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# Cambridge Lower Secondary
# Science

## LEARNER'S BOOK 8

Mary Jones, Diane Fellowes-Freeman & Michael Smyth

Second edition

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# > Introduction

Welcome to Stage 8 of Cambridge Lower Secondary Science. We hope this book will show you how interesting and exciting science can be.

Science is everywhere. Everyone uses science every day. Can you think of examples of science that you have seen or used today?

Have you ever wondered about any of these questions?

- How do bones and muscles make my body move?
- Where does my energy come from?
- What happens to a substance when it dissolves in water?
- How can we stop iron rusting?
- How does the smell of hot food travel faster than that of cold food?
- What makes a rainbow?

You will work like a scientist to find answers to these questions and more. It is good to talk about science as you investigate and learn. You will share your ideas with classmates to help them understand, and listen to them when you need reassurance. You will reflect on what you did and how you did it, and ask yourself: 'Would I do things differently next time?'

You will practise new skills and techniques, check your progress, and challenge yourself to find out more. You will make connections between the different sciences, and how they link to maths, English and other subjects.

We hope you enjoy thinking and working like a scientist.

*Mary Jones, Diane Fellowes-Freeman, Michael Smyth*

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# How to use this book

**This book contains lots of different features that will help your learning. These are explained below.**

This list sets out what you will learn in each topic. You can use these points to identify the important topics for the lesson.

> **In this topic you will:**
> - learn the names of the different parts of the human respiratory system
> - observe carefully, and record your observations, as the structure of lungs is demonstrated.

This contains questions or activities to help find out what you know already about this topic.

> **Getting started**
>
> Respiration is one of the characteristics of living things.
>
> With a partner, decide which statement in each pair is correct.
>
> Be ready to share your ideas.

| | | | |
|---|---|---|---|
| **First pair:** | Respiration happens inside all the cells in your body | or | Respiration only happens in cells in your lungs |

Key words are highlighted and defined in the text when they first appear in the book. You will also find definitions of all these words in the Glossary and Index at the back of this book.

> **Key words**
>
> aerobic respiration
> air sac
> bronchiole
> bronchus
> cartilage

You will have the opportunity to practise and develop the new skills and knowledge that you learn in each topic. Activities will involve answering questions or completing tasks.

> **Activity 1.1.1**
>
> **What does the larynx do?**
>
> Hold the fingertips of one hand against your larynx ([illegible]).
>
> Keep your lips together, and make a loud humming sound.
>
> Can you feel the larynx vibrating?
>
> Your larynx contains your vocal cords. These are bands of muscle that stretch across your larynx. You can think of them as being like guitar strings. When your vocal cords vibrate, they make a sound.
>
> Now make a higher-pitched humming sound. Then try a really deep-pitched sound. Can you feel the larynx changing when you make the different sounds?

This provides an opportunity for you to practise and develop scientific enquiry skills with a partner or in groups.

> **Think like a scientist**
>
> **Why are air sacs so small?**
>
> In this activity, you will use some agar jelly to represent the lungs, and some coloured liquid to represent oxygen in the air.
>
> You will need:
> - two Petri dishes filled with agar jelly
> - two cork-borers, one with a diameter of 10 mm and the other with a diameter of 5 mm
> - some coloured dye
> - a dropper pipette
>
> Method
>
> 1. Use the larger cork-borer to make eight holes in the jelly in one of the dishes. Space the holes evenly in the dish.
> 2. Now use the smaller cork-borer to make 32 holes in the jelly in the other dish. Try to space the holes evenly in the dish.

After completing an activity, this provides you with the opportunity to either assess your own work or another student's work.

**Self-assessment**

Think about how you did the experiment.

Copy each bulleted statement, and then draw a face next to each one according to how well you think you performed.

☺ I think I did this really well.

😐 I did OK, but I could probably do better.

☹ I didn't do this very well at all.

- I worked out which tube the air would go into when I breathed in and when I breathed out.
- I managed to breathe in and out with just the right force to make the air bubble through the limewater.

This contains questions that ask you to look back at what you have covered and encourages you to think about your learning.

The diagram of the respiratory system includes a lot of new words. How are you going to learn this diagram and all of its labels? Remember that, in a test, the diagram might not be exactly the same as this one.

This list summarises the important ideas that you have learned in the topic.

**Summary checklist**

- [ ] I can name the parts of the respiratory system, and identify them on a diagram.
- [ ] I can list the organs that air passes through, as it moves into and out of the lungs.

At the end of each unit, there is a group project that you can carry out with other students. This will involve using some of the knowledge that you developed during the unit. Your project might involve creating or producing something, or you might all solve a problem together.

**Project: Helping white blood cells to protect us from pathogens**

This project is about how scientific knowledge develops over time, and how scientific discoveries can help people all over the world.

**Background**

Our white blood cells are amazing at keeping us safe from pathogens. Most of the time, they manage to destroy the pathogens so that we recover quickly from an infection.

But there are some pathogens that white blood cells cannot destroy in time. The virus that causes rabies is one of these. If the rabies virus gets into a person's body, the body needs outside help in order to stop the virus spreading. Without treatment, most people die if they are infected with the rabies virus.

**Your task**

You are going to work in a group to find out information about rabies, and how it can be successfully treated. Each group will work on a different topic.

Choose **one or two** of the following five topics to research with your group. Also choose how you will present your findings to others. You could make a poster, or give

These questions look back at some of the content you learned in each session in this unit. If you can answer these, you are ready to move on to the next unit.

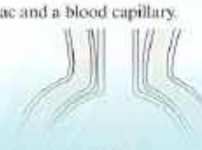
## Check your progress

1.1 The list includes some of the structures that air passes through, as it moves from outside the body to the place where gas exchange happens.

Write the structures in the correct order.

**bronchiole** **trachea** **bronchus** **alveolus (air sac)** [2]

1.2 The diagram shows an air sac and a blood capillary.



# 1 Respiration

## > 1.1 The human respiratory system

**In this topic you will:**

- learn the names of the different parts of the human respiratory system
- observe carefully, and record your observations, as the structure of lungs is demonstrated.

**Getting started**

Respiration is one of the characteristics of living things.

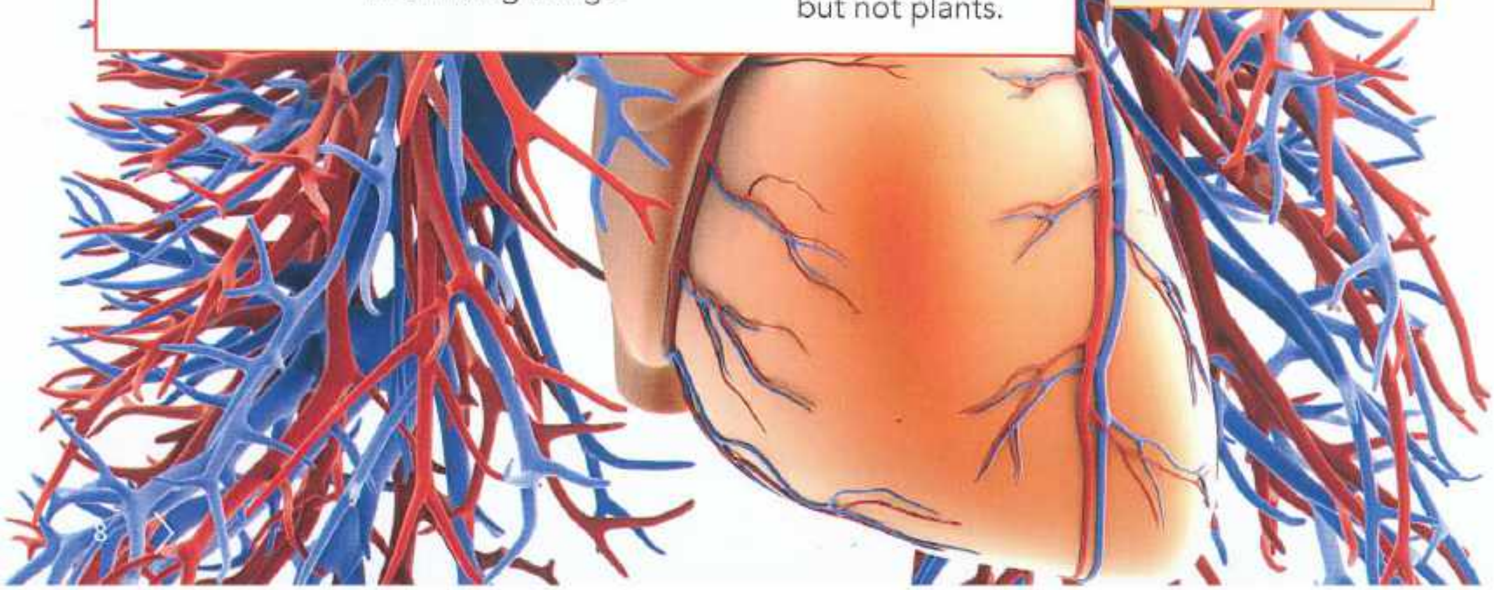
With a partner, decide which statement in each pair is correct.

Be ready to share your ideas.

| | | | |
|---|---|---|---|
| **First pair:** | Respiration happens inside all the cells in your body. | or | Respiration only happens in cells in your lungs. |
| **Second pair:** | Respiration releases energy from food. | or | Respiration uses up energy. |
| **Third pair:** | Respiration happens in all living things. | or | Respiration happens in animals but not plants. |

**Key words**

aerobic respiration
air sac
bronchiole
bronchus
cartilage
larynx
respiration
respiratory system
trachea
vocal cords
voicebox
windpipe



# Why we need oxygen

You may remember that one of the characteristics shared by all living things is **respiration**. Respiration is a series of chemical reactions that happens inside every living cell.

The kind of respiration that usually happens inside our cells is called **aerobic respiration**. Aerobic respiration uses oxygen. The cells produce carbon dioxide as a waste product.

The air around you contains oxygen. When you breathe, you take air into your lungs. Some of the oxygen from the air goes into your blood. The blood delivers the oxygen to every cell in your body, so that the cells can use it for respiration. The blood collects the waste carbon dioxide from the cells, and takes it back to your lungs.

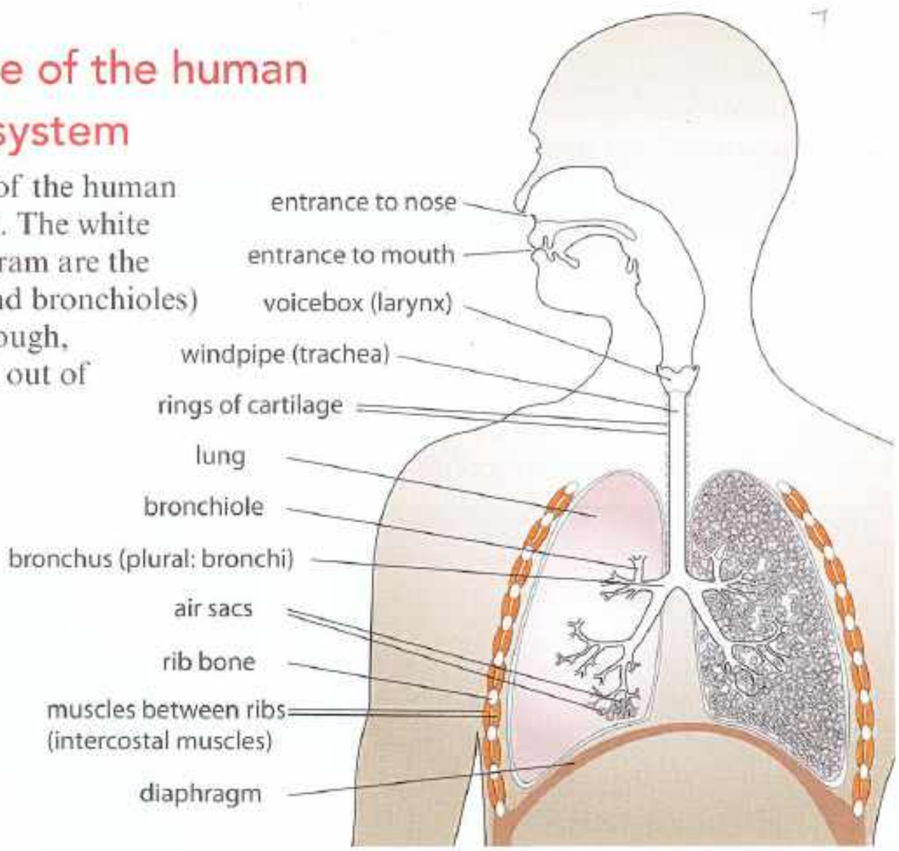
The organs that help you to take oxygen out of the air, and get rid of carbon dioxide, make up the **respiratory system**.

Can you name any of the other organs shown in the picture on the right?

In this model of the human body, the lungs are shown in pink

## The structure of the human respiratory system

This is a diagram of the human respiratory system. The white spaces in this diagram are the 'tubes' (bronchi and bronchioles) that air moves through, as it goes into and out of your lungs.




The human respiratory system

## Questions

1 Put your finger on the entrance to the nose or mouth in the diagram of the respiratory system. Move your finger along the white space and down into the lungs.

Write down the structures that the air passes through, as it moves down into your lungs. Write them in the correct order.

2 Now write the same structures in the order in which air passes through them as it moves out of your lungs and back into your surroundings.

Air gets into your body through your mouth or nose. Your mouth and nose both connect to your **trachea**. The trachea is sometimes called the **windpipe**. It has strong rings of **cartilage** around it. These rings of cartilage keep the trachea open and prevent it collapsing, so that air can be kept moving in and out of your body. If you put your fingers on the front of your neck and move them downwards, you can feel the rings of cartilage on your trachea.

The trachea branches into two **bronchi** (singular: **bronchus**). The bronchi also have cartilage to support them. One bronchus goes to each lung. Each bronchus carries air deep into the lungs. Each bronchus divides into several smaller tubes called **bronchioles**. The structure of these branches allows the air to reach deeper into the lungs.

The bronchioles end by branching into many tiny structures called **air sacs**. This is where the oxygen goes into the blood, and the carbon dioxide comes out. You can find out more about this in the next topic.

### Think like a scientist

#### Looking at lungs

In this activity, you are going to look carefully at some real lungs. You will practise using your senses of touch and sight to make observations, and record your observations. Before you start this activity, look carefully at the questions and make a risk assessment. Think about how you will reduce or overcome any risks. Be prepared to share your ideas.

You will need:

- a set of lungs from an animal, such as a sheep or goat (from a butcher)
- a big board to put the lungs onto
- hot water, soap and towels to wash your hands after handling the lungs

#### Questions

1 Describe what the lungs look like.

If you prefer, you could make a labelled drawing instead of writing about them.

**Continued**

2 Touch the lungs.

What do they feel like when you push them? Can you suggest why they feel like this? (Look at the diagram of the human respiratory system to help you.)

3 Look at the tube that carries air down into the lungs.

a What is the name of this tube?

b Feel the tube. What does it feel like?

c Follow the tube towards the lungs. Can you find where it divides into two? What are the names of these two tubes?

d Now look at the top of the big tube, where it is wider. What is the name of this wide part? What is its function?

The diagram of the respiratory system includes a lot of new words. How are you going to learn this diagram and all of its labels? Remember that, in a test, the diagram might not be exactly the same as this one.

## Activity 1.1.1

### What does the larynx do?

Hold the fingertips of one hand against your **larynx** (**voicebox**).

Keep your lips together, and make a loud humming sound.

Can you feel the larynx vibrating?

Your larynx contains your **vocal cords**. These are bands of muscle that stretch across your larynx. You can think of them as being like guitar strings. When your vocal cords vibrate, they make a sound.

Now make a higher-pitched humming sound. Then try a really deep pitched sound. Can you feel the larynx changing when you make the different sounds?

## Summary checklist

- [ ] I can name the parts of the respiratory system, and identify them on a diagram.
- [ ] I can list the organs that air passes through, as it moves into and out of the lungs.

# 1.2 Gas exchange

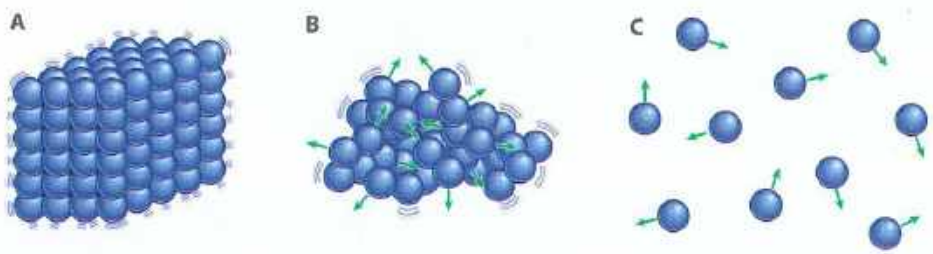
## In this topic you will:

- find out how oxygen gets into your blood from the air, and how carbon dioxide goes in the other direction
- do an experiment to help you to think about why the air sacs in the lungs need to be very small
- do an experiment to compare how much carbon dioxide there is in the air you breathe in and the air you breathe out.

## Getting started

This topic is about two gases – oxygen and carbon dioxide.

Look at these diagrams.




With your partner, answer these questions.

1 Which diagram shows the particles in a gas?

2 Choose the correct phrases to complete these sentences:

In a gas, the particles are **far apart / touching each other**.

In a gas, the particles **move freely / vibrate on the spot**.

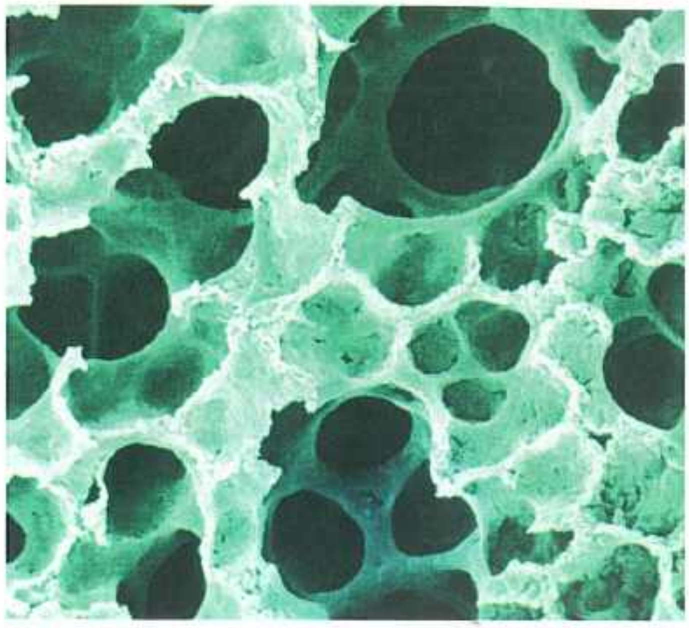
## Key words

alveoli
analogy
capillaries
diffusion
expired air
gas exchange
haemoglobin
inspired air
limewater

## Air sacs

The photograph shows a tiny part of the lungs, seen through a powerful microscope. You can see the lungs are mostly holes. These holes are called air sacs. Another name for them is **alveoli**.

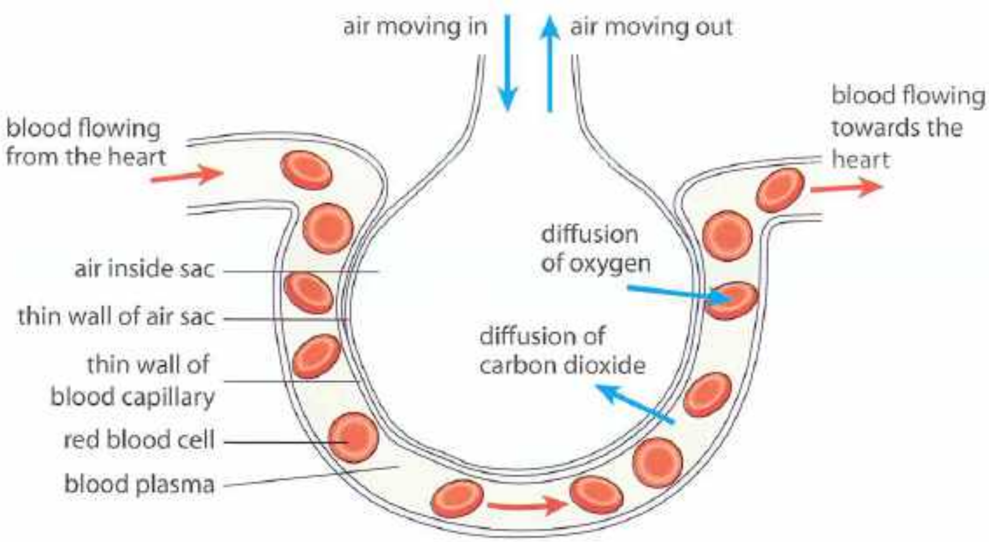
There are also lots of very tiny blood vessels in the lungs, wrapped around the air sacs. You cannot see them in the photograph, but they are shown in the diagram below. These blood vessels are **capillaries**.



Part of the lungs, viewed through a powerful microscope

## The structure of an air sac

This diagram shows one of the air sacs in the lungs. The air sac has a wall made of one layer of cells. These cells are very thin.




An air sac in the lungs

You can see that there is a blood capillary around the outside of the alveolus. The capillary is pressed tightly against the alveolus. The wall of the capillary is also made of a single layer of very thin cells.

## Gas exchange in the air sacs

Inside the air sacs, oxygen from the air goes into the blood. Carbon dioxide from the blood goes into the air. This is called **gas exchange**.

Think about the blood capillary on the left of the diagram. The blood inside this capillary comes from the heart. Before reaching the heart, it came from the organs in the body. These organs contain cells that respire, using up oxygen and making carbon dioxide. So the blood in this capillary contains only a small amount of oxygen, and a lot of carbon dioxide.

Now think about the air inside the air sac. It came from outside the body, where the air contains a lot of oxygen and only a small amount of carbon dioxide.

Inside the alveolus, this air is very close to the blood. There are only two very thin cells between the air and the blood.

The oxygen particles in the air are a gas, so they are moving freely. They can easily move from the air, through the thin-walled cells and into the blood. This is called **diffusion**. You can find out more about diffusion in Topic 3.7. The oxygen particules move from where there are a lot of them (in the air) to where there are fewer of them (in the blood).

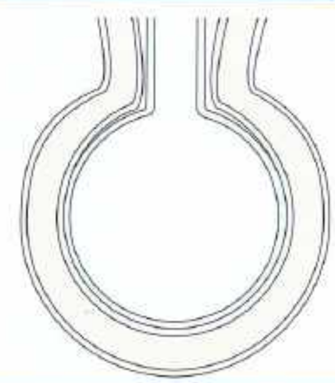
When the oxygen gets into the blood, it dissolves. (You can find out about dissolving in Topic 2.1.) The oxygen goes into the red blood cells where it combines with **haemoglobin**. You will find out what happens to it after that in Topic 1.6.

Now think about the carbon dioxide. There is a lot of it in the blood in the capillary, and only a small quantity in the air inside the air sac. So the carbon dioxide diffuses into the air in the air sac.

### Activity 1.2.1

#### Gases in and out

Copy this diagram.



1 On your diagram, draw a **green** arrow to show how oxygen diffuses from the air into the blood.

2 How many cells does the oxygen move through, as it leaves the air and goes into the blood?

3 On your diagram, draw a **blue** arrow to show how carbon dioxide diffuses from the blood into the air.

## Think like a scientist

### Why are air sacs so small?

In this activity, you will use some agar jelly to represent the lungs, and some coloured liquid to represent oxygen in the air.

**You will need:**

- two Petri dishes filled with agar jelly
- two cork-borers, one with a diameter of 10 mm and the other with a diameter of 5 mm
- some coloured dye
- a dropper pipette

### Method

1 Use the larger cork-borer to make eight holes in the jelly in one of the dishes. Space the holes evenly in the dish.

2 Now use the smaller cork-borer to make 32 holes in the jelly in the other dish. Try to space the holes evenly in the dish.

3 Using the dropper pipette, carefully fill each hole in both dishes with the coloured dye. Try to put the same quantity of dye into each hole. It's really important not to get any dye on the jelly!

4 Leave both dishes for at least 15 minutes.

5 Predict what you think will happen.

6 After 15 minutes (or a little bit longer if things are happening slowly) record your observations.

### Questions

1 The holes that you made in the jelly represent the air sacs in the lungs. The coloured dye represents oxygen in the air sacs. The holes in the jelly are an **analogy** for the air sacs, and the dye is an analogy for oxygen.

Explain how your observations help to show what happens to oxygen in the lungs.

2 The total volume of the 32 small holes is the same as the total volume of the eight large holes. Use your observations to suggest why it is better to have a lot of very small air sacs in the lungs, rather than just a few large ones.

3 Do you think that the agar jelly with holes is a good model for what happens in the lungs? Explain your answer.

## Think like a scientist

### Comparing the carbon dioxide content of inspired air and expired air

In this activity, you will use **limewater** to compare how much carbon dioxide there is in the air that you breathe in, with how much carbon dioxide there is in the air that you breathe out.

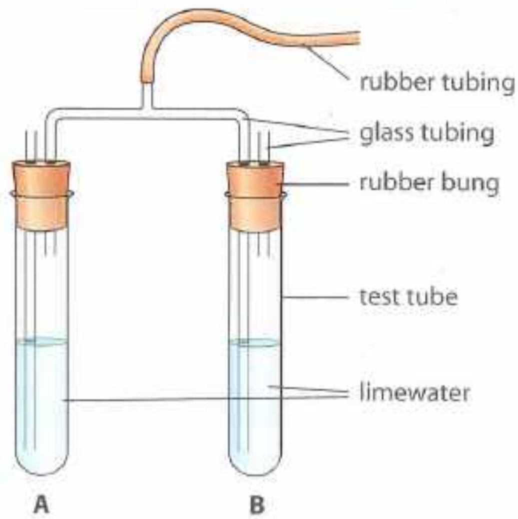
Work with a partner to do this activity.

**You will need:**

- rubber tubing
- glass tubing, as shown in the diagram
- two rubber bungs to fit the test tubes
- two test tubes
- limewater

**Safety**

It is very important that the rubber tubing is perfectly clean before you use it. Do not share the mouthpiece with anyone else or put it on the work surface when you have finished.




**Method**

1 Read through the method and make an assessment of all the risks. Decide how you will overcome or reduce these risks.

2 Look carefully at the apparatus.
Starting with the rubber tubing, follow the glass tube as it branches into the two test tubes.
What is different about the glass tubing that goes into test tube **A** and test tube **B**?

3 Now think about what might happen if you gently blow down the rubber tube.
Predict the tube in which you think bubbles will appear. Why do you think that?

4 Gently blow into the rubber tubing, until bubbles appear in one of the tubes. Was your prediction correct?

5 Now think about what might happen if you gently suck the rubber tube. Try it. Was your prediction correct?

6 Put your mouth over the end of the rubber tubing, and gently breathe in and out. Bubbles will appear in one tube as you breathe out, and in the other tube as you breathe in. Your partner will check the bubbles and can tell you if you are doing it correctly.
**Be careful** – don't suck too hard! Limewater is not poisonous, but it is not a good idea to get it into your mouth.

7 Continue until the limewater in one of the tubes has gone cloudy. Make a note of which tube it is.

Continued

### Questions

1 The air that you breathe out is called **expired air**.
In which tube did your expired air bubble through the limewater?

2 The air that you breathe in is called **inspired air**.
In which tube did your inspired air bubble through the limewater?

3 In which tube did the limewater go cloudy first?

4 Name the gas that makes limewater go cloudy.

5 Copy and complete these sentences. Use some of these words:

**A B expired inspired less more**

The limewater went cloudy first in tube .....................

This is the limewater that ..................... air bubbles through.

Our results show that expired air contains ..................... carbon dioxide than inspired air.

### Self-assessment

Think about how you did the experiment.

Copy each bulleted statement, and then draw a face next to each one according to how well you think you performed.

☺ I think I did this really well.

😐 I did OK, but I could probably do better.

☹ I didn't do this very well at all.

- I worked out which tube the air would go into when I breathed in and when I breathed out.
- I managed to breathe in and out with just the right force to make the air bubble through the limewater.
- I stopped as soon as the limewater in one of the tubes went cloudy.
- I understand what this experiment shows about how much carbon dioxide there is in inspired air and expired air.

Is there anything that you would do differently if you did this experiment again?

## Summary checklist

- [ ] I can describe how oxygen gets into my blood from the air, and carbon dioxide goes the other way.
- [ ] I can explain why it is better to have lots of very small air sacs in the lungs, rather than a few big ones.
- [ ] I can describe how to do an experiment to compare how much carbon dioxide there is in inspired air and expired air.

# 1.3 Breathing

## In this topic you will:

- measure how much air you can push out of your lungs in one breath
- learn how the muscles between your ribs and your diaphragm move air into and out of the lungs.

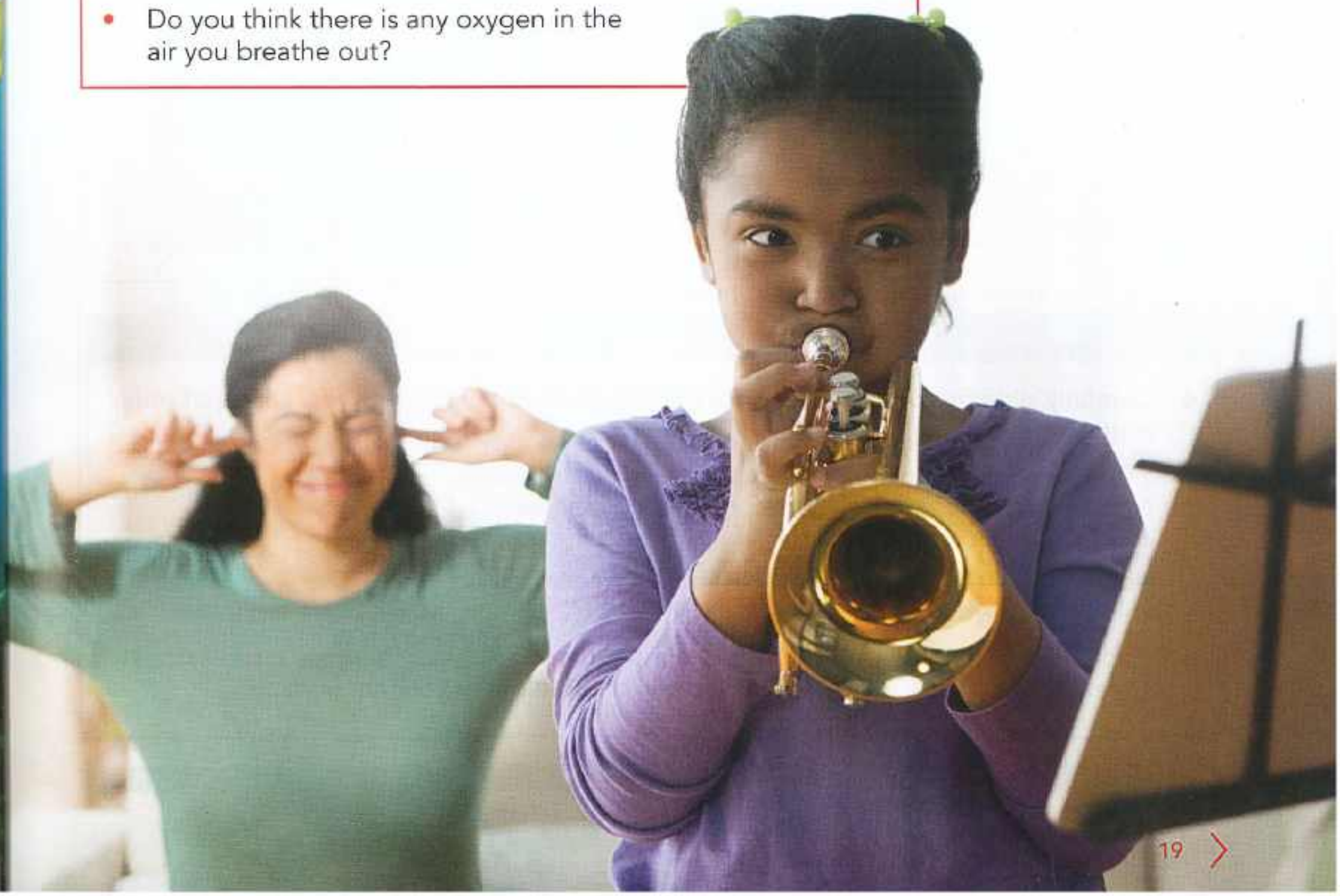
## Getting started

On your own, answer each of these questions.

- What is gas exchange?
- Where does gas exchange happen in your body?
- Does the air you breathe in contain more or less oxygen than the air you breathe out?
- Is there any carbon dioxide in the air you breathe in?
- Do you think there is any oxygen in the air you breathe out?

## Key words

breathing
contract
relax



# How much air can you breathe out?

## Think like a scientist

### Measuring the volume of air you can push out of your lungs

How much air do you think you can push out of your lungs in one breath? In this experiment, you will use some very simple apparatus to find out.

**You will need:**

- big plastic bottle with a lid
- measuring cylinder
- bendy tubing
- marker pen
- water
- big bowl

**Safety**

The bottle and bendy tubing must be clean, and the water you use must be safe to drink. Do not share the mouthpiece with anyone else or put it on the work surface when you have finished.

You may get water on the floor as you do your experiment. Take care not to slip in it.

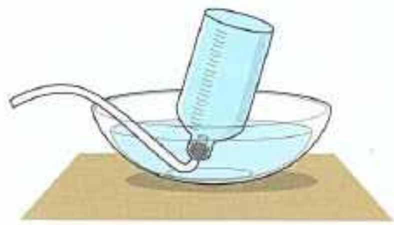
### Method

1 You are going to use the plastic bottle to measure volumes.

In your group of three, discuss how you can use the measuring cylinder to mark a scale on the plastic bottle.

Then mark the scale on the bottle. The scale should go all the way from the bottom to the top of the bottle.

2 Fill the bottle right to the top with water. Put the lid on.



3 Pour water into the big bowl until it is about half full. Turn the bottle upside down, and hold it in the bowl. Very carefully take the lid off the bottle. You should find that all the water stays in the bottle.

4 Carefully slide the bendy tubing into the top of the bottle, under water.

5 Take a deep breath in, then put your mouth over the tubing and breathe out as much air as you can through the tubing. Your expired air will push out some water from the bottle.

Use the scale that you drew on the bottle to record the volume of air you breathed out.

6 If you have time, repeat steps 2 – 5 two more times. Use your three results to calculate a mean value for the volume of air you can breathe out of your lungs.

Continued

7 Replace the tubing with another piece of clean tubing. Now another person in your group can try the experiment.

8 Record all of your results in a table.

### Questions

1 Share your results with the rest of the class. Can you see any patterns in the results? For example:

- Do you think that the volume of air a person can breathe out is related to their size?
- If there is anyone in your class who plays a wind instrument, does this seem to have an effect on how much air they can breathe out?

2 Plan an experiment to investigate this hypothesis:

> People who play the trombone can breathe out more air in one breath than people who play the violin.

## Activity 1.3.1

### What happens when you breathe in?

Sit quietly for a moment. Shut your eyes and think about your **breathing**.

Put a hand just underneath your ribs. Take a deep breath in. You may be able to feel your ribs moving upwards. You might also be able to feel something moving inwards as you breathe.

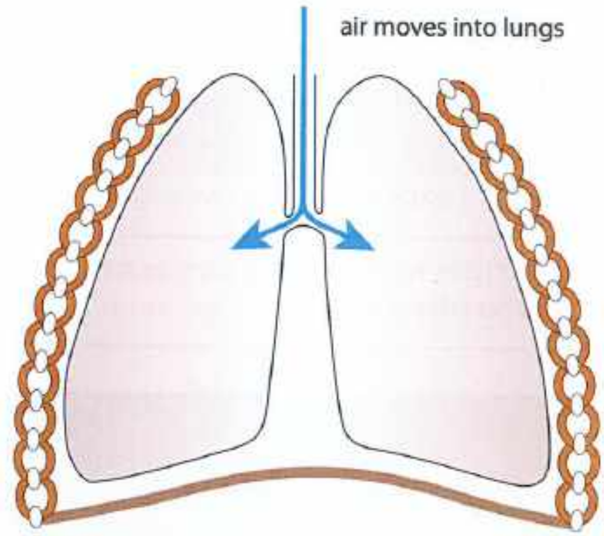
# Breathing

Look at the diagrams of the human respiratory system, in Topic 1.1. Find the ribs, and the intercostal muscles between them. Find the diaphragm.

Remember that air is a gas. The pressure of a gas increases when the volume of its container is decreased. You can find more about pressure in Topic 3.6.

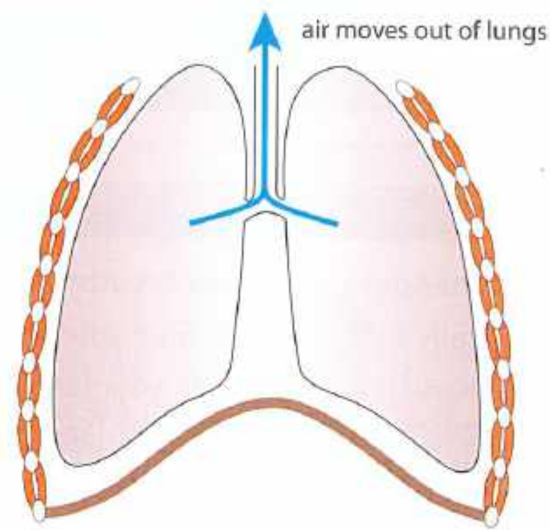
**When you breathe in, these things happen:**

- The intercostal muscles between the ribs **contract** (get shorter). This pulls the ribs upwards and outwards.
- The muscles in the diaphragm contract. This pulls the diaphragm downwards.
- These two movements make more space inside the chest cavity. They increase the volume inside it.
- When the volume increases, the pressure inside the chest cavity and lungs decreases.
- Air moves down through the trachea into the lungs, to fill the extra space.




**When you breathe out, these things happen:**

- The intercostal muscles between the ribs **relax** (return to normal size). This allow the ribs to drop down into their natural position.
- The muscles in the diaphragm relax. This allows the diaphragm to become its normal, domed shape.
- These two movements make less space inside the chest cavity. They decrease the volume inside it.
- When the volume decreases, the pressure increases. So air is squeezed out of the lungs.



## Think like a scientist

### Using a model to represent breathing movements

You will need:

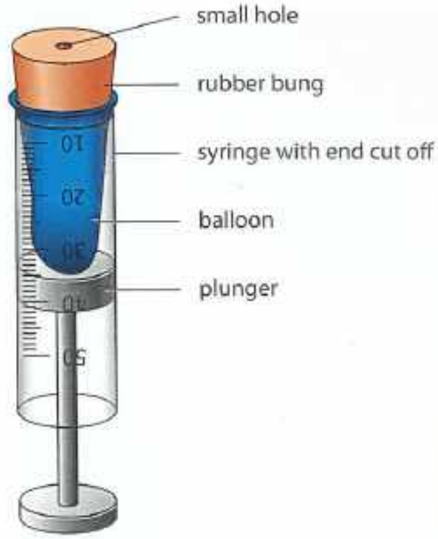
• rubber bung with a hole in it • syringe with end cut off • balloon

#### Method

1 Set up the apparatus as shown in the diagram. Your teacher may do this for you.

2 Carefully and steadily, pull the plunger of the syringe out. Note what happens.

3 Now push the plunger back in again. Note what happens.




#### Questions

1 Which parts of the model represent these structures in the body?

- the lungs
- the trachea
- the diaphragm
- the rib cage

2 Explain why the balloon inflates when you pull the plunger out.

3 Explain how pulling the plunger out represents what happens in your body when you breathe in.

4 Describe **one** way in which this model does not completely represent what happens when you breathe in.

## Questions

1 Copy and complete this table.

Use these words:

**contract** **relax**

| Action | What do the diaphragm muscles do? | What do the intercostal muscles do? |
|---|---|---|
| Breathing in | | |
| Breathing out | | |

**2** Copy and complete these sentences.

Use these words:

**decrease** **increase** **into** **out of**

When we breathe in, the muscles in the diaphragm and between the ribs ..................... the volume of the chest.

This makes air move ..................... the lungs.

When we breathe out, the muscles in the diaphragm and between the ribs ..................... the volume of the chest.

This makes air move ..................... the lungs.

## Summary checklist

- [ ] I can use a measuring cylinder to make a volume scale on a bottle.
- [ ] I can do an experiment to measure the volume of air I can breathe out in one breath.
- [ ] I can describe how the diaphragm and intercostal muscles cause breathing movements.
- [ ] I can explain how these breathing movements make air move into and out of the lungs.

# > 1.4 Respiration

## In this topic you will:

- find out how every living cell gets the energy it needs to stay alive
- do an experiment to investigate how, in respiration, some energy is released as heat
- think about the difference between breathing and respiration.

## Getting started

Think back to Stage 7, when you learned about energy.

With a partner, think about this question:

What has to happen to energy, in order to make something happen?

Can you give some examples?

Be ready to share your ideas.

## Key words

glucose

mitochondria

# Using energy to stay alive

Our bodies need energy for many different reasons. For example:

We use energy when we move around.

We use energy to send electrical impulses along neurones.

We use energy to keep our bodies warm when it is cold.

All of our energy comes from the food that we eat. Carbohydrates are especially good for giving us energy.

When we eat food containing carbohydrates, our digestive system breaks the carbohydrates down to a kind of sugar called **glucose**. The glucose goes into our blood. The blood delivers glucose to every cell in the body. The cells use the glucose to get the energy that they need.

## Releasing energy from glucose

Energy must be changed from one type to another, or be transferred, in order to do something.

The energy in glucose is locked up inside it. Glucose is an energy store. Before your cells can use the energy, it has to be released from the glucose.

This is done by tiny structures called **mitochondria** that are found inside cells. Most cells have many mitochondria inside them. Mitochondria release energy from glucose, so that the cells can use the energy.

The mitochondria carry out a chemical reaction called aerobic respiration. Aerobic means that is uses oxygen, from the air. Here is the word equation for aerobic respiration:

$$\text{glucose} + \text{oxygen} \rightarrow \text{carbon dioxide} + \text{water}$$

In this reaction, some of the energy inside the glucose is released. This is done in a very controlled way. Just a little bit of energy is released at a time – just enough for the cell's needs.


Energy is released from glucose inside mitochondria

### Questions

1 Neurones contain more mitochondria than cheek cells. Suggest why.

2 Look at the word equation for aerobic respiration.

  a What are the reactants in this reaction?

  b What are the products of this reaction?

3 Use the equation for aerobic respiration to explain why the air that you breathe out contains more carbon dioxide than the air that you breathe in.

## Respiration and heat production

In Stage 7, you learned that every time energy is transferred or transformed, some of it is changed to heat energy.

In respiration, chemical energy stored in glucose is transferred to other substances, so that cells can use it. In this process, some of the energy is changed to heat energy. So respiring cells get a little bit warmer than their surroundings.

### Think like a scientist

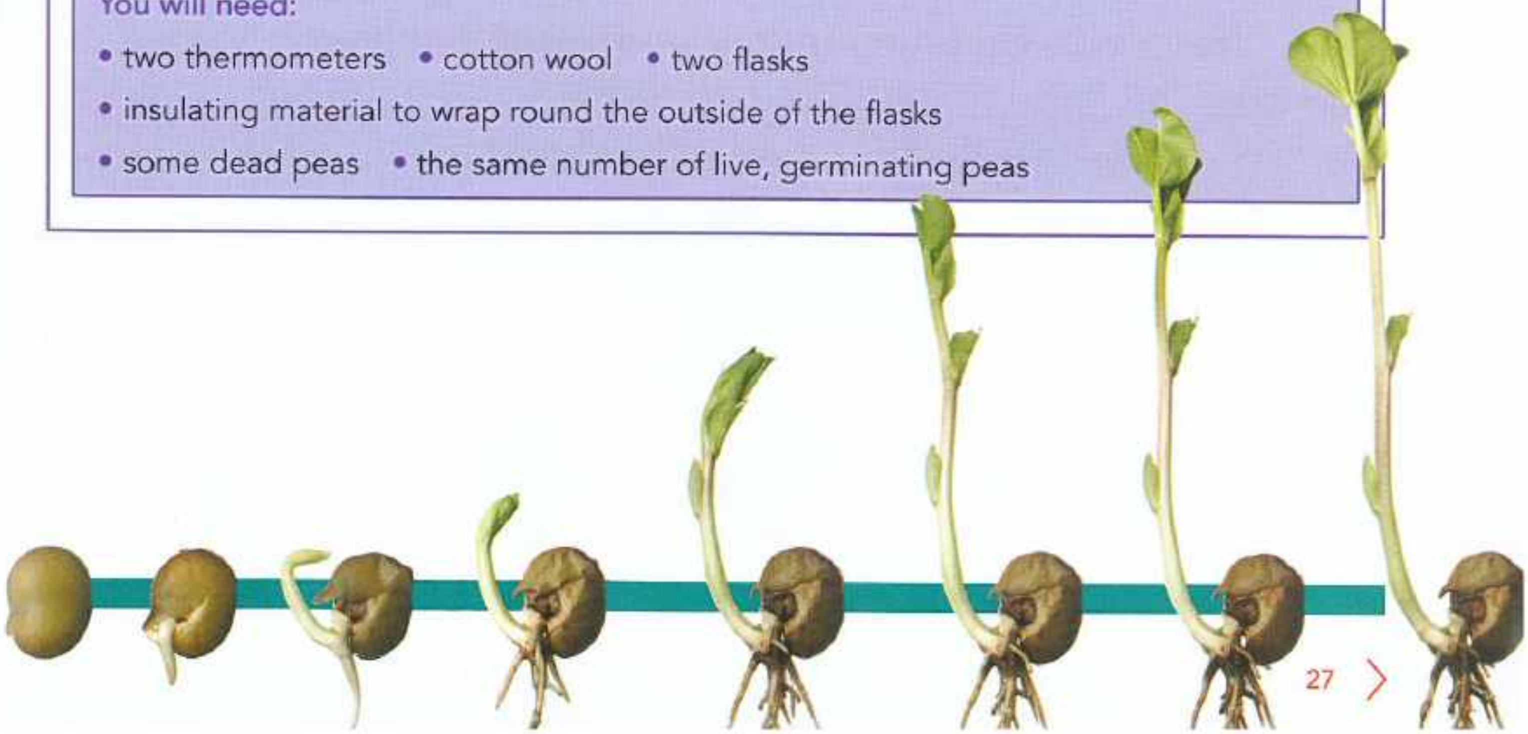
**Investigating respiration in peas**

All living things need energy. So all living things respire. Even seeds respire.

Seeds respire especially quickly when they are germinating, because they need a lot of energy to do this. You can make pea seeds start to germinate by soaking them in water for about an hour.

**You will need:**

- two thermometers
- cotton wool
- two flasks
- insulating material to wrap round the outside of the flasks
- some dead peas
- the same number of live, germinating peas



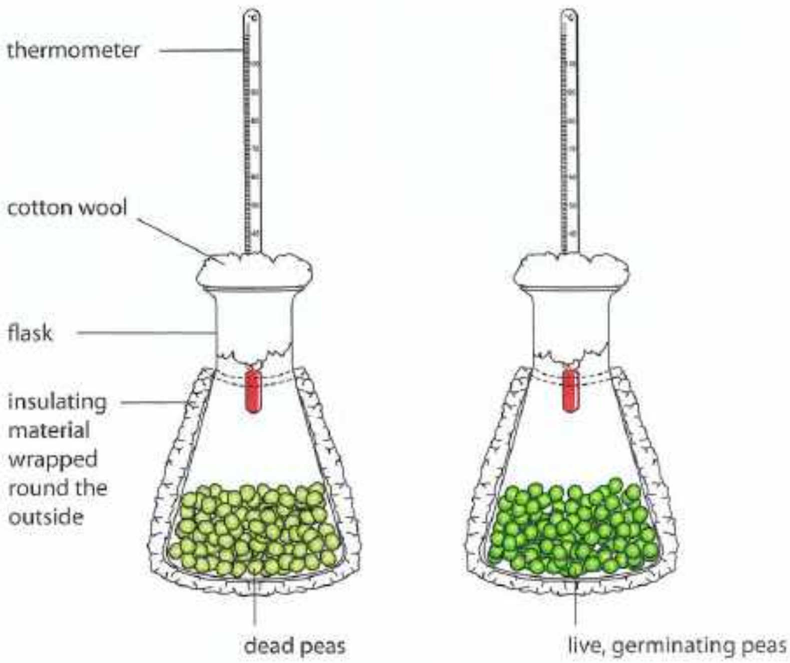
Continued

## Method

1 Set up your apparatus as shown in the diagram. Take care to make everything exactly the same in each piece of apparatus. The only difference is that one flask contains dead peas, and the other flask contains live, germinating peas.

2 Measure the temperature inside each flask. Record it in a results chart.

3 Continue to measure and record the temperature at regular intervals. For example, you could do this every hour during the school day.




4 Display your results as a line graph.

- Put time in hours on the horizontal axis.
- Put temperature in °C on the vertical axis.
- Plot the points for the live peas as neat crosses. **X**
- Plot the points for the dead peas as dots with a circle around them. ⊙
- Join the points for each set of peas with ruled, straight lines between the points.

## Questions

1 What was the variable that you changed in this experiment?

2 Which variables did you keep the same?

3 Which variable did you measure?

4 Suggest an explanation for your results.

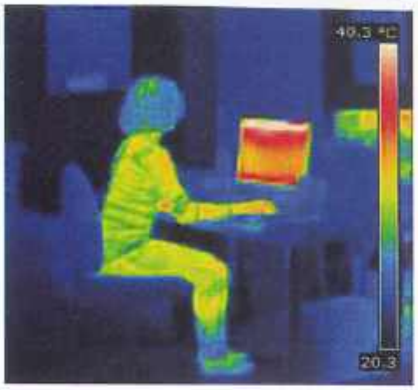
5 If you did the experiment again, would you expect your results to be exactly the same? Explain your answer.

6 Suggest any improvements you would make to your experiment, if you were able to do it again. Explain why each of your suggestions would improve your experiment.

## Activity 1.4.1

### Thinking about a thermogram

This photograph is a thermogram of a woman working at her computer.




The colours on the photograph show the temperatures of the different objects.

In a group of three, think about the photograph, and discuss these questions. Be ready to share your ideas.

1 Which object in the photograph has the highest temperature? Can you suggest why?
2 What is the approximate temperature of most of the woman's body?
3 Explain why the woman's body has a higher temperature than the chair she is sitting on.

## Activity 1.4.2

### Explaining the difference between breathing and respiration

Many people who have not studied science think that respiration and breathing mean the same thing.

In your group of three, think about the meanings of these two words. (Look at Topic 1.3 to remind yourself about breathing.) Think of a good way of explaining the differences between respiration and breathing, to someone else.

Choose one of these methods to give your explanation:

- making a poster
- producing a slide presentation
- giving an illustrated talk.

Decide how to share the tasks between you, and then work on your explanation.

### Self-assessment

How well did you do each of these things as you worked on this activity?

- I made sure that I really understood the difference between breathing and respiration.
- I helped to decide which method we would use to give our explanation.
- I carried out my part of the task really well.
- I helped others in my group to carry out their tasks.
- I discussed what I was doing with the others in my group.
- I think that our explanation helped other people to understand the difference between breathing and respiration.

In the activity, you had to work out for yourself how to explain the difference between breathing and respiration.

Do you think this helped you to understand the difference yourself? Or would it have been better just to be told the difference by your teacher?

Why do you think that?

## Summary checklist

- [ ] I can explain that respiration is a chemical reaction that releases useful energy from glucose, in a controlled way.
- [ ] I can write the word equation for respiration.
- [ ] I can state that respiration happens inside every living cell.
- [ ] I can state that aerobic respiration uses oxygen, and happens inside mitochondria.
- [ ] I can explain the difference between breathing and respiration.

# 1.5 Blood

## In this topic you will:

- learn about the structure of blood
- find out about the functions of red blood cells, white blood cells and blood plasma.

## Getting started

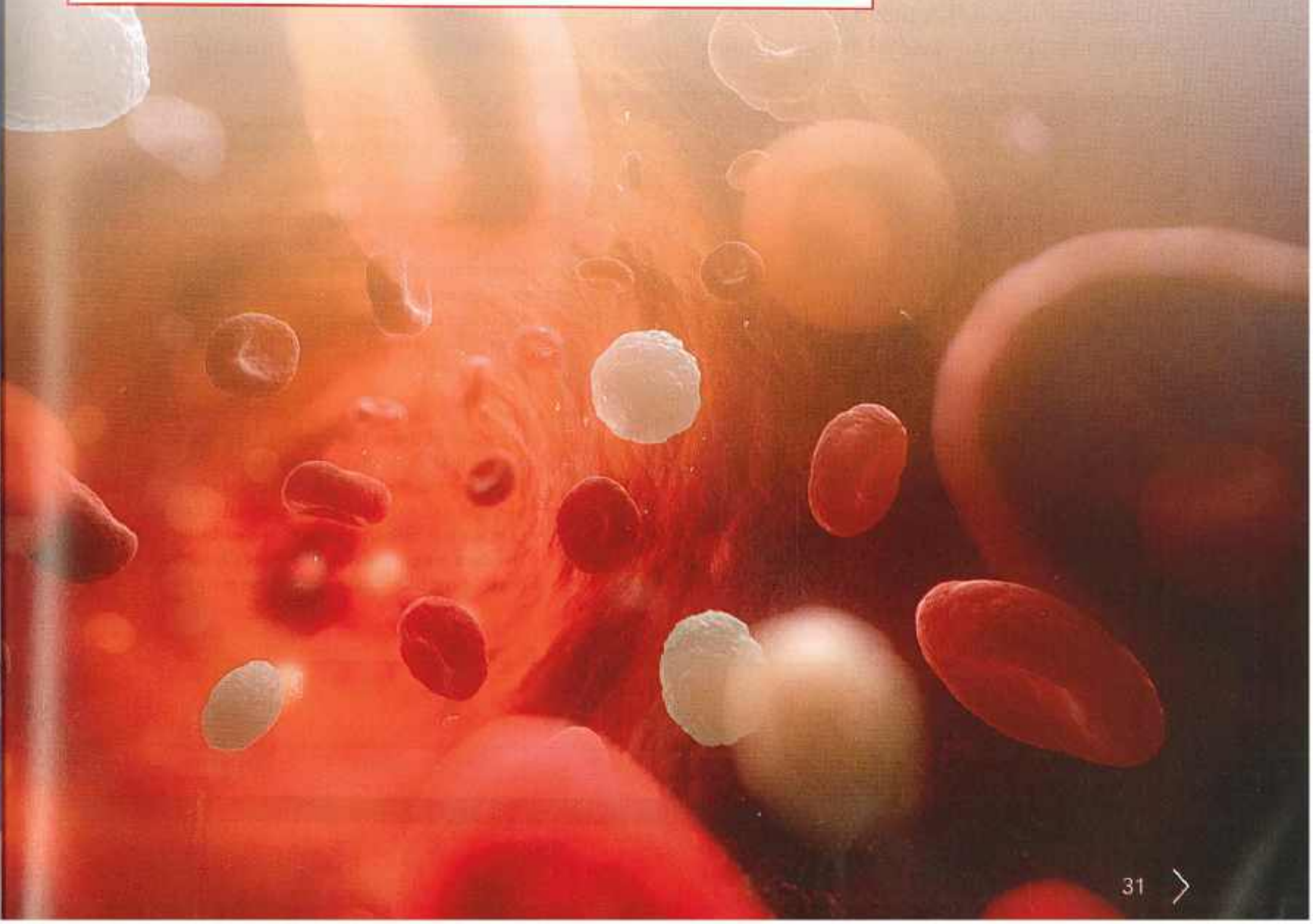
With a partner, think about these questions.

- What do red blood cells look like?
- What is the function of a red blood cell?
- How do the features of red blood cells help them to perform this function?

Be ready to share your ideas.

## Key words

antibodies
blood plasma
oxyhaemoglobin
pathogens
red blood cells
white blood cells



# Delivering the requirements for respiration in cells

You have seen that all of your cells need energy to stay alive. Each cell gets its energy through a chemical reaction called respiration.

Aerobic respiration happens inside the mitochondria in the cells. The reactants are glucose and oxygen:

$$\text{glucose} + \text{oxygen} \rightarrow \text{carbon dioxide} + \text{water}$$

So every cell in your body needs a good supply of glucose and oxygen, and the carbon dioxide and water that the cell makes must be taken away. The delivery and removal is done by the blood.

The blood moves around the body inside blood vessels. The heart pumps constantly, to keep the blood moving.

# What is blood?

Everyone knows that blood is a red liquid. But if you are able to look at some blood through a microscope, you may get a surprise. The photograph shows what you might see.

This is the liquid part of the blood. This liquid is called **blood plasma**. You can see that it is not red at all. It is a very, very pale yellow.

Blood looks red because it contains a lot of **red blood cells**, which float in this liquid. Most of the cells in our blood are red blood cells. An adult person has at least 20 trillion red blood cells in their body. There are about five million of them in every 1 $cm^3$ of your blood.

These are called **white blood cells**. There are not many of them, but some of them may be quite a lot bigger than the red blood cells. They don't look white in the photograph because a stain has been added to the blood, to make the cells show up more clearly. The dark purple areas in these cells are their nuclei. (Red blood cells don't have nuclei.)

Blood viewed through a microscope

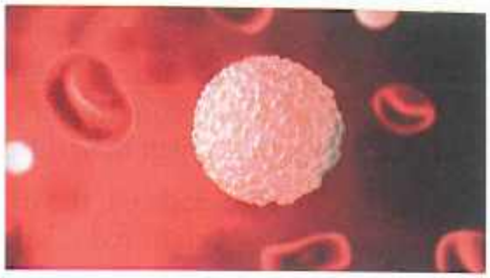
### Questions

1 Look at the photograph on the previous page of blood viewed through a microscope.

Approximately how many times more red blood cells are there than white blood cells?

2 The photograph on the right was taken with a powerful electron microscope.

What differences can you see between the red blood cell and the white blood cell?



A red blood cell and a white blood cell

## Plasma

Plasma is the liquid part of blood. It is mostly water. The red and white blood cells are transported around the body in the blood plasma. Plasma also has many other different substances dissolved in it. For example, glucose, dissolved in blood plasma, is transported from the digestive system to every cell.

You will remember that carbon dioxide is produced in every body cell, by respiration. The carbon dioxide dissolves in blood plasma and is carried away from the cells. The blood takes it to the lungs, where the carbon dioxide diffuses out and is breathed out in your expired air.

## Red blood cells

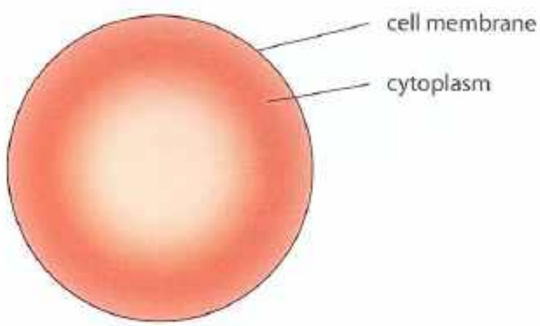
Stage 7, Topic 1.3 described how the structure of red blood cells is related to their function. Now you are going to think about this in a little bit more detail.

Red blood cells are very unusual cells. They do not have a nucleus and they do not have mitochondria. They are full of a red pigment called haemoglobin. It is haemoglobin that makes blood look red. The structure of a red blood cell is related to its function.

There is no nucleus, to make more room for haemoglobin.

The cytoplasm contains a red pigment called haemoglobin, which carries oxygen.

There are no mitochondria in the cytoplasm.

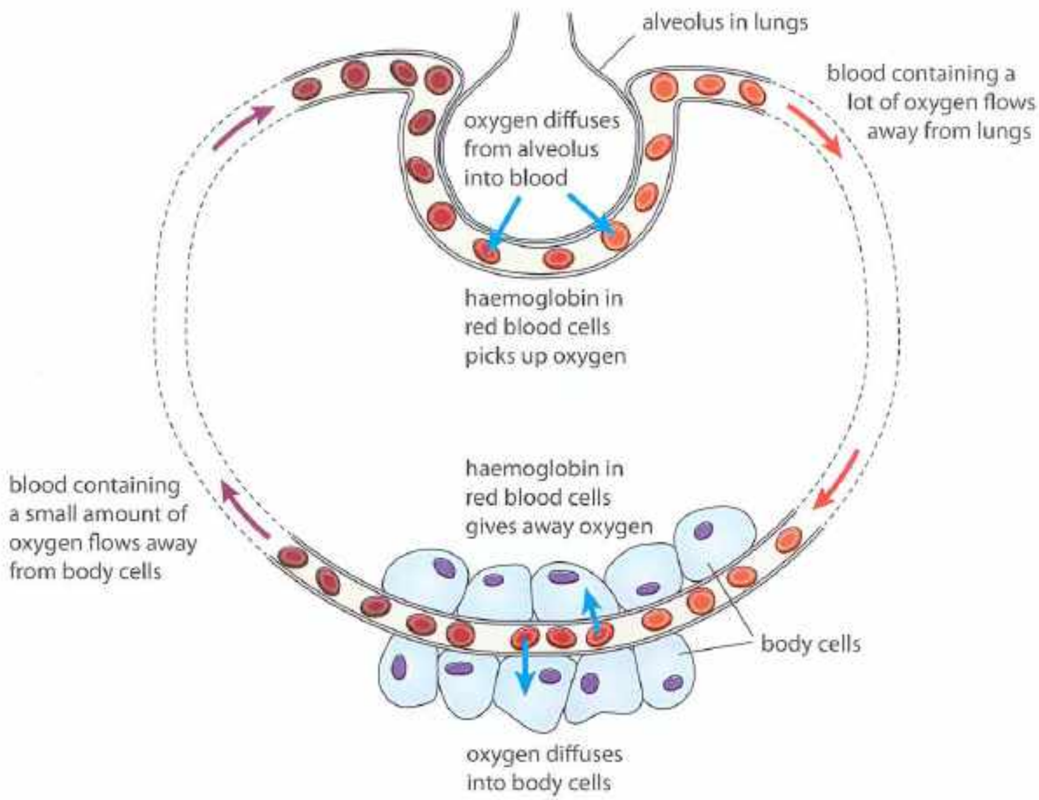



A red blood cell

The haemoglobin helps the red blood cells to transport oxygen.

- As the blood flows through the tiny capillaries next to the alveoli in the lungs, oxygen from the air diffuses into the blood. Once it is in the blood, the oxygen then diffuses into the red blood cells.
- Inside the red blood cell, the oxygen combines with haemoglobin. It forms a very bright red compound called **oxyhaemoglobin**.
- As the blood continues on its journey around the body, it passes cells that are respiring. The oxyhaemoglobin lets go of its oxygen and gives it to the cells.
- The blood, which has given away most of its oxygen, now travels back to the lungs to collect some more.

This explains why red blood cells have haemoglobin – but why don't they have a nucleus or mitochondria? Scientists think that not having a nucleus makes more space for haemoglobin. They also think that not having mitochondria stops the red blood cells from using up all the oxygen for themselves, instead of delivering it elsewhere.




How oxygen is transported around the body

Another way in which red blood cells are adapted for their function is that they are quite a lot smaller than most cells in the body.

Being so small helps them to get through very tiny blood capillaries. This means they can get really close to the alveoli in the lungs, and to the respiring cells in other parts of the body.

### Question

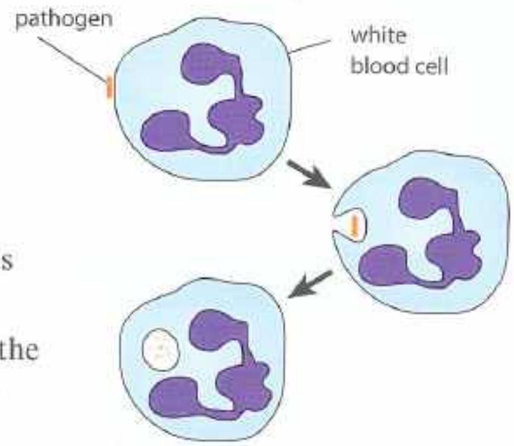
3 Explain why red blood cells might use up oxygen, if they have mitochondria.

## White blood cells

White blood cells are easy to distinguish from red blood cells. They always have a nucleus, which red blood cells do not have. Some kinds of white blood cell – but not all – are larger than red blood cells.

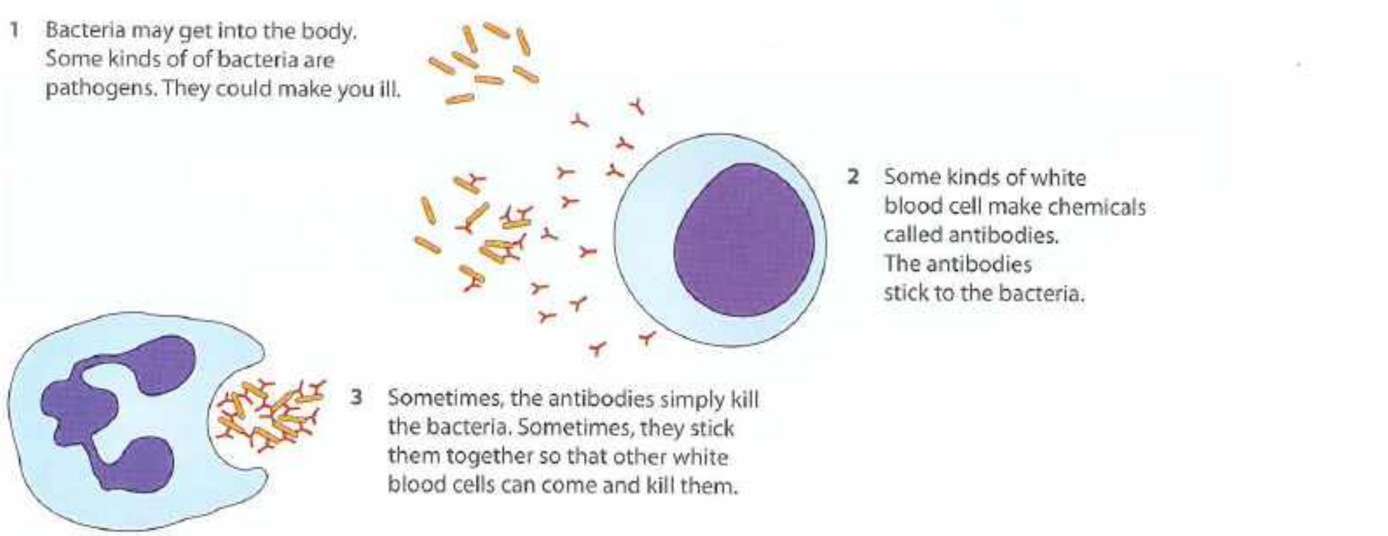
Some bacteria and viruses can cause illness when they get into the body. These bacteria and viruses are called **pathogens**. White blood cells help to defend us against pathogens.

Some kinds of white blood cell can change their shape, and push their cytoplasm out to make 'fingers' that can capture a pathogen. The white blood cell then produces chemicals that kill and digest the pathogen.




Other types of white blood cell produce chemicals that kill pathogens. These chemicals are called **antibodies**. They are shown as little Y-shapes on the diagram below. Different kinds of antibodies are needed for each different kind of pathogen.

The antibodies stick onto the pathogen. Sometimes, they kill the pathogen directly. Sometimes, they glue lots of the pathogens together so that they cannot move. This makes it easy for other white blood cells to capture and kill the pathogens.



## Activity 1.5.1

### Making a picture of blood

You are going to make a picture of some blood, as it might look if you saw it through a microscope. Work as a pair, or in a small group.

**You will need:**

- sheet of plain paper
- some red card
- some white card
- scissors
- glue

### Method

4 Use the red card to make some red blood cells. Think about how many you need to make.

5 Use the white card to make some white blood cells. Use a pen or pencil to draw a nucleus in each one. Think about how many you need to make.

6 Stick the red blood cells and white blood cells onto the white paper. The white paper can represent the blood plasma.

7 Write labels to stick onto the paper. Remember to label the blood plasma.

## Questions

4 Copy and complete this table.

| Component of blood | Appearance | Function |
|---|---|---|
| red blood cell | | |
| white blood cell | | |
| plasma | | |

5 Name **three** things that are transported in blood plasma.

## Summary checklist

- [ ] I can describe what blood plasma is, and its function.
- [ ] I can explain how red blood cells, containing haemoglobin, transport oxygen.
- [ ] I can explain how white blood cells help to protect us against pathogens.

## Project: Helping white blood cells to protect us from pathogens

This project is about how scientific knowledge develops over time, and how scientific discoveries can help people all over the world.

### Background

Our white blood cells are amazing at keeping us safe from pathogens. Most of the time, they manage to destroy the pathogens so that we recover quickly from an infection.

But there are some pathogens that white blood cells cannot destroy in time. The virus that causes rabies is one of these. If the rabies virus gets into a person's body, the body needs outside help in order to stop the virus spreading. Without treatment, most people die if they are infected with the rabies virus.

### Your task

You are going to work in a group to find out information about rabies, and how it can be successfully treated. Each group will work on a different topic.

Choose **one or two** of the following five topics to research with your group. Also choose how you will present your findings to others. You could make a poster, or give an illustrated talk.

*Discovering what causes rabies*

Who first discovered the cause of rabies, and when did they do this?

*First vaccine for rabies*

Who created the first vaccine for rabies, and how did they do this?

*How rabies is transmitted*

How can a person be infected with rabies?

*Preventing rabies*

In which countries is rabies most common? What can people in these countries do to reduce the risk of getting rabies?

*Treatment for rabies*

What should someone do if they have been bitten by an animal with rabies? How do rabies vaccines help our white blood cells to fight the virus?

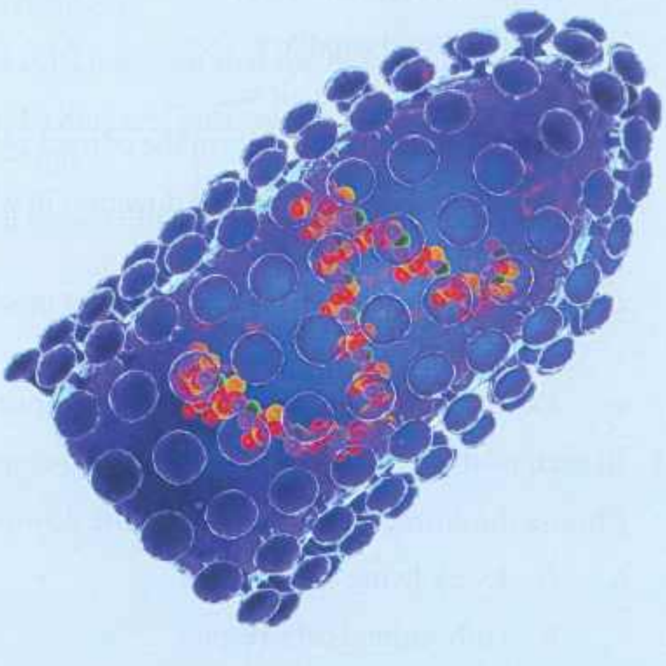


Illustration of a rabies virus

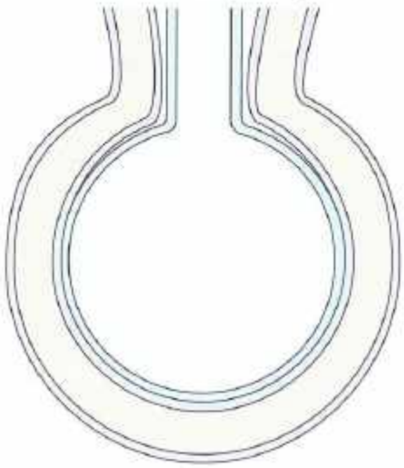
# Check your progress

**1.1** The list includes some of the structures that air passes through, as it moves from outside the body to the place where gas exchange happens.

Write the structures in the correct order.

**bronchiole** **trachea** **bronchus** **alveolus (air sac)** [2]

**1.2** The diagram shows an air sac and a blood capillary.



**a** Copy the diagram. Label:

- the blood capillary
- the wall of the air sac. [2]

**b** Draw **two** red blood cells in the correct place on your diagram. [1]

**c** Draw an arrow to show the direction in which oxygen diffuses. Label your arrow O. [1]

**d** Draw an arrow to show the direction in which carbon dioxide diffuses. Label your arrow C. [1]

**e** Describe how the red blood cells transport oxygen to all the cells in the body. [2]

**1.3** In each of these groups of statements, only one is correct.

Choose the correct statement, and write down its letter.

**a** **A** Every living cell respires.

**B** Only animal cells respire.

**C** Respiration uses up energy. [1]

**b** **A** Expired (breathed out) air contains only carbon dioxide.

**B** Expired air contains more carbon dioxide than inspired (breathed in) air.

**C** Expired air contains more oxygen than inspired air. [1]

**c** **A** Respiration means using your diaphragm to move air into the lungs.

**B** Respiration is the diffusion of gases between the air sacs and the blood.

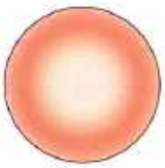
**C** Respiration is a series of chemical reactions that releases useful energy from glucose. [1]

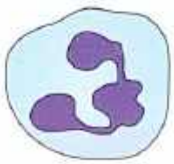
**d** **A** Muscles in the lungs contract to make air move into them.

**B** The diaphragm muscles contract to move air into the lungs.

**C** Muscles between the ribs pull them downwards when we breathe in. [1]

**1.4** The diagrams show two blood cells.





**a** Copy the drawing of the red blood cell.
Label the cell membrane and cytoplasm. [1]

**b** Name **two** structures that most cells have, but that red blood cells do not have. [2]

**c** The white blood cell shown in the diagram kills pathogens by producing chemicals. Describe how it does this. [2]

**d** Other kinds of white blood cell have a different way of killing pathogens. Explain how they do this. [3]

# 2 Properties of materials

## 2.1 Dissolving

**In this topic you will:**

- correctly use the scientific terms associated with dissolving
- investigate the properties of solutions
- practise measuring mass and volume

**Getting started**

With a partner:

- explain the differences between an element, a compound and a mixture
- draw a diagram of the way particles are arranged in a liquid
- share your answers with the class.

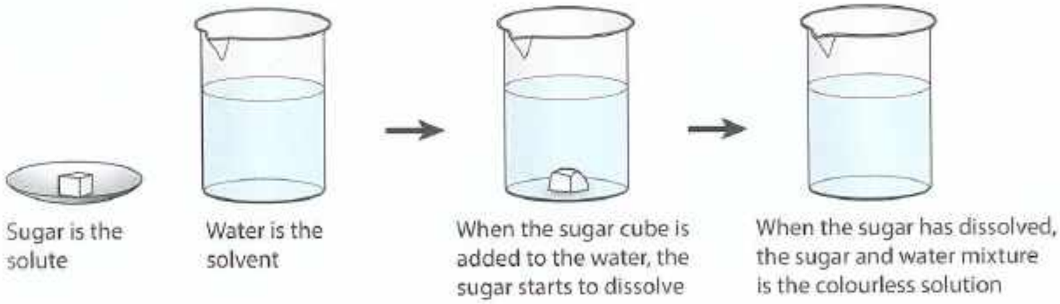
**Key words**

conserved
dissolving
opaque
solute
solution
solvent
transparent

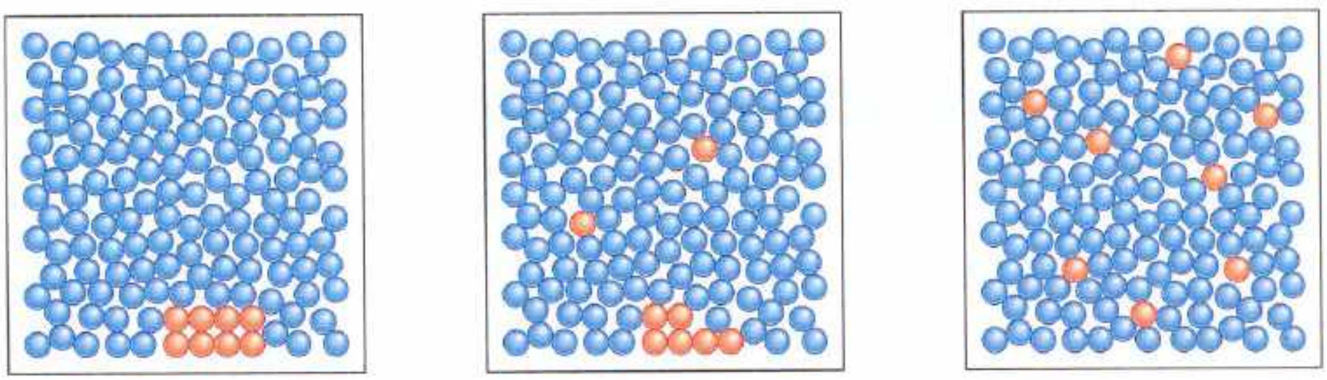
# What is a solution?

When you place a lump of sugar in water, the sugar seems gradually to disappear. The sugar is **dissolving**. You are left with a colourless **solution**. The substance that dissolves is called the **solute**. The substance that it dissolves into is called the **solvent**.

A solution is a mixture. So, in our example, the colourless solution is a mixture of sugar and water. Although the sugar *seems* to disappear, it is still there. The sugar particles have simply spread out among the water particles.




The diagrams below show what happens to the sugar particles when the cube dissolves.



The sugar crystal is visible because it is made of lots of groups of vibrating particles that are tightly packed together.

As the water particles vibrate and slide past one another, they bump into the vibrating sugar particles. The movement helps to separate the sugar particles and they get mixed up with the water particles.

Eventually, the water particles separate all the sugar particles. The sugar particles are no longer in groups and are too small to be seen.

All solutions are **transparent**. This means you can see through them. Transparent *doesn't* mean colourless. For example, if you dissolve a coloured salt, such as copper sulfate, the solution formed is blue. But you can still see through it. It is still transparent.

A liquid such as milk is not transparent. You cannot see through it. It is **opaque**. Because of this, you can tell that milk is not a solution.

Copper sulfate forms a solution; it is transparent

Milk is not a solution; you can tell this because it is opaque

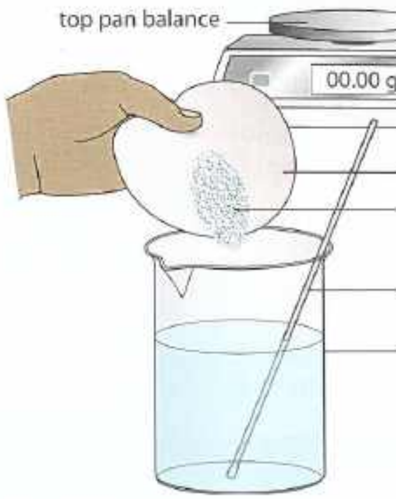
It is easy to confuse melting with dissolving. Remember: dissolving needs two substances, a solute and a solvent.

| Examples of dissolving | Examples of melting |
|---|---|
| Sugar (solute) in black tea (solvent) | Butter in a frying pan |
| Instant coffee (solute) in hot water (solvent) | Ice cream on a warm day |
| Nail polish (solute) in nail polish remover (solvent) | Candle wax as the candle burns |

## Think like a scientist

### Dissolving and mass

You will need:
- top pan balance
- filter paper
- salt
- stirring rod
- beaker of water




#### Method

1. Place the filter paper on the top pan balance. Measure and record its mass.
2. Add about 20–25 g of salt. This is the solute. Measure and record the mass of the salt.
3. Remove the paper and salt from the balance.
4. Place a beaker containing at least 100 $cm^3$ of water on the top pan balance. Measure and record the mass of the water and the beaker together. The water is the solvent.
5. Add the salt to the water. Stir until all the salt has dissolved. Measure the mass of the beaker and salt solution.

#### Questions

1. What was the mass of salt used?
2. What was the mass of the water and the beaker?
3. What was the mass of the solution and the beaker?
4. What does this tell you about the salt solution?

When salt is added to water and it dissolves, it has not disappeared. The salt particles are still in the water. The mass of the solution equals the total mass of the solute and solvent. This is true for any solution.

mass of solute + mass of solvent = mass of solution

No mass has been lost. The mass has been **conserved**.

## Questions

1 In a solution of sugar and water, which is the solvent and which is the solute?

2 What is the difference between dissolving and melting?

3 What mass of salt solution is made when 9 g of salt is dissolved in 50 g of water? Explain how you worked out your answer.

4 A green powder was placed into a beaker of water. After it was stirred, the water looked cloudy and lumps of powder could still be seen. Has a solution been formed? Explain your answer.

5 When measuring the volume of a liquid, what should you do in order to make your measurement as accurate as possible?

## Summary checklist

- [ ] I can use the words solvent, solute and solution appropriately.
- [ ] I can use particle theory to explain some of the properties of solutions.
- [ ] I can measure mass and volume of liquids accurately.

# > 2.2 Solutions and solubility

## In this topic you will:

- make solutions of different concentrations
- compare the number of solute particles in solutions of different concentrations
- investigate solubility
- compare the solubility of various solutes

## Getting started

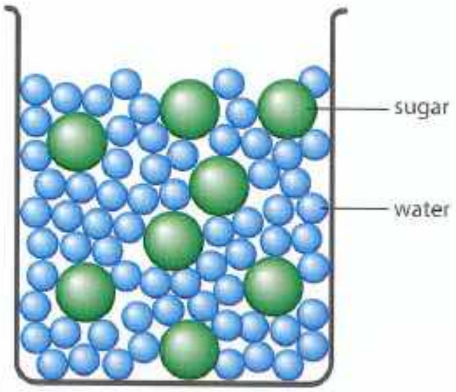
You have one minute to think about the meanings of the words solvent, solute and solution. You have one minute to discuss them with a partner. Now write your meanings on different pieces of paper. Share them with the class.

## Key words

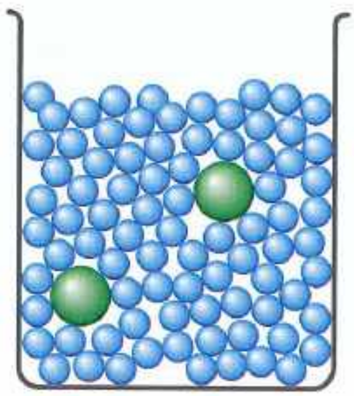
concentrated
dilute
insoluble
saturated
solubility
soluble

# Solutions

A solution is made when a solute is dissolved in a solvent.
More particles of the solute are dissolved in a **concentrated** solution than in a **dilute** solution.




A concentrated solution of sugar has a lot of sugar particles



A dilute solution of sugar has fewer sugar particles

## Think like a scientist

### Making different concentrations of a solution

**You will need:**

- safety glasses
- test tubes
- test tube rack
- pipette
- two measuring cylinders, suitable for measuring 10 $cm^3$
- concentrated solution of food dye
- beaker of water

**Method**

1. Carefully measure out 10 $cm^3$ of the concentrated food dye solution. When you have added about the correct volume you can use the pipette to add or remove the final amount drop-by-drop, so that your measurement is as accurate as possible. Place it in a test tube and leave it in the test tube rack. This is solution A.
2. Carefully measure another 8 $cm^3$ of the concentrated food dye solution. Pour it into a test tube.
3. Measure out 2 $cm^3$ water and add it to the 8 $cm^3$ of food dye. Leave it in the test tube rack. This is solution B.

Continued

4 Use the table below to make up food dye solutions C, D and E. Place the solutions in the test tube rack, in order, from A–E.

| Solution | Volume of concentrated food dye solution in $cm^3$ | Volume of water in $cm^3$ | Total volume in $cm^3$ |
|---|---|---|---|
| A | 10 | 0 | 10 |
| B | 8 | 2 | 10 |
| C | 6 | 4 | 10 |
| D | 4 | 6 | 10 |
| E | 2 | 8 | 10 |

5 Look carefully at the solutions you have made.

### Questions

1 What do you notice about the solutions?

2 How can you tell which is the least concentrated?

3 If you repeated this task using a salt or sugar solution, would you be able to identify the most and least concentrated solutions? Explain your answer.

4 Why is it important to measure the food dye solution and the water accurately?

5 If you only had a measuring cylinder that measured up to $100\,cm^3$, would using these same volumes of copper sulfate and water be accurate?

6 Compare the number of particles of food dye in the most concentrated solution of food dye and the most dilute solution.

## Solubility

A solid that dissolves in a solvent such as water is said to be **soluble**. Sodium chloride (common salt) and sugar are soluble.

A solid that will not dissolve in water is **insoluble**. Iron filings are insoluble in water.

If you keep adding a soluble solid to a beaker of water, there comes a point where no more of the solid will dissolve. You have made a **saturated** solution.

Some soluble substances are more soluble than others. If you have $100\,cm^3$ of water, you would be able to dissolve a lot of sodium chloride in it, but only a tiny amount of lead chloride. Sodium chloride has greater **solubility** than lead chloride.

## Think like a scientist

### Solubility in water

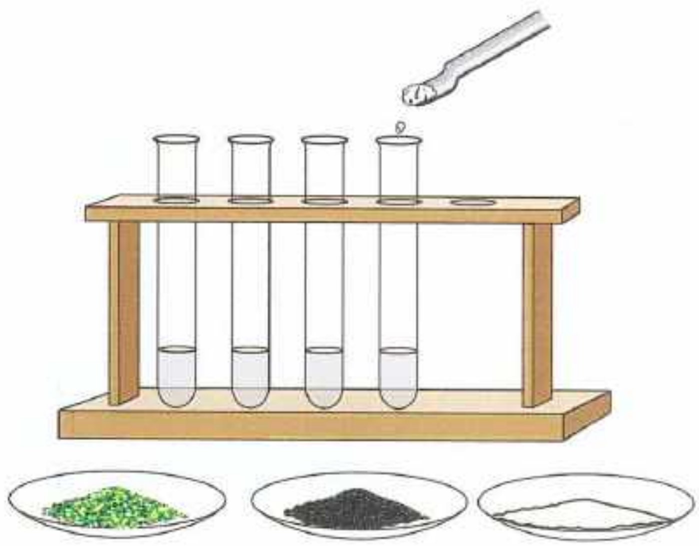
You will need:

- test tubes • test tube rack • safety glasses • measuring cylinder • spatula
- a range of solutes such as sodium chloride, potassium sulfate and sugar

In this task you will use various solutes and investigate their solubility in water. You will use water at room temperature.

#### Method

1. Place a measured volume of water in a number of test tubes. Use a different test tube for each of the solutes.
2. Add the first solute to the water. Count how many spatulas of the solute you can add until no more will dissolve. After you add each spatula of the solute, shake or stir the contents of the test tube carefully.
3. Repeat for the other solutes.
4. Record your results in a table.



#### Questions

1. Which was the most soluble of the solutes you used?
2. Which was the least soluble of the solutes you used?
3. In this investigation you used the number of spatulas as a measure of the quantity of solute added. Suggest another way of measuring the quantity of solute used, to improve the accuracy of the results.

How can you ensure your results are as accurate as possible?

## Comparing solubility

To compare the solubility of different solutes you must measure how much of each solute will dissolve in a known amount of the solvent.

The table shows the solubility of different salts. It shows how much of each salt can be dissolved when it is added to 100 g of water at 20 °C.

| Solute | Solubility in grams of solute per 100 g of the solvent at 20 °C |
|---|---|
| sodium chloride | 36 |
| copper sulfate | 32 |
| calcium chloride | 74 |
| potassium chlorate | 7 |
| lead chloride | 1 |

### Questions

1 What is a saturated solution?

2 How much copper sulfate will dissolve in 100 g water at 20 °C?

3 How much potassium chlorate will dissolve in 200 g water at 20 °C?

4 How much sodium chloride will dissolve in 50 g water at 20 °C?

5 Use the data in the table to draw a bar chart to show the solubility of the various solutes in 100 g water at 20 °C.

## Temperature and solubility

Most solutes will dissolve more quickly and easily in hot water than in cold water. Think about what happens to the particles when they have more energy. The more energy the particles have, the more they vibrate and move.

You can dissolve a greater mass of a solute in hot water than in the same volume of cold water. In other words, as the temperature increases, the solubility of most solutes also increases.

For example, if you have 100 g of water at 20 °C you can dissolve 204 g of sugar in it. If you heat the water to 80 °C, you can dissolve 362 g of sugar in it.

## Worked example

### Question

204 g of sugar dissolves in 100 g of water at 20 °C.

a How much sugar will dissolve in 200 g of water at 20 °C?

b How much sugar will dissolve in 50 g of water at 20 °C?

### Answer

a 200 g of water is twice as much as 100 g, so twice as much sugar will dissolve: $204 \times 2 = 408$ g

b In 100 g water, 204 g sugar dissolves

In 1 g water, $204 \div 100$ g sugar dissolves = 2.04 g

In 50 g water, $2.04 \times 50$ g sugar dissolves = 102 g

### Questions

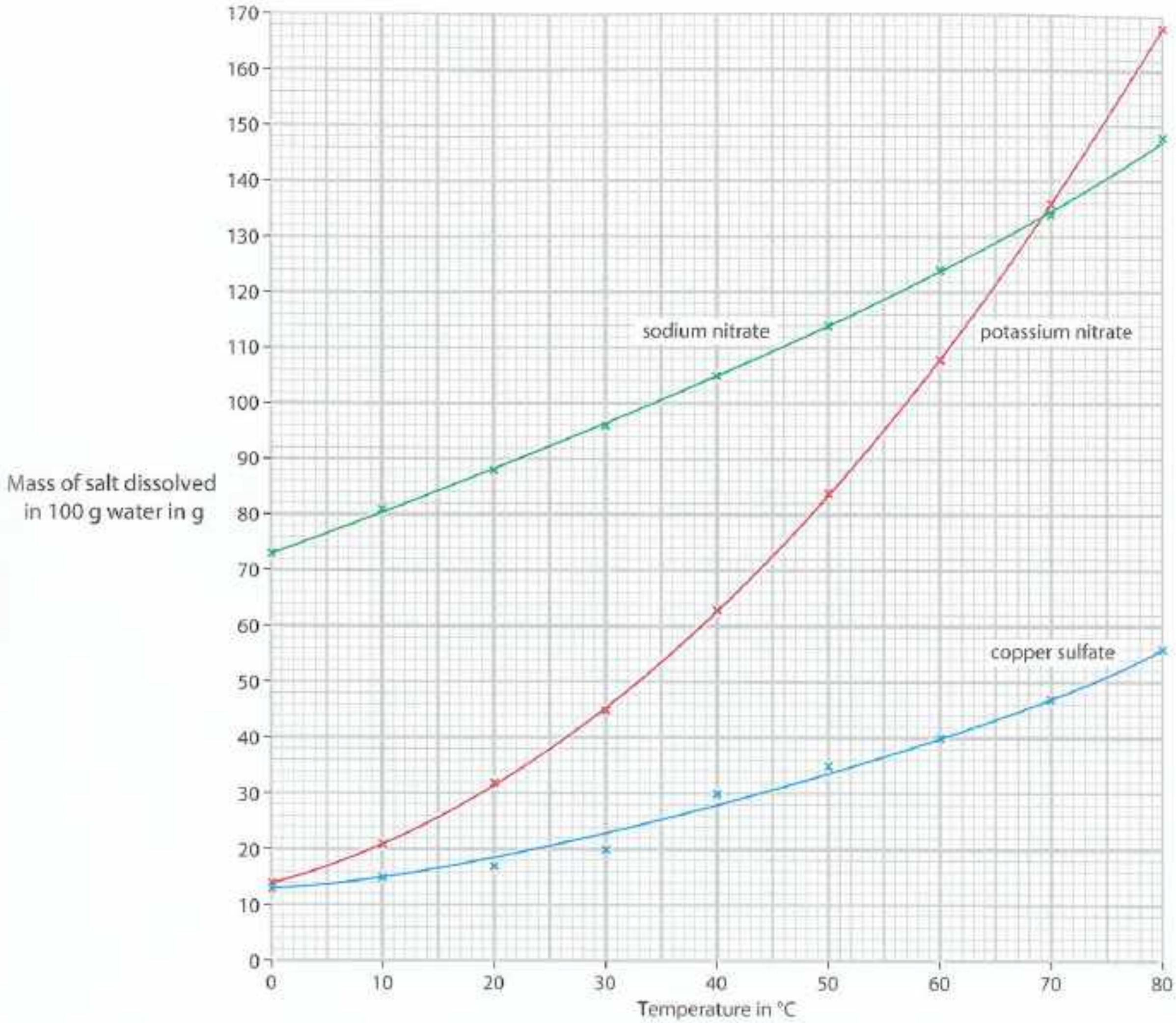
6 How much sugar can be dissolved in 250 g of water at 20 °C?

7 How much more sugar can be dissolved if the 250 g of water is at 80 °C?

## Comparing the solubility of different salts

This table and the graph on the next page show the solubility of three salts at a range of temperatures. Look carefully at the graph and answer the questions.

| Temperature in °C | Potassium nitrate in grams per 100 g of water | Sodium nitrate in grams per 100 g of water | Copper sulfate in grams per 100 g of water |
|---|---|---|---|
| 0 | 14 | 73 | 13 |
| 10 | 21 | 81 | 15 |
| 20 | 32 | 88 | 17 |
| 30 | 45 | 96 | 20 |
| 40 | 63 | 105 | 30 |
| 50 | 84 | 114 | 35 |
| 60 | 108 | 124 | 40 |
| 70 | 136 | 134 | 47 |
| 80 | 168 | 148 | 56 |




Graph showing the solubility of three salts at a range of temperatures

## Questions

**8** What is the general trend for the solubility of all three salts?

**9** What is the solubility of potassium nitrate at 45 °C?

**10** Which of these three salts is most soluble at 10 °C?

**11** Which salt is the most soluble at 80 °C?

## Other solvents

Water is not the only solvent. Some substances that are insoluble in water will dissolve in other solvents.

For example, some types of oil paint are not soluble in water. So, if you need to clean your brushes after you've used oil paint, you will need to use a solvent that the paint will dissolve in, such as methanol (methylated spirits).

Nail polish does not dissolve in water but dissolves in nail polish remover. Most nail polish remover contains the solvent propanone (acetone).

These paint brushes are being cleaned in jars of methylated spirit

The nail polish remover on the cotton pad contains propanone (acetone)

### Summary checklist

- [ ] I can describe how to make solutions of different concentrations.
- [ ] I can compare the number of solute particles in solutions of different concentrations.
- [ ] I can carry out an investigation safely.
- [ ] I can compare the solubility of various solutes.

# > 2.3 Planning a solubility investigation

**In this topic you will:**

- plan an investigation, considering all the variables
- carry out an investigation.

**Getting started**

Discuss with a partner the difference between accurate results and reliable results. Share your ideas with the class.

**Key words**

control variables

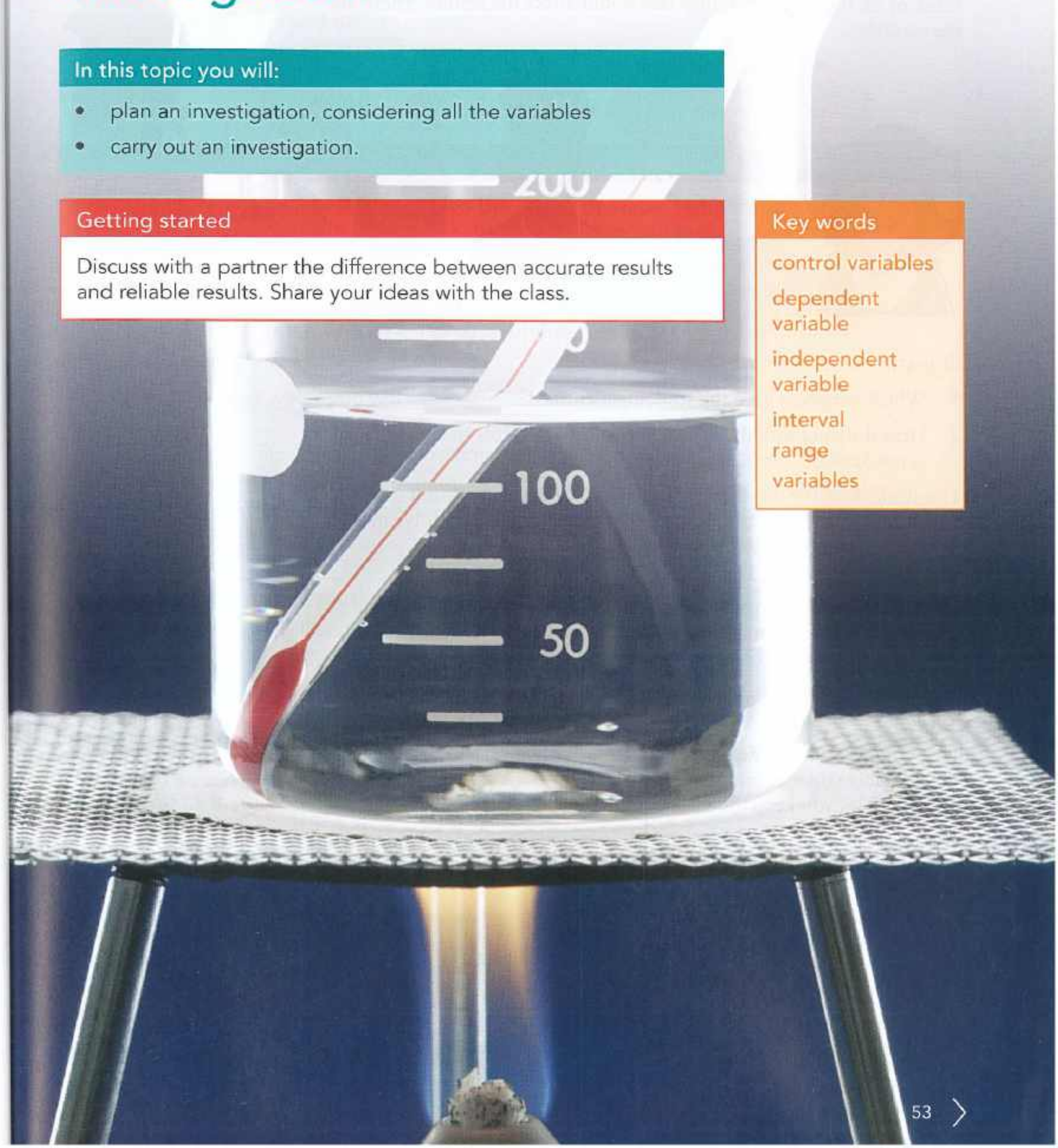
dependent variable

independent variable

interval

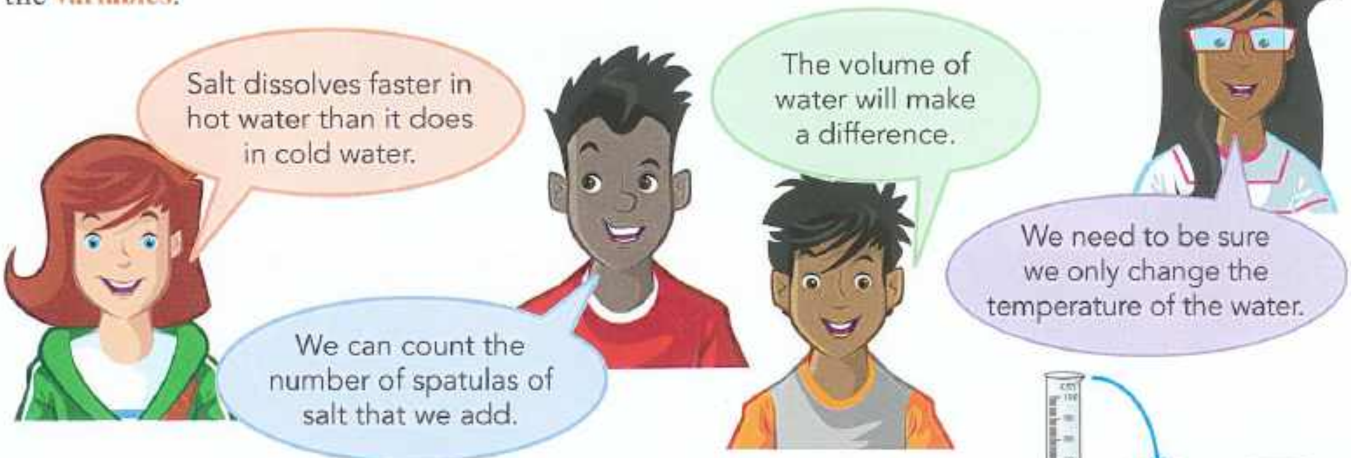
range

variables



# Dissolving salt in water

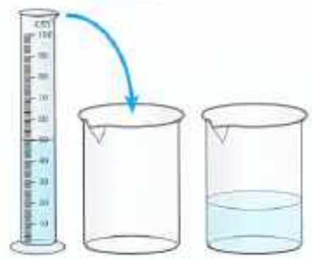
These students are discussing how they will investigate how temperature affects the amount of salt that will dissolve in water. They are trying to think of all the different things that could affect the results. These are the **variables**.

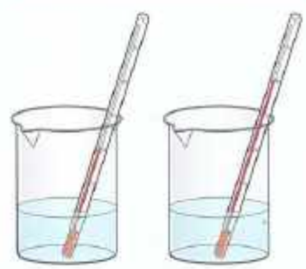



## Questions

1 Which variables have the students identified?

2 How do you think the volume of water will affect the results if it is not kept the same? Explain your answer.


The volume of water is kept the same


The temperature is changed

The number of spatulas used is measured

The students carry out the experiment. They decide to count the number of spatulas of salt (sodium chloride) that will dissolve in 50 $cm^3$ of water. They will repeat the experiment at different temperatures from 20 °C to 80 °C.

The variable they change is the temperature of the water. They will count the number of spatulas of salt that will dissolve. This is the variable that depends on the temperature of the water.

The volume of water is the variable that the students keep the same, to ensure that the test is fair.

The variable you change is called the **independent variable**.
The variable you measure is called the **dependent variable**.
The variables you keep the same are the **control variables**.

When you plot a graph of your results, the independent variable always goes along the horizontal axis. The dependent variable always goes up the vertical axis.

## Questions

3 Which variable is the independent variable in the students' investigation?

4 Which variable is a control variable in the students' investigation?
Is there any other variable that needs to be controlled?
(Hint: Think about the spatula.)

5 Which is the dependent variable in this investigation?

6 What would the label be on the vertical axis of a graph of the results of this investigation?

### Think like a scientist

**Plan and carry out an investigation into the effect of water temperature on the amount of sodium chloride (common salt) that will dissolve in it**

*Part 1: Planning the investigation*

In a group of two or three, discuss the plan for your investigation.

You need to consider the variables, risk assessments, equipment and method.

Discuss these questions.

- What volume of water you will use?
- How you will change the temperature of the water **and** how you will keep it at that temperature while you add the sodium chloride?
- What **range** of temperatures you will use? (The highest and lowest temperatures you will use.) Remember to be practical about this.
- What **interval** between temperatures will you use? (Will you use gaps of 10 °C between temperatures, or 5 °C?)
- What will you do to ensure you are safe while carrying out your investigation?
- What equipment will you need?
- What method will you use?

You need to prepare a table to use for your results. Think about how many columns you will need. What headings will you use? What units will you use? How many readings will you take? Will you repeat your tests?

Once you have discussed your plan with your teacher, you may need to change a few things.

Make sure you have a full plan written, including a step-by-step method, before you carry out the investigation.

Have you considered everything you need for your investigation?
How can you improve your planning?

## Think like a scientist

**Plan and carry out an investigation into the effect of water temperature on the amount of sodium chloride (common salt) that will dissolve in it**

*Part 2: Carrying out the investigation*

Collect the equipment that you chose in your plan.

Make sure you have your step-by-step method to follow.

Carry out your investigation.

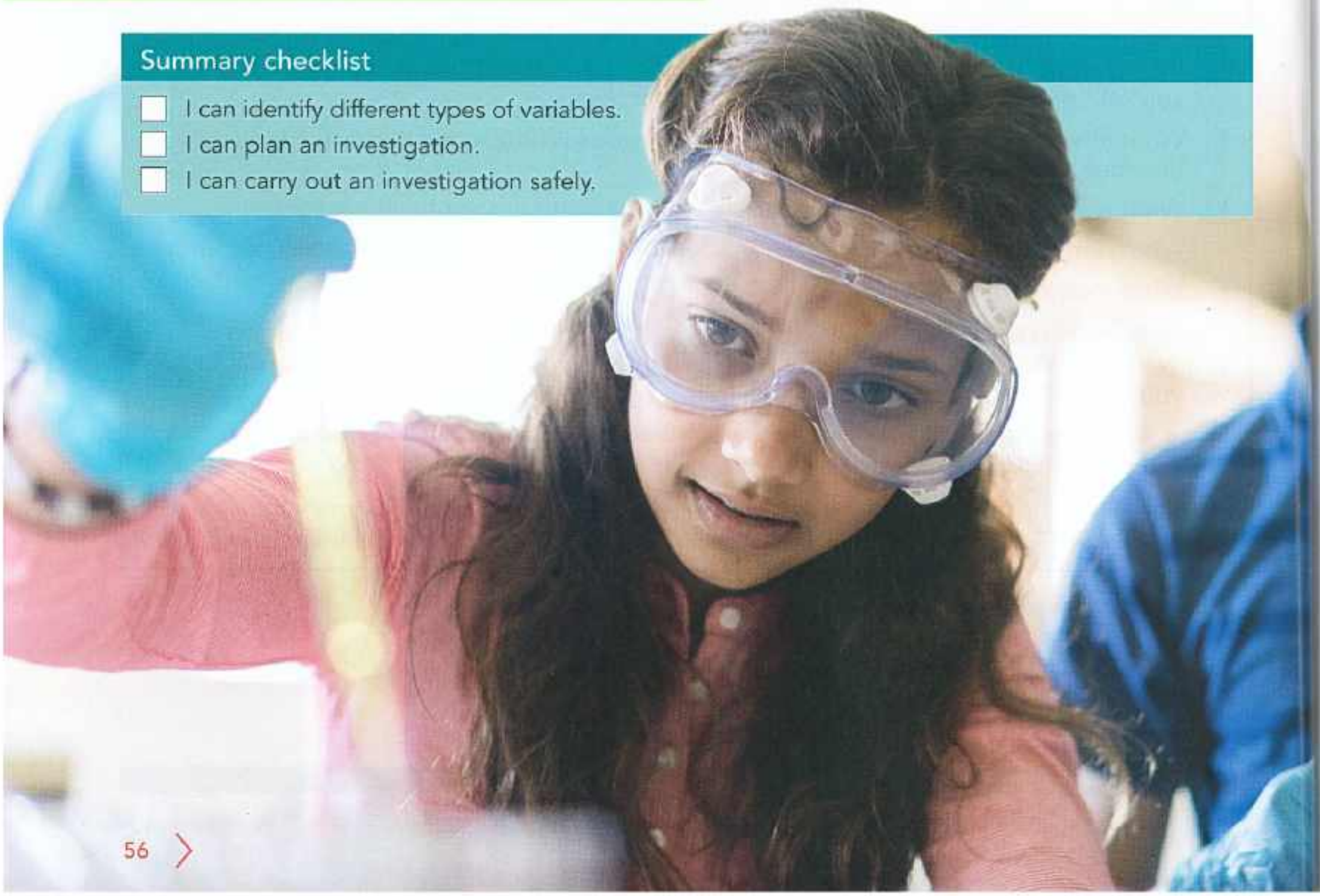
### Questions

1. Plot an appropriate graph.
2. Explain what you have found out.
3. Would you expect similar results if you used another salt, such as copper sulfate or lead chloride?

How accurate were your results?
How could you improve the accuracy?

## Summary checklist

- [ ] I can identify different types of variables.
- [ ] I can plan an investigation.
- [ ] I can carry out an investigation safely.



# > 2.4 Paper chromatography

**In this topic you will:**

- use paper chromatography to separate dissolved substances
- interpret chromatograms
- use scientific language accurately.

**Getting started**

Draw diagrams to show the ways you could separate mixtures that involve solutions. Check your ideas with a partner.

**Key words**

chromatogram

paper chromatography

permanent

solvent front

# Colours in ink

Black coloured ink looks as if it is just one colour – black. In fact, it is a mixture of different coloured inks. You can separate out the coloured inks by using a technique called **paper chromatography**.

Special paper, a bit like filter paper, is used.

Look at the photograph (right). A small drop of black ink has been placed on the paper. The water in the beaker has soaked up into the paper. As the water moves up the paper, the different coloured inks that make black ink separate out.

The resulting image on the paper is called a **chromatogram**.

The coloured inks separate because the water dissolves them. Water is the solvent. As the water moves up the paper, it carries the ink particles with it. The different kinds of ink particles are carried different distances before they are left behind on the paper. This is because not all the ink particles have the same solubility. The more soluble the ink, the further its particles are carried.

In the photograph below, you can see the different coloured inks that make up the ink in three different coloured pens – green, black, and red.

Some ink is not soluble in water, such as the ink in **permanent** marker pens. To separate out the colours in these inks, you would need to use a different solvent, such as alcohol.

## Think like a scientist

### Separating the colours in ink

You will need:

- chromatography paper (or filter paper)
- beaker
- water
- pencil and ruler
- glass rod or wooden spill
- ink or a pen
- various other inks and/or food dyes
- pipette (if using liquid ink)

Method

1 Take a strip of chromatography paper. Draw a pencil line about 1 cm from the end.
2 Place a spot of ink on the pencil line. The spot should be as small as possible.
3 Dry the spot and then add a little more ink.
4 Place about 2 cm depth of water in a beaker.
5 Hang the paper over a glass rod, pencil or wooden spill so that the end with the ink spot is just in the water. Make sure the ink spot stays above the level of the water.
6 Watch what happens as the water moves up the strip of paper.
7 Remove the strip of paper **before** the water reaches the top. You need to be careful as the wet paper can tear easily.
8 Allow the strip to dry and then stick it in your book. This is your chromatogram.

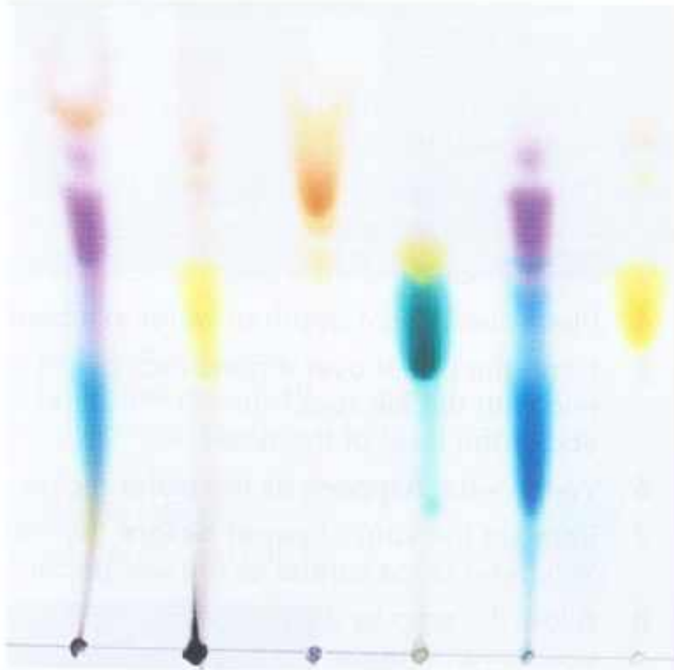
You can try this with all sorts of coloured liquids. Different inks and food dyes, especially from sweets or fruit syrup, are very good. You could also try this with permanent marker pens that have ink that is not soluble in water.

### Questions

1 Why did you use a line drawn in pencil on the paper?
2 Why was it important not to let the ink spot go under the water?
3 Why was it important to remove the strip of paper before the water level reached the end of the strip?
4 Describe your results.

Did you have any difficulties carrying out this practical work?
How did you overcome them?
How could you improve the way you carried out this practical task?

When comparing different substances, a scientist may use a large piece of chromatography paper and place spots of different items alongside each other. The scientist will allow the solvent to move up through all the samples at the same time. To do this, the paper needs to be placed in a large chromatography tank.

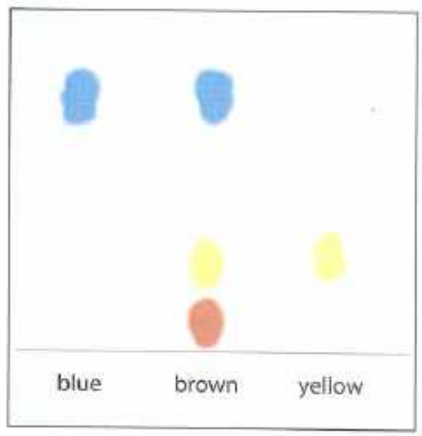


The chromatogram shown here has been produced using this technique. It shows the colours in a number of different felt tip pens.

Scientists use chromatography to study the dyes used in food. Some food dyes contain only one substance; they are a pure substance. Other dyes contain a mixture of substances. It is important to know exactly what is being used when our food is processed – we need to know if any substances could be a health risk; for example, they could be toxic or cause allergic reactions.

## Questions

The drawing of a chromatograph, on the right, shows the results for some food dyes.




1 Which food dyes are pure substances?
2 Which food dye is not a pure substance?
3 Which coloured substance in the food dyes is the most soluble?
4 Which coloured substance in the food dyes is the least soluble?

Public health scientists may also use chromatography to check that the colourings being used in products such as hair dye or the ink in pens are not harmful.

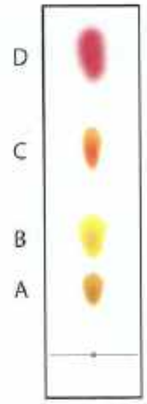
To do this they compare chromatograms taken from a solution of the food, hair dye or ink with chromatograms taken from the colourings that are permitted.

The diagrams here show a chromatogram from a hair dye called Sunny Red and a chromatogram showing all the permitted dyes.

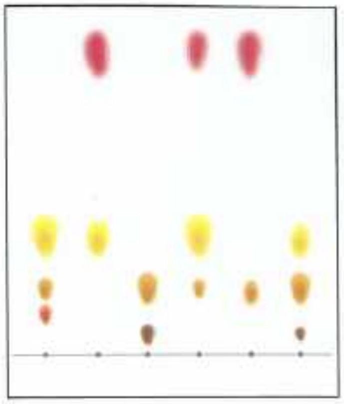
5 The chromatogram for Sunny Red shows four separate substances. Are any not permitted? If so, which?

6 The scientist decides to run the test again. Why does she do that?

7 Which of the substances in Sunny Red is the most soluble? Give a reason for your answer.




chromatogram from Sunny Red



chromatogram of permitted dyes

## Activity 2.4.1

### Using the correct words

This unit uses a number of words that look and sound similar. For example: solute, solvent and solution; chromatography and chromatogram; dissolve and dilute. Your task is to make up a game to help you learn them. You could make a set of cards with the words written on them, and another set of cards with the meanings written on them.

Think how you could use these to make a game. Your game can be for any number of players; you decide how many you want to play.

How do you learn new words and terms? Does a game help? Which is the most effective way of learning for you?

## Think like a scientist

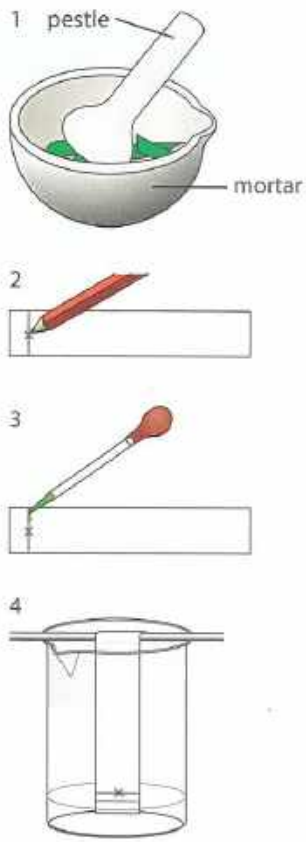
### Is the green colour in plant leaves pure?

You will need:

- fresh plant material such as spinach
- pestle and mortar
- ethanol
- pipette
- chromatography paper
- beaker
- pencil
- glass rod or spill

#### Safety

When using ethanol, make sure you are in a well-ventilated room and there are no heat sources close to you.




#### Method

1 Add a handful of spinach and a few drops of ethanol into the mortar. Use the pestle to crush the spinach and ethanol together. Let it stand for about 10 minutes to leave time for the green pigment to dissolve in the ethanol.

2 Prepare the chromatography paper with a pencil line and a cross, about 1 cm from the end.

3 Use a pipette to load some of the green liquid from the mortar onto the cross. Allow the spot to dry before adding more of the liquid.

4 Place the chromatography paper over a glass rod or pencil. Hang it in a beaker containing some ethanol, so that the pencil line is just above the ethanol.

5 Watch carefully and remove the chromatography paper before the ethanol reaches the top of the paper. The point that the solvent reaches is called the **solvent front**.

Allow the chromatogram to dry and then stick it in your book.

#### Questions

1 Why was ethanol used in this investigation and not water?

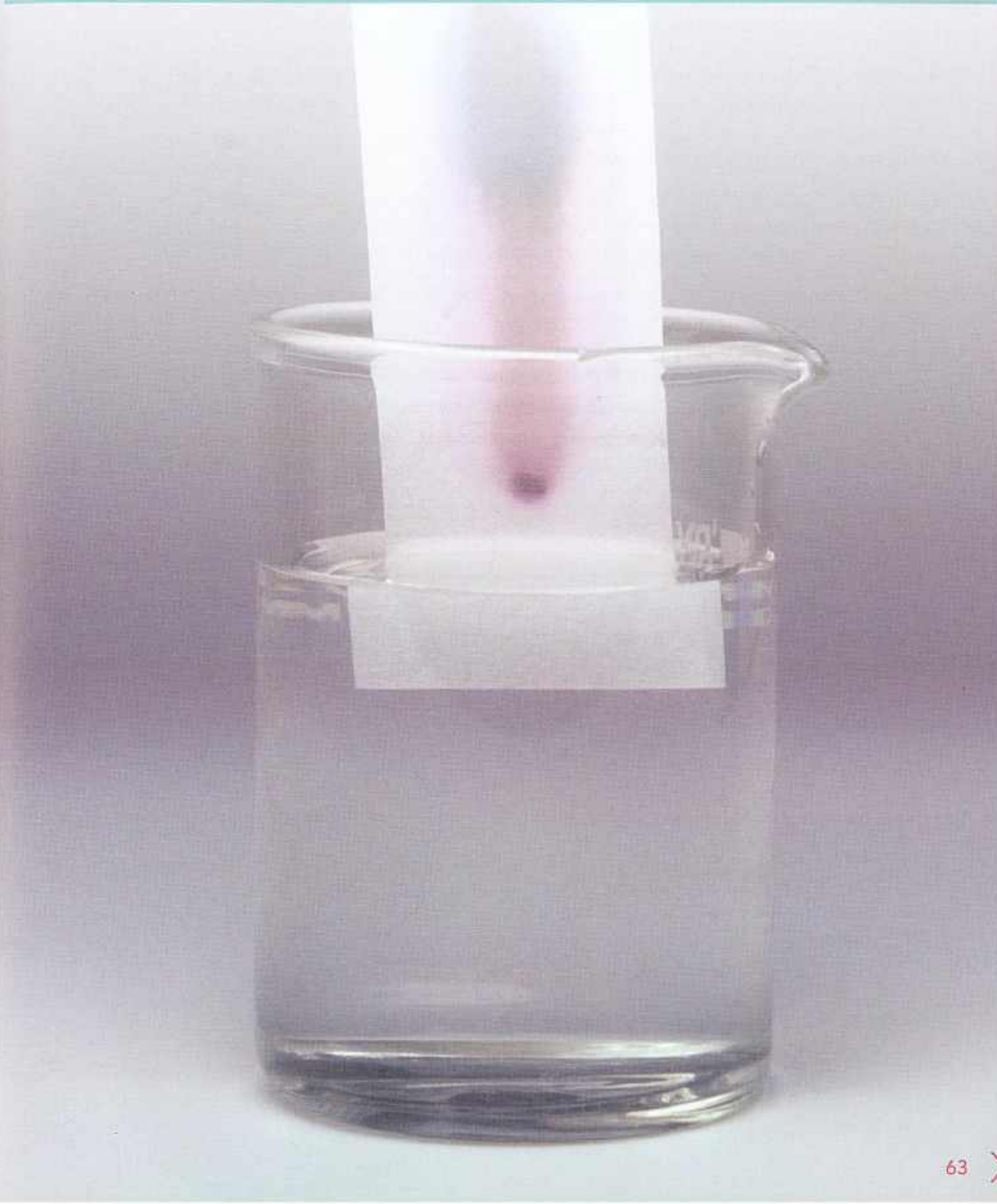
2 Is the green pigment in plants pure? What is your evidence for this?

Did you have any difficulties carrying out this practical work? How did you overcome them?

How could you improve the way you carried out this practical work?

## Summary checklist

- [ ] I can describe how to use chromatography to carry out a practical task to separate dissolved substances.
- [ ] I can explain what the results of a chromatogram show.
- [ ] I can use scientific language accurately.



## Project: The secret formula

This project shows how scientists work together and share their ideas. You can only use the information available and make deductions – just like research scientists. As you share your ideas, you will think about the information in different ways and then develop a theory and suggest more investigations.

### Background

Professor Sneeze has been working on a new medicine that will protect people from coughs and colds. If this medicine works it will save a lot of people from feeling ill and taking time off work or school. It will also make him famous and make a lot of money for his university.

Unfortunately, news that he has produced the medicine has reached some people who want to steal the formula, sell it to a company that will make the medicine and make themselves rich.

While he is working in his laboratory, a note is delivered to Professor Sneeze. The note asks him to meet Professor Clean in her laboratory at 11.00 am as she has an interesting experiment that she wants to show him. Just before 11.00 am he goes to Professor Clean's laboratory. When he arrives, Professor Clean is pleased to see him but has no idea why he has come. She did not send the note.

Dear Professor Sneeze,

I have an experiment due to finish today. I think you will be very interested to see the results as they may help you to improve the way your new medicine can be produced. Please come to my laboratory at 11.00 am when the experiment will have finished and we can discuss the results.

Best wishes,

Professor Clean

By the time Professor Sneeze gets back to his laboratory, his equipment has been damaged and the medicine formula has been stolen.

Continued

### Your task

Your group is going to help the professor try to find out who wrote the note. Ink from the note has been dissolved in water and given to you as a solution. Choose the equipment you will need and produce a chromatogram to show the different components in the ink.

The professor has borrowed pens from the four most likely suspects. Doctor Price: pen A; Doctor May: pen B; Doctor Burns: pen C and Professor Green: pen D.

Your job is to test the ink from all four pens to identify which pen was used to write the note.

In your group, discuss these questions.

- Who do you think wrote the note? Explain why you think that.
- Explain how you produce a chromatogram.
- What precautions must you take?
- Is this enough evidence to be sure you have the person who has the formula?
- What other evidence would you look for?

Present your evidence to the class.

# Check your progress

**2.1** Copy and complete these sentences. Use the words from the list. You may use each word once, more than once or not at all.

| | | | | |
|---|---|---|---|---|
| **solvent** | **mixture** | **solution** | **mass** | **temperature** |
| **solid** | **saturated** | **dissolve** | **volume** | **insoluble** |

A solute is a solid that … in a liquid.

The liquid it dissolves into is called a … .

Together they make a …

A solid that does not dissolve in a liquid is called … .

The solubility of a solid measures how much of a solute will dissolve. When you measure the solubility of a solute you must use the same … and type of solvent at a given … . [6]

**2.2** The table gives the names, colours and solubility in water of four compounds.

| Name | Colour | Solubility in water |
|---|---|---|
| sodium chloride | white | soluble |
| zinc carbonate | white | insoluble |
| iron sulfate | green | soluble |
| copper carbonate | green | insoluble |

The compounds were added to separate beakers of water. There was enough water to dissolve the soluble compounds completely. The contents of each beaker were filtered.

**a** One of the compounds left a white solid in the filter paper. What is the name of this compound? [1]

**b** What is the colour of the filtrate from this beaker? [1]

**c** Describe how you could obtain pure crystals of iron sulfate from a mixture of copper carbonate and iron sulfate. [3]

**2.3** Some learners have been investigating the mass of copper sulfate that can be dissolved in water at different temperatures. The learners added copper sulfate until no more would dissolve. They carefully measured the mass of copper sulfate they added. Here are their results.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Temperature of water in °C | 20 | 30 | 40 | 50 | 60 | 70 | 80 |
| Mass of copper sulfate dissolved in g | 22 | 24 | 28 | 32 | 30 | 46 | 58 |

**a** What name is given to a solution when no more of the solute can be dissolved in it? **[1]**

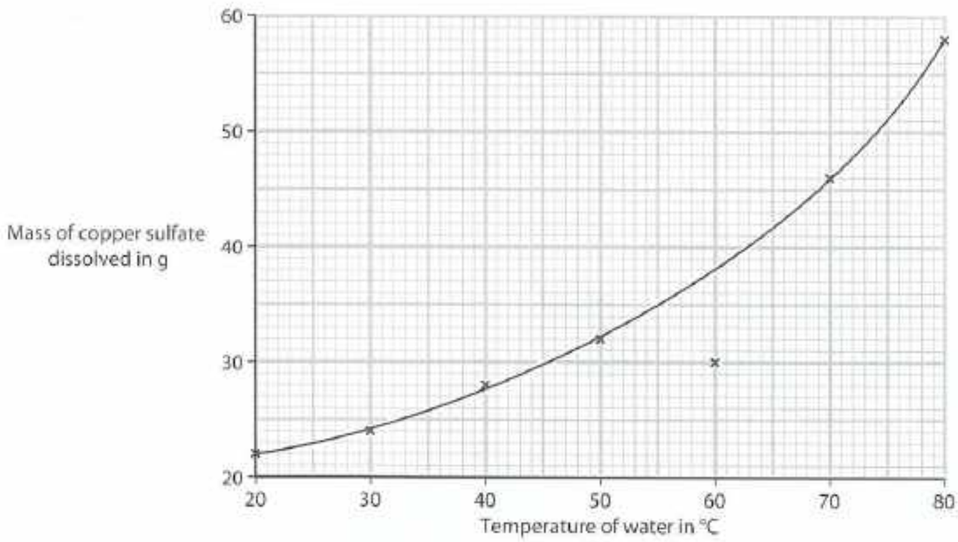
**b** What range of temperatures did the learners use? **[1]**

**c** What interval did the learners use for the temperatures? **[1]**

**d** Name **one** variable that the learners should keep the same. **[1]**

**e** Which is the independent variable? **[1]**

Here is a graph of their results.




**f** Identify any results that do not fit the pattern. **[1]**

**g** What conclusion can the learners draw from their results? **[1]**

# 3 Forces and energy

## > 3.1 Forces and motion

**In this topic you will:**

- understand what is meant by balanced and unbalanced forces
- describe the effects of balanced forces on motion
- describe the effects of unbalanced forces on motion.

**Getting started**

Work in groups to discuss answers to these questions.

1 What is the unit of force?
2 How are forces shown on diagrams?
3 One or more forces always act on any object on Earth. Is this true?

**Key words**

balanced
change direction
direction
force
opposite
slow down
unbalanced

## Balanced or unbalanced?

Look at any object that is not moving.

You may think that if an object is not moving, no **forces** are acting to push, pull or twist it. This is not true.

Look at the rock in the picture. The force of gravity is pulling it toward the centre of the Earth. This force is called its weight. The rock does not move toward the centre of the Earth because the ground is pushing up on the rock. This force is the contact force.

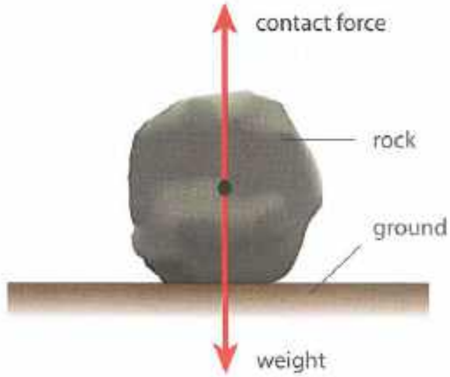
These two forces are **balanced**. This means the forces are equal in size and **opposite** in **direction**.

There could be more than two forces acting on the rock.

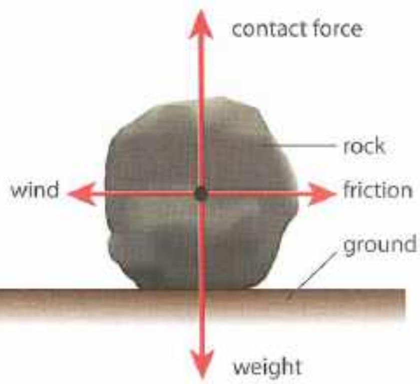
Imagine the wind is blowing. The wind will push the rock from one side.

Why does the rock not move sideways? The pushing force from the wind is balanced by friction between the rock and the ground.

These forces can be shown in a force diagram. In a force diagram, the arrows show the size and direction of each force. The longer the arrow, the bigger the force. So, when you draw a force diagram with balanced forces, make sure the arrows are the same length and point in opposite directions.




The forces acting on the rock




The forces acting on the rock when the wind is blowing

### Starting to move

Imagine the rock is now pushed with a much larger force than the wind, such as a large vehicle.

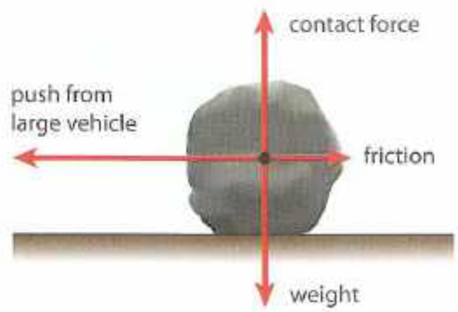
When the vehicle pushes on the rock, the pushing force will be larger than friction.

The rock will now move because the sideways forces are not balanced.

This can be shown on the force diagram.

The rock will now start to move in the direction of the larger sideways force.

The rock will not move up or down because the forces acting up and down are still balanced.




The forces are no longer balanced and the rock will start to move

## Slowing down

**Unbalanced** or unequal forces can also make moving objects **slow down**. A parachute makes a falling object slow down.

When an object is falling quickly, the parachute causes a force of air resistance that is larger than the weight of the object.

These forces can be shown in a force diagram.


When the parachute first opens, the forces are unbalanced. This unbalanced force makes the object slow down.


When the object slows, the air resistance decreases, so the forces become balanced again. Then the object falls at a constant speed.

This force diagram shows the object falling at a constant speed.

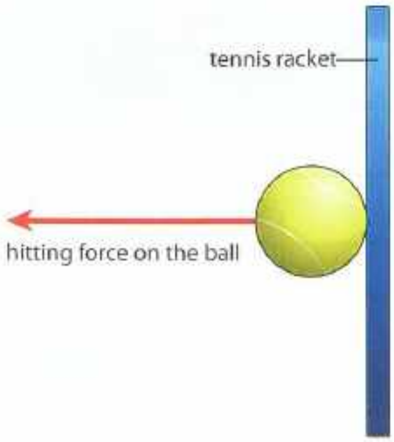
## Changing direction

Unbalanced forces can also make objects **change direction**.

This tennis ball will change direction because of an unbalanced force.

When the ball contacts the tennis racket, the ball pushes on the tennis racket. To make the ball go back in the opposite direction, the hitting force must be larger than the force from the ball.

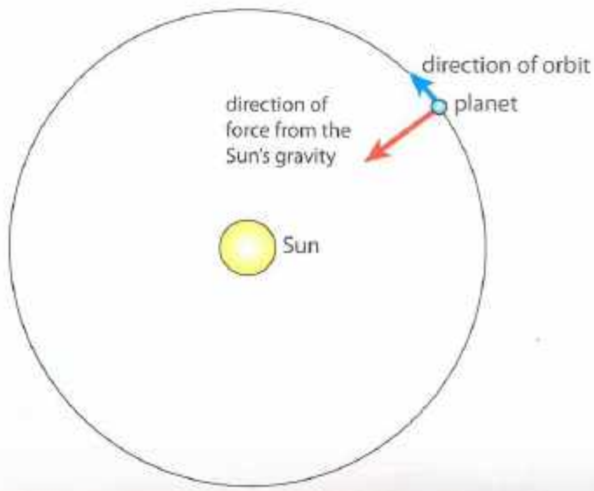
This can be shown in a force diagram.




Stage 7, Topic 3.3 described planets orbiting the Sun due to the force of gravity.

The force of gravity on a planet is a constant, unbalanced force.

When an object moves in a circle, its direction is always changing. A constant unbalanced force is needed to keep an object moving in a circle.



Summary

- When forces are equal in size and opposite in direction, the forces are balanced.
- Balanced forces cause no change in movement.
- When forces are not equal in size and/or act in directions that are not opposite, the forces are unbalanced.
- Unbalanced forces cause change in movement: speeding up, slowing down or changing direction.

| Size of forces | Direction of forces | Balanced or unbalanced | Change in movement |
|---|---|---|---|
| Equal | Opposite | Balanced | None |
| Equal | Not opposite | Unbalanced | Change of direction |
| Not equal | Opposite | Unbalanced | Increase or decrease speed |
| Not equal | Not opposite | Unbalanced | Increase or decrease speed and change of direction |

## Questions

1 a Describe what is meant by 'balanced forces'.

b A box is on the floor. The box is **not** moving.

i Draw a labelled force diagram to show all the forces acting on the box.

ii Arun pushes the box sideways. The box does **not** move. Draw another labelled force diagram to show **all** the forces acting on the box when Arun is pushing.

2 A tug of war is a game played by two teams of people, each pulling on the same rope. The team that pulls the rope to their side wins.

The picture shows a tug of war. The teams in this game are called Team A and Team B.


Both Team A and Team B are pulling on the rope.

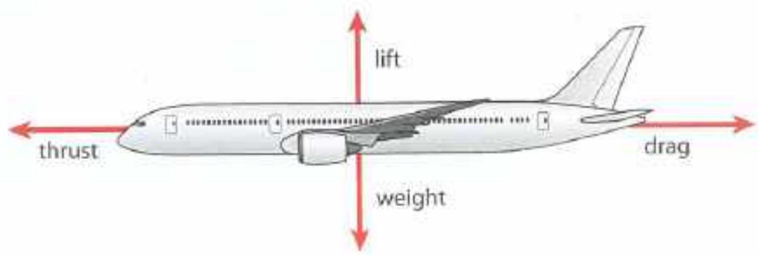
The rope is **not** moving.

Use ideas about forces to answer these questions.

a Explain why the rope is not moving.

b The rope starts to move towards Team B. Give **two** changes that could make the rope move towards Team B.

3 The diagram shows the forces on an aeroplane in the air.




a Explain why this aeroplane is:

i flying at a constant speed

ii not getting higher or lower.

b Name the force that should **increase** to make the aeroplane:

i go faster

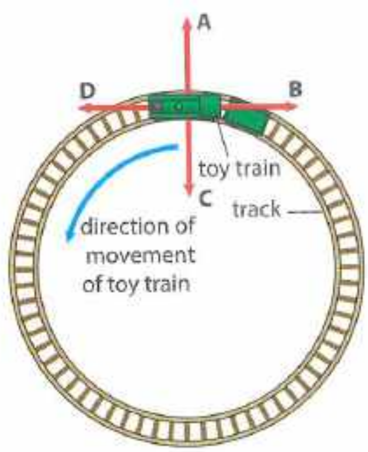
ii go higher

c Name the force that should **decrease** to make the aeroplane:

i go lower

ii go faster.

4 The picture shows a toy train moving around a circular track.




The locomotive contains an electric motor that drives the train. The train moves in a circle at a constant speed.

Give the letter of the arrow that shows the direction of:

a the driving force of the train

b the force of friction on the locomotive

c the force that keeps the train moving in a circle.

## Activity 3.1.1

### Balanced or unbalanced forces?

On a large piece of paper, draw a table with two columns: one for balanced forces and one for unbalanced forces.

Put each of these situations into the correct column, according to the forces that are acting.

The situations are:

- a motorcycle going around a corner
- a boy on a skateboard slowing down
- a bowling ball rolling at constant speed in a straight line
- a girl on a swing getting faster
- a computer sitting on a desk
- a helicopter going straight upwards at a constant speed
- a coconut falling from a tree and getting faster.

How did you decide which situations had balanced forces and which had unbalanced forces?

Did your strategy work?

Could you use this strategy again, or would you change it?

## Think like a scientist

### Measuring balanced and unbalanced forces

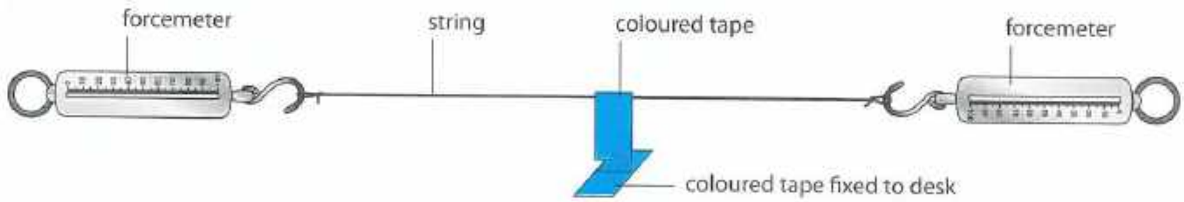
You will investigate the effects of balanced and unbalanced forces.

Work in pairs.

**You will need:**

- two forcemeters • piece of string • coloured tape • scissors

Set up the equipment as shown in the diagram.



Continued

### Method

1 Each person in the pair holds one forcemeter (also known as a newton meter). The string should be tight.

The coloured tape on the string should be lined up with the coloured tape on the desk.

2 Each person pulls with an equal force, for example, 4 N.

### Questions

1 What directions must you both pull to keep the pieces of coloured tape lined up?

2 Both people increase the pulling force to, for example, 8 N.

Explain why the string does not move, even when the force is increased.

3 One person decreases their force by 1 N. If the force was 8 N, then decrease the force to 7 N.

a Describe what happens to the string.

b Use a force diagram to explain what happens to the string.

4 Now make the difference between the forces larger so that, for example, the difference is now 2 N or 3 N.

How does the difference between the sizes of the forces affect the movement of the string?

5 Explain why the two forcemeters do not have to be the same.

6 This investigation is an analogy of a tug of war. That means the investigation can be compared with a tug of war.

State what is represented by the forcemeters in this analogy.

Continued

### Self-assessment

Decide how confident you are about each of these statements.
Give yourself 5 if you are very confident and 1 if you are not confident at all.

- I understand what balanced forces are.
- I can draw force diagrams to show balanced forces.
- I can draw force diagrams to show unbalanced forces.
- I can predict some things that can happen when forces are unbalanced.
- I understand that there can be forces acting on an object even when it is not moving.

## Summary checklist

- [ ] I can describe what is meant by balanced forces in terms of size and direction.
- [ ] I can understand that forces can be acting on an object that is not moving.
- [ ] I can recognise when forces are unbalanced.
- [ ] I can list some of the effects of unbalanced forces.

# 3.2 Speed

## In this topic you will:

- understand what is meant by speed
- learn about the unit of speed
- be able to calculate speed

## Getting started

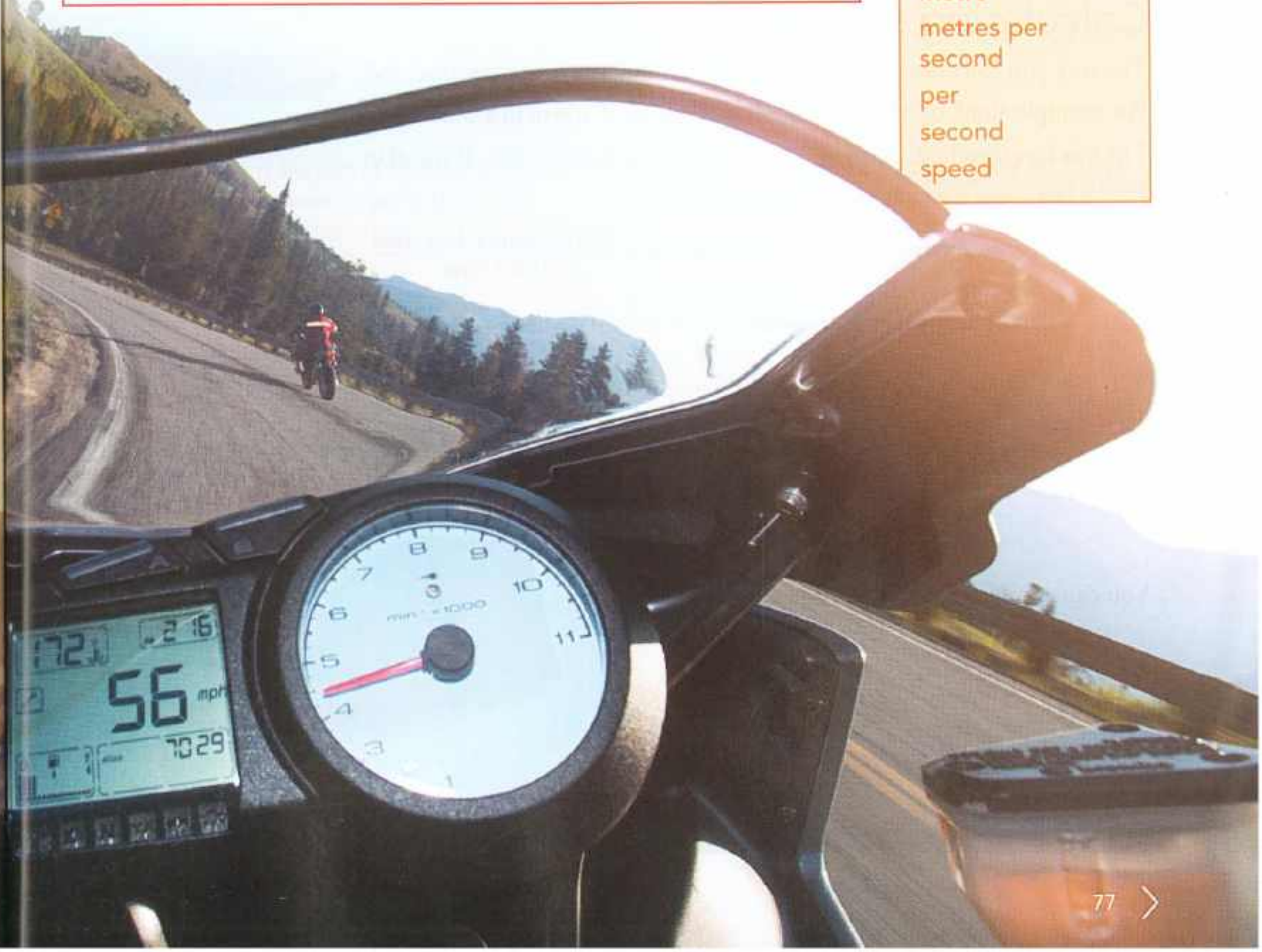
Work in groups to discuss answers to these questions.

1 What are the speed limits for cars where you live?

2 Signs showing speed limits usually do not have units. What are the units used for speeds of cars?

## Key words

average speed
calculate
constant
m/s
metre
metres per second
per
second
speed



# Units of speed

There are many different units of **speed**. Different units are sometimes used in different countries and for different things. For example, the speed of ships is often measured in knots, whereas aeroplanes often use Mach. Some countries have road speed limits in kilometres per hour, whereas some countries use miles per hour.

So, to avoid confusion, scientists use standard units for measurement in all countries.

The standard unit for speed is **metres per second**.

The word **per** means 'in each'. Therefore, metres per second means the number of **metres** travelled in each **second**. For example, a horse running with a speed of 15 metres per second means the horse travels a distance of 15 metres in each second.

Metres per second is written as **m/s**.

# Calculating speed

The way you **calculate** speed is linked to the unit metres per second, m/s.

For example, think of a bus that travels a distance of 100 m in a time of 20 s.

The bus has travelled 100 m in 20 s, so how many metres does it travel in each 1 s?

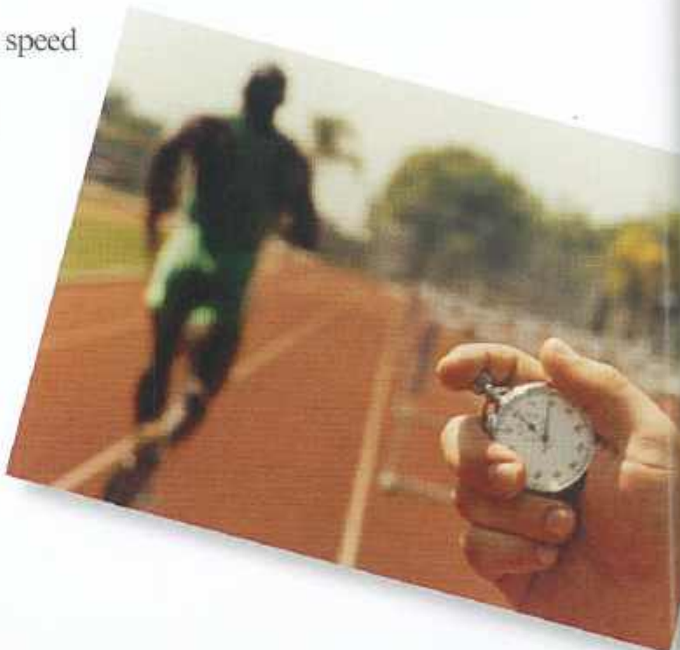
$$\text{number of metres travelled in each second} = \frac{\text{total distance travelled}}{\text{total time}}$$

$$\text{number of metres travelled in each second} = \text{speed}$$

$$\text{speed} = \frac{\text{total distance travelled}}{\text{total time}}$$

$$= \frac{100\,\text{m}}{20\,\text{s}}$$

$$= 5\,\text{m/s}$$



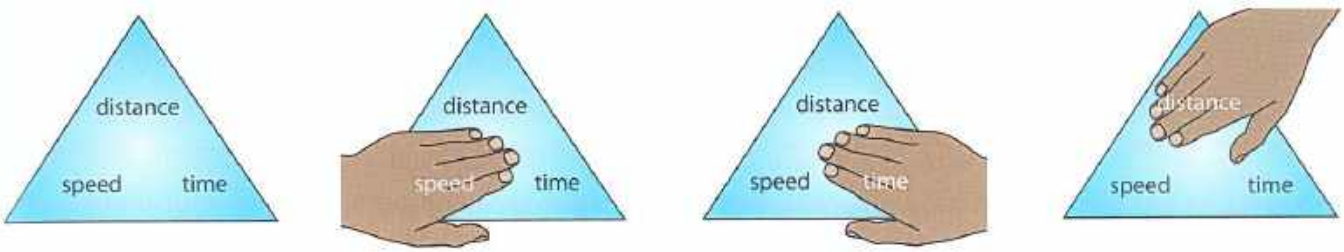
You can summarise this equation for speed as:

$$\text{speed} = \frac{\text{distance}}{\text{time}}$$

Note: the term **average speed** is sometimes used because the speed of an object during a journey is not always **constant**. Constant means not changing. Average speed is calculated in exactly the same way as speed.

The equation for speed can be used in a formula triangle. This means you can also use the equation to calculate:

- the distance travelled, if you know the speed and the time taken
- the time taken, if you know the speed and the distance travelled.




$$\text{speed} = \frac{\text{distance}}{\text{time}} \qquad \text{time} = \frac{\text{distance}}{\text{speed}} \qquad \text{distance} = \text{speed} \times \text{time}$$

A formula triangle

## Worked example

### Question

Marcus rides his bicycle at a speed of 4 m/s for 60 s. How far does he go in this time?

### Answer

$$\text{distance} = \text{speed} \times \text{time}$$
$$= 4 \times 60$$
$$= 240\,\text{m}$$

### Question

Sofia is in a car travelling at a speed of 35 m/s. How long will the car take to travel 2100 m?

### Answer

$$\text{time} = \frac{\text{distance}}{\text{speed}}$$
$$= \frac{2100}{35}$$
$$= 60\,\text{s}$$

The worked examples above both use metres, seconds and metres per second. Sometimes, the values are given in different units. So, for example, if you have a distance in km and a time in hours, the equation will give you a speed in km/h as you are dividing a distance in km by a time in hours.

**Worked example**

**Question**

An aeroplane travels 2500 km in a time of 5 hours. What is the speed of the aeroplane in km/h?

**Answer**

$$\text{time} = \frac{\text{distance}}{\text{speed}}$$

$$= \frac{2500\,\text{km}}{5\,\text{hours}}$$

$$= 500\,\text{km/h}$$

However, unless you are told otherwise, always work in metres, seconds and metres per second. Remember, in calculations, always:

- show the steps you used in working out the answer
- include the correct units with the answer.

## The highest possible speed

Since the 1930s, the highest possible speed is thought to be the speed of light, which is 1 000 000 000 km/h. This was predicted by calculations made by Albert Einstein and confirmed by other scientists doing experiments. No scientist, so far, has observed anything moving faster. This is how science advances: through collaboration (scientists working in groups) and peer-review (scientists checking each other's work).

### Questions

1 a Write an equation for speed, when you know the distance travelled and the time taken.

b Write down the standard scientific unit of speed.

c Write an equation for distance travelled, when you know the speed and the time taken.

d Write an equation for time taken, when you know the speed and the distance travelled.

In each question that follows, show your working and give the unit with your answer.

2 a An Olympic sprinter completes the 100 m race in a time of 10 s. Calculate the average speed of the sprinter.

b Explain why this value is an average speed.

3 A car travels a distance of 210 m in a time of 6 s.

a Calculate the speed of the car in m/s.

b Calculate the distance, in m, travelled by the car in 14 s.

c Calculate the time taken, in s, for the car to travel a distance of 1925 m.

4 a An aeroplane flies between two cities that are 8100 km apart. The aeroplane takes 9 hours to complete the journey. Calculate the average speed of the aeroplane, in km/h.

b A different aeroplane can fly at 800 km/h. Calculate the distance, in km, that this aeroplane could fly in 6 hours.

c Another aeroplane can fly at 950 km/h. Calculate the time taken, in hours, for this aeroplane to travel a distance of 7125 km.

5 Anna sees a worm on the grass. Anna sees the same worm 2 hours later. The worm has moved a distance of 3 m in that time. Calculate the average speed of the worm, in metres per hour.

## Activity 3.2.1

### Speed, distance and time

Use a map or internet search engine to find the distances between some places near to where you live.

You should include:

- some shorter distances, such as from home to school
- some longer distances, such as between cities.

The table gives some typical speeds for different methods of travel.

| Method of travel | Typical speed in m/s |
|---|---|
| walking | 2 |
| cycling | 7 |
| horse riding | 10 |
| bus | 12 |
| small motorcycle | 20 |
| car | 30 |
| train | 35 |
| aeroplane | 200 |

Use the information in the table to calculate the times taken for your different distances.

For each distance, choose some of the most appropriate methods of travel.

## Think like a scientist

### Calculating speed

In this investigation, you will make measurements to calculate the speed of a tennis ball.

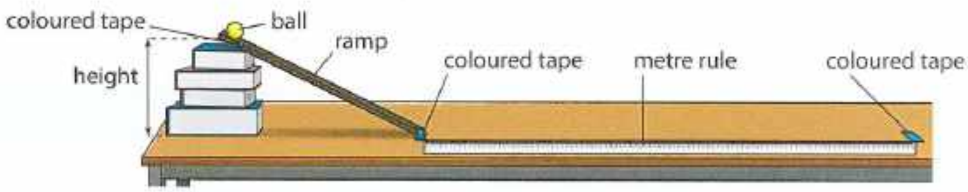
Work in groups of three or four.

**You will need:**

- ramp (such as a plank of wood or thick card)
- tennis ball
- metre rule
- coloured tape
- books
- smooth level surface (such as a desk or the floor)
- stopwatch

#### Method

Set up the equipment as shown in the diagram.




1. Use coloured tape to fix the bottom of the ramp to the desk or floor.
2. Fix some coloured tape 1 m from the end of the ramp.
3. Fix some coloured tape near the top of the ramp to mark where you will release the ball.
4. Measure the height from the desk or floor up to the position where you will release the ball.
5. Release the ball and measure the time the ball takes to move between the two pieces of coloured tape on the desk or floor.
6. Repeat this two more times and calculate the average time to travel between the two pieces of tape.
7. Do this for a range of different heights.

Continued

### Results and questions

1 Record your results in a table.

2 Use your results to calculate the speed of the ball between the two pieces of tape. Add another column to your table, or draw a new table, to include the speed. Remember to put the unit of speed in the column header.

3 Plot a line graph of the results. Put *height* on the hoizontal axis and *speed* on the vertical axis. Include the units on each axis.

4 What is:

  a the independent variable in this investigation

  b the dependent variable in this investigation?

5 State **two** variables that were controlled in this investigation.

6 Explain why each measurement is repeated. Give **two** reasons.

7 Describe the trend in your results.

### Self-assessment

Decide how well you:

- made measurements
- recorded results in a table
- drew the graph of the results.

Choose one thing that you could do better next time.

How will you do this better next time? What will you change?

## Summary checklist

- [ ] I know the equation that links speed, distance and time.
- [ ] I can use the equation to calculate speed, when distance and time are known.
- [ ] I can use the equation to calculate distance, when speed and time are known.
- [ ] I can use the equation to calculate time, when distance and speed are known.
- [ ] I know that metres, seconds and metres per second are standard units.
- [ ] I can calculate speeds using different units.

# 3.3 Describing movement

## In this topic you will:

- learn how to use graphs to describe movement
- understand what a distance/time graph shows
- learn to draw a distance/time graph.

## Getting started

Work in groups to discuss the answer to this question.

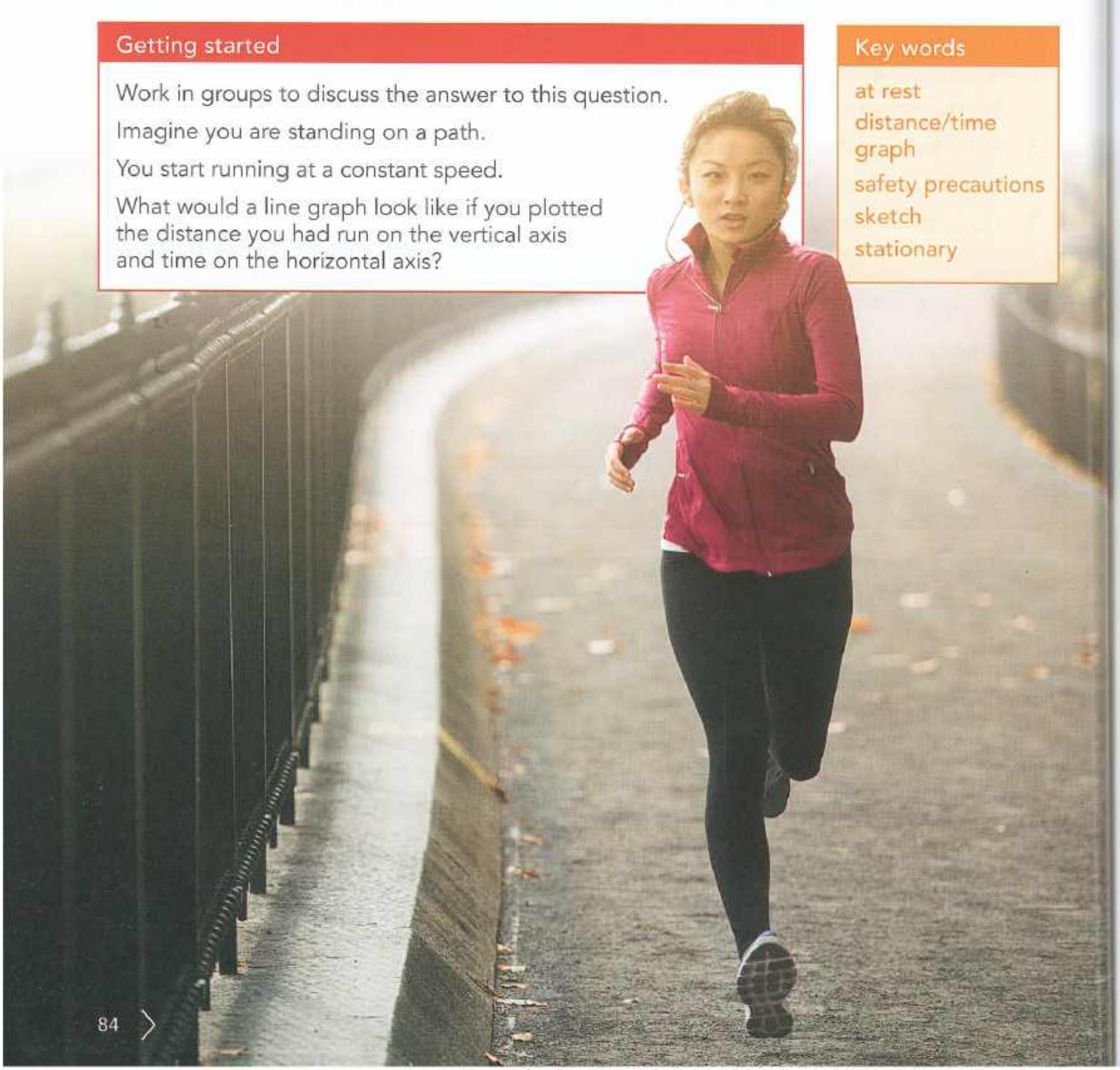
Imagine you are standing on a path.

You start running at a constant speed.

What would a line graph look like if you plotted the distance you had run on the vertical axis and time on the horizontal axis?

## Key words

at rest
distance/time graph
safety precautions
sketch
stationary



# Distance/time graphs

Scientists use graphs to describe how two variables are related.

We can use graphs to describe the movement of an object.

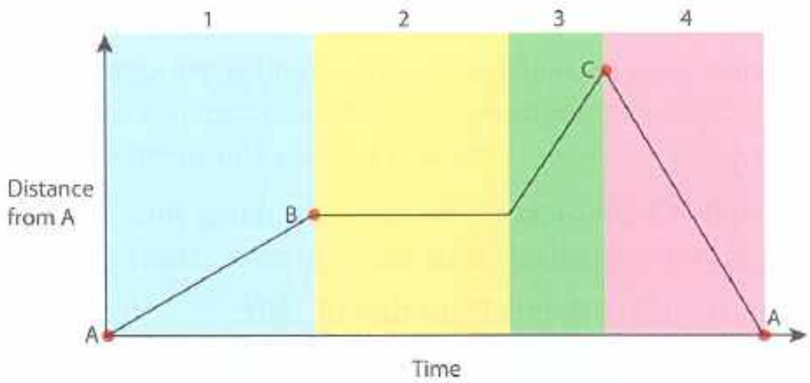
One way to do this is to plot a measure of distance on the vertical axis and a measure of time on the horizontal axis.

A graph like this is called a **distance/time graph**.

Graphs are more useful than words for describing movement because:

- it is easier to see trends and patterns
- you can read any value of distance or time during the journey, from the graph
- other values, such as speed, can be calculated from the graph
- information about the whole journey can be seen easily.

This is a distance/time graph. It shows the journey of a car from a starting position, A, to a destination, C. The car then returns to its starting position.




Now take a closer look at what the graph shows in each of the four sections. These sections are in different colours so you can see them clearly.

1. At the starting position, A, the car has travelled zero distance. The car travels at a constant speed away from the starting position to point B. When moving at constant speed, the car travels the same distance in each second. The distance from A increases with time. The distance/time graph show this as a straight, upward sloping line.
2. The car stops at B. It is **stationary**. Stationary means not moving, with a speed of zero. You can also use the term **at rest** to mean stationary. The distance of the car from A does not change when the object is stationary, but time still passes. The distance/time graph shows a straight line that is horizontal.

**3** The car starts again and moves at a constant speed to its destination, C. It moves faster than when it travelled between A and B, meaning that it travels a greater distance each second. So, the distance/time graph shows this as a **steeper**, straight, upward sloping line.

**4** From C, the car travels at a constant speed back to the starting position, A. The distance of the car from the start **decreases** with time. The distance/time graph shows this as a straight, **downward** sloping line.

The distance/time graph for the car journey was a **sketch**. If you draw a sketch graph you do **not** have to put numbers on your graph axes.

Sometimes, distance/time graphs have values on the axes. This means you can use the graph to make calculations. Read the distance from the vertical axis, and the time from the horizontal axis. Then use the equation:

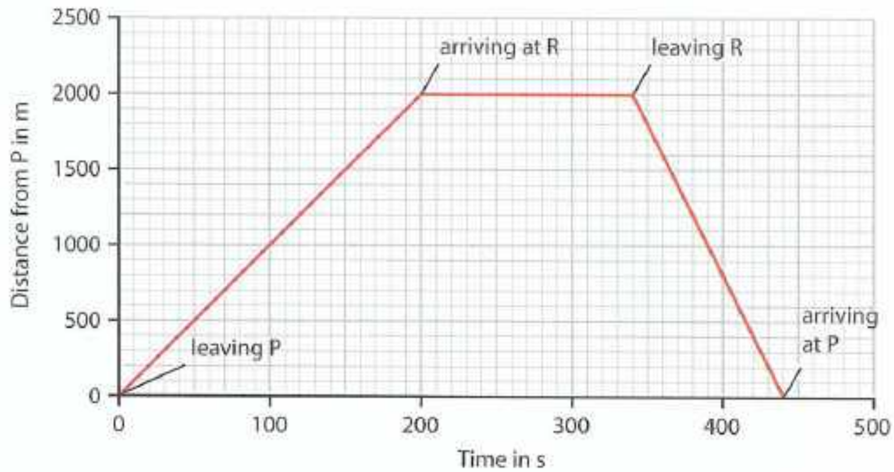
$$\text{speed} = \frac{\text{distance}}{\text{time}}$$

## Worked example

### Question

This distance/time graph shows a short train journey between two stations, P and R, that are 2000 m apart.

- The train leaves station P at time 0.
- The train takes 200 s to travel from P to R.
- The train stops at station R for 140 s.
- The train then travels back from station R to station P in a time of 100 s.




**a** At what speed does the train travel from station P to station R?

**b** What is the speed of the train on the way back from station R to station P?

Continued

**Answer**

a The distance is 2000 m and the time taken is 200 s.

$$\text{speed} = \frac{\text{distance}}{\text{time}}$$
$$= \frac{2000}{200}$$
$$= 10\,\text{m/s}$$

b The distance is 2000 m and the time taken is $440 - 340 = 100$ s.

$$\text{speed} = \frac{\text{distance}}{\text{time}}$$
$$= \frac{2000}{100}$$
$$= 20\,\text{m/s}$$

## Questions

1 a Sketch a distance/time graph for an object moving at a constant speed away from a starting position.

b On the same graph, sketch another line to show another object moving **faster**, away from the same starting position. Label this line 'faster'.

c On the same graph, sketch another line to show another object moving **slower**, away from the same starting position. Label this line 'slower'.

2 Marcus is making a journey from home to a shop.

For the first part of the journey, he rides his bicycle at a constant speed.

Marcus then stops to talk to a friend.

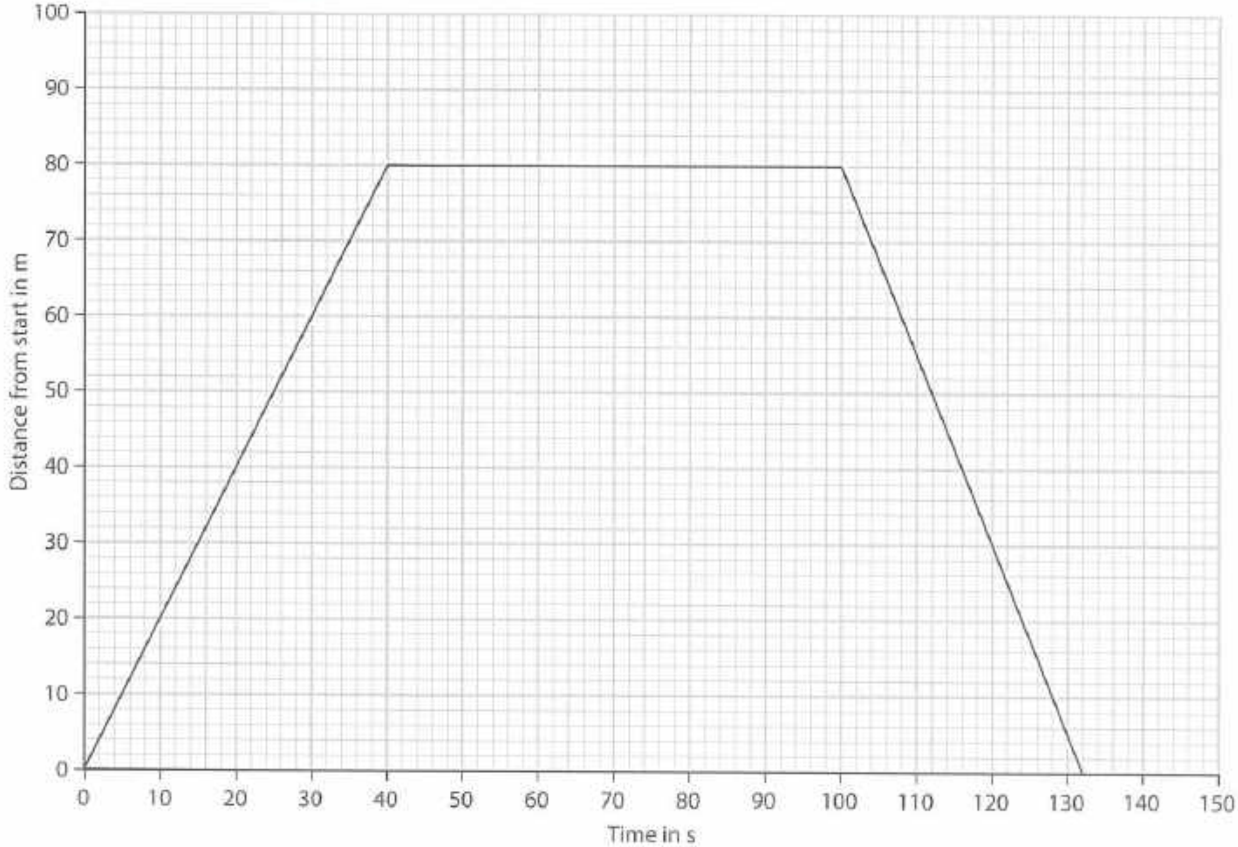
For the last part of the journey, he continues to ride his bicycle at a slower constant speed than before until he arrives at the shop.

a Sketch a distance/time graph for Marcus's journey.

b Label each part of Marcus's journey on your graph.

3 A boat goes straight across a lake. After some time, the boat crosses the lake again to return to its original position.

The graph shows the journey made by the boat.




Use information in the graph to answer these questions.

**a** How far did the boat travel when crossing the lake once?

**b** Calculate the speed of the boat crossing the lake the first time.

**c** How much time did the boat spend stopped before crossing the lake again?

**d** Calculate the speed of the boat crossing the lake the second time.

**e** How much time did the boat take for the complete journey: across the lake, stopped and coming back?

## Activity 3.3.1

### My journey

Think about a journey you made recently.

The journey could be walking or any other method of travel.

The journey could be coming to school or a longer journey.

Sketch a distance/time graph for that journey.

Label your graph with what each part represents.

Swap your graph with someone else.

Can they understand your journey by looking at the graph?

Can you understand someone else's journey by looking at their graph?

## Think like a scientist

### Walking and running

In this activity, you will plan an investigation, make measurements, do calculations and draw a distance/time graph.

Work in groups of three or four.

**You will need:**

- space where you can run **safely**
- tape measure
- stopwatch
- one sheet of graph paper per person

### Method

You need to calculate the average speed of walking for one person in the group, in m/s.

You then need to calculate the average speed of running for one person in the group, in m/s.

It does not have to be the same person.

1. Plan what measurements you will need to make and how you will make these measurements.
2. Make a list of the **safety precautions** that the person who is running should take.
3. Make your measurements safely and record them in a suitable way.

**Continued**

### Questions and results

1. a Calculate the average walking speed for the person, in m/s.

   b Calculate the average running speed for the person, in m/s.

2. Draw a distance/time graph. Put walking and running on the same graph and label the lines clearly.

3. Explain the difference between the two lines. Refer to distance **and** time in your explanation.

### Self-assessment

1. Decide how confident you are about each of these statements.
   Give yourself 5 if you are very confident and 1 if you are not confident at all.
   - I made useful contributions to planning.
   - I made useful contributions to making the measurements.
   - I drew my graph carefully, neatly and accurately.

2. Which do you think is better:
   - drawing a distance/time graph for a journey, or
   - describing a journey in words?

   Explain your answer.

## Summary checklist

- [ ] I can sketch a distance/time graph for an object moving at a constant speed away from a starting position.
- [ ] I can sketch a distance/time graph for a stationary object.
- [ ] I can sketch a distance/time graph for an object moving at a constant speed back towards a starting position.
- [ ] I can tell whether objects are moving quickly or slowly, or are stationary, from a distance/time graph.
- [ ] I can tell what direction an object is moving from a distance/time graph.
- [ ] I can sketch a distance/time graph from a description of a journey.
- [ ] I can draw a distance/time graph accurately.
- [ ] I can read values from a distance/time graph.

# > 3.4 Turning forces

## In this topic you will:

- recognise when a force causes something to turn
- know how to use the term moment
- be able to calculate the moment caused by a force.

## Getting started

Work in groups.

Make a list of things, such as a door handle, that are turned by forces.

## Key words

lever
moment
newton metres
pivot
turn

# Turning effects of forces

When you push down on a door handle, the handle **turns**.

When you push down on the pedal of a bicycle, the crank arm turns.

When you pull on a door, the door turns toward you.

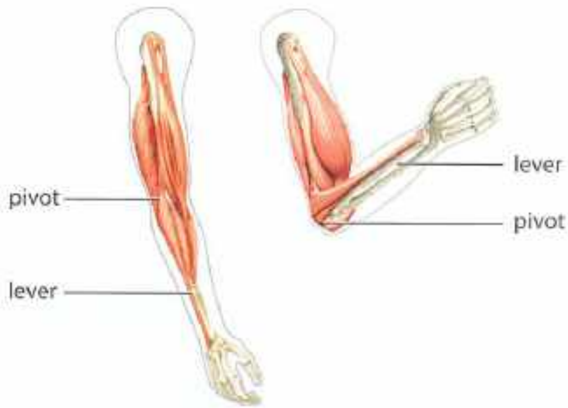
These are all examples of forces that cause an object to turn.

The object that turns is called a **lever**.

The point around which the lever turns is called the **pivot**.

The lever and pivot are shown in the picture of the bicycle pedals.

When you bend your arm, the arm acts as a lever. Your elbow is the pivot.


# Calculating moments

The **moment** of a force describes its the turning effect of a force.

The moment of a force depends on:

- the size of the force (the bigger the force, the bigger the moment)
- the distance between the position where the force acts and the pivot (the greater the distance, the greater the moment).

You can calculate a moment from this equation:

$$\text{moment} = \text{force} \times \text{distance}$$

Distance in the equation is the distance from the pivot to the position where the force acts.

The unit of force is the newton. The unit of distance is the metre.

Therefore, the unit of moment is newton × metre, which is written as **newton metre** or N m.

Remember to use an upper case N and a lower case m when writing N m.

## Worked example

### Question

A pulling force of 35 N is needed to open a door. The distance from the door handle to the door hinges (the pivot) is 0.8 m What is the moment caused by the pull on the door?

### Answer

moment = force × distance

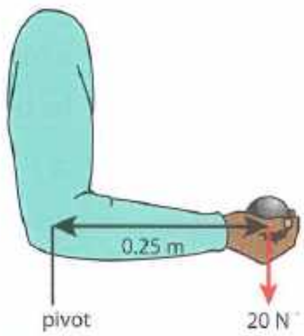
= 35 × 0.8

= 28 N m

## Worked example

### Question

Look at this diagram.
What is the moment caused by the weight on the arm?




### Answer

moment = force × distance

= 20 × 0.25

= 5 N m

## Balancing

A seesaw is a type of lever.

People sit on either side of the pivot of a seesaw and make the lever turn one way and then the other.

The result is that each person moves up and down. A seesaw will be balanced when the moments on both sides of the pivot are equal and opposite.

### Worked example

**Question**

Marcus weighs 600 N and sits at a distance of 2 m from the pivot of a seesaw. Arun weighs 800 N. Where should Arun sit to make sure the seesaw is balanced?

**Answer**

Marcus will exert a moment of $600 \times 2 = 1200\,\text{N m}$

For the seesaw to be balanced, the moment on the other side must also be 1200 N m.

moment = force × distance

So, $\text{distance} = \dfrac{\text{moment}}{\text{force}}$

$$\text{distance} = \frac{1200}{800}$$

$$= 1.5\,\text{m}$$

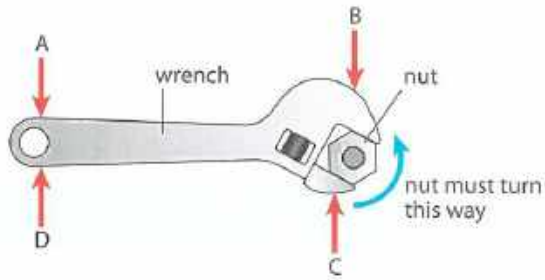
## Questions

1 a Describe what is meant by the word 'moment' in physics.

b Write the equation that links moment, force and distance.

c Write the unit of moment.

2 Arun has a spanner for turning a nut. The direction that the nut must turn is shown by the arrow. The pivot is in the centre of the nut.

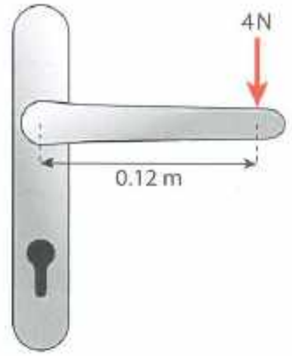



a Which arrow shows the direction that Arun should push on the spanner to produce the largest moment in the direction needed to turn the nut?

Write the letter.

b Explain your answer to part **a**.

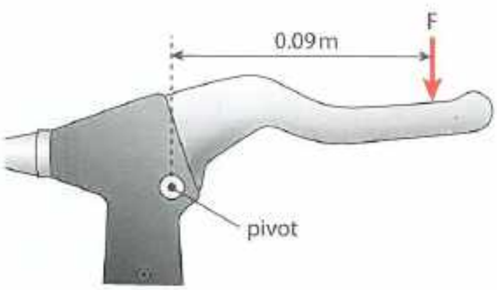
3 The drawing shows a door handle.




Sofia pushes on the door handle with a force of 4 N at the position shown in the drawing.

Calculate the moment caused by this force.

4 The drawing shows a bicycle brake lever.




A moment of 1.8 N m is needed to turn this brake lever.

Calculate the force F needed to produce a moment of 1.8 Nm.

5 Zara weighs 450 N. Zara sits on a seesaw at a distance of 1.5 m from the pivot.

Sofia weighs 500 N.

Sofia sits on the seesaw on other side of the pivot from Zara.

Calculate the distance from the pivot that Sofia must sit to balance the seesaw.

## Activity 3.4.1

### Identifying moments

Look for pictures in old magazines.

Cut out pictures showing objects that use moments to work.

Remember: anything that turns when pushed or pulled uses moments.

Stick the pictures to a large piece of paper to make a display.

Write the name of each object beside it.

Think of a title for your display.

## Think like a scientist

### Calculating moments

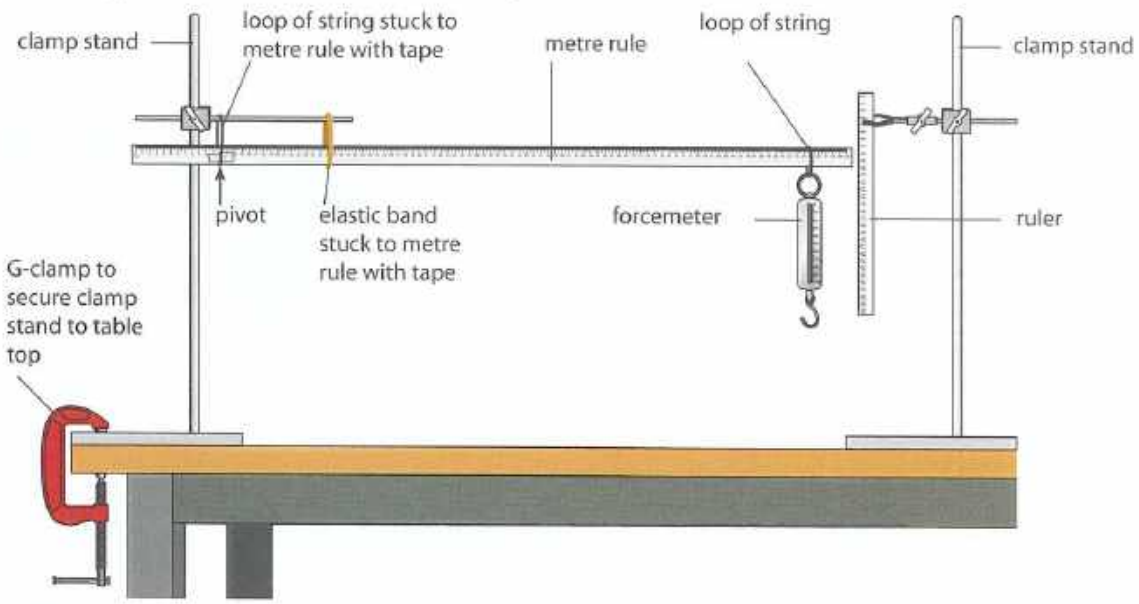
In this investigation, you will investigate how the force needed to turn an object varies with distance from the pivot.

Work in groups of two or three.

**You will need:**

- metre rule
- forcemeter
- two clamp stands
- elastic (rubber) band
- ruler
- string
- sticky tape
- G-clamp

Set up the apparatus as shown in the diagram.



Continued

Make a prediction about what will happen to the force needed to pull the metre rule down as the distance between the force and the pivot decreases.

### Method

1 Move the loop of string with the forcemeter as far from the pivot as you can.

2 Record the distance between the pivot and the forcemeter.

3 Raise the forcemeter so it is not pulling down on the metre rule.

4 Use the forcemeter to pull down on the metre rule. The distance that you pull depends on the strength of the elastic band. The metre rule needs to be pulled down far enough to get a reading of about 1 N at the furthest point from the pivot.

5 Use the ruler to record the distance that the metre rule moves.
This will be the distance the metre rule should be pulled down each time.

6 Record the force.

7 Repeat this, pulling the metre rule down the same distance each time.
Each time, use the loop of string to move the forcemeter closer to the pivot.

8 Your results should be a set of distances and forces.

9 Decide whether you need to repeat any of your measurements.

### Results and questions

1 Describe how you made the experiment safe.

2 Record your results in a table. Make sure that you record distances in metres, so you may need to convert from cm or mm. Remember to reverse the order of your results, so in the table the distances are increasing.

3 Draw a line graph of your results. Put distance on the x-axis and force on the y-axis.

4 Explain the pattern in your results.

5 Was your prediction correct?

6 Explain any improvements you could make to the method that would help get more accurate results.

### Self-assessment

1 Describe anything you did during the investigation to help get more accurate results.

2 a Did you repeat any of your measurements? Explain why, or why not.

b Explain your answer to part **a**.

## Summary checklist

- [ ] I understand that forces can cause turning effects.
- [ ] I understand what is meant by the term moment.
- [ ] I know and can use the equation that links moment, force and distance.
- [ ] I know the unit of moment.

# 3.5 Pressure between solids

## In this topic you will:

- recognise that forces can cause pressure on an area
- understand what affects pressure
- be able to calculate the pressure caused by a force on an area.

## Getting started

Work in groups.

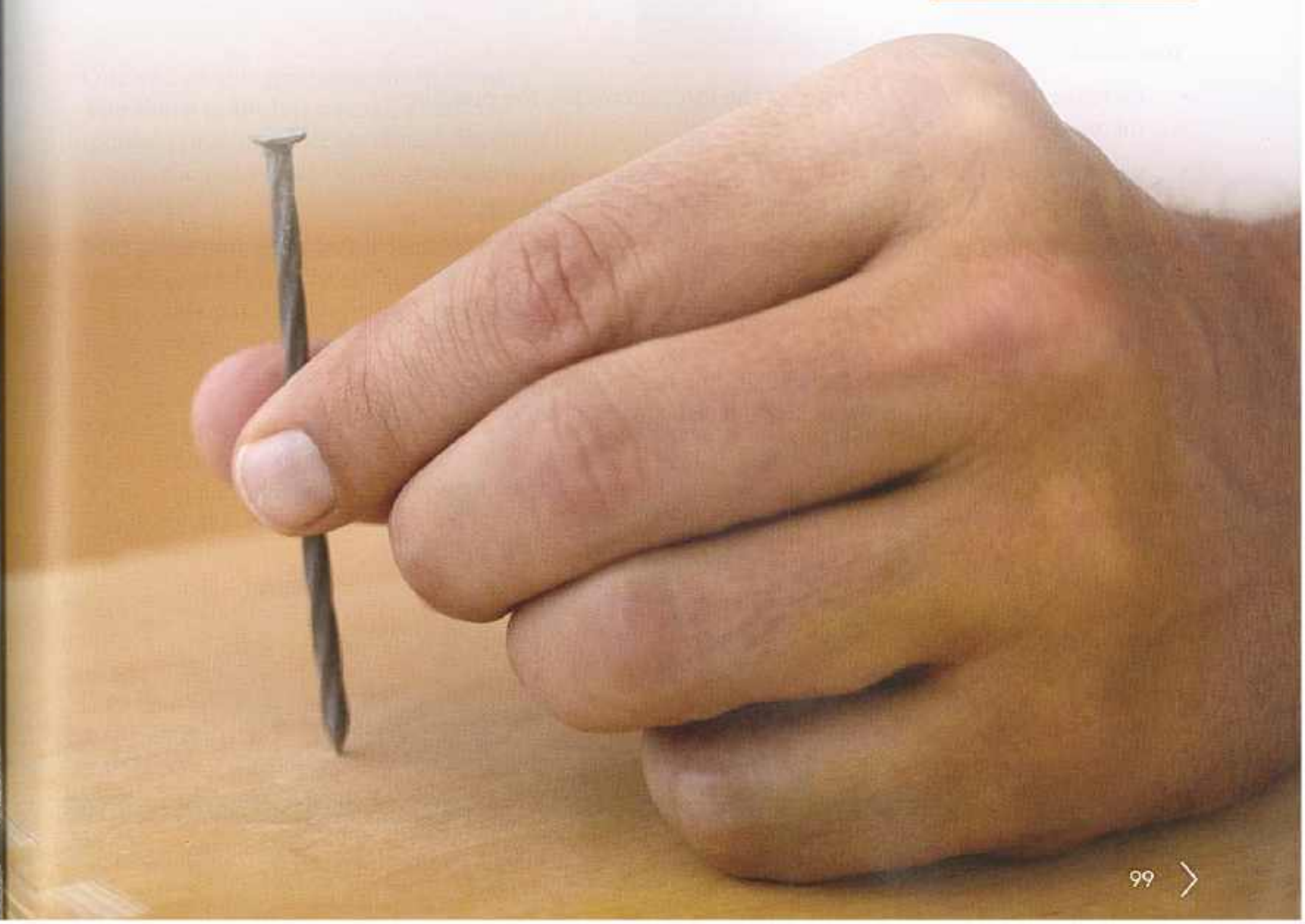
The nail in the picture has a sharp point at one end.

Make a list of some other objects that have sharp points or sharp edges.

What are these things used for?

## Key words

newtons per metre squared
point
pressure
sharp
surface area



# The pushing effect of a force

The picture shows a knife being used to cut modelling clay.

The knife works because the force used to push down on the clay causes **pressure** on the clay.

You can think of pressure as the pushing effect of a force.

Suppose the clay is difficult to cut. How could you increase the pushing effect of the force?

You could:

- increase the force on the knife; as the force increases, the pressure increases
- use a sharper knife (a **sharp** knife has less **surface area** in contact with the clay); as the area decreases, the pressure increases.

The equation linking pressure, force and area is:

$$\text{pressure} = \frac{\text{force}}{\text{area}}$$

Pressure is force divided by area. The unit of force is the newton. The unit of area is the metre squared. That means the unit of pressure is **newtons per metre squared**, or $N/m^2$.

Sometimes you can use smaller areas, measured in $cm^2$. If the area is in $cm^2$ then the unit of pressure will be $N/cm^2$.

If the area was in $mm^2$, the unit of pressure would be $N/mm^2$.

Some things have large areas to decrease pressure; others have small areas to increase pressure.

The camel has large feet. This means the force from the weight of the camel is applied over a large area. The pressure on the sand is decreased, so the camel will not sink in the sand.

The woman in the picture is lying on a bed of nails. Each nail has a sharp **point** on the end. The weight of the woman acts on many hundreds of nails, so the pressure from each nail is very small.

One end of this pin has a sharp point. The sharp point has a small area to increase pressure. The increased pressure means the pin will easily go into wood or card.

The other end has a larger surface area to decrease pressure. The decreased pressure means this part of the pin will not go into your finger.

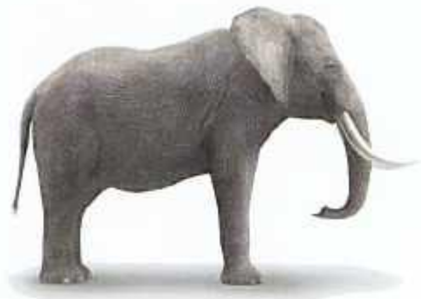
Scissors have sharp blades. The area along the cutting edge of each blade is small. This increases the pressure, making things easier to cut.

# Calculating pressure

## Worked example

### Question

An elephant stands on four feet.



The weight of the elephant is 50 000 N. The total area of all four feet is $0.4\,m^2$.

What is the total pressure that the elephant exerts on the ground?

### Answer

$$\text{pressure} = \frac{\text{force}}{\text{area}}$$

$$= \frac{50\,000}{0.4}$$

$$= 125\,000\ \text{N/m}^2$$

The unit of pressure here is $N/m^2$ because the area is given in $m^2$.

### Question

The total weight of a bicycle and rider is 1000 N.

The bicycle has two tyres in contact with the ground. The weight is supported equally on both tyres.

The area of each tyre in contact with the ground is $5\,cm^2$.

What is the pressure that each tyre exerts on the ground?

### Answer

$$\text{weight on each tyre} = \frac{1000}{2}$$

$$= 500\ \text{N}$$

$$\text{pressure} = \frac{\text{force}}{\text{area}}$$

$$= \frac{500}{5}$$

$$= 100\ \text{N/cm}^2$$

The unit of pressure here is $N/cm^2$ because the area of the tyres is given in $cm^2$.

### Worked example

**Question**

A hammer is used to push a nail into wood.

The area of the point at the end of the nail is $1.5\,\text{mm}^2$

The pressure needed for the nail to go into the wood is $50\,\text{N/mm}^2$

Calculate the force needed from the hammer.

**Answer**

$$\text{pressure} = \frac{\text{force}}{\text{area}}$$

$$\begin{aligned}\text{so, force} &= \text{pressure} \times \text{area}\\ &= 50 \times 1.5\\ &= 75\,\text{N}\end{aligned}$$

## Questions

1 a Write down the equation that links pressure, force and area.

  b Use the equation to explain why:

    i a nail that goes into wood has a sharp point

    ii shoes for walking on snow are wide and flat.

2 Write down the unit of pressure when force is in newtons and area is in:

  a $\text{m}^2$  b $\text{cm}^2$  c $\text{mm}^2$

3 A box has a weight of 60 N. The area of the box in contact with the ground is $0.5\,\text{m}^2$.

  Calculate the pressure that the box exerts on the ground. Show your working and give your answer in $\text{N/m}^2$.

4 A car has a weight of 8000 N. The car is supported by four tyres. The weight on each tyre is equal.

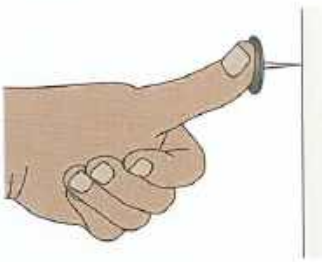
  The area of **one** tyre in contact with the ground is $150\,\text{cm}^2$.

  Calculate the pressure that **one** tyre exerts on the ground. Show your working and give your answer in $\text{N/cm}^2$.

5 A thumb tack has an area of $0.5\,\text{mm}^2$ in contact with a wall.

  A pressure of $40\,\text{N/mm}^2$ is needed for the thumb tack to go into the wall.

  Calculate the force needed to push the thumb tack into the wall. Show your working and give the unit with your answer.



## Think like a scientist

### Calculating pressure

In this investigation, you will investigate how the pressure that a person exerts on the floor varies.

Work in groups of two or three.

You will need:

- a person who is willing to be weighed, or who knows their body mass
- a bathroom scale, if body mass is not known
- sheets of squared paper
- pencil

#### Method

1 Measure or record the body mass of the person.

2 Convert the mass to weight using:

weight in N = mass in kg × strength of gravity in N/kg

Take the strength of gravity as 10 N/kg.

3 Ask the person to place one foot on a piece of squared paper. They can do this while wearing shoes.

4 Use the pencil to draw around the foot of the person.

#### Questions

1 Use the shape of the outline on the squared paper to work out the area of the foot in $cm^2$.

2 Calculate the area of both feet.

3 Calculate the pressure that the person exerts on the ground when they are:

a standing equally on both feet

b standing on one foot.

4 Explain the difference in your answers to **3a** and **3b**.

5 Now ask the same person to put the front of one foot on squared paper as if they were standing on their toes.

Use the same method as above to work out the area of the front of the foot in $cm^2$.

6 Calculate the pressure exerted by the person on the ground when standing on the front of one foot.

7 A person can be supported by the front of one foot during some everyday activities. Give an example of such an activity.

Continued

8 a Describe how you could work out the area in contact with the ground when the person is lying down.

b i Predict how the pressure would change when the person was lying down compared to standing.

ii Explain your answer.

## Self-assessment

1 Decide how confident you are about:

a how force affects pressure

b how area affects pressure.

2 Decide how confident you are about:

a calculating pressure when you know the force and the area

b working out the unit of pressure using the units of force and area.

## Summary checklist

- [ ] I understand that pressure is the pushing effect of a force.
- [ ] I know and can use the equation that links pressure, force and area.
- [ ] I understand how the unit of pressure can be worked out from the units of force and area.

# › 3.6 Pressure in liquids and gases

## In this topic you will:

- recall how particles move in liquids and gases
- understand how particle movement causes pressure in liquids and gases
- predict how changes in liquids and gases affect the pressure.

## Getting started

Work individually.

Draw a diagram to show how particles are arranged in:

**a** a liquid **b** a gas.

## Key words

altitude

atmospheric pressure

collide

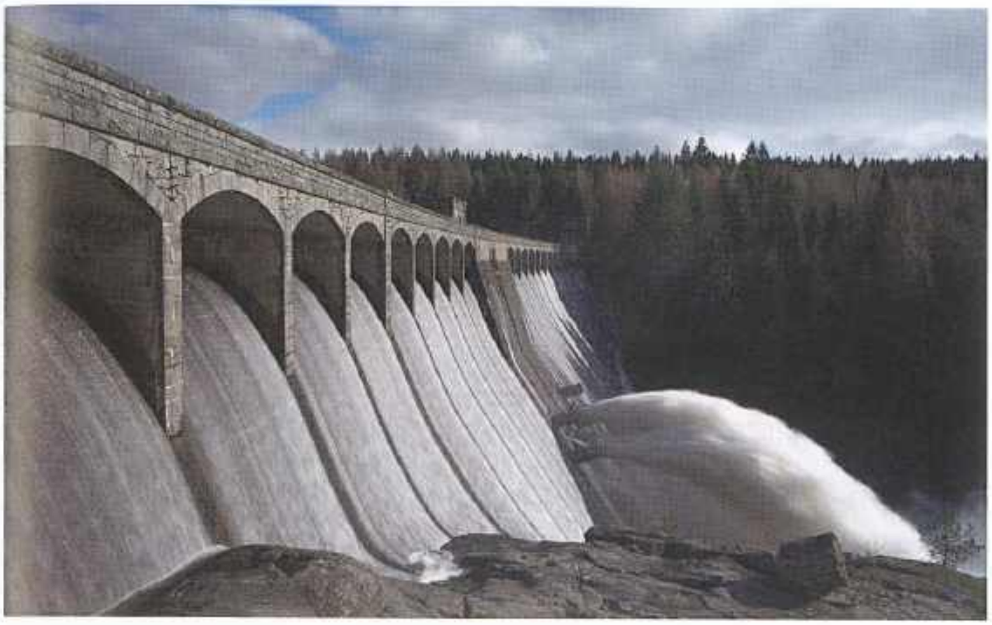
container

depth

sea level

# Pressure in liquids

Look at the picture of a dam. The wall of this dam is wider at the bottom than it is at the top.



Behind the wall of the dam, the water is almost to the top of the wall.

You can see water coming out from two levels.

The water coming out close to the top is coming out with less force.

The water coming out from further down is coming out with more force.

This is because pressure in the water increases with depth.

The wall is wider at the bottom to make the wall stronger where the pressure from the water is greatest.

## Pressure and depth in liquids

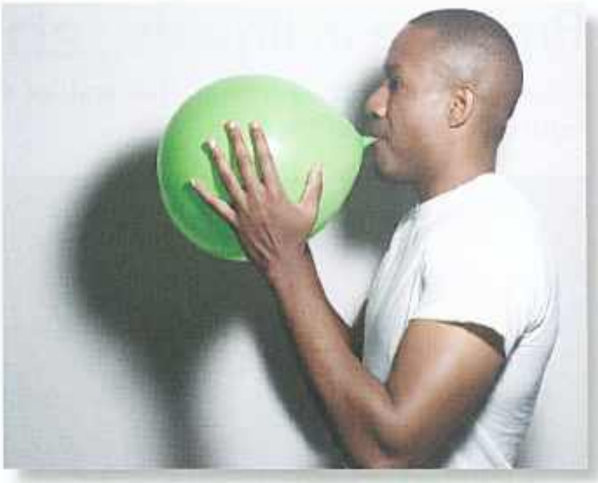
The pressure in a liquid increases with **depth**, but why?

As you go deeper in a liquid, there is more liquid above you. The weight of this liquid, caused by gravity, pushes on the particles of the liquid.

When the particles of the liquid are pushed, the force on the particles increases.

As the particles in a liquid are moving randomly in all directions, then the pressure in the liquid is equal in all directions.

# Pressure in gases

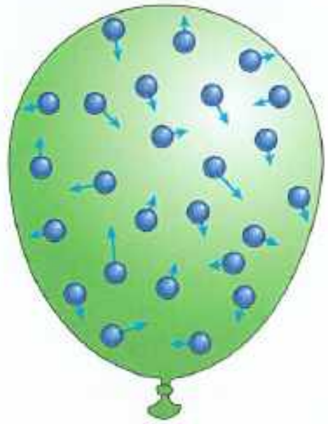


Before you blow up a balloon, there is a small volume of air inside the balloon. The balloon is open at one end, so the pressure of the air inside is the same as the pressure of the air outside.

As you blow air into the balloon, you are adding more gas particles.

Particles in a gas move randomly and **collide** with the walls of the **container**. The container is the balloon.

Every time a gas particle collides with the wall of the container, the particle exerts a small force on the wall.



The more particles there are in the gas, the more collisions happen with the walls, and so the force on the walls increases.

As this force is exerted on an area, the force causes pressure.

The pressure inside the balloon gets bigger as you blow in more air, pushing the walls of the balloon outwards.

Look at the tyre in this picture.

The air inside the tyre is at low pressure. The pressure is not enough to support the weight of the vehicle.

If more air is put inside the tyre, the pressure will increase. More collisions will happen with the inside walls of the tyre, pushing the tyre outward and supporting the vehicle.

## Pressure and depth in gases

As with liquids, the pressure in a gas increases with depth.

Most people on Earth live at low **altitude**. Altitude is height above **sea level**.

The Earth's atmosphere, which we call air, is made from gases. The atmosphere extends to a height of about 400 km above sea level.

Sea level is, therefore, where the atmosphere is at its deepest. So, at sea level, **atmospheric pressure** is highest.

As you go higher in the atmosphere, two variables that affect atmospheric pressure change:

- the number of particles in 1 $m^3$ of air decreases, so the concentration of gas particles decreases
- the weight of air above your current position decreases.

Atmospheric pressure at sea level is about 100 000 $N/m^2$. This pressure is the equivalent of the weight of two large elephants pushing on every 1 $m^2$ of surface! We are not aware of the pressure from the atmosphere because we live in the atmosphere all the time.

## Effects of atmospheric pressure

The effect of atmospheric pressure can be shown by pumping the air out of a metal container.

Before the air is pumped out, the pressure on the inside of the container is equal to the pressure on the outside.

When the air is pumped out, the pressure inside the container becomes close to zero. The pressure on the outside does not change.

The container is crushed by the pressure of the air outside the container. The picture shows a container crushed by atmospheric pressure.

# Pressure and temperature in gases

As the temperature of a gas increases, the speed of the particles in the gas increases.

When particles are travelling faster, their collisions exert more force.

This means that increasing the temperature of a gas will increase the pressure of the gas.

High pressure can be used to cook food.

The picture shows a type of cooking pot called a pressure cooker.

Water and food are placed inside the pressure cooker. The pressure cooker has a sealed lid. When the water boils, the steam cannot escape so the pressure of the gas inside increases. This increases the temperature.

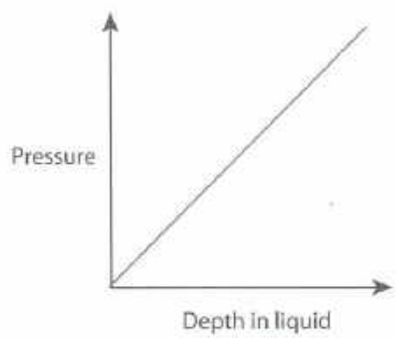
On top of the pressure cooker, there is a weight to control the pressure and valves that allow steam to escape, once the required pressure has been reached.

## Questions

1 a Submarines are ships which are designed to go underwater. Explain why submarines that go to the deepest parts of the oceans must be very strong.

b Explain why the wall of a dam is thicker at the bottom than at the top.

2 The sketch graph shows how the pressure in a liquid changes with depth in the liquid.




a Explain the pattern shown in the graph.

b Copy and complete the sentence using the best word. Use information in the graph.

When the depth in the liquid doubles, the pressure in the liquid ................ .

3 A fish is in water. The water exerts pressure on the fish.

Which of these causes pressure on the fish? Write **one** letter.

A The weight of water beside the fish.

B The weight of water all around the fish.

C The weight of water above the fish.

D The weight of water below the fish.

4 Marcus plays basketball. The ball is filled with air.

  a Explain what causes the pressure inside the ball.

  b Explain how putting more air in the ball will change the pressure inside the ball.

  c Marcus notices that the pressure inside the ball is lower on a cold day and higher on a hot day.

  Explain why the pressure inside the ball is higher on a hot day.

5 A metal container is connected to a vacuum pump. The vacuum pump removes all the air from inside the metal container.

  There is now a vacuum inside the metal container.

  a Explain why the pressure in a vacuum is zero.

  b The metal container collapses when there is a vacuum inside. Explain why.

## Think like a scientist

### Observing the effects of pressure

*Part 1: Pressure and depth in liquids*

In this investigation, you will observe the effect of pressure increasing with depth in water.

Work in groups of two or three.

**You will need:**

- 1- or 2-litre empty plastic bottle
- adhesive tape
- something to make small holes in the side of the bottle
- large tray or sink to collect water

#### Method

1 Make three small holes in the side of the bottle at different heights. Try to make the holes the same size.

2 Predict what will happen when the bottle is filled with water.

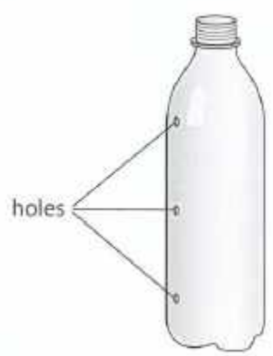
3 Now use one piece of adhesive tape to cover all the holes.

4 Place the bottle in the tray or the sink.

5 Fill the bottle with water, but do **not** put the lid on the bottle.

6 Pull off the adhesive tape to open the holes.

7 Watch what happens.



Continued

### Questions

1 Did your observation fit with your prediction?

2 Draw a labelled diagram to show what you observe.

3 Explain what you observed, using ideas about pressure.

*Part 2: Pressure and temperature in gases*

In this activity, you will observe the effect of changing temperature on the pressure in a gas.

Work in groups of two or three.

**You will need:**

- empty plastic bottle (0.5–2 litre) with lid
- access to a warm place
- access to a cold place, such as a refrigerator

### Method

1 Take the lid off the bottle.

2 Leave the bottle and the lid in a warm place for 5–10 minutes.

3 Put the lid tightly on the bottle **without** squeezing the bottle. Do this while the bottle is still in the warm place.

4 Put the bottle into a cold place for 15–20 minutes.

5 Observe what has happened to the bottle.

### Questions

4 Draw a diagram of the bottle before **and** after the activity.

5 What happened to the pressure of the air inside the bottle when it was moved to the cold place?

6 Explain your answer to **5**.

7 Predict what would happen if you did this activity the other way around. The open bottle starts in the cold place, then the closed bottle is taken to a warm place.

Include ideas about particles and pressure and include the observation that you would make.

Continued

### Peer-assessment

Swap your answers for these activities with another group.

Rate their score for **each** answer on a scale of 0–3.

3 means very good and well explained.

2 means good with some explaining.

1 means difficult to understand, but some explaining is given.

0 means you cannot understand the answers or they are incorrect.

## Summary checklist

- ☐ I understand what causes pressure in a liquid.
- ☐ I understand how pressure changes with depth in a liquid.
- ☐ I understand what causes pressure in a gas.
- ☐ I understand how altitude affects atmospheric pressure.
- ☐ I understand how the quantity of gas in a container affects the pressure.
- ☐ I understand how the temperature of a gas in a closed container affects the pressure.

# 3.7 Particles on the move

## In this topic you will:

- describe how random movement of particles causes diffusion
- understand how diffusion happens in liquids and gases.

## Getting started

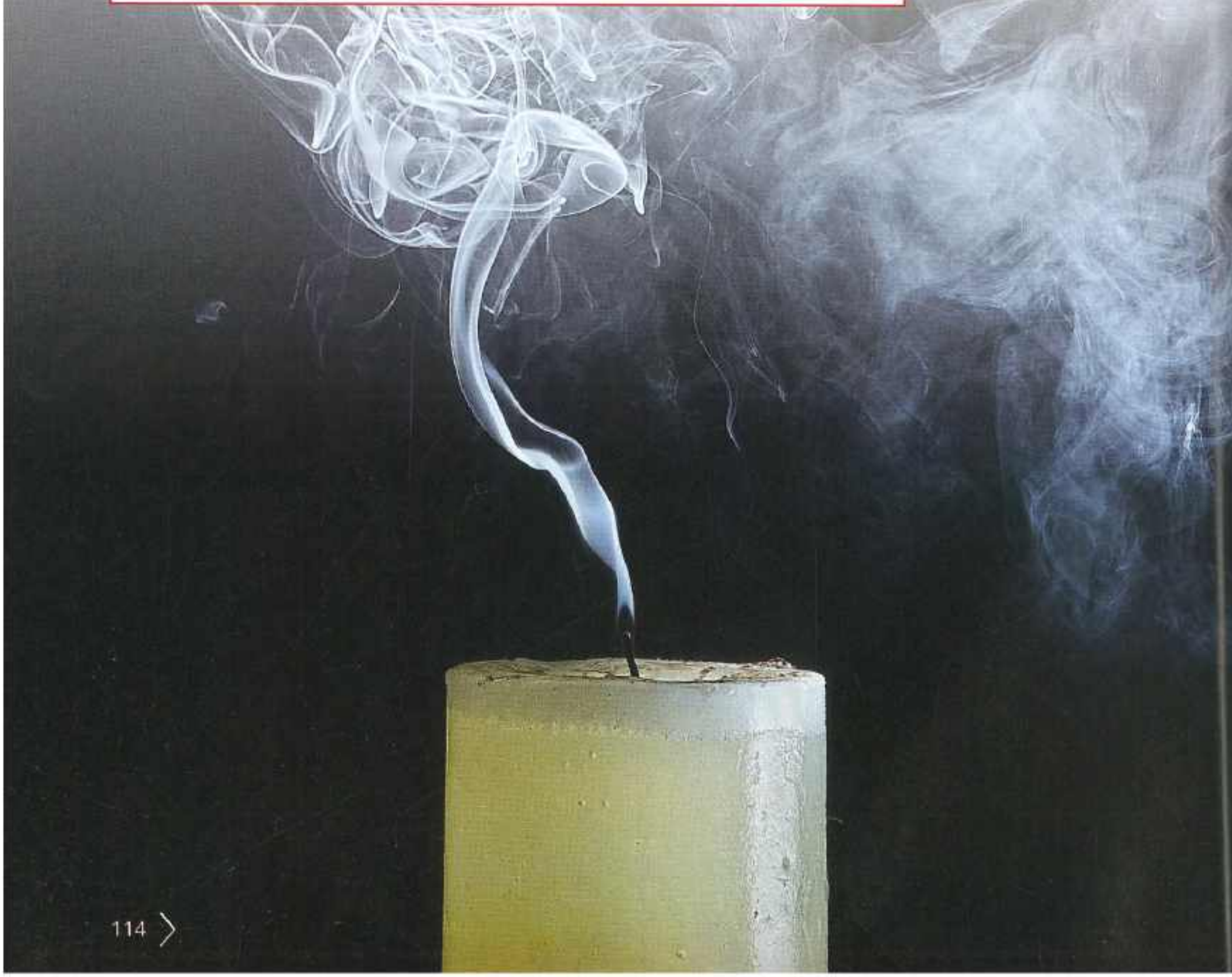
Work in groups to discuss the answers to these questions.

1 How can you smell food cooking when you are some distance away from the food?

2 When you pour orange juice into water, why does all the liquid eventually turn orange?

## Key words

concentration



# Mixing gases

The particles in a gas move randomly. Both the speed of the particles and the direction of the particles are random.

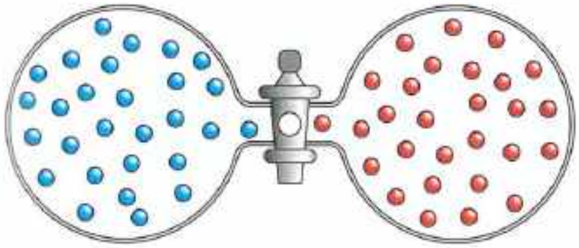
If we mix two gases in one container, each one will have particles that move randomly.

That means each gas will spread to fill the container.

The movement of the particles of each gas is called diffusion.

Diffusion means the overall random movement of particles from an area where they are in higher **concentration** to an area where they are in lower concentration. Concentration is the number of particles in a particular volume.

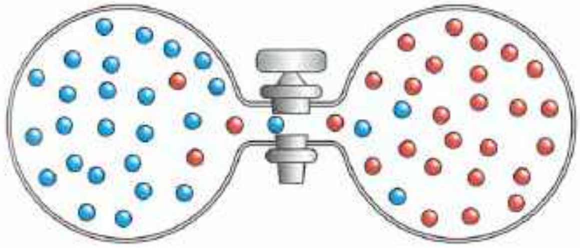
Look at the diagrams. They show how two gases diffuse.



1 At the start, the tap is closed.

The blue gas particles are at high concentration on the left, and zero concentration on the right.

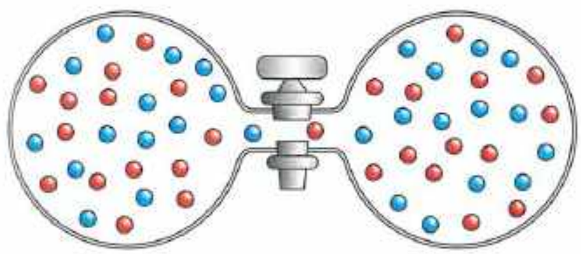
The red gas particles are at high concentration on the right, and zero concentration on the left.



2 The tap is opened and the gases start to spread out (diffuse). At random, some particles of each gas will pass through the space where the tap opens.

The blue gas particles are now at quite high concentration on the left, and low concentration on the right.

The red gas particles are at quite high concentration on the right, and low concentration on the left.



3 After some time, the gases have completely diffused.

There is equal concentration of both gases on both sides.

Diffusion stops when the concentrations are equal. However, the movement of individual particles does not stop when diffusion stops.

Diffusion explains how you can smell food when it is cooking.

When food is heated, some particles in the food change state and become gas.

The gas particles from the food move randomly and so spread out through the air by diffusion.

The strength of the smell will get stronger as you move closer to the food. This is because the concentration of the particles is higher, the closer you get to the source of the particles.

Many animals use this change in strength of smell to find food.

# Mixing liquids

Diffusion also happens in liquids. Particles in a liquid also move at random.

The picture shows what happens when blue ink is added to water.

The blue ink moves from the area of high concentration to the areas of low concentration, until it is completely diffused throughout the water.

# Speed of diffusion

The speed of diffusion depends on:

- the difference in concentration of the particles
- temperature.

The bigger the difference in the concentrations of the particles, the faster the diffusion.

The higher the temperature, the faster the diffusion. Higher temperature makes particles move faster, so the particles can spread out faster.

For example, when you make a cup of tea, the tea diffuses through the water. It diffuses faster in hot water than it does in cold water.

## Questions

1 Zara's mother opens a bottle of perfume. Zara is at the other side of the room.

After a few minutes, Zara can smell the perfume.

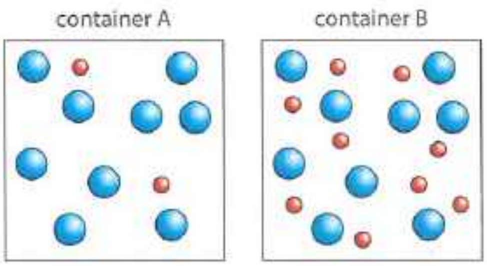
- a Which of these explains why Zara smells the perfume? Write **one** letter.
  - A All the gas particles of the perfume move in one direction.
  - B All the gas particles of the perfume move randomly.
  - C All the particles in the air move in one direction.
  - D All the particles in the air are stationary (not moving).
- b Which of these changes would result in Zara smelling the perfume in a shorter time?

  In each case, **no** other variable changes.

  Write the letters for **all** the correct statements.
  - A The perfume in the bottle is at a higher temperature.
  - B Zara moves further away from the bottle of perfume.
  - C Zara's mother puts the lid on the perfume bottle.
  - D The air in the room is at a lower temperature.

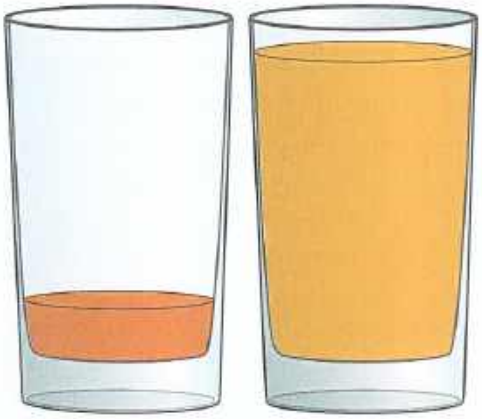
2 Describe what is meant by the term 'diffusion'.

3 The diagram shows two types of particle in containers, A and B. The containers have the same volume.




- a Explain whether the particles in the containers are in a solid, liquid or gas state.
- b Explain how the concentrations of the blue particles compare in containers A and B.
- c Explain how the concentrations of the red particles compare in containers A and B.

4 Sofia is making an orange flavour drink. She pours a small volume of concentrated orange juice into a glass. She then adds water until the glass is full.



- a Explain how the orange colour from the juice spreads into the water.
- b Sofia says: 'When the orange colour has stopped spreading, the particles in the liquid have stopped moving.'

  Explain whether Sofia is correct.

5 Which of these will result in diffusion?

Write the letters for **all** the correct statements.

A Adding milk to coffee.

B Adding sand to water.

C Adding salty water to pure water.

D Allowing gas from a cylinder to escape into the air.

E Throwing small pieces of rock into the air.

## Activity 3.7.1

### Watching diffusion

In this activity, you will observe the diffusion of a coloured solution in water.

**You will need:**

- transparent container, such as a 200 $cm^3$ (or larger) glass beaker
- water
- water-soluble ink or food dye
- dropper pipette
- glass tube or drinking straw

### Method

1. Fill the container with warm water.
2. Leave the container to stand for a few minutes so the water stops moving.
3. Use the dropper pipette to carefully add one or two drops of ink or food dye to the bottom of the container. Squeeze the top of the pipette gently so it does not squirt out into the water and start mixing.
4. Observe what happens.

### Questions

1. Write about what you did in this activity. Write this in your own words and do not copy the method shown here.
2. Make a series of labelled drawings to show your observations in this activity.
3. Predict what would happen if the activity was repeated with water at a higher temperature.

## Think like a scientist

### The effect of temperature on the speed of diffusion

In this investigation, you will investigate how temperature affects the speed of diffusion in liquids.

Work in groups of two or three.

**You will need:**

- three or more identical beakers
- water
- a way to heat the water
- a way to cool the water (optional)
- water-soluble ink or food dye
- measuring cylinder
- thermometer
- dropper pipette
- stopwatch

#### Method

1. Add equal volumes of water at different temperatures to each of your beakers.
2. Measure and record the temperature of the water in each beaker.
3. Use the dropper pipette to carefully add a small volume of ink or food dye to the bottom of each beaker. Squeeze the top of the pipette gently so it does not squirt out into the water and start mixing.

   Add the ink or food dye to the water in order from the lowest to the highest temperature.
4. Use a stopwatch to time the diffusion process in each beaker.
5. Stop the stopwatch when the ink or food dye has fully spread out through the water of the beaker being tested.

#### Questions

1. Describe the trend in your results.
2. Explain this trend.
3. Explain why you used the same volume of water in all the beakers.
4. Suggest at least **two** improvements to the method that would give more reliable results.

#### Peer-assessment

Swap your answers with another group.

You will assess their answers to questions **2** and **4**.

Instead of marking their answers, write some feedback to the group.

Include:

- what they have done well in their answers
- how they could improve their answers.

## Summary checklist

- [ ] I know how to describe diffusion.
- [ ] I understand how diffusion happens in gases.
- [ ] I understand how diffusion happens in liquids.
- [ ] I understand that the speed of diffusion is affected by the difference in concentration and by the temperature.

## Project: Making a balance for weighing

This project is about using moments to find the weights of objects. You will make a balance and then use it to find some unknown weights.

### Background

The earliest balances for weighing needed equal weights on both sides of the balance.

The unknown weight was placed on one side, and known weights were added on the other side until the system balanced.

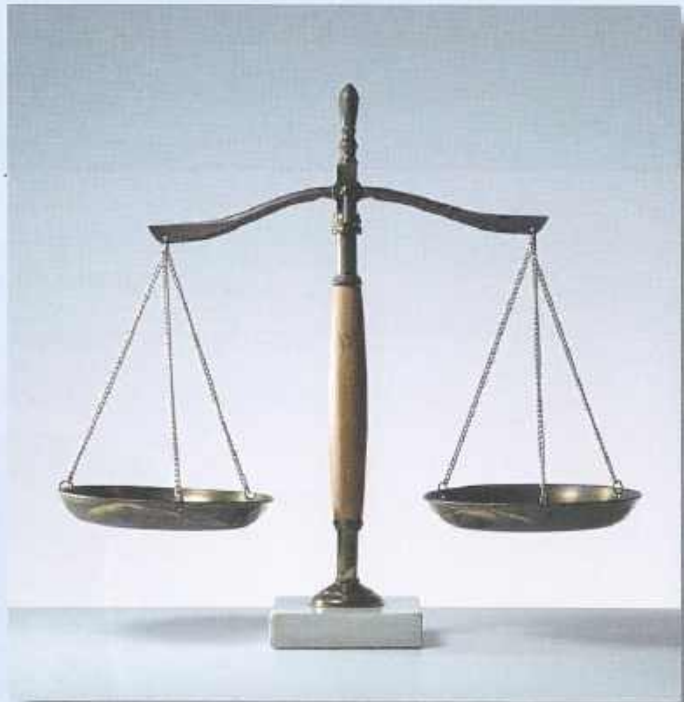
A system such as this is balanced because there are two moments acting.

One moment tries to pull one side down.

The other moment tries to pull the other side down.

When the moments are equal and opposite, the system is balanced.

This happens when the weights are equal because the distances from the pivot are also equal.



### Your task

Make a balance that can be used to weigh a range of different weights **without** changing the known weight.

Your balance will work in a different way to the one in the picture, so yours will **not** look like this.

Work in groups.

You can use equipment such as:

- a metre rule
- a triangular prism
- a known weight
- any other equipment that your teacher makes available.

## Continued

Remember:

- do not confuse weight with mass
- weight is a force
- the moment caused by a force depends on the distance from the pivot.

When your balance is made and working, you can demonstrate to the class how it works.

## Check your progress

**3.1** An object has balanced forces acting on it.

Which of these describes the movement of the object? [1]

Write **two** letters.

A The object could be moving at a constant speed in a straight line.

B The object could be moving at a constant speed in a circle.

C The object could be stationary.

D The object could be getting faster in a straight line.

**3.2** Describe the effects of the unbalanced forces on each of these objects.

a A bicycle is moving in a straight line. There is an unbalanced force opposite to the direction the bicycle is moving. [1]

b A car is moving in a straight line. There is an unbalanced force in the same direction as the car is moving. [1]

c A ball is moving in a straight line. There is an unbalanced force sideways to the direction the ball is moving. [1]

**3.3** Which of these is the standard unit of speed used by scientists? [1]

Write **one** letter.

A km/h

B m/s

C $N/cm^2$

D Nm

**3.4** Marcus goes running. After some time, Marcus gets tired and starts walking. Marcus does **not** stop.

Sketch a distance/time graph for Marcus. [3]

**3.5** A train travels a distance of 550 m in 10 s at a constant speed.

a Draw a distance/time graph for the train. [4]

b Calculate the speed of the train. Show your working and give the unit with your answer. [3]

**3.6** There have been different units of measurement throughout history.

This picture shows the unit of length called the rod.

One rod is the total length of the left feet of 16 people.

In the picture, the 16 people have been chosen at random.

**a** Explain **one** disadvantage with using the rod as a unit of length. [1]

**b** Explain **one** advantage of using the rod as a unit of length. [1]

**3.7** Zara has a metre rule, a stopwatch and a forcemeter.

Zara can directly measure some quantities with this equipment.

Zara must calculate some quantities that cannot be directly measured using this equipment.

Draw a table with these headings.

| Can be measured | Must be calculated |
|---|---|
| | |

Write each of these quantities into the correct column in the table. [2]

force moment length area pressure time speed

**3.8** **a** Write the equation that links moment, force and distance. **[1]**

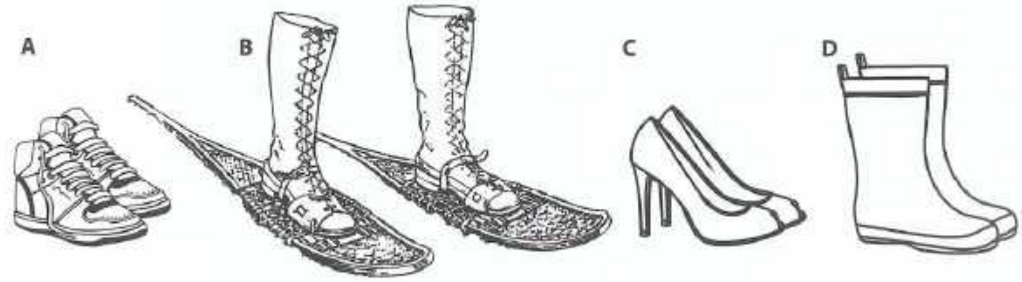
**b** Arun is trying to turn a nut with a spanner.

Arun exerts his maximum force on the spanner, but the nut will **not** turn.

Explain why Arun can make the nut turn if he uses a longer spanner. **[2]**

**3.9** **a** Write the equation that links pressure, force and area. **[1]**

**b** The picture shows four different types of shoes.




Write the letter of:

i the shoes that would be best for **not** sinking in snow **[1]**

ii the shoes that could make holes in a soft wood floor. **[1]**

**3.10** Which statement is true about a liquid? **[1]**

Write **one** letter.

**A** Pressure increases with depth.

**B** Pressure decreases with depth.

**C** Pressure does not depend on depth.

**D** There is no pressure in a liquid.

**3.11** Write down **two** variables that will increase the speed of diffusion of a gas. **[2]**

# 4 Ecosystems

## > 4.1 The Sonoran Desert

### In this topic you will:

- find out about some of the animals and plants that live in a desert
- think about how these animals and plants interact with each other
- learn what an ecosystem is
- think about some of the different habitats in a desert ecosystem.

### Getting started

Cacti (the plural of cactus) are plants that are adapted to live in deserts.

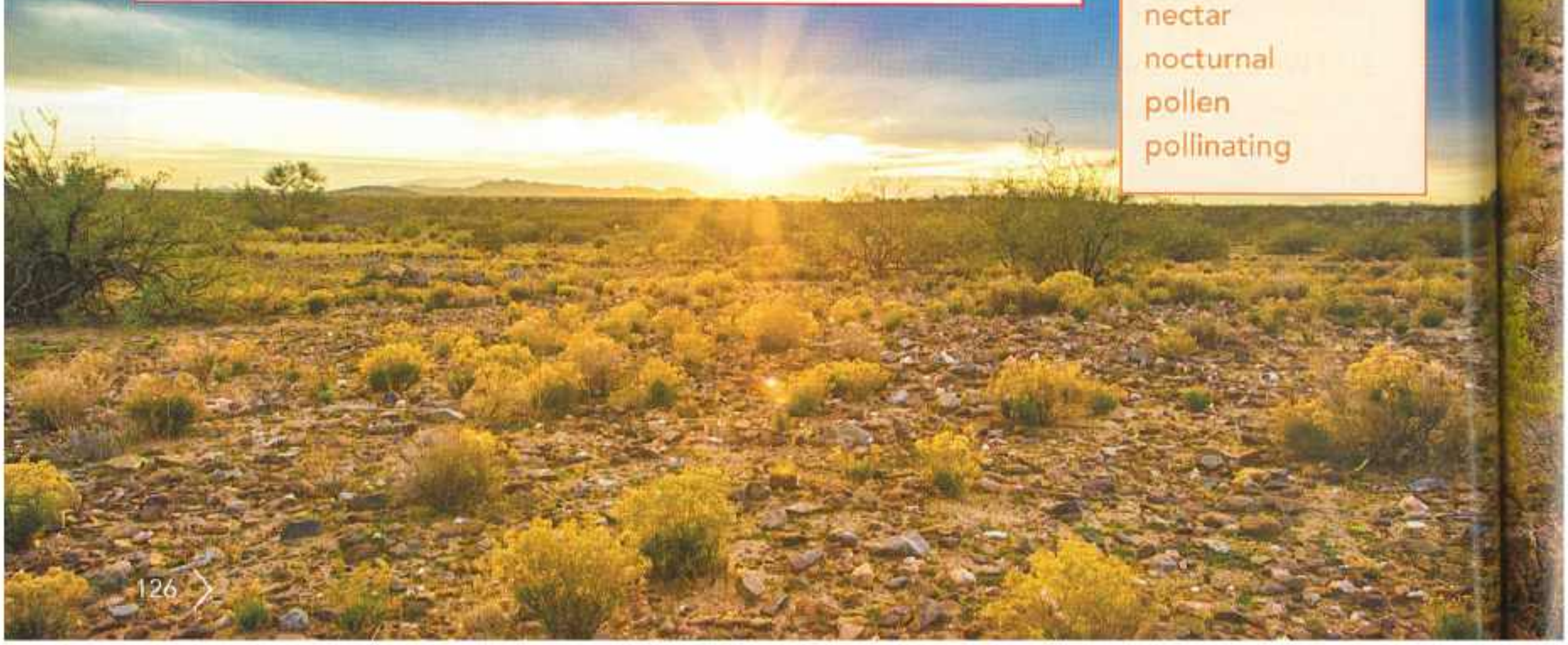
Look at a cactus, or a picture of one.

With a partner, discuss these questions.

- Why is a desert a difficult place to live?
- How are cacti adapted to live in a desert?

### Key words

adaptations
ecology
ecosystem
environment
food web
habitat
interact
nectar
nocturnal
pollen
pollinating



## A desert in Arizona

The photograph shows the Sonoran Desert in Arizona, in the USA.

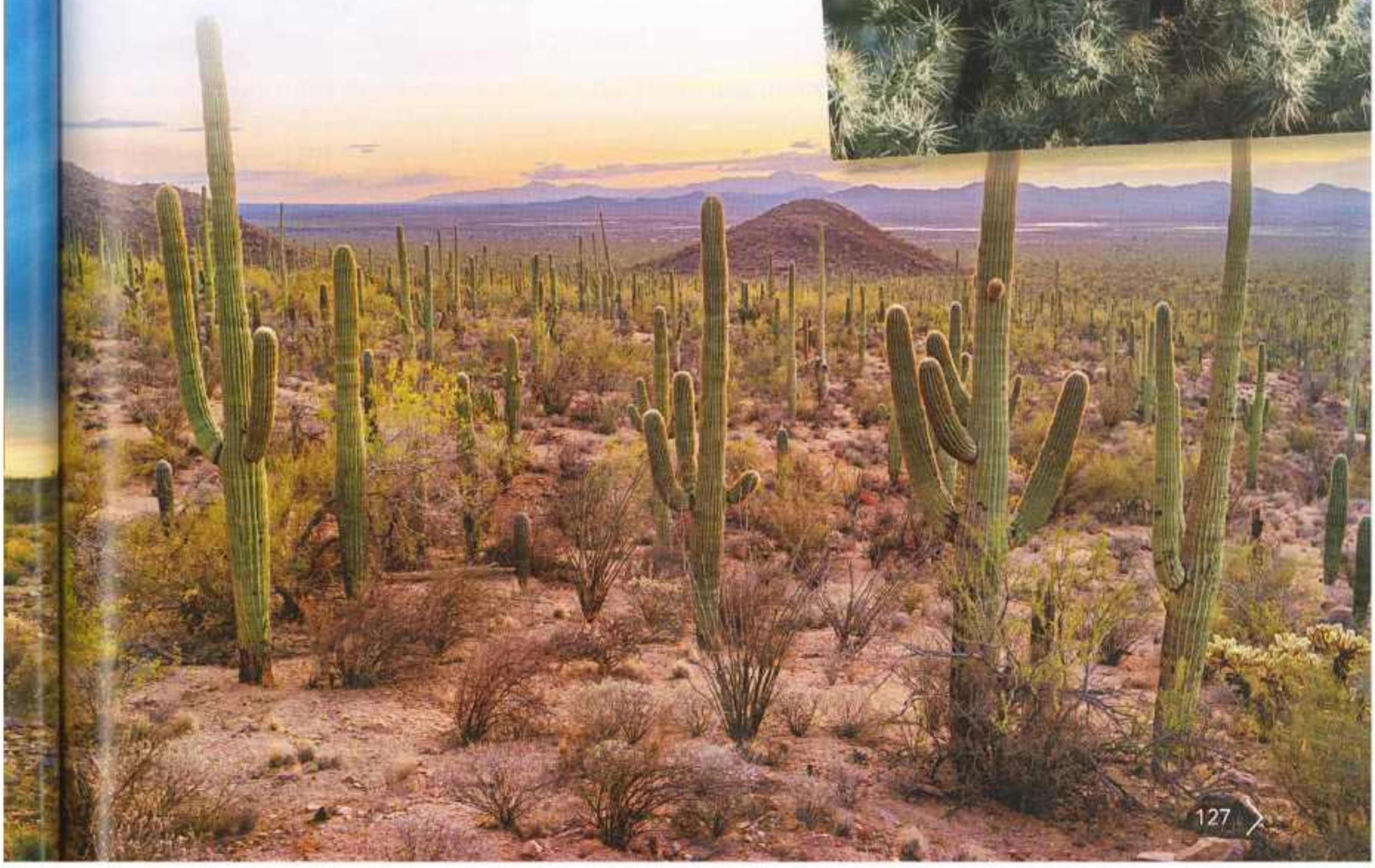
Deserts are not easy places for animals and plants to live. Deserts do not get much rainfall, so the organisms that live there must have **adaptations** that help them to survive with little water.

The tall plants in the photograph are saguaro cacti. They grow very slowly. The ones in the photograph may be more than 100 years old. Their roots spread out widely just underneath the soil, ready to absorb any rain that falls.

Many animals live among the cacti and other desert plants.

Gila woodpeckers make holes in the cacti, to make their nests. Other birds also visit these holes.

Cactus wrens often use a different kind of cactus, called a teddy bear cholla, to make their nests. Teddy bear chollas are so spiky that very few other animals will get close to them. So the cactus wren's eggs and young ones are protected from predators.



During the hot days, lizards, tortoises and other animals rest in the shade of the plants, or burrow into the soil where it is cooler. At night, when the temperature falls, kangaroo rats come out to feed, wary of their predators such as rattlesnakes and coyotes.

In the Sonoran Desert, it usually rains heavily at least once a year. When the rains come, the desert is transformed. Many plants quickly produce flowers.

Insects feed on the **nectar** and **pollen** in the flowers, helping the plants to reproduce by **pollinating** them. At night, bats feed on nectar from the flowers of agave plants.

Seeds fall to the ground and are collected by ants, to take into their nests to provide a food store. Many months or years later, some of the uneaten seeds may germinate to produce new plants.

## Interactions in the Sonoran Desert

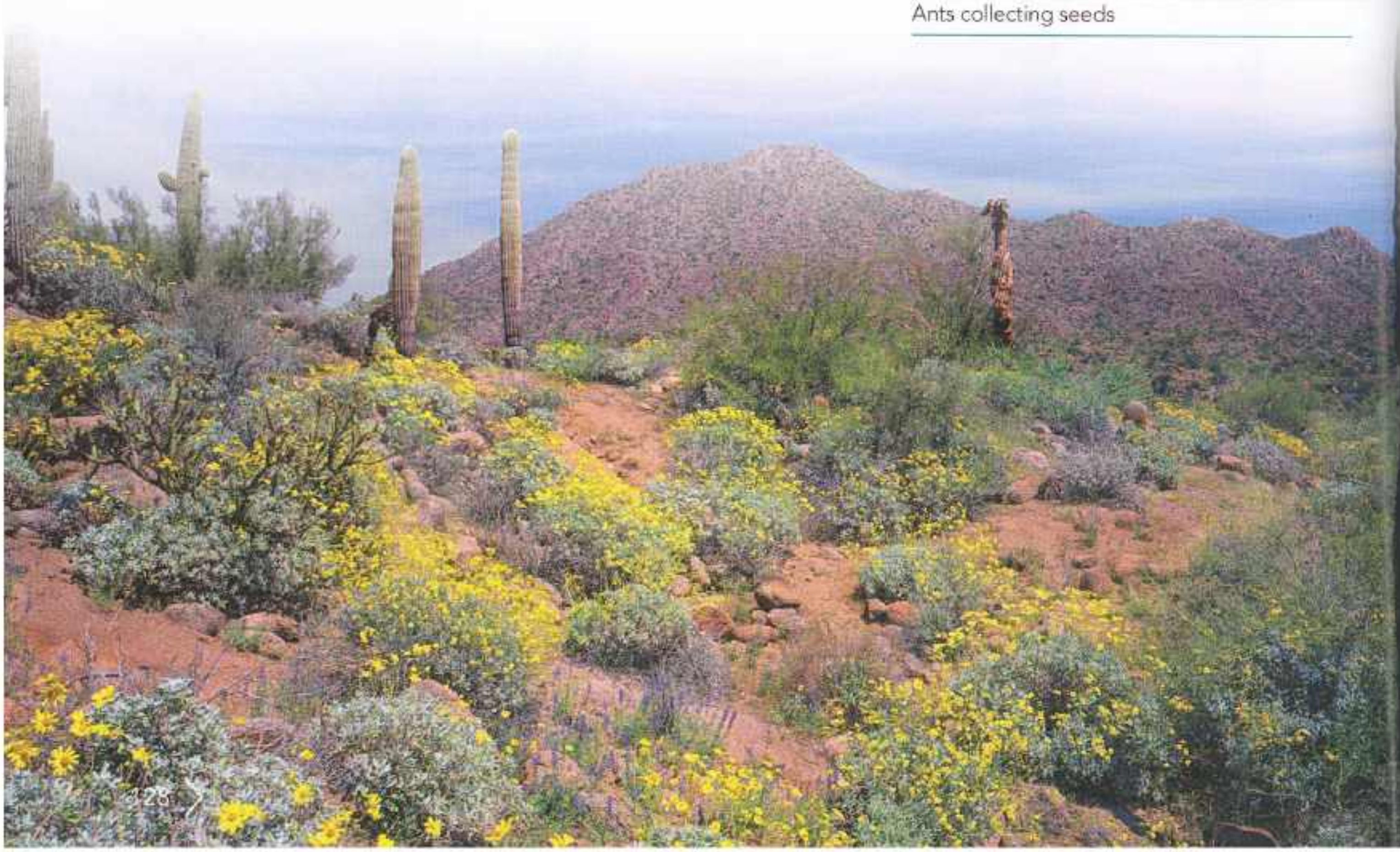
As you read the information above, and looked at the photographs, you may have realised that all the different animals and plants depend on each other.

They **interact** with each other. The actions of one organism affect another.

A kangaroo rat

A bat feeding on agave nectar

Ants collecting seeds



## Activity 4.1.1

### Interactions between organisms in the desert

Work with a partner.

You will need:

- a large sheet of paper
- coloured pens
- (optional) pictures of the animals and plants in the desert, that you can cut out
- (optional) scissors and glue

Read the information about life in the Arizona Sonoran Desert, and look at the photographs. Make a list of different ways that the animals and plants interact with one another.

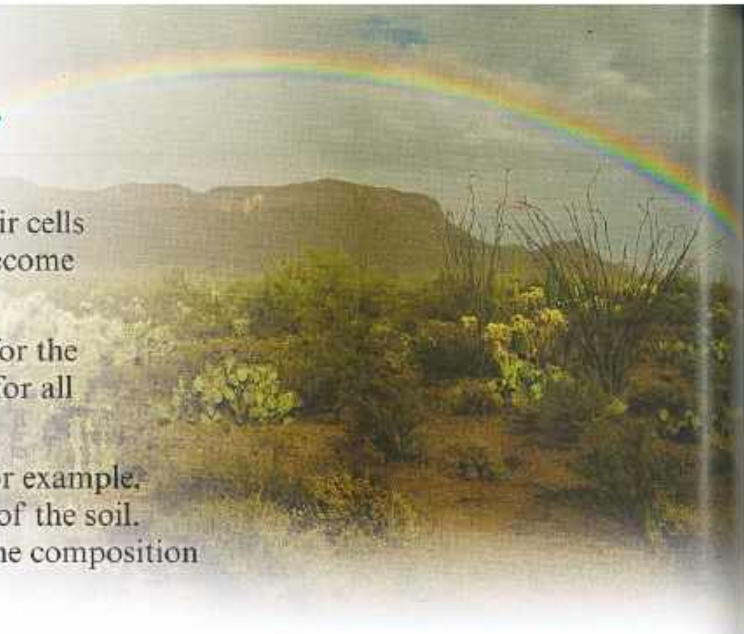
Now think about how you could show these interactions in a picture.
On a piece of rough paper, make a rough sketch of the design for your picture.

Build up your picture on a large sheet of paper. You could draw pictures of the organisms, or stick cut-out pictures of them onto the paper.
Write descriptions about how they interact with each other.

## Non-living things in the desert

It is not only other organisms that affect the plants and animals in the Sonoran Desert. There are also interactions between the organisms and the non-living parts of their **environment**.

- **Light**: The bright sunlight helps the plants to photosynthesise, producing food that other organisms can eat.
- **Temperature**: The temperature is often very high during the day, but much lower at night. Some animals are **nocturnal**, which helps them to avoid overheating or drying out. It is cooler underneath the soil, so some animals – such as the tarantula in the picture – dig burrows for shelter during the day.
- **Soil**: Rocks and soil provide minerals for the plants to grow, as well as building material for ground-nesting birds.



- **Water**: All organisms need water to keep their cells alive. Rain, when it comes, allows them to become more active and to reproduce.
- **Air**: The desert air provides carbon dioxide for the plants to use in photosynthesis, and oxygen for all the organisms to use in respiration.

The organisms also affect their environment. For example, droppings from the kangaroo rats become part of the soil. The gases that they take in and give out affect the composition of the air.

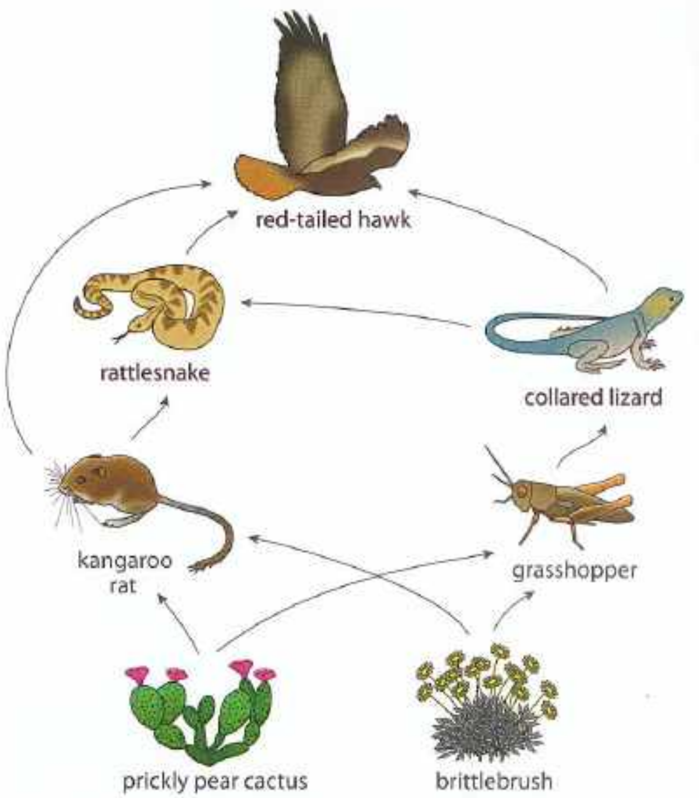
## The desert ecosystem

Everything in the desert interacts with everything else. All of these interactions make up the desert **ecosystem**. An ecosystem is a network of interactions between all the living organisms and the non-living things around them.

Some of the interactions in an ecosystem involve **food webs**. Remember that plants are the producers in a food web. They use energy in sunlight to make food.

As animals eat the desert plants and each other, the energy is passed through the desert food web.

Food webs are a very important part of the interactions in an ecosystem, but they are not the only interactions. For example, plants may provide places for some of the animals to make nests. Plant roots help to hold the soil together, so that it does not wash away when it rains. Animals help plants to reproduce by pollinating their flowers or spreading their seeds.




A food web in the Sonoran Desert

The interactions in an ecosystem are usually very complicated. The study of ecosystems is called **ecology**. No ecologist would ever claim to have discovered all of the different interactions in an ecosystem. There is always something new to find out, even in an ecosystem that scientists have been studying for a long time.

## Questions

1 Name the **two** producers in the diagram of a food web in the Sonoran Desert.

2 Explain why the food web could not exist without the producers.

3 What do the arrows in the food web represent?

4 Give **two** examples of interactions between organisms in the desert that are **not** to do with feeding.

# Habitats in a desert ecosystem

The place where an organism naturally lives is called its **habitat**. There are many different places to live in a desert.

- The habitat of a saguaro cactus is the open desert.
- The habitat of a Gila woodpecker is a saguaro cactus (where it makes its nest) and the air and ground in the open desert (where it collects food).
- The habitat of a desert ant is underneath the rocks and soil and on the soil surface.
- Termites live at the base of the saguaro stems.
- Sap beetles live inside the saguaro flowers.
- Kangaroo rats live in burrows and come out to look for food at night.

## Question

5 Explain the difference between an ecosystem and habitat.

## Activity 4.1.2

### How a species fits into the desert ecosystem

Work in a group of three or four for this activity.

You are going to choose **one** species that lives in the desert. You could continue to think about the Sonoran Desert in Arizona, or you could choose a different desert.

Investigate how your species interacts with other organisms, and with the non-living things around it. You could choose one of the species mentioned in this topic, or a completely different species.

Use the internet and the library to find out as much as you can about your species. Concentrate especially on how your species interacts with other organisms, and with its environment. For example, you could try to find out:

- what it eats, and what eats it
- the habitat it lives in within the desert ecosystem
- how the species is adapted to survive in its habitat
- how its actions (other than feeding) affect other organisms, or non-living parts of the ecosystem
- how other organisms and non-living things affect it (other than feeding).

Use your information to make an illustrated poster or presentation that you can share with the rest of your class.

### Questions

1 Where did you find the best and most interesting information?

2 When you used the internet to find information about your species:

   a which websites were most relevant for your research?

   b how did you choose websites that were most likely to provide correct information?

## Summary checklist

- [ ] I can describe some of the interactions between the organisms in a desert ecosystem.
- [ ] I can describe some of the interactions between the organisms and the non-living parts of the environment in a desert ecosystem.
- [ ] I can name some of the different habitats in a desert ecosystem.
- [ ] I can explain the difference between a habitat and an ecosystem.

# › 4.2 Different ecosystems

## In this topic you will:

- learn about some of the many different kinds of ecosystem on Earth
- describe some of the different habitats in an ecosystem.

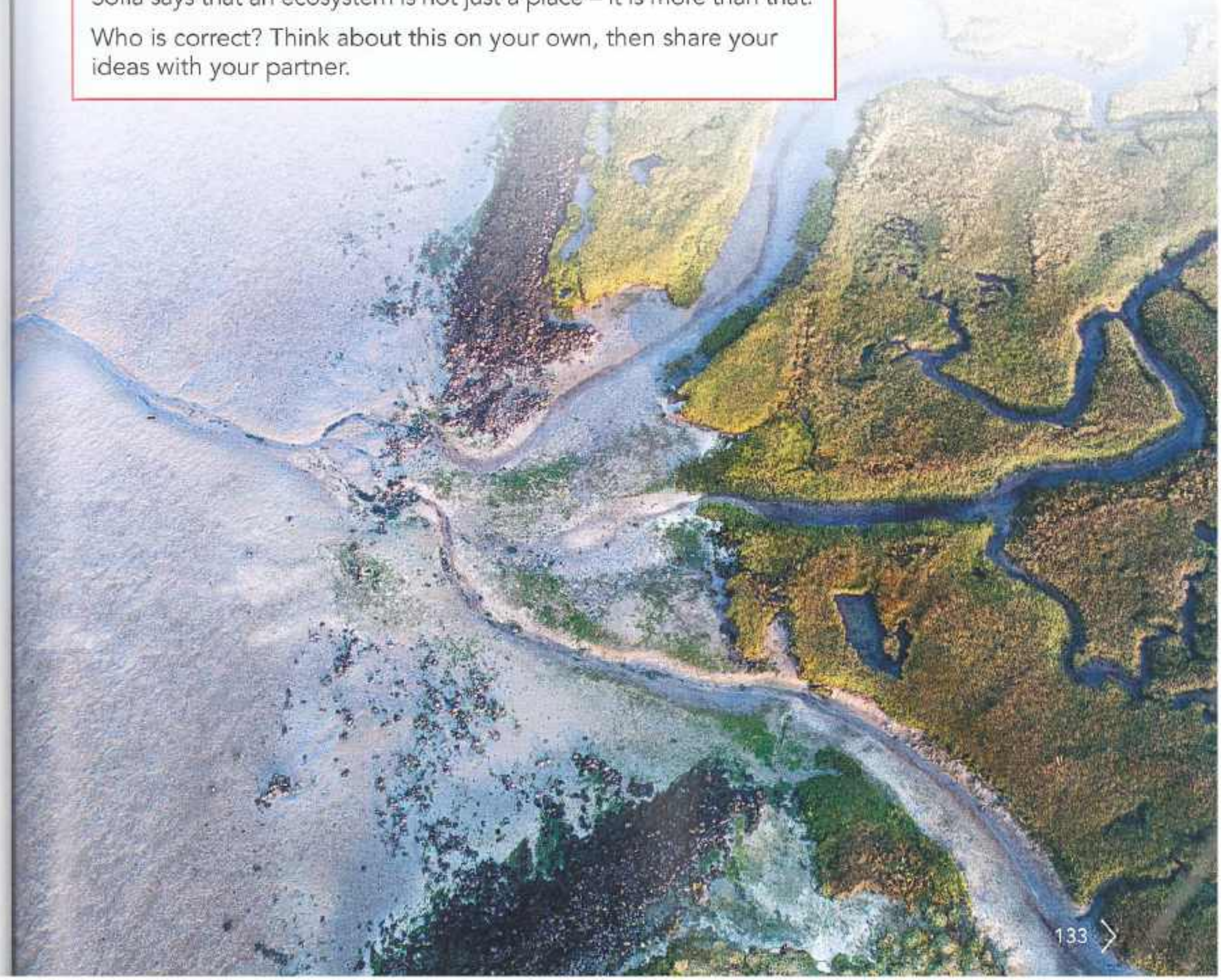
## Getting started

Work with a partner.

Marcus says that an ecosystem is a place.

Sofia says that an ecosystem is not just a place – it is more than that.

Who is correct? Think about this on your own, then share your ideas with your partner.



# More about ecosystems

The ecosystem in the Arizona Sonoran Desert is just one of many different ecosystems on Earth. Here are three more examples of ecosystems: mangrove forests, sea ice in the Arctic Ocean, and a rice paddy.

## Mangrove forest

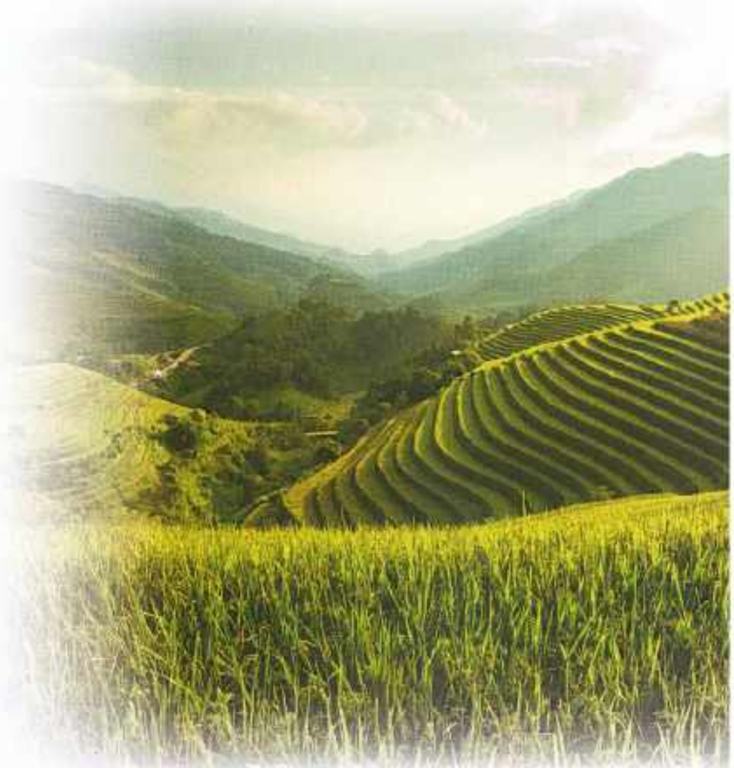
- Mangroves are trees that can grow with their roots in sea water. They form forests along the coasts of many tropical countries.
- Young fish live among the mangrove roots, safe from larger fish that might eat them. Mud skippers climb out onto the mud when the tide is out, feeding on whatever they can find.
- As the mangrove leaves fall onto the mud, they are decomposed by bacteria. Prawns and crabs eat the partly decomposed leaves.
- Crab-eating macaques, a type of monkey, climb through the trees and catch crabs on the tree roots and mud.

## Sea ice in the Arctic Ocean

- During the winter in the Arctic Ocean, it is so cold that some of the sea water freezes.
- Seals hunt for fish in the water, but have to come to the surface to breathe air.
- Polar bears patrol the ice, looking for seals to kill and eat. Polar bears are good swimmers, and can move from one ice floe to another.
- Arctic foxes also look for food on the ice.
- Enough light passes through the ice to allow tiny algae (single-celled plants) to grow on the underside of the ice floes.
- Tiny shrimp-like organisms eat the algae. Fish eat the shrimp-like organisms.

## Rice paddy

- Not all ecosystems are natural. This area of rice paddies in Malaysia is farmed by people.
- At some times of year, the paddy fields are flooded with water. Algae grow in this shallow water, and on the mud at the sides of the flooded areas.
- Fish swim into the flooded paddies from the irrigation canals. Frogs and dragonflies breed in the water.
- Because the water is shallow, it heats up quickly during the day, and cools down quickly at night.
- Farmers often add fertiliser to the paddy fields, making not only the rice but also the algae grow faster, providing more food for the animals.
- Many birds feed in and around the paddy fields.



### Activity 4.2.1

**Habitats in an ecosystem**

Choose **one** of the ecosystems shown in the photographs. Use the internet to find out more about your chosen ecosystem.

Make a list of the different habitats in this ecosystem, and some of the organisms that live in each of the habitats in your list.

### Think like a scientist

**Investigating a local ecosystem**

You are going to investigate an ecosystem near your school. For example, you could investigate:

- a garden area
- a group of trees
- part of the playing field
- a pond.

**Safety**

You will be working outside. It is important to stay in the same area as the rest of your class. Always stay with a partner.

Continued

You will need:

a selection of the apparatus and materials shown; choose what is suitable for the ecosystem you are studying. These items are not drawn to scale.

This is a pitfall trap. This one is made from a plastic cup which has been set into the ground as shown. Small animals that crawl or run over the surface of the ground – such as beetles – fall in and cannot get out.

It is important to check your pitfall trap regularly. If not, you may find just one extremely fat carnivorous beetle in it, and nothing else.

This is a sweep net. It has a large net on the end of a long pole. It is useful for catching insects. You can sweep it through long grass. You can also use it to catch organisms in a pond or small stream.

You can use this apparatus to find insects living in the lower branches of trees. Gently hit a branch with the stick, as your friends hold the large piece of material or a sheet underneath. If you haven't got any material, you can use an upside-down umbrella.

A hand lens is useful for looking at very small organisms.

A camera is useful for taking photographs of organisms, especially if you do not know their names. You can use your photos to try to identify the organisms later.

You can use books to try to identify the animals and plants that you find. Quick identification keys are also very useful.

Continued

It is important to remember that, if you catch any animals, you must take great care of them. Do not take them away from their habitat. Release them exactly where you found them.

### Method

1 Look all around the area you are studying. What kind of ecosystem is it? Write a short description of it or draw a picture. For example:
   - How big is it?
   - What kind of plants grow there?
   - Is there a lot of light, or is it shady?
   - Is it damp or dry?

2 Find different habitats in the ecosystem. For example, if you are studying a garden, habitats could include underneath stones, in the soil, on the soil surface, on leaves, in flowers, on tree trunks and in the air.

3 Look for organisms living in each habitat. Make a list of them. If you don't know their names, take a picture or make a drawing. You might find some fungi, as well as plants and animals. If there are animals, what are they doing?

4 If possible, visit the ecosystem at different times of day – or even at night. How does it change?

5 Draw a diagram to show some of the interactions you have seen between the organisms, and between organisms and the non-living parts of the environment. For example, if you were looking at a garden:
   - Did you see any insects visiting flowers?
   - Did you see any animals eating anything?
   - Did you find anything hiding from predators or the hot Sun underneath part of a plant?
   - Had anything made a burrow in the soil?
   - Did you see any decomposers?

## Continued

### Self-assessment

Read these statements, then assess yourself on how well you did the activity.

Give yourself:

0 if you did not try

1 if you think you did quite well

2 if you are quite pleased with how well you did.

- I was careful to stay with the group and stay safe.
- I made a good description or picture of the study area.
- I found at least five different habitats in the ecosystem.
- I used at least two different methods to find organisms.
- I found at least ten different kinds of organism.
- I made a good diagram, showing interactions in the ecosystem.

If you gave yourself two marks for everything, the best possible score would be 12. How many marks have you given yourself out of 12?

If you did a similar investigation in future, how could you do it better?

## Summary checklist

- [ ] I can describe some of the habitats and interactions in an ecosystem.
- [ ] I can use different methods to find out about habitats and interactions in an ecosystem near my school.

# › 4.3 Intruders in an ecosystem

**In this topic you will:**

- learn about how new or invasive species can affect an ecosystem.

**Getting started**

Work in a group of three.

Think about the saguaro cacti in the Sonoran Desert.

Now imagine that someone brings a new species of cactus that can grow and reproduce faster than the saguaro cactus.

What might happen to the saguaro cacti?

What might happen to some of the other species in the Sonoran Desert?

Make a list of your ideas, ready to share.

**Key Words**

eradicate
extinct
invasive species
native species

# New species in an ecosystem

In your studies of ecosystems, you have seen how all the different organisms interact with each other and their environment. In this topic, you will find out what happens if a new species suddenly arrives. How does the new species fit into the network of interactions? How does this affect the species already there?

## Introduced species in New Zealand

New Zealand is a country in the Pacific Ocean. New Zealand became separated from all the other areas of land in the world about 66 million years ago. Because of this separation, the species that developed in New Zealand were different from those elsewhere on Earth.

Before humans arrived in New Zealand, there were no predatory mammals there. Many of the **native species** of birds nest on the ground. There were no predators to eat their eggs, so the eggs and young birds were safe. Even the adults of several species of native bird – such as the kiwi – cannot fly.

Nobody knows exactly when humans first arrived in New Zealand, but it was probably about 700 years ago. Humans brought species of animals with them that did not belong in New Zealand. For example, rats stowed away on their boats. Rats now live in most of the country. The rats eat birds' eggs and defenceless young birds.

Since then, other species have been introduced to New Zealand. Farmers brought sheep, to farm for their wool and meat. Rabbits were brought on sailing ships, to use as food. But the rabbits escaped and began to eat grass in the sheep pastures. So people brought stoats from Europe to control the rabbits.

Now stoats have spread all over New Zealand. They are fierce hunters and breed rapidly. They can kill and eat birds much larger than themselves. Stoats have made several species of native bird **extinct**, including the laughing owl and the New Zealand thrush. Stoats eat almost 60% of kiwi chicks.

People in New Zealand are now trying to **eradicate** (completely get rid of) stoats, but this is very difficult to do. The best that can be done is to control their numbers.

Scientists think that 53 species of native bird in New Zealand have become extinct since humans arrived. The extinctions have been partly caused by people hunting and killing the birds, but mostly because of introduced **invasive species**.

## Questions

1 In your own words, explain what a 'native species' is.

2 Name some native species in your own country.

3 Suggest why it is very difficult to eradicate an introduced species, once it has settled into a new place.

### Activity 4.3.1

**Why do some introduced species cause problems?**

Stoats normally live in Europe. Stoats are not a 'problem animal' in the ecosystems where they normally live.

1 With your partner, think of ideas to explain why stoats are such a problem in New Zealand, but not a problem in their native countries.

2 When everyone is ready, share your ideas with the rest of the class. Make a list of the ideas on the board.

3 Once all your ideas have been listed, work together with the rest of the class to make a shorter list. For example, perhaps you can explain some of the ideas more clearly if you use fewer words. Or perhaps two of the ideas are really the same idea, and can be combined.

## Questions

4 Buffelgrass is native to Africa, Asia and the Middle East. It was planted in Arizona in the 1930s, as food for cattle. Now, it is spreading rapidly through the Sonoran Desert.

What is the name for a plant, such as buffelgrass, that is growing in an ecosystem where it does not belong?

5 Buffelgrass grows in dense patches. It takes water and nutrients from the soil.

Look at the picture that you made in Topic 4.1, showing interactions in the Sonoran Desert. Suggest how buffelgrass could affect some of the native species in the desert.

### Summary checklist

- [ ] I can explain how new or invasive species can affect an ecosystem.
- [ ] I can describe examples of invasive species and their effects.

# › 4.4 Bioaccumulation

## In this topic you will:

- find out about DDT
- use a model to explain what happens to DDT in a food chain
- learn what bioaccumulation is, and why it happens.

## Getting started

Think about what you learned about decomposers in Stage 7. With a partner, answer these questions.

1 What is a decomposer?
2 What kinds of substance can decomposers break down?
3 What kinds of substance are decomposers unable to break down?

## Key words

accumulate
bioaccumulation
biodegradable
biomagnification
insecticide
persistent
toxic

# DDT

DDT is an **insecticide**. This means that it kills insects.

DDT was first produced in the 1940s. It was used to kill insects that transmit diseases. It was especially useful for killing mosquitoes that transmit malaria, and fleas that transmit a disease called typhus. DDT was also used to kill insects that eat crops.

No one thought that DDT could harm organisms other than insects. This old picture was taken in the 1940s. It shows a beach being sprayed with DDT to kill mosquitoes. The people on the beach are being sprayed, too.

DDT is very good at killing insects. But gradually, people began to realise that it was also harming animals that no one wanted to kill. In 1962, an American author called Rachel Carson wrote a book called *Silent Spring*. She described how DDT was killing not only mosquitoes, but also birds.

Her book made many people realise that some insecticides, including DDT, are very harmful to the environment. Scientists now understand how it causes harm to ecosystems.

## DDT in food chains

We now know that DDT does not break down. It is a **persistent** chemical. It stays in the environment for many years. It is not broken down by decomposers.

When DDT is sprayed, some of it is carried up high into the air. It can be blown for very long distances, far away from where it was used.

When DDT gets into an animal's body, it stays there for the whole life of the organism – it never breaks down.

DDT is very harmful to many kinds of animal. It is **toxic** (poisonous). For example, it makes the shells of birds' eggs very thin and easy to break. This old photograph shows some eggs of a bird called an ibis. The eggs did not hatch, because the female ibis that laid them had DDT in her body.

## Think like a scientist

### Modelling DDT in a food chain

You will need:

- at least 25 people to do this activity – it's even better with 30
- at least 200 tokens, some blue, some yellow, and some red
- a stopwatch
- a cup or small bag for each person, to put tokens in
- one card with 'eagle' written on it
- about eight cards with 'small bird' written on them
- about 21 cards with 'insect' written on them
- one bag, big enough to hold all the cards
- a method of marking out an area of ground outside, for example, traffic cones (you could borrow something from the sports department, or you might be able to use a marked-out part of a pitch used for sports)
- a clipboard and paper so that someone (the teacher, or the eagle) can record results

Method

1. Mark out an area big enough for people to run around. It could be 25 m by 25 m, but the exact size does not matter.
2. Spread all of the coloured tokens randomly in the marked-off area.
3. Put all of the cards into the large bag. Each person puts a hand into the bag and takes one card.
4. Everyone takes a small bag, and then stands on the edge of the marked-off area.
5. One person (it could be your teacher) starts a stopwatch and says: 'Go!' Each 'insect' goes and 'feeds' in the area. They do this by picking up tokens and putting them into their bags. Only one token can be picked up at once!
6. After 15 or 20 seconds, the timer shouts: 'Stop!' The insects stop feeding. Each 'insect' counts the tokens in their bag. They count how many tokens of each colour they have. The recorder writes down the results for each 'insect'.
7. The timer starts the stopwatch again, and the 'small birds' go and feed on the 'insects'. They do this by tapping an 'insect' on the shoulder. The captured insect transfers their tokens into the small bird's bag. A 'small bird' can only eat one 'insect' at a time.

Continued

8 After 15 or 20 seconds, the timer shouts: 'Stop!' The 'small birds' stop feeding. The 'insects' (whether or not they have been eaten) move outside the marked area. Each small bird counts the tokens in their bag. The recorder writes down how many tokens of each colour each small bird has.

9 Now repeat steps **6** and **7**, but this time the 'eagle' feeds on the 'small birds'.

10 Go back into your classroom. The recorder can now write all of the results onto the board.

**Questions**

1 a Calculate the mean number of red tokens that an 'insect' collected.

b Calculate the mean number of red tokens that a 'small bird' collected.

c How many red tokens did the 'eagle' collect?

2 Copy and complete this 'food chain', using your results.

| insects | → | small birds | → | eagle |
|---|---|---|---|---|
| ... red tokens each | | ... red tokens each | | ... red tokens each |

3 Explain why the mean number of red tokens that each animal has increases as you go along the food chain.

4 Now imagine that the red tokens represent DDT. What happens to the quantity of DDT in an animal's body as you go up the food chain? Why does this happen?

5 In this activity, you modelled what happens to DDT in a food chain. Do you think this is a good model of what happens in a real ecosystem? Explain your answer.

## Bioaccumulation and biomagnification

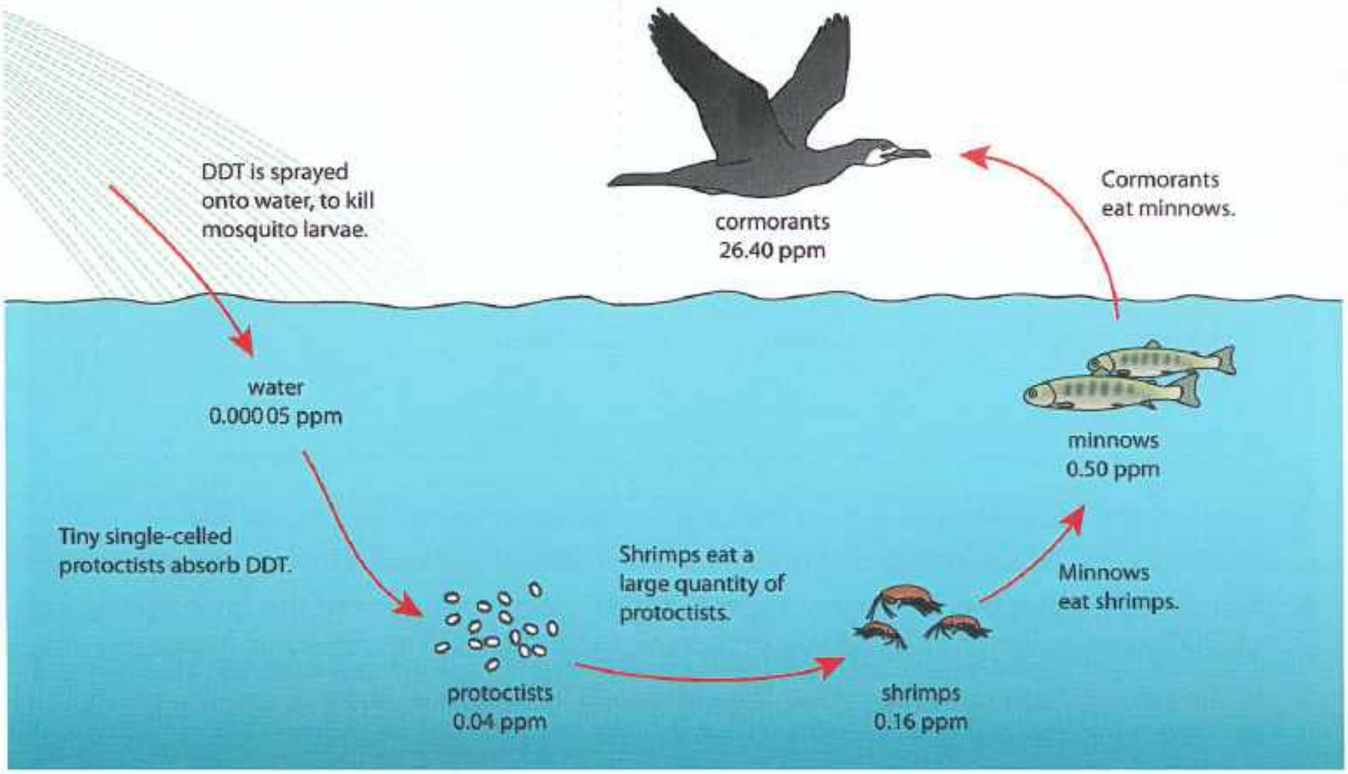
Imagine that DDT has been sprayed onto some water. Tiny algae take up some of the DDT. Shrimps eat the algae, and fish eat the shrimps. Cormorants (fish-eating birds) eat the fish.

All the DDT in all of the algae that a shrimp eats over its lifetime **accumulates**, or builds up, in its body. The longer the organism lives, and the more DDT it takes in, the more DDT it gets in its body. This process is called **bioaccumulation**.

All of the DDT in all of the shrimps that a fish eats accumulates in the fish's body. Eventually, all the DDT in all of the fish that a cormorant eats in its lifetime accumulates in the cormorant's body.

This means that the concentration of DDT in an animal's body increases as you go up the food chain. This is called **biomagnification**.

The next diagram shows how the concentration of DDT in the bodies of species in a food chain increases along the chain. The concentration is measured in parts per million (ppm). This is the number of grams of DDT in one million grams of the organisms.




## Questions

1 How many times greater is the concentration of DDT in a cormorant's body than in a minnow's body?

2 Explain, in your own words, why the concentration in the cormorant is greater than in a minnow.

People often get confused between bioaccumulation and biomagnification. How will you try to remember the difference between them?

## Activity 4.4.1

### Biodegradable insecticides

Work in a group of three for this activity.

Some insecticides are **biodegradable**. This means that they can be broken down by microorganisms in the environment, or inside an animal's body.

### Questions

In your group, discuss these two questions.

1. Do you think biodegradable insecticides show biomagnification? Explain why.
2. Why doesn't everyone stop using DDT, and change over to using biodegradable insecticides?

Be ready to share your ideas with the other groups in your class.

## Summary checklist

- [ ] I can explain what is meant by bioaccumulation.
- [ ] I can explain why DDT shows bioaccumulation.
- [ ] I can explain why organisms at the top of a food chain have higher concentrations of DDT in their bodies than organisms at the base of the food chain.

## Project: Impact of an introduced species

This project is about how people develop and use scientific understanding, and how the uses of science can have a global environmental impact.

### Your task

Work in a group of three or four.

You are going to investigate how a new or invasive species has affected an ecosystem.

Use the internet to find an example of a species that has been introduced into an ecosystem in your country.

Try to answer some of these questions.

- Where does the species normally live?
- Why and when was the new species introduced to your country?
- How has it affected the ecosystems it has been introduced to?
- Is it an invasive species? If so, why is it invasive in your country, but not its native country?
- Why did people not realise that the species might be a problem, when it was first introduced? How has understanding improved over time?
- Are people trying to eradicate or control the species? If so, how are they doing this, and how successful are they? Is everyone happy about this, or do some people want to protect the species?

Make a presentation about your findings, and be ready to share with others.

# Check your progress

**4.1** Tropical rainforests are very complex ecosystems.
Many different species live in a tropical rainforest.

Bromeliads are plants that grow in a tropical rainforest. They often grow on tall forest trees.

Bromeliads have spiky leaves arranged in circles. They trap rainwater in their centres. Small animals often live in the little ponds in a bromeliad plant.

- **a** Use the photographs to describe **two** habitats in the tropical rainforest ecosystem. **[2]**
- **b** Suggest the advantages to bromeliads of growing in their particular habitat. **[2]**
- **c** Suggest the advantages to the frog of living in their particular habitat. **[2]**
- **d** Explain the difference between an ecosystem and a habitat. **[2]**

**4.2** Coral reefs are formed by tiny animals called coral polyps. Their hard skeletons provide many different habitats where other species can live.

One of these species is a single-celled alga that makes a toxic substance called ciguatoxin. Herbivorous fish eat the alga. Carnivorous fish eat the herbivorous fish. Humans often eat the carnivorous fish.

- **a** Thousands of different species live on coral reefs.
Use the information to suggest why so many species can live there. **[2]**
- **b** What is meant by 'a toxic substance'? **[1]**
- **c** Use the information to construct a food chain. **[3]**

**d** Ciguatoxin does not break down inside a fish that has eaten it. Instead, it builds up in the head, liver and skin of the fish.

What is the name for this process? Choose one of these words.

**bioaccumulation** **ecosystem** **poisoning** [1]

**e** People who have eaten fish containing ciguatoxin can become very ill. Suggest why eating a carnivorous fish is more likely to make you ill than eating a herbivorous fish. [2]

**4.3** Winged loosestrife is a plant with purple flowers. It grows in North America.

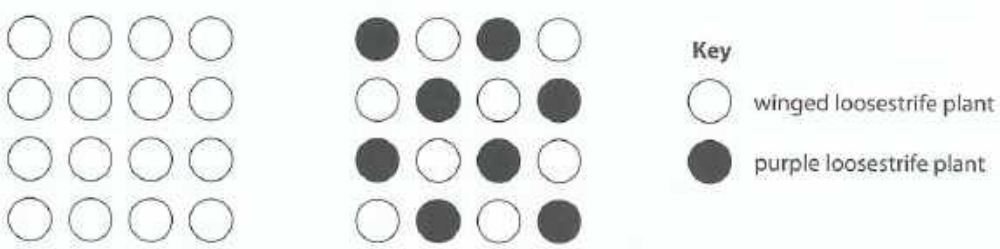
Purple loosestrife, shown in the photograph, also has purple flowers. It normally lives in Europe and Asia. It is an introduced species in North America.

Both species of loosestrife are pollinated by insects. After pollination, the flowers produce seeds.

Scientists noticed that numbers of winged loosestrife plants were decreasing in places where purple loosestrife had been introduced.
They did an experiment to test this hypothesis:

> When purple loosestrife is present, fewer winged loosestrife flowers are successfully pollinated.

- They grew plants of winged loosestrife in pots. They also grew plants of purple loosestrife in pots.
- When all the plants had flowers, the scientists arranged the pots in a field. They used two different patterns.



- The scientists counted how many insects visited the flowers on each winged loosestrife plant over a 15 minute period.
- They left the plants in their pots until they produced seeds. Then they counted how many seeds each plant produced.

Their results are shown in the table.

| Arrangement of plants | Mean number of insect visits to each winged loosestrife plant in 15 minutes | Mean number of seeds produced by each winged loosestrife plant |
|---|---|---|
| winged loosestrife alone | 35 | 80 |
| winged loosestrife and purple loosestrife | 26 | 58 |

**a** Explain what is meant by an 'introduced species'. [2]

**b** Explain why the scientists used two different patterns when they put the plants in the field. [3]

**c** Describe how the presence of purple loosestrife affected the number of insect visits to winged loosestrife. [2]

**d** Do the results support the scientists' hypothesis? Explain your answer. [2]

**e** Suggest **two** ways the scientists could improve their experiment. Explain each of your suggestions. [4]

# 5 Materials and cycles on Earth

## 5.1 The structure of the atom

### In this topic you will:

- describe the structure of the atom
- list the particles found in an atom
- describe some of the properties of the particles found in an atom.

### Getting started

These three cups have been filled with water.

Would you expect these three cups to have:

**a** exactly the same mass

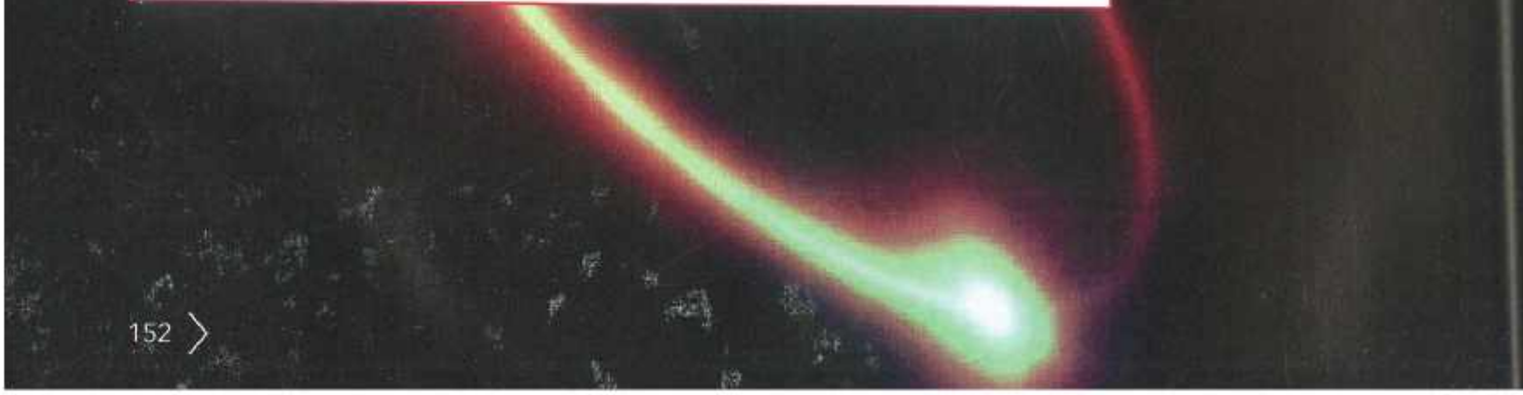
**b** masses that were nearly the same

**c** masses that were very different?

Discuss this with a partner. Give reasons for your choice.

### Key words

atoms
deflected
electrical charge
electrons
electrostatic attraction
neutrons
nucleus
protons
sub-atomic particles



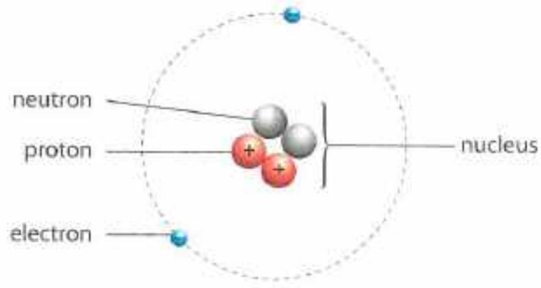
# Atoms

In Stage 7 you learnt that **atoms** are so small that you cannot see them without using the most powerful microscopes yet invented. The word 'atom' comes from a Greek word that means 'cannot be split'.

All the atoms of a particular element are the same. Different elements have different atoms.

## What is an atom like?

Scientists have discovered that atoms are made up of even smaller particles, called **sub-atomic particles**. Atoms are made up of three kinds of particles **protons**, **neutrons** and **electrons**.




A helium atom

The particles are arranged in a similar way in all atoms.

The protons and neutrons are grouped closely together in the centre of the atom. They form the **nucleus** of the atom. (Be careful not to confuse the nucleus of a cell with the nucleus of an atom.)

The electrons move around the nucleus.

The three different particles in an atom have different properties.

- Protons and neutrons have much more mass than the electrons. In fact, electrons have almost no mass.
- Protons and neutrons have the same mass.
- Protons have a positive **electrical charge**.
- Neutrons have no electrical charge.
- Electrons have a negative electrical charge.

There is a lot of empty space between parts of the atom. This space really is completely empty – there is nothing in it at all.

There is an attraction between the positive and negative charges. This **electrostatic attraction** between the positive charge on the protons and the negative charge on the electrons is what holds individual atoms together.

## Questions

1 Which sub-atomic particle has a positive electrical charge?

2 Which sub-atomic particle has the smallest mass?

3 Which sub-atomic particles make up the nucleus of an atom?

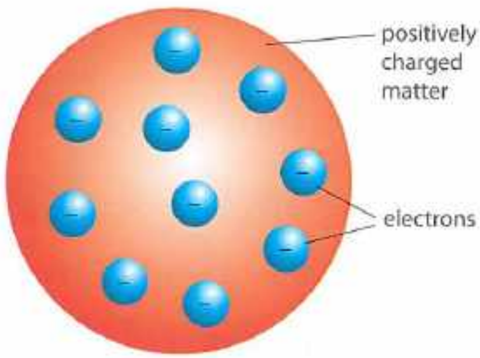
4 The size of the negative charge of an electron is exactly the same as the size of the positive charge on a proton. What is the overall charge of the helium atom shown in the diagram?

5 How are the individual atoms held together?

# How did scientists come up with this model of the structure of the atom?

Scientists from all over the world have worked on different ideas. Together, the ideas have led to the model of the atom, that scientists use today.

In the late 1890s a British scientist called J. J. Thompson discovered the electron. His model for the atom was that the electrons were scattered throughout the structure of the atom. It is sometimes called the 'plum pudding model' because the particles are arranged randomly throughout the model, like fruit in a cake or pudding.



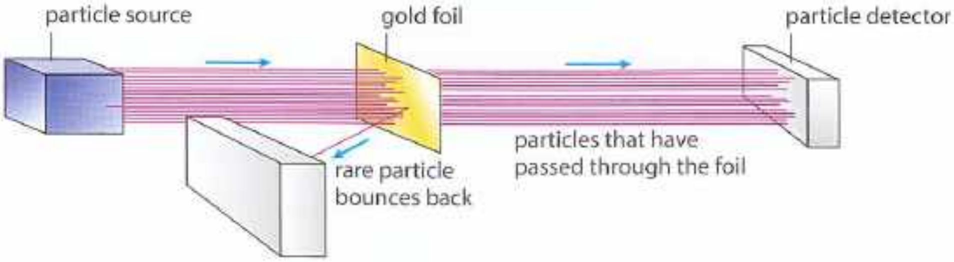

J. J. Thompson's model of the atom

One of Thompson's students was originally from New Zealand. His name was Ernest Rutherford. Rutherford discovered the proton in 1909 and the nucleus in 1911.

Ernest Rutherford

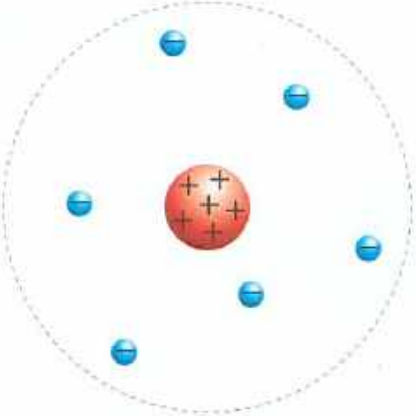
Rutherford's most famous experiment was the gold foil experiment.

In this experiment, Rutherford fired fast moving particles, smaller than an atom, at very thin gold foil. Most of the particles passed straight through the foil. Only a few of the particles (about 1 in 8000) were **deflected** in various directions. (Deflected means that the direction of the particle was changed.)




Rutherford's gold foil experiment

The results of this experiment led Rutherford to the idea that the gold atoms must be mostly empty space, with their particles packed into a dense nucleus at the centre.



Rutherford's model of the atom

James Chadwick also worked with Rutherford and Thompson. In 1932, he proved that neutrons exist.

When scientists make a discovery, they write about what they have done and what they think it means. Sometimes, if the work is very complicated, many different scientists may be involved. These different scientists often live in different countries, but still work together. This is called collaboration. Other scientists then look closely at the findings to see if they can repeat the experiments. Some scientists look for mistakes in the work, or whether the conclusions about the results are wrong. This is called peer review.

When work is peer reviewed it must be done fairly. More than one person must do the review and they must consider whether there are sufficient observations or measurements to support the conclusions. The scientists who carry out the review cannot be influenced by the people who did the original work.

Each scientist builds on the ideas and the discoveries of others. Chadwick, Rutherford and Thompson won Nobel prizes for their work. Their experiments and ideas have helped us to understand the structure of the atom.

There is still a lot we do not know about atoms. Scientists continue to work to improve our understanding of the structure of the atom. For example, scientists from all over the world are using the Large Hadron Collider in Switzerland to further understand the structure of matter.


Tunnel in the Large Hadron Collider

## Questions

6 Explain how Thompson's model of the atom is different from the one scientists use today.

7 Who discovered the electron? When did they discover it?

8 Who proved that the neutron existed? When did they do this it?

9 What two things did Rutherford discover about the structure of the atom?

10 How is Rutherford's model different from the model scientists use today?

### Activity 5.1.1

#### An atomic timeline

In a group of three, make a time line of the discoveries that have led to the model of the atom we use today. Do some research on the three scientists J. J. Thompson, Ernest Rutherford and James Chadwick. Find out where and when they worked and some personal details; add this to your time line.

How does the use of a model help me to understand the structure of the atom?

### Summary checklist

- [ ] I can describe the structure of the atom.
- [ ] I can list the particles found in an atom.
- [ ] I can describe some of the properties of the particles found in an atom.
- [ ] I can describe some of the discoveries that have helped to create the model of the atom that is used today.

# › 5.2 Purity

## In this topic you will:

- explain what is meant by purity
- calculate percentage purity
- describe how it is difficult to get a pure product.

## Getting started

Answer the three questions on your own and then check with a partner. Be ready to share your answers with the class.

1 What does it mean if a substance is pure?

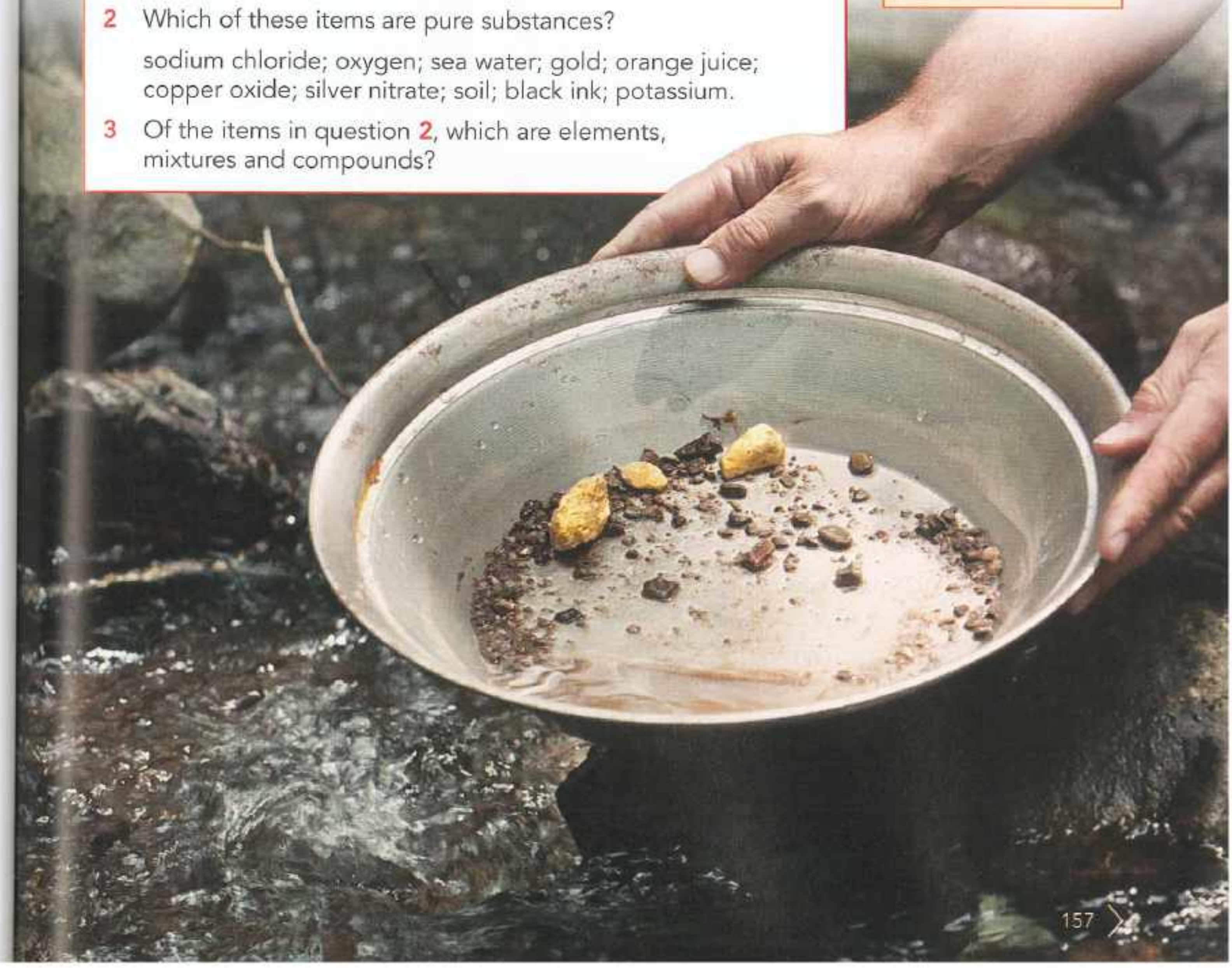
2 Which of these items are pure substances?

sodium chloride; oxygen; sea water; gold; orange juice; copper oxide; silver nitrate; soil; black ink; potassium.

3 Of the items in question **2**, which are elements, mixtures and compounds?

## Key words

carat
suggest
translucent



# Pure elements

If an element is pure, it means that every one of its atoms is exactly the same and made of just one type of atom. For example, pure gold is made of gold atoms.

When you buy gold it is usually marked to state if it is pure gold (24 **carat**) or an alloy such as 18 carat or 9 carat. This is a measure of its purity. The more gold it has, the higher its purity. 18 carat gold has 18 parts out of 24 that are gold; the rest (6 parts out of the 24) is made up of other metals such as silver or copper. 18 carat gold has a purity of 75%. To calculate this:

$$\frac{18}{24} \times 100 = 75\%$$

The photograph shows samples of 8 carat, 14 carat, 18 carat, and 24 carat gold. You can see that the colour changes from slightly coppery to yellow-gold.

When silver is sold, it is usually marked with the number of parts per thousand that are silver. So, silver marked 925 has 925 atoms out of 1000 that are silver, and 75 atoms of some other metal. You can see this mark in the photograph of the silver ring. Silver marked 900 is of lower purity than silver marked 925.

This silver ring has the mark 925.

The ring contains 925 parts silver out of 1000 parts.

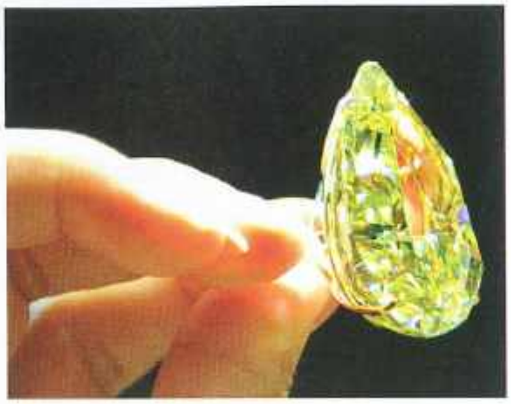
$$\frac{925}{1000} \times 100 = 92.5\%$$

So, it is 92.5% pure silver.

Diamonds are made from the element carbon. The carbon atoms are arranged in a particular way. If they are pure, diamonds contain no other elements. Pure diamonds are colourless and **translucent** (lets the light through).

If diamonds have other elements mixed in with the carbon atoms, they can be different colours. For example, if a few carbon atoms per million are replaced with nitrogen, the diamond will be yellow. If some carbon atoms are replaced by atoms of the element boron, then the diamond will be blue. The rarest of all is a green diamond, formed when one atom per 1000 of carbon atoms is replaced by nitrogen, nickel or hydrogen.

A pure diamond



A yellow diamond

A blue diamond

A green diamond

## Questions

1 What percentage of 9 carat gold is gold?

2 What percentage of silver is in silver marked 900?

3 Which element mixed with carbon in diamonds makes them blue?

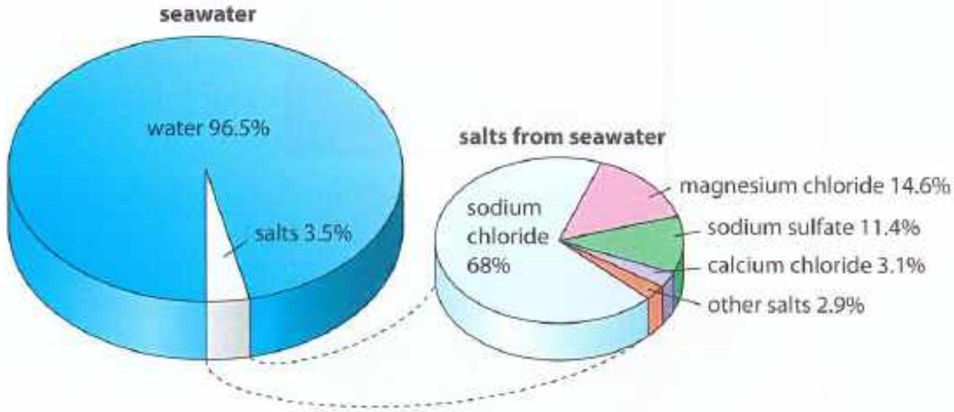
4 Which elements may cause a diamond to be green?

# Seawater

Workers carrying salt in Nha Trang, Vietnam

Seawater is made up of water and various salts, such as sodium chloride. If you want to obtain sodium chloride from seawater you can evaporate off the water. In some countries, this is done by letting seawater fill flat and shallow areas called beds, and allowing the water to evaporate in the heat from the Sun.

If you take 1000 g of seawater, about 35 g (or 3.5%) of it is made up of salts. Of this 35 g, about 68% is sodium chloride; the rest is made up of magnesium chloride, sodium sulfate, calcium chloride and some other salts. If you want pure sodium chloride, you need to do some work to remove the other salts.




The salt that is obtained from this seawater is only 68% sodium chloride. The mass of sodium chloride in 1000 g seawater is:

$$\frac{68}{100} \times 35 = 23.8\,\text{g}$$

Salts are compounds made from acids. The names tell you which acid has been used to form them. For example, sodium chloride, is formed from hydrochloric acid and sodium sulfate is formed from sulfuric acid.

## Questions

5 Draw up a table to show the percentage of salts found in seawater.

6 What mass of magnesium chloride would you expect to find in the seawater sample?

## Think like a scientist

### Finding the mass of salts in seawater

You will need:

- evaporating basin • tongs • Bunsen burner • tripod • pipe-clay triangle
- safety glasses • top pan balance • seawater sample

#### Method

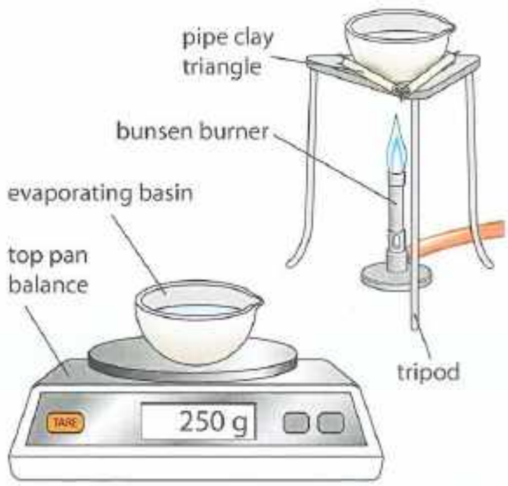
1 Read through the method and think very carefully about any risks there may be when you carry out this task. Write a risk assessment.

2 Place an evaporating basin on a top pan balance and record its mass.

3 Add some seawater and find the mass of the seawater.

4 Heat the seawater until it begins to spit. Remove from the heat and allow the rest of the water to evaporate.

5 When there is no longer any water remaining and the basin is cool, find the mass of the salts.




#### Questions

1 What mass of salts did you obtain from the seawater?

2 What percentage of the seawater is this?

3 About 68% of the salt in seawater is sodium chloride. Estimate the mass of sodium chloride in your sample.

4 Is this about what you expected? If not, why not?

5 What difficulties did you have carrying out this investigation? How did you try to overcome them?

6 What safety measures did you have in place whilst carrying out this investigation?

# Pure products

Often, when scientists carry out a chemical reaction, it is important that they obtain a pure product. For example, if they are carrying out a chemical reaction to make a medicine, impurities in the product could stop the medicine from working, or it could harm the patient.

In some simple reactions there is only one product. For example:

magnesium + oxygen → magnesium oxide

In other reactions, there may be more than one product. For example:

| | | |
|---|---|---|
| silver nitrate + sodium chloride | → | sodium nitrate + silver chloride |
| sulfuric acid + sodium hydroxide | → | sodium sulfate + water |
| barium chloride + sodium sulfate | → | barium sulfate + sodium chloride |
| lead nitrate + potassium iodide | → | potassium nitrate + lead iodide |
| copper carbonate + hydrochloric acid | → | copper chloride + water + carbon dioxide |

When there is more than one product they are mixed up together. These products need to be separated and purified to produce whichever pure product you want. The products may also be mixed up with some of the reactants if they have not all been used up in the reaction.

## Think like a scientist

### Reactions with more than one product

You will need:

• safety glasses • test tubes • test tube racks • universal indicator solution
• conical flask • measuring cylinder • burette • boiling tube
• delivery tube with bung • clamp stands • safety glasses • limewater
• chemical reactants as listed above

#### Safety

You must wear safety glasses to carry out all these reactions. Wash your hands after handling any chemicals.

#### Method

The equations above are examples of chemical reactions you could carry out. You can try other reactions if your teacher prefers. Remember, if you are going to do a neutralisation reaction, you will need to measure the reactants carefully. Carry out a risk assessment for each reaction you attempt.

Continued

*Reaction 1*

**Safety:** Silver nitrate is an irritant. Take care when you use it.

Half fill a test tube with silver nitrate solution. Slowly add some sodium chloride solution.

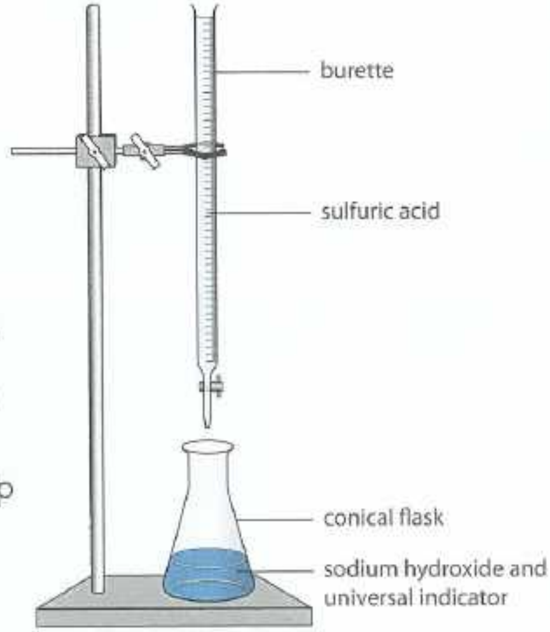
*Reaction 2*

**Safety:** Sulfuric acid and sodium hydroxide are irritants: take care when you use them. Fill the burette carefully using a small funnel.

Your teacher may decide to do this as a demonstration as a burette can be difficult to use.

Place 20 $cm^3$ of sodium hydroxide in a conical flask, as shown. Add a few drops of universal indicator solution. Put sulfuric acid in the burette and add to the flask until the alkali is neutralised.

Take care when you use the burette and ask for help if you have not used one before.




*Reaction 3*

**Safety:** Barium chloride is harmful if swallowed.

Half fill a test tube with barium chloride solution and add sodium sulfate solution.

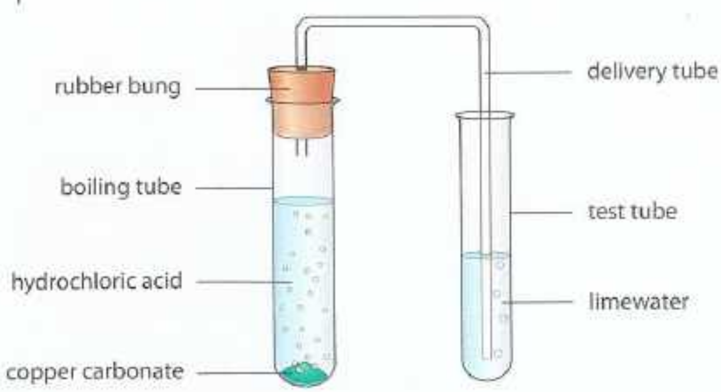
*Reaction 4*

Place lead nitrate in a test tube and add potassium iodide. Wash your hands after handling lead compounds.

*Reaction 5*

**Safety:** Copper carbonate is harmful so wash it off you skin if you spill any.

Place a few spatulas of copper carbonate in a boiling tube and add hydrochloric acid. Place the delivery tube bung in the mouth of the boiling tube and allow the gas to be passed into a test tube of limewater (see diagram).



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**Questions**

1 Record each reaction you carry out. For each one, write the word equation and your observations.

2 For each reaction **suggest** or offer ideas on how the products could be separated and purified.

3 What safety measures did you have in place whilst carrying out these reactions?

What does 'pure' mean? When chemical reactions take place how can you be sure you have a pure product?

## Summary checklist

- [ ] I can explain what is meant by purity
- [ ] I can calculate percentage purity
- [ ] I can explain why it is difficult to obtain a pure product.