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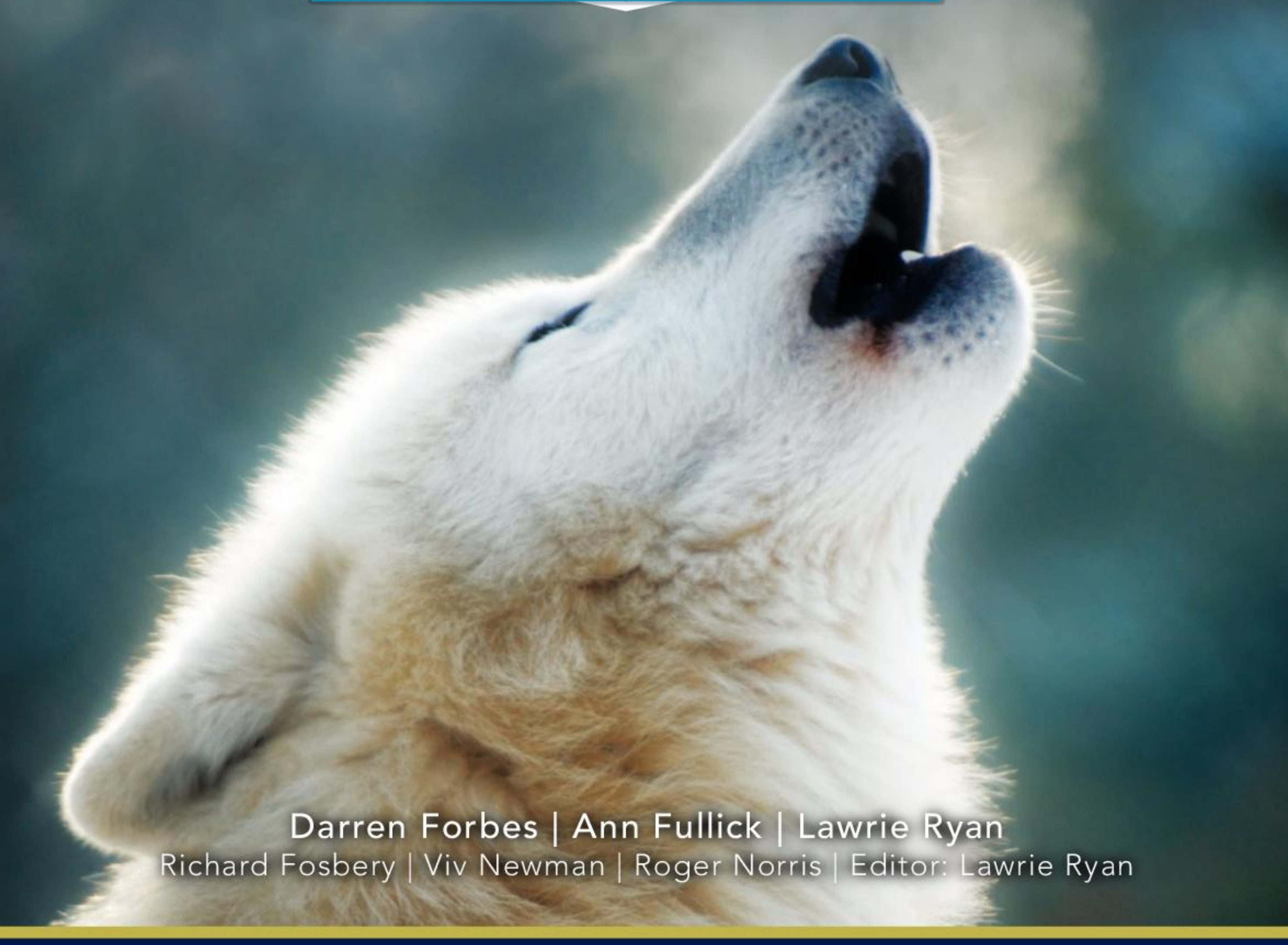
ESSENTIAL SCIENCE STAGE 7

FOR CAMBRIDGE SECONDARY 1



Darren Forbes | Ann Fullick | Lawrie Ryan
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Contents

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Introduction

Welcome to *Science for Cambridge Secondary 1*!

This Student book covers Stage 7 of the curriculum and will help you to prepare for your Progression test and for studying Stages 8 and 9, and later, your Cambridge IGCSE® Sciences (Biology/Chemistry/Physics).

Using this book

This book is divided into the three main disciplines of science, **Biology**, **Chemistry** and **Physics**, though you will find overlap between the subject areas. Each chapter starts with Science *in context!* pages. These pages put the chapter into a real-world or historical context, and provide a thought-provoking introduction to the topics. You do not need to learn or memorise the information and facts on these pages; they are given for your interest only. Key points summarise the main content of the chapter.

The chapters are divided into topics, each one on a double-page spread. Each topic starts with a list of learning outcomes.
These tell you what you should be able to do by the end of that topic.
Key terms are highlighted in **bold type** within the text and definitions are given in the glossary at the end of the book.
Each topic has a list of the key terms you should understand and remember.
Summary questions at the end of each topic allow you to assess your comprehension before you move on to the next topic.
Expert tips are used throughout the book to help you avoid any common errors and misconceptions.
Topics, text or artworks marked with a rosette icon are not part of the core curriculum, so will not be tested as such in your Progression or Checkpoint test. They have been included to assist your understanding of core topics or prepare you for topics in a subsequent stage.

Learning outcomes

Key terms

Summary questions

Expert tips

At the end of each chapter there is a double page of examination-style questions for you to practise your examination technique and evaluate your learning so far.

Answers to Summary questions and End of chapter questions are supplied on a separate Teacher's CD.

Scientific enquiry

Scientists collect information through experiments, observation and enquiry, to try and discover more about the world in which we live and the wider Universe. This course supports you in starting to think and act like a scientist. Practical activities are suggested throughout the book, and will help you to plan investigations, record your results, draw conclusions, use secondary sources and evaluate the data collected. On pages 218–223 you will find a section dedicated to enhancing your scientific enquiry skills.

Practical activity

Student's website

The website included with this book gives you additional learning and revision resources in the form of interactive exercises, to support you through Stage 7.

Science *in context!*

The story of appendicitis

Sometimes things in your body go wrong. Nagesswar has been admitted to hospital with bad pains in his tummy. These could be caused by many different things. He could have fallen and hurt himself. He might have an infection which will cause sickness and diarrhoea. Nagesswar could have problems with his liver or his pancreas. What is happening in his tummy?

Your body contains many organ systems. One common cause of bad stomach pain in young people is appendicitis. This is an infection in the appendix, a small organ that is part of your digestive system.

The doctors will listen to all of Nagesswar's symptoms. They will examine him carefully. They may take samples of his blood and urine and test them to see if they show he has an infection. When they have decided he has appendicitis they will operate to remove the infected organ.

Once a doctor has removed Nagesswar's appendix, a pathologist will look at the cells under a microscope to find out exactly what was wrong.

This inflamed appendix will make Nagesswar feel very unwell

Young patients like Nagesswar often feel better very quickly once their infected appendix has been removed. They just have to recover from the effects of the operation and wait for the cells of the body to repair the damaged tissues.

If the appendix is not removed in time it may burst. All of the infection then spreads from the appendix into the tissues around the organs of the body. This is called peritonitis and it is very serious. The infection can spread quickly to the blood and then to all the different organs of the body. It can rapidly lead to collapse and death. So a quick response to symptoms like Nagesswar's is very important indeed.

Treatment of diseases like this is possible because we understand about cells, tissues and organs in the body.

Section of an appendix showing some of the cells

In this chapter you are going to learn about living organisms. You will discover the amazing world of cells through the microscope. You are also going to look at how these cells work together to form the organs, which make up the bodies of the plants and animals you see around you every day.

Key points

- All living things move, take in or make food, respond to changes in the world around them, grow, reproduce (produce offspring), get rid of waste products and get energy from their food.
- Plants use carbon dioxide, water and light to make their own food. Animals have to eat other organisms, either plants or other animals.
- Respiration releases energy from food. You can bubble the carbon dioxide produced through clear limewater and it will turn cloudy.
- The main organs in plants are the roots, stems, leaves and flowers.
- Organ systems in mammals include the respiratory system, the digestive system and the excretory system.
- A microscope has an eyepiece lens, a stage, a clip to hold the specimen in place, an objective lens, a mirror or light source and focusing knobs. You need a microscope to look at most cells.
- A simple animal cell has a nucleus, cell membrane and cytoplasm.
- A simple plant cell has a nucleus, cell membrane and cytoplasm as well as a cell wall and a permanent vacuole.
- Cells often become specialised to carry out a particular job in the body; for example, in animals: red blood cells, white blood cells, nerve cells; in plants: leaf cells, root hair cells.
- The human skeleton is made up of many bones. It supports the body against gravity, protects the delicate organs and allows movement.
- The joints allow the bones to move smoothly. They have special tissues such as cartilage, which make them smooth and cushioned.
- Muscles are special proteins, which contract and pull on the bones making them move. Muscles can only pull in one direction so they are found in pairs that work against each other.

1.1 The characteristics of life

Learning outcomes

After this topic you should be able to:

- name the seven main characteristics of all living organisms
- find each of these seven characteristics of life in different organisms
- record results and ideas in a table.

Key terms

- **excretion**
- **growth**
- **movement**
- **nutrition**
- **reproduction**
- **respiration**
- **sensitivity**

Paulina finds a black and green rock but Michelle thinks the green part is a strange plant. If you found a new and strange object like this, what could you look for to tell if it was living or non-living?

What characteristics will tell you if the green part of this rock is living or non-living?

All living things have certain characteristics in common.

Checklist for life

Photo **A** and photo **B** both show elephants, but only the one in photo **B** is alive. Here is a check list of things that living organisms do or need. Try them out on the elephants below.

A

B

Checklist for life	Elephant A	Elephant B
Movement – moves some or all of itself		
Nutrition – must make or take in food (fuel)		
Sensitivity – responds to changes in the world around it		
Growth – gets bigger and stays bigger		
Reproduction – makes more of the same, produces offspring		
Excretion – makes and removes waste products		
Respiration – gets energy from its food, often using oxygen		

Practical activity Is it alive?

Go and collect three things from your school surroundings and see if you can decide if they are living organisms or not.

- Make a checklist like the one above to help you and fill it in.

Look at the images below – they show living things (known as living organisms) – carrying out several characteristics of living things.

- Now try question **2** from the Summary questions below.

C

D

Summary questions

1 Imagine you are leading a team of scientists on a mission to Mars. Your job is to find out if there is any life on the planet. What would you take with you to help you with your investigation? What would you do to decide if you had discovered life or not? What would help to convince scientists on Earth that you had discovered life?

2 Look carefully at the list of key terms and the photos **C** and **D**. Decide which of the features of life you can see in each photo.

1.2 Investigating living organisms

Learning outcomes

After this topic you should be able to:

- explain some of the ways in which you can demonstrate the characteristics of living organisms
- list some of the ways in which scientists work.

If you are asked if something is living or not, you have to work like a scientist to find out. This means asking lots of questions and looking very carefully to make **observations**. Scientists may look, smell, listen, take photos or record sounds as part of their observations. Scientists often measure things. They carefully **record** their evidence. Scientists try to explain what they observe as well.

What is the fuel for life?

All living organisms need to make or take in food for fuel. This fuel gives them the energy they need to live. Animals cannot make their own food. They have to eat other organisms. What could you do to find out what different animals eat?

Plants don't need to eat food. They use light, carbon dioxide and water to make their own food. They make sugar, and oxygen is their waste product. They need to take minerals from the soil as well.

Scientists observed that some plants trap and digest animals. They found out that these plants cannot get the minerals they need from the soil so they eat animals instead!

Respiration

Living organisms respire to get energy from their food. When organisms respire they often use **oxygen** to break down their food. They produce **carbon dioxide** and water as waste products. They also produce heat. Getting rid of the carbon dioxide that is made during respiration is also excretion.

Carbon dioxide is a poisonous gas. If you bubble carbon dioxide through a colourless liquid called limewater, the limewater turns cloudy white in colour. This is a good way to show that respiration is taking place.

Carbon dioxide turns clear limewater cloudy

You breathe in and out thousands of times a day. Your body gets the oxygen it needs from the air you breathe in. What do you think happens when you breathe out? Think of a way to test your idea.

Sensing the world around you

All living organisms need to know if the world around them changes. It means they can find food and keep out of danger. The main human senses are sight, hearing, smell, taste, touch and temperature detection.

Practical activity Testing the connection between taste and smell

Your sense of smell and your sense of taste work very closely together. You can taste things much better if you can also smell them.

- Plan and carry out a scientific way of showing this using flavoured snacks or different types of crushed fruit.

Growth and reproduction

Many living organisms take a long time to grow. Reproduction also often takes a long time. Think about the difference between growth and reproduction.

The importance of movement

Movement is vital for living organisms to survive. For example, animals need to find food, find shelter and avoid danger. Plants need as much light as possible if they are to make food.

In the great migration, animals such as zebra and wildebeest move to find plants to eat. Carnivores such as crocodiles, lions and hyenas move to follow their animal prey

Expert tips

When a fly enters a trap on a Venus fly trap shown opposite, it touches very sensitive hairs and the trap shuts tight very quickly. The plant then starts to digest the fly. When this happens, the plant shows sensitivity, movement and nutrition.

Key terms

- **carbon dioxide**
- **observation**
- **oxygen**
- **record**

Summary questions

1 Think again about your answer to question **1** on page 5. Answer the same question again – but now make your answer as scientific as possible.

2 Amir kept one plant by the window in the classroom for a month. He watered it regularly. He put another plant in the dark for a month and forgot all about it until he wanted to make his observations at the end of his investigation. The plant in the dark was dead. Amir decided this was evidence that the plant needed light to make food. Ehan did not agree. He did not think the investigation was very scientific.

a) Explain why Amir thought the investigation showed that light is needed for plants to make food.

b) Suggest why Ehan was right to think that the investigation was not scientific.

c) Plan a more scientific investigation to show that plants need light to make food.

1.3 Organs in plants

Learning outcomes

After this topic you should be able to:

- give the position of the main organs of flowering plants – the stem, leaves, roots and flowers
- explain the functions of the main organs of flowering plants
- make careful observations and drawings.

Plants grow all over the world. Wherever you live, plants will be part of your life. People eat plants, wear materials made from plants and build houses from plant materials such as wood. All flowering plants have some structures in common.

Date palms

Expert tips

Making drawings of plants and animals is a very good way to make detailed observations. Drawing a specimen makes you look carefully. You can also take photos of specimens, but often a drawing can show things that do not come out well in a photo.

Orchids

Flowering cacti

Although plants from around the world look very different they all have the same plant organs

Practical activity Identifying the main organs of a plant

Collect four different complete plants from your school grounds, your garden or the environment around you. Make sure you have permission from an adult to dig up the plants. Gently wash the soil off the roots.

Spread each plant out on a piece of paper and identify the main organs.

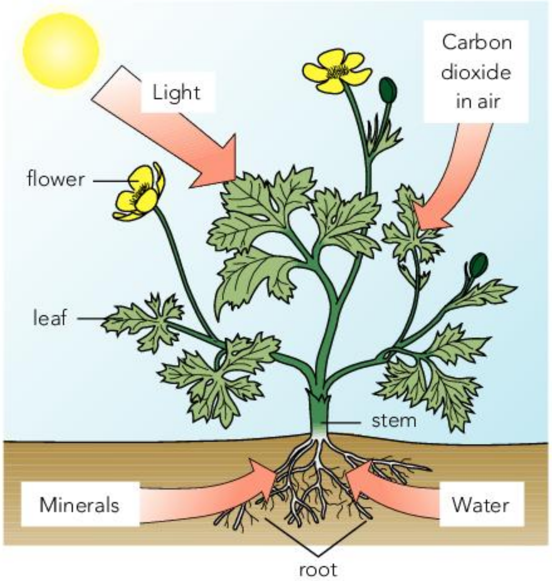
- Draw each of your plants and label the organs.
- Compare the size and shape of the same organs in different plants.

Plant organs

What the organs do

Each plant organ has jobs (functions) in the plant. It is where the plant carries out the functions of living organisms. The organs of a plant keep growing all through the plant's life.

- **Leaves** need to make food in a process called photosynthesis (see page 16). The leaves are usually green. It is this green colour that traps the sunlight the leaves need to make food. The leaves are often big and flat so they catch as much light as possible. The leaves also let the plant take in oxygen and lose waste carbon dioxide at night. They are therefore important for respiration and excretion as well as photosynthesis.
- The **flowers** are the reproductive organs of the plant. They may be sensitive to the light and close up when it gets dark.
- The **stem** supports the plant. It holds up the flowers so that insects or the wind can bring pollen into them. The stem also holds up the leaves to the Sun so they can make lots of food. The stem is sensitive to the light and it moves by bending so that the leaves are exposed to as much light as possible.
- The **roots** grow into the soil. They hold the plant into the ground. They take up water and minerals from the soil, which the plant needs to make food. The roots may store food to help the plant reproduce.



The structure of a flowering plant

Key terms

- **flower**
- **leaf**
- **root**
- **stem**

Summary questions

1. Not all of the plants that you look at will have flowers. Why not?
2. Sometimes the organs of plants look very strange. They are carrying out special functions in the plant. For example, the spines on a cactus are really very thin, hard leaves, which help the plant to lose less water. They also protect it from being eaten. Find out about three really unusual plants from your country and explain the functions of their special or unusual organs.

1.4 Organs in humans

Learning outcomes

After this topic you should be able to:

- give the positions of the main organ systems in the human body
- explain the functions of the main organ systems in the human body.

Expert tips

MRI scans are just one way in which doctors can see inside the human body. What other ways are there? Find out what doctors can discover by using these methods.

Plants are not the only living things to have organs. Humans, like lots of other animals, have many different organs inside their bodies. Each organ has a particular job to do. Often several organs work together in an **organ system** to carry out a job in the body. Your heart is an organ that pumps blood. It is part of your circulatory system, which transports substances all around your body.

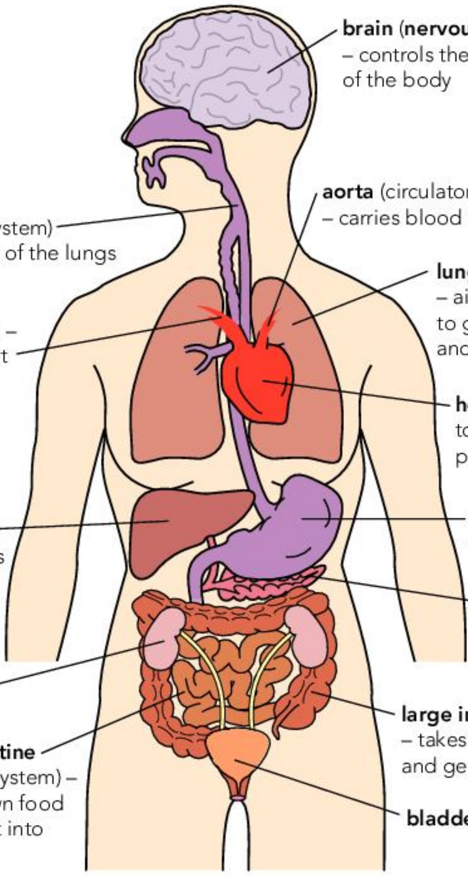
Seeing inside your body

Using special machines, doctors and scientists can now see inside the human body without cutting it open. Look at the photo below of a magnetic resonance imaging (MRI) scan of a human body. What can you see?

An MRI scan

The main human organs

MRI scans are not always easy to understand. However, if you know the main organs in the body, you will find it much easier to see what is going on when you look at the scan!



Key terms

- **circulatory system**
- **digestive system**
- **excretory system**
- **nervous system**
- **organ system**
- **respiratory system**

Summary questions

1. Make a list of all the organs you can identify on the MRI scan using the information from the diagram of the human body.
2. Using the diagram of the human body, and any other resources you may have, draw separate diagrams of the respiratory system, the circulatory system, the digestive system and the excretory system.

1.5 Looking at cells

Learning outcomes

After this topic you should be able to:

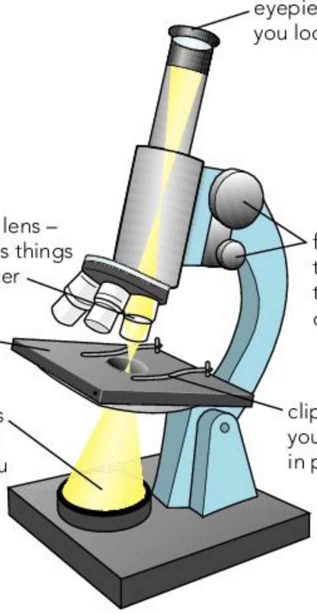
- set up a light microscope and use it to make careful observations of cells
- name the main structures seen in an animal cell under a light microscope
- name the main structures seen in a plant cell under a light microscope.

At Legoland you enter a world where all the buildings are made of small plastic Lego bricks. In the same way, all living things are made of building blocks called cells

What is a microscope?

Cells are very small – we need a special tool called a **microscope** to see them.

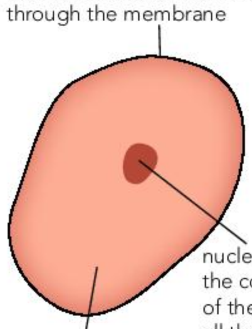
A microscope makes small things look bigger. It is rather like a complicated magnifying glass. It can make things look 4×, 10×, 100× or even 400× bigger than they really are! We can use it to see bits of living organisms or non-living things such as crystals that we could never see just using our eyes.



Light from the light source goes through the material you want to look at on your microscope slide. It travels up through the objective lens and the eyepiece lens until it reaches your eye. You see a clear, magnified picture of your specimen many times bigger than it really is.

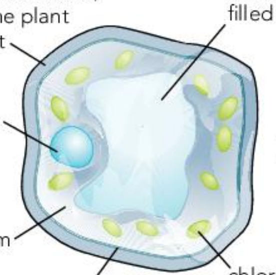
Animal cells

Microscopes have made it possible for us to see the **cells** that make up animals and plants. If you look at one of the simple cells that line the human mouth through a microscope, this is what you see.



Plant cells

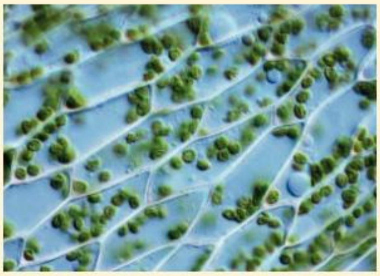
Many of the structures in a plant cell are the same as in an animal cell. However there are some big differences between them.



Practical activity Which is which?

Here are some animal cells and some plant cells photographed using a powerful light microscope.

- Decide which cells are which and then pick out all the main things you would expect to see.



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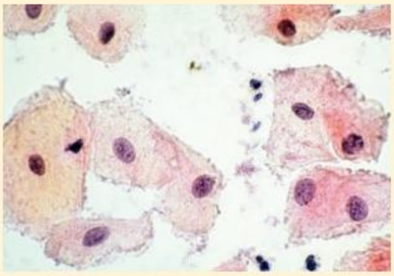


× 1000

Practical activity Model cells

- Plan and make a model of an animal cell and a model of a plant cell. Choose the materials that you will use.

Key terms

- **cell**
- **microscope**

Summary questions

1 Microscopes have changed the way scientists look at the living world. Explain why they are so important.

2 Explain the similarities and differences between plant and animal cells to someone who has not studied biology.

3 Look at the models that you and your classmates have made of plant and animal cells. Decide which you think are the best and explain what makes them particularly good.

1.6 Specialised animal cells

Learning outcomes

After this topic you should be able to:

- explain how cells, tissues, organs and organ systems are arranged
- give some examples of specialised animal cells.

Single cells are very small – often only about 0.01 mm across. Some organisms are made up of single tiny cells. But bigger organisms such as human beings, trees, insects and mosses are **multicellular**. This means they are made up of many cells. For example, you are made up of billions of tiny cells all working together.

All of the cells that make up a body are not the same. They are **specialised** to carry out different jobs, for example nerve cells carry electrical messages. Specialised cells have different features so they can do a particular job in the body.

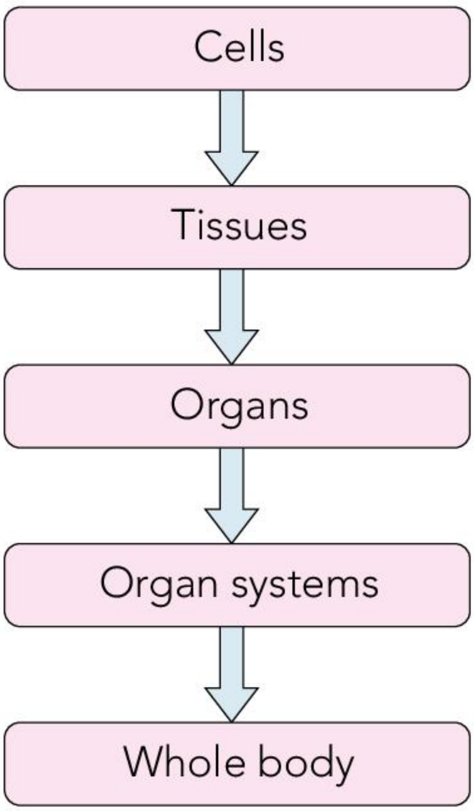
Cells, tissues and organs

Lots of specialised cells of the same type working together make up a **tissue**. A tissue carries out a special job in the body, for example muscle tissue contracts and moves bits of the body. Several tissues working together in the body form an organ, for example muscle tissue works with other types of tissue to form the biceps muscle in the arm, and to form the stomach.

Sometimes several different organs work together to carry out a specialised job in the body. They form an organ system such as the digestive system and the excretory system you saw in topic 1.4. Organ systems are needed to form complex organisms.

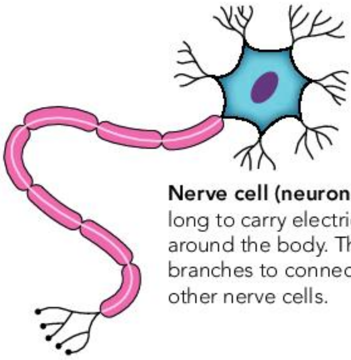
Key terms

- **multicellular**
- **specialised**
- **tissue**



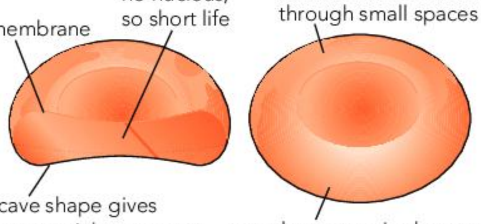
Specialised cells

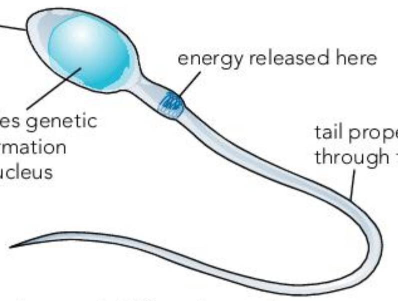
When cells become specialised to carry out one job, they look very different to the simple animal cell you looked at on page 13. Look carefully at the cells and you will be able to see how they have changed to carry out their special job.



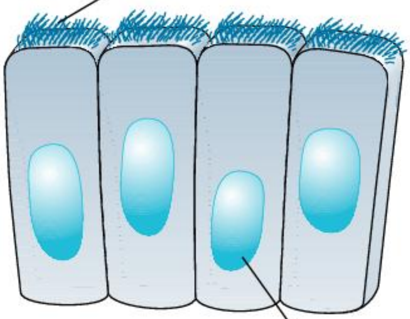
Nerve cell (neurone): These are long to carry electrical messages around the body. They have branches to connect to many other nerve cells.

Red blood cell: Special shape gives a large surface area so oxygen goes into the cell. No nucleus to make more room for the special red substance (haemoglobin) that carries oxygen.





Sperm cell: Carries genetic information to the egg. It is specialised to get to the egg cell with its tail and the energy-releasing middle region, and then to break into the egg with its head.



Ciliated epithelial cells: These cells are covered with tiny, hair-like cilia which beat to move things about in the body, for example mucus from the lungs. They use lots of energy.

Summary questions

1 a) Design a cell that would be good at storing fat and label it to explain the specialised structures.

b) Design a cell that would be good at detecting light. Label it to explain the specialised structures.

c) Use the internet or other books to look up fat cells and light-detecting cells, and see how well your design compares to what the real cells look like.

2 Draw a table like this one and fill it in to compare nerve, sperm and red blood cells.

Nerve cells	Sperm cells	Red blood cells

1.7 Specialised plant cells

Learning outcomes

After this topic you should be able to:

- give some examples of specialised plant cells
- explain how specialised plant cells are grouped together to make tissues and organs.

Pitcher plant

Expert tips

Xylem and phloem are the transport tissues in roots, stems, leaves and flowers. Xylem transports water and phloem transports sugars.

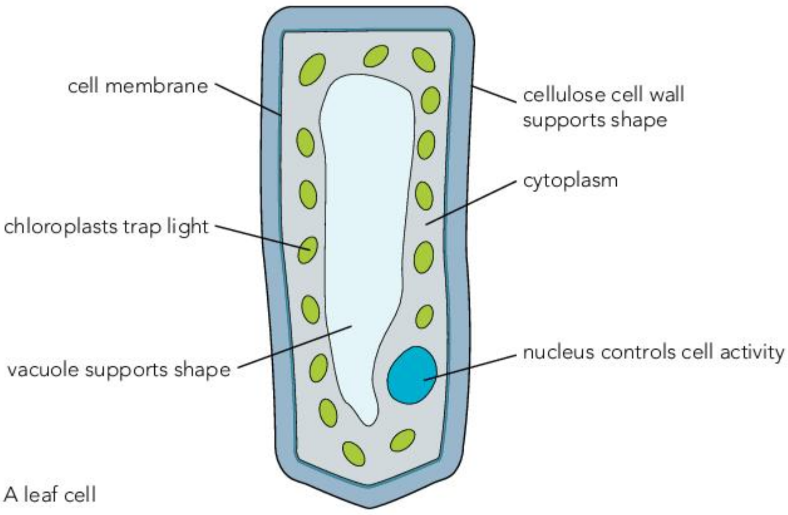
What do the pitcher plant and mangrove shown in the photos below have in common?

Mangroves

These strange looking plant organs carry out special jobs. The pitcher traps insects and the mangrove roots get air and water into the trees. These plant organs are made up of specialised cells organised into tissues. Several tissues work together to form the organ. For example, the roots contain transport tissue made up of xylem and phloem cells as well as supporting tissue.

Cells for making food

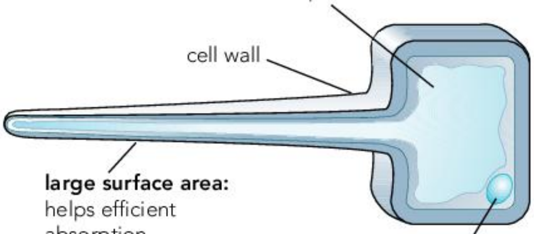
The way plants make their own food is called **photosynthesis**. In the green parts of plants (the leaves and the stems) many of the cells have special green structures called chloroplasts that carry out photosynthesis. The green substance in these structures is called chlorophyll. Chlorophyll captures the energy from the Sun, which is needed by the plant to make sugar. Plant leaf cells containing lots of chloroplasts make specialised palisade tissue, which is where most of the photosynthesis takes place.



A leaf cell

Root hair cells

You find **root hair cells** close to the tips of growing roots. Plants need to take in a lot of water and minerals when they are growing. The root hair cells help them take up more water. They give the plants microscopic 'hairs' on the roots so there is a very large area of root surface that can take in water. Root hair cells are always found close to the transport tissue in the roots so the water can be carried up to the rest of the plant.



A root hair cell

The structure and function of cells

When you look through a microscope at cells, you can try to work out what job they do. For example, cells that have a big surface area probably take in substances through their surface. Remember that when you look under the microscope cells don't always look as clear and simple as they do in a diagram.

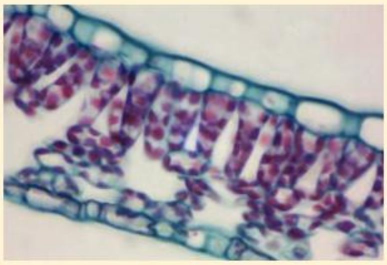
Key terms

- **photosynthesis**
- **root hair cell**

Practical activity Drawing cells

Here is part of a plant leaf and a plant root under a light microscope. The cells are stained (coloured) to make them show up more clearly.

- Make careful drawings of a palisade cell from the leaf and a root hair cell as they appear seen through a light microscope.
- Label as many things as you can.
- Make a note of anything that is labelled on the diagrams of the leaf cell (on the opposite page) and the root hair cell (above) that you cannot see in these micrographs.



Light micrograph of a plant leaf (× 200)

Light micrograph of a plant root (× 15)

Summary questions

1 Fatima looked at the cells of a plant leaf under the microscope and saw the green chloroplasts. She also looked at onion cells. Even though the onion cells had no chloroplasts she could still see that they were plant cells not animal cells.

a) What are the main differences between plant and animal cells?

b) Why do you think there are chloroplasts in some plant cells and not in others?

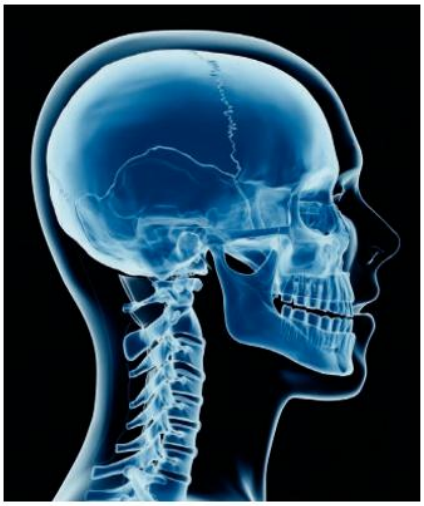
2 Some plant cells are adapted for taking in water from the soil and others are adapted for photosynthesis. Think carefully about what other types of cells might be needed in a plant. See if you can find out about two more specialised types of plant cells. (Hint: moving substances into leaves or around the plant.)

1.8 The human skeleton

Learning outcomes

After this topic you should be able to:

- explain how the skeleton gives the body support, protection and movement
- name the main bones of the body.

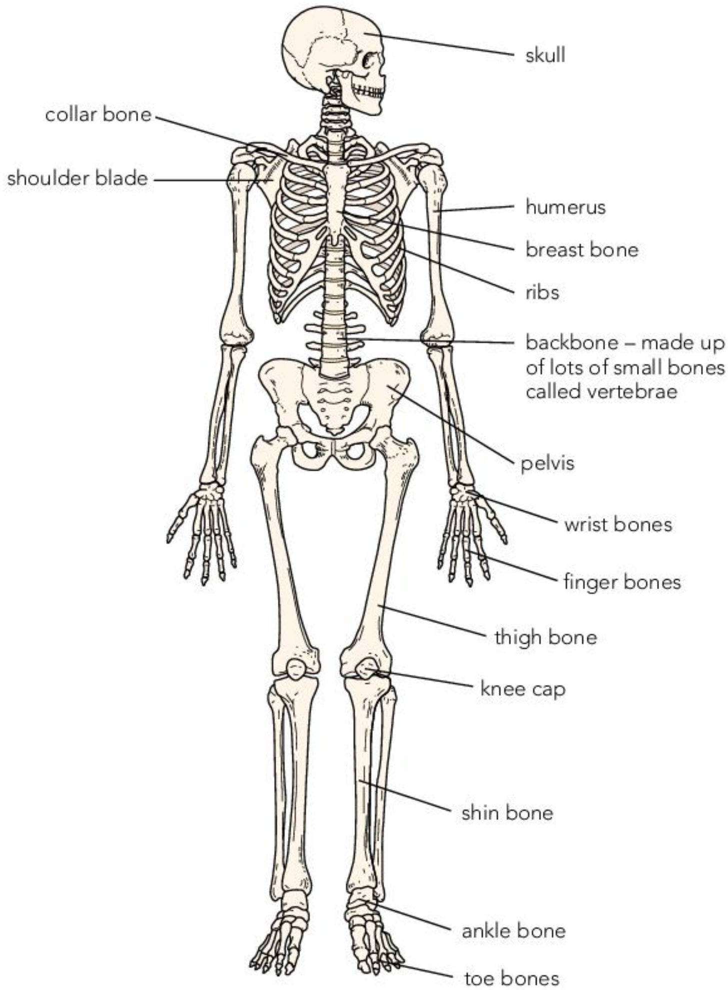


X-ray pictures let us see the bones inside a living body

All living organisms move, including people. We are **vertebrates** with a bony **skeleton** inside of our bodies. We use that skeleton to help us move about.

Inside the body

If we can see our bones it helps us to understand what they do. To see the bones inside our bodies we use **X-ray photographs**. X-rays go straight through the soft parts of our bodies, so on X-ray photographs only the hard bones can be seen.



The human skeleton

What does the skeleton do?

The skeleton does three main jobs:

- it supports the body
- it protects delicate organs
- it is jointed so we can move easily.

We all need a strong support system to hold us up – otherwise we would be giant, rubbery blobs! The bones of the skeleton are made of a strong but slightly flexible material that holds us up well.

We need protection for the delicate bits of our bodies, such as our brains and our hearts. Strong, bony 'cages' like the skull and the ribs give us the protection we need.

We need to be able to move about quickly and easily. The place where two bones meet is called a joint. The joints between the bones mean the skeleton allows us plenty of movement, as well as support and protection.

Key terms

- **skeleton**
- **vertebrate**
- **X-ray photograph**

Broken bones

If you fall badly or are in an accident you may break a bone. A broken bone hurts and it does not support your weight. However, broken bones do get better. If they are kept still for several weeks, your body makes new bone tissue, which heals the break. A plaster or splint is put around the broken bone to keep it still as it heals.

Practical activity Broken bones

Look carefully at these two X-rays.

Try and work out which bones have been broken in X-ray **A** and X-ray **B**.

- Make a sketch and label the broken bones.
- Explain how you decided which bones were broken.

A

B

Summary questions

1 Here are some of the bones of the body. Use them to answer the questions.

ribs   thigh bone   backbone (vertebrae)   shin bone   skull   toe bones

a) Which parts of the skeleton are very important in holding the body upright?

b) Which parts of the skeleton protect delicate organs?

2 The skeleton is not one single large bone. It is made up of lots of smaller bones with joints in between them. Explain why this is important.

3 Babies and small children have bones that are more flexible than those of an adult. This makes it possible for them to keep growing.

a) Apart from making growth possible, why is it a good thing that the bones of small children are quite flexible?

b) Adults would not get on very well if their bones were as bendy as those of a small child. Why not?

1.9 Muscles and joints

Learning outcomes

After this topic you should be able to:

- explain how the joints make it possible for you to move
- explain how the muscles work against each other (in antagonistic pairs) to move the bones of the skeleton.

Expert tips

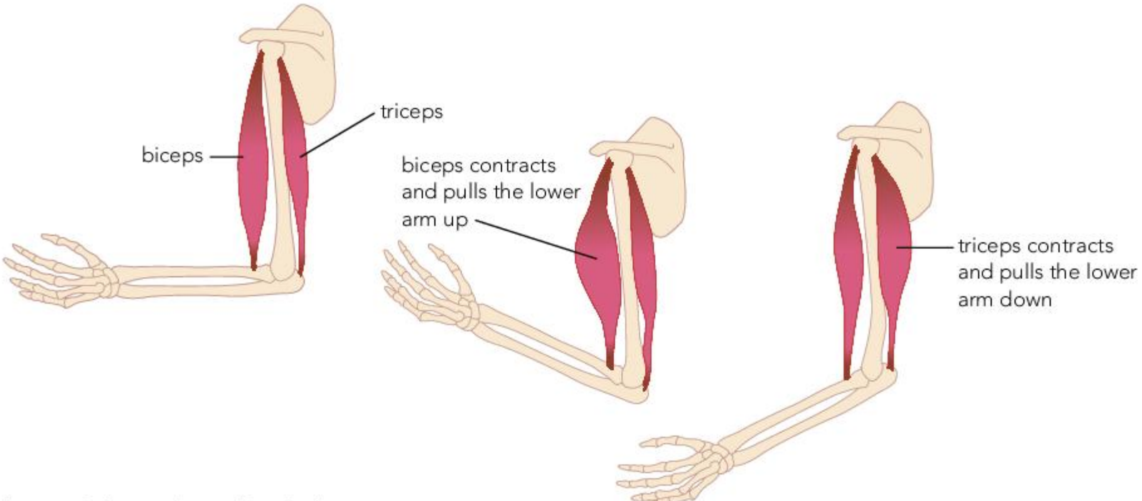
During their training the muscles of these athletes grow larger and become stronger. During the race the muscle tissue respires very fast to provide the energy it needs.

The bones of the skeleton can move, but only if you make them. The bones inside your body move thousands of times a day. Pick up your pen and lift it up to your shoulder. Which bones did you move?

Muscle power

To move our bones we need muscles. Athletes train to get extra big, strong muscles which are easy to see, as in the photo above. Most people can't see their muscles quite so clearly! Muscles are bundles of fibres which can **contract** or shorten.

Each end of a muscle is joined to a different bone by non-stretchy tissue called tendons. When a muscle contracts, it shortens to pull a bone into a different position.



Antagonistic muscles working in the arm

Your muscles can only pull – they can't push the bone back to where it came from. Another muscle must contract to pull the bone back. While the second muscle contracts, the first **relaxes**. Muscles that work in pairs like this are called **antagonistic muscles** because they work against each other.

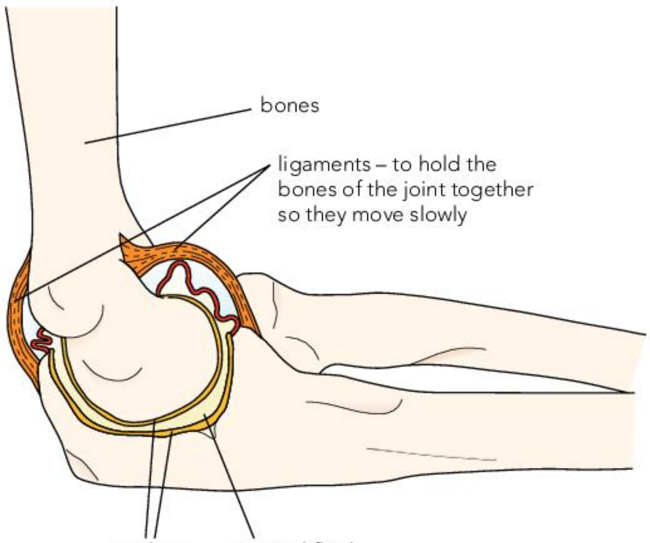
Practical activity Muscles and movement

Try the arm movements shown opposite. See if you can feel your muscles as they shorten and stretch.

- Which other parts of your body are moved by pairs of muscles working like this? Make a list of all the ones you can think of.

Joints and movement

The tread of human feet can wear away stone over hundreds of years. But in the joints of our skeletons bones are moving past each other all the time without wearing away.



A synovial joint

The ends of your bones are covered with tough, rubbery cartilage to protect them. In places where the bones move a lot, such as your hips, knees and elbows, you make **synovial fluid**. This fluid cushions and lubricates the joint. It makes sure that the bones move smoothly without grinding against each other – it is your body's version of oil in the engine of a car!

If the joints become damaged or diseased it is very painful to move. Some joint problems such as arthritis are more common in older people as all the tissues of the joint suffer from wear and tear with time.

Key terms

- **antagonistic muscles**
- **contract**
- **relax**
- **synovial fluid**

Summary questions

1. Copy the diagram of a joint into your book. Label each part of the joint and describe what it does.
2. Guntur notices that the muscle which lifts his arm up (his biceps) is bigger than the muscle which pulls his arm down (his triceps). Can you think of a scientific explanation for this?
3. Make a poster to show the structure of a joint, the way it works and what happens when it goes wrong. Work in groups – each group can find out about a different joint.

End of chapter questions

1 The seven features of living things and their definitions are listed below. Draw a table matching each feature with its definition.

Feature

Excretion

Growth

Movement

Nutrition

Reproduction

Respiration

Sensitivity

Definition

breaks down food releasing its energy, often using oxygen

changes the position of all or part of the body

increases in size and stays larger

makes and removes waste products from the body

makes more of the same by producing offspring

makes responses to changes in the surrounding environment

obtains from the surroundings sources of energy and the chemicals needed to make bodies *[7]*

2 A scientific expedition travels to a remote island to investigate the bird life. For each of the following, state **one** feature of living things which is being shown by the birds.

a Nest building.

b Parent birds bringing food to their chicks.

c The increase in mass of the chicks.

d Parent birds diving for fish.

e Chicks opening their mouths when they hear the parent birds approaching the nest.

f Young birds making energy available in the muscles to flap their wings. *[6]*

3 a Arrange the following in the sequence smallest to largest:

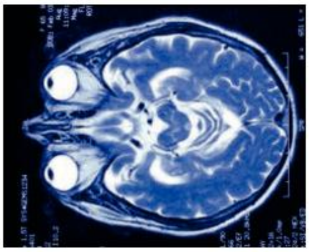
nucleus, **tissue**, **organ**, **cell**, **organism**, **organ system** *[3]*

b Which of the following are plant organs?

stem, **root hair**, **root**, **petal**, **leaf**, **chloroplast**, **vacuole** *[3]*

4 a What is the meaning of the term *organ*? *[2]*

This is an MRI scan of part of the human body.

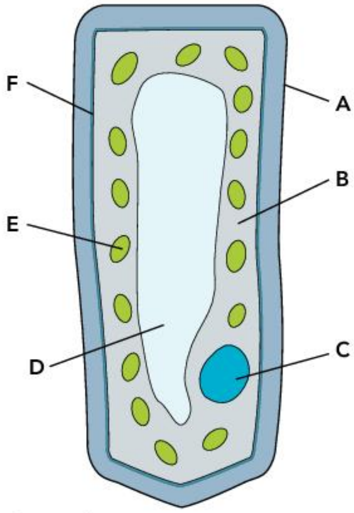


b List the organs that you can see. *[3]*

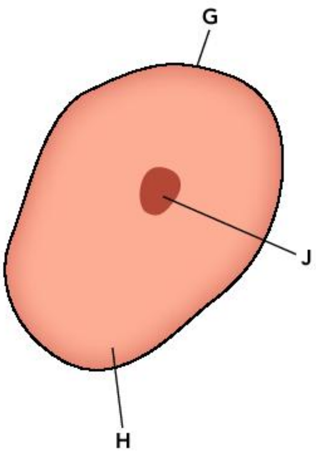
c State one function of each of the following organs:

kidneys, **stomach**, **liver**, **bladder**, **heart**, **lungs** *[6]*

5 The diagrams show a plant cell from a leaf and a human cell from the inside of the mouth.



Plant cell



Human cell

Match each of the labelled parts of the cells with one of the structures below. You may use each name once, more than once or not at all.

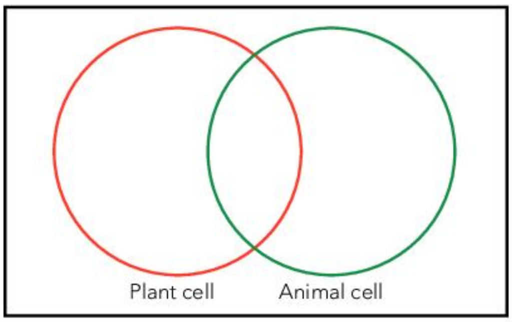
cell wall, **cytoplasm**, **nucleus**, **vacuole**, **chloroplast**, **cell membrane** *[9]*

6 a Copy and complete the table to compare plant and animal cells. You may complete the table using ticks and crosses.

Feature of cells	**Plant cell**	**Animal cell**
cell membrane		
cell wall		
chloroplast		
cytoplasm		
large vacuole		

[5]

b Use the information in the table to draw a Venn diagram to show the features of plant and animal cells. Your Venn diagram will look like this:



The features that are found in both plant and animal cells will be in the middle where the two circles overlap. *[5]*

7 Copy out this list of specialised cells.

red blood cell
white blood cell
root hair cell
muscle cell
leaf cell
nerve cell

Match each cell to a function from the list below. Write the function next to the name of each cell.

protects the body against disease
carries electrical messages from the brain to the muscles
carries out photosynthesis
absorbs water and mineral nutrients
carries oxygen around the body
contracts to move parts of the body

[6]

8 a One of the functions of the skeleton is to protect the body.

Name the parts of the skeleton that protect the following parts of the body:

i heart and lungs
ii brain
iii spinal cord *[3]*

b State two other functions of the skeleton. *[2]*

c What advice would you give to someone who had broken a bone? *[3]*

d What do you call muscles that work in pairs against each other? *[1]*

e Joints are found where two bones meet. Explain the way in which the following help movement at joints, such as the elbow joint:

muscles, **tendons**, **ligaments**, **cartilage**, **synovial fluid** *[5]*

Science *in context!* Medicines for the future

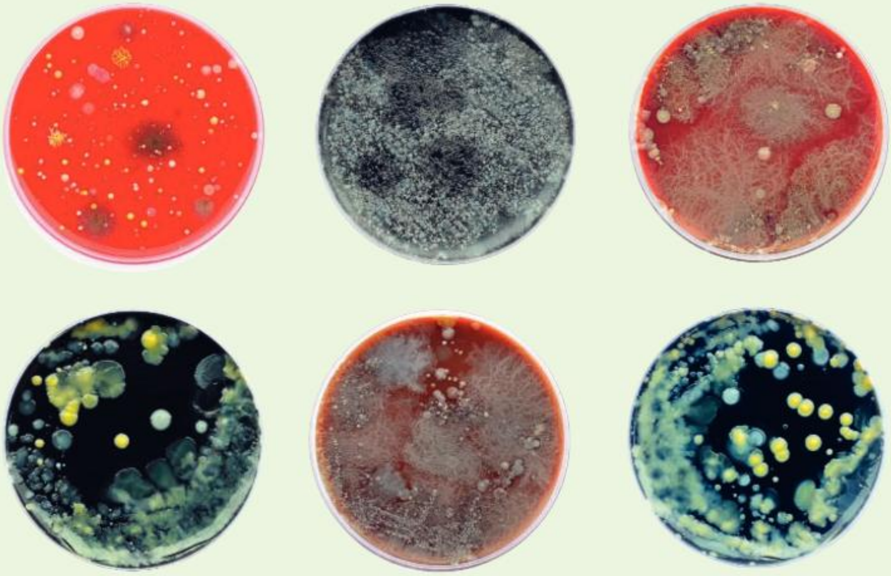
Scientists have to look for chemicals that kill bacteria, viruses or fungi but which don't hurt people. That isn't easy and they have to look in all sorts of different places.

Scientists have to make careful **observations** and ask the right questions. They do experiments to see if they are right and collect **evidence** they can show to other scientists. They have to be able to develop **explanations** that convince other people about their ideas.

Here are some examples of the way scientists are looking for new chemicals to kill bacteria:

- Many of the antibiotics, such as penicillin, that we use are made by mould fungi. Many mould fungi are found in the soil. Some scientists wonder if there are moulds in the soil which would make new chemicals to kill bacteria. They are investigating moulds from soils all over the world.
- Some scientists ask questions about what disease-causing bacteria need to live and grow. Then they use computers to try and design new chemicals that will stop the bacteria growing or kill them.
- The slime that fish make to cover their bodies seems to protect them from infections. If they lose their slime, their scales get infected very quickly. Some scientists observed this. Now they are investigating different chemicals from fish slime to see if they can find one that kills bacteria.

- People in Ancient Egypt used honey to help heal wounds. Modern scientists asked if this could really work. They have found there are chemicals in honey which seem to stop infections caused by bacteria. Some honey-based medicines are now used in hospitals. Scientists hope to make more and better medicines from honey.



A set of Petri dishes with different culture media and micro-organisms growing. They show the diversity in micro-organisms

- Crocodiles live in filthy water. They often fight and bite each other. Although their teeth are dirty, the bites don't get infected. Scientists looked at crocodile blood and found a chemical that kills a wide range of bacteria. They are working hard to see if this can be made into an antibiotic medicine to cure people with bacterial infections.

In this chapter you will explore the link between micro-organisms and disease, including the work of the famous French scientist Louis Pasteur. You will also be looking at the importance of micro-organisms in food production and in the natural decay process.

Key points

- Remember that the seven characteristics of living organisms are nutrition, respiration, reproduction, excretion, movement, sensitivity and growth.
- Micro-organisms are very small living organisms, which often can only be seen using a microscope.
- Bacteria are one of the most common types of micro-organisms. They are made up of single cells, which have a cell wall, genetic material, plasmid, cytoplasm, slime capsule and flagellum. Bacteria carry out all the common activities of living things.
- Some bacteria are very useful to people, some have no effect and some are harmful and cause diseases in people, other animals and plants.
- Fungi are micro-organisms but they can be very large. They carry out all the characteristic activities of living things.
- Yeasts are single-celled fungi. They reproduce by budding. Moulds are fungi made up of tiny thread-like structures called hyphae. Fungi reproduce by making spores.
- People use fungi for food and to make bread but they can also cause diseases in people, other animals and plants.
- Viruses are incredibly small micro-organisms which are made up of a protein coat and genetic material. They are parasites – they can only reproduce by taking over the cell of another living organism and using it to make new viruses. All viruses cause disease.
- Micro-organisms such as bacteria and yeasts are involved in the process of decay.
- Bacteria, viruses and fungi all cause diseases in animals (including people) and plants.
- One of the first people to make discoveries about micro-organisms was the French scientist Louis Pasteur.

2.1 Bacteria

Learning outcomes

After this topic you should be able to:

- label a diagram of a bacterium
- explain that bacteria are living organisms
- list some of the ways bacteria affect people.

When you look around you can see your classmates. You may see plants and animals. But there are millions of tiny living organisms you cannot see. These are **micro-organisms**. They are on your desk, on your skin and even in the air you breathe. One of the most common types of micro-organisms are **bacteria**. Micro-organisms are sometimes called microbes for short.

What are bacteria?

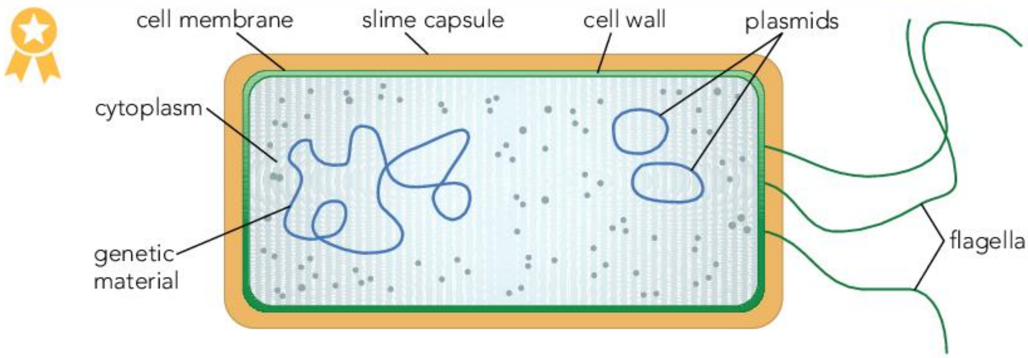
Bacteria are some of the smallest of all living organisms and come in lots of shapes and sizes. About 100 of the largest bacteria lined up would just about stretch across this full stop. You cannot see individual bacteria without using a microscope. Each bacterium is a single cell.

Practical activity Plant and animal cells

What do plant and animal cells look like when you look down a microscope?

- Work in a small group and make a quick labelled drawing of an animal cell and a plant cell to remind yourselves of what they look like.

Now look at a typical bacterial cell in the diagram below.



A bacterial cell (× 74 000)

Bacterial cells look rather different to plant and animals cells. They don't have a proper nucleus. They have a loop in the cytoplasm that carries all the information about how to make a new cell (the genetic information). Bacteria often have other small pieces of genetic information called plasmids.

Bacteria are living organisms. What do all living things do? Bacteria take in food and respire. They excrete carbon dioxide and other waste products. They can grow and they reproduce by simply splitting in half. If they have all the things they need, some bacteria can split in half every 20 minutes. Some bacteria have flagella to move themselves about.

Key terms

- **bacteria**
- **colony**
- **culture**
- **micro-organisms**

Useful and harmful bacteria

Some bacteria cause diseases in humans and other in organisms such as animals and plants, for example:

- *Salmonella* bacteria cause stomach upsets.
- Bean blight is caused by bacteria.

Many bacteria are harmless and some are very useful to us. For example:

- Bacteria help to decay the bodies of dead plants and animals.
- Bacteria in our guts and on our skin help to keep us healthy.
- We use bacteria to make cheese, yoghurt, wine and vinegar as well as for treating human sewage.

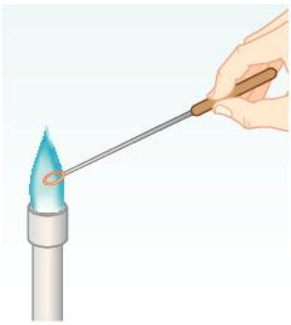
Growing bacteria in the laboratory

Growing bacteria

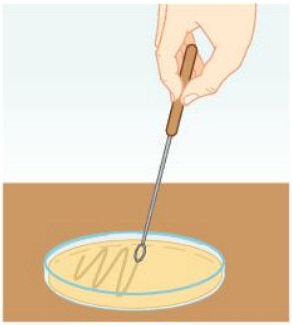
If you grow bacteria on special jelly that contains all the nutrients (food) they need, they form **colonies**. These colonies are big enough to be seen without a light microscope. This makes it easy for scientists to see if a chemical will kill disease-causing bacteria. But take great care when you **culture** bacteria and follow these instructions carefully to avoid any risk from harmful bacteria:

Expert tips

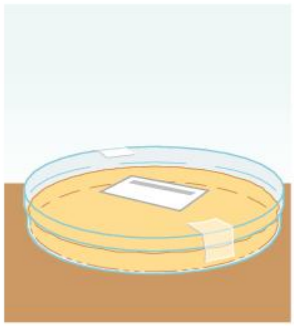
We will use the word nutrient in slightly different ways. Here it means all the food substances that the bacteria require, such as simple sugars and mineral salts.



Sterilise the inoculating loop used to transfer micro-organisms to the agar by heating it until it is red hot in the flame of a Bunsen and then letting it cool. Do not put the loop down or blow on it as it cools.



Dip the sterilised loop in a suspension of the bacteria you want to grow and use it to make zigzag streaks across the surface of the agar. Replace the lid on the dish as quickly as possible to avoid contamination.



Seal the lid of the Petri dish with adhesive tape to prevent micro-organisms from the air contaminating the culture – or micro-organisms from the culture escaping. Do not seal all the way around the edge so oxygen can still get into the dish. This is so that harmful bacteria that do not need oxygen are not able to grow.

Summary questions

1. Make a table to compare a bacterial cell with a plant cell and an animal cell. You will need four columns – one for each type of cell and one for the features you are comparing.
2. Bacteria grow fast when they have just the right conditions. Write a plan to investigate the best temperature for bacteria to grow as fast as possible. You could present your plan as a series of drawings or as a flow chart.
3. The diagram of the bacterial cell on the opposite page is 74 000 times its actual length. Calculate its actual length and show your working.

2.2 Fungi

Learning outcomes

After this topic you should be able to:

- explain that yeast and moulds are types of fungi
- describe yeasts and moulds.

We do not need a microscope to see all micro-organisms. **Fungi** are called micro-organisms but they can grow very big indeed!

This puffball is a very large micro-organism. The apple gives you an idea how large it is

Fungi destroy millions of tonnes of food around the world every year

Expert tips

You can see that green mould is growing on these oranges. Spores from the air grew hyphae, which entered the fruits through breaks in the surface. At first the mould looks white, then it makes spores that make it look green. Let some oranges go mouldy and then look at some of the fungus under a microscope to see the hyphae and spores.

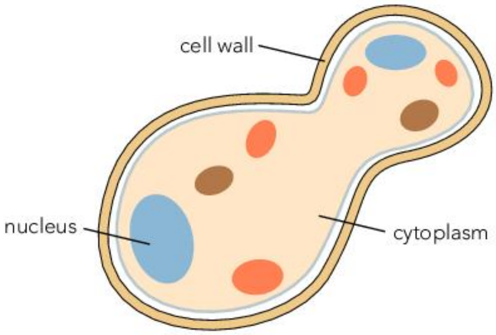
Finding out about fungi

You will probably have seen fungi on market stalls, growing wild or as part of your food. The mushrooms and puffballs you have seen are the parts that the fungus uses for reproduction. Most of the rest of the fungus spreads out in the soil as very thin, thread-like structures called **hyphae**. Many fungi are very useful to people. However, all fungi get their food from dead or other living organisms and so some of them cause a lot of damage. They digest crops and food and make them rot.

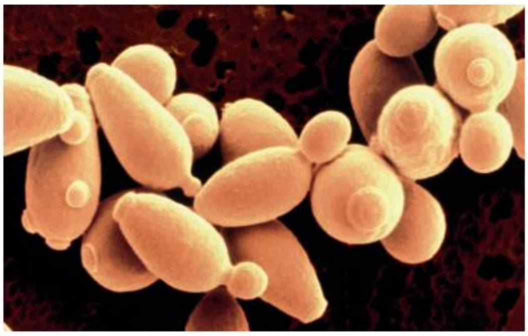
There are lots of different types of fungi. They usually need moist conditions to grow. You are going to look at **yeast** and moulds. The cells of these fungi can be seen under the microscope. You will find they look very different both from plant and animal cells and from each other.

Yeasts

Yeasts are single-celled organisms. They are found all around us. They often grow on the skins of fruits, feeding on the sugar in the fruit. They usually respire using oxygen from the air, but they can respire without oxygen if there is none available. Each yeast cell has a nucleus, cytoplasm and a membrane with a cell wall round it. They reproduce by budding, with a small new yeast cell forming from the old one as you can see in the diagram and photo at the top of the opposite page.



Yeast cell

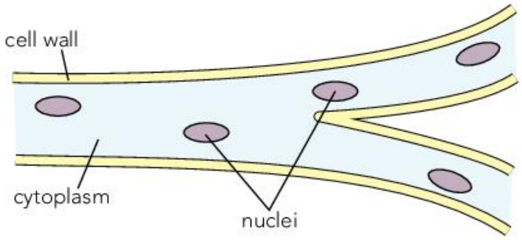


Scanning electron micrograph of yeast cells (× 1500)

There are many different types of yeast. People have used some types of yeast for centuries to make bread and drinks such as beer and wine. But different yeast cells can also cause diseases of the skin, the lungs and the brain.

Moulds

Moulds are very different from yeasts. They are made up of tiny, thread-like structures called hyphae. Hyphae are not made up of individual cells. Have a look at the structure of a mould hypha in the diagram below. See how it differs from the structure of the yeast.



Mould hyphae

Moulds need oxygen to respire. They get their food by digesting it outside their bodies and then taking in all the substances they need. This is why mouldy food goes very soft because it is being digested. Moulds reproduce, but they do not split in two. They make little fruiting bodies that are full of spores. Each spore can grow into a new mould.

You will be finding out more about fungi on pages 32, 39 and 41.

Key terms

- **fungus (plural fungi)**
- **hypha (plural hyphae)**
- **yeast**

Summary questions

1 a) Explain the ways in which we can tell that fungi are living organisms.
  b) Draw a table to compare yeasts and moulds.

2 Moulds can make food go bad. Suggest ways to investigate the conditions moulds need to grow.

3 Describe a method to make a slide so that you could study some yeast or mould under the microscope.

4 What is the actual diameter of the yeast cells shown in the photo above? Explain the way you arrived at your answer.

2.3 Viruses

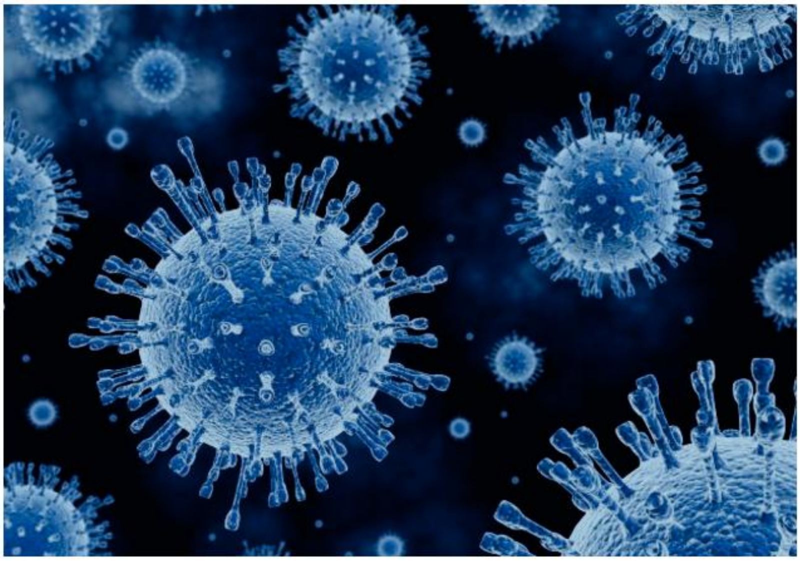
Learning outcomes

After this topic you should be able to:

- describe the structure of a virus
- explain what is meant by a parasite
- explain why viruses are such effective parasites.

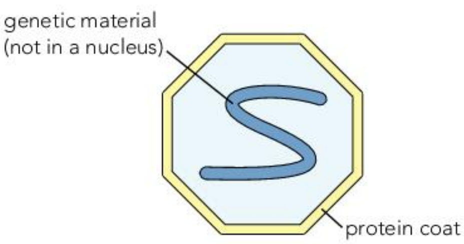
Imagine a micro-organism that doesn't respire, feed, move, excrete or have any sensitivity – but which can reproduce by taking over other organisms. It sounds unbelievable – but this is what viruses do.

What is a virus?



Viruses look like something from outer space

A **virus** is incredibly small, about 0.0001 mm long. Viruses can reproduce, but only inside the cells of another living organism such as an animal or a plant. Viruses don't respire or move themselves, feed or excrete so they are unlike any other living organism. Under very powerful microscopes viruses can be seen as strange shapes, which are made of protein and genetic material.



The structure of a virus

Expert tips

Viruses are so simple, yet they can be so deadly. Unlike bacteria, fungi, animals and plants, they do not have cells. They have genetic material enclosed in a protein coat. Some, like HIV, are also surrounded by a membrane taken from their host cell.

A single sneeze like this releases millions of viruses into the air for other people to breathe in – and catch your cold!

Viruses and disease

All viruses cause diseases in living organisms. Diseases caused by viruses include colds, influenza, chickenpox, measles, polio and HIV/AIDS. Viruses cannot move themselves from one organism to another but they have found ways of spreading around in different ways. For example, the virus that causes the common cold spreads when people cough or sneeze.

Practical activity Make a virus!

Work in a group. Look for different images of viruses on the internet or in books. Choose one virus and find out what it looks like and what disease it causes.

Plan to make a model to show the structure of your virus. If there is time, make your model and present it to the class.

Viruses are parasites

Viruses are **parasites**. Some people say they are the ultimate parasite. But what does this mean? A parasite is an organism that takes what it needs to live from another living organism known as the host. A parasite always hurts its host, and sometimes it will even kill it.

As well as viruses our parasites include:

- animals, such as tapeworms and threadworms
- bacteria, such as *Mycobacterium leprae*, which causes leprosy
- fungi, such as *Candida*, which causes thrush.

Most parasites rely on their host for food, and sometimes protection. Viruses rely on their host for everything. Once viruses get into the body they invade the cells. The protein coat of the virus often stays outside the cell but the genetic material is injected through the cell membrane. The genetic material of the virus then takes control of the nucleus of the host cell. It uses the host to make lots of new viruses. Eventually the cell bursts and releases all of the new viruses. These then spread through the body and infect more cells. They can also leave the body and infect someone else.

We have developed antibiotic medicines which can be used to cure diseases caused by bacteria. However, we do not yet have medicines which can destroy viruses and so we cannot cure viral diseases.

Expert tips

We have used the scientific names for the bacterium that causes leprosy and the fungus that causes thrush. Each species has a name like this. Viruses, however, are named very differently without using words taken from Latin or Ancient Greek.

Key terms

- **parasite**
- **virus**

Summary questions

1 Why do some people think that viruses are not living organisms?

2 You may need to do some research to answer this question. State the range of lengths in millimetres of the following:

virus, **bacterium**, **animal cell**, **plant cell**

3 Make a diagram, chart or some models to compare the sizes of the different cells in question **2**.

4 Why are drawings and photos of micro-organisms always magnified? What is the magnification of the viruses shown in the illustrations on these pages? Show your working.

2.4 Micro-organisms and food production

Learning outcomes

After this topic you should be able to:

- explain how yeast is used in the production of bread
- explain the way bacteria are used to make yoghurt and cheese
- make conclusions from data collected in an investigation.

Every time you eat cheese, yoghurt or bread you are eating foods made using micro-organisms.

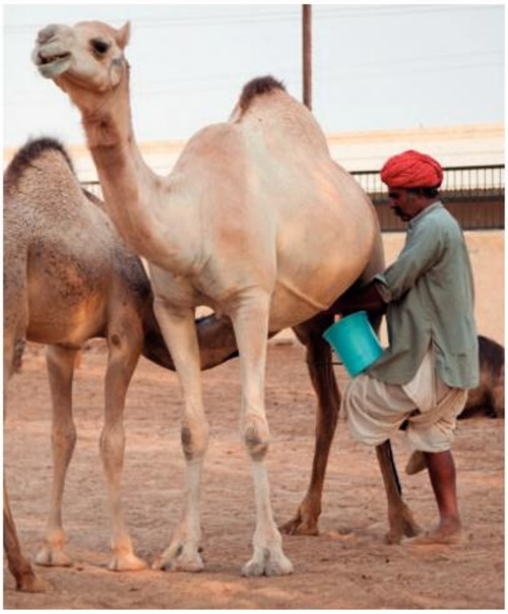
Bread making with yeast

If yeast cells have air, warmth and plenty of sugar, they will respire and grow very quickly, making lots of carbon dioxide as a waste product. For thousands of years people have used this to help them make bread that is light and airy. Flour, sugar, yeast and some water or milk are mixed together to make dough. The dough is kept somewhere warm to rise. As the yeast respires, the carbon dioxide bubbles make the dough get bigger. Its texture gets lighter. When the bread is cooked, the bubbles of gas get bigger and the dough rises even more.

The yeast in this naan bread made it rise when it was cooking

Yoghurt making using bacteria

Yoghurt is a creamy solid made by mixing bacteria with warm milk. The bacteria feed on the sugar in the milk and make a chemical called lactic acid. This gives the yoghurt its sharp, tangy taste. The lactic acid causes the milk to clot and solidify into yoghurt, and the action of the bacteria also helps to give it a smooth, thick texture. Once the yoghurt-forming bacteria have worked on the milk, they also help to stop other bacteria growing, which might turn the milk bad.



Many different animals including camels are used for milking. If the right bacteria are added, the milk soon turns into yoghurt

Practical activity Keeping milk good

Ordinary milk goes bad in just a few days – less than that if it gets really warm. Yogurt lasts much longer.

Set up a simple investigation to show how the yoghurt-forming bacteria help keep the milk good for a long time.

- Measure out 10 cm^3 of milk into each of two small containers or test tubes. Label the tubes 'Milk – room temperature' and 'Milk – cool'.
- Put 10 cm^3 of yoghurt into each of two small containers or test tubes. Label the tubes 'Yoghurt – room temperature' and 'Yoghurt – cool'.
- Place one milk and one yoghurt container at room temperature on the side of your classroom
- Place one milk and one yoghurt container somewhere cool, such as a fridge.
- Observe all the containers every day and record the appearance and the smell of the contents. Once they have gone off, throw them away!
- Display your results and make your conclusions.

Make sure you do not taste the milk and yoghurt used in your experiment!

Using bacteria to make cheese

Cheese is made by the reaction of certain bacteria with milk, changing the texture and taste and also preserving it. Some cheeses can survive for years without going bad.

The bacteria used in cheese making produce a lot of lactic acid. This makes the milk separate into a very solid part (curds) and a liquid part (whey). Sometimes juices from the stomachs of young animals such as calves are added to make the milk separate even more.

The curds can be used fresh, often with herbs and seasoning added. They can also be mixed with salt and other bacteria, or even moulds, and then pressed and left to dry out. These hard cheeses can last a very long time.

Sometimes moulds are added to cheeses, or the cheeses are wrapped in the leaves of different plants. Both the moulds and the leaves give the cheese extra flavour.

In cheese making, solid curds are made by the action of bacteria on milk. The curds can be eaten fresh or turned into hard cheeses using more bacteria and salt

Key terms

- **yoghurt**

Summary questions

1 a) Explain why bread dough put in the fridge or when cooked immediately after it is made does not rise.

b) Describe an investigation to find the effect of temperature on the bacteria that are used to make bread.

2 Work together in a group and find out about the making of a local cheese **or** yoghurt. Make a poster to explain the process. You could use your poster to contrast home production with industrial production using information from websites.

2.5 Micro-organisms and decomposition

Learning outcomes

After this topic you should be able to:

- describe how micro-organisms break down the remains of animals and plants
- explain how decomposition by micro-organisms can be both useful and harmful to people
- record observations over time.

Expert tips

Mineral nutrients are sometimes called mineral salts or just salts (see page 27). Farmers add chemical fertilisers to their land so that their crops have a good supply of these nutrients.

What happens to a piece of fruit if you leave it too long before you eat it? It will soon be covered in mould and, in time, the mould will break it down completely.

Micro-organisms, such as this mould, quickly break down a piece of fruit

Decomposition in nature

Living things are constantly taking materials from the world around them. Plants take minerals from the soil and these are then passed on to the animals that eat the plants. If nothing was returned to the soil, the resources of the Earth would soon be used up. However, the mineral nutrients held in the bodies of dead animals and plants, and in animal droppings, are released back into the soil by the action of micro-organisms. These micro-organisms are known as **decomposers**.

The decomposers feed on waste droppings and dead organisms. They break them down (digest them) and use some of the nutrients to grow themselves. They also release waste products. These are nutrients broken down into a form that plants can use. When we say that things decay, they are actually being broken down and digested by these micro-organisms.

In a cycle of life and death, the decomposers break down dead organisms and return nutrients to the soil

Practical activity The effect of temperature on the decomposers

You can work in groups to find out the effect of changing the temperature on the micro-organisms that decompose living organisms.

- Each group collects either some whole fruit, or some plant waste, for example fruit and vegetable peelings, grass cuttings, fallen leaves.
- Divide the material into three plastic bags and lightly tie the top of the bag (black plastic bags are fine).
- Put one bag in the fridge, one somewhere around 20 °C if possible and one somewhere hot, say 30 °C or higher.
- Open and observe the organic material after one day, three days and one week. Record your observations (photos are a good way to do this).
- Compare your results with the rest of the class and make your conclusions about the effect of temperature on the rate of decomposition.

Using decomposers

The number of people in our country keeps growing. People produce a lot of bodily wastes. The more people there are, the more waste gets produced! Whether we use a pit latrine or have flushing toilets and a sewage system, we rely on micro-organisms to break down our **sewage** and make it harmless to us and to the world around us.

People also use decomposers to break down vegetable waste, dead plants and grass cuttings. They turn this waste into a rich brown substance, which is added to the soil to help plants grow bigger and better. This partially decayed material is called **compost**.

Decomposers as destroyers

Decomposers break down dead organisms, but they will also break down things we need. Bacteria and fungi destroy crops in the fields. They also decompose millions of tonnes of stored food every year. If we can stop micro-organisms decomposing the food we want to eat, it would help to prevent people suffering from lack of food around the world.

Key terms

- **compost**
- **decomposers**
- **sewage**

Summary questions

1. To make the best compost you need warmth, moisture and oxygen. Explain why all these are needed.
2. Explain why it is so important that micro-organisms break down waste material and dead bodies in nature.
3. Read the practical activity instructions carefully. Suggest what you should do to make this investigation a fair test.

2.6 Micro-organisms and disease – general principles

Learning outcomes

After this topic you should be able to:

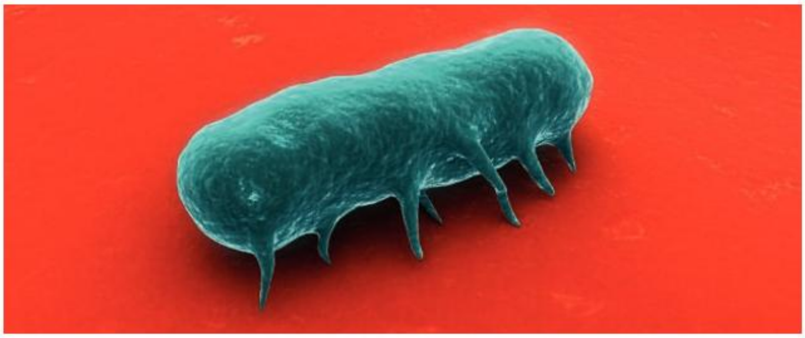
- explain how infectious diseases are spread.

Many illnesses and diseases are infectious. This means they can be spread from one person to another. There are many different **infectious diseases**. Think of as many as you can and draw a table like this one to describe them.

Illness	Parts of body affected	How it makes people feel
Cold	Nose, throat	Tired, with a headache, nose feeling blocked up

Infectious diseases

Many diseases are caused by micro-organisms such as bacteria and viruses. They can make us feel unwell and even kill people.



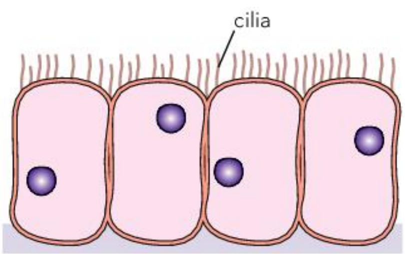
This *Salmonella* bacterium has been magnified thousands of times. *Salmonella* bacteria cause food poisoning

Bacteria and viruses cause diseases ranging from tonsillitis to tuberculosis. Bacteria and viruses can get into your body through your body openings such as your mouth and your nose, or through cuts in your skin. Once inside they attack the cells of your body and quite soon you begin to feel unwell. But most times you don't stay ill for ever. That is because your body has its own natural defences against the micro-organisms that cause disease.

The first line of defence – don't let them in!

Your body works hard to prevent disease-causing organisms from getting in. Your skin covers and protects most of your body tissues. Micro-organisms getting into your mouth are dropped straight into the acid of your stomach! The easiest place for micro-organisms to enter is your respiratory system, when you take air right into the delicate tissues of your lungs.

The hairs in your nose filter the air you breathe in. Also, many micro-organisms get stuck in the mucus produced in your respiratory system. The mucus is then removed by the action of **cilia** found on special cells (ciliated epithelial cells) that line the airways leading to the lungs.



Ciliated epithelial cells are ideally suited for the job they have to do

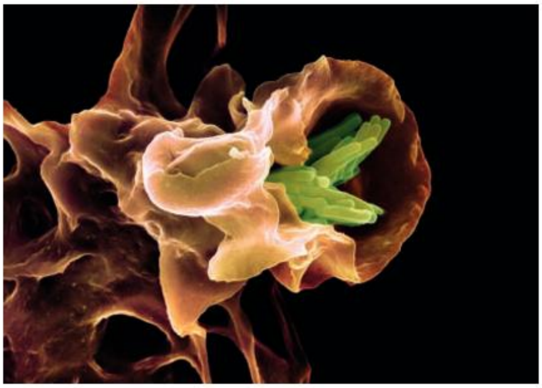
The cilia beat to move the mucus carrying dust, bacteria and viruses **away** from the lungs. The cilia in your respiratory tract are beating all the time but you don't notice them. However, you see the results of their efforts when you have a cold. What happens then?

Whenever you cut yourself your body is open to attack by all the micro-organisms around. Your blood clots to form scabs to help cope with this danger. These scabs:

- stop you bleeding
- stop micro-organisms from getting in
- let your new skin form underneath, protected from any further knocks.

Second line of defence – destroy the invaders

When bacteria or viruses actually get into your body, cells in your blood take over the defence. Your body has an army of **white blood cells**, which engulf and destroy the bacteria or viruses. When you get an infection your body works hard to make lots of extra white blood cells. They are made in special glands in your neck and other places around your body. This is why when you are ill, you often have swollen glands. The glands are very busy making white blood cells to fight off the micro-organisms which are the cause of your illness.



A white blood cell engulfing and destroying a bacterium

Key terms

- **cilia**
- **infectious disease**
- **white blood cell**

Summary questions

1 Draw and label a big diagram to show the main places that micro-organisms can get into your body. On the same diagram add labels in a different colour to show the way in which your body defends itself against disease.

2 Explain why ciliated epithelial cells are ideally suited for the job that they have to do.

3 'Cigarette smoke stops the cilia on the ciliated epithelial cells in your breathing system from beating.'
'People who smoke often get more coughs and colds than people who do not smoke.'
Suggest a scientific explanation for why these two statements might be linked.

Micro-organisms and disease in animals

Learning outcomes

After this topic you should be able to:

- describe a bacterial disease in animals and explain how it can be treated and prevented
- describe a viral disease in animals and explain how it can be prevented
- describe a fungal disease in animals.

Bacteria, viruses and fungi can all cause diseases in animals (including human beings). Some of these diseases are internationally important. They kill people, kill livestock and affect the health of millions of people around the world.

Tuberculosis – a bacterial disease

Tuberculosis (TB) is caused by bacteria. In cattle and people it often affects the lungs. TB makes animals and people cough up blood, lose weight and sometimes die. In people, TB is spread by droplet infection from coughs and sneezes. But you need to be in close contact with someone for some time to catch the disease. Cattle live in herds so they easily spread the disease from one to another. People can get TB if they drink untreated milk from an infected cow.

When cows are infected by TB they do not give much milk or meat and cannot work in the fields. Many people do not get enough food as a result

Some people do not have enough food to eat or their immune system is damaged, e.g. by HIV/AIDS. These people have a higher risk of catching TB. About 2 billion people – about one third of the world population – are infected with TB and about 2 million of them die every year.

If cattle are infected with TB they are often slaughtered. People may be treated. TB is caused by bacteria so it can be cured by **antibiotics**. It takes a very long course of antibiotics to cure TB. Sadly, people do not always finish their medicine so they become ill again.

TB can be prevented by **vaccinations** which make people immune to the disease. It can also be prevented if people are well fed and have good living and working conditions.

Polio – a viral disease

Polio is a disease caused by a virus. It attacks your nervous system and it can cause paralysis. If this affects breathing muscles it can kill people. The virus is passed on in faeces and in contaminated food and water. In the past, many people were left paralysed. Now polio only exists in about three or four countries. It has been largely wiped out by a world-wide programme of vaccination.

Vaccination lets your body meet a dangerous micro-organism in a safe way. Then, if you ever meet the real thing, your body can make the white blood cells needed to destroy it before you become ill.

Many countries have worked very hard to vaccinate their populations and help wipe out polio

Thrush – a fungal disease

Fungi do not cause many diseases in animals although they can cause serious infections of the brain, the lungs and the heart. **Thrush** is the most common fungal disease in people. It is caused by a type of yeast that lives on our skin. Most of the time these yeast cells are harmless; but if you have to take antibiotics or if you are seriously ill, the fungi attack your skin. This makes your skin itchy and sore. Anti-fungal chemicals can usually kill the fungus and make you better.

Thrush is not often serious but it can be very sore and painful

Key terms

- **antibiotic**
- **polio**
- **thrush**
- **tuberculosis (TB)**
- **vaccination**

Summary questions

1 Work in a small group. Write down all the different illnesses you can think of. Try and find out which of them are caused by bacteria, which by viruses and which by fungi.

2 a) TB is spread more easily when people are poor and when they live and/or work in overcrowded conditions – why do you think this is so?

b) Explain why TB in cattle affects people in several different ways.

c) Why do you think that we vaccinate and treat people against TB but do not treat or vaccinate cattle?

3 Why is it important to vaccinate people when they are babies rather than leaving it until they are older?

Micro-organisms and disease in plants

Learning outcomes

After this topic you should be able to:

- describe a bacterial disease in plants and explain how it is spread and can be prevented
- describe a viral disease in plants and explain how it is spread and how it can be prevented
- describe a fungal disease of plants and explain why it is so serious.

Micro-organisms infect plants and cause disease. When plants get sick and die, people don't get enough food to eat, so plant diseases can be very serious for people too.

Xanthomonas – bacterial diseases in plants

There are some bacteria that cause diseases in all sorts of plants from fruit trees, such as lemons, figs and bananas, to houseplants. These bacteria all belong to the same group known by the scientific name *Xanthomonas* (pronounce it as if it starts with a 'Z').

For example, one type causes citrus canker. This attacks citrus fruits such as lemons, oranges and limes. The bacteria affect the leaves so they look brown and cannot make food properly. They affect the fruit so they are spotty and fall off the tree too soon. They can ruin a crop once they get into a citrus grove.

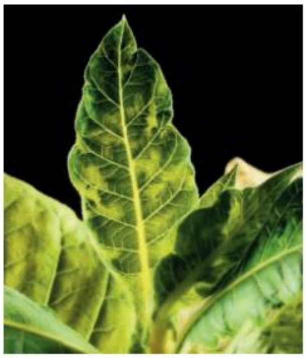
Diseases, such as this citrus canker, can destroy farms and ruin lives

The bacteria ooze out of the fruits and leaves of an infected plant. They are then spread easily from plant to plant in water when it rains – or even when the trees are watered by the farmer.

When plants are infected they have to be destroyed to stop them infecting other plants. So *Xanthomonas* costs farmers millions of dollars every year in lost crops.

Mosaic viruses in plants

There are many different viruses that attack and damage plants, such as the different mosaic viruses. They get into plants when the leaves are damaged, for example when insects bite the leaves. The mosaic viruses take over the plant cells to make new viruses. They usually affect the leaves of the plant which develop a mosaic pattern of different colours. The viral infection stops the plant growing well and often stops it producing a very good crop.



The yellow areas in these leaves are infected with tobacco mosaic virus. Mosaic viruses like this can damage an entire crop

There is no cure for plants infected with viruses. They have to be destroyed. It is a big problem to stop the virus spreading to more plants from infection in the soil. The virus is spread by people's hands or is carried by insects that feed on plants.

Fusarium wilt – a disease caused by fungi

Fungi don't cause many serious diseases in animals but in plants they cause terrible problems. *Fusarium* wilt (also called vascular wilt and Panama disease) has destroyed banana crops in almost every country where they are grown. The spores of the fungus are in the soil and they attack the small roots of young plants. They get in to the special water transport tissue (xylem) in the plant and damage and destroy it. If the plant cannot transport water it will soon die. As the plant is dying the fungus makes lots more spores. The spores fall into the soil and wait to infect more plants.

Millions of tonnes of crops – like these bananas – are lost worldwide every year as a result of fungal plant diseases

Anti-fungal chemicals will help get rid of fungi that grow on the surface of plants. However, they are not much use against fungi that invade the tissues. It is very hard to get the spores out of the soil. The plants have to be destroyed. The best chance for the future is to breed crop plants that are resistant to as many diseases as possible.

Summary questions

1. Plant diseases often affect people as well as plants. Why is this?
2. Rice, wheat and maize are three of the world's major crop plants. Find out the names of the main diseases that attack each crop and the type of micro-organism (virus, bacterium or fungus) that causes each disease.
3. Make a warning poster that could be used to help prevent farm workers from spreading plant diseases from one place to another.

2.9 Louis Pasteur: decay and food production

Learning outcomes

After this topic you should be able to:

- explain how Louis Pasteur helped explain the way micro-organisms break down organic matter
- explain the way Louis Pasteur made food safer for all of us.

Vaccinations prevent serious diseases such as polio. Pasteurising or heat treating milk helps to preserve it. Covering our food helps to keep it good. All of these things are based on the work of Louis Pasteur. He was a French scientist who lived and worked in the 19th century. Although that was a very long time ago, the work of Louis Pasteur is still important in our lives today.

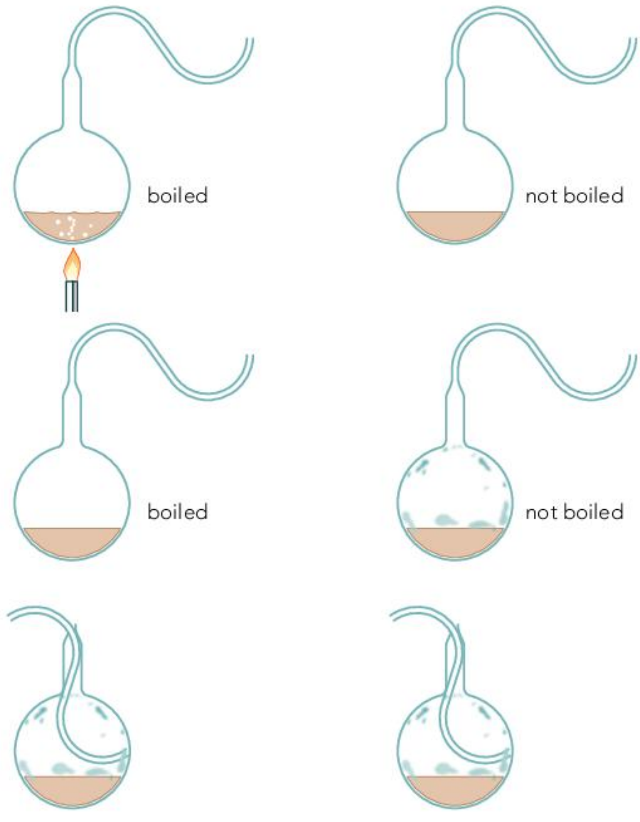
Micro-organisms and decay

For hundreds of years people thought that living things appeared from nothing. Scientists thought things went bad because moulds and other organisms appeared in them as if from nowhere (spontaneously). Louis Pasteur did not believe this. He thought that these organisms grew from some existing organisms. He set up some experiments which showed that it was micro-organisms from the air that grew on the food (organic matter), breaking it down and causing decay.

Pasteur put broth in two flasks and boiled one of them to kill the micro-organisms he was sure were there. The swan neck on each flask would stop micro-organisms getting in from the air.

Nothing grew in the boiled flask. The broth in the flask which was not boiled went cloudy and covered with mould.

Pasteur broke off the necks which trapped micro-organisms from the air and put them in the flasks of broth. Now the boiled broth went cloudy and mouldy too as bacteria and mould spores from the air were put into it.



Louis Pasteur's famous experiments with swan-necked flasks helped prove his ideas about the connection between micro-organisms in the air and decay. They also helped disprove the ideas of his rivals about spontaneous generation.

Micro-organisms and food production

In many countries, the milk you drink and the milk used to make dairy products, such as yoghurt and cheese, has all been pasteurised

Louis Pasteur discovered that micro-organisms are needed to make alcohol and vinegar. They break down sugars without any oxygen to make alcohol in a process known as **fermentation**. When the alcohol or vinegar went bad, it was because conditions were not right for the yeast to grow properly. Other micro-organisms got in and made it decay. Once people knew this, they could make sure they did their fermentations in the best possible conditions.

Pasteur also showed that if milk is heated, it will kill off most of the bacteria and moulds which make it go bad. Most of the milk you can buy in shops today will have been heated in this way. The process is called **pasteurisation** in honour of Louis Pasteur. The milk lasts longer and is safer to drink because pasteurisation also kills off the micro-organisms that cause diseases such as TB.

Pasteurisation is used to preserve many different foods now, from fruit juice, milk, yoghurts and cheeses to wines and beers. It has saved millions of lives over the years because it has stopped food going bad and prevented people from getting food-borne infections.

A change of direction

For the first part of his career Louis Pasteur worked in universities and with local industries. This is where he discovered the scientific evidence for the part played by micro-organisms in decay and fermentation.

As he got older, Pasteur became more interested in understanding some of the terrible infectious diseases he saw around him. He had five children but three of them died young from infections such as typhoid. His youngest daughter Camille was only two when she died. Pasteur became determined to stop the spread of some of these diseases in both people and in animals.

Key terms

- **fermentation**
- **pasteurisation**

Summary questions

1 a) Explain the way that pasteurisation protects people against food-borne infectious diseases.

b) Find out the difference between the pasteurisation of milk and the process that produces UHT milk.

2 Find out as much as you can about the life of Louis Pasteur. Present your findings as a timeline of his life, or a poster about his life and work or as an entry in a book about great scientists. Work in a group and use books and the internet to help you. Also look at the next few pages of this book for ideas.

3 Explain why the lives of many children in the world have improved as a result of the scientific discoveries since the time of Louis Pasteur.

2.10 Louis Pasteur: the fight against disease

Learning outcomes

After this topic you should be able to:

- explain how Louis Pasteur showed that micro-organisms were involved in the spread of disease
- describe a scientific experiment by Louis Pasteur that showed a way to help prevent disease
- talk about the importance of questions, evidence and explanations in developing new scientific ideas.

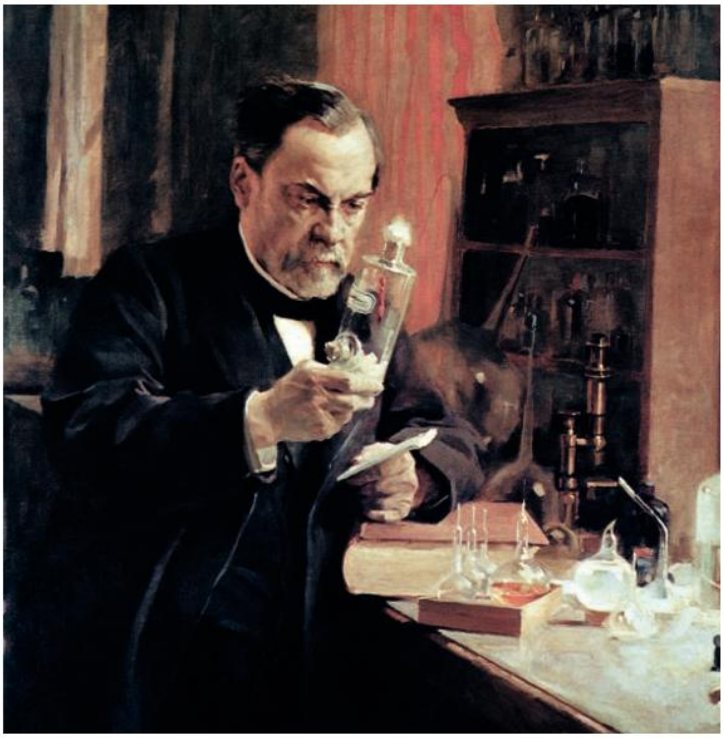
Expert tips

Bacteria were first seen through a very simple light microscope 350 years ago. Scientists knew that there were disease-causing organisms smaller than bacteria at the end of the 19th century but no one saw viruses until the 1930s when the first electron microscopes were developed.

As a scientist Louis Pasteur was always asking questions. What causes infectious diseases? How do they spread? How can we prevent them? He thought he knew the answers to these questions – but he needed the evidence to convince other scientists that his explanations were right.

Protecting against disease

Louis Pasteur knew about the work of Edward Jenner who had developed a **vaccine** against smallpox. After his work on decay, fermentation and pasteurisation, Louis Pasteur was sure that all infectious diseases were caused by germs (micro-organisms) passed from one person to another. This is the **germ theory** of disease. Pasteur wanted to find ways to grow these disease-causing micro-organisms. His plan was to make them weaker, so he could use them as a vaccine to protect animals or people against a disease.



Louis Pasteur had his own specially built laboratory in Paris where he did research on his germ theory of disease

The battle against anthrax

Anthrax is a deadly disease of farm animals and humans caused by a bacterium. It took Louis Pasteur a long time to grow the bacteria that cause anthrax in his laboratory. Then he could not make it safe to use as a vaccine. Not all scientists accepted Pasteur's germ theory of disease. One of them challenged him to prove that anthrax was caused by germs – by vaccinating some sheep against it. Pasteur's vaccine was not fully tested, but he took up the challenge.

The trial of the anthrax vaccine

- 25 sheep were given Pasteur's anthrax vaccine. Another 25 sheep were not vaccinated.
- A month later all of the sheep were injected with anthrax from infected animals.
- Three days later, all of the unvaccinated sheep were dead or dying of anthrax. All of Pasteur's vaccinated sheep were still alive and well.

Pasteur had won the challenge and many more scientists now accepted his ideas about germs and disease.

Pasteur and rabies

In 19th century France about 100 people died each year from the bites of animals with rabies. When Louis Pasteur was a little boy of eight, a rabid wolf came down from the mountains and attacked people, including some from his village. He never forgot their screams as they had their wounds cauterised with red hot irons. In spite of this, eight people died of rabies. Pasteur never forgot the horror of this.

Pasteur knew if he could find the micro-organism which caused rabies and make a vaccine, no one could doubt his germ theory of disease. However, Pasteur could not find the germ that causes rabies. We now know this is because it is a virus, and viruses are so small they cannot be seen with a normal light microscope.

Pasteur kept trying. He worked with the spinal cord taken from rabbits with rabies to try and make a vaccine. One day a little boy who had been bitten by a rabid dog was rushed to see Pasteur. Two doctors said he faced certain death. So Pasteur tried a new vaccine treatment on the little boy and the boy never developed rabies. Three months later he used the same method on a 15 year old shepherd boy badly bitten by a rabid wolf. Pasteur treated him with the vaccines and the brave shepherd boy was saved from rabies.

Now everyone accepts Pasteur's germ theory of disease. Ever since that time scientists and doctors have worked to discover more ways of both curing and preventing disease.

This is one of Pasteur's own flasks. It contains the dried spinal cord of a rabbit with rabies

Key terms

- **germ theory**
- **vaccine**

Summary questions

1 a) What was Pasteur's germ theory of disease?
   b) You know a lot more about what causes infectious diseases than the great Louis Pasteur did. Write a letter to Louis Pasteur explaining to him what we know about micro-organisms today.

2 Why do you think Louis Pasteur tried out his vaccine on children before it had been properly tested? Would this be allowed today?

3 Work in small groups and find out as much as you can about some of the other people who were important in helping us understand about micro-organisms and disease, for example Edward Jenner, Lady Mary Wortley Montagu and Joseph Lister. Make a poster or a presentation of what you find out.

End of chapter questions

1 Seven terms to do with micro-organisms are listed below. Definitions of these seven terms are also given. Write out a table matching each term with its definition.

Term

bacterium

infectious disease

mould

parasite

virus

vaccine

yeasts

Definition

micro-organism composed of cells without a nucleus

micro-organism composed of hyphae

any organism that lives in or on a host from which it obtains its food

micro-organism that reproduces within the cells of its host

single-celled fungi

preparation of a disease-causing organism that provides long-term protection against that disease

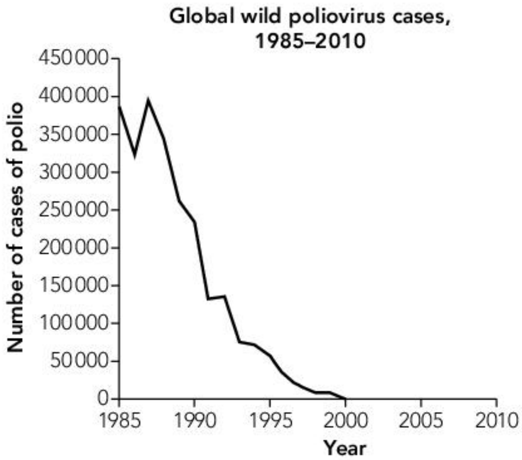
an illness caused by a parasitic organism *[7]*

2 Copy and complete the table.

Disease	Host organism	Type of disease-causing organism
tuberculosis	humans and cattle	bacterium
polio		
citrus canker	citrus plants	
	banana plants	fungus

[4]

3 The graph shows the number of cases of polio worldwide between 1985 and 2010.



a Describe what happened to the number of cases of polio between 1985 and 2010. *[4]*

b Explain the use of vaccination in the eradication of polio from many parts of the world. *[3]*

c Why is it important to continue to vaccinate young children against polio even though the number of cases of the disease worldwide is very low? *[3]*

4 Explain why the following are used in cheese making:

pasteurised milk

bacteria

a fungus *[5]*

b Explain why some cheeses can keep for a long time without going 'off'. *[2]*

5 Several children became very ill with the same symptoms. Scientists from the local health authority asked their families questions to find out how the children had become ill. All the families had drunk some apple juice from a local farm. The scientists found that the apple juice was contaminated by soil bacteria. The farmer said that unpasteurised apple juice tasted much better than pasteurised juice.

a Describe briefly what happens when foods such as milk or apple juice are pasteurised. *[2]*

b Suggest why children and not adults became ill after drinking the apple juice. *[1]*

c The farmer was told to make changes to his production process if he wished to continue to sell unpasteurised juice. Suggest three changes that he should carry out. *[3]*

6 Kathryn's father brews his own beer. He has made two batches, one is very good, but the other tastes foul. Kathryn doesn't like beer and says both taste awful, but agrees that one of them has gone 'off'. She thinks it has bacteria in it as well as yeast and that the bacteria have produced an acid giving the foul taste. She takes samples of both batches to school.

a Explain the way in which Kathryn could find out whether one batch has acid in it. *[2]*

b Kathryn's teacher says there are two ways she could use to show that there are bacteria in the samples. Write out some instructions for Kathryn to follow for each of these methods. *[5]*

c Explain briefly the process in which yeasts produce drinks such as wine and beer. *[3]*

7 Miloš and Alexandra have to make a presentation on the life of Louis Pasteur. Rather than make a poster or write a biography, they decide to repeat his experiment on spontaneous generation and show the class their results. Their teacher gives them some laboratory apparatus although he tells them that the school has no swan-necked flasks and they will have to think of another way to demonstrate this part of Pasteur's experiment.

Miloš and Alexandra start by making some nutrient broth that contains glucose and some mineral salts. These are the nutrients that bacteria require to grow. They boil the broth and pour it into some flasks that they had washed in boiling water. They also made up some broth that they did not boil and poured that into some unwashed flasks. They covered some of the flasks with foil and left others open to the air.

a Explain what is meant by the term *spontaneous generation*. *[2]*

b Suggest a way in which the students could make some apparatus resembling Pasteur's swan-necked flask. *[3]*

c Write out a plan to show how the two students could use their apparatus and materials to demonstrate Pasteur's experiment. *[8]*

8 Ahmed and Mohammed investigated the factors needed for the decomposition of leaves from the trees in their neighbourhood. The streets are lined with trees all of the same type.

They collected many leaves and divided them into six groups, **A** to **F**. They weighed each group on a balance to make sure they were all the same mass. They then treated the leaves as follows:

A washed thoroughly in a sterilising fluid and kept in a sealed container at 4 °C.

B as **A**, but kept at 25 °C.

C put straight into a sealed container and kept at 4 °C.

D as **C**, but kept at 25 °C.

E put straight into a perforated container that allows air to mix with the leaves and kept at 4 °C.

F as **E**, but kept at 25 °C.

After several weeks Ahmed and Mohammed took the leaves out of the containers and weighed them again. Each group of leaves lost mass, but some lost more than others.

a Ahmed and Mohammed designed their investigation to find out the effect of three factors on the decomposition of the leaves. Name these three factors. *[3]*

b Explain why they only used leaves from one type of tree and not several different types. *[2]*

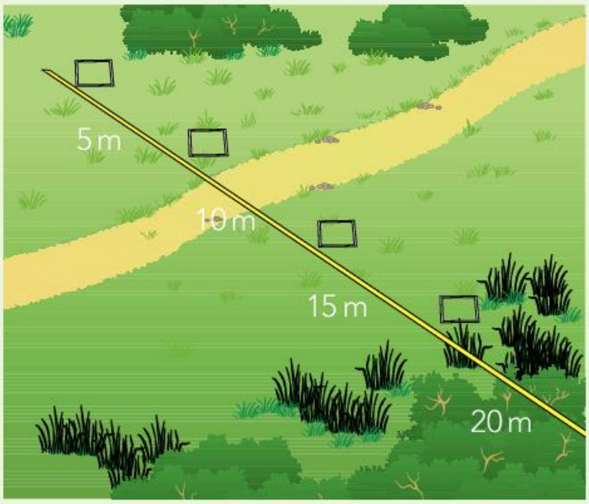
c Suggest why they put the same mass of leaves in each container. *[1]*

d Predict which group of leaves, **A**, **B**, **C**, **D**, **E** or **F** lost the most mass. Explain your answer. Make sure that you refer to the factors that affect decomposition in your explanations. *[6]*

Science *in context!* Working in the field

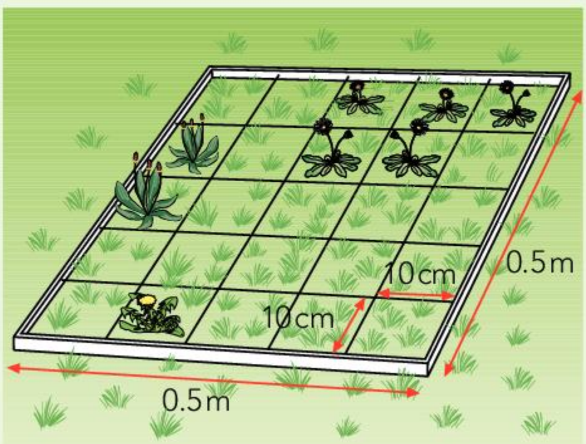
Checking for weeds

Mr Dhawan thinks that the school field has too many weeds. He tells the students that he thinks half of the field is made up of weeds instead of grass. Using simple pieces of equipment, a group of students are looking into his claim.



A transect lets you take samples in an organised way

- The students marked out a transect using a long piece of string.
- They put a frame called a quadrat down at regular intervals.
- They counted the numbers of squares of each quadrat that contained a weed plant.



On average the students found eight squares out of 25 contained a weed

- Students worked out the percentage of the field that contained weeds. It was only 32% so they could tell their teacher that the playing field was not yet half covered with weeds!

Taking random samples

Some of the students decided to do quadrats that were not on the transect lines. One group found a patch of the field which had lots of weeds and did their quadrats there. They thought they would show Mr Dhawan he was right. Another group found an area with no weeds at all and decided to do quadrats there. They really wanted to prove their teacher was wrong!

Mr Dhawan would not allow the results of either of these groups to be counted. Their results were not from the transect and they were not from random sites, so the scientific evidence they had collected was not valid.

Looking for living organisms

When they looked at the weeds on the field, several students decided they wanted to find out what animals lived on the playing fields too. They decided to look in the middle of the field, at the path that went through the middle and in the long grass and bushes which grew at the sides.

Using:

- pooters
- nets
- pitfall traps
- beating trays

the students found many different types of insects, snails, slugs, woodlice and worms. They decided to make a careful record of everything they had found and to repeat their field work every month throughout the year, just to see if the living organisms around them changed during the year.

You can investigate the organisms living in the habitats around your school, just as this student is doing

In this chapter you will find out about where organisms live, the ways in which organisms interact with each other and the environment, as well as the influences humans have on the natural environment.

Key points

- Remember that the habitat of an organism is its home.
- There is a wide variety of different habitats around the world.
- You can investigate a habitat using simple apparatus such as quadrats, pooters, sweep nets and pitfall traps.
- Plants are green organisms which make their own food by photosynthesis. Fungi are not green and they feed off other organisms which may be alive or dead.
- Herbivores eat plants, carnivores eat other animals and omnivores eat both plants and animals.
- A plant is a producer, a herbivore is a primary consumer and a carnivore is a secondary consumer.
- Organisms are linked together in feeding relationships known as food chains.
- Humans can have a negative effect on food chains, for example by using pesticides such as DDT.
- Organisms are adapted to their habitat. They are well suited to the place they live and the way they feed.
- Organisms may be adapted to be active during the day or during the night (if they are nocturnal).
- Organisms may be adapted to survive seasonal differences in the weather conditions and the amount of food available.
- Organisms have many different adaptations which make it possible for them to live underwater and in extreme conditions of heat, cold, altitude and depth under the ocean.
- The enormous growth of the human population is having negative effects on the environment such as increased global warming and the thinning of the ozone layer (ozone hole).
- As people become aware of the problems, they are having a more positive effect on the environment in some parts of the world.

3.1 Habitats

Learning outcomes

After this topic you should be able to:

- explain that the habitat of an organism is its home
- describe some different habitats.

Expert tips

This photo shows that much of the Earth's surface is covered with water. The oceans are divided into different ecosystems, for example, the open ocean, coral reefs, very deep water and shallow lagoons, all of which have different communities of organisms. There is still a lot we don't know about the oceans.

The planet Earth is home to millions of different types or **species** of living organisms. Looking at the Earth from up in space, you can see that its surface is not the same all over. There are many, many places for the various organisms to live in. The place where an animal or a plant lives is called its **habitat**. The habitat of an organism is its home.

Where is home?

Look at the pictures on the opposite page. They show habitats located all over the world. But contrasting habitats don't have to be a long way apart. In a single garden or park there may be many habitats. A single rotting log can provide a home for many different organisms!

Practical activity Habitats all around you

Work in a small group. Think of as many different habitats as you can. You can start with the ones you see in the first photo below.

- Write down a list of your ideas. Then share your list with the rest of your class.

The ice of Antarctica, the African savannah and a tropical rain forest in Borneo are three very different habitats

Different habitats are usually home to very different types of animals and plants. Dragonflies and slugs that live near ponds and in damp places could not live in a hot desert. Monkeys that live in hot forests would not survive on a cold treeless Northern plain.

Living together

The type of soil, the local temperature and the weather in an area all affect what organisms can live there. The physical conditions along with the animals, plants and micro-organisms living in a particular area are all part of the **ecosystem**. Animals, plants and micro-organisms make up a **community** and they all need a habitat which suits them. They live in balance with the other organisms around them and the living conditions in their ecosystem.

When you look at the habitat of a particular type of living organism, think about everything working together. Often one organism cannot live in a habitat without another different type of organism. For example, fungi need dead plants or animals to feed on, sheep need grass and bacteria in their guts and penguins need fish.

Key terms

- **community**
- **ecosystem**
- **habitat**
- **species**

Summary questions

1 Explain the difference between a habitat and an ecosystem.

2 Desert animals do not live in very cold habitats and plants from the Arctic do not grow in tropical countries. Explain why human beings can live in most of the land habitats on the Earth.

3 Think about your school and its surroundings. Describe three different habitats along with the kinds of living thing you might find there.

3.2 Investigating habitats

Learning outcomes

After this topic you should be able to:

- describe ways of investigating a habitat
- carefully observe and describe living things
- record results accurately in a variety of different ways, e.g. drawings, using tables
- make conclusions from data you have collected.

Some schools have many different habitats, from the sports field to the flower beds. When a group of students study a habitat they need to find out the different types of organisms that live there. They also need to count the numbers of the organisms. Some simple pieces of equipment can be used to help find out about the habitat being studied.

Using a quadrat

The simplest way to build up a picture of a habitat is to count the number of organisms there. A **quadrat** will help you do this scientifically. A quadrat is usually a square frame of wood or metal with an area of either 1 m^2 or 0.25 m^2 that you lay on the ground. This outlines your sample area. You use the same quadrat every time and sample as many areas as you can.

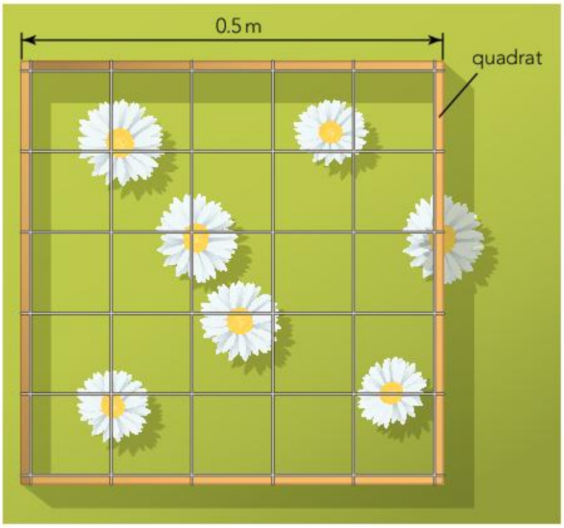
Quadrats are useful for counting organisms that do not move, such as plants or fungi. They are also used to count the numbers of slow moving animals, such as snails, barnacles or sea anemones.

Practical activity Random samples

When you use a quadrat it is important that you choose your sample areas at random. This means you can't choose an area which has many interesting plants – or just bare earth!

The person with the quadrat closes their eyes, spins round, opens their eyes and walks ten paces in that direction before dropping the quadrat. Repeat this for every sample. If you use a random number generator to decide where to put down your quadrat it is even better.

It doesn't matter if you count organisms partly covered by a quadrat as **in** or **out** as long as you decide what you are going to do and stick to it. In the diagram below, you have six or seven plants per 0.25 m^2 (that's 24 or 28 plants per m^2) depending on the way you choose to count them.

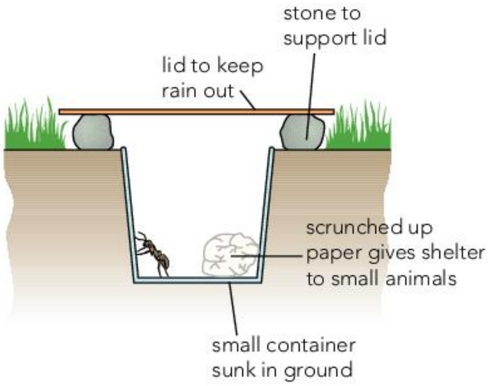


Organisms often fall partly in and partly outside a quadrat. You have to decide whether to count them in or out

Finding animals

You can easily observe large mammals and birds in a habitat by sitting and watching them. But each habitat also contains many small **invertebrate** animals which are not so easy to see or identify. There are several ways to find smaller animals:

- A **pooter**: This is a simple piece of equipment that can pick up small invertebrates. It works like a simple vacuum cleaner – you suck on one tube and the invertebrate is sucked up another one so you don't swallow it. The invertebrates are gently moved into a collecting chamber where you can examine them. Once you have caught your organisms, a magnifying lens will help you to see them more clearly.
- A pitfall trap: Some animals, such as many beetles, are too big to be sucked up with a pooter. You can make a pitfall trap, which will catch beetles and other small animals that don't fit into a pooter. They are easy to make, but you must be careful to empty them out regularly so the animals which are trapped do not die.



A pitfall trap

- A sweep net: A large net you sweep through long grass. You can then investigate any organisms that are caught in the net.
- Tree beating: Hold a white sheet or large sheet of card under a tree or bush. Then gently hit or shake the bush and collect the animals that fallout.

Using a pooter to collect insects

Expert tips

When you collect animals and plants to study you must be careful to disturb their habitat as little as possible. You should return animals to where you found them and only remove parts of plants to study them in the laboratory. Do not dig them up.

Key terms

- **invertebrate**
- **pooter**
- **quadrat**

Summary questions

1. You have been asked to find out which are the most common organisms in a habitat close to your school. Describe the habitat and the method for using a quadrat in this study.
2. Write a plan to make a pooter from an old plastic drinking bottle, two straws and a piece of fine cloth.
3. Why might the animals that get caught in a pitfall trap be at risk if you do not check it regularly?

3.3 Grouping organisms

Learning outcomes

After this topic you should be able to:

- identify some ways to group living organisms
- explain that a habitat will contain a number of different types of organisms
- use information from secondary sources.

In any one habitat you will find many different living organisms. Some of them are large, such as baobab trees, elephants, giraffes, redwood trees, gorillas and whales. Some of them are small, such as ants, caterpillars, duckweed and krill. Each habitat is different. However, the organisms found in different habitats share features in common, and this allows us to put them into groups. Each habitat has similar groups.

Plants make food

In most of the places you look, the first group you will find are **plants**. Plants are usually green. They have leaves, stems and roots. Plants make food by photosynthesis, using energy from the Sun. They are very important. In most habitats, all of the other organisms depend on the plants. This may be directly as food, or because they feed on other organisms which have fed on plants.

Fungi

In a habitat you will find other organisms growing which may look a bit like plants. They grow up from the soil or from the trunks of trees. They are not animals because they do not move around. These are part of a group of living organisms called fungi. They cannot make their own food. They often feed on the remains of other living organisms.

These organisms are plants …

and these are fungi

Practical activity Plants versus fungi

Work in a group.

- Make a poster to show the main differences between plants and fungi. Find out as much as you can about the way they get their food and find a variety of good images to show the range of different plants and fungi that exist in the living world.

Herbivores, carnivores and omnivores

Many animals in a habitat eat the plants that grow around them. Some feed on grasses, others feed on the leaves of bushes or trees, and some eat flowers, fruits or berries. Every animal which eats plants is known as a **herbivore**.

There are many animals which feed only on other animals. They may eat insects or worms, birds or large mammals. They may eat herbivores, or they may eat animals which eat other animals. They are all known as **carnivores**.

These carnivores will eat this herbivore once they have killed it

There are a small number of animals which eat both plants and animals as part of their normal diet. They include rats and human beings. These animals are known as **omnivores**.

Key terms

- **carnivore**
- **herbivore**
- **omnivore**
- **plant**

Summary questions

1 What are the main differences between a plant and a fungus?

2 a) What are the differences between carnivores and herbivores?

b) In what ways do omnivores differ from herbivores and carnivores?

c) Draw a table with three headings – herbivore, carnivore and omnivore. In each column write three examples of each type of animal.

3 Ana thinks there will always be more herbivores than carnivores in an ecosystem. Zia disagrees. She thinks that there are more carnivores than other animals. What do you think? Explain your answer.

3.4 Food chains

Learning outcomes

After this topic you should be able to:

- state that food chains are composed of different trophic levels
- explain the terms 'producer', 'primary consumer' and 'secondary consumer'
- draw simple food chains with three trophic levels.

Expert tips

The arrows in a food chain show the energy that flows from the producer at the base of the food chain. The arrows point from the food to the feeder.

A food chain is a way of showing how different organisms in a habitat feed on each other. As you look at habitats around you, you can start to identify the organisms in the different food chains. This simple food chain tells us that antelopes eat grass and cheetahs eat antelopes. It doesn't tell you anything about the numbers of plants or antelopes or cheetahs!

Food chains are a simple way of showing how energy can pass from one living thing to another in a habitat. The arrows show the direction in which energy is passing along the chain.

Grass → antelope → cheetah: a food chain

Producers and consumers

A general food chain looks like this:

producers → primary consumers → secondary consumers

The different stages of the food chain are known as **trophic levels**.

Plants produce their own food by photosynthesis. This is why they are called **producers**. Every food chain you see in the habitats around you starts with a producer, and most of those producers are

Three trophic levels in a food chain: **leaf → caterpillar → bird** plants. Animals consume plants or other animals so they are known as **consumers**. The animals which eat plants (the herbivores) are known as **primary consumers**. Some animals eat the herbivores. They are carnivores and are called **secondary consumers**. Omnivores can be both primary and secondary consumers because they eat both plants and animals.

In the food chain at the bottom of the opposite page, the leaf of the plant is the producer. The caterpillar eating the leaf is the primary consumer, and the bird eating the caterpillar is the secondary consumer. Think about the living organisms you have found as you have studied local habitats and write down some food chains. Do some extra research if you need to so you can complete them all.

Practical activity Making three-item food chains

- Draw out as many three-item food chains as you can. You can use organisms you have found and identified in your local habitat or organisms from other habitats further away.
- Make large coloured drawings of the organisms in one of the food chains you have built up. Cut out the shapes and hang them up, with the producer at the bottom of the food chain.

Moving along the chain

grass → antelope → cheetah

How many antelope do you think a cheetah eats in a week? How many blades of grass do you think an antelope would have eaten in the same week? Thousands of grass plants will only feed a small number of antelope. Those antelope will only feed an even smaller number of cheetahs.

It is important to think about what happens to the food as it passes along the chain. When an animal eats a plant, not all of the food in the plant ends up as new living material in the animal. Some of the food gets used for other things. The animal uses the food to move about and grow. Some of the food will not be digested and will be passed out of the body. When an animal is eaten itself, it passes along only the food that has become part of its body. The next organism gets only the small amount of food that was turned into new biological material. This biological material is called **biomass**.

Key terms

- **biomass**
- **consumer**
- **primary consumer**
- **producer**
- **secondary consumer**
- **trophic level**

Summary questions

1 Make up three different food chains. Use one from your local habitat, one from a freshwater habitat and one from a habitat of your choice.

2 Explain why the arrows pass from the plant onwards through a food chain.

3 What happens to the biomass as it passes along a food chain? Suggest as many ways as possible in which it is used or lost.

3.5 Human effects on food chains

Learning outcomes

After this topic you should be able to:

- explain how the activity of people can have a negative effect on food chains
- explain how people can have a positive effect on food chains.

When we grow animals for food, we manage a food chain. When we manage a forest to grow timber, we change the food chains and food webs that are there. Sometimes we have a good effect, and sometimes our effect is a negative one.

Supplying water in regions where the soil is very dry allows many more plants to grow so more food chains can develop

We sometimes put chemicals in rivers without knowing what they will do to the food chains there. When things go wrong it is often the bigger fish that suffer most

People can cause problems

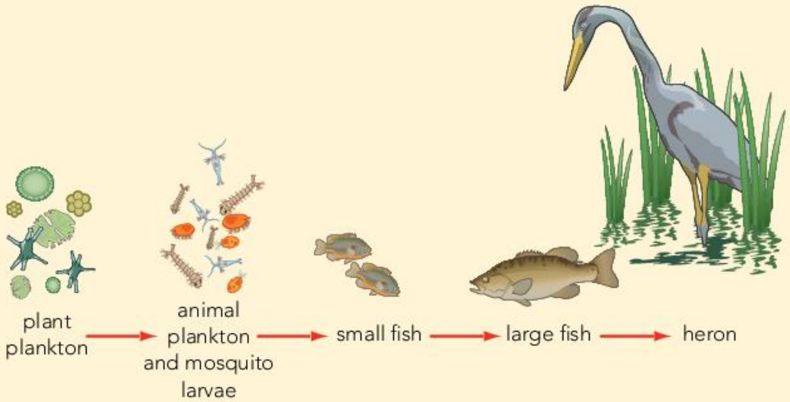
There are many different ways in which people can cause problems in food chains. One good example is the story of DDT. DDT is a powerful **pesticide**. It kills the insect pests that destroy crops and spread diseases such as malaria.

Unfortunately DDT does not break down in the bodies of animals. It is simply stored in their fat. Not long after farmers started using DDT, many large water birds such as herons failed to reproduce successfully. They started to lay eggs with very thin shells which broke when the parent bird sat on the nest.

Practical activity Why did the herons start to die out?

Look at the food chain below. Why do you think the herons were so badly affected by the DDT?

- Write down your ideas; then read on to see if you are right.



DDT in the food chain

DDT was sprayed onto fields. It got washed into streams and rivers by the rain. It got into the bodies of the tiny plants and animals in the water. They took in such small amounts of DDT they were not harmed.

Each small fish ate lots of tiny animals. All the DDT stayed in the bodies of the small fish. The fish did not contain enough DDT to hurt them. Then each big fish ate lots of little fish. The big fish had more DDT in their body fat, but still not enough to hurt them. Each heron ate lots of big fish. The level of DDT in the heron was enough to affect the strength of its egg shells, so the numbers of herons fell.

When people realised the terrible effect of DDT, it was banned in many countries. Now it is only used where pests do so much damage it is worth the risk of using DDT – for example to kill the mosquitoes that cause malaria.

Other ways of affecting food chains

People cause pollution in many different ways, through body waste (sewage), pesticides, industrial waste, car fumes and more. We pollute the oceans, rivers, lakes and the land. All of this can have a bad effect on food chains.

We have also polluted the air. We have destroyed part of the ozone layer which protects us from UV radiation and this is affecting life on Earth. We have changed the climate by producing too much carbon dioxide – and this means food chains are affected too.

But people do many positive things. We conserve habitats that are threatened. We take water to dry areas and prevent erosion of soil. We replant areas with new forests. We create food chains as well as destroying them. Find out more in topic 3.10.

Key terms

- **pesticide**

Summary questions

1 Describe the positive effect on food chains of supplying water in dry regions.

2 Here are some of the ways people affect food chains. Think about each one, find out about it and decide whether its main effect on food chains and the environment will be good or bad. Explain your answer.

Emptying sewage into the sea

Planting grasses, such as marram grass, on sand dunes

Putting factory waste into rivers

Making nature reserves

Stopping whale hunting

Spraying crops with pesticides

3.6 Adaptation for survival

Learning outcomes

After this topic you should be able to:

- describe some of the different habitats organisms live in
- explain how organisms are adapted for survival
- communicate your ideas supported by evidence
- make and present conclusions by bringing together evidence from different sources.

Key terms

- **adaptation**

The ways in which organisms fit into their habitat and survive there are known as **adaptations**. By looking at the adaptations of an animal or plant, you can get a good idea of where and how it lives.

Surviving

Living organisms are adapted in many ways to survive in different conditions. Some have developed fantastic ways to overcome the problems of survival. For example, plants have adaptations of their roots and leaves to cope with different conditions. Here are some examples of the ways living organisms are adapted to their particular way of life.

The long neck of a giraffe allows it to feed on the leaves from the tops of trees that few other animals can reach

The habitat of the Venus fly trap has soil containing very few minerals. The leaves of the plant are adapted to catch and digest insects. The minerals the plant needs to grow and reproduce come from the insects it digests

Fact files on organisms

The barn owl has:
- excellent hearing
- large eyes
- a sharp beak and claws
- light bones and feathers.

A cheetah has:
- very small ears
- spotted fur
- sharp pointed teeth
- very long legs.

The rabbit has:
- long ears
- large eyes
- strong hind legs
- flat grinding teeth.

The cactus has:
- a thick stem with lots of water-storing cells
- tiny spines as leaves
- a thick waxy outer layer
- very deep roots.

Practical activity Working out the adaptations

Look at the fact files of the four organisms you have been given above.

- For each one write a paragraph explaining the ways in which the organism is adapted to its habitat and way of life. Do some research using different books and on the internet.

Summary questions

1 Many animals can change colour or have colours which blend in with their background. This is called camouflage. Why do you think this is an adaptation for survival?

2 Work in a small group. Think of four habitats. Write down at least one organism from each. Make a fact file to show each organism's adaptations to its habitat.

3.7 Local and seasonal adaptations

Learning outcomes

After this topic you should be able to:

- describe the adaptations of some local animals and plants to their habitats
- describe some adaptations for the day and the night in living organisms
- describe some seasonal adaptations in different animals and plants
- communicate your ideas supported by evidence.

Bush babies search for food at night

Animals and plants have to be adapted to changes in their environment to survive.

Day and night adaptations

Habitats change every 24 hours. The daytime is usually much warmer and lighter than the night-time. Some organisms are adapted to be most active during the day. For example, most plants open their flowers during the day when insects are flying around to pollinate them. Many animals use their eyesight to find food in the light. Amphibians and reptiles are cold-blooded and need the warmth of the day to be active.

Some animals are nocturnal. They are active during the night. Sometimes this is to avoid being eaten, although there are some predators that hunt at night. These nocturnal animals usually have large eyes which use as much of the dim light as possible. Some flowers open at night. They are pollinated by nocturnal animals such as moths or bats. They often have a strong scent to attract the moths, which detect the scent with their feathery antennae.

Seasonal adaptations

In some parts of the world, near the equator, the weather is very similar all year round. But in many other places it changes a lot through the year. In temperate regions such as Northern Europe a tree might get 16 hours of sunshine and a temperature of around 20 °C in the summer. But in the winter these change to around eight hours of light and 5 °C. There isn't enough sunlight for the leaves to make the food the tree needs and they would all be killed by frost. So the tree becomes dormant. It loses its leaves and slows down all the processes of life.

By becoming dormant in winter this tree can survive until the warmer weather and longer days of spring

Many other smaller plants also become dormant. They survive the winter as seeds, or as bulbs below the ground.

Animals have to survive these changes in conditions too. Some animals change their behaviour. Some change the way they look and others change the way their bodies work. Hedgehogs, polar bears and some other animals hibernate in cold weather. They eat a lot and build up fat stores in the summer. Then their bodies slow down to save energy through the winter in a sheltered hiding place. They become active again when the days get longer and warmer.

Some animals migrate – they leave bad conditions and move to good conditions. Some birds and mammals travel thousands of miles every year. Swallows spend the summers in Europe and winters in Africa. The great migration in Africa involves enormous herds of wildebeest and zebra moving across the continent. The herds are following the rains to eat the new grass which grows because of the rain.

Many animals develop thick, shaggy coats to keep them warm through the colder part of the year. They lose the thick coat in the spring

Expert tips

Plants, animals and micro-organisms occupy many different types of habitat and have many different ways of life. However, they all require resources from their surroundings. Think about these resources and how the animals and plants get them as you read this and the next few pages.

Practical activity — Investigating adaptations

Using the techniques you learnt about in topic 3.2, collect a selection of animals and plants from your local habitats. Look at their adaptations and use them to help you decide where they live and whether they are active in the day or during the night.

Summary questions

1 Describe three adaptations you would expect in an organism that is active during the daytime and two adaptations you might expect to find in organisms that are active at night.

2 Why do many animals in temperate countries grow thick coats before winter?

3 Before a polar bear hibernates it:

- builds up as much body fat as possible
- makes a den to hide in under the snow.

When it hibernates it slows all of its body processes right down.

Explain the way each of these adaptations helps the polar bear survive the winter.

3.8 Adaptation for extreme environments

Learning outcomes

After this topic you should be able to:

- describe some of the adaptations of animals and plants to extremes of heat and cold in their environment.

These *Euphorbia* survive hot dry conditions with their fleshy leaves, deep roots and the spiny thorns that protect them from being eaten

Many parts of the world have extreme conditions, ranging from very hot and dry to very cold and dry. For an organism to survive in extreme conditions, it must have special adaptations.

Hot habitats

In many places around the world the daily temperature gets very high. Often water is in short supply as well. This makes life hard for animals and plants. Deserts are the most extreme hot environments.

Desert plants often have roots that spread widely or go deep down into the ground to reach water. The leaves are often small and have thick waxy outer layers to reduce water loss. Desert plants often store water in their stems, their leaves or their roots. Many plants growing in hot dry conditions also have sharp spines to protect themselves from animals that want to eat them. Plants adapted to hot conditions are called xerophytes. Cacti are the best known example.

Mammals that live in hot climates often have very little fur and big, thin ears to help them lose heat. Some animals such as desert rats can use all the water in the food they eat so they hardly need to drink. Many different types of animals also have behavioural adaptations – they hide away from the heat of the day in the shade of rocks or in burrows which they dig.

Elephants have large, thin ears, wrinkled skin and very little hair in order to help them lose heat

Cold habitats

Plants that survive in very cold conditions are often very small. They may have hairy leaves to trap a layer of air to keep them warm. Some have special antifreeze chemicals in their leaves which stop them freezing in the low temperatures.

Animals also have special adaptations to live in cold places. Many mammals have a thick layer of fat (blubber) beneath their skin to insulate them from the cold. They have thick fur which also helps to keep them warm. Birds have extra layers of soft feathers to keep them warm. Reptiles and amphibians do not live in very cold climates as they cannot get their bodies warm enough to move about. Many animals hibernate or hide away through the coldest weather. Polar bears retreat to a den under the snow for the winter.

Even cold climates have summers and winters. The landscape changes colour completely when the snow and ice comes. Many animals adapt for the change of seasons with a change in their colour as well as the thickness of their fur to help them survive. Their colour change means they are camouflaged all through the year (see the photos below of the Arctic fox).

You can see clearly the difference in the colour and the thickness of the fur of the Arctic fox in summer and winter – and the effect it has on how well they are camouflaged in the different seasons

Adaptation to altitude

When animals live at very high altitude they have to be adapted to cope with less oxygen in the air as well as cold temperatures. Special adaptations for altitude include:

- extra red blood cells to carry more oxygen
- bigger lungs to take in more air
- more blood vessels in the lungs to take more oxygen from the air.

Summary questions

For each of the four organisms listed below describe:

a) where the organism lives

b) the way in which the organism feeds

c) its adaptations that enable it to live in its habitat.

1 tiger
2 camel
3 polar bear
4 reindeer

3.9 Underwater adaptations

Learning outcomes

After this topic you should be able to:

- describe some of the adaptations of living organisms to life underwater.

Aquatic habitats are those in which organisms live in water. If the habitat is in sea water then they are called marine habitats; if the water is not salty then they are called freshwater habitats, for example lakes, rivers, streams and ponds. Water is very different to the air. It is much thicker – it is much harder to move through water than through the air. Organisms which live underwater also need to have adaptations to get the oxygen they need from the gas dissolved in water, and water contains a lot less oxygen than air.

Underwater plants

A big problem for all of the organisms that live in water and make food by photosynthesis is a lack of light. These organisms include seaweeds and **phytoplankton** (microscopic organisms that photosynthesise), as well as freshwater plants. Even in the clearest water, light cannot penetrate beyond about 200 m. Often water is not clear – it is mixed with sand or mud – and then the light can penetrate even less. So everything that relies on photosynthesis for its energy needs to be able to float and grow in the top 200 m. No photosynthesising organism can grow in really deep water because there is no light.

Another problem for underwater plants is the movement of the water. Plants need to be firmly rooted in the bed of the river or stream or they will be carried away in the current. In the sea, seaweeds, such as kelp, fasten themselves to rocks or the seabed. This helps prevent them from being broken and destroyed by the waves.

A kelp forest needs to be fastened firmly to the seabed so it is not washed away

Breathing underwater

Tiny living organisms in the water can get the oxygen they need through their body surface. But bigger organisms have special adaptations. The best known of these are the **gills** of fish. As the water flows over the gills, the fish take oxygen into their bloodstream. Many fish have gill flaps which cover their gills so they can pump water over them and 'breathe'. Sharks and rays have open gills and they need to swim to keep the water moving over their gills all the time.

Moving underwater

To move fast underwater you need to be streamlined. Fish usually have a sleek streamlined shape. They are covered with smooth scales and have strong tails which push them quickly through the water. Their fins help to balance and steer them. Some living organisms simply keep themselves afloat in the water and allow the ocean currents to carry them along. Jellyfish do this and travel thousands of miles, feeding as they go.

Fish such as these Sergeant Major fish are beautifully adapted for life underwater

Pressure, cold and dark

Deep underwater there are some extreme conditions. It is completely dark, very cold and there is a lot of pressure from the weight of water. Food is very scarce. Some of the organisms that live in the depths have strange adaptations. The Gulper eel has an enormous mouth to take in as much food as possible. The deep Sea angler fish looks like prey to other fish and produces light for them to see it by – when they come close, it snaps them up with its large mouth full of teeth. These fish are adapted to living at great pressure. If they are brought to the surface quickly, they explode!

These adaptations allow the Sea angler fish to live far below the surface of the ocean

Key terms

- **gills**
- **phytoplankton**

Summary questions

1 What are the main problems which organisms living underwater have to overcome?

2 Give three adaptations to underwater life you would expect to see in a fish.

3 Look at the photo of kelp and the photo of the Sea angler fish. Make a poster about adaptations for life underwater using your two examples to illustrate them.

3.10 Human population growth

Learning outcomes

After this topic you should be able to:

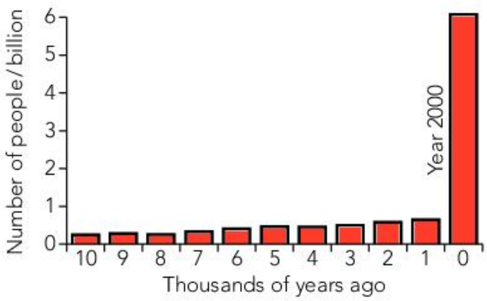
- describe how the human population of the Earth has grown
- explain how the increasing number of people has had positive and negative effects on the environment.

Human beings have been on the Earth for less than a million years. However our activity has changed the balance of nature on the planet enormously.

The growth of the human population

For thousands of years there were only a few million people scattered all over the world so our actions had only small, local effects on the environment.

In the last 2000 years or so, the human population has grown very quickly indeed. There are now over 7 **billion** people on the Earth. Now the things we do really can affect the environment and even the whole planet.

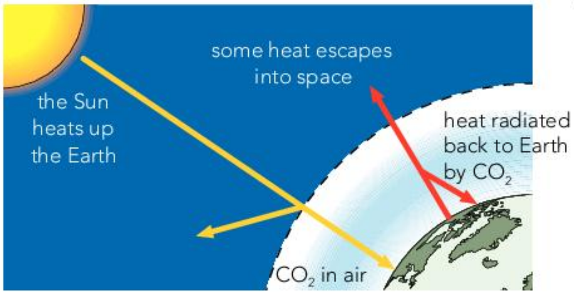


The growth of the human population is amazing

Normally when a population of organisms grows really fast, it is quickly reduced again by predators, lack of food, a build up of waste products or disease. But human beings have discovered how to grow plenty of food to eat. We can cure or prevent many killer diseases. We have no natural predators. This all helps to explain why the human population has grown so fast.

Negative effects

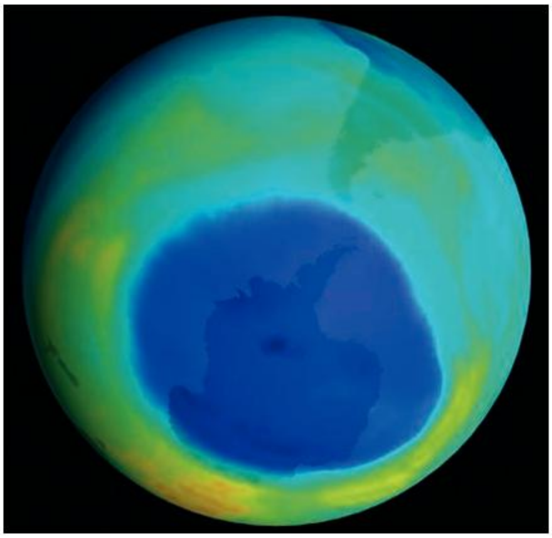
More people use up more of the Earth's resources. As a result, we are having a negative influence on the environment. Here are three negative effects.



The greenhouse effect is a natural process which keeps the Earth warm enough for life to exist. But extra carbon dioxide means extra warming, which may not be a good thing

- We burn fossil fuels, such as coal, oil and gas, to make electricity and heat buildings. Oil products are also burnt in vehicle engines. When they burn they produce carbon dioxide, which adds to the carbon dioxide which is already in the atmosphere. The increasing amount of carbon dioxide traps extra heat energy from the Sun. The surface of the Earth gets warmer. This is known as the enhanced **greenhouse effect**. As a result, the climate seems to be changing all over the world. **Climate change** affects the habitats of animals and plants and changes what can live in different parts of the world. Some animals and plants are in danger of becoming **extinct** as a result.

- We cut down very large areas of forest to grow crops such as oil palms and raise cattle for beef. This destroys a rich habitat and means hundreds of types of living organisms are becoming extinct every year.
- Chemicals called **CFCs** used in fridges and aerosol sprays have built up in the atmosphere and destroyed some of the ozone, a form of oxygen. The ozone in the atmosphere protects the Earth from damaging ultraviolet (UV) light from the Sun. The **ozone 'hole'** is where the layer has become thinner and allows more UV through. This can cause damage to many living organisms by causing more cancers to appear. The good news is that people now use far fewer CFCs and the ozone layer is getting thicker again.



The ozone hole from space

Positive effects

As people have become more aware of the problems they are causing they are working hard to protect the planet by:

- planting more trees
- preventing the destruction of more rainforests
- protecting areas where rare plants and animals are found so the numbers can grow
- finding alternatives to fossil fuels, for example biofuels
- reusing, recycling and replacing resources.

Key terms

- **CFCs**
- **climate change**
- **extinct**
- **greenhouse effect**
- **ozone 'hole'**

Summary questions

1 Make a list of the different reasons why the human population has grown so much in recent years.

2 Work in a group. Using the examples given here and your own research, make two posters. In one explain people's negative effects on the environment, in the other show some of the positive effects people can have on the environment. Compare the posters and use them to discuss whether humans are good for the Earth or not.

Chapter 3 End of chapter questions

1 Copy and complete these sentences using key terms from this chapter.

The place where an organism lives is called its ______ .

______ are animals that only eat plants.

A diagram that shows the flow of energy between three or more different organisms is called a ______ ______ .

An ______ is a place where different organisms interact with each other and their environment. *[4]*

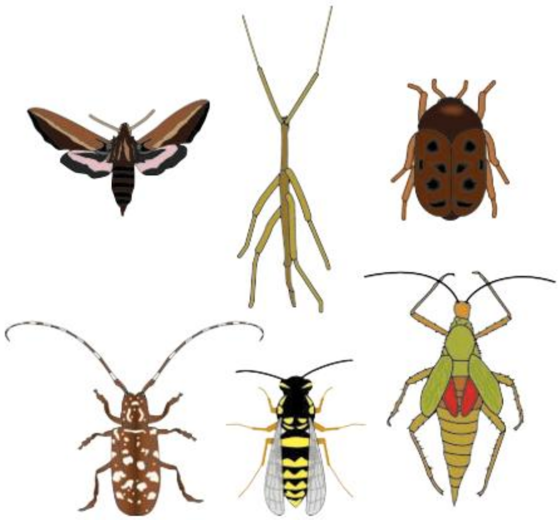
2 Some students decided to investigate the animals that live on the trees in the school yard. The school gardener told them that there were two different types of tree:

type **A** that has thin, broad leaves and produces flowers and soft fruits

type **B** that has thick, narrow leaves and produces cones.

Nisha and Dinendra think that they will find different types of animals on the two types of tree.

The class divided into two groups to make collections of animals from the trees. They used a beating tray and pooters to make their collections. The figure shows some of the animals collected by Nisha's group from trees of type **A**.



Dinendra's group found fewer animals on trees of type **B**. The students did not know the names of the animals that they found, so they called them species 1, 2, etc. and recorded the colour of each type.

a Explain the way in which the two groups could present the results to their teacher. *[3]*

b Suggest why there were fewer animals on trees of type **B**. *[3]*

c Explain why most of the animals were green or brown. *[2]*

The teacher was very critical of the method that the students used to make their collections. He said that the two groups did not use exactly the same method when collecting the animals with the beating tray and pooters.

d Suggest ways in which the students could improve their method to satisfy their teacher. *[4]*

3 a Copy and complete this food chain to show the feeding relationships between these three organisms found in an African nature reserve:

grass antelope cheetah *[2]*

The food chain has three trophic levels.

b State the trophic level for each organism in the food chain. *[3]*

Vultures are scavengers that will eat the bodies of dead antelope and dead cheetahs.

i Add vultures to the food chain you have drawn. *[2]*

ii What are omnivores? *[2]*

4 Animals are adapted to the habitats in which they live.

a Explain what is meant by the term *adaptation*. *[2]*

The photo shows a red slender loris, which is a nocturnal animal that lives in the forests of Sri Lanka. *[2]*

b Look carefully at the photo and suggest three ways in which the red slender loris is adapted to a nocturnal life in forests. *[3]*

c Describe three ways in which the flowers on some plants attract animals. *[3]*

5 The environmental conditions in deserts are very extreme. Deserts provide a habitat for many types of plants and animals that are adapted to these conditions.

a Describe the extreme conditions that plants and animals experience in deserts. *[4]*

b i Name a type of plant and a type of animal that are adapted to survive in deserts. *[2]*

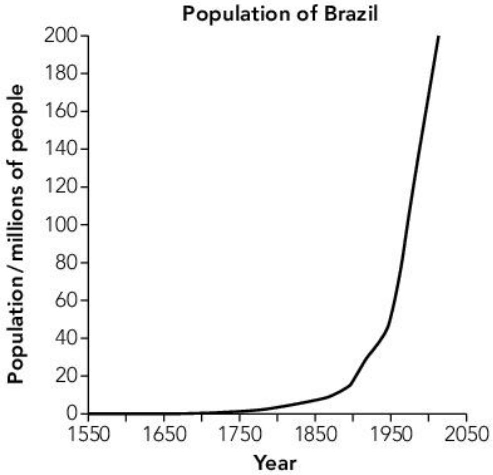
ii Explain the adaptations of each of these organisms to the conditions in the desert. *[6]*

6 Sperm whales are mammals and have lungs for breathing air. They are ideally adapted to a life at great depths in the sea, hunting squid and fish. They spend about 90% of their lives at great depth and are rarely seen at the surface of the oceans.

a What are the problems that sperm whales experience in hunting food at great depths in the sea? *[4]*

b Explain the ways in which sperm whales are adapted to survive and feed at great depths in the sea. *[4]*

7 The graph shows the increase in the human population of Brazil between 1550 and 2012.



a Describe what the graph shows has happened to the population of Brazil between 1550 and 2012. *[4]*

b Why has the human population increased so much? *[4]*

c Suggest some problems that a country such as Brazil will have if its population continues to increase. *[5]*

d Suggest ways in which the government of Brazil may stop its population continuing to increase. *[5]*

e Some scientists make predictions about the future. Some predict that the human population will continue to increase, then peak and show a rapid decline. Suggest what reasons they have to make this prediction. *[3]*

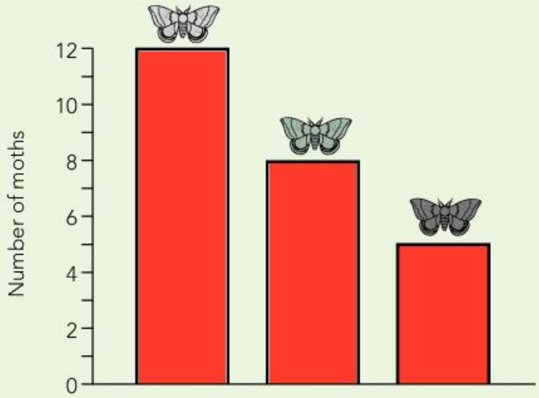
4 Variation and classification

Science *in context!* Variety in moths

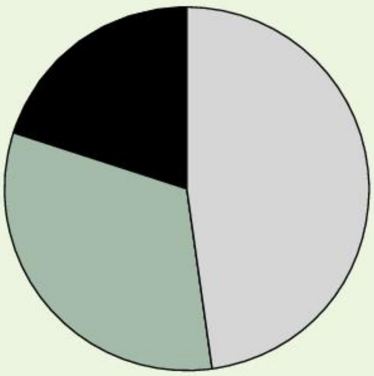
Jalal collected 25 moths that he found on the bark of the trees in his local woodland. They were all the same type of moth but they had several different colours. Some of them were pale grey. Some of them were a very dark grey. Some of them were a greeny-grey colour. He made a tally table to show the different types he had collected.

Colour of moth	pale grey 	greeny-grey 	dark grey 
Tally	𝍸 𝍸 II	𝍸 III	𝍸
Total number of moths	12	8	5

Jalal's teacher suggested he show his results in a more interesting way, which made it easier for other students to see what he had found. Jalal tried two different ways of showing his data – a bar chart and a pie chart. Which do you think works best?



A bar chart to show the different colour of the moths in the sample



A pie chart to show the different colour of the moths in the sample

Here are some questions about Jalal's moths. See what you think!

- Is it possible to find out if the sample of moths Jalal caught is typical of the moths in the wood?
- Why are there fewer dark moths than the other two colours?
- What might happen to the colour of the moths if the wood became polluted by factory smoke?

Cecropia moth

The history of the peppered moth

Jalal is not the first person to investigate variety in the colour of moths. Many years ago in the UK scientists noticed that the peppered moth came in two varieties – one pale and one dark. Peppered moths spent their days on the light coloured bark of trees. There were far fewer dark moths than light moths because the birds would see dark moths easily and eat them (see the left-hand photo below).

After the British Industrial Revolution, the smoke from factories made the bark of many trees dark and dirty. Scientists noticed that after a time there were many more dark moths than light coloured ones. Birds could now see the light moths more easily than the dark ones and so the light moths got eaten (see the right-hand photo below).

In recent years the air and the woodlands have been cleaned up. Now pale peppered moths are the more common form in British woodlands once again.

These photos show the two varieties of the peppered moths on different coloured tree trunks

In this chapter you will find out about the importance of classification in the animal and plant kingdoms and how biologists go about classifying living things.

Key points

- Living organisms can be classified into groups based on the differences and similarities between them.
- Plants, animals, fungi and micro-organisms are some of the main groups.
- To put living organisms into groups you make careful observations and measurements of their characteristics.
- Animals are divided into invertebrates, which do not have a skeleton inside their bodies, and vertebrates, which have a hard, bony skeleton inside their bodies.
- Invertebrates can be divided into several other groups including different types of worms, molluscs and arthropods.
- Vertebrates can be divided into five groups – fish, amphibians, reptiles, birds and mammals.
- Plants are divided into mosses, ferns, conifers and flowering plants. Flowering plants are divided again into monocots and dicots.
- The smallest group used in classification is a species. A species is a group of organisms which all breed successfully with each other to produce fertile offspring.
- Variation between organisms is used to put them into different species.
- Extinction is when all of the members of a species die out.
- When a species cannot respond to changes in its environment it may become extinct. Breeding between species to help them survive is not possible.
- Variation between the organisms in a species can help to stop them going extinct.

4.1 Classification

Learning outcomes

After this topic you should be able to:

- explain that we classify living organisms by putting them into groups
- describe the main classification of animals into vertebrates and invertebrates.

The world around us contains millions of living organisms of different types. Scientists put living organisms into groups or **classify** them by looking at the differences and similarities between them.

Sorting things out

Two of the main groups of living organisms are animals and plants. Have a look at the images below and divide the organisms into these two groups. Do they all fit in? One of them, the fungus, isn't a plant or an animal. There are also many tiny organisms which can only be seen under a microscope. They are called micro-organisms and they are not plants or animals either.

The animal kingdom and the plant kingdom

Practical activity Listing animals

Work in a small group.

- Make a list of as many different types of animals as you can in three minutes. Think of local animals and animals you have heard about from other countries.

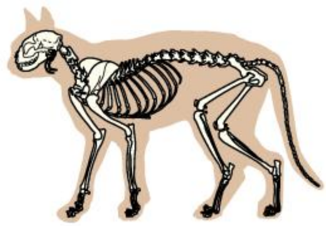
We all have our own ideas about what an animal is. But when one scientist talks about an animal, it is very important that other scientists all over the world know exactly what is meant. Members of the animal kingdom all feed on other living organisms – plants or other animals. They are relatively fast moving, they usually move their whole bodies about and they all have **nerves** to coordinate their bodies. Animals can be very big like an elephant or very small like a tiny beetle, but they all have these characteristics.

Plants are very different to animals. They are food producers. They make sugar using energy from the Sun. Plants are green. They don't move their whole bodies around, and the parts of plants that do move usually move very slowly by growing.

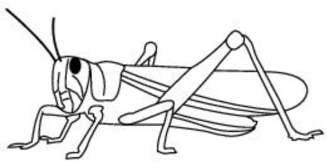
A typical animal and a typical plant

More about animals

To help us identify the thousands of types of animals in the world we put them into groups. We look for things that are similar – and things that are different – to help us decide where an animal belongs. The greatest difference is between the vertebrates (animals that have backbones) and the invertebrates (animals without backbones).



The cat is a vertebrate



The locust is an invertebrate

The vertebrates

Vertebrates have a hard, bony **internal skeleton** inside their bodies. This gives them support, protects the delicate organs inside the body and lets them move about. They all have a backbone – made up of lots of little bones – which supports the body, allows it to move and protects the delicate spinal cord.

The invertebrates

Invertebrates come in all shapes and sizes. Many of them have soft bodies but others have skeletons. They may have shells inside or outside their bodies or a tough **external skeleton** on the outside of the body. None of the invertebrates has a bony skeleton with a backbone.

Key terms

- **classify**
- **external skeleton**
- **internal skeleton**
- **nerves**

Summary questions

1 What do we mean by *classifying* organisms?

2 In what way do vertebrates differ from invertebrates?

3 Look at the list of animals you made in the Practical activity on the opposite page. Draw a table with two columns, one for vertebrates and one for invertebrates, and place all of the animals in one column or the other.

4.2 Classifying animals

Learning outcomes

After this topic you should be able to:

- describe different ways of grouping organisms including the main groups of invertebrates and vertebrates.

Expert tips

Describe the different habitats that these invertebrate animals live in. For human parasites like this roundworm, their habitat is us!

Roundworms have thin, smooth, rounded bodies

You can choose almost any way of putting organisms into groups, but many of them are not very scientific. Think of big animals, or animals that eat plants, or land animals. What is wrong with these groups?

Some characteristics such as height or weight vary during life – they depend on how much food an animal can find. So scientists use characteristics which can be counted or measured or which are always the same, such as the number of legs or whether an animal lays eggs in water.

Invertebrate groups

There are more invertebrates than any other type of animal. They range from simple jelly-like blobs to large and intelligent animals. Invertebrates can be split up into seven main groups to make it easier to recognise them. Two of them are found only in the sea:

Jellyfish and sea anemones have jelly-like bags for bodies and tentacles covered with stinging cells to catch their food.

Starfish belong to a group where all the animals have a star shaped pattern with five 'arms' and spiny skin.

All of the other types of invertebrates can be found on the land as well as in water.

Flatworms have simple flattened bodies.

Segmented worms, e.g. earthworms all have long bodies divided into segments.

Molluscs, e.g. snails, squid and octopi all have very muscular bodies and a shell either inside or outside their bodies.

Insects, crabs and centipedes, are part of a group called arthropods. All arthropods have jointed legs and a hard external skeleton.

Although there are fewer vertebrates than invertebrates, they are much bigger and more noticeable. They can grow larger, even on land, because they have skeletons inside the body to hold them up.

The vertebrates

Just as invertebrates can be divided into several groups, so can vertebrates.

Expert tips

This picture shows some land-dwelling vertebrates and some aquatic vertebrates. Write out some food chains using the organisms that are in this picture.

Practical activity — Classifying the vertebrates

Work in groups of five.

- Each take one of the five groups of vertebrates described above and find out as much as you can about the types of animals in this group, with lots of examples. Take it in turn to present your findings to the rest of your group.

Summary questions

1 What are the main groups of the animal kingdom? Draw a large table and use lots of pictures to show your answers.

2 Look back at the list of animals you thought of in the previous topic. Sort them out into the different animal groups in as much detail as you can. What percentage of your animals were vertebrates?

4.3 Sorting out plants

Learning outcomes

After this topic you should be able to:

- explain how plants are classified in different groups
- describe some of the main plant groups
- present results in the form of a bar chart.

Expert tips

The two groups of flowering plants are the monocots and the dicots. These names are shortened from the terms *monocotyledons* and *dicotyledons*. One of the differences between them is the number of seed leaves that they have. Monocots have one, dicots have two.

Just as the animal world can be divided up into smaller groups, so can the plant kingdom.

Practical activity Thinking about plants

Make a list of as many different plants as you can think of, both local plants and ones from other parts of the world that you have heard about. Now think about ways to divide these plants up into groups.

a

b

c

d

a Mosses are small plants which need damp places to live. This is because they have thin leaves which do not have a waterproof covering and no transport system for water in the plant. Mosses reproduce by making spores; they do not make seeds.

b The ferns are much bigger plants than mosses. They have strong stems, roots and leaves and their leaves are waterproof. Ferns also have a transport system for water and so they don't have to live in damp places. Ferns reproduce by making spores; they do not make seeds.

c Conifers are usually evergreen – they have thin, needle-like leaves which they shed a few at a time all through the year. They have a water transport system and waterproof leaves. Conifers produce seeds which are formed inside cones.

d Flowering plants reproduce using flowers. The flowers produce seeds inside fruits. They have a water transport system and usually have broad waterproof leaves.

Flowering plants

Just like the animals, the large plant groups can be split into smaller ones.

Most of the plants we see around us are flowering plants. Some of them, such as trees and shrubs, are woody and can live for many years. Others are not woody and only live for one or two years. The flowering plants are split into just two main groups:

Monocots are not usually woody. The leaves have lots of veins running side by side and the top and bottom surfaces of the leaf are the same. The flowers are usually green or brown, although some can be very colourful.

Cordgrass

Dicots are often woody. Their leaves have a network of veins, and the top and bottom surfaces of the leaf are different. They often have very brightly coloured and scented flowers which attract insects to pollinate them.

Hibiscus

Key terms

- **dicot**
- **monocot**

Practical activity Plant sorting

Go out into the area around your school.

- Find and identify as many different types of plants as you can.
- Make a bar chart to show how many times flowering plants, conifers, ferns and mosses turned up on the lists.

Summary questions

1 Trees can belong in more than one group of plants. Name the groups.

2 Marshes are wet places where mosses grow well. Hillsides are drier places where many flowering plants grow but mosses do not. Explain these observations.

3 Look again at the first list of plants you made and put them into groups. What percentage of the plants you thought of came from each of the four main groups of plants?

4.4 Species and variation

Learning outcomes

After this topic you should be able to:

- describe what is meant by a species
- discuss reasons why a species has or could become extinct
- measure variation between members of a species and present the data in different ways.

Expert tips

As you can see on page 150 there are many organisms that are extinct. We only know about them from fossils. Extinction is a fact of life on Earth. However, owing to the changes we are causing, more organisms are becoming extinct than has happened in the recent past.

The smallest group used when we classify living organisms is a species. We put organisms into different species based on variations between them.

What is a species?

The members of a species can breed and produce offspring which can also reproduce. If two animals or two plants cannot successfully reproduce and have **fertile** offspring, they are from separate species. For example, horses and donkeys look quite similar and can produce offspring called mules. But mules are not fertile – they cannot reproduce. This tells us that horses and donkeys are two separate species. Each species has its own **characteristics** which are passed on from parents to offspring.

Horses and donkeys have many similarities but they are different species

Around the world, many species have become extinct, or are in danger of becoming extinct soon. Extinction means that a species disappears from the Earth completely. This often happens when there are changes in the environment where a species lives. Each species is adapted to its own environment. If there is a change in the environment and a species of plant or animal cannot change to cope with the new conditions, it will die out. One species cannot breed with another species to help it survive.

The dodo was a flightless bird that lived on Mauritius. Within 100 years of the island being discovered by sailors, who ate the birds, all the dodos were gone. In modern times, climate change means the ice at the polar regions is melting. The number of polar bears is falling fast. They are adapted to living in the ice and snow and numbers will continue to fall in areas where the sea ice is melting fastest.

Variation within a species

You have seen that there is **variation** between different groups of living organisms. There is also variation between different members of the same species. For example, all of your classmates are members of the same human species – but you all look different. There is variation between you. Investigate several different specimens of the same type of plant or animal. You will find many similarities – but they will also have differences which you can observe, record and measure.

Practical activity Looking at variation

Look at the Harlequin ladybirds. They are all members of the same species.

- List as many of the differences between them as you can. What do they have in common?

If there is a change in the environment, some members of the species might have a variation which means they survive better than the others. They may be able to breed successfully and continue the species even if most of the rest die out. So variation is very important for the survival of species, particularly when their environment changes.

Key terms

- **characteristic**
- **fertile**
- **variation**

Practical activity Investigating variation

Some types of variation can be easily observed such as attached and unattached earlobes and dimples when you smile. Some types of variation can only be seen clearly when you measure them, e.g. hand span, height and body mass.

- Use your class mates and measure easily observed variation in people, e.g. earlobes or dimples. You can draw a bar chart, a pie chart or a table to show your results.
- Use your class mates again to look at variety which needs to be measured, e.g. hand span or height.

Work in a group. Collect a number of seeds, leaves, pods or flowers from different members of the same species of bean or other local plant.

- Investigate which features vary. Measure as many examples as you can and choose the best way to display the data you collect.

Summary questions

1 a) What do scientists mean when they use the term *species*?

b) List the characteristics which you think are common to all the different types of horses.

c) Do some research and list some of the variations you can find in different breeds of horses.

2 Find an example of an organism that shows clear variety between the different members of the species and explain why this is important in any species for survival.

3 Find out why scientists think the following became extinct: passenger pigeon, great auk, the quagga, sabretooth tiger, mammoth.

Chapter 4 End of chapter questions

1 Six groups of animals and their features are listed below. Draw a table matching each group with its feature.

Groups of animals

vertebrates
mammals
fish
birds
reptiles
amphibians

Features

moist skin covered in scales
dry skin with scales
skin with feathers
skin with hair on most or some of the body
moist skin with no scales
backbone made of bone or cartilage

[6]

2 Which of the following statements is **not** correct?

A all birds can fly

B all amphibians have four limbs

C some mammals lay eggs instead of giving birth to live young

D some fish have a backbone made of cartilage *[1]*

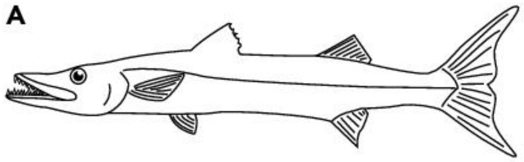
3 Biologists used to divide all animals into two groups – vertebrates and invertebrates. As they learnt more about organisms they realised that this division was too simple. However, we still refer to vertebrate and invertebrate animals as it is a useful way to start learning about classification. The many thousands of animal species can all be classified into these two groups.

a In what way do invertebrates differ from vertebrates? *[1]*

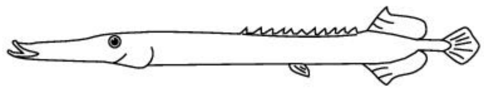
b Explain what is meant by the term *species*. *[2]*

4 The drawings show four different species of fish found in the Caribbean.

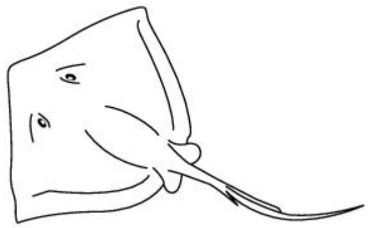
A



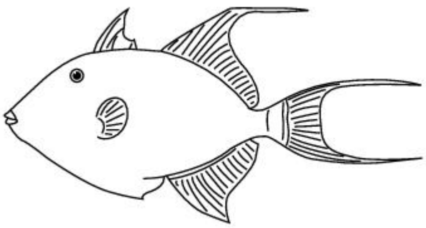
B



C



D



Biologists use keys to help them identify different species.

a Use the identification key to name the four different types of fish. *[4]*

1 (a) Body shape is long and thin: go to 2
  (b) Body shape is not long and thin: go to 3
2 (a) Two fins on the upper surface of the body; sharp teeth *Sphyraena barracuda*
  (b) Many small, sharp fins on the upper surface *Aulostomus maculatus*
3 (a) Tail fin is long and thin *Dasyatis americana*
  (b) Tail fin has two long, thin projections *Balistes vetula*

b State two features of fish that would **not** be useful in this identification key. Explain each of your answers. *[4]*

5 All domestic cattle belong to the same species which is known as *Bos taurus*. Around the world there are many different types (or breeds) of cattle. Four of these breeds are shown below.

Ankole

Zebu

Jersey

Hereford

The breeds differ from each other in several ways. For example, they are different heights.

a Look carefully at the drawings of the heads of the four breeds of cattle. List four features that vary between the cattle. *[4]*

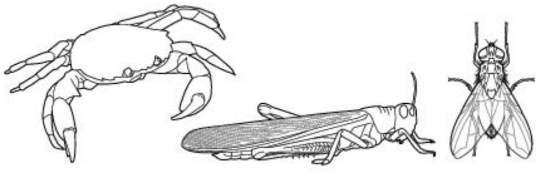
b Suggest three other ways in which the breeds may differ from each other. *[3]*

In some countries each cow in a herd is identified by a tag in its ear. Most farmers keep herds of cows that are all the same breed.

c Suggest three ways that a farmer can tell the difference between individual cows in a herd if they are not tagged. *[3]*

d Explain why cattle from all over the world are classified in the same species. *[3]*

6 The drawings show three arthropods.



a Copy and complete the table to compare these three arthropods.

Feature	Shore crab	Desert locust	Housefly
Presence of claws			
Presence of antennae			
Presence of eyes			
Number of legs			
Number of wings			

You may use ticks and crosses for the first three features in the table. *[5]*

b State two features that all arthropods have in common. *[2]*

7 A class of 30 students was studying variation. The teacher asked Sam and Sara to look carefully at everyone's ear lobes. They discovered that 25 had free ear lobes and 5 had attached ear lobes.

a Draw a bar chart to show these results. *[5]*

The class then measured the span of the left hand in millimetres. They did this by stretching out their fingers on a piece of paper and measuring the distance between the tip of the thumb and the tip of the little finger. Sam and Sara collected the data as follows:

210	200	175	195	205	193
190	205	182	195	213	202
223	240	210	208	219	186
192	228	183	197	195	214
188	220	205	204	199	184

b i What are the smallest and largest hand spans in the class? *[3]*

ii Use your answers to **i** to calculate the range in hand span within the class. *[2]*

c Organise the data by making a tally table using the class sizes: 170–179 mm; 180–189 mm; 190–199 mm and so on. (See page 72 to remind yourself how to do this.) *[3]*

d Use the data in your tally table to draw a histogram to show the variation in hand span in the class. (A histogram is like a bar chart but there are no gaps between the bars on the graph.) *[5]*

e Suggest three reasons for the variation in hand span in the class. *[3]*

Science *in context!*

Amazing demonstrations

The name of Otto von Guericke will always be linked to his beloved city of Magdeburg in Germany. His wealthy family had lived there for three centuries before Otto was born on 20th November, 1602. He went to university at the age of 15, and finally studied law at the Dutch university of Leiden for three years until he was 23. Whilst at Leiden he also studied engineering and was especially interested in building fortresses.

He will be best remembered for his famous demonstrations about the pressure caused by the gases in air. Having invented the air pump in 1650, Otto was able to create a vacuum. He could remove the air from a container and show the great force that air pressure can produce. Otto really knew how to impress people. Look at two of his experiments below and opposite:

Otto von Guericke

In this experiment a group of up to 20 men, using a pulley, tried to pull a piston upwards, as one man tried to pull it downwards by sucking air out of the cylinder. People were amazed when the 'one man' (plus the help of air pressure) won the tug of war

Two teams of horses could not separate the two halves of the copper sphere – all because of air pressure

Otto had two halves of a copper sphere made so that they fitted together perfectly. He had the local blacksmith and some helpers use a pump to suck the air out of the sphere. On his signal the two teams of horses pulled and pulled, but they could not separate the two halves of the sphere. The crowd of curious onlookers cheered.

They were even more impressed when the horses had stopped and Otto returned to the copper sphere. He asked for silence as he released a valve and a hissing sound could be heard. As the air rushed back inside the sphere, it suddenly fell into its two halves. The crowd were amazed and delighted!

Otto's demonstrations continued to be a great success as he toured around Europe, performing at several royal courts.

In this chapter you will find out about the particle theory of matter and how this can explain the properties of solids, liquids and gases, including changes of state.

Key points

- We can explain the properties of solids, liquids and gases using particle theory. This describes a model that explains the observations we make of how materials behave.
- In a solid the particles are packed very close together, touching their nearest neighbouring particles around them. They are fixed in position but do vibrate.
- In a liquid the particles are still very close together, but can slip and slide over each other.
- In gases, the particles move around rapidly at random and there is lots of space on average between the particles in the gas.
- Solid → liquid = melting
- Liquid → solid = freezing / solidifying
- Liquid → gas = evaporating / boiling
- Gas → liquid = condensing
- Solid → gas = sublimation

5.1 Classifying everyday materials

Learning outcomes

After this topic you should be able to:

- recognise that some materials are difficult to classify as a solid, liquid or gas
- display your results in a table.

You already know about the properties of **solids**, **liquids** and **gases**. Solid, liquid and gas are called the three **states of matter**. Look at the table below:

State of matter	General properties
solid	fixed shape cannot be squashed (**compressed**)
liquid	no fixed shape can flow very difficult to squash
gas	no fixed shape spreads out to fill its container easily squashed

But some materials are difficult to classify.

Would you classify this jelly as a solid or a liquid? Why?

Practical activity Which are the solids, liquids or gases?

Look at each of the materials listed in the table and classify them as a solid, a liquid or a gas.

Explain your reasoning behind each choice.

You can use a microscope to help if one is available.

- Record your results in a table similar to the one that follows.

Substance	Solid, liquid or gas?	Reasoning
sugar		
toothpaste		
wallpaper paste		
talc		
sauce		
cling-film		
hair gel		
hair spray		
sponge		
wet clay		

Now share your ideas with another group.

Do you disagree over any classifications?

Try to agree on a final version of your table before discussing your results as a class.

Now try the next activity.

Practical activity Making a key

- Using the properties of solids, liquids and gases, make a key to help classify substances.

Try out your key on some of the materials in the previous Practical activity box.

Key terms

- **compress**
- **gas**
- **liquid**
- **solid**

Summary questions

1 Copy and complete the table:

	Does it have its own fixed shape?	Is it easy to compress?	Does it spread out or flow easily?
Solid			
Liquid			
Gas			

2 Classify the following substances as solids, liquids or gases at room temperature. Put your answers into a suitable table.

petrol; oxygen; nitrogen; concrete; engine oil; iron; carbon dioxide; perspex; vinegar

3 Name one material that is difficult to classify as a solid, a liquid or a gas. Explain why.

5.2 Gases

Learning outcomes

After this topic you should be able to:

- explain that gases are made up of particles
- describe how the particles in gases are, on average, spread widely apart and describe how they move
- explain the properties of gases using the particle model.

Expert tips

All gases do have mass, but they are very light. We say gases have a low density.

Gases are all around us all the time. The air is made up mainly of nitrogen gas and oxygen gas. Other gases you might know are:

- chlorine
- hydrogen
- helium
- carbon dioxide.

This airship is filled with helium gas. This gas has a very low density, even for a gas

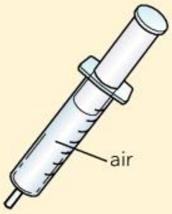
Practical activity Exploring gases

Blow up and tie a rubber balloon so that it is full of air. Hold it in both hands and press gently inwards, then release.

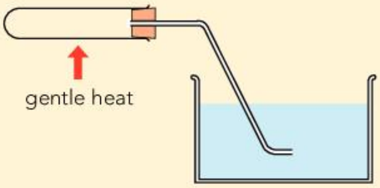
- Describe what happens.

Fill a plastic syringe with air up to its maximum reading and press your thumb over the nozzle.

- What is the volume of gas in the syringe?
- Now press the plunger downwards, without letting any air escape.
- What is the new reading on the syringe?
- By what percentage has the volume of the air in the syringe decreased?



Watch your teacher warm a boiling tube of air as shown below:



- Describe what happens.

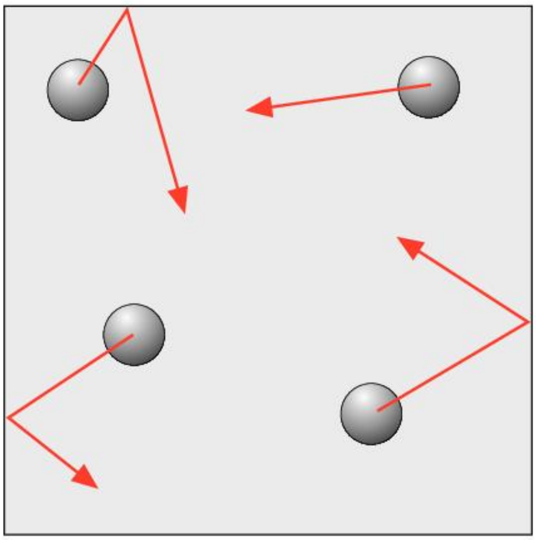
Particles in gases

Scientists believe that all matter, including gas, is made up of particles. The arrangement of particles and their movement in solids, liquids and gases is described by the **particle theory**. The particles are too small to see, but using this theory we can explain the properties of materials.

Look at the box below showing the particles of a gas.

Notice that there is a lot of space between the particles in a gas. The particles in a gas are free to move around rapidly in any direction. We say that they move in a **random** manner. They **collide** with each other and with the walls of their container.

- When we squash a gas, its particles are pressed closer together. So there is less space within the gas and its takes up a smaller volume.
- When we heat a gas, its particles gain energy and move around more quickly. A hot gas takes up a greater volume than the same mass of a cool gas (at the same pressure).



Key terms

- **collide**
- **particle theory**
- **random**

Summary questions

1 Name five common gases.

2 Describe the arrangement and movement of the particles in a gas. Include a diagram in your answer.

3 Explain why gases:

a) have a very low density

b) spread out to occupy their container.

4 Explain why a hot air balloon rises.

5.3 Liquids

Learning outcomes

After this topic you should be able to:

- describe how the particles in a liquid are arranged
- describe how the particles in a liquid move
- explain the properties of liquids using the particle model.

You get a good idea of the properties of a liquid when you go for a swim or walk through a stream. Is it easier to move through air or water? What does this suggest about the spaces between the particles in a liquid compared with a gas?

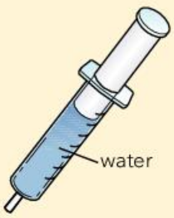
Water is the most common liquid on Earth

Practical activity Exploring liquids

a) Fill a plastic syringe with water up to its maximum reading and seal the nozzle with your thumb.

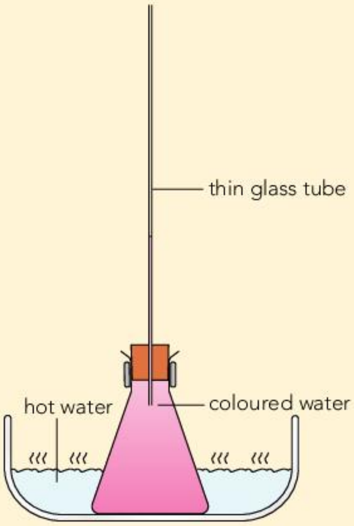
Now press the plunger downwards, without letting any water escape.

- Does the volume of the water in the syringe decrease? Compare this with the result of the same experiment using a syringe of air.



b) Warm a flask of coloured water which has a very narrow glass tube inserted as shown:

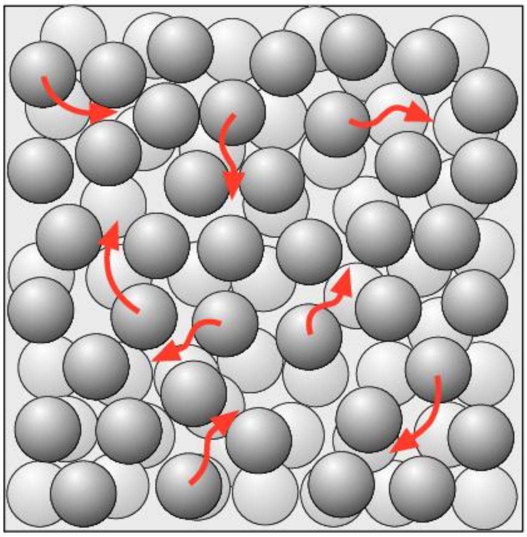
- Describe what happens.



Particles in liquids

The particles in a liquid are arranged randomly. There is no fixed pattern. There is very little space between the particles. The particles can slip and slide over and around each other.

Look at the diagram of the particles in a liquid:



- We cannot compress a liquid to any extent because its particles are touching their neighbouring particles.
- A liquid can flow because its particles are free to move around. Liquids flow to take the shape of their container.
- When we heat a liquid, its particles gain energy and slip and slide over each other more quickly. This causes the liquid to **expand** when it is heated so that it has a slightly greater volume.

Key terms

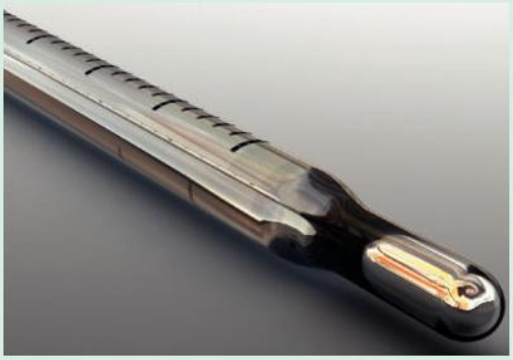
- **expand**

Summary questions

1 Why can a liquid flow?

2 Explain the results of the Practical activity 'Exploring liquids' on page 90, using the particle model.

3 Mercury is a silvery liquid used in the thin tube inside some thermometers. Explain the way in which a mercury thermometer works.



A mercury thermometer

5.4 Solids

Learning outcomes

After this topic you should be able to:

- describe the arrangement and movement of the particles in a solid
- explain the properties of solids using the particle model.

You already know about the properties of solids, such as wood, plastic and metals. Each solid material is different but they all have certain things in common. For example, all solids have a fixed shape. They stay where they are put and cannot flow like liquids and gases.

Gold is one of the most expensive solid materials. It is a rare metal that people use to make jewellery because of its beautiful, shiny appearance. Gold is a dense, hard metal

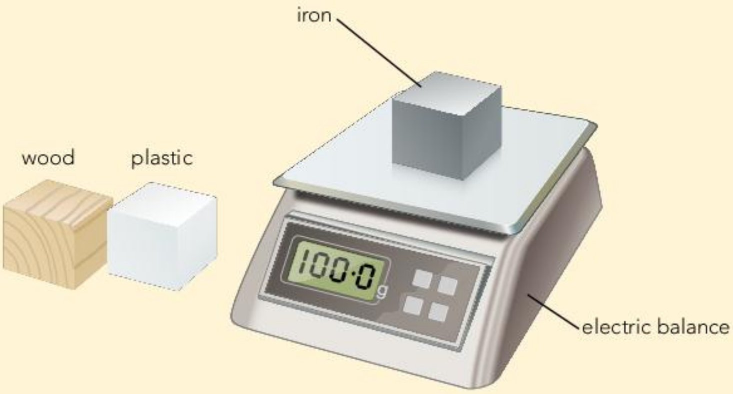
Practical activity — Exploring solids

Take three equal-sized blocks of different solid materials, such as iron, wood and plastic.

Place each block on top of some water in a plastic container.

- What happens?

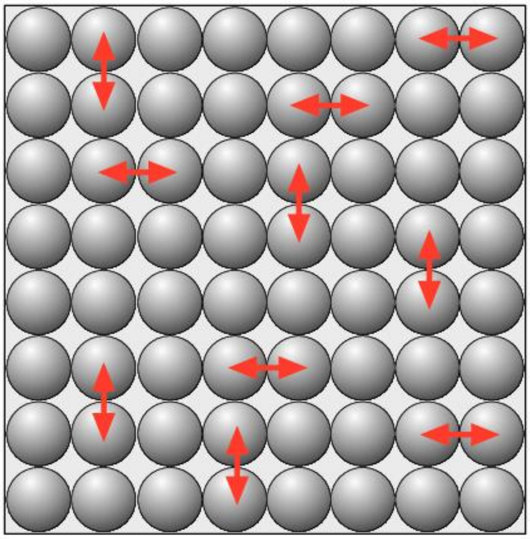
Dry each block then find its mass using a balance.



- Record your results in a table.
- All solids are made up of particles. Discuss the results of the experiments. Think of ideas about these particles that could explain the results.

Particles in solids

The particles in solids are arranged in regular patterns. They are fixed in their positions, touching the particles next to them. The particles cannot move around like those in liquids or gases, but they do **vibrate**. The hotter the solid, the more the particles vibrate. Look at the diagram of the particles in a solid:



Practical activity Model solid

Make a model to show the particles in a solid using polystyrene balls.

The balls should all be the same size and you can use glue to stick them to each other.

- **Evaluate** your model. In what ways is it a good model? What are its drawbacks?

- We cannot compress a solid because its particles are touching their neighbouring particles.
- A solid cannot flow because its particles are touching each other in fixed positions. So solids have a fixed shape.
- When we heat a solid, its particles vibrate more quickly and more vigorously. This causes a solid to expand when it is heated.

Expert tips

The particles in a solid are **not** motionless. They vibrate constantly.

Key terms

- **evaluate**
- **vibrate**

Summary questions

1 Why do solids have a fixed shape?

2 Solids cannot be compressed. Explain why in terms of the particle theory.

3 The density of a solid tells us the mass of 1 cm^3. Why do different solids have different densities?

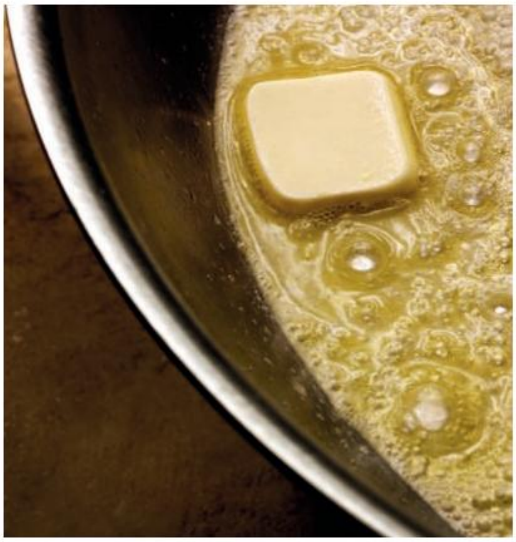
5.5 Changes of state

Learning outcomes

After this topic you should be able to:

- name each change of state
- explain what happens in changes of state using the particle theory.

What happens when we heat some butter in a pan? The solid butter will turn into a liquid. We say that the butter melts. **Melting** is an example of a change of state – a solid changes to a liquid.



An everyday example of a change of state – butter melting in a pan

These are the changes of state:

- solid → liquid is called melting
- liquid → solid is called **freezing** or solidifying
- liquid → gas is called **boiling** (or **evaporating** when it takes place below the boiling point)
- gas → liquid is called **condensing**

Some solids turn directly into a gas without melting into a liquid.

- solid → gas is called **sublimation**

Practical activity Observing some changes of state

Watch your teacher heat the following substances which are solids at room temperature:

butter ice wax sulfur (in a fume cupboard)

Your teacher will measure the temperature at which each substance changes from a solid to a liquid. This is the **melting point** of the substance.

- Record the results in a table.
- What happens to hot liquids when they are allowed to cool down again?

Your teacher will place a test tube containing a little ethanol into a beaker of hot water from a kettle.

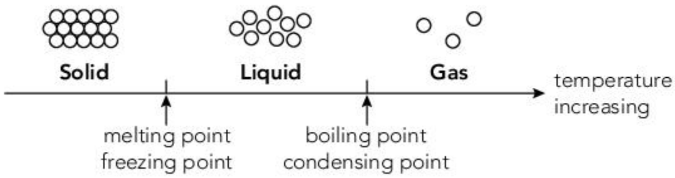
- What do you see happen?

Watch your teacher warm a few crystals of iodine in a test tube.

- What happens?
- What is the name given to this change of state?

Most substances can exist as solids, liquids or gases depending on their temperature.

Look at the temperature line below:



Changes of state on a temperature line

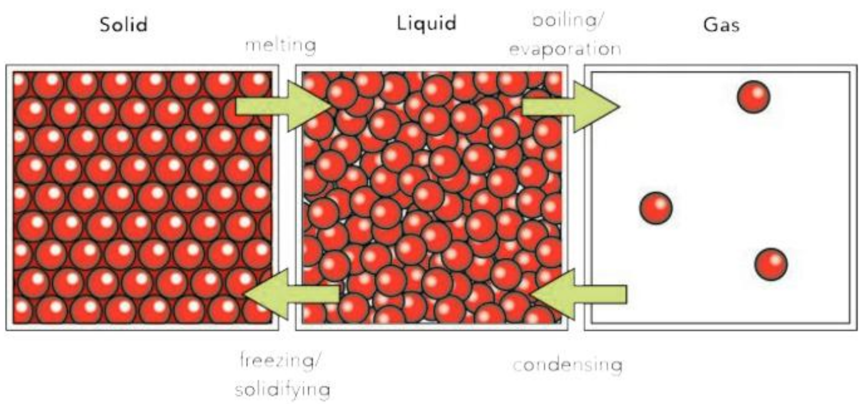
Notice that substances melt and freeze at a particular temperature. They also boil and condense at a certain temperature. Scientists often use melting points and boiling points to identify unknown substances.

Expert tips

When a substance changes state, its particles do not change. It is their arrangement and movement that changes.

Particles and changing state

Look at the particle boxes below:



Changes of state

The particles in a solid are packed closely together and are vibrating. As we heat up a solid, its particles start to vibrate more and more vigorously. Eventually the particles shake about so much that they break free from each other and are able to move about. This is when the solid melts.

As we heat up a liquid, more particles gain enough energy to escape from the attractive forces of their neighbouring particles. The liquid starts to evaporate more quickly. Eventually, the liquid reaches its boiling point. At this temperature, particles are leaving the liquid readily and you see bubbling within the liquid.

Key terms

- **boiling**
- **condensing**
- **evaporating/evaporation**
- **freezing**
- **melting**
- **melting point**
- **sublimation**

Summary questions

1 Define the following words:
   a) condensing b) melting c) boiling d) freezing

2 What do we call the change when a solid changes directly into a gas?

3 Explain what happens when a substance melts, using the particle theory.

5.6 Using models in science

Learning outcomes

After this topic you should be able to:

- explain why scientists use models
- recognise that models change over time.

Scientists use physical models like this to help explain the world

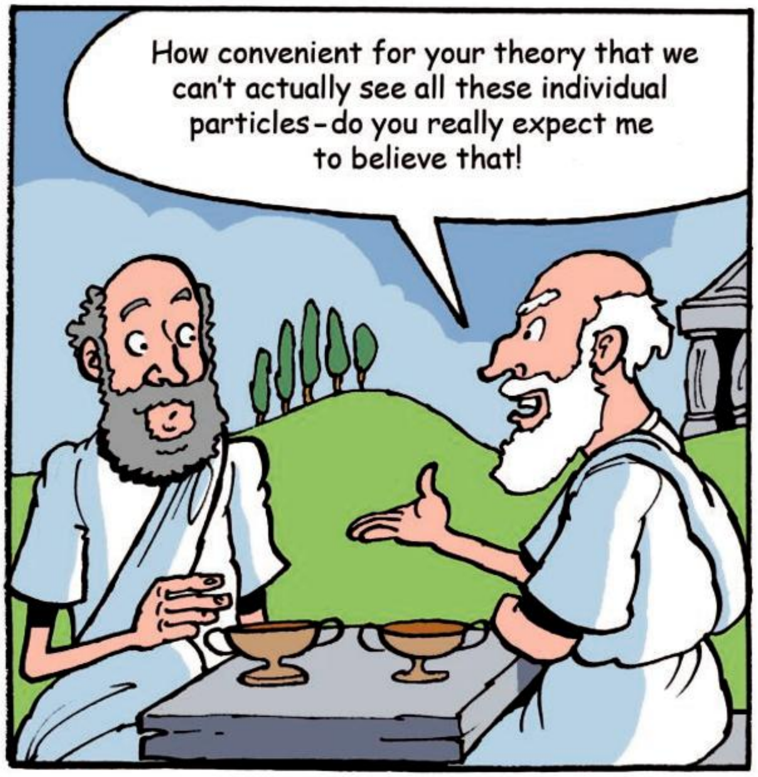
Scientists use **models** to help them explain the way the world works. A scientist's model might be a theory, a mathematical equation or a computer simulation that explains our observations.

We can then use the model to make predictions in new situations. If the prediction proves to be correct, then the model is more likely to be accepted as a good one by other scientists.

Changing models

The Ancient Greeks were the first people to suggest that everything is made of tiny particles. The Ancient Greeks were great thinkers about the world they lived in. A Greek philosopher, called Democritus, put forward his model to explain the way materials behave.

The particles he wrote about were so small that you couldn't see them.



He imagined that the particles were hard and could not be destroyed.

Our word 'atoms' comes from the Greek '*atomos*'. It means indivisible (or something that can't be broken down).

Democritus explained the properties of materials by saying that their particles were different. For example, a runny liquid must be made up of smooth, round particles so that they can tumble over each other.

On the other hand, hard solids must be made up of particles that are sharp and jagged. These particles get stuck in position – which explains why they don't flow and are hard.

This model appealed to the logical mind of Democritus. However, most people still believed in a model suggested by another, more famous Greek philosopher called Aristotle. He said that all materials were mixtures of earth, air, fire and water.

In this model, all materials differed because they contained different proportions of earth, air, fire or water. This was a powerful theory, too, as people could use it to explain many observations.

Eventually, over 2000 years later, scientists developed the theory of particles that is still useful today. We don't think that everything Democritus suggested is correct, but we do believe in particles.

Experiments carried out around 1800 played a big part in refining our ideas about particles. Experimenting was not something the Ancient Greeks thought worthwhile!

Democritus was a wealthy Greek philosopher, born in 460 BC. He has been commemorated on Greek stamps and has a large research institute near Athens named after him

Practical activity Modelling particle theory

Imagine that you and your classmates are particles in a solid, a liquid and a gas.

Discuss a way that you could model the behaviour of the particles changing from a solid to a liquid to a gas.

- Try out your ideas.
- Evaluate your model. In what ways is it a good model and what are its drawbacks?

Key terms

- **model**

Summary questions

1 Why are models used in science?

2 Give one difference between the Democritus model of a solid and the one you have used in the particle theory introduced in this chapter.

3 Why do models change over time?

5.7 Heating and cooling curves

Learning outcomes

After this topic you should be able to:

- describe what happens to the temperature of a solid when it is heated beyond its melting point
- describe what happens to the temperature of a liquid when it is cooled below its freezing point.

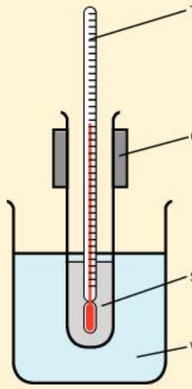
You have seen how solids can melt when we heat them and how the resulting liquids solidify when they cool down. In this topic we will see what happens to the temperature during changes of state.

A suitable substance to investigate is stearic acid.

Practical activity Investigating melting

Solid stearic acid will be melted by heating it in a beaker of hot water.

Set up the apparatus as shown in the diagram:



Using a thermometer, take the temperature of the stearic acid every 30 seconds.

Do not remove the thermometer from the stearic acid throughout the experiment.

Keep taking readings until the temperature reaches about 70 °C.

- Record the results in a table.

(Time should be in the first column, and temperature in the second column.)

Now carry out the next experiment as quickly as possible.

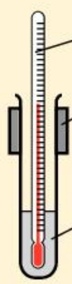
Practical activity Investigating freezing

Use the clamp stand to lift the tube of molten stearic acid from the hot water.

The tube of stearic acid will start cooling down when removed from the hot water.

Take the temperature every 30 seconds.

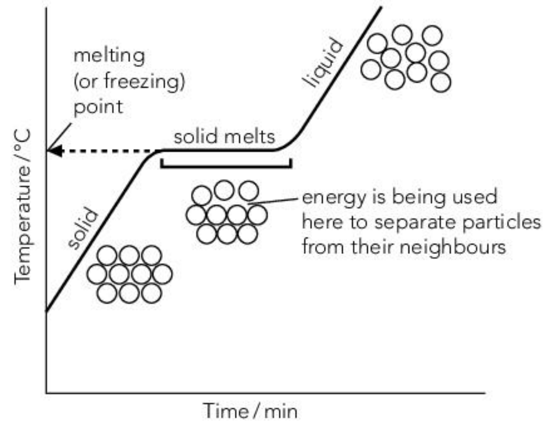
- Record the results in a table, as in the previous experiment.
- Draw a line graph for each set of results from the tables in the two experiments.
- Comment on any patterns you see on the graphs.



Explaining heating and cooling curves

The line on the graph for the Practical activity 'Investigating melting' on the opposite page is called a **heating curve**.

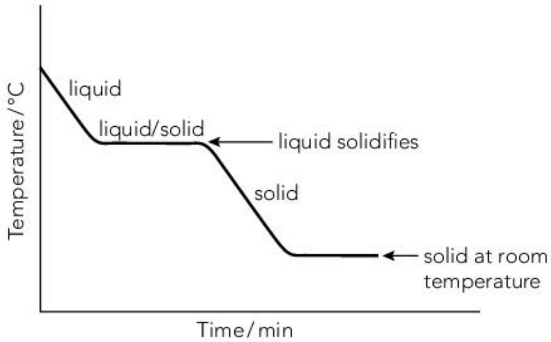
Look at the graph below:



A heating curve

You can see that there is a flat (horizontal) section on the line. The temperature stays the same for a while even though the substance is still being heated. At this point both solid and liquid are present in the tube. This temperature is the melting point of the solid substance (which is the same as its freezing point). The temperature remains the same until all the solid melts as it takes energy to separate its particles from each other.

The line on the graph for the Practical activity 'Investigating freezing' on the opposite page is called a **cooling curve**.



A cooling curve

Key terms

- **cooling curve**
- **heating curve**

Summary questions

1 **a)** What is the difference between a heating curve and a cooling curve?
  b) From which part of a heating curve can we tell the melting point of a substance?
  c) Compare the melting point in part **b** with the freezing point of the substance.

2 Sketch a cooling curve for a substance with a melting point of 60 °C, showing its change from a liquid at 70 °C to a solid at 20 °C.

3 Explain the flat section of the line on the cooling curve you sketched in question **2**.

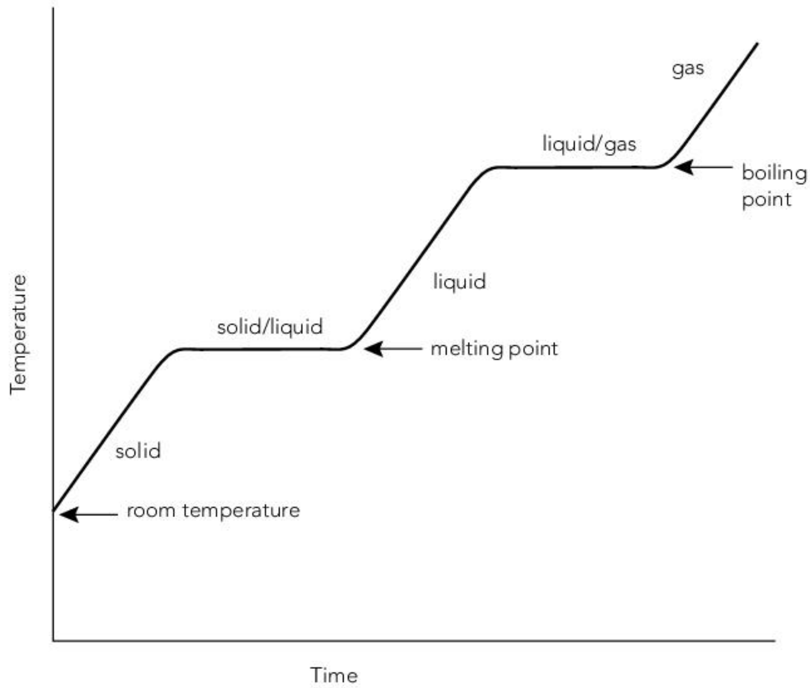
Investigating water

Learning outcomes

After this topic you should be able to:

- plan an experiment to produce the heating curve for water, including the apparatus required
- present results in tables and graphs
- recognise anomalous results.

A heating curve has a flat section at the melting point of the substance. This curve can be extended to show another flat section at the boiling point of the substance. Look at the graph below:



A heating curve

The heating curve above remains flat as the liquid is boiling. This is because energy is needed to separate the particles in a liquid as they form a gas and bubble from the liquid.

A cooling curve for a gas cooling to a liquid and then to a solid also has two flat sections. The first shows the condensing point. The second shows the freezing point.

Practical activity — Investigating ice, water and steam

Plan an experiment to plot a heating curve for water.

Your experiment should start with water in its solid state, as ice.

It should finish when both liquid and gas (steam) are present.

- Predict a sketch of the heating curve for water.
- Write a plan for the method you will use. Include a diagram and an apparatus list.
- In what way will you record your results?
- In what way will you display your results?
- Check your prediction against your results.
- Evaluate your experiment.

Do not start any practical work before your teacher has checked your plan.

Anomalous results

Sometimes we get a reading from an experiment that does not follow the pattern of the rest of the results. Such a result is called an **anomalous result**. This might be because of human error. You might have made a mistake reading the measuring instrument. Or you might have used the measuring instrument incorrectly. For example, some measuring instruments need to be set at zero before using them in order to get an accurate reading.

Plotting your results on a graph will help you to spot any anomalous results. If possible you should repeat the readings again. If this is not possible, do not include the anomalous point when you draw your line of best fit on the graph.

Expert tips

Remember that lines of best fit on a graph are not always straight lines.

Practical activity Analysing data

The results for part of a heating curve of a substance are shown in the table below:

Time / min	Temperature / °C
0	63
0.5	66
1	67
1.5	67
2	77
2.5	67
3	67
3.5	70
4	73

- Plot these results on a graph.
- Put a circle around the anomalous result.
- What should you do with the anomalous result?
- Now draw a line of best fit through the points.

Key terms

- **anomalous result**

Summary questions

1 a) What is the boiling point of water?
b) What is the freezing point of water?

2 Sketch a cooling curve for a substance starting as a gas and finishing as a solid.

3 a) Explain what an anomalous result is.
b) You discover an anomalous result as you analyse the data collected in an experiment. Explain what you should do with this anomalous result.

5.9 Investigating evaporation

Learning outcomes

After this topic you should be able to:

- plan an investigation into the evaporation of water
- choose the key variables in the investigation
- make and evaluate a prediction.

When a liquid changes into a gas, at any temperature below its boiling point, we call the change in state **evaporation**.

Evaporation is important when we dry our clothes after washing them.

What variables affect how quickly the water evaporates from washing on a line?

Evaporation is also important when we extract salt from seawater. The seawater is left in shallow pools called salt-pans for the water to evaporate.

A white solid is left when water evaporates from seawater. This is a mixture of different salts, but it is mainly sodium chloride

Practical activity Investigating the rate of evaporation

So what affects how quickly the salt is obtained from a salt-pan?

You can now apply the particle theory to explain and investigate one of the factors that affects how quickly water evaporates from a salt solution.

- List the factors (variables) that might affect how quickly water evaporates from salt solution.
- Choose one factor to investigate.
  This is your **independent variable**. You can choose which values it has in your investigation.
- What will you measure to find out how quickly the water evaporates?
  This is your **dependent variable**. (Its value depends on the values you choose for the independent variable.)
- Write down the question you will investigate and make a prediction.
  Explain your prediction using particle theory.
- Which factors must you keep constant to make it a fair test?
  These are your **control variables** (see page 218).

Plan your tests – what apparatus will you need?

⚠ **When you have planned what to do, let your teacher check your plans before you start.**

- Record your results in a suitable table and display the data on a graph.
- What pattern can you see in your data?
- Check if your data supports your prediction or not.
- Evaluate your investigation.
  Explain any ways in which you could improve your investigation.

Key terms

- **control variable**
- **dependent variable**
- **evaporation**
- **independent variable**

Summary questions

1 Define the word 'evaporation'.

2 Why do some particles escape from the surface of a liquid at a temperature below its boiling point but others do not?

3 A group of students investigate the question 'How does temperature affect the time it takes salt to dissolve?'

   a) What is the independent variable in their investigation?

   b) What is the dependent variable in their investigation?

   c) Name two control variables in their investigation.

Chapter 5 End of chapter questions

1 a Classify the following substances as solids, liquids or gases at 20 °C.

Put your answers into a suitable table. *[9]*

orange juice; hydrogen; helium; granite; seawater; steel; sulfur dioxide; polythene; diesel

b Name two materials that would be difficult to classify as a solid, a liquid or a gas. *[2]*

2 Copy and complete the table below to describe the differences between solids, liquids and gases in terms of:

a their shape *[1]*

b how easy they are to compress *[1]*

c their ability to flow. *[1]*

	Does it have its own fixed shape?	**Is it easy to compress?**	**Does it spread out or flow easily?**
Solid			
Liquid			
Gas			

3 Copy and complete the sentences, using words from the following list:

vibrate pressure around walls quickly gas space solid

The particles in a ______ are fixed in position but they do ______ .

In a liquid, the particles can move ______, slipping and sliding over each other.

In a ______, the particles move very ______ and there is a lot of ______ between particles (on average). As they collide with the ______ of their container they produce a force that causes gas ______ . *[8]*

4 A class is going to model solids, liquids and gases using marbles and the lid of a shoe box.

Draw diagrams that show the arrangement of the marbles in the model of:

a a solid *[1]*

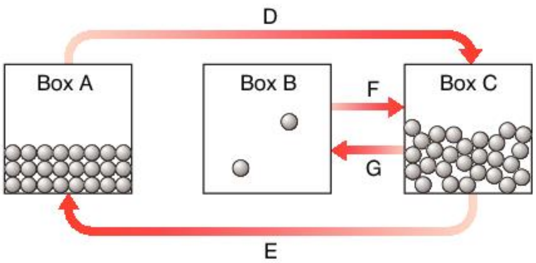
b a liquid *[1]*

c a gas. *[1]*

5 Solid, liquid and gas are called the three states of matter.

The particles in a solid, liquid and gas are shown below.

The arrows represent changes of state:



a Which box contains:

i a solid?

ii a liquid?

iii a gas? *[3]*

b Which state of matter is most easily compressed? *[1]*

c i Identify the changes of state labelled D, E, F and G. *[4]*

ii Which changes of state require cooling down to take place? *[2]*

d Sima wanted to see how easily sulfur powder melts.

Sulfur burns in air to form toxic sulfur dioxide gas.

Give two safety precautions that Sima should take in her experiment. *[2]*

6 a What do you think happens to the vibrations of the particles when you heat a solid? *[1]*

b Use the particle theory to explain why liquids can be poured. *[1]*

c Use the particle theory to explain why it is easy to move through a gas. *[1]*

7 Copy and complete these sentences using the particle theory:

a Solids have a fixed shape because ______ .

b Liquids have no fixed shape because ______ .

c Gases take up a large volume because ______ . *[3]*

8 Imagine that the people in your class are particles. You can use them to demonstrate the arrangement and movement of particles in a solid, liquid and gas.

Think up a set of instructions for this modelling activity. *[6]*

9 Write a short story or cartoon strip about a water particle that starts off in an ice cube inside a freezer. The next day it ends up in a drop of water on the inside of the kitchen window. Tell the tale of '24 hours in the wonderful world of a water particle'. *[10]*

10 Read this information about rubber:

The particles that make up rubber are long and zig-zagged in shape and are arranged in a random manner. When we stretch rubber its particles straighten out and become lined up with each other. When you remove the force the particles go back to their original orientation.

a Draw the particles of rubber in a piece of elastic band. *[1]*

b Draw the particles of rubber in a piece of elastic band that is being stretched. *[2]*

c What happens to the elastic band if you stretch it too far? *[1]*

d Explain your answer to part **c**, referring to the particles of rubber. *[2]*

e Rubber can be strengthened by heating it with sulfur. This makes 'vulcanised' rubber, which contains linkages between these rubber particles. Draw four particles in a piece of vulcanised rubber. *[2]*

11 A group of students investigated the heating curve of a substance, **X**.

X is a solid at room temperature. The group heated half a boiling tube of **X** in a water bath and recorded the temperature of **X** every two minutes. Here are their results:

Time / min	Temperature / °C
0	21
2	26
4	31
6	36
8	51
10	53
12	53
14	53
16	53
18	58
20	63

a Draw a scientific diagram of the experiment to show the heating of substance **X**. *[4]*

b Plot a graph to show the results of the experiment. *[4]*

c What was room temperature when the experiment was carried out? *[1]*

d What is the melting point of substance **X**? *[1]*

e Explain the flat section of the line on your graph using the particle theory. *[3]*

Science *in context!*

Developing a new material

Can you imagine the satisfaction you must get from inventing a new material that has saved thousands of lives? A new fibre was discovered by Stephanie Kwolek in 1965. It had properties that even she found hard to believe.

Stephanie had been working as a research chemist for DuPont, a chemical company based in the US, for almost 30 years. She worked with a team of chemists in DuPont's Pioneering Research Laboratory. They were researching ways to make new polymers (very large particles made of thousands of repeating units).

In the 1960s, people started to worry about a shortage of crude oil and DuPont wanted to make a new material for lightweight, but durable, car tyres. Their theory was that the new lighter tyres would help save fuel.

Stephanie and her team worked on the problem. One day the chemicals she mixed formed a milky liquid, unlike the clear liquid she was expecting. Instead of throwing the liquid away and starting again, she decided to test the liquid. This would involve 'spinning' the liquid into fibres by forcing it through narrow jets in a machine.

Stephanie Louise Kwolek was born in 1923

She sent her discovery to the test laboratory, but they were reluctant to 'spin' it into a fibre. They argued that it would probably block up their machine. Eventually, they gave in and sent the results of their tests on the fibre back to Stephanie. This stuff was incredible! It was nine times stronger than a similar mass of steel, yet was only half as dense as fibreglass. Stephanie insisted on re-tests until she was absolutely sure no mistake had been made.

She and her team then had to work out how to scale up the reaction she had performed in her laboratory. They needed a process that could manufacture tonnes of the new fibre. This included the necessary safety and environmental checks on their process and the new fibre.

Finally, in 1971, the new fibre was launched under the name of Kevlar. It is used to reinforce tyres, but research continued and it is now used in hundreds of different applications. Some of these are called composites. In these, Kevlar fibres are mixed with other materials to give new products with improved properties. For example, it is used extensively in commuter aircraft to reduce weight but maintain strength.

But perhaps Kevlar's most famous application is in bullet-proof vests – and that is why Stephanie Kwolek can be proud that she has helped to save thousands of lives.

Sheets of Kevlar fibre are compressed together to make the body armour which saves lives

The racing 'leathers' of this rider are in fact synthetic and contain Kevlar. They protect the rider against abrasion in an accident where they come off their bike and slide across the tarmac at high speed

This canoe is made out of Kevlar. It is used to provide a strong, stiff, lightweight structure that is impact resistant

The Kevlar in this oven glove provides protection from heat

Kevlar fibre is used in this sail to provide strength and flexibility

In this chapter you will find out more about everyday materials and their physical properties, looking in detail at metals and non-metals.

Key points

- Materials are chosen for particular uses according to their properties.
- Properties of materials include:
  - hardness
  - density
  - melting point
  - flexibility
  - brittleness
  - absorbency
  - transparency
  - thermal conductivity
  - electrical conductivity.
- Metals are good conductors of heat and electricity whereas non-metallic materials are insulators.

6.1 Materials and their uses

Learning outcomes

After this topic you should be able to:

- distinguish between materials and objects
- describe the properties of some everyday materials
- link the uses of everyday materials to their properties.

Materials and objects

Before studying the materials that make up our world, you must understand the difference between materials and objects. Materials are the substances we use to make objects. For example, we can use wood to make a table. We can use wood to make a matchstick. The objects made (the table and the matchstick) can be very different but the material used to make them (wood) is the same.

All these objects are made of wood

Practical activity Survey of materials and objects

Look at the non-living things around you.

- Make a list of all the objects you can see and a list of all the materials in these objects.
- Which list is longer? Why?

Materials and their properties

We describe a material by its properties. A **property** must describe any piece of a material. For example, the words 'heavy' and 'light' are not properties of a material. You can have a nail or a girder made from iron. The iron that makes both objects is the same; it has the same properties (even though the nail is light and the girder is heavy). The property that describes a material's 'heaviness for its size' is called **density**. We can say that iron has a high density. An iron nail might have a small mass but it will seem heavy for its size. So density is a property of a material but mass is not.

Practical activity Property survey

Look at the materials around you.

- Make a list of properties of each material.

Remember that a property must be relevant to any size or shape of material.

- Make a list of all the words you used to describe the materials.
- Discuss as a group if all the words in this list are suitable for use as a property of a material.

Expert tips

Scientists use properties to describe materials, not objects.

Using materials

The material from which we choose to make a particular object depends on what the object is used for. For example, we might need to make some packing material to protect a TV in its box when it gets moved around. The main property in choosing a material for the packaging will be **softness**. If the TV box gets knocked the packaging needs to cushion the blow.

Nowadays such packaging is often made of a material called expanded polystyrene. It is a plastic that has gas blown into it as it sets. The trapped bubbles of gas make the packaging very spongy and soft. Another useful property of expanded polystyrene is its low density. This is useful when transporting electrical goods around. Less fuel is used in vehicles delivering the goods and the boxes are easier to lift.

The softness and low density of expanded polystyrene make it an excellent material for use in protecting goods during transportation

Key terms

- **density**
- **property**
- **softness**

Summary questions

1 Which of the following words refer to properties of materials and which do not?
Heavy
Dense (high density)
Large
Hard

2 A builder requires a material that is soft and that can be moulded into shapes before it sets into a very strong material that can support heavy loads. Name a suitable material.

3 Why **don't** we make:

a) pans from plastic?

b) slippers from wood?

4 Why do we use nylon to make ropes?

6.2 Absorbent and waterproof materials

Learning outcomes

After this topic you should be able to:

- distinguish between absorbent and waterproof materials
- plan a fair test to find out how absorbent different paper towels are.

The materials used to build homes and used in the home have a great variety of properties.

For example, slate tiles are used for roofs in countries with wet climates. Slate is a rock that is **waterproof**. Water cannot pass through slate, so it is ideal for making roof tiles. Not only that, the slate rock can be split into thin sheets which can be cut to make regular-shaped tiles.

This roof is covered in waterproof slate tiles. The rain runs off the tiles into guttering, down drain-pipes and then into underground pipes that take the water away from the building

Other roof tiles can be made from baked clay.

This roof is covered in terracotta tiles

Baked clay is also used to make house bricks. These are not waterproof and do absorb (soak up) some water through their surface. The brick is described as slightly **absorbent** or porous. This absorbed water usually evaporates off in warm weather. However, if the bricks in a house are constantly in contact with water, the water is absorbed deeper and deeper into each brick. It also spreads from one layer of bricks up to the next. As the bricks never get a chance to dry out, the walls become damp. This can cause serious problems in the house. For example, mould can grow on the inside walls.

Look at the experiment below to see another problem caused by water absorbed into brick.

Practical activity Brick damage

Place a brick in a bucket of water for a week.

After a week, remove the wet brick from the water, wrap it in a plastic bag and tie the top of the bag. Then place it in a freezer.

Look at the brick at the start of the next lesson.

Leave the brick in a warm place for the ice to melt.

- Make a note of your observations.
- Explain the damage that the repeated freezing and melting of water in wet bricks could cause to a building.

Absorbent materials

Being slightly absorbent is a disadvantage of bricks used in buildings. However, some materials are chosen for certain uses because they are very absorbent. For example, in the kitchen we may use paper towels to mop up any liquids we spill.

There are many different makes of paper towel on sale in shops. But how do we know which type is the most absorbent? In the following investigation you can test paper towels yourself and report your findings.

Many paper towels claim to be best at absorbing water – but which is really the most absorbent?

Practical activity Which type of paper towel is the most absorbent?

You can test four different types of paper towel.

Use a magnifying glass or microscope to observe a small piece of each type of paper towel.

- What do you see?
- From your observations, predict which paper towel will absorb water best. State your reasoning.

Now plan a fair test to check out your prediction. There are several ways you can measure the water absorbed.

- Make a list of apparatus you will need to carry out your plan.
- In what way will you record your results?
- Will you display your results using a bar chart or a line graph? (See page 222.)

⚠ **Do not start any practical work before your teacher has checked your plan.**

After carrying out your tests, comment on your prediction.

- Evaluate your method.

Compare your results with other groups.

- Did all the groups place the paper towels in the same order?
- Did it matter which way you chose to test the paper towels?

Key terms

- **absorbent**
- **waterproof**

Summary questions

1 What is the difference between a waterproof and an absorbent material?

2 State a word, other than absorbent, that describes a rock that soaks up water.

3 Refer to the investigation on paper towels above.

a) What was the independent variable in your investigation? (See page 218.)

b) What was the dependent variable in your investigation?

c) Name two of your control variables.

d) Explain the type of graph you used to display your results.

6.3 More physical properties

Learning outcomes

After this topic you should be able to:

- describe a wider variety of different properties of materials
- design a table in which to record results.

The properties we have looked at in this chapter are all called physical properties. Physical properties describe a material and the way it behaves in tests. For example, we might test the temperature at which a material melts. This is called the material's **melting point**. The temperature at which it boils is called its **boiling point**. We might test its tensile strength by pulling the material until it snaps and measuring the force required.

There are other properties of materials called chemical properties. These look at the chemical reactions of materials. In chemical reactions, new substances are formed. We will look at chemical reactions in more detail in the next chapter. Before that we will investigate some more physical properties.

Brittle materials

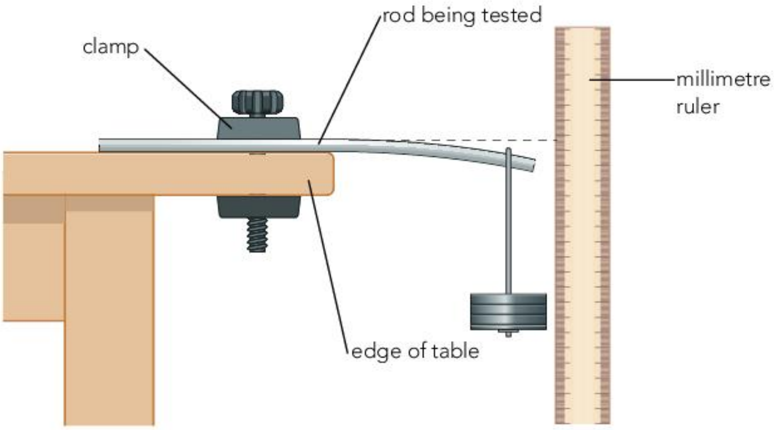
Brittle materials smash or break apart when struck with a hard object such as a hammer. Glass is a brittle material. It can be described as a hard, but brittle, material.

Glass is brittle

Flexible materials

Flexible materials will bend when a force is applied. The plastic used to make rulers is flexible.

Some types of plastics are flexible



Testing the flexibility of a material

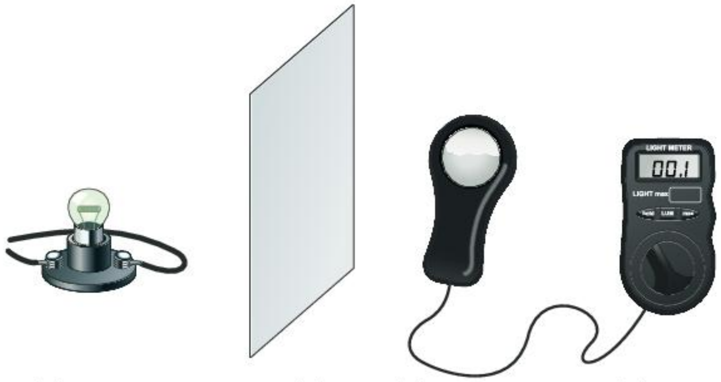
Malleable materials

Some materials can be hammered into new shapes without smashing. These materials are described as **malleable**. Metals are malleable.

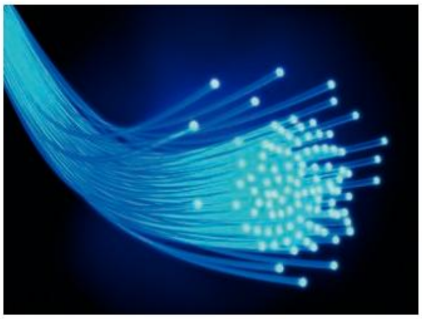
Copper is a malleable material. What would happen if the copper shown here was brittle?

Transparent/opaque materials

Most materials are **opaque**. You cannot see through them. Light is either absorbed by or reflected off their surfaces. However, a few materials are **transparent**. Light can pass through these materials so you can see through them.



Testing transparency – the light sensor measures the amount of light that passes through the material being tested and displays this on the light meter



Optical fibres carry light signals for communications

Practical activity Exploring properties

Watch your teacher heat the middle of a glass rod strongly with a Bunsen burner.

- What does this tell you about the melting point of glass?

You will be given some materials to test for flexibility, brittleness, malleability and transparency.

- Record your observations in a table.

Make sure you wear eye protection when testing flexibility, brittleness and malleability.

Key terms

- **boiling point**
- **brittle**
- **flexible**
- **malleable**
- **melting point**
- **opaque**
- **transparent**

Summary questions

1 Describe briefly a method you could use to test a material for:
a) malleability b) transparency c) flexibility.

2 Put the following materials in order of melting point – with the one with the highest melting point first.
water sand oxygen wax

3 Rubber stretches when it is pulled and returns to its original size when the forces are released. Find out what we call this property.

6.4 Testing metals and non-metals

Learning outcomes

After this topic you should be able to:

- describe what is meant by electrical and thermal conductivity
- distinguish between metals and non-metals by comparing their electrical and thermal conductivity
- draw conclusions from data collected.

Two other important properties of materials are **thermal conductivity** and **electrical conductivity**.

Good thermal conductors allow heat energy to pass through them easily. Poor thermal conductors are called **thermal insulators**.

The base and sides of the pan are made of steel – a good conductor of heat. The pan handle is made of wood – a thermal insulator

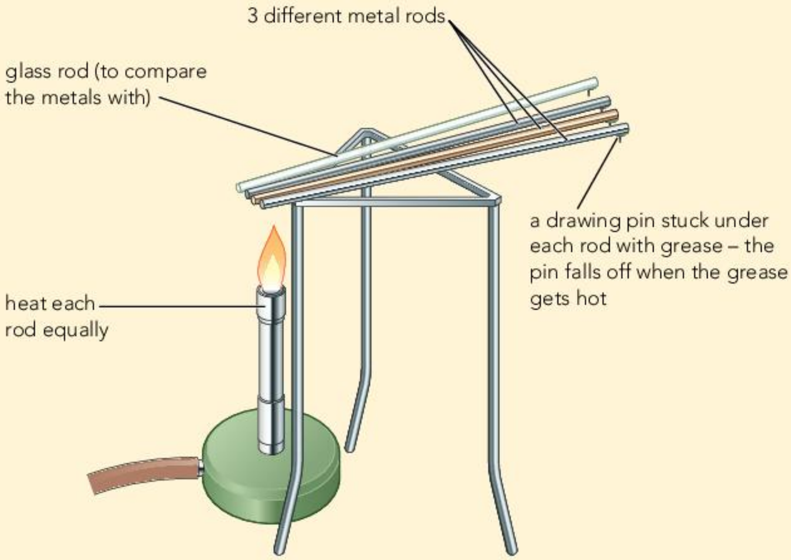
Good electrical conductors allow electricity to pass through them easily. Poor electrical conductors are called **electrical insulators**.

Practical activity Testing thermal conductivity

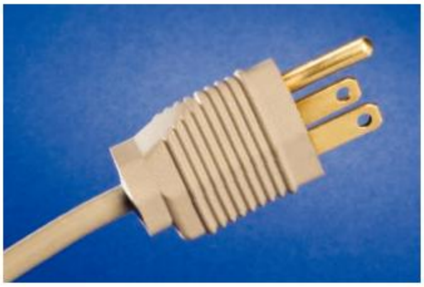
Your teacher will heat some rods made of different metals as well as a glass rod, as shown in the diagram on the right:

The grease will melt and the drawing pin will drop off as heat energy travels along the rod. The rod whose drawing pin drops off first is the best thermal conductor tested.

- Record the results in a table.
- What conclusion can you draw from the results? What type of material always conducts heat? Are there any exceptions to this rule?
- Comment on the fairness of this test.



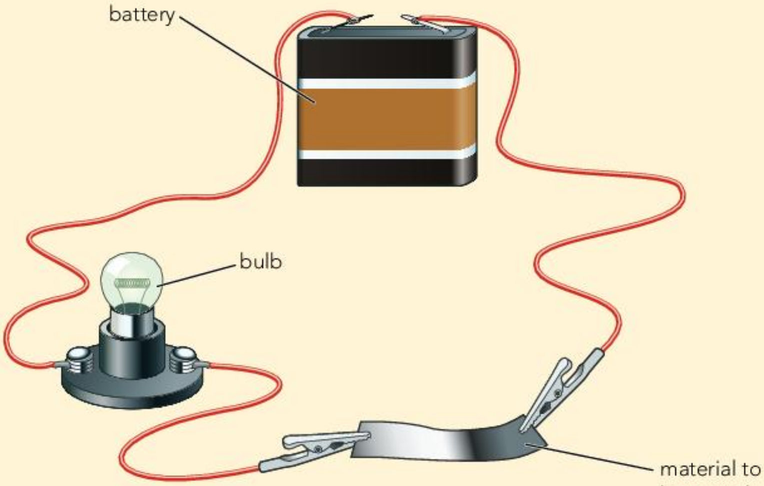
We find that all metals are good thermal conductors, although some are better than others. Non-metal materials are poor thermal conductors. They are thermal insulators.



The three pins in this plug are made of brass – a good conductor of electricity. The plug's outer casing is made of plastic – an electrical insulator

Practical activity Testing electrical conductivity

You can test the electrical conductivity of materials using a circuit, as shown below:



The bulb will light up if the material placed in the gap in the circuit is an electrical conductor. The bulb lights up when the circuit is complete.

- Record the results in a table.
- What conclusion can you draw from the results?

Expert tips

Graphite is an exceptional non-metal as it is a good conductor of heat and electricity.

All metals are good electrical conductors.

Non-metals, except carbon in the form of **graphite**, are electrical insulators.

Key terms

- **electrical conductivity**
- **electrical insulator**
- **graphite**
- **thermal conductivity**
- **thermal insulator**

Summary questions

1 Define thermal conductivity and electrical conductivity.

2 a) What do we mean by a thermal insulator?
b) Give an example of a thermal insulator.

3 What type of material will always conduct electricity and heat?

4 Why is graphite an exceptional non-metal?

6.5 Data on metals and non-metals

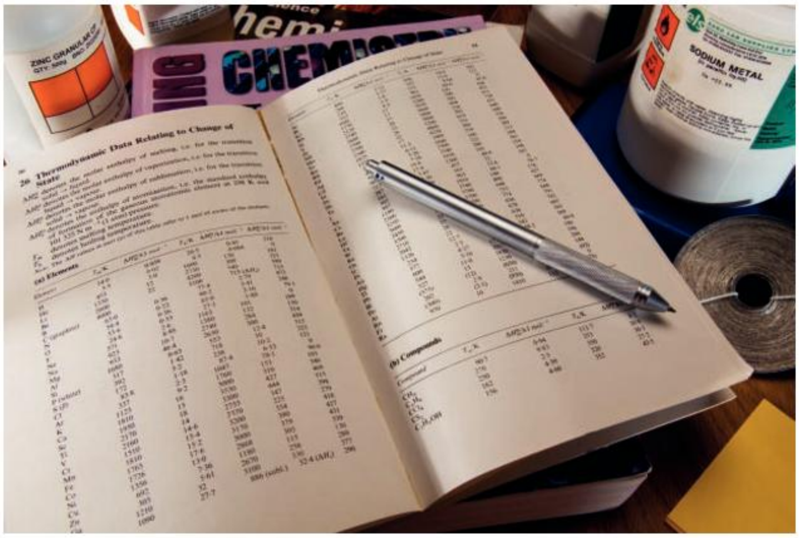
Learning outcomes

After this topic you should be able to:

- distinguish between metals and non-metals using secondary data.

Scientists have collected data on materials and these have been recorded in books of data and on computer databases.

Typical information will include a material's melting point, boiling point and density.



Scientists collect data which can be used to identify unknown materials

There are some data in the table below:

Material	Metal or non-metal	Melting point / °C	Boiling point / °C	Density / g/cm^3
aluminium	metal	660	2350	2.7
argon	non-metal	−189	−186	0.0017
bromine	non-metal	−7	59	3.1
chromium	metal	1860	2600	7.2
copper	metal	1084	2580	8.9
helium	non-metal	−270	−269	0.00017
iron	metal	1540	2760	7.87
lead	metal	327	1760	11.3
mercury	metal	−39	357	13.6
neon	non-metal	−249	−246	0.00084
nickel	metal	1455	2150	8.9
phosphorus	non-metal	44	280	1.8
platinum	metal	1772	3720	21.5
sulfur	non-metal	115	445	1.96
titanium	metal	1670	3300	4.51
zinc	metal	420	913	7.1

Aluminium is a metal

Sulfur is a non-metal

Practical activity Analysing data

Use the table of data on the opposite page to answer these questions:

1 Which material has:
  a) the highest melting point?
  b) the lowest boiling point?
  c) the highest density?
  d) the lowest density?

2 Which materials are gases at 20 °C?

3 On average, do the metals or the non-metals have the higher melting points?

4 On average, do the metals or the non-metals have the higher density?

5 Which metal is a liquid at 20 °C?

6 Graphite sublimes at 3720 °C. What does sublime mean?

7 Which two metals in the table would be best to use in the manufacture of aeroplanes? Why?

8 A material X has a density of 19.3 g/cm^3 and a melting point of 1064 °C. Predict whether this material will conduct electricity. Explain your answer.

Practical activity Researching metals and non-metals

Carry out research to find out some other general properties of metals and non-metals besides those included in the table on the opposite page.

Expert tips

If a material conducts electricity well at room temperature when it is solid, it is highly likely to be a metal. (The exception is graphite.)

Summary questions

1 Using data provided in the table, draw your own table showing the materials which are solids, which are liquids, and which are gases at 20 °C.

2 Explain which property you would choose to decide if a material is a metal or a non-metal.

3 Using the data table, what is the mass of a block of lead with a volume of 5 cm^3?

4 Many metals have high melting points. Which metal in the table is an exception? Will this metal conduct electricity and heat? Explain your answer.

End of chapter questions

1 Match the objects, materials and their most useful property from the jumbled lists below:

Object	**Material**	**Most useful property**
roof tile	wood	transparent
window pane	steel	high tensile strength
rope	plastic foam	opaque
cooking foil	nylon	soft
hammer-head	slate	thermal conductor
cushion	aluminium	waterproof
window blinds	glass	hard

[7]

2 a Draw a diagram of the apparatus you could use to test whether materials are electrical conductors or insulators. *[3]*

b Name four materials that conduct electricity. *[4]*

3 List three ways in which the properties of metallic and non-metallic materials differ. *[3]*

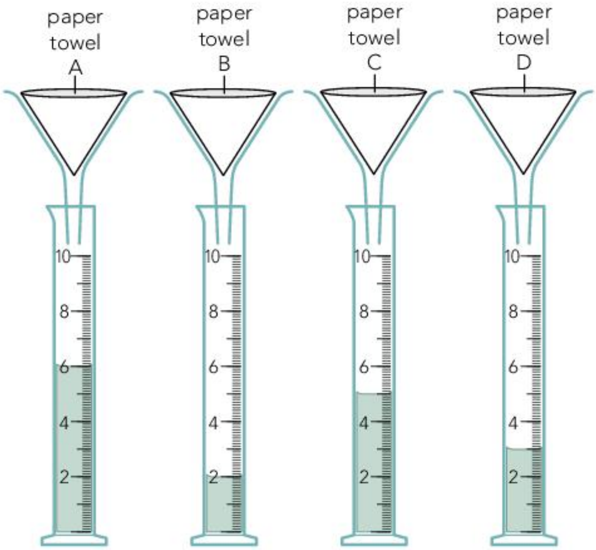
4 Blocks of two different materials, **A** and **B**, were tested by striking them sharply with a hammer.

Material **A** was found to be brittle and Material **B** was malleable.

Describe the way in which each material changed during the test. *[2]*

5 A group poured the same volume of water through different types of paper towel (labelled **A** to **D**) to see which was best at soaking up water. They measured how much water came through each paper towel.

Here are the results of their test:



a Which property of the paper towels were the group investigating? *[1]*

b The title used by the group for their investigation was 'Which paper towel is best?'

Suggest a better question for the title. *[1]*

c Put their results into a table like the one shown below:

Paper towel	**Volume of water that passed through / cm^3**
A	
B	
C	
D	

[1]

d Give one variable that the students had to keep constant to make this a fair test. *[1]*

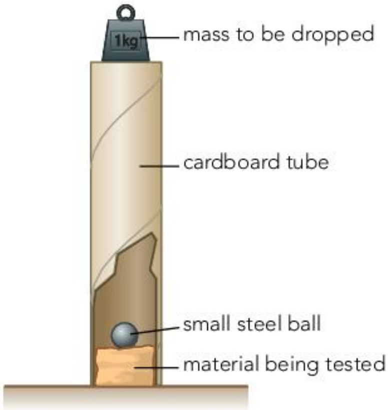
e i Name the independent variable in their investigation. *[1]*

ii Name the dependent variable. *[1]*

f Draw a bar chart to show their results. *[3]*

g Put the paper towels into order (with the most absorbent first). *[1]*

6 Look at the test below:

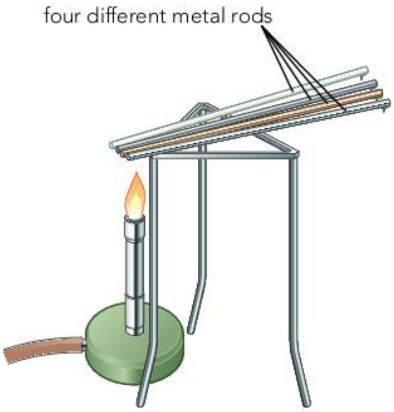


a What property is being tested? *[1]*

b If you tested two different materials, name two control variables you would need to consider to make this a fair test. *[2]*

7 A group of students were testing four metals (**W**, **X**, **Y** and **Z**).

They set up the apparatus below and timed how long it took for each drawing pin to drop off the different metals.



Here are their results:

Metal	**Time for drawing pin to fall / s**
W	550
X	470
Y	360
Z	545

a Copy and complete the question that the students were investigating.

Which metal is the best ______ ? *[1]*

b Which two metals should they test again to make sure their results are reliable? Why? *[2]*

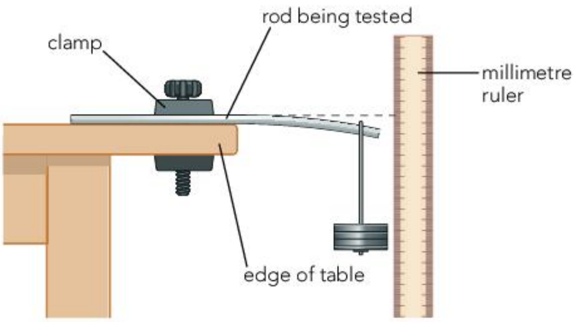
c Give two ways in which the students tried to make their investigation a fair test. *[2]*

d Display the students' results on a graph. (Will you use a bar chart or a line graph?) *[4]*

e Before their tests, the students felt the metals. They predicted 'Metal **Y** will be the best because it feels coldest.'

Do their results support their prediction? Explain your answer. *[2]*

8 The flexibility of different plastic rods was tested using the experiment shown below:



Four different types of plastic (**K**, **L**, **M** and **N**) were tested.

a Name a control variable in this investigation. *[1]*

b Describe the method used to carry out the tests on **K**, **L**, **M** and **N**. *[3]*

c What unit would be used to measure the flexibility? *[1]*

d The rod made of plastic **M** did not bend at all in the test. What word is used to describe the property of **M** shown in this test? *[1]*

Science *in* context! Acids and health

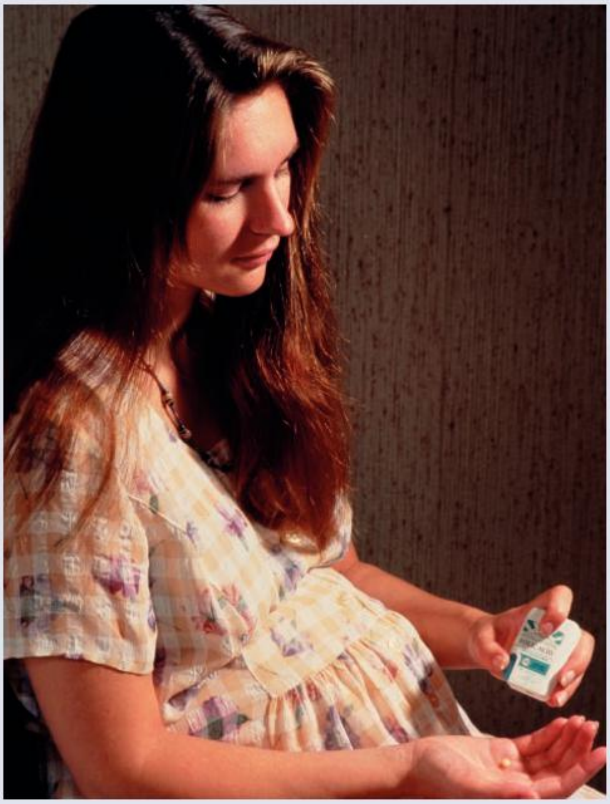
We come across acids everyday in our lives – often without realising it! You will find acids in oranges, fizzy drinks, vinegar and even rain. People are generally familiar with the word acid, but not many know that the word comes from the Latin word '*acidum*', meaning sharp. Most people are less sure about the meaning of bases, the chemical opposites of acids. However, by the end of this topic you will know a lot more!

Acids and vitamins

Have you ever looked at the ingredients on a bottle of vitamin supplements? You will see quite a few different acids listed on the label. The chemical name for vitamin C is ascorbic acid. In vitamin pills it is often taken in the form of a neutral compound closely related to ascorbic acid. Why do you think this is a good idea?

You will also find folic acid in most multi-vitamins. This vitamin is essential during pregnancy. It can also reduce the risk of heart disease. Pantothenic acid, also known as vitamin B5, is another ingredient in vitamin supplements.

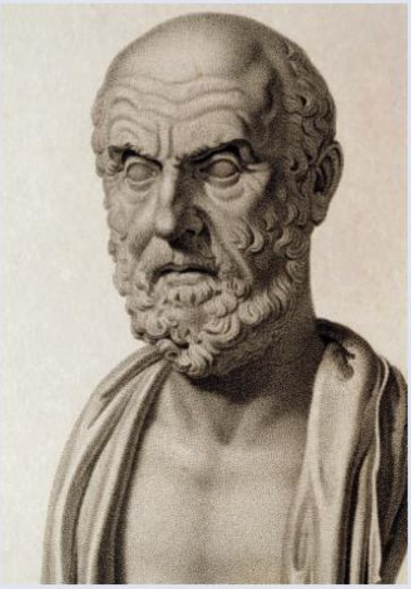
People who don't eat enough fruit and vegetables may benefit from taking multivitamin tablets



This pregnant woman is taking a tablet containing folic acid supplement

The story of aspirin

The Ancient Greeks used the leaves and bark of the willow tree to relieve pain.



The Ancient Greek doctor, Hippocrates, gave women tea made from willow bark and leaves to relieve pain during childbirth

In the 19th century scientists found out that it was an acid that caused the pain to go away. They named it salicylic acid (after the Latin word for willow – *salix*). However, the acid caused painful ulcers in the mouth and attacked the lining of the stomach. So a salt made from salicylic acid was tried, and the side effects disappeared. Unfortunately, the salt tasted absolutely horrible so the search for another painkiller went on.

In 1853, a French chemist made the first aspirin. He used salicylic acid as his starting material. He didn't call his new substance aspirin. 'Aspirin' is a trade name used by the German chemical company that eventually marketed the drug at the start of the 20th century.

The latest research on aspirin suggests that its effects go much further than pain relief. For people over 50 years of age, a small, regular dose appears to reduce their chances of heart disease, certain cancers and strokes. However, around 6% of people still suffer stomach problems as a side effect.

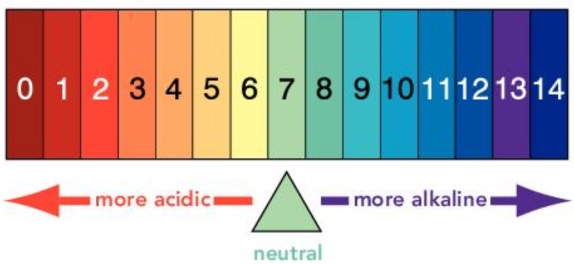
Doctors are calling for more research to assess the full benefits of this 'not-so-new' wonder drug.

Aspirin is made from salicylic acid

In this chapter you will find out how to tell if a solution is an acid or an alkali using indicators and the importance of using the pH scale. You will also learn about neutralisation reactions and some of their applications in society.

Key points

- Not all acids are dangerous.
- Concentrated solutions of strong acids are corrosive (they attack materials and living tissue).
- The more dilute you make an acid (by watering it down), the safer it is to use.
- Indicators are substances that change colour in acids and alkalis.
- Universal indicator changes to a range of colours. We can match the colour to a pH value (or pH number) on the pH scale.



- pH values less than 7 indicate acidic solutions.
- pH values more than 7 indicate alkaline solutions.
- A pH value of 7 indicates a neutral solution.
- Acids and alkalis react together in a chemical reaction called neutralisation.

7.1 Acids

Learning outcomes

After this topic you should be able to:

- list some common acids
- recognise hazard symbols.

This common cola fizzy drink brand, and other cola brands, contain phosphoric acid

Expert tips

The acid in fizzy drinks attacks the enamel on your teeth. Many also contain lots of sugar, which the bacteria that cause tooth decay can feed on.

Common acids

Acids have a really bad reputation with most people. They only think of acids as **harmful**, fuming liquids. However, we all come across acids every day, often without realising it – and we aren't in danger of damaging our skin! In fact, many common acids are found in food and drink. For example, oranges, apples, lemons, yoghurt, tea and vinegar all contain weak acids.

Here is a table of some common acids you can find at home:

Acid found in …	**Name of acid**
citrus fruit, such as oranges, lemon, limes	citric acid
apples	malic acid
tea	tannic acid
yoghurt	lactic acid
vinegar	acetic acid (ethanoic acid)
cola	phosphoric acid

Hazard symbols

In laboratories and in industry the three most common acids are:

- hydrochloric acid
- sulfuric acid
- nitric acid.

These are all examples of strong acids.

When we have a concentrated solution of these acids, they are **corrosive**. They 'eat away' materials.

By adding very acidic solutions to more water, we can make them safer to use. By diluting them down, the solutions become **irritant** (which can still damage skin). Even more water will make the **acidic** solutions harmless.

To warn us of the dangers when using acids and other chemicals, we label their containers with hazard symbols.

Look at the commonly used hazard symbols below:

Corrosive
These substances attack and destroy living tissues, including eyes and skin.

Toxic
These substances can cause death. They may have their poisonous effects when swallowed, or breathed in, or absorbed through the skin.

Irritant
These substances are not corrosive but can cause reddening or blistering of the skin.

Harmful
These substances are similar to toxic substances but less dangerous.

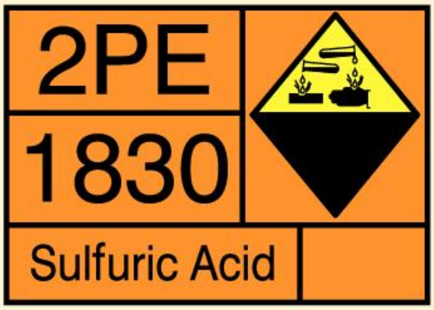
Highly flammable
These substances easily catch fire.

Oxidising
These substances provide oxygen which allows other materials to burn more fiercely.

Practical activity Transporting hazardous chemicals

Chemicals are transported from factories in road tankers.

The road tanker carries a sign at the back with a hazard symbol. Look at the example from a tanker carrying concentrated sulfuric acid:



Find out what this sign means to firefighters attending a tanker accident.

Key terms

- **acidic**
- **corrosive**
- **harmful**
- **highly flammable**
- **irritant**
- **oxidising**
- **toxic**

Summary questions

1 List three acids found in the kitchen.

2 What are the three main acids used in science laboratories?

3 What is the difference between a liquid that is corrosive and a liquid that is irritant?

4 What can you do to make a concentrated solution of a strong acid safer to use?

7.2 Distinguishing acids and bases

Learning outcomes

After this topic you should be able to:

- list some common bases
- describe how an alkali differs from a base
- distinguish between acidic and alkaline solutions.

Whenever we study acids, there will always be **bases** in the same topic. Acids and bases are like chemical opposites. They react with each other, as we will see on page 132.

If a base is soluble in water, it is called an **alkali**. A soluble base forms an **alkaline** solution with water. These solutions feel soapy to the touch. However, it is not wise to touch concentrated strong alkaline solutions. They are corrosive, just like concentrated solutions of strong acids.

Here are some common bases:

- sodium hydroxide
- potassium hydroxide
- calcium hydroxide
- ammonia solution.

Sodium hydroxide is an alkali – a soluble base

Using indicators

Some substances change colour in solutions of acids and alkalis. These substances are called **indicators**. We use indicators as a quick way to distinguish between acidic and alkaline solutions.

Litmus is a common indicator. Look at its colours in acid and alkali.

Litmus is red in acid and blue in alkali

Litmus can be added to the solution being tested as a liquid in a dropping pipette. We can also stain absorbent paper with litmus solution and dry it. Then we can just add a couple of drops of the solution being tested onto the litmus paper and observe the colour change.

Practical activity Litmus indicator

In this experiment you can try using litmus solution and litmus paper to test:

a) an acid (use dilute hydrochloric acid)

b) an alkali (use dilute sodium hydroxide solution)

c) a neutral solution (use distilled water, which is neither acidic nor alkaline).

- Describe what happens.

⚠ **Make sure you wear eye protection.**

Other indicators

Scientists have found many other indicators.

Here are some other indicators and the colour they turn in acid and in alkali:

Indicator	Colour in acid	Colour in alkali
methyl orange	red	yellow
phenolphthalein	colourless	red/pink
bromocresol green	yellow	blue

Practical activity Acidic or alkaline?

In this experiment your teacher will provide you with solutions A to E, to test which are acidic and which are alkaline.

Test the solutions with two indictors from the table above.

- Make a table for your results.
- Check your answers with your teacher.

⚠ **Make sure you wear eye protection.**

Key terms

- **alkali**
- **alkaline**
- **base**
- **indicator**

Summary questions

1 What is an acid–base indicator?

2 Describe a way to distinguish an acidic solution from an alkaline solution. Give the results of any tests.

3 A student tests an unknown solution with phenolphthalein, which remains colourless, and with methyl orange, which turns red. What does this tell us about the solution?

7.3 Making indicators

Learning outcomes

After this topic you should be able to:

- explain the function of indicators
- make an indicator from plant material
- choose apparatus and use it correctly when investigating possible indicators.

Dyes extracted from plants often make good indicators. You can make your own indicator in the next experiment.

Litmus is extracted from lichen

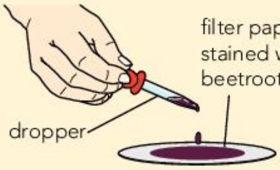
Practical activity Making an indicator

Step 1

Chop up some beetroot and place it in a mortar. Add a little water, then use a pestle to crush it.

Step 2

Use a dropper to transfer the dye to a piece of filter paper.

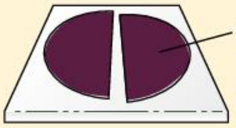


Step 3

Leave the stained filter paper to dry in a warm place.

Once it has dried, tear it in half and place each half on a white tile.

You have now made indicator paper.



Step 4

Add a few drops of acid to one half of your indictor paper.

Add a few drops of alkali to the other half.

- What colour does your indicator go in:
  - **i)** acid?
  - **ii)** alkali?

Step 5

Repeat Steps 1 to 4 using red cabbage instead of beetroot.

Stick your dried pieces of indicator paper in your notebook to show your results.

⚠ **Make sure you wear eye protection.**

Practical activity Which plant material makes the best indicator?

Your task is to investigate which plant material will make the best indicator.

Discuss what makes a good indicator.

- What will you keep constant to make your tests fair?

Try out different plant extracts in acidic and alkaline solutions.

- Which acidic and alkaline solutions will you use to test your indicators?

Compare your results with those from other groups.

- Which was the best indicator made in your class?
- Evaluate your investigation. Think about the fairness of your tests. Which variables were difficult to control or measure?

⚠ **Make sure you wear eye protection.**

Summary questions

1. What living things are used to make litmus?
2. Describe the best way to extract as much coloured dye as possible from a plant.
3. Draw a table to summarise all the results in acid and alkali for the various plants tested in your experiments.

The pH scale

Learning outcomes

After this topic you should be able to:

- understand the advantage of using universal indicator
- use the pH scale
- make careful observations.

Universal indicator

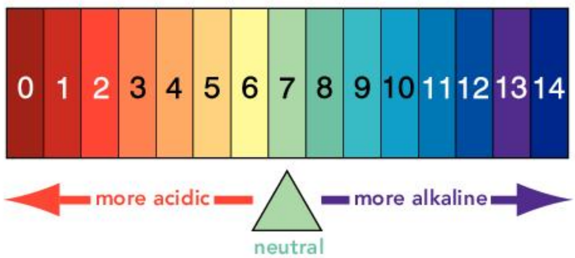
In the previous experiments with indicators, could you tell which solutions were strongly acidic or just weakly acidic? Or was the colour of the indicator the same in all the acidic solutions? What about the alkaline solutions?

Universal indicator can tell us how strongly acidic or alkaline solutions are. It contains a mixture of dyes, so it can turn a whole range of colours. It can even show if a solution is neither acidic nor alkaline. We call these solutions **neutral**. In a neutral solution universal indicator turns green.

Universal indicator (UI) is commonly used in science laboratories

The pH scale

We match the colour of the universal indicator to a pH number, as shown on the **pH scale** below.



The pH scale

If the pH value is below 7 – the solution is acidic.

If the pH value is 7 – the solution is neutral.

If the pH value is above 7 – the solution is alkaline.

- The lower the pH value, the more acidic the solution is.
- The higher the pH value, the more alkaline the solution is.

Practical activity Testing the pH of solutions

Your teacher will provide a variety of solutions. Your task is to test their pH values.

You can do this by adding a few drops of universal indicator to a small amount of each solution in a clean test tube. Alternatively, you can put a few drops of the solutions to be tested into the wells of a spotting tile. Then add a drop of universal indicator to each solution.

- Design a table that shows the colour of the universal indicator, the pH number of the solution, and what this tells us about the solution.

a) Which is the most strongly acidic solution you tested?

b) Which is the most strongly alkaline solution you tested?

c) Name any solutions you tested that are neutral.

d) Which solutions are most hazardous to use and which are safest?

⚠ **Make sure you wear eye protection.**

Practical activity Testing everyday solutions

Using one of the methods described in the previous experiment, test the pH of the following:

– toothpaste
– fruit drinks
– indigestion tablets
– soil shaken with water and filtered

- Comment on the pH of each substance tested.

⚠ **Make sure you wear eye protection.**

Expert tips

The lower the pH number, the more acidic the solution.

Key terms

- **neutral**
- **pH scale**
- **universal indicator**

Summary questions

1 What is special about universal indicator compared with other indicators?

2 Draw a pH scale and explain what it is used for.

3 **a)** Arrange these solutions in order, with the most acidic first:
pH numbers: **2 8 6 3 12 7**

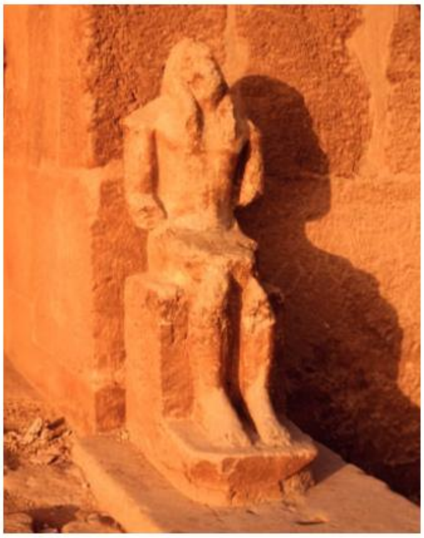
b) **i)** Which of the solutions in part **a** is neutral?
ii) What colour is universal indicator in a neutral solution?

7.5 Investigating acidic problems

Learning outcomes

After this topic you should be able to:

- describe some problems caused by acids
- suggest ideas about milk turning sour that can be tested
- plan investigations, choosing and controlling variables
- present results and conclusions in appropriate ways.



Acid rain has worn down the features of this statue

Acids can be very useful – just think of all those acids in the kitchen! However, they can also cause us some problems. Here are some examples – choose one to investigate.

Acid rain attacks buildings

Acidic gases given off from burning fuels cause our rain to be more acidic than it should be. This pollution results in many problems. One of these is when acid rain attacks buildings and statues made of limestone.

Practical activity Investigating the effect of acid rain

Collect a little limestone powder on a watch glass.
Slowly drip a few drops of dilute hydrochloric acid onto the powder.

- What effect does acid have on limestone?
- What might affect how quickly acid reacts with limestone?
- Discuss this question and make a list of variables that might matter.

Choose one variable to investigate (your independent variable). (See page 218.)

- Predict what effect this variable will have.
- What will you measure to find out how quickly the limestone and acid react?
- Plan a fair test.

⚠ **Before starting any practical work, your teacher should check your plan.**

- Discuss the presentation of your results – design a table and decide what type of graph you will use.
- Carry out your tests, record your results and come to a conclusion.
- Evaluate your investigation.

Acidic soil

Different crops grow best in soils of different pH.

Plant	pH range of soil
apple	5.0–6.5
potato	4.5–6.0
blackcurrant	6.0–8.0
mint	7.0–8.0
onion	6.0–7.0
strawberry	5.0–7.0
lettuce	6.0–7.0

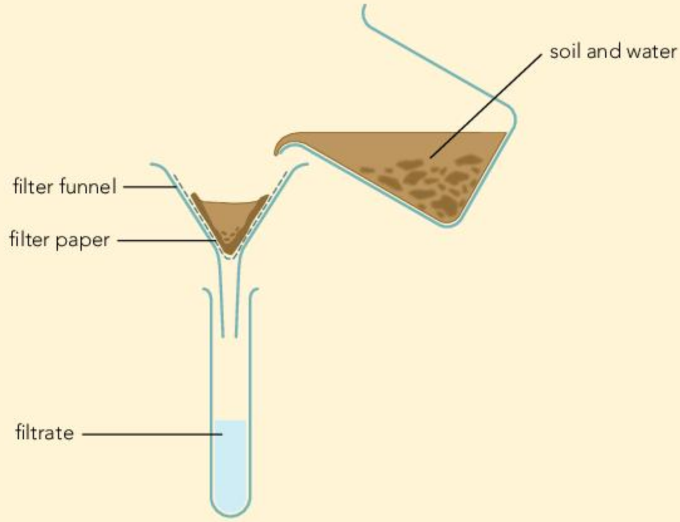
Practical activity Investigating the pH of soils

Collect different soil samples and test their pH.

Add soil to half a beaker of water and stir.

Then filter the mixture and add a few drops of universal indicator (UI) to the filtrate. Alternatively, dip a piece of UI paper in the filtrate.

- Record the pH values in a table.
- Conclude which plants will grow well in each type of soil.



Milk turns sour

Have you ever tasted milk that has been kept too long? The milk tastes sour because its sugar (lactose) has turned into acid (lactic acid).

Why do we keep milk in a fridge?

Practical activity Investigating milk

- What affects the pH of milk?
- Make a list of variables.

We know that milk turns acidic when it goes off.

- Plan an investigation to find out how one of your identified variables affects the pH of milk.

Allow your teacher to check your plan before starting any practical work.

- Make sure your report has a title (in the form of a question), prediction, plan/method, results, conclusion and evaluation.

Summary questions

1 Why are limestone buildings in big cities showing signs of damage?

2 Use the table opposite that shows plants and their preferred pH ranges to answer these questions.

a) Which plants grow well over the largest **range** of pH values?

b) Which plant can grow in the most acidic soil?

c) Describe a method you can use to test the pH of a soil.

3 Which acid causes milk that has gone off to taste sour?

7.6 Neutralisation

Learning outcomes

After this topic you should be able to:

- explain what a neutralisation reaction is
- carry out a neutralisation reaction.

Key terms

- **neutralisation**

We can think of acids and alkalis as chemical opposites. They react together, 'cancelling each other out'. When you mix them in just the right amounts, they will form a neutral solution. That's why we call the reaction of an acid with an alkali a **neutralisation** reaction.

Practical activity — Adding acid to alkali

Use a dropping pipette and a small measuring cylinder to collect 5 cm^3 of dilute sodium hydroxide solution in a test tube.

Place the test tube in a test tube rack and add a few drops of universal indicator solution.

- What is the pH value of the solution?

Add 4 cm^3 of dilute hydrochloric acid to the same test tube.

- What is the pH value of the solution now?
- What does this tell you about the solution?

Now use a clean dropping pipette to add dilute hydrochloric acid to the test tube, a drop at a time. After each addition, shake the tube from side to side. Add only enough universal indicator to turn the mixture green. You will have to be very careful to do this successfully.

- What is the pH value of the solution when you have added equal quantities of acid and alkali together?
- What happens to the pH of the solution if you add too much acid?

If you add too much acid, you don't have to start the whole experiment again.

- What can you do to make your solution neutral without having to start all over again?

⚠ **Make sure you wear eye protection.**

The fact that we can get a neutral solution from an acid and an alkali shows that a chemical reaction has taken place. A new substance or substances must have been formed.

If acid and alkali are mixed in the right proportions:

acid + alkali → a neutral solution

Practical activity — Adding alkali to acid

Using a dropping pipette and a small measuring cylinder, repeat the previous experiment but start with 5 cm^3 of dilute hydrochloric acid. Then you can add sodium hydroxide solution a little at a time to the acid.

- What do you notice about the pH change when the point of neutralisation is reached in both experiments?

⚠ **Make sure you wear eye protection.**

Neutralising acidic soil

As you saw on pages 130 and 131, the pH of a farmer's soil makes a big difference to the crops that can be grown.

Many farms suffer from soil that is too acidic so the farmer needs to increase the pH of the soil. The cheapest, most easily applied substance is powdered limestone or lime. Both react with acids to neutralise them.

Farmers spread lime or limestone powder on acidic soil to raise its pH value

You can try neutralising soil in the next experiment:

Practical activity Treating acidic soil

Collect two spatulas of acidic soil in a beaker and half fill it with distilled water.

Filter into a conical flask and test the pH with universal indicator.

- What is the pH value of the soil?

Repeat this experiment but mix powdered limestone with the acidic soil before adding the water and then filtering.

- What is the pH value after treating the soil with powdered limestone?

Repeat a second time but this time add powdered lime to the acidic soil.

- What is the pH value after adding powdered lime?
- Which powder would you recommend to the farmer?

⚠ **Make sure you wear eye protection.**

Summary questions

1 Copy and complete:

When we add an acid to an alkali, the pH value of the solution goes ______.

When the right amount of acid and alkali ______ with each other, we get a ______ solution formed, with a pH value of ______.

2 Give one use of a neutralisation reaction that can be helpful to farmers.

3 Sketch a graph to show the pH of the solution changing when an acid is added to an alkali, as in the first experiment on the opposite page.

7.7 Preparing common salt

Learning outcomes

After this topic you should be able to:

- prepare a sample of salt, following a neutralisation reaction
- explain the separation of crystals of salt from its solution.

In the last experiment on page 132, you neutralised an acid with an alkali. If you ever get stung by a bee, you might be grateful for that reaction!

A bee's sting is said to be acidic. So, in theory, it can be neutralised by an alkali. The pain is certainly eased by treating it with bicarbonate of soda (a weak alkali)

A wasp's sting is said to be alkaline. What could you use to treat a wasp sting?

The reaction between sodium hydroxide and hydrochloric acid produces sodium chloride (common salt) and water.

We can get a sample of sodium chloride from the neutral solution left after the reaction by evaporating off the water.

Practical activity Preparing a sample of salt

Make sure you wear eye protection.

Follow the method from the experiment 'Adding acid to alkali' on page 132 to make a neutral solution from an acid and an alkali.

(Alternatively, collect some salt solution from your teacher.)

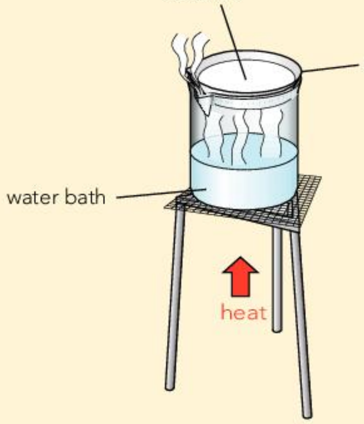
If your neutral solution contains universal indicator you can remove its colour by adding a spatula of charcoal powder to the green solution and then boiling.

Stir the solution with a glass rod. The charcoal takes the colour out of the solution.

Filter the mixture. You should get a transparent, colourless solution.

Pour the solution into an evaporating dish.

Now heat it on a water bath, as shown:



Stop heating when you see some white crystals around the edge of the solution.

Leave your evaporating dish for a few days. The rest of the water will evaporate off slowly.

Slower evaporation gives bigger crystals.

- What is the chemical name for the salt you have made?
- What shape are your salt crystals?

Sodium chloride is a very important substance in the chemical industry.

Chemists use sodium chloride solution as the starting material to make the following:

- Hydrogen – used to make margarine.
- Chlorine – used to make bleach and PVC plastic. It is also used to sterilise drinking water.
- Sodium hydroxide – used to make soaps, detergents, bleach, paper and fibres for synthetic fabrics.

Chlorine and sodium hydroxide make bleach

Summary questions

1. What do we call the type of reaction in which sodium chloride is made from an acid and an alkali?
2. Draw a flow chart to show the method used to prepare a sample of sodium chloride crystals from dilute hydrochloric acid and sodium hydroxide solution.
3. Explain, in terms of particle theory, what happens when sodium chloride solution is heated.

7.8 Uses of neutralisation

Learning outcomes

After this topic you should be able to:

- describe some uses of neutralisation.

Indigestion remedies

Did you know that your stomach contains hydrochloric acid? It is used to help in the breakdown of your food and to kill bacteria. But sometimes, for example if you eat too much too quickly, you can produce too much acid. That's when you get that burning feeling we call **indigestion**.

Have you ever had indigestion? If you have, you may well have taken a tablet to relieve the discomfort. These indigestion remedies are called **antacids**.

Practical activity Investigating indigestion remedies

Look at a variety of antacids and write down the names of their active ingredients. The active ingredients will react with acids to neutralise them. These are substances called **bases**. They include alkalis, but bases do not necessarily dissolve in water (whereas all alkalis do).

You will be given several different indigestion remedies to test.

As a group, decide on a question you would like to investigate.

- Plan your investigation, remembering to make it a fair test.
- Try out some of your ideas to help you plan how much acid and antacid you will use, and how you will measure the effects.
- Record your question, method, results and conclusion.
- Discuss your investigation with other groups.
- Then evaluate your method, comparing it with those used by other groups.
- Summarise the findings of your class and evaluate the effectiveness of the different remedies.

Make sure you wear eye protection.

Treating stings

Bee stings are said to be acidic. You can ease the pain of bee and ant stings with bicarbonate of soda (sodium hydrogencarbonate) – a weak alkali.

Wasp stings are alkaline. You can neutralise them with vinegar (ethanoic acid) – a weak acid.

Using sodium hydrogencarbonate

Baking powder helps cake-mix to rise. This powdered mixture contains sodium hydrogencarbonate (known as bicarbonate of soda) and a weak acid. When water is added the two react, giving off carbon dioxide gas. The carbon dioxide gets trapped in the cake-mix. Self-raising flour has baking powder already added.

We also use sodium hydrogencarbonate in cleaning agents and in some toothpastes. It neutralises acidic solutions.

The reason for including sodium hydrogencarbonate in toothpaste is because acids are formed by the bacteria in our mouths that feed on sugars. These acids attack the enamel on our teeth causing cavities. So a weak alkali will get rid of the acids that cause tooth decay.

Key terms

- **antacid**
- **indigestion**

Summary questions

1 a) Which acid causes indigestion?

b) What can we do to treat the symptoms of indigestion?

2 Why is it a good idea to treat a wasp sting with vinegar?

3 a) Explain why sodium hydrogencarbonate is used in baking powder.

b) Explain why the sodium hydrogencarbonate in a toothpaste can help prevent tooth decay.

End of chapter questions

1 a What does the following hazard warning symbol mean? *[1]*

b What do the hazard warning signs for irritant and harmful have in common? *[1]*

c What would you do to treat a person who has splashed some dilute hydrochloric acid in his or her eye? *[1]*

d Look at the two bottles of hydrochloric acid below:

Why do the bottles have different hazard warning signs on them? *[2]*

2 A group of students made their own indicator solution in the laboratory from blackberries. They tested some solutions with their indicator. Here are their results:

Solution tested	Colour of indicator
vinegar	red
ammonia solution	green
lemon juice	red
oven cleaner	green
sodium hydroxide	green
sour milk	red

a What apparatus would you use to get as much dye as possible from the blackberries? *[2]*

b Identify each substance in the table as acidic or alkaline. *[6]*

c What would be the advantage of using universal indicator solution instead of blackberry juice when testing the solutions? *[2]*

3 Ahmed tested some solutions with universal indicator paper.

He wrote down their pH values:

1, 5, 7, 14

but forgot to write the names of the solutions.

Can you help him by copying and completing the table below, matching the pH values to the correct solutions tested? *[4]*

Solution tested	pH
distilled water	
sulfuric acid	
sodium hydroxide	
vinegar	

4 When an acid and an alkali react together, a substance called a salt is formed. A salt is a solid substance made of crystals.

a Why do you think that you do not see a salt forming in this experiment? *[1]*

b Describe the method you could use to get crystals of salt from the neutral solution formed. *[3]*

5 You can try to make your own indicator using some coloured flower petals.

A group of students made some indicator solution from petals of three different colours. They added their indicator to an acid and an alkali. Here are their results:

Colour in water (pH 7)	Colour in a solution of pH 1	Colour in a solution of pH 14
yellow	yellow	yellow
red	red	green
purple	pink	blue

a What colour would the red petal indicator be in a solution of sulfuric acid? *[1]*

b What colour would the purple petal indicator be in a solution of salt which is neutral? *[1]*

c What colour would the purple petal indicator be in a solution of sodium hydroxide? *[1]*

d Explain which colour of flower petal would make the best indicator for both acids and alkalis. *[2]*

6 The table below shows the pH values of five solutions whose labels have been lost.

Solution	pH value
A	6.0
B	7.5
C	7.0
D	4.5
E	8.0

a Which solutions are acidic? *[2]*

b Soap solution is weakly alkaline. Which of the solutions could be soap solution? *[2]*

c i Give two solutions that would react together. *[1]*

ii What do we call this type of reaction? *[1]*

iii Two new substances are made in the reaction. One is a salt. What is the other substance formed? *[1]*

7 Maria was investigating which of four indigestion tablets was most effective. She crushed an equal mass of each tablet and added it to 25 cm^3 of water and an indicator.

Then she added dilute hydrochloric acid 1 cm^3 at a time, until the indicator changed colour.

Here are her results:
Fizzo – 18 cm^3, Neutratabs – 17 cm^3, Soothers – 9 cm^3, Alkomix – 12 cm^3

a Put her results in a suitable table. *[4]*

b What type of graph would you use to show Maria's results? *[1]*

c Which tablet was the most effective? *[1]*

d What could Maria have done to make her results more reliable? *[1]*

8 A student tested five solutions with universal indicator solution.

Solution	pH value
A	5
B	9
C	1
D	7
E	13

a Which solution is most strongly acidic? *[1]*

b Which solution is weakly alkaline? *[1]*

c Which word describes solution **D**? *[1]*

d What would happen to the pH of solution **E** if you added plenty of water to it? *[1]*

Science *in context!*

Finding out about the Earth

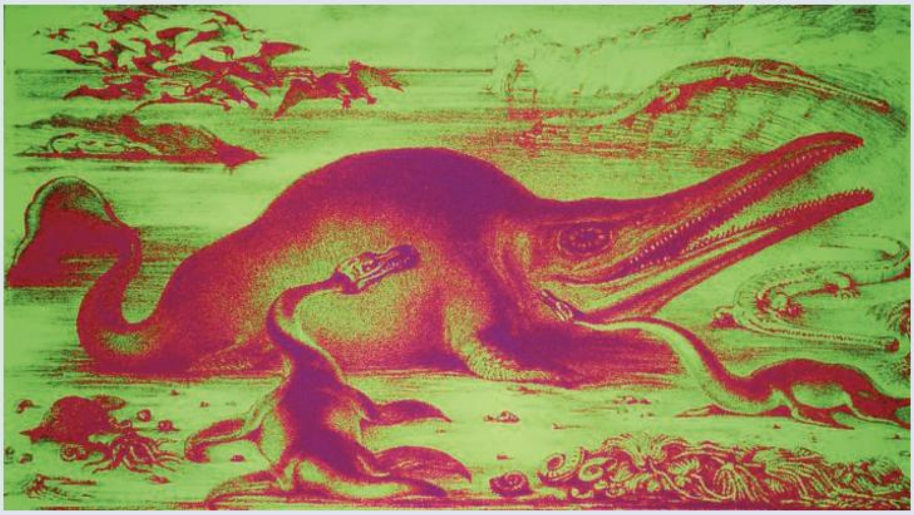
Mary Anning – fossil hunter

Mary Anning had the thrill of discovering a fossil of a complete ichthyosaurus when she was only 11 years old.

Mary has been described as the greatest fossil collector ever.

She did manage to scrape a meagre living for her family with the support of a small grant from the government.

Mary was made an honorary member of the Geological Society of London before she died (a great honour indeed for a woman in Victorian times!).



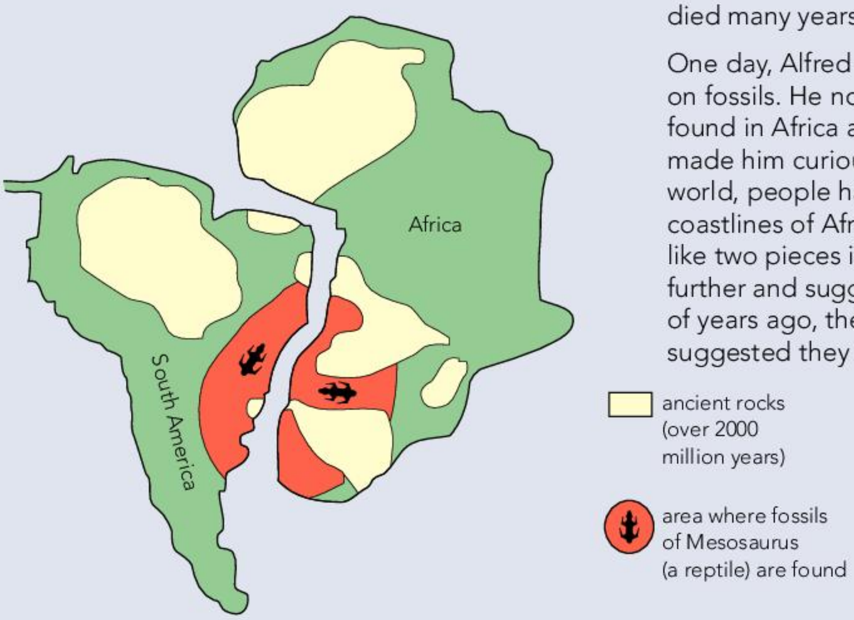
The actual fossil is now in the Natural History Museum in London

The story of Alfred Wegener

The idea that continents are moving around on the surface of the Earth is difficult to believe.

It was in 1915 when Alfred Wegener first suggested his theory of continental drift. Few of his fellow scientists took his ideas seriously. It took about 50 years for them to come around to his way of thinking. Unfortunately, Alfred had died many years before that happened.

One day, Alfred was studying a scientific paper on fossils. He noticed how similar the fossils found in Africa and South America were. This made him curious. Looking at an atlas of the world, people had already spotted that the coastlines of Africa and South America looked like two pieces in a jigsaw. But Alfred went further and suggested that at one time, millions of years ago, they had been joined together. He suggested they had slowly drifted apart.



Evidence that Africa and South America were once joined together

He could offer scientific evidence to support his idea. He noticed matches between the types of rock found in Africa and South America. There were also matching rocks across other continents. This led him to think that millions of years ago all the continents had been joined together. He called this 'super-continent' Pangaea.

Pangaea

However, scientists already had a theory that could explain the similar fossils on different continents. They believed that in the past bridges of land linked the continents to each other. But, they argued, the bridges must have sunk below the oceans by now. And Alfred couldn't explain **how** the continents had moved. So his ideas were never accepted in his lifetime.

Over 20 years after his death, scientists discovered direct evidence of Alfred's drifting continents. Exploring the ocean floor, they found new rock forming on either side of massive cracks that run between continents. Then the old 'land bridge' theory was dropped. A new theory, called plate tectonics, which could explain Alfred's ideas, became accepted by the scientific community.

In this chapter you will find out about the different types of rocks and soils. You will also discover what scientists know about the internal structure of the Earth, and how fossils and the fossil record can be used to estimate the age of the Earth.

Key points

- We can characterise rocks by properties such as their texture (arrangement of grains) and porosity (ability to absorb water).
- **Sedimentary rocks** are formed when layers of sediment are buried under more recent deposits. Under the pressure, and with the help of mineral 'cements' between the particles of sediment, rocks are formed.
- **Metamorphic rocks** are formed when existing rock experiences high pressure and/or temperature (without melting). Bands of minerals are often visible if the metamorphic rock is formed under pressure.
- **Igneous rocks** are formed when molten rock solidifies. Slow cooling, inside the Earth's crust, produces rock with large crystals. Faster cooling, at or near the Earth's surface, produces rock with small crystals.
- The Earth consists of a thin crust on top of a largely solid layer of rock called the mantle. Below that we get the Earth's core, made up of nickel and iron.
- Fossils and rocks give us evidence for the events that took place on Earth during the period of ancient history, before humans existed on our planet.

8.1 Investigating rocks

Learning outcomes

After this topic you should be able to:

- describe properties of rocks, such as texture and porosity
- explain why some rocks are porous
- make careful observations and measurements.

There are many different rocks formed by different **mixtures of minerals**.

Look at the photo of granite rock below:

Granite is a rock made from a mixture of minerals. How many different minerals can you see?

Practical activity Comparing rocks

Record your descriptions of the different rocks provided. Use a hand lens to aid your observations.

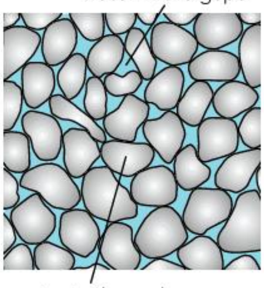
- Sort your rocks into groups on the basis of your observations.
- Compare your groupings with others in your class.

Texture and porosity of rocks

The **texture** of a rock describes the way its grains fit together. There are two main types of texture in rocks:

- **Crystalline** texture. The mineral grains are crystals in the rock. The grains all **interlock**. There are no gaps between the crystals. Granite is an example.
- **Fragmental** texture. The minerals form randomly shaped fragments or grains that do not fit together neatly. Another mineral often 'cements' the grains to each other. Sandstone is an example.

  Rocks that have spaces between their grains can soak up water better than rocks with interlocking crystals. The water fills the gaps between grains in rocks such as sandstone. We say these rocks are **porous**.



Porous rocks have grains that do not interlock

The grains in sandstone are non-interlocking

Key terms

- **crystalline**
- **fragmental**
- **interlock**
- **porous**
- **texture**

Practical activity A closer look at granite and sandstone

Texture

Use a hand lens to look at the structure of granite and sandstone.

- What do you notice about the way the individual 'grains' interlock? Which rock has grains that do not interlock?

Porosity

- Predict which of the two rocks will be better at soaking up water (which rock is more porous). Explain your reasoning.

Weigh a sample of each rock when dry.

- Record the masses in a table like the one below:

Rock	Mass when dry / g	Mass when wet / g	Increase in mass / g	Percentage increase in mass
granite				
sandstone				

Now submerge each rock in water.

- What do you notice?

Remove the rocks from the water and let excess water drip off. Then weigh the rocks again.

- Record your results in your table and fill in the rest of the table.
- What is your conclusion? Was your prediction correct?

Summary questions

1 Copy and complete:

Most rocks are ______ of minerals. There are two main types of rock ______ : crystalline and ______.

When the grains in a rock do not ______ the rock is ______, meaning it can ______ up water.

2 Try to think up a model you could use to help explain the porosity of rocks to a younger student. It should demonstrate the interlocking and non-interlocking minerals.

8.2 Types of rock

Learning outcomes

After this topic you should be able to:

- explain how sedimentary, metamorphic and igneous rock are formed
- list the characteristics of each rock type.

Sedimentary rock

Pieces of weathered rock eventually settle in another place as sediment. Over time, layers of sediment build up. The separate bits of rock become a layer or bed of rock.

You can imagine the pressure building up as layer upon layer of sediment is deposited. This squeezes water out from the gaps between the grains of sediment. Under this pressure, the edges of the grains can join together. This is called **compaction**.

Sand grains as they are deposited; water fills spaces between grains

As more sediments build up, the pressure increases and pushes grains of sand closer together, squeezing out the water

The edges of the grains can fuse together under this pressure, forming solid rock

Another process also helps the sediments to form rock. Water that passes between the gaps in grains can evaporate. This leaves behind any solids that were in solution. The solid that comes out of solution acts like a glue or cement. It sticks the grains of sediment together. This is called **cementation**.

Rocks formed like this are called **sedimentary rock**.

Sedimentary rocks:

- are porous (absorb water)
- usually have grains that do not interlock
- can contain fossils.

Expert tips

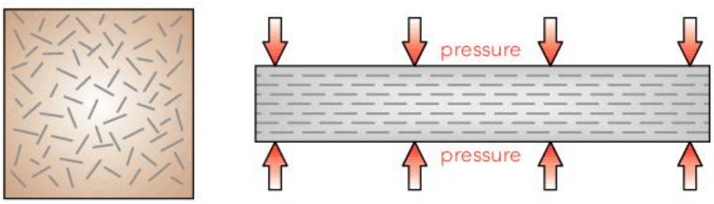
Some sedimentary rocks, such as chalk, crumble easily when you rub them. However, there are also some which are hard because their mineral cement is very strong.

Metamorphic rock

Rocks under pressure

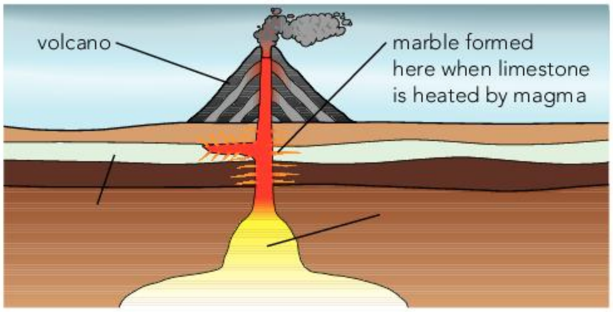
Sometimes sedimentary rocks are subjected to very high temperatures and/or pressures. When this happens, chemical reactions take place in the solid rock. New minerals will form crystals. The new rock formed is called a **metamorphic rock**.

Slate is a metamorphic rock, formed under high pressure. It was made from mudstone or shale, which are both examples of sedimentary rock. In mudstone the clay minerals are mainly jumbled up. The new minerals in slate are all lined up in one direction:



mudstone slate

Heating up rocks



Beneath the Earth's surface, rocks can get very hot. They can be subjected to extreme heat near molten rock, called **magma**.

The magma rises towards the surface in areas where we find volcanoes. The Earth movements that build mountains also generate great heat. During metamorphism, the rocks may get very hot but do not melt. Marble is formed by the action of heat on limestone or chalk.

The general characteristics of metamorphic rocks are:

- they are made of crystals that are often too small to see with the naked eye
- their crystals are usually interlocking, so the rocks are non-porous
- they often have bands of minerals running through them
- they do not usually contain fossils (any fossils that are found will be distorted).

Igneous rock

Forming crystals

Granite is an example of an **igneous rock**. It is hard and shiny. We saw above how molten rock, called magma, can rise towards the Earth's surface. Sometimes it actually escapes from the surface during volcanic eruptions. The molten mixture of materials that breaks through the surface is called **lava**.

As magma or lava cools down, the interlocking crystals that make up igneous rock are formed. Large crystals form when magma cools down slowly deep underground, as in granite. Small crystals form when molten rock cools quickly, as when basalt forms on the seabed.

Igneous rocks generally:

- are hard and non-porous
- are made up of interlocking crystals
- contain no fossils as these are destroyed in molten rock.

Key terms

- **cementation**
- **compaction**
- **igneous rock**
- **lava**
- **magma**
- **metamorphic rock**
- **sedimentary rock**

Summary questions

1 Copy and complete the following sentences:

Sedimentary rock is formed by the processes of ______ and ______. The ______ increases as ______ of sediment and rock build up above. This causes the edges of ______ to fuse ______, and water is squeezed out. ______ left behind act as a ______ between the grains, so forming rock.

2 Copy and complete the following sentences:

New rocks that have been formed by the action of ______ and/or heat (without ______ the rock) are called ______ rocks. You can often see ______ of minerals running through the rock.

3 Explain the formation of igneous rocks, including why some have small crystals and some have large crystals.

8.3 Types of soil

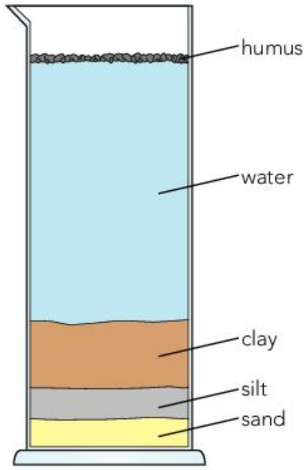
Learning outcomes

After this topic you should be able to:

- identify different types of soil
- make careful observations and measurements
- carry out tests on soil samples.

The characteristics of each type of soil are determined by:

- the size of the rock fragments it contains
- the chemical composition of the rock fragments
- the amount of organic materials mixed in it. This organic material is called **humus** and originates from living organisms.



Sedimentation test: stir two large spatulas of soil in a measuring cylinder of water then leave it to stand overnight. The densest bits in the soil settle out first and sink to the bottom. The low density humus floats on top

Some people classify soils into six main types:

clay, sandy, silt, peat, chalky, loam

Others simplify this to just three categories of soil:

- clay
- sandy
- loam

A **clay** soil contains very tiny pieces of weathered rock. This means that there are few gaps between particles for water to drain through. Therefore clay soil can become waterlogged in heavy rain. It contains little air, especially when wet, because there is not much space between its small particles. You can recognise clay soil as it is lumpy and sticky when wet but turns rock-hard and can crack when dried out.

Compare this with a **sandy soil**, which feels gritty to the touch, and drains water quickly because of its larger grains of rock. This also means that there are more gaps between soil particles for air. (This is needed by organisms that live in the soil, e.g. the roots of plants.) The sandy soil does have a disadvantage in that heavy rain can wash away the soluble nutrients from the soil. We say that the nutrients are leached from the soil.

Loam soil has a more equal mixture of small and large grains of rock. This means it can retain water without getting waterlogged. It also contains more humus than clay or sandy soil.

Practical activity Investigating soil

Water content

We can test the water content of a soil by warming it gently in an oven.

- Weigh the soil sample before and after warming to work out the mass of water lost.

Spread the soil out to dry on a dish in the warm oven. This will evaporate the water.

- Calculate the percentage of water in each sample of soil tested.

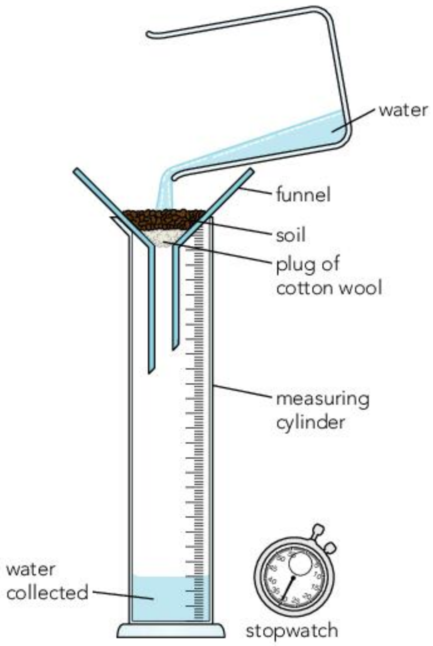
Humus content

Take a sample of soil that has been warmed to evaporate the water (as in the previous test) and weigh it.

Spread the dried soil sample on a tin lid. Heat it strongly on the tin lid. It is best to do this in a fume cupboard to limit the smells in the laboratory. Heating strongly burns off the humus from the soil.

- Calculate the percentage of humus in each sample of dry soil tested.

Make sure you wear eye protection.



Permeability test: This measures the rate at which water will drain through a soil sample so that soils can be compared

Key terms

- **clay**
- **humus**
- **loam**
- **sandy soil**

Summary questions

1 What else, besides deposited rock fragments, do we find in soil?

2 Draw a table to compare the grain sizes, ease of drainage and amount of air in clay, sandy and loam soils.

3 What differences would you see between a sandy soil and a loam soil in a sedimentation test?

4 Describe a method to carry out the permeability test shown above to compare the three types of soil.

8.4 Inside the Earth

Learning outcomes

After this topic you should be able to:

- describe the structure of the Earth
- collect secondary data to gain information about the structure of the Earth.

The crust

Have you ever wondered what is inside our planet? To get inside, first of all you would have to go through the Earth's relatively thin **crust**. It can be as thin as 5 km under the oceans, increasing to about 70 km under the continents. Compare these distances to the 13 000 kilometres of the Earth's diameter. This thin crust is the least dense of the Earth's layers.

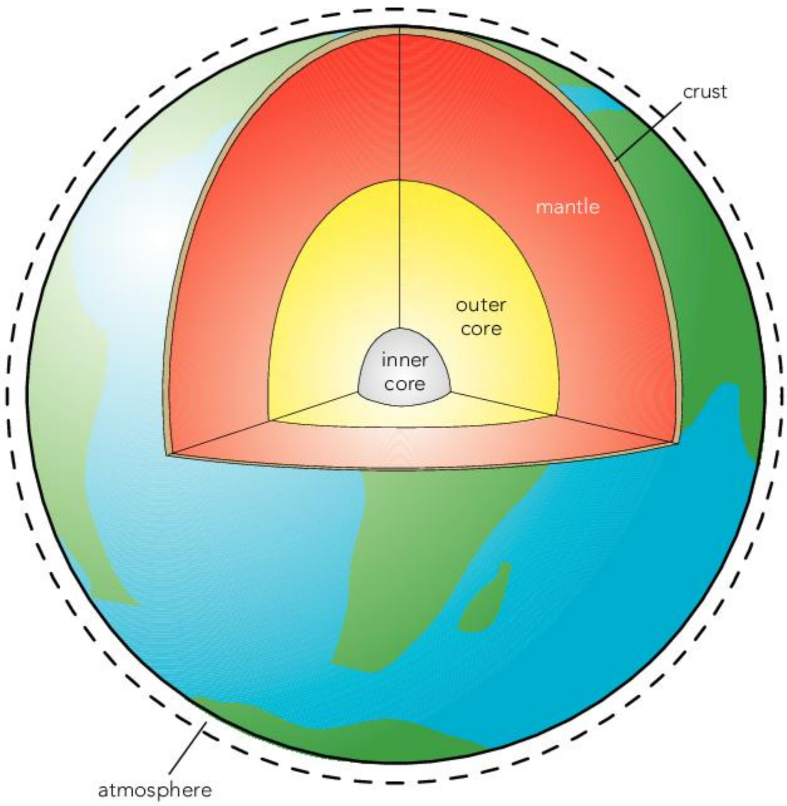
The mantle

Under the crust is the Earth's **mantle**. This layer goes down almost halfway to the centre of the Earth. The mantle is almost entirely solid. However, there is a small amount of molten material between the crust and the uppermost part of the mantle.

The Earth's crust and upper mantle is made up from huge slabs of rock, called tectonic plates. These move very slowly and cause earthquakes and volcanic activity where the giant plates rub against each other.

The Earth's core

Beneath the mantle is the **outer core**. This is a dense liquid, made of molten iron and nickel. Both of these metals are magnetic.



The structure of the Earth

Finally, at the centre of the Earth, there is the **inner core**. This is the densest part of the Earth. Unlike the outer core it is solid because of the very high pressure. It is also made of iron and nickel.

The outer and inner cores make up just over half of the Earth's diameter.

Practical activity Researching planet Earth

a Old models of the Earth

People have had different theories about the structure of the Earth over the ages.

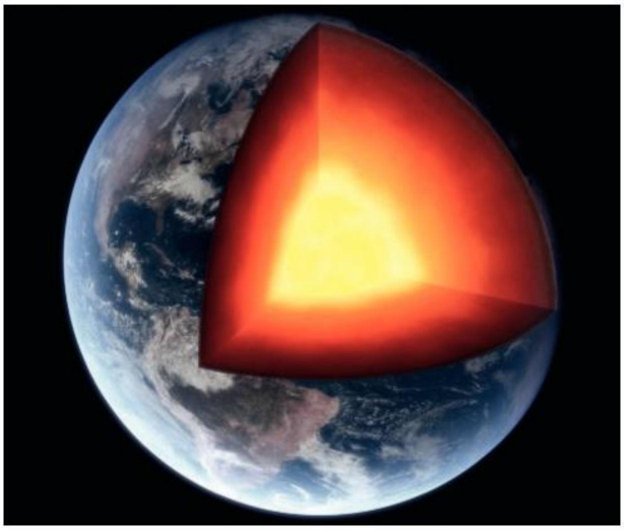
Find some of these old ideas about our planet using secondary sources, such as books, the internet or videos.

b Finding out what is inside the Earth

The Earth is about 13000 kilometres in diameter but the deepest hole ever drilled is only about 13 kilometres deep. So how do scientists know what is deep within our planet?

Using secondary sources, find out the ways in which scientists obtain their information.

Present your results from **a** and/or **b** on a poster to share with the rest of your class.



3-D illustration of a view through to the Earth's core

Expert tips

Only about 10% of the Earth's mantle is a thick (viscous) liquid, found around the edges of mainly solid rock. But this is enough to cause movement of the Earth's huge tectonic plates.

Key terms

- **crust**
- **inner core**
- **mantle**
- **outer core**

Summary questions

1 Draw a labelled diagram of the Earth shown in cross-section (as though the Earth had been sliced in half).

2 Where do we find the thinnest parts of the Earth's crust?

3 Why does the Earth behave like a giant magnet?

4 Some people compare the structure of the Earth to an egg with cracks in its shell. Evaluate this model, explaining its good points and its faults.

8.5 Evidence from the past

Learning outcomes

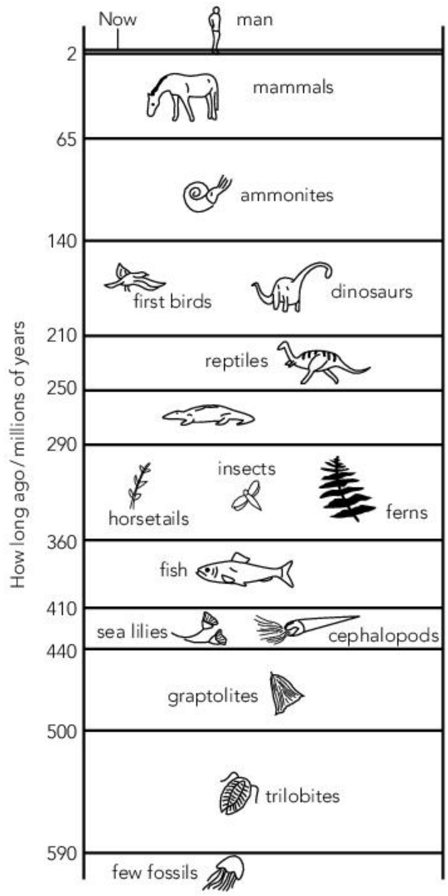
After this topic you should be able to:

- explain how fossils can be used to compare the age of rocks
- discuss why the fossil record does not give evidence to estimate the age of the Earth.

Fossilised remains are made of minerals absorbed into the hard parts of organisms, such as shells or bones

In this topic we will look at some of the evidence scientists use to make deductions about the history of our planet from its rocks and **fossils**.

Fossils are the remains (or imprints) of animals and plants that lived thousands or even millions of years ago. The dead plant or animal was preserved in sediments that eventually turned into rock (see page 144). The hard parts of their bodies were replaced by minerals. Look at the ages of some organisms that have lived on Earth:



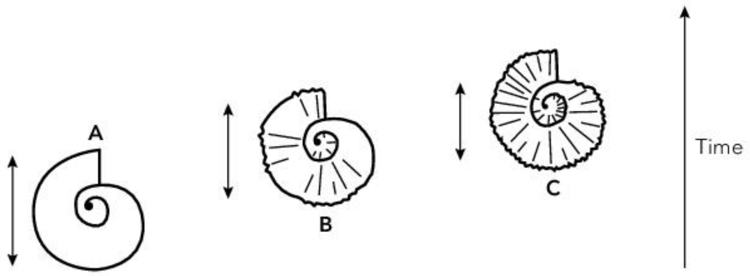
Fossils can tell us the approximate age of the rock they are found in

Fossils found in rock give us clues about the history of the Earth. For example, the fossils of tropical fern leaves found in coal deposits suggest that coal formed in areas with hot, swampy conditions. Because of its coal deposits, many scientists believe that Britain was once near the Equator, and that it has gradually moved thousands of miles northwards as a result of continental drift (see page 140).

Where we find the same fossil species in rocks from different parts of the world, we can deduce that the rocks are about the same age. Such deductions are more reliable when the fossils used are of animals or plants that existed for a relatively short period of time.

We can also get some idea of the relative age of rocks by studying the changes in the fossils present. Throughout time, species of plants and animals have become extinct or have evolved into new forms. We can use evidence from their fossils to deduce which rocks are older. The simpler and less developed an organism, the longer ago it must have lived. More sophisticated organisms evolved from these original simple forms.

Fossils of species that only existed on Earth for a relatively short time period are more useful for dating rocks than those species that existed for a long time.



Fossils show signs of evolving over time

The age of the Earth

People have always been interested in finding out the age of the Earth. But can fossil evidence help us to answer the question 'How old is the Earth?' Scientists are doubtful. It is unlikely that there was any life when the Earth was first formed. It is thought that the early Earth was a ball of molten rock. When it did cool down enough to form a crust around the outside, the molten rock constantly burst through. This created a volcanic atmosphere, unsuitable for life.

So scientists use the oldest rocks they can find to estimate the age of the Earth. These igneous rocks contain some radioactive substances. Some of these substances take millions of years to break down into different substances. Scientists know how quickly they decay into other substances. By analysing the amount of these other substances that are present in a rock, scientists can estimate its age. Their best estimates at present place the Earth at about 4.6 billion years old (that is 4 600 000 000 years old).

This is much older than the oldest fossils ever found.

Expert tips

The vast timescales involved in geological history are hard for anyone to imagine. But if the history of the Earth was represented by a 24-hour clock, then humans only arrived on Earth at about one second to midnight!

Key terms

- **fossil**

Summary questions

1 What is a fossil?

2 Look at the fossils in the illustration above.

a) Which of the three fossils is the oldest?

b) Which can give the most precise age of the rock it is found in?

3 a) What is the problem with trying to age the Earth from fossil evidence?

b) What do scientists use instead of fossils to estimate the age of the Earth?

End of chapter questions

1 Identify the rocks below as igneous, metamorphic or sedimentary.

Rock **X**: It is made from plate-like crystals all lined up in the same direction. The rock fragment has parallel flat sides where it has been split. *[1]*

Rock **Y**: There are particles of sand visible held together by an orange–brown mineral. Bits of sand crumble off the surface of the rock quite easily. *[1]*

Rock **Z**: There are three different types of interlocking crystal arranged randomly in this hard rock. *[1]*

2 **a** Explain the process whereby limestone can be changed into marble. *[2]*

b Explain the process whereby slate can be formed from mudstone. *[2]*

3 **a** **i** Name an igneous rock made up of large crystals. *[1]*

ii Under what conditions is this type of rock formed? *[1]*

b **i** Name an igneous rock with very small crystals. *[1]*

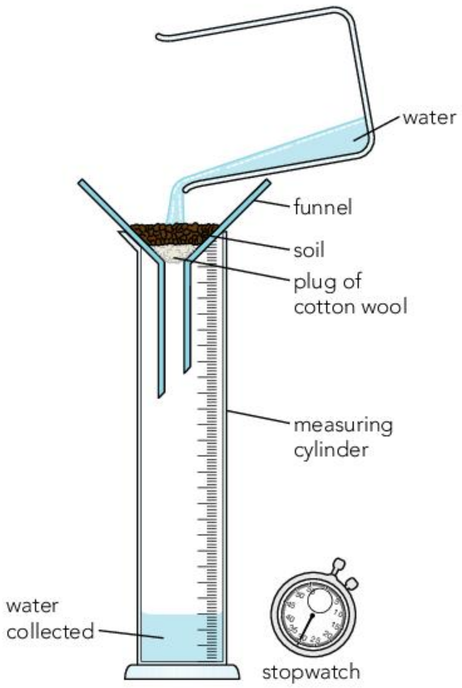
ii Under what conditions is this type of rock formed? *[1]*

c Explain the difference we find in the size of crystals in igneous rocks using the particle theory where necessary. *[2]*

4 A scientist says that the oldest fossils found are 600 million years old so the age of the Earth is 600 million years.

Do you think the scientist is correct? Explain your answer. *[2]*

5 An agricultural scientist wanted to find out which of his trial fields would drain most quickly. He took soil from each of his four fields, labelled them **A** to **D**, and carried out the test shown below:



He found that it took soil **A** 45 seconds to drain a set volume of water, soil **B** took 32 seconds, soil **C** took 17 seconds and soil **D** took 78 seconds.

a Put the scientist's results into a suitable table. *[2]*

b Show his results on a suitable graph. *[4]*

c Which property of the soils was the scientist testing? Choose i, ii, iii or iv.

i How acidic the soil is

ii How well the soil drains

iii Its density

iv Its texture *[1]*

d Which soil would be best suited to a crop that needs well-drained soil to grow well? *[1]*

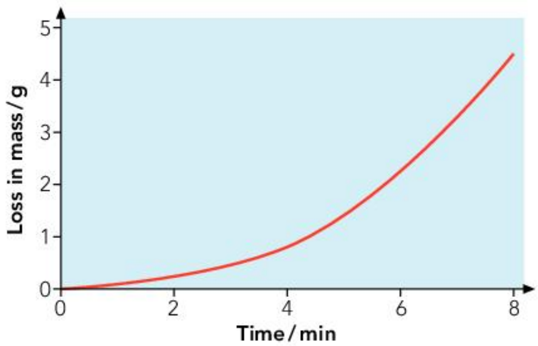
e Which soil is most likely to be a clay soil? Explain why. *[2]*

f Which soil is most likely to be a sandy soil? Explain why. *[2]*

6 Sami and Des were investigating how rocks can be worn down.

They made six cubes from plaster of Paris. They weighed the cubes then put them in a tin can with a lid. They shook them for 30 seconds then weighed the six largest blocks again, making sure no bits were lost from the can. They replaced the blocks in the can and repeated this several times.

Here is a graph of their results:



a Why did the blocks lose mass? *[1]*

b What happens to the edges of the cubes in their experiment? *[1]*

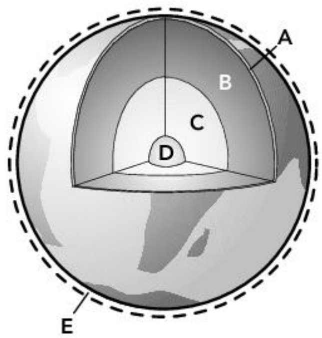
c If they weighed the tin can plus its contents before and after the experiment, what should they find? Choose i, ii or iii.

- **i** The mass had decreased after the experiment.
- **ii** The mass had increased after the experiment.
- **iii** The mass remained the same. *[1]*

d i What do we call the rock formed from fragments of rock that settle in layers? *[1]*

ii If these rocks are put under high pressure and baked at high temperatures, what type of rock forms? *[1]*

7 The structure of the Earth is shown below:



a Name the parts of the Earth labelled **A** to **E**. *[5]*

b Which layer of the Earth:

- **i** contains fossils? *[1]*
- **ii** is made up of solid iron and nickel? *[1]*
- **iii** is found beneath the Earth's giant tectonic plates? *[1]*
- **iv** varies in thickness between 5 km and 70 km? *[1]*

c i Which of the following is the best estimate of the age of the Earth?

- 4.6 thousand years old
- 4.6 million years old
- 4.6 billion years old *[1]*

ii Scientists can estimate the age of the Earth. State what they observe and measure to work this out. *[2]*

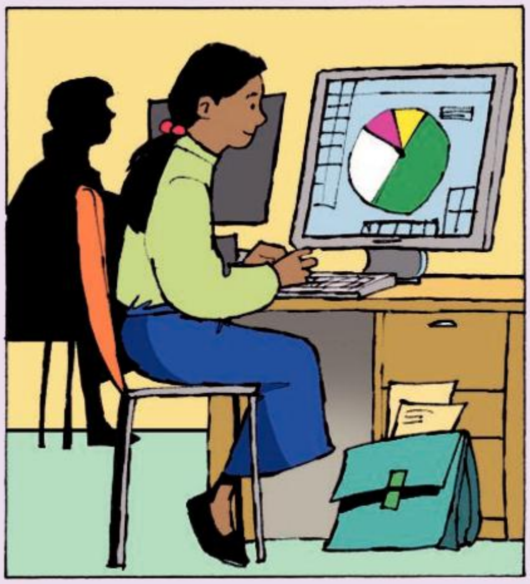
9 Energy transformations

Science *in context!* An energetic day

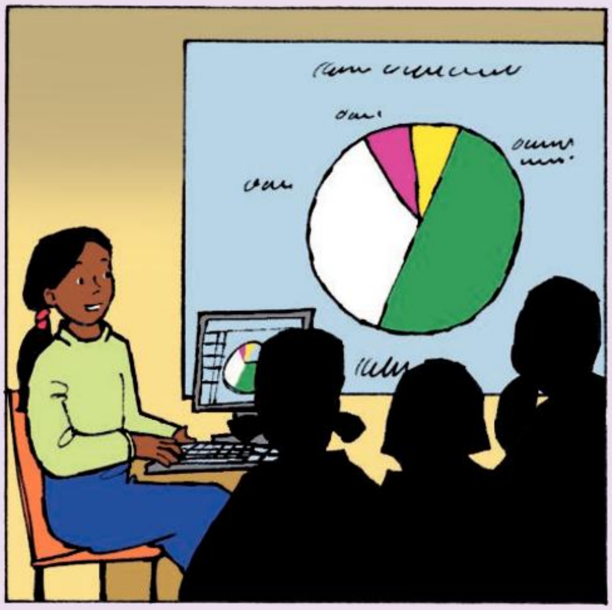
We need energy every day for everything we do.

In the morning Aditi has a big breakfast. She has a busy day ahead and she needs to stock up on the **chemical energy** that will keep her going

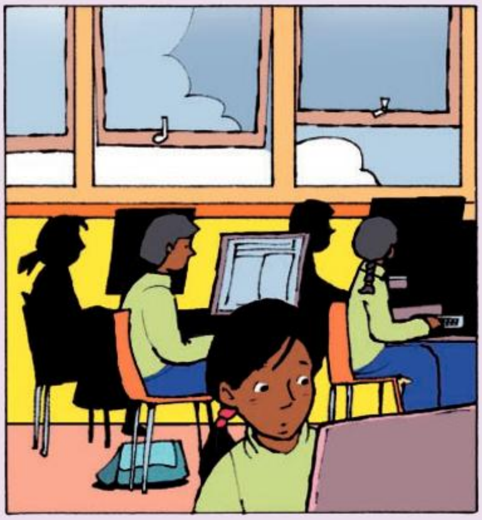
She takes the bus to school through the city's busy traffic. The bus uses chemical energy too but the energy comes from diesel. The bus engine turns the chemical energy into kinetic energy to make the bus move



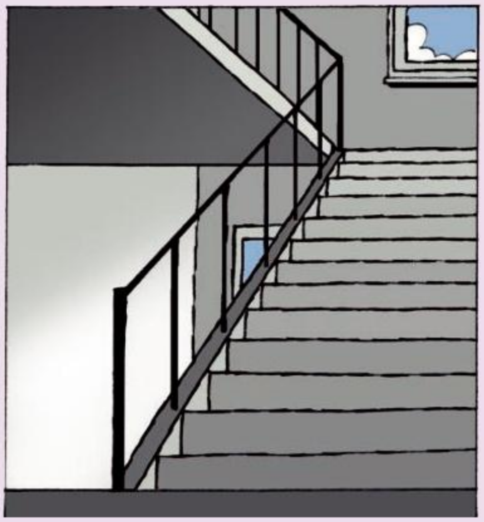
During one of her classes she uses a computer for research on her project. It needs **electrical energy** from the mains supply



She uses the computer projector to show her project. It produces a lot of **light energy**



There are many computers and students in the room. They all produce a lot of **heat energy** and **sound energy**. Cooler air blows in through the open windows



Aditi's next lesson of the day is on the top floor. It will be hard work gaining all of the **gravitational energy** she needs to climb the stairs and she will transfer a lot of her remaining energy

Aditi has been performing energy transfers all morning and it's still only time for lunch!

Think about the things you have been doing over the last day. All of them involve some energy transformations. In this chapter you will explore the different energy transformations and see why energy is so important to us.

Key points

- Energy is transformed when any event happens.
- There are several forms of energy; all of them are measured in a unit called joules.
- Energy is conserved; it cannot be created or destroyed but it can become less useful to us.
- Food provides us with the energy our bodies need; different foods contain different amounts of energy.
- Electrical energy is very useful and most electricity is generated in large power stations that burn fossil fuels.
- Renewable energy resources will not run out but non-renewable ones will eventually run out.
- Scientists are trying to develop more efficient technology to solve our energy problems.

9.1 Ideas about energy

Learning outcomes

After this topic you should be able to:

- describe how energy can be transformed
- use correct descriptions for the forms of energy.

Huge amounts of energy are transferred when stars explode

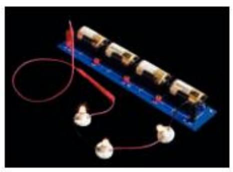
Energy is needed for anything to happen, from the smallest chemical reactions in our cells to giant stars exploding. Every event is really an energy **transformation** – energy changing form or moving from one place to another.

When you are running around, your stores of energy are quickly released. Eventually you will have to take in new supplies of energy by eating. Even reading this book needs a range of energy transformations to take place.

Energy in action

During energy transformations there are different ways to describe what is happening to the energy as it is **transferred** from place to place. We use the idea of 'forms of energy' to help explain what is happening in the transformations.

Here are some of the ways that energy can move from place to place:

Light energy		The energy is transferred very quickly through rays of light
Thermal energy		Movement of energy from hot places to colder places
Electrical energy		Transfer of energy around an electric circuit
Sound energy		Transfer of energy by sound waves through the air or other materials
Kinetic energy		This is the energy an object has when it is moving

Storing energy

Energy can also be stored in an object. Here are three examples of how energy can be stored. Stored energy is called **potential energy**.

Chemical energy	Energy, stored in materials, which can be released by chemical reactions, such as burning a fuel
Elastic strain energy	Energy stored in materials that are stretched or squashed
Gravitational energy	Energy stored in an object that can fall; for example a book on a shelf

Examples of energy transformations

When you light a Bunsen burner there is a range of energy transformations happening as the gas burns. The chemical energy from the gas is transformed into **heat** and **light** (and a little **sound**).

When you bounce a ball on the ground (or your head) there is a transfer of gravitational potential energy into **kinetic** energy and back again.

Key terms

- **energy (chemical, gravitational, elastic strain, potential, kinetic, heat, light, sound)**
- **potential energy**
- **transfer**
- **transformation**

Summary questions

1 Copy and complete these sentences using some of the key terms and the words used to describe the forms of energy.

When you switch on a torch it transforms ________ energy in the battery into ______ and ______ energy given out by the lamp.

A television set is designed to transform ________ energy into ______ energy and ______ energy. It also produces some ______ energy.

2 Describe the main energy transformations that happen when:

a) you pedal a bicycle and it speeds up

b) you use the brakes to stop the bicycle.

3 Write down some examples of when these energy transformations could happen:

a) chemical energy transforming to heat and light

b) gravitational energy transforming to kinetic energy

c) elastic strain energy transforming to kinetic energy.

9.2 Exploring energy transformations

Learning outcomes

After this topic you should be able to:

- describe a range of energy transformations
- interpret and draw energy transformations accurately.

Battery-operated torch

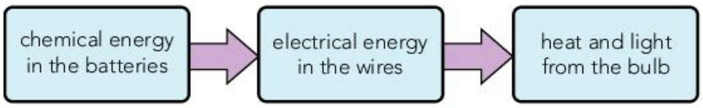
When we are describing energy transformations we need to be very clear about the form of energy involved and the places where the energy is stored or acting.

- When you turn on a torch the chemical energy in the batteries is transferred into electrical energy passing through the wires. The electrical energy is transferred into light and heat in the bulb.
- When you ride a bicycle the chemical energy that was stored in your body is transferred to kinetic energy as the bicycle moves. When you use the brakes to stop, the kinetic energy is transformed into heart energy in the brakes and the surroundings.

Energy transfer diagrams

It can be quite complicated to give a clear description of energy transformations in sentences. But we can summarise the transformations of energy with simple **energy transfer diagrams**. These show the changes in where energy is and in the form the energy is taking.

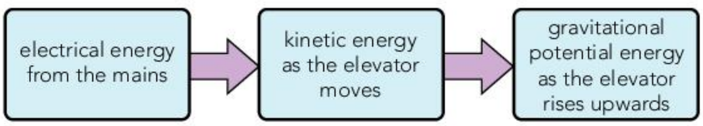
This energy transfer diagram shows the energy changes that take place in the torch.



A battery-operated torch transforms chemical energy into electrical energy which is then transformed into light energy and heat energy

Arrows are used to show the 'flow' of energy over time, from one place to another.

This is the energy transfer diagram for an elevator rising up through a building.



An elevator

Practical activity Investigating energy transformations

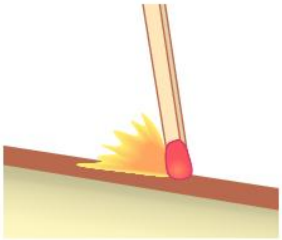
You have been given a set of small experiments involving energy transformations.

- For each of the experiments you need to investigate the transformations that take place and describe them.

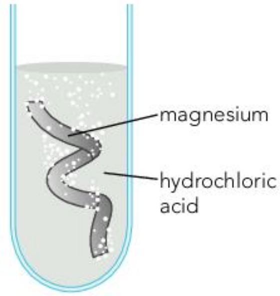
When you carry out the experiments you should think about:

- in what form the energy was stored at the start
- in what form the energy is transferred
- where the energy ends up after the transformation.

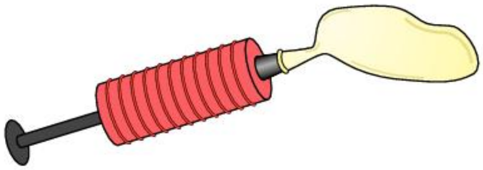
Wind-up torch



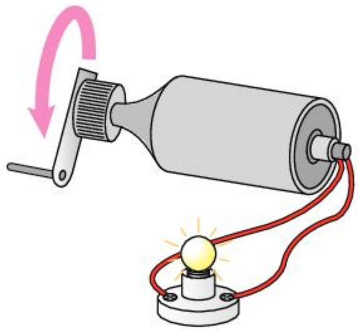
Match catching light



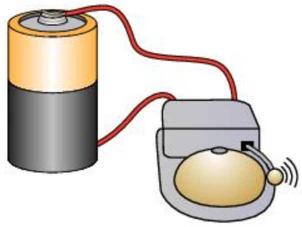
Metal bubbling in acid



Balloon being inflated



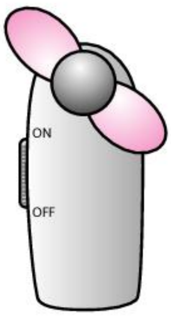
Hand-turned generator and a bulb



Battery and an electric bell

Candle burning

Mass on a spring



Hand-held electric fan

Expert tips

Only use these words for describing energy transformations: light, heat, electrical, sound, kinetic, chemical, elastic strain, gravitational.

Key terms

- **energy transfer diagram**

Summary questions

1. Copy and place these activities in order – from the smallest amount of energy transformation involved to the largest: boiling a full kettle of water, running 10 metres, climbing a 10 metre flight of stairs, stretching a small elastic band, burning one match.
2. Draw an energy transfer diagram for each of the activities you carried out in the experiment above.

9.3 Wasted energy

Learning outcomes

After this topic you should be able to:

- compare energy transfers
- describe how energy is wasted during energy transformations
- plan and carry out an investigation into cooling a liquid down
- make conclusions from collected data.

Measuring energy

You need different amounts of energy to do different jobs. We measure the amount of energy transformed in a scientific unit called the **joule**, which is represented by the symbol J. When there are large amounts of energy involved we can use kJ (**kilojoule**), where 1 kJ is 1000 J.

- Lifting this book one metre from the table will transfer only 3 or 4 joules of energy to it.
- Burning one litre of gasoline will release 35 million joules of energy into the surroundings.

Useful and wasted energy

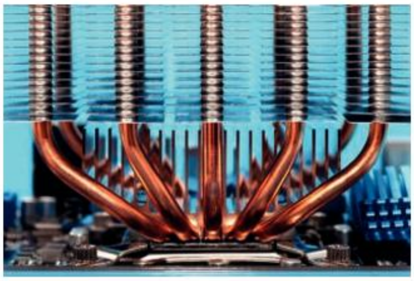
When we use a light bulb we want to transform the electrical energy into light but the bulb also transforms the energy into heat. We say that some of the energy has been usefully transferred and some has been wasted during the transformation.

Device	Useful energy transformation	Wasted energy transformation
television	light, sound	heat
motorcycle	kinetic energy	heat, sound
wind turbine	electricity	sound, heat

This table gives some examples of useful and wasted energy transferred by different devices

Wasted energy by heating

In all energy transfers some energy is wasted. This wasted energy is nearly always transferred to the surroundings, heating them up. The energy transferred this way cannot be used in any more transformations so it is useless to us.



This cooling unit keeps the central processing unit of the computer cool enough to operate. It is designed to let heat energy escape quickly by providing a large surface area

In electrical circuits, the flow of electricity in the wires causes them to heat up. This is why televisions and computers become hot. Sometimes so much heat energy is released that the electronics need cooling fins or even fans to enable the heat to escape before the device is damaged.

Sometimes we actually want to tranfer heat energy in this way. For example, electrical fires and the heating elements in kettles are not wasting energy as heat.

These coils of wire in an 'electric fire' are giving out so much heat energy they are glowing red hot!

More wasted energy

When mechanical objects, such as the parts in an engine, rub against each other the friction causes them to heat up. You will find out more about this in chapter 10. The other common form of wasted energy is sound; many machines produce useless sound when they operate.

This jackhammer produces so much wasted sound energy that the user has to wear ear protection

Expert tips

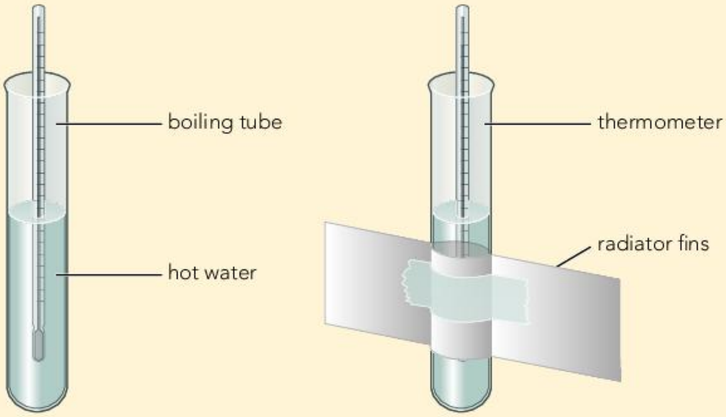
Think carefully about what you want a device to do before deciding which of the transformations is producing wasted energy.

Key terms

- **joule**
- **kilojoule**

Practical activity — Cool it

Sometimes we want objects to cool down quickly. Design a system of cooling fins to see if you can get the water in a boiling tube to cool more quickly. Use the same volume of hot water in two different boiling tubes. Leave one 'normal' and add some cooling fins made out of aluminium foil to the other.



Your task is to find out if larger cooling fins will let the water cool faster.

- Share results with other groups to confirm your conclusions.
- You can also design an experiment to test whether a larger surface area lets liquid cool faster.
- What could you do to record the temperature decrease in more detail over the cooling period?

Be careful with hot water – it can cause burns.

Summary questions

1 Copy and complete this table to show conversions between joules and kilojoules:

Joule / J	Kilojoule / kJ
5000	
	2.5
200	
	0.1

2 Decide what the useful and wasted energy transformations are for these devices:

a refrigerator, an aeroplane, a solar panel, a loudspeaker, a computer

3 When you use a handheld games console or a tablet computer for a while it begins to feel warm. Explain why this is happening in terms of energy transfer.

9.4 Conservation of energy

Learning outcomes

After this topic you should be able to:

- state the principle of conservation of energy
- use the principle to find out how much energy has been successfully transformed or wasted in a range of situations.

You have seen that energy is transferred to the surroundings in all energy transformations. This does not mean that the energy is gone. It is just too difficult for us to use the energy again in another transformation.

Conservation of energy

Energy never disappears; it just gets harder and harder to transfer usefully. This is a very important idea in science and gives us the principle of **conservation of energy**.

The total amount of energy before and after a transformation is the same.

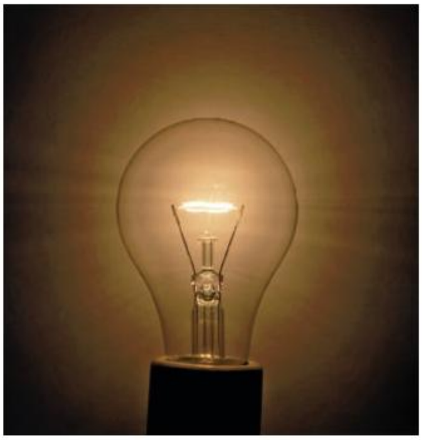
This means that we can't make energy or destroy it; we can only transform or transfer it.

Using the principle of conservation of energy

We can use the idea of conservation of energy to find out how much energy is transformed in useful ways or wasted. All we need to remember is that there will be the same amount of energy after a transformation as there was before it.

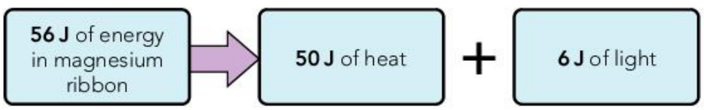
Here are some examples:

- Imagine that we use 20 J of energy to light up a torch bulb but we only get 4 J of light. Then the principle of energy conservation tells us that 16 J has been transferred by heating the surroundings and is wasted.



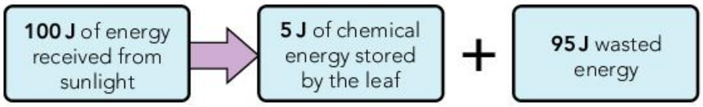
Conservation of energy in an electrical bulb

- In an experiment a sample of magnesium ribbon is burned releasing 50 J of heat and 6 J of light. That means there must have been 56 J of chemical energy available before the reaction started.



Conservation of energy in a chemical reaction

- A plant transfers energy by photosynthesis. This process uses energy from sunlight to convert simple molecules of water and carbon dioxide into sugars. A leaf will only be able to store 5 J of chemical energy for every 100 J of energy received from sunlight. This means that 95 J is wasted.

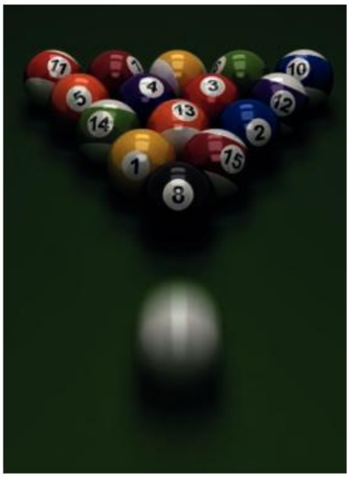


Conservation of energy in a plant

Spotting the changes

The principle of conservation of energy is always obeyed. However, sometimes it is not obvious where all of the energy has been transferred to or it is difficult to obtain accurate measurements. To spot where the energy has gone we have to look out for:

- changes in temperature that show that heat energy has been released
- changes in the speed or movement of an object that show us that there has been a change in kinetic energy
- changes in the position of the object – a rocket flying upwards, for example, shows us that it has gained gravitational potential energy
- changes in the shape of an object that can show us it has gained or lost elastic strain energy.



When this pool ball collides with the pack, the balls will fly off in different directions. Kinetic energy is transferred from one ball to the others

Expert tips

Add up the energy before and after any transformation and make sure they are the same amounts. If they are not then you've missed something out – so check again

Key terms

- **conservation of energy**

Summary questions

1 When you roll a ball across a flat field it quickly stops. Where does the kinetic energy go?

2 When an acid is added to an alkali a neutralisation reaction happens and the solution becomes hot. Where did the heat energy come from?

3 The Sun releases a huge amount of energy every day. Carry out some research to find out the source of this energy – it is one you have not studied yet. Produce a brief report on it.

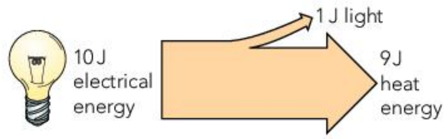
9.5 Sankey diagrams for energy transformations

Learning outcomes

After this topic you should be able to:

- interpret and draw a range of Sankey diagrams for energy transformations
- use the principle of conservation of energy to find missing values of energy in a Sankey diagram.

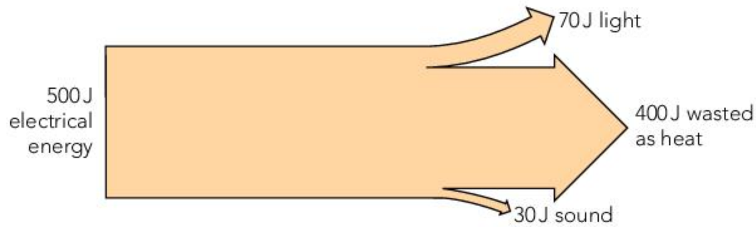
A **Sankey diagram** is a diagram that can be used to show the types of energy changes that happen. It also clearly shows the amounts of energy that are transferred. Here is a simple Sankey diagram showing the energy transformations in a light bulb.



Sankey diagram for a bulb transforming 10 J of electrical energy but only producing 1 J of light

The width of the arrows in the diagram tells us how much energy is transformed in different ways. You can see that the bulb wastes most of the energy supplied to it because the heat arrow is far wider than the light part of the arrow.

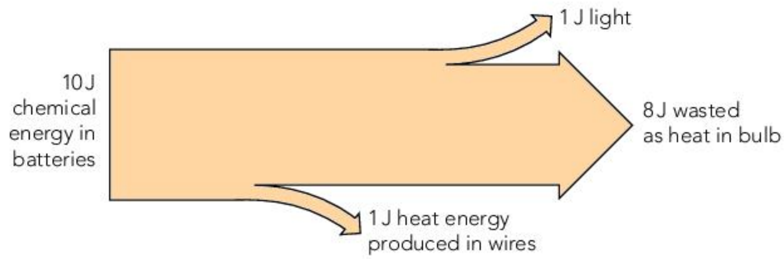
In this next example there are several forms of energy produced by the television. The width of each arrow clearly shows the amounts of energy.



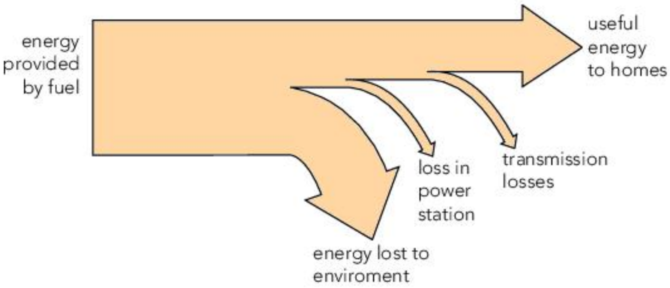
Sankey diagram for a television set

Changes in stages

A Sankey diagram can be used to show the energy changes at different stages in a process. For example, in a torch the energy starts out as chemical energy inside the battery. It is then transferred as electrical energy through the wires where some of the energy is wasted in heating the wires. Finally the remaining electrical energy is transformed into heat and light in the bulb.



A Sankey diagram showing the different energy transfers in a torch



Some Sankey diagrams can get quite complex. This diagram shows the energy transfers involved in generating electricity and transmitting it to homes.

Practical activity Making Sankey diagrams

Make some large Sankey diagrams for display around the room. Take time to make sure that the width of the arrows are in the correct proportion and that the labels are clear. You must use the principle of conservation of energy to find any missing values. You can use the examples from previous pages about energy transformation or you can try any of the following:

- A car that uses 100 kJ of chemical energy from fuel to produce 20 kJ of kinetic energy, 75 kJ of heat and 5 kJ of sound.
- A ski lift that uses 40 kJ of electrical energy to produce 25 kJ of potential energy when it lifts you up a mountain. The rest is wasted as heat.
- A slide that can convert 1000 J of gravitational potential energy into 800 J of kinetic energy and the rest as heat.

Expert tips

Draw Sankey diagrams neatly with a ruler. If you use small squared paper it can help to get the widths right.

Key terms

- **Sankey diagram**

Summary questions

1 Explain why Sankey diagrams are more useful for showing energy transformation than ordinary energy transfer diagrams.

2 Draw a Sankey diagram based on the following information about an electrical buzzer. It is powered by batteries that provide 30 J of chemical energy. 5 J of energy are lost as heat as the electricity passes through the wires of the circuit. The buzzer produces 5 J of sound; the rest is wasted as heat energy.

9.6 Energy efficiency

Learning outcomes

After this topic you should be able to:

- describe how different devices can be compared to find out which is the most energy efficient
- calculate the efficiency of a device or energy transformation
- draw a line graph to display experimental data.

An electrical motor converts electrical energy into kinetic energy. This large motor is used in elevators

Expert tips

If you ever find an efficiency rating of more than 1, go back and check your calculation.

Imagine you have two electrical motors (A and B). You have been asked to test the motors by making them lift an object so that you can decide which motor transfers the least energy.

- Motor A needs 100 J of electrical energy to lift the object and gives it 5 J of energy. This means it has wasted 95 J of energy. It is not a very good motor.
- Motor B does exactly the same job but needs only 25 J of electrical energy. It is obviously a better motor.

Comparing devices

Comparing the two motors was fairly easy, but it can be harder to compare devices if they don't transfer the same amount of energy. We can make a fair comparison of how effective a device is by calculating its **efficiency**. The efficiency is a measure of the fraction of the energy given to a device that is usefully transferred.

Because there is always some energy wasted in a transformation this fraction will be less than 1.

Calculating efficiency

To find the efficiency we use a formula:

efficiency = useful energy out of device ÷ total energy into device

Here are some examples showing how to calculate the efficiency of the two motors described earlier.

- Motor A: efficiency = useful energy out ÷ total energy in
  = 5 ÷ 100
  = 0.05
- Motor B: efficiency = useful energy out ÷ total energy in
  = 5 ÷ 25
  = 0.20

Changes in efficiency

The efficiency of a device can depend on its surroundings or situation.

- An electric motor might be efficient at lifting small objects but inefficient at lifting larger ones.
- The efficiency of a loudspeaker might improve when the sound level is louder.

When you choose which device to use you should examine all of the data to decide on its efficiency. Carry out the practical activity to see how the efficiency of a device can change.

Is this loudspeaker system more efficient when the volume is turned right up?

Key terms

- **efficiency**

Practical activity Does the efficiency of a Bunsen burner change when it is used to heat different volumes of water?

Time how long it takes a Bunsen burner to heat up different volumes of water in a boiling tube by 40 °C. You could use 4 cm^3 of water up to 12 cm^3 of water in 1 cm^3 steps. Make sure that the Bunsen flame is set at the same level and the boiling tube is placed at the same point each time.

- When you double the volume of water, does the time taken to boil it double?
- Plot a line graph of the time taken to increase the temperature by 40 °C against the volume of water.
- Where does the wasted energy go?

Ensure the boiling tube is not pointing at anyone.

Summary questions

1 Copy and complete this sentence:

A device that uses ____ energy to do the same job is more _____. If we use efficient devices we will save more _____ and this will save us money and resources.

2 A loudspeaker in a music system uses 400 J of electrical energy and produces 50 J of sound.

a) How much energy is wasted?

b) What is the efficiency of the music system?

9.7 Reducing wasted energy

Learning outcomes

After this topic you should be able to:

- explain why it is important to improve the efficiency of machines and electrical devices
- test materials to see which one reduces heat energy transfer the most
- make predictions about the rate of energy transfer.

It costs money to produce energy in useful forms such as electricity. If we don't transform that energy efficiently then we are wasting both money and resources.

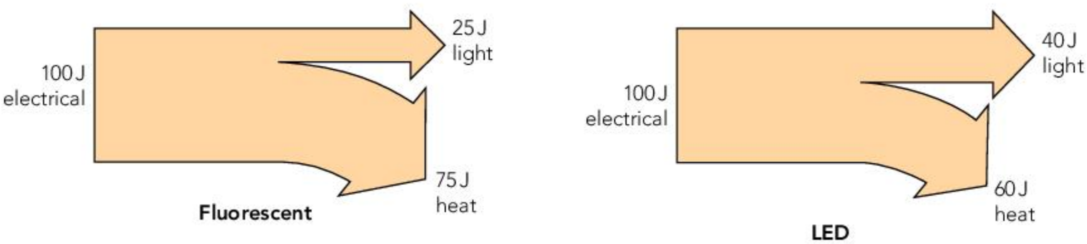
Better bulbs

We use a lot of energy to light our buildings, workplaces and streets. So improving the efficiency of this lighting is important.

The original electric light is called a filament bulb. It was invented towards the end of the 19th century and has been developed ever since. It is based on a simple idea: a thin wire inside a glass bulb gets so hot that it gives off light when electricity passes through it. This makes it cheap to make but it has very low efficiency.

Fluorescent lamps were developed 40 years later. These were more energy efficient but early designs were too large to use in houses. They were mostly used in office buildings or factories.

More recently, compact fluorescent lamps, which are much more energy efficient, have been developed for homes. The newest generation of lighting is based on light emitting diodes (**LED**). These are even more efficient than fluorescent lamps. They can last for much longer before they need replacing.



Sankey diagrams for fluorescent bulbs and LEDs

Bulb	Lifespan / hours of use	Efficiency / %	Cost to buy
filament	2000	5	1
fluorescent	8000	20–25	×10
LED	25 000	30–40	×40

Comparing different light bulb technologies

Keep it cool

A refrigerator is used to keep food cold. If we allow heat energy to enter from the surroundings it would not be very efficient. So we use **insulation** to slow down the transfer of energy from the outside to the inside. The insulating material will slow down the movement of heat energy. You can test the effectiveness of some materials in the practical activity.

Practical activity Keep the heat out

Carry out an experiment to keep water cold inside a container to explore the ways refrigerators are insulated. You should use water in a container and test different insulation materials or techniques to see which one keeps the water colder for longer.

Use very cold water so that the temperature changes more quickly but don't have any ice in the water.

Use a precise thermometer so you can detect small changes in temperature.

- Predict which material is the best at reducing heat entering the water.
- Predict whether the thickness of the material matters. Modify your investigation to find out.
- Predict whether the temperature of the room has any effect.

Key terms

- **fluorescent**
- **insulation**
- **LED**

Summary questions

1 Why don't LED lights get as hot as filament lamps? Look carefully at the Sankey diagrams and explain.

2 Some light bulb manufacturers are concerned that if they increase the lifespan of their bulbs then they will start to lose money. Why might this happen?

3 In cold countries such as Canada, filament lamps are still popular in houses because they are not viewed as being wasteful. Why not?

9.8 Investigating the energy in food

Learning outcomes

After this topic you should be able to:

- compare the different energy contents in foods using the correct units
- carry out and evaluate an experiment to measure the energy content in different food samples.

We need energy to keep the cells in our body working. We get this as chemical energy in the food we eat. Different foods have different amounts of energy. So we need to make sure that we eat enough of the right foods to have enough energy to stay healthy.

This fish tagine meal provides plenty of nutrition and enough energy to get through the day

A calorimeter is used to accurately measure the energy content of food samples

Measuring the energy content

The energy content of food is only one measure of its nutritional value but it is an important one.

Food scientists work out the energy content in foods. They take small samples, burn them and calculate the energy released by measuring the temperature rise in water. They have to make sure they do not let any unmeasured energy escape into the environment.

Units for the energy in food

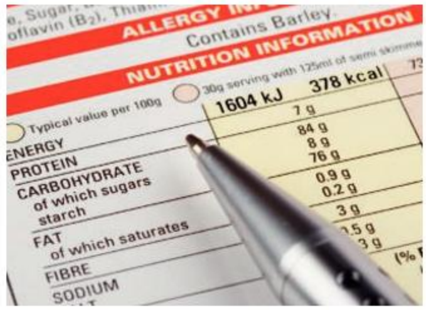
Because foods contain large amounts of energy, the energy is measured in kilojoules. On food labels a different unit called the kilocalorie can be used. One **kilocalorie** is 4200 J of energy (4.2 kJ).

Example foods

Food	Energy content / kJ per 100 g	Food	Energy content / kJ per 100 g	Food	Energy content / kJ per 100 g
cooked rice or couscous	540	olive oil, sunflower oil or palm oil	3360	red meat	780
cooked pasta	660	sugar	1540	chicken	690
cooked lentils	480	honey	1280	fish	400

Energy values for 100 grams of different foods

Fats contain the largest amount of energy per 100 g; sugars also contain large amounts of energy. This is why eating a diet that contains large amounts of sugar and fat can lead to you becoming overweight or even obese. **Obesity** is a serious medical problem in some countries.



Examining the food label will usually tell you the energy content in kJ and kilocalories

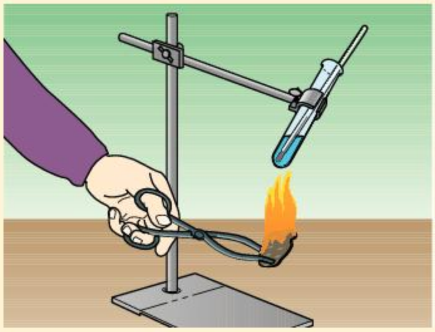
Food labelling

In most countries packaged food has to carry a label to help customers understand the energy and nutritional content of the food. The regulations about what must be shown are different around the world. The label usually gives information about the nutrients in the food and its energy content in 100 g and in a serving.

Practical activity Comparing the energy content in food

We can measure the energy content in food by burning it and using the heat to warm up water. In this experiment there will be quite a bit of energy escaping without being measured so we can only rank the foods in order of which releases the most and which releases the least energy.

Use samples of food to heat 15 cm^3 of water in a boiling tube. You will have to light the food and then quickly use the flames to heat the water. If the sample goes out then relight it quickly and continue to heat the water until the food sample is used up.



- Record the increase in temperature of the water for each of the foods.
- Rank the food samples in order of which heated the water most to which heated it the least.
- Which food provides the most energy?
- What can be changed in the experiment in order to make the measurements more reliable?

Be careful with the flames. Some foods can cause allergic reactions – don't use ones you or anybody near you is allergic to!

Key terms

- **kilocalorie**
- **obesity**

Summary questions

1. Why is the energy content of foods given in kJ per 100 g? In what way can this make it more difficult to know your food energy intake?
2. Make a record of your food intake over a period of a week and calculate your average energy intake per day. Are you getting enough energy?
3. Find out about the energy intake of people in different countries and the obesity levels. Is there a clear link?

9.9 Producing electricity

Learning outcomes

After this topic you should be able to:

- describe, in simple terms, how an electricity-producing power station operates.

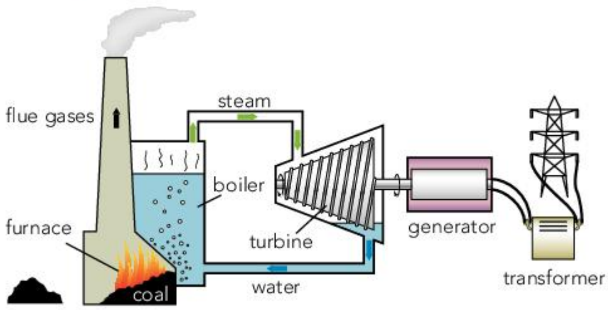
Expert tips

Electricity generation can be very inefficient. Engineers are always looking for ways to improve the efficiency.

Most of the electricity we use is generated at large power stations. These transfer energy from various forms into electrical energy so that it can be easily transferred over long distances to our homes. Once there it can be transformed into almost any form of energy we need.

A fuel-burning power station in Jakarta

Inside a power station



The basic parts of a fuel-burning power station

Fuel-burning power stations burn a fuel such as the fossil fuels coal, oil or natural gas in a **furnace**. This heats water in a **boiler** to produce high pressure steam.

The hot steam is used to spin **turbines** giving them kinetic energy as they rapidly rotate. These spinning turbines are attached to **generators** containing magnets and coils of wire. The magnets spin within the wire coils and this transforms the kinetic energy into electricity.

chemical energy in the fuel → heat energy in the high pressure steam → kinetic energy of the rotating turbines → kinetic energy in the generator → electrical energy in the wires

Energy changes in a fuel-burning power station

Because the coal, oil or natural gas burned cannot be replaced, the fuel is a **non-renewable** resource. These resources are in limited supply so become more expensive as they begin to run out.

Nuclear power

Most of a **nuclear power** station is the same as a fuel-burning one. The major difference is in how the heat is released. Nuclear fuel is a heavy metal called uranium. The atoms of uranium are unstable. When they are placed together in a high enough concentration, they break down releasing large amounts of heat.

Nuclear power stations create very dangerous radioactive waste products. If anything goes wrong, because of an accident, natural disaster, war, etc., the environment can be badly affected.

A tsunami in Japan in 2010 damaged the Fukushima nuclear reactors. Hundreds of square kilometres of land had to be evacuated for health and safety reasons

Practical activity Generating your own electricity

You can generate small amounts of electricity with a hand generator or dynamo. Use one to light up a bulb.

- What happens to the brightness of the bulb as you spin the generator faster?

Be careful with the generator – they can easily break if you spin them too hard.

Key terms

- **boiler**
- **furnace**
- **generator**
- **non-renewable**
- **nuclear power**
- **turbine**

Summary questions

1. In a power station, for every 1000 J of chemical energy 200 J are lost as heat in the boiler, 400 J more are lost in the turbines as the steam turns back into water and 50 J are wasted in the generator as it spins. The remainder are transformed into electricity. Draw an energy transfer diagram (like on page 162) and work out how much energy is transformed into electricity.
2. Your town is in need of more electrical supplies. Which type of power station would best suit your area? Give reasons for your choice.

9.10 The future of energy sources

Learning outcomes

After this topic you should be able to:

- describe alternative sources of energy, including energy to produce electricity and to power cars
- design an experiment to compare how long batteries last.

As fuels become more expensive we need to develop alternative sources. We also need to improve the efficiency of all the devices that depend on fossil fuels.

Renewable energy sources

More and more countries are exploring **renewable** energy resources, such as wind, solar or wave power. These will not run out and will enable us to generate electricity for a very long time.

This is a large hydroelectric power station. The gravitational potential energy stored in this water trapped behind a dam can be transformed into electricity using water turbines at the base of the dam

Renewable resources have problems that limit their use. This might be:

- the efficiency of the technology,
- the availability of the resource, or
- the expense of constructing the power stations.

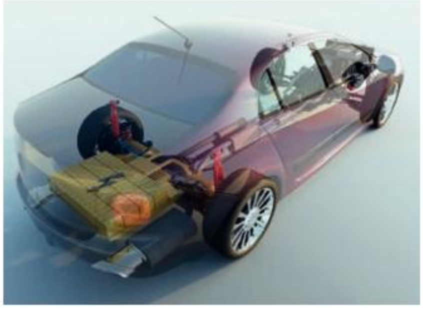
For example, solar cells are expensive to build and operate best in very sunny environments.

These panels of solar cells are very effective at generating electricity in a desert because of the reliable bright sunlight

Future cars

One important cause of the increase in the use of fossil fuels is the growth in the number of cars over the past 20 years.

Electric cars are one possible solution. The motors are more efficient than petrol engines but there are major problems to overcome. The cars need large batteries that require expensive components so the cost of the car increases. The batteries also take a lot more time to recharge than just adding more petrol.



In an electric car the batteries (shown in yellow) are very heavy, expensive to make and take hours to recharge

Scientists are working on **fuel cell** technology for use in cars. In these cells chemical energy can be directly transformed into electrical energy to power electric motors. Most of these use hydrogen extracted from water as a fuel. These would be much quicker to refuel and so be much more user-friendly.

There are still only a few electric or fuel cell cars available. However, as the technology improves they might start to replace petrol and diesel cars in the long term.

An experimental hydrogen fuel cell car being refuelled; this is much quicker than charging the battery in a normal electric car

Practical activity Recharge or throw away?

Design an experiment to see how long a rechargeable battery can power a toy car or other model. Investigate the time it takes to recharge the battery.

- You can compare the rechargeable battery to a disposable battery. Compare them in terms of performance and cost.

If you have data logging equipment you can use this in your experimental design.

- Do you think children would use a toy car that needed to be recharged for several hours before they played with it again?

⚠ **Do not try to recharge disposable batteries – they can explode.**

Key terms

- **fuel cell**
- **renewable**

Summary questions

1 Wood can be burned in a power station instead of other fuels. Is wood a renewable resource? Are there any other renewable fuels that can be burned?

2 Electric cars rely on batteries and these need to be charged using electricity. The hydrogen used in fuel cells also needs to be extracted from water using electrical energy. Where does this electricity come from? Do electric cars really save on fossil fuels? You can research the ideas further.

Chapter 9 End of chapter questions

1 a Which of these words describe the forms that energy can take?

chemical, steam, heat, light, kinetic, elastic strain, coal, oil *[5]*

b Which of those from the list can be described as potential energy? *[2]*

2 Which of these is the correct statement of the principle of conservation of energy?

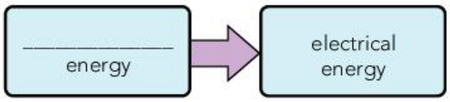
A The types of energy do not change in an energy transformation.

B There is always heat produced in an energy transformation.

C The total amount of energy before and after a transformation is the same. *[1]*

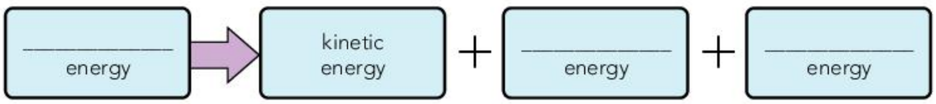
3 Copy and complete the energy transfer diagrams for each of these items:

a a solar powered calculator



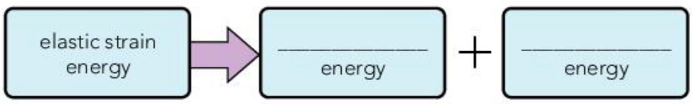
[1]

b a battery powered electric drill



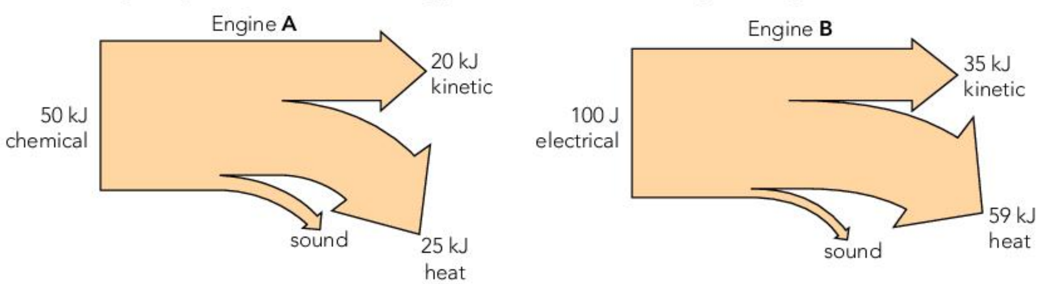
[3]

c a wind up alarm clock



[2]

4 These Sankey diagrams show the energy transfers in a motorcycle engine.



a How much energy is wasted as sound in each of the two engines? *[2]*

b Which is the most efficient engine? *[1]*

5 A group of students is investigating the efficiency of two small kettles that are used to boil different volumes of water. Their results are shown in the table.

a Which two variables do the students need to control to make the test a fair one?

- the time each kettle was used
- the starting temperature of the water
- the energy supplied to the kettles each second
- the colour of the kettle *[2]*

b Which is the most efficient kettle for small volumes of water? *[1]*

c Which is the most efficient kettle for large volumes of water? *[1]*

Volume of water heated / cm^3	Time taken by kettle A / s	Time taken by kettle B / s
300	32	35
400	44	47
500	58	59
600	70	61
700	84	82

6 Two students test electric motors to find which one is most efficient. They use the motors to lift a 0.5 kg mass 30 cm off the ground. Motor **X** uses 40 J of energy to lift the mass in 5 seconds. Motor **Y** uses 30 J of electrical energy to lift the mass in 7 seconds.

a Which is the most efficient of the motors? *[1]*

b Where does the wasted energy from the motors go? *[1]*

7 A student is preparing a simple vegetable soup using the following ingredients:

500 g potato, 300 g carrots, 300 g parsnips, 200 g onions, 100 g cream

Food	Energy content / kJ per 100 g
potato	323
carrots	147
parsnip	300
onion	176
cream	311

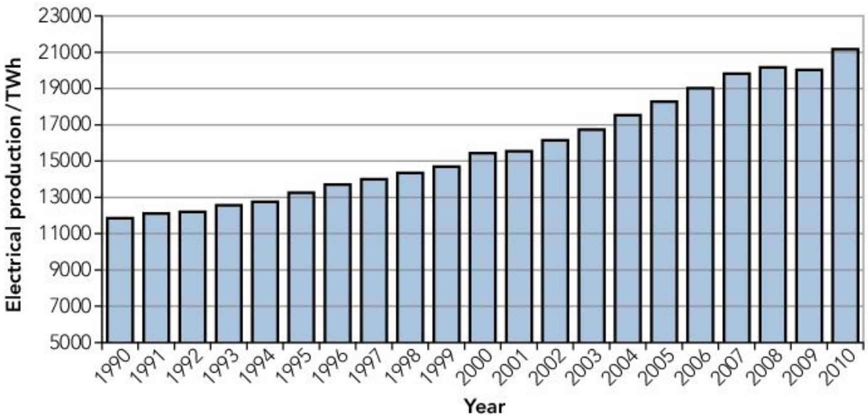
a What is the energy content of the soup? *[1]*

b What is the energy content of one portion of the soup (350 g)? *[1]*

8 This graph shows electricity production over a 20 year period.

a Describe the trend in the graph. *[2]*

b Explain why this trend is happening. *[2]*



9 This table summarises some of the properties of the fuels used in power stations.

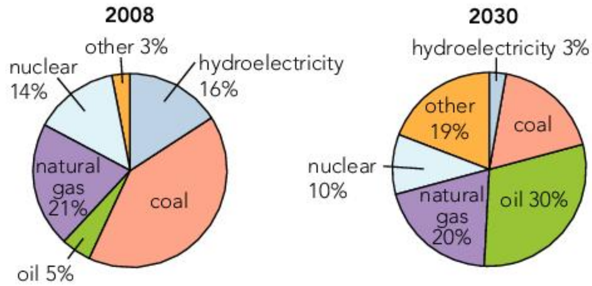
Fuel	Energy content / kJ per g	Level of pollution produced	Cost
natural gas	55	low	high
oil	45	medium	medium
coal	30	high	lowest
wood	1.5	low	high

a What advantage does wood have over the other three fuels? *[1]*

b What disadvantages does wood have? *[1]*

c Which type of fuel would be best used in a town? Give your reasons. *[2]*

10 These pie charts compare the resources used across the world in the year 2008 and the predicted resources in 2030.



a What percentage of the world's energy was / will be generated using coal in these years? *[2]*

b Describe the changes in resources being used. Why do you think these changes are happening? *[2]*

c Give three examples of 'other' energy resources that are shown in the charts. *[3]*

Science *in context!*

It's a record!

Athletes train for years to compete in championships or to make attempts at beating world records. To do this they have extensive training to develop their strength and stamina. But records are not being broken just because the athletes are getting fitter. The equipment they use and tracks they race on all make it easier to go that little bit faster.

On your marks

The fastest runners are sprinters; they have to be able to run at over 10 metres per second and even tiny things can slow them down. Their shoes, clothing, and even the starting blocks, are designed to help them out.

You need a big force to get you off to a good start. Sprint athletes can use starting blocks to push themselves forwards

Get a grip

The track material and the running shoes are designed to allow for better grip as the athletes run. If the track was too hard then there would be less grip and the athletes feet would slip. The shoes have spikes that dig into the track to help the athlete push forwards.

The spikes on these shoes will grip the track and allow the athletes to push themselves forwards quickly

Bobsleighs slide along icy tracks at over 100 km/s powered only by an initial push and the force of gravity. To steer the sleigh the metal runners need to dig into the ice. Aerofoils at the front of sleigh push downwards allowing for better grip at high speeds.

The aerodynamics of this bobsleigh allow it to reach 150 km/s

Cutting down the drag

It's not just the track athletes that get better. Take a look at the kit these cyclists wear and the bicycles themselves; they don't look much like street cycles. Scientists and engineers have studied how the bikes move through the air and have spent years making them more aerodynamic. Even the shape of the helmets is designed to be streamlined. All of these changes mean that they can go just a little bit faster than their competitors.

A modern sprint cyclist. Every aspect is designed to improve the top speed

Competitive yachts are pushed by the force of the wind and so the shapes of the yachts' sails need to be carefully designed to generate as much force as possible with minimum drag. The yachts' streamlined hulls cut through the water. Tiny differences in shape of the sail or hull can make the difference between winning and losing.

Drag needs to be reduced both above and below the water

In this chapter you will be looking at how forces affect objects, changing their shape or speed. You will see how, by applying our understanding of how forces work, we can keep on getting faster. You will also see how forces can make things float or sink, and learn about the force that keeps your feet on the ground.

Key points

- Forces can change the shape or movement of an object.
- Forces are measured in newtons.
- Friction is a force that acts to prevent the movement of objects. It is caused by surface contact.
- When forces are in balance on an object, it stays still or moves at a steady speed.
- When forces are not balanced, an object accelerates.
- The mass of an object is the amount of material in it and is measured in kilograms.
- The weight of an object is the force caused by its attraction to the Earth.
- When objects move through liquids or gases, drag forces slow them down.
- The density of a material is a measure of its mass per unit volume.

10.1 What are forces?

Learning outcomes

After this topic you should be able to:

- describe what forces can do
- use newtonmeters and scales to measure the size of forces.

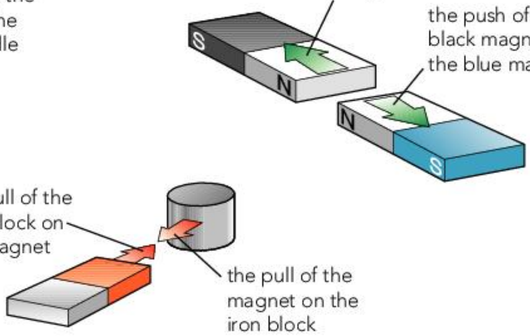
When you pull on an elastic band it stretches. When you let go of the end it shoots forwards and flies out of your hand. Both of these effects are caused by **forces**.

When a force is doing something we say that it is 'acting' on an object. Forces act on objects and can change their shape or how they are moving.

Showing forces

We can see or feel the effects of forces but we can't see the forces themselves. To explain them it is important that we can show what they are doing so we draw them as arrows on diagrams.

- The direction of the arrow shows the direction the force is acting (pushing or pulling).
- The length of the arrow indicates how large the force is.



A newtonmeter

Measuring forces

Forces are measured in a unit called the **newton** (N). One newton is a fairly small force: holding a 100 g mass in your hand needs an upward force of one newton.

Newtonmeters

A **newtonmeter** (sometimes called a forcemeter) is a spring with a scale attached. The force causes the spring to stretch and a pointer to show how large the force is. Different springs can be used to measure a range of forces. Strong springs are used to measure large forces while weaker springs are used to measure small ones.

Scales and balances

A scale or top pan balance can also be used to measure forces. Scales can be very precise and measure the weight of small objects much more accurately than a newtonmeter.

Practical activity Measuring forces

- Use a range of newtonmeters to measure the force needed to lift or drag a range of objects. You can also measure the weight of some smaller objects using a top pan balance.
- Record all of your results in a table with clear headings and units.

Make sure you select a newtonmeter with the right range for each of the objects. Don't use one that only measures up to 10 N to lift a chair!

Make sure your balance is set to measure in newtons (force) and not grams (mass).

This top pan balance is being used to measure the weight of a small sample

Key terms

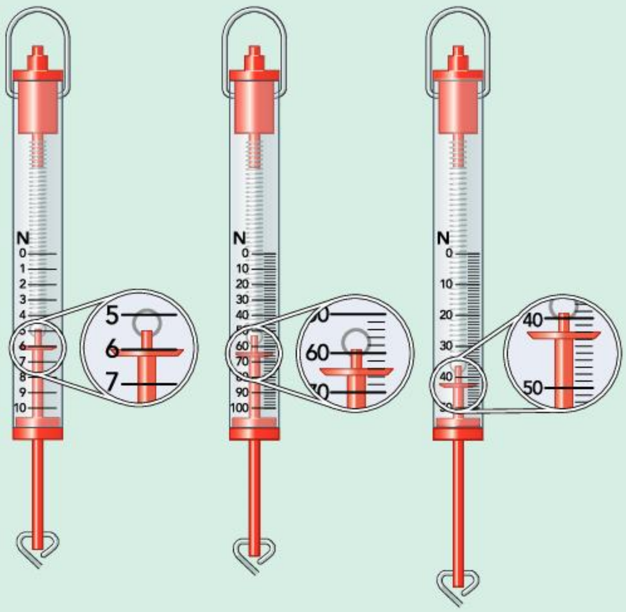
- **force**
- **newton**
- **newtonmeter (forcemeter)**

Summary questions

1 Copy and complete this sentence:

Forces are measures in a unit called ______. Forces can be shown as _____ on diagrams. A ______ can be used to measure a force.

2 What are the readings on these three newtonmeters?



3 Draw a diagram to show the forces that are acting on your book as it rests on the table.

10.2 Frictional forces

Learning outcomes

After this topic you should be able to:

- describe how friction acts to prevent or reduce movement
- repeat readings, display your results in a table and calculate averages.

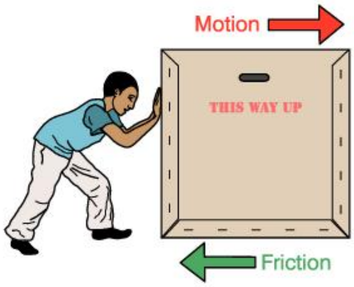
Expert tips

Frictional forces always try to prevent movement, so you should be able to work out the direction in which they are acting.

Key terms

- **friction**

When you slide an object across a flat surface it eventually stops. A force we call **friction** is acting on the object as it moves and this force slows it down.



The frictional force opposes the push on the box

When you try to push a heavy box; it can be hard to move. This is because there is a frictional force between the box and the ground. This frictional force is in the opposite direction to your pushing force. Frictional forces always oppose the movement of objects – if you went around to the other side of the box and tried to push it, the frictional forces would still push back against you.

Explaining friction

Friction is caused because the surfaces of the two objects lock together slightly. You can see this when you look at rough materials such as sandpaper. If you try to slide two pieces of sandpaper past each other, the rough pieces grip other rough pieces and the paper is hard to move.

Although surfaces look smooth, all of them are rough if you look closely enough. When the two surfaces get pushed past each other, the roughness causes them to catch – just like the sandpaper.

The rough parts of the surfaces catch on each other and prevent movement

The effect of weight

Another factor that affects the size of the frictional force is the weight of the object. A heavier object pushes further into the surface it is moving across, making the rough surfaces stick together more. This is why it is more difficult to push a box when it is full.

Practical activity Testing the size of frictional forces

Use newtonmeters to measure the size of frictional forces when a block is dragged across the floor or a desk.

- Record the results in a table like the one shown below.

Test the size of the forces when the block is dragged across different materials. You will find that the results are not very reliable, so repeat the tests to find average values for the forces.

Modify the experiment to test the effect of different masses by adding loads on top of the wooden block. The masses will push the surfaces into closer contact.

- Does doubling the weight of the object double the size of the frictional forces?

Make sure you have a clear space to carry out the experiments.

Surface material	Frictional force / N			
	Test 1	Test 2	Test 3	Mean (average)

Summary questions

1 What causes frictional force?

2 Two students measured the size of the frictional force when different masses were dragged across the floor.

Mass / kg	0.5	1.0	1.5	2.0	2.5
Frictional force / N	4.5	5.5	5.4	6.2	7.1

a) What conclusion can you make about the relationship between the size of the mass being dragged and the size of the fractional force?

b) What causes this relationship?

c) Which of the results are anomalous (do not fit the pattern)?

d) What improvements could you make to the experiment to make your conclusion more reliable?

10.3 Dealing with friction

Learning outcomes

After this topic you should be able to:

- investigate how frictional forces can be reduced using lubricants
- improve the quality of data collected
- describe how frictional forces can be increased to improve grip.

Friction can be a big problem and also a big help. We usually want things to move easily so we need to reduce friction. Sometimes, though, we want to increase the grip between objects.

Reducing friction

In engines, frictional forces between the moving parts release a lot of heat energy and this reduces the engine's efficiency. Sometimes the engine parts expand and seize up completely.

To reduce friction we can separate surfaces so that they do not rub together using a **lubricant**. This is a liquid that gets between the two surfaces and stops them touching. In an engine we use oil as the lubricant. There will still be a little frictional force between the engine parts and the oil but far less than before.

Engines contain hundreds of moving parts. Without a coating of oil they would not work

Oil is commonly used as a lubricant for machines but any liquid can act as a lubricant. If you slide down a waterslide, the water reduces the friction between you and the slide, making you go faster.

Practical activity Testing lubricants

Use a plank of wood and a 1 kg metal block or similar object to investigate the effect of lubricants on friction. The greater the angle you have to tilt the plank before the block begins to slide, the more friction there is. You can measure the height you have to lift the end of the plank to. Coat the plank in different lubricants and see how much you need to tilt it before the block begins to slide.

- How many times will you repeat each test?
- Record your results in a table.
- To display your results, will you use a bar chart or a line graph? (See page 222.)

Make sure you do not slip on the lubricants. Do not let them drip onto the floor.

Increasing friction

Sometimes we want to increase the amount of friction between surfaces, to increase grip. Materials such as rubber or plastic give high amounts of friction so they are added to surfaces where extra friction is helpful.

Car tyres are made of rubber to increase the friction between them and the road. They also have tread patterns to drive off the water, which can act as a lubricant and make the car slide.

This close-up shows the deliberately rough surface of a matchbox. When you strike a match, so much friction is caused that the match head bursts into flame

This rubber car tyre has good grip on the road and the tread pattern helps to push the water (a lubricant) out of the way

Practical activity Improving grip

Investigate which tread patterns on shoes give the best grip. Test how easy it is to pull different shoes across a surface. (You will probably need to weigh down the shoes a bit by putting a block of metal inside them.)

- Does the material that the sole of the shoe is made from make a difference?
- Does the tread pattern have any effect on the grip of the shoe?

Key terms

- **lubricant**

Summary questions

1 What is a lubricant?

2 What will happen to a car engine if it is not regularly topped up with oil?

3 a) Which parts of a bicycle need to have low levels of friction and which need high levels?

b) What materials are used for these different parts?

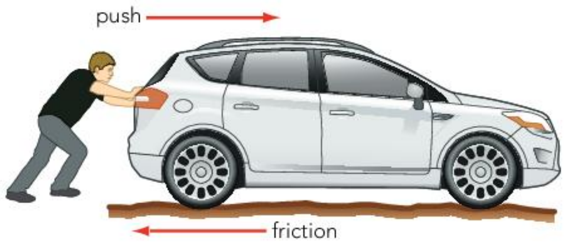
10.4 Forces in balance

Learning outcomes

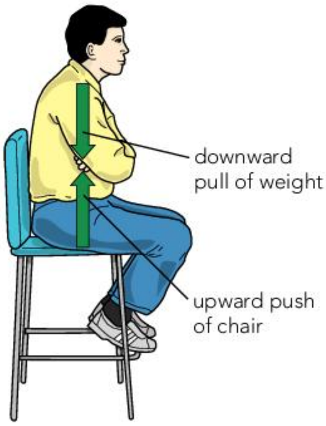
After this topic you should be able to:

- state what happens when forces are balanced or unbalanced
- calculate the resultant force acting on different objects.

If you try to push a car stuck in mud it probably will not move. Friction acts against the push and the two forces cancel each other out. We say that the forces are **balanced**.



The forces on this car are balanced



When you sit still the forces acting on you are balanced

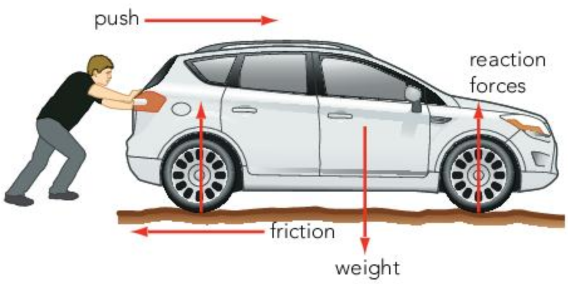
Balanced forces

When the forces on an object are balanced, the object can do one of two things:

- if the object is stationary, it stays stationary
- if the object is moving, it keeps moving at the same speed in a straight line.

Looking both ways

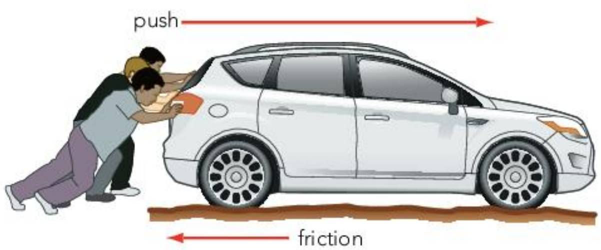
To understand what the forces are doing overall, we have to look at the forces that are acting horizontally and then the forces that are acting vertically. When you are pushing a car that is stuck in the mud, the friction and your push cancel each other out and these horizontal forces are balanced. There is also a force acting in the opposite direction to the weight of the car and these forces are balanced too.



Don't forget to think about all the forces when checking to see if they are balanced

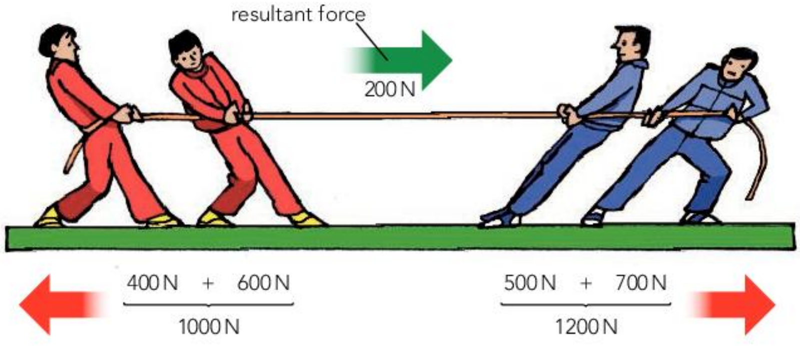
Unbalanced forces

A little help might get the car to start moving



If you get some friends to help, you might be able to make the car move. The frictional forces can't match your combined pushing force – the forces are **unbalanced**. We can find the overall effect of these unbalanced forces by finding the **resultant force**.

To find the resultant force you can add all of the horizontal forces going in one direction and then take away the forces going in the opposite direction.



The resultant force here is 200 N to the right

Acceleration

An unbalanced force will change the speed or direction of the object it is acting on. This change is called acceleration.

The size of the acceleration will depend on the size of the resultant force and the mass of the object. A small resultant force will accelerate a large object a small amount; a large resultant force will accelerate it more.

Key terms

- **balanced**
- **resultant force**
- **unbalanced**

Practical activity Testing balanced forces

Use newtonmeters to test the idea of balanced forces. Tie two newtonmeters to a piece of string and use them to pull in one direction and use a third newtonmeter to pull in the opposite direction. Try this for a range of 'pulls' to see if you always get a resultant force of zero.

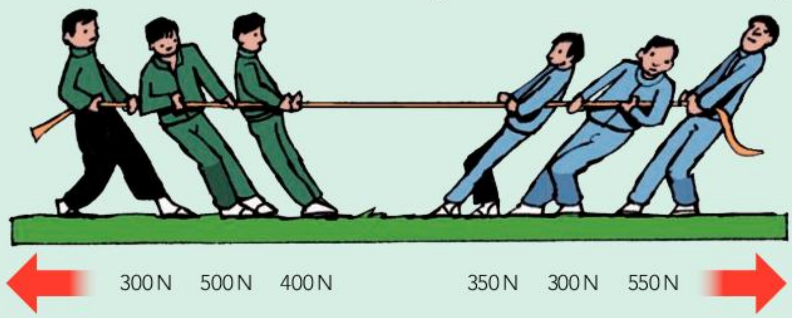
- Comment on the accuracy of your readings.

⚠ **Don't pull too hard on the meters and over-stretch them.**

Summary questions

1 What are balanced forces? What do unbalanced forces cause?

2 Work out the resultant force in this tug of war. Which side is winning?



3 Which one of these involves balanced forces?

A a car that is stationary

B a car speeding up

C a car travelling at a steady speed

10.5 Gravity and weight

Learning outcomes

After this topic you should be able to:

- explain the difference between mass and weight
- calculate the weight of objects in different locations using the strength of gravity.

This piece of material is a copy of the 'International Prototype Kilogram' and it has a mass of exactly 1 kg

When you 'weigh' yourself on bathroom scales you are actually measuring your mass. There is an important difference between the mass of an object and its weight.

Mass

The mass of an object is a measure of how much matter (material) is in it. That depends on how many particles there are inside it. Mass is measured in kilograms (kg).

The mass of an object is always the same. If a metal block has a mass of 1 kg in a laboratory then it will have a mass of 1 kg even if it were on the Moon because it still has the same number of particles in it.

Weight and gravity

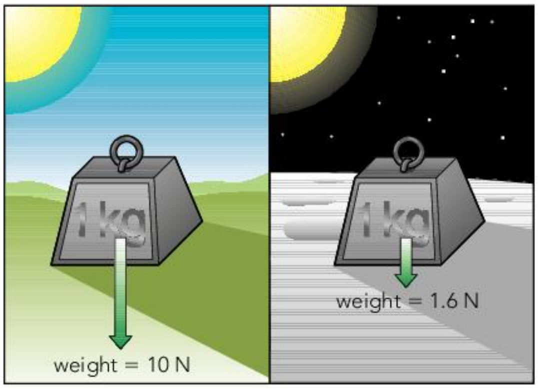
The **weight** of an object is the force that pulls it downwards. This force only exists because it is near the Earth. The mass of the Earth attracts the mass of the object and this is what causes the weight.

Because weight is a force it is measured in newtons, just like all other forces.

To find the weight of an object you need to know how strong gravity is. On Earth the **strength of gravity** is approximately 10 newtons per kilogram of mass in the object.

- A 1 kg object on the Earth would weigh 10 N (1 × 10).
- A 40 kg object on the Earth would weigh 400 N (40 × 10).

If you could take the object to the Moon it would weigh less. This is because the Moon is smaller than the Earth and the Moon has less mass, so the gravitational attraction is smaller. On the Moon, the strength of gravity is only 1.6 newtons per kilogram.



The mass stays the same but the weight is different

If you took an object far away from any planet or other large object it would be weightless because there would be no gravity.

Practical activity What would it weigh?

The weight of objects changes depending upon the planet they are on.

- Copy and complete this table to show the weights of some common objects on different planets and the Moon.

Object	Location	Strength of gravity / N/kg	Mass / kg	Weight / N
Lunar Roving Vehicle	The Moon	1.6	210	
Venera-13 space probe	Venus	8.9	760	
a car	Mercury		100	370
a helium airship	Jupiter	24.8		30 000

- Once you have completed the calculations you can produce posters illustrating the differences in the weight of objects on different planets. Make sure that these clearly explain the difference between mass and weight.

The Lunar Roving Vehicle was used to explore the Moon in the 1970s

Expert tips

It is easy to get confused about mass and weight. Make sure that you can explain the difference clearly.

Key terms

- **strength of gravity**
- **weight**

Summary questions

1 **a)** Explain the difference between mass and weight.

b) The strength of gravity on Earth is actually closer to 9.8 newtons per kilogram. Recalculate all of the weights of the masses mentioned in the examples on these pages.

2 Scales are often used to measure the mass of objects. Why wouldn't these work properly on the Moon?

3 An Olympic weightlifter can lift 472 kg on Earth.

a) What is the size of the force the weightlifter uses to do this?

b) If the weightlifter could go to Mars, where the strength of gravity is 3.7 N/kg, what is the maximum mass he could lift up?

10.6 Moving through fluids

Learning outcomes

After this topic you should be able to:

- explain the meaning of air resistance (drag)
- test the effect of streamlining on movement through fluids
- record and display your results effectively.

Expert tips

Smooth, curved shapes are more streamlined than angular or straight edges.

When you run quickly through the air or ride on a bicycle you can feel the air rushing past your face. You can also feel water pushing against you as you try to swim though it. Gases and liquids are **fluids** – their particles can be moved about and we can pass through them (see page 89).

It is very difficult to push yourself through water at high speed

Moving through the air

It is fairly easy to push through the air when you are moving slowly but it becomes harder when you go quickly. The faster you travel the more particles you need to push out of your way each second. This means that you need to use a bigger force. As you travel the air resists your movement (the particles push back). We say there is **air resistance** or **drag**. The faster you go, the larger the drag will be.

Streamlining

Air resistance will slow you down or even bring you to a stop, just like other frictional forces. Modern cars are **streamlined** to reduce air resistance. Their shape allows air to flow over them smoothly.

This sports car is highly streamlined

Moving through water

The particles in water are much closer together than those in air so you have to push more of them out of the way to move through it. This makes it much harder to move through water than to move through air.

Boats need large engines to overcome this drag from the water and it limits their top speed.

To go really fast, boats are designed to lift themselves out of the water as much as possible so that they don't have to push through it.

This fast boat skims across the top surface of the water, reducing the water resistance

Key terms

- **air resistance**
- **drag**
- **fluid**
- **streamlined**

Practical activity Testing streamlined shapes

You can find out if changing the shape of an object affects how easily it moves through a fluid. Use 10 g pieces of modelling clay and design a set of shapes (such as spheres, disks and teardrops). Drop the shapes down a cylinder containing a thick fluid and record how much time it takes for them to fall to the bottom. Sketch all your designs before you start dropping them through the fluid.

- Why was it important to make all of the objects 10 g in mass?
- In what ways will you record and display your results?
- Which shapes were the most streamlined and which were the least?

⚠ **Be careful to avoid spilling the liquid.**

Summary questions

1 Copy and complete:

Gases and liquids are both ____ because their particles are free to move. When we move through the air there is a force called ________ (or ________) that opposes this movement. To make this movement easier, cars and other vehicles are ____________ using smooth curved shapes.

2 **a)** Why is it more difficult to travel through water than it is to travel through air?

b) Why don't artificial satellites need to be streamlined?

3 This truck is not very streamlined. Draw a new design that would allow the lorry to move more efficiently.

10.7 Stretching and squashing

Learning outcomes

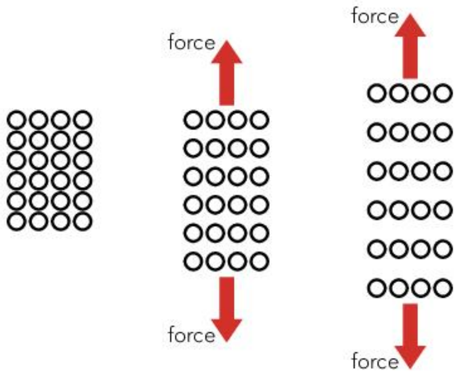
After this topic you should be able to:

- investigate the behaviour of elastic as it stretches
- design an experiment to test how a material can be compressed
- make scientific predictions about stretching materials
- present conclusions to others in different ways.

Forces can change the motion of an object. They can also change the shape of an object by stretching or squashing it.

Stretching

When a solid object is stretched by forces, the particles in the solid are pulled and move further apart. This makes the object longer. As you use more force the object continues to stretch. If the force becomes too large the particles can separate from each other and the material breaks.



The particles are being pulled further apart making the object longer

An object that is being stretched is under **tension**. Some materials will not stretch much before they break but others will stretch a great deal. It's easy to see this stretching behaviour in elastic. When you apply a force to the elastic it stretches and becomes thinner. The force is untangling the chains of particles inside the elastic and so the elastic becomes longer.

Practical activity Stretching elastic

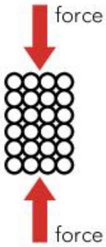
You have been given an elastic band or piece of elastic. Design and carry out a test to see if there is a relationship to how much it stretches when different forces act on it. You will have to measure the length of the elastic when different masses are attached to the end to produce different sized forces.

- Plot a graph to show the relationship.
- Test a second, thicker elastic band and see if the relationship is the same.
- Carry out the same test on metal springs. Make a prediction before you start. Plot a graph and describe the relationship. Do the springs behave in the same way as elastic? Try to explain why.

Be careful not to drop any of the masses on your feet.

Squashing

When forces squash an object we say that it is being **compressed**. The particles are forced closer together. As they get closer they repel each other more and more, and it gets more difficult to force them closer together. There is therefore a limit to how much we can squash an object. The particles in solids or liquids are already very close together so they are fairly incompressible. On the other hand, gases can be easily compressed.



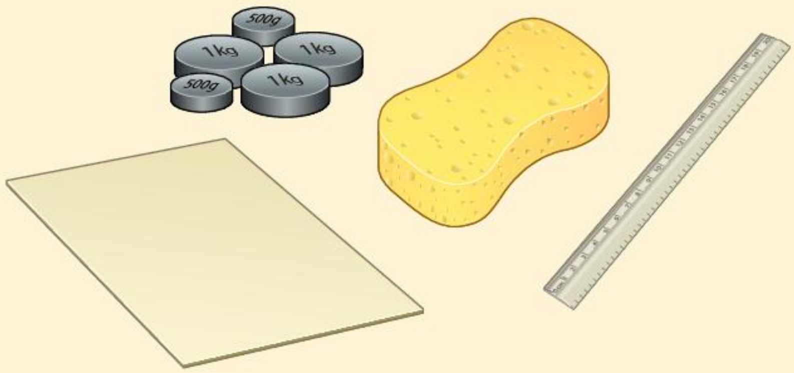
The particles are being forced closer together. This makes the object shorter

Key terms

- **compressed**
- **tension**

Practical activity Squashing a sponge

Think of a way to test if there is a relationship between the force applied to a sponge and how much it gets compressed. Use the equipment you have been given to design a test and then carry it out. You will have to measure the size of the sponge when there are different forces squashing it down.



- Plot a graph showing the amount of force (or mass) used to squash the sponge against how much it has been squashed.
- Design your own way to present your conclusions clearly to the rest of the class.

Be careful not to drop any of the masses on your feet.

Summary questions

1 Two students think that there is a relationship between the diameter of a strip of elastic and the amount it stretches. They test their idea by stretching five strips of elastic with different diameters using a force of 10 N. Their results are shown below.

Diameter / mm	1	1.2	1.5	1.7	2	2.5
Extension / cm	60	50	39	40	23	11

a) Plot a suitable graph to show their results.

b) Describe the relationship of the results and give a conclusion for the experiment.

c) Are there any anomalous results? If so, identify them.

2 Plan a test to see if there is a relationship between the force applied to a gas and its volume. You will need to include a container that can contain gas and enable you to measure the volume of the gas when it is squashed by different forces.

10.8 Measuring density

Learning outcomes

After this topic you should be able to:

- calculate the density of a material
- carry out an experiment to measure the density of an irregularly shaped object.

Material	Density / g/cm^3
air	0.001
water	1.00
aluminium	2.70
lead	11.34

Some example densities; you can find more in the table in topic 6.5 (page 116)

In chapter 6 you found out about the properties of a material. One of these properties was **density**. The density was a measure of how 'heavy' the object was for its size. Now that you understand the difference between mass and weight you will be able to calculate the density of materials or objects by measuring them.

Different materials have different densities

Defining density

Density is defined as the amount of mass an object has in a fixed volume. This means that if you can measure the mass and volume of a sample you can easily calculate the density.

Calculating density

To calculate the density of a piece of material you need to use the simple formula:

density = mass ÷ volume

For example, if a block of iron has a mass of 160 g and a volume of 20 cm^3:

density of the iron = 160 ÷ 20 = 8.0 g/cm^3

There are two sets of units that are commonly used for density:

- mass in grams and volume in cubic centimetres give density in g/cm^3
- mass in kilograms and volume in cubic metres give density in kg/m^3.

When you are using small amounts of material you will probably use g/cm^3. For larger amounts, use kg/m^3.

Measuring density

To measure the density of a material you need to measure its mass and volume.

Simple shapes

Many objects have regular shapes such as cubes or spheres. You can find their volume with simple calculations and their mass with a balance.

Expert tips

Remember that you have to use the mass of an object to find the density – not its weight.

Key terms

- **density**

Practical activity The density of simple objects

You have been given a set of materials with simple shapes. Lift them up and put them in order of what you estimate to be increasing density. Use a ruler to measure the dimensions of the objects and calculate their volumes. Then use the top pan balance to measure their mass. Use these figures to calculate the density of the objects.

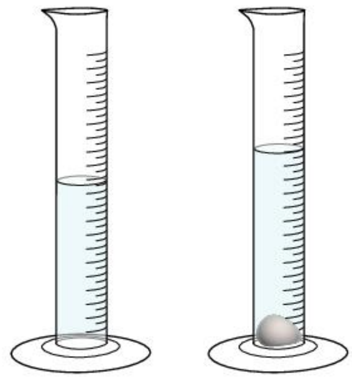
- Put all of your measurements in a clear table.
- Measure volume in cm^3 and mass in grams.

Did you correctly estimate the order of the samples before you measured them?

Unusual shapes

Most objects are not simple shapes; you can't find their volume using a ruler and calculator.

If you place an object that sinks into a container partly full of water then the level of the water will rise. You can measure the increase in volume if you use a measuring cylinder as the container. This increase in volume is the same as the volume of the object that you dropped in.



Using a measuring cylinder to find the volume of objects

Practical activity Measuring the density of unusually shaped objects

Use a measuring cylinder to measure the volume of the objects provided.

- Half fill the cylinder with water and record the volume measurement.
- Now add an object and record the new volume reading.
- Find the increase in volume reading; this is the volume of the object.
- Use a top pan balance to measure the mass of the object. You can then calculate its density.

As you are working with small objects, measure mass in grams and volume in cm^3.

Summary questions

1 Copy and complete this table to show the densities of the samples of material.

Material	Mass / g	Volume / cm^3	Density / g/cm^3
gold	965	50	
diamond	0.5	0.14	
expanded polystyrene		250	0.075

2 Some objects float on water. Design an experiment that will let you measure the volume of an object that floats so that you can find its density. (Hint: you have to **make** the object sink.)

10.9 Upthrust, floating and sinking

Learning outcomes

After this topic you should be able to:

- explain why some objects float and some do not
- measure carefully the upthrust acting on a range of objects.

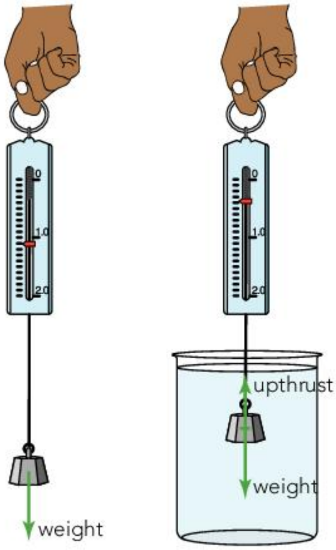
Upthrust

When an object is placed in water a force called **upthrust** acts on it and pushes it upwards.

- If this upthrust is the same as the weight of the object, the object will float. The forces are balanced.
- If the upthrust is less than the weight of the object, it will sink.

With careful design huge objects can be made to float on water.

Some super tankers weigh over five billion newtons. The upthrust from the water keeps them afloat



The upthrust reduces the measured weight of an object

Practical activity Measuring the effect of upthrust

You can use a newtonmeter to calculate the upthrust on an object.

- Measure and record the weight of an object.
- Place the object in water so that it fully submerges and record the new reading on the newtonmeter.

The upthrust will be the difference between these two readings.

Sinking and floating

For an object to float the upthrust has to match the weight of the object. The balanced forces mean that the object will stay on the surface.

Making ships float

A solid block of steel will sink quickly. The block has a high density and the upthrust from water cannot match the weight of the block.

Most ships are built from steel but they are hollow. They contain lots of air. The overall density of a ship is therefore much less than that of a solid block. The ship floats because the upthrust can match its weight.

If you load a ship with cargo, the ship will become heavier and sink lower into the water. This causes an increase in the upthrust, which again balances the weight. If you keep on adding cargo to the ship, it will eventually sink.

Controlled sinking

Submarines are able to float or sink when they need to. They contain large tanks that can be filled with water or air.

- When the tanks are filled with air the submarine's weight is the same as the upthrust provided by the water. This makes the submarine float just like a ship.
- When the submarine needs to submerge the tanks are pumped full of seawater. The submarine's weight is now greater than the upthrust so it sinks.

To get back to the surface this submarine will push the seawater out of its tanks and reduce its weight

Key terms

- **upthrust**

Summary questions

1 Copy and complete:

Objects float when the ____________ is the same size as their weight; they sink when their ______ is greater than the ___________. When a ship is loaded with cargo its weight _______ and its upthrust _______, this means that it ________.

2 Deep-sea divers have large tanks of air attached to their backs. The divers all need to have masses attached to them. Why do they need the masses?

10.10 Forces at work

Learning outcomes

After this topic you should be able to:

- describe how engineers use shapes to spread forces through a building
- use your understanding of forces to design a strong bridge or tower.

Engineers design buildings using their knowledge of forces. They need to understand how the forces will affect a building's strength. This involves very complicated analysis using computer simulations and careful testing of materials.

Strong shapes for building

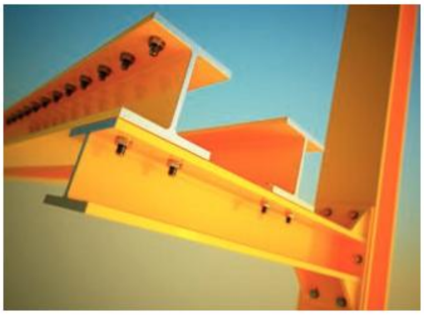
Arches have been used in construction, especially bridges, for thousands of years. Arches are very good at supporting weight and spreading out the stress on the building. Roman viaducts and amphitheatres used rows of arches on top of each other so that very tall buildings could be constructed. Similar arch shapes can be seen in some modern road bridges where the road is suspended by cables from a strong arch above it.

This Roman viaduct in Pont du Gard, France, has stood for 2000 years

Skyscrapers are built from grids of steel girders joined at right angles. These can be strengthened with concrete, which is very strong when it is being compressed (squashed).

These skyscrapers in Dubai have been built using steel grids for strength

To stop large buildings from bending, triangular supports are sometimes used. These act in a similar way to arches, spreading the forces through the structure.



I-beams are used in the construction of large buildings. They are much lighter than solid beams and nearly as strong

Practical activity Bridge building

You have been given a set of construction materials. Your job is to construct the longest span of bridge possible. The bridge needs to be able to support a 50 g mass placed in the middle of it.

- Use the ideas from this page to make your bridge as strong as it can possibly be.
- You could also attempt to build the tallest tower possible from the materials.

Forces in crashes

Engineers have to understand what happens to cars when they crash. Strong box shapes around the driver and passenger area are used to keep it in shape during collisions. They also design areas of the cars, called **crumple zones**, which will deliberately fold up to absorb the kinetic energy of a collision.

This car has crashed into a steel pole. Nobody was hurt because the front part of the car crumpled and absorbed the kinetic energy of the car

The inside of this racing car has extra steel tubing to create a strong protective cage for the driver. Normal cars are designed to have strong passenger areas too

Practical activity Crumple zone

Use the materials you have been given to build a crumple zone for a toy car.

Attach it to the car and see how effective it is at absorbing the energy of a crash.

Use a ramp to make sure the car crashes into a wall at the same speed each time.

- What can you use to simulate a passenger in the car?

Key terms

- **crumple zone**

Summary questions

1. Why are arches used in construction?
2. Find out about of the construction of the tallest building or longest bridge in your region.
3. What safety features, besides the ones mentioned on these pages, are used in cars to protect the driver and passengers?

Chapter 10 End of chapter questions

1 Which of the following words can be used describe what a force can do?

speed, stretch, pull, expand, push, change, energy, turn *[4]*

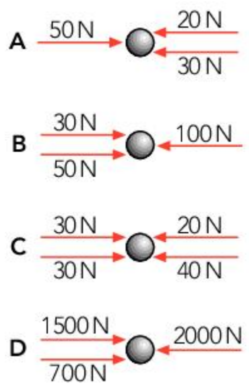
2 Copy and complete the following table of information about mass and weight.

Quantity	Definition	Measured in	Can it change?
mass			
weight			

[2]

3 Why are wet floors slippery? *[2]*

4 Copy and complete the table below, showing in which of these diagrams the forces are balanced. *[4]*



Ball	Forces to left	Forces to right	Forces balanced?
A			
B			
C			
D			

5 Describe a way you can increase the friction to help move a car that is stuck in mud. *[1]*

6 Which of these weighs the most?

a a 5 kg mass placed on Earth (strength of gravity 10 N/kg) *[1]*

b a 10 kg mass placed on Mars (strength of gravity 3.7 N/kg) *[1]*

c a 50 kg mass placed on the moon Titan (strength of gravity 1.35 N/kg) *[1]*

7 Felipe and Rafael are investigating how a spring behaves when it stretches. They hang masses from it and measure the changes in length as accurately as they can.

Weight / N	Length of spring / mm	Increase in length / mm
0	50	0
2	64	
4	78	
8	93	
10	106	
12	120	

a Copy and complete the table to show the increases in length. *[1]*

b Draw a graph showing the results. *[4]*

c Make a detailed conclusion about the way in which the spring behaves. *[2]*

8 Which of these factors can affect how long a car takes to stop?

A the speed of the car

B the mass of the car

C the colour of the car

D whether or not the road is wet

E the tread on the tyres *[4]*

9 A boat weighing 10 000 N is floating on a lake. A group of people weighing a total of 3000 N gets into the boat.

a What is the size of the upthrust on the boat before the people get on? *[1]*

b What is the size of the upthrust on the boat after the people get on? *[1]*

c Draw a force diagram of the boat before the people get on. *[1]*

d Draw a force diagram of the boat after the people get on. *[1]*

e What happens to the depth the boat is in the water when the people get on? *[1]*

10 In an experiment to find the frictional force produced when pushing a weighted tray across different surfaces, students gathered these results.

Surface	Friction / N				
	Test 1	Test 2	Test 3	Test 4	Test 5
wooden desk-top	12.5	14.0	20.5	21.5	21.5
floor	16.5	18.5	21.0	24.0	16.0
carpet	40.5	25.0	34.0	39.0	36.0

a Why did the students repeat each test five times? *[1]*

b Which surface produced the greatest average frictional force? *[1]*

c Comment on the reliability of the results. What evidence did you use? *[2]*

11 A cube of metal with a side length of 15 cm has a mass of 1 kg. What is the density of the metal? *[2]*

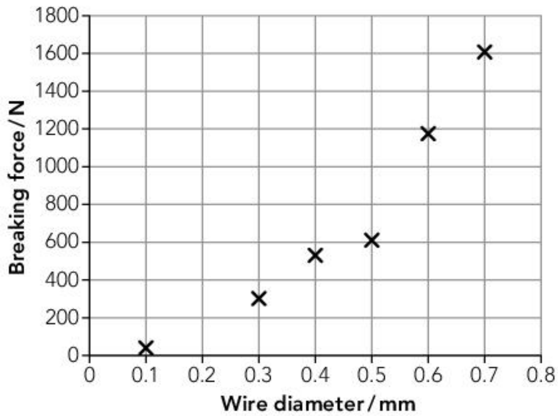
12 Aluminium has a density of 2.7 g/cm^3. Lead has a density of 11.34 g/cm^3. What volume of aluminium has the same mass as a 100 cm^3 lead block? [2]

13 Engineers in a laboratory tested the strength of carbon fibre cables to evaluate their usefulness in construction. The engineers increased the force acting on wires of different diameters until the wire snapped. The results of the tests are shown in the graph.

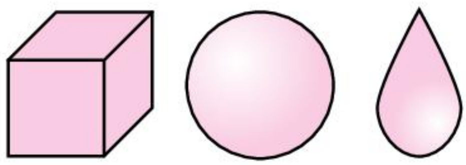
a Which of the results from the experiment was anomalous? *[1]*

b Describe the relationship between the wire diameter and the force required to break the wire. *[1]*

c Estimate the force required to break a carbon fibre cable with a diameter of 0.2 mm. *[1]*



14 Three metal objects, all with the same mass are dropped into a deep pool of water.



a Which of the objects will reach the bottom of the pool first? *[2]*

b Explain your answer. *[1]*

Science *in context!* Resources in the Solar System

'Big blue marble'

The Earth has limited resources to provide the materials and energy we need. As we use up these resources they become harder to obtain. But the Earth is only a tiny part of the Solar System, and scientists and engineers are already thinking about how we could harvest resources from space.

Mining asteroids

Most of the metal on the Earth is trapped far beneath the surface where we can't reach it. However, there is a huge supply of metals within asteroids, and it might be easier to go and mine these than try to dig even deeper into the Earth.

Most asteroids are located in the asteroid belt but there are thousands much closer. These 'near-Earth asteroids' contain massive quantities of metals such as nickel and iron. They even contain precious metals such as gold and platinum.

Some governments and companies are already investigating the idea of mining asteroids to obtain their resources. These could be used in space to build new bases and spacecraft. This might be much cheaper than transporting the materials from the Earth's surface using rockets.

An artist's concept of a mining settlement on the double asteroid 90 Antiope; bases like this could be used to collect resources from asteroids

Limitless energy?

Some scientists have ideas about building giant solar panels in space to collect energy and transfer it to the Earth. These panels would be very difficult to build on Earth and send into orbit, and would need huge amounts of fuel. There might be another way of building large objects in space.

A robotic probe (spacecraft) could be sent to a near-Earth asteroid or even the asteroid belt to collect materials. It could use these materials to build a second robotic probe and these two probes could make more and more robots. Eventually there would be millions or billions of robots that could be used to build gigantic solar power plants in space. These could provide us with almost limitless energy and collect all of the resources we need to move out into the Solar System.

The new Space Race

In the past, government agencies such as NASA and the Soviet Space Programme were the only organisations with enough money and resources to explore space. These explorations were carried out to improve scientific knowledge and develop new technologies. Now new countries including China and India and even private companies are starting to reach out into space. With technology being developed that will help us to start harvesting the riches of asteroids we might be at the start of the second Space Race. Will you be part of it?

In this chapter you will learn about the behaviour of the Earth and Moon as they travel around the Sun. You will find out how scientists have explored the Solar System and discovered the wonders of the wider Universe.

China has invested heavily in space exploration and is planning a manned visit to the Moon and Mars

Key points

- The Earth takes 24 hours to rotate about its axis; this causes day and night.
- The Earth takes one year to orbit the Sun. Its axis is tilted and this tilt causes the seasons.
- The Moon orbits that Earth every 28 days.
- The phases of the Moon are caused when we see different parts of the Moon's surface lit up by sunlight.
- The Solar System contains one star (the Sun) orbited by eight planets.
- There are millions of other smaller objects in orbit around the Sun including dwarf planets, asteroids and comets.
- A galaxy is a collection of billions of stars and their Solar Systems and the Universe contains billions of galaxies.
- Our ideas about the Solar System and the greater Universe have changed over time as new ideas and new technology have allowed us to gather more evidence.

11.1 The Earth and the Sun

Learning outcomes

After this topic you should be able to:

- describe why we experience days, nights and seasons
- describe the apparent movement of the stars during the night and during the year
- construct a model of the Earth and Sun.

Day and night. You can see that only half of the Earth is in daylight at any one time

Each curved line in this image shows the apparent movement of a star at night. The star named Polaris is directly in line with the Earth's axis of rotation and so does not appear to move

For thousands of years people have looked up into the sky and wondered about what they saw. Through careful observations our ideas have developed into our models of the Solar System and greater Universe.

Day and night

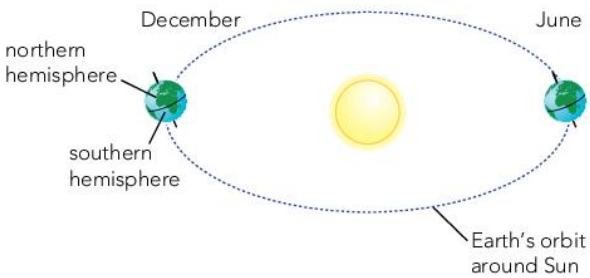
The Earth is a large sphere that rotates on its **axis** as it travels around the Sun. Each rotation takes 24 hours so this is the length of one **day**. The light from the Sun only falls on one half of the Earth at a time so we always have half of the Earth in daytime. The other half is in night-time.

Because the Earth is rotating it looks as though the Sun moves across the sky during the day. It is hard to believe that the Earth is rotating because we cannot feel it moving but this movement can be detected by careful measurement.

The apparent movement of the stars also gives evidence about the Earth's rotation. As planet Earth spins, the stars appear to move across the night sky. The stars are not actually moving in this way; they just look as though they are because of the Earth's rotation.

The year

As the Earth rotates, it **orbits** the Sun in an almost circular path (a slight ellipse), taking one **year** to complete each orbit. During this time it rotates on its own axis $365\frac{1}{4}$ times and so a year is $365\frac{1}{4}$ days long. To make our lives easier, we have 365 days in most years and then an extra day in each fourth year (called a leap year).



The Earth's path around the Sun. The different hemispheres are tilted towards the Sun six months apart causing the seasons

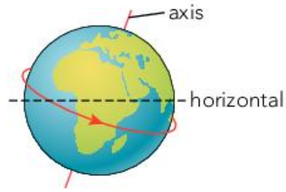
As the Earth orbits the Sun during the year the positions of the stars seem to change in relation to the Sun. The positions of the stars in relation to each other do not change because they are all very far away.

Seasons

The Earth rotates about an imaginary line, called its axis. The axis passes from the South to North poles. This is tilted at 23 degrees compared to the orbit path.

Because of this tilt, the northern part of the Earth (the northern hemisphere) is tilted towards the Sun during the months of May to August compared to the southern hemisphere. During these months the northern hemisphere gets more sunlight and the temperature is higher because of this extra energy from the Sun. The southern hemisphere is tilted away from the Sun during these months and so is colder and experiences winter. The situation is reversed six months later when the southern hemisphere is in summer and the northern hemisphere in winter.

The seasons are not as obvious near the equator. The temperature differences are much smaller over the year and the weather is more dominated by amounts of rainfall giving wet and dry seasons.



The Earth's tilted axis makes some parts of it point towards the Sun more than others

Practical activity A simple model of the Earth and Sun

The behaviour of the Earth and Sun can be explored with a simple model. Use a bright lamp to simulate the Sun and a ball (or a small globe if you have one) to represent the Earth.

Rotate the ball and you should see that half of it is always illuminated by the sunlight while the other half is in darkness.

- Draw a dot on the 'Earth' to represent your position and rotate the Earth slowly anticlockwise. Imagine what you would see if you were standing on the dot; the Sun would appear to be moving from east to west.

A model of the Earth and the Sun

The lamp may become very hot so don't touch it until it has cooled.

Key terms

- **axis**
- **day**
- **orbit**
- **year**

Summary questions

1 Copy and complete these sentences:

During summer in Australia the days are ______ than they are in winter. This is because the _______ hemisphere is tilted ______ the Sun. At the same time the northern hemisphere is in ________.

2 During winter in the northern hemisphere the North Pole and other locations at extreme northern latitudes are in complete darkness for several months. During summer they have no night time at all. Draw a diagram to explain why this happens.

11.2 The Moon

Learning outcomes

After this topic you should be able to:

- explain why the Moon appears to change shape over the course of a month
- explain how solar and lunar eclipses happen.

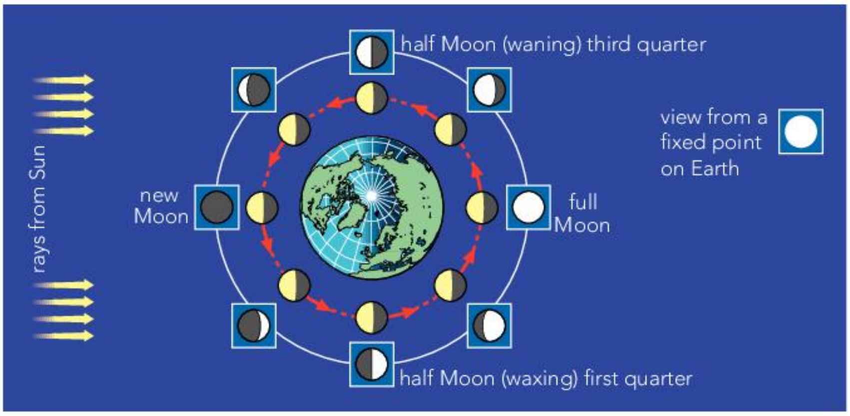
The Moon is a large ball of rock, about a hundredth of the mass of the Earth, and it orbits us once in about every 28 days. Because the Moon is so obvious in the sky it has been studied in great detail.

Phases of the Moon

The Moon does not produce light; it reflects light from the Sun off its silvery grey surface. This means that we can only really see the parts of the Moon that are facing the Sun. Depending on our position on the Earth we will see different parts of the Moon lit up on different days. The changing shapes that we see are called the **phases of the Moon**. Use the practical activity to help you to understand why we see different parts of the Moon at different times.

Expert tips

Remember the Moon does not change shape; it only looks like it does because you view it from different angles during the lunar month.

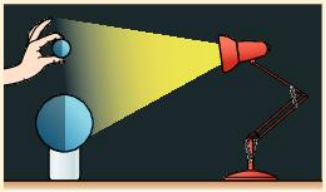


This illustration shows the phases of the Moon as you would see them from the Earth

Practical activity Exploring the phases of the Moon

Use a lamp and two balls to model the phases of the Moon. Use the large ball to represent the Earth and the smaller one to represent the Moon. (The lamp represents the Sun.)

- You can mark points on the 'Earth' and try to draw what you would see when the 'Moon' is in different positions during its orbit around us.
- It can help to see the pattern if you colour half of the 'Moon' black and always keep this part pointing away from the 'Sun'.



Model to illustrate the phases of the Moon

The lamp may become hot so do not touch it until it has cooled.

Eclipses

At different times, the Earth and Moon can each get in front of each other. This leads to spectacular events, called eclipses.

Solar eclipse

On rare occasions the Moon can pass directly between the Earth and Sun. Because the Moon appears almost exactly the same size as the Sun (it is much smaller but also much closer) the Moon can block out all of the light. This leaves parts of the Earth in complete darkness; a total **solar eclipse**. These events allow us to observe the outer atmosphere of the Sun directly.

Never look directly at the Sun with the naked eye.

Other parts of the Earth have some of the light blocked out by the Moon but they are not in complete darkness. This is called a partial eclipse.

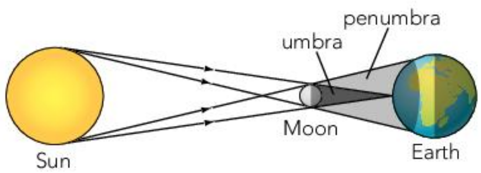


Diagram showing a solar eclipse

Lunar eclipse

Sometimes the Earth blocks the light from the Sun reaching the Moon. As the Moon passes through the Earth's shadow parts of the Moon's surface seem to vanish. When the Moon is completely in the shadow the surface can just be seen as it is lit up by light refracted (bent) by the Earth's atmosphere.

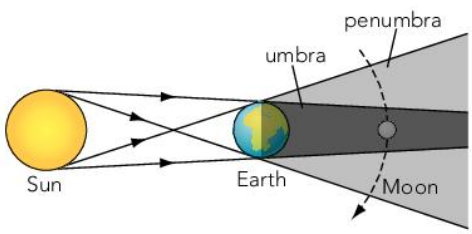


Diagram showing a lunar eclipse

Key terms

- **phases of the Moon**
- **solar eclipse**

Summary questions

1. What evidence is there that the Moon does not give out light of its own?
2. Copy and complete this sentence:

   A _______ eclipse happens when the _____ passes between the __________ and the Sun.

   It blocks out the light from the ____ and puts part of the Earth in shadow.
3. Imagine you are standing on the Moon during different types of eclipse.
   a) Describe what you would see happening during a lunar eclipse.
   b) What would be happening during a solar eclipse if you stood on a part of the Moon facing the Sun?

11.3 The Sun and the planets

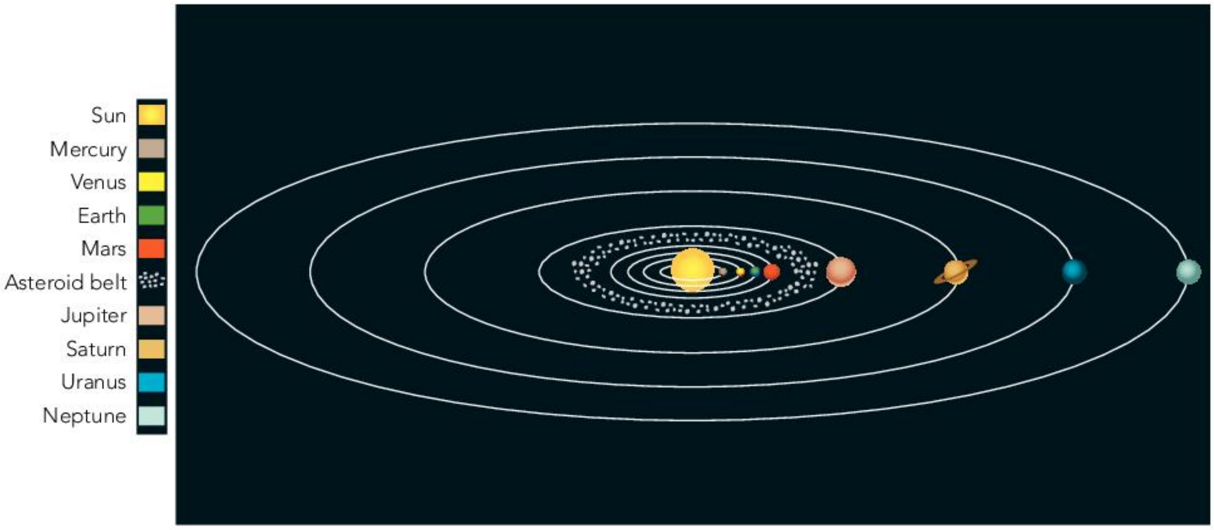
Learning outcomes

After this topic you should be able to:

- describe the characteristics of the eight planets
- construct a scale model of the Solar System.

The Solar System is made up of a very large number of objects that orbit around our star: the Sun. The Sun is the central point in our Solar System and is the only source of visible light. There are eight planets that orbit the Sun at different distances. We can observe the planets using the light they reflect from the Sun.

Describing the planets



The Solar System (not to scale)

Mars – a terrestrial (rocky) planet

The inner planets

The four planets nearest the Sun are Mercury, Venus, Earth and Mars. These are all composed of solid rock and are called the 'terrestrial planets'.

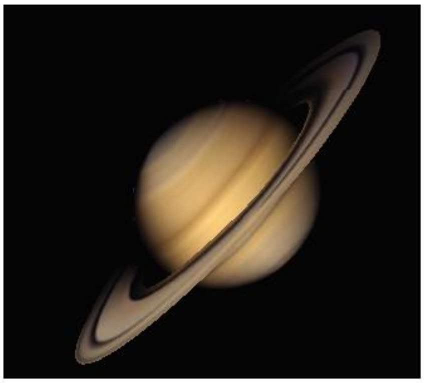
Mercury is the closest planet to the Sun. It is the smallest planet and has a very high surface temperature because of the amount of sunlight it receives on its surface. Mercury has no atmosphere.

Venus is very similar in size to the Earth but it has a much thicker atmosphere. This atmosphere traps in heat energy through a process called the greenhouse effect. This trapped heat makes Venus the hottest planet.

Earth is our home world. It is at just the right distance from the Sun to have liquid water covering most of its surface. The Earth is also large enough to hold on to an atmosphere of nitrogen and oxygen. This enables life to exist.

Mars is about a third of the mass of the Earth. Its reddish colour comes from the iron oxide in its soil. Mars has a very thin atmosphere of carbon dioxide.

The outer planets


Saturn – a gas giant with clearly visible rings

The four outer planets are very different from the inner planets. They are much, much larger and do not have solid surfaces. Instead they are composed of swirling layers of cold gases, such as hydrogen or helium, and super-cool liquids such as ammonia.

Jupiter is the largest planet in the Solar System by far. Its surface consists of bands of rapidly rotating gases which form massive storms. The Great Red Spot is a huge storm which has been raging for three hundred years. Jupiter has over 60 moons with a wide range of sizes.

Saturn is another gas giant but it has an amazing system of 'rings' around it. These are trillions of tiny particles of dust and ice that have formed a series of layers (rings) that orbit around the planet.

Uranus is a smaller gas giant and, because it is more distant from the Sun, its surface is much colder and its atmosphere contains solid ammonia. It has a smooth blue appearance.

Neptune is the most distant planet from the Sun and so has the coldest surface. It is very similar to Uranus but its atmosphere shows more weather patterns. It has white 'clouds' and huge storms called 'great dark spots'.

Practical activity Helping to understand the sizes of the planets

It can be difficult to understand the size of the planets compared to each other and the Sun. Use the data from this table to make a set of planets from a range of sports balls and modelling clay. Work to a scale of 1:1000 000 000. You will have to draw out a circle to mark out the size of the Sun: its diameter is 1 391 000 km so it will have a diameter of nearly 1.4 metres in the model.

Planet	Mercury	Venus	Earth	Mars	Jupiter	Saturn	Uranus	Neptune
Real diameter / km	4878	12 104	12 756	6787	142 800	120 000	51 118	49 528
Model diameter / mm	5	12	13	7	143	120	51	50

You can use the data from the next pages to make a scale model of the Solar System. The Earth would be 149.5 m from the Sun using the scale for the planets model. You might find it difficult to fit in any of the gas giants in your scale model.

Summary questions

1 Summarise the differences between the inner and outer planets.

2 A mnemonic can be used to help learn the order of the planets from the Sun. For example 'My Very Easy Method, Just Speeds Up Names' can be used, each word has the same first letter as the planets in the same order. Think up your own mnemonic to help you remember the order.

3 We see Jupiter and Mars because they reflect sunlight towards us. Jupiter is a much larger planet than Mars.

a) Why does the brightness of Jupiter appear to change over time?

b) Why does Jupiter often look brighter than Mars?

11.4 Exploring the conditions on other planets

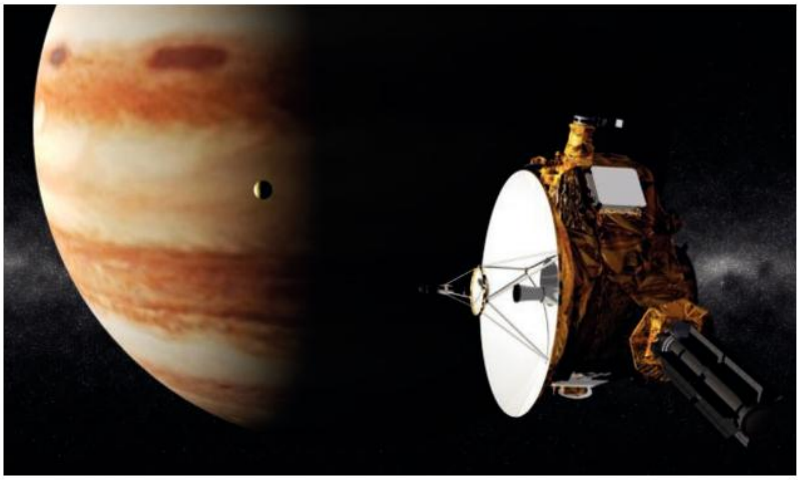
Learning outcomes

After this topic you should be able to:

- describe how scientists collect data about the planets and other objects in the Solar System
- analyse data about the planets to find patterns in their behaviour (correlations)
- use secondary sources to collect data on the planets.

Although we haven't been able to send people to explore the other planets yet, we have sent a large number of robotic probes. These have made detailed measurements of the planets' characteristics. They have also produced thousands of images that help us understand the conditions on these strange worlds.

Sending probes



The New Horizons probe in orbit around Jupiter

We can make basic observations about the objects in our Solar System using telescopes on Earth. However, to get extra detail we need to visit them. These explorations are carried out by spacecraft, or probes, that can also act as robots.

The earliest probes visited the Moon and then Venus and Mars as these were the nearest objects to us. Now, as technology advances, every planet in the Solar System has been visited by robotic explorers.

At first the probes would just fly by the planets collecting data over a few days. The most recent probes now enter orbit and stay for several years. Some land on the surface of the planets or drop modules into the atmosphere.

The Curiosity rover is the most recent and largest probe sent to Mars. It landed in August 2012

Probe	Target	Dates
Luna series	The Moon	1950s
Veneria series	Venus	1960s
Pioneer series	Jupiter and Saturn	1970s
Viking 1 and 2	Landing on Mars	1975
Voyager 1 and 2	Uranus and Neptune	1977
Hayabusa	Near-Earth asteroid	2003
Chandrayaan-1	Moon impact	2008
Curiosity	Landing on Mars	2012

A few examples of space probes – there have been many more

Analysing data

The measurements taken from Earth and the probes have produced a lot of data. Scientists have to analyse that data and use it to develop explanations about the planet's characteristics.

For example, the data in the table below can be used to show that the further a planet is away from the Sun, the longer the planet takes to complete its orbit. This is because the length of the path the planet takes is longer the further it is from the Sun.

Planet	Mercury	Venus	Earth	Mars	Jupiter	Saturn	Uranus	Neptune
Mass (compared to Earth)	0.055	0.815	1	0.107	318	95	15	17
Diameter / km	4878	12 104	12 756	6787	142 800	120 000	51 118	49 528
Density / g/cm^3	5.43	5.25	5.52	3.93	1.33	0.71	1.24	1.67
Distance from the Sun (compared to Earth)	0.39	0.72	1	1.52	5.20	9.54	19.18	30.06
Surface temperature / °C	−180 to 430	465	−89 to 58	−82 to 0	−150	−170	−200	−210
Orbital period / Earth years	0.24	0.62	1	1.88	11.86	29.46	84.01	164.8
Rotational period / Earth days	58.65	243	1	1.03	0.41	0.44	0.72	0.72
Number of moons	0	0	1	2	63	62	27	13

Data collected about the eight planets from observations

Practical activity Finding patterns in the planets

Scientists look for patterns in the behaviour of the planets (correlations) and then try to explain these patterns using scientific principles.

- Use the data from the table and other sources to describe the possible relationship between:
  - the surface temperature of the planet and its distance from the Sun
  - the mass of a planet and the number of moons it has
  - the rotational period of a planet and its distance from the Sun.
- Use graphs to show clear correlations when appropriate.
- You can try to find other relationships too; for example is there a connection between how fast a planet rotates and the time the planet takes to orbit the Sun?
- Extend your exploration of the planets by finding additional information about each of them. You could research the date they were discovered or the strength of gravity on their surfaces.

Summary questions

1. Use the data from the table to explain why the planets have been placed into two different groups.
2. Why is it easier to send robotic probes to explore the Solar System than to send people?
3. Exploring the Solar System is very expensive; only the richest of countries or groups of countries can afford to do this. Could the money used be spent on other, more urgent projects or should space exploration continue? Write a short report containing your opinions based on your research.

11.5 Beyond the planets

Learning outcomes

After this topic you should be able to:

- describe some of the other objects in the Solar System
- compare asteroids and comets using their similarities and differences
- plan and carry out an investigation into asteroid impacts.

Expert tips

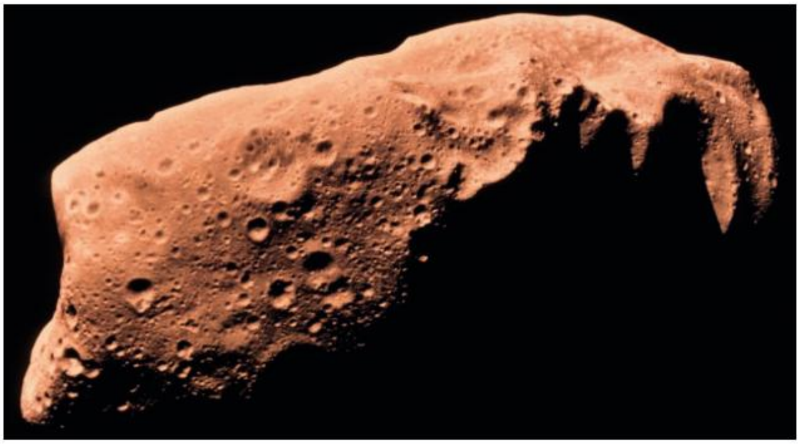
Pluto is a large icy rock that orbits the Sun in a wide ellipse. For over 50 years it was considered to be the ninth planet, but more recent observations have found similar objects in our Solar System. So astronomers have reclassified Pluto as a dwarf planet – larger than an asteroid but just not big enough to be a full planet.

Halley's Comet during its last pass in 1986

There may only be eight planets but there are hundreds of thousands of other objects in the Solar System. Our Solar System is only a tiny part of all that exists; the **Universe**.

Asteroids

Between Mars and Jupiter there are a huge number of iron rich rocks in the **asteroid belt**. Some of these **asteroids** are many kilometres across, each with a mass of trillions of kilograms. Others are much smaller, only a few kilograms each.



The asteroid Ida photographed by the Galileo probe

Comets

Comets are large balls of ice and dust that orbit the Sun in long elliptical paths. They spend most of their time far outside the orbits of the planets. However, when they do approach the Sun a dramatic change happens. The ice begins to evaporate and a long tail of gas is pushed away from the Sun. This leaves the comet with a bright tail millions of miles long.

We can use mathematics to calculate when comets will appear. Some only reach the inner Solar System every ten thousand years. Others may visit every hundred years or so.

Halley's Comet is a large comet that passes through the inner Solar System regularly enough for some people to see it twice in a lifetime. It gets close enough to see every 76 years and last passed close by in 1986.

The Universe

When we look at the night sky we see the light produced by distant stars. This light has travelled for many years to reach the Earth. Our Solar System is only one of billions in a vast collection of stars called the **Milky Way** galaxy. A **galaxy** is a huge collection of stars held together by gravity. Our galaxy slowly rotates around its centre as a swirling spiral disk.

Even the Milky Way is tiny when compared to the parts of the Universe we have observed. Billions of galaxies, many larger than the Milky Way, surge apart from each other, spreading through all of space. Scientists have only just begun to explore these unimaginably distant regions.

A typical spiral galaxy containing billions of stars

Practical activity Asteroid alert

Use the equipment provided to discover if there is a correlation between the size of a crater and the speed of the impact of the object that caused it.

- You can drop the marbles or stones from different heights to generate different speeds of impact.
- You can also investigate whether the mass of the 'asteroid' affects the size of the crater created.
- Decide whether you need to measure the depth of the crater, its diameter, or both, during the experiment.

Plot a graph comparing the size of the crater to the height the 'asteroid' was dropped from. Is there a clear correlation? Explain the results using the ideas about kinetic energy you studied in chapter 9.

Key terms

- **asteroid**
- **asteroid belt**
- **comet**
- **galaxy**
- **Milky Way**
- **Universe**

Summary questions

1 When will Halley's Comet next be visible from Earth? How old will you be? How old will you be when it visits for a second time?

2 If a large asteroid or comet were to hit the Earth it could cause massive damage. Carry out some research and then write a short report about whether it is possible to protect the Earth from this danger. If it is, consider whether it would be worth the cost.

11.6 Changes in our model of the Solar System

Learning outcomes

After this topic you should be able to:

- compare a geocentric model of the Solar System with a heliocentric one
- use secondary sources to outline some of the history of discoveries about the Solar System
- describe how scientific theories change over time.

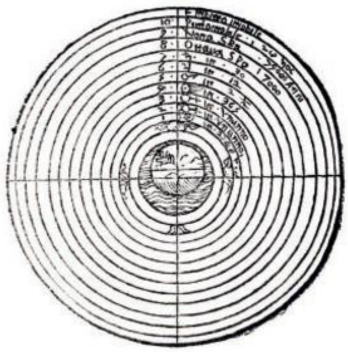
Expert tips

Our ideas about the Solar System change as we find new evidence.

Early ideas

Early sky watchers only had the evidence of their own eyes on which to base their ideas about the Solar System. Nobody could feel the Earth moving through space (or rotating). So people assumed that the Earth was standing totally still. It appeared that the Sun moved across the sky during the day and the stars moved around us during the night. So the early astronomers based their ideas and models on the assumption that the Earth was the centre of everything. This idea that the Earth is the centre of everything is called the **geocentric** model.

This system, based on centuries of ideas and data from many civilisations, was first described fully by an Egyptian astronomer Ptolemy. He came up with explanations about the paths of the stars and planets around the Earth. In this model the planets moved around on celestial spheres.



The heavenly spheres

A new model

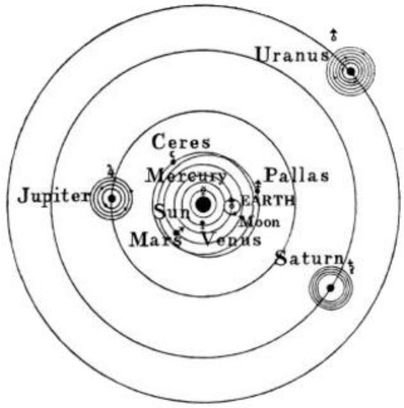
The Ptolemaic system was complicated and could not easily explain the apparent motion of all of the planets. As more observations were made by astronomers with more advanced equipment the problems became more difficult to explain.

In 1543, Nicholas Copernicus described a model of the Solar System where the Sun was at the centre and the planets orbited around it. This is called a **heliocentric** model. Copernicus was not the first to suggest this idea. However, he backed it up with a great deal of evidence and it was hard to find a fault with his model.

In the early 17th century, Galileo Galilei developed the first astronomical telescopes. He gathered new evidence about the Solar System. He found evidence that the Moon has mountains and that Jupiter has moons that move around it. This led him to believe in the heliocentric model. His publications brought him into conflict with the Catholic Church. Galileo was put on trial and confined to his house until his death in 1642.

The heliocentric model of the Universe was revolutionary and it was very hard for scientists to accept it. They found, however, that it could

Copernicus came up with a model of the Solar System that places the Sun at the centre explain the observed evidence much better than the old geocentric ideas. Scientists eventually accepted the improved model.



A diagram that uses the heliocentric model of the Solar System drawn in the 19th century

Modern astronomy

Modern astronomers have discovered a much bigger Universe than expected. They have discovered that the Sun is not the centre, and even the Milky Way galaxy is not the centre. In fact, there is no centre of the Universe.

Scientists use tools such as space telescopes and **radio telescopes** to gather information from the Universe. During the last hundred years this has resulted in a new revolution in the way we understand the Universe and our place in it. But there are still many puzzles to solve.

The square kilometre array (SKA) radio telescope, soon to be built in Australia and South Africa

Practical activity Great discoverers

Hundreds of scientists around the world have made discoveries about the Solar System, galaxies and the Universe. Find out about one of these scientists, summarise their work and explain why their discoveries are important.

- Some examples of scientists who have made major contributions to our understanding of the Universe are: Abū Rayḥān al-Bīrūnī, Isaac Newton, Abū 'Alī al-Ḥasan ibn al-Ḥasan ibn al-Haytham, Hipparchus, Aryabhata, Edwin Hubble, Johannes Kepler, Subrahmanyan Chandrasekhar and Stephen Hawking.

Key terms

- **geocentric**
- **heliocentric**
- **radio telescope**

Summary questions

1 What are the differences between the geocentric model and the heliocentric model of the Solar System?

2 Why did it take time for scientists to change their ideas about the Solar System?

3 Research some of the problems with the geocentric model. Use this information to give an explanation of why the heliocentric model is a better one.

End of chapter questions

1 These amounts of time and their definitions have been muddled up. Copy and rearrange them in the correct order.

Property	Cause	Length of time
a day	Time it takes for the Earth to complete one orbit around the Sun	$365\frac{1}{4}$ days
a year	Time it take for the Earth to rotate about its axis	28 days
phases of the Moon	Time it takes for the Moon to orbit the Earth	24 hours

[3]

2 a Draw a diagram showing the positions of the Earth, Moon and Sun during a lunar eclipse. *[2]*

b Draw a second diagram showing a solar eclipse. *[2]*

3 Copy and complete these sentences, using words from the list below.

asteroids, eight, star, comets, elliptical, circular, moons

At the centre of the Solar System is our ______, the Sun. Around it orbit the ________ planets, which travel in almost _______ paths. Some of the planets have objects in orbit around them; these are called ______.

Between Mars and Jupiter there are billions of rocks called _________. There are also objects called _____ that are formed from ice and dust that orbit the Sun in very ______ paths. *[7]*

4 a Which two of these objects are planets in our Solar System?

Saturn, Vega, Andromeda, Mercury, Halley *[2]*

b Place these objects in order of size starting from the smallest and moving to the largest:

planet, moon, galaxy, star, Universe, Solar System, asteroid *[7]*

5 This table shows the length of year for the different planets. State the pattern revealed in this data, and give two reasons for it. *[3]*

Planet	Mercury	Venus	Earth	Mars
Orbital period (year length)	0.24	0.62	1	1.88

Planet	Jupiter	Saturn	Uranus	Neptune
Orbital period (year length)	11.86	29.46	84.01	164.8

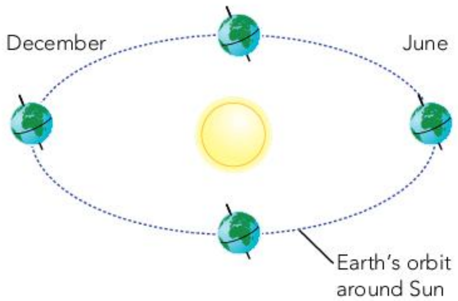
6 Two students are discussing the causes of the phases of the Moon.

Student **A** says: The phases of the Moon are caused when different parts of the Moon give out light.

Student **B** says: Half of the Moon is always lit up by sunlight. We see the phases because we can only see different parts of the lit up side at one time.

Explain which student is correct and the evidence they can base their explanation on. *[2]*

7 Copy this diagram. Label the four globes with the correct names of the seasons in the northern hemisphere. *[4]*



8 Astronomers collect information about the Universe by making observations with telescopes. They collect the light travelling from distant objects and analyse it.

a Draw a table that shows which of the following objects produce their own light and which can only be seen because they reflect light:

asteroid, moon, star, planet *[2]*

b Place the following in order of size (starting with the largest).

Sun, Universe, Earth, asteroid, Moon, galaxy *[3]*

9 Astronomers have measured the speed of the planets as they orbit the Solar System. The measurements are shown in this table.

Planet	Mercury	Venus	Earth	Mars
Orbital speed / km/s	47.89	35.03	29.79	24.13

Planet	Jupiter	Saturn	Uranus	Neptune
Orbital speed / km/s	13.06	9.64	6.81	5.43

The asteroid belt lies between Mars and Jupiter.

a Use the data to estimate the speed of a typical asteroid as it orbits the Sun. *[1]*

b A typical asteroid has a mass of billions of kilograms. Use your understanding of energy transfer from chapter 9 to explain why an asteroid impact with the Earth would cause a great deal of damage. *[2]*

10 Every year astronomers detect thousands of objects inside our Solar System. In 2010, the WISE satellite detected 11 new comets and thousands of new asteroids. Use the information below to decide which of the objects is an asteroid and which of them is a comet. Explain your answers.

Object **A**: Orbital period 8.4 years, circular orbit, constant brightness.

Object **B**: Orbital period 400 years, elliptical orbit, increasing brightness. *[2]*

11 Which of these pieces of equipment are used to gather information about distant galaxies?

radio telescopes, microphones, a compass, space probes *[1]*

12 Astronomers use powerful telescopes to search for planets that orbit other stars. One of the methods is to detect when the planets move directly between their own star and the Earth.

What would happen to the amount of light the astronomers were detecting from the stars when this happens? *[2]*

13 In the 17th century most astronomers slowly changed from using the geocentric (Earth centred) to the heliocentric (Sun centred) model of the Solar System.

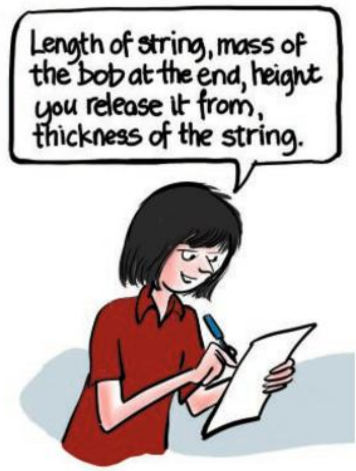
Suggest two reasons why it took some time for astronomers to move to the new model of the Solar System. *[2]*

The skills of investigation (1)

Learning outcomes

After this topic you should be able to:

- plan a fair test
- plan a safe test.



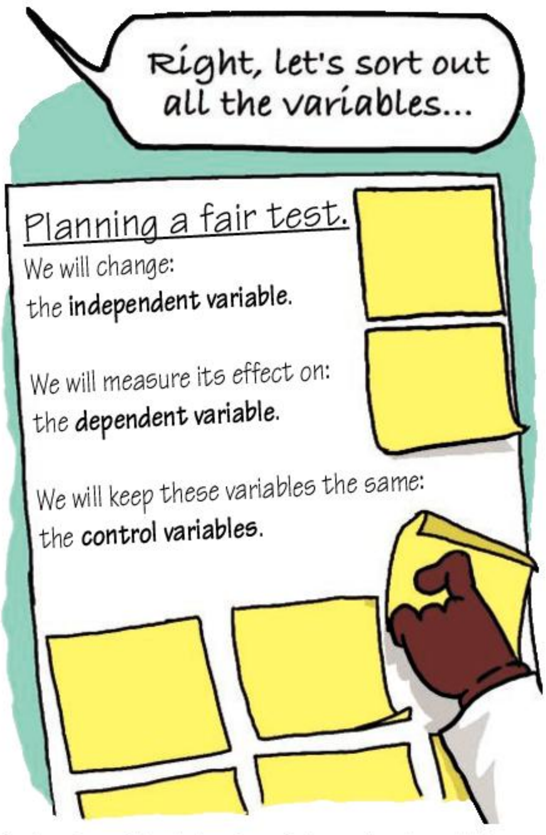
Planning fair tests

Have you ever swung on a rope tied to a tree? If you have, you were acting as a human pendulum. Without thinking about it, you were finding out the answer to the question 'What affects how quickly a pendulum swings?'

You can find the answer more scientifically by carrying out a fair test.

First of all, you list all the factors, called variables, which might affect how the pendulum swings.

On a planning grid like the one shown opposite, fill the boxes at the bottom of the grid with a 'sticky note' with each variable. You can choose one of these variables to investigate. This is the start of planning your fair test.



A planning grid to help plan a fair test (to show all the key variables)

On the planning grid you will see the term **independent variable**. This is the variable that you have chosen to change in each test. In your investigation it will be the 'length of the string'. All the other variables listed at the bottom of the grid that might affect the pendulum are kept constant. We call these **control variables**.

You will also see the term **dependent variable**. We use this variable to judge the effect of changing the independent variable. In your investigation it will be the 'number of swings in 20 seconds'.

Practical activity Completing a planning grid

Use an A3-sized planning grid and a pad of 'sticky notes' to plan a fair test using a pendulum.

Your investigation should answer the question 'How does the length of the string affect the number of swings in 20 seconds?'

Planning safe tests

Key terms

- **control variables**
- **dependent variable**
- **independent variable**

In any investigation, you must think about safety.
Ask yourself:

- What could go wrong? In what ways might it be dangerous?
  The hazard might be caused by:
  - the way you carry out your investigation
  - the equipment you have chosen
  - the materials you plan to use or which are made in your investigation.
    You need to know the hazard symbols below to judge this.

All hazardous chemicals will have one of these labels on their container:

Oxidising
These substances provide oxygen which allows other materials to burn more fiercely.

Harmful
These substances are similar to toxic substances but less dangerous.

Highly flammable
These substances easily catch fire.

Irritant
These substances are not corrosive but can cause reddening or blistering of the skin.

Corrosive
These substances attack and destroy living tissues, including eyes and skin.

Toxic
These substances can cause death. They may have their poisonous effects when swallowed, or breathed in, or absorbed through the skin.

- What is the risk of harm? How likely is it that someone could get hurt?
- Can you change your plan to reduce any risks?
- If an accident did happen, what would you need to do?

Your teacher must check that your plan is safe before you start any practical work.

Summary questions

A group were investigating friction. They wanted to see how the mass in a box affected the force needed to move the box.

1 The title of their investigation was phrased as a question. What is the title of the investigation?

2 What was the independent variable in their investigation?

3 What was the dependent variable?

4 Which variables did they have to control?

The skills of investigation (2)

Learning outcomes

After this topic you should be able to:

- plan to collect data
- plan to record the data collected.

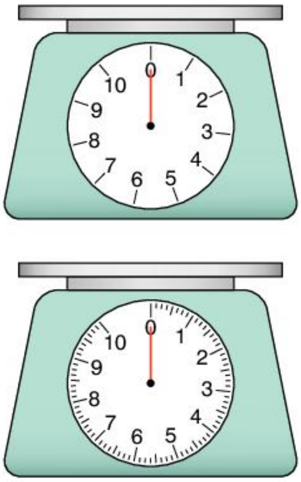
Planning to collect data

Think about your pendulum investigation again.

You will be changing the length of the string in each test.

You will be counting the number of swings in 20 seconds.

You should think about how **accurate** your data needs to be. For example, the length of the string measured with great precision could be 10.10013 cm. However, for our investigation a ruler with a millimetre scale will be good enough. It can give the same measurement as 10.1 cm (as long as you read it properly!).



Which balance would give a more accurate measurement of mass?

Planning to record data

You should also think ahead about how you will record your data.

Scientists record data in tables as they carry out tests.

They usually put the independent variable in the first column. They put the dependent variable in the second column. Any units can be put in brackets. So in the pendulum investigation the table would be:

Length of string / cm	Number of swings in 20 seconds

Some data can be tricky to collect. The data might not be reliable. To help improve the reliability we can repeat readings. We can have more trust in the readings if the repeats are all close together. We say the readings are **precise**. If one of the repeat readings is very different to the others (an **anomalous result**), you should ignore it and try the test again.

However, if you are doing something wrong in each test, repeating tests won't give more accurate data. Accurate data are near to the true value you are trying measure.

We record repeat readings in a table with the second column split up into smaller columns. For example:

Length of string / cm	Number of swings in 20 seconds			
	1st test	2nd test	3rd test	Mean (average)

You add up the three tests and divide the answer by three to work out the mean (average).

Practical activity Carrying out trial runs

Carry out some trial runs of your pendulum investigation. These will help you to decide:

How long should I make the string? What will be the shortest and longest lengths? (This is called the **range**.)

How much should I change the length by between each test? How many different lengths shall we test?

How big should the bob at the bottom of the string be?

Do I need to repeat readings?

- Now you can draw a table to collect your data for when you carry out the investigation.

Key terms

- **accurate**
- **anomalous result**
- **precise**
- **range**

Summary questions

A group were investigating how the temperature affects the time it takes sugar to dissolve in water. It was difficult to judge exactly when the sugar had completely dissolved in each test. They decided to do their investigation at 20, 30, 40, 50 and 60 °C and to repeat each test three times.

1 Design a table that the group could record their results in.

2 They asked their teacher for a stop-watch reading to one hundredth of a second to do their timing. Why did the teacher say that the second hand of the clock on the wall was good enough for this investigation?

The skills of investigation (3)

Learning outcomes

After this topic you should be able to:

- analyse the data you collect
- evaluate your investigation.

Now you can collect the data to answer the question below:
'How does the length of the string affect the number of swings in 20 seconds?'

Practical activity Carrying out a fair test

Carry out your pendulum investigation, recording the data in your table from last lesson.

Analysing your evidence

Having carried out your investigation, you should try to answer your original question. You need to **analyse** the data collected. The best way to see any patterns in the data is to draw a graph.

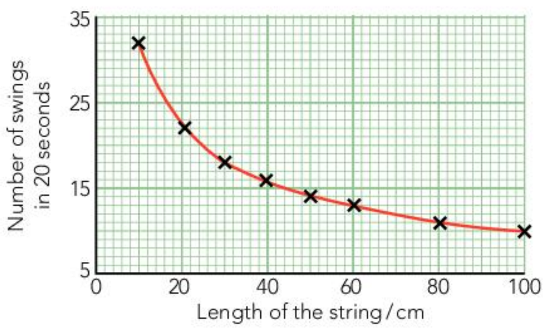
You can draw a **line graph** because the independent variable, the length of the string, can have any value. You might choose 10 cm, 20 cm, etc. but you could have chosen 10.2 cm, 13.8 cm or any other lengths. This type of variable is called a **continuous variable**. Your independent variable always goes along the bottom of your graph (on the horizontal axis).

The dependent variable, the number of swings in 20 seconds, goes up the side (on the vertical axis).

You plot the points as small, neat crosses.

Then you can draw a line of best fit through your mean results. Do not join the points 'dot-to-dot'.

Here is some pendulum data presented on a graph:



In some investigations the independent variable is described by words, not numbers. Then we call the variable a **categoric variable**.

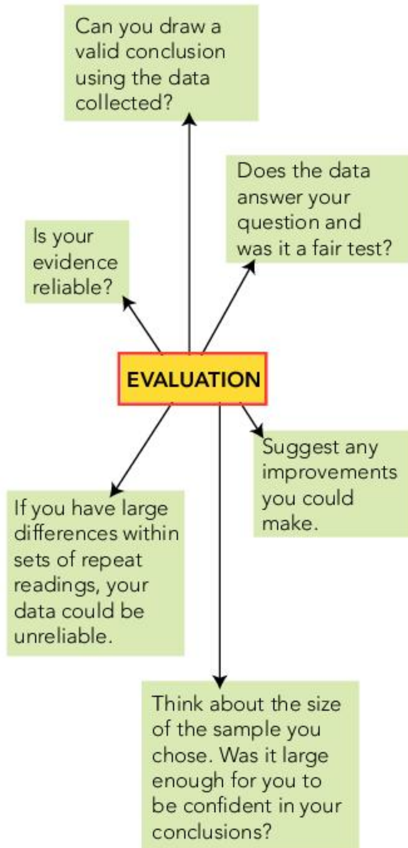
For example, in the investigation to answer the question 'Which type of paper absorbs most water?' The independent variable is the type of paper, e.g. tissue paper, filter paper, newspaper, writing paper, etc. There are no values in between each type of paper. So we cannot draw a line joining points together to form a line graph. We should draw separate bars for each type of paper tested on a

bar chart.

Evaluating your evidence

As you carry out your enquiries, and certainly at the end, you should always consider the strength of your evidence. The questions below will help you to **evaluate** your investigations. The skill of evaluation enables you to improve your methods of data collection.

- Can you draw a **valid** conclusion using the data collected? Does it answer your question and was it a fair test? For example, you might choose a poor range for the length of the string. It might be a narrow range of 10.1, 10.2, 10.3, 10.4 and 10.5 cm. This could give data that shows no pattern between the length of string and the rate of swing. Also, was the mass of the bob the same in each test (especially if you did the tests over a couple of lessons)?
- Is your evidence reliable? If you, or somebody else, did the same investigation again would the data be the same? If the data is the same, you have collected repeatable and reproducible data. These data provide us with stronger evidence for any conclusions you come to. If you have large differences within sets of repeat readings, your data could be unreliable. Then you can't place much trust in your conclusions.
- What could you do to improve your enquiry? Suggest any improvements you could make. Think of any changes you could make to your method and explain why they would improve the data collected.
- If you are doing a 'pattern seeking' enquiry, especially those involving living things, think about the size of the sample you chose. Was it large enough for you to be confident in your conclusions?



Things to consider when you are asked to 'evaluate your investigation'

Key terms

- **analyse**
- **categoric variable**
- **continuous variable**
- **evaluate**
- **valid**

Summary questions

1. What is the difference between a continuous variable and a categoric variable?
2. Classify the following variables as categoric or continuous variables:
   distance moved **hair colour** **type of material** **volume of liquid** **time to dissolve**
3. Evaluate your pendulum investigation using the questions on this page.

Glossary

A

Absorbent Describes a substance that soaks up water. **110–11**

Accurate Very close to the true value. **220–1**

Acidic Describes a substance that forms a solution with a pH value less than 7.0 **122–3**

Adaptation A feature that makes an organism well suited to its habitat. **60–7**

Air resistance The frictional force produced on an object as it moves through the air. **190**

Alkali A soluble base that will react with and neutralise acids. **124–5**

Alkaline Describes a substance that forms a solution with a pH value greater than 7.0 **124–5**

Analyse To examine a set of data in order to understand or explain it. **211, 222**

Anomalous result A result that does not follow the same pattern as other data collected. **101, 220–1**

Antacid A mild base used to treat excess acid in the stomach. **136**

Antagonistic muscles Muscles that work in pairs against each other across a joint. **20**

Antibiotics Drugs that can kill bacteria or slow down the rate at which they grow. **38–9**

Asteroid A large lump of rock in the Solar System. Most asteroids are found in the asteroid belt. **212, 213**

Asteroid belt The location of most of the asteroids found in the Solar System. The asteroid belt is found between the orbits of Mars and Jupiter. **212**

Axis The imaginary line that passes through the Earth from pole to pole. The Earth rotates about this line. **204–5**

B

Bacteria One of the most common types of micro-organism, some of which cause bacterial diseases. **26–7**

Balanced Forces that are equal in size and opposite in direction so that the effect of the forces cancel each other out. **186–7**

Base A substance that neutralises an acid, forming a salt and water. **124–5, 136**

Biomass The living material that makes up an organism. **57**

Boiler The part of a power station where water is heated and turned into high pressure steam. **172–3**

Boiling The change of state from a liquid to a gas, at the boiling point of a substance. **112–13**

Boiling point The temperature at which a substance turns from a liquid to a gas, with bubbles forming inside the liquid and rising to the surface. **94–5**

Brittle Describes a substance that smashes when struck with a hard object. **112–13**

C

Carbon dioxide The gas which is produced as a waste product of respiration. **6**

Carnivore An animal that feeds on other animals. **55**

Categoric variable A variable whose values are described by words, e.g. type of material. **222**

Cell The smallest single unit of a living organism. **13**

Cementation The process whereby dissolved solids come out of solution to stick rock fragments together, helping to form sedimentary rock. **144–5**

CFCs Chlorofluorocarbons, chemicals that damage the ozone layer. **69**

Characteristic A feature which is typical of a particular species of organism. **80**

Cilia Small hair-like projections on cells that beat to move substances around. **36–7**

Circulatory system Organ system that pumps blood around the body carrying food and oxygen and removing carbon dioxide and urea from the cells. **11**

Classify Putting living things, materials or objects into groups. **74–9**

Clay Tiny pieces of weathered rock found in soils. **146–7**

Climate change The long-term change in global temperature and rainfall. **68–9, 80**

Collide To bump into each other. **89**

Colony A large group of bacteria growing on a culture medium which can be seen with the naked eye. **26–7**

Comet A large mass of ice and rock that has a very elliptical orbit around the Sun. **212**

Community All the organisms living in an ecosystem. **50–1**

Compaction The process whereby pressure builds up on sediment as layers are deposited on top, resulting in the particles fusing together, helping the formation of sedimentary rock. **144–5**

Compost The brown nutrient-rich material made by the action of bacteria on waste vegetable material and garden waste. **35**

Compress To squash or apply pressure to. **86–7, 91, 93, 198**

Compression A force that is squashing a material. **192–3**

Condensing The change of state from a gas to a liquid. **94–5**

Conservation of energy A principle that says that energy cannot be created or destroyed in any transformation. **162–3**

Consumers Animals that eat other plants and animals. **56–7**

Continuous variable A variable that can have any numerical value, so any variable that is measured in an investigation is a continuous variable, e.g. length, volume, time. **222**

Contract To shorten and thicken, e.g. muscles working. **20**

Control variables The variables kept constant in an investigation in order to make it a fair test. **103, 218**

Cooling curve The line on a graph of temperature against time produced when a substance cools down. **99**

Corrosive Describes a substance that attacks and destroys living tissues, including eyes and skin. **122–3**

Crumple zone A part of a car that is designed to fold up in a collision and reduce the force of any impact. **199**

Crust The thin, outer, solid layer of the Earth. **148–9**

Crystalline Describes a solid made up of regular-shaped particles, e.g. the mineral grains in a crystalline rock. **142–3**

Culture To grow bacteria in the laboratory. **26–7**

D

Day The length of time it takes for the Earth to rotate once on its axis. Other planets have days of different lengths as they rotate at different rates. **204–5**

Decomposers Micro-organisms that break down the bodies of dead animals and plants and animal waste and release the nutrients back into the soil. **34–5**

Density The mass per unit volume; measured in g/cm^3 or kg/m^3. **108–9, 194–5**

Dependent variable The variable observed or measured in order to judge the effect of changing the independent variable (see *Independent variable*). **103, 218**

Dicot Plants that are often woody. They have branched veins in their leaves and usually have brightly coloured flowers. **79**

Digestive system Organ system that breaks down food into small soluble molecules. **11**

Drag The frictional force produced on an object as it moves through a fluid. **190–1**

E

Ecosystem All of the different things that affect the home of an organism, e.g. other animals and plants, the weather and the soil. **50–1**

Efficiency A measure of how good a device is at transferring energy in a useful way. Higher efficiency devices waste less energy. **166–7**

Electrical conductivity The measure of the ability of a material to pass electricity through it. **115**

Electrical conductor A substance that allows electricity to pass through it. **114–15**

Electrical insulator A substance that does not allow electricity to pass through it. **114–15**

Energy The thing that allows something to do work. There are several forms of energy described in topic 9.1. **154–7**

Energy transfer diagram A diagram that shows the transfers involved in an energy transformation. **158–9**

Evaluate To make judgements on strengths and weaknesses of a model or an investigation. **93, 223**

Evaporating/evaporation The change of state in which a liquid turns into a gas, below the boiling point of the substance. **94–5, 102–3**

Excretion Removal of waste products from the body. **4–5**

Excretory system Organ system which removes urea from the blood and produces and stores urine. **11**

Expand To get larger. **91**

External skeleton A skeleton found on the outside of the body. **75**

Extinct All members of a species die out so the species is lost. **68–9**

F

Fermentation When micro-organisms use a source of energy without oxygen and produce a useful product. **43**

Fertile Able to reproduce. **80**

Flexible Describes a substance that bends when subjected to forces. **112–13**

Flower The part of the plant which contains the reproductive organs. **9**

Fluid A liquid or a gas. The particles are free to move past each other. **190**

Fluorescent A light source that relies on an electric current passing through a gas tube. **168–9**

Force A push or a pull. **180–1**

Fossil The remains (or imprints) of animals and plants that lived thousands or even millions of years ago, made by the hard parts of their bodies getting replaced by minerals. **150–1**

Fragmental Describes the texture of rock made up of randomly shaped fragments or grains that do not fit together neatly. **142–3**

Freezing The change of state from a liquid to a solid. **94–5, 98–9**

Friction A force between two surfaces that makes it difficult for them to move past each other. **182–5**

Fuel cell A device that converts chemical energy from a fuel into electrical energy. **174–5**

Fungus (plural **fungi**) A type of micro-organism that can grow very large. **28–9**

Furnace The place where fuels are burnt in a power station to produce heat. **172–3**

G

Galaxy A collection of billions of stars held together by gravitational forces. **112–13**

Gas A substance that has, on average, large spaces between its fast-moving particles. A gas has a very low density, takes the shape of its container and can flow. **86–9**

Generator A device that converts kinetic energy into electrical energy. **172–3**

Geocentric A model of the Solar System that places the Earth at the centre with all other objects orbiting the Earth. This model has been shown to be incorrect. **214**

Germ theory The idea that infectious diseases are caused by microscopic organisms known as germs. **44–5**

Gills The organs through which gas exchange takes place in many aquatic organisms such as fish, tadpoles. **67**

Graphite A soft, slippery form of carbon that conducts electricity. **115**

Greenhouse effect The warming effect on the surface of the Earth caused by the layer of greenhouse gases such as carbon dioxide in the atmosphere. **68–9**

Growth When an organism gets bigger and stays bigger. **4–5, 7**

H

Habitat The place where an animal or plant lives. **50–1**

Harmful Describes a substance that causes some damage to the body if swallowed, breathed in or absorbed through the skin. **122–3**

Heating curve The line on a graph of temperature against time produced when a substance is warmed up. **99**

Heliocentric A model of the Solar System with the Sun at the centre and the planets in orbit around the Sun. **214**

Herbivore An animal which feeds on plants. **55**

Highly flammable Describes a substance that burns easily. **122–3**

Humus The organic material found in soils. **146–7**

Hypha (plural **hyphae**) The thin thread-like structures that make up most of a fungus. **28–9**

I

Igneous rock Rock types formed by the solidification of molten rock. **141, 145**

Independent variable The variable that is under investigation and is changed systematically in the investigation. **103, 218**

Indicator A substance that changes colour in acidic and alkaline conditions. **124–9**

Indigestion The condition caused by excess acid in the stomach. **136**

Infectious disease Disease caused by micro-organisms known as pathogens which can be passed from one person to another. **36–7**

Inner core The central region of the Earth, made of solid iron and nickel. **148–9**

Insulation Material used to reduce the flow of heat energy from one place to another. **168–9**

Interlock To join neatly together. **142–3**

Internal skeleton A skeleton found inside the body. **75**

Invertebrate An animal without a backbone, e.g. starfish, jellyfish, worms, molluscs and arthropods. **53, 75, 76–7**

Irritant Describes a substance that is not corrosive but can still cause reddening or blistering of the skin. **122–3**

J

Joule The unit for measurement of energy also written as the symbol J. One joule is a small amount of energy. **160–1**

K

Kilocalorie A unit of energy usually used for food. One kilocalorie is the same as 4200 J. **170–1**

Kilojoule A unit of energy equal to 1000 joules. **160–1**

Glossary

L

Lava Molten rock that escapes through the Earth's surface from inside the Earth. **144–5**

Leaf A green part of a plant where most of the photosynthesis takes place. **9**

LED A light emitting diode, a modern form of electrical lighting. **168–9**

Liquid A substance that can flow, take the shape of its container and is made up of randomly moving particles that are very close together. **86–7, 90–1**

Loam A type of soil containing a mixture of large and small grains of rock. **146–7**

Lubricant A liquid that reduces frictional forces by separating surfaces. **184–5**

M

Magma Molten rock beneath the ground. **144–5**

Malleable Describes a substance that can be hammered into different shapes. **112–13**

Mantle The layer of the Earth beneath its crust. **148–9**

Melting The change of state from a solid to a liquid. **94–5, 98–9**

Melting point The temperature at which a solid turns into a liquid. **94–5, 98–9, 112–13**

Metamorphic rock Rocks whose structure and/or mineral content has been changed by the action of heat and/or pressure. **141, 144–5**

Micro-organisms Very small organisms most of which can only be seen under the microscope. **26–7**

Microscope An instrument for magnifying very small things and making them look bigger. **12**

Milky Way The galaxy that contains our Solar System. **212–13**

Models These can be theories, mathematical equations or computer simulations that help scientists to explain their observations. **96–7**

Monocot Plants which are not usually woody and have lots of veins running side by side in their leaves. They usually have green or brown flowers pollinated by the wind. **79**

Movement Moving something from one place to another. **4–5, 7**

Multicellular An organism made up of more than one cell. **14**

N

Nerve Bundles of hundreds or thousands of neurones. **75**

Nervous system Organ system in animals that coordinates the activities of the body. **11**

Neutral A substance that has a pH value of 7.0 so is neither acidic nor alkaline. **128–9**

Neutralisation The chemical reaction between an acid and a base. **132–4, 136–7**

Newton The unit of force also written as the symbol N. **180–1**

Newtonmeter (**forcemeter**) A device used to measure forces, usually a spring attached to a scale. **180–1**

Non-renewable An energy source that is limited because it will run out. **172–3**

Nuclear power Using the energy stored in the nucleus (centre) of atoms to generate electricity. **172–3**

Nutrients The food substances needed by an organism. **27**

Nutrition Making or taking in food. **4–5**

O

Obesity A medical condition where somebody is so overweight that their health is affected. **171**

Observation Looking very carefully to gather information. **6–7, 24, 210–11**

Omnivore An animal which eats animals and plants. **55**

Opaque Describes a substance that does not let light pass through it. **113**

Orbit The path a planet takes around the Sun or the path a moon takes around its planet. **204–5**

Organ system Several different organs working together to carry out a particular function in the body. **10**

Outer core The layer of the Earth between the mantle and the inner core, made up of molten iron and nickel. **148–9**

Oxidising Describes a substance that provides oxygen, which allows other materials to burn more fiercely. **122–3**

Oxygen The gas taken in from the atmosphere in breathing which is used for respiration in the cells. **6**

Ozone hole Region in the ozone layer which has become thinner due to the presence of CFCs in the atmosphere. **68–9**

P

Parasite An organism which takes what it needs to live from another living organism (known as its host). The host is harmed by the parasite. **30–1**

Particle theory The theory that all matter is made up of particles. The theory describes the arrangement and motion of these particles. **89**

Pasteurisation The process of heating food to kill most of the micro-organisms and prevent it from going bad. **42–3**

Pesticide A chemical that kills insect pests. **58–9**

pH scale A chart of colours to match the colour of universal indicator against, in order to give a pH value. **128–9**

Phases of the Moon The sequence of shapes we see from the Earth as we view the lit-up surface of the Moon from different angles during the lunar month. **206**

Photosynthesis The process by which plants make their own food using energy from the Sun, carbon dioxide and water to make simple sugars. **16**

Phytoplankton Microscopic organisms that carry out photosynthesis. **66**

Plants Living organisms which make their own food by photosynthesis. **54–5**

Polio An infectious disease caused by viruses that can result in paralysis and death. **39**

Pooter A simple piece of equipment for picking up small invertebrates. **53**

Porous Describes a substance that will absorb water. **142–3**

Potential energy Energy that is stored in an object because of the object's shape or position. **156–7**

Precise Describes results that when repeated are closely grouped together. **220–1**

Primary consumer An animal that eats plants. **56–7**

Producer An organism that produces its own food by photosynthesis. **56–7**

Property A description of the way a substance looks or behaves. **108–15**

Q

Quadrat A piece of equipment with a known area. **52**

R

Radio telescope An instrument used to detect radio emissions from space. **215**

Random Without any predictable pattern. **89**

Range The maximum and minimum values of the independent or dependent variables, e.g. 10 cm to 54 cm. **220–1**

Record Write down observations or measurements during a practical investigation. **6**

Relax The opposite of contract – when a muscle is relaxed it can be pulled long and thin again. **20**

Renewable An energy source that does not get used up and will not run out. **174–5**

Reproduction Making more of the same type of organisms, producing offspring. **4–5, 7**

Respiration The breakdown of food to release energy, often using oxygen. **4–5**

Respiratory system The organ system that brings air into the lungs and allows gas exchange to take place. **11**

Resultant force The result of adding all of the forces on an object together taking into account their direction. **186–7**

Root The part of a plant that is underground. **9**

Root hair cells Specialised plant cells found close to the tips of growing roots which increase the surface area for the absorption of water and mineral ions. **17**

S

Sandy soil A type of soil containing a large proportion of large grained sand particles. **146–7**

Sankey diagram A type of energy transfer diagram that shows the amount of energy that is transformed in different ways. **164–5**

Secondary consumer An animal that eats herbivores. **56–7**

Sedimentary rock Rock types formed from the compaction and cementation of sediment. **141, 144**

Sensitivity Responding to changes in the world inside or outside of the body. **4–5**

Sewage Human waste and run-off rain water. **35**

Skeleton A strong structure found in animals which may be inside or outside the body. It is important for protection, support and movement. **18–19**

Softness How easily a substance can be deformed. **108–9**

Solar eclipse When the Moon is directly between the Sun and a point on the surface of the Earth, leaving this point in shadow. **207**

Solid A substance that has a fixed shape and volume, made up of regularly arranged, touching particles that vibrate in fixed positions. **86–7, 92–3**

Specialised A cell which is adapted to carry out a particular function in the body. **14–15**

Species Animals or plants of the same type that can reproduce together successfully to produce fertile offspring. **50–1**

Stem The part of a plant that supports the leaves, buds and flowers. **9**

Streamlined An object that is shaped so that air can move smoothly over its surface and so lower the air resistance of the object. **190–1**

Strength of gravity The amount of force that acts on each kilogram of material on a particular planet. On Earth the strength of gravity is approximately 10 N/kg. **188–9**

Sublimation The change of state from a solid directly to a gas. **94–5**

Synovial fluid The fluid formed by the synovial membrane which lubricates the joint. **21**

T

Tension A force that is stretching a material; for example the forces in a rope. **192–3**

Texture Describes the way the grains in a rock fit together. **142–3**

Thermal conductivity The measure of the ability of a material to pass heat energy through it. **114**

Thermal conductor A substance that allows heat energy to pass through it. **114–15**

Thermal insulator A substance that does not allow heat energy to pass through it. **114–15**

Thrush A fungal disease of the skin. **39**

Tissue Many specialised cells working together to carry out a particular function in the body. **14**

Toxic Describes a substance that can cause death when swallowed, breathed in or absorbed through the skin. **122–3**

Transfer When energy moves from place to place or object to object. **156–7**

Transformation When energy changes from one form to another during a transfer. **156–7**

Transparent Describes a substance that lets light pass through it. **113**

Trophic level The position of an organism in a food chain. Producers such as plants are always in the first trophic level. **56–7**

Tuberculosis (TB) A bacterial disease which can affect the lungs and other parts of the body and causes many deaths around the world every year. **38**

Turbine A set of metal blades in a power station that are rotated by steam. **172–3**

U

Unbalanced Forces that are unequal in size so that they produce an overall resultant force. **186–7**

Universal indicator A mixture of dyes that produce a range of colours depending on the pH of the solution being tested. **128–9**

Universe All of physical existence; the Universe contains billions of galaxies. **212–13**

Upthrust A force produced when an object rests in a fluid. The upthrust acts against the weight of the object. **196–7**

V

Vaccination A way of stimulating the immune system and producing immunity to a disease. **38–9**

Vaccine The material put in to the body in a vaccination. **44–5**

Valid Suitability of an investigation to answer the questions being asked; an investigation will provide valid data and conclusions if a fair test is carried out and the results are reliable. **223**

Variation The differences between individuals of the same species and between different species. **80–1**

Vertebrate An animal that has an internal skeleton which includes a backbone made up of a number of small bones called vertebrae. **18, 75, 77**

Vibrate To move back and forth about a fixed position. **93**

Virus The smallest living organisms which can only reproduce within the cells of another living organism. **30–1**

W

Waterproof Describes a substance that does not let water pass through it. **110–11**

Weight The force that attracts an object towards the centre of a planet. Weight is caused by gravity. **188–9**

White blood cells Cells in the blood that defend against disease. **37**

X

X-ray photograph A way of taking an image using X-rays which can see through the soft tissue of the body. **18–19**

Y

Year The length of time it takes the Earth to complete one orbit around the Sun. Other planets have different year lengths from the Earth as they take different times to complete an orbit of the Sun. **204–5**

Yeast A type of fungus used for making bread and alcoholic drinks. **28–9**

Yoghurt A food made by the action of bacteria on milk. **32–3**

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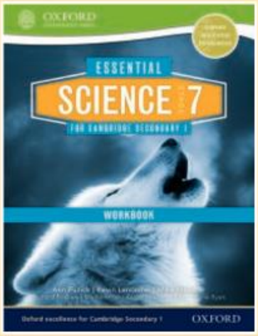

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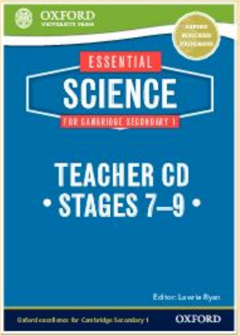

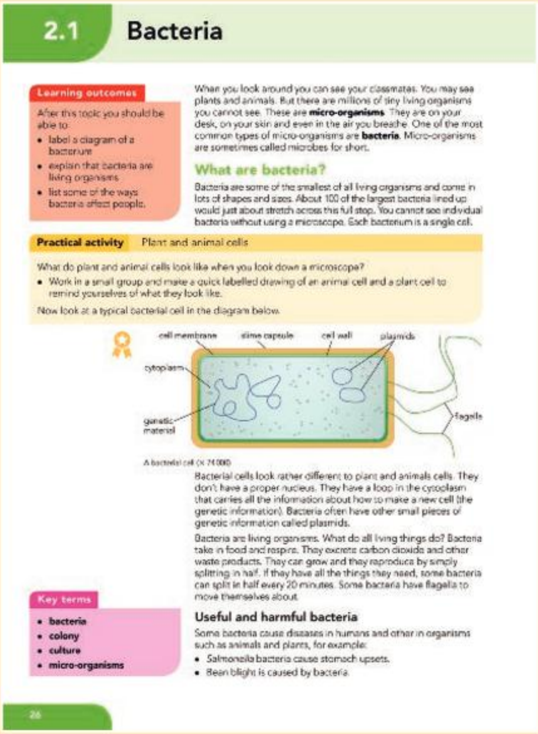

2.1 Bacteria

Learning outcomes

After this topic you should be able to:

- label a diagram of a bacterium
- explain that bacteria are living organisms
- list some of the ways bacteria affect people.

When you look around you can see your classmates. You may see plants and animals. But there are millions of tiny living organisms you cannot see. These are **micro-organisms**. They are on your desk, on your skin and even in the air you breathe. One of the most common types of micro-organisms are **bacteria**. Micro-organisms are sometimes called microbes for short.

What are bacteria?

Bacteria are some of the smallest of all living organisms and come in lots of shapes and sizes. About 100 of the largest bacteria lined up would just about stretch across this full stop. You cannot see individual bacteria without using a microscope. Each bacterium is a single cell.

Practical activity Plant and animal cells

What do plant and animal cells look like when you look down a microscope?

- Work in a small group and make a quick labelled drawing of an animal cell and a plant cell to remind yourselves of what they look like.

Now look at a typical bacterial cell in the diagram below.

cell membrane, slime capsule, cell wall, plasmids, cytoplasm, genetic material, flagella

A bacterial cell (× 74 000)

Bacterial cells look rather different to plant and animals cells. They don't have a proper nucleus. They have a loop in the cytoplasm that carries all the information about how to make a new cell (the genetic information). Bacteria often have other small pieces of genetic information called plasmids.

Bacteria are living organisms. What do all living things do? Bacteria take in food and respire. They excrete carbon dioxide and other waste products. They can grow and they reproduce by simply splitting in half. If they have all the things they need, some bacteria can split in half every 20 minutes. Some bacteria have flagella to move themselves about.

Key terms

- **bacteria**
- **colony**
- **culture**
- **micro-organisms**

Useful and harmful bacteria

Some bacteria cause diseases in humans and other in organisms such as animals and plants, for example:

- Salmonella bacteria cause stomach upsets.
- Bean blight is caused by bacteria.

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