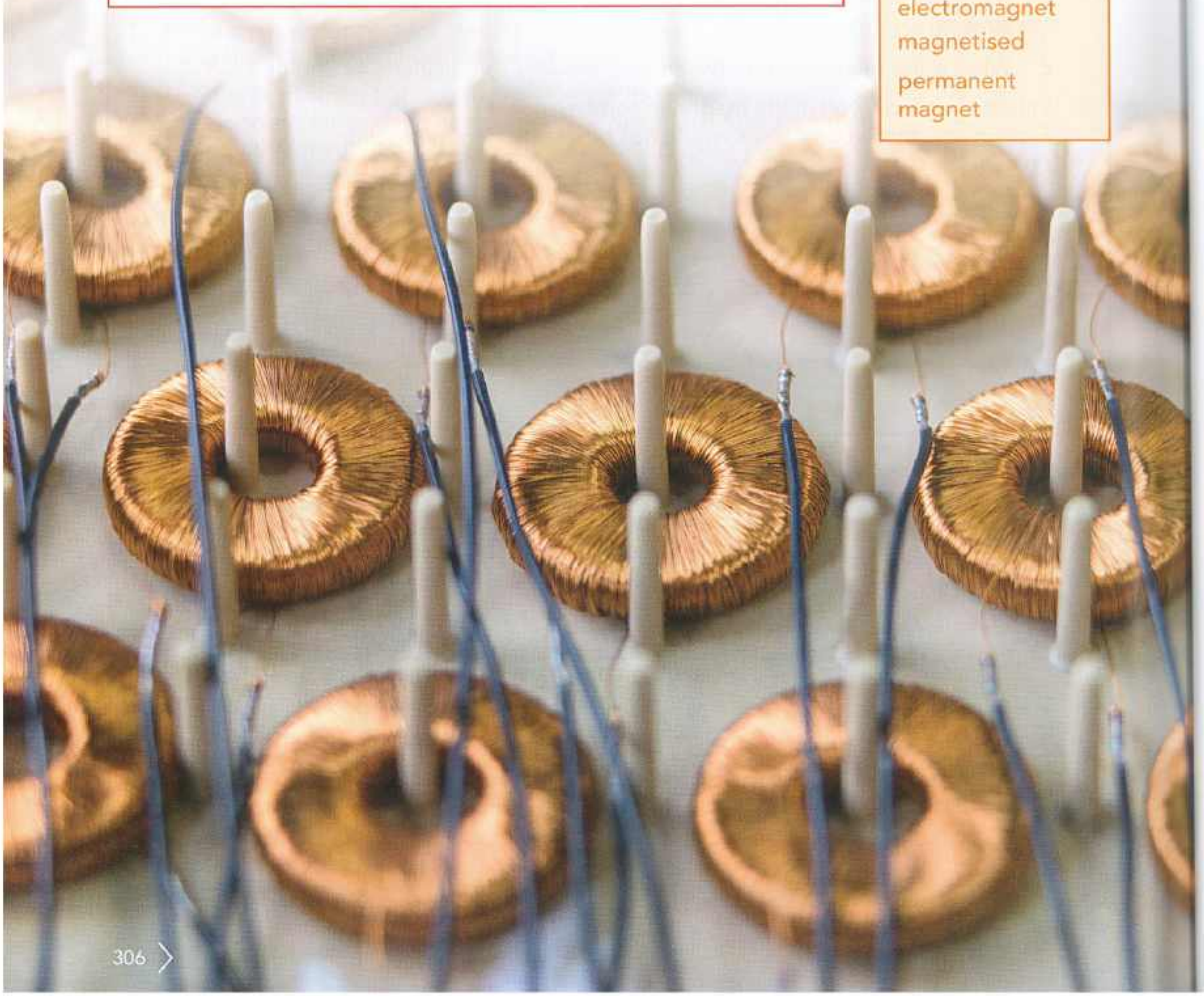
- describe how to make an electromagnet
- recall some applications of electromagnets.

**Getting started**

Work in groups to consider applications where it would be useful to have a magnet that could be switched on and off.

**Key words**

coil
core
electromagnet
magnetised
permanent magnet



## Properties of magnetic materials

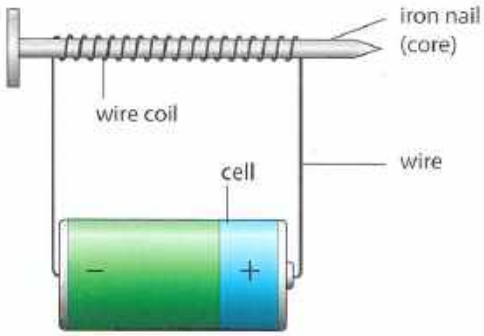
A material is described as magnetic if it is attracted to a magnet. Magnetic materials include the metals iron, nickel and cobalt. Steel is another common magnetic metal. Steel is a mixture that contains a large proportion of iron.

Magnetic materials can be **magnetised**. Magnetised means turned into a magnet. The magnets you have used were all made by magnetising magnetic materials.

The magnets you have used are called **permanent magnets** because they have a magnetic field that is always there. You cannot switch the magnetic field off and on again.

One way to magnetise a magnetic material is by using electricity. When this method is used, the magnet is called an **electromagnet**.

## Electromagnets




An electromagnet is made by wrapping a wire around a magnetic material, such as iron. The wire that is wrapped around is a called a **coil**. The material in the middle of the coil is called the **core**.

When current passes through the coil, the magnetic material becomes magnetised.

When the current is switched off, the magnetic material loses most of its magnetism.

The diagram shows the simplest type of electromagnet.

### Poles of an electromagnet

An electromagnet has two poles, similar to a bar magnet.

You can find out which pole is which in two simple ways.

- Use a magnetic compass. A magnetic compass points along magnetic field lines, so will point towards the south pole.
- Use a bar magnet with known poles. Opposite poles attract and like poles repel so, by bringing the bar magnet close to the electromagnet, you can detect which pole is which.

You can reverse the poles of an electromagnet in one of two ways.

- Wrap the coil around in the opposite direction.
- Reverse the connections on the cell or power supply.

## Applications of electromagnets

Electromagnets are used in many applications where a permanent magnet would not be useful.

The fire door in the picture is held open with an electromagnet. The electromagnet is connected to the fire alarm. When the fire alarm is switched on, the magnet is switched off and the door closes.

Some types of scanners in hospitals use powerful electromagnets. An MRI scanner is used to produce images from inside the human body. MRI stands for magnetic resonance imaging.

Electromagnets can be used for sorting scrap metal. The electromagnet will attract iron and steel, leaving other non-magnetic metals behind. Common non-magnetic metals include copper, aluminium and zinc. When the magnetic metals have been lifted, they can be moved away and then dropped by switching off the magnet.

In a toaster, when the handle is pushed down, an electromagnet holds down a metal basket with bread in it. A timer turns the electromagnet off and the metal basket pops up with toast.

An electric bell uses an electromagnet to make the hammer move. When the electromagnet is on, the hammer is pulled onto the bell. The movement breaks the circuit and the hammer moves away from the bell. The circuit becomes complete again and the hammer is pulled back to the bell. This continues until the power supply is turned off. Electric bells are used in schools, as fire alarms and as door bells.

Electric motors use electromagnets to change electrical energy into kinetic energy.

## Questions

1 Which **two** of these metals can be magnetised?

**copper iron aluminium steel silver tin**

2 Explain the difference between 'magnetic' and 'magnetised'.

3 State **one** difference between an electromagnet and a permanent magnet.

4 Draw a diagram to show how an electromagnet could be made from a cell, a switch, a coil of wire and an iron nail.

Use circuit symbols for the cell and the switch.

5 a List **three** applications of electromagnets.

b For **one** of your applications, explain why a permanent magnet would **not** be suitable.

## Activity 9.3.1

### Making an electromagnet

Work in groups of two or three.

**You will need:**

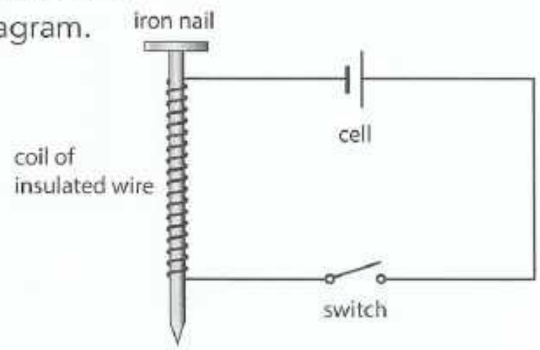
- cell • cell holder or adhesive tape
- about 1 m of plastic-coated wire with about 1 cm of insulation removed at each end
- leads for use in circuits • switch • large iron nail • paperclips

### Method

1 Wrap the insulated wire around the iron nail to form a coil, as shown in the picture. Wrap the turns tightly around the nail and use as much of the length of the nail as you can.

Leave enough wire at each end to connect to the cell. Make sure only the plastic coating of the wire is in contact with the nail.

2 Connect the coil into a circuit as shown in the diagram.




3 Test your electromagnet to see if the end of the nail will pick up paperclips. Use the pointed end of the nail.

Only switch on your electromagnet for the shortest possible time, otherwise the cell will not last long.

## Continued

### Questions

1 Suggest why it is important that only the plastic coating of the wire makes contact with the nail.

2 In this activity, the whole length of the nail becomes magnetised. Suggest why you test the electromagnet by attaching paperclips to the end of the nail and not the middle of the nail.

3 a Describe how you could find out whether the pointed end of the nail was the north pole or south pole of the electromagnet.

  b State what would happen to this pole if the cell in the circuit were reversed so current flowed in the opposite direction.

### Self-assessment

Answer these questions after completing the activity.

- Could you make an electromagnet by yourself?
- If not, what would you need help with?

## Summary checklist

- [ ] I can understand the difference between an electromagnet and a permanent magnet.
- [ ] I know how to make an electromagnet.
- [ ] I know some applications of electromagnets.

# > 9.4 Investigating electromagnets

## In this topic you will:

- discover which factors (or variables) affect the strength of an electromagnet
- investigate how these variables affect the strength of an electromagnet.

## Getting started

Work in groups to discuss these questions.

What are some differences between the electromagnets used for:

- sorting scrap metal and for working a toaster
- keeping a fire door open and for working an electric bell.

## Key words

demagnetised

factors

soft iron

# Strength of electromagnets

Topic 9.3 listed the three things that are needed to make an electromagnet:

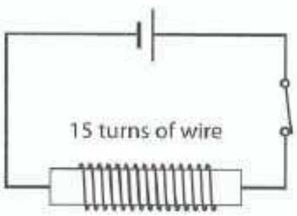
- a coil of wire
- a magnetic core inside the coil
- an electric current flowing in the coil.

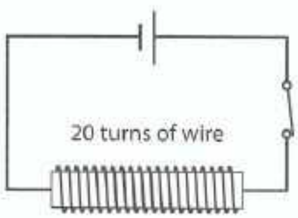
These three things give the **factors** that will affect the strength of an electromagnet. A factor is another word for a variable that will affect something.

- The number of turns in the coil. The more turns in the coil, the stronger the electromagnet.
- The material of the core. Iron and some types of steel in the core make the strongest electromagnets.
- The current in the coil. The greater the current, the stronger the electromagnet.

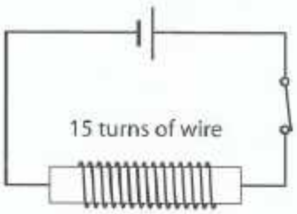
The diagrams show the three ways to increase the strength of an electromagnet:

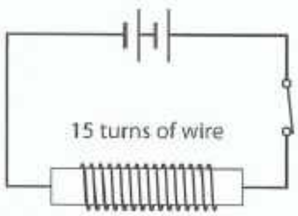
1 Increase the number of turns on the coil. Keep the current and core the same.



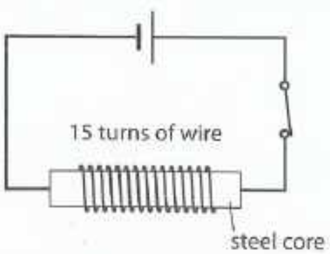



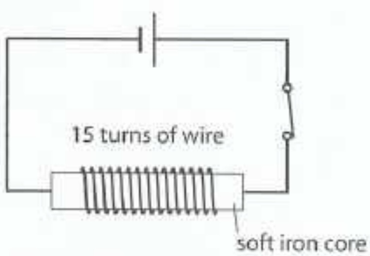

2 Use more cells to increase the current. Keep the number of turns on the coil and the core the same.




3 Use a soft iron core in place of a steel core. Keep the number of turns on the coil and the current the same.



**Soft iron** is not soft in the same way as modelling clay is soft.
Soft iron is the term used for iron that is easily magnetised and also easily **demagnetised**. Demagnetised means it has lost its magnetism.

In 2019, scientists broke the world record for the strongest electromagnet. They made an electromagnet 4500 times stronger than a school bar magnet. It uses more electricity than three million electric lamps!

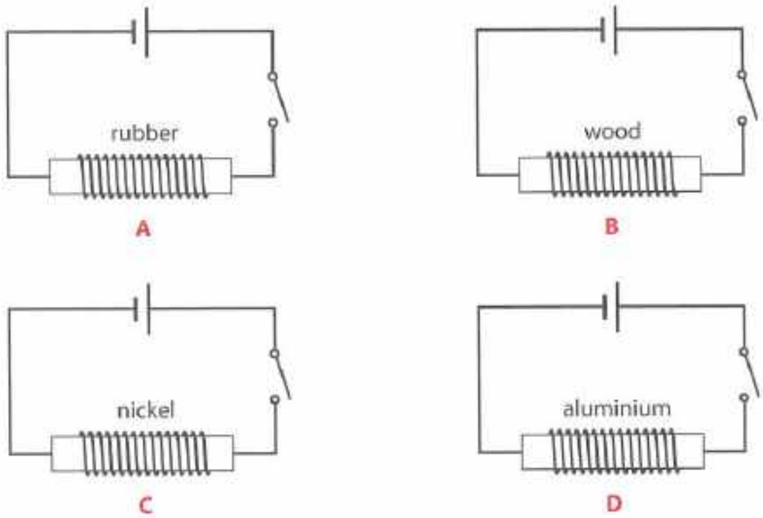
The strength of an electromagnet can be measured by the force that the electromagnet exerts on a magnetic material. The easiest way to do this is to see how many magnetic objects that the electromagnet can lift and hold.

## Questions

1 Explain why an electromagnet for sorting scrap metal needs to be stronger than the electromagnet that holds the handle of a toaster down.

2 State the three factors that affect the strength of an electromagnet.

3 The diagrams show circuit diagrams for four electromagnets. Each has the same current and the same number of turns in the coils. The material of the core is shown on each diagram.




Which of the circuit diagrams will make the strongest electromagnet?

Write **one** letter.

4 A science laboratory called CERN in Switzerland uses lots of very strong electromagnets. The electricity used by CERN is the same as that of a small city. Suggest why CERN uses so much electricity.

## Think like a scientist

### Investigating electromagnet strength

In this activity, you will carry out investigations and plan further investigations on the strength of electromagnets.

Work in groups of two or three.

You will need:

- three 1.5V cells or an adjustable d.c. power supply with safety cut-out (d.c. means the current flows in the same way as from cells. A safety cut-out stops the current from becoming too large.)
- leads and connectors • switch • ammeter • iron nail
- paperclips of different sizes • plastic-coated wire at least 1 m long with about 1 cm of plastic removed from each end • selection of similar-sized cores to the iron nail, such as a wooden pencil, roll of paper, plastic pen and at least one other metal

### Safety

Only keep your electromagnet switched on for the shortest possible time, otherwise your cells will not last long.

Check that the wire in the coil is not becoming hot. If the wire becomes hot, switch off immediately and tell your teacher.

Method: Part 1 – changing the number of turns in the coil

1. Make an electromagnet. Use the number of cells or the power supply setting that your teacher advises. (You should recall how to make an electromagnet from Topic 9.3.)

   Use the iron nail for the core.

   Wrap the wire around the core to make five turns.
2. Switch on the electromagnet and see how many paperclips it will hold. Record this result.
3. Switch the electromagnet off and increase the number of turns on the coil by five.
4. Switch on the electromagnet and see how many paperclips it will hold. Record this result.
5. Repeat steps 3–4 until you can't fit any more turns on the core.
6. Repeat the entire investigation. If any of your results are different, you may need to repeat them a third time.

Continued

### Questions

1 Record your results in a table.

2 Calculate the average number of paperclips for each number of turns in the coil.

3 Draw a line graph of your results. Put number of turns in the coil on the horizontal axis.

4 Describe the trend in your results.

### Method: Part 2 – changing material in the core

1 Make an electromagnet. Use the iron nail as the core. Wrap the maximum number of turns in the coil that will fit on the core. Use the number of cells or the power supply setting that your teacher advises.

2 Switch on the electromagnet and see how many paperclips it will hold.

3 Repeat this with other core materials. The other cores should be about the same diameter, so you should not have to unwind the coil each time.

4 As in Method: Part 1, repeat each of your measurements.

### Questions

5 Record your results in a table.

6 For each core material, calculate the average number of paperclips for each number of turns in the coil.

7 Draw a bar chart of your results. Put the materials of the core on the horizontal axis.

8 Describe any trends in your results.

9 Explain why a line graph was used in Part 1 and why a line graph would **not** be suitable in Part 2.

### Method Part 3 – changing the current in the coil

In this part, you will plan the investigation yourself.

The aim of this part is to investigate how the current in the coil affects the strength of the electromagnet.

1 Decide which variable to change and how you will change it. Your teacher can help with this.

2 Decide which variables you will control.

3 Draw a circuit diagram for your electromagnet.

4 Make a prediction for your investigation.

5 Decide whether large or small paperclips will give better results. Explain your choice.

Continued

6 If you have time, carry out your investigation and record your results in a suitable table.

### Questions

**10** Explain whether a line graph or a bar chart is more suitable to display your results.

**11** Display your results in the type of graph you have chosen.

**12** Explain whether your prediction was accurate.

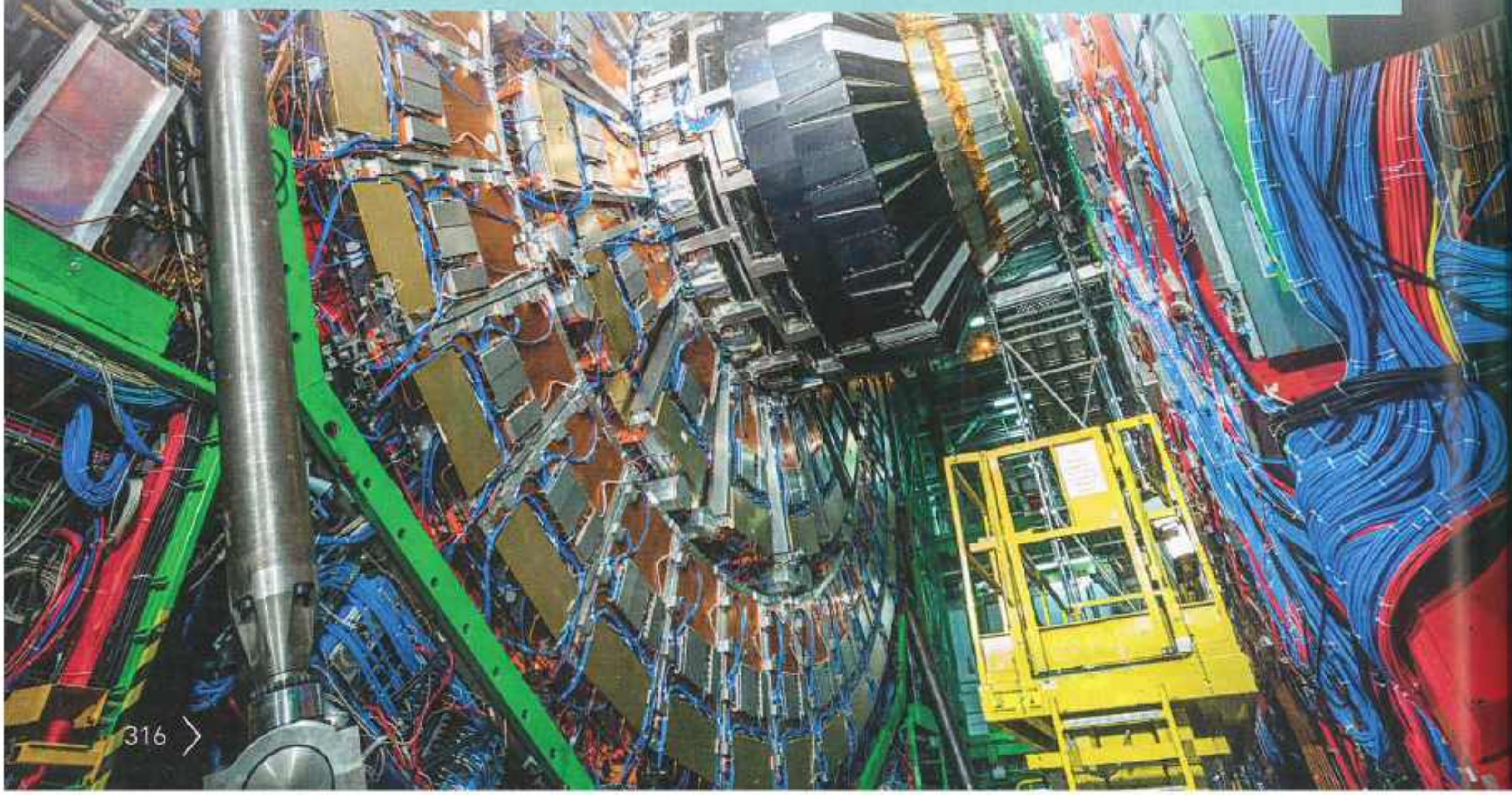
### Self-assessment

Rate your confidence in each of these statements.

- I can recall the three factors that affect electromagnet strength.
- I could plan an investigation to test the effect of changing one of these factors.
- I can understand whether a line graph or bar chart is more suitable for presenting results.

## Summary checklist

- [ ] I can recall the factors that affect the strength of an electromagnet.
- [ ] I can predict how a change in any one of these factors will affect the strength of the electromagnet.



## Project: Investigating magnetism

### Background

Magnetism is all around us in our daily lives. For example, fridge magnets, computer hard disc drives, electric motors and headphones all use magnetism.

Topic 9.2 gave some information about the discovery of magnetism, and a little information about how some animals use the Earth's magnetic field.

### Your task

Work in groups of three or four.

Your group should find out about some of the following aspects of magnetism.

- Early discoveries in magnetism.
- How animals use magnetism.
- How the Earth's magnetic field protects us.
- Magnetic fields around other planets in the Solar System.
- The strongest known natural magnets in the Universe.
- The many and varied uses of magnets.

You do not have to include all of these, or you could find out about other aspects of magnetism.

Connect the information you find to tell a story.
Present this story in any way you choose, for example:

- a picture story board
- a poem
- a stage play
- a song.

All members of the group should have a role in presenting the story. You should also add some information about the reliability of your sources of information. For example, how did you decide whether an information source was reliable?

# Check your progress

**9.1** What is a magnetic field? [1]
Write **one** letter.

**A** An area where you can use a magnet.

**B** An area where magnetism can be detected.

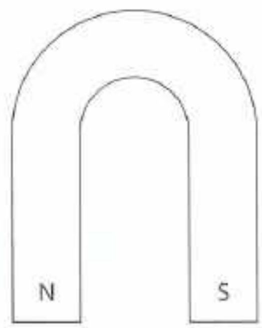
**C** An area to store magnets.

**D** An area where no magnets are allowed.

**9.2** What direction do magnetic field lines point? [1]

N → S S → N S → S N → N

**9.3 a** Copy the diagram of a horseshoe magnet.

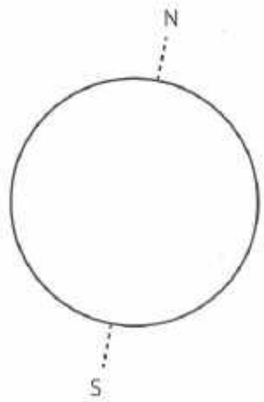



Draw the magnetic field pattern of the horseshoe magnet on your diagram. [3]

**b** Copy the diagram of two south poles from different magnets.


Draw the magnetic field pattern between these two south poles on your diagram. [3]

**9.4** Copy this diagram of the Earth on its axis.




The letters N and S on the diagram show the geographic poles.

Draw the pattern of the Earth's magnetic field on your diagram. [3]

**9.5** A soft iron does **not** attract paperclips.
A coil of wire is wrapped around the soft iron cylinder.

Electric current is passed through the coil.

What change happens in the soft iron cylinder? [1]
Write **one** letter.

**A** It becomes magnetic.

**B** It becomes a permanent magnet.

**C** It becomes magnetised.

**D** It becomes demagnetised.

**9.6** **a** State the name given to a magnet that can be switched on and off. [1]

**b** Draw a labelled diagram to show how this type of magnet could be made. [4]

**9.7** Arun makes an electromagnet using:

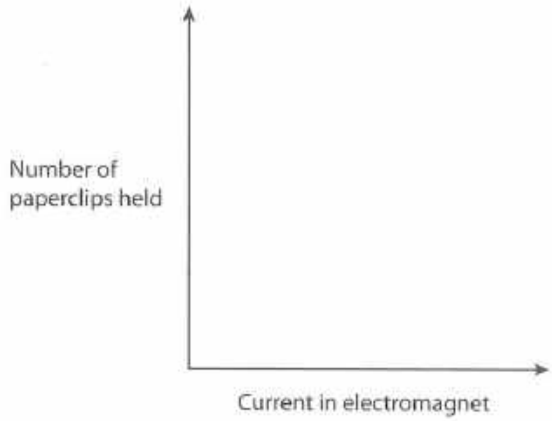
- one 1.5 V cell
- an iron nail 15 cm in length
- 10 turns of wire around the nail.

**a** State the effect on the strength of this electromagnet if Arun increases the number of turns of wire around the nail to 20. [1]

**b** Arun uses an ammeter to measure the current in the electromagnet circuit. He then varies the current. For each current, Arun measures the number of paperclips that the electromagnet will hold.

- **i** State the independent variable in this investigation. **[1]**
- **ii** State the dependent variable in this investigation. **[1]**
- **iii** Copy these graph axes and sketch the shape of graph you would predict for the results.

  Assume both axes start at zero. **[2]**




**c** Arun wants to investigate the effect of changing the material in the core of his electromagnet.

- **i** List **two** factors that Arun will need to keep constant when changing the material in the core. **[2]**
- **ii** Which of these materials in the core will make the strongest electromagnet?

  Write **one** letter. **[1]**

  **A** paper

  **B** copper

  **C** plastic

  **D** cobalt

# > Science Skills

## Making more accurate measurements

In Science, we often take measurements. We do this to find out more about what we are investigating.

Measurements are taken using measuring instruments. These include rulers, balances, timers, and so on.

We want our measurements to be as **accurate** as possible. In other words, we want them to be as close as possible to the **true answer**. Then we can be more confident that our conclusions are correct.

### Measuring instruments

How can we be sure that our measurements are as accurate as possible? We need to think about the instruments and methods we use. Here are two examples:

- You want to measure a $50\,cm^3$ volume of water. It is better to use a $100\,cm^3$ measuring cylinder than a $50\,cm^3$ beaker, even though the beaker may have a line indicating the level which corresponds to $50\,cm^3$. A $100\,cm^3$ measuring cylinder is better than one which measures $1000\,cm^3$ because $50\,cm^3$ is only a small fraction of $1000\,cm^3$.
- You want to time a toy car moving a distance of 1.0 m. You could use the clock on the wall, but this is not a good choice as it is not accurate. You could use a stopwatch, but it is tricky to start and stop the watch at the exact moments when the car crosses the starting and finishing lines. You would have to take account of your reaction time. It would be better to time the car over a distance of at least 2 m, as then the time is longer, and your reaction time is a smaller proportion of the time you measure.

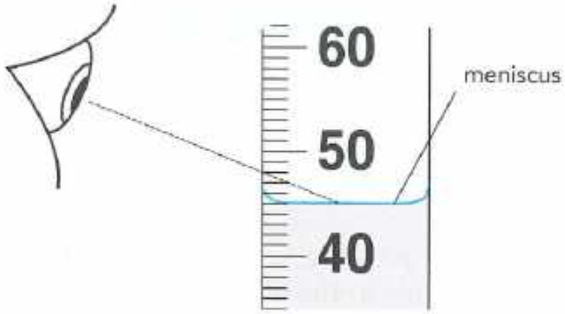
We also need to think about how we use measuring instruments.

For example:

- When using a ruler to measure the length of an object, the ruler needs to be placed directly alongside the object. Make sure that one end of the object is exactly next to the zero of the ruler's scale.


This diagram shows how **not** to do it; you might think the end of the leaf stalk is at 0.0 cm but it is actually at 0.2 cm

- When using a measuring cylinder, look horizontally at the surface of the liquid and read the scale level with the bottom of the meniscus.




This diagram shows how **not** to do it; you might read this as 46, when it should be read as 45

- When using a balance to find the mass of an object, check that it reads zero when there is nothing on it. Similarly, a forcemeter (or newton meter) should read zero when no force is pulling on it. It may be possible to reset these instruments if they are not correctly set to zero.


This diagram shows how **not** to do it. There is usually a 'tare' button on the balance, which you can press to make sure it reads 0 before you put the object onto it

# Anomalous results

Sofia did an experiment to find out how light intensity affects the rate of photosynthesis of a water plant. She placed a lamp at different distances from the plant, and counted the number of bubbles it gave off in one minute.

Sofia made three counts for each distance of the lamp from the plant. This table shows her results.

| Distance of lamp from plant in cm | Number of bubbles per minute | | |
|---|---|---|---|
| | 1st try | 2nd try | 3rd try |
| 20 | 28 | 29 | 27 |
| 40 | 19 | 33 | 18 |
| 60 | 12 | 14 | 13 |
| 80 | 8 | 10 | 10 |

Sofia thought that one of her results didn't look right. Which one is it?

A result like this, that does not fit the pattern of all the other results, is called an **anomalous result**.

If you get a result that looks anomalous, there are two things that you can do.

1 The best thing to do is to try to measure it again.

2 If you can't do that, then you should ignore the result. So Sofia should not use this result when she is calculating the mean. She should use only the other two results for that distance from the lamp, add them up and divide them by two.

## Questions

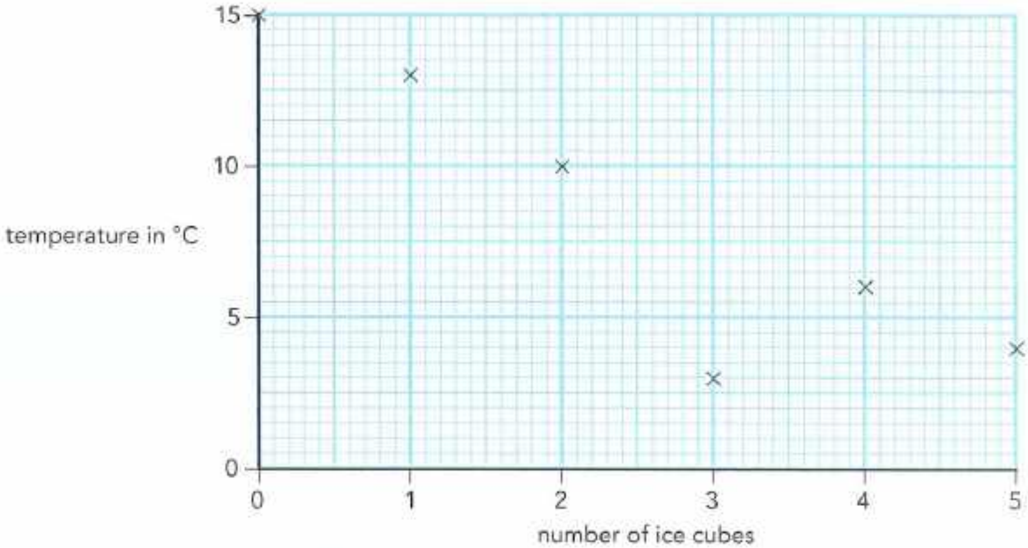
1 Which is the anomalous result in Sofia's table?

2 Explain why you decided that this result is anomalous.

3 Calculate the mean number of bubbles per minute for each distance of the lamp. Remember – don't include the anomalous result in your calculation!

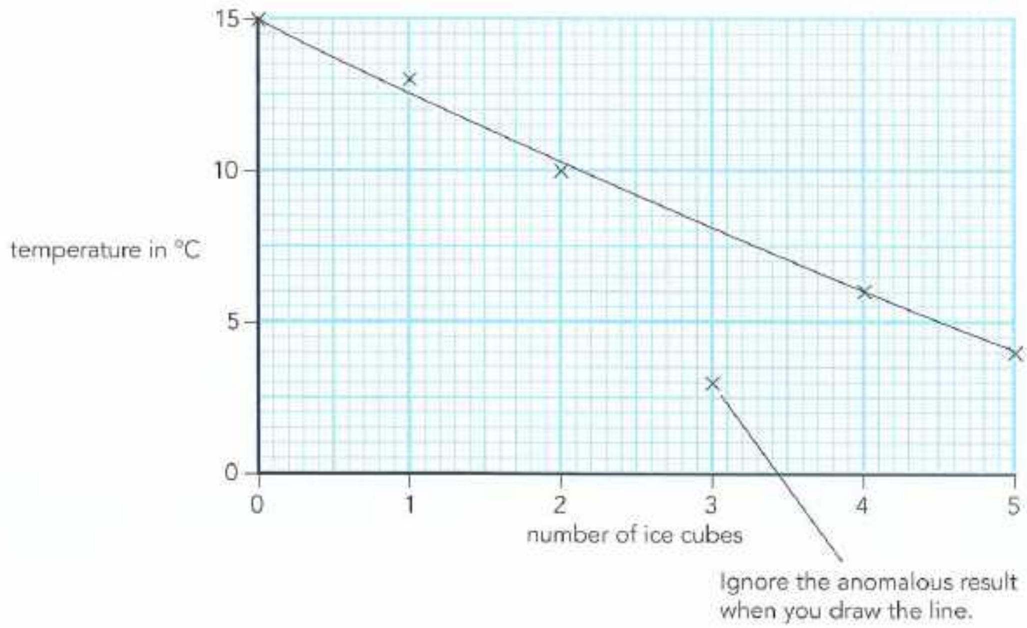
Finding an anomalous result in a results table can be quite difficult. It is often much easier if you have drawn a graph.

Arun did an experiment to investigate how adding ice to water changed its temperature. He added a cube of ice to 500 $cm^3$ of water and stirred the water until the ice had completely melted. Then he measured the temperature of the water before adding another ice cube. The graph shows his results.




It's easy to see that the point at (3, 3) doesn't fit the pattern of all the other results. Something must have gone wrong when Arun was making that measurement.

When Arun draws the line on his graph, he should ignore this result. He should also think about why it might have gone wrong. Perhaps he misread the thermometer – was the correct reading 8 °C? Or perhaps he forgot to stir the water and measured the temperature where the cold ice had just melted. If you think about why an anomalous result has occurred, it can help you to improve your technique and avoid such problems in the future.



## Understanding equations

In Topic 3.2 Speed, you studied three equations that relate speed, distance and time. Here are the three equations:

$$\text{speed} = \frac{\text{distance}}{\text{time}}$$

$$\text{distance} = \text{speed} \times \text{time}$$

$$\text{time} = \frac{\text{distance}}{\text{speed}}$$

How can you remember these three equations? It will help if you think about the *meaning* of each quantity involved. It can also help to think about the *units* of each quantity.

**Speed** is the distance travelled per second or per hour. The word 'per' means 'in each', and this should remind you that the distance must be divided by the time.

Another way to think of this is to start with the units. Speed is measured in metres per second, so you must take the number of metres (the distance) and divide by the number of seconds (the time).

**Distance** is how far you travel. The faster you go (the greater your speed), and the longer you go for (the greater the time), the greater the distance travelled. This tells us that the two quantities must be multiplied together.

**The train is travelling at 75 m/s.**

**Time to pass observer = 3.6 s.**

**length of train = speed × time**
**= 75 × 3.6**
**= 270 m**

# Glossary and index

| | | |
|---|---|---|
| **absorbed** | of light, cannot pass through an object or be reflected from it | 211 |
| **accumulate** | gradually increase in quantity | 145 |
| **adaptations** | features of organisms that help them to live and reproduce in their habitat | 127 |
| **aerobic respiration** | chemical reactions inside cells, where oxygen is used to break down glucose and release energy | 9 |
| **air sac** | one of the tiny air-filled spaces inside lungs; also called an alveolus | 10 |
| **altitude** | height, usually measured vertically from sea level | 109 |
| **alveoli** | air sacs in the lungs | 13 |
| **anaemia** | not having enough haemoglobin in the blood, so not enough oxygen is delivered to respiring cells | 239 |
| **analogy** | a comparison that helps to explain something | 15 |
| **angle of incidence** | the angle made by a light ray arriving at a surface, measured from the normal | 192 |
| **angle of reflection** | the angle made by a reflected light ray on leaving a surface, measured from the normal | 192 |
| **angle of refraction** | the angle made by a ray of light that has bent at a surface, measured from the normal | 199 |
| **antagonistic muscles** | a pair of muscles that work as a team; the contraction of one of the muscles causes bones at a joint to move in one direction, and the contraction of the other muscle causes movement in the opposite direction | 257 |
| **antibodies** | chemicals produced by white blood cells, which kill pathogens | 35 |
| **asteroid belt** | the ring that contains most asteroids in the Solar System, located between the orbits of Mars and Jupiter | 223 |
| **asteroids** | rocky objects, smaller than planets, that orbit the Sun | 223 |
| **at rest** | not moving | 85 |
| **atmosphere** | the layer of air that surrounds Earth or the layer of gas that surrounds any other object in space | 166 |
| **atmospheric pressure** | the force exerted by the air around us on a $1\ m^2$ area; atmospheric pressure varies slightly, but at sea level is approximately $100\,000\ N/m^2$ | 109 |
| **atoms** | tiny particles of matter | 153 |
| **average speed** | calculated as $\frac{\text{distance travelled}}{\text{time taken}}$, usually having the unit m/s | 79 |

| | | |
|---|---|---|
| **away from the normal** | when a light ray bends so its angle measured from the normal increases | 199 |
| **balanced** | forces or moments are balanced if they are equal and opposite, so their effects cancel out | 69 |
| **balanced diet** | daily food intake that contains all the different types of nutrient, and the right amount of energy | 242 |
| **ball-and-socket** | a type of joint where one bone has a ball-shaped end that fits into a socket on the other bone; it allows a circular movement | 253 |
| **bent** | in refraction, the change in direction of a light ray | 199 |
| **biceps** | a muscle that is attached to the shoulder blade and the radius bone; when it contracts, it makes the arm bend at the elbow | 255 |
| **bioaccumulation** | gradual increase of a substance in an organism's body; it happens when the substance cannot be broken down inside the body cells | 145 |
| **biodegradable** | something that can be broken down naturally by bacteria and fungi | 147 |
| **biomagnification** | increase of the concentration of a substance as you go up a food chain | 146 |
| **bioplastics** | useful materials made from natural renewable sources and not from oil | 186 |
| **blood plasma** | the liquid part of blood | 32 |
| **boulder** | large rock | 174 |
| **breathing** | using muscles to make movements that cause air to move in and out of the lungs | 21 |
| **bronchiole** | one of the small tubes leading into the lungs from a bronchus | 10 |
| **bronchus** | one of the two tubes that branch from the trachea, and which carry air into the lungs | 10 |
| **calculate** | work out a value using a mathematical method or equation | 78 |
| **capillary** | the smallest type of blood vessel | 13 |
| **carat** | a measurement of purity of gold | 158 |
| **carbohydrate** | one of the essential nutrients in the diet; it is broken down to release energy by respiration inside body cells | 234 |
| **carbon monoxide** | a gas formed from one atom of carbon and one atom of oxygen | 250 |
| **cartilage** | a tough but bendy material, which makes up the supporting rings around the trachea | 10 |
| **change direction** | a bend in the path taken by a moving object | 71 |
| **chromatogram** | the results which show the separation of substances after carrying out chromatography | 58 |

| | | |
|---|---|---|
| **climate** | the weather condition prevailing in an area over a long period of time | 169 |
| **climatology** | the study of climate | 169 |
| **coil** | the shape made by a wire when it is wound around a cylinder | 307 |
| **collapses** | gives way or falls down | 279 |
| **collide** | to hit into something | 108 |
| **coloured filters** | transparent pieces of glass or plastic that are coloured to allow only some colours of light to pass through | 211 |
| **combustion** | burning | 264 |
| **compass** | a magnetic compass is used to show the direction of a magnetic field; it contains a rotating needle that will point away from a magnetic north pole and towards a magnetic south pole | 294 |
| **concentrated (solution)** | a solution in which a large mass of solute is dissolved | 46 |
| **concentration** | a measure of how many particles there are in a particular space; more particles in a space is a higher concentration than fewer particles in the same space | 115 |
| **conserved** | stays the same | 43 |
| **constant** | does not change | 79 |
| **constipation** | a condition where the digestive system works too slowly, so that faeces are not passed out regularly | 244 |
| **container** | an item that is used to hold other things, such as a beaker that contains water | 108 |
| **contract** | of a muscle: get shorter | 22 |
| **contraction** | the shortening of a muscle | 255 |
| **control variables** | factors that are kept the same in an investigation so that the test is fair | 54 |
| **core** | in magnetism, the object in the middle of the coil in an electromagnet | 307 |
| **craters** | bowl-shaped dents in the surface of a planet or moon caused by an object colliding with that surface | 223 |
| **cyan** | a blue-green colour, made by adding blue light and green light | 211 |
| **cycle** | a regular changing pattern from one thing to another, such as the water cycle | 173 |
| **deflected** | the direction of an object was changed | 155 |
| **deforestation** | cutting down large areas of trees | 181 |
| **demagnetised** | having lost a magnetic field so no longer attracts magnetic objects | 313 |

| | | |
|---|---|---|
| **dependent variable** | the factor that changes in an investigation as a result of changing the independent variable | 54 |
| **depth** | the distance from the bottom of something to the top | 107 |
| **development** | of a human: the gradual changes in the body as the person grows up | 249 |
| **diffusion** | the random movement of particles from an area where they are in high concentration to an area where they are in lower concentration | 14 |
| **dilute (solution)** | a solution in which a small mass of solute is dissolved | 46 |
| **direction** | the path taken by a moving object, or the line along which a force acts | 69 |
| **dispersion** | separating white light into its component colours | 205 |
| **dissipate** | spread out through the surroundings | 264 |
| **dissolving/dissolve** | the complete mixing of particles of a solid with a liquid to form a solution | 41 |
| **distance/time graphs** | a way to represent the movement of an object with a line or curve, where distance travelled or distance from a starting point is on the (vertical) $y$-axis and time is on the (horizontal) $x$-axis | 85 |
| **distorted** | changed to become unclear | 198 |
| **ecology** | the study of organisms in their natural environment | 130 |
| **ecosystem** | a network of interactions between all the living organisms in a habitat, and the non-living things around them | 130 |
| **electrical charge** | a property of an object which causes it to attract or repel other objects with a positive or negative charge | 153 |
| **electromagnet** | made by winding a coil around a magnetic material and passing a current through the wire; this results in the magnetic material being magnetised as long as the current flows | 307 |
| **electrons** | negatively charged particles found surrounding the nucleus of an atom | 153 |
| **electrostatic attraction** | the force that holds individual atoms together | 153 |
| **elliptical** | oval-shaped | 218 |
| **embryo** | a young organism before it hatches or is born | 249 |
| **emissions** | gases produced and given off | 180 |
| **endothermic process** | a process (such as change of state) in which energy is transferred from the surroundings | 271 |
| **endothermic reaction** | a chemical reaction in which energy is transferred from the surroundings | 270 |

| | | |
|---|---|---|
| **environment** | everything around an organism that affects it | 129 |
| **eradicate** | get rid of; totally destroy | 140 |
| **exoskeleton** | a skeleton on the outside of the body; insects, for example, have exoskeletons | 253 |
| **exothermic reaction** | a chemical reaction in which energy is transferred to the surroundings | 264 |
| **expired air** | air that is breathed out | 17 |
| **extinct** | no longer existing | 140 |
| **factors** | in science, another word for variables | 312 |
| **fat** | one of the essential nutrients in the diet; it can be broken down to release energy, or can be stored inside cells as an energy reserve | 234 |
| **fibre** | a component of food that cannot be digested; it is mostly made up of cellulose from plants, and helps to prevent constipation | 244 |
| **food web** | a diagram showing many interconnected food chains | 130 |
| **force** | an interaction which, if unbalanced, will change the shape or change the movement of an object | 69 |
| **fossil fuels** | fuels such as oil, coal and gas, formed from the remains of living organisms | 179 |
| **fuel** | a store of chemical energy | 264 |
| **galaxy** | a collection of stars with their planets, dust and gas | 218 |
| **gas exchange** | the movement of gases into and out of organisms | 14 |
| **geographic north** | one of the points where the Earth's axis of rotation meets the Earth's surface; located in the Arctic Ocean and normally shown at the top of a world map or globe | 301 |
| **glacial period** | the coldest part of an ice age | 173 |
| **glaciers** | rivers of ice formed from snow that have become compressed over a long time | 174 |
| **global warming** | an increase in the overall temperature of the Earth's atmosphere over time | 182 |
| **glucose** | a sugar that cells break down in respiration to release energy | 26 |
| **greenhouse effect** | heat energy from the Sun is trapped in the atmosphere | 182 |
| **habitat** | the place where an organism lives | 131 |
| **haemoglobin** | the red pigment in red blood cells | 14 |
| **hinge joints** | joints where one bone moves in one plane in relation to the other – like a door moving on its hinges | 253 |

| | | |
|---|---|---|
| **humidity** | a measure of how much water vapour is in the atmosphere | 166 |
| **ice ages** | times when part of the Earth has permanent ice | 173 |
| **impacts** | collisions | 224 |
| **incident ray** | a beam of light arriving at a surface | 191 |
| **independent variable** | the factor that is changed by the experimenter in an investigation | 54 |
| **inert** | does not react | 278 |
| **insecticide** | a chemical used to kill insects | 143 |
| **insoluble** | a substance that will not dissolve | 47 |
| **inspired air** | air that is breathed in | 17 |
| **interact** | affect one another | 128 |
| **interglacial period** | a warmer part of an ice age | 173 |
| **interval** | the difference between two things; used here for the changes in the independent variable. | 55 |
| **invasive species** | a species that has been introduced into an ecosystem where is does not belong | 140 |
| **irregular** | of a galaxy, having no clearly defined shape | 218 |
| **joints** | places where two bones meet | 253 |
| **larynx** | voicebox; it is found at the top of the trachea, and contains strong cords that vibrate to make sounds when we speak | 11 |
| **law of reflection** | the statement that the angle of reflection is equal to the angle of incidence | 191 |
| **lenses** | pieces of glass or transparent plastic designed to refract light in certain ways | 200 |
| **lever** | a rigid length of material that can turn about a pivot | 92 |
| **like poles** | magnetic poles that are the same: north and north, or south and south | 296 |
| **limewater** | a solution of calcium hydroxide that goes cloudy when mixed with carbon dioxide | 16 |
| **locked up** | stored: for example, carbon is locked up in oil or coal until it is burnt | 179 |
| **magenta** | a pink colour, made by adding red light and blue light | 211 |
| **magnet** | a metal object that will attract magnetic objects | 294 |
| **magnetic** | attracted to a magnet | 294 |
| **magnetic field** | an area where the effects of a magnet can be detected | 294 |
| **magnetic field lines** | lines drawn with arrows to show the shape and direction of a magnetic field; the arrows point from north to south | 294 |

| | | |
|---|---|---|
| **magnetic north** | the position of the Earth's magnetic field towards which a magnetic compass points; it is located close to the geographic north pole and is actually equivalent to the south pole of a magnet | 301 |
| **magnetised** | has been given the properties of a magnet | 307 |
| **medium** | of light (or waves), the substance through which the light (or waves) travel | 198 |
| **meteorology** | the study of weather | 169 |
| **metres** | the standard scientific unit of distance, symbol m, where $1\,m = 100\,cm$ | 78 |
| **metres per second (m/s)** | the standard scientific unit of speed | 78 |
| **minerals** | substances that we need in small quantities in the diet, such as calcium and iron | 239 |
| **mitochondria** | tiny structures inside cells, where aerobic respiration happens, releasing energy from glucose | 26 |
| **moment** | the turning effect of a force, calculated as force × distance from a pivot | 92 |
| **muscles** | organs that produce pulling forces when they contract | 255 |
| **native species** | types of organism that are living in their natural habitat | 140 |
| **naturally occurring** | present without the need of any human activity | 301 |
| **navigate** | work out the path of a journey | 301 |
| **nectar** | a sugary liquid made by flowers, to attract insects for pollination | 128 |
| **neutrons** | particles found in the nucleus of an atom that have no electrical charge | 153 |
| **newton metres** | the standard unit of moment, written as N m | 93 |
| **newtons per metre squared** | the standard unit of pressure, written as $N/m^2$ | 100 |
| **nicotine** | the addictive substance in tobacco smoke | 250 |
| **nocturnal** | active at night | 129 |
| **non-luminous** | does not give out its own light | 213 |
| **normal** | in a ray diagram, this is a line drawn at 90° to a surface from which the angles of light rays are measured | 191 |
| **nucleus** | a dense area at the centre of an atom that contains protons and neutrons | 153 |
| **nutrients** | substances in food that are needed in the diet | 235 |
| **oil** | liquid fat | 234 |

| | | |
|---|---|---|
| **opaque** | a substance that does not allow light to pass through | 42 |
| **opposite** | acting against something | 69 |
| **oxidation reaction** | a reaction where oxygen combines with another substance | 266 |
| **oxyhaemoglobin** | haemoglobin that is combined with oxygten | 34 |
| **paper chromatography** | a way of separating mixtures of dissolved chemicals using special paper | 58 |
| **particulates** | tiny solid particles in air or smoke, that cause damage when they get into the lungs | 250 |
| **pathogens** | microorganisms that cause disease; some bacteria and viruses are pathogens | 35 |
| **peat bog** | an area of wetland where dead plant material decays very slowly | 175 |
| **per** | in each, represented by the symbol / in units, so m/s is metres per second: the number of metres travelled in each second | 78 |
| **permanent** | something that remains and does not change | 58 |
| **permanent magnet** | magnetic objects that have a magnetic field around them all the time | 307 |
| **perpendicular** | at $90^0$ | 191 |
| **persistent** | a persistent substance stays in the environment for a long time | 143 |
| **photosynthesis** | chemical reactions in which plants make carbohydrates, using energy from light | 179 |
| **pivot** | the point about which a lever can turn and from which distance of a force is measured when calculating a moment | 92 |
| **plane mirror** | a flat, shiny surface designed to reflect light and produce clear reflected images | 191 |
| **point** | a position, such as on a graph, or the sharp end of an object such as a pin | 101 |
| **pollen** | tiny grains made by flowers, which contain male gametes | 128 |
| **pollinating** | moving pollen from an anther where it is made, to a stigma | 128 |
| **preliminary work** | practical work you do before an investigation to find out how you will carry it out; for example, you might find out the range or interval you will use | 268 |
| **pressure** | the pushing effect of a force, calculated as $\frac{\text{force}}{\text{area}}$ | 100 |
| **prevent** | to stop something happening | 278 |
| **primary colours** | the colours of light that cannot be made by mixing any other colours of light: red, green and blue | 210 |
| **prism** | a three-dimensional shape with a constant cross-section | 205 |

| | | |
|---|---|---|
| **protein** | one of the essential nutrients in the diet; protein is used to make new cells, and also to make substances such as haemoglobin and antibodies | 234 |
| **protons** | positively charged particles found in the nucleus of an atom | 153 |
| **protractor** | a tool for measuring angles | 192 |
| **range** | the difference between the highest and lowest values | 55 |
| **ray diagram** | a way of showing the path taken by light using straight lines | 191 |
| **rays** | the paths of light | 191 |
| **reactive** | how readily a substance takes part in a reaction | 278 |
| **reactivity** | how reactive something is | 283 |
| **reagents** | chemicals that are used in a reaction | 287 |
| **recycled** | used again | 179 |
| **red blood cells** | the most common cells in blood; they contain haemoglobin which transports oxygen from the lungs to body cells | 32 |
| **reflection** | when light bounces off a surface without being absorbed | 191 |
| **refraction** | a change in the direction of light caused by a change in the speed of the light when passing from one medium into another | 198 |
| **relax** | of a muscle: stop contracting | 22 |
| **renewable resources** | natural resources that do not run out and can be replaced by normal processes within a human's lifetime | 184 |
| **respiration** | a series of chemical reactions that takes place in all living cells, in which energy is released from glucose | 9 |
| **respiratory system** | the lungs and other organs that help oxygen to enter the body and carbon dioxide to leave it | 9 |
| **rust** | a chemical reaction where iron combines with oxygen in the presence of water to form iron oxide | 279 |
| **safety precautions** | actions taken to reduce the risk of accident or injury; they are specific to the experiment and more than just basic laboratory rules | 89 |
| **salt** | a compound formed when a metal reacts with an acid, for example magnesium chloride | 287 |
| **sandpaper** | rough paper | 283 |
| **saturated (solution)** | a solution in which no more solid will dissolve | 47 |
| **sea level** | the position of the surface of the oceans, usually taken mid-way between high tide and low tide | 109 |
| **second** | the standard scientific unit of time; there are 60 seconds in 1 minute | 78 |
| **set square** | a drawing tool in the shape of a right-angled triangle | 192 |

| | | |
|---|---|---|
| **sharp** | having an edge or a point that can cut or push into another object | 100 |
| **skeleton** | a structure that supports an animal's body | 253 |
| **sketch** | a sketch graph has only axis labels but no numbers or units on the axes and shows the relationship between two variables | 86 |
| **slow down** | decrease speed | 70 |
| **soft iron** | iron that is easily magnetised and easily demagnetised | 313 |
| **solubility** | how soluble a substance is | 48 |
| **soluble** | a substance that will dissolve | 47 |
| **solute** | a substance that is dissolved | 41 |
| **solution** | a mixture formed when a solid dissolves in a liquid | 41 |
| **solvent** | a liquid in which other substances will dissolve | 41 |
| **solvent front** | used in chromatography and is the level the solvent has reached as it travels up the paper | 62 |
| **spectrum** | the continuous range of colours in white light: red, orange, yellow, green, blue, indigo, violet | 205 |
| **speed** | distance travelled per unit time, usually the number of metres travelled in one second; a measure of how fast something moves | 78 |
| **spiral** | a shape with curved arms extending out from its centre | 218 |
| **starch** | a type of carbohydrate, which is often stored inside plant cells | 234 |
| **stationary** | not moving | 85 |
| **statistics** | analysis of large quantities of numerical data | 169 |
| **stellar dust** | small solid particles with masses of less than 0.1 g, found in space | 219 |
| **sub-atomic particles** | atomic particles that are smaller than an atom | 153 |
| **subtraction** | taking something away | 211 |
| **suggest** | to give an idea | 164 |
| **surface area** | all or part of the area of the surface of an object | 100 |
| **tar** | a mixture of chemicals found in tobacco smoke that increase the risk of developing many different types of cancer | 250 |
| **tendons** | strong, non-stretchy cords that attach muscles to bones | 255 |
| **towards the normal** | when a light ray bends so its angle measured from the normal decreases | 199 |
| **toxic** | poisonous | 143 |
| **trachea** | the tube that carries air from the back of the mouth, down through the neck towards the lungs | 10 |
| **translucent** | allows light to pass through it | 159 |
| **transmit** | of a filter, to allow light to pass through | 211 |

| | | |
|---|---|---|
| **transparent** | something that allows light to pass through so that you can see clearly | 42 |
| **triangular** | describing a shape with three straight sides | 205 |
| **triceps** | a muscle attached to the scapula and ulna, which straightens the elbow joint when it contracts | 255 |
| **turn** | rotate about a point or change direction | 92 |
| **unbalanced** | forces or moments are unbalanced if their effects add together or are opposite but do not completely cancel out | 70 |
| **Universe** | all of space and everything contained within it | 218 |
| **variables** | factors that can be changed in an investigation | 54 |
| **visibility** | how far you can see | 166 |
| **vitamin A** | a nutrient that we need for good eyesight | 238 |
| **vitamin C** | a nutrient that we need to keep blood vessels and bones healthy | 238 |
| **vitamin D** | a nutrient that we need for strong bones and a good immune system; as well as getting vitamin D in food, the skin can make it when exposed to sunlight | 238 |
| **vitamins** | substances made by plants and other living organisms, that are required in the diet in small quantities | 238 |
| **vocal cords** | bands of muscle that stretch across inside the larynx, which we vibrate to make sounds | 11 |
| **voicebox** | another name for the larynx | 11 |
| **weather** | the conditions in a particular place: sunny, rainy, frosty, for example | 166 |
| **white blood cells** | blood cells that help to protect against pathogens | 32 |
| **windpipe** | another name for the trachea | 10 |

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