Integrated Science for CSEC®

Derek McMonagle
Pauline Anning
Denise Hernandez
Richard Johnson
Lucy Madhosingh
Jennifer Murray

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School-based assessment and extra materials – on your CD

Introduction

To the student reader

Integrated Science for CSEC® is a complete course designed for the Integrated Science syllabus at CSEC® level. The syllabus covers topics from Physics, Chemistry and Biology, with some topics from Earth Sciences and Meteorology. These topics have been chosen to help you understand and explain many of the situations that you will encounter in the home, the workplace and the wider environment. The authors are experienced teachers who designed the book to incorporate features which will make it easier for you to learn and master the material at this level.

Each unit of this book is divided into sub-units and the learning objectives for each are given so that you can see what it is you are expected to learn and to be able to do.

In each topic, text, diagrams and tables are used to make explanations clear. There are also Tips to help you and Information boxes with further details or additional examples. Key words and terms are highlighted and defined.

You will find a range of different practical experiments and investigations throughout the text. These have been designed to help you develop your experimental and critical thinking skills and also to encourage you to apply scientific concepts and principles to everyday situations. Your teacher may use some of these experiments to assess School-Based Assessment (SBA) skills.

There are questions at the end of each topic to test your understanding of its content. The questions at the end of each unit have been carefully developed and designed so that they are varied, achievable, interesting and useful for both revising and deepening your understanding of the content and skills taught in the unit. Examination-style questions can be found at the end of each unit.

On the accompanying CD, you will find a Unit summary for every unit of the book, which will help you with revision. You will also find extra support for the SBA practicals, support for mathematical skills, and a variety of worksheets and interactive activities.

To the teacher

Integrated Science for CSEC® has been carefully planned and developed to support the teaching of the Integrated Science syllabus.

The book offers:

- complete coverage of the three sections outlined in the CSEC® syllabus, including process skills, opportunities for practical work and experimental design and references to the local environment
- a list of objectives for each topic, so that students can understand clearly what is required of them
- interesting and challenging practical activities, many of which can be used for SBA purposes, to illustrate principles and concepts
- emphasis on Caribbean examples to encourage students to understand their own environment
- questions at the end of each topic to test knowledge and understanding if the material
- key words and terms highlighted and a useful summary of each unit as a guide for revision
- examination-style revision questions
- extra support for SBA and mathematical skills.

School based assessment

Unit	Practical number	Practical	Page number	ORR	M&M	AI	P&D	Drawing
1	1.5.2	Investigating osmosis (I)	17	X		X		
	1.5.3	Investigating osmosis (II)	18	X		X		
2	2.2.1	Investigating asexual reproduction in plants	24					X
	2.3.1	Investigating flower structure	26					X
	2.3.2	Fruits and seeds	27	X				
	2.9.1	Observing germination	40	X				
	2.9.2	Do seeds need light for germination?	41				X	
	2.9.3	Measuring and recording growth	41	X				
3	3.1.2	Testing for starch	48	X	X			
	3.4.1	Testing for reducing sugars	58	X				
	3.4.2	Testing for non-reducing sugars	59	X				
	3.4.3	Testing for protein (biuret test)	60	X	X			
	3.4.4	A simple test for lipids	60	X	X			
	3.4.5	An alternative test for lipids	60	X				
	3.4.6	To find the energy content of a peanut	62		X	X		
	3.5.1	Investigating the conditions in which bread mould grows	66	X			X	
	3.7.1	Investigating the activity of salivary amylase at different temperatures	70				X	
	3.7.2	Investigating the optimum pH for salivary amylase	71	X				
	3.7.1	Identifying types of teeth	74					X
	3.8.1	Effect of acid on teeth	76	X				
4	4.1.2	To show the transport of water in a stem	80	X				X
	4.1.3	Investigating water uptake by a leafy shoot	81				X	
	4.2.1	Different types of blood cell	82					X
	4.2.2	Measuring pulse rates	85	X				
	4.7.1	Investigating the effect of exercise on heart rate	98	X		X		
5	5.2.1	Looking at lung tissue and drawing alveoli	111					X
	5.3.1	Measuring heat energy from germinating seeds	114	X		X		
	5.5.1	Investigating air pollution	119	X				
6	6.2.1	Investigating kidney structure	130	X				X
7	7.2.1	Looking at the mammalian eye	137	X				X
	7.2.3	Making a pinhole camera	139	X	X			
	7.3.1	Lighting	140		X	X		
	7.5.1	Using a water prism	143	X				
	7.8.1	Investigating touch receptors in the skin	151	X				
9	9.1.1	Investigating the conduction of heat	181	X		X		
	9.1.2	Investigating heat radiation	183	X	X	X		
	9.1.3	Which is the better absorber of radiation?	183				X	

Unit	Practical number	Practical	Page number	ORR	M&M	AI	P&D	Drawing
	9.4.2	Factors affecting evaporation	189				X	X
	9.4.3	How surface area affects the rate of evaporation	189		X			
10	10.4.1	Conservation of momentum	204	X				
11	11.1.1	Good and bad conductors	206	X				
	11.2.1	How different resistances affect current	210		X	X		
	11.3.1	Wiring a plug	213		X			
	11.8.2	Comparing filament lamps of different wattage	224	X				
	11.10.1	Design an experiment showing the effect of carbon dioxide on combustion	228	X				
12	12.2.1	Investigating inclined planes	235	X	X	X		
	12.2.2	Pulleys	237	X				
13	13.1.1	Measuring elasticity	245	X	X	X		
	13.1.2	Testing wood	246	X	X	X		
	13.3.1	Formation of metal oxides	250	X	X			
	13.3.2	Reactions of metals with acids	251	X		X		
	13.5.1	How much copper and zinc is in a sample of brass?	253		X	X		
	13.6.1	Investigating the conditions needed for rusting	255	X		X		
	13.6.2	Electroplating	257	X				
14	14.2.2	Investigating indicators (II)	266	X				
	14.3.1	Investigating solubility	267	X				
	14.4.1	Investigating the removal of acidic or basic stains	269	X		X		
	14.8.1	Making soap	281	X				
16	16.2.2	Investigating the air content of soil	303		X			
17	17.2.2	Distillation	329		X			
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18	18.1.1	Investigating the Bunsen burner flame	345	X				
19	19.1.1	A balloon rocket	361			X		
	19.1.3	Investigating friction on different surfaces	363	X	X		X	
	19.3.1	Finding the centre of gravity of an object with an irregular shape	368	X				
	19.4.1	Investigating moments	371	X	X			

Section A

1 Matter

Learning outcomes

By the end of this topic you will be able to:

- name the states of matter: solid, liquid, gas and plasma
- describe the arrangement of particles in solids, liquids and gases
- explain how the properties of different states of matter are related to the arrangement of particles
- name the processes by which matter changes state.

Matter is all around us. It is made up of particles. Matter can exist in four different states: solid, liquid, gas and, under extreme conditions, plasma. The arrangement and movement of particles in matter are different in solids, liquids and gases. This explains why these three states of matter have different properties.

Organisms are made up of simple basic units called cells. Most cells are too small to be seen by the naked eye and their structure is only visible when thin strips, or slices, of tissues are viewed using a microscope. Plant cells appear as box-like structures, because they have cell walls. Animal cells, usually much smaller, lack cell walls and most do not have such regular shapes.

Microbes are single-celled organisms that can only be seen with a powerful microscope. Some microbes have positive effects on our lives, while others have negative effects.

Substances move into and out of cells by the processes of diffusion, osmosis and active transport.

1.1 States of matter

All of the materials you see around you can be placed into one of three groups according to whether they are solid, liquid or gas. These are called states of matter. The state of a substance depends on physical conditions, such as room temperature and atmospheric pressure.

Water is most familiar as a liquid because it is a liquid at normal room temperature and atmospheric pressure.

If liquid water is placed into a freezer, where the temperature is below 0 °C, the liquid water soon becomes solid water or ice.

Similarly, if liquid water is boiled in a kettle, its temperature will reach 100 °C. At this temperature, the liquid water becomes gaseous water or steam.

▲ **Figure 1.1.1** Liquid water, solid water or ice, and gaseous water or steam

There is a fourth state of matter called plasma. However, you will not see this in everyday life as it only forms under extreme conditions, such as high temperatures and strong magnetic fields, for example in stars (naturally occurring) or in neon signs (artificial). The properties of plasma are very different to those of a solid, liquid or gas.

Did you know?

Steam is actually invisible. The 'steam' that leaves the spout of the kettle is, in fact, a small cloud formed by tiny droplets of liquid water condensing in the cooler air.

Properties of solids, liquids and gases

Practical Activity 1.1.1

Pouring solids and liquids from one container into another

Materials:

- 250 cm^3 beaker
- 500 cm^3 beaker
- 250 cm^3 conical flask
- 2 cm^3 × 3 cm^3 × 3 cm^3 wooden block
- Water

Method:

1 Place the wooden block in the 250 cm^3 beaker and observe its shape.
2 Move the wooden block into the 500 cm^3 beaker and observe its shape again.
3 Does the solid block take the shape of its container?
4 Fill the 250 cm^3 beaker with water and observe its shape.
5 Pour the water into the 500 cm^3 conical flask and observe its shape again.
6 Does the liquid water take the shape of its container?

It is easy to see that a liquid flows and can be poured from one container to another. It is not so easy to see if a gas flows because many gases are invisible. However, it is possible to detect some gases by their properties. Carbon dioxide is an invisible gas. It doesn't support combustion so it can be used to extinguish a flame.

Practical Activity 1.1.2

Pouring a gas from one container into another

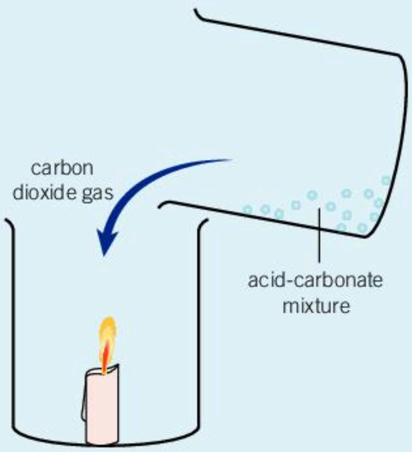
Materials:

- Two 250 cm^3 beakers
- Candle 2 cm long
- Calcium carbonate powder
- Dilute hydrochloric acid
- Matches

Method:

1 Place a small amount of calcium carbonate powder into one of the beakers.
2 Add sufficient dilute hydrochloric acid to cover the powder. There will be a rapid **effervescence** due to the release of bubbles of carbon dioxide gas.

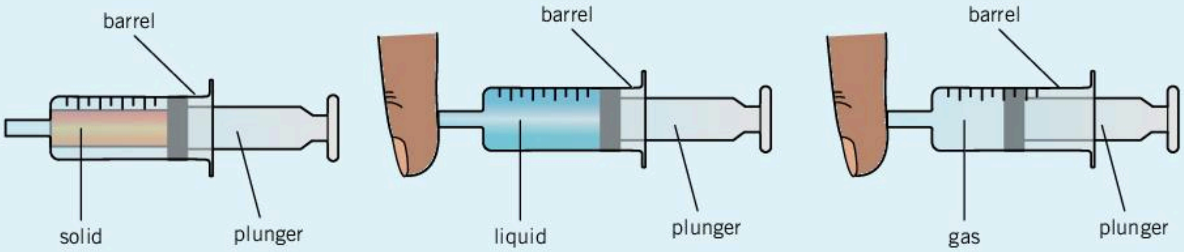
3 Place the candle in the other beaker and light it.
4 Place the two beakers together as shown in the diagram. Tilt the beaker containing the acid–carbonate mixture as if you were pouring water. Do not let any of the mixture pour from one beaker to the other.
5 What happens to the candle in the beaker?
6 Is it possible to pour carbon dioxide gas?



Practical Activity 1.1.3

Compressing or squashing solids, liquids and gases

Materials:
- Three plastic syringes
- Short length of wooden dowel that fits inside one of the syringes
- Water



Method:
1 Place the wooden dowel in one syringe and try to force the plunger down the barrel.
2 Draw water into another syringe until it is nearly full. Place a finger over the end of the syringe and try to force the plunger down the barrel.
3 Draw air into the last syringe until it is nearly full. Place a finger over the end of the syringe and try to force the plunger down the barrel.
4 Of the three states – solid, liquid and gas – which was easy to squash and which was difficult or impossible to squash?

The properties of solids, liquids and gases are summarised in Table 1.1.1.

Table 1.1.1

	Fixed shape	Ability to flow (Can be poured)	Compressibility (Easy to squash)
Solid	✓	✗	✗
Liquid	✗	✓	✗
Gas	✗	✓	✓

Question

1 Copy and complete the following sentences using only words from the box.

fixed	heated	poured	shape	squashed

A solid has a __________ shape. When a liquid is __________ it always takes the __________ of its container. A gas can be __________ into a smaller space.

Changing between these states of matter involves only physical changes. For example, ice, water and steam all contain the same water particles, which are chemically identical.

If this is the case then:

- Why does a solid have a definite shape but a liquid takes the shape of its container?
- Why can gases be easily squashed but solids and liquids cannot?

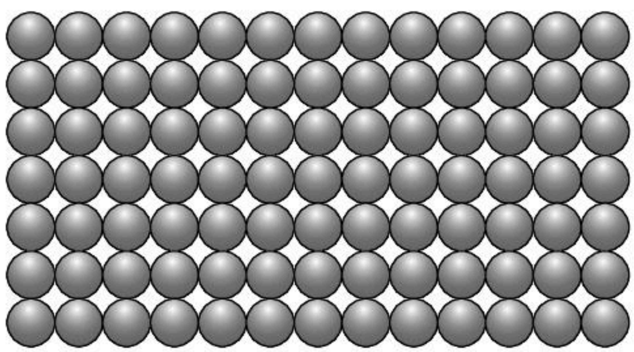
An understanding of how the particles in solids, liquids and gases are organised and how they are able to move is needed to answer these questions.

Position and movement of particles

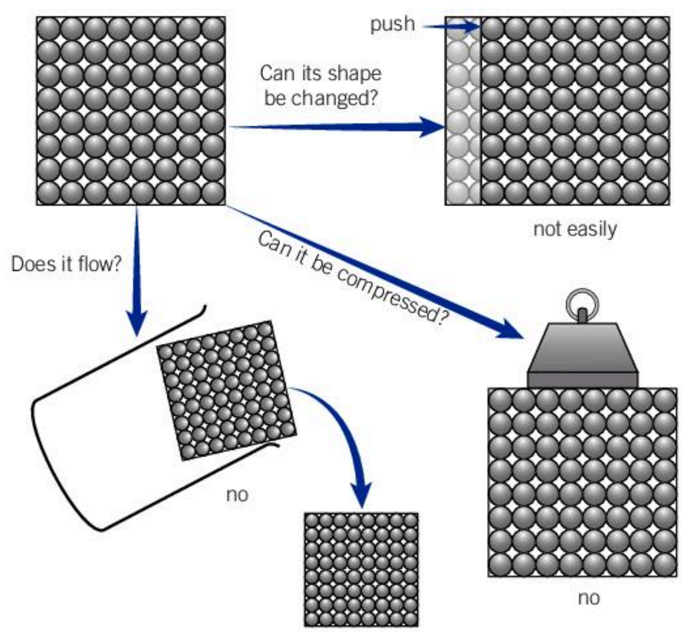
Solids

In solids, the particles are closely packed together. They form a regular framework or lattice (see Figure 1.1.2).

The forces of attraction between particles in a solid are very strong so the particles cannot change position. However, the particles vibrate continually about fixed points, so they are not entirely still.



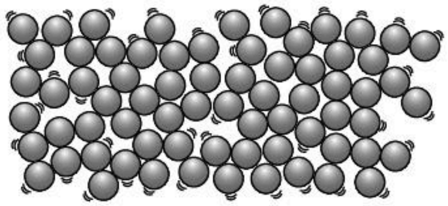
▲ **Figure 1.1.2** Particles in a solid



▲ **Figure 1.1.3** Properties of a solid

The particles in a solid are close together and held in fixed positions. So, as Figure 1.1.3 shows, solids:

- have a definite fixed shape and volume
- cannot be poured
- cannot easily be compressed.

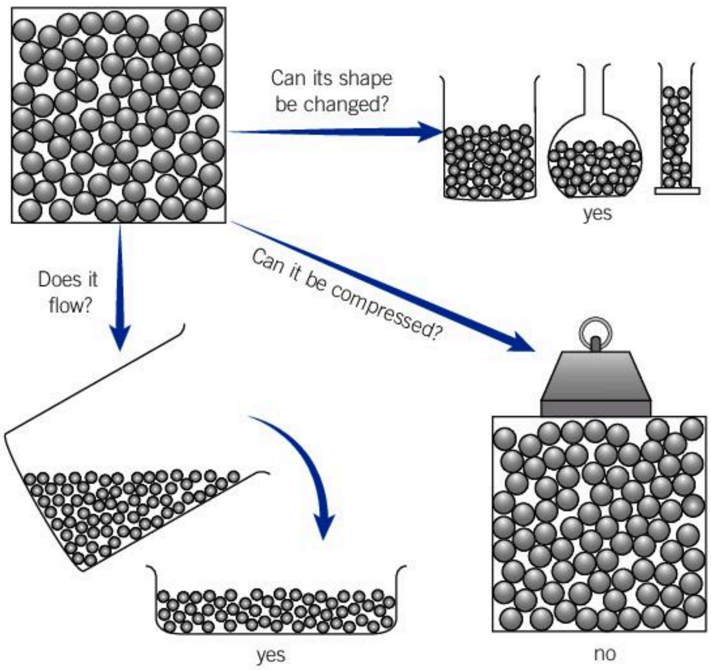


▲ **Figure 1.1.4** Particles in a liquid

Liquids

The particles in a liquid are close to each other. There are strong forces of attraction between them (see Figure 1.1.4).

The particles have more kinetic (movement) energy than those in a solid. This is enough for them to change position, but not to separate.

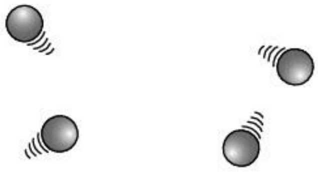


▲ **Figure 1.1.5** Properties of a liquid

The particles of a liquid are close together but they are able to move position. So, as Figure 1.1.5 shows, liquids:

- take the shape of their container
- can flow or be poured from one container to another
- are difficult to squash into smaller volumes.

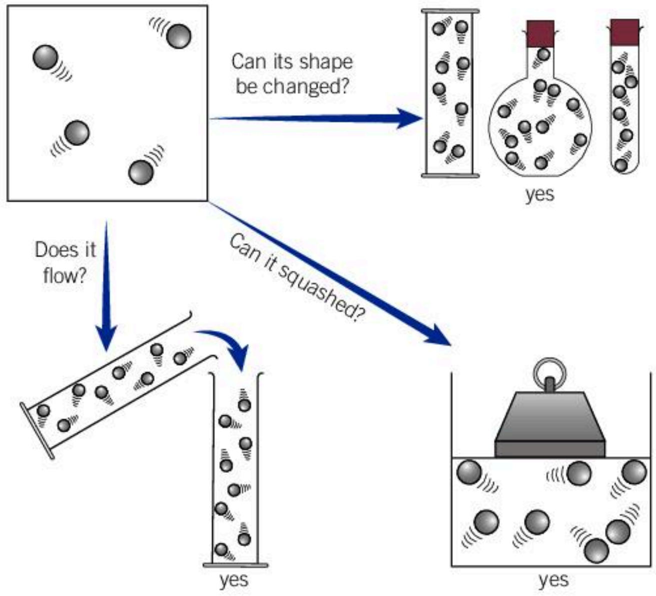
Gases



▲ **Figure 1.1.6** Particles in a gas

The particles in a gas are further away from each other compared to those in a solid or liquid. Gas particles have much more kinetic (movement) energy than the particles in a solid or a liquid (see Figure 1.1.6).

The attractive forces between particles become weaker as the particles move further apart. The particles in a gas move in random directions at very high speeds.



▲ **Figure 1.1.7** Properties of a gas

The particles in gases move very quickly and are far apart. So, as Figure 1.1.7 shows, gases:

- take the shape of the container
- can flow or be poured from one container to another
- can easily be squashed into smaller volumes.

Questions

1 Draw diagrams to show how particles are arranged in each of the following states.

a Solid b Liquid c Gas

2 Explain each of the following observations in terms of the arrangement of particles and how they move.

a A liquid takes the shape of its container but a solid does not.

b A gas can be easily squashed but a liquid cannot.

c When a small volume of water is boiled it produces a large volume of steam.

Changing state

When most solids are heated, they become liquids first and then gases. These changes of state are physical changes that are easy to reverse. If gases are cooled, they become liquids first and then solids.

$$\text{SOLID} \underset{\text{solidifying or freezing}}{\overset{\text{melting}}{\rightleftharpoons}} \text{LIQUID} \underset{\text{condensing}}{\overset{\text{boiling}}{\rightleftharpoons}} \text{GAS}$$

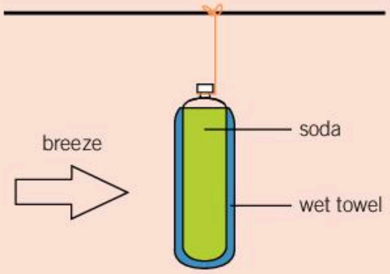
The symbol '$\rightleftharpoons$' is used to show that changes of state are reversible changes.

Energy is needed to melt a solid or to boil a liquid. Melting and boiling are described as **endothermic** processes. Conversely, when a gas condenses or a liquid freezes, energy is released. Condensing and freezing are described as **exothermic** processes.

▲ **Figure 1.1.8** Evaporation takes place at any temperature

Questions

1. Draw a diagram to show the changes of state for water.
2. Give definitions for the processes shown in your diagram.
3. The diagram shows a simple way of keeping soda cool on a warm day.
   The bottle is wrapped in a damp towel and hung on a washing line.
   Explain how this will cool the soda.



▲ **Figure 1.1.9** Solid carbon dioxide or dry ice

When a solid melts to become a liquid at a particular temperature, this is called its **melting point**. The melting point of ice is 0 °C. This is also the temperature at which water turns to ice when cooled.

When a liquid boils to become a gas at a particular temperature, this is called its **boiling point**. The boiling point of water is 100 °C. This is also the temperature at which steam turns to water when cooled.

Evaporation

If a glass of water is left on a sunny window ledge, the water will soon 'disappear' leaving an empty glass. The water changes to gas and goes into the atmosphere.

Although the Sun's rays are hot, they will not heat the water to 100 °C, so the water in the glass does not boil. Therefore, there must be another process that can change a liquid into a gas.

The water particles each have different amounts of energy. At any given time a tiny proportion of the particles have enough energy to overcome the forces of attraction with other particles and become gas. This process is called **evaporation**. Evaporation is the process by which a liquid becomes a gas or vapour at temperatures below its boiling point.

The term 'vapour' is often used to describe a gas below the boiling point of the liquid from which it has formed. When water evaporates, it forms water vapour rather than steam.

There are two important differences between evaporation and boiling.

- A substance only boils at a particular temperature. This is called its boiling point. Evaporation takes place at any temperature but is greatest in warm moving air.
- Evaporation only takes place at the surface of a liquid, while boiling takes place throughout the liquid.

Although evaporation takes place below the boiling point of a liquid, energy is still needed to convert a liquid to a vapour as the forces of attraction still have to be overcome.

If a small amount of a volatile liquid, such as perfume, is placed on the back of the hand, it will quickly evaporate leaving the hand feeling cold. Heat energy needed for evaporation is transferred from the skin.

Sublimation

When heated at standard atmospheric pressure, most solids melt to become liquids. On further heating, the liquids boil and become gases. However, a few solids do not become liquids when heated but change directly from solids to gases. This process is called **sublimation**.

$$\text{SOLID} \underset{\text{sublimation}}{\overset{\text{sublimation}}{\rightleftharpoons}} \text{GAS}$$

For example, below −78 °C the gas carbon dioxide exists as a white solid. If this solid is allowed to warm up, it does not become a liquid, but sublimes to form carbon dioxide gas. For this reason, solid carbon dioxide is sometimes called dry ice. Other examples of common substances that sublime are iodine and naphthalene.

1.2 The structure of cells

Some organisms, such as some members of the Monera (e.g. bacteria) and Protoctista (e.g. *Amoeba*), are **unicellular**, consisting of a single cell. They are able to carry out all the functions needed to sustain life, such as respiration, nutrition and reproduction, within one cell. Most plants and animals are **multicellular**, having large numbers of different types of cell organised into tissues and organs. In these organisms, the cells are specialised to carry out specific functions.

Even with a microscope it is difficult to see the structures within the cells, so the tissues are often stained with special dyes in order to make them visible. In the 1930s, powerful electron microscopes were developed allowing scientists to discover the detailed structure of cells. This resulted in a greater understanding of the internal organisation of cells and how they function.

All cells have the following structures:

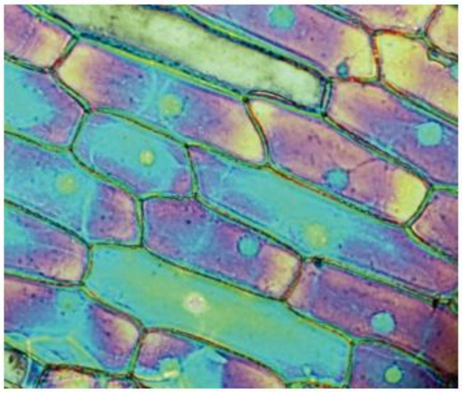
- a **cell membrane** surrounding the cell contents
- **cytoplasm** containing many smaller structures called **organelles**
- a nucleus containing the **chromosomes**
- organelles, such as **mitochondria** and **ribosomes**, which are too small to be seen using a light microscope.

Figures 1.2.2 and 1.2.3 show the basic structures found in a plant cell and an animal cell.

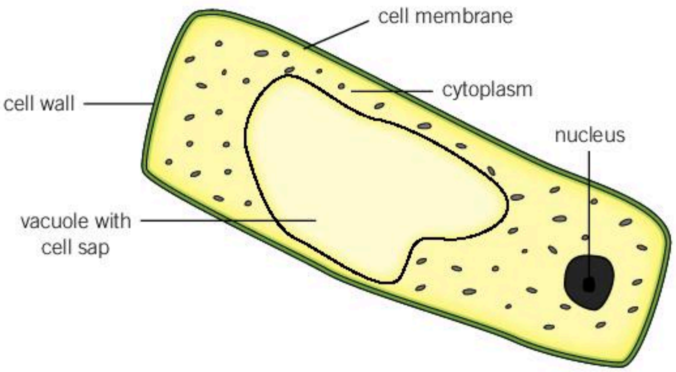
Learning outcomes

By the end of this topic you will be able to:

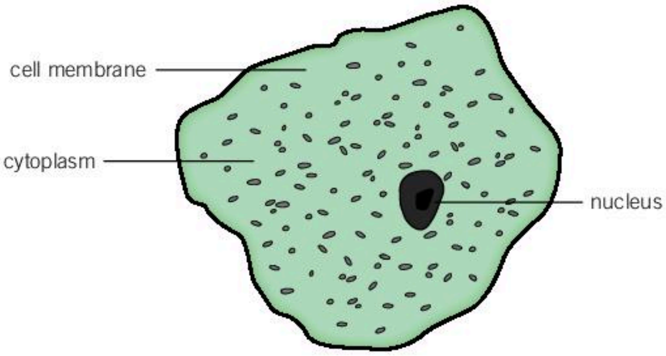
- draw a simple diagram of an unspecialised plant cell
- draw a simple diagram of an unspecialised animal cell
- name the structures found in unspecialised cells
- label diagrams of plant and animal cells
- construct a model of a cell using found materials.



▲ **Figure 1.2.1** Cells from the inner epidermis of an onion bulb as seen under a light microscope

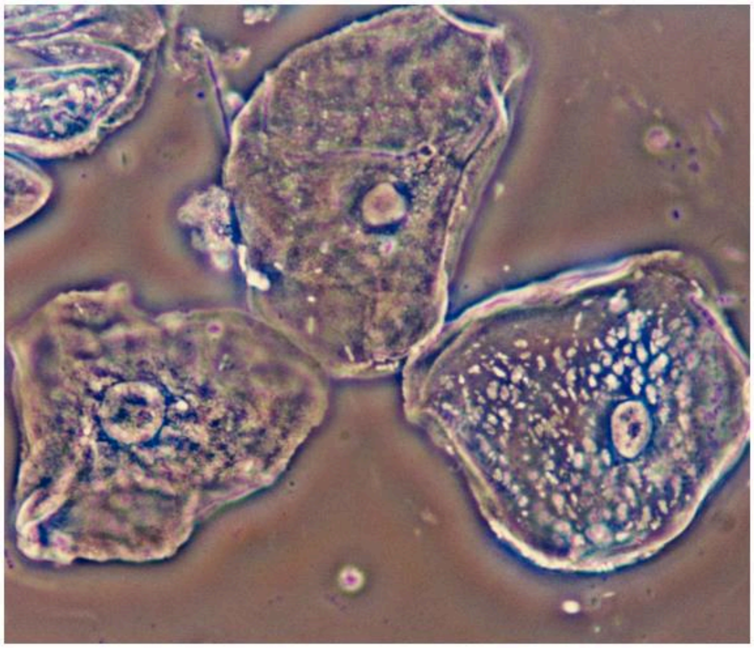


▲ **Figure 1.2.2** A simple plant cell



▲ **Figure 1.2.3** A simple animal cell

Animal cells do not have rigid **cell walls**, whereas plant cells do. Most plant cells have a large central **vacuole** filled with **cell sap** (a solution of sugars and minerals). Animal cells do not usually have vacuoles but, if present, they are very small. Some plant cells are involved in photosynthesis and have **chloroplasts** in their cytoplasm. Chloroplasts are organelles containing the green pigment **chlorophyll** which absorbs the light energy needed for photosynthesis.



▲ **Figure 1.2.4** Cells from the lining of the cheek as seen under a light microscope

Practical Activity 1.2.1

Drawing and modelling cells

Look carefully at the photomicrographs and diagrams of simple cells. Use the diagrams to help you identify the different structures on the photomicrographs.

1 Make large clear diagrams of an animal cell and a plant cell, labelling all the structures.
2 Build a model of a plant cell and an animal cell using Plasticine or other materials you have at home or in the laboratory. Think about using a small box to represent the cell wall of the plant cell and a plastic bag to represent the cell membrane.

Questions

1 Give two examples of unicellular organisms.
2 Explain what is meant by 'multicellular'.
3 What is an 'organelle'? Give two examples of organelles found in cells.
4 Where are the chromosomes in a cell?
5 Name two structures that are present in plant cells but not in animal cells.
6 Where is chlorophyll found in plant cells?

1.3 The functions and importance of cell structures

Learning outcomes

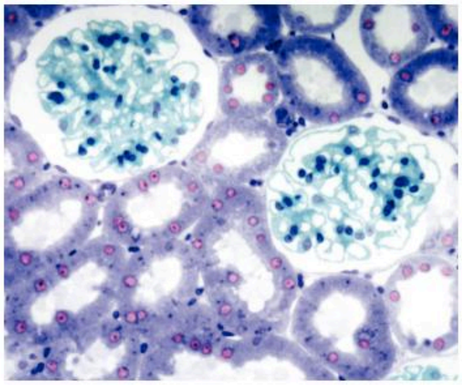
By the end of this topic you will be able to:

- state the functions of the cell wall, cell membrane, nucleus, chromosomes, cytoplasm, mitochondria, vacuoles and chloroplasts
- explain the importance of these structures in plant and animal cells.

The structures which are found in cells all have specific functions. These functions and their importance are summarised in Table 1.3.1.

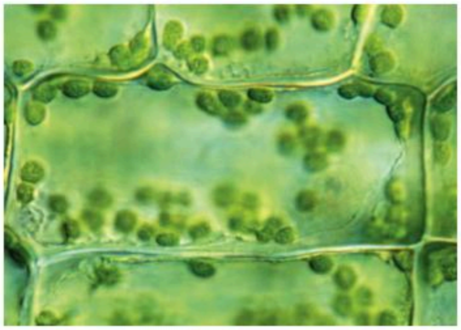
▼ **Table 1.3.1** The function and importance of cell structures

Structure	Function and importance
Cell membrane	It forms the boundary between the cell contents and the surroundings. It can control the movement of substances into and out of the cell.
Cytoplasm	All the activities of the cell take place here. It contains cell organelles, such as mitochondria and ribosomes, and food reserves such as glycogen, starch or oil droplets. It may look granular.
Nucleus	It contains the chromosomes which are made up of deoxyribonucleic acid (DNA) and contain the genetic code. Information in the nucleus controls the development and all the activities of the cell.
Mitochondrion (plural: mitochondria)	The mitochondrion is the organelle in which respiration takes place, releasing energy for cell activities. Active cells, such as liver cells, contain large numbers of mitochondria. The structure of the mitochondria is not easy to see as they are only just visible when cells are viewed using a light microscope.
Cell wall	The cell wall is a non-living layer outside the cell membrane of a **plant cell**. It allows liquids and dissolved substances to pass freely through it. The cell wall gives the cell shape and support. Cell walls are not present in animal cells.
Vacuole	A mature **plant cell** has a large central vacuole filled with cell sap, which is a dilute solution of salts and sugars. It may also contain pigments. If vacuoles are present in animal cells, they are small and not permanent.
Chloroplast	A chloroplast is an organelle, containing the green pigment chlorophyll, found in the cytoplasm of **plant cells**. Chloroplasts are present in large numbers in cells, such as the palisade cells in a leaf, where photosynthesis takes place. Chloroplasts are not found in animal cells.



▲ **Figure 1.3.1** Section through kidney tissue

The photomicrograph in Figure 1.3.1 shows a section through kidney tissue as seen using a light microscope. The tissue has been stained to show details of the cells. Notice that the cells do not have cell walls. The nuclei are clear and the cytoplasm appears granular, but it is not possible to see any other organelles at this magnification as they are too small. Compare this photomicrograph with Figure 1.3.2, which shows some cells from the leaf of Canadian pondweed (*Elodea canadensis*). The leaf cells have definite cell walls and large numbers of chloroplasts.



▲ **Figure 1.3.2** Canadian pondweed

Questions

1. Name the organelle in which respiration takes place. Where in a cell would you find this organelle?
2. What is the function of the cell wall?
3. What is the function of the nucleus?
4. Why are the leaves of plants green? Explain the importance of this green colour to the life of the plant.
5. What is cell sap? Where is it found?
6. Make a table of the differences between plant and animal cells.

Learning outcomes

By the end of this topic you will be able to:

- appreciate that some living organisms consist of a single cell
- name examples of fungi, bacteria and viruses
- describe some positive and some negative aspects of fungi, bacteria and viruses.

▲ **Figure 1.4.1** Fungi growing on stale bread

1.4 Microbes

The plants and animals you see in everyday life are multicellular. This means they consist of many millions of cells. There are, however, some organisms called **microbes** that are **unicellular**. This means they consist of only one cell. They are so small they can only be seen with powerful microscopes. There are many groups of microbes; you will find out about three groups: fungi, bacteria and viruses.

Fungi

Fungi, such as mushrooms and yeast, may be unicellular or multicellular organisms. Fungi cells are different from plant cells in that their cell walls are composed of a substance called chitin and not cellulose.

You may have seen fungi growing on waste food (see Figure 1.4.1), but fungi can be useful. One type of fungus makes penicillin, which is an important antibiotic. Although mouldy bread may look and smell unpleasant, the fungi are carrying out an important job. They are **decomposers**, organisms that break food down so that the nutrients it contains can be released. When nutrients go back into the soil, they can be taken up again by other organisms (e.g. plants).

Practical Activity 1.4.1

Examining bread mould

Materials:

- Slice of bread
- Polythene bag
- Hand lens
- Water

Method:

1. Spray a little water on the bread to make sure it is damp.
2. Place the bread in a plastic bag for a few days until you can see that mould has formed.
3. Carefully examine the mould with a hand lens.

Yeast is a unicellular fungus used in the manufacture of alcoholic drinks, such as beer, and in making bread.

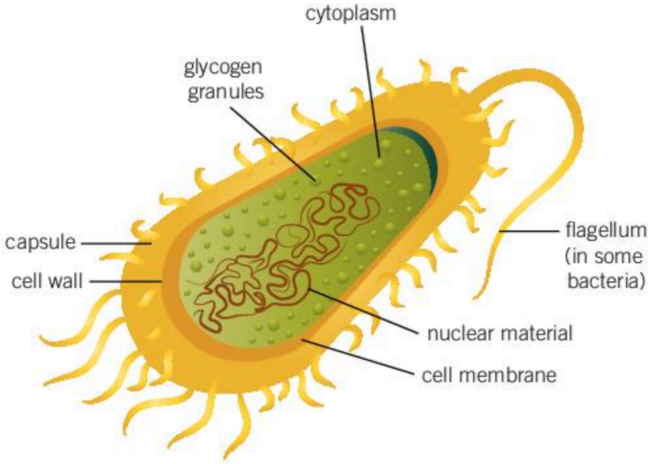
When yeast is mixed with sugar solution, it converts the sugar to alcohol and carbon dioxide gas. In beer making, the carbon dioxide is allowed to escape leaving the alcohol behind.

In bread making, the yeast is mixed with flour and sugar to form dough. When the dough is baked, bubbles of carbon dioxide gas cause the bread to rise and swell, while the alcohol evaporates into the air.

Although fungi can be useful, they can also be the cause of some unpleasant skin conditions in humans. Athlete's foot is caused by a fungal infection. The area between the toes becomes very itchy and, if not treated, will become inflamed and very sore.

Bacteria

Bacteria are unicellular organisms but they differ in structure from both animal and plant cells.



▲ **Figure 1.4.2** Structure of a typical bacterium

A bacterium consists of a capsule, made of a cell wall and membrane, enclosing cytoplasm. Unlike plant cells, the cell wall of a bacterium is not made of cellulose. Some bacteria have whip-like structures called flagella that help them to move.

A bacterium has no nucleus, but instead the 'nuclear' material is distributed in the cytoplasm. The cytoplasm also contains a store of glucose in the form of granules of glycogen.

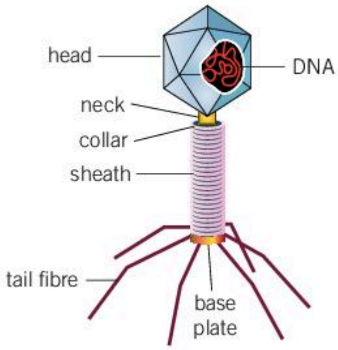
Like fungi, bacteria also play an important role as decomposers by breaking down vegetable waste so that nutrients are recycled.

Bacteria can also have a negative impact on our lives. There are many diseases caused by **parasitic** bacteria entering the body. Table 1.4.1 gives some common examples of bacteria as disease-causing **pathogens**.

▲ **Figure 1.4.3** Bacteria break down vegetable waste in a compost heap

▼ **Table 1.4.1**

Diseases caused by bacteria	Comment
cholera	causes diarrhoea and vomiting
diphtheria	affects the nose and throat
salmonella	causes food poisoning
tetanus	causes muscular spasms and stiffness
typhoid	causes fever which, if left untreated, can lead to internal bleeding and other complications
tuberculosis	affects the lungs
whooping cough	affects the lungs



▲ **Figure 1.4.4** Structure of a typical virus

Viruses

Viruses are much smaller than bacteria and consist of 'nuclear' chemicals wrapped in a protein coat (see Figure 1.4.4). They can live and reproduce only in living organisms, but under favourable conditions they can reproduce very quickly.

As is the case with a bacterium, a virus does not have a nucleus. The 'nuclear' material is held within the head of the virus. Viruses, such as *Escherichia coli*, are used in genetic engineering and medicine.

There are many diseases caused by viruses entering the body. Table 1.4.2 gives some common examples.

▼ **Table 1.4.2**

Diseases caused by viruses	Comment
chicken pox	affects skin and nerves
common cold	affects the nose and throat
hepatitis	inflammation of the liver
influenza (flu)	affects the nose and throat, and may cause headaches, coughing, muscular pain and fatigue
measles	affects the skin and lungs
mumps	affects the salivary glands
rubella (German measles)	affects the skin and glands but may also cause fever, coughing and aching joints

Question

1 Diseases caused by microbes have existed as long as humans have been on Earth. Explain why people did not know what caused these diseases until relatively recently.

1.5 Diffusion, osmosis and active transport

Diffusion

Liquids and gases are composed of tiny particles called **molecules**. These have energy and are always moving about in random directions. As a result of this movement, they spread out to fill the space available. **Diffusion** is the movement of molecules from a region where they are in a higher concentration to a region where they are in a lower concentration until they are evenly distributed.

Diffusion in gases can be shown using bromine. At room temperature, bromine is an orange-brown volatile liquid. If we pour some of this liquid into a gas jar and invert another gas jar over the top, the liquid bromine vaporises and the gas molecules diffuse and spread into the upper gas jar (see the Key fact box on the right).

Diffusion also takes place in liquids. You can demonstrate this by carrying out the practical activity below. A crystal of potassium manganate(VII) is dropped into the bottom of a beaker of water. Initially the purple colour will be intense at the bottom of the beaker, but after a few hours the whole solution will become a uniform purple colour.

Practical Activity 1.5.1

Demonstrating diffusion

Materials:

- A beaker of distilled water
- A crystal of potassium manganate(VII)

Method:

1. Carefully drop the crystal of potassium manganate(VII) into the beaker by letting it slide down the side of the glass.
2. Observe what happens.
3. Leave the beaker undisturbed for an hour and describe what has happened.
4. If possible, leave the beaker undisturbed overnight and then describe its appearance.
5. Explain all your observations using what you have learnt about diffusion.

A **diffusion** or **concentration gradient** refers to the difference in the concentrations of molecules in two areas. If there is a steep concentration gradient, the molecules will diffuse from the area of higher concentration to the area of lower concentration at a rapid rate. If the concentration gradient is less steep, the rate of diffusion will be slower (see Figue 1.5.2).

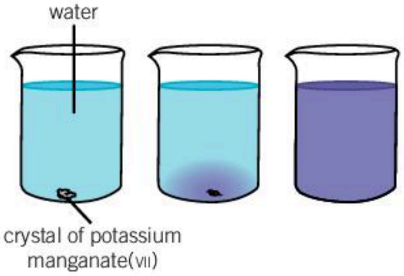


Figure 1.5.1 The potassium manganate(VII) diffuses until the concentration of the molecules is the same throughout the solution

Learning outcomes

By the end of this topic you will be able to:

- describe the process of diffusion
- carry out experiments that demonstrate diffusion
- describe the process of osmosis
- explain that the cell membrane is partially permeable
- carry out simple investigations to show the movement of molecules and ions.

Key fact

Eventually the colour in the upper and lower gas jars will be the same. There is an equal amount of bromine gas in each gas jar. The bromine molecules have not stopped moving. They diffuse in random directions. The colour in the gas jars remains the same because an equal number of molecules diffuse upwards and downwards.

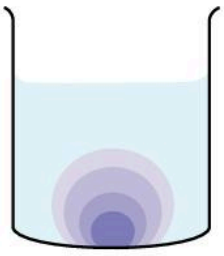
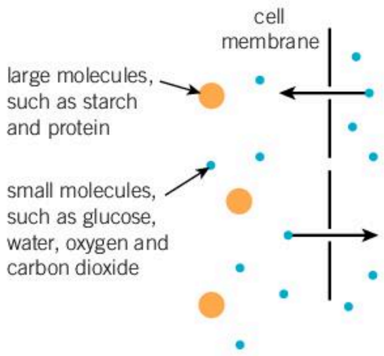
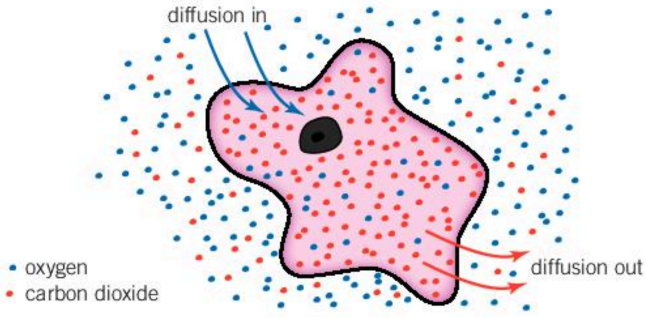


Figure 1.5.2 The concentration of molecules will decrease from the centre outwards



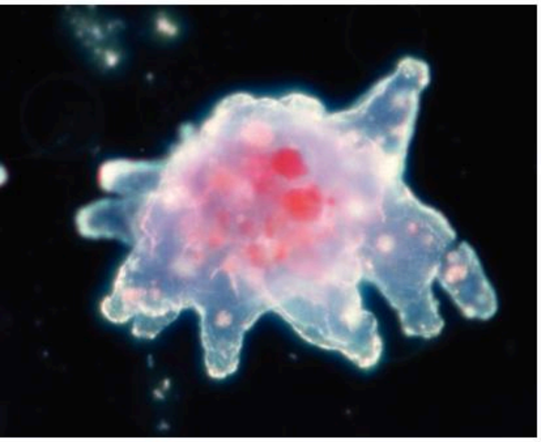
▲ **Figure 1.5.3** Only small molecules can pass through the cell membrane



▲ **Figure 1.5.4** Diffusion in *Amoeba*

Diffusion and cell membranes

In living organisms, substances pass into and out of a cell through a cell membrane. We can think of the cell membrane as a barrier with many tiny holes or pores in it. Small molecules, such as oxygen, carbon dioxide, water and glucose, are able to diffuse easily through the membrane but others with larger molecules, such as starch and proteins, cannot. So a cell membrane is **partially permeable**, allowing some substances to pass through but not others.

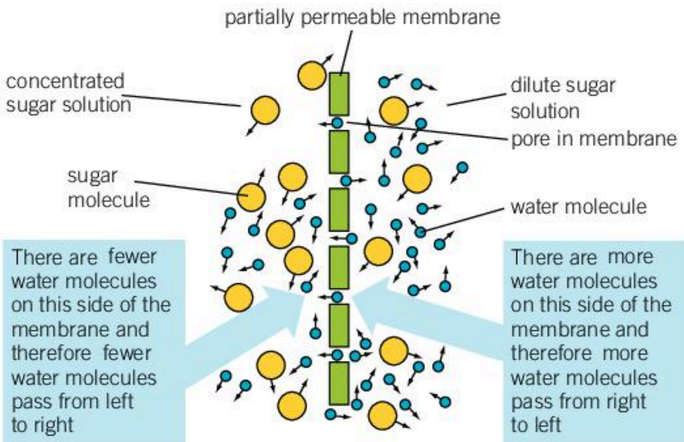


▲ **Figure 1.5.5** An *Amoeba* as seen under a light microscope

Diffusion and the total surface area to volume ratio

The surface area of an object refers to the area of its outer surfaces and its volume is the amount of space it occupies. As an object increases in size, the ratio of its total surface area to volume decreases. This affects small organisms that rely on diffusion for survival as their size will determine the rate at which they can obtain vital substances, such as oxygen and water.

In microscopic, unicellular organisms such as *Amoeba*, the surface area: volume ratio is very high, so that oxygen and nutrients can diffuse quickly through the cell membrane. The needs of the organism can be supplied by diffusion alone. In larger organisms, such as humans, the surface area: volume ratio is much smaller and specialised exchange surfaces with large surface areas are required to meet the demands of the cells. For example, there are large surface areas in our lungs for the exchange of gases and provided by the villi of the small intestine for the absorption of the products of digestion.



▲ **Figure 1.5.6** Water particles move through the membrane by osmosis until equilibrium is reached

Osmosis

Osmosis is a special kind of diffusion in which water molecules pass through a partially permeable membrane from a solution where they are in higher concentration to one in which they are in lower concentration. If two solutions are separated from each other by a partially permeable membrane, water molecules will move by osmosis from the weaker, or more dilute, solution to the stronger, more concentrated, one.

When the concentration of water molecules is the same on either side of the membrane, the rate at which the water molecules pass in each direction will be the same. The system is in equilibrium as equal numbers of water molecules move in both directions.

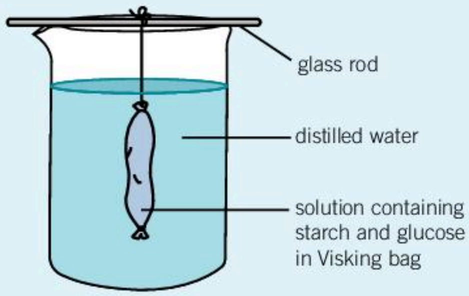
Practical Activity 1.5.2

Investigating osmosis (I)

Skills assessed: Observation/Recording/Reporting and Analysis and Interpretation.

Materials:

- About 10 cm of Visking tubing
- Cotton thread
- Beaker filled with distilled water
- Solution containing starch and glucose
- Funnel
- Glass rod
- Iodine solution to test for starch
- Glucose test strips



Method:

1. Test the water in the beaker for starch and glucose before you begin.
2. Tie off one end of the Visking tubing to create a bag.
3. Using a funnel, pour some of the solution of glucose and starch into the bag until it is three-quarters full.
4. Tie the top of the bag with thread leaving a length of thread about 8 cm long still attached.
5. Tie this thread to the glass rod so that the bag containing the solution can be suspended in the beaker.
6. Leave the bag suspended in the solution for an hour.
7. Then test the water in the beaker for starch and glucose.
8. Record all your observations, including any changes to the shape of the bag, and explain your results.

If starch is present, the iodine solution will stain the starch blue-black.

Glucose test strips or Benedict's solution can be used to test for glucose. If Benedict's solution is used, the presence of glucose is indicated by the development of an orange-red precipitate on heating.

Synoptic link

See Unit 4 Topic 4.1 Practical 4.1.1 and Topic 4.2.

Key fact

A solution consists of **solute** molecules dissolved in a **solvent**. For example, a glucose solution consists of glucose molecules (solute) dissolved in water (solvent).

Exam tip

To calculate the surface area of a cube, find the surface area of one surface and multiply this by the number of surfaces. So a cube with sides of 1 cm will have a surface area of 6 cm^2.

To calculate volumes multiply the length by the breadth by the height. The cube with side 1 cm will have volume of 1 cm^3.

Questions

1. Write a definition of diffusion.
2. Explain how unicellular organisms obtain oxygen and nutrients, and get rid of carbon dioxide.
3. What is meant by the term 'partially permeable membrane'?
4. In Practical activity 1.5.2, why is it important to test the water in the beaker for starch and glucose before you put the Visking tubing bag into the beaker?
5. In Practical activity 1.5.3, why was a potato cup without sugar included?

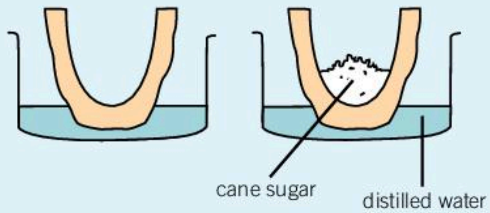
Practical Activity 1.5.3

Investigating osmosis (II)

Skills assessed: Observation/Recording/Reporting and Analysis and Interpretation.

Materials:

- A potato
- A scalpel or knife
- Distilled water
- Two dishes to hold the potato halves
- Sugar



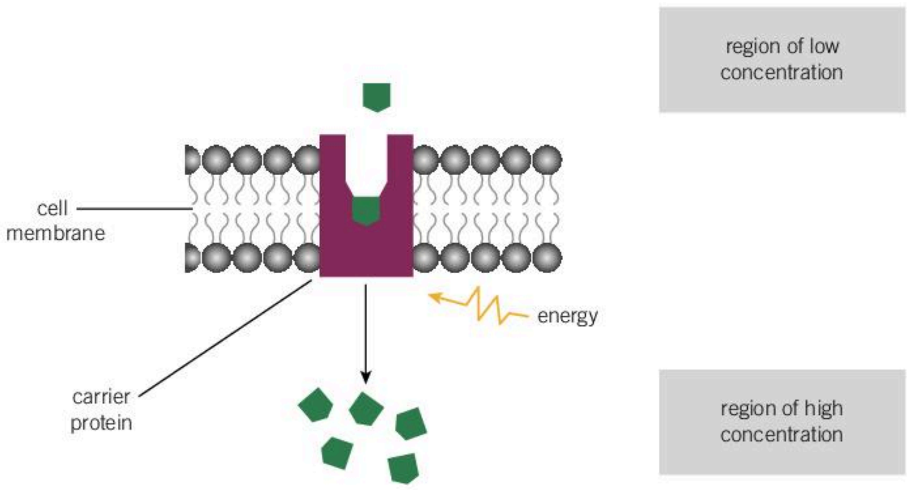
Method:

1. Use the scalpel or knife to peel the potato, cut it in half and hollow out the middle of each half to make two cups.
2. Half fill one of the cups with sugar.
3. Stand each cup in a dish of distilled water for an hour.
4. At the end of the hour, carefully examine the inside of both cups.
5. Record your observations and explain your results.

Active transport

Dissolved substances sometimes move across a cell membrane from a lower concentration to a higher concentration by a process called **active transport**. This process needs energy and a special protein (called a carrier protein).

The cell provides energy to the carrier protein allowing it to change its shape to let particular substances through. The protein is then able to move the substances through the cell membrane against the concentration gradient as shown in Figure 1.5.7.



▲ **Figure 1.5.7** Active transport

There are many examples of active transport in living organisms. Plant roots absorb minerals from the soil water surrounding them by active transport. In the human body, the glucose formed during digestion passes from the small intestine into the blood stream by active transport.

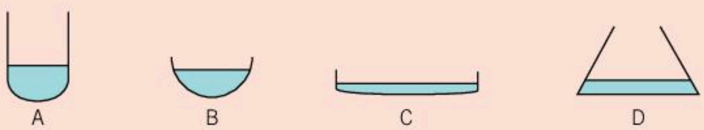
Exam-style questions

Multiple choice

1 During which of the following changes does a gas become a liquid?
A Boiling
B Condensing
C Freezing
D Melting

2 Which of the following is a feature of solids but **not** liquids and gases?
A Easily squashed
B Fixed shape
C Particles vibrate
D Takes shape of container

3 In an experiment an equal volume of water was placed in four containers and they were left under the same conditions. From which container will the water evaporate quickest?



4 Animal cells do not have
A a nucleus **B** a cell membrane
C chloroplasts **D** chromosomes

5 The organelle which is responsible for releasing energy in cells is
A a chloroplast **B** a ribosome
C a chromosome **D** a mitochondrion

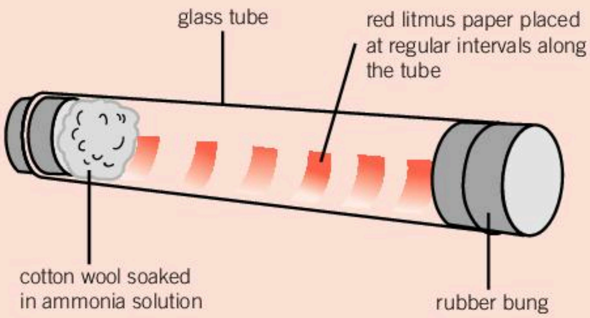
6 A partially permeable membrane does not allow the passage of
A glucose **B** proteins
C water **D** mineral ions

Structured questions

7 A botijo (earthenware drinking jug) is a porous clay pot traditionally used in Spain to keep water cool. It has a spout through which it can be filled and water can be drunk.

Explain how a botijo is able to keep water cool.

8 Ammonia, a gas, dissolves in water to form ammonia solution. If you open a bottle of ammonia solution, some ammonia molecules will escape and diffuse out of the bottle. Ammonia is an alkali and changes red litmus paper blue.



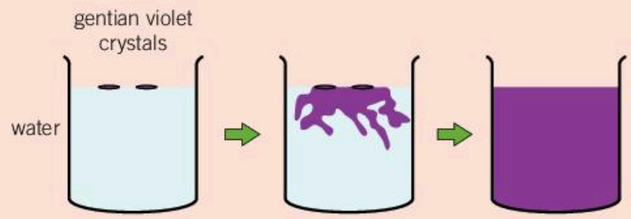
a What would happen to the colour of the litmus paper as the ammonia molecules move?
b What is the name of the process by which the ammonia moves?

9 a Draw and label fully a typical plant cell.
b On your diagram underline those structures that are not found in animal cells.

10 a Write a definition of diffusion.
b Explain why osmosis is a special case of diffusion.
c How does active transport differ from osmosis?

11 a Explain what is meant by surface area to volume ratio.
b Explain why a large organism requires special structures in order to carry out gas exchange and absorb nutrients.

12 A student placed two small crystals of the dye gentian violet on the surface of cold water in a beaker. The diagram shows what happened over the following hour.



a By what process do particles spread through water?
b Describe what happened to the crystals during the hour.
c How can you tell that the dye particles are distributed evenly throughout the solution?
d Predict what would have happened if the same crystals had been placed in a large beaker containing ten times as much water.
e Predict what would happen if the same crystals had been placed in a beaker of warm water.

Section A

2 Reproduction and growth

All living things reproduce. Reproduction is one of the characteristics of life. It is the ability of an organism to produce offspring. Genetic material is transferred from parents to offspring. There are two types of reproduction: asexual and sexual. Living things grow and develop before they reproduce.

2.1 Asexual and sexual reproduction

Learning outcomes

By the end of this topic you will be able to:

- define asexual reproduction
- describe the process of simple cell division (binary fission)
- describe the important features of sexual reproduction
- compare asexual and sexual reproduction
- explain the advantages and disadvantages of asexual and sexual reproduction.

Reproduction involves the production of offspring. Offspring produced by **asexual reproduction** have only one parent, whereas in **sexual reproduction** two parents are required.

Asexual reproduction in plants and animals

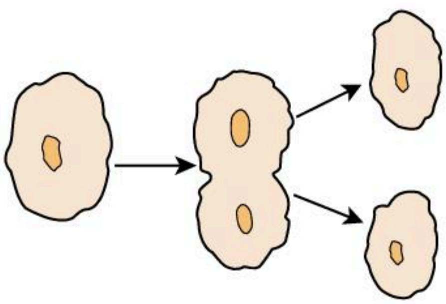
Asexual reproduction is the production of new individuals from a single parent. Asexual reproduction takes place in many single-celled or unicellular organisms, such as bacteria and protists, and in some simple multicellular animals, such as hydra and the sea anemone. Some insects, such as aphids, are also able to reproduce asexually if conditions are suitable. The offspring are identical to the parent. Identical offspring from a single parent are referred to as a **clone**.

Did you know?

Cloning has been carried out with animals, including sheep. A sheep that was named Dolly was the first cloned animal. There are strict laws concerning cloning. Many people are concerned that cloning of humans may be carried out.

Simple cell division

Unicellular organisms, such as bacteria and protists, can reproduce asexually by the process of **binary fission**. The genetic material inside the nucleus is copied. This means that there is enough genetic material for two new cells. Each new cell is formed using some of the cytoplasm of the parent. Two new identical cells are formed. In suitable conditions binary fission can take place quickly and result in a rapid increase in the size of the population.

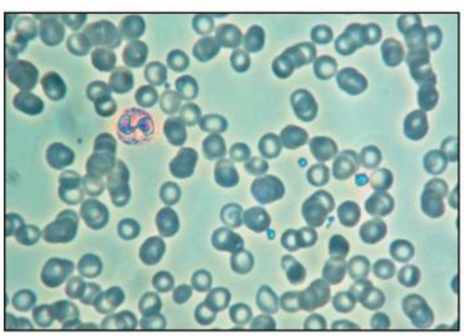


▲ **Figure 2.1.1** *Amoeba* reproduces by binary fission. The nucleus divides into two followed by the cytoplasm. The two small cells then feed and grow

Key fact

Parasites live on, or inside, other organisms. These are called hosts.

The protist *Entamoeba* is a parasite that causes dysentery. *Entamoeba* is spread by contaminated drinking water. It reproduces asexually by binary fission inside the small intestine. The new protists are excreted in the faeces and move on to another host.



▲ **Figure 2.1.2** Malarial parasite in human blood

Another protist, *Plasmodium*, is the parasite that causes malaria in humans. It has two hosts, a human and a mosquito. In both hosts asexual reproduction takes place. Vast numbers of the parasite are produced to infect new hosts and continue its life cycle.

Sexual reproduction

Sexual reproduction involves the joining together of sex cells called **gametes**. The male gamete joins with the female gamete in a process called **fertilisation**. The result of fertilisation is called a **zygote**. It will grow into a new organism. The new organisms produced are not identical to their parents or to each other.

Both male and female gametes may be produced by one parent, as is the case in many flowering plants and some animals, such as earthworms. In most animals, there are male and female organisms; the male produces the male gametes called **sperm** and the female produces female gametes called **eggs** or **ova**.

▼ **Table 2.1.1** Comparison of sexual and asexual reproduction

Sexual reproduction	Asexual reproduction
• Two parents: male and female • Sex cells called gametes produced • Fertilisation	• One parent • No gametes • No fertilisation
Advantages: • Offspring are different both from each other and to parents. • It produces **variation** in the offspring so organisms gradually change or evolve. • There will always be a proportion of organisms which can survive and adapt to unfavourable changes, so the population is less likely to die out.	**Advantages:** • Offspring can be produced quickly. • Often large numbers of offspring. This is useful to parasites where any individual stands only a small chance of finding a new host. • Desirable characteristics can be artificially bred into a population giving them certain advantages. For example, farmers have been able to produce high-yield or disease-resistant crops and livestock.
Disadvantages: • Mating partners must be available. • Fewer offspring are produced.	**Disadvantages:** • Offspring are genetically the same as their parents. • There is no variation, so population is less likely to survive adverse changes to their environment.

Exam tip

Some form of comparison between asexual and sexual reproduction often forms the basis of a question.

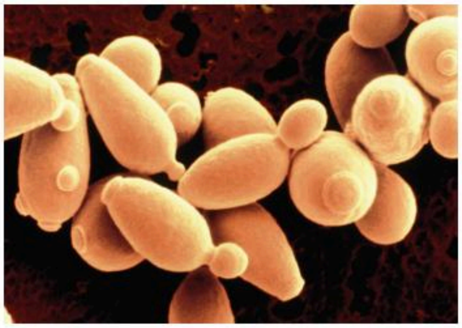
Questions

1. Explain the term *asexual reproduction*.
2. Name a multi-cellular animal that reproduces asexually.
3. Describe the process of simple cell division.
4. State two advantages of asexual reproduction.
5. What is the significance of variation in the offspring produced by sexual reproduction?
6. What are the disadvantages of sexual reproduction?

Learning outcomes

By the end of this topic you will be able to:

- describe asexual reproduction by budding and using spores
- name some organisms that use asexual reproduction
- explain what vegetative reproduction is
- describe some different methods of vegetative reproduction.



▲ **Figure 2.2.1** Yeast cells reproducing by budding. A cell can produce more than one bud at a time

▲ **Figure 2.2.3** *Polypodium* showing spores on the back of a frond

Synoptic link

See Unit 3.2 Crop production.

2.2 Methods of asexual reproduction in plants and animals

Budding

Some unicellular organisms, such as the fungus yeast, reproduce asexually by **budding**. The parent cell develops an outgrowth of cytoplasm called a bud. When the bud has grown nearly as big as the parent cell, the nucleus of the parent is copied and divides into two. One of the nuclei moves into the bud which breaks off to give a new cell. Sometimes a chain of budded cells forms when new buds develop their own buds before they have broken off.

Another organism which reproduces by budding is *Hydra*, a simple multicellular animal found living in freshwater. The body of *Hydra* is made up of two layers of cells, the ectoderm on the outside and the endoderm on the inside. The cells of the endoderm are concerned with the digestion of food, while the ectoderm contains cells with different functions. *Hydra* can produce buds on the side of its body.

▲ **Figure 2.2.2** Hydra budding

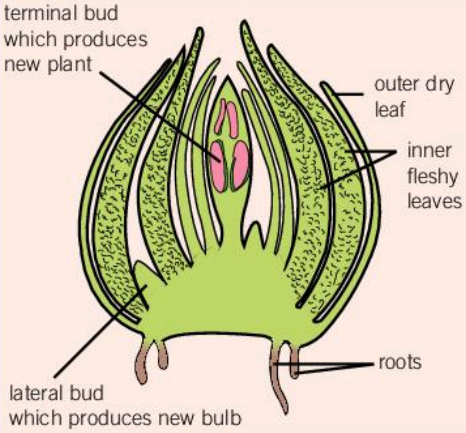
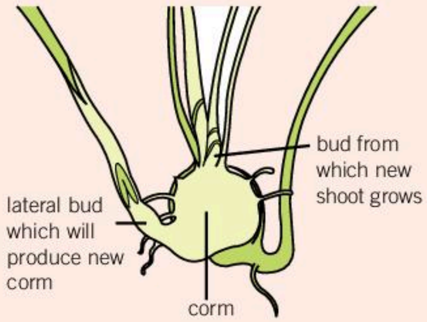
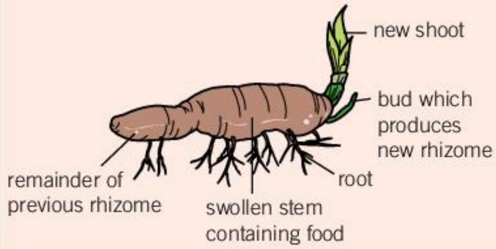
Vegetative reproduction

Asexual reproduction in flowering plants is called **vegetative reproduction**. One, or more, new plants may grow from part of the parent plant, such as the root, stem or even the leaves. This occurs naturally, but can also be made to happen artificially to produce or **propagate** new plants. For example, a potato will produce a new shoot in favourable conditions.

When a plant reproduces naturally by vegetative reproduction, it may develop a **storage organ** from a stem or root. The storage organ stores food. If growing conditions become unfavourable, the parent plant may die but the storage organ will remain. When the conditions improve, a new plant will grow from this using the stored food.

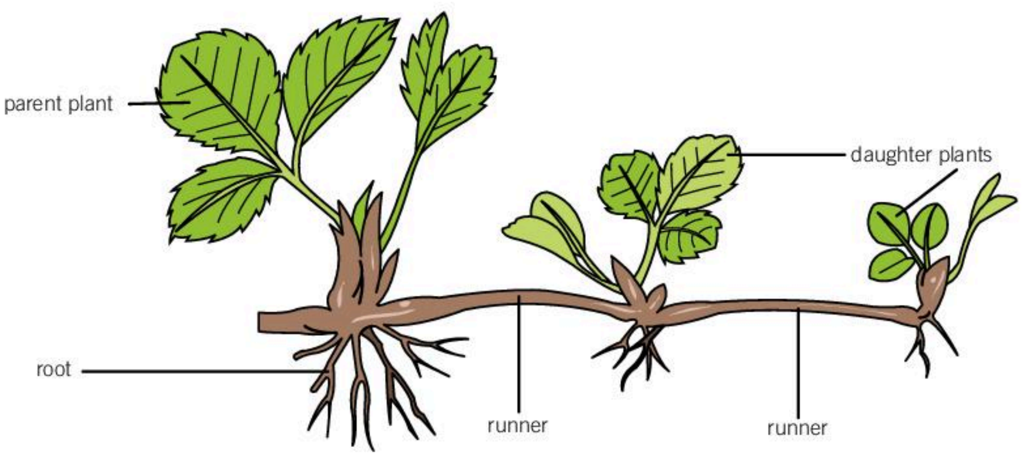
There are different types of storage organs such as corms, bulbs and rhizomes.

▼ **Table 2.2.1** Bulbs, corms and rhizomes

Bulbs	**Corms**	**Rhizomes**
Underground stems surrounded by fleshy leaves storing food	Short, swollen, vertical underground stems storing food	Swollen horizontal underground stems storing food
		
Examples: onion and garlic	Examples: dasheen and eddo	Examples: ginger, canna and lily

Runners

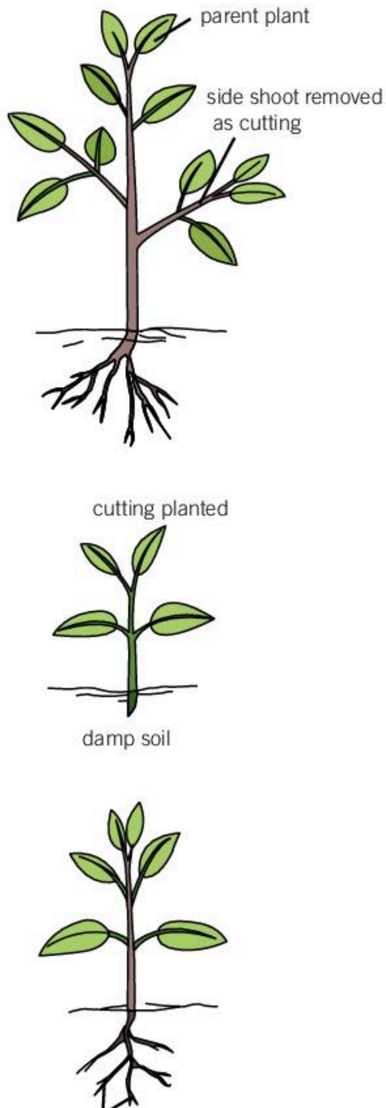
Vegetative reproduction by **runners** does not involve a storage organ. A runner is a stem that grows horizontally away from the parent plant. The tip of the runner forms roots, which grow down into the soil. Shoots also form which become new plants. Nutrients pass from the parent plant to the new plant through the runner until the new plant can produce its own food and become independent, after which the runner dies. Examples of plants that produce runners are strawberries and water grass.



▲ **Figure 2.2.4** A runner

Cuttings

Gardeners and farmers can produce new plants by artificial vegetative reproduction using **cuttings**. A part of the plant, such as a stem, is cut from the parent plant and placed in suitable conditions, such as damp soil. The cutting grows roots and a shoot to form a new plant. Hibiscus, cassava and sugar cane are examples of plants from which cuttings can be taken.



▲ **Figure 2.2.5** Growing plants from cuttings

Tissue culture

This technique is often referred to as **micropropagation** and is a form of **cloning** as only one parent plant is involved. Tissue can be taken from a stem tip, root tip or bud and used to produce whole new plants. The tissue is carefully dissected out, surface sterilised to destroy micro-organisms and then placed on agar in a Petri dish. The agar contains nutrients and plant hormones. The cells will grow, and produce shoots and roots. Once the plantlets have become established, they can be transferred to pots and hardened off in a glasshouse.

This method of producing new plants has many advantages:

- large numbers of plants can be produced
- the parent plant can be chosen for its advantageous characteristics (e.g. resistance to disease)
- it is a quick way of producing new varieties.

▲ **Figure 2.2.6** Plant being cut up for cloning by micropropagation

Practical Activity 2.2.1

Investigating asexual reproduction in plants

Skills assessed: Drawing.

Materials:

- Corms, bulbs, rhizomes, runners
- Knives or scalpels
- Microscope set up
- Slides of yeast budding
- Slide of *Hydra* with bud

You will be supplied with a variety of examples of vegetative reproduction and microscope slides of yeast budding and *Hydra*.

1. Carefully cut the storage organs in half vertically.
2. Make a drawing of what you can see.
3. Label the parts and write notes about their functions.
4. Observe the slides of yeast budding and *Hydra*.
5. Make a labelled drawing of your observations.

Questions

1. What is a spore?
2. Give an example of a plant that produces a rhizome.
3. Runners and rhizomes are both methods of vegetative reproduction. Explain how they are different from each other.
4. Name one organism that reproduces by budding.
5. Name three plants that are propagated by cuttings.
6. What are the advantages of tissue culture?

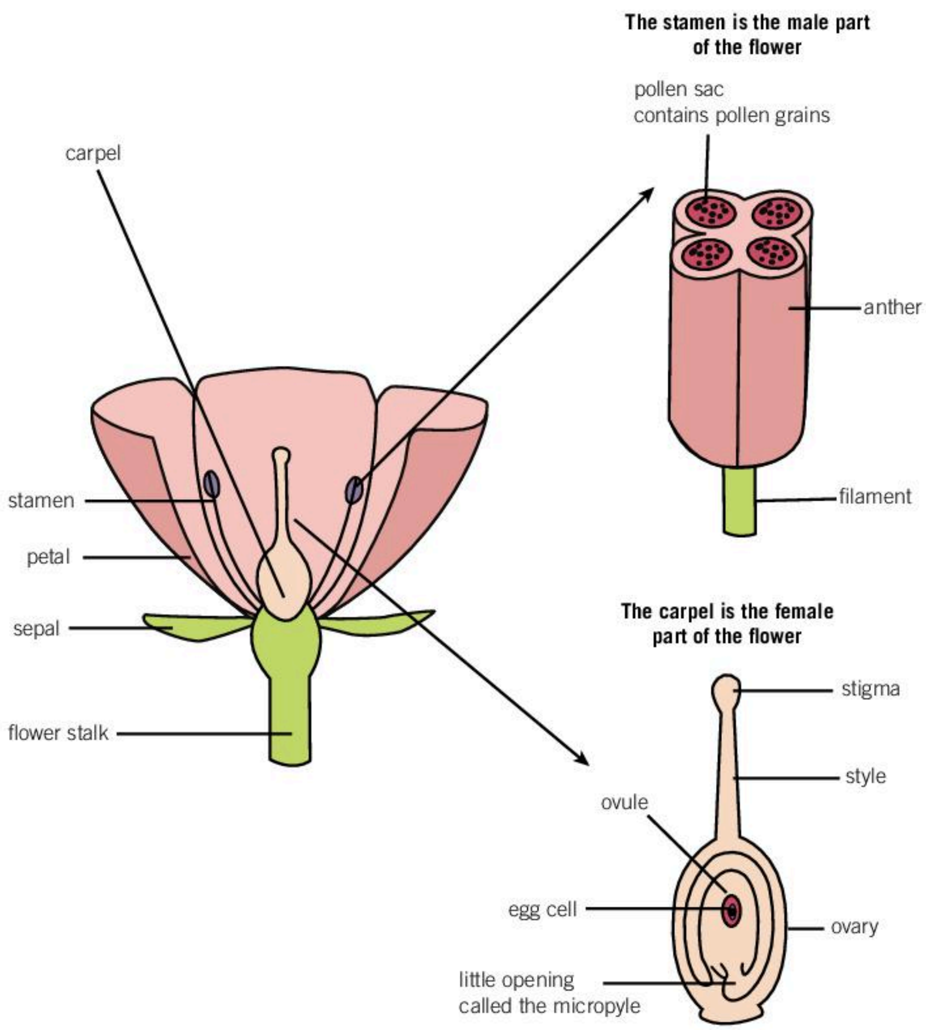
2.3 Sexual reproduction in plants and animals

Sexual reproduction in flowering plants

The **flower** is the organ of sexual reproduction in plants.

The outer-most part of a flower consists of the **sepals**. These are usually green and look similar to leaves. They protect the flower while it is developing as a bud. The flower **petals** form inside the sepals and are often brightly coloured. Both male and female parts are usually contained on the same flower. The male part is called the **stamen** and the female part is called the **carpel**.

- The stamen consists of a slender stalk or **filament**, and a swollen end which is the **anther**. Pollen grains containing male gametes form inside the anthers.
- The carpel consists of the **stigma**, the **style** and the **ovary**. The stigma is a swollen, sticky structure. Pollen grains are transferred to the stigma. The style is the stalk which connects the stigma to the ovary. Inside the ovary are one or more **ovules**, each containing a female gamete.



▲ **Figure 2.3.1** Structure of a flower

Learning outcomes

By the end of this topic you will be able to:

- describe the structure of a flower
- explain the importance of pollination
- describe some differences between wind-pollinated and insect-pollinated flowers
- explain what takes place during fertilisation
- describe the changes that happen at puberty
- draw and label a diagram of the female reproductive system
- draw and label a diagram of the male reproductive system.

▲ **Figure 2.3.2** Grass flowers showing long filaments and large anthers

Practical Activity 2.3.1

Investigating flower structure

Skills assessed: Drawing.

Your teacher will provide you with a flower.

1. Carefully cut the flower in half vertically.
2. Draw what you see.
3. Label your drawing.

Pollination

Pollination is the process by which pollen grains are transferred from the anther to the stigma. Types of pollination:

- **Self-pollination** is the transfer of pollen to the stigma on the same flower, or a flower on the same plant.
- **Cross-pollination** is the transfer of pollen from a flower on one plant to the stigma of a flower on another plant of the same species.

Cross-pollination produces a greater chance of variation in offspring, since the gametes come from different plants. This means that offspring may have a greater chance of survival in a changing environment. To increase the likelihood of cross-pollination, many plants have flowers whose male parts mature before the female parts. The flowers are able to release pollen before the stigmas are ready to be pollinated.

Methods of pollination

▲ **Figure 2.3.3** An insect-pollinated flower

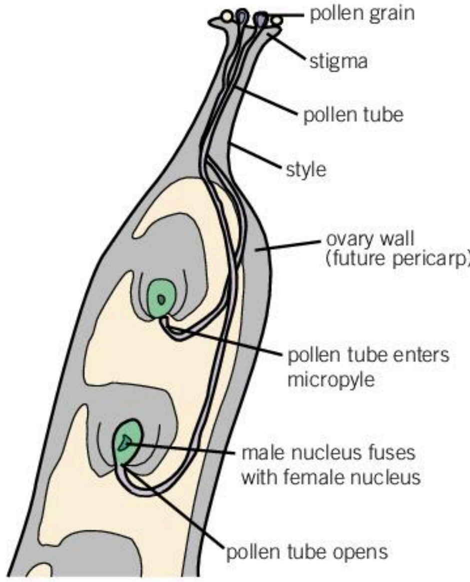
Pollen is carried by **pollinating agents**, such as the wind, birds or insects. The structure of flowers is modified to suit their pollinating agent. Typical features of wind- and insect-pollinated flowers are summarised and compared in the following table.

▼ **Table 2.3.1** A comparison of wind-pollinated and insect-pollinated flowers

Wind-pollinated flowers	Insect-pollinated flowers
Small inconspicuous petals or no petals	Large brightly coloured petals to attract insects
No scent or nectar	Often scented and/or produce nectar to attract insects
Large quantities of light, dry pollen that can be carried through the air	Smaller quantities of rough or sticky pollen that adheres to the bodies of insects
Long filaments and large anthers that hang out of the flower where they can be shaken by the wind	Stiff filaments and anthers inside the flower which have to be pushed aside by insects searching for nectar
Large stigma which is feathery and sticky and hangs out of the flower to catch passing pollen	Small, stiff, sticky stigma pushes against insects so pollen is transferred from the insect body

Fertilisation

Fertilisation is the fusion of the male and female gametes. In flowers, once a pollen grain has landed on a stigma, a small tube grows out of the pollen grain, down the style into the ovary, and into an ovule. The male gamete passes down the pollen tube and fuses with the female gamete. This produces a zygote which develops inside a **seed**. The surrounding ovary becomes the **fruit**.



▲ **Figure 2.3.4** Fertilisation

Seeds and fruits

A **seed** consists of an embryo, together with a food store, surrounded by a tough outer coat called the **testa**. The food store develops after fertilisation. When the embryo has developed fully, the tissues in the seed lose water and become hard and dry. The seed can remain in this state for a long time, until the conditions are right for germination when it will develop into a new plant.

In most plants, after fertilisation has occurred, the ovary becomes a **fruit**. The ovary wall may become hard and dry, as in ochro, peas and balata, or it may become fleshy and juicy, as in tomatoes, mangoes and paw-paws.

Fleshy fruits are eaten by animals and birds, so the seeds pass through their digestive systems and are dispersed away from the parent plant. Seeds from dry fruits may be dispersed by wind, water or by attaching themselves to the coats of animals.

Practical Activity 2.3.2

Fruits and seeds

Skills assessed: Observation/Recording/Reporting.

1. From the area around your home or school collect some examples of different fruits.
2. Carefully cut each fruit in half lengthways.
3. Write down the features of the fruit that you notice, including the position of the seeds and an estimate of how many there are.
4. Decide how you think the seeds are dispersed and explain your choice.

Sexual reproduction in humans

Puberty

As humans mature, their bodies undergo changes that prepare them for reproduction. The age at which these changes occur varies in different individuals. This time is known as **puberty** and it happens during adolescence. The table below describes some of the changes that occur in girls and boys.

▼ **Table 2.3.2** Changes at puberty

In girls	In boys
• ovaries start to produce the female hormone oestrogen; menstrual cycle starts	• testes start to produce the male hormone testosterone
• breasts enlarge	• facial hair develops
• pubic hair starts to grow	• pubic hair starts to grow
• fatty tissue is deposited in hips, thighs and arms	• voice deepens
	• metabolic rate increases
• metabolic rate increases	• body size increases
• hips broaden	• sex organs increase in size

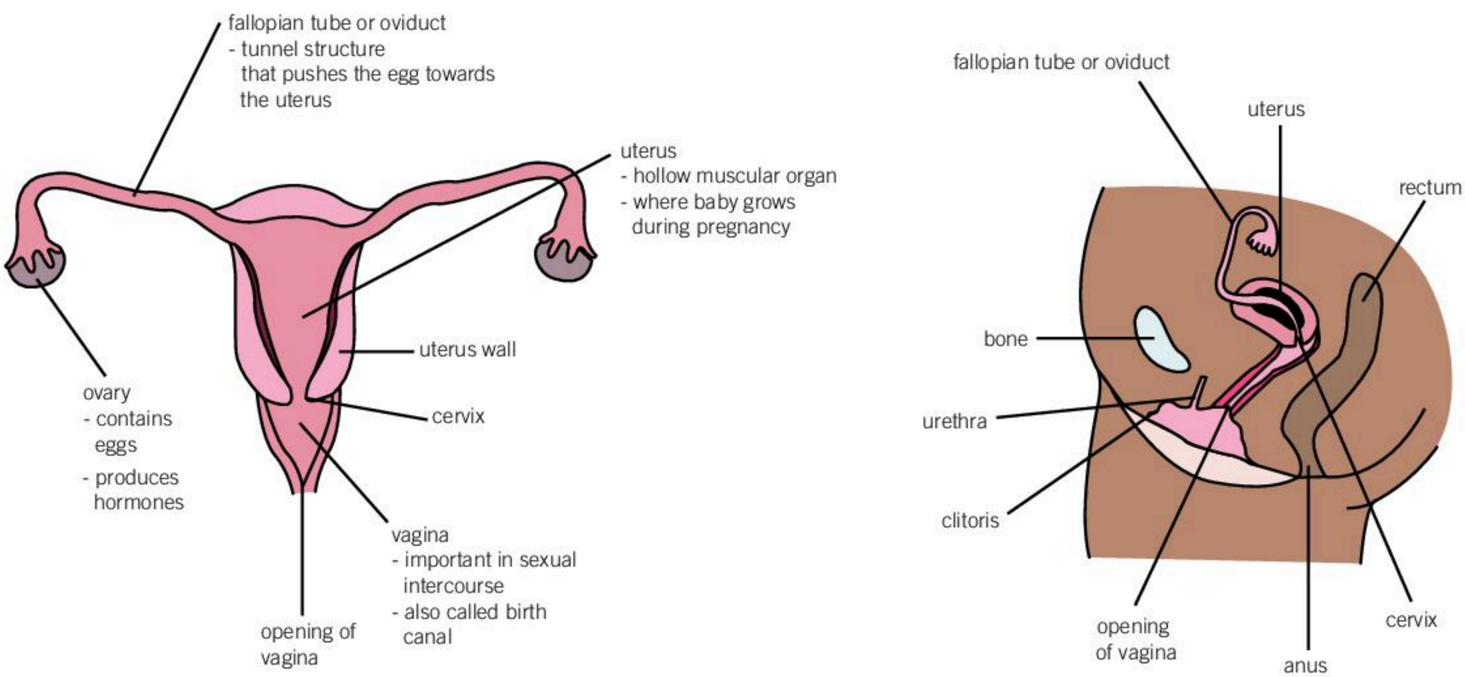
Exam tip

Make sure that you can draw and label diagrams of the male and female reproductive systems.

The observable physical signs of this are called secondary sexual characteristics. Puberty begins at around 10 to 11 years in females and around 12 to 13 years in males.

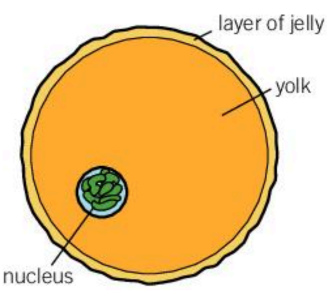
The female reproductive system

The female reproductive system consists of the **ovaries**, **uterus**, **oviducts** and **vagina**.



a) front view **b) side view**

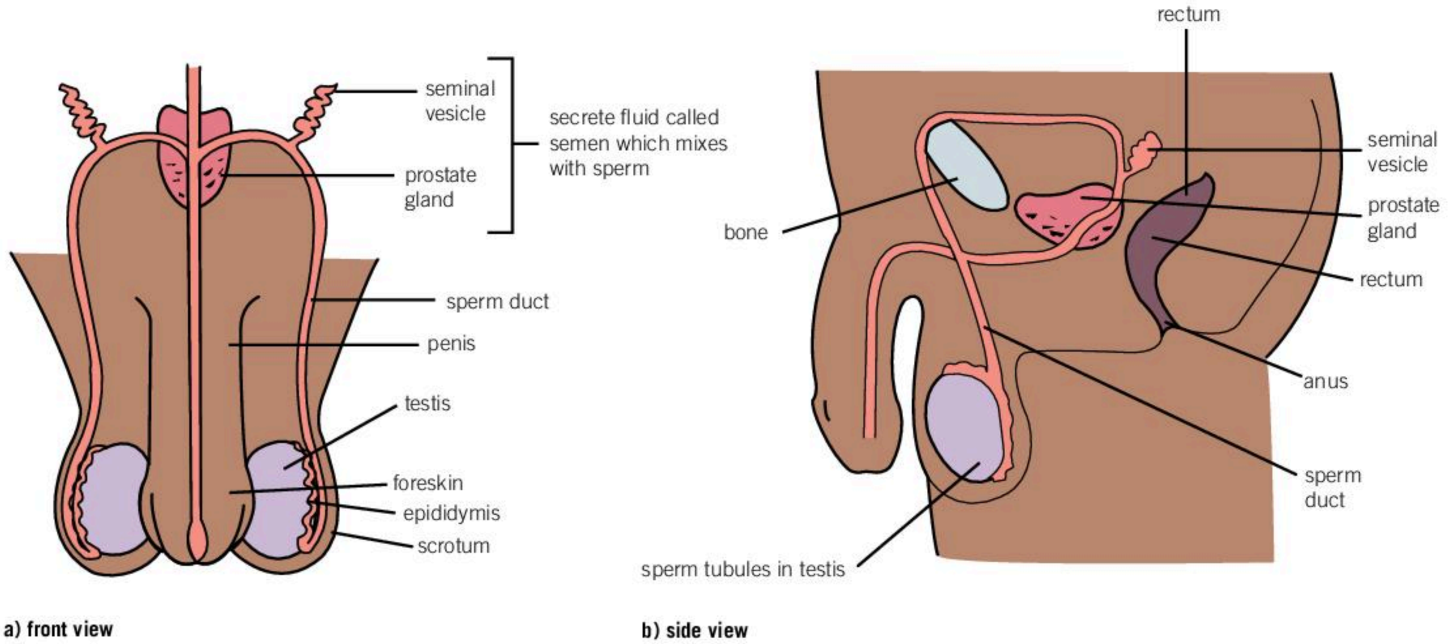
▲ **Figure 2.3.5** The female reproductive system



▲ **Figure 2.3.6** An ovum

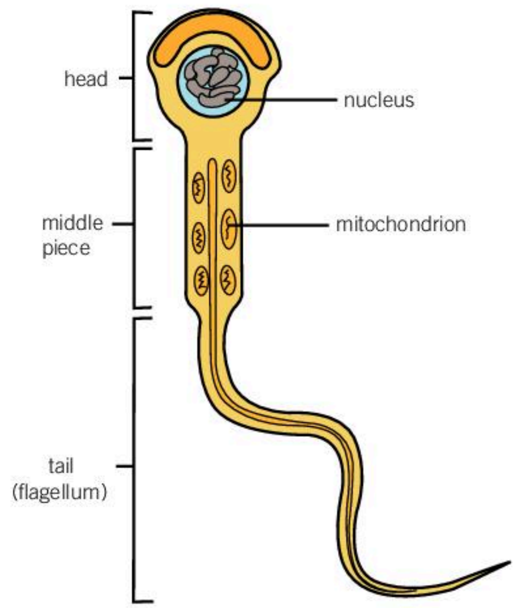
A female baby is born with all the eggs (ova, singular: ovum) that will be released in her lifetime already in her ovaries. After puberty one egg matures each month and passes from the ovary along the fallopian tube (oviduct) to the uterus (womb). This is called **ovulation**.

The male reproductive system



▲ **Figure 2.3.7** The male reproductive system

Sperm are produced in the **testes** which hang outside the body. The sperm pass into a coiled tube called the **epididymis** where they are stored. Eventually they pass along to the **seminal vesicles**, where they are mixed with fluid from the seminal vesicles and the **prostate gland**, to produce **semen**. The semen passes out of the body through the **penis**.



▲ **Figure 2.3.8** A sperm cell

Questions

1 Why do grasses typically have flowers without bright petals?

2 Name the male parts of a flower.

3 Name the female parts of a flower.

4 Why is it usually desirable that seeds are dispersed away from the parent plant?

5 Explain the difference between self-pollination and cross-pollination.

6 State the name of the hormone that causes:

a a girl to develop secondary sexual characteristics

b a boy to develop secondary sexual characteristics.

7 Describe the changes that take place during puberty in:

a females

b males.

Learning outcomes

By the end of this topic you will be able to:

- describe the menstrual cycle
- state the names of the hormones that control the female menstrual cycle
- explain the roles of oestrogen and progesterone
- describe the menopause.

Exam tip

You should be able to describe what happens to the levels of hormones during the menstrual cycle.

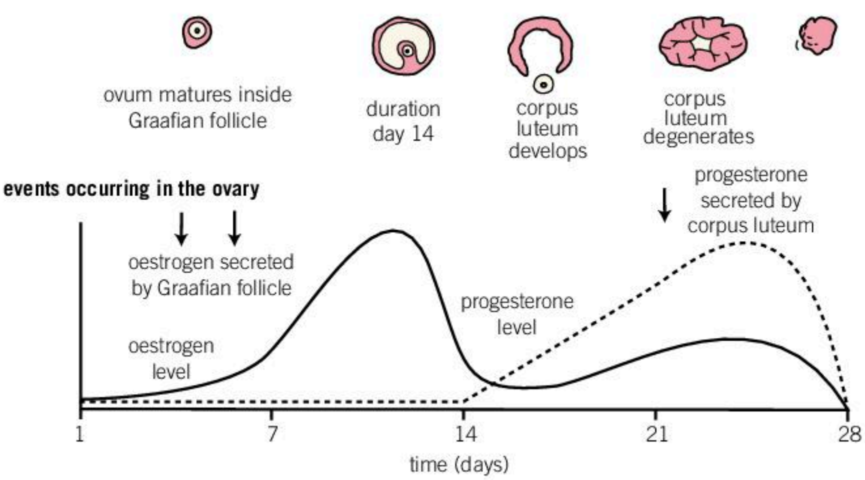
2.4 The menstrual cycle

The menstrual cycle

During a woman's reproductive years, she has a regular menstrual cycle approximately 28 days long. The cycle starts during puberty, around 12 years of age, and continues until the menopause, around 50 years of age. The cycle involves changes in the levels of female hormones in the body, as well as changes in the ovaries and uterus.

The cycle is started by the release of **follicle stimulating hormone (FSH)** from the pituitary gland. This hormone causes an egg (ovum) to mature inside a **Graafian follicle** in one of the ovaries. The hormone oestrogen is secreted by the Graafian follicle and causes the lining of the uterus to get thicker, ready for the possible implantation of a fertilised egg. As the level of oestrogen rises, the production of FSH from the pituitary gland is reduced. This is an example of a feedback mechanism. The level of oestrogen then begins to drop and **luteinising hormone (LH)** is released from the pituitary gland. LH triggers ovulation, during which the mature egg is released from the Graafian follicle into the fallopian tube.

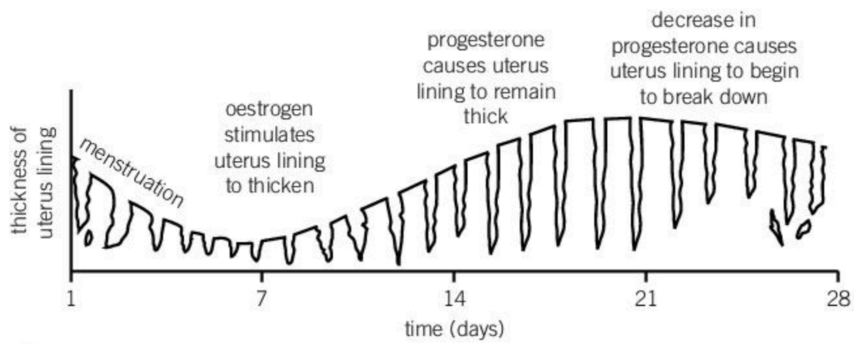
The remains of the Graafian follicle form a structure called the **corpus luteum**. About a week after ovulation, the corpus luteum starts to produce a hormone called **progesterone**. This further stimulates the lining of the uterus to thicken.



▲ **Figure 2.4.1** The menstrual cycle

If the egg is not fertilised, the corpus luteum disintegrates and the level of **progesterone** falls. The lining of the uterus breaks down and is discharged from the body through the vagina. This process is called **menstruation**, or having a period. This loss of blood and tissues lasts between two and five days. As progesterone levels fall, the pituitary gland is triggered to produce FSH, another egg begins to mature and the cycle starts over again.

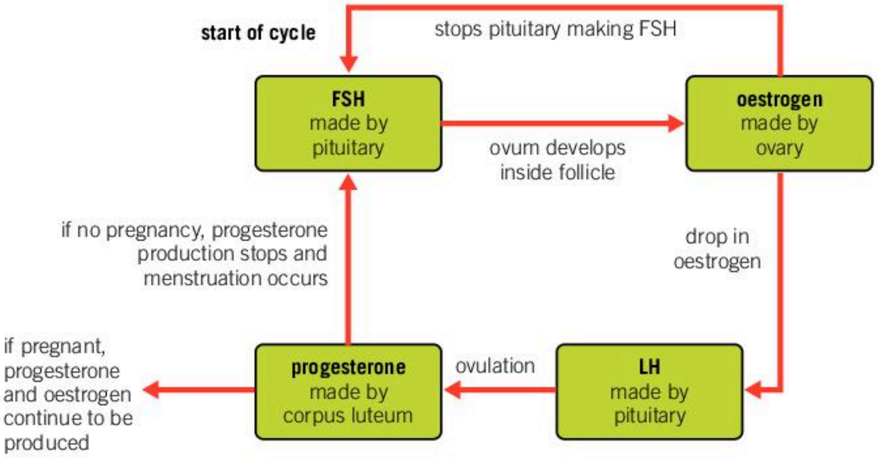
If implantation of a fertilised egg occurs, oestrogen and progesterone continue to be produced and stop the pituitary gland from producing FSH. The oestrogen and progesterone maintain the thickness of the lining of the uterus.



▲ **Figure 2.4.2** Hormones in the menstrual cycle

Length of the cycle

The whole cycle takes around 28 days, but this varies from woman to woman. The first day of menstruation is called the first day of the cycle, as it is the easiest stage to identify. Ovulation occurs around the 14th day. Sexual intercourse around the time of ovulation can result in fertilisation. After successful implantation, the woman is pregnant and her normal monthly periods stop.



▲ **Figure 2.4.3** Feedback is important in regulating and controlling hormone release

Menopause

A woman will produce an egg every month from puberty until she reaches the age of about 50. Her ovaries stop producing eggs, menstruation does not occur and she can no longer become pregnant. These changes occur because the production of sex hormones gradually declines. This is called the **menopause**.

Men do not go through a change of this kind and can continue to produce sperm throughout their life. However, the levels of the sex hormones gradually decline as men get older.

Questions

1 What is a Graafian follicle?
2 What hormone is released by the corpus luteum?
3 Why does menstruation occur?
4 Describe the role of the pituitary gland in the menstrual cycle.
5 What changes happen to a woman at the menopause?

Learning outcomes

By the end of this topic you will be able to:

- explain what sexual intercourse is
- describe ovulation, fertilisation and implantation
- describe how a foetus gets nutrients from its mother during pregnancy
- describe the stages of labour and birth.

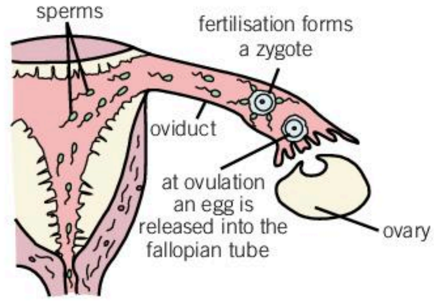
Did you know?

The length of pregnancy varies in different mammals. The pregnancy of a cat lasts for 2 months and for an elephant lasts 20 months!

2.5 Pregnancy and birth

Sexual intercourse

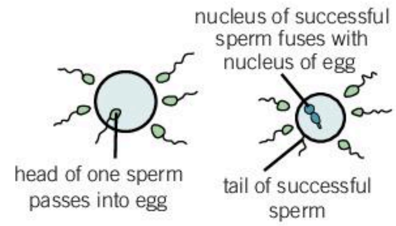
Sexual intercourse occurs when the penis is inserted into the female vagina. When the penis is stimulated, spaces between the spongy tissues fill with blood. It becomes hard and erect. Sexual stimulation leads to **ejaculation** during which semen, containing millions of sperm, is released into the top part of the vagina. The sperm swim through the cervix and the uterus, and into the fallopian tubes.



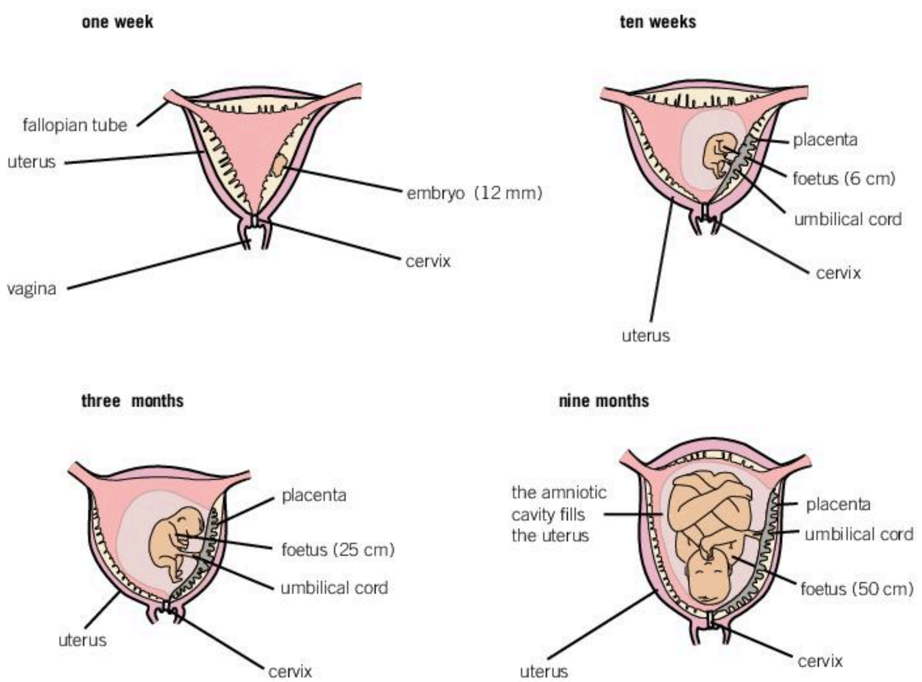
▲ **Figure 2.5.1** Ovulation

Fertilisation

If there is an egg in the fallopian tube when sexual intercourse takes place, fertilisation may occur. The egg becomes surrounded by sperm trying to penetrate its outer membrane. The head of only one sperm enters an egg and its tail remains outside. The sperm nucleus fuses with that of the egg to form a zygote. The zygote is pushed along the fallopian tube towards the uterus by cilia. In the uterus, it implants itself into the wall and can start to develop and grow into a baby.



▲ **Figure 2.5.2** Fertilisation



▲ **Figure 2.5.3** Development of the foetus

Pregnancy

As the zygote passes down the fallopian tube, it divides to form more cells. At this stage it is called an **embryo**. **Implantation** occurs when the embryo becomes embedded in the wall of the uterus where it develops.

After the first 12 weeks, an embryo starts to develop body organs and looks like a miniature baby with fingers, toes and facial features. It is now called a **foetus**. A structure called the **placenta** develops. It grows into the uterus wall and is linked to the developing baby by the umbilical cord. Nutrients and waste products are exchanged between the mother and her baby through the placenta and the umbilical cord without any mixing of their blood.

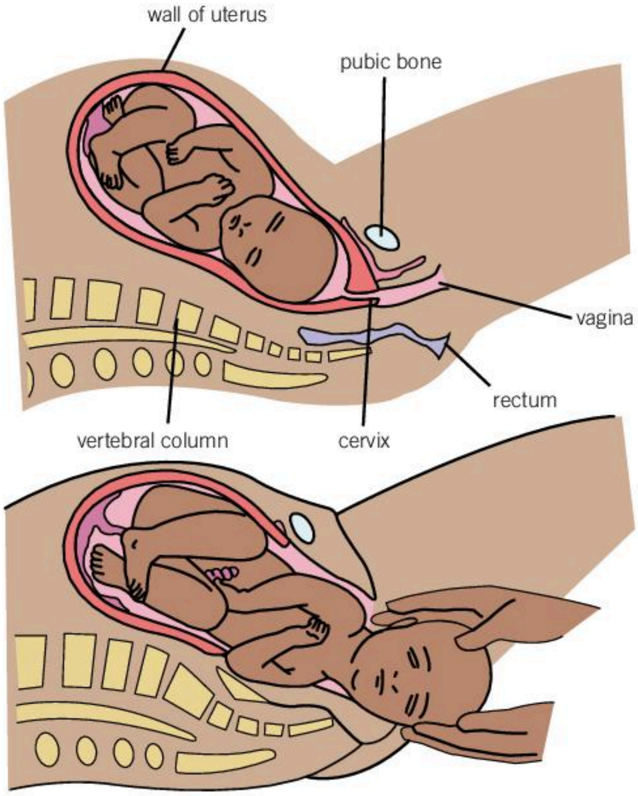
Pregnancy lasts around 40 weeks. During this time the baby floats in a fluid-filled sac called the amniotic sac.

Birth

When the baby is ready to be born, a hormone called **oxytocin** is released by the pituitary gland. This causes the muscular walls of the uterus to contract. The contractions cause the amniotic sac to break and the amniotic fluid escapes. The mother is said to be **in labour**. There are three stages:

- During the first stage of labour, the uterus contracts and the cervix opens (dilates).
- During the second stage, the powerful contractions push the baby down through the cervix and out of the mother's body through the vagina, to be born.
- During the third and final stage, the uterus contracts and expels the placenta. Afterwards the uterus quickly reduces in size.

Sometimes there are complications with the mother or baby and then a **Caesarean section** is performed. This is where a horizontal incision is made through the wall of the abdomen and uterus to deliver the foetus.



▲ **Figure 2.5.4** Labour and birth

▲ **Figure 2.5.5** A newborn baby

The umbilical cord is no longer needed and it is clamped and cut close to the baby. After a few days it will shrivel and drop off, leaving the navel. During pregnancy, the foetus received oxygen from the placenta. The first breath is stimulated by the sudden drop in temperature and the build-up of carbon dioxide in the blood after the umbilical cord was cut. If a foetus is born earlier than 37 weeks, it is known as a premature baby. It needs highly specialised care as it is not fully developed and lacks the ability to cope with conditions outside the uterus.

Did you know?

Sometimes amniotic fluid is used for screening for genetic abnormalities.

Synoptic link

See Topic 4.3 Blood groups.

Questions

1. Explain what happens during ovulation.
2. Describe the journey of a sperm from where it is produced in the testis of a male to where it fertilises an egg inside a female.
3. What is the function of amniotic fluid?
4. Describe the three stages of labour.
5. Why is a Caesarean section carried out?
6. Why is the umbilical cord no longer needed after birth?

Learning outcomes

By the end of this topic you will be able to:

- describe different methods of birth control
- discuss the advantages and disadvantages of the different methods.

2.6 Birth control

Contraception

Contraception can be used to prevent pregnancy. It allows people to choose when to have children and to determine the size of their family. This choice is called **birth control** or **family planning**. The decisions are personal, and require a responsible and mature attitude. Pregnancy does not have to be a mistake or an accident.

There are four main methods of birth control: natural, barrier, hormonal/chemical, surgical. Table 2.6.1 shows the different methods, together with their advantages and disadvantages.

▼ **Table 2.6.1** Methods of birth control

Method	How it works	Advantages
Natural: Withdrawal (coitus interruptus)	• male withdraws penis from vagina before ejaculation	• no side effects
Natural: Rhythm methods i) Temperature ii) Mucus (the Billing's method)	• i) relies on monitoring the menstrual cycle for temperature rise associated with ovulation or ii) for the mucus secreted (at ovulation more mucus is secreted and it is thinner) • intercourse is avoided for a few days before and after this time	• no side effects • no costs • only method recommended by the Catholic religion
Natural: Abstinence	• refrain from sexual intercourse	• 100% effective • no side effects or costs
Barrier: Condoms i) Male condom (sheath, rubbers, French letters (FL)) ii) Female condom	• i) a sheath of strong latex rubber is placed over the erect penis before intercourse to collect semen • ii) a tube of synthetic material is inserted into the vagina and remains there during intercourse. It prevents sperm entering the vagina	• no side effects • easy to obtain • offers some protection against sexually transmitted diseases including Human Immunodeficiency Virus (HIV)
Barrier: Intra-Uterine Contraceptive Device (IUCD, coil, loop, copper-T)	• a plastic or copper device which is placed into the uterus by a doctor and remains there • it prevents implantation	• once inserted, it can remain for 2–5 years without further concern • fairly reliable and inexpensive
Barrier: Diaphragm (cap)	• a thin, circular, dome-shaped sheet which is inserted into the vagina six hours before intercourse and removed three hours afterwards • it covers the cervix and prevents entry of sperm	• few side effects • offers some protection against STIs
Hormonal: i) The pill, hormonal patches ii) Hormonal injection	• i) contains oestrogen and/or progesterone, take one a day ii) same as the pill but it is given once every three months • prevents production of ova • prevents fertilisation by changing the cervical mucus so preventing the movement of sperm • prevents implantation	• i) simple and easy to take ii) convenient • reliable
Hormonal: Spermicides	• chemicals which kill sperm and block sperm from entering the uterus • often used together with other methods • available as creams, foams or gels	• simple to use and easy to obtain • provides extra lubrication for intercourse
Surgical: Sterilisation	• in females the oviducts are cut and tied so that the ovum cannot reach the uterus; this is called **tubal ligation** • in males the vas deferens is cut (**vasectomy**); sperm cannot leave the scrotum	• 100% effective • permanent control • no effect on virility in males

Questions

1 Suggest another reason why condoms may be used during sexual intercourse other than to prevent pregnancy.

2 Scientists have tried to develop a 'male contraceptive pill'. Suggest why such a contraceptive might not be widely used.

3 What are spermicides and how are they used?

4 Why is the rhythm method not a very reliable method of contraception?

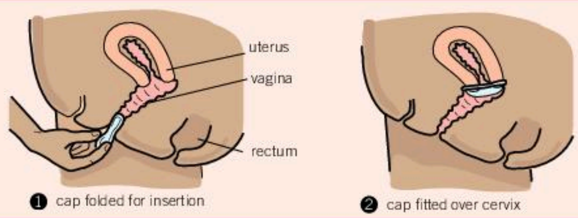
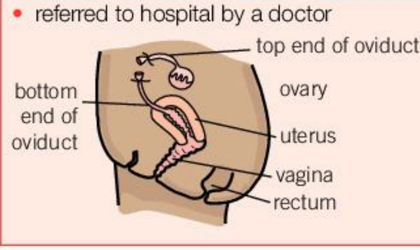
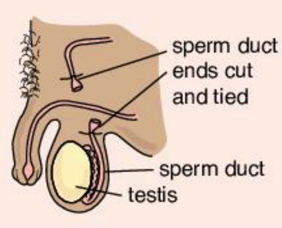
5 What is sterilisation?

Key fact

The 'morning after' pill contains hormones that prevent implantation of an embryo. It is taken as emergency contraception within two days of unsafe or unplanned sex.

Exam tip

You should check the internet for new methods of birth control.

Disadvantages	Where it can be obtained
• no protection against STIs, extremely unreliable • fluid secreted before ejaculation may contain sperm	
• not very reliable as timing of ovulation may be inaccurate, so pregnancy can result • requires self-discipline	• special ovulation thermometers are available from pharmacies
• requires self-discipline	
• can only be used once (cost) • interrupts love-making • may reduce sensitivity of penis • not as effective as the pill • more effective if used with spermicide • female condom can be difficult to use	• easy to buy from pharmacies, supermarkets • use only safety-approved condoms 
• may lead to increased menstrual flow • can cause uterine infections • no protection against STIs	• must be inserted by a doctor or health worker at a clinic
• may be damaged during intercourse • more reliable if used with spermicide	• clinic or pharmacy 1 cap folded for insertion 2 cap fitted over cervix
• no protection against STIs • must be taken at precise time intervals to be very reliable • should not be taken by smokers • increased risk of heart disease and high blood pressure • not reliable if vomiting or diarrhoea occurs within hours of taking • not reliable if taken while on a course of antibiotics	• must go to doctor or clinic for a medical check-up
• very unreliable if used alone • may sometimes cause irritation • no protection against STIs	• clinic or pharmacy
• not often reversible	• referred to hospital by a doctor 

Learning outcomes

By the end of this topic you will be able to:

- state what is meant by pre-natal and post-natal care
- explain why a healthy diet is particularly important in pregnancy
- describe some things a mother can do to ensure a healthy pregnancy
- explain why breastfeeding is best for the baby.

Key fact

Folic acid ensures that the eggs in a woman's ovaries are healthy before conception. During pregnancy it ensures correct development of the spinal cord.

Key fact

The baby's brain and heart develop in the first six weeks of pregnancy. It is very important that the mother leads a healthy lifestyle and eats a balanced diet.

▲ **Figure 2.7.1** An ultrasound scan

2.7 Pre- and post-natal care

Pre-natal care

Pre-natal, or **antenatal** care, is the care taken of both the pregnant mother and her developing baby before the birth. The mother's diet and lifestyle during pregnancy are important to ensure healthy development of the baby. Monitoring the development of the baby is also important in antenatal care.

A woman who wants to conceive a child may decide on a healthy lifestyle even before conception. This may include giving up smoking and drinking alcohol and taking supplements, such as folic acid, to ensure that her body is ready for pregnancy.

Diet

A developing baby relies on its mother for the nutrients it needs to grow, and form healthy organs and bones.

Protein is needed for the development of cells and muscles in the baby. Carbohydrates give the mother the energy required to carry the developing foetus. Fats are needed for the development of the baby's brain and cells and to provide the baby with an energy reserve.

The pregnant mother also needs more vitamins and minerals than normal to supply the baby's needs, as well as her own. Calcium, phosphorus, vitamin D and folic acid are especially important as they are used in the formation of the baby's bones and teeth. The mother needs a good supply of iron to produce a healthy placenta and for the formation of the baby's red blood cells.

Monitoring the baby

A pregnant woman normally regularly attends a clinic. Her weight, blood pressure, urine and the size of her uterus are checked as they can all provide early signs if there are problems with the pregnancy.

During pregnancy, **ultrasound scans** may be carried out. These use very high frequency sound waves to create an image of the foetus. The image is produced on a computer screen and measurements can be taken of the size of the baby's brain and spine to check that it is growing properly.

In the past, these scans were carried out using X-rays, but X-rays are not safe because they can cause damage to the genetic material in foetal cells resulting in abnormalities.

Drugs in pregnancy

Some drugs taken by the mother during pregnancy can travel through her blood and be transferred across the placenta to the baby's blood. Both prescribed drugs, as well as recreational drugs, can be transferred. Some drugs taken in pregnancy can cause miscarriage, stillbirth, and physical and mental abnormalities in the baby. Pregnant women should not smoke or drink alcohol. Carbon monoxide from tobacco smoke restricts the amount of oxygen carried by the red blood cells and is likely to result in a low birth- weight baby. Drinking alcohol puts an extra strain on the mother's liver and may affect the baby's developing nervous system.

Diseases in pregnancy

Some organisms that cause diseases, such as viruses and bacteria, can pass from the mother to the baby. If the mother suffers from German measles (rubella) in the early stages of pregnancy, there is a high risk that the baby will be born with physical abnormalities, such as deafness or heart defects. Sexually transmitted diseases, such as syphilis, herpes and Human Immunodeficiency Virus (HIV), can all be passed to the baby in the uterus via the placenta.

Post-natal care

Post-natal care is the care taken of the mother and the baby after the birth. A human baby is completely incapable of looking after itself, so it must rely on others for all of its needs. After the birth, the mother may need support from family and friends. The parents are responsible for looking after the baby.

After birth, the baby is no longer attached to the uterus by the placenta, so must breathe and feed for itself. It produces urine and faeces. At birth the baby's temperature control mechanism is not fully developed and it has little fat under its skin. Even in the Caribbean it needs to be kept warm with sufficient clothing and blankets. At around six weeks after the birth, a post-natal check is carried out to ensure that both mother and baby are healthy.

Breastfeeding

The production of milk is called **lactation**. The milk is produced in response to hormones and is released from the nipples. It is stimulated by the sucking infant. If the newborn baby is placed on the breast immediately after birth, it stimulates the expulsion of the placenta. For the first few days after birth, the mammary glands produce a fluid called **colostrum** which is rich in nutrients, as well as protective antibodies, to protect the infant from infections and boost the baby's immune system. After a few days, rich creamy milk is produced.

Breastfeeding is also an important part of the bonding process between mother and baby. The mother needs to drink extra fluid and have a good diet to provide sufficient milk for the baby. The baby can start to have a small amount of solid food from four to six months of age.

Some mothers decide to feed their babies with specially designed baby food called **formula** in a bottle. This is a powder that is diluted with sterile water. Bottles must also be sterilised. It is very important that the water used for making up the formula is also sterilised or boiled to prevent contamination.

Immunisation

The baby should be immunised against diseases that could cause death or lasting damage, such as whooping cough, diphtheria, tetanus and polio. Different vaccinations are given at different ages.

Table 2.7.1 Advantages and disadvantages of breastfeeding

Advantages
Breast milk is at the correct temperature.
It contains a perfect balance of proteins, carbohydrates, fats, minerals, vitamins and is easily digestible.
It develops a close bond between mother and child.
It contains all the nutrients a baby needs in the correct amounts.
It is sterile.
It contains antibodies to help the baby resist infections.
It can reduce the severity of some allergies.
It can reduce the risk of infant death.
It can reduce the incidence of some childhood diseases, such as diabetes, bowel and liver diseases.
It reduces the risk of obesity.
It reduces the risk of diabetes, thyroid and breast and ovarian cancer in the mother.
Disadvantages
It is time-consuming.
It can be difficult to get started.
The baby consumes whatever the mother eats so she must be careful (e.g. alcohol consumption).
HIV can be transmitted from the mother to a breastfeeding baby.

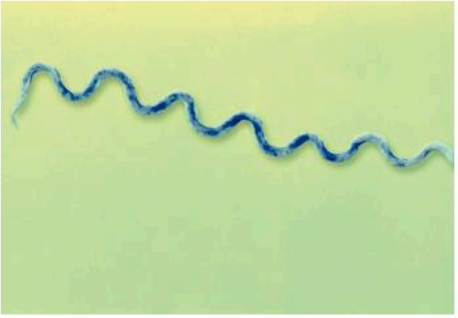
Questions

1. Why does a pregnant mother need to eat more calcium and vitamin D than normal?
2. What is an ultrasound scan and why is it useful?
3. Why is it particularly important to keep a new-born baby warm?
4. Explain why it is best to breastfeed a new-born baby if possible.
5. At around what age does a baby start to have solid food?

Learning outcomes

By the end of this topic you will be able to:

- discuss the causes of sexually transmitted infections
- describe the symptoms of sexually transmitted infections
- understand how these infections can be controlled and prevented.



▲ **Figure 2.8.1** Syphilis bacterium: the spirochaete *Treponema pallidum*

Synoptic links

See Topic 1.4 Microbes and Topic 4.5 Natural and artificial immunity.

2.8 Sexually transmitted infections

Sexually transmitted infections (STIs), or sexually transmitted diseases, are passed from one person to another during sexual activity.

Some infections, such as syphilis and gonorrhoea, are caused by bacteria, while Acquired Immune Deficiency Syndrome (AIDS) and herpes are caused by viruses.

Table 2.8.1 summarises some of the most common STIs.

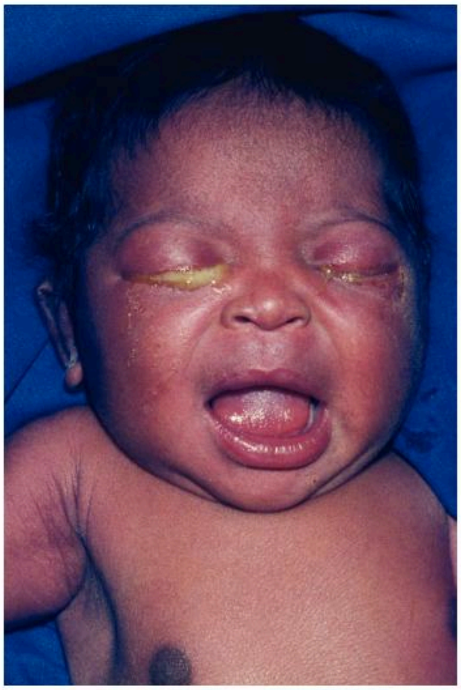
▼ **Table 2.8.1** Some sexually transmitted infections: causes, symptoms and treatment

Infection	Caused by	Symptoms	Treatment
syphilis – can be contracted by men and women	*Treponema pallidum* – a bacterium	sores on the genitals; incubation period of 2 to 4 weeks. After 8 to 12 weeks, rash on the body and swollen lymph nodes	daily injections of antibiotics
gonorrhoea – can be contracted by men and women; women may show no symptoms	*Neisseria gonorrhoeae* – a bacterium	difficulty in passing urine, fever, headache, discharge from urethra; incubation period about 5 days. Infection may spread to other parts of the body	sensitive to antibiotics, so treatment is effective if caught early
genital herpes – can be contracted by men and women	*Herpes simplex* – a virus	small red painful ulcers on the genitals	no cure, but treatment with anti-viral medicine alleviates symptoms
hepatitis B – can be contracted by men and women	virus infection of the liver	jaundice, tiredness, nausea, weight loss	anti-viral medication; interferon injections to boost the immune system
AIDS (Acquired Immune Deficiency Syndrome)`	Human immuno-deficiency virus (HIV)	incubation period 6 weeks to 6 months; flu-like symptoms initially, then latent period followed by infections. Can cause Kaposi's sarcoma (a skin cancer) and a rare form of pneumonia	anti-HIV medication to control reproduction of the virus; drugs to block the ability of the virus to replicate
thrush or candidiasis – more common in women than in men	*Candida albicans* – a yeast-like fungus	vaginal discharge, itching, soreness and pain on passing urine; men may have soreness at the tip of the penis	treated with anti-fungal tablets or cream

Prevention and control of STIs

Prevention of sexually transmitted infections depends on the following basic principles:

- **Abstinence:** Avoidance of sexual intercourse means that a person is not exposed to any of these diseases. The more sexually active a person is, the greater the risk of coming into contact with an infected person. People in stable, long-term relationships are at less risk than those who have many sexual partners.
- **Correct diagnosis and treatment:** Accurate diagnosis is essential and this can often only be made by isolation of the organism responsible. In the case of gonorrhoea, the symptoms may be vague or absent and the infection goes unnoticed. In other cases, such as syphilis, the symptoms are clear and diagnosis is easily made. Once the disease has been diagnosed, treatment can be given. It is important that the treatment is completed.
- **Tracing contacts:** Tracing the sexual partners of infected people is important in attempts to prevent the spread of the disease. The infected person is responsible for this and it is often a stumbling block where many casual relationships have occurred. However, it should be understood that it is for everyone's benefit, particularly in the case of gonorrhoea where a women can be infected and show no symptoms.
- **Follow-up visits:** It is important that once treatment has been given, the patient attends follow-up sessions to ensure that the infection has been cured. It is also important to abstain from sexual intercourse until recovery is complete.
- **Education:** A knowledge of the facts concerning STIs, how they are spread and their symptoms is important in prevention. It is not just the biological facts that are needed, but some understanding of social issues can help avoid the spread of these infections.
- **Use of condoms:** The use of condoms gives some measure of protection against STIs, as well as preventing unwanted pregnancies. Since the introduction of the contraceptive pill, young women and girls have preferred this method above others. Since the incidence of STIs has increased, there is greater encouragement to use condoms as a preventative measure.



▲ **Figure 2.8.2** Baby with gonorrhoeal eye infection. If a mother has gonorrhoea, the infection can be passed to her baby during birth

Questions

1. Name two STIs that are caused by bacteria and two that are caused by viruses.
2. What are the symptoms of thrush and how can it be treated?
3. Explain why diagnosis of some infections is easy whilst that of others is difficult.
4. Why can antibiotics be used to treat syphilis but not herpes?
5. Why is it important to trace the contacts of infected people?
6. Explain how the use of condoms can help to prevent the spread of STIs.

Learning outcomes

By the end of this topic you will be able to:

- explain what a life cycle is
- describe germination and growth in plants
- plot a graph of plant growth at regular intervals
- describe and analyse charts of human growth
- understand that there are differences between the growth rates of boys and girls.

Practical Activity 2.9.1

Observing germination

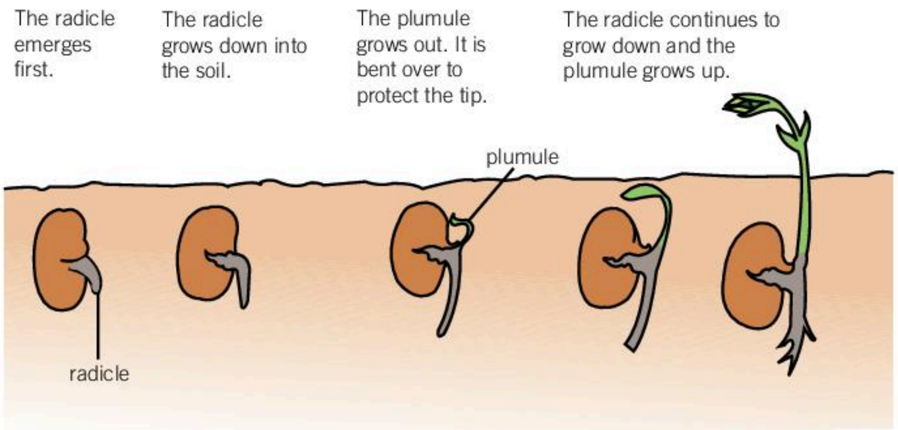
Skills assessed: Observation/Recording/Reporting.

1. You have been given seeds, two test tubes, some cotton wool and some foil.
2. Push a small piece of cotton wool into each test tube.
3. Moisten (i.e. not too much water) the cotton wool in one test tube and leave the other dry.
4. Place some seeds in each test tube and seal the top of each with foil.
5. Leave the test tubes somewhere warm but out of direct sunlight.
6. Predict what the results of this experiment will be.
7. Check the seeds each day and keep a record of your observations.
8. What conclusion can you make about germination?

2.9 Growth patterns

Germination

Germination is the process that occurs when a seed begins to develop into a new plant. In suitable growing conditions, the seed first develops a root, called the **radicle**. A shoot called the plumule emerges, growing upwards out of the soil.



▲ **Figure 2.9.1** Germination

A germinating seed needs energy, oxygen, warmth and water in order to develop into a plant. Energy is provided by food stored inside the seed in the cotyledons. This food supply is used until the plant can make its own food by **photosynthesis**. Oxygen is obtained from the air and is used for respiration.

Temperature for germination varies in different plants. However, if the temperature is too high or too low, germination will not take place.

Water in the soil is essential for germination. The seed swells during germination and the seed coat is softened by water. This makes it easier for the shoot and radicle to grow out of the seed.

Growth of plants

A seed that has germinated and has started to grow it is called a **seedling**. Seedlings grow at different rates. Some grow very quickly and you can easily measure their growth. When a plant is mature it will form flower buds. When the flowers open, the plant is able to reproduce sexually. The plant will reproduce and make seeds. Some plants then die and the life cycle begins again with new plants from the seeds. These plants complete their life cycle in one growing season and are called **annual plants**. Many of our crop plants, such as beans and maize, are annual plants. Some plants last for many years, and produce more flowers and seeds each year. Some plants become trees and can live for hundreds of years.

Practical Activity 2.9.2

Do seeds need light for germination?

Skills assessed: Planning and Designing.

1. Seeds germinate in the soil where it is dark. Some people think that light is needed for germination.
   Design an experiment to test if this is the case or not.
2. Write down a list of the apparatus that you would need and the method you would use.

Key fact

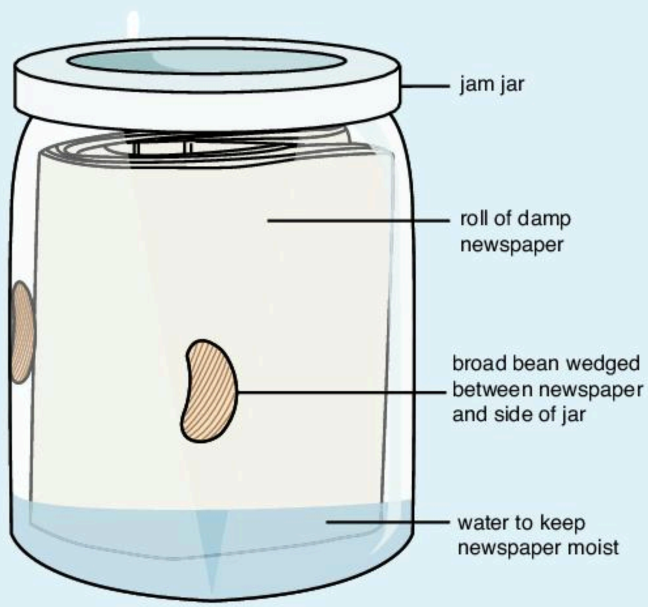
To work out the average height of the seedlings: record the height of each of the three seedlings, add these together and divide by three.

Practical Activity 2.9.3

Measuring and recording growth

Skills assessed: Observation/Recording/Reporting.

1. Your teacher will give you some seeds, such as bean, balsam or maize that have been soaked in water for several hours.
2. Line a large jam jar with a roll of newspaper. Put a small amount of water in the bottom of the jar and tip it around. Make sure there is some water left at the bottom of the jar that will keep the newspaper damp.
3. Push three seeds, spaced around the jar, between the newspaper and the glass.
4. Observe the seeds each day for 21 days. Record what you see each day.
5. After the seeds have germinated, measure and record the height of the shoot for each seedling every day.
6. Work out the average height of your seedlings each day.
7. Draw a graph of the average height of the seedlings against time.
8. On day 10, try and predict what the average height of your seedlings will be on day 21. See if you were right.

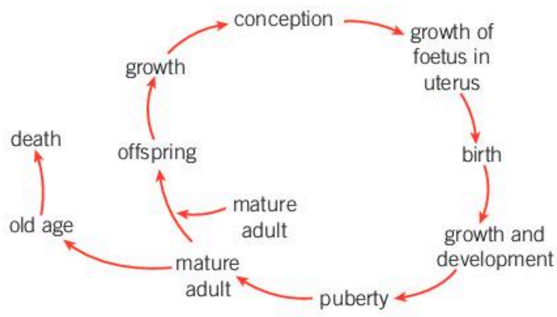


Growth of humans

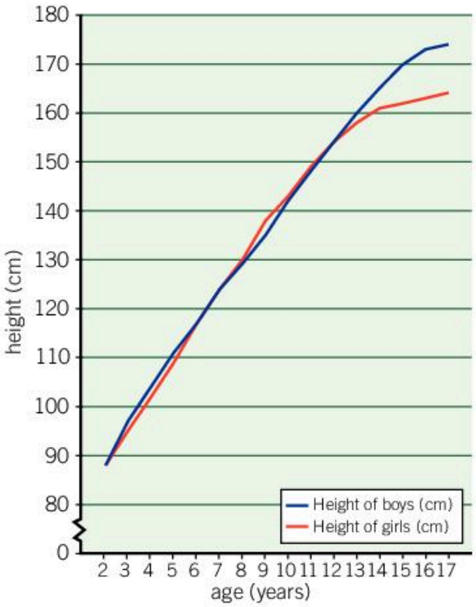
Like plants, humans have a life cycle. Figure 2.9.2 shows some stages in a typical human life cycle.

A baby's growth is rapid during the first year of its life. By the age of one, most babies will be able to sit and crawl, and may be able to stand and walk. After this the rate of growth slows down, but the child continues to grow. At the start of puberty, the rate of growth increases again and the body changes rapidly as it develops secondary sexual characteristics.

The body reaches maximum height at around 18 years of age. Body weight changes throughout life due to a person's diet and their level of activity.



▲ **Figure 2.9.2** Life cycle of humans



▲ **Figure 2.9.3** Height against age of girls and boys

Practical Activity 2.9.4

Investigating the height of boys and girls

1. Measure and record the height in centimetres (without shoes) of students in your class.
2. Record each student's age in years and months.
3. Find the average height for each age.
4. Do the same thing for other classes in your school.
5. Produce your own chart of average height against age for students in your school.

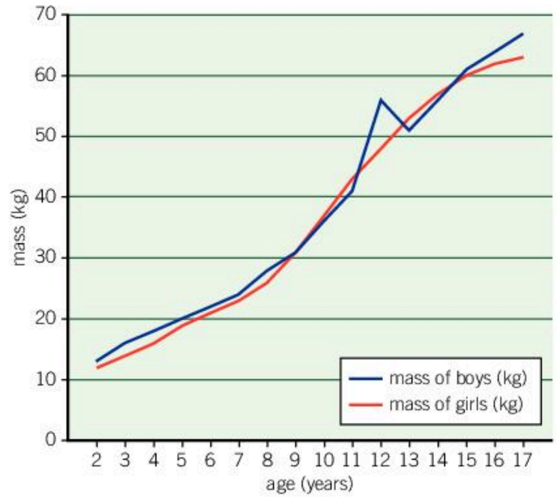
Between the ages of around 45 to 55, the female body reaches menopause. Ovulation and menstruation stop, and a woman can no longer have children. Males continue to produce sperm throughout their life.

In old age, most people become slightly shorter as the discs in their spine compress and they are less able to stand up straight.

Growth charts

Growth charts are graphs showing height plotted against age for females and males. They are used to check that children are growing normally.

Similar charts are obtained by plotting mass against age. People grow outwards, as well as upwards. Being too fat is called obesity and can lead to serious illness.



▲ **Figure 2.9.4** Mass against age of girls and boys

Questions

1. Describe what happens when a seed germinates.
2. State two conditions most seeds require for germination.
3. At what age is the rate of growth for girls greatest:
   - **a** below the age of 8
   - **b** above the age of 8?
4. At what age is the rate of growth for boys greatest:
   - **a** below the age of 8
   - **b** above the age of 8?
5. What is the average mass of a girl:
   - **a** age 5
   - **b** age 13?
6. What is the average mass of a boy:
   - **a** age 5
   - **b** age 15?

2.10 Human population control

World population

The population of the world is 6.6 billion people. That is 6600000000 and it is increasing every day!

Reasons for population growth

The population grows when the birth rate is higher than the death rate. This means that the number of people born each year per 1000 people is greater than the number of people who die each year per 1000 people in the population.

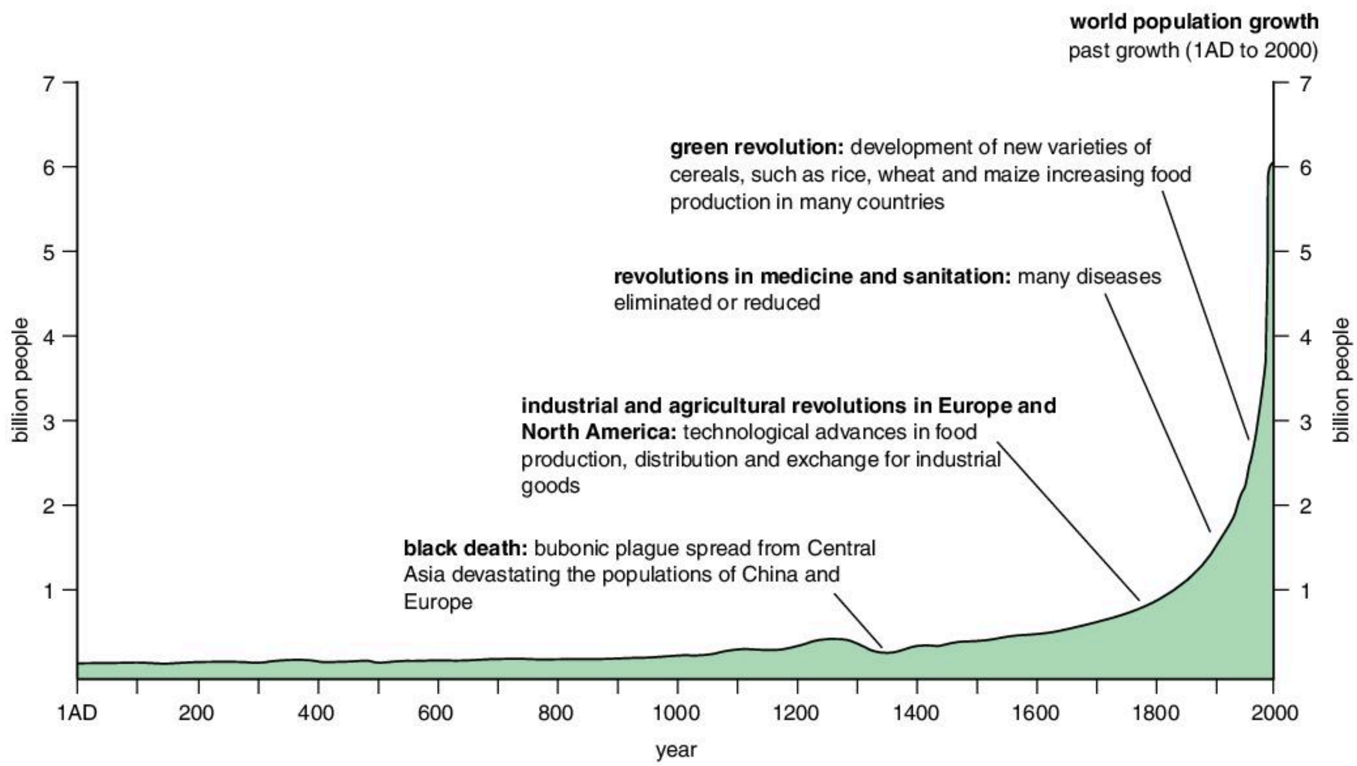
The rate of population growth has increased in the last 150 years for the following reasons:

- Babies are more likely to survive than in the past because of better pre-natal and post-natal care.
- There is better health care and people live longer.
- Diseases that used to kill large numbers of people, such as smallpox, yellow fever and cholera, are now preventable by vaccination or treatable with drugs.
- There have been huge improvements in sanitation, clean water supplies, nutrition, agriculture and education in many parts of the world.
- Many more people have access to clean hospital facilities and life-saving drugs.

Learning outcomes

By the end of this topic you will be able to:

- give reasons for population growth
- discuss some of the effects of population growth
- consider the effects of teenage pregnancy
- review the ways in which overpopulation can be reduced.



▲ **Figure 2.10.1** The human population over time

In the highly industrialised countries of the world these changes, which have reduced the death rate, have occurred alongside a decrease in the birth rate, due to the availability of contraception. In many developing countries, a reduced death rate has not been accompanied by a decreasing birth rate and the result has been a rapid increase in the population.

The effects of population growth

A rapid growth in population in a country has a big effect on the quality of life for its citizens. It can lead to:

- food shortages
- land shortages
- shortages of materials, such as for building
- overcrowding
- unemployment
- poverty
- problems with water and sanitation supplies
- an increase in pollution
- an increase in the spread of diseases.

Often the distribution of people in a country becomes unbalanced, leading to overcrowded cities and large, sparsely populated rural areas. This is called urbanisation.

▲ **Figure 2.10.2** Queuing for water in Haiti

Reducing overpopulation

Some countries try to reduce population growth by educating their citizens about family planning. This involves encouraging people to limit the size of their family by planning how many children they will have and when they will have them.

Methods of birth control have been described in Topic 2.6, together with their advantages and disadvantages.

Practical Activity 2.10.1

Investigating how human activities have affected your local environment

Carry out a study to investigate how human activities have altered your local environment.

Try to separate out the positive effects from the negative effects.

Present your findings as a written report or a poster which can be displayed in your school.

Teenage pregnancy

Girls who become pregnant, while they are still teenagers, may risk their physical health, as their own bodies are usually still maturing. It is particularly important that young pregnant girls receive medical supervision throughout their pregnancy to avoid serious complications.

There are sometimes also social problems associated with teenage pregnancy. Girls who become pregnant are more likely to drop out of school early.

Questions

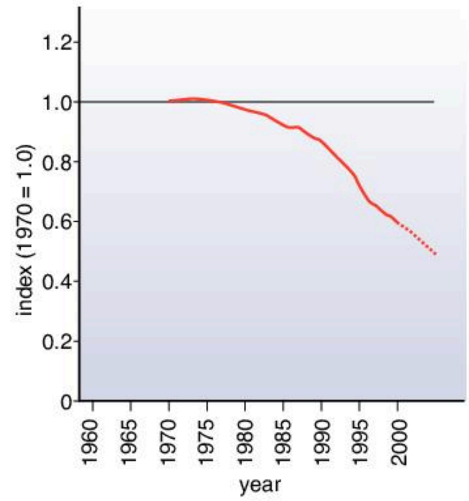
1 How is population growth defined?

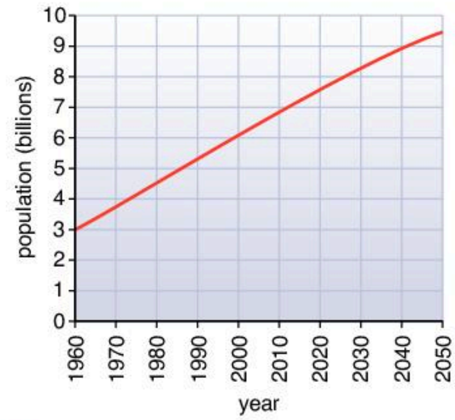
2 Why has the rate of world population growth increased over the last 150 years?

3 What are the effects of a rapid growth in population on a country?

4 How can overpopulation be reduced?

5 What is meant by urbanisation?





▲ **Figure 2.10.3** Humans are destroying plant and animal species at an alarming rate. Top – average trend in populations of plants and animals worldwide since 1970. Bottom – world human population since 1960 and future predications.

Did you know?

Remember that birth control helps to prevent teenage pregnancy.

Exam-style questions

Multiple choice

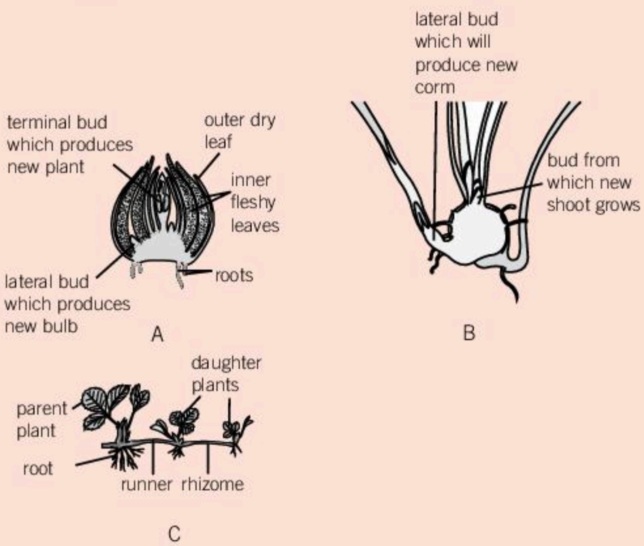
1 The part of a flower that produces a female gamete is called
A the stigma **B** the anther
C the ovary **D** the ovule

2 In a human male, sperm are produced in the
A seminal vesicles **B** vas deferens
C penis **D** testes

3 Syphilis is a sexually transmitted infection caused by
A a virus **B** a bacterium
C a fungus **D** a yeast

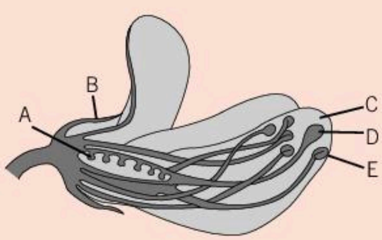
Structured questions

4 The diagrams A–C show three storage organs.



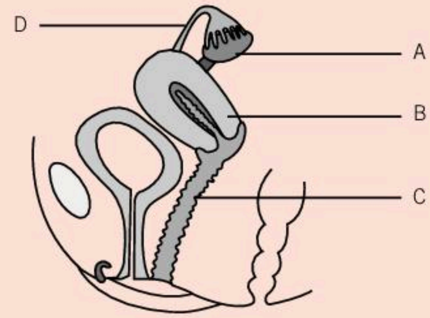
a Identify A to C.
b From which part of the plant does storage organ A develop?
c What structure in storage organ A can produce a new plant?

5 The diagram below shows a section through a bean flower.



a Name the parts A and B.
b This flower is insect pollinated. Suggest how parts C, D and E help in the pollination of this flower.
c After pollination the ovules develop into seeds. Describe the events which occur after pollination and which result in the formation of seeds.

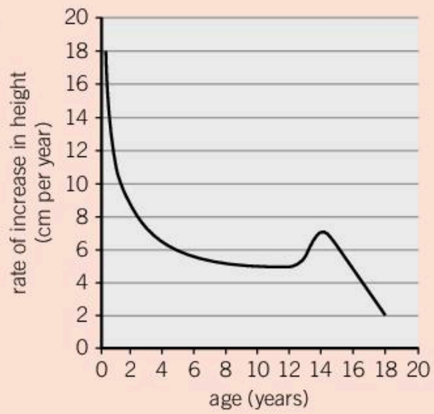
6 The diagram shows the female reproductive system.



a Provide labels for parts A to D.
b In which part:
 i) does fertilisation occur
 ii) does implantation take place
 iii) are female gametes produced?
c Give two functions of oestrogen in the menstrual cycle.

7 Contraceptive methods can be grouped into natural and artificial methods. Choose one method from each group and describe how it works, how effective it is, its advantages and disadvantages.

8



The graph shows the average rate of increase in height of boys from 6 months to 18 years.

a At what ages is the average rate of increase in the boys' height 4 cm per year?
b Describe what happens to the rate of growth in boys between 12 and 14 years of age.
c With what biological process do you connect the increase of rate of growth between 12 and 14 years of age?
d Mention two other changes that might occur in boys of this age.

Section A

3 Food and nutrition

Food is essential to all living things. Green plants make their own food by photosynthesis using energy from sunlight. Green plants are at the start of every food chain and provide animals either directly, or indirectly, with the nutrients they need to live. Humans plant many agricultural crops, which are used for food. People obtain the nutrients needed for a healthy existence by digesting the food that they eat. Sometimes micro-organisms, such as mould, can attack food and special food preservation methods are needed to prolong its shelf life.

Learning outcomes

By the end of this topic you will be able to:

- explain what photosynthesis is
- write a word equation for photosynthesis
- write a chemical equation for photosynthesis
- state that food is stored as starch in a plant
- describe a chemical test for starch
- state the conditions necessary for photosynthesis
- give details of experiments which prove that chlorophyll, carbon dioxide and light are necessary for photosynthesis.

3.1 Photosynthesis

Finding out about photosynthesis

Photosynthesis is the process by which green plants use energy from sunlight to make their own food. During this process, light energy is changed into chemical energy.

Photosynthesis is a series of chemical reactions that can be summarised by the following equations:

word equation:

$$\text{carbon dioxide} + \text{water} \xrightarrow[\text{chlorophyll}]{\text{sunlight}} \text{sugar (glucose)} + \text{oxygen}$$

chemical equation:

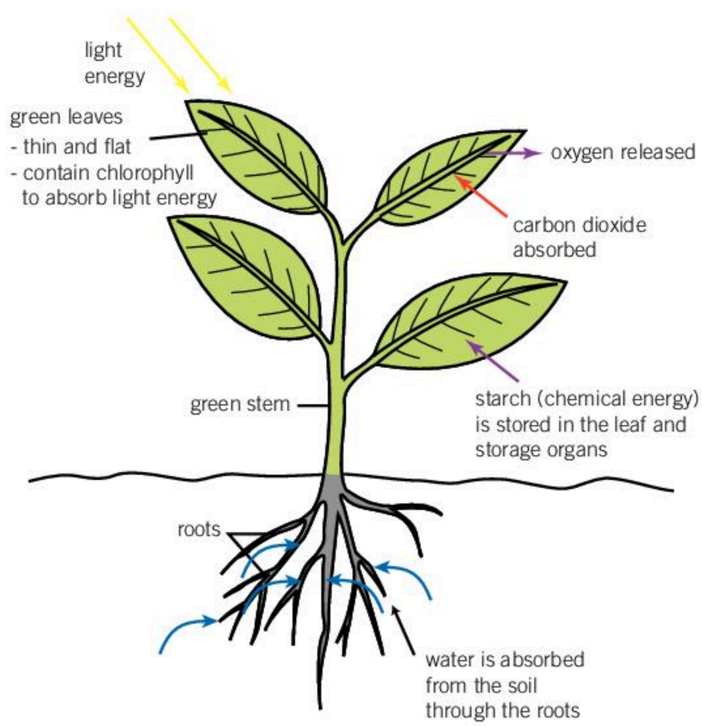
$$6CO_2 + 6H_2O \xrightarrow[\text{chlorophyll}]{\text{sunlight}} C_6H_{12}O_6 + 6O_2$$

Photochemical reactions are triggered by the absorption of light. Photosynthesis is a photochemical reaction as light energy is absorbed by chlorophyll. This energy is used to convert carbon dioxide and water into sugars, such as glucose. Oxygen is also produced.

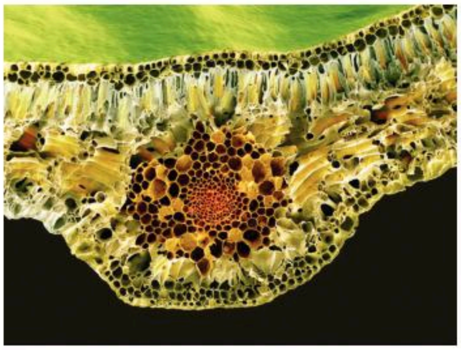
Glucose can be converted to other sugars, such as sucrose and cellulose, which is used to make plant cell walls, and starch which is stored for use at a later stage. Glucose is broken down during respiration to release the energy for cellular work.

Leaves are well suited for photosynthesis:

- They are thin and flat so they have a large surface area through which light energy can easily be absorbed.
- The surfaces of the leaves contain tiny pores called **stomata** (singular: **stoma**) through which gases can diffuse. The carbon dioxide needed for photosynthesis diffuses into the leaf from the atmosphere, while the oxygen produced passes out.

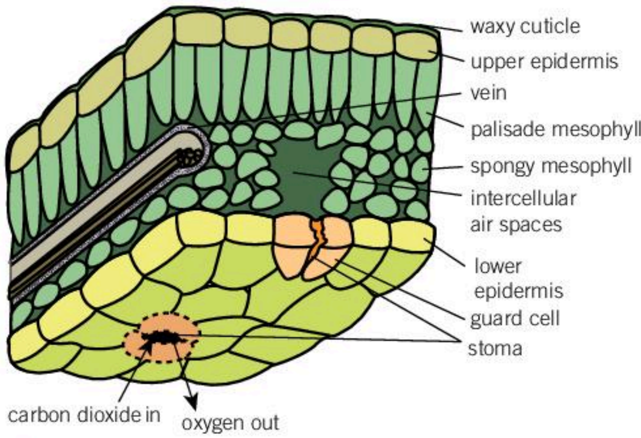


▲ **Figure 3.1.1** The conditions needed for photosynthesis



▲ **Figure 3.1.3** Transverse section through a leaf

- Their cells have chloroplasts containing chlorophyll. The reactions of photosynthesis take place here.



▲ **Figure 3.1.2** The internal structure of a leaf

Practical Activity 3.1.1

External features of leaves

Your teacher will give you a hibiscus leaf.

1. Look at the shape of the leaf. How is it adapted to its function of photosynthesis?
2. Draw and label the external structure of the leaf.

Water for photosynthesis is absorbed from the soil by the plant's roots.

Plants use some of the sugars that they make for respiration. Most sugars are converted to starch. Starch is stored in the leaves, and sometimes in other parts of the plants, such as the stem and the root. In some plants, the storage organs may grow very large.

Testing for starch

If photosynthesis has occurred in a leaf, starch will be present. You can test a leaf with iodine solution to find out if there is any starch present.

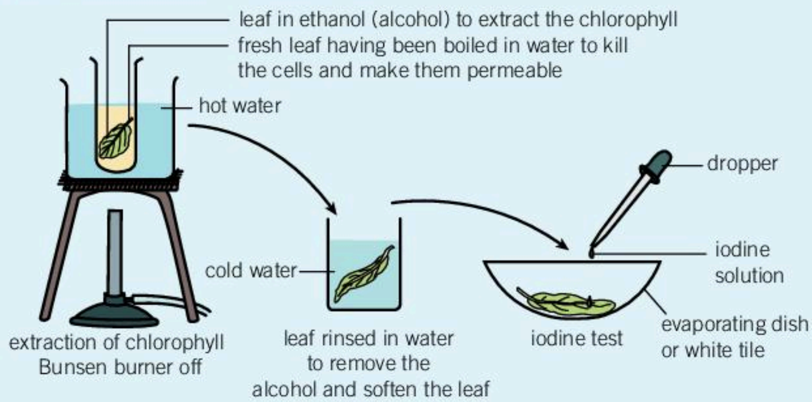
Iodine stains the starch blue-black.

Practical Activity 3.1.2

Testing for starch

Skills assessed: Observation/Recording/Reporting and Manipulation/Measurement.

1. Dip a leaf in boiling water for about 1 minute. This softens the leaves and allows iodine to penetrate the cells.
2. Turn off your burner so there is no flame.
3. Put the leaf into a boiling tube containing enough ethanol to cover it. Place the boiling tube in the beaker of hot water and leave it for about 10 minutes. Why is it important to turn off the burner? The ethanol removes the chlorophyll from the leaf.



4. Take the leaf out of the ethanol and wash it in cold water. What does the leaf look like now?
5. Spread the leaf out in an evaporating dish, or on a white tile, and place a few drops of iodine solution onto it. What colour does the leaf turn? Was there any starch present in the leaf you tested?

The importance of photosynthesis

Photosynthesis is important for the following reasons:

- high-energy food molecules, such as starch, can be synthesised and stored in plants
- it provides an important energy source that can be used by other living organisms when they eat plants or other animals
- plants are grown on a large scale in agriculture to provide food for the growing human population
- it maintains the correct balance of oxygen and carbon dioxide levels in the air.

The conditions needed for photosynthesis

In a plant leaf, glucose is converted to starch so the presence of starch can be regarded as evidence that photosynthesis has taken place.

In experiments to demonstrate the conditions needed for photosynthesis, we need to start with plants that contain no starch at all in their leaves. A potted plant is **destarched** by leaving it in a dark cupboard for 2 or 3 days. After this time, a leaf should be tested for starch to ensure there is none present before the plant is used in experiments.

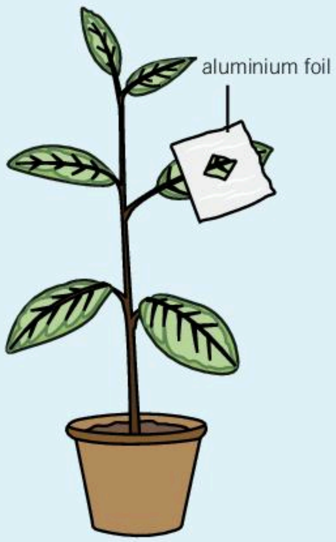
The following series of experiments show that chlorophyll, light and carbon dioxide are all essential for photosynthesis to take place.

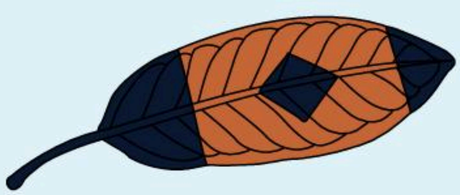
Practical Activity 3.1.4

Is light necessary for photosynthesis?

Cut a simple shape out of a strip of aluminium foil and place this onto a leaf of a previously destarched planting fold it over to hold it in place. Leave the plant in sunlight for several hours.

After a few days, remove the leaf and take the foil off. Test the leaf for starch as in Practical activity 3.1.2. Once again, only part of the leaf turns blue-black, the part which has been exposed to light.



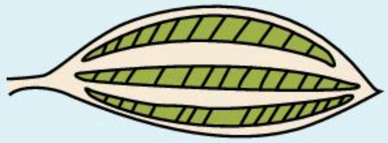


Practical Activity 3.1.3

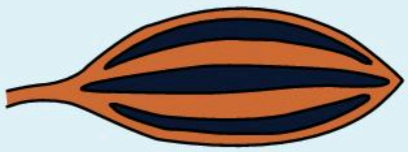
Is chlorophyll necessary for photosynthesis?

Some plants have **variegated leaves**. A variegated leaf is one that has some areas that are white where there is no chlorophyll. The parts of the leaf that contain chlorophyll are green. Pelargonium and Tradescantia plants have variegated forms whose leaves are often used for this experiment.

Take a destarched plant with variegated leaves which has been exposed to light for several hours. Remove one of its leaves and test for starch as in Practical activity 3.1.2. Only the green parts of the leaf turn blue-black (see below).



before starch test



after starch test

Practical Activity 3.1.5

Is carbon dioxide necessary for photosynthesis?

Potassium hydroxide solution reacts with carbon dioxide and removes this gas from the air.

Take a previously destarched plant and cover with an inverted polythene bag. Place a small dish of potassium hydroxide solution with the plant before the bag is sealed. Leave the plant for several hours in sunlight, then remove a leaf and test it for starch, as in Practical activity 3.1.2.

The leaf does not turn blue-black indicating that no starch is present. This proves that photosynthesis has not taken place.

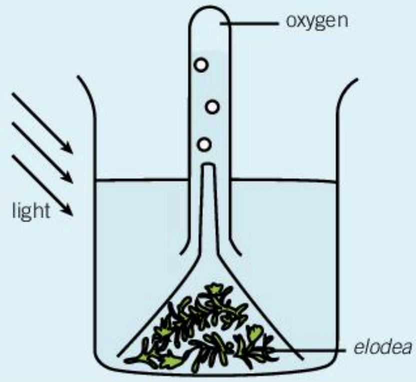
Exam tip

You should know the substrates, conditions and products of photosynthesis.

Practical Activity 3.1.6

Is oxygen produced by photosynthesis?

Oxygen is a product of photosynthesis. It is impossible to demonstrate this with a pot plant but it can be done with a submerged water plant, such as Elodea. Set up the experiment as below. You will see bubbles of gas being released from the plant. The bubbles of gas collect in the test tube and can be tested with a glowing splint. If the splint ignites, it shows that the gas is oxygen.



Other factors influencing photosynthesis

Temperature

Since photosynthesis consists of chemical reactions, it is dependent on temperature. The higher the temperature, the faster the rate of photosynthesis up to a point. If the temperature is too high, the enzymes that control the chemical reactions will be destroyed and photosynthesis will stop.

Water

If water is in short supply, the plant will not be able to use it to combine with carbon dioxide and photosynthesis will stop.

Questions

1 Name the green pigment found in plant leaves.
2 What provides the energy for photosynthesis to take place?
3 a During photosynthesis what two substances are:
   i) used up   ii) formed?
  b Write a word equation for photosynthesis.
  c Write down a chemical equation for photosynthesis.
4 In what form is food stored in a plant leaf?
5 What substance is used to test a plant leaf for the presence of this food?
6 What energy transfer takes place during photosynthesis?
7 What gas is removed from the air by potassium hydroxide?
8 What is missing from some parts of a variegated leaf?
9 How can a pot plant be destarched?
10 How could you show that the gas produced during photosynthesis was oxygen?

3.2 Crop production

Over thousands of years, farmers have developed practices that produce good crops, and also protect the soil and maintain its fertility. Some of these practices are described in Table 3.2.1.

Learning outcomes

By the end of this topic you will be able to:

- describe how soil is conserved and nutrient losses reduced by different farming practices
- describe the effects on crop yield that result from adding fertiliser to a field
- explain how using excess fertiliser may damage the environment
- compare different methods used in the production of crops
- describe some small-scale methods of crop production.

▼ **Table 3.2.1** Farming practices

Farming practice	Reason for use
Strip planting	Strips of different crops are planted in the same field. The crops are harvested at different times so there is never a time when the whole field is left exposed to erosion
Green fertilisers	Planting crops, such as leguminous plants, are grown with the specific intention of being ploughed back into the soil. The roots of the leguminous plant are covered in nodules containing bacteria which convert nitrogen in the air into nitrates, which can be used by the plants to make proteins. All the time that the leguminous plant is growing, the fertility of the soil is increasing. When the plant is ploughed back, it increases the humus content of the soil and decomposes releasing more nutrients
Planting methods	Hoeing breaks up the topsoil and separates soil particles. This makes it easier for water to soak into the soil therefore reducing erosion
Lying fallow	Land is left uncultivated so that there is time for nutrients to be replaced by micro-organisms
Improving drainage	Channels can improve drainage especially in clay soils. Addition of lime to clay soil also improves drainage and aeration by causing the clay particles to clump together. Soil acidity can also be reduced. Excessive lime application will kill any organisms in the soil
Crop rotation	One type of crop is alternated with another (especially leguminous plants) after each harvest. This allows the nutrients to be replaced in the soil
Contouring	Land is ploughed perpendicular to the slope (contour ploughing) and the crops are planted. The flow of water from the slopes is reduced, so preventing erosion
Terracing	Banks built across the slope reduce the flow of water and the risk of erosion

▲ **Figure 3.2.1** Terrace farming

Animals eat plants to obtain the nutrients they need for healthy growth. Plants obtain nutrients from the soil. It is not possible to keep on taking nutrients out of the soil, while not putting anything back. Eventually, the soil will become infertile and nothing will grow in it.

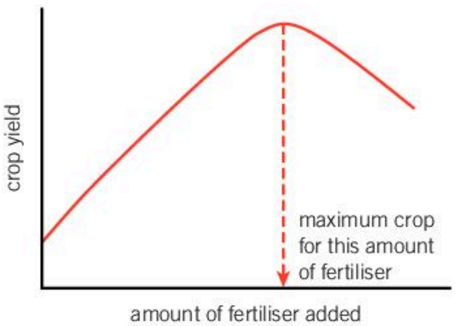
In nature, nutrients are recycled. Leaves fall to the ground and rot, releasing their nutrients into the soil. When plants and animals die, their bodies decompose and nutrients return to the soil.

When crops are removed from fields or gardens, the nutrients they contain are removed, so they will not return to the soil. Farmers need to replace nutrients in their soil and they do this by spreading fertiliser on the fields (see Table 3.2.1).

▲ **Figure 3.2.2** Organic fertiliser

▲ **Figure 3.2.3** Modern chemical fertilisers

> **Key fact**
>
> NPK fertilisers provide plants with three essential elements: nitrogen (N), phosphorus (P) and potassium (K). Together with other nutrients these are used to increase crop yield.



▲ **Figure 3.2.4** Fertiliser only increases crop yield up to a point

▲ **Figure 3.2.5** Pollution in a river caused by excessive use of chemicals fertilisers

Historically, farmers used organic fertilisers, such as animal dung and many still do today. The dung is dug into the ground and releases nutrients as it decays. Organic fertilisers are bulky and time consuming to apply. They take time to decay but are very cheap, especially when a farmer both keeps animals and grows crops. Organic farmers use only organic fertilisers.

Farmers may also use chemical fertilisers, for example NPK fertilisers. These are compounds which contain the nutrients needed by plants. The nutrients are released immediately the fertiliser is spread on the soil. Chemical fertilisers are expensive, but can be easily and quickly spread onto fields.

Crop yields

It might appear that the more fertiliser a farmer puts on a field the greater the yield of crops it will produce. This is true up to a certain point, but beyond that adding more fertiliser actually reduces the yield (Figure 3.2.4).

Plant roots absorb nutrients from the soil in solution. Their ability to do this depends upon the concentration of nutrients in the soil water. If this concentration is too high, perhaps as a result of adding too much fertiliser, the plant roots will be unable to absorb any nutrients.

Adding too much fertiliser to a field is a waste of money and is also harmful for the environment. Excess nutrients are readily washed from the soil into streams and rivers where they cause a rapid increase in plant growth which unbalances the whole ecosystem (Figure 3.2.5).

Small-scale crop production

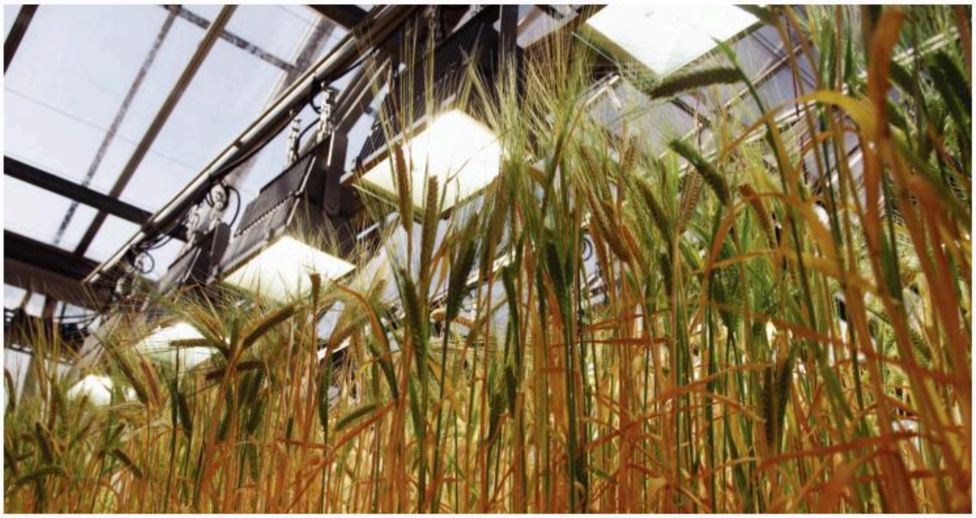
When we think of growing crops, we tend to think about farmers ploughing their fields. However, there are other methods of cultivation that people use to grow smaller amounts of crops, such as greenhouse farming, rooftop farming, indoor farming, container gardening and hydroponics.

Farmers grow some crops under glass or plastic in a greenhouse (Figure 3.2.6). This allows the farmer to keep careful control of the growing conditions. Doing this makes it less likely that crops will be damaged by adverse conditions, such as high winds or eaten by animals.

▲ **Figure 3.2.6** Greenhouse farming in Martinique

Some modern buildings have flat roofs that are ideal for rooftop farming. This allows a flat owner to cultivate the roof like a very small field (Figure 3.2.7). The crop gets lots of sunlight because it is not in the shadow of trees, which is sometimes the case when crops are grown in a garden.

▲ **Figure 3.2.7** Rooftop farming



▲ **Figure 3.2.8** Indoor farming

It is possible to grow crops indoors if they are provided with sufficient light, water and nutrients. If necessary, artificial light can be provided by banks of electric lights (see Figure 3.2.8).

Even where people have little or no garden, they can grow crops, such as vegetables in large containers (Figure 3.2.9). These crops must be regularly watered as their growing compost will dry out more quickly than soil in a garden.

Hydroponics is a method of growing plants without soil (Figure 3.2.10). The plants grow in an inert medium, such as gravel and a mineral nutrient solution is pumped through the growing medium. This allows the farmer to control the type and amounts of minerals supplied to the plants, and the growing medium can be used many times.

Key fact

Inert means unreactive. So growing plants in an inert medium means the plants will only absorb nutrients from nutrient solution pumped through the hydroponic system.

Practical Activity 3.2.1

Visiting local farms

Your teacher will arrange for you to visit one, or more, local farms to observe how it operates. During your visit you should make notes on what you see, including:

- a list of the crops grown
- the different agricultural methods used
- crops grown under special conditions, such as in a greenhouse
- how the farming methods are linked to conservation.

▲ **Figure 3.2.9** Container gardening

▲ **Figure 3.2.10** Growing crops using hydroponics

Questions

1 What would happen if a farmer did not spread fertiliser on his fields?
2 Which nutrient is released into the soil by bacteria on the roots of clover?
3 What do the letters NPK stand for?
4 Explain why organic fertilisers are better for the soil than chemical fertilisers.
5 Why does a farmer leave a field fallow?
6 Why are chemical fertilisers easy to use?

3.3 Food chains and food webs

Food chains

All food chains, including those in terrestrial environments, start with a **producer**. This is a green plant that makes its own food by photosynthesis. The green plant is then eaten by an animal, a **primary consumer**, which might then be eaten by another animal, a **secondary consumer**, and so on.

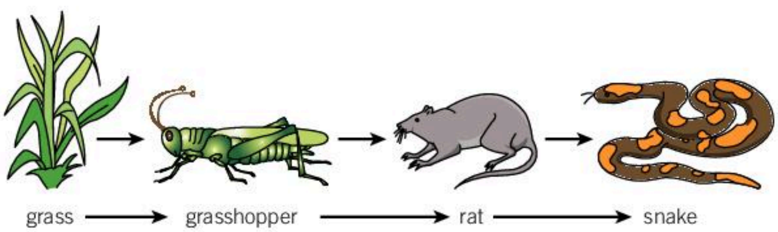
producer ⟶ primary consumer ⟶ secondary consumer ⟶ tertiary consumer

Primary consumers are always **herbivores** since they eat green plants. Secondary consumers and tertiary consumers are **carnivores** since they eat other animals. **Ominvores** eat both plants and animals, so they can be primary, secondary or tertiary consumers.

The Sun is the source of energy for all food chains. The producer uses the Sun's energy to convert small molecules (i.e. water and carbon dioxide) into large food molecules, glucose. Consumers obtain energy by breaking down this food during respiration.

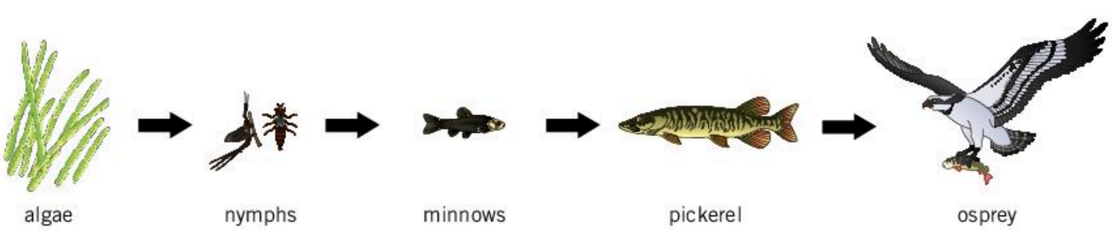
The arrows in a food chain indicate the direction in which **energy** is flowing through the chain. They also indicate 'is eaten by', for example the producer is eaten by the primary consumer.

The following food chain (Figure 3.3.1) involves organisms found in a terrestrial environment. The consumer may only eat part of a plant.



▲ **Figure 3.3.1** A terrestrial food chain

Figure 3.3.2 shows a food chain containing five organisms that live in and around a lake, which is an aquatic environment. Food chains can contain different numbers of organisms.



▲ **Figure 3.3.2** An aquatic food chain

Some organisms belong to more than one food chain. The relationship between organisms is more accurately shown as a food web.

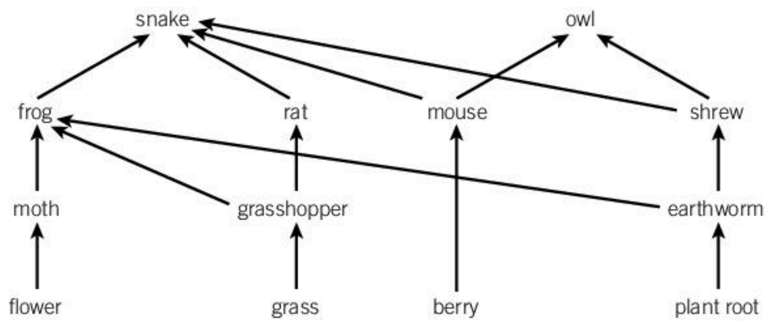
Learning outcomes

By the end of this topic you will be able to:

- state that the Sun is the source of energy for all food chains
- state that a food chain always starts with a producer
- explain the significance of the arrow in a food chain
- state that primary consumers are herbivores and subsequent consumers are carnivores
- understand that a food web is formed by combining a number of related food chains
- appreciate the effects of a change in the population of one organism in a food web on the populations of a number of other organisms
- describe how much energy is trapped by plants
- explain how energy is lost to the environment in a food chain
- distinguish between ecosystems, communities, habitats and populations.

Food webs

The information given in the food chains for a terrestrial environment can be combined into a food web.



▲ **Figure 3.3.3** Food chains combine in a food web

The food web shows the complex relationships that exist between different organisms in an environment. A change in the population of any one organism will affect the populations of several others.

For example:

- If fewer earthworms were available, perhaps as result of a dry period making it difficult for animals to dig into the soil, the population of shrews would decrease as there would be less food for them to eat.
- Snakes and owls would have fewer shrews to eat and so they would eat more of the other organisms in their diet, such as mice.
- If more mice were eaten, the mice that remained would eat fewer berries so more berries would be available for other consumers.

Passing energy along a food chain

Only about 3% of the energy in sunlight is trapped by green plants in photosynthesis. Of this about one-third is used up by the plant during respiration and the remainder is used to form plant tissue. This is stored energy that passes into a food chain when the plant is eaten. At each subsequent step in a food chain, energy is lost to the surroundings.

All animals respire and some of the food they eat is used to provide them with the energy needed to drive their body metabolism and allow them to move about.

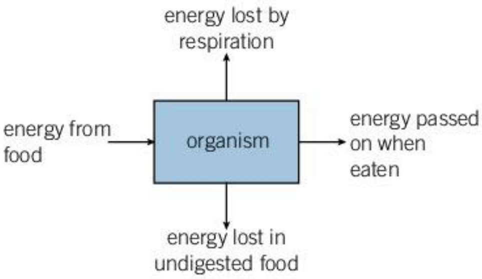
When a herbivore eats a plant, or a carnivore eats another animal, some of the food passes through its body without being digested. In herbivores, as little as 10% of the food eaten is digested and 90% passes out of the body undigested as faeces. Carnivore digestion is more efficient with typically 45% being digested and 55% being wasted.

Did you know?

Some primary consumers feed on decaying plant material.

decaying plant material ⟶ woodlouse ⟶ spider ⟶ frog

The decaying plant material is a producer because it was formed from green plants.



▲ **Figure 3.3.4** Energy is lost at each stage in a food chain

The terrestrial environment

On land there are many places where the living and non-living components interact with each other. These places are called **ecosystems**. For example, a pond or a garden may form a terrestrial ecosystem. Within each ecosystem there will be a variety of **habitats**. Different organisms occupy different habitats. They obtain all they need to survive from it. All the organisms that live in a particular ecosystem form a **community**. There will be many species of plants and animals in a community. Organisms of the same species in a particular environment form a **population**. These organisms are very similar to each other and can interbreed.

▲ **Figure 3.3.5** A mangrove forest is an ecosystem with many habitats where organisms live and interact with the non-living environment

Practical Activity 3.3.1

Investigating ecosystems

Your teacher will take you to a local area or a selected part of the school grounds.

1. Decide what sort of ecosystem you are in (e.g. grassland, woodland).
2. Write down the names of all the plants that you can see. If you do not know the names, ask your teacher or look them up in a reference book. Do not pick any of the plants.
3. Try to find out about the animals present. Record the names of any birds or small animals you see.
4. If time permits, you can use nets to sweep the vegetation for insects or set traps for beetles and woodlice. Remember not to harm any wildlife you find.
5. When you have a list of the organisms, decide which are producers, consumers, decomposers, herbivores and carnivores. Build up a food web of the relationships between the organisms in your ecosystem.
6. Display your information as a poster.

Did you know?

Decomposers, such as fungus and bacteria, break down dead and decaying matter into nutrients plants can use. They are not usually shown on a food chain or a food web. You will find them in the carbon and nitrogen cycles where they play an important role.

Questions

1. What is the source of energy for all food chains?
2. What type of animal is a primary consumer?
3. What does an arrow → signify in a food chain?
4. Why does a food web give a more accurate picture of the relationships between organisms in an environment than a food chain?
5. State one way in which energy is lost to the environment at each step in a food chain.

Learning outcomes

By the end of this topic you will be able to:

- name the main groups of foods and give examples of sources in the diet
- describe the functions of the main nutrients
- describe tests for carbohydrates, proteins and fats
- describe the use of food additives and their effects on health
- interpret food labels to find out the nutritive content of food
- understand what is meant by a 'balanced diet'
- describe how diets are related to age, gender and occupation
- carry out experiments to determine the energy value of foods.

Exam tip

You need to know about the five food groups that we require in our diet.

▲ **Figure 3.4.1** All these foods are good sources of carbohydrates

3.4 The importance of food

The need for food

Humans need a variety of foods to ensure that they have a healthy, balanced diet that provides them with the energy and materials necessary for growth, and maintenance of the body. Foods contain different proportions of five **food groups**. These are carbohydrates, proteins and lipids (fats and oils), together with small quantities of vitamins and mineral salts. Water and fibre are also essential. Neither of these has any nutritional value, but fibre, or **roughage**, provides bulk and helps the passage of food through the digestive system.

The main groups of food

Carbohydrates

Carbohydrates are large molecules made from the elements carbon, hydrogen and oxygen. Some of them, such as starch, are made up of many smaller subunits of glucose. Carbohydrates are important energy-giving foods. The body can obtain energy from carbohydrates, proteins and fats. However, energy can be obtained much more quickly from carbohydrates so they are an important part of the diet, particularly when we are very active. A deficiency of carbohydrates may result in a person lacking energy.

The carbohydrates in our food are mainly sugars, such as glucose, fructose, sucrose and starch. Cellulose is also a carbohydrate but does not provide the body with any nutrients. It is important as roughage. Good food sources of carbohydrates include bread, pasta, rice, root vegetables, such as potatoes and yams, and fruits.

The test for starch has already been described in Topic 3.1. Food can be tested for the presence of reducing sugars, such as glucose, using **Benedict's reagent**.

Practical Activity 3.4.1

Testing for reducing sugars

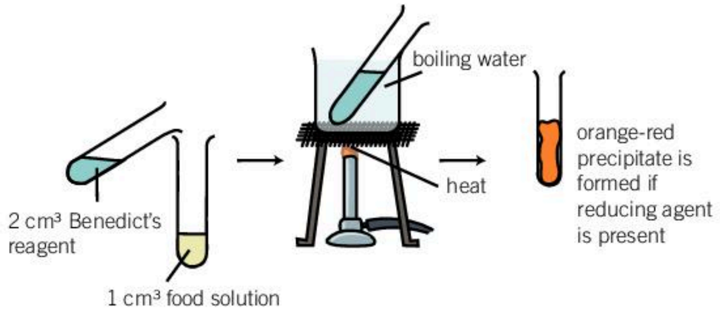
Skills assessed: Observation/Recording/Reporting.

Materials:

- A number of foods, such as fruit, cereals and milk
- Test tubes and rack
- Beaker of water and Bunsen burner for a water bath
- Spatula or spoon
- Benedict's reagent

Method:

1 Make a solution of the food by shaking it up in a test tube with 1 cm^3 of water.
2 Decant the solution formed into a second test tube.
3 Add 2 cm^3 of Benedict's reagent to the food solution.
4 Heat the tube in boiling water for about 5 minutes. If a reducing sugar is present an orange-red precipitate is formed.
5 Record all your results in a table, remembering to include the colour change on heating.



▲ **Figure 3.4.2** Steps in the test for the presence of a reducing sugar

Practical Activity 3.4.2

Testing for non-reducing sugars

Skills assessed: Observation/Recording/Reporting.

1. Make a solution of sucrose by dissolving a few grams of table sugar in 2 cm^3 of water.
2. Divide the sucrose solution into two test tubes, solution A and solution B, and use them as follows.
3. Carry out a test for reducing sugars on solution A using Benedict's reagent.
4. Add a few drops of dilute hydrochloric acid to solution B and warm the test tube in boiling water for three minutes. The acid splits the sucrose into glucose subunits.
5. Remove the test tube from the boiling water and add solid sodium hydrogencarbonate to the test tube in small amounts to neutralise the contents, until the solution no longer fizzes.
6. Carry out a test for reducing sugars on this solution using Benedict's reagent.
7. Describe your observations and suggest an explanation for them.
8. Now test some fruit juices for reducing and non-reducing sugars.
9. Record your answers in a table.

Proteins

Proteins consist of large numbers of subunits called **amino acids**. These are joined together to form long molecules.

The main function of proteins in the diet is to provide the body with the amino acids it needs to make new tissues, repair old tissues and to make enzymes. Protein can also be used to provide energy. A deficiency of protein leads to protein energy malnutrition (PEM) which manifests itself as diseases, such as **kwashiorkor** and **marasmus**.

Good sources of protein include meat, fish, nuts, lentils, legumes (beans and peas) and dairy products, such as milk and cheese.

The presence of protein in food can be shown by the **biuret test**. This involves adding two chemicals to a solution of the food.

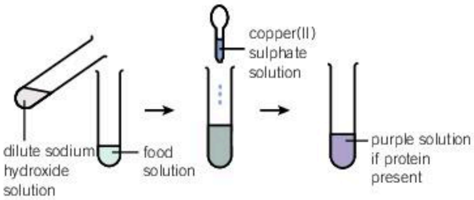
Key fact

A reducing agent is a substance that can carry out a type of chemical reaction called reduction. Glucose is a reducing agent but sucrose is not. Sucrose must first be split into two glucose molecules before it gives a positive test with Benedict's reagent.

Key fact

Enzymes are protein molecules that speed up chemical reactions. You will learn more about them in Topic 3.7.

▲ **Figure 3.4.3** All these foods are good sources of protein



▲ **Figure 3.4.4** Steps in the test for the presence of proteins

▲ **Figure 3.4.5** All these foods are good sources of lipids

Practical Activity 3.4.4

A simple test for lipids

Skills assessed: Observation/Recording/Reporting and Manipulation/Measurement.

1. Squeeze the food in a folded filter paper. If the food contains either lipids or water a mark will be left.
2. Wave the filter paper above a Bunsen burner flame or a hot-air blower for a few minutes.
3. If the mark has gone this means it was caused by water and there are no lipids in the food.
4. If the mark remains there are lipids in the food.

Practical Activity 3.4.3

Testing for protein (biuret test)

Skills assessed: Observation/Recording/Reporting and Manipulation/Measurement.

1. Make a solution of the food by shaking it up in a test tube with 1 cm^3 of water. Decant the solution formed into a second test tube.
2. Add 1 cm^3 of sodium hydroxide to the food solution.
3. Then add several drops of a 1% solution of copper(II) sulphate to the mixture.
4. If any protein is present the mixture will turn purple.
5. Use this test to find out if cheese, milk and fish contain protein. You will need to grind up the cheese and fish.
6. Record your results in a table.

Lipids

Lipids are fats and oils. At room temperature, fats are solids, while oils are liquids. Lipids are made from the elements carbon, hydrogen and oxygen. They consist of fatty acids and glycerol molecules that are joined together. They are insoluble in water.

Fats are often associated with people being overweight. This problem is not brought about simply by eating lipids but by eating too much of the wrong sorts of food. Excess carbohydrates are converted to fats. However, fats and oils are an essential part of everybody's diet. They provide the body with a long-term energy store. The body stores fat around some of the vital organs, which gives them protection, and under the skin where it provides the body with insulation.

Good sources of fats include margarine, lard, red meat, nuts and dairy products, such as cream, butter and cheese. Oils are obtained by crushing the seeds or fruits of various plants.

A simple test for the presence of lipids in a food is to see if the food leaves a greasy mark on a filter paper.

Practical Activity 3.4.5

An alternative test for lipids

Skills assessed: Observation/Recording/Reporting.

1. Make a solution of a food which is a good source of lipids, such as butter, by shaking a small amount up in a test tube with 2 cm^3 of ethanol. The solution formed should be decanted into a second test tube.
2. Add 2 cm^3 of distilled water to the food solution.
3. Describe your observations and explain them.

Vitamins

Vitamins are present in many of the foods that we eat. They are essential for a number of different processes in the body. We only need vitamins in very small amounts each day. If any are lacking in a person's diet for any length of time, they may suffer serious **deficiency diseases**.

Some vitamins are water-soluble, while others are fat-soluble. Water-soluble vitamins are easily transported around the body in the blood. They cannot be stored and any excess vitamins are excreted.

Fat-soluble vitamins are absorbed from lipids in our diet. Vitamin D is made by the action of sunlight on fat under the skin. Fat-soluble vitamins can be stored in the body, so foods containing them do not have to be eaten as regularly as the water-soluble ones.

▼ **Table 3.4.1** The importance of some vitamins

Vitamin	Soluble in fat or water	Foods which are useful sources	Deficiency disease
Vitamin A (retinol)	fat	fish liver oil, milk, butter, margarine, green vegetables	Night blindness – inability to see in low light
Vitamin B_1 (thiamine)	water	brown rice, cereals, legumes, peanuts	Beri-beri – loss of energy, swelling of hands and feet, muscular weakness, nervous disorders, eventual paralysis
Vitamin B_2 (riboflavin)	water	whole grains, cheese, milk, egg yolk, legumes, green vegetables	Poor growth, mouth sores, mental disorder
Vitamin B_3 (niacin)	water	liver, eggs, lean meat, grains	Pellagra – loss of appetite and eventually loss of weight, damage to the skin, mental disorder
Vitamin C (ascorbic acid)	water	citrus fruits, green vegetables	Scurvy – bleeding gums, wounds that do not heal
Vitamin D (calciferol)	fat	fish liver oil, dairy products, vegetable oils	Rickets – bones grow deformed
Vitamin E (tocopherol)	fat	wheat germ, vegetable oils, nuts	Greater chance of infertility

▲ **Figure 3.4.6** Swollen inflamed gums in scurvy

Minerals

Minerals are also required in small amounts for specific purposes within the body. The following table contains information about some important minerals and the problems that arise if there is insufficient of them in a person's diet.

▼ **Table 3.4.2** Important minerals needed in the diet

Mineral	Foods which are useful sources	Deficiency disease
Calcium	dairy products, such as milk and cheese, green vegetables	Bones and teeth do not develop correctly, rickets
Iron	green vegetables, red meat, liver, fish	Shortage of red blood cells results in anaemia, weakness and tiredness
Sodium	table salt	Muscle cramps and also affects transmission of nerve impulses
Iodine	seafood and sea salt or iodised table salt	Shortage of the hormone thyroxine leads to impaired mental ability and an enlargement of the thyroid gland known as goitre
Phosphorus	red meat, fish, eggs	Deformed bone development, gum disease and impaired functioning of the kidneys and nervous system

The energy value of food

Most of the food we eat is used by the body to provide energy. **Metabolism** refers to all the chemical reactions inside the body. Some of these reactions use up energy and some produce it. Carbohydrates provide energy quickly, while lipids are a longer term energy source. Excess amino acids are not stored. They are converted to glucose in the liver by a process called **deamination**. This is discussed in Topic 6.1.

▲ **Figure 3.4.7** This food label shows the energy values of potatoes

The energy content of food is the amount of energy released when the food is completely metabolised. Information is often given on the contents label of a food package. The label in Figure 3.4.7 comes from a packet of potatoes.

The energy provided by the carbohydrates, lipids and proteins in a food can be estimated using the following values:

- 1 g of carbohydrates as glucose provides 16 kJ
- 1 g of lipids provides 38 kJ
- 1 g of protein provides 17 kJ.

Foods that are rich in lipids have the highest energy content since lipids provide more than twice as much energy per gram as carbohydrates or proteins. This is the reason why foods containing high proportions of lipids are fattening. If the body takes in more food than is needed to provide energy, the excess is stored as fat.

When food is metabolised in the body, it is oxidised. Oxygen is chemically combined with it. This is like a combustion reaction when fuel is burnt. We can estimate the energy content of a food by burning it and using the energy released to heat water in a boiling tube.

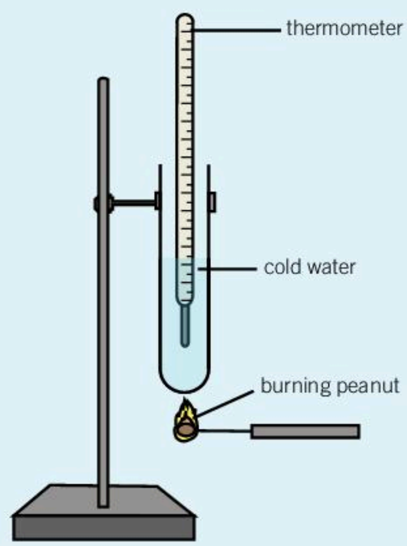
Key fact

Energy is measured in joules (J) or kilojoules (kJ).

Practical Activity 3.4.6

To find the energy content of a peanut

Skills assessed: Manipulation/Measurement and Analysis and Interpretation.



1. Record the mass of a peanut (m).
2. Measure 25 cm^3 of cold water into a boiling tube and mount the tube on a stand and clamp.
3. Record the temperature of the cold water (T_1).
4. Impale the peanut on a mounted needle and start it burning in a Bunsen burner flame. Once the peanut is burning place it under the boiling tube of water.
5. Mix the water with a thermometer and record the highest temperature the water reaches before the peanut is completely burnt (T_2).
6. It requires 4.2 J of energy to increase the temperature of 1 g of water by 1 °C. Use the following equation to calculate the energy that would be given out by 1 g of peanut.

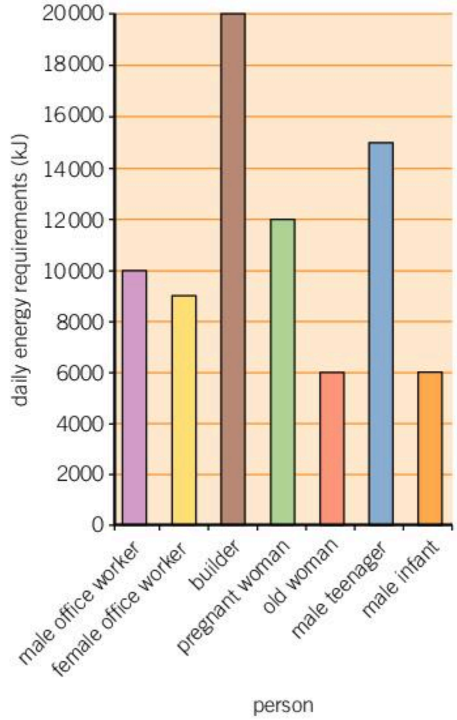
$$\text{energy per gram } \frac{25 \times 4.2 \times (T_2 - T_1)}{m} \text{ joules}$$

Safety: Tell your teacher if you are allergic to nuts.

Balanced diet

A **balanced diet** is one in which a person receives the right amounts of the different food groups that their body needs to remain healthy. Typically a balanced diet will consist of 55% carbohydrates, 15% lipids (to provide energy), 20% protein (for body building and repair) and 10% water, vitamins and minerals.

The amount of energy a person needs each day depends on their age and gender. Young children need the same amount of energy regardless of gender but, as they grow older, boys and men need more energy than girls and women. In general, the energy needed per day rises until a person is fully grown and then remains fairly constant during adulthood.



▲ **Figure 3.4.8** Bar chart to show the energy requirements of different people

Nutritional needs will be different depending on the person. A pregnant or lactating mother will need larger amounts of foods containing proteins and vitamins. An active builder will need more energy-giving foods.

Sportspeople need a diet that is rich in proteins and carbohydrates because they must build up their muscles through regular exercise.

Malnutrition occurs when a person does not receive sufficient of one, or more, food groups, that is, they do not eat a balanced diet. It can also occur when they eat too much of one, or more, of the food groups. Kwashiorkor and marasmus are diseases that result from a deficiency of protein. Eating more of one food group does not compensate for eating less of another because they have different roles in the body. A person who does not eat sufficient protein will be malnourished even if they can eat unlimited amounts of carbohydrates.

A person who is **obese** is also malnourished. Obesity occurs when a person eats more food than is needed to satisfy the energy requirement of their body. Excess food is stored as fat under the skin and in other places in the body. Being overweight is just as unhealthy as being underweight because the extra weight puts strain on the body.

Diabetes is sometimes associated with diet. It is a condition where the body cannot control the amount of glucose in the blood. There are two different types of diabetes.

- **Type 1 diabetes:** The pancreas does not produce the hormone insulin, which is responsible for regulating blood sugar levels.
- **Type 2 diabetes:** The body either does not produce enough insulin or does not react to insulin.

! Key fact

Human energy requirements can be expressed as the sum of three factors:

1. Basic metabolic rate (BMR): the energy needed for living processes, such as heart beat, breathing and maintaining body temperature.
2. Everyday activities: the activities which people do irrespective of their job. These include walking about, washing, etc.
3. Occupation: the energy needed depends on a person's job. Jobs may be sedentary, moderately active or very active.

▲ **Figure 3.4.9** Child suffering from malnutrition

Type 2 diabetes is far more common than type 1 and is linked to a person's diet and their lifestyle. The chances of a person developing type 2 diabetes increase if they:

- are overweight or obese
- do not exercise regularly
- have a poor diet.

Type 2 diabetes is a particular problem in the Caribbean. The percentage of the population who have this condition is significantly higher than the average in other parts of the world.

▲ **Figure 3.4.10** Food additives

Food additives

Substances are added to food for a variety of reasons. These are called **food additives**. The substances are grouped according to their function.

▼ **Table 3.4.3** Functions of common additives

Additive	Function	Examples
Colours	make the food look more attractive	tartrazine; cochineal
Preservatives	increase the shelf life of the food; prevent the food from going off	potassium sorbate; sodium benzoate
Antioxidants	prevent the food from reacting with oxygen from the air and going off	ascorbic acid; calcium ascorbate
Thickeners, stabilisers and emulsifiers	modify the consistency of the food; prevent different components from separating out on standing	sodium alginate; acacia gum
Acidity regulators	alter the pH of food	ammonium carbonate; magnesium hydroxide
Flavour enhancers	make food more tasty	glutamic acid; monosodium glutamate

Many people are opposed to food additives. They claim that they are often unnecessary and that some additives can make people ill. For example, there is evidence that sulphites, which are used as preservatives in foods, such as dried fruits, can induce asthma. Some of the food colourings and other additives used in sweets and soft drinks are believed to affect the behaviour of some children. A number of substances that were once added to food have now been banned because they have been shown to be a cause of cancer.

Questions

1. What reagent(s) are used to test for: **a** starch **b** reducing sugars?
2. What are the colour changes observed in the above food tests?
3. What is the main function of proteins in the diet?
4. Why does a lack of iron in the diet result in weakness and tiredness?
5. What is added to table salt to make it iodised and why is it done?
6. Which food group should make up around half of a balanced diet?
7. How can a person have lots of food to eat but still be malnourished?
8. A portion of porridge contains 4.7 g of protein, 23.4 g of carbohydrate and 3.7 g of lipids. Estimate the energy content of this portion.
9. Suggest why the daily energy requirement of a woman increases if she becomes pregnant.
10. Give two examples each of sedentary jobs, moderately active jobs and very active jobs.

3.5 The growth of micro-organisms

A **pest** is a destructive micro-organism, insect or other animal that attacks food, crops and livestock. Some pests cause disease. They are **vectors** for disease-causing organisms. This means that they carry the disease-causing organisms in their bodies and pass them on to other organisms.

Micro-organisms

Micro-organisms are organisms which are so small they cannot be seen without the help of a lens or microscope. Examples include bacteria and some fungi. Micro-organisms can live in a variety of habitats: in the air, in soil, in water and in our bodies. Many micro-organisms are parasites that feed on living material. Some are responsible for the decay of food.

Micro-organisms form **colonies** by growing and dividing at regular intervals. If conditions are ideal the numbers of micro-organisms making up colonies of bacteria, such as *Escherichia coli* (*E. coli*) which is found in the human large intestine, can double every 20 minutes.

Conditions for growth of micro-organisms

Micro-organisms need **oxygen, water** and a **suitable temperature** to grow. Oxygen is needed for respiration, water for chemical reactions and a temperature of between 25 °C and 35 °C for optimal enzyme action and cell division. Micro-organisms that cause decay of food need a warm, damp environment. Understanding the conditions that different micro-organisms need to grow, helps us to find ways to preserve food.

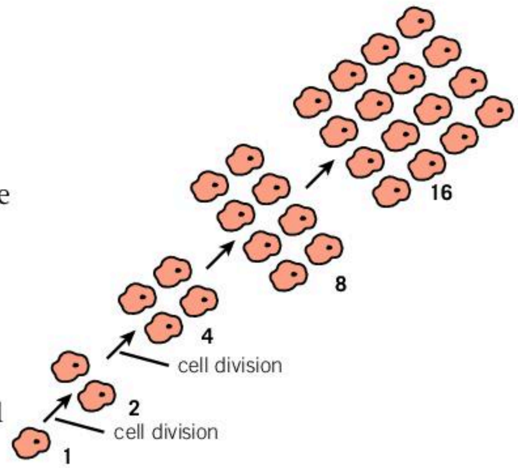
In order to identify bacteria, scientists grow colonies on plates of nutrient jelly. A sterile nutrient plate is inoculated with a sample of the bacteria, sealed with tape and left in a warm place for several days.

▲ **Figure 3.5.2** Bacterial colonies growing on a nutrient plate

Learning outcomes

By the end of this topic you will be able to:

- explain what a pest is
- describe how colonies of bacteria are grown
- describe the action of micro-organisms on food.



▲ **Figure 3.5.1** Micro-organisms produce colonies very quickly

Synoptic link

See Topic 1.4 Microbes.

Action of micro-organisms on food

If micro-organisms grow on food, they can produce poisons or toxins. When we eat contaminated food, the organisms themselves or the toxins they produce can make us ill. We may feel sick, vomit or have stomach cramps and diarrhoea. If the symptoms are severe and persist, hospital treatment may be necessary. The micro-organisms may get on the food if it has been kept uncovered, prepared by someone with dirty hands or it has come into contact with other contaminated food. Any contaminated food should be thrown away.

▲ **Figure 3.5.3** Mouldy bread

Practical Activity 3.5.1

Investigating the conditions in which bread mould grows

Skills assessed: Observation/Recording/Reporting and Planning and Design.

Mould will form on bread which is left in a warm, dark place for a few days.

Your teacher will give you a supply of bread, clear polythene bags, sticky tape and access to a refrigerator and a warm oven. Work in groups.

1 Plan an experiment to investigate:
   a whether water must be present for mould to grow on bread
   b whether the rate at which mould grows on bread varies with temperature.
2 Decide how you would do the investigation.
3 Remember to make sure that it is a fair test.
4 Do the investigation using the bread, polythene bags and sticky tape.
5 Observe what happens to the bread.
6 Explain your results.
7 Write a short paragraph explaining what happened to the bread in different conditions.

Questions

1 Starting off with a single bacterium which divides every 20 minutes how many bacteria would there be:
   a after one hour
   b after one day?
2 What type of cell division is responsible for this increase in numbers?
3 Why must the nutrient plate in Figure 3.5.2 be sterile?
4 Why is the plate sealed with tape?

3.6 Food preservation

Food preservation is about preventing the growth of micro-organisms, such as bacteria and fungi that cause the food to decay. Food preservation can be done by adding substances to the food or establishing conditions which inhibit or slow down the growth of micro-organisms.

Learning outcomes

By the end of this topic you will be able to:

- state what preservatives are
- give examples of different methods of food preservation
- describe the effects of low temperatures on the growth of micro-organisms

Preservatives

Preservatives are chemicals which kill micro-organisms.

1 **Pickling** is a traditional method of preserving that is achieved by placing the food in vinegar, which is a dilute solution of ethanoic acid. Many of the micro-organisms that cause food to decay cannot survive in such acidic conditions.

   Pickling is of limited use since the food acquires the taste of the vinegar. It is used for onions, gherkins and some other vegetables, and sometimes fish.

▲ **Figure 3.6.1** Pickling

2 **Smoking** is another traditional method of preserving that works in a similar way.

   The acidic chemicals in the wood smoke are absorbed into the food and kill any micro-organisms. Smoking is used to preserve fish and meat, and leaves the food with a characteristic smoky smell and taste.

3 Modern preservatives, such as **sodium benzoate** and **potassium sorbate** (see food additives Topic 3.4), are added to food to kill micro-organisms. These extend the shelf life of the food without altering its flavour.

▲ **Figure 3.6.2** Smoking

Removing water

The micro-organisms that bring about food decay need water to live and multiply. If water is removed from food then micro-organisms can no longer flourish.

1 **Salting** is one of the oldest methods of preserving food. It involves rubbing salt into food, or placing the food in a concentrated solution of sodium chloride (brine).

   The salt removes water from the surface of food so micro-organisms cannot live on it. This method of preservation is still used with some meats and fish.

▲ **Figure 3.6.3** Anchovy fillets that have been preserved by salting

2 **Dehydration** involves removing all of the water in food to prevent decay.

   A range of foods are now available as powders including milk, instant potato, soups and sauces. They will keep for a long time in sealed packets and can be reconstituted by adding water.

▲ **Figure 3.6.4** Freeze-drying

▲ **Figure 3.6.5** Jamming

Fruits and vegetables can be preserved by drying, and also some meat products, such as beef jerky.

3 **Freeze-drying** is a special technique for removing the water from food without altering its taste. The food is first frozen and then placed in a vacuum. Under these conditions, the ice in the food sublimes to form water vapour without passing through a liquid phase. Instant coffee is prepared by freeze-drying as are many other powdered foods.

4 **Adding sugar** preserves food by removing water from it. When jams are made, food is heated in a sugar–water syrup and then sealed to prevent the entry of micro-organisms. Fruit is preserved with sugar as jams and jellies.

Low temperature

Colonies of micro-organisms grow much more slowly at low temperatures than they do at room temperature.

1 The temperature inside a **refrigerator** is typically around 3 °C. This allows some foods to be kept for several days and others for several weeks without going off. Cooked food should always be allowed to cool before being placed in the refrigerator.

2 The inside of a domestic **freezer** is kept much colder, typically around –20 °C. At such low temperatures, micro-organisms are inactive and food can be kept for many months.

Heating

Micro-organisms are killed when food is heated. If the food is then sealed to prevent the entry of micro-organisms from the air as it cools, it can be preserved for long periods of time.

In **canning** the food is cooked and sealed in tin cans while still hot. A very large range of food is preserved by canning.

Irradiation

Irradiation is a modern method of increasing the shelf life of foods by exposing them to radiation from a radioactive source.

- Some people claim that irradiation is a cheap method of preservation. It does not alter the flavour of food and can be carried out after the food has been sealed in its container, so there is no danger of contamination from the air. Since it increases the shelf life of food, there is less wastage.
- Other people claim that irradiation may alter the molecular structure of the food, which could lead to the growth of cancers in people who regularly eat food preserved in this way.

Questions

1 What liquid is used to pickle food?
2 What type of chemical is sodium benzoate?
3 What is removed during freeze-drying?
4 What is a typical temperature for a domestic refrigerator?
5 What substance is added to fruit to make jam?

Practical Activity 3.6.1

Food labels

1 Your teacher will ask each student to collect food labels from different foods.
2 Your teacher will divide the class into groups. Each group can then use their labels to compare the content of the foods under the following headings: carbohydrates; protein; energy; food additives.
3 Each group can then present their findings about the nutritive content of each food found from their labels to the rest of class.

3.7 Human digestion

Digestion is the breaking up of the food molecules in the alimentary canal so that they can be absorbed into the body. This involves mechanical processes, such as chewing in the mouth and churning in the stomach, and chemical processes in which the large molecules that make up food are broken down into smaller molecules by enzymes.

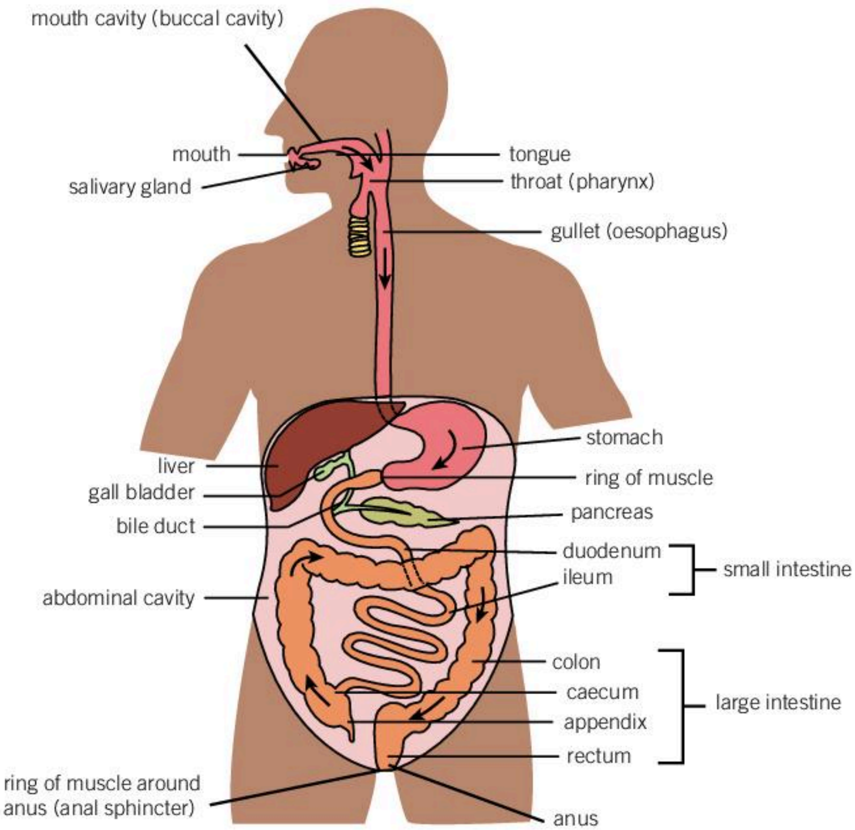
Learning outcomes

By the end of this topic you will be able to:

- explain the need for digestion
- describe mechanical digestion
- explain the role of enzymes in chemical digestion
- state how the activity of enzymes depends on temperature and pH
- describe chemical digestion in different parts of the alimentary canal
- name the digestive juices and enzymes
- name the substrates and products of digestive enzymes
- describe how the structure of the alimentary canal is suited for absorption, assimilation and egestion.

The alimentary canal

The alimentary canal, or gut, is a long tube that runs from the mouth to the anus. As food passes through it, both mechanical and chemical digestion takes place and the products of digestion are absorbed into the body.

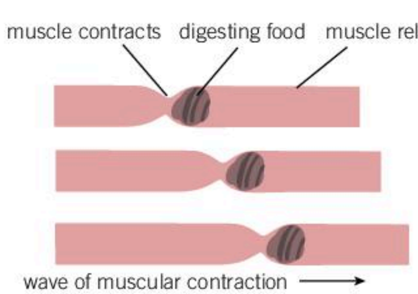


▲ **Figure 3.7.1** The main parts of the alimentary canal

Mechanical digestion – in the mouth

When we eat food it is first chewed in the mouth. Chewing with teeth chops and grinds food into smaller pieces before they are swallowed. This increases the area on the food that is available for chemical digestion. Chewing also mixes and moistens food with saliva. The resulting ball of food or **bolus** can then be easily swallowed.

The bolus that forms in the mouth is swallowed and passes down the oesophagus into the stomach. It is pushed downwards by the action of muscles in the wall of the oesophagus. The circular muscle contracts and relaxes in a wave-like motion. This is called **peristalsis**.



▲ **Figure 3.7.2** Diagram to show peristalsis

> **Did you know?**
>
> The names of enzymes often end in the suffix 'ase'. So if you see a substance and its name has this ending it is likely to be an enzyme. They are usually named according to the substrate that they act on. For example, sucrase acts on sucrose.

Mechanical digestion – in the stomach and small intestine

The churning action of the muscles in the wall of the stomach grinds the food until it eventually becomes a fluid called **chyme**. Roughage helps the movement of the food through the small intestine. The churning mixes the food molecules with digestive juices.

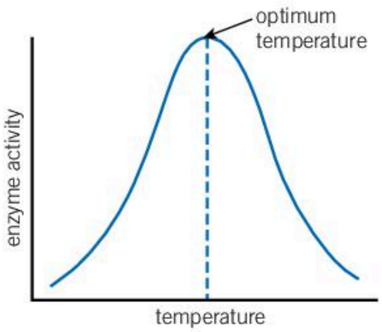
Enzymes

Chemical digestion is brought about by special chemicals called **digestive enzymes**. Enzymes are **catalysts**. They speed up reactions but they are not changed by them. One enzyme molecule can be used over and over again, and so it can break down many food molecules.

Enzymes act on molecules called **substrates** and change them into one or more **product** molecules.

$$\text{substrate molecule} \xrightarrow{\text{enzyme}} \text{product(s)}$$

Enzymes are specific for particular substrates. For example, an enzyme that catalyses the break down of proteins will not act on lipid molecules. This is referred to as **specificity**.



▲ **Figure 3.7.3** All enzymes work best at an optimum temperature

Factors that influence enzyme action

Temperature

All enzymes work best at an optimum temperature. The optimum temperature for human digestive enzymes is around 37 °C.

Below the optimum temperature, the enzyme reaction starts to slow down and at very low temperatures it will stop. The ability of an enzyme to break down food molecules depends on its 3-dimensional structure. The food molecule fits onto the surface of the enzyme like a key fits in a lock. When an enzyme is heated, its 3-dimensional structure changes and it rapidly ceases to work. The enzyme is said to be **denatured**.

> **Practical Activity 3.7.1**
>
> **Investigating the activity of salivary amylase at different temperatures**
>
> Skills assessed: Planning and Design.
>
> **Materials:**
>
> - Starch solution
> - Salivary amylase solution
> - Iodine solution in a dropping bottle
> - Test tubes
> - A measuring cylinder
> - A white spotting tile
> - A thermometer
> - Water baths set at 10 °C, 20 °C, 30 °C, 40 °C and 50 °C
>
> Plan an experiment to investigate the rate of reaction of salivary amylase over the temperature range 10–50 °C. You should state what you would do, and how you would obtain and display your results.

> **Exam tip**
>
> It is a common mistake in examinations for students to describe enzymes as being killed. Enzymes are not living organisms. They are protein molecules. When an enzyme is heated it becomes denatured and stops functioning but it is not killed.

pH

Enzymes also work best under optimum pH conditions. pH refers to the acidity or alkalinity of a solution. The pH changes along the alimentary canal. The enzymes in the stomach, for example, work best at around pH 3.

The activity of an enzyme falls either side of its optimum pH value as changes in the pH of the conditions causes the 3-dimensional structure of the enzyme to change.

You will see how this is important in chemical digestion of food in the alimentary canal. Different parts of the alimentary canal have different pHs. This means that enzymes that function at different pHs will work best in particular parts. For example, the enzymes that function in the stomach, which has an acidic pH, work best in an acidic medium.

Practical Activity 3.7.2

Investigating the optimum pH for salivary amylase

Skills assessed: Observation/Recording/Reporting.

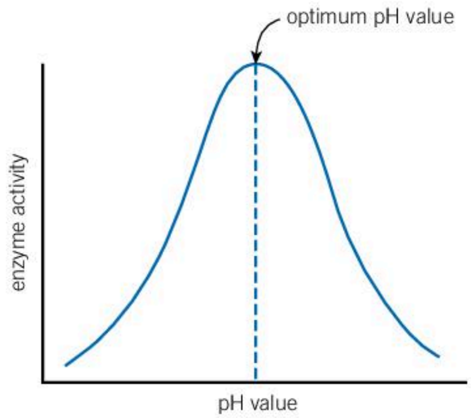
1 Prepare a sample of starch solution by shaking 1 cm^2 of bread in 3 cm^3 of water. The solution formed should be decanted into a second test tube.
2 Divide the decanted solution equally into three test tubes, A, B and C.
3 Add three drops of dilute hydrochloric acid to test tube A.
4 Add three drops of dilute sodium hydroxide solution to test tube B.
5 Add 0.5 cm^3 of salivary amylase solution to each of test tubes A, B and C.
6 After 2 minutes place one drop of solution from each test tube on a spotting tile and add one drop of iodine solution. Record your observations.
7 Repeat step 6 at 2 minute intervals for 20 minutes.
8 Record your results in a table.

Questions

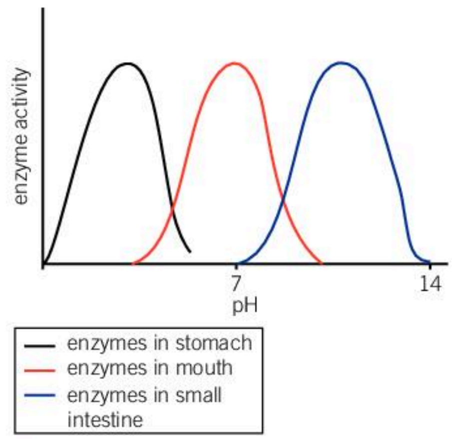
1 What is meant by the terms ‘optimum temperature’ and ‘optimum pH’?
2 What is meant by the term ‘3-dimensional structure’?
3 Why do all digestive enzymes not work on all groups of food?
4 Many washing powders contain digestive enzymes. Suggest why this makes them more efficient.

Key fact

Acids have a pH less than 7; alkalis have a pH greater than 7.



▲ **Figure 3.7.4** All enzymes work best at an optimum pH value



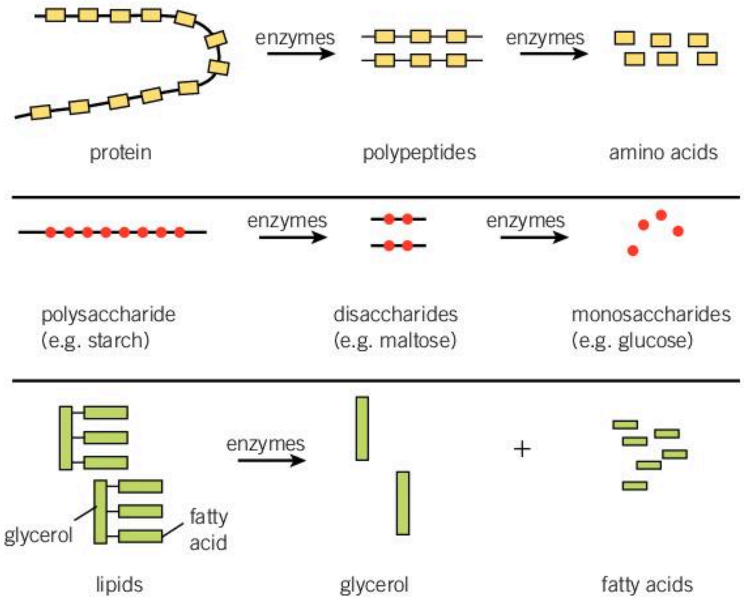
▲ **Figure 3.7.5** Different enzymes work best at different pH values

Key fact

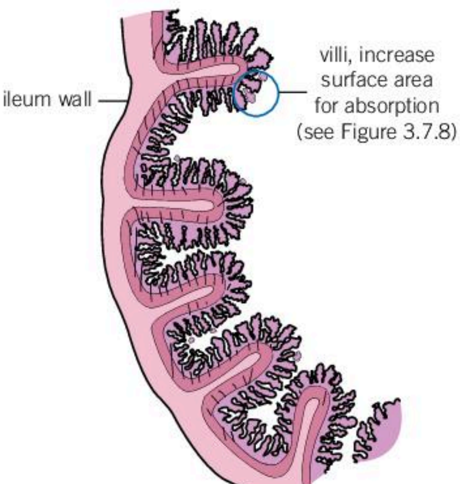
The pH of the different parts of the alimentary canal enables enzymes to work optimally.

Chemical digestion of food molecules

In Topic 3.4 you learnt about different types of food groups. In the alimentary canal these food molecules are broken down by specific enzymes. Large insoluble molecules are converted to small soluble molecules that can be absorbed from the alimentary canal into the blood.



▲ **Figure 3.7.6** Substrates and products of digestion

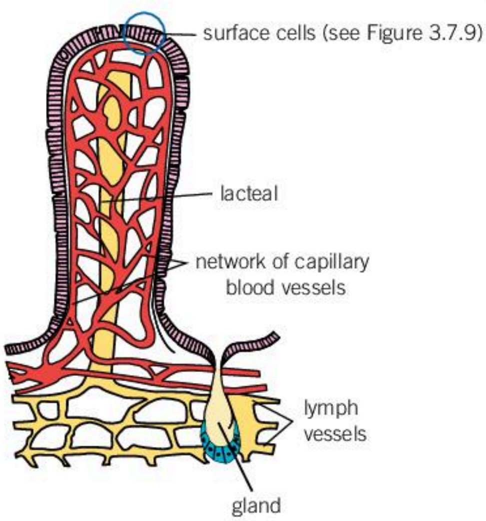


▲ **Figure 3.7.7** Diagram to show the internal structure of the ileum

In the stomach

The stomach is a muscular sac in which food remains for a few hours. During this time it is churned about, and mixed with hydrochloric acid and **gastric juice** containing an enzyme called pepsin. Pepsin converts proteins into smaller polypeptides. It works best in an acidic medium.

The hydrochloric acid also helps in the breakdown of food and kills many of the micro-organisms that enter the stomach in the food.



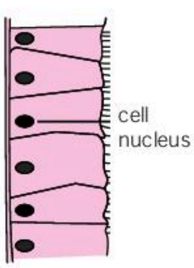
▲ **Figure 3.7.8** Diagram to show the structure of the villus

In the small intestine

The small intestine is divided into two parts, the duodenum and the ileum. As the chyme enters the duodenum, it mixes with bile, from the liver, and pancreatic juice, from the pancreas.

Bile is very alkaline. The acidic chyme becomes alkaline. Although bile contains no enzymes, it plays an important role in digestion by emulsifying lipids into small droplets so they can be digested more efficiently.

Pancreatic juice contains several enzymes that work optimally in an alkaline medium. These are described in Table 3.7.1.



▲ **Figure 3.7.9** Diagram to show the structure of the surface cells of a villus. Absorption takes place through these cells

In the large intestine

By the time the digested food reaches the large intestine, all the products of digestion have been absorbed and all that remains is undigested food, fibre and water.

Some water is absorbed in the colon. The remaining undigested food eventually passes out of the body through the anus as **faeces**. This process is known as egestion.

▼ **Table 3.7.1** Digestive juices, enzymes, substrates and products

Part of alimentary canal	pH	Digestive juice	Enzyme	Substrate	Products
mouth	slightly alkaline	saliva	salivary amylase	starch	maltose and glucose
stomach	acidic	gastric juice	pepsin	proteins	polypeptides
			renin	milk proteins	peptides
small intestine: duodenum	alkaline	pancreatic juice	trypsin	proteins and polypeptides	amino acids
			amylase	starch	maltose and glucose
			lipase	fats and oils	fatty acids and glycerol
small intestine: ileum	alkaline	intestinal juice	maltase	maltose	glucose
			sucrase	sucrose	glucose and fructose
			lactase	lactose	galactose and glucose
			galactase	galactose	glucose
			lipase	fats and oils	fatty acids and glycerol
			peptidase	small peptides	amino acids

Absorption, assimilation and egestion

After digestion, food molecules are small and soluble. They are able to move through the walls of the intestine into the blood by diffusion, osmosis or active transport. You learnt about these processes in Unit 1. The blood takes them to the cells, or to the liver, where they can be stored or changed into other substances.

Most absorption takes place in the ileum. Its inner wall is lined with finger-like projections called **villi** (singular: **villus**) which greatly increase the surface area. The wall of a villus is only one cell thick, making it easy for the products of digestion to be absorbed.

Substances which are water-soluble, such as some vitamins, minerals, glucose and amino acids, are absorbed into blood capillaries and carried in the blood to the liver. Substances which are fat-soluble, such as other vitamins, fatty acids and glycerol, are absorbed into lacteals and carried to the liver in the lymph system.

Assimilation

The movement of the products of digestion to different parts of the body where they are needed is called assimilation. This allows all the cells of the body to obtain the nutrients they need to function properly.

Egestion

Following absorption of soluble food from the intestine, the remaining undigested food passes out of the body through the anus as faeces. This process is called egestion. Do not confuse egestion with the process of excretion, which is the expulsion of the waste products of metabolic processes from the body. The undigested remains of food are not waste products because they were not produced by a metabolic process.

Questions

1. Which part of the alimentary canal is most acidic?
2. Suggest a likely optimum temperature for lipase and a likely optimum pH for trypsin.
3. Why are vitamins and minerals not broken down in the digestive system?
4. In which part of the alimentary canal does most absorption of nutrients take place?
5. Explain why a person who is suffering from diarrhoea should drink plenty of water.
6. What is the difference between mechanical digestion and chemical digestion?

Learning outcomes

By the end of this topic you will be able to:

- recall the number, type and location of teeth in an adult
- describe the role of each type of tooth and relate this to its structure
- explain the role of teeth in digestion
- draw and label a longitudinal section of a tooth
- explain the causes of tooth decay
- describe ways of caring for the teeth
- discuss the benefits of fluoridation of drinking water.

Did you know?

The grinding action of the teeth in herbivores is sufficient to wear away even the hard layer of enamel, so the teeth of some animals grow continually throughout their lives.

Practical Activity 3.8.1

Identifying types of teeth

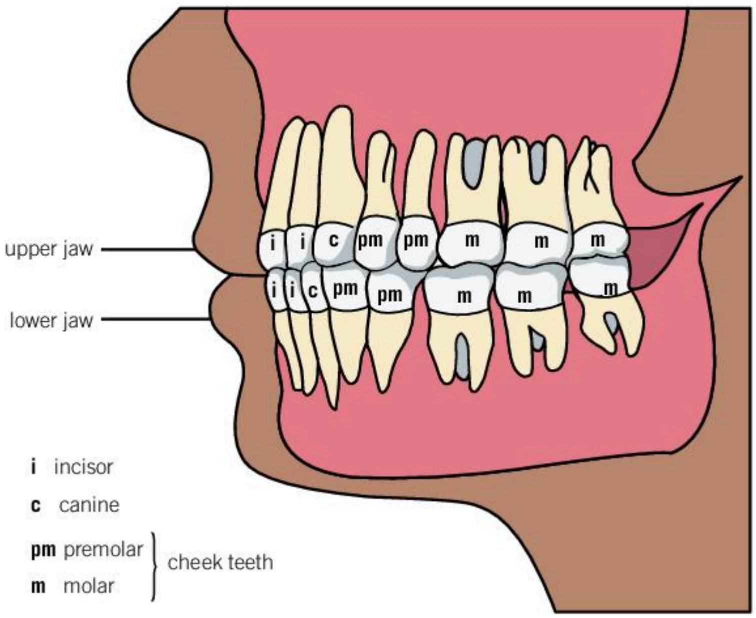
Skills assessed: Drawing.

Your teacher will give you some teeth.

1. Identify the type of tooth.
2. Make a labelled drawing of the tooth.
3. Make accurate measurements of the tooth and calculate the magnification of your drawing.

3.8 The teeth

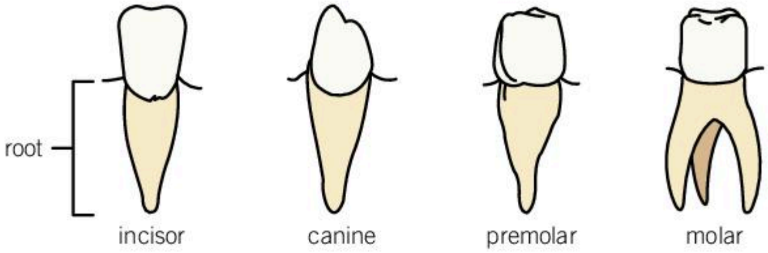
There are 32 teeth in a complete set of adult teeth. They are arranged symmetrically in the upper and lower jaw. There are four kinds of teeth which have different shapes related to their functions.



▲ **Figure 3.8.1** Position of the different types of teeth

▼ **Table 3.8.1** The shape and function of the different types of teeth

Name of teeth	Shape	Function
incisors	flat, chisel-shaped	cut and slice food
canines or eye teeth	pointed	pierce food and tear pieces off
premolars	large and flat with bumpy surfaces; two roots	crush and grind food
molars	large and flat with bumpy surfaces; three roots	crush and grind food



▲ **Figure 3.8.2** The shape of the different types of teeth

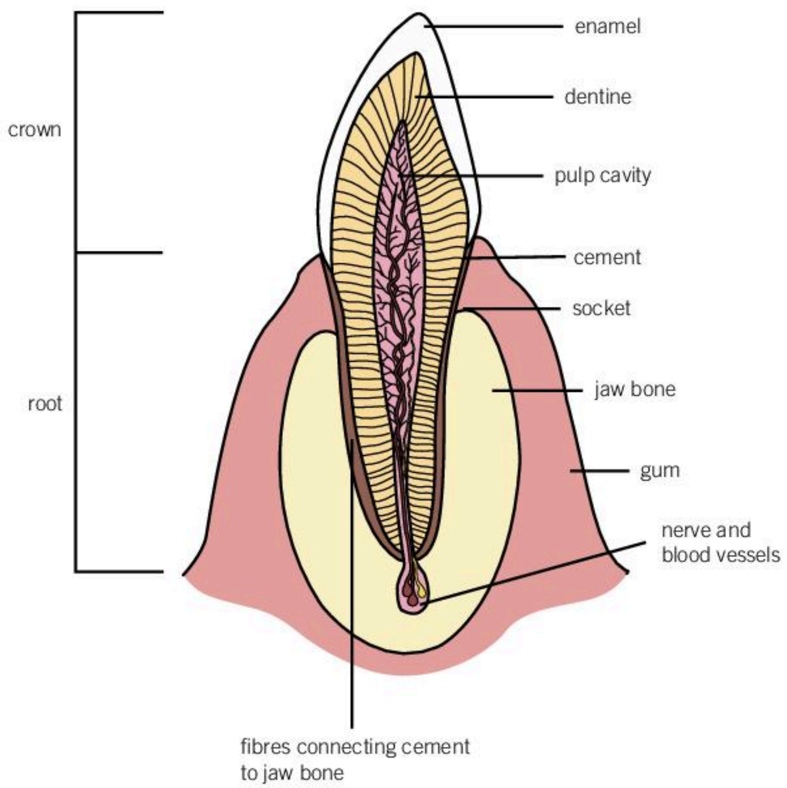
Structure of a tooth

A tooth has two parts: the part you can see above the gum, which is called the **crown**, and the part you cannot see that is embedded in the jaw. This is called the **root**.

The crown of the tooth is covered in a layer of bone-like material called **enamel**. This is the hardest substance in the human body and it is essential to keep the tooth healthy. Without this enamel coating, the abrasive action of eating would soon wear a tooth away.

The main body of the tooth is composed of **dentine**. At the centre is the blood supply and nerve which together are called the **pulp**. This part of the tooth is very sensitive and if it is exposed, perhaps as a result of tooth decay, it is very painful.

The root of the tooth is not covered in enamel but in a rough layer called **cement**. This allows the attachment of many tiny fibres that hold the tooth firmly in place in the jaw bone.



▲ **Figure 3.8.3** Longitudinal section through an incisor tooth to show its structure

Care of the teeth

Our adult teeth have to last for a long time so they must be looked after. This involves regular brushing and regular visits to the dentist.

After eating, a sticky layer of food particles and bacteria, called **plaque**, is deposited on the teeth. The bacteria feed on sugars in the food particles and produce harmful acids. If the plaque is not removed at regular intervals, these acids will gradually eat away at the enamel. This creates cavities in the teeth. Once a small cavity forms, more food and bacteria are deposited in it. The cavity gets deeper until eventually it reaches the pulp and the tooth starts to ache.

Also a build-up of plaque between the teeth and the gums can cause the gums to become infected and bleed. If left untreated, the plaque gradually destroys the fibres between the teeth and the jaw. Teeth become loose and will eventually fall out.

The best way of avoiding cavities is to clean the teeth thoroughly several times each day, particularly after meals. Flossing between the teeth is useful because it removes any small particles of food which are trapped between the teeth.

A person should visit the dentist at least every six months to have their teeth examined and treated if necessary.

Fluoridation

Research into tooth decay shows that the people who live in areas where there is a small amount of fluoride in the drinking water have fewer cavities than those living in other areas. The fluoride strengthens the enamel on the tooth making it more resistant to attack by acids. In many places fluoride is now added to drinking water as a public health service to reduce tooth decay. Fluoride is also a component of many brands of toothpaste.

Practical Activity 3.8.2

Effect of acid on teeth

Skills assessed: Observation/Recording/Reporting.

1. You are provided with a tooth which is completely covered in candle wax. Remove some wax from the crown of the tooth so that you expose a small area of enamel.
2. Place the tooth in a test tube containing dilute hydrochloric acid and leave it for one week.
3. Pour off the dilute hydrochloric acid and wash the tooth thoroughly to remove any residues of acid before handling it.
4. Remove some wax from another part of the crown to expose another area of the enamel.
5. Examine the appearance of the two areas of enamel.
6. Try to push a mounted needle into each of the two areas and note any difference in the texture.

Questions

1. In what ways is the shape of premolar and molar teeth appropriate to the job they do?
2. Fizzy drinks are acidic. Why does this make them bad for the teeth?
3. Should dental floss be used instead of, or as well as, toothpaste? Explain your answer.

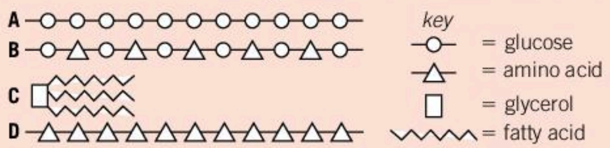
Exam-style questions

Multiple choice

1 To show that a green plant releases carbon dioxide, in which conditions must it be placed and why?

	Condition	Reason
A	dark	To prevent photosynthesis
B	dark	To prevent respiration
C	light	To allow photosynthesis
D	light	To allow respiration

2 Which of the following shows the structure of a fat?



Structured questions

3 a Name:

i) the requirements for photosynthesis
ii) the products of photosynthesis.

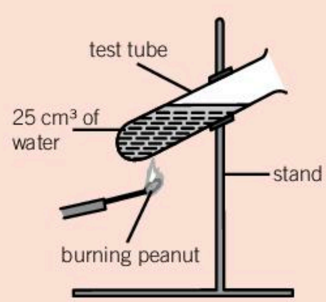
b Describe four ways that leaves are structurally well suited to photosynthesis.

4 A student was asked to find out which food molecules were in each of three test tubes. The table shows the student's results from carrying out a series of tests with the reagents named.

Test tube	Reagents added to the test tube		
	Test A	Test B	Test C
	10% sodium hydroxide + 1% copper sulphate	Benedict's solution	Iodine
X	purple	blue	brown
Y	blue	orange-red precipitate	brown
Z	blue	blue	blue-black

a Name the test A.
b Identify the substances X, Y and Z.

5 An experiment was carried out to find out how much energy was in a pea and a peanut by using the apparatus shown.



The results of the experiment are shown in the table:

Food	Mass (g)	Initial temperature of water, t_1 (°C)	Final temperature of water, t_2 (°C)	Rise in temperature (°C)	Energy released (J)
peanut	20	20	46		
pea	20	20	29		

a Copy the table and

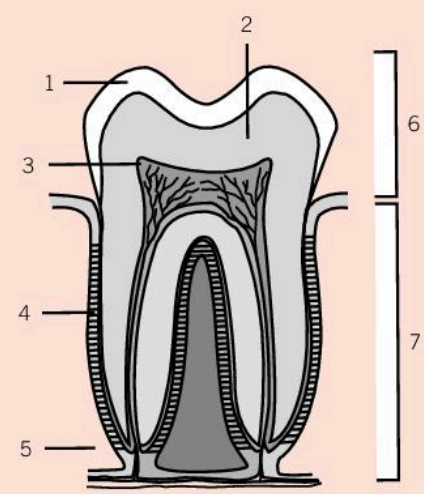
i) calculate the rise in temperature for the peanut and pea, and enter it in the correct column

ii) use your answers to part i) to calculate the energy released by the pea and the peanut by using the equation

$$\text{Energy (J)} = \frac{\text{mass of water} \times 4.2 \times (t_2 - t_1)}{\text{mass of food}}$$

6 a Explain the term *balanced diet.*
b Why is there no such thing as a diet that suits every individual?
c Name one disease that occurs as a result of malnutrition.

7 The diagram below shows the structure of a human tooth.



a Provide labels for parts 1–7.
b Describe the cause of tooth decay.
c How does fluoride reduce tooth decay?

8 Give three reasons why food additives are added to food.

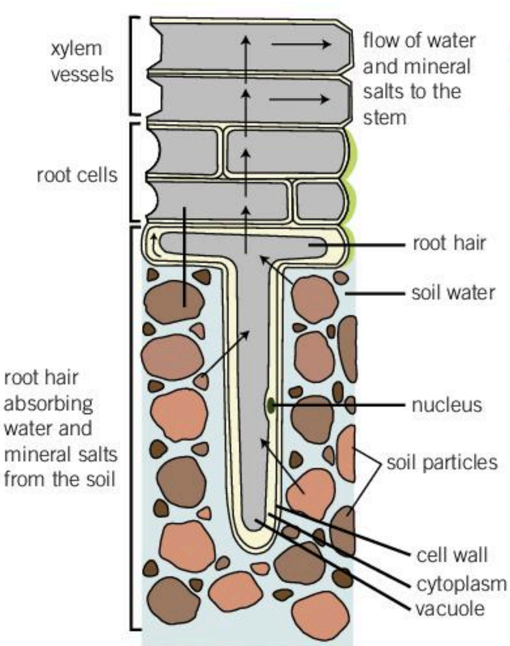
Section A

4 Transport systems

Learning outcomes

By the end of this topic you will be able to:

- explain the importance of a transport system in plants
- describe the location and structure of the transporting tissues in plants
- explain how plant roots absorb water and mineral salts from the soil
- explain the importance of capillarity in a plant
- describe the role of xylem in transporting water
- explain the importance of capillarity
- describe how transpiration occurs
- describe the role of the phloem in translocation.



▲ **Figure 4.1.1** Water passes from the soil through the root cells into the xylem by osmosis

All living cells need to be supplied with oxygen, and nutrients and the waste products removed. Multicellular organisms have transport systems to move substances from place to place but unicellular organisms rely on diffusion alone.

The skeleton and muscles allow humans to move their bodies from place to place.

4.1 Transport in plants

Plants have a transport system consisting of specialised tissues in which water, mineral salts and food are moved around. Water and mineral salts are transported from the roots to the aerial parts in the **xylem**. Sugars made in the leaves are transported to the rest of the plant in the **phloem**. The xylem and the phloem are found in the **vascular tissue** which extends throughout the plant in the roots, stems and leaves.

Absorption through the roots

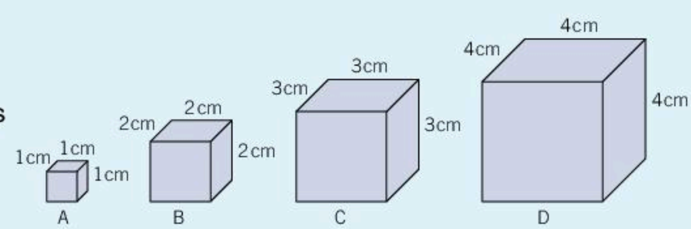
Water and mineral salts are absorbed from the soil by the roots. The outer layer of the young roots is covered with large numbers of root hairs which increase the surface area available for absorption. The cell membranes of the root hair cells are partially permeable, allowing water to enter the cell from the soil by osmosis. The water passes along a diffusion gradient from a high concentration in the soil to a lower concentration in the root hair cells.

Practical Activity 4.1.1

Looking at surface area to volume ratio

Materials:

- Agar cubes
- Four petri dishes
- Coloured water
- Ruler
- Knife



Method:

1. Draw a table with five columns and four rows. Label the columns ‘Shape’, ‘Total surface area’, ‘Volume’, ‘Ratio of total surface area to volume’ and ‘Observations’.
2. Complete the table for shapes A to D.
3. Cut agar cubes to match the dimensions given in the diagram.
4. Put 1 cm^3 of coloured water in each petri dish and label the dishes A, B, C and D, respectively.
5. Put one agar cube into each petri dish and leave for 30 minutes.
6. Record your observations in the table and compare them to the total surface area to volume ratio.

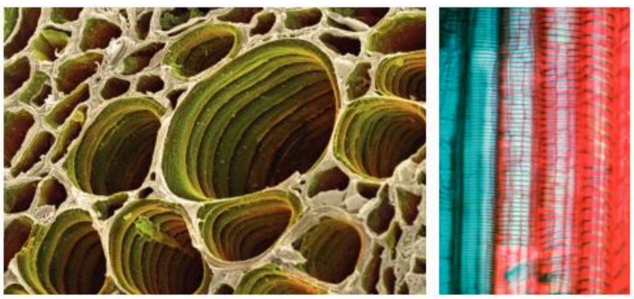
As absorption takes place, the concentration of water in the root hair cell rises and becomes greater than the concentration in the adjoining cell, so water passes into the adjoining cell by osmosis. In this way, water passes from cell to cell until it reaches the transporting vessels called xylem. This results in **root pressure**.

Mineral salts are often in greater concentration in the cells than in the soil, so their absorption into the roots cannot be explained by diffusion. The salts are absorbed against the diffusion gradient by another process called active uptake, which requires energy from the plant.

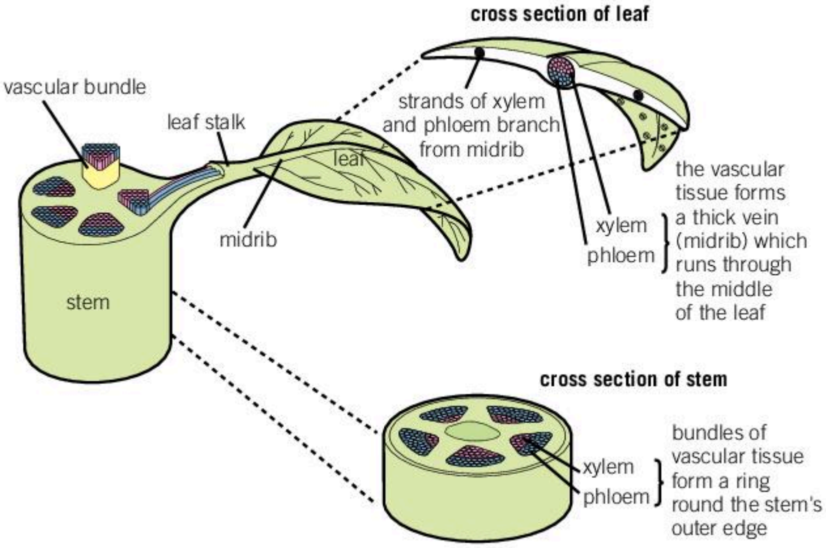
The xylem vessels consist of thin hollow tubes. The water and dissolved mineral salts, which are absorbed by the roots, pass into the xylem and up to different parts of the plant. The minerals are used to make substances, such as proteins, while some of the water is used in photosynthesis. The remaining water is lost from the plant during **transpiration** (see page 80).

The xylem is not composed of living cells, so it is impossible for the solution of mineral salts to pass up the plant by osmosis. Instead it rises by **capillarity**. This phenomenon occurs when liquids are in narrow diameter tubes.

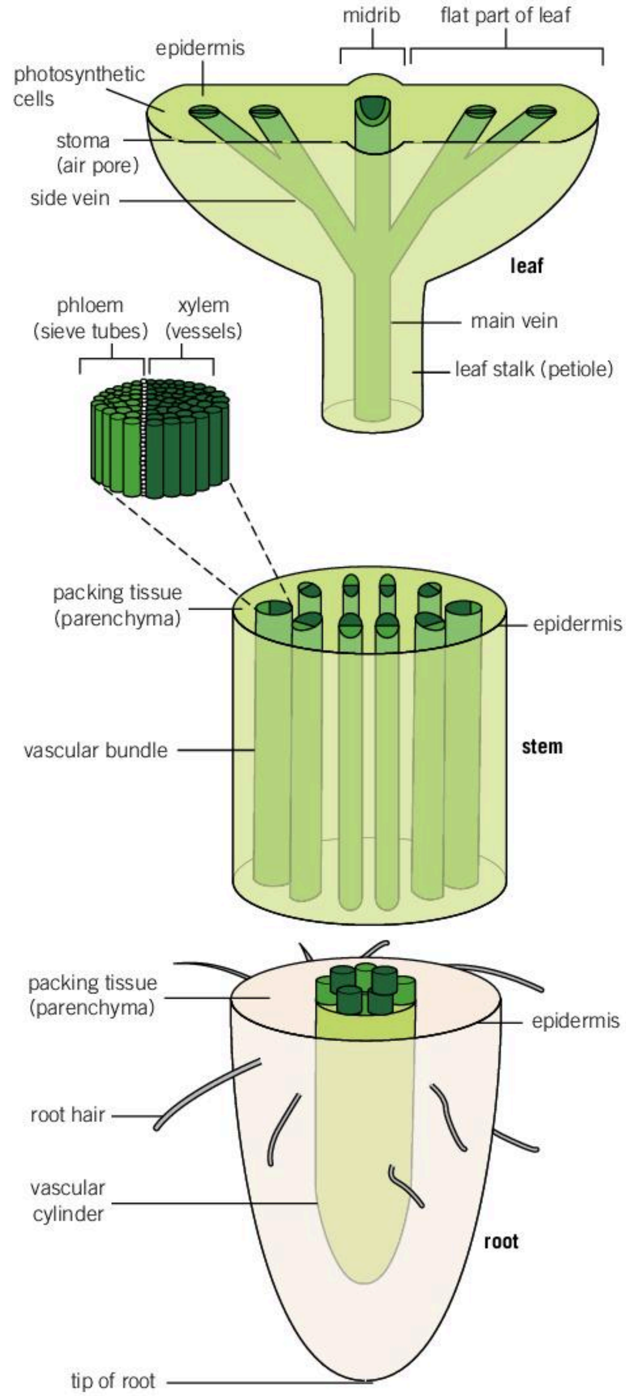
When a narrow diameter tube is stood in a beaker of water, the water rises higher in the tube than the level in the beaker. This is due to forces of attraction between water molecules and the inside of the tube. Water moves up the xylem partly as a result of capillarity.



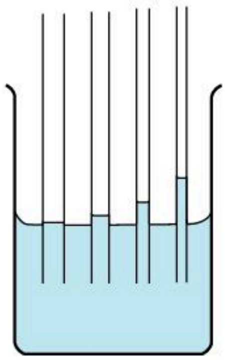
▲ **Figure 4.1.3** (a) Transverse section of xylem tissue (b) Longitudinal section of xylem tissue



◀ **Figure 4.1.4** Vascular bundles contain both xylem and phloem



▲ **Figure 4.1.2** Diagram to show vascular tissue in leaf, stem and root



▲ **Figure 4.1.5** The narrower the inside of the tube, the greater the effect of capillarity

Exam tip

Evaporation is the process when water molecules change from a liquid to a gaseous state.

Practical Activity 4.1.2

To show the transport of water in a stem

Skills assessed: Observation/Recording/Reporting and Drawing.

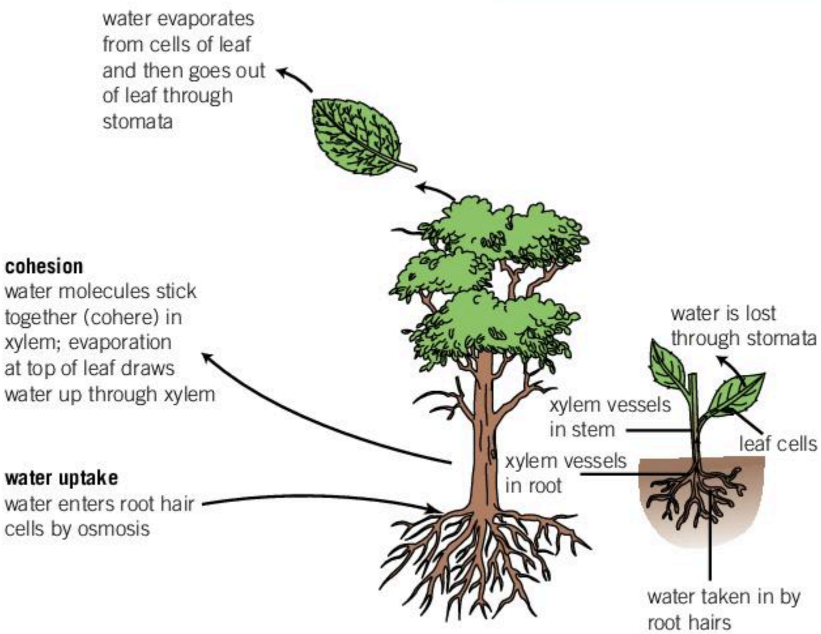
Materials:

- Long cutting of a soft-stemmed plant, such as balsam or celery
- Beaker containing water and a dye, such as eosin or red ink
- Razor blade or scalpel
- Hand lens

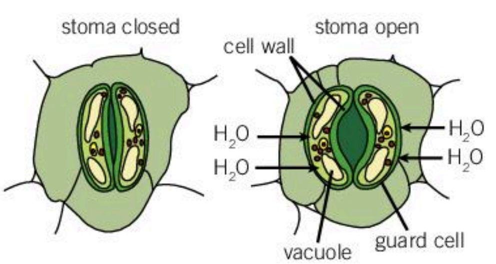
You will need to set up this experiment 24 hours before you examine it.

Method:

1. Place the cutting into the beaker of water containing the dye. Leave for 24 hours.
2. Using a razor blade or scalpel, cut sections across the stem in four different places.
3. Examine the sections with a hand lens and make drawings of your observations.
4. From your observations, determine how high the water has risen up the stem in 24 hours.



▲ **Figure 4.1.6** Transpiration



▲ **Figure 4.1.7** The opening and closing of the stomata is controlled by the guard cells

Transpiration

Even in the narrowest of xylem vessels, water is only able to rise about three metres. Since there are many trees taller than this, there must be processes other than capillarity that assist in transporting water and mineral salts.

Transpiration is the loss of water, by evaporation, from those parts of a plant above the ground. Most transpiration occurs on the lower surface of leaves through tiny pores called **stomata** (singular – stoma). You learnt about these in Topic 3.1.

Water molecules diffuse out of the stomata from the air spaces in the leaf and a diffusion gradient is set up. There will be fewer water molecules in the air spaces than in the cells in the leaf. Water will evaporate into the air spaces leaving fewer water molecules in these cells than in those adjacent to them. Water moves by osmosis from one cell to another. Eventually water moves out of the xylem into the leaf cells. As a result of transpiration, water is continually being lost from the leaf surface and more water is drawn up through the xylem to replace it. This is called the **transpiration pull**.

Factors affecting the rate of transpiration

The rate at which transpiration takes place depends upon the following conditions around the plant.

- Temperature – The rate of transpiration increases in warm weather because more energy is available to turn water into water vapour. This means that water vapour diffuses more quickly from the stomata.
- Humidity – Humidity refers to the concentration of water vapour in the air. There is a limit to the amount of water vapour that can be held in the air before it becomes saturated. The rate of transpiration decreases when the air is very humid.
- Wind – In still conditions, the air around a plant becomes saturated with water vapour and the rate of transpiration decreases. In windy conditions, the water vapour is continually blown away from the plant so the air never becomes saturated and the rate of transpiration increases.
- Surface area – Water evaporates from the surface of the leaf. The larger the leaf surface, the more water vapour will be lost. Plants that live in situations where water is scarce have leaves with reduced surface areas. In cacti, the leaves are reduced to spines and transpiration occurs through the stem.

Translocation

Unlike xylem vessels, the phloem consists of living tissue. Sieve cells and companion cells in the phloem work together to transport sugars from the leaves, where they are made during photosynthesis, to where they are needed in the plant. Some of the sugar is used to release energy during respiration, while the remainder is converted into starch for storage. The movement of sugars and other substances through the sieve cells is called **translocation**.

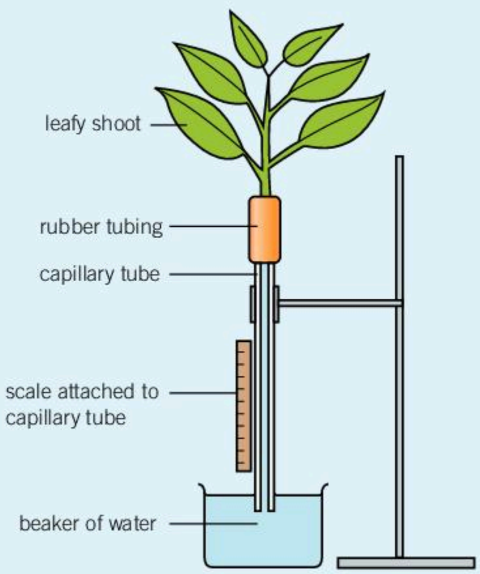
Practical Activity 4.1.3

Investigating water uptake by a leafy shoot

Skills assessed: Planning and Design.

The following apparatus could be used to investigate the rate at which water is taken up through a leafy shoot.

Plan an experiment to investigate the rate at which water is taken up through a leafy shoot under different conditions. You should state what different conditions you would use, what you would measure and how you would display your results. Mention one source of error in the apparatus shown.



Key fact

A stoma consists of an opening, or pore, surrounded by two sausage-shaped cells called guard cells.

- When water flows into the guard cells they swell up and become more curved. The pore gets bigger and more water is lost.
- When water flows out of the guard cells they shrink and become less curved. The pore becomes smaller and less water is lost.

Stomata never close completely because the plant needs the transpiration pull to maintain a supply of water and minerals.

Synoptic link

See Topic 1.5 Diffusion, osmosis and active transport.

Questions

1 By which process do plant roots absorb:
a water **b** mineral salts?

2 State one difference between the structure of the xylem and the phloem.

3 In hot regions the leaves of some plants are curved back on themselves in such a way that the underside is not exposed to the atmosphere. What advantage does this have for the plant?

4 What are the factors that affect the rate of transpiration?

Learning outcomes

By the end of this topic you will be able to:

- name the main constituents of blood and describe their function
- identify the heart as a pump
- name the four associated chambers of the heart and the blood vessels
- describe what happens during a heartbeat
- measure your pulse rate
- describe the structure and function of an artery, a vein and a capillary
- describe a network of blood vessels in the body.

Practical Activity 4.2.1

Different types of blood cell

Skills assessed: Drawing.

Your teacher will give you a prepared microscope slide of blood.

1. Set up a microscope to view the slide.
2. Make a clearly labelled drawing of the cells that you can see.

Did you know?

White blood cells are larger than red blood cells but there are far fewer of them. One cm^3 of blood typically contains around 5 000 000 red cells and 3 000 white cells.

4.2 The human circulatory system

Composition of blood

Blood consists of a suspension of **blood cells** in a solution called **plasma**. Each component of blood has an important function in the body.

Plasma is a pale straw-coloured liquid consisting of 90% water and 10% dissolved substances. Its function is the transport of substances in solution to and from the body cells. The dissolved substances include:

- the products of digestion: glucose, amino acids, lipids
- vitamins and minerals
- metabolic wastes: urea and carbon dioxide
- hormones.

It also contains plasma proteins, such as albumen, globulins and fibrinogen, which make the blood slightly sticky and play a role in helping the body to fight invasion.

There are three main groups of **blood cells**. Their structure and functions are summarised in Table 4.2.1.

Table 4.2.1 The structure and functions of the blood cells

Type of blood cell	Structure	Function
Red blood cells (erythrocytes)	Biconcave discs; no nucleus; contain haemoglobin	Haemoglobin combines with oxygen to form oxyhaemoglobin; transport of oxygen to body cells
White blood cells (lymphocytes and phagocytes)	Colourless cells; nuclei Lymphocytes have large round nuclei. Phagocytes have lobed nuclei	Lymphocytes produce antibodies; help to destroy microbes. Phagocytes surround and engulf invading organisms
Platelets	Fragments of cells; made in bone marrow	When we cut ourselves, platelets release substances which activate clotting of blood to seal the wound

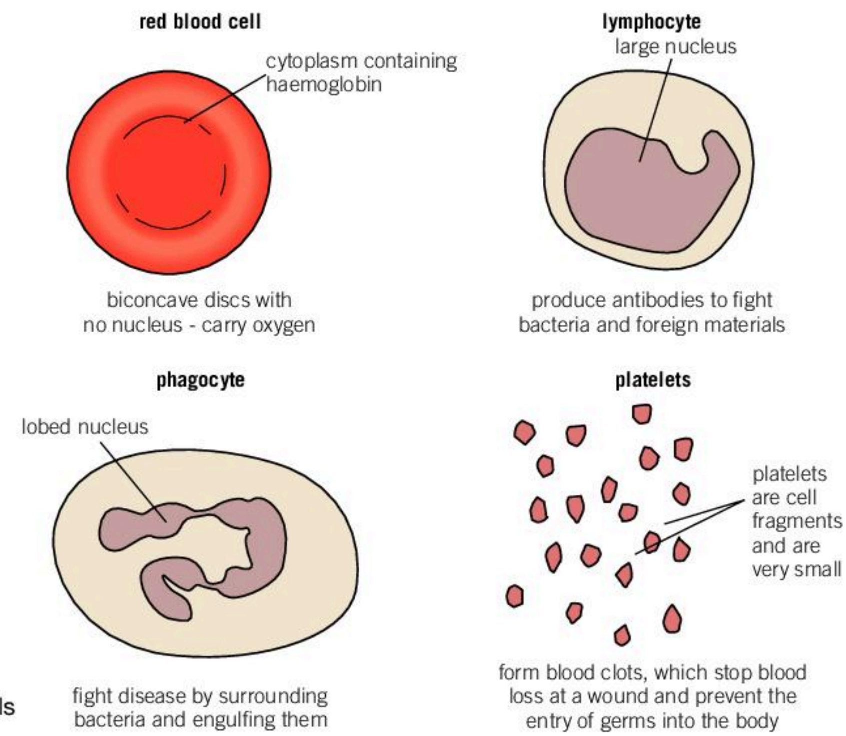
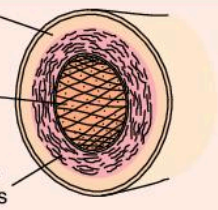
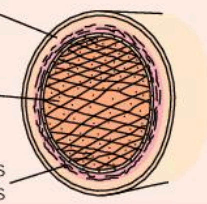


Figure 4.2.1 The functions of the blood cells

When we cut ourselves, the platelets bring about the formation of thrombin, which causes fibrinogen in the plasma to form fibres of fibrin. These fibres form a mesh across the cut, and trap platelets and red blood cells. A clot is formed and hardens, preventing loss of blood and allowing the tissue beneath to heal.

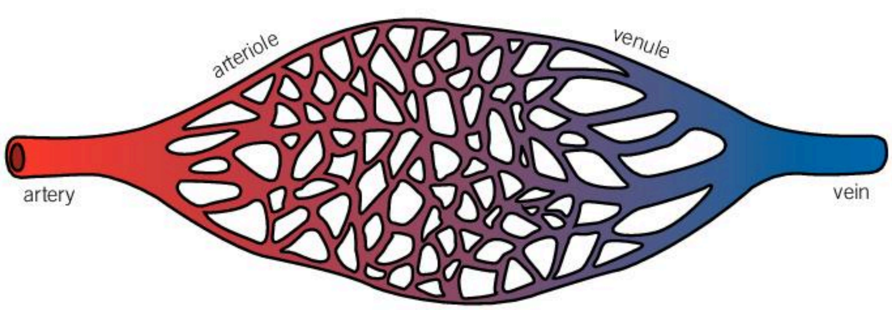
Blood vessels

▼ **Table 4.2.2** A comparison of arteries and veins

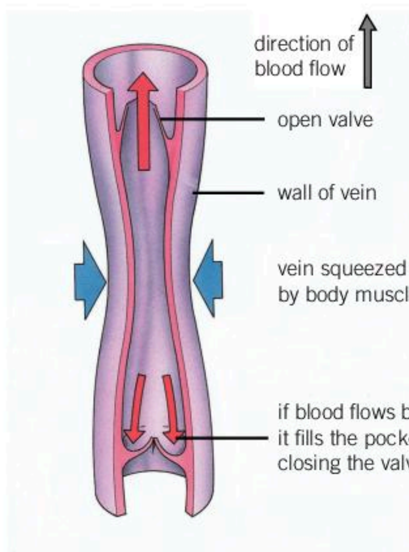
Arteries	Veins
A cross section through an artery 	A cross section through a vein 
Carry oxygenated blood away from the heart to organs and tissues (except for the pulmonary artery which carries deoxygenated blood from the heart to the lungs)	Return deoxygenated blood to the heart from organs and tissues (except pulmonary vein which carries oxygen-rich blood from the lungs to the heart)
Blood is at high pressure	Blood is at low pressure. Body muscles squeeze the veins to help push the blood to the heart
Have a pulse, because the vessel walls expand and relax as blood is pumped from the heart	Do not have a pulse, since blood flows smoothly at low pressure
Have thick elastic and muscular walls to withstand pressure of blood	Have a thin wall and a large diameter lumen which reduces the resistance to the flow of blood returning to the heart, also contain valves to keep blood flowing in one direction only

Blood flows around the body in a network of tubes called blood vessels. There are three types of blood vessels: **arteries**, **veins** and **capillaries**. The main blood vessels are the arteries and veins. Their structure and functions are compared in Table 4.2.2.

Capillaries are tiny vessels with walls one cell thick linking arteries to veins. They form dense networks in the tissues of the body and are the sites of the exchange of nutrients and gases with the cells. Oxygen and nutrients diffuse from the capillaries to the cells, and carbon dioxide and other waste substances diffuse from the cells into the capillaries.

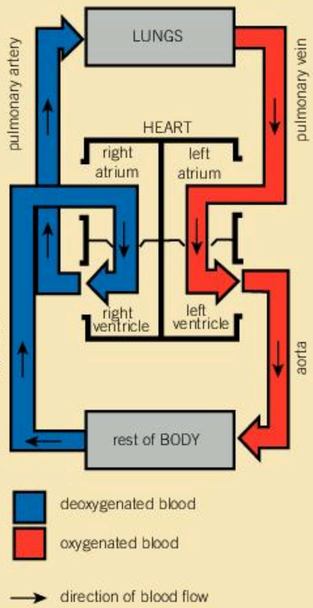


▲ **Figure 4.2.2** Capillaries link arteries to veins

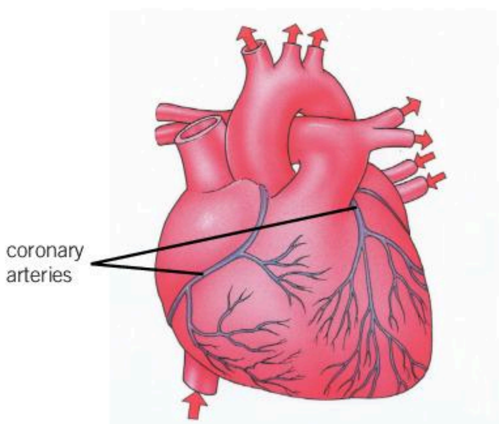


▲ **Figure 4.2.3** Valves make sure the blood does not flow backwards through veins

Exam tip



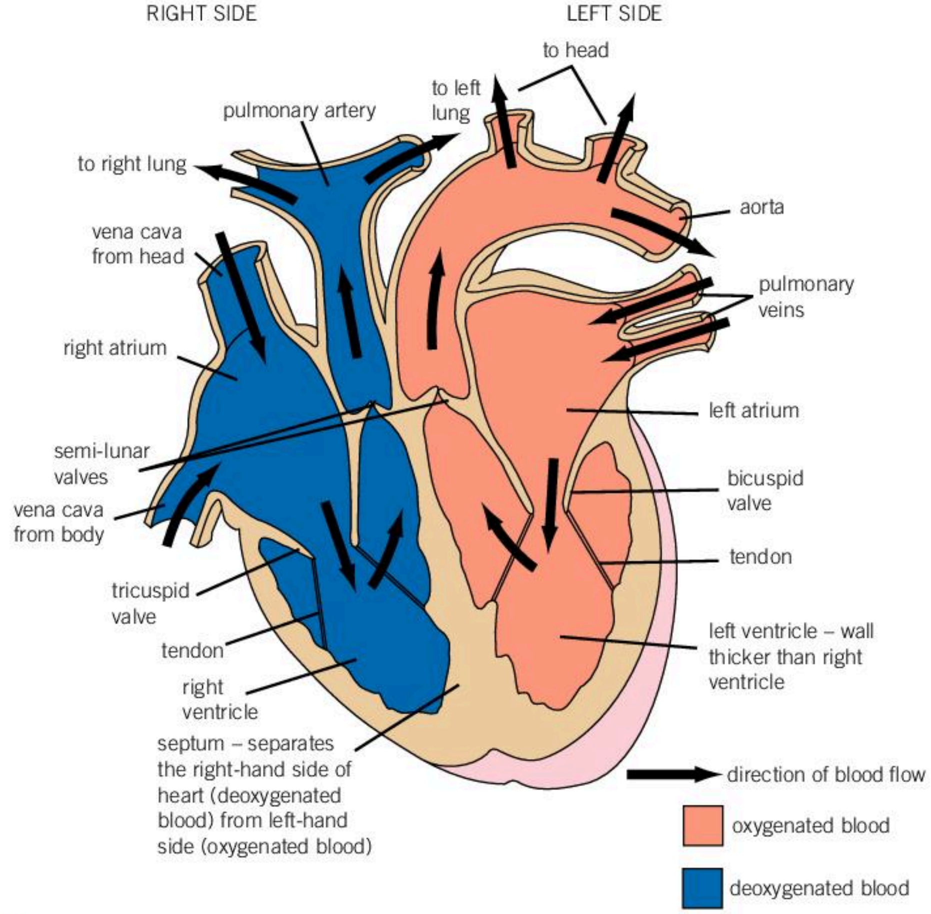
The heart acts as a double pump. The right side is concerned with deoxygenated blood, while the left side is concerned with oxygenated blood. When we draw the heart we always draw it as it would appear if we were viewing it from the front – so the left side of the diagram corresponds to the right side of the heart!



▲ **Figure 4.2.5** The coronary arteries supply blood to the heart muscle

The heart

The heart is a muscular organ that is continually contracting and relaxing in order to pump blood around the body. In a resting adult it does this about 70 times each minute. It is made of a special kind of muscle called **cardiac muscle**.



▲ **Figure 4.2.4** A cross section of the heart viewed from the front

The heart has four chambers: an atrium and a ventricle on the right side which receive deoxygenated blood from the body and pump it on to the lungs, and an atrium and a ventricle on the left side which receive oxygenated blood from the lungs and pump it to the body.

Humans have a **double circulation**; blood flows through the heart twice. Blood containing a lot of carbon dioxide is called **deoxygenated** blood. Blood with large amounts of oxygen is called **oxygenated** blood.

Deoxygenated blood flows from the body to the heart via the vena cava. It is pumped to the lungs via the pulmonary artery where it is oxygenated. It flows back to the heart through the pulmonary veins and then it is pumped to the body via the aorta.

The heart muscle itself receives blood via the coronary arteries. Deoxygenated blood is taken away from the heart muscle via the coronary veins.

The series of valves inside the heart ensure that blood is always pumped in the correct direction. Here is what happens during each heartbeat. This is called the **cardiac cycle**.

1 At the start of the cycle the muscles are relaxed and blood flows into the atria from the veins.

2 Next the atria contract. The increased pressure forces blood through the tricuspid and bicuspid valves into the ventricles.

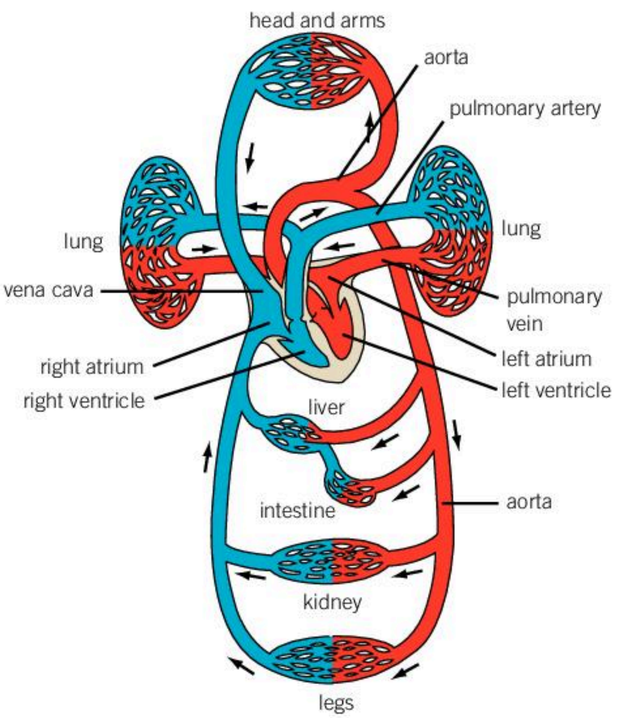
3 Finally, the ventricles contract. The increased pressure seals the tricuspid and bicuspid valves, which prevents blood flowing back into the atria, and opens the semi-lunar valves which forces blood out of the heart through the arteries.

The left side of the heart is more muscular than the right side because it needs greater force to pump the blood around the body than just to the lungs.

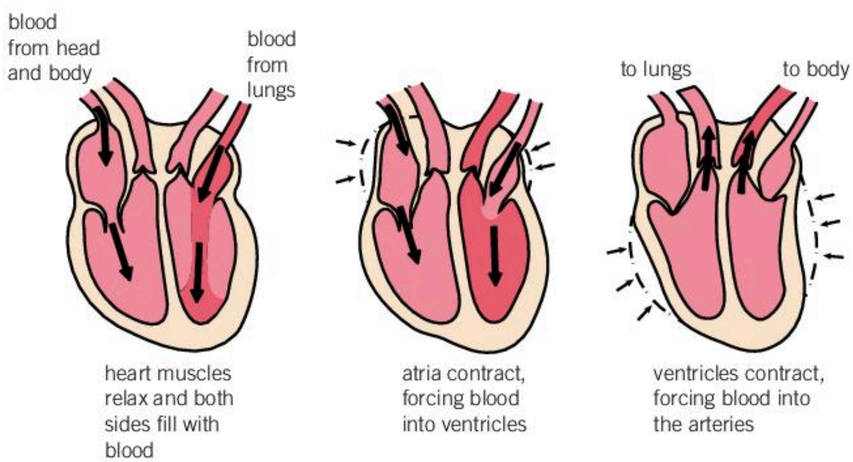
> **Key fact**
>
> The period when the heart muscle is relaxed is called the **diastole** and the period when it is contracting is called the **systole**. They produce a characteristic two-tone sound that the doctor may listen to with a stethoscope.

The circulatory system

Oxygenated blood is pumped from the heart to the different organs and parts of the body along arteries. After passing through networks of capillaries, the deoxygenated blood returns to the heart via veins.



▲ **Figure 4.2.7** The network of arteries, veins and capillaries in the body



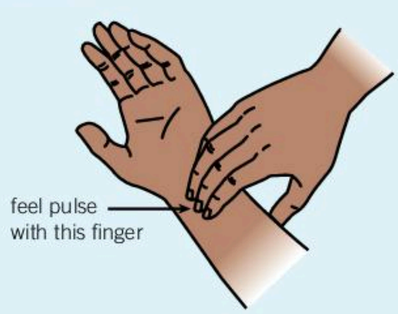
▲ **Figure 4.2.6** The different stages of the cardiac cycle

Practical Activity 4.2.2

Measuring pulse rates

Skills assessed: Observation/Recording/Reporting.

There are several places on your body, such as your wrist, where you can feel your pulse.



1 Place your middle finger on your wrist and move it about until you can feel your pulse.
2 Count how many times you feel a pulse during one minute. Try doing a little gentle exercise and then measure your pulse rate again. Has it changed?
3 Try exercising a little harder – but do not hurt yourself. What effect does that have on your pulse rate?

Questions

1 Name the different types of blood cell and state a function for each type.
2 Name the components of the plasma.
3 Which blood vessel carries deoxygenated blood back to the heart?
4 State two differences in the structure of a vein compared to an artery.
5 From which chamber of the heart is oxygenated blood pumped to the body?
6 Explain the significance of the capillaries in the circulatory system.

Learning outcomes

By the end of this topic you will be able to:

- name the four blood groups
- name the antigens and antibodies associated with the different blood groups
- explain the value of blood donors
- identify groups of people who should not donate blood
- explain the need to cross-match blood between donor and recipient
- work out whether a particular donor can give blood to a particular recipient
- understand the Rhesus factor
- explain the problem that arises when a Rhesus-negative mother gives birth to a Rhesus-positive baby.

▲ **Figure 4.3.1** This person is a blood donor

Did you know?

The Rhesus factor is so called because it was first discovered in the red blood cells of Rhesus monkeys.

4.3 Blood groups

Blood group

Everybody's blood belongs to one of four types or groups: **O**, **A**, **B** or **AB**. Your blood group is an inherited characteristic. An individual's blood group is determined by the **antigens** which are present on the surface of their red blood cells and the **antibodies** found in their blood plasma.

▼ **Table 4.3.1** Blood groups

Blood group	Antigens present on the surface of red blood cells	Antibodies present in blood plasma
O	none	anti-A and anti-B
A	A	anti-B
B	B	anti-A
AB	A and B	none

It is important that the antigens on the red blood cells are different from the antibodies in the plasma. If they were the same, the antigens would react with the antibodies causing the cells to clump together by a process called **agglutination**.

Blood transfusion

Blood is essential for maintaining life. If a person loses a lot of blood very quickly, perhaps as a result of an accident or during surgery, they may die unless doctors replace this blood by giving them a **blood transfusion**.

Blood transfusions are possible because healthy people are prepared to donate their blood. Every six months they can give one unit of blood (about 500 cm^3). This does not harm them and they can make up the volume of blood in a few weeks. The donated blood is held in a blood bank until it is needed.

The blood group of a person is found before they are given a blood transfusion. It is cross-matched against donor blood. If they were given blood from a donor of the wrong group, it would cause agglutination and may kill them.

All adults can be blood donors. However, pregnant women and people who are anaemic should not donate blood since they need it for their own well-being. Blood is not accepted from people who have certain illnesses, such as HIV/AIDS, malaria and hepatitis-B, where there is a risk of passing the illness on to a recipient. People with sickle cell disease should not donate blood.

Rhesus factor

The Rhesus factor is a protein found in the red blood cells of some people. If a person has this protein they are **Rhesus-positive (Rh+)**, and if they do not have the protein they are **Rhesus-negative (Rh–)**. This is genetically determined.

If Rh+ blood and Rh– blood are mixed, agglutination occurs in the same way as when some blood groups are mixed. This creates a potential problem when giving a blood transfusion as the Rhesus factor is part of the cross-matching process. During pregnancy, there may also be complications. If a mother is Rh– her body will detect Rhesus factor as foreign. If she carries a Rh+ foetus and her blood mixes with the foetal blood, the mother will make antibodies

Practical Activity 4.3.1

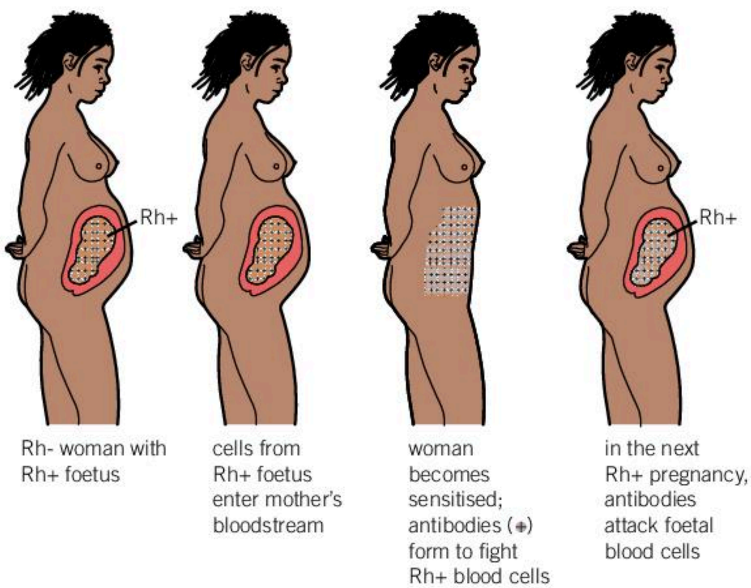
Investigating blood groups

1 Copy the following table into your exercise book.
2 Add the antigens present in each donor's blood and the antibodies present in each recipient's blood.
3 Consider each combination of donor and recipient. If the recipient can safely receive blood from the donor put a tick (✓) and if they can't put a cross (×).
4 A person with one of the blood groups is a **universal donor** because they can donate blood to anyone. Which group is this?
5 A person with one of the blood groups is a **universal recipient** because they can receive blood from anyone. Which group is this?

Donor's blood group	Recipient's blood group			
	O (anti-A and anti-B)	A (..................)	B (..................)	AB (..............)
O (no antigens)				
A (..................)				
B (..................)				
AB (..................)				

against the Rhesus factor. These antibodies will destroy the foetus' red blood cells. This does not usually affect a first pregnancy. However, the anti-Rhesus antibodies will remain in the mother's blood. If she becomes pregnant with a second Rh+ baby, the antibodies will destroy large numbers of the foetus' red blood cells. This results in the developing baby becoming anaemic. Agglutination may also occur making it impossible for blood to circulate through the tiny blood vessels, so the developing baby will die from lack of oxygen. If the baby does survive, it usually has to have a blood transfusion at birth.

The problem can be solved by giving a Rh– mother an injection of a substance called **anti-D** immediately after the birth of the first Rh+ child. These anti-Rh antibodies destroy any foetal Rh+ red blood cells that may have entered her blood during birth. Anti -D prevents her body from making any antibodies against them.



▲ **Figure 4.3.2** A Rhesus-negative woman carries a Rhesus-positive child and manufactures antibodies that attack future Rhesus-positive offspring

Questions

1 To what recipient blood groups could a person of blood group B donate blood?
2 From what donor blood groups could a person with blood group AB receive blood?
3 Explain why no problem arises when a mother who is Rh+ gives birth to a baby who is Rh–.

Synoptic link

See Topic 2.5 Pregnancy and birth.

Learning outcomes

By the end of this topic you will be able to:

- describe hypertension
- describe how blood pressure is measured
- suggest reasons why blood pressure can be high
- identify the coronary arteries and coronary veins
- explain how a person's coronary arteries can become blocked
- describe what happens in a heart bypass operation
- identify some factors that contribute to heart disease.

? Did you know?

Electronic devices that measure blood pressure are widely available. People sometimes buy them for the home so they can monitor their own blood pressure on a regular basis. Some devices are more accurate than others so they should be used with caution.

4.4 Causes of cardiovascular disease

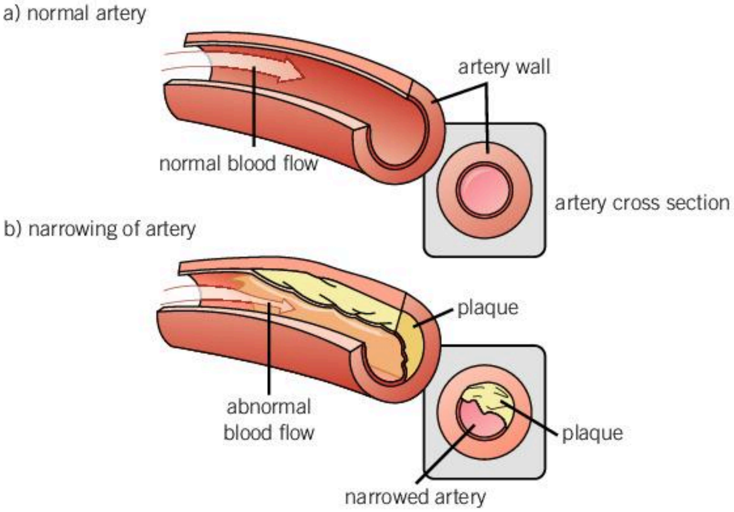
Blood pressure

Health workers can monitor the state of a person's circulation system by measuring their blood pressure using a **sphygmomanometer** and a stethoscope.

Pressure is applied to the top of the arm using a cuff to stop the blood flow through the artery. The pressure is then slowly released until the blood starts to flow. From this a health worker can read the pressure when the heart is pumping (the **systolic pressure**) and when it is relaxing (the **diastolic pressure**). The blood pressures in a healthy adult at rest will typically be 120/80. The first reading is higher because that is when the heart is forcing blood out through the arteries.

▲ **Figure 4.4.1** Measuring blood pressure

When a person suffers from **hypertension**, or high blood pressure, their blood pressure is higher than normal. The pressure exerted on the arteries when the heart contracts will be greater than 120. Hypertension may be the result of hardening of the arteries. As a person grows older the arteries become less elastic. This means that they cannot expand as much when blood is forced through them. It may also be the result of arteries becoming narrow due to the deposition of fatty deposits called plaque on their walls, much like the inside of pipes becoming coated with limescale in hard water areas. This is called **atherosclerosis**. Both of these conditions put greater pressure on the heart because it has to force blood through a narrower diameter vessel.



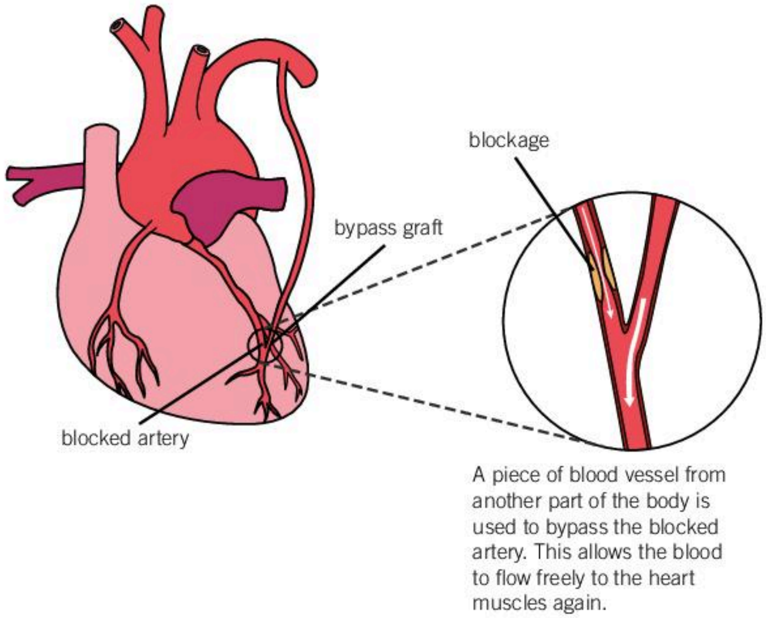
▲ **Figure 4.4.2** Atherosclerosis causes narrowing of the arteries

Heart attack

Like all other cells in the body, the heart cells need a continuous supply of oxygen and glucose. This is supplied through the coronary arteries. The conditions described above which bring about hypertension are particularly serious if they affect the coronary arteries.

Hardening of the coronary arteries restricts the flow of blood to the heart muscle causing severe chest pains. This condition is called **angina**.

As well as restricting the flow of blood to the heart, fatty deposits inside the coronary arteries create a rough surface which may cause a blood clot to form. If the clot is large enough it may block a blood vessel, stopping blood reaching parts of the heart. This is called a thrombosis and if it takes place in a coronary artery it is a **coronary thrombosis**. The result is a heart attack which, if very severe, might even stop the heart from beating.



▲ **Figure 4.4.3** A blocked blood vessel can be bypassed

If the blood vessels that serve the heart become badly restricted the person might undergo a heart bypass operation. A short piece of blood vessel is removed from their leg and used to bypass the damaged section of blood vessel on the heart.

Stroke

When a person has a stroke their brain does not receive blood. The main cause of a stroke is a blood clot that blocks the blood vessels leading to the brain. Strokes can lead to brain injury, disability or sometimes death.

A person who has had a stroke will show some obvious symptoms, such as a sagging face, an inability to raise their arms or slurred speech. The quicker they receive medical care, the better their chances of making a full recovery.

Figure 4.4.4 Symptoms of a stroke

People in the Caribbean have a higher than normal risk of strokes due to a natural tendency to hypertension. Smoking, being overweight, not taking exercise and having a poor diet will also increase a person's chances of having a stroke.

Did you know?

A heart bypass operation does not involve bypassing the whole heart but one or more of the arteries that supply it with blood. Sometimes more than one blood vessel may be damaged and the person may have a double or triple bypass.

Questions

1 Which blood vessel supplies blood to the heart?
2 What information does a doctor get from measuring a person's blood pressure?
3 Why might a person need a heart bypass operation?
4 Where does the new blood vessel used in a bypass operation come from?
5 Why does a diet containing a lot of meat increase the risk of heart disease?

Healthy heart

There is no single reason why a person should suffer from heart disease but there are a number of factors which are known to increase the risk of a person developing heart problems.

- The fats we obtain from animals are called **saturated fats**, while those we obtain from plants are called unsaturated fats. Hypertension is more common in countries where people have a large proportion of 3 animal (saturated) fat in their diet. It is healthier to eat less meat and more plant products.
- **Cholesterol** is a type of lipid found in eggs and fatty meat. The body needs a certain amount of cholesterol but a diet containing too much increases the risk of atherosclerosis and heart attacks.
- **Salt** is the mineral sodium chloride. People who have lots of sodium in their diet are more prone to hypertension than those who do not. The body needs some sodium to remain healthy but too much is harmful.
- People who lead **stressful lives** are at greater risk of heart attacks. Aggression and impatience lead to increased blood pressure and heart rate.
- People who are **overweight** have a higher risk of heart disease.
- Heart disease is more common in people who **do not exercise** regularly.
- **Smoking tobacco** increases the chances of developing heart disease in later life.
- Some people may **inherit a tendency** towards developing heart disease from one or other of their parents.

The chances of developing heart disease are greatly reduced by following a sensible diet, watching your weight, taking regular exercise and not smoking tobacco.

4.5 Natural and artificial immunity

The blood plays an important role in protecting the body and is responsible for **immunity** and the **immune response**.

Immunity is the body's resistance to a specific condition or disease. When a specific pathogen, such as measles, enters the body and is destroyed by the internal defences, we describe the person as being 'immune' to that disease. The immunity may last for a short time or for life.

Natural immunity occurs when a person comes into contact with an infected person and the body's immune system is triggered.

Artificial immunity occurs when we introduced a pathogen by other means (e.g. a vaccine). The body's immune system is still triggered but the pathogen has been injected into the person.

The body's immune response is its reaction to being invaded by specific foreign materials, such as viruses, bacteria, toxins or other unrecognised proteins. The body recognises that these substances are foreign and it responds by trying to destroy them. Substances which cause an immune response are called **antigens**. The immune response involves the lymphocytes and the production of **antibodies**. These are proteins which the body produces in response to specific antigens. The antibodies bind onto the targeted antigens and destroy them.

Antibodies produced against a particular antigen will attack only that antigen. The antibody is said to be specific to that antigen. This means that the antibodies produced against typhoid bacteria will not attack pneumonia bacteria. The body is able to produce tens of millions of specific antibodies in a lifetime.

Natural immunity

The antibodies that are produced against a micro-organism may stay in the body for some time ready to attack the same micro-organisms when they attack the body again. Even if the antibodies do not remain in the body, the antigens of the micro-organism are recognised by the lymphocytes on

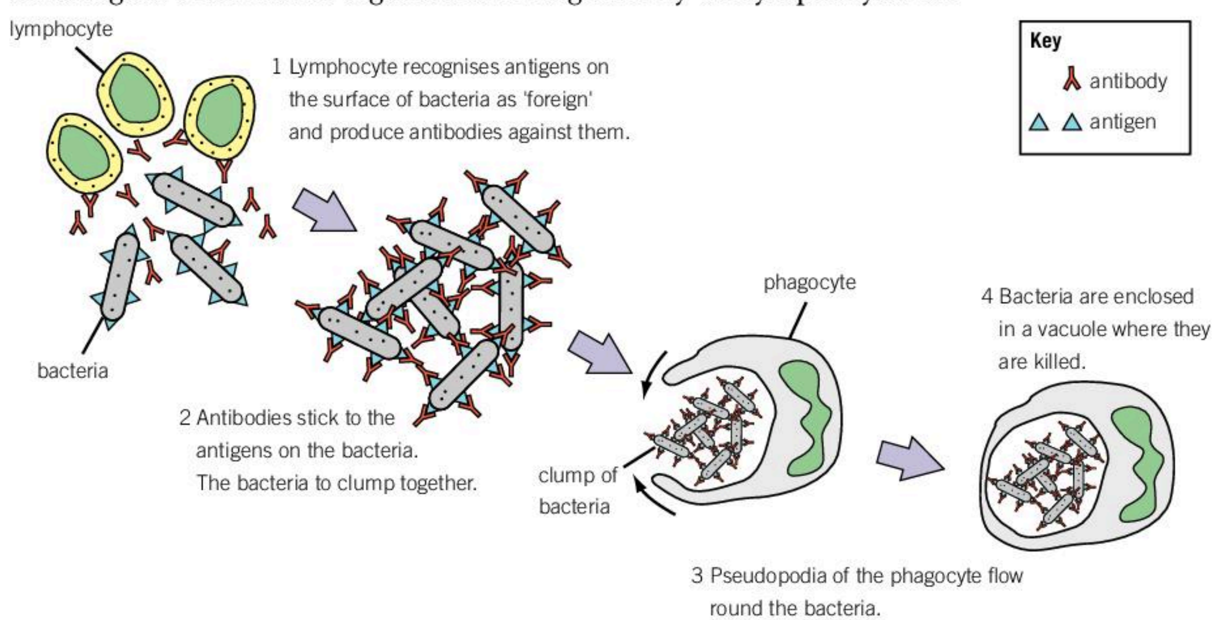
Learning outcomes

By the end of this topic you will be able to:

- explain how antibodies are formed
- describe the role of antigens and antibodies in the prevention of infection
- explain the role of vaccines in controlling infections
- understand how damage can be caused to the immune system
- understand the consequences of damage to the immune system with reference to AIDS.

Did you know?

The body sometimes produces antibodies against harmless substances. When this happens, the person suffers from allergies. Common allergens are pollen and animal hair. Common symptoms of an allergy are itchy and swollen skin, red eyes and a runny nose.



▲ **Figure 4.5.1** The action of lymphocytes and phagocytes further attacks. The lymphocytes then rapidly produce large quantities of the antibody. This means that the re-infection is dealt with by an immune reaction which is even more effective than the first reaction. We say the body has become 'resistant' to the disease. This is why you rarely contract diseases, such as chicken pox and measles, more than once.

Vaccines and how they work

Vaccines are given to people to promote **active** or **passive immunity** to pathogenic (disease-causing) micro-organisms. Vaccines are produced using:

- dead micro-organisms (e.g. whooping cough vaccine)
- a weakened form of the micro-organism (e.g. the vaccine against tuberculosis). This type of vaccine is known as an **attenuated vaccine**.
- a substance from the pathogenic micro-organism (e.g. the diphtheria vaccine). The substance does not itself cause the disease.

Vaccinations can be given to provide:

- Active immunity – the vaccine contains antigens which stimulate the lymphocytes to produce antibodies to that particular antigen. The antibodies remain in the blood for a long time and provide protection should the micro-organism invade the body. Vaccinations against diseases, such as measles, whooping cough and polio, provide active immunity. Levels of immunity may drop off and booster vaccinations can be given.
- Passive immunity – the vaccine consists of antibodies produced by another organism in response to infection by the pathogen. If you cut yourself deeply on something dirty, you are given a tetanus injection made from antibodies.

Synoptic link

See Topic 1.4 Microbes.

Babies cannot make their own antibodies until they are about three months old but they gain passive immunity as antibodies from the mother pass across the placenta during pregnancy. There are also antibodies in the mother's milk, providing them with protection until they can make their own.

Children are routinely vaccinated against the following diseases:

- diphtheria, which affects the throat and causes damage to the heart
- tetanus, which affects the muscles and causes lock-jaw
- whooping cough
- poliomyelitis (polio) which damages the nervous system
- tuberculosis
- German measles (rubella) which can damage unborn babies if pregnant women are exposed to the virus.

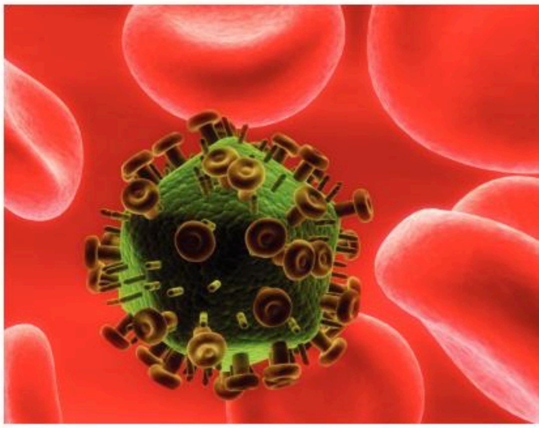
These diseases are now rare in most countries but a drop in the number of children who are vaccinated would cause an increase in their incidence.

HIV/AIDS

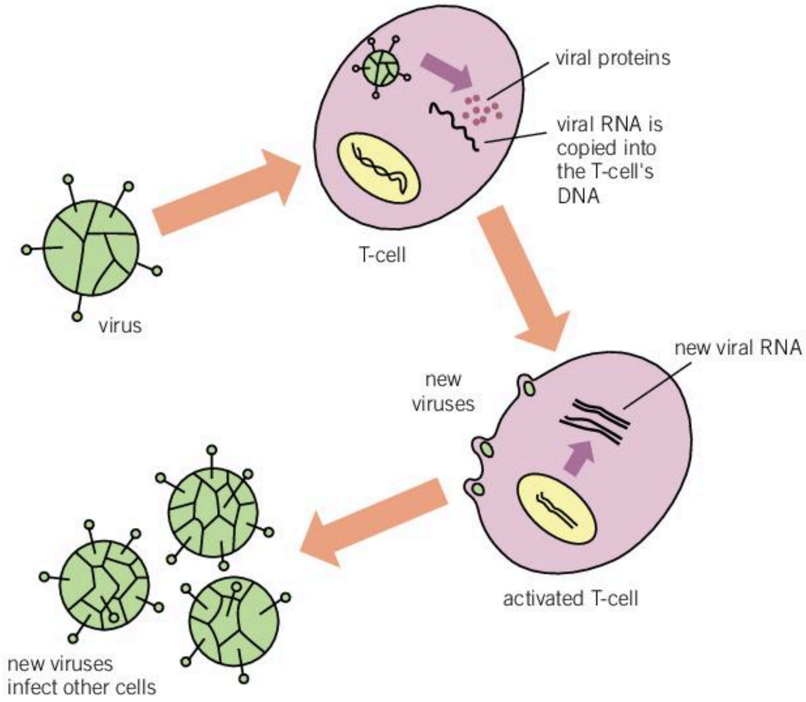
The body's immune system may not function very efficiently, leading to immune deficiency diseases, where the body's defences are suppressed and unable to defend against invading micro-organisms.

AIDS is short for Acquired Immune Deficiency Syndrome. It is caused by a virus called the Human Immunodeficiency Virus or HIV. The virus attacks the lymphocytes which are an important component of the body's defences against disease.

HIV attacks some of the lymphocytes called T-helper cells. Without these cells, the immune system cells cannot work properly and cannot make the antibodies needed to protect the body.



▲ **Figure 4.5.2** The Human Immunodeficiency Virus (HIV)



▲ **Figure 4.5.3** How HIV infects T-cells

Once the virus enters the T-cell, it is able to replicate itself. Viruses that can do this are sometimes described as **retroviruses**.

HIV does not attack the body but weakens its defences, leaving it open to attack by other microbes. A person infected with the virus may not show any symptoms for several years. During this time the number of T-helper cells in the bloodstream steadily falls, which makes the person increasingly susceptible to infection.

AIDS is described as a syndrome rather than a disease. This is because it manifests itself in the body as a collection of diseases that all result from a weakened immune system. The first symptoms of AIDS are very much like flu. They include a high temperature and swollen glands. As the body's immune system becomes weaker, the body may develop more serious conditions, such as pneumonia and different types of cancer.

Questions

1. Explain the differences between active and passive immunity.
2. What is a vaccine?
3. How are vaccines made?
4. Describe how lymphocytes and phagocytes work together to control infections.
5. Name five diseases which children are routinely vaccinated against.
6. Describe two ways by which young babies acquire passive immunity.

Learning outcomes

By the end of this topic you will be able to:

- state what a drug is
- name some common drugs
- describe the effects that some drugs have on the body
- discuss how some drugs are used and mis-used
- describe the effects of blood doping.

4.6 Drug use and mis-use

A drug is any substance that has a physiological effect when introduced into the body. It might be ingested, inhaled or injected directly into the bloodstream. In this topic we will discuss the effects of using some drugs.

Alcohol

Alcoholic drinks, such as beers, wines and spirits, are a part of the social life of many adults (Figure 4.6.1).

All of these drinks contain a chemical called ethanol. When this is drunk in small amounts it can give a person a feeling of well-being but it can also affect their behaviour in other ways. For example, alcohol increases reaction time so the person is less able to carry out activities, such as driving a car.

▲ **Figure 4.6.1** Alcohol consumption can harm your body

Drinking small amounts of alcohol occasionally does not seem to damage the body. However, regularly drinking large quantities of alcoholic drinks has many harmful effects. It can damage vital organs, such as the brain, heart, liver and kidneys. It can also weaken the immune system so the person's body cannot fight disease as well as it normally does. Heavy drinking also increases the risk of certain types of cancer.

As well as damaging the body, heavy drinking can lead to social and economic problems. People who drink heavily tend to lose their friends. Heavy drinking makes it more difficult to do a job effectively, which ultimately may lead to dismissal and a loss of income.

▲ **Figure 4.6.2** Suboxone is a substitute drug for heroin

Prescription drugs

Some drugs are too dangerous to be sold at pharmacies and so they are only available with a prescription from the doctor. These include strong painkillers, such as tramadol and codeine phosphate.

Doctors sometimes prescribe substitute drugs to help people to stop taking illegal drugs. For example, methadone or suboxone may be prescribed to help a person to stop taking heroin (Figure 4.6.2).

Non-prescription drugs

Drugs that can be bought at the pharmacy without a prescription are called non-prescription drugs. They are also sometimes called 'over-the-counter' drugs. They include drugs, such as painkillers, cough medicine and indigestion tablets, as well as vitamin and mineral supplements (Figure 4.6.3).

Most people take non-prescription drugs occasionally, for example when they have a cough or a headache.

Although non-prescription drugs can be obtained without a prescription from the doctor, this does not mean that they are harmless. Taking too many painkillers, for example, can damage the body or even cause death. You should always read the recommended dosage on a drug container carefully and make sure that you do not exceed it.

▲ **Figure 4.6.3** Paracetamol is often taken for pain relief

Illegal drugs

Some drugs are considered so dangerous or addictive that they are not even available with a prescription. These include marijuana, heroin, cocaine and ecstasy. It is illegal to buy or use these drugs but some people buy them from illegal sources.

These drugs can damage the body and many of them are also highly addictive. Once a person starts to take an addictive drug, they become dependent on it and need to keep on taking it.

A drug addict has few friends apart from other addicts. Because the addictive drug affects the body, the person can become unreliable and unable to keep a job. To satisfy their addiction, and to pay for the drug, the person may turn to petty crime and could end up in prison.

Drugs such as marijuana, heroin and cocaine can damage important organs and the immune system. This means that the body is less able to fight infection. A drug addict often has a poor diet, which weakens their body even more.

Did you know?

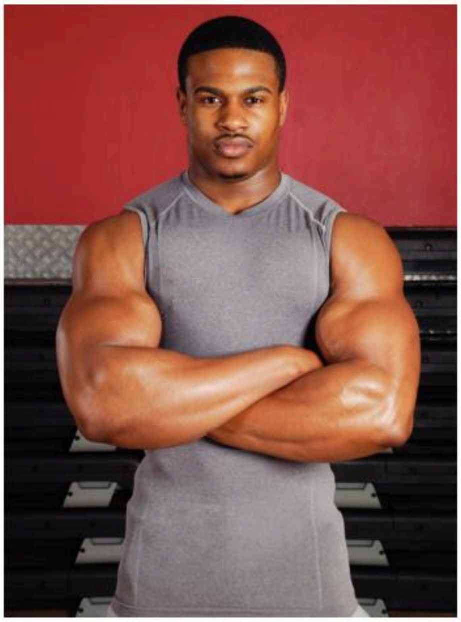
In February 2015, Jamaica decriminalised marijuana allowing small quantities to be sold for personal use. This has not yet occurred in the rest of the Caribbean so marijuana is still illegal throughout the Caribbean except for Jamaica.

Steroids

Steroids are prescription drugs that have important uses in treating illness. For example, the steroid cortisone is used to treat inflamed muscles. However, steroids may also be mis-used.

Anabolic steroids may be used by sports people to aid the formation of proteins and build up muscle. In many countries this is illegal. The use of steroids, however, also has some serious side effects.

- There is a greater chance of injury because the tendons and ligaments do not increase in size at the same rate as the muscles.
- There is an increased risk of damage to vital organs, such as the heart and the liver.
- Sportsmen may develop breasts and their testicles may shrink.
- Sportswomen may develop facial hair and their voices may deepen. Their menstrual cycle may be disrupted.



▲ **Figure 4.6.4** Steroids can be used to build muscle

Diet pills

Diet pills or slimming aids are designed to help overweight people to become slimmer. They work in a variety of ways. One type of pill increases body metabolism so calories are used up more quickly.

Many people in modern society have become obsessive about their weight. They resort to using diet pills when it would be much easier, safer and cheaper to simply eat less food and exercise more.

Diet pills are relatively new and they are not as well regulated as some other types of drugs. Some diet pills have been found to be effective, while others are harmful to the body. Even taking diet pills that do actually reduce weight can be risky. There are reports of people becoming addicted to diet pills and as a result they have lost huge amounts of weight and become anorexic.

Hormonal injections

Hormones are chemical messengers that are carried around the body in the bloodstream. People may receive hormonal injections for various reasons. For example, hormonal treatment is given for certain types of cancer including prostate cancer.

Some women receive hormone therapy to ease the symptoms of the menopause, such as hot flushes, vaginal dryness and mood swings.

Blood doping

▲ **Figure 4.6.5** Blood is removed from an athlete and replaced at a later date

Blood consists of liquid plasma containing red and white blood cells. The red blood cells carry oxygen around the body. Blood doping involves increasing the amount of red blood cells therefore increasing the amount of oxygen in the bloodstream. This is an advantage to athletes because it increases their endurance.

The simplest form of blood doping involves taking, typically, two pints of blood from an athlete a few weeks before a race. The athlete's body then makes new red blood cells to replace those which have been taken. The day before the race, the removed blood is put back into the bloodstream so the athlete now has extra red blood cells.

Blood doping may also involve introducing chemicals that carry oxygen into the bloodstream, which enables more oxygen to be absorbed in their lungs when the athlete breathes in.

Blood doping is illegal all around the world. Apart from cheating, it also has some dangerous side effects including blockages in the blood vessels leading to heart attacks and strokes.

Practical Activity 4.6.1

Research Project

Research how common drugs, such as alcohol, can be mis-used in society.

Questions

1. Explain why some drugs can be bought over the counter but others can only be obtained with a doctor's prescription.
2. Identify which type of drug an athlete might take to increase the size of their muscles.
3. State two social and two economic consequences of drug use.
4. Explain why it is an advantage to increase the number of red blood cells in the bloodstream.
5. Explain why people find it difficult to stop using some illegal drugs.
6. A good friend has started drinking large amounts of beer several times each week. Suggest some arguments you could use to persuade them to reduce their drinking.

4.7 The physiological effects of exercise

Most people would agree that taking exercise and keeping the body in shape is a good idea. Lifestyles have changed and the work that our grandparents and parents did was more physically demanding than the work we do today. This change in lifestyles has been brought about by the invention of many labour-saving devices.

Learning outcomes

By the end of this topic you will be able to:

- give reasons why we need to exercise
- appreciate that there are different forms of exercise
- explain the effects of exercise on the circulatory system
- explain the effects of exercise on the respiratory system
- describe the effects of exercise on balancing energy input and output.

Taking exercise

Taking exercise benefits us in many ways, including:

- the maintenance of a healthy heart and circulation
- the possible reduction in the levels of cholesterol in the blood
- the prevention of obesity and its possible consequences of high blood pressure, diabetes and damage to the joints
- increasing lung capacity and efficiency
- the reduction of stress.

The form of exercise suitable for a person depends on their age, gender and general state of health. Different forms of exercise need different amounts of energy. When you are standing around for an hour, you use up 400 kJ of energy. If you are working at your desk, you will use about 600 kJ but walking briskly for an hour uses 1200 kJ. Table 4.7.1 summarises the energy needed for an hour for different forms of exercise and the benefits to the body.

Table 4.7.1 Exercise, energy needs and benefits to the body

Type of exercise	Energy needed for 1 hour (kJ)	Benefit to the body
Walking	700	Not a great deal of benefit
Brisk walking	1200	Improves heart and lung function
Aerobic training	1900	Good for heart and lungs
Tennis	2000	Good for heart and lungs
Squash	2400	Good for heart and lungs
Soccer	2500	Good for heart and lungs
Cycling	2600	Excellent for heart and lungs
Swimming	3000	Excellent for heart and lungs

During exercise, your heart beats faster. Extra carbon dioxide is produced by the muscle cells as they are working more quickly and needing more energy. The carbon dioxide builds up in the bloodstream and this increase is detected by the brain. Nerve impulses are sent to the heart, making it beat faster. This has the effect of supplying the muscles with more blood containing oxygen and glucose, and removing the carbon dioxide.

At the same time, you begin to breathe more quickly and deeply, bringing more air into the lungs. More oxygen can be taken up by the blood and more carbon dioxide is expelled. As people take more exercise and become fitter, they breathe more deeply: unfit people taking exercise tend to breathe more quickly taking shallower breaths. During training, athletes work to control their breathing and build up stamina. This is particularly important for long-distance runners and for endurance sports, such as cycling and rowing.

Questions

1 Why did people need to take less exercise to keep fit in the past?
2 How does regular exercise benefit the heart?
3 Which exercise needs most energy per hour: cycling, swimming or squash?
4 What would be a sensible form of exercise for a 50-year-old man who is just starting to exercise regularly in order to get fitter?
5 Why do we breathe more deeply when we begin to exercise?
6 Explain how athletes benefit from a training programme.

Being overweight is often due to lack of exercise. If you do not exercise and you eat food containing a lot of sugar and fat, you are likely to gain weight. Studies have shown that overweight people are more likely to suffer from high blood pressure, heart problems and diabetes. There is strong support for the idea that regular exercise combined with a sensible, healthy diet will help to maintain fitness. Dietary input, that is how much you eat, should generally balance energy output.

Athletes use a great deal of energy and need diets that contain high-energy foods, such as carbohydrates, particularly before a race. They also need to eat plenty of protein for muscle-building. It is also important for them that their diet contains enough of the vitamins and minerals required to maintain health. During training, and during a race, athletes may sweat a lot and lose water and salt. It is vital that they drink enough water to replace lost fluids and that they do not become dehydrated.

Practical Activity 4.7.1

Investigating the effect of exercise on heart rate

Warning – Do not carry out this activity if you have a health problem or if you are feeling unwell.

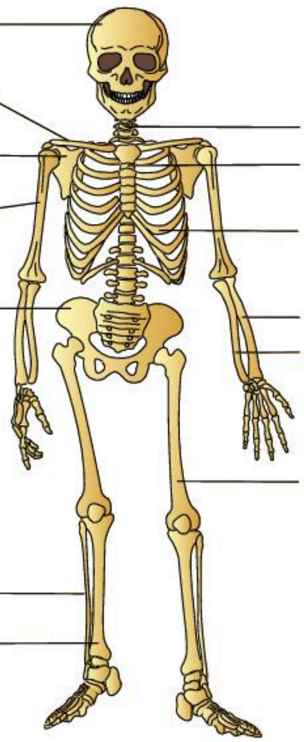
Skills assessed: Observation/Recording/Reporting and Analysis, and Interpretation.

1 Make sure you know how to take your pulse. If you are uncertain look at Topic 4.2.
2 Measure your rest pulse rate for 30 seconds.
3 Step up onto and down off a step 30 times per minute for 5 minutes.
4 Sit down and rest for 1 minute.
5 Measure your pulse for 30 seconds and make this value *X*.
6 Rest for another 30 seconds.
7 Measure your pulse for 30 seconds and make this value *Y*.
8 Rest for another 30 seconds.
9 Measure your pulse for 30 seconds and make this value *Z*.
10 What were the values of *X*, *Y* and *Z*?
11 How do the values *X*, *Y* and *Z* compare to your rest pulse rate?
12 Find the total of *X* + *Y* + *Z* and use it to assess your fitness in the table.

	Value of *X* + *Y* + *Z*	
	Boy	**Girl**
very fit	170 or less	190 or less
↕	↕	↕
very unfit	230 or more	250 or more

4.8 The skeleton

The body is built around a framework of bones. These bones form the skeletal system or skeleton. There are 206 bones in the human skeleton. The largest bone is the femur in the upper leg; the smallest bones are in the middle ear.



▲ **Figure 4.8.1** The human skeleton

The vertebral column runs from the head to the bottom of the back. It is made up of a series of small bones called vertebrae. Below the head the clavicles and scapulae form the pectoral girdle to which the arms are attached. At the bottom of the vertebral column is the pelvic girdle to which the legs are attached.

Eating foods rich in calcium, such as green vegetables and dairy products, and foods rich in vitamin D, such as oily fish and eggs, helps develop strong bones. The body also makes vitamin D using the action of sunlight on the layers of cells under the skin's surface.

Practical Activity 4.8.1

Feeling your skeleton

Using your fingers try to feel the different bones in your body. The following suggestions will help you.

1. Feel up and down your neck, and your back. Can you feel the bumps along your vertebral column?
2. Feel around your head and your face. Can you feel the sockets where your eyes fit into the cranium?
3. Feel the back of your shoulders. Can you feel the flat scapula?
4. Feel your hips. Can you feel the edge of the pelvic girdle?
5. Feel your sides. Count the number of ribs on each side.

Learning outcome

By the end of this topic you will be able to:

- name the major bones of the skeleton.

Questions

1. What are the common names of each of the following parts of the skeleton?
   a. Scapula
   b. Vertebral column
   c. Thorax
   d. Cranium
   e. Clavicle
2. The lower arm and the lower leg both consist of two bones. Why might we think they consist of only one bone?
3. How many ribs are on each side of the rib cage?

Learning outcomes

By the end of this topic you will be able to:

- describe the role of the skeleton in support and movement
- explain how the skeleton protects vital organs and blood vessels
- describe the role of the rib cage in breathing
- state that blood cells are made in the bone marrow.

4.9 Functions of the skeleton

The skeleton has a number of important functions.

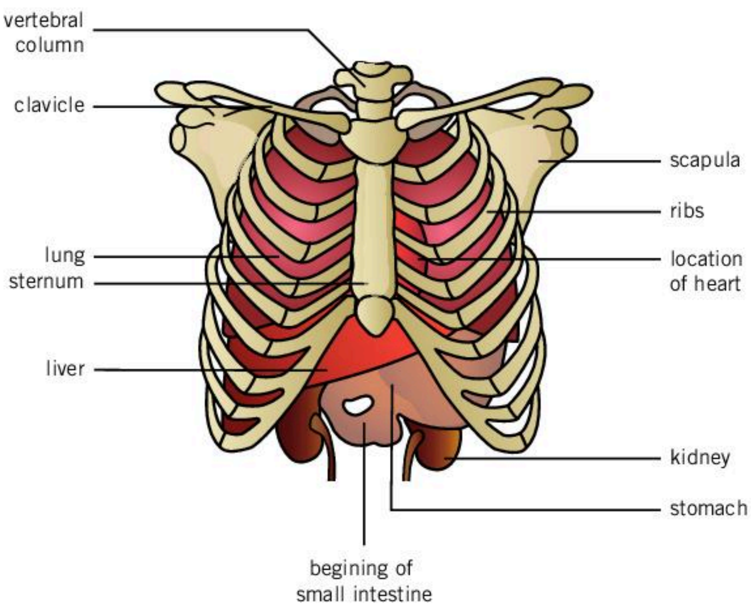
Shape and support

The skeleton gives the body shape. The vertebral column is a series of bones in your back that gives your body shape and height. Vital organs inside the body are supported by the skeleton.

The rib cage has an important role in breathing, which you will learn about in Unit 5.

Protection

Parts of the skeleton protect some of the vital organs. For example, the cranium protects the brain.



▲ **Figure 4.9.1** Organs protected by the rib cage

The ribs form a rib cage that protects vital organs, such as the heart and lungs in the chest.

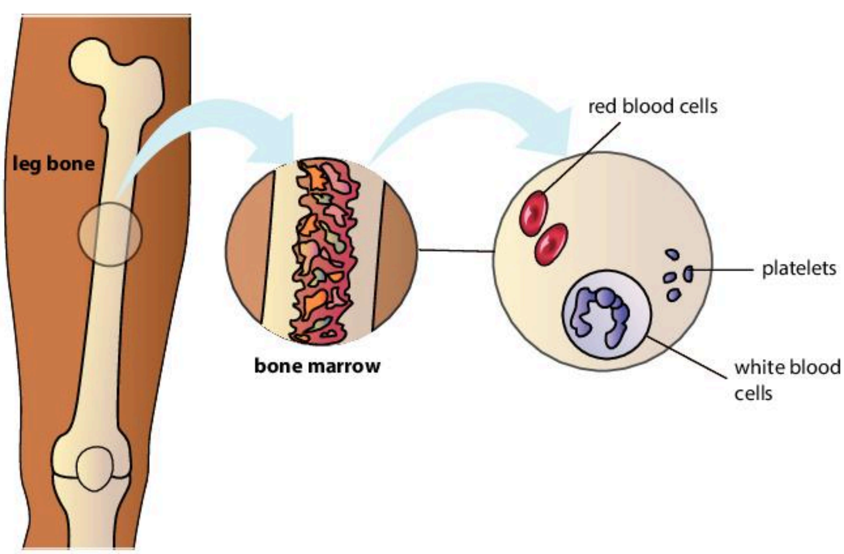
The arteries that carry blood from the heart to the different parts of the body are deep in the flesh near the bones, so they are protected from being squashed or folded.

Muscle attachment and movement

The skeleton provides places for muscle attachment. The muscles attached to the skeleton make it possible for us to move.

Making blood cells

Red blood cells and white blood cells are produced in the marrow at the centre of some of the bigger bones.



▲ **Figure 4.9.2** Blood cells form in bone marrow

Questions

1. Name two organs protected by the rib cage.
2. In what ways is the cranium like a 'crash helmet'?

4.10 Joints

A joint is where two bones meet. Joints can be fixed or moving. Most joints are moving joints.

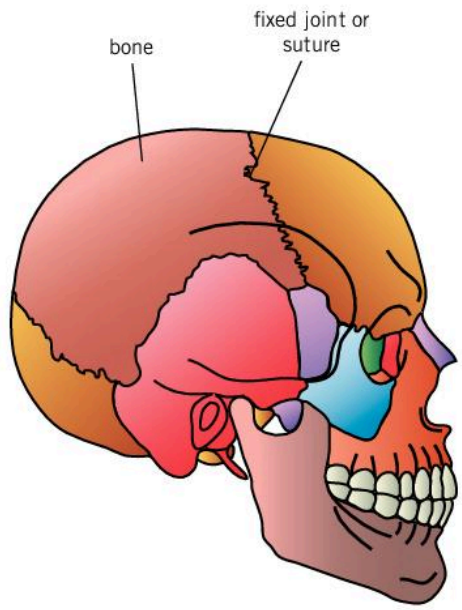
The cranium is not one single bone but 22 different bones connected by fibrous tissue. There is some movement between the bones in a newborn baby but, as the baby grows older, the bones fuse together forming **fixed joints**.

The most obvious places where we have moving joints is in our arms and legs. Moving joints include hinge joints (found at the elbow and knee) and ball and socket joints (found at the shoulder and hip) (see Figure 4.10.2). See Practical activity 4.10.1 for more about the type of movement in joints.

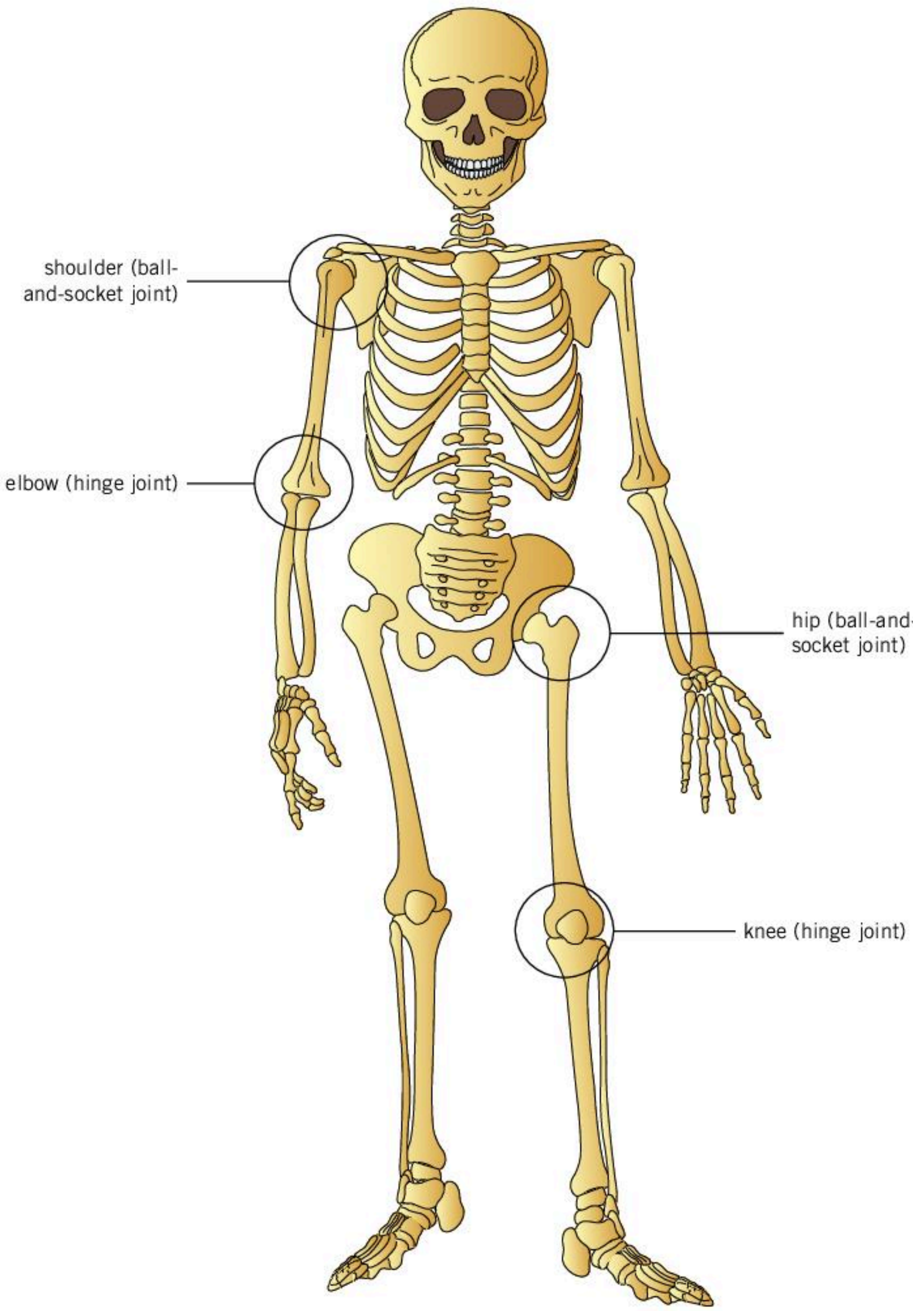
Learning outcomes

By the end of this topic you will be able to:

- describe a ball and socket joint and give examples from the body
- describe a hinge joint and give examples from the body
- explain about fixed joints.



▲ **Figure 4.10.1** Fixed joints

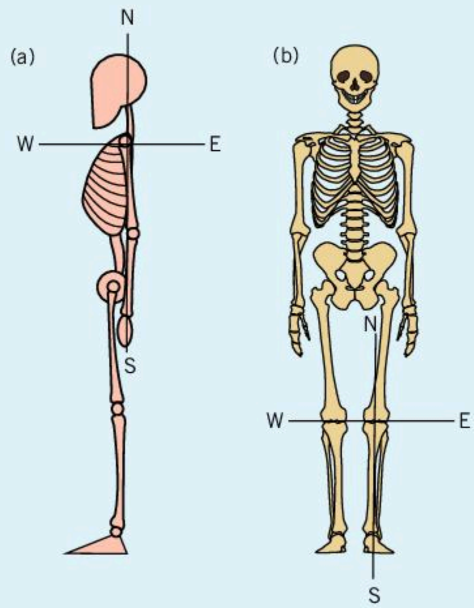


▲ **Figure 4.10.2** Joints allow bones to move

Practical Activity 4.10.1

Investigating movement about different joints

There are ball and socket joints, and hinge joints, at different places in the body. The diagram shows the joint at your shoulder (a) and the joint at your knee (b).



1 There is a ball and socket joint at your shoulder. Imagine four directions from your shoulder, N, S, E and W. In how many of these directions can you move your arm?

2 Describe the movement around a ball and socket joint.

3 There is a hinge joint at your knee. Imagine four directions from your knee, N, S, E and W. In how many of these directions can you move your leg?

4 Describe the movement around a hinge joint.

Questions

1 State what type of joint is shown in the diagram.

2 State what type of joint allows the fingers and toes to bend.

3 Identify a place in the body where there is a pivot joint that allows you rotational movement.

4 Arthritis is a condition where joints become worn or damaged. Do any of your relatives suffer from arthritis? Describe how arthritis would affect someone's everyday life.

4.11 Skeletal muscle

Learning outcomes

By the end of this topic you will be able to:

- explain the role of antagonistic muscles
- describe the effects of exercise on muscle toning.

The muscular system

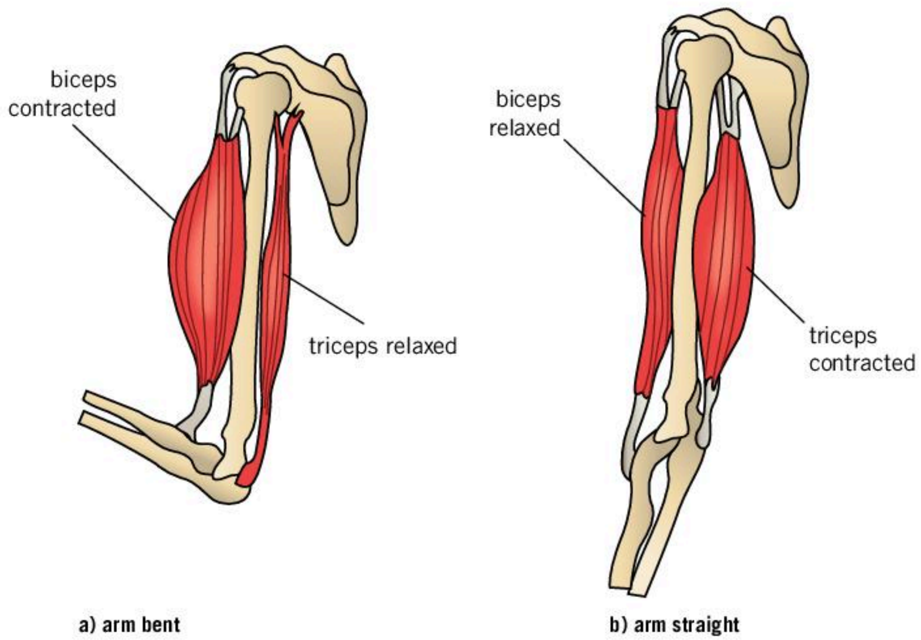
The human muscular system consists of about 650 muscles. The muscles are attached to the bones of the skeleton.

Muscles make it possible for our bodies to move in many different ways. Each muscle is an organ composed of muscle tissue, blood vessels, tendons and nerves.

▲ **Figure 4.11.1** Muscular system

Antagonistic muscle action

Many of the movements we make are the result of pairs of muscles working in opposition to each other. This is called antagonistic muscle action.



▲ **Figure 4.11.2** Antagonistic muscle action in the arm

The movement of the lower part of an arm is controlled by an antagonistic pair of muscles called the biceps and the triceps (see Figure 4.11.2).

- When we bend our arm at the elbow the biceps gets shorter, or contracts, while the triceps gets longer or relaxes.
- When we straighten our arm the opposite happens: the biceps relaxes, while the triceps contracts.

Practical Activity 4.11.1

Investigating antagonistic muscle action in the arm and in the leg

1. Investigate what happens to the biceps and triceps when you bend your arm, and when you straighten your arm.
2. The pair of muscles that control the movement of the lower leg are called the quadriceps (front of leg) and hamstrings (back of leg). Investigate what happens to these muscles when you bend your leg and when you straighten your leg.

Muscle tone

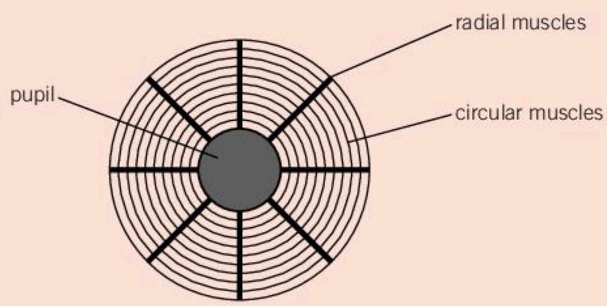
Muscle tone is when muscles are in a slight tension and ready to be used.

Regular exercise improves muscle tone and also increases the size of muscles so they have better endurance. People who exercise find it easier to do everyday chores, such as carrying shopping and working in the garden.

Muscle tone also improves posture, which is very important in many sports. Good posture means less chance of straining muscles, tendons and ligaments.

Question

1 The pupil is the hole at the centre of the eyeball (it looks black). It allows light into the eye.



The size of the pupils is controlled by a pair of antagonistic muscles: circular muscles that lie around the pupil and radial muscles that run outwards like the spokes of a wheel from the edge of the pupil.

Copy, and complete, this table stating whether the circular and radial muscles are contracted or relaxed when the pupil size is reduced, and when the pupil size is enlarged,

Pupil size	Circular muscle	Radial muscle
Reduced		
Enlarged		

Exam-style questions

Multiple choice

1 Arteries have thicker and more elastic walls than veins. This is because blood in the arteries:
A contains more nutrients
B contains more oxygen
C is under greater pressure
D has to go to all parts of the body

2 In which conditions will the rate of transpiration be the highest?
A hot and humid
B cool and humid
C hot and dry
D cool and dry

3 A person will need to drink more water on:
A a hot dry day when they do no exercise
B a cool day when they exercise
C a hot dry day when they do strenuous exercise
D a cool day when they do no exercise

4 Which of these is correct?

	Example of a ball and socket joint	Example of a hinge joint
A	shoulder	hip
B	knee	shoulder
C	elbow	knee
D	hip	elbow

5 Which important organ is protected by the cranium?
A brain
B heart
C lungs
D stomach

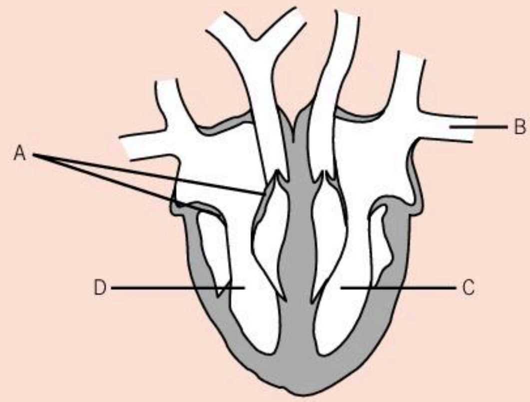
6 Which of these is correct when a person straightens their arm?

	Biceps	Triceps
A	contracts	contracts
B	contracts	relaxes
C	relaxes	relaxes
D	relaxes	contracts

Structured questions

7 **a** Explain why some people may need blood transfusions.
b Which people should not be blood donors?
c A person with which blood group is a universal donor?

8 The diagram shows a section through a heart.



a Look at the diagram and answer the following questions.
i) Name the parts labelled A and B.
ii) On which side of the heart does oxygenated blood flow?
iii) Suggest why the wall around the chamber C is thicker than that around the chamber D.

b **i)** Which blood vessels supply the heart itself with blood?
ii) Suggest two activities in a person's lifestyle that may lead to blockage of these arteries.
iii) Explain what the probable result of a blockage would be.

9 The amount of energy needed for different types of exercise is shown in the table below.

Type of exercise	Amount of energy needed (kJ per hour)
running	2500
swimming	3000
squash	2400
walking	700

a Draw a bar chart to show the data in the table.
b For which type of exercise in the table would a high-energy carbohydrate diet be appropriate?

10 Your friend wants to start an exercise programme.
a Describe one thing that he should do before starting to exercise to avoid injury.
b List three reasons why exercise helps people improve their lifestyle.

11 Copy and complete the following sentences.

a The skeletal system consists of a framework of ____________.

b A joint is a place where bones ____________.

c The lungs are protected by the ____________.

d The biceps and triceps can be described as ____________ muscles.

12 Here is an X-ray of a joint.

a What kind of joint is it?

b Explain how you know.

Section A

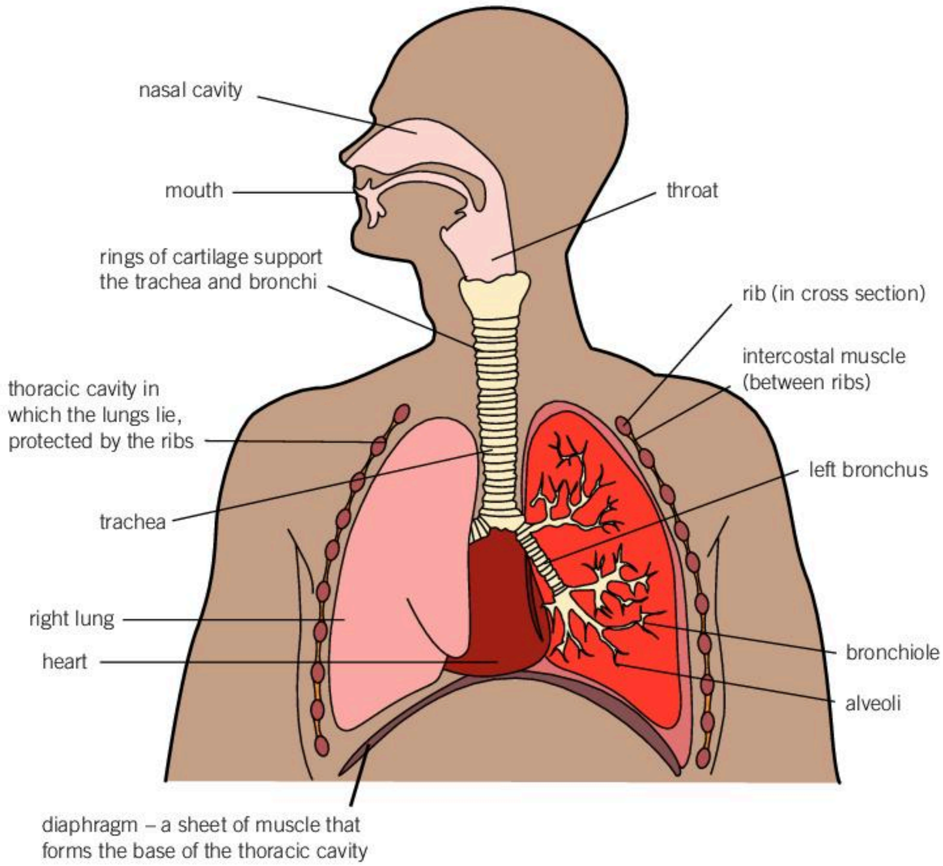
5 Respiration and air pollution

Respiration is the process by which organisms obtain the energy needed to drive the chemical processes that take place in their cells. This process takes place in all organisms, sometimes in the presence of oxygen and sometimes in the absence of oxygen. In humans, the oxygen needed for respiration is obtained from gaseous exchange in the lungs. Unfortunately, the air around us is not always clean as it has been polluted by dust, emissions, gases and other toxic substances.

5.1 The mechanism of breathing

Parts of the respiratory system

Humans have a respiratory system that consists of many parts as shown in the Figure 5.1.1. Air enters the body through the nose and mouth, and passes into the wind pipe or **trachea**. The trachea divides into two **bronchi** (singular: bronchus) which take air to and from each of the lungs.



▲ **Figure 5.1.1** The human respiratory system

The **lungs** are located in the chest, or thoracic cavity, where they are surrounded by the rib cage. A sheet of muscle called the **diaphragm** seals the bottom of this cavity.

Learning outcomes

By the end of this topic you will be able to:

- understand inhalation and exhalation
- identify the main parts of the respiratory system
- describe the pressure and volume changes involved in breathing
- understand the roles of the rib cage and diaphragm
- use a simple model to explain the mechanism of breathing
- state how the composition of exhaled air differs from that of inhaled air
- describe an experiment to show that the concentration of carbon dioxide is greater in exhaled air than in inhaled air.

Synoptic link

See Topic 11.9 First aid.

Did you know?

The trachea and bronchi have rings of cartilage to prevent them from collapsing. If you run your finger up and down your throat you will be able to feel some of these rings.

The mechanism of breathing

Breathing involves inhalation, when air is taken into the lungs, and exhalation when air is expelled from the lungs.

During inhalation:

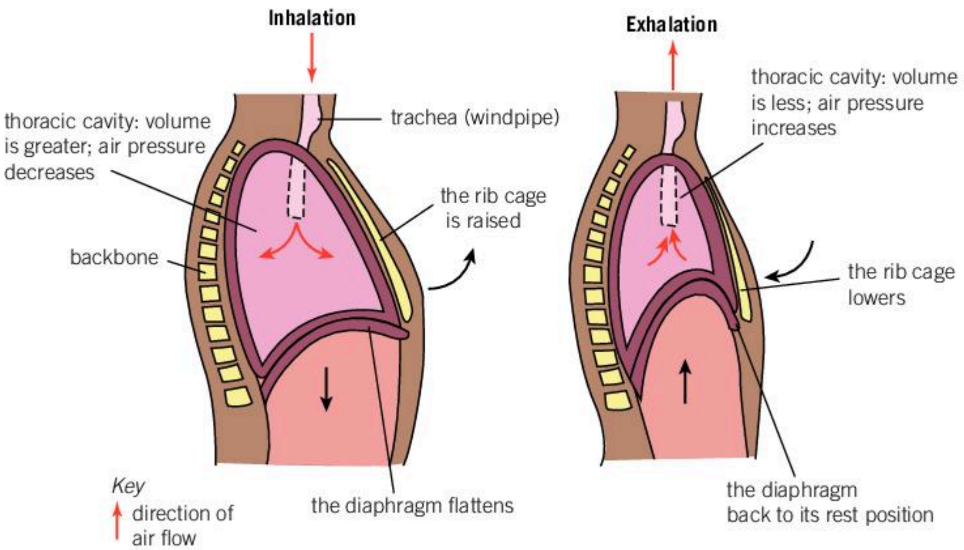
- intercostal muscles (the muscles between the ribs) contract causing the rib cage to move upwards and outwards
- the diaphragm muscles contract causing the dome-shaped diaphragm to flatten
- the volume of the thoracic cavity increases so the air pressure in the thoracic cavity decreases making it lower than atmospheric pressure
- as a consequence, air is drawn down the trachea into the lungs.

During exhalation:

- intercostal muscles relax causing the rib cage to move downwards and inwards
- the diaphragm muscles relax causing the diaphragm to resume its domed shape
- the volume of the thoracic cavity decreases so the air pressure inside is increased
- air is forced out of the lungs.

Key fact

The rate at which we breathe is controlled by part of the brain called the medulla oblongata.

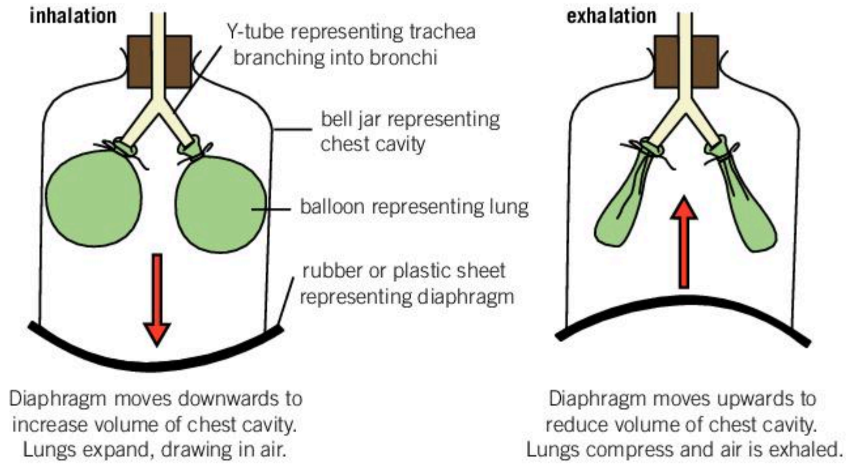


▲ **Figure 5.1.2** Inhalation and exhalation

Did you know?

Scientists sometimes use models to help them to understand how things work. A model can be useful, even though it may not work in exactly the same way as the real thing.

Figure 5.1.3 shows a simple model of the respiratory system. The lungs are represented by balloons, the chest cavity by a bell jar and the diaphragm by a rubber sheet. The chest cavity is not rigid like a bell jar. The rubber, or plastic, sheet representing the diaphragm can be pulled down or pushed up.



▲ **Figure 5.1.3** A model of the respiratory system

Inhaled and exhaled air

Breathing is important for the provision of oxygen for respiration and for the removal of the waste products of this process. The composition of inhaled air is the same as that of the atmosphere. Exhaled air contains more carbon dioxide, more water vapour and less oxygen than inhaled air (see Table 5.1.1).

▼ **Table 5.1.1** A comparison of inhaled and exhaled air

Component	Inhaled air (%)	Exhaled air (%)
oxygen	21	16
carbon dioxide	0.04	4
nitrogen and other gases	79	79
water vapour	variable	saturated
heat	variable	body temperature

Practical Activity 5.1.2

Ventilator machine research project

Research the use of the ventilator machine. Your report should answer these questions:

1 What is a ventilator machine?
2 How does it work?
3 Who should use it?
4 What is the advantage of keeping a ventilator machine on your school campus?

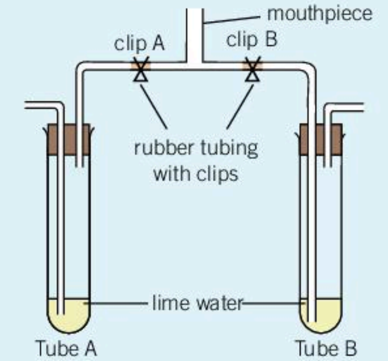
Questions

1 Write the following in the order that air passes through them when entering the lungs: alveolus, bronchiole, bronchus, trachea.
2 What is the function of the rings of cartilage in the trachea?
3 What happens to the volume of, and the pressure in, the thoracic cavity when the diaphragm is pulled down?
4 Explain the difference between the water vapour content of inhaled and exhaled air.

Practical Activity 5.1.1

Testing for carbon dioxide in exhaled air

Your teacher will provide you with the following apparatus.



1 Make sure there is no more than 2 cm depth of lime water in each tube.
2 With clip A open and clip B closed, breathe in gently through the mouthpiece.
3 Hold your breath, close clip A and open clip B.
4 Breathe out gently through the mouthpiece.
5 Repeat the procedure twice more and observe the tubes of lime water.
6 Through which tube does air enter your lungs?
7 Through which tube does air leave your lungs?
8 What happens to the appearance of the lime water in each tube?

Key fact

Cardiopulmonary resuscitation (CPR) is a lifesaving technique which can be used when someone's heart stops beating or the person has stopped breathing. CPR can keep blood flowing to the brain and other vital organs, saving someone's life. To learn CPR properly you need to take a first-aid training course. *Always* call 911 before beginning CPR.

Learning outcomes

By the end of this topic you will be able to:

- define gaseous exchange
- state the features of a respiratory surface
- describe gaseous exchange in humans
- describe the structure of an alveolus
- describe how the alveoli are involved in gaseous exchange
- describe gaseous exchange in plants
- describe the structure of a stoma.

Did you know?

The total area of the alveoli in the human lungs is about 90 square metres, the same as the area of a tennis court.

5.2 Gaseous exchange

What is gaseous exchange?

Gaseous exchange is the exchange of oxygen and carbon dioxide across a membrane called a gaseous exchange or respiratory surface. This process takes place by diffusion. Oxygen, which is needed for respiration, enters the organism, while carbon dioxide, a product of respiration, is removed. Gaseous exchange is also important during photosynthesis in plants.

Features common to respiratory surfaces

For efficient gaseous exchange, a respiratory surface must:

- have a large surface area
- be moist so gases can diffuse easily
- be thin.

Gaseous exchange takes place continually in animals, such as humans, and also in plants.

Gas exchange in humans

Gaseous exchange is the exchange of oxygen and carbon dioxide across a respiratory surface. In the human respiratory system, gaseous exchange takes place in the lungs. Oxygen, needed for respiration, diffuses from the lungs into the blood. Carbon dioxide, a waste product of respiration, diffuses from the blood into the lungs.

Breathing is the process by which air containing oxygen is inhaled into the lungs and air containing carbon dioxide is exhaled. Breathing is a mechanical process, involving muscular action to increase and decrease the volume of the thoracic cavity. The resulting changes in pressure cause the flow of air into and out of the lungs.

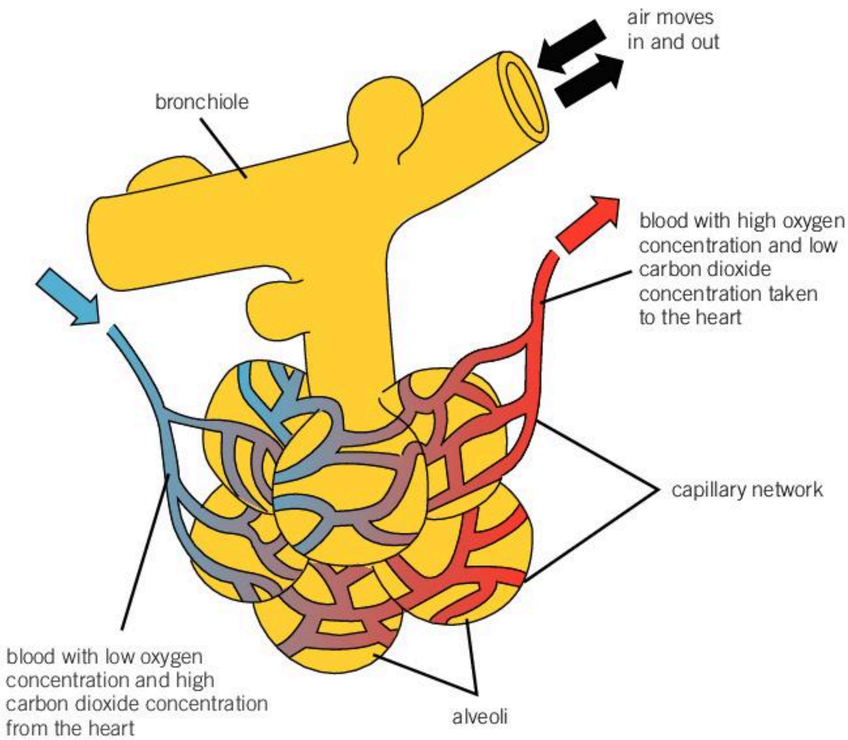


Figure 5.2.1 Cluster of alveoli

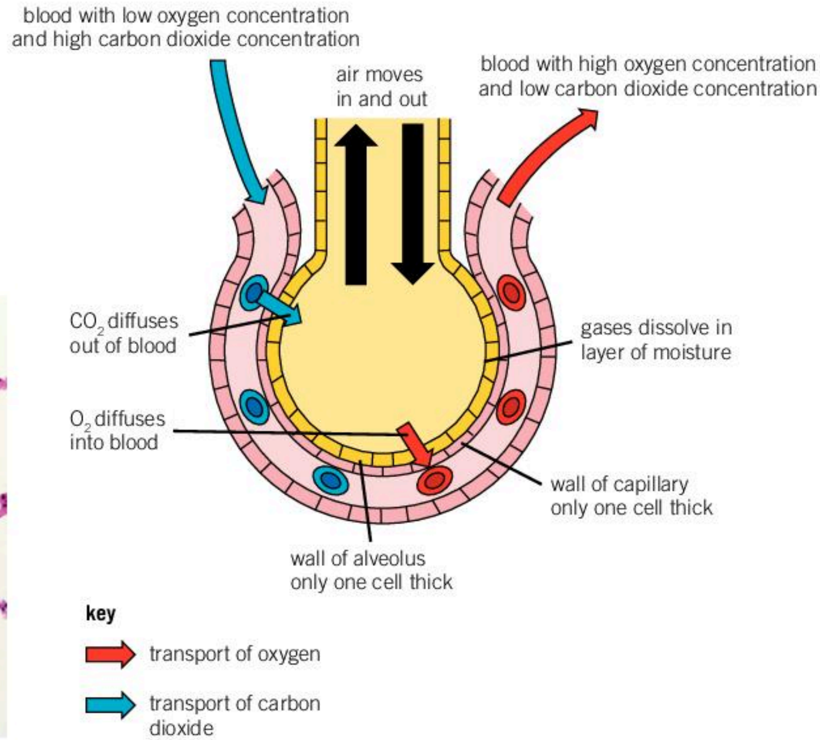
In the lungs, each **bronchus** (plural: **bronchi**) branches many times to form smaller tubes called **bronchioles**. The bronchioles divide and sub-divide, finally ending in clusters of tiny sacs called **alveoli** (singular: **alveolus**). Gaseous exchange takes place in the alveoli.

The alveoli are ideally suited for gaseous exchange because they:

- provide a large surface area
- have walls which are one cell thick allowing gases to diffuse through easily
- have a moist inner surface which allows gases to dissolve and therefore diffuse more easily
- are surrounded by a dense network of blood capillaries so gases diffuse directly into the bloodstream.

Oxygen from the air in the alveolus dissolves in the thin layer of moisture, and diffuses through the wall of the alveolus and the capillary wall into the blood. There is a higher concentration of oxygen in the alveolar air than there is in the blood, so there is a diffusion gradient causing oxygen to diffuse into the blood (see Topic 1.5). The carbon dioxide concentration in the blood is higher than that in the alveolar air, so carbon dioxide diffuses from the blood, through the capillary wall and through the alveolar wall into the alveolus.

▲ **Figure 5.2.3** Lung tissue



▲ **Figure 5.2.2** Section through an alveolus showing gaseous exchange

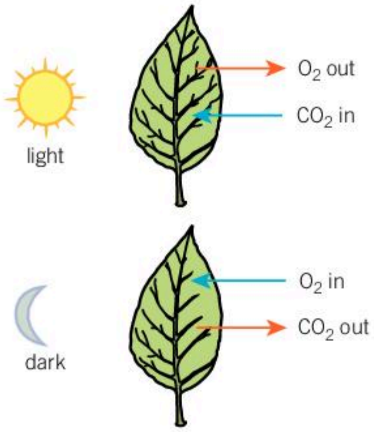
Practical Activity 5.2.1

Looking at lung tissue and drawing alveoli

Skills assessed: Drawing.

For this activity, your teacher will set up a microscope with some slides of normal lung tissue for you to observe. Take care when focusing the microscope. Alternatively, a projector may be used to show a slide to the class.

1. Try to identify the alveoli, capillaries and red blood cells. You may also have parts of a bronchiole on the slide you are viewing.
2. Make a careful drawing of several alveoli to show their shape and structure.
3. Find out the magnification you are using (your teacher can tell you) and then put a scale on your drawing.



▲ **Figure 5.2.4** Gaseous exchange in plants at different times of the day

Gaseous exchange in plants

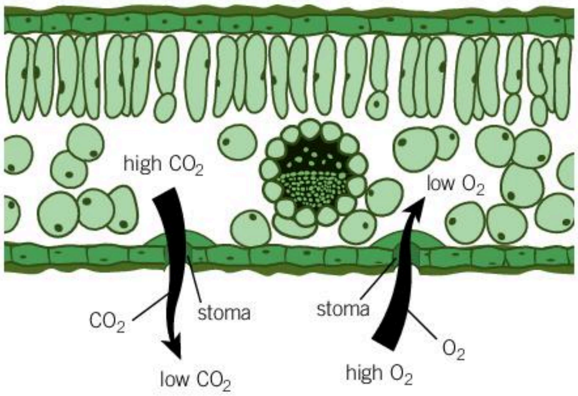
Plants do not have lungs to inhale and exhale air. Instead, plants rely on air diffusing in and out through tiny holes called **stomata** (one is called a stoma). You have already learnt about these in Units 3 and 4. Stomata occur on the stem and leaves, although they are mostly found on the underside of leaves.

In plants there are two gaseous exchange processes involving oxygen and carbon dioxide: photosynthesis and respiration.

Photosynthesis: carbon dioxide + water + sunlight ⟶ glucose + oxygen

Respiration: glucose + oxygen ⟶ carbon dioxide + water

During the day, carbon dioxide is used in photosynthesis and oxygen is produced. The amount of oxygen produced is more than sufficient for respiration and any extra oxygen leaves the plant. This means that during the day carbon dioxide enters the plant but only oxygen leaves (Figure 5.2.4)



▲ **Figure 5.2.5** Gases diffuse through stomata when it is dark

At night, without light, the plant cannot carry out photosynthesis. Only respiration takes place. The concentration of oxygen inside the plant falls as it is used up in respiration. The concentration of carbon dioxide increases as more is made by respiration. Therefore, in darkness oxygen diffuses into the plant, while carbon dioxide diffuses out.

Key fact

Plants respire all the time (both day and night). Photosynthesis takes place *only* in the day when there is sunlight.

Questions

1. State three structural features of an alveolus that make it suitable for gaseous exchange.
2. Define gaseous exchange. Where else in the body, apart from the lungs, does gaseous exchange occur?
3. Explain why plants give out oxygen during the day but take it in at night.

5.3 The importance of respiration

Respiration

Respiration takes place in all living organisms. It is the chemical break down of food molecules in a series of chemical reactions. Energy in the food molecules is released and becomes available for cellular work.

Respiration may take place in the presence of oxygen. This is called **aerobic respiration**. Sometimes it can take place in the absence of oxygen. This is called **anaerobic respiration**. Aerobic respiration produces much more energy than anaerobic respiration.

Aerobic respiration

Animal cells obtain glucose and oxygen from the blood. In plants, glucose is transported to living cells by the phloem (Topic 4.1) and oxygen passes into the leaves through stomata.

During aerobic respiration, glucose is converted to carbon dioxide and water. Enzymes catalyse the reaction.

Word equation:

$$\text{glucose} + \text{oxygen} \xrightarrow{\text{enzymes}} \text{carbon dioxide} + \text{water} + 2880\text{ kJ}$$

Chemical equation:

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O$$

The aerobic respiration of 180 g of glucose releases 2880 kJ of energy.

The equation is really a summary of many reactions that take place in cell respiration.

The energy released by respiration is used by the cells. The maximum amount of energy is released from the glucose because it is completely broken down in aerobic respiration. Carbon dioxide and water are released as waste products.

The reactions that occur to release energy in respiration take place in the mitochondria which are present in the cytoplasm of cells. Some cells, such as muscle cells and nerve cells, require large amounts of energy and have many mitochondria. Fat cells do not need as much energy and have fewer mitochondria.

During respiration, energy is released in small amounts and used to build up molecules of ATP (adenosine triphosphate) from ADP (adenosine diphosphate). For every molecule of glucose that is broken down about 38 molecules of ATP can be made. ATP is often referred to as the energy currency of cells as it can carry energy to the parts of the body that need it. For example, when you run, your muscles need energy in order to contract so ATP transfers the energy from glucose to the muscle cells. When it releases its energy, it is converted back to ADP, ready to be built up into ATP again.

When glucose is broken down in aerobic respiration, about 40% of the energy is used to build up molecules of ATP and the rest is released as heat. This heat energy is used to help maintain our body temperature at around 37 °C, which is the temperature at which our cells and enzymes function efficiently.

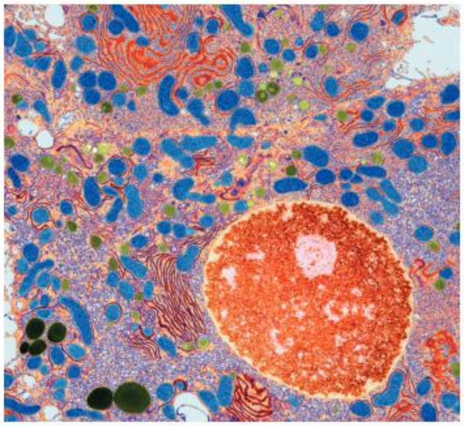
Learning outcomes

By the end of this topic you will be able to:

- state that respiration is the way in which living organisms obtain the energy needed to live
- understand that respiration can take place in the presence or absence of oxygen
- write word and chemical equations for the process of aerobic respiration
- understand the importance of energy release
- understand that energy release takes place at the cellular level
- carry out experiments to show the release of energy and carbon dioxide by organisms.

Key fact

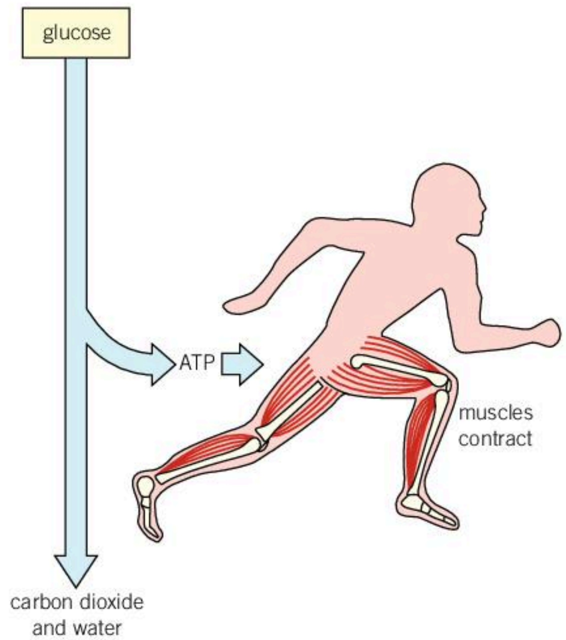
Respiration takes place in the cells of organisms. The word is sometimes incorrectly used to describe breathing. In order to avoid confusion the term 'cell respiration' may be used.



▲ **Figure 5.3.1** A liver cell with large numbers of mitochondria

Did you know?

It is interesting to note that proteins and glucose produce almost the same amount of energy (ATP), while fats produce twice as much energy as protein or glucose.



▲ **Figure 5.3.2** ATP is the link between the breakdown of glucose and muscle contraction

Practical activity 5.3.1

Measuring heat energy from germinating seeds

Skills assessed: Observation/Recording/Reporting and Analysis, and Interpretation.

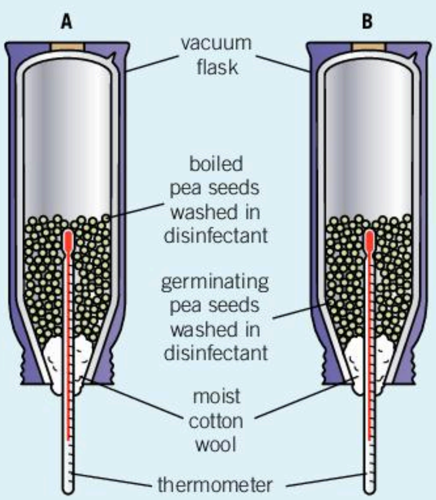
Respiration releases energy in the form of heat. In this investigation, you will measure the amount of heat produced by germinating seeds.

Materials:

- Two vacuum flasks
- Two thermometers
- Two clamps and stands
- Cotton wool
- Germinating peas (or beans)
- Germinating peas (or beans) that have been boiled (to stop germination) and cooled
- Dilute disinfectant solution

Method:

1. Rinse both sets of germinating peas in dilute disinfectant solution to kill microbes and fungi.
2. Pour the germinating peas into one of the vacuum flasks, insert the thermometer and plug the top with cotton wool. Make sure that you can read the thermometer and that the cotton wool plug is a tight fit.
3. Invert the flask and secure it with the clamp as shown in the diagram.
4. Repeat with the second flask, filling it with the boiled peas and inserting the thermometer and cotton wool plug.
5. Record the temperature in each flask.
6. Leave the flasks for 24 hours and record the temperature in each flask.
7. Write up your experiment, drawing your apparatus, recording the temperatures and explaining your results.



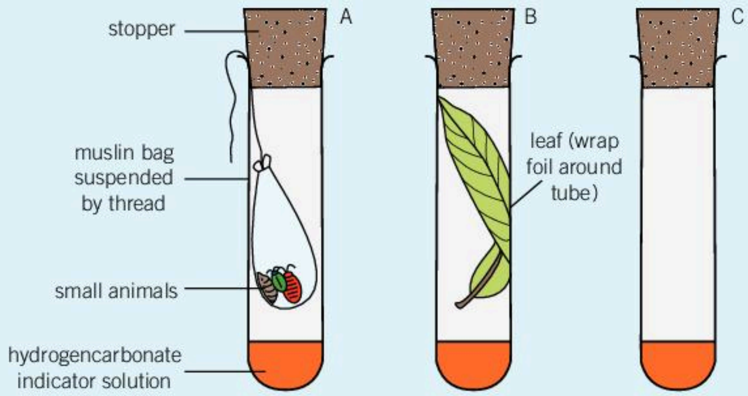
Practical Activity 5.3.2

Showing that small animals and plants give out carbon dioxide

Hydrogencarbonate indicator solution is reddish-orange when neutral but goes yellow when it is acid. Carbon dioxide dissolves in water to give an acid solution.

Materials:

- Three boiling tubes with stoppers in a test tube rack
- Hydrogencarbonate indicator solution
- Muslin bag
- Cotton thread
- Aluminium foil
- Small animals (woodlice, earthworms, caterpillars)
- Fresh green leaf



Method:

1. Pour some hydrogencarbonate indicator solution (about 5 cm^3) into each boiling tube. Note that the solution is a reddish-orange colour.
2. Place some of the small animals in a muslin bag and tie the bag with the cotton thread, leaving a length by which the bag can be suspended.
3. Carefully lower the bag into one of the boiling tubes and place the stopper in firmly so that it holds the thread.
4. Carefully place a fresh green leaf into the second tube. If necessary, suspend the leaf with a piece of cotton thread and place the stopper in the tube firmly.
5. Cover the outside of this second tube with aluminium foil.
6. Leave the third tube with the stopper in.
7. Leave all three tubes in the rack for an hour.
8. Give each tube a gentle shake and observe the colour of the hydrogencarbonate indicator. Record your results.

Questions

1. What is the purpose of respiration?
2. Write the word equation and the chemical equation for respiration.
3. Explain why muscle cells have many mitochondria but fat cells have very few.
4. Why was one flask filled with boiled germinating peas in Practical activity 5.3.1?
5. Why is it important that respiration releases energy from glucose in small amounts?
6. In Practical activity 5.3.2, the tube with the green leaf in it was covered with aluminium foil. Explain why this was done. What do you think would have happened if this had not been done?

5.4 Aerobic and anaerobic respiration

Learning outcomes

By the end of this topic you will be able to:

- state that aerobic respiration takes place in the presence of oxygen and produces a large amount of energy
- state that anaerobic respiration takes place in the absence of oxygen and produces a small amount of energy
- write word equations to represent anaerobic respiration in yeast cells and muscle cells
- give examples of industrial processes involving anaerobic respiration.

Exam tip

Notice that the summary equation for aerobic respiration is the reverse of the equation for photosynthesis. In photosynthesis, a plant uses energy from sunlight to make glucose, while in respiration the glucose is broken down to release energy.

If there is insufficient oxygen available for cells to respire aerobically, glucose is not completely broken down and **anaerobic respiration** occurs. In humans and other animals, muscle cells are able to respire anaerobically when there is a shortage of oxygen. Glucose is converted to lactic acid and there is a small amount of energy released. Lactic acid is a waste product and is toxic to the cells if it accumulates. 180 g of glucose releases 150 kJ of energy in this process, often referred to as **lactic acid fermentation**:

$$\text{glucose} \longrightarrow \text{lactic acid} + 150\,\text{kJ}$$

If we are very active, such as running in a race, we cannot breathe fast enough to get sufficient oxygen to the muscle cells. Our muscles can work for a short time without oxygen. Anaerobic respiration occurs and the muscles produce energy by making lactic acid. The lactic acid accumulates in the muscles, making us feel tired and building up an **oxygen debt**. Once we have stopped running at the end of the race, the blood can supply the muscles with enough oxygen to get rid of the lactic acid by converting some of it to carbon dioxide and water. The remainder is converted back to glucose:

$$\text{lactic acid} + \text{oxygen} \longrightarrow \text{carbon dioxide} + \text{water}$$

A sprinter can hold his breath during a 100 m sprint and the oxygen debt that builds up is paid back by breathing deeply at the end of the race. During a long-distance race, lactic acid builds up to begin with but is removed while the athlete is running.

Yeast and other micro-organisms can also respire anaerobically. Glucose is broken down into ethanol and carbon dioxide in a process known as **alcoholic fermentation**:

$$\text{glucose} \longrightarrow \text{ethanol} + \text{carbon dioxide} + 210\,\text{kJ}$$

180 g of glucose releases 210 kJ of energy in this type of fermentation.

Important processes involving anaerobic respiration

Anaerobic respiration is important in a number of **industrial processes**. The fermentation of sugars by yeast to make bread and alcoholic drinks has been used for thousands of years. More recently, the fermentation of sugar cane in the Caribbean has been a source of ethanol for fuel.

▲ **Figure 5.4.1** Fermentation mixture during rum production

Bread is made by mixing the ingredients and yeast with water to form bread dough. This is left somewhere warm for several hours. Over this period, the yeast cells respire and produce many tiny bubbles of carbon dioxide gas which cause the dough to rise. When the dough is eventually baked in a hot oven, it produces bread that is light and fluffy. Ethanol is also produced in the bread dough but this is driven off during baking. The heat also kills the yeast cells before too much ethanol is produced.

In the production of **alcoholic drinks**, the yeast cells convert sugars into ethanol and carbon dioxide gas. The carbon dioxide is allowed to escape into the atmosphere leaving behind a solution of ethanol in water.

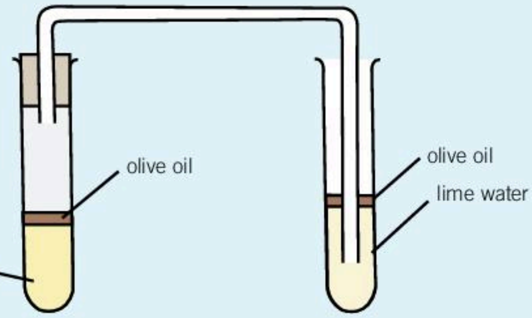
Practical Activity 5.4.1

Does yeast give off carbon dioxide during anaerobic respiration?

Skills assessed: Observation/Recording/Reporting and Analysis, and Interpretation.

Materials:

- A boiling tube with a bung and a delivery tube
- A second boiling tube
- 20 cm^3 of 10% glucose solution made using boiled water
- Yeast
- Lime water
- Olive oil or liquid paraffin



Method:

1. Add some yeast to the glucose solution and mix thoroughly.
2. Set up the apparatus as shown in the diagram.
3. Leave the apparatus overnight in a warm place in the laboratory.
4. The next day, carefully examine the liquid in each tube and record any changes you see.
5. Carefully remove the bung and smell the contents of the boiling tube.
6. Record all your observations.

Different alcoholic drinks contain different proportions of ethanol; beers are typically 4–6%, while **wines** contain 10–12%. It is not possible to produce alcoholic drinks much above 14% ethanol by fermentation alone, as at this concentration the ethanol poisons the yeast. Drinks which we call **spirits**, such as rum and gin, are typically 40% ethanol and are made by distilling the fermented mixture to separate the ethanol from the water.

▲ **Figure 5.4.2** Products of lactic acid fermentation by bacteria

Many types of bacteria can respire anaerobically, fermenting sugar but with different end products. Some produce lactic acid (lactic acid bacteria) and are used in making butter, cheese, yoghurt, soy sauce and silage for feeding livestock. The lactic acid gives the product a characteristic sour taste. Some bacteria convert ethanol into ethanoic acid (acetic acid) and are used to make vinegar.

Did you know?

Proof and percentage ethanol in a drink are not the same thing. Historically the proportion of ethanol in a spirit was tested by pouring some of the spirit onto gunpowder. Ethanol burns, while water does not. If there was sufficient ethanol in the mixture the gunpowder would ignite and the mixture was said to be proof spirit. The minimum proportion of ethanol to do this is 57.1% by volume. Mixtures containing less than this are under-proof, while those containing more than this are over-proof.

Questions

1. Place the following in order of the amount of energy they produce, starting with the one that produces the least.
   Aerobic respiration in plant and animal cells
   Anaerobic respiration in animal cells
   Anaerobic respiration in plant cells
2. Distinguish between alcoholic and lactic acid fermentation.
3. Name three industrial applications of anaerobic respiration.
4. Rum and beer both contain ethanol. How is it that we can set fire to rum but not to beer?

Learning outcomes

By the end of this topic you will be able to:

- list the causes of air pollution
- describe how sulphur dioxide, carbon dioxide, methane, carbon monoxide and lead get into the atmosphere
- explain the affinity of carbon monoxide to the haemoglobin of red blood cells.

5.5 The causes of air pollution

Pollution is caused by an increase in the amount of harmful chemical substances in the environment. Air pollution affects us all as it alters the quality of the atmosphere and can contribute to breathing problems.

A **pollutant** is a harmful substance which accumulates and causes damage to plants, animals and the environment. The table below summarises the main air pollutants and their sources.

▼ **Table 5.5.1** Main air pollutants and their sources

Pollutant	Source
Carbon dioxide	Burning fossil fuels, such as coal, petrol and oil; motor vehicle exhausts
Carbon monoxide	Motor vehicle exhausts
Sulphur dioxide	Burning fossil fuels in power stations and factories
Nitrogen oxides	Formed at high temperatures in factories, mining and metal industries; motor vehicle exhausts
Methane	Motor vehicle exhausts
Lead compounds	Motor vehicle exhausts; burning coal; by-product of metal ore industries

In addition to the chemicals listed in Table 5.5.1, **smoke** from burning fossil fuels is a widespread pollutant. The smoke contains gases, such as carbon dioxide and sulphur dioxide, as well as fine particles of carbon. These particles settle on buildings and trees, turning them black. The particles can get into our respiratory system, causing irritation and contributing to conditions, such as bronchitis and emphysema.

Grit and **dust** can also get into the air we breathe, causing irritation and allergies.

▲ **Figure 5.5.1** Air pollution

Photochemical smog is caused by the action of sunlight on the chemicals present in motor vehicle exhausts. It occurs when there is a **temperature inversion**, in which a warm layer of air develops above a layer of colder air, trapping it so that it cannot escape. Under these circumstances, a brown haze develops, making people's eyes sting and causing headaches. This type of smog damages plants and was thought to be the cause of reduced yields of citrus fruits in California.

Practical activity 5.5.1

Investigating air pollution

Skills assessed: Observation/Recording/Reporting.

Materials:

- Six glass microscope slides coated with a thin layer of agar jelly
- Six small labels
- A binocular microscope

Method:

1. Choose locations outside to place the slides so that they are exposed to the atmosphere.
2. Label each slide with its location and the date.
3. Leave the slides for 24 hours.
4. Bring them back to the laboratory and compare the amounts of dust on the slides (recording which location had the most, which the least).
5. Using the microscope, examine the slides, noting the density of the particles, the variation in size, and look for evidence of pollen grains and other spores.
6. Record your findings and compare them with other members of your class.

Carbon monoxide is a poisonous gas present in car exhaust fumes and in cigarette smoke. It has a greater affinity for haemoglobin than oxygen, so it combines faster with the red blood cells than oxygen does. If we breathe in carbon monoxide, it displaces the oxygen from the red blood cells and oxygen cannot be carried to the tissues of the body. Breathing in concentrated carbon monoxide gas for more than a few minutes can cause death. There are only small amounts of the gas in cigarette smoke. People who are not used to smoking often feel faint when they smoke a cigarette.

Questions

1. What gases are given off when fossil fuels are burnt?
2. Name three pollutants present in car exhaust fumes.
3. Suggest why many factories burning fossil fuels have tall chimneys.
4. Explain how photochemical smog is formed.
5. Why is it dangerous to run a car engine in a closed garage?
6. Write a definition of a pollutant.

Did you know?

In some cities, the pollution from car exhausts is so bad that the police wear face masks when directing the traffic.

▲ **Figure 5.5.2** Traffic pollution

Key fact

Carbon monoxide combines with haemoglobin 300 times more readily than oxygen does.

Learning outcomes

By the end of this topic you will be able to:

- link respiratory disorders with air pollution
- understand the link between asthma and allergies
- describe the causes and effects of bronchitis, pneumonia, pneumoconiosis and emphysema
- discuss the causes of lung cancer
- describe the effects of acid rain on plants
- describe other effects of air pollution on plants.

5.6 Problems caused by air pollution

Oxygen is essential for life. If the ability of the lungs to absorb oxygen is impaired in any way, it will be a threat to our well-being.

We obtain oxygen from the air. This means that we will also inhale dust, pollen, bacteria, viruses and any other particles that happen to be in it. Most of the time, it is not a problem as the body can deal with these invading particles and micro-organisms. The situation is more serious for people who live or work where the air is polluted or who pollute the air themselves by smoking tobacco.

Many of the pollutants found in the atmosphere have harmful effects on our bodies. Table 5.6.1 summarises some of the problems associated with high levels of the major pollutants.

▼ **Table 5.6.1** Major pollutants and their effects on human health

Pollutant	Effect on human health
Carbon monoxide	Combines with haemoglobin and reduces oxygen uptake by the blood
Sulphur dioxide	Irritates mucous membranes; can cause asthma and bronchitis
Nitrogen oxides	Can contribute to breathing problems and respiratory diseases
Lead compounds	Toxic in high concentrations; can cause diseases of the nervous and digestive systems; may cause retarded development in children
Ozone	Makes it more difficult to breathe, especially for people who suffer from conditions, such as asthma
Particulates	In the short term they irritate the eyes, nose and throat. They also make it more difficult for people to breathe. Long-term exposure can lead to chronic lung diseases.

Ozone is a form of oxygen that is formed by the action of sunlight on nitrogen oxides from motor vehicle exhausts and atmospheric oxygen.

Particulates are small particles present in the air. Some occur naturally, such as pollen. Others are the result of human activity, such as burning wood, vehicle exhausts and tobacco smoke. The size of particles varies but they are all small enough to be carried in the air.

Synoptic link

See Topic 4.2 The human circulatory system and 5.1 The mechanism of breathing.

▲ **Figure 5.6.1** Using an inhaler to control asthma

Asthma and allergies

Asthma is not a disease but a set of conditions triggered by an **allergy** to a whole range of things, including pollen, dust, smoke, bacteria and various pollutants in the air.

The resulting allergic reaction causes the bronchial tubes to narrow and it becomes more difficult for the individual to breathe.

Mild attacks of asthma can be controlled by using an inhaler which releases drugs called **bronchodilators** into the airways. These drugs widen the airways so the person can breathe normally.

Respiratory disorders

1 **Bronchitis** is an inflammation of the bronchial tubes and can be caused by bacterial or viral infection. The sufferer has a persistent cough that produces lots of phlegm. Pollutants in the atmosphere can also cause bronchitis or make the symptoms worse for sufferers.

2 **Pneumonia** is an inflammation of the lungs caused by a bacterium. Fluid collects in the alveoli, reducing the surface area available for gaseous exchange. As a result, the patient becomes breathless and lacks energy.

3 **Pneumoconiosis** is the result of a person inhaling dust particles over a long period of time. The particles cause chronic inflammation in the lungs and scar tissue forms, reducing the ability of the lungs to absorb oxygen. In the past, miners and quarrymen were particularly prone to this condition. A condition known as **asbestosis**, resulting from the inhalation of asbestos fibres, has similar effects on the lungs.

4 **Emphysema** is the result of damage caused to the alveoli by repeated coughing. The delicate walls break down forming large air spaces. The total surface area available for gaseous exchange is reduced and the sufferer finds it more difficult to breathe.

5 **Lung cancer** can be caused by breathing in asbestos dust over a long period of time. There is also a definite link between the incidence of lung cancer and smoking (see Topic 5.7).

Air pollution and plants

Many of the air pollutants, such as ozone and particulates that affect people, can also have an adverse effect on plant growth. **Acid rain** also negatively affects plants.

As well as affecting humans, ozone can affect plant growth by damaging leaves (Figure 5.6.5).

When particulates settle on the surface of leaves they reduce the amount of light available for photosynthesis. They may also block up the stomata on the leaves preventing gases from passing in and out.

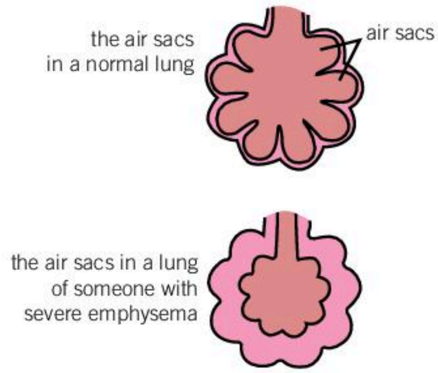
Acid rain is rain that is more acidic than normal. All rain is acidic, even in the absence of pollutant gases, such as sulphur dioxide and nitrogen oxides. Air contains about 0.04% carbon dioxide which dissolves in moisture in the atmosphere to form a weak acid called carbonic acid. Such rain typically has a pH value of about 5.2.

Both nitrogen and sulphur are non-metals and combine with oxygen to form acidic oxides. These oxides dissolve in water to form acids. Sulphur dioxide dissolves in water in the atmosphere to form sulphurous acid. This is subsequently oxidised to sulphuric acid. Similarly, nitrogen oxides dissolve and are oxidised to form nitric acid. When these pollutant gases are present in the air, the pH of rain can fall to as low as 3.0.

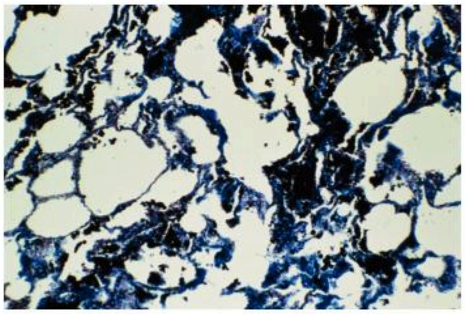
Acid rain causes massive damage to forests. The acid harms the leaves and needles. It also removes essential nutrients from the soil and releases aluminium, which hinders water absorption from the soil. The overall effect is to make it more difficult for plants to obtain nutrients from the soil.

Did you know?

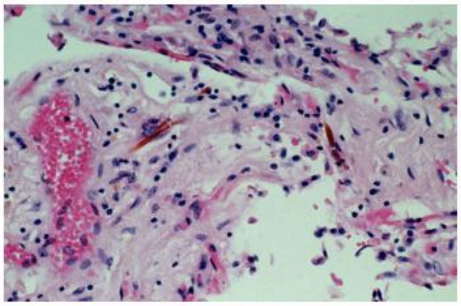
People working with hazardous materials wear face masks containing air filters.



▲ **Figure 5.6.2** A person with emphysema is short of breath because the surface area of the alveoli has been reduced



▲ **Figure 5.6.3** Coal particles in lung tissue



▲ **Figure 5.6.4** Asbestos fibres in lung tissue

▲ **Figure 5.6.5** Effects of ozone on leaves

Questions

1. Explain why a person with emphysema is short of breath.
2. How do bronchodilators help a person suffering an asthma attack?
3. Name a disease caused by inhaling asbestos fibres.
4. Which part of the respiratory system is affected by bronchitis?
5. a Name two sources of particulates.
   b How do particulates affect humans?
   c How do particulates affect plant growth?
6. Explain how acid rain may damage trees in a forest.

5.7 The effects of smoking on the respiratory system

Learning outcomes

By the end of this topic you will be able to:

- describe the main components of tobacco smoke
- understand that tobacco smoking aggravates other lung conditions
- appreciate that tobacco smoking increases the risk of a person developing lung cancer
- explain the importance of smoke-free environments.

Smoking

Many lung conditions are either caused, or made worse, by smoking tobacco. Cigarettes, cigars and pipe tobacco all introduce harmful chemicals into the lungs. Tobacco smoke contains many chemicals but three substances, nicotine, carbon monoxide and tar, are known to cause damage to the lungs and other parts of the body.

As the tobacco smoke passes through the trachea, it prevents mucus from being removed. The mucus builds up in the bronchi causing the famous 'smoker's cough'. Over a period of time, repeated bouts of coughing will cause emphysema.

At the same time, micro-organisms in the mucus may cause the lining of the bronchi to become inflamed, giving rise to bronchitis. In a regular smoker, this may result in chronic bronchitis which persists or lasts for a long time instead of getting better.

In **lung cancer**, abnormal cells grow in an uncontrolled way, often rapidly, to form a tumour. The tumour destroys the lung tissue around it, reducing the ability of the lungs to absorb oxygen. Cancer may spread from the lungs to other organs of the body.

Not every person who smokes will develop lung cancer. But smoking greatly increases a person's chances of developing lung cancer.

Cigarette smoke contains about 4000 poisonous chemical substances, including traces of acetone, ammonia, butane and phenols. Cigarette smoking is the single largest preventable cause of disease and premature death. It has been linked with chronic lung disease but it is a contributory factor in coronary heart disease and strokes. Apart from causing lung cancer, it can cause cancer of the mouth, larynx, oesophagus and bladder, as well as being associated with cancer of the cervix, pancreas and kidneys.

The main harmful chemicals in cigarette smoke and their effects on the body are summarised in Table 5.7.1.

▲ **Figure 5.7.1** X-ray showing lung cancer

▼ **Table 5.7.1** The harmful effects of chemicals in cigarette smoke

Harmful chemical	Effect on the body
Carbon monoxide	• combines irreversibly with haemoglobin • prevents haemoglobin transporting oxygen to the body cells
Nicotine	• a powerful poison • raises the heart rate and increases blood pressure • addictive
Tar	• contains carcinogens (chemicals that cause cancer) • paralyses and damages the cilia in the respiratory tract • coats the air passages and settles in the lungs • leads to increased mucus production

Practical Activity 5.7.1

Dealing with data on lung cancer

The following table contains data about different regions of the world. It shows what proportion of the number of reported cases of cancer were cancer of the lung.

Area of the world	Percentage of cancers which are cancer of the lung
North America	14
Caribbean	10
Eastern Europe	16
North Africa	7
Central Asia	6
Eastern Asia	17

1 Which area of the world had the highest and which the lowest percentage of lung cancer?

2 In the Caribbean there were 66 000 reported cases of cancer. How many cases of lung cancer were there?

3 In Eastern Asia there are several countries in which over 50% of all males smoke tobacco. Does this appear to have any link with the incidence of lung cancer? Explain your answer.

Questions

1 How does smoking affect a person with bronchitis?

2 Why is it inadvisable for a pregnant woman to continue smoking?

3 What is the effect of tar on the cilia in the respiratory tract?

4 Nicotine patches are often used by people who want to give up smoking. Explain why these patches could be helpful.

5 Make a list of the areas in your environment which are smoke-free.

6 Explain how oxygen levels in the blood can be affected by smoking.

Smoke-free environments

Passive smoking means breathing in the smoke from other people's cigarettes or pipes. If you spend time in a smoky room, you breathe in the smoke and the chemicals can get into your lungs. Nicotine has been found in the blood of non-smokers up to 40 hours after exposure to smoke from other people's cigarettes. In many countries there is legislation banning smoking in the workplace and in public areas, creating smoke-free environments. Life is much pleasanter for people who do not smoke and there are usually designated areas for smokers: out-of-doors.

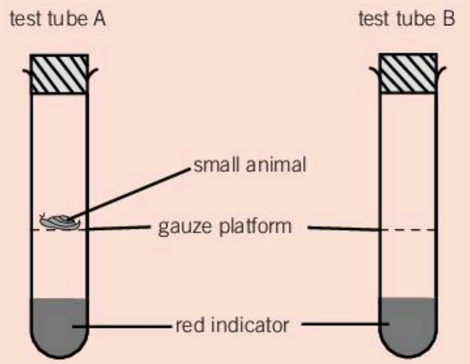
Women are advised not to smoke during pregnancy as the chemicals can pass from the mother's blood into the blood of the unborn baby across the placenta. Research has shown that babies born to mothers who smoked during pregnancy were generally smaller and lighter than those whose mothers were non-smokers. There is also a risk of the baby being born prematurely.

The most obvious way of preventing deaths from chronic lung conditions and cancer is not to start smoking in the first place. If people are addicted, it is often very hard to stop, but there are many schemes available which help people. If a heavy smoker gives up smoking completely, his or her chances of getting lung cancer gradually fall and after a few years are the same as for a non-smoker.

Exam-style questions

Multiple choice

1 An experiment is set up as shown.

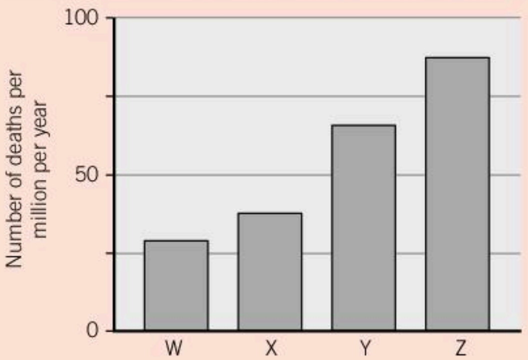


The red indicator turns yellow when carbon dioxide levels inside the tubes increases. After a few hours the indicator in test tube A turns yellow, while that in test tube B remains red.

This shows that:

A transpiration has occurred
B the small animal is using up oxygen
C the small animal is producing carbon dioxide
D the small animal is dead

2 The bar chart shows the relationship between smoking and the number of deaths as a result of lung cancer.



W – non-smokers
X – stopped smoking for more than ten years
Y – stopped smoking for less than ten years
Z – still smoking

Which one of the following deductions can be made from this data?

A Cigarettes contain toxic substances
B Cigarettes contain substances which cause cancer
C Most smokers who die of cancer are elderly
D Smoking can increase the chance of death due to lung cancer

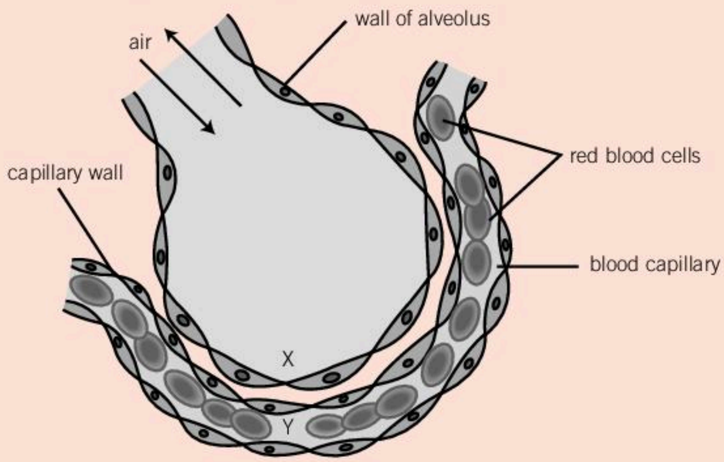
3 In plants during the night:

A oxygen is released
B carbon dioxide is released
C carbon dioxide is used up
D both oxygen and carbon dioxide are produced

Structured questions

4 **a** List three differences between aerobic and anaerobic respiration.
b What is the name of the type of respiration that yeast performs in the absence of oxygen?
c Name two industrial uses of anaerobic respiration.
d **i)** What type of respiration do muscles use to produce energy when there is a shortage of oxygen?
ii) What product accumulates in the muscles as a result of this process?

5 The diagram shows a section through an alveolus and through a capillary passing around it.



a How does oxygen move from X to Y?
b Describe three ways that the alveolus is an efficient gaseous exchange surface.

6 Asthma is a condition that affects the respiratory system.
a What can cause asthma?
b What happens to a person during an asthma attack?
c How can it be controlled?

7 Ozone can affect both humans and plants.
a Where does ozone come from?
b What effect does ozone have on humans?
c What effect does ozone have on plants?

Section A

6 Excretion

Learning outcomes

By the end of this topic you will be able to:

- differentiate between excretion and egestion
- explain the term metabolism
- state that waste products result from the metabolic processes in an organism
- explain that waste products are often poisonous to cells and must be removed
- identify carbon dioxide and water as waste products of respiration
- identify urea as a nitrogenous waste product in mammals
- describe deamination.

Synoptic link

See Topic 3.7 Human digestion and Topic 4.2 The human circulatory system.

Key fact

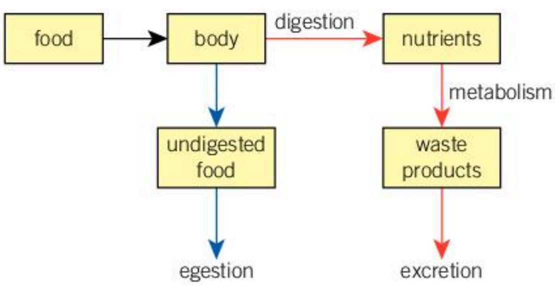
Large animals do not generally digest food efficiently. In herbivores as little as 10% of food may be digested and absorbed into the body. The remaining 90% of the food is undigested and is egested as faeces. Carnivores are more efficient with typically 45% of the food being digested and absorbed into the body and 55% being egested.

In the cells of all living things there are always chemical processes taking place which are necessary for the organism to survive. The processes are collectively called metabolism and they produce a variety of waste products. In order for the organism to remain healthy, these waste products must be removed or excreted.

6.1 Excretion and egestion

Once nutrients are absorbed into the cells, they make take part in chemical reactions controlled by enzymes. These chemical reactions are collectively referred to as the organism's **metabolism**.

As a result of metabolism, substances, called **metabolic waste products**, are formed in the cell. **Excretion** is the removal of metabolic waste products. They must be removed from the cell otherwise, if they accumulate, they would become toxic and the cells would die. For example, carbon dioxide is formed during respiration and dissolves in water to give an acidic solution. If it is not removed from the cell it will lower the pH of the cytoplasm. This will interfere with other chemical reactions.



▲ **Figure 6.1.1** Excretion and egestion in animals are different processes

In animals, food is broken down by **digestion** to release energy. However, some food is not digested. In humans, undigested food passes out of the body as **faeces**. The process of getting rid of undigested food is called **egestion**.

Most of the waste products that plants produce are used in other metabolic processes. Oxygen produced in photosynthesis is used in respiration and carbon dioxide produced during respiration may be used in photosynthesis.

If these processes occurred at the same rate then there would be no waste products to excrete. All the O_2 produced by photosynthesis would be used up by respiration and all the CO_2 produced by respiration would be used in photosynthesis.

Excretion in humans

Like all living things, humans respire and the waste products of respiration, carbon dioxide and water, are excreted by the body. Carbon dioxide is lost from the lungs in the air we exhale. Water is lost through the lungs, through the skin and as urine. A small amount of water is also lost in the faeces.

In addition to respiration, waste products are also formed as a result of other metabolic processes taking place in the body. One important process is the **deamination** of amino acids.

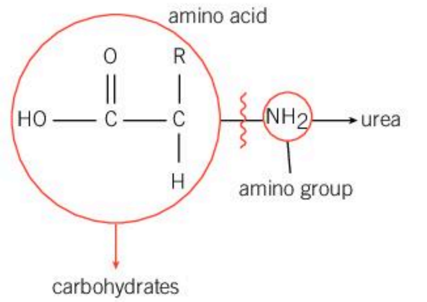
Proteins consist of long chains of amino acids. Proteins are very large molecules which cannot be absorbed in the alimentary canal. During digestion, proteins are broken down into much smaller amino acids which can be absorbed by the body. Amino acids are used by the body to make new proteins. Excess amino acids cannot be stored in the body. Instead of wasting them, the body converts them into carbohydrates which can be used to provide the body with energy.

Deamination of amino acids takes place in the **liver**. It involves removing the amino group (NH_2) by first converting it to ammonia (NH_3) and then to urea ($(CO(NH_2))_2$).

$$CO_2 + NH_3 \longrightarrow (CO(NH_2))_2$$

Urea is the waste product of deamination. It is excreted both through the skin, in sweat, and in solution in urine.

When red blood cells wear out, they are broken down in the liver. The unwanted haemoglobin is converted to coloured substances, called **bile pigments**, which pass out of the liver in the bile. The bile passes into the duodenum and the pigments are excreted in the faeces. The pigments give the faeces their brown colour.



▲ **Figure 6.1.2** Deamination removes the 'amino' part of an amino acid

Did you know?

Ammonia is very toxic to mammal body cells so it is converted to urea for transport around the body and excretion. Urea is excreted in solution which means water is also lost from the body. In some groups of animals (reptiles, birds and insects) water loss in this way would be a problem so nitrogenous waste is lost as uric acid which is insoluble in water.

▼ **Table 6.1.1** Major waste products of metabolism

Waste product	Produced by	Where produced	Where excreted
Carbon dioxide	Cellular respiration	All living cells	From gas exchange surfaces: lungs in mammals, stomata in leaves of plants
Water	Cellular respiration	All living cells	From leaves of plants as water vapour; through lungs and skin, in urine and faeces in mammals
Oxygen	Photosynthesis in green plants	In chloroplasts of plant cells	Through stomata in leaves of plants
Urea	Deamination of amino acids in mammals	In the liver	From the kidneys in the urine
Bile pigments	Breakdown of haemoglobin in mammals	In the liver	In the bile, eventually excreted in the faeces

Questions

1. What is metabolism?
2. Are faeces egested or excreted? Explain your answer.
3. Urea is sometimes used as a fertiliser. Which element does it contain which is important for plant growth?
4. Define excretion.
5. Name four metabolic waste substances produced by mammals.
6. Why does deamination occur in animals but not in plants?

Learning outcomes

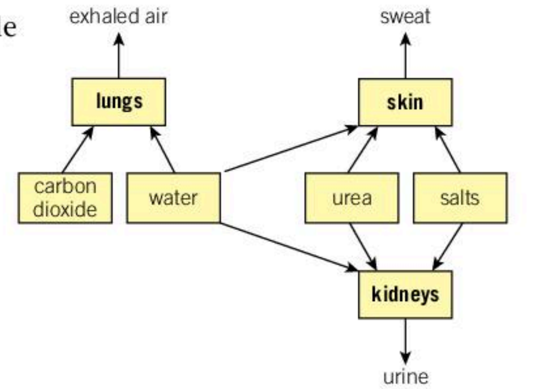
By the end of this topic you will be able to:

- identify the lungs, skin and kidneys as excretory organs
- state that carbon dioxide and water vapour are excreted through the lungs
- describe the structure and functioning of the skin as an excretory organ
- describe the structure of the kidney
- describe the structure of a nephron
- describe the process of ultrafiltration
- describe the process of selective reabsorption
- state that waste from the kidney collects as urine in the bladder
- explain how the kidney balances the amount of water in the body
- describe the role of the pituitary gland in osmoregulation and describe the action of the anti-diuretic hormone (ADH)
- describe kidney dialysis.

6.2 Excretion in humans

There are three organs responsible for excretion from the human body. The organs are the **lungs**, the **skin** and the **kidneys**.

Together they ensure that metabolic waste products are excreted from the body before they accumulate to levels where they become harmful.



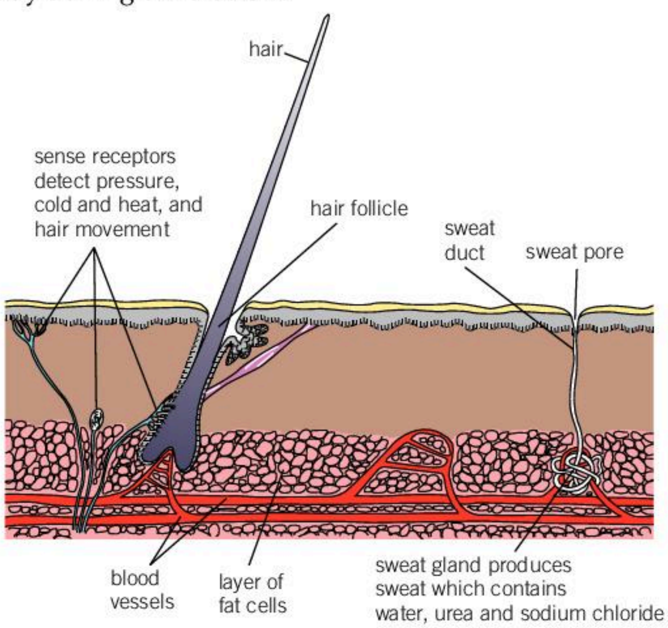
▲ **Figure 6.2.1** Excretion from the human body

The lungs

The structure of the lungs and gaseous exchange was discussed in Topic 5.2. The alveoli are well suited for their function of gaseous exchange. Both carbon dioxide and water vapour are excreted from the body during exhalation.

The skin

The skin is the largest organ in the human body. It has several important functions including the excretion of waste products (in the form of **sweat**) and temperature regulation.



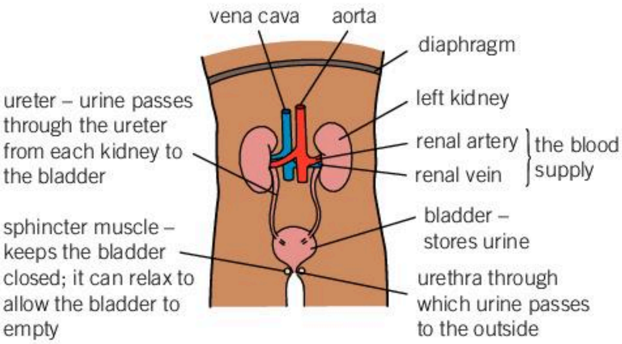
▲ **Figure 6.2.2** Section through human skin

Sweat is mostly water containing about 1% urea. It also contains between 1% and 2% sodium chloride. Although salt is essential to keep the body healthy, we generally take in more than is needed. The excess is removed from the body both in sweat and in urine.

The skin contains many **sweat glands**. They consist of tubes, or sweat ducts, which pass from the blood capillaries beneath the skin up to the surface. A solution of waste products diffuses from the blood capillary into the base of the sweat gland and then passes up the duct.

The greater the concentration of waste products in the blood, the greater the diffusion gradient and therefore the greater the amount of waste excreted. Sweat is also produced in order to cool the body. Humans are warm-blooded with a body temperature of about 37 °C. The heat produced by respiration can be lost through the surface of the skin. We tend to sweat more in hot weather or when we have been active.

Once the sweat reaches the surface of the skin, the water evaporates leaving a residue of urea and salt. Unless they are removed regularly by washing, the urea and salt accumulate on the skin. Urea may be broken down by bacterial action giving rise to the stale smells we associate with poor personal hygiene.



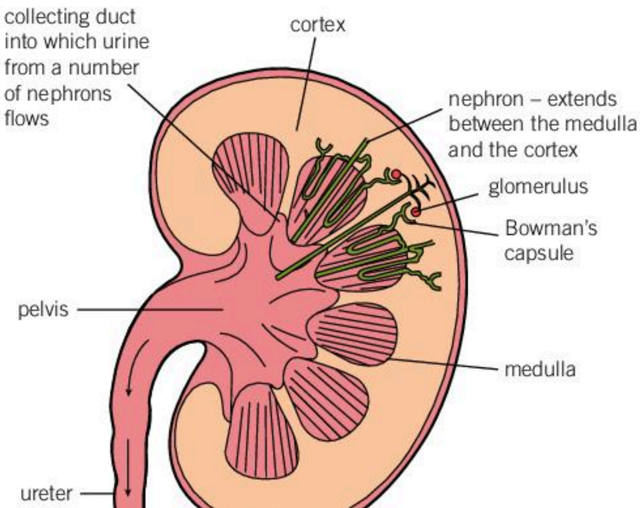
▲ **6.2.3** The position of the kidneys in the body

The kidneys

The kidneys are the main excretory organs of the body. There are two kidneys situated in our lower abdomen (Figure 6.2.3).

The kidneys filter waste products from the blood, together with a certain amount of water. This waste solution is stored in the bladder and eventually passes out of the body as **urine**.

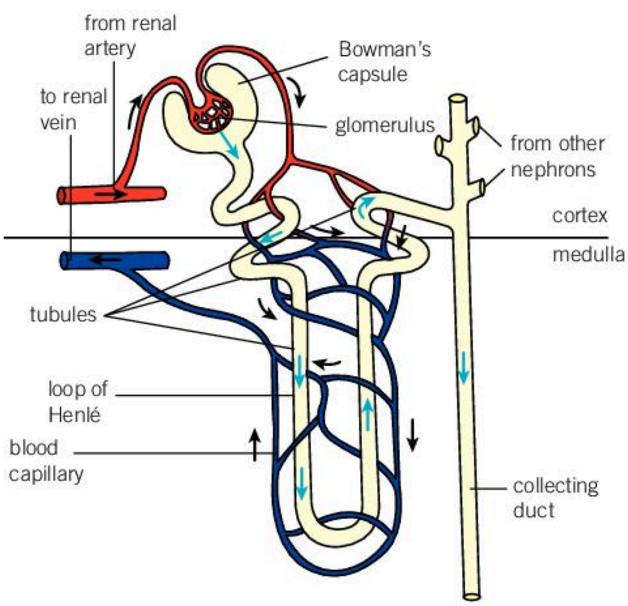
Each kidney is divided into three regions, called the medulla, cortex and pelvis (see Figure 6.2.4). A large number of tiny tubular structures called **nephrons** extend between these regions. The nephrons are involved in removing waste from the blood and reabsorbing useful substances. This is called **ultrafiltration** and **selective reabsorption** respectively.



▲ **Figure 6.2.4** Section through the kidney showing the different regions

Blood, containing waste substances, passes into the kidney through the renal artery. This artery divides and subdivides forming a knot of capillaries called a **glomerulus**. As blood is forced through the glomerulus, a solution called **filtrate** is formed. This contains both useful and waste products, such as amino acids, glucose, water, urea and mineral salts. The filtrate is forced out of the capillary into Bowman's capsule. This process is called ultrafiltration because it removes only small molecules from the blood.

As the filtrate passes down the nephron tubule, amino acids and glucose, together with some water, are selectively reabsorbed back into the blood through the capillary walls. The remaining waste products pass, in solution, to collecting ducts in the pelvis. This solution is called **urine**. It passes through the ureter into the bladder. The proportion of waste substances in urine is much greater than in the blood that passes into the glomerulus.



▲ **Figure 6.2.5** Structure of a nephron

There should be no glucose remaining in urine. The presence of glucose in a person's urine may indicate that they are **diabetic**. Diabetes is a condition where the body is unable to control the amount of glucose in the blood. The level may rise so high that some glucose remains in the urine, even after reabsorption.

All of the chemical reactions in the cells of the body take place in solution so a certain amount of water must be retained by the body in order to keep us healthy. Water typically accounts for around 60% of a person's body mass. The water content of the body is kept constant by ensuring that equal amounts enter and leave the body each day. Water enters and leaves the body in a variety of ways. Some typical values for a person over a 24-hour period are given in Table 6.2.2.

▼ **Table 6.2.1** Percentage by mass of different substances in blood and urine

Substance	Blood in the glomerulus	Urine
Water	91.8	96.3
Protein	7.1	0.0
Glucose	0.1	0.0
Amino acids	0.05	0.0
Salts	0.46	0.83
Urea	0.03	2.0

▼ **Table 6.2.2** Water gains and water losses in humans

Water coming into the body (cm^3)		Water leaving the body (cm^3)	
From respiration	500	From the lungs	700
		From the skin	800
From food and drink	2400	In faeces	250
		As urine	1150
Total water in	2900	Total water out	2900

The amount of water which the body releases as urine depends upon the concentration of water in the blood. This is maintained at a constant level by a part of the brain called the **pituitary gland**, which controls the action of the kidneys by releasing a hormone called the **anti-diuretic hormone (ADH)**. The regulation of water occurs by **feedback mechanisms** that you will learn about in Unit 7.

Practical Activity 6.2.1

Investigating kidney structure

Skills assessed: Observation/Recording/Reporting and Drawing.

Your teacher will provide you with a whole kidney from a small mammal, such as a pig or a lamb.

1. Using a sharp knife, carefully cut through the middle of the kidney along the long axis.
2. Draw the section through the kidney and label the cortex, the medulla, the blood vessels leading to and from the kidney and the ureter. (You will not be able to see individual nephrons as they are very small.)

In the kidneys water is removed from the blood by filtration and returned by reabsorption. Maintaining the balance between these two processes is called **osmoregulation**.

The amount of water reabsorbed from the solution in the tubules depends upon the amount of ADH released by the pituitary gland. The more ADH released by the pituitary gland the more water is reabsorbed back into the blood.

The kidneys can continuously maintain the water content of the blood at a constant level. On a cool day, or a day when the body is not very active, less water is lost from the lungs and skin. Less water is reabsorbed by the kidneys and more is lost as urine. On a hot day, or a day when the body is very active, more water is lost from the lungs and skin. More water is reabsorbed by the kidneys and less is lost as urine.

Key fact

The blood contains large molecules, such as proteins. These are far too big to pass through the capillary wall and remain in the blood during ultrafiltration.

Dialysis

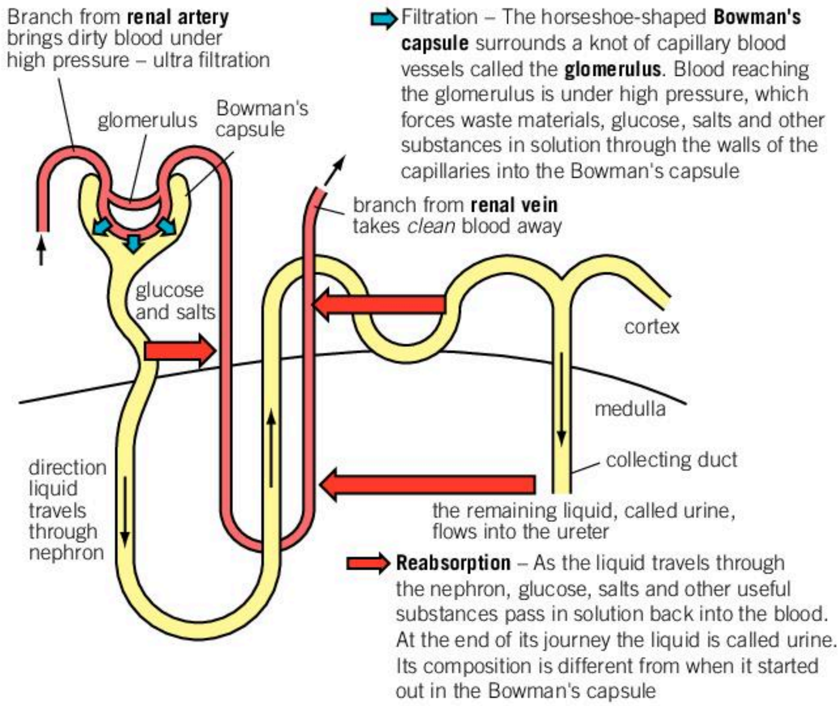
Kidneys can be damaged by disease, or by high blood pressure, and cease to work effectively. If waste substances are not removed from the blood the levels will increase to the point where the patient will die. The blood must be filtered artificially by a process called **dialysis**.

The blood of a person needing dialysis is passed through a machine in which the blood is separated from the dialysis fluid by a partially permeable membrane. The membrane allows small molecules, such as urea and minerals, to pass through but does not allow the passage of proteins and blood cells.

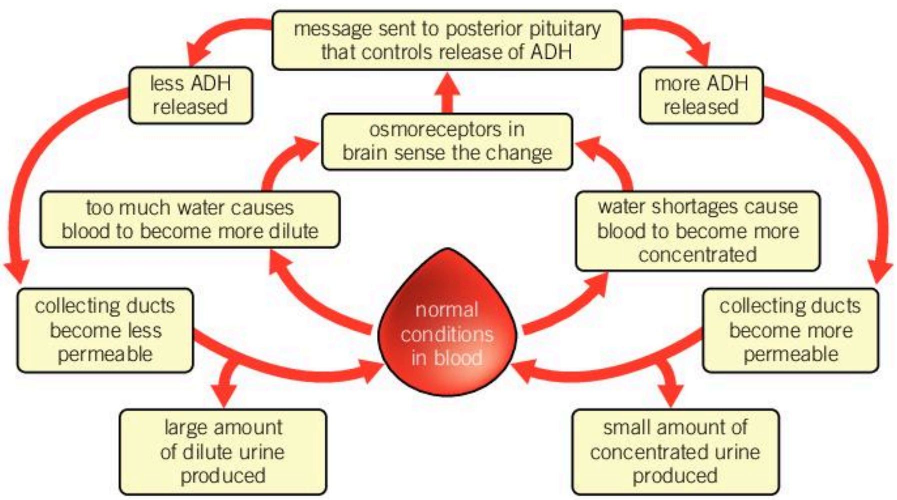
During dialysis, urea and mineral salts diffuse from the blood through the membrane into the dialysis fluid. Since glucose is also a small molecule, any glucose in the blood will also be removed. The dialysis fluid contains the same concentration of glucose and salts as clean blood, so glucose and mineral salts diffuse in the opposite direction back into the blood. The cleaned blood is then passed back into the body through the vein.

A person whose kidneys do not work at all must spend about five hours, three times per week on a dialysis machine. Sometimes they will go to hospital for this, but portable machines are now becoming available which allow people to carry out the procedure for themselves once they have received training.

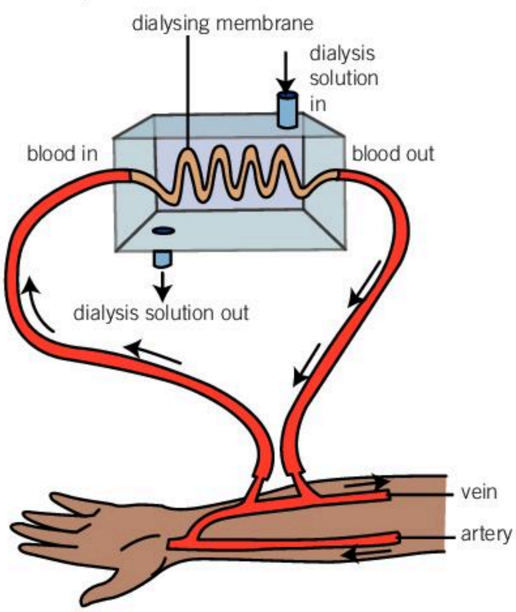
Dialysis machines provide kidney patients with a reasonable standard of life. However, regular dialysis makes it difficult for a person to have a regular job. Sometimes the best solution is for the person to receive a kidney transplant. In a transplant operation, the patient receives a healthy kidney from a kidney donor. This may be from someone who has recently died, perhaps in an accident, or someone who decides to donate one of their kidneys. The body tissue of the kidney donor and the recipient must be closely matched or the kidney will be rejected by the recipient's body.



▲ **Figure 6.2.6** The functioning of a nephron



▲ **Figure 6.2.7** The more ADH is released by the pituitary gland, the more water is reabsorbed in the kidney



▲ **Figure 6.2.8** A simplified diagram of what happens during kidney dialysis

Questions

1. Name the substance which is excreted only from the lungs.
2. State one function of the skin other than excretion.
3. Describe how waste substances pass from blood capillaries to the surface of the skin.
4. In which part of the kidney does ultrafiltration take place?
5. Where is urine stored before it is passed out of the body?
6. In what sense are ultrafiltration and selective reabsorption opposite processes?
7. Why is urine often a deeper colour on a hot day?
8. Why is dialysis carried out using dialysis fluid rather than pure water?

Key fact

A hormone is a chemical messenger that allows one part of the body to control what happens in another. Hormones travel around the body in the bloodstream.

Learning outcomes

By the end of this topic you will be able to:

- identify the waste products of respiration and photosynthesis in flowering plants
- describe how plants re-use their waste products
- describe ways in which plants get rid of other waste products
- discuss ways in which plants conserve water
- describe how osmoregulation in plants is linked to environmental factors.

Exam tip

Do you remember the word equations for respiration and photosynthesis?

Respiration:

glucose + oxygen ⟶ carbon dioxide + water

Photosynthesis:

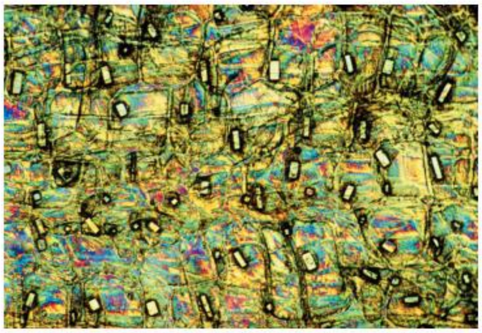
carbon dioxide + water ⟶ glucose + oxygen

▲ **Figure 6.3.2** Paper-bark maple tree showing bark shedding

6.3 Excretion and osmoregulation in flowering plants

As we learnt in Topic 6.1, plants produce carbon dioxide and water as waste products of respiration and oxygen as a waste product of photosynthesis. Oxygen is required for respiration and carbon dioxide is required for photosynthesis. During the day, both respiration and photosynthesis take place and any carbon dioxide released in respiration is used in photosynthesis. Photosynthesis takes place more rapidly than respiration, so the net gas exchange is that carbon dioxide is taken up and oxygen is released. During the night, there is no light so photosynthesis does not take place, but respiration continues. The net gas exchange is that oxygen is taken up and carbon dioxide is released.

Plants do produce other metabolic waste products, such as tannins and crystals of calcium salts, which are stored as insoluble compounds. A good example is seen in Begonia leaves, where crystals of calcium oxalate can be seen in the cells (see Figure 6.3.1).



▲ **Figure 6.3.1** Calcium oxalate crystals (black rectangles) in plant cells

Such substances are got rid of when the plant sheds its leaves.

Tannins can be stored in the woody tissues no longer used for transport and in the bark of trees, where they do not interfere with metabolic processes. In some trees, the bark peels off and is shed. The waste substances are then got rid of at the same time.

Plants can be put into groups based on the environmental conditions in which they live. The environment can affect the ways in which the plants obtain, store and prevent the loss of water. These groups are:

- **hydrophytes** that live in freshwater (e.g. water lilies and pondweed; they have a constant supply of water and have no special structures for osmoregulation)
- **mesophytes** that live on land and have enough water for their needs (e.g. most flowering plants; the leaves have waxy cuticles, protected stomata or small size to prevent water loss through transpiration)
- **xerophytes** that are adapted to live in dry situations (e.g. cacti and oleanders; plants have different structures and adaptations for the conservation of water (summarised in Table 6.3.1))
- **halophytes** that are adapted to living in salty conditions (e.g. mangroves; some are able to excrete salt through special glands on their leaves).

▼ **Table 6.3.1** Adaptations of xerophytes

Method of saving water	Structures adapted for this purpose
Slowing or reducing rate of transpiration	Waxy covering (cuticle) on leaves. Fewer stomata. Sunken stomata which provide a moist micro-environment. Stomata that close in daytime and open at night. Fine hairs on the surface of plant to trap moisture. Curled leaves to provide a moist micro-environment. Small leaves or spines that reduce surface area for water loss. Leaf fall during times of dryness.
Storing water for times of shortage	Fleshy, succulent leaves with flexible surface. Fleshy, thick stems that can store water. Fleshy underground tubers.
Increased water uptake	Shallow, widespread roots to absorb maximum surface water. Very long deep roots to reach underground water. Some plants have a dual root system, which combines a deep tap root with shallow radial roots for maximum water uptake.

▲ **Figure 6.3.3** Cacti

Synoptic link

See Topic 3.1 Photosynthesis.

Practical Activity 6.3.1

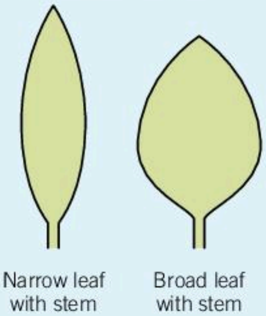
Modelling how leaf shape affects water loss

In this investigation you are going to model different leaf shapes to see how the shape of leaves affects the rate of transpiration. Modelling allows you to make conclusions about what will happen in the real world without using complicated procedures and expensive equipment.

Hypothesis: Plants with narrow leaves will lose less water through transpiration than plants with broad leaves.

Materials:

- Thick white paper
- Scissors
- Measuring cylinder
- Plastic wrap
- Beakers or test tubes
- Water



Method:

1. Cut out paper leaves in two different shapes, one narrow and one broad as shown above.
2. Make the stems the same length and width, and try to keep the total leaf area (length x breadth) more or less the same.
3. Make five copies of each leaf shape.
4. Fill two containers with water and cover each with plastic wrap.
5. Make five tiny holes in the plastic wrap of each container just big enough to push a leaf stem through. Place the five narrow leaves into the plastic wrap of one beaker and the five broad leaves in the other container.
6. Place the containers in the same location.
7. After one hour check to see which leaf shape has used the most water. Measure the volume of water left in each container and subtract this from the original amount.

Questions

1. Explain the net gas exchange of a plant during the daytime.
2. Name a metabolic waste product of plants that is stored in woody tissue.
3. What is the name given to the group of plants that live in freshwater?
4. Give three examples of mesophytes.
5. How can plants living in dry situations increase their water uptake?
6. Explain why plants with hairy leaves have a reduced rate of transpiration.

Exam-style questions

Multiple choice

1 Which of the following terms describes a plant that is adapted to living in freshwater?
- **A** halophyte
- **B** hydrophyte
- **C** mesophyte
- **D** xerophyte

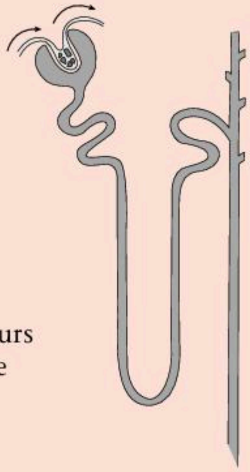
2 In which part of the kidney nephron is glucose reabsorbed?
- **A** glomerulus
- **B** Bowman's capsule
- **C** tubule
- **D** collecting duct

3 Normal urine contains urea, water and:
- **A** amino acids
- **B** glucose
- **C** proteins
- **D** salts

Structured questions

4 **a** Write a suitable definition for the term excretion.
b Name two organs, apart from the kidney, which have an excretory function in humans. For each organ name one substance that is excreted by it.
c What waste product is formed during the deamination of excess amino acids and how is it excreted?
d Explain what happens to the waste products in plants.

5 Redraw the diagram on the right.



a Draw a line to separate the cortex and medulla, and label these parts.
b Add the following labels to the diagram:
Bowman's capsule; glomerulus; collecting duct; loop of Henlé
c On the diagram write:
i) X where filtration occurs
ii) Y where reabsorption occurs
iii) Z where urine flows to the bladder.

6 Too much water, or too little, can damage the cells. Fortunately we have mechanisms that keep the levels of water constant in our bodies.
a What is this process called?
b Which organ is responsible for controlling the amount of water in the blood?
c **i)** What is the name of the hormone that is secreted when the levels of water are too low?
ii) From which part of the brain is it secreted?
d The table shows the amount of water gained or lost during a day by a student. To keep healthy the total water taken into the body must equal the total water passed out of the body.
i) Calculate the amount for *X* and *Y*.
ii) Explain why there is a difference between the amount of urine produced on a cold day and the amount produced during a school sports day.

Volume of water taken in or out during one day (cm^3)

	Water gained by				Water lost in				
	Drinking	**Food**	**Respiration**	**Total**	**Urine**	**Sweat**	**Breathing out**	**Faeces**	**Total**
Normal day	1500	750	250	2500	1000	1000	400	100	2500
School sports day	*X*	1000	500	5000	1300	3000	600	100	5000
Day out in cold weather	1500	750	350	2600	1600	500	400	*Y*	2600

Section A

7 Sense organs and coordination

Many different processes take place simultaneously in our bodies, even when we are asleep. To make sure that all these processes occur in a controlled and ordered way, they must be carefully monitored and regulated. Coordination of the body's processes is achieved by the nervous system and the endocrine system. The nervous system transmits messages around the body in the form of nerve impulses. The endocrine system produces hormones that act as chemical messengers in the body.

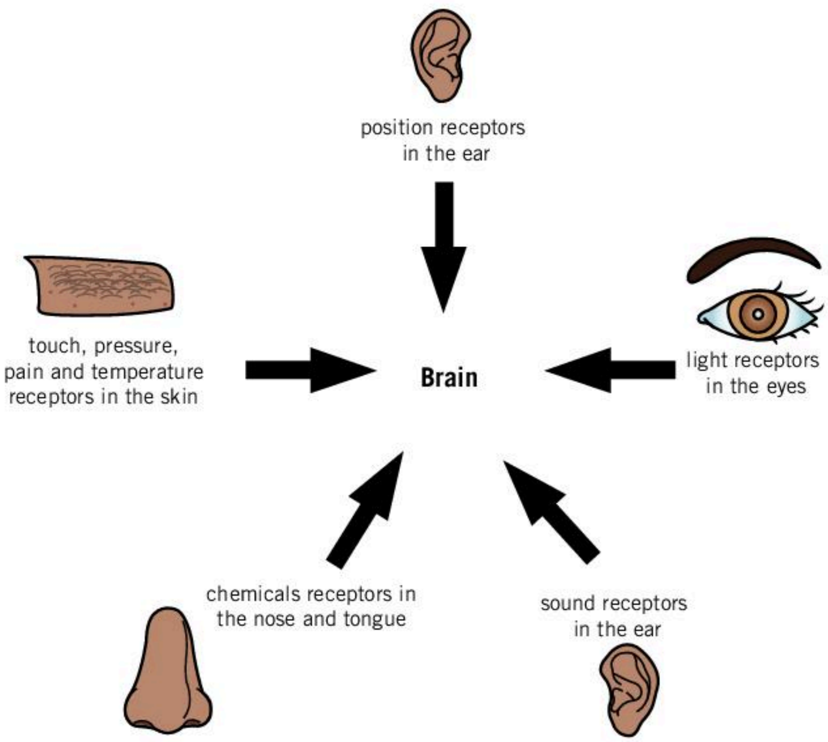
Learning outcomes

By the end of this topic you will be able to:

- name the five sense organs
- describe the function of each.

7.1 The sense organs

Sense organs are parts of the body that respond to external stimuli (changes in the environment) and send messages to the brain. It is through your sense organs that you gather information about your surroundings.



▲ **Figure 7.1.1** The five sense organs

Question

1 Copy and complete the following table.

Name of sense organ	Function of sense organ
eye	
	detects sounds
	detects smells
tongue	
skin	

Learning outcomes

By the end of this topic you will be able to:

- describe the structure of the eye
- identify parts of the eye
- explain how images are formed
- describe the importance of the fovea and the blind spot
- explain focusing of light rays on the fovea
- explain how the amount of light entering the eye is controlled
- explain accommodation
- compare the operation of the eye with a simple camera
- use a pinhole camera.

7.2 The mammalian eye

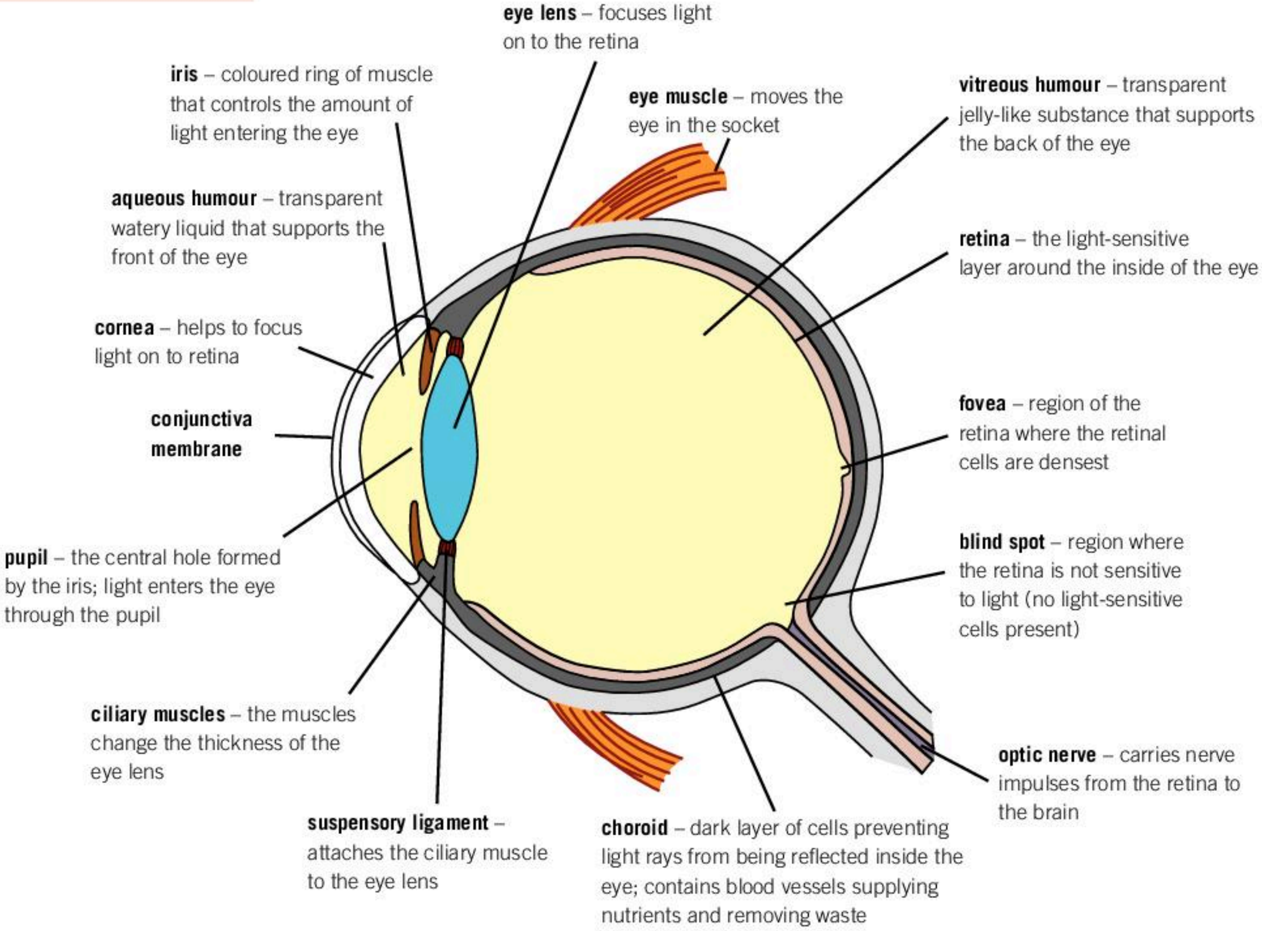
Structure of the eye

The eye is a sense organ that contains sense receptors that are stimulated by light.

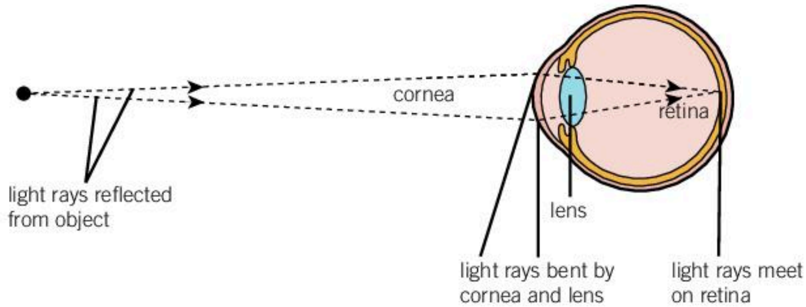
Light rays enter the eye through the **cornea**, which is a transparent layer of cells at the front of the eye. The light rays pass through a **lens** and strikes a layer of light-sensitive cells called the **retina**, at the back of the eye. These cells are most abundant around the **fovea**.

The light rays stimulate the receptor cells to produce nerve impulses which are carried from the retina along neurones to the **optic nerve** and then to the brain where the image is interpreted. There are no light-sensitive cells at the point where the optic nerve leaves the eye. The eye cannot detect light at this point therefore it is called the **blind spot**.

Both the cornea and the lens bend the light rays inwards. This bending of light is called **refraction**. If a person has normal vision, light rays from both close and distant objects are focused on the retina.



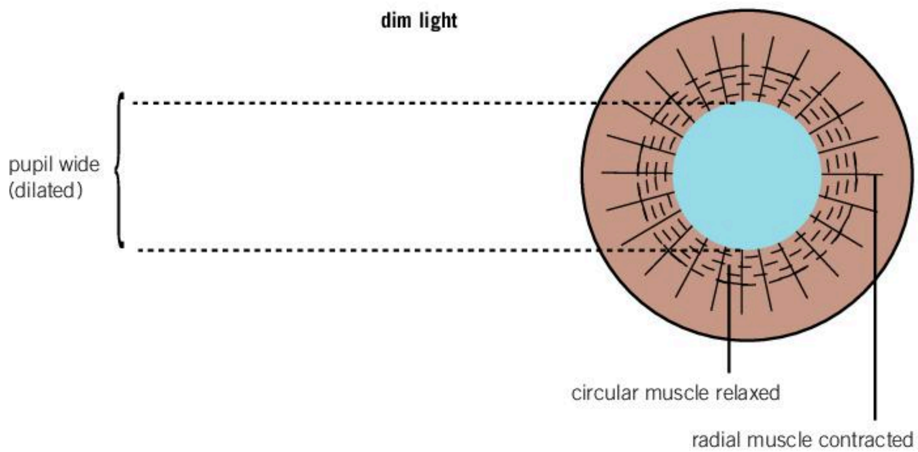
▲ **Figure 7.2.1** Structure of the eye

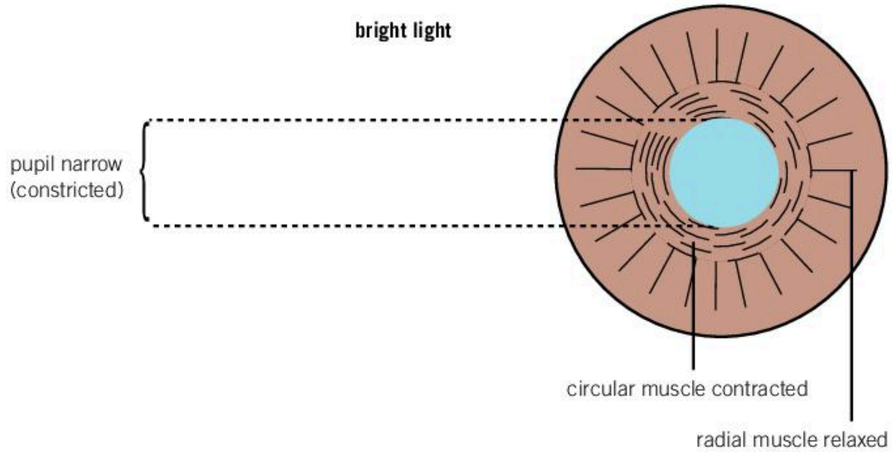


▲ **Figure 7.2.2** Light rays are refracted by the cornea and lens, and are focused on the retina

The amount of light entering the eye is determined by the size of the **pupil** and this, in turn, is controlled by the **iris**. The iris has both circular and radial muscles.

- When the light is dim, the circular muscles relax and the radial muscles contract. This makes the pupil large or dilated, so lots of light can enter the eye.
- When the light is bright, the circular muscles contract and the radial muscles relax. This makes the pupil small or constricted, so very little light can enter the eye.





▲ **Figure 7.2.3** The size of the pupil is controlled by muscles in the iris

Practical Activity 7.2.1

Looking at the mammalian eye

Skills assessed: Observation/Recording/Reporting and Drawing.

Your teacher will provide you with the eye of a pig, goat or cow which has been obtained fresh from the butcher.

1. Look at the external structure of the eye and identify the cornea, iris, pupil and optic nerve.
2. Draw the eye and label these parts.
3. Place the eye in a dish with the cornea pointing upwards. Cut around the cornea with some sharp pointed scissors and lift the cornea off. Describe what you see.
4. Using a scalpel, cut around the iris and lift it off. Describe what you see.
5. Lift out the lens and examine it. Remove the lens and look what is behind it.
6. Turn the eye upside down so all of the liquid drains out of it. Turn the eye inside out and examine the retina. Can you locate the fovea and the blind spot?
7. Draw a diagram and label these parts.

Practical Activity 7.2.2

Finding the blind spot

Use the following test to investigate the blind spot in each of your eyes.

1 Hold the book 30 cm from your face and place the cross in front of your right eye.
2 Close your left eye.
3 While staring at the cross, slowly move the book closer to your face.
4 To start with you will be able to see the dot in your field of vision but at some point it will disappear. What has happened to it?
5 What happens if you continue to move the book towards your face?
6 Try the same thing again but this time look at the dot with you left eye and close your right eye.
7 Does the dot/cross disappear when the book is the same distance from your face each time?

Accommodation

Accommodation is the ability of the eye to focus on objects that are at different distances from it.

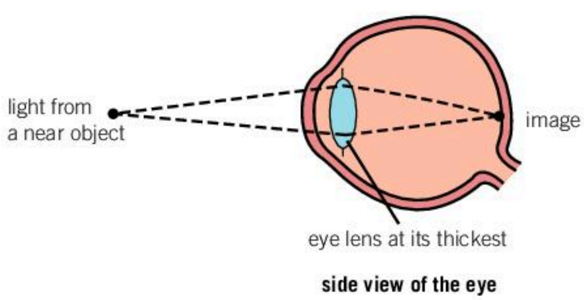
This is possible because the lens is able to become fatter or thinner. The lens is attached to a circular **ciliary muscle** by a series of **suspensory ligaments**. It is this muscle that controls the shape of the lens.

When the eye is viewing near objects, the ciliary muscle contracts and the suspensory ligaments become slack. This allows the lens to become fatter at the centre.

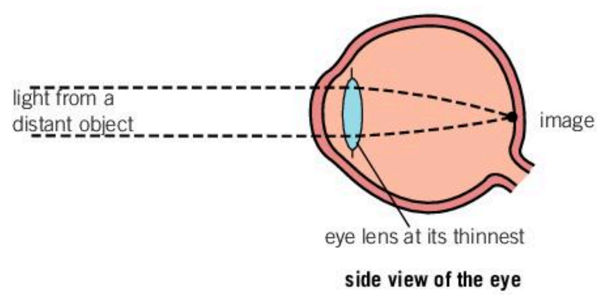
When the eye is viewing distant objects, the ciliary muscle relaxes and the suspensory ligaments become taut. This pulls the edge of the lens causing it to become thinner at the centre.

Key fact

The suspensory ligaments are not muscles and are not able to contract or relax. They become slack, or taut, as a result of changes to the circular ciliary muscle.



▲ **Figure 7.2.4** When looking at near objects, the lens is thick at the centre

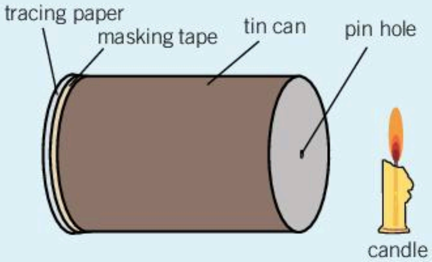


▲ **Figure 7.2.5** When looking at far objects, the lens is thin and flat

Practical Activity 7.2.3

Making a pinhole camera

Skills assessed: Observation/Recording/Reporting and Manipulation/Measurement.

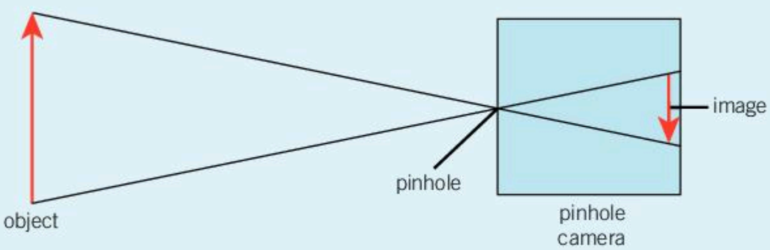


Materials:

- A large tin can
- Some tin foil
- Tracing paper
- Masking tape
- A lit candle

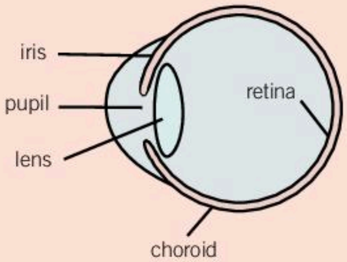
1. Make a small hole in the closed end of the tin can.
2. Cover the open end of the tin can with tracing paper and fasten it with masking tape. This will be the screen for the image.
3. Darken the room and look at the image of the lit candle.
4. What do you notice about the candle flame?

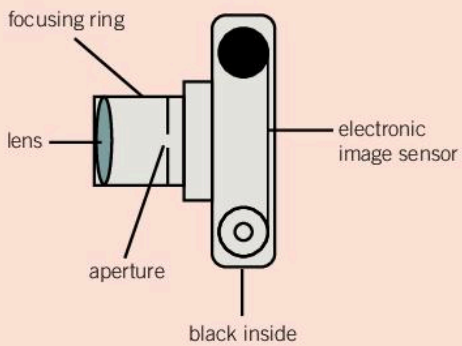
You should find that the image produced is upside down. It is called an inverted image. The lens of a camera and the eye produce similar images. The brain changes the image so that we see it the right way up.



Questions

1. At which point on the retina are there:
   - **a** the greatest concentration of light-sensitive cells
   - **b** no light-sensitive cells?
2. Which part(s) of the eye focus light rays?
3. What word is used to describe the ability of the eye to focus on objects at different distances from it?
4. The eye is often compared to the camera in terms of its structure and the way it works.
   - **a** Draw a table and list the following parts of the eye: lens, iris, retina and choroid. Alongside each part, name the part of the camera that does the same job.
   - **b** Both the eye and a camera are able to focus on objects at different distances. Do they do this in the same way or in different ways? Explain your answer.





Learning outcomes

By the end of this topic you will be able to:

- state the difference between natural and artificial lighting
- state some examples of artificial light sources
- describe the problems of poor lighting
- discuss the ways in which lighting can be controlled in buildings.

Practical Activity 7.3.1

Lighting

Skills assessed: Manipulation/ Measurement and Analysis and Interpretation.

1. Measure the height and width of each of the walls in your classroom. Calculate the total area of the walls.
2. Measure the height and width of each of the windows in your classroom. Calculate the total area of the windows.
3. Calculate the percentage of the walls that are windows using the formula: percentage of area that is

$$\text{window} = \frac{\text{area of windows}}{\text{total area of walls}} \times 100$$

4. Repeat this for your bedroom at home.
5. Which room has the biggest percentage of window area? What conclusions can you make about the amount of natural light entering each room?
6. For each of the rooms you have measured, list the number and types of light.
7. Which room do you think provides the best lighting for you to study by and why?

7.3 Lighting

We need adequate lighting to be able to live comfortably and work efficiently. We can obtain this from natural or artificial sources. New buildings should be designed to make the best use of natural light. Different types of artificial light have different efficiencies and therefore cost different amounts to use.

Natural lighting

The light we obtain from the Sun is called **'natural' light**. It is only available between sunrise and sunset. The intensity of the light varies during the day; it is at its strongest at midday when the Sun is highest in the sky. When natural light is not available we need to find a way of producing **'artificial' light**.

Artificial light

Artificial light is any light we make ourselves, for example light from fires, candles, oil lamps and electrical lamps. The colours of objects often appear different when they are seen in artificial light compared to when they are seen in natural light. For example, if you buy clothes in a shop which has bright artificial lighting you may find that the colour looks very different in natural light. This is because natural light contains the full visible spectrum.

Problems of poor lighting

Poor lighting can cause problems. It is not easy to work or study if the lighting is poor. In dim lighting the pupils of our eyes dilate to allow maximum light into the eyes (see Topic 7.2). Trying to read in light that is not bright enough can cause eye strain and headaches. Also, accidents are more likely to occur in dim light.

Buildings and lighting

One way to increase the amount of natural light entering a building is to design the building with many big windows. However, this may not always be the best solution. A room with many big windows may become uncomfortably hot. It may be difficult to read a computer screen if the light is too bright or it may not be possible to sit without casting a shadow over your work. The amount of natural light varies with the time of day and the time of year. It can be controlled to some extent using curtains, shutters and blinds.

Artificial lighting may be controlled easily by turning lights on or off, or using dimmer switches to vary the light intensity. Lamps can be used to illuminate particular areas, such as a desk. Artificial lighting can be kept the same whatever the time of day or year.

Different lighting effects are also produced depending on the colour of the walls in a room and whether the finish on the walls is matt or glossy.

Questions

1. Explain why the intensity of natural light varies during the day and from day to day.
2. Describe the sources of artificial light.
3. Why is it a bad idea to study when the light is too dim?
4. Describe how the colour of the walls and the number of windows in a room can affect the light that is available.

7.4 Transparent, translucent and opaque materials

Materials can be put into different groups according to the amount of light that can pass through them.

▲ **Figure 7.4.1** Glass is transparent; woven cotton is translucent; wood is opaque.

Glass is a **transparent** material. A transparent material lets most light pass through it.

Woven cotton is a **translucent** material. A translucent material lets some light pass through it.

Wood is an **opaque** material. An opaque material lets no light pass through it.

Questions

1 Here are six materials.

aluminium foil	clear glass	grease-proof paper
cling film	newspaper	cardboard

State which of these materials is:

a translucent

b opaque

c transparent.

2 Explain why the packaging of fresh food stocked in shops is often made of transparent materials.

Learning outcomes

By the end of this topic you will be able to:

- explain the differences between transparent, translucent and opaque materials
- give examples of transparent, translucent and opaque materials.

Practical Activity 7.4.1

Investigating how much light passes through materials

Materials:

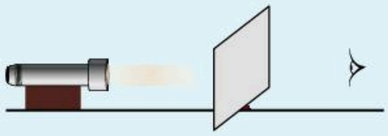
- Torch
- Sheets of some different materials
- Moulding clay

Method:

1 Place a torch on a book at one end of your table.

2 Look from the other end of the table.

3 Hold the material between the torch and your eye, or stand it on the table using moulding clay as shown in the diagram.



4 Observe how much light is passing through the material. You must ignore any light shining on from other sources.

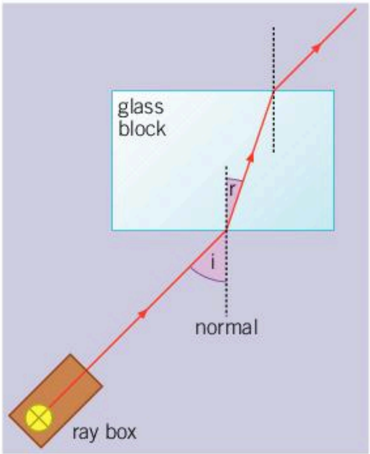
5 Record all your observations in a table.

7.5 Dispersion of light

Learning outcomes

By the end of this topic you will be able to:

- describe what happens when a ray of light is refracted
- explain refraction in terms of speed of light in different media
- state what is meant by dispersion
- describe a diagram to show dispersion through a prism
- explain why a mixture of rays of light of different colours is dispersed
- state the colours of the spectrum in order
- describe how dispersion takes place in water.



▲ **Figure 7.5.1** Refraction

Exam tip

You need something to help you remember the colours of the spectrum in order, such as 'Rinse Out Your Greasy Bottles In Vinegar' or 'Richard Of York Gave Battle In Vain'.

Refraction

The refraction of light takes place because the light changes speed as it crosses the boundary between one substance and another. The change in speed causes the light to change direction unless it is travelling along a normal, that is, it strikes the boundary at 90°.

When light enters a more optically dense medium (e.g. it crosses from air into glass or air into water) it slows down and its direction bends towards the normal.

When light enters a less optically dense medium (e.g. it crosses from glass into air or water into air) it speeds up and its direction bends away from the normal.

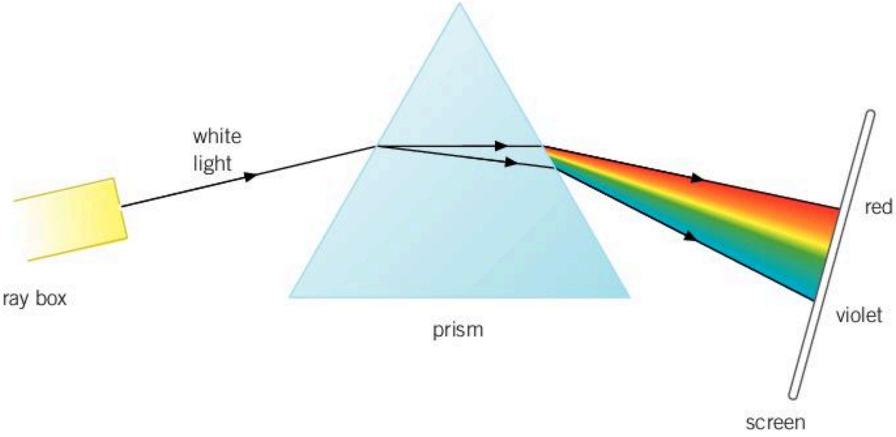
The following terms are used when talking about the refraction of light.

- The angle between the incident ray and the normal is called the **angle of incidence** (i).
- The angle between the refracted ray and the normal is called the **angle of refraction** (r).

Dispersion by prisms

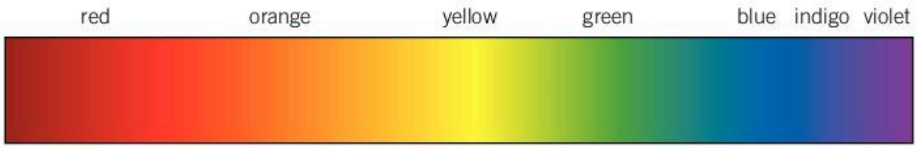
Different colours of light travel through different materials, such as glass and water, at slightly different speeds. As a result they are slowed down, and refracted, by slightly different amounts. We can see this because if a ray of white light is shone on a glass prism the different amounts of refraction cause the different colours of light to spread out and produce **a spectrum**. This process is called **dispersion**. From this we can see that white light is not really a colour, but a mixture of different colours of light.

We do not obtain this effect with a rectangular glass block, because the dispersion that occurs as the white light enters the block is reversed as it leaves the parallel side. In a prism, the sides are not parallel so further dispersion is produced as the light emerges from the second side into the air.



▲ **Figure 7.5.2** Dispersion by a prism

The colours of the spectrum are always in the same order:



If you try this you may find it difficult to distinguish between the indigo and the violet.

- Violet light slows down the most, so it is refracted the most.
- Red light slows down the least, so it is refracted the least.

Dispersion by water

Rainbows are caused by the dispersion of sunlight by water droplets in the atmosphere. They can be observed when the Sun is low in the sky behind the observer and there are rain droplets in front of the observer. You can try producing dispersion with water yourself.

Practical Activity 7.5.1

Using a water prism

Skills assessed: Observation/Recording/Reporting.

1. Make prisms out of ice. Use plastic strips to form triangular moulds.
2. Use your ice prisms and a white light source to make a spectrum. Try using different light sources, such as a ray box, a torch or a narrow beam of sunlight.
3. Use a plant or perfume sprayer to produce a fine mist of water drops. Try and produce a spectrum by spraying this into a beam of bright sunlight or light from a ray box or projector. You will need to try different angles between the light and the spray. Try it with coarser and finer sprays.
4. Put some water into a shallow dish. Place a plane mirror partly in the water. Change the angle of the mirror to try and produce a spectrum by reflecting sunlight on to a white card.
5. For each experiment carefully draw the apparatus that you use and record what you see.

Questions

1. What is ‘white light’?
2. What are the colours of the spectrum?
3. Which colour of the spectrum is diffracted the most and which the least?
4. Why can you produce dispersion with a triangular prism but not with a rectangular glass block?

Learning outcomes

By the end of this topic you will be able to:

- describe the reasons for short-sightedness and long-sightedness
- explain how these defects can be corrected
- understand colour blindness
- describe some ways in which the eye can be damaged.

Key fact

- A concave lens is a diverging lens. It causes light rays to bend or refract away from each other.
- A convex lens is a converging lens. It causes light rays to bend or refract towards each other.

7.6 Sight defects

Short- and long-sightedness

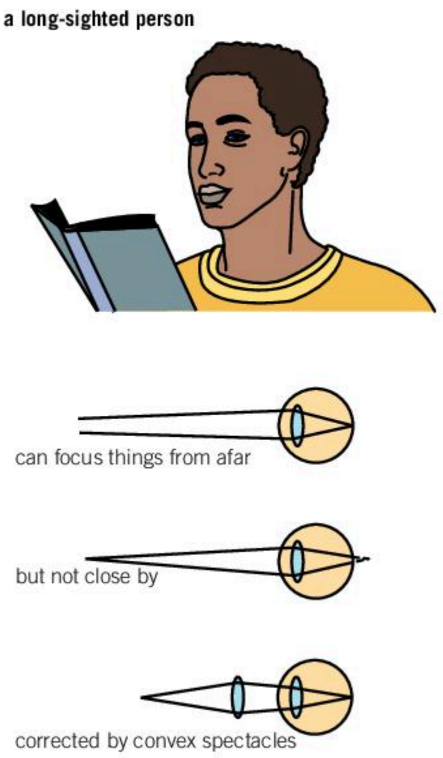
If people have perfect vision the image of what they see always falls exactly on the retina, no matter how far away an object is from the eye. Sadly, many people have less than perfect vision. Two common eye defects result in an image being focused in front of the retina: (**short-sightedness**) or behind the retina: (**long-sightedness**).

People who are short-sighted can see near objects clearly, so they can read a book without any trouble, but light rays from distant objects are focused in front of the retina so the image is blurred. Short-sight is corrected by wearing spectacles with **concave lenses**. These lenses cause the light rays to **diverge** so when they are eventually focused by the eye, the image falls on the retina.

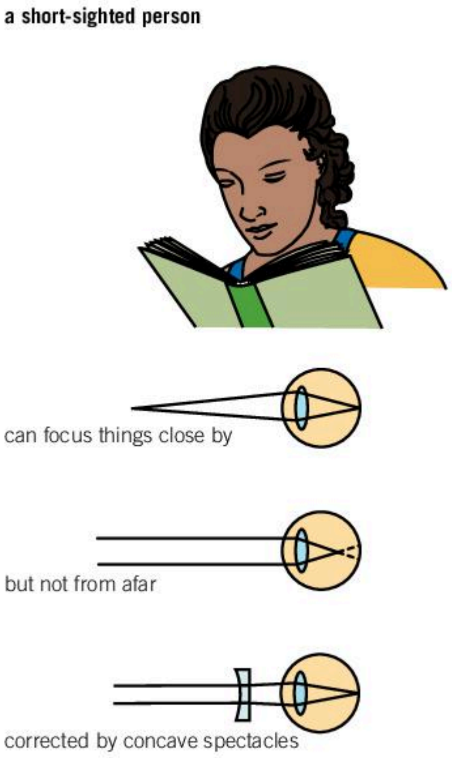
People who are long-sighted can see distant objects without any trouble, but light rays from near objects are focused behind the retina. When they try to read a newspaper, for example, the image is blurred. Long-sight is corrected by wearing spectacles with **convex lenses**. These lenses cause the light rays to **converge** so the image is focused on the retina.

Lack of accommodation

As we get older, the lenses in our eyes usually get a bit stiffer and are not able to change their shape as easily to accommodate objects at different distances. You might have noticed that older people hold newspapers or menus at arm's length to read them properly.



▲ **Figure 7.6.1** Long-sight is corrected by convex lenses



▲ **Figure 7.6.2** Short-sight is corrected by concave lenses

Converging (convex) lenses are normally used to correct for lack of accommodation.

If you are short-sighted and you suffer from lack of accommodation you need different kinds of lenses. Opticians have developed bifocal lenses so that people don't need two pairs of glasses. A bifocal lens is a diverging lens at the top and a converging lens at the bottom. If you wear bifocals, you look through the top of the glasses when you are looking at objects far away. You look down through the bottom of the lens to read or see things that are close up.

Contact lenses

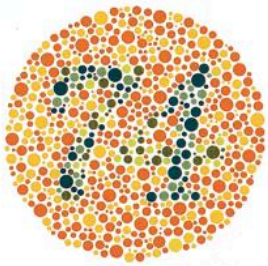
Contact lenses are small lenses that are worn directly on the eyeball in front of the cornea. Contact lenses can be convex or concave, depending on the person's vision defect. People who wear contact lenses find they have more natural vision than with glasses. There are two reasons for this.

- There is no distortion of vision caused by looking through different parts of a lens, so objects look normal and they appear the right size.
- The lenses move with the eyes, so the person is always looking through them and he, or she, gets a wider, clearer field of vision.

Colour vision

Most people see images in colour. There are different cells in the retina responsible for detecting red light, green light and blue light. All of the other colours we see are combinations of these three primary colours.

Colour blindness is an inability to see properly in colour. Most often this does not mean that a person sees only in black and white, but the cells responsible for seeing one or more colours do not work properly. Red–green deficiency is a common form of colour blindness that occurs mainly in males.



▲ **Figure 7.6.3** Can you see the number? If not you are red–green colour blind

Damaging the eyes

The retina in our eyes is extremely sensitive to light. Sunlight is the primary source of ultraviolet (UV) radiation that can damage tissues of the eye. Spending long hours in the Sun without eye protection increases the chances of developing eye diseases. It may increase the incidence of **cataracts**. Cataracts are a form of eye damage that causes the loss of transparency in the lens, clouding vision.

Glaucoma is a disease which causes optic nerve damage. As a result of glaucoma, eye pressure plays a role in damaging the delicate nerve fibres of the optic nerve. When many nerve fibres are damaged, blind spots develop in the field of vision. Once nerve damage and visual loss occur, it is permanent. Most people do not notice these blind areas until much of the optic nerve damage has already occurred. If the entire nerve is destroyed, blindness results. Glaucoma is a leading cause of blindness in the world, especially in older people. The exact causes of optic nerve damage from glaucoma are not fully understood.

Physical injury can also occur especially when playing sports. For example, a ball can hit a player in the eye causing damage to the cornea or eye socket.

Questions

1 Copy and complete the following table.

Eye condition	Long-sightedness	Short-sightedness
Position of image with respect to the retina		
Type of lens used to correct the condition		

2 What happens when a person suffers from lack of accommodation?

3 Explain how bifocal lenses work.

4 Describe the advantages of contact lenses used to correct vision defects.

5 Explain how glaucoma can lead to blindness.

6 How do cataracts affect vision?

Practical Activity 7.6.1

Investigating convex and concave lenses

Materials:

- Low voltage power pack
- Ray box
- Single slit, to provide thin ray of light
- Demonstration lenses – convex and concave
- Lens holder or sticky material to hold lens in place
- A4 plain paper
- Pencil
- Ruler

Safety: Be careful when using ray boxes – they can become very hot.

Method:

1 Place the convex demonstration lens in the centre of the paper and draw around it.

2 Draw five horizontal lines onto the paper up to the lens.

3 Add arrows to the lines, to represent the direction the light will travel.

4 Insert the slit into the ray box. Replace the demonstration lens into position on the paper.

5 Aim the ray of light along the top horizontal line. Where the ray of light emerges, draw small crosses onto the paper.

6 Join the crosses together and then complete the ray of light which travels through the lens itself.

7 Repeat steps 5 and 6 for the remaining lines.

8 Repeat the entire experiment, using the concave demonstration lens.

Learning outcomes

By the end of this topic you will be able to:

- draw a diagram to show the internal structure of the ear
- identify parts of the ear
- explain how sound passes from the outer ear to the cochlea and how information is transferred to the brain
- explain the function of the eustachian tube
- state the function of semicircular canals
- describe sound as a vibration that travels through air in the form of sound waves
- be aware that sound is characterised by both loudness and frequency
- appreciate the advantage of having two ears
- state that the frequency of sound is measured in hertz (Hz)
- state that the typical audible range of a human is around 20–20 000 Hz
- state that loudness is measured in decibels (dB)
- have an idea of the decibel scale
- explain how wax can be removed from the outer ear
- explain the problems that arise when the bones in the middle ear cease to function correctly
- describe how hearing aids work
- appreciate that regular exposure to very loud sound may lead to permanent deafness.

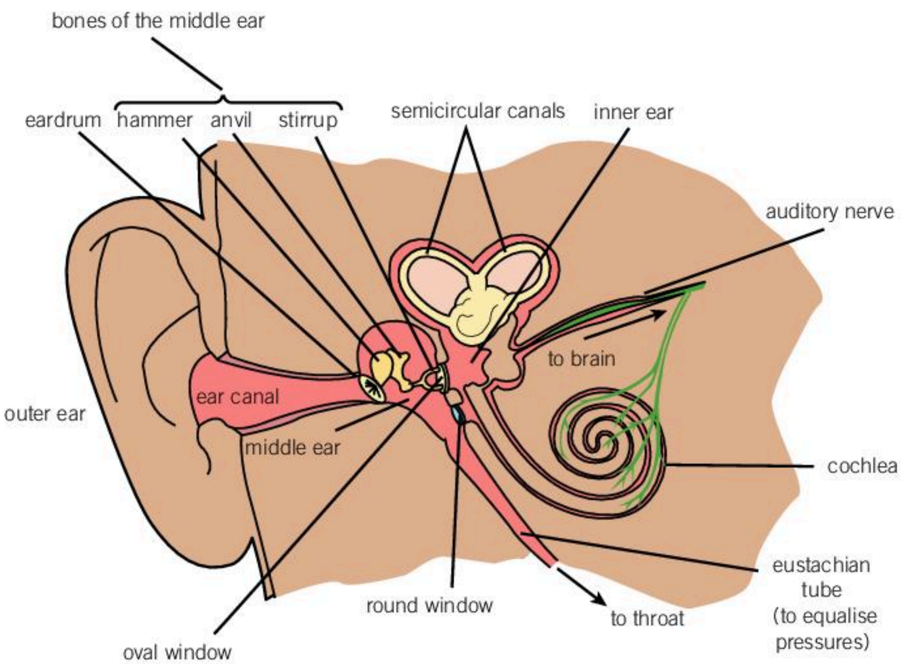
Did you know?

The ossicles are sometimes referred to by their Latin names: *malleus* (hammer), *incus* (anvil) and *stapes* (stirrup).

7.7 The mammalian ear

Structure of the ear

The ear is a sense organ that is stimulated by sound.



▲ **Figure 7.7.1** Structure of the human ear

Sound is collected by the outer ear and directed down the **ear canal** to the ear drum. The **ear drum** is a membrane which is so called because it acts like the skin on a drum. Sound waves cause the ear drum to move in and out, transferring the vibrations to the middle ear.

The middle ear contains the three smallest bones in the body called ossicles: the hammer, the anvil and the stirrup. These bones act as levers to magnify the vibrations and pass them to the **oval window** through which they pass into the inner ear.

If the middle ear was completely sealed, any movement of the ear drum and oval window would cause changes in pressure. In order to avoid this problem, the middle ear is connected to the throat via the **eustachian tube**. Air is able to pass into and out of the middle ear through this tube so the pressure is kept constant.

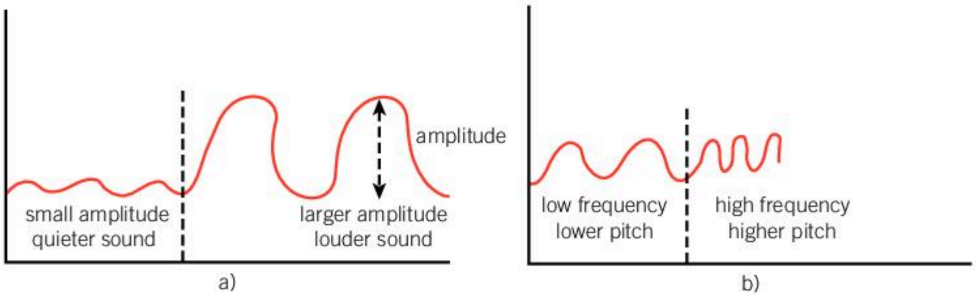
In the inner ear, the **cochlea** contains receptor cells that are stimulated by vibrations. They detect the sound and send information along the **auditory nerve** to the brain where it is interpreted.

The inner ear also contains **semicircular canals** that are concerned with balance. Information is sent from here to the cerebellum in the brain which is responsible for maintaining balance.

The nature of sound

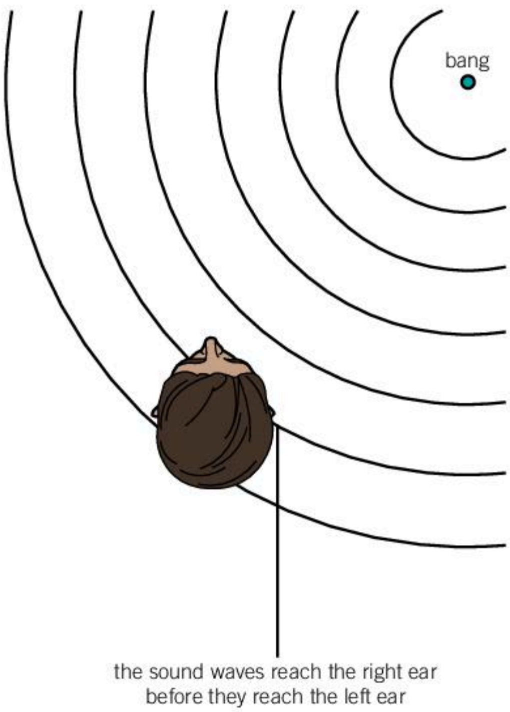
Sound is produced when objects vibrate. The vibrations travel through the air as sound waves. These have speed, wavelength and frequency. We can define sound in terms of both loudness and pitch.

- The loudness of the sound you hear depends on the incoming waves' **amplitude** – a bigger amplitude means a louder sound.
- The **pitch** of the sound refers to the type of sound or tone (low or high) of the sound. It depends on the incoming waves' **frequency** – a higher frequency means a higher pitch. The rumble of heavy lorries and the lowing of cattle are low-pitched sounds and have a low frequency.



▲ **Figure 7.7.2** a) Sound waves for quieter and louder sound b) Sound waves for lower and higher pitch

Two ears are better than one. A sound arrives at one ear slightly before the other. The brain is able to interpret this information in order to determine the direction of the sound.



▲ **Figure 7.7.3** Two ears allow us to determine the direction of sound

Audible range

Although our ears detect sound, they only work within a particular range of frequencies. The upper and lower values of this range are called the **limits of audibility**.

We measure the frequency of sound in hertz (Hz).

- The lowest frequency of sound we can hear is around 20 Hz. Sounds below this value are called **infrasound**.
- The highest frequency of sound we can hear is around 20 000 Hz. Sounds above this value are called **ultrasound**.

Although we can hear all sounds within the audible range, our ears are most effective at hearing sounds around 3000 Hz. The sensitivity of the ears decreases at frequencies above and below this.

Did you know?

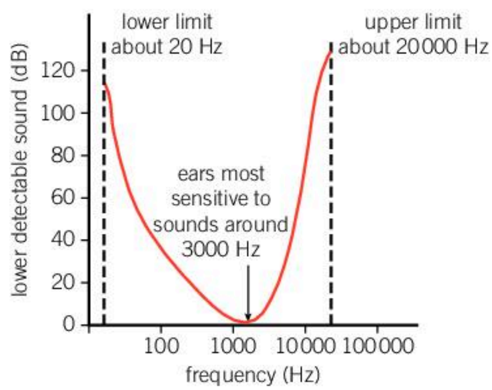
When you have a cold you get a lot of mucus in the back of your throat. This sometimes affects your hearing because the mucus blocks the eustachian tube, preventing the equalising of pressure in the middle ear.

Key fact

Like light, sound travels as a wave, but much more slowly.

Sound travels through the air at about 330 metres each second.

Light travels through the air at about 300 000 000 metres each second.



▲ **Figure 7.7.4** Humans can hear sound frequencies within the audible range

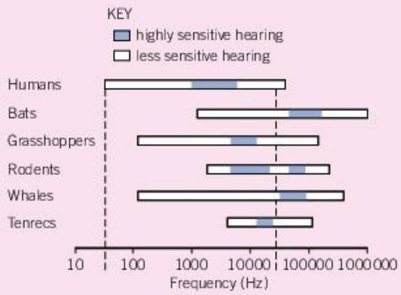
Exam tip

The prefixes kilo and mega can be used in front of hertz just like any other SI (*Système International*) unit.

1 kilohertz (kHz) = 1000 hertz (Hz)
1 megahertz (MHz) = 1 000 000 hertz (Hz)

Did you know?

Different animals are able to hear over different audible ranges.



▲ Diagram showing the audibility range of different animals

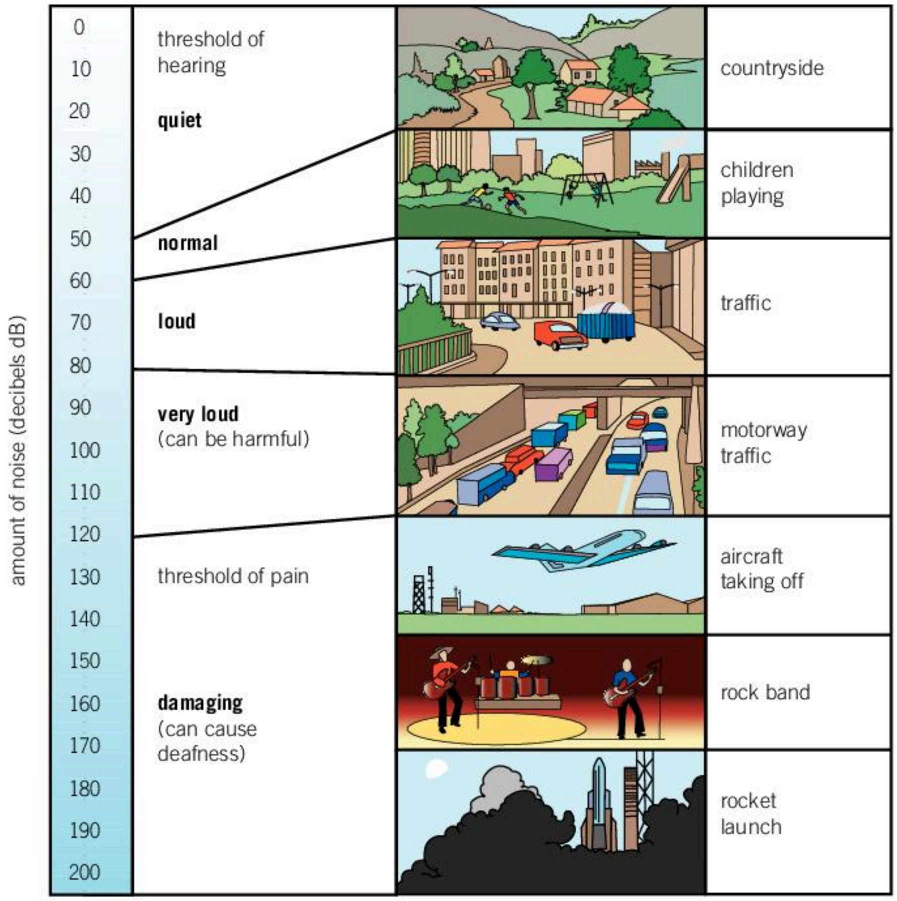
Many animals can hear sounds in the ultrasound region.

The audible range changes with age. As we grow older the range of sounds we can hear becomes less. The ability to hear very high frequency sound is often the first sign that our hearing is deteriorating.

Loudness

We measure the loudness of sound in decibels (dB).

The sounds we encounter in everyday life are mostly in the region of 50–60 dB. Small bursts of louder sounds do not cause any permanent problems provided the sound is not too loud. However, very loud sounds are painful and may cause permanent damage to the hearing.



▲ **Figure 7.7.5** The amount of energy in sound increases with loudness

Practical Activity 7.7.1

Investigating audible range

For this activity you will need a sound generator and a loud speaker.

A sound generator can produce sounds of different frequencies. Your teacher will create sound at different frequencies to determine the lowest frequency and the highest frequency sounds you can hear.

Do not be concerned if you cannot hear very low, or very high, frequency sounds even if other students can. The audible range varies a little from person to person.

Keep a record of the different audible ranges of the students in your class. Investigate ways of showing this on a graph or a diagram, so that you can find out the highest, lowest and the mean.

Deafness

Deafness can be the result of a number of problems. Some of these are easy to treat, while others are irreversible.

We may find it difficult to hear from time to time when the ear canal is blocked with hard wax. This is easily remedied by putting drops in the ears to dissolve the wax or getting the ears syringed at a medical centre.

An ear drum may be burst by a sudden pulse of loud noise, such as an explosion. A burst ear drum will often heal naturally, although surgery is sometimes necessary.

One function of the bones in the middle ear is to amplify sound. As we grow older they become less efficient and are not able to amplify sound sufficiently for it to be detected effectively by the cochlea. The bones may also become diseased or connective tissue may prevent them from working properly.

Deafness, resulting from problems of the middle ear, can often be corrected by amplifying the sounds before they enter the ear using an electronic amplifying device that we commonly call a hearing aid.

Subjecting the ears to frequent or constant loud noise causes damage to the cells that detect sound in the cochlea. This can be an occupational hazard. People who work in noisy environments should wear ear protectors to reduce the level of sound reaching the ear. Damage to the cochlea is irreversible – therefore there is no cure for deafness caused in this way.

Did you know?

Young people who frequently listen to loud music through headphones are just as likely to end up with damaged cochlea and permanent deafness as a person operating a hydraulic drill.

▲ **Figure 7.7.6** Ear protectors reduce the amount of sound entering the ear

▲ **Figure 7.7.7** A hearing aid amplifies sound

Questions

1. Between which two parts of the ear is the oval window?
2. What is the job of the bones in the middle ear?
3. How many hertz are the same as 5 kilohertz?
4. How many decibels is the sound of a jet aircraft taking off?
5. Why should a person working a hydraulic drill wear ear protectors?
6. Why is it dangerous to remove wax from the ears with a sharp object, such as a pencil?
7. Why are people sometimes made deaf by an explosion? Is this loss of hearing permanent?

Learning outcomes

By the end of this topic you will be able to:

- explain the terms receptor, stimulus and effector
- describe the central nervous system (CNS) and the peripheral nervous system (PNS)
- recall the components of the CNS and the PNS
- name some stimuli and describe possible responses to them
- describe the cerebrum, cerebellum and medulla oblongata and describe some functions of each
- name three types of neurone and describe their structure
- identify a synapse and explain how it functions
- explain the difference between a voluntary action and an involuntary action, and give examples of each
- explain why reflex actions are important and give examples of them
- identify paralysis as an effect of damage to the nervous system.

Key fact

The skin is an important sense organ. It contains different kinds of receptors that are stimulated by touch, pain, pressure, hot and cold.

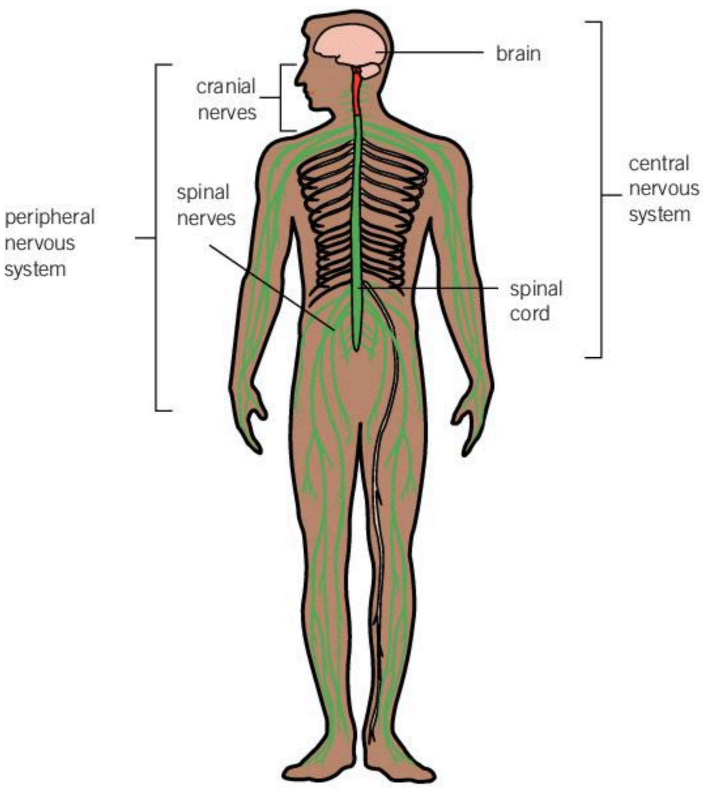
7.8 The structures and functions of the nervous system

Structure of the nervous system

The nervous system enables humans to respond to changes in their environment. This means that we can detect changes using our senses, process information and act on it. It allows us to act quickly using reflex actions. The nervous system also controls processes, such as temperature control and movement.

There are two parts to the nervous system.

- **Central nervous system**, or CNS, which consists of the brain and the spinal cord, and is the main control centre of the body.
- **Peripheral nervous system**, or PNS, which consists of a complex network of nerves that extend out from the CNS into all parts of the body.



▲ **Figure 7.8.1** The nervous system

The body collects information about the environment from sensory cells called **receptors** which are located in sense organs, such as the eyes and ears. This is often the result of a change in the environment called a **stimulus**. The information is sent through the PNS to the CNS, where decisions are made about how the body should respond. Messages are sent back through the PNS to **effectors**, which are muscles and various glands, and these bring about the **response**.

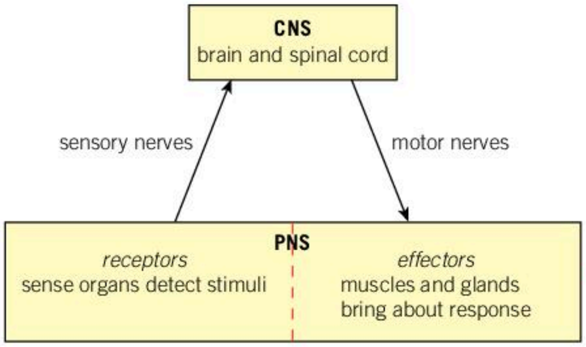


Figure 7.8.2 Impulses pass both ways between the CNS and PNS

The CNS is well protected since damage to it can be fatal. The brain is surrounded by the bony skull and the spinal cord is contained within the vertebrae which make up the back bone.

Practical Activity 7.8.1

Investigating touch receptors in the skin

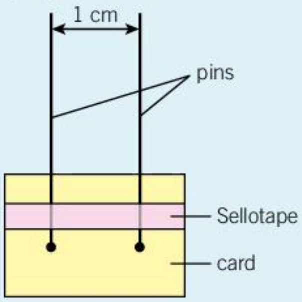
Skills assessed: Observation/Recording/Reporting.

For this activity you must work with a partner. Your teacher will provide you with a pair of pins fixed on a card. You are going to use the pins to investigate touch receptors in the skin.

Safety: The ends of the pins should only be placed onto and not into the skin.

Touch receptors are not spread evenly over the skin. Some areas of skin have more touch receptors that others. You can use the pins to identify those areas with more touch receptors and those areas with fewer.

1. Your partner should not watch what you are doing but simply respond when you touch them.
2. Choose an area of skin, such as the back of the hand.
3. Touch your partner's skin with either one or two pins but do not tell them which.
4. Ask them whether they felt one pin or two and record whether they were right or wrong.
5. Do this 10 times on the back of the hand. How many times did your partner answer correctly and how many times did they answer incorrectly?



6. Repeat the procedure on some different parts of the body, such as the back, the shoulder and the ends of the fingers.
7. Write your results in the form of a table which shows the area of the body, the number of correct answers and the number of incorrect answers.
8. For which parts of the body did your partner make the greatest number of correct answers?
9. For which parts of the body did your partner make the greatest number of incorrect answers?
10. Which parts of the body have the greatest number of touch receptors? Explain why you think this.

Did you know?

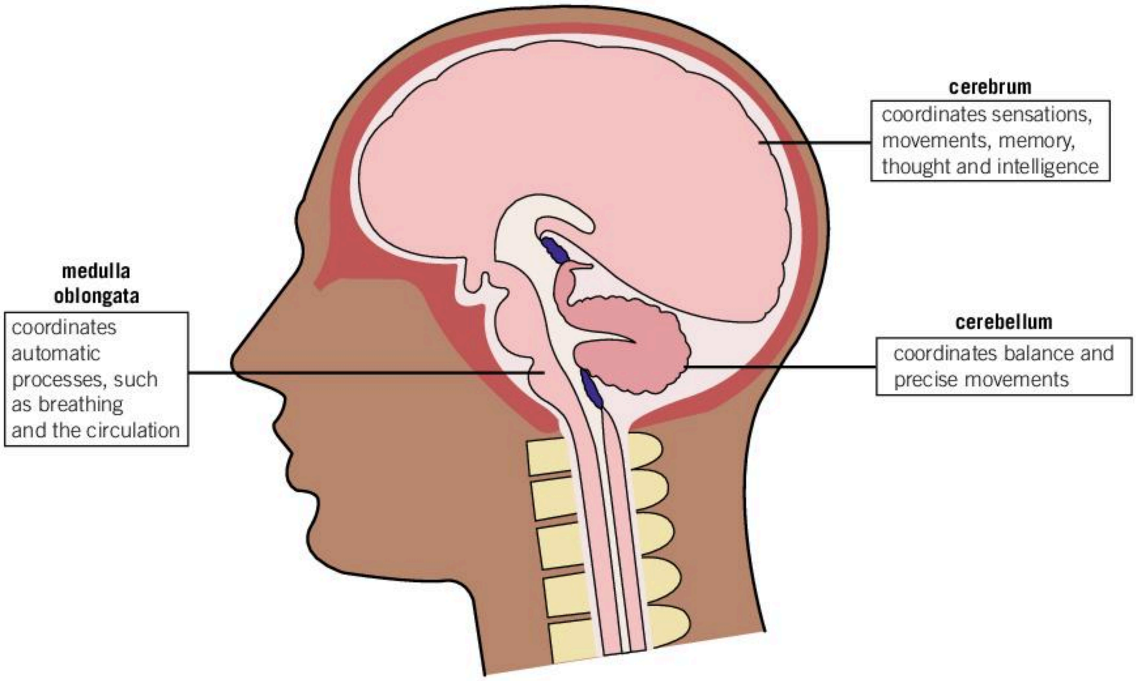
Here is what happens if you are crossing a road and a car suddenly comes around the corner:

1. Receptors in the eye see the car and send a message to the brain.
2. The brain reasons that if you do not move quickly you will be run over and hurt.
3. The brain sends a message to the muscles in the legs telling them to move more quickly.

The car provides the stimulus and moving more quickly is your response.

The central nervous system

In the CNS the brain gathers information and decides how the body should respond. The brain has three main parts, each of which has particular functions.



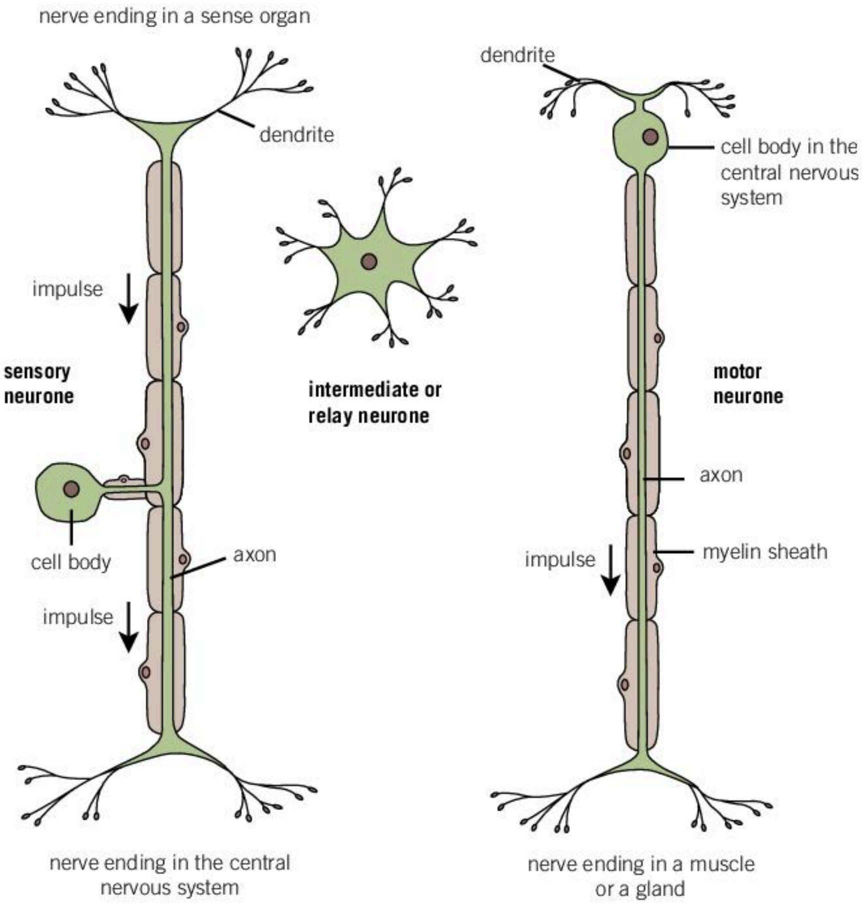
▲ **Figure 7.8.3** Major areas of the brain

- The **cerebrum** is divided into two cerebral hemispheres. It is where information is sent and stored. This information allows us to reason and make decisions about voluntary actions. **Voluntary actions** are those actions that we can control (e.g. bending down to pick something from the floor). Parts of the cerebrum also control functions, such as speech, learning and memory.
- The **cerebellum** is a region at the bottom of the brain. It is concerned with coordinating muscles in order to control our balance. This allows us to stand upright and move about without falling over or tripping over our own feet. These are **involuntary actions** because they work automatically.
- The **medulla oblongata**, or brain stem, is the region where the brain joins the spinal cord. It controls breathing, heartbeat, peristalsis and digestion. It is also responsible for maintaining a constant body temperature. These are also involuntary actions.

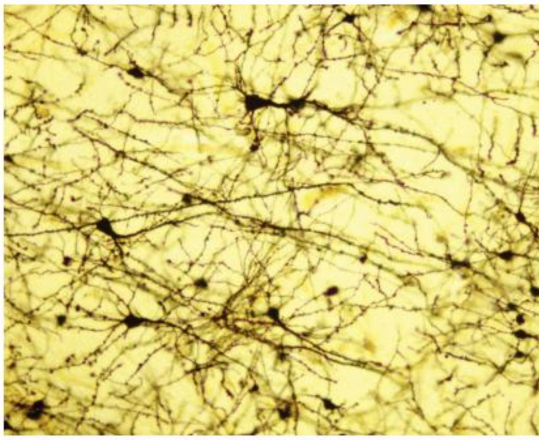
▲ **Figure 7.8.4** MRI scan of the brain

Nerve cells

Messages are sent from the CNS to the rest of the body in the form of electrochemical signals called **nerve impulses**. These impulses are carried by nerve cells or **neurones**. Sensory neurones carry impulses from a receptor, such as the eye, to the CNS, while **motor neurones** carry impulses from the CNS to an effector, such as a muscle. Intermediate or **relay neurones** provide a link between sensory neurones and motor neurones.



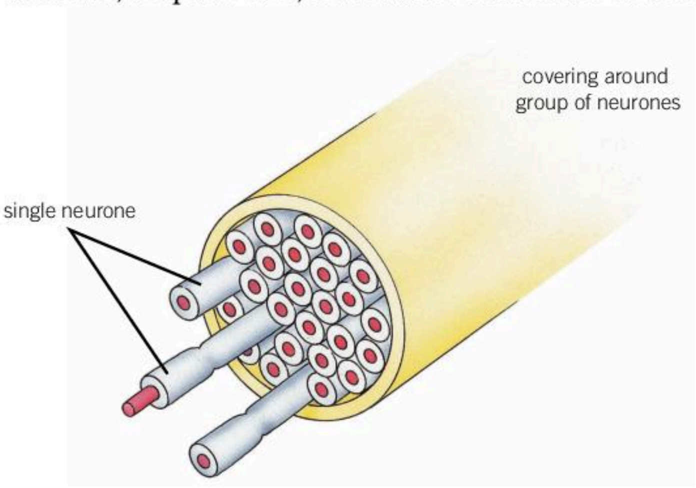
▲ **Figure 7.8.5** Different types of neurones



▲ **Figure 7.8.6** Nerve cells as seen under a light microscope

The **cell body** contains the nucleus of the nerve cell. Extending from the cell body are cell extensions. An **axon**, along which the stimulus travels, transmits an impulse from a sensor to the central nervous system, or from the central nervous system to the effector. It is surrounded by a **myelin sheath**. Myelin is a lipid material which insulates the axon from the cells around it and helps in the transmission of the impulse. Axons can be long. A single axon might run from the spinal cord to the tip of a finger. A **dendrite** transmits an impulse towards the cell body.

Neurones are gathered together in bundles to form **nerves**. Once a nerve enters the brain, or spinal cord, individual neurones are connected to a relay neurone.

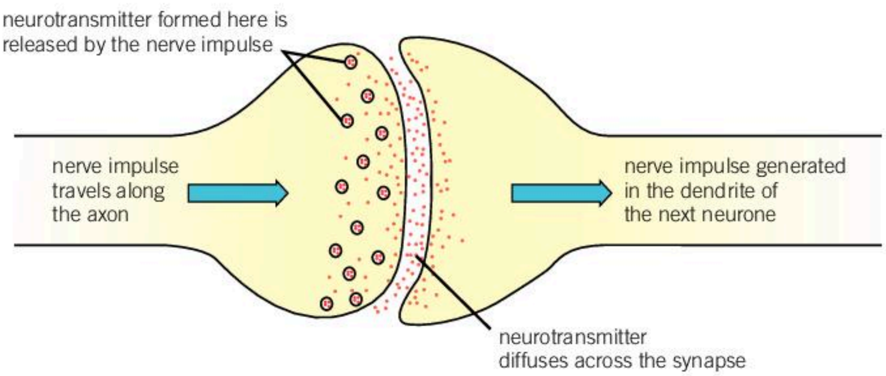


▲ **Figure 7.8.7** Neurones come together in bundles and form a nerve

When neurones link, they do not actually touch each other; there is a small gap between them called a **synapse**. As an impulse reaches a synapse it triggers the release of a special chemical called a **neurotransmitter**. This chemical diffuses rapidly across the synapse and triggers an impulse in the adjoining neurone. The synapse then rapidly resets ready for the next impulse.

Exam tip

A nerve impulse travels along an axon as an electric signal but across a synapse as a chemical signal.



▲ **Figure 7.8.8** A nerve impulse passing across a synapse

Reflex actions

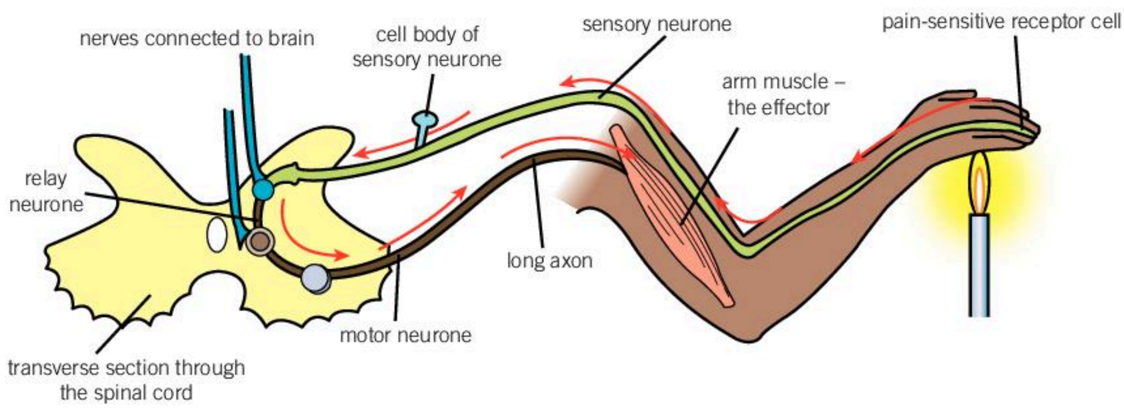
Reflexes, or **reflex actions**, are involuntary, automatic responses to a stimulus. They protect us by enabling us to react quickly to dangerous situations.

Sometimes voluntary actions may not be quick enough to prevent the body from injury. Consider what would happen if you accidentally put your hand near a flame.

If you had to rely on voluntary action, this is what would happen:

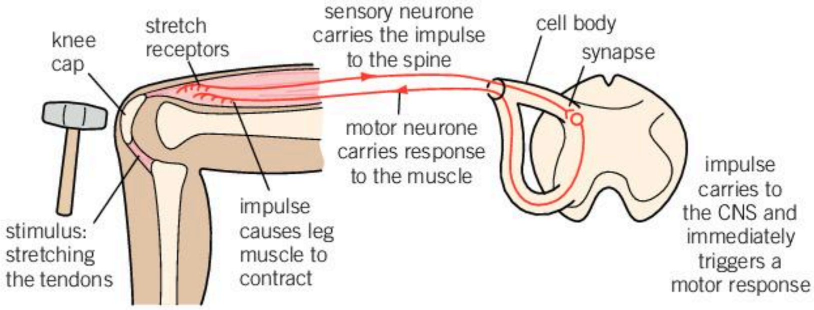
1. Heat receptors in the skin would send a message to the brain.
2. You would reason that if you did not remove your hand it would be damaged.
3. Your brain would send a message to the muscles in your arm telling them to move your hand away from the flame.

Even though nerve impulses travel very quickly, this would not be fast enough to prevent injury. The body has a faster way of moving your hand.



▲ **Figure 7.8.9** A reflex arc

The reflex action occurs as a result of a **reflex arc**. Heat receptors send a message to the spinal cord and the reflex response is sent directly from there to the arm muscles. The brain is not involved. There are neurones running from the brain along the spinal cord, so the brain is aware of what is happening, but it does not bring about the response.



▲ **Figure 7.8.10** Testing the knee jerk reflex

Blinking and the knee jerk reflex are other examples of reflexes. Testing reflex actions provides a doctor with a simple way of testing whether the nervous system is working properly. The reflex action most often used is the knee jerk. If the knee is tapped in a certain place, it causes the leg to give a little kick.

Damage to the nervous system

If nerves are damaged by being cut in an accident, information will not be transmitted. If a sensory nerve is damaged, the brain will not receive information about stimuli. If a motor nerve is damaged, the brain will not be able to transmit information to effectors.

If the brain or spinal cord are damaged, by a physical accident or by a disease, many body functions may be affected. **Paralysis** may occur. This is the loss of muscle control. Damage to the cerebrum may affect the sense organs. Loss of memory, mental ability and personality changes may result from damage to other areas of the brain.

Practical Activity 7.8.2

Testing the knee jerk reflex

For this activity you must work with a partner. You are going to test each other's knee jerk reflex action.

1 Sit your partner on a chair so that one leg is crossed over the other.
2 Stand to the side of them (if you stand in front of them their leg might jerk up and kick you).
3 Gently tap them just below the patella or knee cap with the edge of a book or side of your hand. It is not necessary to hit the knee hard. When you find the right place the leg will jerk up very easily.
4 Get your partner to cross their legs in the opposite way so you can test their other knee.

Questions

1 What do the abbreviations CNS and PNS stand for?
2 Which part of the brain allows us to make voluntary decisions about things?
3 Name three sense organs.
4 What is a stimulus?
5 What is the difference between a voluntary action and an involuntary action?
6 State one similarity and one difference between a sensory neurone and a motor neurone.
7 What happens at a synapse?
8 In what order does a nerve impulse travel through the different types of neurones in a reflex arc?
9 Why does a reflex arc not pass through the brain?
10 How does a doctor often test a patient's reflex actions?

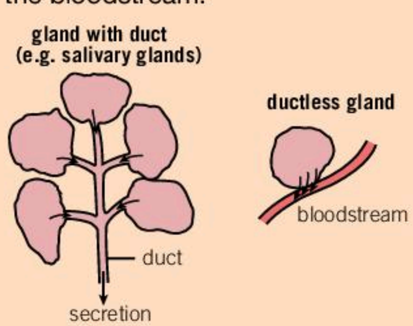
Learning outcomes

By the end of this topic you will be able to:

- name the endocrine glands that make up the endocrine system
- identify where each endocrine gland is found in the body
- state that endocrine glands are ductless glands
- explain how ductless glands differ from other glands
- name the hormone(s) produced by each endocrine gland
- briefly describe the role of each hormone
- describe the type of change and coordination brought about by hormones
- discuss the importance of the pituitary gland as the master endocrine gland
- make comparisons between the nervous system and the endocrine system.

Key fact

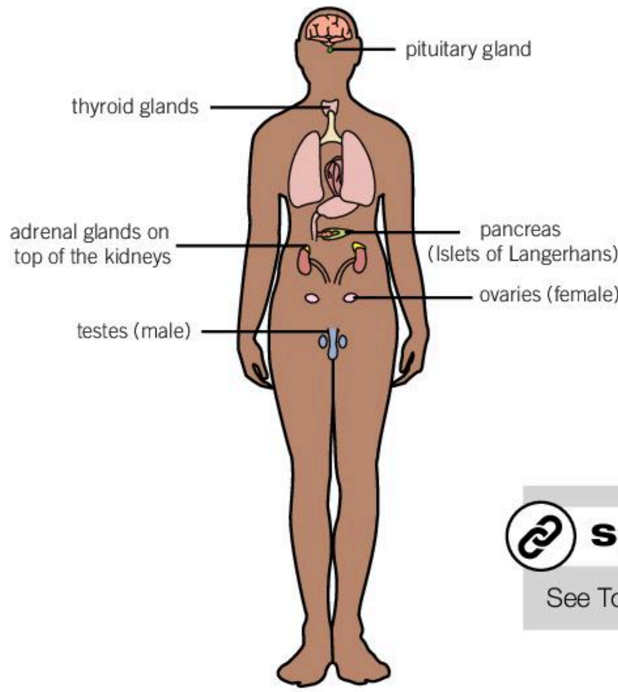
In some glands substances are secreted into tubes or ducts before leaving the gland. Endocrine glands are unusual in that they have no ducts and are therefore described as **ductless glands**. The substances they produce are secreted directly into the bloodstream.



7.9 The endocrine system

Endocrine glands

In addition to the nervous system, the body has another system which is involved in coordination, called the **endocrine system**. This is composed of various **endocrine glands** which are found in different parts of the body.



▲ **Figure 7.9.1** The endocrine glands

Synoptic link

See Topic 2.4 The menstrual cycle

The nervous system coordinates the body by carrying nerve impulses. The endocrine system coordinates the body by releasing special chemicals called **hormones** into the blood to be carried around the body.

Hormones

Each endocrine gland produces one or more special chemical called **hormones**. When released into the bloodstream, a hormone affects a particular organ, called the **target organ**.

Adrenal glands

The adrenal glands are located on the top of the kidneys and release several hormones including adrenaline. Adrenaline is often described as the 'fight or flight' hormone since it is released at times when the body is excited, frightened or stressed.

Adrenaline causes a number of changes which allow the body to deal with the emergency situation. The overall effect is an increase in the rate of respiration which provides the body with more energy.

Nervous system and endocrine system

Since hormones travel in the blood, they take much longer than nerve impulses to go from one part of the body to another. Hormones are not involved in bringing about rapid changes, such as a reflex reaction. Their role is to bring about gradual changes to the body, such as the development of secondary sexual characteristics when a person reaches puberty. They also control the internal environment, such as regulating the functioning of the kidney to ensure the body does not retain too much or too little water.

▼ **Table 7.9.1** Important hormones and their effects on the body

Endocrine gland	Hormones produced	Part played in coordination
Pituitary gland – sometimes called the 'master gland' because it controls the release of hormones by other endocrine glands	growth hormone some male and female reproductive hormones anti-diuretic hormone (ADH) controls the release of hormones by other endocrine glands	Regulates growth of the body Controls sperm and egg production Controls reabsorption of water in the kidneys. A high concentration of ADH causes the kidneys to retain more water, while a low concentration results in more urine being produced
Thyroid gland	thyroxine	Controls the rate of body metabolism The released thyroxine is controlled by the pituitary gland
Pancreas (Islets of Langerhans)	insulin and glucagon	Regulates level of glucose in the blood
Adrenal gland	adrenaline	Prepares the body for emergencies, increases rate of heartbeat and breathing, causes glycogen to be converted into glucose in the liver and causes an increase in the blood supply to the brain and muscles
Ovaries	oestrogen and progesterone	Development of female secondary sexual characteristics and regulation of menstrual cycle
Testes	testosterone	Development of male secondary sexual characteristics

▼ **Table 7.9.2** Difference between the nervous system and the endocrine system

Characteristic	Nervous system	Endocrine system
Form of message	electrical impulses along neurones and chemical messenger called a neurotransmitter across synapses	chemical messengers called hormones
Way in which message is sent	along nerve cells or neurones	carried in the bloodstream
Speed of message	very fast	slow
Body response to message	immediate or short-term response	long-term changes
Reason for response	usually in response to a stimulus	usually concerned with gradual change and maintaining the internal environment of the body (homeostasis)

? Did you know?

Hormone imbalances

If too much growth hormone is produced a person will grow into a giant, while if too little is produced the person will be a dwarf.

The rate of body metabolism is controlled by the hormone thyroxine, produced by the thyroid gland. If too much of this hormone is produced a person's metabolism speeds up and they need more energy. The person becomes thin as the body's energy reserves are used up. If too little is produced a person's metabolism slows down. In children this causes a condition called **cretinism**. In adults it causes tiredness and the face may become swollen and puffy in a condition called **myxoedema**.

✔ Exam tip

You may be asked to compare the different characteristics of the nervous system and the endocrine system.

Questions

1. In which part of the body is the adrenal gland?
2. How are hormones transferred from one part of the body to another?
3. Which hormone is released by the thyroid gland?
4. What type of change is coordinated by the endocrine glands?
5. Why would the endocrine system not provide an effective reflex reaction?

Exam-style questions

Multiple choice

1 From which endocrine gland is anti-diuretic hormone secreted?
A adrenal gland **B** kidney
C pituitary gland **D** thyroid gland

2 Our ears are most effective at hearing sounds of:
A 400 Hz **B** 2000 Hz
C 3000 Hz **D** 1500 Hz

3 The part of the brain responsible for voluntary actions is the:
A cerebellum **B** cerebrum
C medulla oblongata **D** pituitary gland

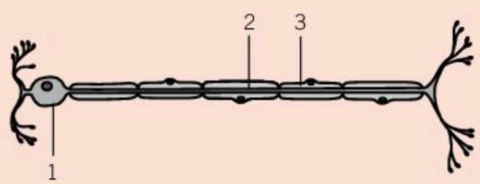
4 Which of the following is a natural source of light?
A candle **B** kerosene lamp
C Sun **D** torch

Structured questions

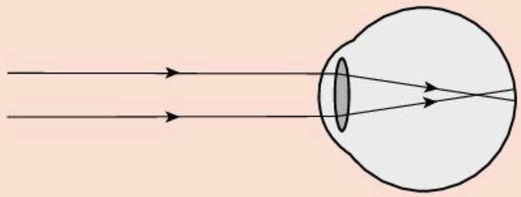
5 a Explain the difference between a transparent, a translucent and an opaque material, giving one example of each.
b Which type of material would be best for a bathroom window? Explain your answer.

6 a What is the process in which white light is separated into light of different colours when passed through a glass prism?
b Why does this separation take place?
c Give the names of the different coloured lights in order starting with red.

7 The diagram below shows a neurone.
a What type of neurone is shown?
b Provide labels for parts 1 to 3.
c Explain how a nerve impulse can pass from one neurone to another.



8 The diagram shows someone with defective vision.

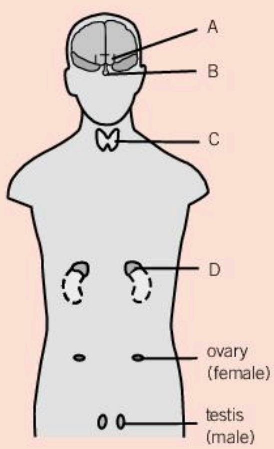


a From what defect does the person suffer?
b How could the defect be corrected and what type of lens would be needed?

9 From the list below select the structure which carries out the function described in the statements **a** to **f**:

auditory nerve, ear drum, cochlea, ossicles, eustachian tube, semicircular canals, oval window
a enables pressure to be equalised on either side of the ear drum
b the region where sounds are converted to nerve impulses
c transmits vibrations to the inner ear
d helps maintain balance
e takes nerve impulses to the brain
f transmits sound waves to the middle ear

10 The diagram shows the position of some endocrine glands.



a What is an endocrine gland?
b Give the letter of the gland(s) which:
  i) produces a hormone that increases the heart rate
  ii) produces a hormone that regulates metabolic rate
  iii) is described as the 'master gland'.
c Name one endocrine gland that is NOT shown on this diagram and describe one effect on the body of increased secretion of the hormone from this gland.

Section A

8 Health and sanitation

Keeping yourself, and your environment, clean and tidy is an essential part of modern society. Personal hygiene should be a matter of personal pride, so you can always look your best. Keeping the surroundings tidy and free from waste is a statement about how much the environment is cared for. Many pests are attracted to food and housing. If they are given the opportunity, organisms, such as cockroaches, mosquitoes and houseflies, can cause damage and disease. Suitable methods need to be in place to protect people and the environment from pests. The environment needs to be clean so that pests are not provided with conditions in which they can thrive.

Learning outcomes

By the end of this topic you will be able to:

- state the importance of good personal hygiene
- explain why the skin, hair, nails and teeth must be regularly cleaned
- state the importance of good hygiene in school and in the workplace
- recall some of the potential dangers associated with poor hygiene
- state what sewage is
- explain why the safe disposal of sewage is very important
- describe some of the problems associated with leaving garbage lying around
- explain the importance of regular garbage collection.

8.1 Good personal and community hygiene

Personal hygiene

Personal hygiene is about keeping ourselves clean and looking after our bodies.

Our skin is amazing. It stretches and bends as we move, and it keeps out harmful microbes that would otherwise invade our bodies and make us ill. However, our skin can only do these things if we look after it properly.

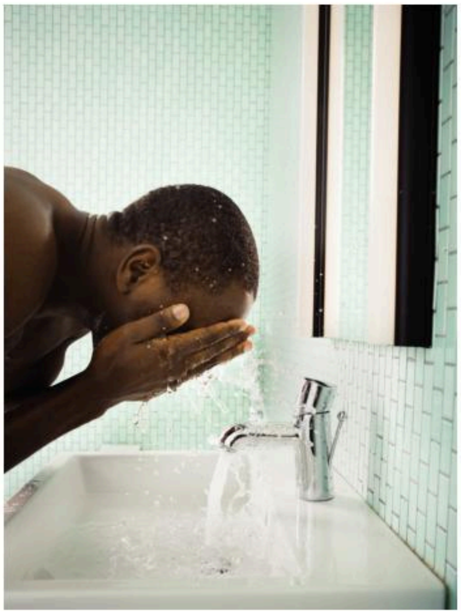
Your skin gets dirty through the day as you come into contact with dust and dirt. Urea is a waste product that is released by the body. Most of it leaves the body in solution as urine but some is also excreted through the skin as you sweat. If you don't wash your skin every day, the urea will build up on your skin and will soon start to release bad odours. People tend to sweat around the genitals, so this area must be regularly washed to prevent odours. Possible infections, such as rashes, can also develop as a result of poor hygiene.

Washing should also involve the areas around your eyes and in your ears. Ears produce wax which, if allowed to build up, may lead to ear infections and may also affect your hearing. Sometimes washing doesn't remove all of the wax from your ears, so you may need to use moistened ear buds.

A cotton bud is a small piece of cotton wool attached to a stick which, if used gently, can clean the inside of the ears without harming them. Don't ever be tempted to clean your ears with sharp objects, such as pencils and sticks. They may cause damage that will lead to ear infections.

Your hair and your scalp – the skin under the hair – needs to be washed and combed at least once each day.

Apart from keeping hair neat and tidy, regular combing ensures that you don't pick up any parasites, such as head lice, which feed on blood and make your head itchy.



▲ **Figure 8.1.1** Washing keeps our skin clean

Finger nails and toe nails should be regularly trimmed, and any sharp edges rubbed down with a nail file or an emery board. Long nails often split and microbes may cause the ends of the fingers to become infected.

Dirt should be regularly removed from the ends of nails, and they should be washed with soap and a small nailbrush to make sure they are really clean.

Teeth are an essential part of your digestive system. Once your adult teeth have erupted, they cannot be replaced, so it is essential that you look after them.

A substance called **plaque** builds up on your teeth each day. Traces of the food that you eat are absorbed by the plaque and turned into harmful acids. The acids attack the outside layer or enamel of the teeth.

Fortunately, the action of plaque is very slow, so if you clean your teeth regularly they should remain in good condition. You should also pay regular visits to the dentist to check that your teeth are healthy.

Practical Activity 8.1.1

Report – Visiting the dentist

Write a report about the last time you visited the dentist. Here are some questions you might ask yourself to compile your report.

- What did the dental surgery look like?
- What did the dentist say?
- What did the dentist do?
- Did you have to have any treatment?
- How long did the examination take?
- How did you feel before, and after, the examination?

Question

1 Copy and complete the following sentences.

a We should always wash our hands before ___________.

b ___________ on food may enter the body when we eat.

c When nails split, microbes may cause finger tips to become ___________.

d Regular combing makes sure we don't get ___________, such as head lice.

e We should never clean our ears with ___________ objects.

Hygiene in school and the workplace

As well as keeping yourself clean, it is important that you develop good hygiene habits both in school, and later, in your workplace.

Although the skin provides a barrier against microbes, it is still possible for microbes to enter the body through the mouth. For this reason you should regularly wash your hands, particularly after you have used the toilet. This reduces the chances that you, and the people you sit with and play with, will become infected.

You should always wash your hands before eating food. If you do not, microbes may be transferred from your hands to the food you eat and enter your body.

Toilets and bathrooms must be washed and disinfected regularly so that microbes do not have an opportunity to build up and infect the people who use those rooms.

People, such as chefs, who prepare food for others, or who serve in shops that sell food must be exceptionally careful to keep themselves and their workplace clean and free from microbes. Food must be covered to prevent flies landing on it and kept in a refrigerator until it is needed. When preparing a meal, food must be well cooked to kill any microbes that may be present on it.

Doctors and nurses who are working with sick people must also be constantly aware of the need for good hygiene practices. It is possible for them to transfer an infection from one person to another if they do not wash their hands after examining each patient.

▲ **Figure 8.1.2** Microbes can enter the body on food

Question

1 Read the following passage:

A group of eight people had dinner at a restaurant. They had a variety of dishes including soup and rice, and vegetables with chicken. The next day, five of the people had stomach pains and suffered with diarrhoea. The doctor who examined them said that they were suffering from food poisoning.

- a Suggest how the people got food poisoning in the restaurant.
- b Suggest why only five of the eight people were affected.
- c What action should the authorities take?

▲ **Figure 8.1.3** Sewage is broken down at special treatment plants

Links

See Topic 17.5 Water pollution.

Waste disposal

Our bodies produce waste in the form of urine and faeces. This type of waste is called **sewage**. Apart from being unsightly and very smelly, sewage is a potential source of infections. For these reasons, it must be disposed of in a way that will not damage the environment.

There must be adequate toilet facilities for people so that they are not tempted to leave their waste in the open. Insects may lay eggs in the exposed waste and it could also be washed into the fresh water system when it rains. Some parasites can be passed on from one person to another in contaminated drinking water.

Sewage should not be dumped directly into rivers, or into the sea, because it contains chemicals that will damage the environment. Some chemicals in sewage can kill organisms. Other chemicals can cause a huge increase in the growth rate of aquatic plants. The process of **eutrophication** – when the increased plant population dies and decomposes – can lead to the death of aquatic animals, such as fish.

Sewage should be sent to a sewage treatment plant where the harmful components are broken down. The water that remains after treatment can be safely released into the environment. The solid remains are usually used to fertilise fields to improve crop growth.

As well as looking unsightly, garbage is also potentially dangerous because:

- it is a breeding ground for many pests, such as houseflies and rodents
- people might trip over it and hurt themselves
- it might release harmful substances into fresh water supplies.

Garbage should be regularly collected for disposal at designated landfill sites where it will be spread out and eventually covered with soil.

Question

1 Village A does not have a sewage treatment plant, so sewage is released into the river. Village B is one mile downstream from Village A. Village B relies on the river to supply fresh water for drinking.

What problems might the release of sewage at Village A have for:

a the organisms in the river

b the people who live in Village B?

8.2 Household pests and parasites

Pests and parasites

As we have seen, a pest is an organism that causes harm or damage to crops and livestock. A **parasite** is an organism that lives on, or in, another living organism, called its **host**. A parasite gets all its food from the host. Some parasites, such as tapeworms and the organism that causes malaria, live inside their hosts; others, such as fleas and lice, live on the outside. Fleas, lice and ticks feed on blood from humans and animals. Tapeworms live in the small intestine of humans and other animals, and absorb digested food from their hosts. All parasites cause harm to their hosts.

A pathogen is a bacterium, a virus or another type of micro-organism that can cause disease. For example:

- salmonella food poisoning is caused by a bacterium
- influenza is caused by a virus
- ringworm is caused by a fungus
- amoebic dysentery is caused by a single-celled organism.

A **vector** is an organism that spreads diseases by carrying the pathogen from one host to another. The vector does not contract the disease, for example rats spread many diseases that do not affect them.

Household pests

There are organisms that can create problems in the home. Examples include flies, cockroaches, rats, mice and mosquitoes. See Table 8.2.1.

Controlling pests

If our environment is kept tidy and clean there is less chance that pests will be attracted to it.

▲ **Figure 8.2.3** Mosquito net being used for protection

Learning outcomes

By the end of this topic you will be able to:

- distinguish between a pest, a parasite and a pathogen
- list types of household pests and the conditions that attract them
- describe the health problems associated with some pests
- list ways to control pests
- list ways to control parasites.

▲ **Figure 8.2.1** Flies are a common pest

Synoptic link

See Topic 1.4 Microbes.

▲ **Figure 8.2.2** Black rat

Did you know?

In 2006, there was an outbreak of malaria in Kingston, Jamaica. It lasted into 2009. Insecticide-treated nets were donated to help combat the spread of the disease. There have been cases of dengue fever in Trinidad, especially when temperatures are high.

- Surfaces should be regularly cleaned with disinfectant.
- Food waste should be removed to prevent rats and mice getting to it.
- Food should be stored correctly in closed containers to prevent flies landing on it.
- Screens on windows can be fitted to stop flies and mosquitoes entering homes.
- Pesticides including insecticides can be applied to control pests.

▼ **Table 8.2.1** Household pests

Pests	Conditions that encourage breeding	Effects on humans
Flies	Breed in decaying food and animal waste. They are attracted to food and faeces from which they can pick up bacteria and viruses.	Can carry diseases, such as dysentery, cholera and typhoid fever. The eggs hatch into maggots.
Cockroaches	Breed in warm, dark and moist places, such as empty bottles, paper bags, beneath piles of paper. Attracted to food.	Carry bacteria on their bodies, and in their faeces, which may be passed on to humans if tainted food is eaten causing food poisoning. When faeces dry out the bacteria can be carried into the body with inhaled air. Can cause allergies.
Rats and mice	Breed in warm, dark places. Attracted by food even if it is in containers; most active at night.	Can transmit bacterial diseases including leptospirosis. A severe form of this is called Weil's disease and it can be fatal. Rats carry parasitic fleas which can also transmit disease.
Mosquitoes	Breed in stagnant water where there is decaying plant material (e.g. a pond or swamp); also found in blocked drain pipes, old pots or discarded buckets that contain water. Adult mosquitoes are more active at night in warm, still conditions.	Mosquito eggs hatch into larvae which live and grow in water. Eventually they form pupae from which the adult mosquitoes emerge. Mosquitoes are vectors that spread parasitic organisms which cause serious illnesses.
Anopheles mosquitoes	Lay eggs in any stagnant water	Spread malaria
Culex mosquitoes	Lay eggs in stagnant water or on moist surfaces, in mud and damp leaves	Spread elephantiasis
Aedes mosquitoes	Lay eggs in stagnant water	Spread dengue fever and yellow fever

Controlling parasites

Parasites are passed on from person to person, or sometimes from animal to person, so we must develop habits that prevent this.

Head lice are parasites that live on the scalp. They lay eggs in the hair that are called nits. Head lice can be passed from person to person if you put your head close to someone who has lice or if you share a comb or brush with them.

Nits can be removed from hair using a fine nit comb. Head lice can be easily treated using special shampoo.

Parasitic threadworms (sometimes called pinworms) live in the intestine. They sometimes make the area around the anus itchy. If you scratch the affected area or use the toilet without washing your hands, eggs can get onto your food and re-infect you, as well as anyone else whose food you touch. Always wash your hands thoroughly using a small brush to clean under your nails after you have used the toilet.

Threadworms can be treated by taking worming tablets containing the drug mebendazole.

It is not just humans that can be a host to parasites. Animals may also carry parasites. One particular roundworm, called *Toxocara canis*, which is carried by dogs, can be transmitted to humans. It can cause serious damage to vital organs, such as the brain.

Pet dogs and cats should be dewormed regularly. Never allow a dog or cat to lick you, especially around the face. Always wash your hands thoroughly after playing with pets.

▲ **Figure 8.2.4** Nits are the eggs of head lice

▲ **Figure 8.2.5** Parasitic worms live in the intestine

Questions

1. What are the characteristic features of parasites?
2. What are maggots?
3. Which pest may transmit the disease leptospirosis?
4. Which type of mosquito is responsible for spreading malaria?
5. State what a pathogen is.
6. Explain how a person working in the kitchen of a restaurant could pass on parasites to customers.

Learning outcomes

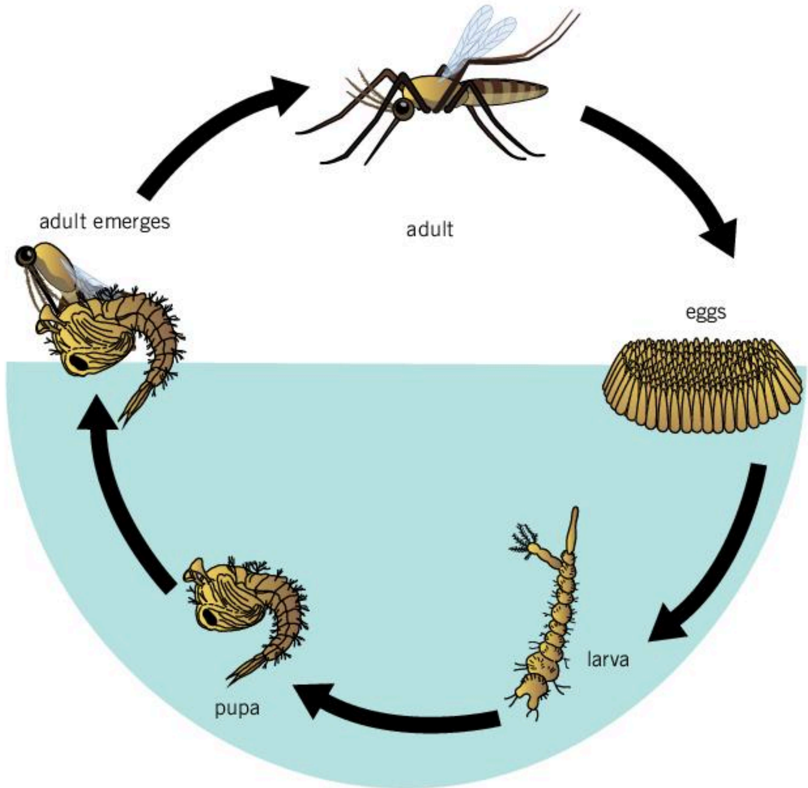
By the end of this topic you will be able to:

- state the different stages in the life cycle of mosquitoes
- describe how mosquitoes can be controlled at each point in their life cycle
- state the different stages in the life cycle of houseflies
- describe how houseflies can be controlled at each point in their life cycle.

8.3 Methods of controlling the mosquito and the housefly

Mosquitoes

You already know from the previous topic that mosquitoes are pests that can transmit several very unpleasant diseases. It is important to understand the life cycle of the mosquito to combat this threat.



▲ **Figure 8.3.1** Life cycle of the mosquito

Adult mosquitoes lay their eggs in water. You can prevent mosquitoes from laying their eggs in water at home by making sure that drains aren't blocked and that there is no rubbish lying around that fills with water when it rains (e.g. old tyres or plastic pots). An old bucket would be big enough to allow a mosquito to lay its eggs and the larvae to grow.

◄ **Figure 8.3.2** Small fish, such as guppies, feed on mosquito larvae

Mosquito larvae are active in water and must come to the surface to breathe. One method of chemical control is to spread a thin film of oil over the water. This prevents the larvae from obtaining oxygen but it also affects other aquatic organisms. An alternative biological control is to introduce small fish, such as guppies, which eat mosquito larvae and pupae, to the water.

The pupae hatch to release adult mosquitoes that live in the air. Individual mosquitoes can be squashed with suitable objects, such as a fly swat or a rolled-up newspaper.

▲ **Figure 8.3.3** Electronic insect killer

Insecticide sprays provide a chemical control. They contain chemicals that kill mosquitoes and other insects. They can be used to kill mosquitoes in the home. Covering doors and windows with fine mosquito mesh will prevent mosquitoes entering the home from outside.

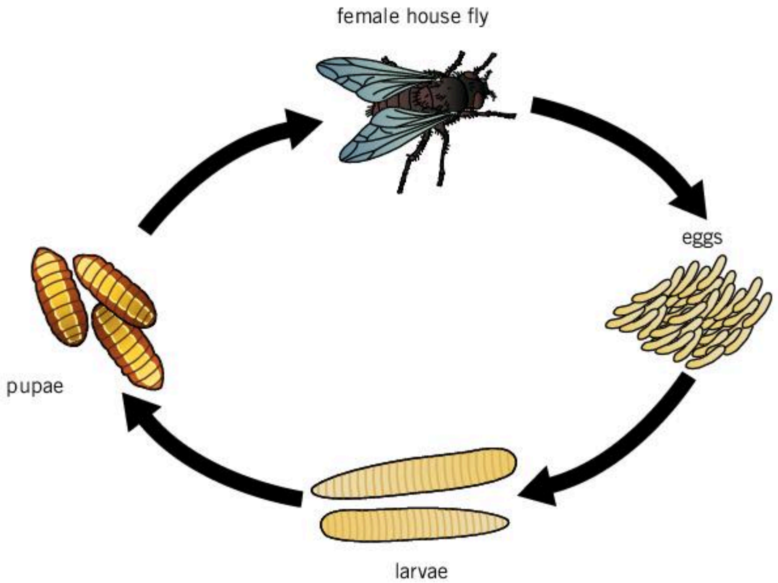
Electronic insect killers provide a mechanical control. They contain a light that attracts the mosquitoes and when they get close enough they are electrocuted.

One biological control method, that might become important in the future, is the release of a large numbers of sterile male mosquitoes into an area. The idea is that the sterile males will breed with female mosquitoes and no offspring will be produced. As there will be a decreased number of normal males breeding with female mosquitoes, fewer mosquito eggs will be laid. It is hoped that repeating this strategy in the same area for several years will drastically decrease the mosquito population in that area.

▲ **Figure 8.3.5** Fly paper

Houseflies

Houseflies can also be controlled in various ways during different stages of their life cycle.



▲ **Figure 8.3.4** Life cycle of the housefly

Houseflies lay their eggs on food or on animal waste.

You can prevent houseflies from laying eggs on food by making sure it is never left uncovered and that surfaces are disinfected. Any waste outside, such as faeces from pets, should be placed in a bin with a lid or buried in the ground. The larvae and pupae of houseflies will eventually grow into flies if they are not destroyed. One biological control is to put any infected food outside. Birds will quickly eat the larvae and pupae.

Houseflies, like mosquitoes, can be controlled chemically using a spray, or mechanically using an electronic fly killer.

An alternative method of mechanical control is sticky fly paper. The flies land on it and then cannot take off again so they remain stuck on the paper and die.

Questions

1 Explain the difference between biological control, chemical control and mechanical control.

2 Explain how mosquitoes may be controlled using each of these methods.

8.4 Food contamination

Ways in which food may be contaminated

Food is contaminated when it contains either organisms or chemicals that should not normally be there. These may have been added deliberately or they may have found their way into our food by accident. We are not usually aware of them unless they spoil the taste of the food or they make us ill.

The following are some common contaminants of food.

Pollutants, such as particulates from burning fossil fuels or caustic fumes from processing bauxite, can end up on our food.

Pesticides are often sprayed on to crops by farmers to kill pests and increase yield. If the amount applied is too high, or if the crops are sprayed near harvesting time, then some pesticide residues may be found on, or in, our food.

Fertilisers may be washed off fields and find their way into drinking water. This water may also be used to wash fruits and vegetables ready for the market.

Animal hormones, such as diethylstilbestrol (DES), have been fed to beef cattle and chickens in order to improve their growth. Residues of these hormones in the meat we eat can have a negative effect on our health.

Micro-organisms, such as bacteria, may be introduced into our food by flies landing on it or from peoples' hands when the food is handled.

Reducing the risk of contamination

Some of the contaminants mentioned earlier are beyond our control. It is impossible to know if vegetables or fruit came from a farm that was near a busy, polluted road, or whether the farmer sprayed his crops with pesticides the week before they were harvested. These contaminants would not alter the appearance of the food. Therefore, sensible precautions need to be taken to reduce the risk from contaminants.

▲ **Figure 8.4.1** Washing fruit and vegetables

Learning outcomes

By the end of this topic you will be able to:

- state some different ways in which the food we eat might become contaminated
- describe ways in which contamination may be removed or prevented.

All fruit and vegetables should be washed to remove any residues that may be on the outside. Any areas of the skin that look damaged should be cut away before eating.

Before starting to prepare food, you must wash your hands thoroughly to make sure that you do not contaminate the food yourself. Preparation surfaces, such as a chopping boards, must be wiped down and all the utensils you use should be clean.

▲ **Figure 8.4.2** Covers prevent insects from landing on food

When food is to be left out it should be covered (e.g. with a mesh fly cover) to prevent insects from landing on it.

Some foods, such as meat and fish, are **perishable**. They will spoil if they are kept at normal room temperature. These foods should be stored in a refrigerator until they are needed. The refrigerator should also be used to store food during preparation or prepared food that is to be eaten later. This prevents insects and air-borne micro-organisms from landing on it.

Question

1 You are going to cook curry chicken skewer served with eggplant relish. What steps would you take to ensure the food doesn't become contaminated during the preparation?

8.5 Controlling pests

Learning outcomes

By the end of this topic you will be able to:

- explain the difference between biological, chemical and mechanical control and give examples of each
- appreciate the advantages and disadvantages of the different methods of control.

Control

Control in this context means controlling populations of pests and eliminating them. There are four main methods of control.

- Sanitary control by which the conditions which attract pests are eliminated.
- Biological control in which control is achieved by natural means.
- Chemical control in which chemicals are used.
- Mechanical control in which some sort of device is used.

Sanitary control

Many pests, such as rats, cockroaches and flies, are attracted by garbage. Old food wrappers smell inviting and there may be left-over food in them.

▲ **Figure 8.5.1** Garbage is a magnet for pests

It is inevitable that garbage dumped on the side of the road or on empty plots of land will attract pests. To control pests, dumped garbage should be removed and disposed of properly in the correct place. Refraining from dumping garbage inappropriately would be the ideal solution.

The same philosophy should be applied in the home and workplace. If surfaces, and areas, are kept free from waste food and food spillages, there is nothing to attract the pests.

Biological control

Most organisms have a natural predator – something that feeds on them. Biological control makes use of this feeding relationship by introducing a natural predator of the pest.

Cats were originally kept in houses to control mice. In some countries, the same is done by boa constrictor snakes!

▲ **Figure 8.5.2** Biological control of aphids using ladybirds

▲ **Figure 8.5.3** Biological control organisms are introduced to the area where the pest is active

There are many examples of biological control used in agriculture, particularly in greenhouse cultivation (see Table 8.5.1).

▼ **Table 8.5.1**

Agricultural pest	Biological control used
whitefly	a small parasitic wasp that is originally thought to come from South America a long shiny black ladybird beetle is also used to combat whitefly
spider mite	a predatory mite originally from Chile
mealy bugs	a ladybird predator which originally comes from Australia
scale insect	a parasitic wasp
aphids	a small midge a two-spotted ladybird is also used to control aphids
cutworms and caterpillars	a pathogenic nematode controls these pests in the soil
vine weevil	a pathogenic nematode is also used to control this pest

A small sample of the control organism is introduced to the area where pests are a problem. Since there is plenty of food for the predator, its numbers will soon increase, and the numbers of pests will fall.

Biological control is preferred to chemical control because:

- the crop is not tainted with potentially harmful chemicals
- the control organism is easy to introduce and does not require time-consuming spraying
- repeat treatment is not necessary; once the control organism is established it will continue to control the pest.

Chemical control

Chemical control involves using chemicals called **pesticides** to kill pests. Pesticide may be applied by a hand sprayer, from a tank pulled by a tractor or even from the air using a special plane.

▲ **Figure 8.5.4** Pesticides can be sprayed over crops using a special plane

Chemical controls are still widely used but the availability of alternative biological controls is making them less popular. Although chemical pesticides are effective in controlling pests, there are certain problems associated with them.

- They are indiscriminate and, as well as killing pests, they may kill other organisms that are not pests.
- They may leave harmful residues on food.
- They may get into food chains and affect other animals.
- Over time, pests might develop a natural immunity to the pesticide.
- The spraying must be repeated at regular intervals as more pests move into the area.
- Spraying large areas of crops is time consuming.

Mechanical control

You have already read about some examples of mechanical control in the form of fly paper and electronic insect killers in the topic on controlling mosquitoes and houseflies.

Traps are a method of mechanical control of pests. The mousetrap is a traditional method of controlling mice.

A wasp trap is a mechanical control which is often used to remove wasps from areas where the family eats outside and where the wasps become a nuisance.

Practical Activity 8.5.1

Making a wasp trap

Materials:

- Empty two litre plastic bottle
- Scissors
- String

Method:

1. Remove the cap from the bottle.
2. Cut around the bottle about one-quarter of the way from the top.
3. Turn the top part upside down and push it into the bottom part.

4. Make two holes in opposite sides of the trap near the top using the point of the scissors.

Safety: Be careful not to make holes in your fingers at the same time.

5. Tie some string between the holes so the trap can be hung up.
6. Try out your trap at home by putting fruit cordial (syrup) in the bottom to a depth of 1 cm and hang it where wasps are a nuisance.

▲ **Figure 8.5.5** A wasp trap

▲ **Figure 8.5.6** A fruit cage

Mechanical controls do not necessarily have to kill the pest. For example, netting spread over fruit to prevent birds eating it is a method of mechanical control. Mechanical control devices do not contaminate the area around them like chemical controls. However, they can be very time consuming to set up and may not be effective against a large populations of pests.

Questions

1 What type of control is each of the following?
   - a Mosquito netting
   - b Fly insect spray
   - c Hens digging up pests in a vegetable garden
   - d Keeping garbage in a sealed bin

2 A farmer has an outbreak of whitefly in a greenhouse where he grows tomatoes for the market. Why might he prefer to use a biological control rather than a chemical control?

8.6 Waste

There are three types of waste that humans must remove: domestic, industrial and biological waste. If this waste accumulates it will cause land, water and air pollution.

- **Domestic waste** is household waste or garbage.
- **Industrial waste** is produced as a result of building and manufacturing. For example, mines produce large quantities of rock once minerals have been extracted.
- **Biological waste** is sewage which is produced by humans (urine and faeces).

Learning outcomes

By the end of this topic you will be able to:

- describe three types of waste that humans produce
- describe materials that can be recycled and re-used
- explain how compost is formed
- describe how biogas is formed.

Biodegradable and non-biodegradable materials

Materials that can be broken down naturally by micro-organisms are called **biodegradable**. Food waste and paper are biodegradable and can be allowed to break down in compost heaps without special treatment. Human sewage is also biodegradable but is disposed of in sewage treatment plants because of the risk of diseases being spread. Most plastics and other modern materials cannot be broken down naturally and are called **non-biodegradable**.

Reduce, recycle and re-use

There is only a limited area of land on Earth that can be used for waste disposal. As the human population grows and more waste is produced, the need for finding ways to reduce waste production increases.

- We need to **reduce** the amount of resources that we take from the environment.
- Some materials can be made into something else instead of being thrown away. This is called **recycling**. For example, plastic, paper and glass can be recycled.
- Many things that we think of as waste can in fact be **re-used**. For example, plastic bags and glass jars can be used more than once.
- Waste vegetable material can be allowed to rot in a **compost heap** to provide valuable fertiliser for the garden.

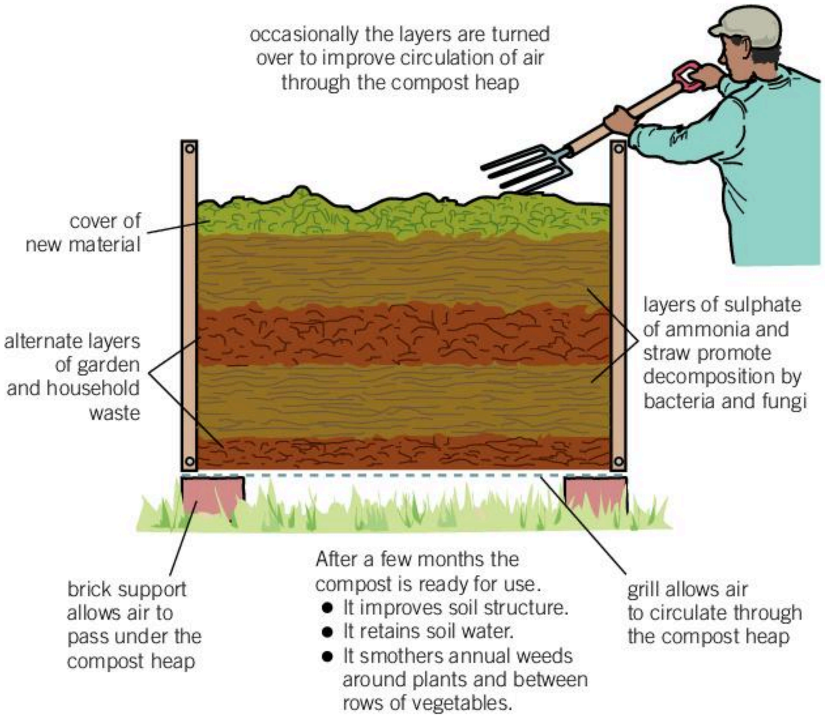
▲ **Figure 8.6.1** Recycling reduces the demand for raw materials

Practical Activity 8.6.1

Recycling in your area

Find out what provision there is for recycling in your area.

1 What materials are recycled?
2 Where is the nearest place where you can take these materials for collection?
3 What happens to these materials?
4 Does your school have a policy on recycling?



▲ **Figure 8.6.2** The structure of a compost heap

Biogas

Energy from animal waste (dung) produced on farms can be harnessed. This is called **biogas**. The fuel that is produced, as anaerobic bacteria decay the dung, can be used for cooking and heating. Dung can also be used to fertilise crops.

Questions

1. Name three materials from household waste that can be recycled.
2. Explain ‘reduce, recycle and re-use’.
3. List the three types of waste that humans produce, giving examples of each.
4. Why are sulphate of ammonia and straw used in a compost heap?
5. Explain how biodegradable materials differ from non-biodegradable materials.
6. What is biogas made from?

8.7 Waste disposal

Problems caused by household pests can be reduced by maintaining a clean and tidy environment around us. This includes good sanitation by disposing of all forms of waste. This is called **waste management**. Good sanitation is about disposing of waste promptly and in a way which is not going to damage the environment. Poor sanitation and waste management can lead to illness and spread diseases.

Communities need to dispose of their waste quickly and safely with the minimum impact on the environment.

Waste disposal companies and local governments are responsible for removing waste and providing adequate facilities for sewage disposal.

▼ **Table 8.7.1** Methods of waste disposal

Disposal methods	Suitable for	Environmental impact
Dumping	Biodegradable materials	Unsightly Breeding ground for pests, such as rats, mice, cockroaches and flies. Pollutes air with unpleasant smell. Can cause water pollution and rainwater filters through dumps and carries chemicals into the ground water and into rivers and the sea
Burying in landfills	Non-biodegradable materials	Can cause water pollution
Burning	Non-toxic materials	Causes air pollution and can release toxic fumes
Treatment plants	Sewage	Must be treated to remove any organisms and to reduce the spread of disease

▲ **Figure 8.7.1** Efficient waste management is important

Learning outcomes

By the end of this topic you will be able to:

- describe waste disposal
- describe the environmental impact of some waste disposal methods
- appreciate the need for efficient waste disposal
- appreciate the need for good sanitation to reduce the spread of disease
- list some diseases that are spread by poor sanitation.

Practical Activity 8.7.1

Report – Local provision for waste disposal

1. Carry out some research into what provisions are made in your area for the disposal of solid waste.
2. Use the information you find to write a brief report.

Questions

1. Name two diseases which are spread through contaminated water.
2. Explain why good sanitation is vital to the health of the community.
3. What is potable water?
4. Draw a table with three columns: domestic, industrial and biological waste. In each column describe what this type of waste is and how it can be disposed of.

▲ **Figure 8.7.2** Landfill site with truck dumping rubbish

Sanitation

Sanitation refers to public health, specifically to the hygiene of an area. Regular garbage collection, waste disposal and adequate toilet facilities will reduce the risk of diseases and pest infestation. Toilet and latrines (pit toilets) ensure that human waste does not enter **potable** water supplies. This is water that is used for drinking.

Diseases

Poor sanitation associated with polluted water and poor personal hygiene can lead to the spread of diseases.

1. **Dysentery** can be caused by either a protist or a bacterium. These organisms live in the faeces of an individual where they cause diarrhoea, resulting in dehydration. This disease is passed on through contaminated water or handling food without washing the hands thoroughly.
2. **Cholera** is caused by a bacterium and produces diarrhoea which leads to severe dehydration. This disease is spread through contaminated water, which is either drunk or used to wash fruit and vegetables which are subsequently eaten.
3. **Typhoid** is caused by a bacterium which causes high fever and intestinal upsets. The disease is spread by flies, from untreated sewage, and from contaminated food.
4. **Parasites** (e.g. tapeworm) can be passed on by contact with parasite eggs from the faeces of a person carrying the parasite. This might occur when food becomes contaminated because of a lack of personal hygiene, inadequate toilet facilities or improper sewage treatment.

Exam-style questions

Multiple choice

1 Weil's disease can be transmitted by
- **A** flies
- **B** cockroaches
- **C** rats
- **D** mosquitoes

2 A treatment plant is used to dispose of
- **A** glass jars
- **B** vegetable material
- **C** sewage
- **D** paper

Structured questions

3 The diagram below shows an unhealthy environment.
- **a** Describe three things that you can see that make this an unhealthy place.
- **b** Name two pests that would be attracted to this area.
- **c** Mention three types of waste that humans produce.
- **d**
  - **i)** What is recycling?
  - **ii)** Name three materials that can be recycled.

- **e**
  - **i)** What is a vector?
  - **ii)** Which vectors could be attracted to the environment in the diagram and why?
  - **iii)** Name two diseases that they may carry.

4
- **a** Farmers sometimes use pesticides to protect their crops.
  - **i)** Suggest two advantages of doing this.
  - **ii)** Suggest two disadvantages of doing this.
- **b** Explain the term 'biological control'.
- **c** Explain why a farmer would be better advised to control pests with biological controls rather than pesticides.

5
- **a** Draw a diagram to show the different stages in the life cycle of a mosquito.
- **b** Describe how mosquitoes can be controlled during each stage of their life cycle.

6
- **a** Name one disease that can be transferred from person to person by contaminated water.
- **b** Describe circumstances where this might happen.
- **c** Describe what could be done to prevent the spread of this disease.

Section B

9 Temperature control and ventilation

Learning outcomes

By the end of this topic you will be able to:

- state the methods of heat transfer
- describe the process of conduction
- explain the difference between conductors and insulators
- give some examples of conductors and insulators
- describe the process of convection
- describe some examples of convection currents
- explain what is meant by radiation
- state the factors that affect the amount of radiation emitted by an object
- state which types of surface are the best absorbers of radiation
- describe some everyday examples of emission and absorption of radiation.

The buildings in which we live and work must be kept at a comfortable temperature and supplied with fresh, unpolluted air. An understanding of temperature measurement, different methods of heat transfer and ventilation can help us to achieve this.

9.1 Methods of heat transfer

Heat is a form of energy. It can be transferred from one place to another because of a temperature difference between them. Heat is also called thermal energy or internal energy. It is always transferred from a hotter region to a colder region.

There are three ways in which heat energy is transferred. They are conduction, convection and radiation.

Conduction

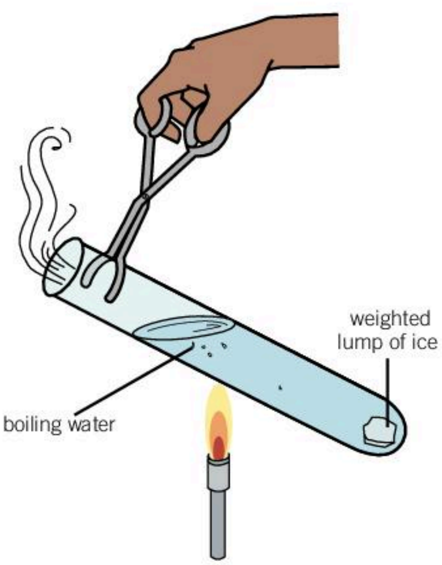
Conduction is the transfer of heat energy through a solid. The particles that make up any substance are vibrating all the time. Like all moving things, they have **kinetic (movement) energy**. The more kinetic energy they have the higher the **temperature** of the substance. Temperature is a measure of the amount of heat energy that a substance has.

In a solid, the particles are held closely together. If one end of a solid is heated, the particles at that end gain energy and vibrate more. This causes their neighbouring particles to vibrate more, increasing their kinetic energy, which causes their neighbouring particles to vibrate more, and so on. In this way, heat energy is transferred through the solid causing its temperature to rise. In most solids this process is quite slow.

Conductors and insulators

All metals contain free electrons, not bound to a particular nucleus. If one end of a metal is heated, these electrons gain energy and are able to move very quickly. They pass their energy on by collision with other electrons in the metal, so heat is transferred quickly. We say that metals are **good conductors**.

Liquids and gases are generally poor conductors. Materials that are poor conductors, such as paper, wood and glass, are called **good insulators**. Any material that contains trapped air, such as bubble wrap, styrofoam or expanded polystyrene, is a good insulator.



▲ **Figure 9.1.1** Water is a poor conductor of heat

The apparatus shown in Figure 9.1.1 can be used to demonstrate that water is a very poor conductor. A piece of ice is weighted down at the bottom of the test tube. When the test tube is heated at the top, the water at the top boils before the heat is conducted through the water to melt the ice.

Conduction in the kitchen

There are many examples of good conductors and insulators in the kitchen. Most cooking pots are made of metals because they are good conductors. The heat from the electrical or gas ring on the cooker is conducted quickly through the bottom of the pot to heat the food inside. If the handle of the pot is also made from metal, it will also heat up quickly and may burn you. For this reason, the handles of cooking pots are often made from insulators, such as wood or plastic. When you lift a hot cooking pot, you may need to protect your hands. You might use a thick cloth because it is a poor conductor and so will stop you getting burnt.

Convection

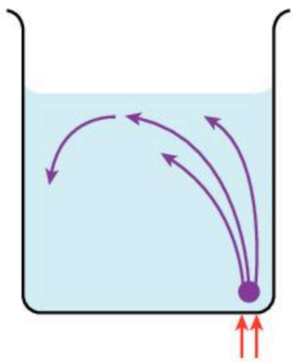
Convection is the movement of heat energy through liquids and gases. In conduction, heat energy is transferred from one part of the substance to another. In convection, the heat is transferred from one place to another by movement of the liquid or gas particles themselves.

The particles that make up liquids are not bound as tightly to each other as they are in solids. They are able to move relative to each other so that the liquid can flow.

When one part of a liquid is heated, the particles vibrate more and push each other further apart, so that part of the liquid expands and becomes less dense. This makes it rise upwards and it is replaced by cooler liquid which is then heated and rises, and so on. In this way **convection currents** are set up.

The same process occurs when a gas is heated. The particles in a gas are not bound to each other but are free to move, so the gas takes up all of the space available.

The apparatus shown in Figure 9.1.2 can be used to demonstrate convection currents in a liquid. Crystals of potassium manganate(VII) are placed at the bottom of a beaker. When the water near the crystals is heated, the convection currents can be observed as the water is coloured by the potassium manganate(VII).



▲ **Figure 9.1.2** Observing convection

Convection currents

Convection currents are set up in everyday objects, such as hot water tanks, ovens and refrigerators.

In a **hot water tank**, the heating element is placed at the bottom of the tank (see Figure 9.1.3). This heats the water at the bottom of the tank which rises upwards and is replaced by colder water falling to the bottom of the tank. These convection currents continue until all the water in the tank is heated from the top downwards. Hot water is drawn off from the top of the tank and cold water is fed in from the bottom.

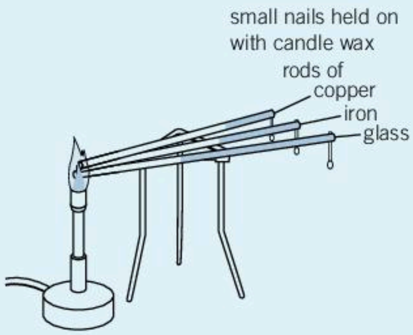
In a **refrigerator**, air at the top of the cabinet is chilled so it becomes more dense and sinks. Warmer air rises to the top and is chilled and then sinks, so a cooling convection current is set up and the temperature of the air in the fridge decreases.

Practical Activity 9.1.1

Investigating the conduction of heat

Skills assessed: Observation/Recording/Reporting and Analysis, and Interpretation.

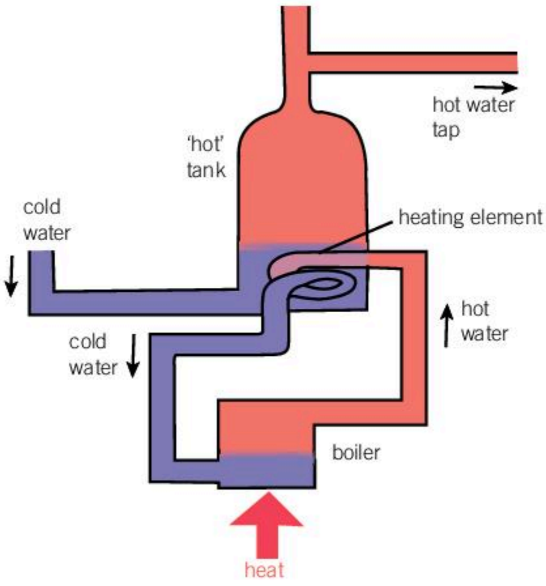
1 You will need rods of the same size but made from different materials, such as copper, steel and glass.
2 Rest the rods on a tripod and attach a small nail at one end of each rod using a drop of candle wax. Try to use the same amount of candle wax for each nail.



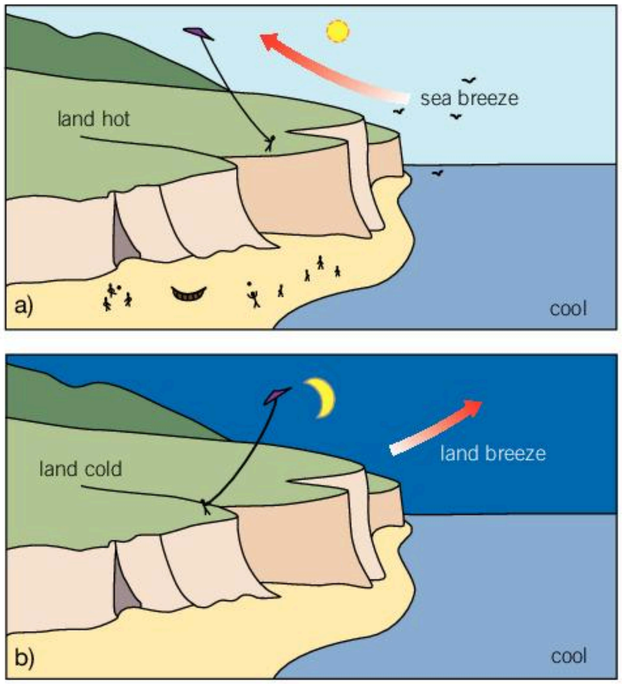
3 Start a stopwatch and begin to heat the other ends of the rods with a Bunsen burner.
4 Time how long it takes for each nail to fall off.
5 Record your results on a bar chart.
6 Which material is the best conductor? Which is the worst?

Exam tip

Remember that convection takes place in both liquids and gases. It is not heat that rises but the warmed liquid or gas molecules.



▲ **Figure 9.1.3** A boiler and hot water tank



▲ **Figure 9.1.4** a) onshore breeze b) offshore breeze

▲ **Figure 9.1.5** An array of solar panels

Sea breezes

Sea breezes are examples of natural convection currents. During the day, the land heats up more quickly than the sea. The land heats the air above it which rises and is replaced by colder air from over the sea. If you stand on the shore during the day, you will feel this convection current as an **onshore breeze**, blowing from the sea onto the land.

At night the land cools rapidly, whereas the temperature of the sea changes very little. The land becomes cooler than the sea so the air over the sea is warmer and rises. Cooler air moves from over the land to over the sea. The change in direction produces **offshore breezes** at night blowing from the land onto the sea. You will learn more about air movements as a result of convection in Topic 16.6.

Radiation

Radiation is the transfer of heat energy by electromagnetic waves. Both conduction and convection require particles in order to transfer heat energy. Radiation does not require particles, so it is the only way in which heat can be transferred through a vacuum. It is the method by which heat from the Sun reaches the Earth through the vacuum of space.

Any hot object emits heat by radiation. The hotter the object, the more heat energy it emits. All objects absorb heat emitted from things around them. If an object absorbs more heat energy than it emits, it will warm up. If it emits more heat energy than it absorbs, it will cool down.

> **Exam tip**
>
> Remember that conduction and convection both involve particles but radiation does not. Remember that all objects emit and absorb heat radiation all the time.

Emitting heat radiation

The amount of heat energy an object emits by radiation depends on its temperature, its surface area, and the colour and texture of its surface. Dark, matt surfaces are good emitters of radiation. Light, shiny surfaces are poor emitters of radiation.

Absorbing heat radiation

The amount of heat energy an object absorbs also depends on the colour and texture of its surface. Dark, matt surfaces are good absorbers of radiation. Light, shiny surfaces are poor absorbers of radiation; they reflect the radiation away.

Examples of emitters and absorbers:

- After an accident, rescue teams may wrap survivors in thermal blankets that have shiny, silver outer surfaces. This stops them losing body heat by radiation.
- In hot countries, houses may be painted white to stop them absorbing radiation and so keeping them cooler.

- Fire fighters may wear shiny suits to stop them absorbing radiation and heating up when fighting a fire.
- Solar panels absorb radiation from the Sun and use it to warm water in pipes. The pipes are painted matt black so that they absorb the maximum amount of radiation (see Figure 9.1.5).
- Cricketers wear white clothes which absorb less heat and keep the players cool.

Key fact

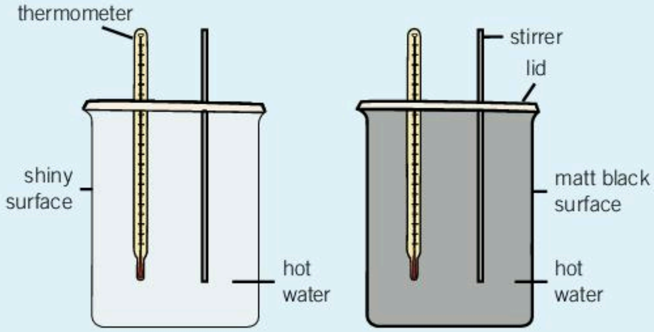
An object that is cooler than its surroundings will gain heat energy and warm up. An object that is warmer than its surroundings will lose heat energy and cool down.

Practical Activity 9.1.2

Investigating heat radiation

Skills assessed: Observation/Recording/Reporting, Manipulation/ Measurement and Analysis, and Interpretation.

1. You will need two cans of the same size. One can should be polished and shiny, and the other should be sprayed with matt black paint.
2. Each can needs a lid with two holes, one for a stirrer and one for a thermometer.
3. Pour an equal volume of hot water into each can.
4. Stir the water and record the temperature of the water in each can every minute.



5. On the same axes plot a graph of temperature against time for each can.
6. Which can cools down more quickly? Which can is emitting heat energy by radiation more quickly?

Figure 9.1.6 Light colours absorb less radiation

Practical Activity 9.1.3

Which is the better absorber of radiation?

Skills assessed: Planning and Design.

Two students are arguing over which type of surface is a better absorber of radiation. One student says shiny metal can absorb radiation better than a can sprayed with black matt paint. The other student says the opposite is true. Plan and design an experiment to determine which student is correct. Write down any measurements you will make and what you will do to make sure that your experiment is a fair test.

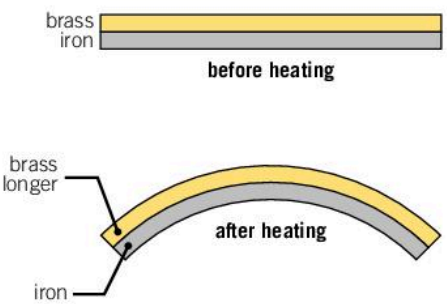
Questions

1. Name the three methods of heat transfer.
2. Why will sitting in a cold bath cool your body down?
3. Why are metals good conductors?
4. Why does convection not take place in solids?
5. Why are metals better conductors than other solids?
6. How does heat energy radiated by a body depend on its temperature?
7. How does heat energy from the Sun reach the Earth?
8. Which surfaces are the best emitters of radiation?
9. Which surfaces are the best absorbers of radiation?
10. Why will a shiny, silver teapot keep tea hot for longer than a dull, brown one?

Learning outcomes

By the end of this topic you will be able to:

- describe how a bimetallic strip is made
- explain how a bimetallic strip can be used in a thermostat
- describe how a gas thermostat is used to control the temperature of an oven.



▲ **Figure 9.2.1** A bimetallic strip

Exam tip

In an exam question you might be asked to describe how a bimetallic strip can be used to control the temperature of an appliance, such as an electric oven or an iron, that needs to switch on when the temperature drops. Or you might be asked to describe how the strip can be used to control the temperature of something, such as a refrigerator, where the motor needs to switch on when the temperature rises.

Questions

1. What two metals are often used to make a bimetallic strip?
2. Explain why the strip bends when it is heated.
3. What is a thermostat?
4. Describe how the thermostat in an iron works.
5. What is invar?
6. How is the gas thermostat different from the thermostat in an iron?

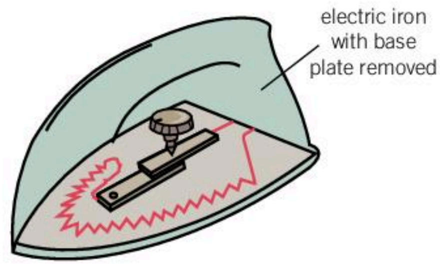
9.2 Thermostats

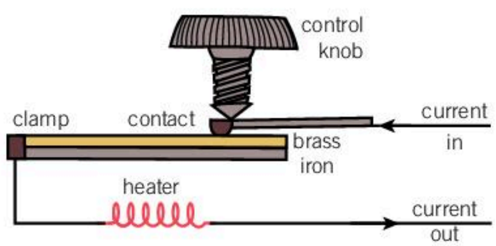
Bimetallic strip

A bimetallic strip is made from two strips of different metals bonded together. Both of the metals expand when they are heated but by different amounts. Two metals commonly used in bimetallic strips are brass and iron. If the strip is heated the brass expands more than the iron. In order for this to happen the strip has to form a curve with the brass on the outside. When the strip cools to its original temperature, the metals return to their original size and the strip becomes straight again.

A **thermostat** is used to keep something at a particular temperature. A bimetallic strip can be used in a thermostat, for example to keep an electric iron at the correct temperature. When the strip is straight, it forms part of an electric circuit. Current flows through the circuit, the heater is on and the iron warms up. If the iron becomes hotter than the required temperature, the strip bends away from the contact, the circuit is broken and the heater is switched off. As the bimetallic strip cools, it straightens again, eventually completing the circuit so current flows and the heater is switched on again.

The temperature at which the heater in the iron is switched on and off can be controlled by screwing the control knob in and out. The same principle is used to control the temperature in an electric oven.



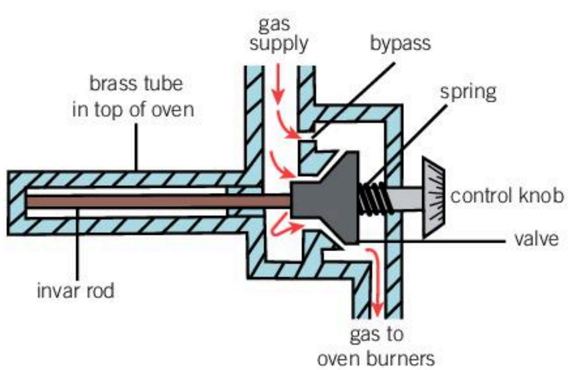


▲ **Figure 9.2.2** A thermostat for an electric iron

Gas thermostat

A gas thermostat is used to control the temperature in a gas oven. This thermostat contains a rod made of an alloy of steel and nickel called **invar**. Invar only expands by tiny amounts when heated.

As the temperature of the oven rises, a brass tube expands. The invar rod is attached to this tube, so it moves to the left as shown in Figure 9.2.3. The expansion of the invar is tiny so the valve is pulled closed, reducing the flow of gas to the burner. As the brass cools, the rod moves the other way, opening the valve and increasing the flow of gas. The control knob can be used to alter the position of the valve and so control the steady temperature of the oven.



▲ **Figure 9.2.3** A gas thermostat

9.3 Thermometers

Temperature

Sensors, or receptors, in our skin are sensitive to temperature. Temperature is a measure of the amount of heat energy or the hotness of an object. Temperature is measured with a thermometer.

Thermometers

The particles that make up any object are moving, or vibrating, all the time, so they have kinetic energy. The higher the temperature, the more kinetic energy the particles have. Temperature can be defined as the average kinetic energy of the particles of an object. It is not possible to directly measure this energy, so thermometers need to measure some property that changes with temperature, such as the volume of a liquid, the pressure of a gas or the resistance of a wire.

Temperature scales

A scale of temperature is obtained by choosing two temperatures, called the **fixed points**, and dividing the range between them into an equal number of divisions.

On the **Celsius scale**, the lower **fixed point** is 0 °C. This is the temperature of pure melting ice. The ice must be pure, as impurities lower the melting point. The upper fixed point is 100 °C. This is the temperature of steam above boiling water at normal atmospheric pressure. The temperature of the boiling water is not used because impurities in the water raise the boiling point.

When the two fixed points have been marked on the thermometer the distance between them is divided into 100 equal divisions called **degrees**. A thermometer with a scale is **calibrated**.

Liquid-in-glass thermometers

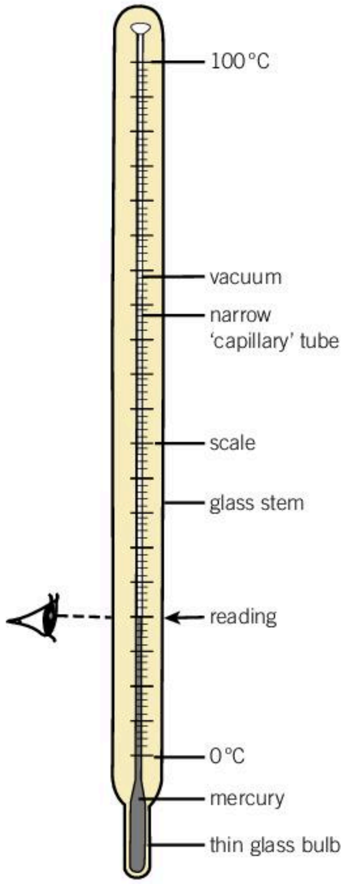
Many thermometers use the expansion of a liquid to measure a change in temperature and are called **liquid-in-glass thermometers**. These thermometers have a glass bulb attached to a tube with a very narrow hole down its centre, called a capillary tube. This is surrounded by a glass case called the stem. The bulb of the thermometer is filled with a liquid and the air is removed from the capillary tube, which is then sealed. When the thermometer is placed somewhere warm the liquid in the bulb expands and moves up the tube. This expansion takes place because the particles of the liquid gain kinetic energy, so pushing each other further apart. The higher the temperature, the further up the tube the liquid moves. The stem of the tube is marked with a scale and the temperature is read from the scale, while the thermometer is in place. It is important to read a thermometer with your eye on the same level as the end of the thread of liquid in the capillary tube.

Liquid-in-glass thermometers usually contain either mercury or alcohol. There are advantages and disadvantages to using both liquids.

Learning outcomes

By the end of this topic you will be able to:

- state some properties that change with temperature and can be measured with thermometers
- describe what is meant by a temperature scale
- describe the upper and lower fixed points on the Celsius temperature scale
- describe how a liquid-in-glass thermometer works
- state some advantages and disadvantages of using mercury and alcohol in liquid-in-glass thermometers
- draw a labelled diagram of a clinical thermometer
- draw a labelled diagram of a maximum and minimum thermometer.



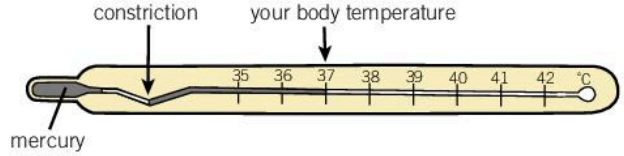
▲ **Figure 9.3.1** A liquid-in-glass thermometer

▼ **Table 9.3.1** Comparison of mercury thermometer with alcohol thermometer

Mercury thermometer	Alcohol thermometer
It has a high boiling point, so it can be used to measure high temperatures	It cannot be used to measure high temperatures
It freezes at –39 °C, so it cannot be used to measure very low temperatures	It can be used to measure very low temperatures as it freezes at –115 °C
It is opaque, so it can be seen in the bore of the thermometer	It is transparent so a dye is added to it so that it can be seen
It does not wet the sides of the tube as it contracts down the tube on cooling	It wets the sides of the tube; this can lead to inaccuracies in reading the thermometer
Mercury is a better conductor of heat than alcohol	Alcohol is not as good at conducting heat as mercury
It is more expensive	It is less expensive

Clinical thermometers

A clinical thermometer is a special type of thermometer used to measure the temperature of the human body. It has a short scale that only extends a few degrees either side of normal body temperature. There is a constriction in the capillary tube just beyond the bulb. When the thermometer is placed in the body, normally under the tongue, the mercury expands and pushes its way through the constriction to rise up the tube. After about two minutes, the thermometer is removed. The mercury cools and contracts, and the thread breaks at the constriction. This leaves a thread of mercury in the capillary tube showing the body temperature which can be read off on the scale. Shaking the thermometer moves the thread past the constriction and back down to the bulb.



▲ **Figure 9.3.2** A clinical thermometer

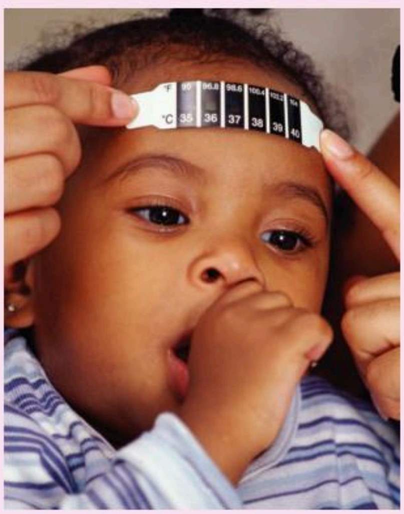
Maximum and minimum thermometer

This thermometer is used to measure the maximum and minimum temperatures over a period of time, such as 24 hours. It is useful for people, such as gardeners, who need to know maximum and minimum temperatures in a greenhouse.

The thermometer contains both mercury and alcohol in a U-shaped tube. The bulb on the top of the left-hand side of the tube contains alcohol. As the alcohol gets hotter, it expands, and pushes the mercury around the tube and up the right-hand side. The metal index on top of the mercury is pushed up with it. When the temperature drops, the alcohol contracts and the mercury moves back down the right-hand tube leaving the base of the metal index to show the highest temperature reached. The mercury moves up the left-hand tube pushing the other metal index with it. When the temperature increases, again the index is left in place and the minimum temperature is read from its base.

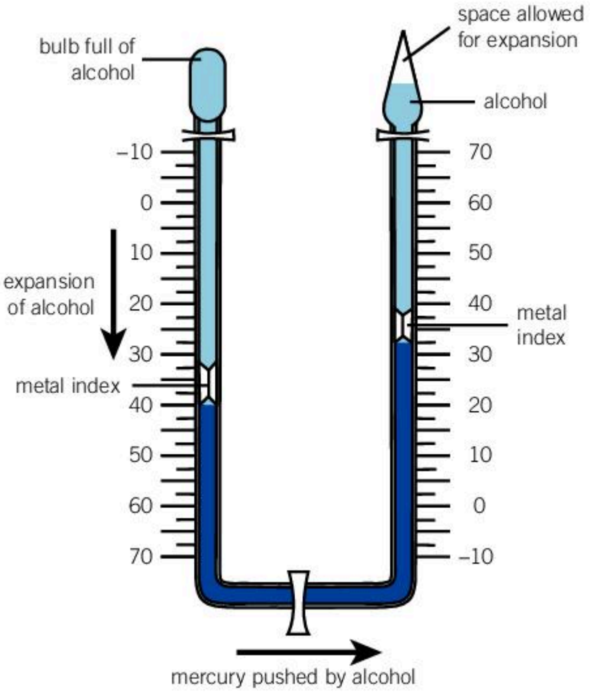
? Did you know?

Clinical thermometers are being replaced by other types, such as liquid crystal thermometers. These consist of a strip containing liquid crystals, the colour of which changes with temperature. The strip is placed on the patient's forehead and the temperature is indicated by the brightest colour. Digital thermometers are also available.



Digital thermometers

Digital thermometers do not use the expansion of mercury to measure the temperature. Instead, the thermal radiation is received by a thermocouple and converted to an electrical signal, the voltage from which is measured digitally.



▲ **Figure 9.3.3** A maximum and minimum thermometer

▲ **Figure 9.3.4** Digital thermometer

Practical Activity 9.3.1

Investigating thermometers

You are provided with a range of thermometers.

1 Make labelled drawings of each type of thermometer.
2 Write a short descriptive paragraph about each, explaining how it works.
3 Practise taking your temperature with a clinical thermometer, making sure you clean it with antiseptic solution before and after use, and that you shake the mercury back down safely.
4 If possible, compare your temperature taken with a clinical thermometer with that taken using a digital or liquid crystal thermometer.

Questions

1 How is a clinical thermometer different from a laboratory thermometer?
2 Why is a thermometer containing alcohol more suitable for measuring very low temperatures than one containing mercury?
3 Why must a laboratory thermometer be left in place to take a reading?
4 Explain why a maximum and minimum thermometer contains both mercury and alcohol.
5 Why are maximum and minimum thermometers useful to gardeners?

9.4 Evaporation

Learning outcomes

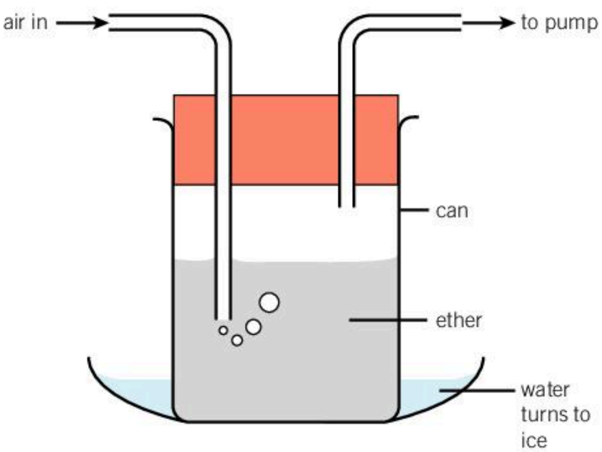
By the end of this topic you will be able to:

- describe the process of evaporation
- explain why evaporation produces a cooling effect
- state the factors affecting the rate of evaporation
- describe how sweating allows humans to regulate their body temperature.

Evaporation

Evaporation is a process that occurs when a liquid changes to a gas. Unlike boiling, evaporation does not happen at a particular temperature. It occurs at the surface of the liquid and without the formation of bubbles.

The molecules that make up a liquid are in continuous random motion. The most energetic molecules may have enough energy to escape from the surface of the liquid. As the less energetic molecules are left behind, the average kinetic energy of the remaining molecules is reduced. Since temperature is a measure of the average kinetic energy of the molecules, the temperature is reduced, so evaporation causes cooling of the liquid.



▲ **Figure 9.4.1** The cooling effect of evaporation

The process of evaporation requires energy called the **latent heat of vaporisation**. This energy is obtained by the liquid from its surroundings, causing the surroundings to cool.

This cooling effect can be demonstrated with the apparatus shown in Figure 9.4.1. The ether is a volatile liquid, which means that it evaporates readily at room temperature, especially if air bubbles are pumped through it. As it evaporates, it takes latent heat of vaporisation from the liquid and then from the water below the can, which quickly turns into ice.

Factors affecting the rate of evaporation

A pool of water on the roadway will evaporate if left. It does so most quickly if it is:

- hot
- there is a wind blowing
- the pool of water has a large surface area
- the atmosphere does not already contain much water vapour.

This is because:

- warm air can take up more water vapour than cool air
- moving air carries water vapour away
- the water molecules escape from the surface
- dry air can take up more water vapour.

The same conditions speed up the drying of clothes on a washing line.

Exam tip

Do not confuse evaporation and boiling. Both require latent heat of vaporisation but evaporation occurs at any temperature and at the surface of the liquid without the formation of bubbles. Boiling takes places at a particular temperature and bubbles are formed within the body of the liquid.

Practical Activity 9.4.1

Investigating the evaporation of alcohol

1. Place a small amount of alcohol on your fingers.
2. Describe what you feel.
3. Explain this in terms of evaporation.

Sweating

Mammals are **endotherms**. Their body temperature remains constant. In humans this temperature is 37 °C. Humans cannot survive for long if their body temperature drops below about 35 °C or increases above 42 °C.

Practical Activity 9.4.2

Factors affecting evaporation

Skills assessed: Planning and Design, / Drawing.

1. Design an experiment to investigate one of the factors that affects evaporation.
2. Explain what you are going to measure and how you will measure it.
3. Write down any factors that you will keep the same.
4. Draw a labelled diagram of the apparatus you will use.

Practical Activity 9.4.3

How surface area affects the rate of evaporation

Skills assessed: Manipulation/Measurement.

1. You will need three containers of different shapes, such as a beaker, a shallow dish and a plate.
2. Add the same, measured, volume of water to each container.
3. Leave the containers in the same place, for example a warm window ledge.
4. After two hours measure the volume of water left in each container.
5. Calculate the volume of water that has evaporated in each case.
6. What effect does the surface area of the container have on the rate of evaporation?

The skin is the main organ that regulates body temperature in humans. This was discussed in Topic 6.2. On a hot day, when the body requires cooling, the skin uses two processes to lose heat and reduce body temperature; these are dilation of blood vessels and sweating.

▲ **Figure 9.4.2** Sweating helps the body lose heat after vigorous exercise

▼ **Table 9.4.1** How the skin helps to control the body temperature

Loss of heat from the skin	Retention of heat by the skin
Blood vessels close to the surface of the skin dilate (vasodilation)	Blood vessels constrict (vasoconstriction)
Blood flow increases	Blood flow decreases
More heat is lost by radiation	Less heat lost by radiation
More sweat produced	Less sweat produced
Increased evaporation of sweat cools the skin	Reduced evaporation of sweat
Hair close to skin; little air trapped	Hair stands on end; air trapped in a layer next to skin

Questions

1. Why should you spread clothes out on a clothes line to dry rather than leaving them in a heap on the floor?
2. State and explain three factors which affect the rate of evaporation.
3. What is the latent heat of vaporisation?
4. What is the difference between evaporation and boiling?
5. Explain how sweating helps to cool the body.

Learning outcomes

By the end of this topic you will be able to:

- explain why ventilation is important
- describe how an air-conditioning unit works
- describe how a humidifier works.

9.5 Ventilation

Ventilation

The air around us is warmed up by the following everyday activities:

- breathing
- running electric motors
- using electric lights
- washing and drying clothes
- cooking food.

The composition of the air around us can also be changed by:

- breathing (adds water vapour, removes oxygen and adds carbon dioxide)
- chemical pollutants
- pollen
- dust
- bacteria
- tobacco smoke
- odours.

▲ **Figure 9.5.1** Well-ventilated rooms are comfortable to be in

These changes will make the air stale if it stays in a confined space. This may make us feel hot, sticky, dizzy, give us headaches and make us less efficient at work. Some pollutants in the atmosphere may cause illnesses, such as hay fever, asthma and even cancer. Damp, warm air encourages the growth of bacteria, mould and fungi which can be bad for health.

To stop the air becoming stale, we need ventilation. This allows the hot, stale air to be replaced by cool, fresh air.

Ventilation may simply involve opening windows to allow stale air out and fresh air in. This is most effective if windows are opened in both lower and upper levels of a building, as natural convection currents will make warmer, stale air leave the building at the top to be replaced by colder, fresh air at the bottom. In this case, the speed with which the stale air is replaced by fresh air depends on the speed of the wind, and the difference in temperature between the inside and the outside of the building. The process can be speeded up if the air movement is created by fans or air extractors.

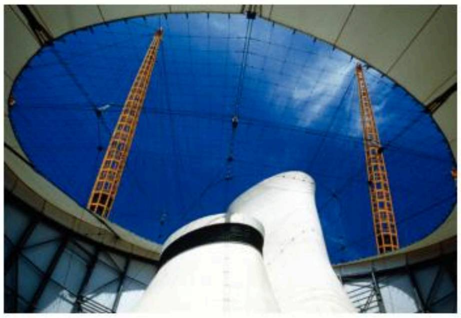
All buildings should be built with adequate ventilation. Even in cold countries, where doors and windows are usually kept closed to keep heat in, there should be means of continuously replacing stale air with fresh air. Small vents fitted in window and door frames and 'air bricks', which are bricks with holes in them, increase ventilation.

Ventilation is especially important in rooms where there is likely to be a lot of water vapour in the air, such as kitchens, bathrooms and laundry rooms.

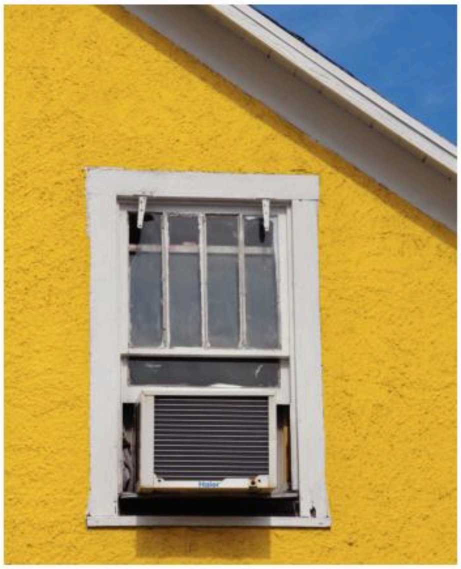
Air-conditioning

An air-conditioning unit may be used to prevent the inside of a building becoming uncomfortably hot. A fan is used to move hot air over a set of cooling coils. The coils contain a fluid called a refrigerant. The liquid refrigerant passes through an expansion valve and the rapid expansion causes it to change to a gas. It requires latent heat of vaporisation for this change which causes it to cool its surroundings. The cold gas moves through the cooling coils and air is cooled as it passes over the coils. This air then cools the room.

The refrigerant gas is warmed by the heat from the air. It is pumped through a compressor so that its pressure increases and it condenses to form a liquid. As it condenses it gives out latent heat of vaporisation warming the air outside. The air is moved past the unit by a fan. The liquid refrigerant passes through the expansion valve again and so on. The air passing through the unit is usually filtered to remove pollutants.



▲ **Figure 9.5.2** Air vents in the Millennium Dome, London



▲ **Figure 9.5.3** Air-conditioning unit on the outside of a building

Humidifiers

Humidifiers are devices used to increase, or maintain, the humidity of the air. They can either be used to maintain humidity in a single room or can form part of a heating, ventilation and air-conditioning system (HVAC) for a whole building.

The simplest types of humidifiers consist of a wick, a reservoir and a fan. The wick absorbs water from the reservoir. The fan blows air on to the wick and aids the evaporation of the water. Evaporation of water from the wick depends on the relative humidity of the room: the drier the atmosphere in the room, the greater the evaporation rate.

Humidifiers can help to prevent antiques, wooden furniture and fabrics from being damaged by an over-dry atmosphere.

Questions

1 Describe how everyday activities can alter the composition of the air.
2 Explain why good ventilation is important.
3 Why is good ventilation especially important in a bathroom?
4 Explain how an air-conditioning unit cools the air.
5 Describe how a simple humidifier works.

Practical Activity 9.5.1

Ventilation features at your school

Make a list of all the ways that your school buildings are ventilated.

Exam-style questions

Multiple choice

1 The best absorbers of heat are:
A light, dull surfaces
B black, shiny surfaces
C black, dull surfaces
D light, shiny surfaces

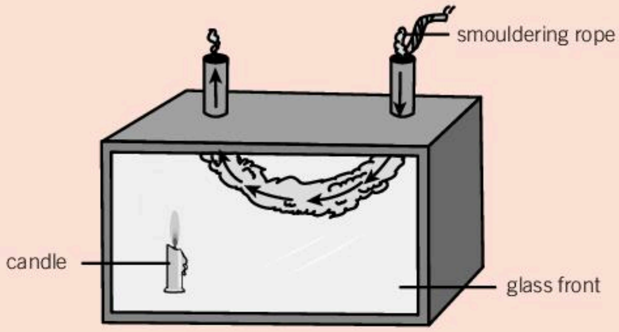
2 Heat passes through a single pane of window glass by:
A convection
B conduction
C radiation
D convection and conduction

3 In which substances can convection happen?
A solids and gases
B solids and liquids
C liquids and gases
D solids, liquids and gases

4 The heating effect of the Sun results from which types of radiation?
I infrared radiation
II visible light radiation
III microwave radiation
IV gamma radiation
A I and II only
B III and IV only
C II and IV only
D I and III only

Structured questions

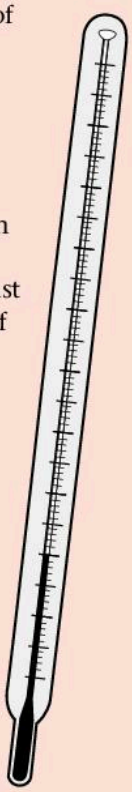
5 A group of students set up the apparatus as shown in the diagram.



a What does the apparatus show?
b What happens to the smoke as it enters the box?
c Explain why the smoke travels along the path shown.

6 a What is evaporation?
b After washing her clothes, a student hangs some of them on a washing line and leaves the rest in pile on the floor.
i) Which washing would dry the quicker?
ii) List one factor that affects the rate of evaporation.

7 The diagram shows a thermometer.



a What type of thermometer is this?
b What liquids are commonly used in this type of thermometer?
c Give one advantage of using each liquid in the thermometer.
d Which type of thermometer has a bend just above the bulb and what is the function of the bend?

8 Copy and complete the following sentences.
a More heat can be lost from the surface of the skin when the blood vessels .... This is called ....
b To reduce heat loss the hairs stand .... This traps a layer of .... air next to the skin.
c All mammals are ....

9 a Give two reasons why good ventilation in a working environment is important.
b i) Name one electric appliance that can improve air circulation.
ii) Name one natural way that air circulation can be improved.

Section B

10 Conservation of energy

It is difficult to say what energy is but easy to say what it does. Energy is the ability to do work. All energy is the same but it is often useful to talk about forms of energy when we are talking about energy in different contexts. Energy can be transformed from one form into others without any loss taking place.

Learning outcomes

By the end of this topic you will be able to:

- explain what energy is
- explain that kinetic energy is associated with movement
- describe heat energy as the energy transferred to cooler objects
- explain that potential energy is energy that is stored
- describe different types of potential energy
- appreciate that potential energy and kinetic energy are associated with some other forms of energy
- describe light, sound, electrical, nuclear and solar energy
- give the unit of energy.

10.1 Concept of energy

We cannot see energy but we see the effect of energy on systems in the world around us. For example, a car is a system that consists of various parts. The energy of the parts will affect the whole car and the car itself will also have energy. The parts of the car move because of fuel and so the whole car moves. The engine gets hot. The lights can be switched on. These are all examples of energy. Energy is the ability to do work. There are different forms of energy.

Forms of energy

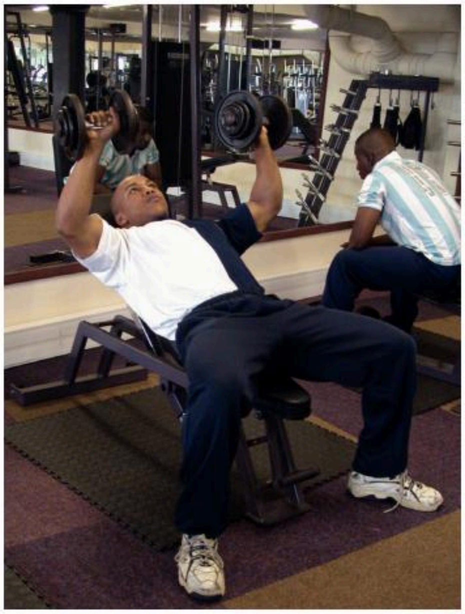
- **Kinetic energy** is the energy which an object has when it is moving. It is also called movement energy. All moving objects have kinetic energy. When molecules are heated, their movement increases and so does their kinetic energy.
- **Heat energy** is energy which passes from a hot object to a cooler one. When an object is heated, its particles gain kinetic energy and therefore move more quickly. When a hot object loses heat energy its particles slow down. The greater the heat energy of particles in a substance, the higher its temperature. The main sources of heat energy are the Sun and combustion of fuels.
- **Potential energy** is stored energy that can be released to do work. There are different types of potential energy. For example, when an object is lifted above the surface of the Earth, it gains **gravitational potential energy**. If we were to let it go, it would be pulled back down to Earth by the force of gravity. The higher it is lifted, the more potential energy it has. Also, the heavier it is the more gravitational potential energy it gains when it is lifted.

  An object's gravitational potential energy depends on three things: its mass, its height above the Earth and the force of gravity.

  As the object falls the potential energy will be changed to kinetic energy. We will discuss energy changes in Topic 10.2.
- **Chemical potential energy** is another type of potential energy. When fuels, such as petrol or paraffin burn, they release large amounts of energy.

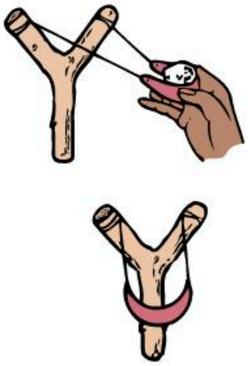
  The food that we eat stores chemical potential energy. This energy is released when the food molecules are 'burnt' during respiration. Energy is produced so that cells can do work.

▲ **Figure 10.1.2** The guitar string vibrates when stroked and in turn causes the air inside the guitar to vibrate



▲ **Figure 10.1.3** If the weight is dropped, potential energy is transformed to kinetic energy

- An elastic object is any object that returns to its original shape, or form, after being stretched, or squeezed, out of shape. Potential energy is stored in an elastic object by either stretching or compressing it. When an object is stretched, it is pulled and when an object is compressed, it is squashed. The more it is stretched or compressed, the greater its **elastic potential energy**. We can estimate the amount of elastic potential energy an object has by seeing how much work it can do.



▲ **Figure 10.1.1** In the catapult, elastic potential energy is transformed to kinetic energy

- **Light energy** comes from the Sun and other luminous sources. It provides us with the ability to see because it is the form of energy that can be detected by our eyes. It is essential for green plants to synthesise food. Since green plants are the producers in all food chains, it is therefore essential for all life.

  Natural light comes mainly from the Sun. We can produce artificial light using candles, paraffin lamps and electric light bulbs. These devices also produce heat energy.

- **Sound energy** is energy that is carried through material as sound waves. It can be detected by our ears. Sound travels through gases, liquids and solids but cannot travel through a vacuum. As sound travels through a material its particles vibrate; the louder the sound the greater the vibration. The vibrating particles have kinetic energy.

  Musical instruments produce sound when part of them, or the air inside them, vibrates.

- **Electrical energy** is the result of moving electrons in a conductor (see Topic 11.1). It is a very convenient form of energy which can be transferred from place to place through wires.

  Electrical energy is so useful because it can be transformed into many other forms of energy.

- **Nuclear energy** is a form of potential energy. Energy stored in the nuclei of some atoms is released during nuclear reactions. These reactions result in changes to the nuclei of atoms. The released energy can be changed into other forms of energy, such as electrical and heat energy.

  Nuclear energy is responsible for the production of energy in the Sun. Another type of nuclear reaction is used to generate electricity in nuclear power stations.

  Sadly, nuclear energy has also been misused by people in the past to make weapons of mass destruction.

- **Solar energy** is energy in the form of light and heat that is released from the Sun.

Unit of energy

The unit of energy is the joule (J). One joule in everyday life represents the energy required to lift a small apple (with a mass of approximately 100 g) vertically through one metre of air.

One joule is only a small amount of energy. We often need to express large amounts of energy and to do this we use the kilojoule or kJ. There are 1000 joules in one kilojoule.

You might have noticed that the labels on food packaging sometimes tell you how much energy your body will receive from eating a portion of the food. This information is often also given in kilocalories or kcal. The calorie is an old unit of energy from which we get phrases, such as low-calorie and calorie counting.

Nutrition

Typical values	100 g contains	Each slice (typically 44 g) contains	% RI*	RI* for an average adult
Energy	985kJ	435kJ		8400kJ
	235kcal	105kcal	5%	2000kcal
Fat	1.5g	0.7g	1%	70g
of which saturates	0.3g	0.1g	1%	20g
Carbohydrate	45.5g	20.0g		
of which sugars	3.8g	1.7g	2%	90g
Fibre	2.8g	1.2g		
Protein	7.7g	3.4g		
Salt	1.0g	0.4g	7%	6g

This pack contains 16 servings
*Reference intake of an average adult (8400kJ / 2000kcal)

▲ **Figure 10.1.4** Food labels often show energy content

Questions

1. What type of potential energy does an object placed on a shelf have?
2. What happens to the kinetic energy of the particles in a substance when it is heated?
3. Which other form of energy is often produced by devices that emit light energy?
4. What type of potential energy do fuels contain?
5. What can nuclear energy be used for?

Learning outcomes

By the end of this topic you will be able to:

- state the law of conservation of energy
- describe some energy transformations
- write a general equation for all energy transformations
- state that during many energy transformations some output energy does not do useful work and is wasted
- appreciate that during an energy transformation the total energy output is the same as the total energy input
- state that in many energy transformations energy is wasted as low-level heat
- describe how heat may be lost at each stage in a sequence of energy transformations
- understand that during nuclear reactions a small amount of mass is converted into energy
- describe nuclear fusion and nuclear fission as energy sources
- explain the difference between the use of nuclear technology in a nuclear power station and a nuclear bomb
- understand that energy can be changed from one form to another
- describe methods of reducing the polluting effects of the internal combustion engine.

10.2 Conversion and conservation of energy

The law of conservation of energy states that energy is neither created nor destroyed but converted from one form to another.

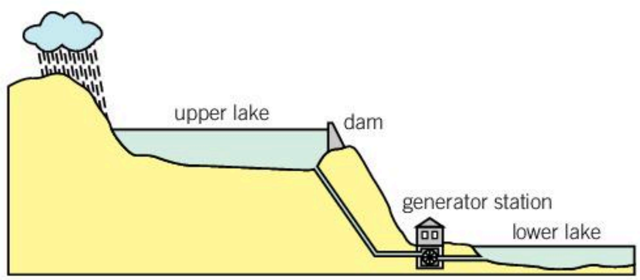
If you leave a metal spoon in a cup of hot coffee, the spoon gets hot. The heat from the coffee is transferred to the spoon. Heat energy has been passed or **transferred** to the spoon. You discussed energy flow through an ecosystem in Topic 3.3.

▲ **Figure 10.2.1** Energy is transformed in food chains

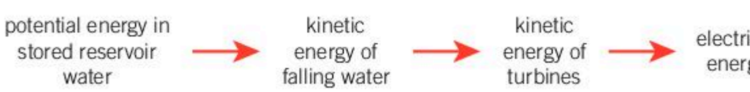
In an electric circuit, electrical energy will flow or be transferred around the circuit.

When you switch an electric kettle on, the water gets hot. The electrical energy is changed to heat energy. There has been an **energy transformation**. Transformation means change. All around us energy is constantly changing from one form to another.

In some cases, there is a series of energy transformations. For example, when water is used to generate electricity (hydroelectric power) the following transformations occur.



▲ **Figure 10.2.2** Gravitational potential energy is transformed into electrical energy at a hydroelectric power station



▲ **Figure 10.2.3** Energy transformations when water is used to generate electricity

The following general equation can be applied to all energy transformations:

$$\text{energy input} \rightarrow \text{energy output}$$

In many transformations, more than one form of energy is produced. We sometimes call these 'useful energy' and others 'wasted energy' depending on whether they do useful work or not.

$$\text{energy input} \rightarrow \text{useful energy} + \text{wasted energy}$$

For example, a light bulb produces light so the light energy can be described as useful energy. The light bulb also produces heat, which is not usually wanted. We can describe this heat energy as wasted energy.

electrical energy → light energy + heat energy
(useful) (wasted)

The proportion of energy which a device transforms to do useful work is sometimes called the **efficiency**. It can be expressed as a fraction or a percentage.

electrical energy → light energy + heat energy
100 J 10 J 90 J

The efficiency of a light bulb is 10/100 = 0.1 or 10%.

In any energy transformation:

total energy input = total energy output

▲ **Figure 10.2.4** The filament in an electric light bulb produces light energy and heat energy

Conserving energy

In a vehicle, chemical energy is stored as fuel and transformed into other forms of energy by an internal combustion engine.

The following transformations take place in a petrol engine:

chemical energy → kinetic energy + heat energy + sound energy
100 J 25 J 70 J 5 J

Only one-quarter of the energy in the fuel is used to do useful work in making the vehicle move. The remaining three-quarters is wasted, mostly as heat which simply heats up the air around the engine.

Practical Activity 10.2.1

Energy output

Your teacher will supply you with a battery, spring, bell, calculator, connecting wires and a lamp.

1 Connect the lamp to the battery and observe what happens.
2 Repeat the procedure with the spring, telephone and calculator.
3 Name the form of energy output which is useful and any other forms of energy output which may be regarded as wasted energy.

Different types of energy are being tested for use in vehicles. These include biogas and electricity. These energy sources will reduce the negative impact that fossil fuels have on the environment. However, sufficient energy needs to be safely generated from them for the running of the vehicle.

In many transformations, energy is wasted as heat. This is often described as low-level heat energy. It cannot be used to do useful work and is lost to the surroundings.

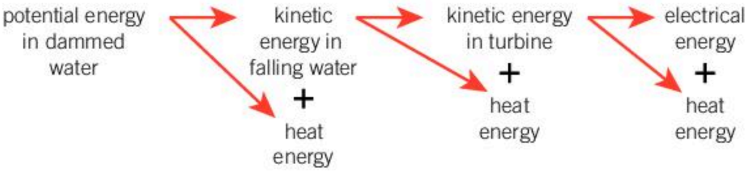
In all devices which have motors, some electrical energy is always transformed into heat as a result of the wire in the motor heating up and friction at the motor bearings.

When objects move, some energy is always transformed into heat as a result of friction between the object and the fluid in which it is travelling.

▲ **Figure 10.2.5** Electric motors get warm after a short time of use

> **Did you know?**
>
> The physicist Albert Einstein suggested a formula which connects energy (E) and mass (m). He showed that $E = mc^2$, where c is the speed of light in metres/second. One kilogram of mass is therefore equivalent to 9×10^{16} joules of energy.

Where a sequence of energy transformations occurs, some heat will be produced and lost to the surroundings at each step. The production of heat energy in a hydroelectric power station is shown by the following energy transformations.



▲ **Figure 10.2.6** Heat energy can be lost during some energy transformations at a hydroelectric power station

As water falls from the dam to the turbines:

potential energy → kinetic energy + heat energy (friction between water and pipes)

As the moving water drives turbo-generators:

kinetic energy → electrical energy + heat energy (friction in bearings)

Some of the electrical energy passing along the cables is transformed to heat and subsequently lost to the surroundings.

Reducing the polluting effects of the internal combustion engine

Fuel combustion takes place in internal combustion engines.

In the past tetraethyl lead was added to petrol in order to make it burn more smoothly in the engine. Different lead compounds were formed during combustion and these were expelled from the car in the exhaust gases. These compounds created air pollution and health risks, as well as environmental hazards.

Lead is a cumulative poison that builds up in the body and gradually causes parts of the body, such as the brain, to stop working properly. This illness is known as lead poisoning. Many workers in factories producing leaded gasoline, as well as other members of the public, have succumbed to this illness.

As a result, the use of leaded gasoline was universally eradicated from global use in 2013. Leaded fuels are being replaced by unleaded or lead-free fuels. These fuels still burn smoothly in the engine because the lead compound has been replaced by a different harmless chemical.

Motor vehicles are powered by petrol or diesel. These fuels are mixtures of chemicals called hydrocarbons, such as octane. In an ideal world, the hydrocarbons would undergo complete combustion and the only exhaust gases would be carbon dioxide and water.

Unfortunately, internal combustion engines are not so efficient. The combustion is incomplete so the exhaust gases will also contain unburnt hydrocarbons, represented by CH and the poisonous gas carbon monoxide, CO.

Nitrogen is generally regarded as an inert gas but under the conditions that exist in the internal combustion engine, nitrogen combines with oxygen to

▲ **Figure 10.2.7** Unleaded fuels

▲ **Figure 10.2.8** Catalytic converter

form a mixture of nitrogen oxides which is represented by the formula NO_x.

Many modern cars have exhaust pipes fitted with catalytic converters. These contain a thin layer of catalyst, such as the metal rhodium, on a ceramic matrix. As the exhaust gases pass through the converter, various changes take place (see Figure 10.2.9).

▲ **Figure 10.2.9** Changes inside a catalytic converter

The pollutant gases from the engine are converted in the converter into harmless gases by a series of chemical reactions.

Conserving mass and energy

After the discovery of nuclear reactions, scientists had to think again about energy transformations. The conservation of energy became the conservation of mass and energy.

Nuclear energy is not the result of transforming another form of energy but of converting a small amount of mass into energy. Solar energy results from **nuclear fusion** in the Sun. Small atoms combine to form larger ones. A small mass of matter is converted into a large amount of energy. Energy is produced in nuclear power stations by **nuclear fission**. Large atoms divide to form smaller atoms. Again, a small amount of mass is converted into a large amount of energy.

Nuclear bombs also use nuclear fission reactions. In a nuclear power station, the nuclear reaction is carefully controlled to give a steady amount of energy. In a nuclear bomb, a large amount of energy is released over a very short period of time with devastating results.

Questions

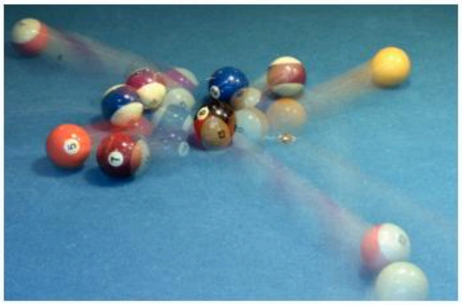
1. In what sense is 'wasted' energy wasted?
2. A fluorescent light is 15% efficient. How many joules of light energy are produced from every 100 joules of electrical energy?
3. What form of energy is produced by an electric motor in addition to kinetic energy?
4. Write down the energy transformations that take place:
   - **a** in a telephone
   - **b** when a crane lifts a crate
   - **c** in shock absorbers when a vehicle drives over a bump.
5. Car exhaust gas contains pollutants including carbon monoxide, nitrogen oxides and unburnt hydrocarbons.
   - **a** Briefly describe the structure of a catalytic convertor.
   - **b** Draw a flow diagram to show what happens to the above pollutants.
   - **c** In the catalytic converter, which pollutants are oxidised and which are reduced?

Learning outcomes

By the end of this topic you will be able to:

- explain the difference between inelastic collisions and elastic collisions
- give examples of inelastic and elastic collisions
- explain the transfer of energy by a wave method
- demonstrate how pulses and wavetrains occur
- describe the uses of curved mirrors in reflecting and focusing energy.

▲ **Figure 10.3.1** Cars sometimes have inelastic collisions



▲ **Figure 10.3.2** Billiard balls scattering after impact – an example of elastic collisions

10.3 Transport and transfer of energy

Types of collision

Kinetic energy is the energy which objects have by virtue of the fact that they are moving. Collisions between moving objects may be described as inelastic or elastic depending on what happens to the kinetic energy.

1 An **inelastic collision** is one in which objects change shape.

Kinetic energy is transformed when work is done on causing the deformation. This energy is eventually transformed into heat.

2 An **elastic collision** is one in which objects do not change shape.

All of the kinetic energy is transferred from one object to another with no energy wasted as heat.

Transport by rolling

Rolling is a type of motion that combines rotation and translation of an object with respect to a surface (either one or the other moves).

Most land vehicles use wheels and therefore rolling for displacement. Ball bearings in rotating devices are another aspect of rolling motion.

Rolling objects are also frequently used as tools for transportation. A flat object is placed on a series of lined-up rollers or wheels. The object is moved along in a straight line as long as the rollers and wheels rotate.

The most practical application today of objects on wheels are cars, trains, buses and other human transportation vehicles.

Transfer of energy by a wave method

If a slinky spring is fixed at one end and then stretched out along a bench top, waves can be generated by shaking the other end. The wave motions can be pulses or wavetrains.

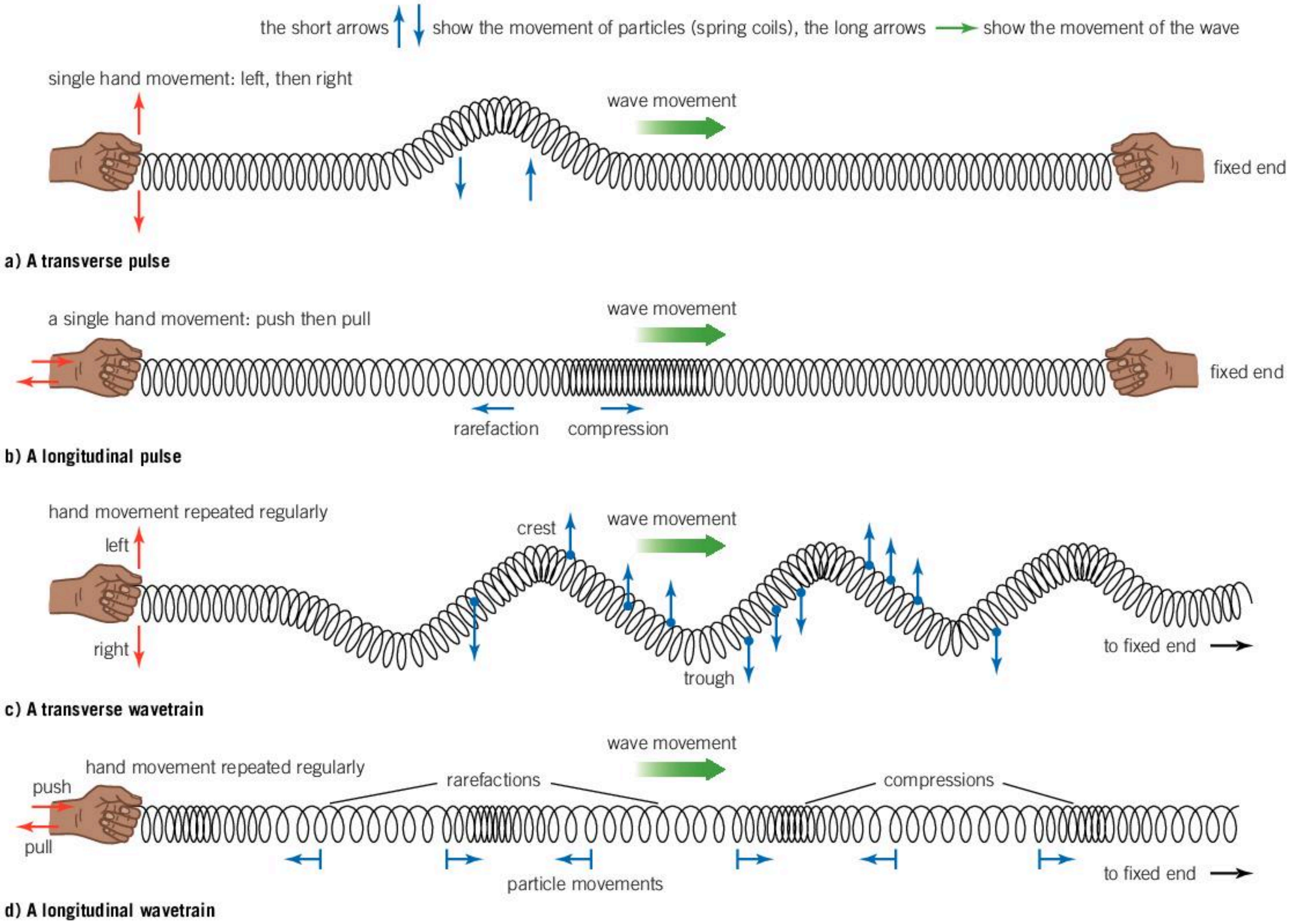
A **pulse** is a single, or short-lived, wave motion. A transverse pulse can be produced by a quick flick of the hand using a to-and-fro sideways movement at right angles to the spring. A longitudinal pulse can be produced by a quick push and pull movement along the line of the slinky.

A **wavetrain** is a continuous group of waves which can be generated by regular repeated hand movements.

Pulses and wavetrains are shown in Figure 10.3.3.

Transverse waves can be recognised by their crests and troughs. The displacement of the coils of the slinky is at right angles to the direction of travel of the wave motion. Longitudinal waves have compressions, where the coils are pushed closer together, and rarefactions where the coils are pulled apart.

The waves transfer energy along the spring.



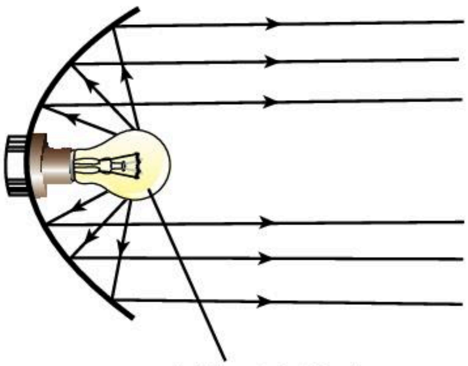
▲ **Figure 10.3.3** Wave motions on a slinky

Practical Activity 10.3.1

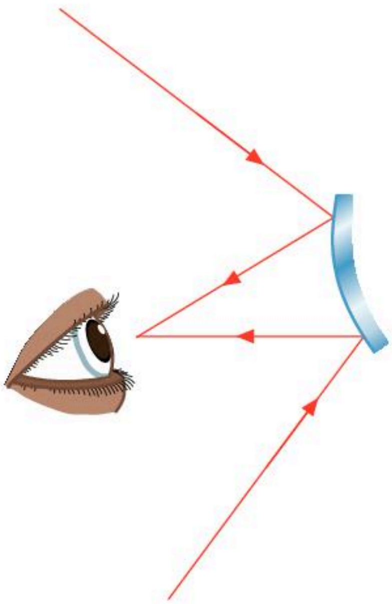
Observing waves

Your teacher will provide you with a slinky.

1. Stretch out the slinky on the top of a smooth bench. Allow plenty of room on either side.
2. Hold one end of the slinky fixed and generate a transverse pulse by moving your hand from left to right once.
3. With one end fixed, generate a longitudinal pulse by pushing your hand forward and pulling it back.
4. Generate transverse and longitudinal wavetrains by repeated movements of your hands in the directions described above.
5. Record your observations and for each type of wave motion describe what happens to a single coil.
6. Do the waves vary according to how far the slinky is stretched?
7. What happens to the pulses when they get to the fixed end?



▲ **Figure 10.3.4** Concave mirror used in a car headlamp



▲ **Figure 10.3.5** Convex rear-view mirror

Reflection and focusing of energy

Curved mirrors

There are two types of curved mirror: **concave** and **convex**. If you imagine the curved mirror to be part of a sphere the centre of the sphere would be at the **centre of curvature**, C.

The rays of light from the same point on a distant object are effectively parallel. If a parallel beam of light strikes a concave mirror it is brought to focus at **the focal point** (also called the principal focus), **F**.

Concave mirrors are used as reflectors for car headlamps. The headlamp bulb is positioned at the focal point of a concave mirror. The light is reflected from the mirror as a parallel beam.

Concave mirrors are used in reflecting telescopes. They gather as much light as possible from objects in space.

Radio waves and sound waves can also be reflected by concave mirrors.

A satellite dish is designed to receive radio waves from communications satellites. The dish has a parabolic shape and the signal is focused on to a small aerial at the focal point of the dish. The signals are converted from electromagnetic or radio waves into electrical signals.

Convex mirrors give a wider field of view than plane mirrors so they are used as rear-view mirrors in cars. Sometimes they are placed on poles on the roadside to enable drivers to see around a 'blind spot'.

You can use a large shiny spoon as a mirror. The inside of the bowl of the spoon is a concave mirror. The outside of the bowl is a convex mirror.

Questions

1. What type of collision occurs when a car hits a tree?
2. What happens to kinetic energy when objects undergo an elastic collision?
3. Describe how you can distinguish between transverse waves and longitudinal waves.
4. Explain why a curved mirror is used in a car headlamp.
5. Why are convex mirrors used in rear view mirrors?

10.4 Conservation of momentum

Momentum

Momentum is concerned with objects in motion. If an object is stationary it has no momentum.

It can be calculated using the equation:

momentum (in kg m/s) = mass (in kg) × velocity (in m/s)

The amount of momentum an object has depends on both its mass and its velocity.

A car of mass 800 kg travelling at a velocity of 13 m/s has a momentum of:

momentum = 800 kg × 13 m/s = 10 400 kg m/s

A lorry of mass 4000 kg travelling at a velocity of 10 m/s has a momentum of:

momentum = 4000 kg × 10 m/s = 40 000 kg m/s

Although the lorry is moving more slowly than the car, it has a greater momentum because its mass is so much more than the car.

Conservation of momentum

Momentum, like velocity, has both size and direction. This is important when considering changes in momentum when objects collide.

The law of conservation of momentum states that:

> **when two or more objects collide, the total momentum of the objects after the collision will be equal to the total momentum of the objects before the collision providing that no external forces (such as friction) are involved.**

In other words:

total momentum before collision = total momentum after collision

In carrying out calculations involving momentum, it is necessary to take one direction as corresponding to a positive velocity and the opposite direction as corresponding to a negative velocity. Conventionally, positive is taken as moving from left to right.

Here is what happens when identical cars travelling in opposite directions at the same speed collide:

Figure 10.4.3 The momentum of the cars is equal in size but opposite in direction

Taking velocity to be positive from left to right:

momentum of car A = 800 kg × +10 m/s = + 8000 kg m/s

momentum of car B = 800 kg × −10 m/s = − 8000 kg m/s

total momentum before collision =

momentum of car A + momentum of car B = + 8000 + (−8000)

= 0 kg m/s

Learning outcomes

By the end of this topic you will be able to:

- give the equation for calculating momentum
- calculate the momentum of a moving object
- state the law of conservation of momentum
- carry out calculations based on the conservation of momentum
- carry out a practical activity to prove that momentum is conserved.

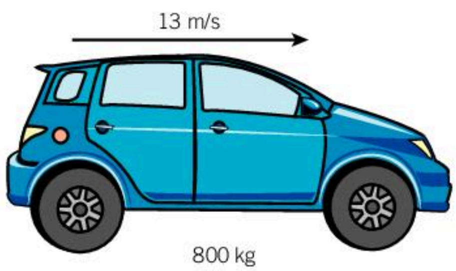


Figure 10.4.1 Car in motion

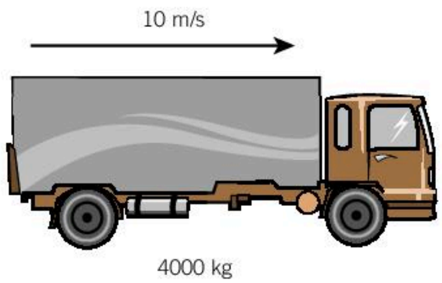


Figure 10.4.2 Lorry in motion

Exam tip

Speed and velocity are not the same thing. Speed tells you how fast something is moving, while velocity tells you how fast something is moving in a particular direction.

The total momentum after the collision will be zero therefore the cars will be motionless.

What happens if car A is going faster than car B?

▲ **Figure 10.4.4** The momentum of the cars is different in both size and direction

$$\text{momentum of car A} = 800\,\text{kg} \times 15\,\text{m/s} = +12\,000\,\text{kg m/s}$$

$$\text{momentum of car B} = 800\,\text{kg} \times -10\,\text{m/s} = -8000\,\text{kg m/s}$$

$$\text{total momentum before collision} = +12000 + (-8000) = +4000\,\text{kg m/s}$$

The total momentum after the collision is **+4000 kg m/s**.

The total mass of the cars after the collision is 800 + 800 = 1600 kg. If their total momentum is +4000 kg m/s their velocity will be:

$$\text{velocity} = \frac{\text{momentum}}{\text{mass}} = \frac{+4000}{1600} = \mathbf{+2.5\,m/s}$$

So after colliding the cars will continue moving to the right with a velocity of 2.5 m/s.

Exam tip

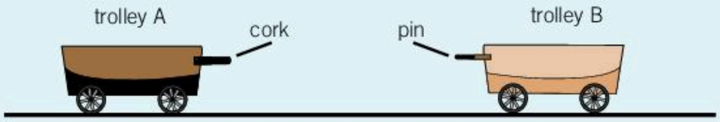
To answer some questions on momentum you might need to use different forms of the momentum equation. You should be able to rearrange the momentum equation into the form that you want.

Practical Activity 10.4.1

Conservation of momentum

Skills assessed: Observation/Recording/Reporting.

Your teacher will provide you with two trolleys (trolley A has a cork attached and trolley B has a pin attached, a length of track and two sets of light gates or ticker timers.



1 Measure and record the masses of the trolleys.
2 Arrange the trolleys on the track so that the trolley A is at the centre and trolley B is at one end. Trolley A will initially be stationary, while trolley B will be pushed towards trolley A. When they collide the pin will stick in the cork and both trolleys will move in the same direction.
3 Place light gates in suitable positions to measure the velocity of trolley B before the collision and trolleys A and B after the collision.
4 Record your results in a suitable table.
5 Use your results to demonstrate that momentum is conserved during the collision.

Questions

1 What is the unit of momentum?
2 What is the momentum of a motor car, of mass 600 kg, travelling at a velocity of 8 m/s?
3 Under what circumstances would a head-on collision between two vehicles result in the vehicles being motionless immediately after the collision?

Exam-style questions

Multiple choice

1 The Sun is a source of
- **A** kinetic energy
- **B** chemical energy
- **C** sound energy
- **D** heat energy

2 Wasted energy is usually in the form of
- **A** potential energy
- **B** chemical energy
- **C** heat energy
- **D** electrical energy

3 The food we eat is a good source of
- **A** nuclear energy
- **B** light energy
- **C** chemical energy
- **D** sound energy

Structured questions

4 Copy and complete the table.

Form of energy	Present in (or example)
Sound	Given off by vibrating objects (e.g. guitar string, loud speaker)
	Stretched rubber band or spring
Chemical potential energy	
Light energy	Given off by very hot objects
	Possessed by all moving objects or particles
	Stored in the nucleus of an atom
	Possessed by an object that is lifted above the ground
	Carried by an electric current
Heat energy	

5 Copy the sentences and fill in the missing words.

Energy enables an object to do …… .

Potential energy is energy that is …….. in an object.

Food contains …………. .

When an object is held above the ground it has ……. .

Kinetic energy is energy of ……….. .

Energy is measured in ………. .

6 **a** **i)** What are nuclear reactions?
ii) Where is it used to make energy?

b Show the energy transformations for the following:
i) a torch
ii) an electric heater.

7 **a** Distinguish between an elastic and an inelastic collision.

b A car of mass 600 kg is travelling at a velocity of 10 m/s and collides with a truck of mass 3600 kg travelling in the opposite direction at 4 m/s.
i) Calculate the momentum of the car before the collision.
ii) Calculate the momentum of the truck before the collision.
iii) Calculate the total momentum after the collision.
iv) Calculate the velocity of the vehicles after the collision.

Section B

11 Electricity and lighting

Learning outcomes

By the end of this topic you will be able to:

- explain the difference between conductors and insulators
- name some conductors
- name some good insulators
- explain why all metals are good conductors
- describe the conditions needed to produce an electric current
- draw some common circuit symbols
- describe the differences between series and parallel circuits.

Electricity is a very useful form of energy. We can use electrical devices to transform energy from one form to another at the flick of a switch. For most people electrical energy is supplied by the mains. It is important to use this supply safely and carefully to conserve energy.

11.1 Electrical conductors

Electric current

Electric current is a flow of charged particles. In order for the current to flow, there must be a complete path around which the charged particles can move. This path is called an **electric circuit**. There must also be a source of electrical energy, such as a cell, a battery or the mains supply.

Conductors

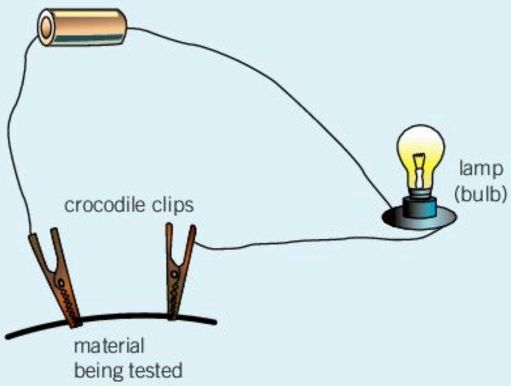
Substances that allow electric current to flow through them easily are called **good conductors**. Substances that do not allow electric current to flow through them easily are called **poor conductors**.

Practical Activity 11.1.1

Good and bad conductors

Skills assessed: Observation/Recording/Reporting.

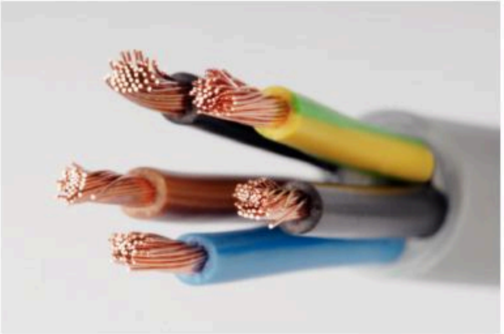
1 Join a cell and a lamp (bulb) together with connecting wires as shown in the diagram.
2 Use the crocodile clips to connect a piece of wire in the gap. The ends of the wire must be bare.
3 Observe what happens. As the wire is a conductor it completes the circuit and the lamp lights.
4 Place different materials in the gap and decide if they are good conductors or poor conductors. You could try glass, plastic, string, wood, rubber, pencil lead, fabric, salt crystals and sugar crystals.
5 Record your results in a suitable table.



Electrons

All substances are made up of particles called **atoms**. Each of these consists of a nucleus with negatively charged particles called **electrons** surrounding it. Electrons are the charged particles that flow as an electric current in a solid. Metals contain free electrons that are not bound to a particular nucleus, so they can move easily through the metal as an **electric current**. As a result, all metals are good conductors. Wires made from copper are normally used to form electrical circuits as copper is a good conductor and is relatively cheap.

Some non-metals can conduct electricity but less well than metals. These materials are known as **semi-conductors** and are used in the manufacture of electronic devices. Examples are carbon, in the form of graphite, together with germanium and silicon.



▲ **Figure 11.1.1** Bundle of insulated wires inside a cable

In non-metals, the electrons are usually bound to a particular nucleus and are not able to flow around the material, so these substances are poor conductors. Another name for poor conductors is **insulators**. Plastics, perspex, rubber and nylon are examples of insulators. This makes these substances useful, as they prevent current in electrical circuits flowing where it is not wanted. For example, copper wires are usually covered in plastic to prevent 'short circuits' between wires and a plug has a plastic, or rubber case, to stop current flowing through anyone touching the plug.

Tap water conducts electricity because it contains dissolved, charged particles called **ions**. For this reason, it is important to have electrical supplies kept away from wet areas, such as baths and showers, and not to handle electrical equipment with wet hands.

Did you know?

Conventionally we say that current flows from the positive side of the supply around the circuit to the negative side. In fact electrons in the circuit flow from the negative side of the supply to the positive side.

▲ **Figure 11.1.2** Electricity cables and insulators on a pylon

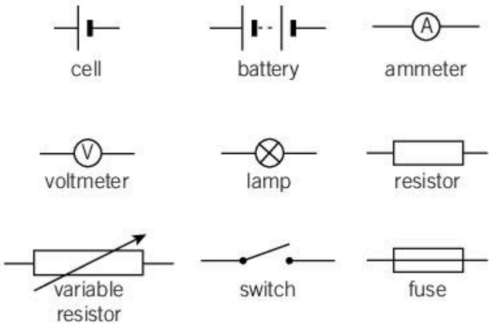
Electric circuits

Current flows through a circuit. An electric circuit needs a source of electricity, such as a cell or battery, connecting wires and an appliance that uses the energy from the electrons to do work. The size of the current in a circuit is measured using an **ammeter**. The unit of current is the **ampere**, often shortened to amps. The symbol is **A**.

Rather than using pictures to show circuits, we use symbols to represent the different components in a **'circuit diagram'**.

Circuit symbols and diagrams

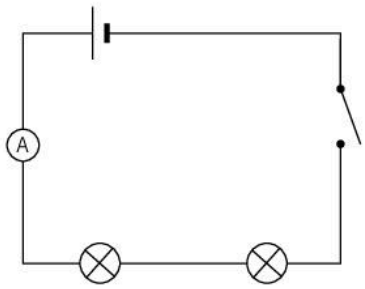
The circuit symbols are used all over the world by engineers, scientists and electricians. The circuit symbols for some common components are shown in Figure 11.1.3. Circuit diagrams are shown in Figure 11.1.4 and 11.1.5.



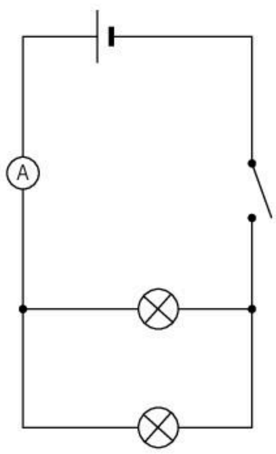
▲ **Figure 11.1.3** Circuit symbols

Exam tip

Make sure that you know and can draw circuit symbols. Use a sharp pencil and make sure that your diagrams are neat.



▲ **Figure 11.1.4** Lamps connected in series



▲ **Figure 11.1.5** Lamps connected in parallel

Types of circuits

There are two ways that circuits can be connected: in series and in parallel.

Series circuits

If the components in a circuit are connected one after another, the circuit is called a **series circuit**. There is only one path the current can follow so the current is the same in each part of the circuit. You can test this yourself by setting up a circuit like the one shown in Figure 11.1.4 and putting an ammeter at different points in the circuit. At each position of the ammeter, close the switch and measure the current. An ammeter is always connected to a circuit in series, so that the current it is measuring passes through it.

If there is a break at any point in a series circuit, no current will flow through the other components so the whole circuit is turned off.

Parallel circuits

If the components in a circuit are connected in parallel, there is more than one route that the current can take to move around the circuit. At a junction the current 'splits' between the branches. This means that separate branches may have different currents. The current through the supply is found by adding the currents in the individual branches.

You can test this yourself by setting up a circuit like the one shown in Figure 11.1.5 and putting an ammeter at different points in the circuit. At each position of the ammeter, close the switch and measure the current.

If there is a break at any point in a parallel circuit, current can still flow in the other parallel parts of the circuit. Parallel circuits are more useful than series circuits as switching off one appliance does not mean switching off all of the others.

Questions

1. What is a conductor?
2. Why are metals good conductors?
3. Why are copper wires in circuits usually surrounded by plastic or rubber?
4. Draw a circuit diagram for a circuit with a cell, a switch, a lamp and a resistor in series.
5. Draw a circuit diagram for a circuit with three lamps in parallel with each other and a cell.

11.2 Current, voltage and resistance

Voltage

For current to flow in an electrical circuit, there must be a source of electrical energy, such as a cell, a battery or the mains supply. The source gives electrical energy to each electron moving in the circuit. This energy is known as **electromotive force** or **emf**. The unit of emf is the **volt, V**.

As the electrons move around the circuit, they transfer their energy to the components in the circuit. For example, in a bulb the electrical energy is transferred to light energy and heat energy, and in a resistor the electrical energy is transferred to heat energy.

Across each component in the circuit there is an electrical energy difference called the **potential difference (p.d.)** or **voltage**. The unit of voltage is the **volt**. It is measured with a **voltmeter**. Voltmeters are always placed in parallel across a component to measure the voltage across it.

Resistance

Resistance is the opposition to current flow in a circuit. The larger the resistance of a component, the more energy is transferred from electrical to other forms when charge passes through it, so the larger the voltage across it at any given current. The unit of resistance is the **ohm, Ω**.

Voltage, current and resistance are related by the formula:

$$V = IR$$

where V is the voltage in volts, I is the current in amps and R is the resistance in ohms. So, if the resistance of a resistor is 4 Ω and the current is 3 A, you can calculate the voltage as follows:

$V = IR$

$V = 3 \times 4$

$V = 12$ V

Learning outcomes

By the end of this topic you will be able to:

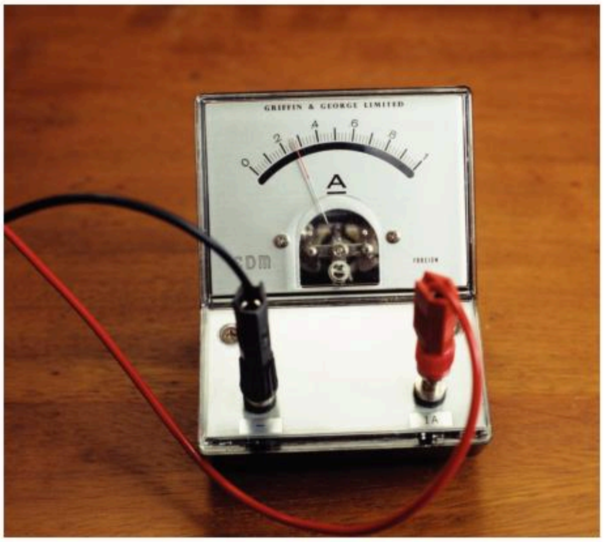
- explain what is meant by voltage
- explain what is meant by resistance
- state the formula that relates voltage, current and resistance, $V = IR$
- calculate values of voltage, current and resistance, and state their units
- explain the differences in voltage in series and parallel circuits.

Key fact

Ohm's law states that the current in a conductor maintained at a constant temperature is proportional to the potential difference between its ends.

Exam tip

Ammeters are always connected in series and voltmeters are always connected in parallel.



▲ **Figure 11.2.1** Ammeter

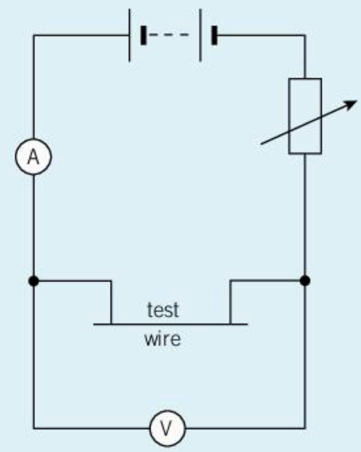
▲ **Figure 11.2.2** Digital and analogue voltmeters

Practical Activity 11.2.1

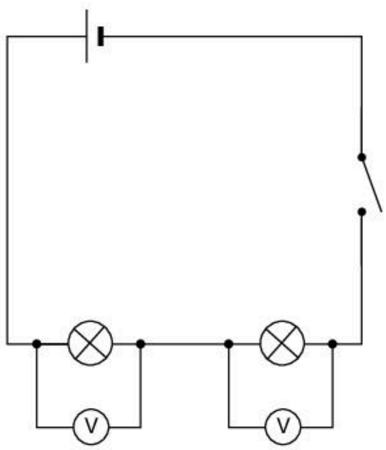
How different resistances affect current

Skills assessed: Manipulation/Measurement and Analysis, and Interpretation.

1 Set up the circuit as shown in the diagram.
2 Adjust the variable resistor to give the lowest current possible through the wire.
3 Record the current on the ammeter and the voltage on the voltmeter.
4 Adjust the variable resistor to give a different value for current, and record the current and the voltage.
5 Repeat step 4 until you have five evenly spaced values for current and five corresponding values for voltage.
6 Plot a graph of voltage against current for the wire.
7 What conclusion can you make from your graph?
8 Repeat the experiment using a filament bulb in place of the wire. What conclusion can you make from your graph?



Voltage in series circuits



▲ **Figure 11.2.3** Lamps connected in series

In a series circuit the current through each component in the circuit is the same, because each electron passes through each component.

The voltage (emf) of the supply is a measure of the energy transferred by the supply to each electron that passes through it. Each electron then passes through each component so the voltage of the supply is shared between the components, that is the voltages across the individual components add to equal the supply voltage.

You can test this yourself, by setting up a circuit like the one shown in Figure 11.2.3 by putting a voltmeter across each component in the circuit.

If two cells are connected together, each electron is given energy by each cell, provided they act in the same direction. So, the **total voltage of cells in series is found by adding the voltages of the cells together**.

You can test this yourself by adding a second cell to the one in the circuit above and repeating your measurements.

Key fact

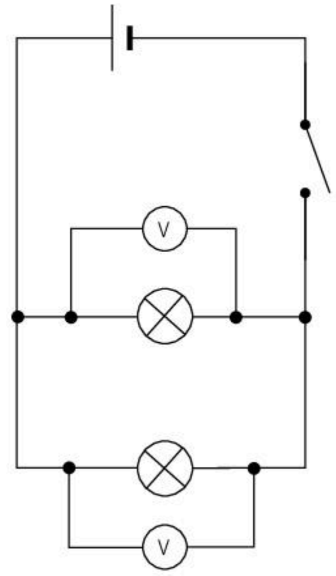
The graph of voltage against current is a straight line for a resistor, provided the temperature of the resistor stays constant. A filament bulb contains a piece of resistance wire coiled round many times. When the bulb is switched on and current flows through the wire its temperature increases rapidly, which increases its resistance, so the V–I graph for the bulb is a curve.

Voltage in parallel circuits

In a parallel circuit, the current through the parallel branches can be different because the current splits at each junction. The current through the supply is the sum of the currents in the individual branches.

Each electron in a parallel circuit passes through one parallel branch or the other, so each electron transfers the same amount of energy regardless of which branch it passes through. So, **the voltage across each parallel branch is the same**.

You can test this yourself, by setting up a circuit like the one shown in Figure 11.2.4 by putting a voltmeter across each component in the circuit.



▲ **Figure 11.2.4** Lamps connected in parallel

Questions

1. What is meant by the emf of a supply?
2. Sketch a graph of voltage against current for a resistor at a constant temperature.
3. Draw a circuit diagram for a cell, a lamp and a resistor in series. Add an ammeter and a voltmeter to the diagram, which would measure the current through, and the voltage across, the lamp.
4. Calculate the resistance of a resistor if there is a voltage of 12 V across it when the current through it is 3 A.
5. What is the current through a 9 Ω resistor when the voltage across it is 4.5 V?

Learning outcomes

By the end of this topic you will be able to:

- calculate the power of an appliance
- state the correct colour codes for the wires in a three-pin plug
- wire a three-pin plug correctly
- explain the use of fuses as safety devices.

11.3 Plugs and fuses

Power

The power of an electrical appliance is the rate at which it transfers electrical energy to other forms. It is the energy transferred per second in the appliance. The unit of power is the **watt**. The symbol is **W**. The power of an appliance can be calculated using the formula:

$$W = IV$$

where W is the power in watts, V is the voltage in volts and I is the current in amps.

The mains supply

Cells and batteries supply current that passes around a circuit in one direction only. This is known as **direct current** or **d.c.** The mains supply provides a current that passes around a circuit in one direction, then in the opposite direction. This is known as **alternating current** or **a.c.**

The voltage of the mains supply in Barbados, Jamaica and Trinidad is 110 V, in most other Caribbean countries it is 240 V.

Wiring a plug

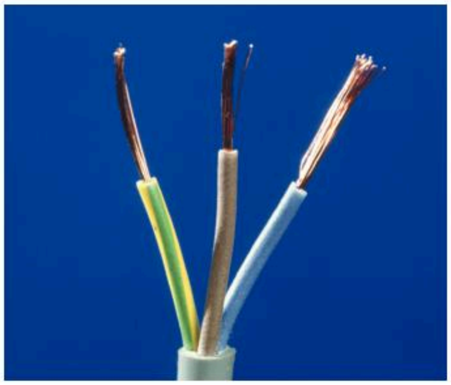
Most electrical appliances used in the home are connected to the mains supply using a cable, also called **flex**, and a **three-pin plug**. The three pins are made of brass, which is a good conductor. It is also hard and does not rust. The outer case of the plug, the part that you hold to connect the plug to a socket, is made from plastic or rubber as these materials are good insulators.

Each pin in the plug is connected to a different wire, called the **live**, **neutral** and **earth wires**. The pins are marked **L**, **N** and **E**. It is dangerous to connect the wrong wire to a pin. The wires are colour-coded to make it easier to see which is which. **The live wire is coloured brown, the neutral wire is coloured blue and the earth wire is coloured green and yellow**.

Each 'wire' consists of a bundle of fine copper wires, surrounded by an insulating cover of plastic. The live, neutral and earth wires are held together in another layer of plastic outside the plug and the cable grip holds this tightly in place. There should be no bare wires showing inside the plug.

Exam tip

Make sure that you can identify faults in the wiring of a three-pin plug.



▲ **Figure 11.3.1** Wires from a cable

▲ **Figure 11.3.2** An electric plug

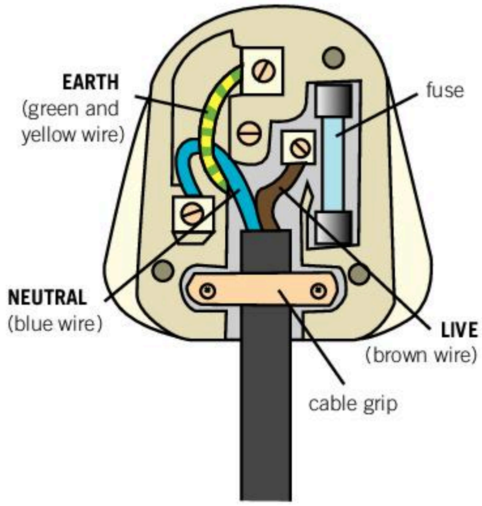
Practical Activity 11.3.1

Wiring a plug

Skills assessed: Manipulation/Measurement.

Your teacher will give you a cable and a plug.

1. Strip off the last 5 cm of the outer insulation to expose the inner, coloured insulation.
2. Cut about 2 cm off the end of the live and neutral wires to make them shorter than the earth wire.
3. Strip the last 1 cm of insulation from the end of the earth wire and twist the ends of the copper wires tightly together. Repeat this for the live and neutral wires.
4. Loosen the screw attached to the pin marked live. Carefully push the copper wire into the hole at the top of the pin and tighten the screw down onto the wire. Make sure that the screw is tightened onto the wire, not the insulation.
5. Repeat for the neutral and earth wires.
6. Pull gently on the flex to make sure that all the connections are tight.
7. Screw the cable grip firmly across the outer insulation where the flex leaves the plug.
8. Carefully draw your correctly wired plug. Label the different parts of the plug and make a note of the coloured coding on each wire.
9. Screw the top of the plug on.



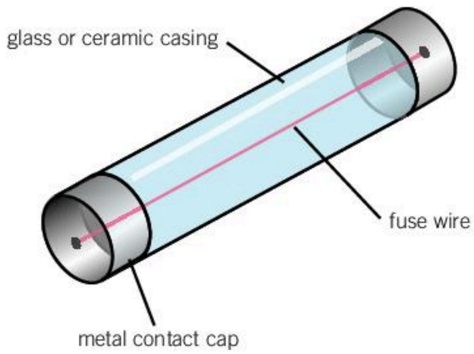
▲ **Figure 11.3.3** Inside a plug

Fuses and earthing

Appliances with metal cases must be **earthed**. This means that the earth wire is attached to the metal case of the appliance. If a fault develops in the appliance, the live wire might touch the case making it live too. If this were to happen, anyone touching it could get a severe electric shock.

If a fault develops in an appliance, a large current flows melting the fuse and cutting off the supply. A **fuse** is a piece of wire designed to melt if a current larger than a particular value passes through it. The fuse is placed in the live wire.

Fuses have different ratings. The fuse must be chosen to have a rating only slightly higher than the normal working current of the appliance. If it is higher than this, the appliance, or the supply cable, could be damaged before the fuse melts. If it is lower, the fuse will melt every time the appliance is switched on.



▲ **Figure 11.3.4** Inside a cartridge fuse

Questions

1. Explain the difference between an a.c. and d.c. supply.
2. Why must the fuse in a plug be connected to the live wire?
3. What are the names and colours of the wires found in an earthed three-pin plug?

Learning outcomes

By the end of this topic you will be able to:

- understand the formula $I = W/V$
- calculate the size of fuses for different appliances
- explain the use of thick flexes for heavy-duty appliances.

▲ **Figure 11.4.1** Electrical fuses

Did you know?

Appliances with plastic cases do not need to be earthed as current cannot flow through the case. These are called double insulated. The flex connected to them contains only live and neutral wires.

▲ **Figure 11.4.2** Pylons and a sub-station

11.4 Calculating the size of a fuse

The power of most mains appliances is written on a plate fixed to the appliance. The normal working current of the appliance is calculated using the formula:

$$I = W/V$$

where I, the normal working current of the appliance, W is the power of the appliance and V is the voltage of the mains supply.

Fuses are available in a range of sizes, such as 1 A, 2 A, 3 A, 10 A and 13 A. The fuse should be chosen with a rating slightly higher than the calculated current.

Worked example

What fuse should be used in a 500 W heater when used with a 230 V mains supply?

Use the formula $I = W/V$ to calculate the current in the heater ($W = 500$ W and $V = 230$ V).

So $I = 500/230$

$= 2.17$ A

Therefore, a fuse of 3 A should be used.

Wires and flexes

Electricity produced at a power station is sent to a sub-station by means of high-voltage cables, called transmission wires, supported on pylons. At the sub-station, the voltage is reduced before the electricity is distributed by means of overhead wires to buildings. These cables are well-insulated.

Some very powerful household appliances, such as electric ovens, use very large currents. The power rating of an electric oven can be 10 000 watts or 10 kilowatts (10 kW) and a water heater may be 7500 watts (7.5 kW). Such appliances may be wired with a very thick flex and wired directly into the mains supply, so that they do not have to be plugged in.

Questions

1 What is the power of an appliance that takes a current of 10 A and is powered from a 240 V mains supply?

2 You have 3 A, 5 A and 13 A fuses available. What fuse would you put in the plug for a 2000 W electric iron?

3 What fuse should be used in a 500 W heater when used with a 120 V mains supply?

11.5 Using electrical energy

Electrical appliances

Mains-operated electrical devices are extremely useful to us. At the flick of a switch they transform electrical energy to other forms of energy.

Some common electrical devices are:

- kettles, irons and stoves, which produce heat energy
- electric mixers, drills and motors, which produce kinetic (movement) energy
- speakers, which produce sound energy
- bulbs, which produce light energy.

Some devices usefully transform electrical energy into more than one other form of energy.

- Hairdryers produce heat and kinetic energy.
- Televisions produce light and sound energy.

Calculating electrical energy

Electricity companies charge their customers for the amount of electrical energy they use.

The usual unit of energy is the joule, J but it is too small to be useful in this situation, so the electricity companies use a unit called the **kilowatt-hour, kW h**. A kilowatt-hour is the amount of energy that is transferred by a one kilowatt device when it is used for one hour.

We can use the following formula to calculate the energy transferred by an appliance.

energy transferred (kilowatt-hours, kW h) = power (kilowatts, kW) × time (hours, h)

For example, to find the energy transferred by a 1 kW fan heater when it is used for 30 minutes:

energy transferred (kW h) = 1 (kW) × 0.5 (hours)

= **0.5 kW h**

The power rating of the appliance is usually written somewhere on the appliance.

Heating appliances, such as immersion heaters, radiant heaters, irons, kettles and stoves, transfer more energy in a given time than radios, televisions, amplifiers and fans, so they cost more to use.

Table 11.5.1 Comparison of heating and non-heating appliances

Heating appliances				Non-heating appliances			
Appliance	Watts	Monthly Use (h)	Energy (kWh)	Appliance	Watts	Monthly Use (h)	Energy (kWh)
Air conditioner	1500	200	300	Clock	3	720	2.2
Dryer	5000	20	100	Ceiling fan	80	100	8.0
Microwave oven	1500	20	30	Incandescent bulbs	60	150	9.0
Stove and oven	3000	10	30	Fluorescent lights	40	200	8.0

Learning outcomes

By the end of this topic you will be able to:

- list some electrical appliances and the energy transformations they produce
- calculate the electrical energy transformed by a device, in kilowatt-hours
- calculate the cost of using a particular appliance for a defined length of time.

Key fact

Remember that all electrical appliances will transform some electrical energy to heat but this is not always a useful energy transformation.

Exam tip

Remember:
60 minutes = 1 hour
1000 watts = 1 kilowatt

Table 11.5.1 *Continued*

Iron	1000	20	20	Compact fluorescent	20	200	4.0
Toaster	1400	15	21	VCR / DVD	20	120	2.4
Vacuum cleaner	1600	20	32	Cordless phone	5	150	7.5
Washer	500	40	20	Floor fan	100	90	9.0
Water heater	4500	90	395	Radio	30	300	9.0
Colour television	200	200	40	CD tape radio system	200	30	6.0
Coffee maker	1200	15	18	Outdoor lighting	100	90	9.0
Computer system	300	150	45	Table fan	25	200	5.0
Curling iron	1500	10	15	Satellite dish	30	150	4.5
Dishwasher	1400	25	35	Home internet router	10	150	1.5
Frying pan	1200	10	10	Mobile phone charger	2	200	0.4
Coffee maker	1200	40	48	Stereo	30	30	0.9
Refrigerator freezer	500	360	180	Clock radio	10	720	7.2
Blow dryer	1000	15	15	Blender	300	30	9.0

Practical Activity 11.5.1

Energy consumption of appliances

To calculate the energy consumption of different electrical appliances, using six heating and four non-heating appliances regularly used in your home.

This activity will be done over a period of one month.

1. Read your electricity meter on Saturday during the day. Note the exact time that you read the meter, as well as the meter reading.
2. Identify the six heating and four non-heating appliances that are most regularly used in your home.
3. Estimate the number of hours per day (over a 24 hour period) that each appliance is used.
4. Keep a daily usage log for each appliance. Record in a table format.
5. Read your electricity meter on the Saturday one month after you started at the exact same time. Record the meter reading.
6. Calculate the average daily use of each appliance – in hours.
7. Calculate the average daily energy consumption of each appliance using the formula:
   $$\frac{\text{appliance wattage} \times \text{hours used per day}}{1000} = \text{kWh consumption}$$
   Note: The wattage is usually stamped either on the back, bottom or name plate of the appliance.
8. Calculate the monthly energy consumption of each appliance.
9. Calculate the cost to run each appliance:
   $$\text{monthly energy consumption (kWh)} \times \text{utility rate per kWh}$$
   Check your local electricity bill to obtain the utility rate per kWh cost.
10. From your results obtained in step 8, compare the electricity costs for heating and non-heating appliances.

Questions

1. What energy transformations take place in a washing machine?
2. What quantity is measured in kilowatt-hours?
3. How many mains electrical appliances do you have in your home?
4. What type of energy transfer takes place in each appliance?
5. A 2000 W electric fire is run for 8 hours. How much electrical energy, in kWh, does it transform to heat during this time?

11.6 Electricity bills

Learning outcomes

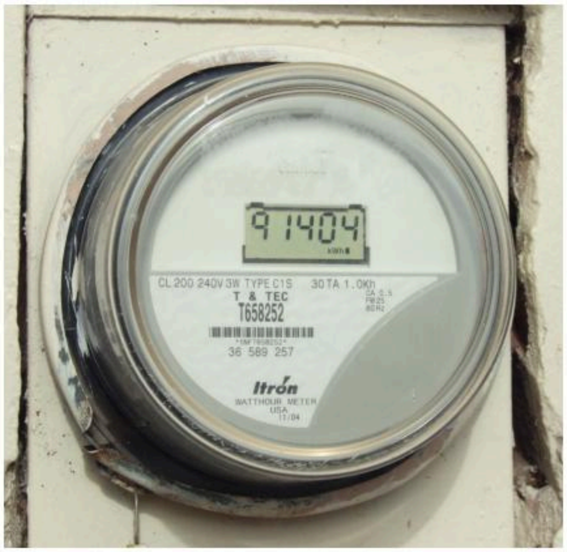
By the end of this topic you will be able to:

- describe how to read electricity meters
- explain a typical electricity bill.

Electricity meters

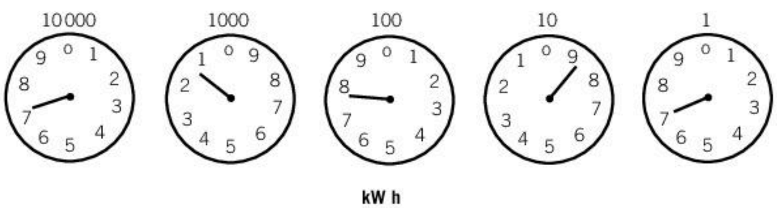
Electricity meters are digital or analogue. The newer, digital meters are easy to read – just read the numbers shown on the display.

Analogue meters are more difficult. An analogue meter usually has five dials, with the numbers 0 to 9 around them. The numbers increase in a clockwise direction on some dials and in an anticlockwise direction on the others.



▲ **Figure 11.6.1** Reading a digital electricity meter

To read an analogue meter, start with the dial the furthest to the left. Write down the number on the dial that the pointer is exactly lined up with or has just passed. This gives the 'ten thousand' digit. Repeat with the next dial on the left to get the 'thousand' digit and so on, until you reach the right-hand end.



▲ **Figure 11.6.2** Reading an analogue electricity meter

Exam tip

Be sure that you can convert from kilowatts to watts and from watts to kilowatts.

To convert from watts to kilowatts divide by 1000.

To convert from kilowatts to watts multiply by 1000.

Practical Activity 11.6.1

Energy use in a school

This activity will take place over one week, starting on Monday morning and finishing on the following Monday morning.

1. Find your school electricity meter. Do this first thing every morning Monday to Friday and the following Monday.
2. Draw the dials or display. Is your school's meter digital or analogue?
3. Record the readings shown.
4. Repeat your reading at the end of the day.
5. Record all your readings in a table.
6. Calculate (a) the number of kilowatt hours of electrical energy used each day (b) the number of kilowatt hours of electrical energy used over the weekend.
7. What is the electricity usage for your school for the week?
8. Compare the electricity use in the school during the week to that of the weekend.

Did you know?

On an electricity bill 1 kW h is sometimes called '1 Unit'.

Electricity bills

The electricity company regularly reads the meter, for example every three months, and sends the consumer a bill. The bill shows the latest meter reading and the previous meter reading.

Subtracting the previous reading from the latest reading gives the number of kW h of electrical energy used between the readings.

Electricity bills vary slightly from country to country and between suppliers but they all show the price charged for each kW h of electrical energy used. In some cases, the price for each kW h is the same; other suppliers charge more for the first kW h used and the price for each further kW h is less.

Sometimes there is a fixed charge called the **standing charge** or the **customer charge** that must be paid even if no energy is used. This charge covers things such as the cost of reading the meter and preparing the bill, and for maintaining the supply. This charge is added to any energy charges.

Other charges can include:

- Meter rentals – Electricity meters are usually the property of the electricity authority in each country. Therefore, when an installation is carried out (residential, business or commercial), the monthly electricity bill contains a charge for the rental of the equipment (meter).
- Fuel adjustment charges – Since the price of fuel used in the production of electricity fluctuates, the cost of providing electricity to customers will vary every month. This variation in the price of fuel is charged to the customer monthly under this heading.

In some islands, for example Trinidad and Tobago, these costs are no longer reflected on the electricity bills.

CURRENT CHARGES FOR METER # 835240

Billing Cycle	No. of Days	Billing Exchange Rate	Base Exchange Rate	Deposit	Multiplier
09	33	65.63	62.00	$2000.00	1

From: 13-Apr-2008 To: 16-May-2008

Register Type	RDG Type	Current Reading	Previous Reading	Description	Usage	Rate	Current Period Charges
KWH	Actual	22538	22205	Energy 1st	100	4.809	$480.90
				Energy Next	233	8.466	$1972.58
				Cust Charge			$72.00
				SUBTOTAL			$2525.48
				F/E Adjust @ 4.450%			$112.38
				Fuel & IPP Charge	333	9.068	$3019.64
				TOTAL CURRENT CHARGES			$5657.50

▲ **Figure 11.6.3** An electricity bill shows how much electricity has been consumed

If we know the cost of 1 kW h of energy, we can calculate the cost of using a particular appliance for a particular length of time using:

cost of electricity = number of kW h × cost per kW h

Worked example

How much does it cost to use a 100 W electric light for 4 hours if electrical energy costs $0.25 per kW h?

$$\text{number of kW h} = 0.1\ \text{kW} \times 4\ \text{hours} = 0.4\ \text{kW h}$$

$$\text{cost of electricity} = 0.4\ \text{kW h} \times \$0.25 = \$0.10$$

Worked example

Electrical energy costs $0.30 per kW h. It costs $0.66 to do an hour's ironing. What is the power rating of the iron?

$$\text{cost of electricity} = \text{number of kW h} \times 0.30$$

$$\text{number of kW h} = 0.66 / 0.30 = 2.2$$

Therefore, the power rating of the iron is 2.2 kW.

Questions

1. What is a 'standing charge' on an electricity bill?
2. A student used a 9 kW shower for 20 minutes. Electrical energy costs $0.30 per kW h. What was the cost of the shower?
3. An electricity company charges a standing charge of $7.00 and a fee of $0.25 per kW h. A customer had a previous meter reading of 12 800 kW h and a latest reading of 13 100 kW h. What is the total bill?
4. Explain the difference between an analogue and a digital electricity meter.

11.7 Conserving electrical energy

Learning outcomes

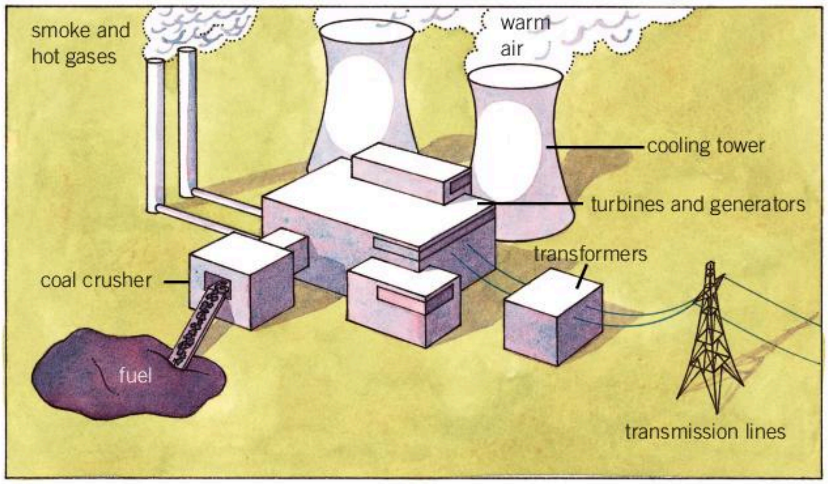
By the end of this topic you will be able to:

- state some examples of renewable and non-renewable energy sources
- state the energy transformations that take place in a power station
- describe some ways of reducing electrical energy consumption in the home.

▲ **Figure 11.7.2** Energy efficient light bulb

Energy sources

Generating mains electricity means using an energy source to drive generators and produce electrical energy. **Non-renewable energy sources** may be fossil fuels, such as coal, oil or gas. **Renewable energy sources**, such as solar, wind, waves, tides and falling water may also be used to produce electrical energy. In power stations, energy transformations occur. Fossil fuels are burnt to produce heat energy which is used to heat water. The water is turned into steam and this turns a turbine attached to a generator. The generator produces electricity.



▲ **Figure 11.7.1** A coal-fired power station

Energy conservation

Since we mainly use non-renewable energy sources that will be used up without being replaced, we must make sure that we conserve electricity. This can be done in many ways.

Lighting

Replacing filament bulbs with fluorescent tubes and bulbs is a good way to conserve energy. Although the fluorescent bulbs cost more to buy, they last longer than filament bulbs and cost much less to run, so over a period of time they save the householder money.

Where filament bulbs are used, they should not be more powerful than really necessary. You should always switch the lights off when you leave a room unoccupied.

Heating and cooling

Heating and cooling homes can use a great deal of energy. Only occupied rooms need to be heated or cooled and thermostats should be set so that the room is not excessively cooled or heated. Good insulation prevents heat from leaving a room we want to stay warm or entering a room we want to stay cool. Curtains, blinds and awnings can be used to keep heat in or out. The filters on heating and cooling systems should be cleaned regularly as this keeps them working efficiently.

Did you know?

Filament bulbs are very inefficient. Less than 10% of the electrical energy supplied to the bulb is converted into light, the rest is wasted as heat.

Energy wastage

Energy is expensive and it is important that we do not waste energy by not using our appliances properly or by using appliances that are faulty.

With the technological advances of the late 20th century and early 21st century, the use of LEDs (light-emitting diodes), LCDs (liquid crystal displays) and plasmas are now evident in everyday life. They have a diverse variety of uses and applications because they are much cheaper to use than conventional appliances, as seen in the Topic 11.8.

Kitchen appliances

Kitchens use many electrical appliances, such as washing machines, tumble driers, dishwashers, electrical cookers, kettles, irons, electrical food mixers, refrigerators and freezers.

It is possible to save energy with thoughtful use of these appliances.

- Only use the washing machine with a full load.
- Only use the dishwasher with a full load.
- Use energy-saving, and quick, programmes in washing machines and dishwashers.
- Dry clothes outside in the air, not in a tumble drier.
- Make sure the rubber seal on the refrigerator door fits, to keep cold air in.
- Avoid opening the refrigerator door too often or for too long.
- Cook several things at once in the oven where possible to make good use of the energy.
- Keep lids on cooking pots to keep the heat in.

Standby

Many modern appliances, such as televisions, computers, DVD and CD players have 'standby' modes. Even in this state the appliance will use electrical energy, so they should be switched off when they are not being used, for example overnight.

▲ **Figure 11.7.3** Computer power switch

Faulty appliances

Electrical energy can be wasted by using inefficient or faulty appliances. Any electrical appliance that is not working properly should be checked and replaced if necessary. In addition to wasting electricity, use of such an appliance could be dangerous. Many domestic fires are caused by bad electrical wiring and damaged flexes

Questions

1. Why does replacing a filament bulb with a fluorescent bulb save money?
2. Suggest three ways of reducing electrical energy consumption in the kitchen.
3. Why must the flex to a 9 kW shower be much thicker than the flex to a 2 kW kettle and what might happen if it is not?

11.8 Filament lamps, fluorescent tubes and LED bulbs

Learning outcomes

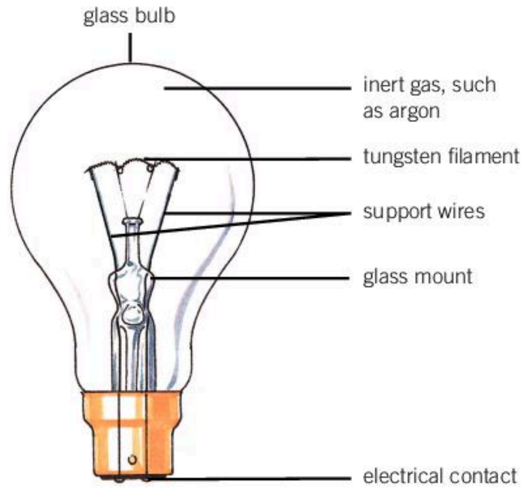
By the end of this topic you will be able to:

- describe how a filament lamp works
- describe how a fluorescent tube works
- describe how an LED bulb or lamp works
- compare the uses of different types of lighting
- state how the wattage of a filament lamp affects its brightness.

Filament lamps

Filament lamps are **incandescent light sources**, which means that they give off light because they are very hot. The filament in the lamp is a coil of very thin tungsten wire. This is connected to an electrical circuit by two stiff pieces of wire. The filament is enclosed in a glass bulb containing an inert gas, such as argon. When the lamp is connected to an electrical supply, a current passes through the filament. This heats the filament to a very high temperature, between 2000 °C and 3000 °C. The filament glows white hot, emits light and a large amount of heat. The heat energy is wasted energy. Tungsten wire is used because of its high melting point of 3400 °C. The inert gas in the bulb prevents the filament evaporating and blackening the inside of the glass. Filament lamps may be clear or the bulb may be coated, called a 'pearl' bulb, to give a softer effect.

These lamps are very inefficient. Less than 10% of the electrical energy is converted into light; the rest is wasted as heat.



▲ **Figure 11.8.1** A filament lamp

Fluorescent tubes

Many homes and businesses use **fluorescent lighting**. A fluorescent tube is a sealed, cylindrical glass tube which contains mercury vapour and has an electrode at each end. The inside of the tube is coated with phosphor. When the lamp is switched on, an electrical current flows through the mercury vapour and causes it to emit ultraviolet radiation. We cannot see the ultraviolet radiation but when this hits the sides of the glass tube it is absorbed by the phosphor coating and re-emitted as visible white light.

▲ **Figure 11.8.2** Fluorescent tube

LED bulbs

LED is short for 'light-emitting diode'. An LED is an electronic component that glows when an electric current passes through it but it has no filament or sealed tube of mercury vapour.

▲ **Figure 11.8.3** LEDs are often used as indicator lamps

Different-coloured LEDs, and particularly red, are often used as indicator lamps on electrical appliances to show that an appliance is turned on or is in standby mode.

An LED bulb or lamp consists of a set of clear LEDs set into a bulb shape. Each LED glows when an electric current flows through it.

▲ **Figure 11.8.4** LED bulb or lamp

Comparing different types of lighting

Table 11.8.1 gives some information about the different types of lighting used in everyday life.

▼ **Table 11.8.1**

	Types of lighting						
Comparison	**Incandescent (filament)**				**Fluorescent**	**LED**	**Solar**
Sub-types	General	Reflectorised	Tungsten Halogen	Xenon	Single tubes Compact Fluorescent (CFL) Circline	Single 3 Way Clustered (cone/globe/tube)	Path lights Ambient/ decorative Spotlights
	General A General G Decorative	Reflector (R) Parabolic Reflector (PAR)	Low voltage (12 V) Line voltage (120V)				
Type of light emitted	Warm yellow white	White light	Brighter, whiter light	Halogen type white	Softer, flat cold light, bluish	Cool white and warm light	White light
Direction of emitted light	In all directions	In one direction	In all directions	In a specific direction	In all directions	In a specific direction	Uni-or multi-directional
Duration – Usage	Does not last long 700 – 1000 h	Last longer than general bulbs	Longer life – 2 to 4 times	Longer life up to 20000 hours	Last longer 7000 –24 000 hours	Up to 25 000 hours	Dependent upon exposure
Shapes of bulbs	Oval, globe, flame, teardrop	Cone shape	Globe, elliptical, pear	Miniature bulbs	Tube – straight, U, circular, screw type base	Very small round bulb in red, green, blue, white, amber colours	Variety of shapes – string, stake, planters, floodlight, tube
Efficiency	Not very efficient, lose 90% of energy as heat		Twice as efficient	More efficient	More efficient – less energy lost as heat – 89%	Most efficient – least energy lost as heat	Very efficient – based on location
Cost	Least expensive – more expensive to operate		Expensive – but cheaper in terms of electricity		More expensive – cheaper electricity	Was expensive technology – much cheaper	No electricity consumption
Areas of use	All areas of lighting		Spot and flood lighting		All areas of lighting Fluorescent lamps in buildings	All areas within home and commercial settings	Walkways/ pathways Landscaped gardens Security lights Spot lights – motion sensors

Over the past decade, in many countries there has been a move away from traditional filament lamps to fluorescent tubes and especially low-energy lamps because they are more efficient, that is, they need less electrical energy to produce the same amount of light.

LED lamps have only become available more recently. Although they are more expensive to buy, they last longer and are cheaper to run, so they will be the choice in the future.

Practical Activity 11.8.1

Observing different types of lamps

Materials:

- Filament lamp
- Low energy fluorescent lamp
- LED lamp

Method:

1. Observe each of the lamps in turn and look how it is made.
2. Is there anything written on any of the lamps?
3. Are the lamps similar in size?
4. What other features are similar and what are different?

Key fact

The unit of brightness, or luminous intensity, is the candela.

Questions

1. Why does a filament lamp contain an inert gas rather than air?
2. What is the purpose of the phosphor coating on the inside of a fluorescent tube?
3. Why are fluorescent tubes more efficient than filament lamps?
4. Explain the relationship between wattage and the brightness of the lamp.

A light switch?

Wondering whether you should change your bulb? Here's a comparison of three light bulbs that emit the same amount of light.

	Incandescent light	Compact fluorescent lamp (CFL)	Light emitting diode (LED)
Energy used	60 watts	13-14 watts	6-9 watts
Lifespan*	3l-42days	333-416 days	2.9 years
Price per bulb	25-50 cents	$1.99-$4.99	$20-$55
Annual cost**	$4.80	$1.20	$1
Negatives	Gets hot, not energy- efficient	Contains traces of mercury, generally not dimmabfe	High price per bulb

* Continuous usage
** Based on Department of Energy's estimate of two hours of operation a day at ll-cents per kilowatt hour

▲ **Figure 11.8.5** Comparing the costs of the three different types of lamp of the same brightness (800 lumens). The LED lamp is cheapest to run and lasts the longest

Brightness of lamps

The power, or wattage, of a lamp is normally printed on it or on the packaging. This is expressed in watts. Lamps convert electrical energy into heat energy and light energy.

$$\text{electrical energy} \rightarrow \text{light energy} + \text{heat energy}$$

The wattage of a lamp is a measure of how much electrical energy is converted into other forms of energy and therefore a measure of the brightness of a lamp. For example, a 100 watt or 100 W filament lamp produces more light than a 40 W filament lamp.

The wattages of different types of lamps cannot be compared directly because they have different efficiencies, that is, they convert different proportions of electrical energy into light energy. You can see from Figure 11.8.5 that a 60 W filament lamp, a 14 W low-energy fluorescent lamp and a 12 W LED lamp all give out the same amount of light.

Practical Activity 11.8.2

Comparing filament lamps of different wattage

Skills assessed: Observation/Recording/Reporting.

1. You will need filament lamps of different wattage, such as 15 W, 40 W, 60 W and 100 W, and a lamp holder and switch in a darkened room.
2. Place the lowest wattage lamp in the lamp holder and switch it on. Note the brightness of the lamp but do not look directly at the light as this could damage your eyes.
3. Repeat with the other lamps in order of increasing wattage.
4. How does brightness vary with wattage?

11.9 First aid

No matter how careful people are, there are always going to be accidents because sometimes unexpected things happen or people get careless. When there is an accident, we need to know how to deal with it in order to help both ourselves and others. Burns, cuts, poisoning, stings and bites, choking, electric shock and sprains need first aid.

Burns

Burns are the result of heat damaging the skin. The first step to treating a burn is to place the area of skin under running cold water for at least 10 minutes to remove the heat.

Burns are classified according to how deeply they have penetrated the skin and how much damage they cause.

1 **First-degree burns** make the skin turn red and are painful but cause no lasting damage. No treatment is necessary. However, creams and sprays can be used to reduce the soreness.

2 **Second-degree burns** are deeper and result in blistering. These should be treated by a nurse or doctor. The burnt area will heal over time.

3 **Third-degree burns** destroy the skin tissue so that it will not grow back. This is the severest form of burning and must be dealt with in a hospital. It can only be repaired by grafting skin from other parts of the body onto the damaged area.

Burns damage the skin and leave the body open to infection. It is often necessary to have a precautionary **anti-tetanus injection** when being treated for a cut or burn.

Figure 11.9.1 Blistering caused by second-degree burns

Sprains

Sprains are the result of joints being twisted out of shape. They are often very painful but generally do not result in any long-term damage.

Pain and inflammation can be reduced by placing a cold pack on the affected joint. A pack of frozen peas is particularly good for this as the pack will take the shape of the joint. Failing this, crushed ice in a towel works well. An elastic bandage can be used to support a joint until any damage is repaired by the body.

If a bone has been broken, then this must be reset by a nurse or doctor and medical assistance must be sought.

Learning outcomes

By the end of this topic you will be able to:

- name injuries that may need first aid
- state how burns are classified
- describe how to treat first-degree burns
- describe how sprains can be bandaged
- describe how to treat an electric shock victim
- describe and carry out mouth-to-mouth resuscitation
- describe and carry out resuscitation.

Practical Activity 11.9.1

Using an elastic bandage

Your teacher will supply you with an elastic bandage. For this activity you must work with a partner.

On your partner, pretend they have sprained a joint. Practise placing bandages on different joints, such as the elbow, wrist and ankle in such a way as to support the joint.

▲ **Figure 11.9.2** An electric shock can be fatal

Electric shock

Electricity is a form of energy and if you accidentally touch a live wire the energy will flow through you as if you were part of an electric circuit.

Electric shocks can cause burns, unconsciousness and even death.

Do not touch a victim of an electric shock until you are sure that he or she is not still touching the source of the electricity. Turn the source of electricity off or use an insulating material, such as a broom handle, to push the victim away from it.

If the victim has stopped breathing, you must give them mouth-to-mouth resuscitation (see below).

Keep the victim warm by placing a blanket over them and give them a hot drink, such as a cup of sweet tea, to help them get over the shock.

Restoring breathing and heartbeat

Mouth-to-mouth resuscitation or artificial respiration must be carried out within three minutes of a person stopping breathing. There are a number of reasons why this might happen, including an electric shock, a heart attack, drowning or choking.

▲ **Figure 11.9.3** Mouth-to-mouth resuscitation is sometimes called the 'kiss of life'

1 Lay the victim on their back facing upwards. Tip the head back and pull the lower jaw down to force the tongue forward and open the air passage.

2 Sweep a finger around the victim's mouth to ensure that there is nothing blocking the windpipe.

4 Pinch the victim's nose closed. Take a deep breath, place your mouth on the victim's mouth, and blow the air firmly and smoothly into their lungs.

5 Remove your mouth and look at the victim's chest. If they are breathing for themselves, you will see their chest moving up and down. If they are not, you must repeat blowing air into their lungs.

▲ **Figure 11.9.4** Pushing down on the chest squeezes the heart

A victim's heartbeat may also have stopped. This is restored by compressing their heart.

Press down on the breastbone just above the victim's heart with the heel of the hand and release. Establish a regular pattern of compression and relaxation as you push down and release.

Once you have done what you can for the victim of an accident, they should be put in the recovery position while you await medical assistance. In this position, they can breathe freely and will not choke if they vomit.

▲ **Figure 11.9.5** The recovery position

Questions

1 What happens to the skin as a result of a second-degree burn?

2 A person receives an electric shock while using electric curlers and collapses. Why shouldn't you pick the curlers out of their hand? Suggest a suitable object for removing the curlers from their hand.

3 Before administering mouth-to-mouth resuscitation why should you run your finger around the inside of the victim's mouth?

11.10 Fires and fire extinguishers

The fire triangle

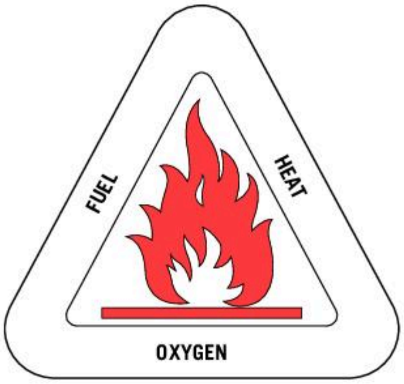
In order for a fire to start there must be three things, as shown in the fire triangle.

If any one of these three things is missing, then there will be no fire. To extinguish a fire, it is necessary to eliminate one of them.

We can remove the **heat** from a barbeque by pouring cold water on it at the end of a meal.

We can remove the **oxygen** from a burning pan of hot oil by placing a fire blanket or a damp towel over it.

You should NEVER attempt to pour water on a burning pan of oil. Oil can be heated to a much higher temperature than boiling water (100 °C) and water is denser than oil, so it will sink into the oil. If you pour water into hot oil it will sink and instantly turn to steam. A small water droplet produces a lot of steam; the droplet will explode and hot oil will spit out in all directions – including over you.



▲ **Figure 11.10.1** The fire triangle

We can remove the **fuel** from a gas fire by turning off the gas.

Fire extinguishers

Fire extinguishers contain chemicals that put out fires. Different types of fire extinguishers are used for different fires.

Electrical fires

Some fires result from electrical equipment malfunctioning or overheating. Such fires present a particular problem because of the possibilities of receiving an electric shock while trying to put them out.

If an electric device, such as a toaster, catches fire the first thing to do is switch it off and remove the plug from the socket.

▼ **Table 11.10.1** Different types of fire extinguisher

Type of fire extinguisher	How it works	What it is suitable for
General purpose	Contains water which is forced out under pressure; may also contain chemicals that produce foam; foam smothers the burning material and prevents oxygen from reaching the fire	Materials, such as wood, cloth and paper Not suitable for burning solvents, such as oil and petrol or electrical fires
Carbon dioxide	Releases carbon dioxide which covers the burning material, preventing oxygen from reaching the fire	Burning solvents and electrical fires
Dry powder	Releases a fine unreactive dry powder which smothers the fire	All fires especially electrical fires

Learning outcomes

By the end of this topic you will be able to:

- name the three components of the fire triangle
- explain why a fire can only take place when all three are present
- give examples of how to extinguish a fire
- classify fire extinguishers
- explain how carbon dioxide extinguishes fire
- describe the hazards of an electrical fire and a chemical fire
- discuss bush fires.

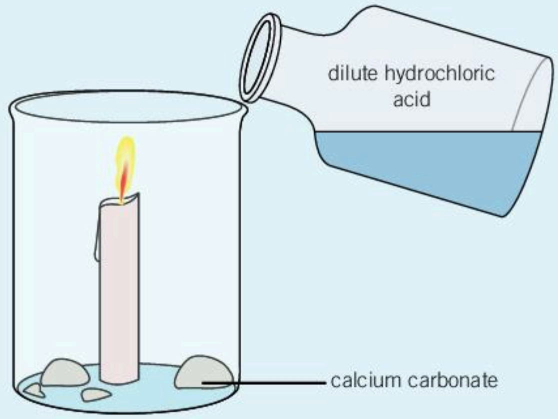
▲ **Figure 11.10.2** Water fire extinguishers cannot be used on all fires

Practical Activity 11.10.1

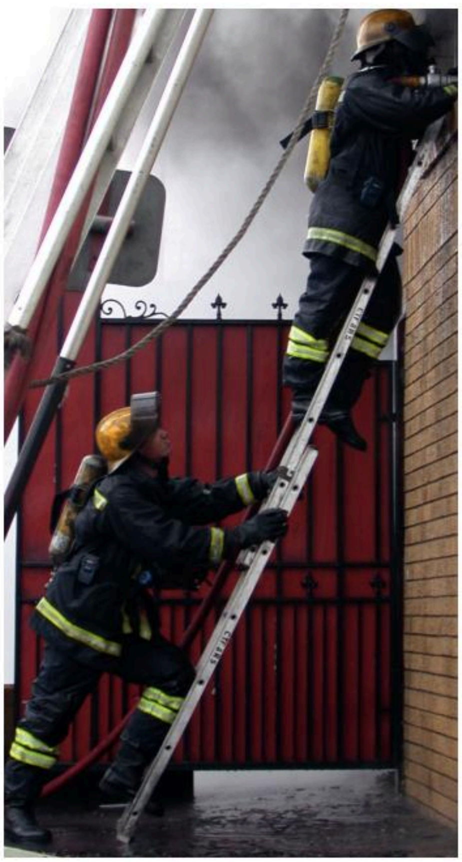
Design an experiment showing the effect of carbon dioxide on combustion

Skills assessed: Observation/Recording/Reporting.

Your teacher will provide you with a small beaker, a short candle, calcium carbonate chippings and dilute hydrochloric acid.



1 Place the candle in the middle of the beaker and carefully light it.
2 Put some calcium carbonate chippings in the bottom of the beaker.
3 Add a small amount of dilute hydrochloric acid to the beaker and observe what happens.
4 What happens to the calcium carbonate chippings when the dilute hydrochloric acid is added?
5 What happens to the candle?
6 What can you say about the density of carbon dioxide compared to air?
7 Does carbon dioxide support combustion?
8 What materials would you need in order to make a homemade fire extinguisher?



▲ **Figure 11.10.3** The combustion products of some chemicals produce harmful gases

The fire can then be tackled by covering the device in a towel or blanket, to prevent oxygen reaching the fire, or by using a carbon dioxide or dry powder extinguisher.

Water extinguishers should never be used on electrical devices even if they have been disconnected from the power supply.

Chemical fires

Chemical fires are particularly hazardous because when some chemicals burn they produce poisonous gases.

Fire fighters tackling a fire at a chemical factory must wear breathing apparatus similar to that worn by a scuba-diver. They breathe clean air from tanks rather than the poisonous by-products of the fire.

Bush fires

Some fires may be so widespread that it is impossible to tackle them in the normal way using fire engines and water hoses.

In hot, dry, windy weather, a small fire in the bush can soon get out of hand resulting in fire covering a large area.

The first priority is to limit the fire to as small an area as possible. This is done by cutting firebreaks in the direction that the fire is heading.

Where fire is threatening people's homes large amounts of water can be dropped on it from aircraft specially equipped with large water tanks.

Questions

1 Name the three components of the fire triangle.
2 How should a fire involving burning oil be extinguished?
3 Which type of fire extinguisher should NOT be used on a fire involving electrical equipment?
4 How does a firebreak work?

11.11 Radiation and voltage hazards

Using mains electricity safely

An electric shock from the mains can kill a person. Plugs should always have the correct fuse fitted. Where the electricity supply enters the house there should be a fuse box or circuit breaker. Both of these cut off the supply if the current becomes too large. The householder should check for the fault and ensure that the necessary repairs are carried out before another fuse is fitted or the circuit breaker is reset.

Devices called **earth leakage circuit breakers** can be used to protect an appliance and its user. They switch off the current very quickly if a fault develops. These are especially useful for electrical appliances that may be used outside, such as electric lawn mowers.

It is important to choose flex of the appropriate size for different appliances. Appliances that use only a small current when working can use a thinner flex than those that use a large current. The larger the current the more energy converted to heat in the wires. If the flex is too small the circuit may become overloaded, overheat and there is a risk that the insulation might catch fire.

If a fire does occur in an electrical circuit, the flames should be smothered with a non-flammable material or a special fire blanket. If a fire extinguisher is used it should be one especially for electrical fires. These normally contain CO_2. Throwing water over an electrical fire may make it worse and can be dangerous.

Radiation hazards

Radiation from natural radioactive substances and from artificial source, such as X-rays, can be dangerous to living organisms. We can be exposed to:

- natural background radiation from naturally occurring materials, such as radium, thorium or uranium
- very low or little radiation from television sets, computers, mobiles and microwaves
- artificial radiation from X-rays and radioactive isotopes used in medicine.

If we are treated with radioactive substances, the doses are very carefully monitored and controlled.

High doses of radiation damage body cells and prevent them from multiplying. Exposure to radiation can have long-term effects, such as cancer, leukaemia and damage to the chromosomes.

People who work with radioactive substances must wear protective clothing and disposable gloves. Masks are worn if there is any danger of inhaling radioactive particles. No eating or drinking is allowed, to avoid the risk of taking particles into the body.

Doses of radiation can be limited by:

- shielding a person or only exposing that part being treated if it is a medical procedure
- making sure that there is a large distance between the person and the source of radioactivity
- keeping exposure as short as possible.

Learning outcomes

By the end of this topic you will be able to:

- discuss the hazards caused by the careless handling of electrical equipment
- explain how to use mains electricity safely
- discuss radiation hazards.

▲ **Figure 11.11.1** An earth leakage device provides extra safety

Questions

1. Explain why an electric plug should have the correct fuse fitted.
2. What happens if the wrong size flex is fitted to an electrical appliance?
3. How should a fire caused by an electrical appliance be extinguished?
4. What are the dangers of over-exposure to radioactive substances?
5. Describe three ways in which doses of radiation can be limited.

Learning outcomes

By the end of this topic you will be able to:

- explain the need for protective clothing
- describe different types of protective clothing.

11.12 Protective clothing

Protecting ourselves from hazards

The products we use in our homes often come with advice about how to protect ourselves when using them. Often this involves wearing rubber gloves and avoiding contact with the skin, or wearing face masks and avoiding inhalation.

The hazards for people working in industry are often much greater and they must wear protective clothing while doing their jobs.

Protecting the hands

Gloves are worn to protect the hands from abrasion and from irritant chemicals. Manual workers and farm workers may wear protective gloves if they are moving heavy or rough objects. Gardeners wear gloves to protect against spines, thorns and irritant plants. In the home, rubber gloves are often worn when washing floors, cleaning ovens and using chemicals, such as bleach. Doctors and nurses wear thin latex gloves when treating patients.

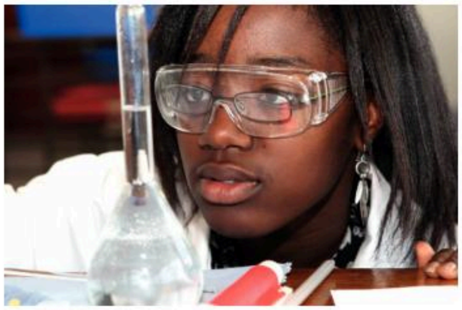
Protecting the eyes and ears

Safety goggles or glasses should always be worn when carrying out experiments in a laboratory. Goggles are worn in industry to protect the eyes from dust, fumes and the possibility of fragments entering the eye. Sometimes it is necessary for these to be tinted to protect against UV light or glare. Swimmers wear goggles to protect their eyes from the chemicals used to treat the water.

▲ **Figure 11.12.1** Loud noise can damage hearing permanently

▲ **Figure 11.12.2** Hard hat being worn on a work site

Ear defenders are used to prevent damage to hearing. Long exposure to loud noises can damage the delicate structures in the ear and cause deafness, so it is important that the ears are protected.



▲ **Figure 11.12.3** Using safety goggles in a science laboratory

Protecting the body

Many people wear overalls, or coats, to protect their clothing from becoming soiled. For example, doctors wear white coats, nurses wear uniforms and fire fighters may wear fireproof clothing which covers them completely. On construction sites, it is necessary to wear hard hats and often special footwear to prevent accidents.

Questions

1 Why are hard hats needed for workers on a construction site?

2 Explain why you should always use safety goggles in a laboratory.

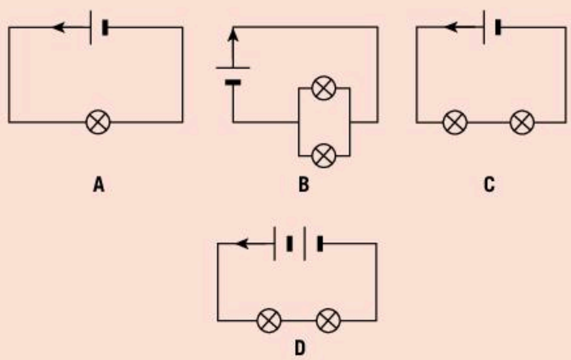
3 List the irritant chemicals that are used for cleaning in your house and explain why you should wear rubber gloves when using them.

4 Explain why gardeners need to wear gloves to protect their hands.

Exam-style questions

Multiple choice

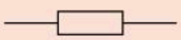
1 In the following electrical circuits all the light bulbs (lamps) are identical. In which circuit will the light bulbs be the dimmest?



2 The resistance of an electrical component is 12 Ω. The current is 3 A. What is the voltage?

A 4 V **B** 36 V
C 15 V **D** 9 V

3 What electrical component does this circuit symbol represent?



A a battery
B a lamp
C a switch
D a resistor

4 Which method is used for treating a sprain?

A The damaged bone is pushed into place.
B A cold ice pack is applied to the region of the sprain.
C A hot compress is applied to the region of the sprain.
D The region is rubbed with antiseptic cream.

5 Artificial respiration would be used in which of the following emergencies?

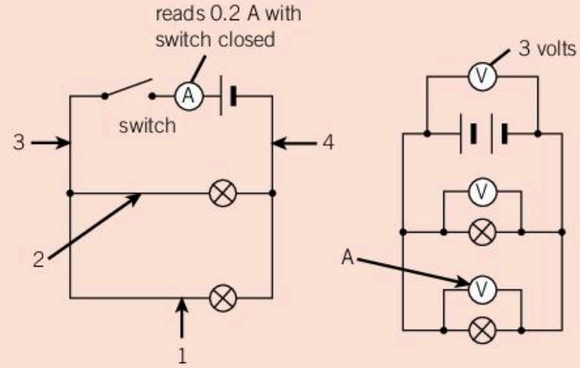
A burn
B choking
C poisoning
D electric shock

6 What type of fire extinguisher is NOT suitable for an electric fire?

A general purpose fire extinguisher
B carbon dioxide fire extinguisher
C dry powder fire extinguisher
D high pressure water hose

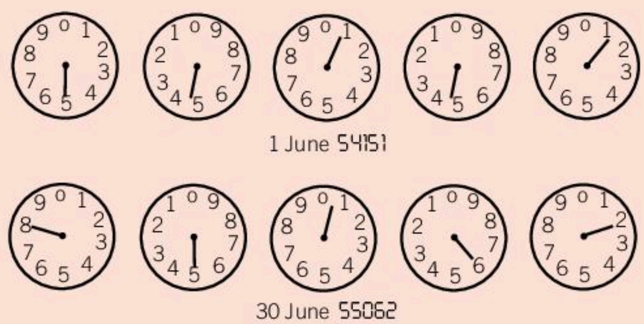
Structured questions

7 The diagrams below show two electric circuits. One circuit has an ammeter in it and the other has three voltmeters.



a What would be the reading on the ammeter if the current was measured at position 1, 2, 3 and 4?
b What would be the reading on the voltmeter at position A?

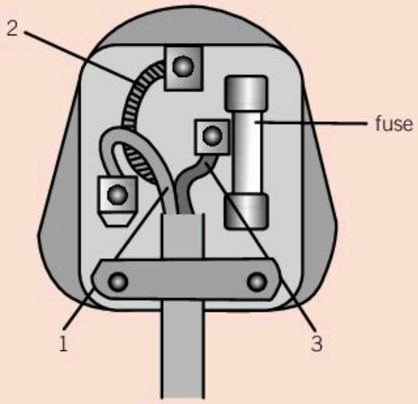
8 The analogue meter in the picture below was read on two dates: 1 June and 30 June.



a What is the reading on the meter on 1 June and 30 June?
b How much electricity did the consumer use in the period indicated?
c The cost of electricity is $1.50 per kW h. What was the electricity bill for the month of June?

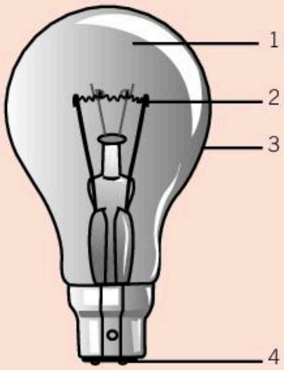
9 **a** List three ways that you could conserve electricity in your home.
b List three safety measures that you would apply when using mains electricity.

10 The diagram shows the wiring of a three-pin plug.



a Provide labels for numbers 1, 2 and 3.
b Calculate what fuse you would need if the plug was used for a 600 W iron with a 220 V mains supply.

11 The diagram shows an incandescent light bulb.



a Name the parts labelled 1–4.
b Explain why the part numbered 2 is used.
c If you had to install light fittings into a new building, would you choose this type of light? Give reasons for your answer.
d Is this type of lighting environmentally friendly? Explain your answer.

12 Your friend receives an electric shock whilst standing in a puddle of water using an electric drill. Another friend rushes to pull him away.
a Why should he NOT do this?
b What should you do first?
c You notice that your friend has stopped breathing. You position his head to start artificial respiration.
   i) How should his head be positioned?
   ii) Write down the next TWO steps that you would take.

Section B

12 Machines and movement

When we think of machines we may think of complicated devices, such as cars, tractors or cranes, but there are many simple machines that we see and use every day. Common simple machines include ramps, bottle openers, gears, screws and pulleys. All complex machines are made by linking together a number of simple machines.

Learning outcomes

By the end of this topic you will be able to:

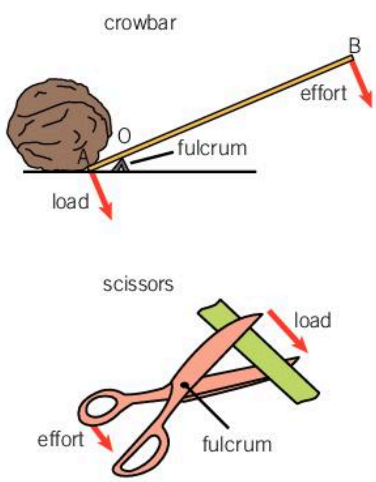
- state that a lever is a simple machine
- identify the load, effort and fulcrum when a lever is used
- give examples of first-order levers
- give examples of second-order levers
- give examples of third-order levers
- identify parts of the body that act as levers
- explain how a wheel and axle act as a lever.

12.1 Levers

Levers are very simple machines and in common use. They usually consist of a rod, or stick, which can be moved about a fixed point, known as the **fulcrum** or **pivot**. The **effort** is the force needed to make the lever work and the **load** is the object being moved.

First-order levers

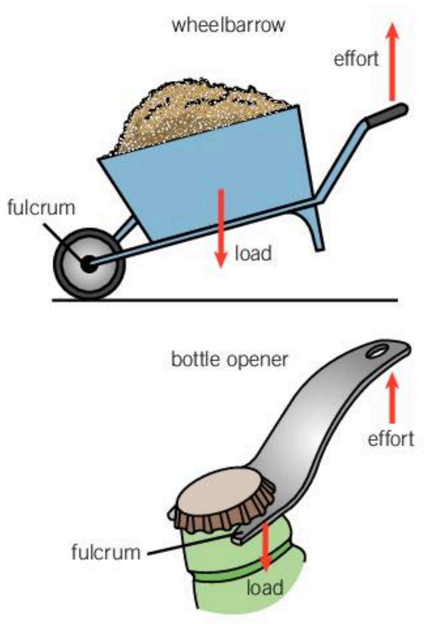
These levers are arranged with the fulcrum in the middle, the load on one side and the effort applied on the other side. Examples are a crowbar and scissors.



▲ **Figure 12.1.1** In a first-order lever the fulcrum is between the effort and the load

Second-order levers

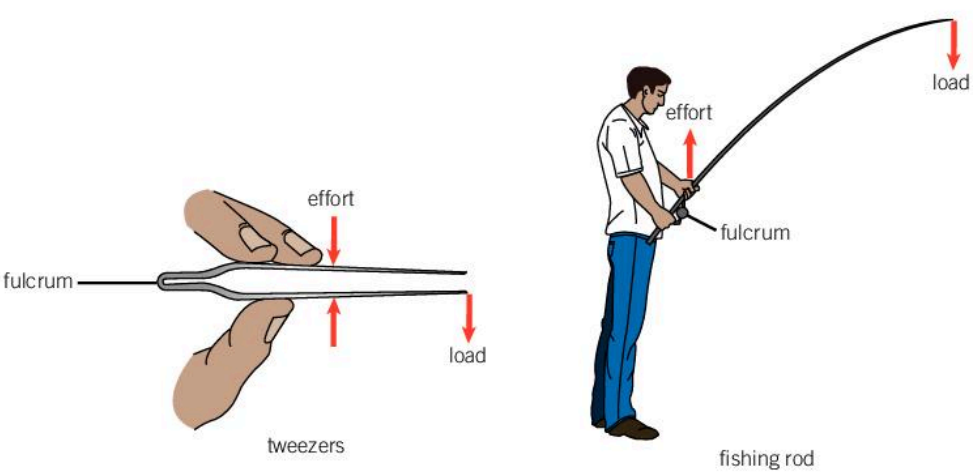
These levers are arranged with the fulcrum on one side, the effort on the other and the load in the middle. Examples are wheelbarrows and bottle openers.



▲ **Figure 12.1.2** In a second-order lever the load is between the effort and the fulcrum

Third-order levers

These levers are arranged with the fulcrum on one side, the load on the other and the effort in the middle. Examples are tweezers and fishing rods.

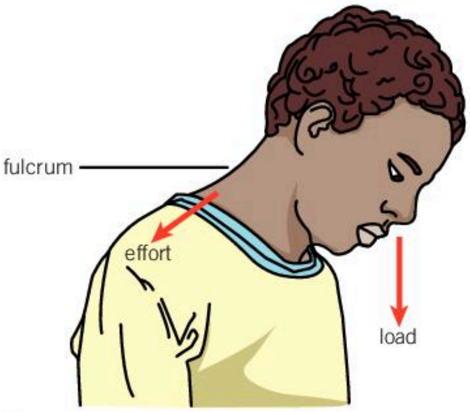


▲ **Figure 12.1.3** In a third-order lever the effort is between the fulcrum and the load

Levers in the body

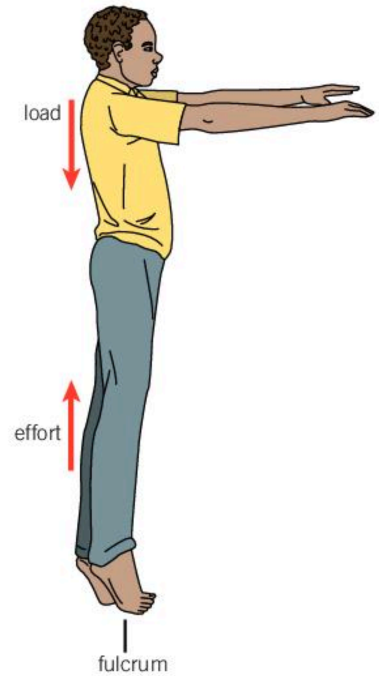
The human skeleton contains examples of all three types of lever.

Your head pivots at the top of your neck, so it can nod up and down. The fulcrum is the bone at the top of your neck, the load is the weight of your head, which is on one side of the fulcrum, and the effort is provided by the muscles in the back of your neck. This is an example of a **first-order lever**.



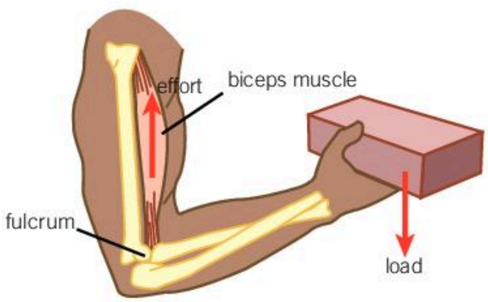
▲ **Figure 12.1.4** Your neck can act as a first-order lever

Stretching up on your toes is an example of a **second-order lever**. When you rise up on your toes the effort comes from the muscles in the back of the leg, the load is the weight of your body which acts down the centre of your leg. The fulcrum is at the ball of your foot.



▲ **Figure 12.1.5** Your leg can act as a second-order lever

Your forearm has a fulcrum at the elbow joint. The effort to lift the forearm comes from your biceps muscles at the front of your upper arm. The load is the weight of your forearm and anything you are holding in your hand, so it is further away from the fulcrum than the effort. So the forearm is a **third-order lever**.

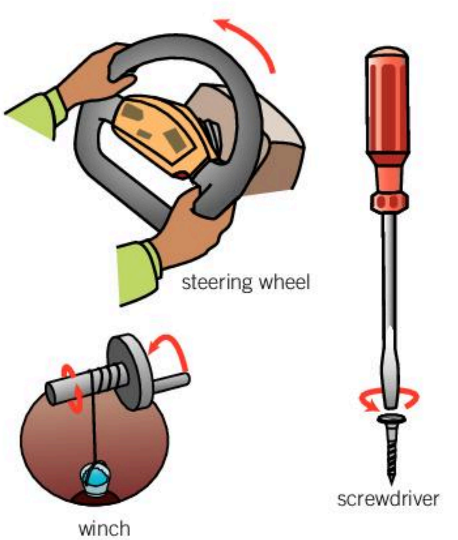


▲ **Figure 12.1.6** Your arm can act as a third-order lever

Wheel and axle

The wheel and axle is an example of a lever. The fulcrum is at the centre of the axle. The load is applied at the edge of the axle and the effort is applied at the edge of the wheel.

Other examples in which the same action takes place are a screwdriver, a steering wheel and a winch.



▲ **Figure 12.1.7** The effort in this type of lever provides a turning motion

Practical Activity 12.1.1

Examples of levers

1. Look around your classroom, school or home. Find examples of each order of lever being used. Try and find different examples than those given in the text.
2. Draw a labelled diagram of each lever in use.
3. Write a brief note to explain where and how the lever was used.

Questions

1. What is another name for the fulcrum of a lever?
2. Give an example of a first-order lever.
3. On a second-order lever which is at the centre: the effort, the load or the fulcrum?
4. When using a third-order lever how does the size of the effort compare to the size of the load?
5. Where is the fulcrum when you bend your arm?

12.2 Simple machines

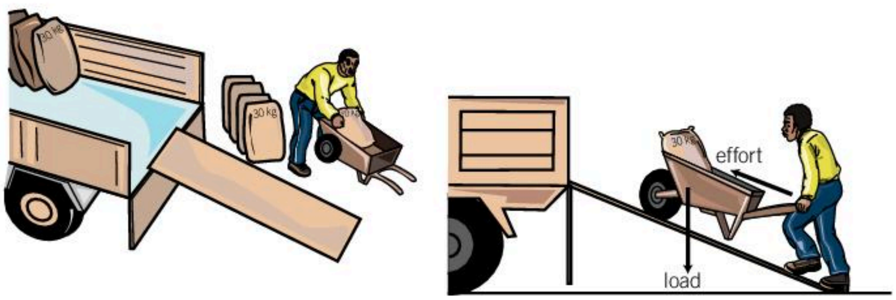
Machines and work

A machine is any device that makes it easier for us to do work. In the context of science, the term 'work' means moving a force through a distance. In a machine, a force, called **the effort**, is applied at one point in order to overcome another force, called **the load**, applied at another point. Inclined planes, pulleys and levers all make work easier.

Inclined plane

An **inclined plane** is one which is not horizontal but sloping. A hill and a ramp are both examples of inclined planes.

It is easier to load bags of cement onto the back of a lorry by pushing them up a ramp rather than lifting them vertically. Each bag can be raised by applying a smaller effort but the effort has to be applied over a longer distance. An inclined plane is a **force multiplier** because the effort applied is less than the load.

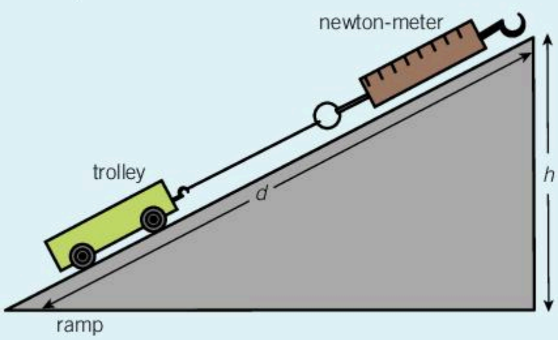


▲ **Figure 12.2.1** A ramp is an inclined plane and makes it easier to load things into lorries

Practical Activity 12.2.1

Investigating inclined planes

Skills assessed: Observation/Recording/Reporting and Manipulation/Measurement and Analysis, and Interpretation.



1. Set up a ramp as shown in the diagram.
2. Mark and measure a distance, *d*, along the surface of the ramp.
3. Measure the height, *h*, of the ramp.
4. Pull the trolley the distance, *d*, up the slope at a steady speed.
5. Record the force on the newton-meter. This is the effort, *E*.
6. Change the angle of the slope. Repeat steps 3 to 5 four more times.
7. Record your results in a table.
8. Plot a graph of *E* against *h*.
9. What can you say about how *E* varies with *h*?

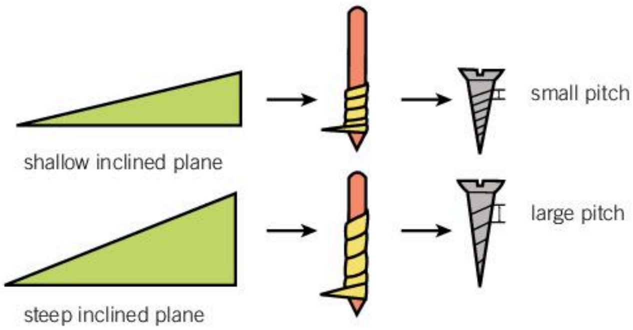
Learning outcomes

By the end of this topic you will be able to:

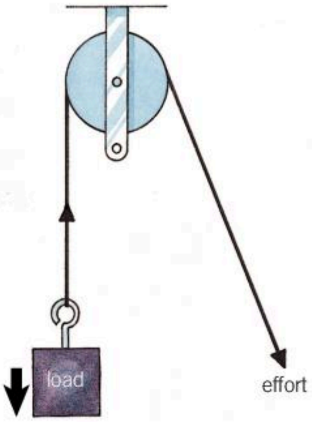
- state that a machine is a device that makes it easier to do work
- describe how an inclined plane makes it easier to do work
- give an example of an inclined plane
- describe how a screw makes it easier to do work
- give an example of a screw
- explain how a single pulley changes the direction of the effort
- explain how multiple combinations of pulleys reduce the effort needed to raise loads
- identify simple levers in the mammalian skeleton.

Screws

A screw is also an inclined plane, although it may not look like one at first sight. A screw consists of a shaft with a continuous groove cut spirally on it. The shaft may taper (as in a wood screw) or have constant diameter (as in a bolt). The thread of the screw acts as an inclined plane wrapped around in a helix. The distance between successive turns of the groove is called the **pitch** of the screw. It is much easier to turn a screw into a block of wood than it is to push it straight in. One complete turn of effort applied at the top of the screw moves the load a distance equal to the pitch of the screw. The smaller the pitch of the screw, the easier it is to turn.



▲ **Figure 12.2.2** A screw is a circular inclined plane



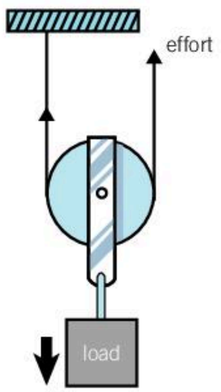
▲ **Figure 12.2.3** A single pulley allows you to apply a force from a different direction

Single pulleys

A pulley is a wheel with a groove cut into the rim. A rope or chain fits into the groove and turns the pulley wheel when it is pulled. Pulleys are used for lifting loads vertically.

If a **single fixed pulley** is used, the effort is equal to the load so it does not act as a force multiplier. However, single pulleys are useful because they can change the direction in which the effort is applied. It is easier to pull downwards with your weight than it is to pull upwards to lift the load.

A single, moving pulley is a pulley attached to the load so that it moves with it. Both sections of the rope support the load, so the effort required is only half the weight of the load, but the distance moved by the effort is double the distance moved by the load.



▲ **Figure 12.2.4** A single moving pulley is a force magnifier

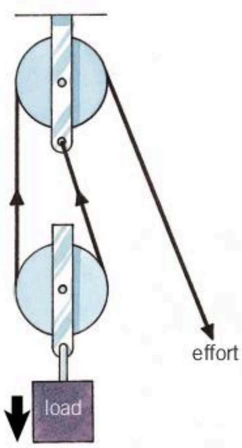
Multiple pulleys

Using two pulleys, one which is fixed and one which moves with the load (see Figure 12.2.5), has the advantages of both single pulleys. The load can be applied downwards and the effort only needs to be half the size of the load.

The more pulleys in a multiple system the less effort is required to move any particular load but the further the distance that must be moved by the effort.

In a two-pulley system the effort is halved but the distance moved by the effort is doubled.

In a three-pulley system in which there are two fixed pulleys at the top, and a single pulley that moves with the load at the bottom, the effort is reduced to one-third but the distance moved by the effort is three times greater than that moved by the load.



▲ **Figure 12.2.5** In a two-pulley system the effort needed to raise a load is halved

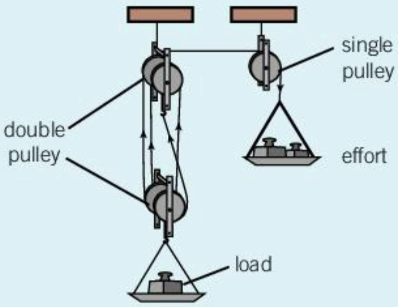
In industry, multiple pulley systems are mounted in frames called **blocks**. They are called **block-and-tackle pulleys**. They are used on cranes for lifting very heavy loads and in garages for lifting engines from cars.

▲ **Figure 12.2.6** Multiple pulleys are often put together as pulley blocks

Practical Activity 12.2.2

Pulleys

Skills assessed: Observation/Recording/Reporting.



1. Set up the pulley system shown in the diagram.
2. Add 50 g to the load pan. This gives a load of 0.5 N.
3. Add weights to the effort pan until the load just begins to move upwards.
4. Record the values of the load and effort, in newtons, in a table.
5. Repeat for five bigger loads.

Questions

1. Why is an inclined plane described as a force multiplier?
2. What is the pitch of a screw?
3. How is the ease with which a screw can be turned related to its pitch?
4. Why is a single pulley not a force multiplier?
5. If a pulley system halves the effort needed to raise a load what happens to the distance that the effort must be applied for?

Learning outcomes

By the end of this topic you will be able to:

- explain what is meant by mechanical advantage
- calculate the mechanical advantage of a machine
- understand the difference between a force multiplier and a distance multiplier
- state that the mechanical advantage of a force multiplier is greater than 1
- state that the mechanical advantage of a distance multiplier is less than 1
- state the equation linking work done, force and distance in the direction of the force
- calculate the work done by a simple machine
- appreciate that the amount of work done by a machine for a given effort depends on its efficiency.

Exam tip

Mechanical advantage is a ratio, so it does not have a unit.

12.3 Energy conversion in machines

Mechanical advantage

Some machines allow a large load to be moved by a much smaller effort. These machines are called **force multipliers**.

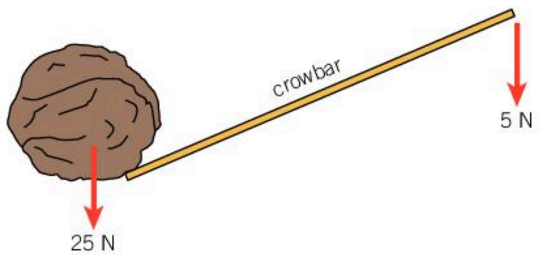
The **mechanical advantage** of a machine is the ratio of the load to the effort.

This can be written as a formula:

$$\text{mechanical advantage (MA)} = \frac{\text{load}}{\text{effort}}$$

For example, calculate the mechanical advantage when an effort of 5 N is applied to one end of a crowbar to move a rock of weight 25 N.

$$\text{MA} = \text{load/effort} = 25/5 = 5$$



▲ **Figure 12.3.1** A crowbar is a force magnifier

If the load is bigger than the effort then the MA is greater than 1 and the machine is a force multiplier. First- and second-order levers are usually force multipliers.

Third-order levers have an MA of less than 1. The effort needs to be bigger than the load but the load moves through a bigger distance than the effort, so these levers are **distance multipliers**.

If the load is equal to the effort, as in the single pulley, the MA is equal to 1. The single pulley is useful because it changes the direction in which the effort is applied.

A bicycle is a machine with a mechanical advantage of less than 1. On a fairly flat road this is not a problem. The cyclist applies an effort greater than the load but the bicycle increases the speed at which he can travel. However, on a hill the mechanical advantage of less than 1 makes things very difficult for the cyclist. The load becomes much bigger due to the increased work needed to overcome the force of gravity. It is usually easier for the cyclist to get off and push the bicycle up the hill!

Energy conversion in machines

When we use a machine we do work.

We can calculate the work done using the formula

work done = force × distance moved in the direction of the force

The unit of force is the newton, N, and the unit of distance is the metre, m. So the unit of work done is the newton metre, N m.

When work is done, energy is transformed, so 1 N m equals 1 joule, J.

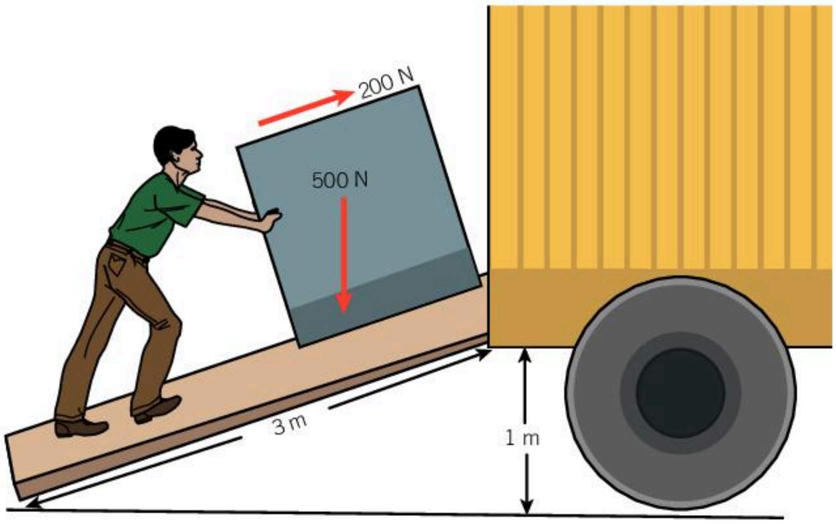
Worked example

A man pushes a crate of weight 500 N up a ramp of length 3 m onto the back of a lorry. The crate moves through a vertical height of 1 m. The man applies a steady force of 200 N to the crate.

What is a) the work done by the man and b) the work done on the crate?

a) The work done by the man = 200 × 3 = 600 J

b) The work done on the crate = 500 × 1 = 500 J



▲ **Figure 12.3.2** Work has a particular meaning in science

If all the work done by the man was used in raising the crate, the two values calculated would be the same.

However, in all machines some of the work done by the effort is wasted. This is because some work is always used to overcome **friction**. Friction is the force that opposes surfaces moving over each other. Friction causes some of the energy put into the machine to be transformed to heat. In the example of the crate, friction between the crate and the surface of the ramp causes some of the energy input from the man to be converted into heat, so the ramp and the crate will warm up.

Questions

1. What is the equation used to calculate mechanical advantage?
2. What type of machine has a mechanical advantage less than 1?
3. What is the unit of work?
4. How much work is done raising a 200 N weight 3 m above the ground?

Learning outcomes

By the end of this topic you will be able to:

- state why machines may be inefficient
- explain how lubrication can reduce friction in machines
- discuss how rust and corrosion may be avoided.

12.4 The inefficiencies of machines

Maintenance of machines

The more energy that is wasted in a machine, the less **efficient** it is. Reducing friction reduces the amount of energy wasted and so improves the efficiency of a machine. In most machines, **lubricants**, such as oil and grease, are used to reduce the friction between moving parts, such as joints, gears and bearings.

As well as keeping a machine efficient, lubrication helps to maintain it. If moving parts are not lubricated regularly they will be worn away by friction.

If friction causes metal surfaces to heat up sufficiently they may fuse together causing the machine to seize up.

Metal parts on machines are often made from steel. This will rust unless properly maintained, particularly if the machine is exposed to moisture. Rusting eventually causes the surface of the machine to crumble away. Rust is prevented by painting the surface, or coating with oil or grease, to exclude moisture from the metal surface.

▲ **Figure 12.4.1** Oil reduces friction between moving parts

▲ **Figure 12.4.2** Rusting bike chain

The careful maintenance of machines prolongs their use. Regular cleaning of motorcars and other domestic machines, such as lawnmowers and bicycles, helps to prevent rusting and corrosion.

Questions

1 How does oiling a bicycle chain improve its efficiency?
2 Explain how energy is wasted when machines are used.
3 How does rust form and how can it be treated?
4 State one advantage of lubricating machines.

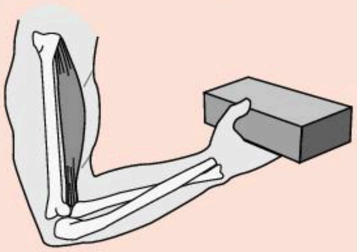
Exam-style questions

Multiple choice

1 What is the mechanical advantage if a load is 400 N and an effort is 200 N?

A 4
B 2
C 1
D 6

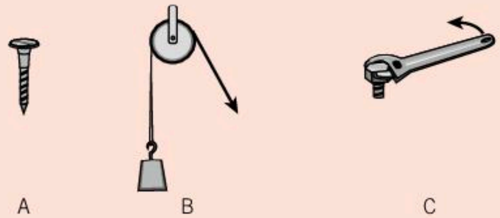
2 The forearm lifting a load is an example of:



A a first-order lever
B a third-order lever
C a second-order lever
D a force multiplier

Structured questions

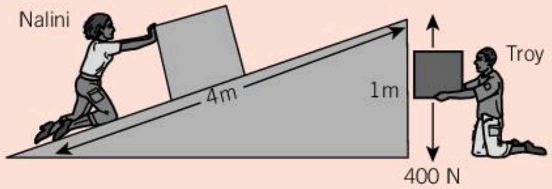
3 a Identify the types of machine shown in the diagrams A, B and C below.



b What does the term 'force multiplier' mean?

4 a Troy lifts a box of weight 400 N to a height of 1 m. How much energy does Troy use?

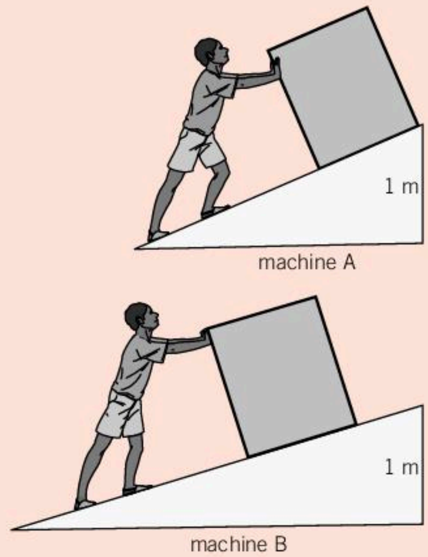
b Nalini pushes the same box up a ramp of length 4 m onto the back of a lorry using a force of 200 N.



What is:

i) the work done by Nalini
ii) the work done on the box?

5 a The diagrams show two machines.

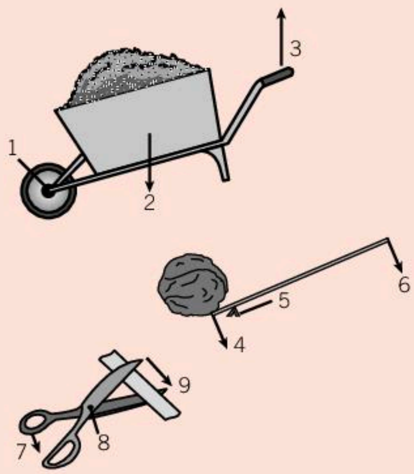


Which of these two machines has the greater mechanical advantage? Explain your answer.

b Calculate the mechanical advantage when an effort of 5 N is applied to one end of a crowbar to move a rock of weight 40 N.

6 What is the efficiency of a pulley system which lifts a load of 30 kg a distance of 2 m using an effort of 300 N through a distance of 5 m?

7



a Provide labels for 1 to 9 in the diagrams.
b What type of lever is:

i) the wheelbarrow
ii) the crowbar?

8 The efficiency of machines can be improved by reducing friction. Describe one way that this can be done.

Section B

13 Metals and non-metals

Learning outcomes

By the end of this topic you will be able to:

- list some general properties of metals
- describe some uses of some metals
- state some general properties of non-metals
- state that some non-metals are naturally occurring, while others are synthetic
- describe uses of some non-metals.

▲ **Figure 13.1.1** Gold nugget

When we look around us we see a range of different materials being used in a variety of ways. Common materials include cement, brick, wood, metal, fabrics, glass, plastics, ceramics and paper. Some materials, such as wood, have been used for many centuries, while others, such as plastics, were invented more recently. The way in which we use different materials depends upon both their physical and chemical properties.

13.1 Uses and properties of metals and non-metals

Since ancient times, people have used whatever materials were available to build their homes and to make the objects they need to live from day to day. As new materials are discovered, people find uses for them which improve the quality of their lives.

There are many ways in which materials can be classified. One simple way is divide them into two groups: metals and non-metals.

Metals

A few metals, such as gold, exist as actual metal in the ground. We call this native metal. Most metals exist as compounds called ores in which they are chemically combined with other elements. The metal can be extracted from the ore by heating or by using electricity.

Metals that can be extracted easily, simply by heating, have been known and used for thousands of years. Others, which can only be extracted using electricity, were only obtained for the first time at the start of the 19th century, around the time when electricity was discovered.

Metals have the following general properties:

- They are good electrical conductors.
- They are good thermal conductors.
- They tend to have high melting points.
- Most have high densities.
- Some metals can be polished to a high lustre.
- Some metals have high tensile strength.
- Some metals are malleable and can be beaten into thin sheets or drawn into thin wires.
- Some metals are sonorous and, when struck, they vibrate in a characteristic way.

Uses of metals

Metals have many uses as they are long-lasting and strong.

▼ **Table 13.1.1** Some properties and uses of metals

Metal	Properties	Uses
Gold	• high lustre • does not corrode	• ornamental purposes and to make jewellery
Platinum	• good electrical conductor • does not corrode	• contacts in switches • jewellery
Silver	• reflective • does not corrode • good heat conductor	• ornaments and jewellery, utensils
Copper	• good conductor of heat and electricity • soft and ductile; easily bent • does not corrode	• cooking pans, electric wires, pipes (can be easily bent and joined)
Tin	• soft metal so easily bent • does not corrode	• manufacture of food containers • manufacture of the alloy solder
Iron and steel	• strong • easily corrodes • magnetic	• mostly alloy mild steel used for cabinets of domestic equipment, such as fridges, freezers and washing machines • also used for many smaller items, such as tools, screws and nails • the engine, chassis and shell of a motor car are all made from mild steel • must be galvanised with zinc to prevent rusting • used for magnets and electrical transformers
Zinc	• unreactive • low melting point	• used for coating iron and steel objects; prevents it from rusting
Aluminium	• light because has low density • good conductor of heat and electricity • reflective • malleable (easily bent)	• many uses in the kitchen, for window and door frames • electrical wiring and cables • aluminium foil for insulation in roofs and for cooking

▲ **Figure 13.1.2** Reel of uninsulated copper wire

Non-metals

Non-metals have the following properties:

- They do not conduct electricity and are therefore insulators.
- They are poor thermal conductors.
- Some non-metals have very high melting points.
- Some non-metals are strong, while others are brittle and are broken easily.

Non-metals are no less important than metals in meeting the needs of a modern society. Some non-metals have been used since ancient times, while others have only become available very recently. Some are naturally occurring, such as wood, and some are man-made, such as plastic.

▼ **Table 13.1.2** Some properties and uses of non-metals

Non-metal	Properties	Uses
Wood	• strong • burns easily	• furniture • timber for building • as a fuel
Ceramics, including glass	• very hard and heat-resistant but often brittle	• crockery, tiles and kitchenware • window panes
Textiles	• natural or synthetic fibres	• clothing, bedding and curtains
Plastics	• waterproof, hardwearing, heat insulators and electrical insulators • some can be coloured	• many uses

▲ **Figure 13.1.3** People have used wood to build their homes for thousands of years

Sports equipment

Most sports require the use of some equipment. A huge range of materials are used in the manufacture of this equipment. The following table gives some examples.

▼ **Table 13.1.3** Materials used in sports equipment

Sports equipment	Materials used in its manufacture
Diving suits	Rubber
Running shoes	Leather and rubber
Cricket bats	Wood
Tennis rackets	Carbon fibre and nylon
Climbing ropes	Plastic
Javelins	Aluminium

In order to decide which materials are most suitable for manufacturing a particular piece of sports equipment, manufacturers carry out a variety of tests.

Testing elasticity

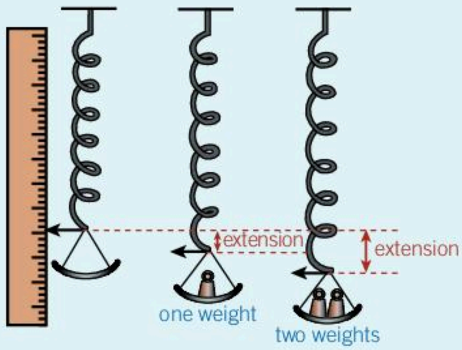
Many materials used in sports equipment need to be **elastic**. Elastic materials return to their original length after a force is applied to stretch or squash them. Elastic materials have an elastic limit. If a force is applied beyond this limit the material does not return to its original length. Materials that do not return to their original length are said to exhibit **plastic behaviour**. Sports manufacturers apply forces to samples of materials and measure the change in length and determine the **elastic limit**. You can carry out the same tests using springs or rubber bands.

Practical Activity 13.1.1

Measuring elasticity

Skills assessed: Observation/Recording/Reporting and Manipulation/Measurement and Analysis, and Interpretation.

1 Hang a spiral spring from a clamp and stand.
2 Fix a pointer to the bottom of the spring.
3 Clamp a metre rule next to the spring so that the position of the pointer can be read from the ruler.
4 Carefully measure the length of the spring using the metre rule.
5 Hang a weight from the bottom of the spring.
6 Measure the new length of the spring and calculate the extension.



7 Repeat for a large range of weights.
8 Plot a graph of extension against load for the spring.

Key fact

To calculate weight, multiply the mass in kg by 10. This gives the weight or load in newtons. For example, for a mass of 200 g (= 0.2 kg):
a mass of 0.2 kg has a weight of 0.2 × 10 = 2 N, so the load = 2 N

Key fact

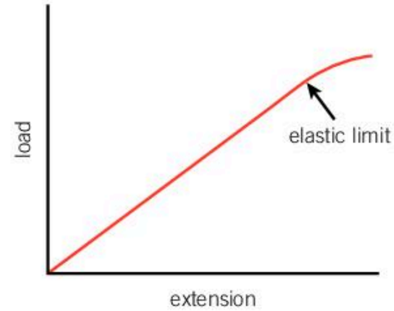
extension = new length – original length (with no load applied)

The graph from your experiment should look like the one in Figure 13.1.4. It is called a **load–extension graph**.

The graph is a straight line through the origin. This means that the extension is proportional to the load. If you remove the load the spring will return to its original length.

If you continue to load the spring you will reach the elastic limit. The graph becomes a curve. Beyond this point if you remove the load the spring does not return to its original length – it is permanently stretched.

Materials that do not produce a straight line graph when loaded in this way are said to exhibit plastic behaviour.



▲ **Figure 13.1.4** Load–extension graph

Strength of materials

The maximum load that a sample of a material can withstand before breaking gives a measure of the strength of the material. The strength depends on the thickness of the sample. In order to make a fair comparison when the test is carried out on samples of different materials, they have the same thickness.

The strength of wood

Some sports equipment is manufactured using man-made materials and some manufactured using natural materials, such as wood.

Cricket bats are made from a particular wood called **willow**. This wood has quite a high elasticity, so it deforms (changes shape) and then returns to its original shape when hit by a ball.

A cricket bat is made so that the grain (the direction of the wood fibres) runs along the length of the bat, rather than across it. Longer fibres are more elastic than shorter ones and the fibres are stronger than the material that holds them together. So, having the grain run along the length of the bat makes it more elastic and stronger.

Exam tip

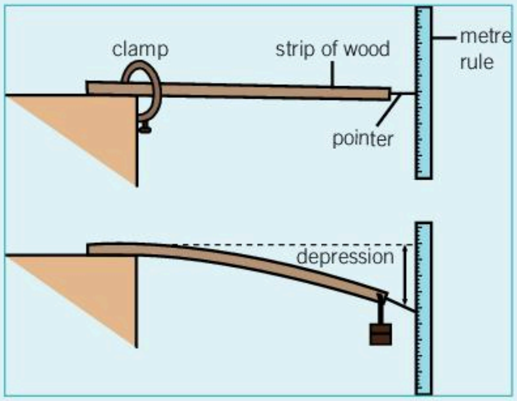
Make sure you know some examples of sports, the equipment they use, the materials used to make the equipment and the properties that make the materials suitable.

Practical Activity 13.1.2

Testing wood

Skills assessed: Observation/Recording/Reporting, Manipulation/Measurement and Analysis, and Interpretation.

1. You will need strips of different types of wood cut to the same length and thickness.
2. Clamp one end of a strip to the bench.
3. Attach a small pointer to the other end.
4. Clamp a metre rule next to the strip so that the position of the pointer can be read from the ruler.
5. Note the position of the pointer on the ruler.
6. Hang a weight from the end of the wood.
7. Note the new position of the pointer and calculate the depression of the end of the wood from the original position.
8. Repeat for a large range of weights.
9. Plot a graph of load against depression.
10. Repeat the experiment with the other strips of wood.
11. Which type of wood was depressed the most? Which types were elastic?



Questions

1. What is an ore?
2. Which metal is used for pipes and electric wires?
3. Is a tin can made of tin?
4. Of what type of material is glass an example?
5. List ten different pieces of sporting equipment.
6. Explain the difference between elastic and plastic behaviour.
7. What is meant by the elastic limit?
8. Why is sample size important when comparing the strength of materials?
9. Why are cricket bats made from willow?

13.2 Plastics

Plastics are very common substances. Since their discovery in the last century they have taken the place of many traditional materials, such as paper, natural fibres, metals and wood, for many purposes.

Plastics do not occur naturally. They are made by people using chemicals obtained from natural gas and crude oil. They consist of very large organic molecules called **polymers**. Some plastics are used for a variety of applications, while others have more specialised uses.

The names of plastics can sometimes be confusing because they are better known by a traditional or a trade name rather than their chemical name.

Uses of plastics

As with any material, the use of a plastic depends upon its properties. Most plastics are waterproof, hard-wearing, heat insulators and electrical insulators, and some can be coloured by adding a dye during their manufacture. They may have other properties, such as being transparent, and able to be drawn into very thin sheets and threads or spun into fibres.

▼ **Table 13.2.1** Some properties and uses of plastics

Plastic	Properties	Uses
High-density polythene (hdpe)	• rigid	• strong containers, such as bowls, buckets and crates
Low-density polythene (ldpe)	• soft so it can be drawn into thin sheets called film	• containers and drink bottles • plastic bags • electrical insulation
Polypropene	• high melting point • high strength	• pots, carpets, ropes, car dashboards, thermal clothing
Polyvinylchloride (pvc)	• may be rigid or made softer and more pliable	• pipes, gutters and bottles • clothing, raincoats and shower curtains
Polystyrene	• rigid • translucent	• food containers
Expanded polystyrene/ polystyrene foam	• good thermal insulator • can be compressed easily	• cooler boxes • protective packaging around fragile objects
Nylon	• strong • hard-wearing • resists attack by chemicals	• fabrics • ropes

▲ **Figure 13.2.1** Expanded polystyrene is used in packaging

▲ **Figure 13.2.2** Materials made from nylon

Learning outcomes

By the end of this topic you will be able to:

- state that plastics are man-made
- state that plastics are formed from the products of natural gas and crude oil
- appreciate that plastics have many uses
- understand that most plastics have similar properties
- give examples of common plastics and some of their uses
- understand that some plastics have particular properties that make them suitable for special uses
- give examples of special plastics and some of their uses
- describe some of the advantages and disadvantages of using plastics
- discuss the disposal of plastics, their impact on the environment and the need to recycle them.

? Did you know?

The old names for polythene and polypropene are polyethylene and polypropylene.

▲ **Figure 13.2.3** This helicopter windscreen is made from perspex

▲ **Figure 13.2.4** Recycling symbol

Plastics with special uses

Some plastics have particular uses because they have a particular property.

▼ **Table 13.2.2** The uses of plastics

Plastic	Properties	Uses
Perspex	• transparent, not as brittle as glass, so can be moulded into different shapes	• windscreens for cars and aircraft • optical fibres
Teflon polytetrafluoroethylene (ptfe)	• high melting point (350 °C) • can be made into a smooth surface	• coating the inside of saucepans and ovenware to make them 'non-stick'
Melamine	• hard and resistant to both heat and attack by chemicals	• work surfaces in kitchens and for table tops
Polyurethane	• forms foams of different hardness	• sailboards • furniture, where it is covered by a fabric • stretch fabrics • for heat insulation
Polyesters (terylene)	• drawn and spun into threads	• hard-wearing and easily washed fabrics, crease-resistant

Plastics and the environment

Disposing of waste plastics is problematic. If they are burnt they will produce unpleasant gases that can cause air pollution. If they are buried in landfills they do not degrade, so remain there forever. The best solution is not to dispose of plastics but to **recycle** them.

Many plastics can be recycled. Plastic containers often have symbols showing the type of plastic and indicating that they can be recycled.

Recycling reduces the demand for raw materials, so they will last longer and it reduces the damage caused to the environment.

▼ **Table 13.2.3** Advantages and disadvantages of using plastics

Advantages	Disadvantages
• Cheap to make at the moment because crude oil is still plentiful.	• Most are deformed and destroyed by heat.
• Can be moulded to complex shapes. Thermoplastics can be remoulded many times by heating, moulding and cooling, while thermosetting plastics retain the shape given when they are formed.	• Almost all will readily catch fire and burn.
• Can be coloured, so they can be made to look attractive.	• When some burn, toxic gases are produced.
• Can be drawn into thin films, which can be used to make bags.	• Are non-biodegradable. They can remain in the ground unchanged for many years.
• Waterproof, so plastic can be used to make a whole range of containers.	
• Resist attack by chemicals and do not corrode like some metals.	
• Easy to clean.	
• Can be recycled.	

Questions

1. From what raw materials are the chemicals used to make plastics obtained?
2. Give one use of high-density polythene.
3. What properties does melamine have which makes it suitable for work surfaces in a kitchen?
4. State two advantages of using plastics.
5. State two disadvantages of using plastics.

13.3 Chemical reactions of metals

Metals may react with non-metals, and with reagents, such as acids and alkalis, but not all metals take part in all reactions. The chemistry of a metal depends on its reactivity.

Reactivity series

A reactivity series is a list of metals in order of how reactive they are. This can be deduced by looking at the different reactions of each metal. Table 13.3.1 summarises some of the reactions of the metals.

Table 13.3.1 Reactions of some metals

Metal	Reacts with oxygen?	Reacts with water/steam?	Reacts with acid?	Reacts with alkali?
Aluminium	✓ (forms oxide layer)	✓ (steam)	✓ (dilute acid)	✓
Zinc	✓	✓ (steam)	✓ (dilute acid)	✓
Iron	✓	✓ (steam)	✓ (dilute acid)	✗
Tin	✓	✗	✓ (concentrated acid)	✓
Copper	✓	✗	✓ (concentrated acid)	✗
Silver	✗	✗	✓ (concentrated acid)	✗

Using this evidence, the order of reactivity, starting with the most reactive metal, is:

$$\text{aluminium} > \text{zinc} > \text{iron} > \text{tin} > \text{copper} > \text{silver}$$

Although aluminium and zinc appear to have the same reactions, aluminium reacts more vigorously and therefore it is placed above zinc in the series. Similarly, tin and copper have similar chemistry but tin is a little more reactive.

Reactions of metals with oxygen

Air consists of about 20% oxygen. Metals can react with oxygen by heating them in air.

Most metals react with oxygen to form **oxides.** This reaction can be represented by the following general word equation.

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

Some examples are shown in Table 13.3.2.

Table 13.3.2 Reactions with oxygen

Reaction	Product	Characteristics of product
zinc + oxygen	zinc oxide	Yellow when hot but turns white as it cools
aluminium + oxygen	aluminium oxide	Aluminium oxide forms on the surface of the aluminium
iron + oxygen	iron oxide	Orange-brown powder forms on the surface of the iron – this is called rust

Learning outcomes

By the end of this topic you will be able to:

- appreciate how metals are listed in a reactivity series
- describe the reaction of some metals with oxygen
- describe the reaction of some metals with steam
- describe the reaction of some metals with acids
- explain the reactivity of metal
- predict the names of salts
- describe the reaction of some metals with alkalis
- write word equations to represent reactions of metals
- compile a reactivity series
- predict some of the chemistry of a metal from its position in a reactivity series.

Practical Activity 13.3.1

Formation of metal oxides

Skills assessed: Observation/Recording/Reporting and Manipulation/Measurement.

1. Weigh out approximately 1 g of copper powder.
2. Place the copper powder in a test tube and heat it until no further changes take place.
3. Allow the test tube to cool.
4. Reweigh the substance in the test tube.
5. What evidence is there that a chemical reaction has taken place?
6. Suggest the name of the product of the reaction.
7. Write a word equation for this reaction.
8. Record the colour changes that occur.
9. Repeat steps 1 to 8 using iron, aluminium, tin and silver.

Key fact

Dilute hydrochloric acid reacts with metals and metal oxides/hydroxides to form metal chlorides. Dilute nitric acid reacts with metals and metal oxides/hydroxides to form metal nitrates. Dilute sulphuric acid reacts with metals and metal oxides/hydroxides to form metal sulphates.

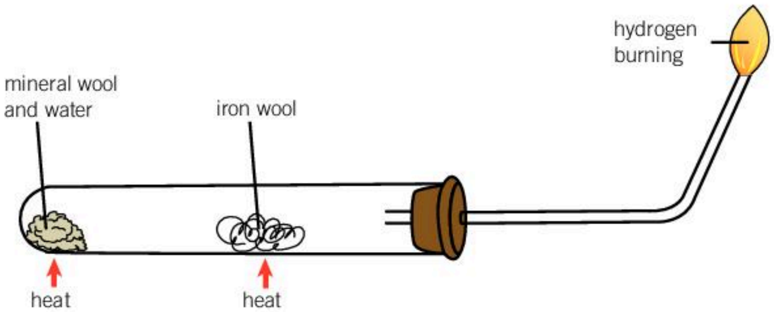
Silver does not react with oxygen because it is too unreactive. The behaviour of aluminium, when heated in air, is misleading. Although it is a reactive metal, it appears not to react.

Reactions of metals with water or steam

Only very reactive metals, such as sodium, will react with water. However, some less reactive metals will react with steam to form the metal oxide and hydrogen gas.

metal + steam → metal oxide + hydrogen

When steam is passed over hot iron wool, black iron oxide is formed.



▲ **Figure 13.3.1** Formation of iron oxide

The other product, hydrogen, is inflammable and can be burnt to demonstrate its presence.

iron + steam → iron oxide + hydrogen

Both aluminium and zinc react in the same way as iron but tin, copper and silver do not react with steam.

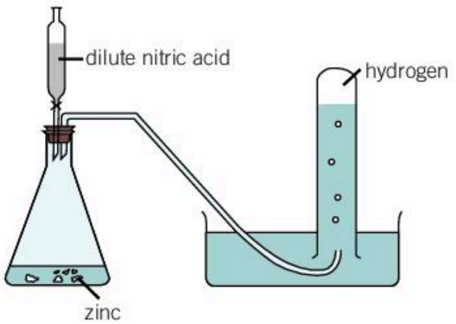
Reactions of metals with acids

Reactive metals will react with dilute acids to form metal salts and hydrogen gas.

metal + dilute acid → metal salt + hydrogen

The salt formed depends on which dilute acid is used.

- zinc + dilute nitric acid → zinc nitrate + hydrogen
- aluminium + dilute hydrochloric acid → aluminium chloride + hydrogen
- iron + dilute sulphuric acid → iron sulphate + hydrogen



▲ **Figure 13.3.2** Formation of zinc nitrate

Less reactive metals will only react with dilute nitric acid but in this case a different gas is formed.

Brown fumes of nitrogen dioxide are given off when copper reacts with dilute nitric acid.

copper + dilute nitric acid → copper nitrate + nitrogen dioxide

Less reactive metals also react with concentrated acids. Silver reacts with concentrated nitric acid to form silver nitrate and nitrogen dioxide.

silver + concentrated nitric acid → silver nitrate + nitrogen dioxide

Reactions of metals with alkalis

Aluminium, zinc and tin all react with sodium hydroxide solution to form salts and hydrogen gas.

- sodium hydroxide + aluminium → sodium aluminate + hydrogen
- sodium hydroxide + zinc → sodium zincate + hydrogen
- sodium hydroxide + tin → sodium stannate + hydrogen

Iron, copper and silver do not react with sodium hydroxide or other alkaline solutions.

Practical Activity 13.3.2

Reactions of metals with acids

Skills assessed: Observation/Recording/Reporting and Analysis, and Interpretation.

1 Weigh 0.5 g each of aluminium powder, zinc power, copper powder and iron filings.
2 Using a measuring cylinder, pour 5 cm^3 of hydrochloric acid, of the same concentration and temperature, into each of four test tubes.
3 Add a metal powder to each test tube and observe what happens.
4 In which test tube were bubbles given off most vigorously?
5 In which test tube were no bubbles given off?
6 Use your observations to deduce the order of reactivity of these four metals and write them down, starting with the most vigorous.
7 Why is it important to use the same volume of acid, of the same concentration and at the same temperature?

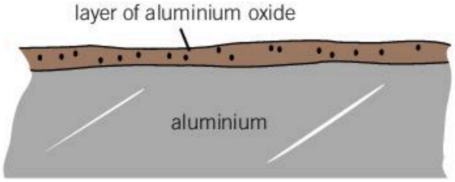
Questions

1 Write a word equation for the reaction that takes place when tin is heated in air.
2 Name the products when iron reacts with steam.
3 Which dilute acid reacts with copper?
4 Sodium reacts vigorously with oxygen, water and dilute acids. Where should sodium appear in the reactivity series?
5 Gold is less reactive than silver. Predict how it will react, if at all, with oxygen, steam, acid and alkali.

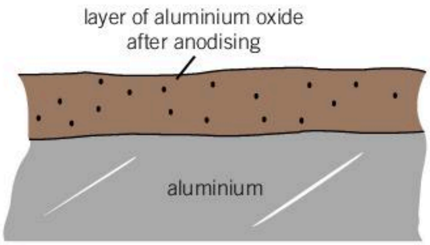
Learning outcomes

By the end of this topic you will be able to:

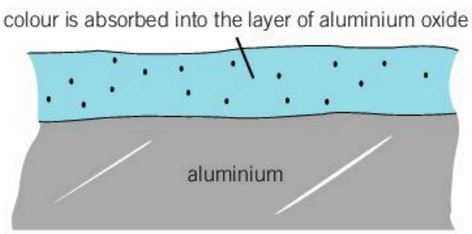
- explain the corrosion of aluminium
- describe the toxicity of aluminium
- explain the dangers of cooking in aluminium pots.



▲ **Figure 13.4.1** A protective layer of oxide forms on aluminium



▲ **Figure 13.4.2** As a result of anodising the layer of oxide is made thicker



▲ **Figure 13.4.3** The layer of oxide can be coloured

13.4 The use of aluminium in cooking and canning utensils

Toxicity of aluminium

It is known that some metal ions have a negative effect on the human body. There has been some suggestion that aluminium ions can cause illness but normally we do not come into contact with high enough concentrations. In some places, drinking water is treated with potassium aluminium sulphate (alum) and it is a common constituent of deodorants and aftershave. It is also used for fire-proofing materials. Aluminium has been linked with Alzheimer's disease.

Aluminium for cooking utensils

When acid foods are cooked in aluminium pots and pans, they react with the aluminium oxide to form a salt. If vinegar and fruits are boiled in the aluminium pans, the oxides on the outside of the aluminium are removed exposing the metal.

Aluminium

The layer of oxide that forms on the surface of metals is not always a bad thing. The layer of aluminium oxide is impermeable and prevents the aluminium reacting with other substances. If the surface layer of aluminium oxide is removed by rubbing with a suitable abrasive it will immediately reform.

Rather than attempt to remove the aluminium oxide, sometimes the layer is made thicker by a process called **anodising**. This process uses an electric current to oxidise more of the aluminium into aluminium oxide.

Anodised aluminium can be made more decorative by adding different colours. The chemical responsible for the colour is absorbed into the layer of aluminium oxide and not into the aluminium.

Questions

1. Why is aluminium used to make cooking pots?
2. Explain why high levels of aluminium are considered dangerous.
3. How does anodising aluminium prevent corrosion?
4. What happens when acidic fruits are boiled in an aluminium pan?

13.5 Alloys

The physical properties of pure metals are often less than ideal for some applications so these properties can be modified by creating an **alloy**. This is a mixture of two or more metals that are melted and mixed together. The alloy possesses the combined properties of the metals from which it is made.

▼ **Table 13.5.1** Properties and uses of alloys

Alloy	Properties	Uses
Gold alloys	• more hard-wearing than pure gold • yellow gold is an alloy of gold with copper and silver • nickel, zinc and palladium are added to make white gold	• jewellery
Sterling silver (92.5% silver; 7.5% copper)	• stronger than pure silver and more hard-wearing	• silver jewellery
Bronze (90% copper; 10% tin)	• hard and strong	• statues
Brass (copper and zinc)	• hard and strong • tarnishes slowly	• plumbing • keys • ornaments • coins
Duralumin (95% aluminium; 5% copper)	• much stronger than pure aluminium	• airframes • general construction • kitchen utensils
Mild steel (alloy of iron containing a small percentage of carbon)	• harder than pure iron and less brittle than wrought iron • cheap to produce • readily corrodes so has to be protected	• large-scale construction • road vehicles • tools • fixtures
Stainless steel (iron, nickel and chromium)	• long-lasting and strong • does not rust	• surgical instruments • tools • kitchen utensils
Plumber's solder (75% lead; 25% tin)	• addition of tin to lead lowers the melting point of the alloy so that it has a much lower melting point than that of pure lead • can be melted at low temperatures using a soldering iron	• joining metal together • attaching wires and components in electric circuits • for making leak-proof joints in water pipes

Practical Activity 13.5.1

How much copper and zinc is in a sample of brass?

Skills assessed: Manipulation/Measurement and Analysis, and Interpretation.

In this activity you will find the percentage by mass of copper and zinc in a sample of the alloy brass.

1. Measure out accurately about 1 g of brass powder.
2. Place the brass powder in a beaker and add 50 cm^3 of dilute hydrochloric acid of concentration 1.0 mol dm^{-3}.

Learning outcomes

By the end of this topic you will be able to:

- state what an alloy is
- appreciate that when a metal is used to form an alloy its properties are modified
- describe the properties and uses of some alloys.

Key fact

The purity of gold is measured in carats. A carat is $\frac{1}{24}$th part so 24 carat is pure gold, 18 carat contains 75% gold and 9 carat contains 37.5% gold. It does not necessarily follow that 9 carat gold is harder than 18 carat gold, since hardness depends on which metals have been added to the gold to make the alloy.

Did you know?

Gold bullion and silver bullion are essentially the pure metals. Countries hold reserves of these metals as bullion but, in order to be of any practical use, they would have to be made into alloys.

▲ **Figure 13.5.1** Gold jewellery

▲ **Figure 13.5.2** A silver coin

3 Warm the mixture by stirring until no more effervescence is seen.
4 Filter the mixture and retain the residue on the filter paper.
5 Wash the residue with distilled water.
6 Dry the residue in an oven at 100 °C and accurately measure its mass.
7 Which metal reacted with the dilute hydrochloric acid and which did not?
8 What was the mass of copper in the sample of brass?
9 What was the mass of zinc in the sample of brass?
10 Use the equation:

$$\text{percentage of metal} = \frac{\text{mass of metal} \times 100}{\text{mass of brass}}$$

to calculate the percentages of copper and zinc in the sample.

▲ **Figure 13.5.3** Stainless steel does not rust

Key fact

Before two pieces of metal can be soldered together they must be very clean. The surfaces are rubbed with wire wool or fine sandpaper until they are shiny. The clean surfaces are then coated with chemical called a flux which prevents them from reacting with oxygen in the air and helps the solder to make a strong joint.

Questions

1 Which metal is found in both bronze and brass?
2 State one property of stainless steel which is not found in mild steel.
3 List the properties of sterling silver.
4 In some countries aluminium has been used to make coins. Suggest one advantage and one disadvantage of this.
5 Suggest which two metals are used to make the alloy cupronickel.

13.6 Rusting

Learning outcomes

By the end of this topic you will be able to:

- state that rust is hydrated iron oxide
- state the conditions needed for rusting
- write a word equation for rusting
- state some different methods of rust prevention and give an example of how each is used.

What is rust?

▲ **Figure 13.6.1** A rusty car

Both iron and mild steel corrode in a particular way called **rusting**. Mild steel has a wide range of uses because it is strong and cheap. However, it must always be protected from rusting or it will rapidly wear away. Many millions of dollars are spent each year protecting objects from rusting or replacing mild steel which has become so badly corroded that it cannot be repaired.

Iron rusts when it is exposed to water and air. Rust is hydrated iron oxide.

iron + oxygen + water → hydrated iron oxide (rust)

Unlike aluminium oxide, hydrated iron oxide does not cover the surface of the iron preventing further corrosion. Instead, it expands and flakes off the iron leaving new surfaces exposed so that further rusting can take place.

Rusting cannot easily be reversed, so the only way to protect iron and mild steel is to prevent rust from forming.

Rust prevention

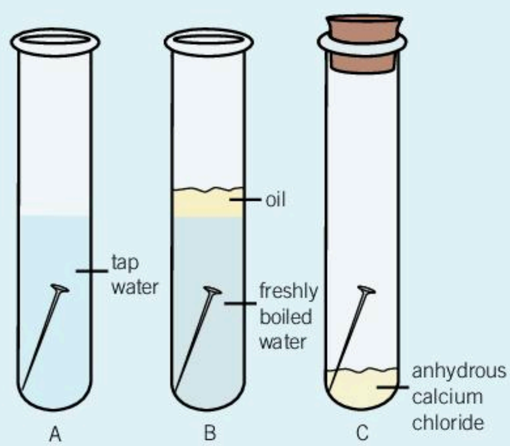
Most methods of preventing rusting involve coating the iron or mild steel with something that stops it coming into contact with moisture and air.

Practical Activity 13.6.1

Investigating the conditions needed for rusting

Skills assessed: Observation/Recording/Reporting and Analysis, and Interpretation.

1. Place an iron nail into each of three test tubes labelled A, B and C.
2. In test tube A, cover the nail in tap water and leave the tube open to the air.
3. In test tube B, cover the nail in freshly boiled water and cover the water by a layer of oil. Leave the tube open to the air.
4. In test tube C, place a small amount of anhydrous calcium chloride and seal the tube with a bung.
5. Leave the test tubes for one week and then observe any changes to the nails.
6. Which nails rusted and which did not? What are the conditions needed for rusting to occur?

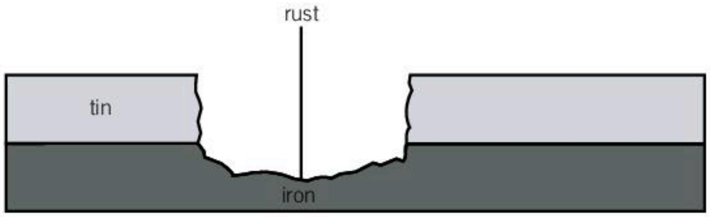


▼ **Table 13.6.1** Methods of rust prevention

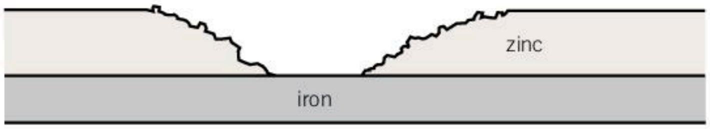
Rust prevention method	Examples
Oil and grease	Engine parts are protected by coating in oil or grease.
Painting	Iron objects are painted to slow down rusting.
Plastic coating	Wire mesh fencing is coated in plastic.
Galvanising	Iron is galvanised by dipping in molten zinc. The iron is covered by a thin layer of zinc which prevents rusting. Galvanised iron sheeting is commonly used for roofing in some parts of the world. If the surface of galvanised iron is scratched, and the iron is exposed, the zinc continues to provide protection against rusting. The zinc will corrode in preference to the iron because it is a more reactive metal.
Tinning	Tin plate consists of iron which is covered by a thin layer of tin. It is made by dipping iron in molten tin. Tin plate is widely used to make cans for storing foods. Many foods contain chemicals which would attack iron, causing corrosion over a period of time. The layer of tin prevents the iron from coming into contact with the food. Tin is a less reactive metal that iron. If the outside of a food container is scratched, the tin no longer offers protection and the iron will rapidly rust.
Electroplating	An electric current is used to deposit a thin layer of a non-corroding metal on the surface of mild steel. Shiny bicycle handlebars are made by electroplating mild steel with chromium. The bicycle handlebars are suspended in a solution containing a salt of the non-corroding metal. A block of chromium is also suspended in the solution. When an electric current is passed through the solution, chromium is deposited on the handlebars. At the same time, chromium from the block passes into solution so the concentration of chromium in the solution remains the same.

▲ **Figure 13.6.2** Oil and grease prevent steel from coming into contact with moisture and air

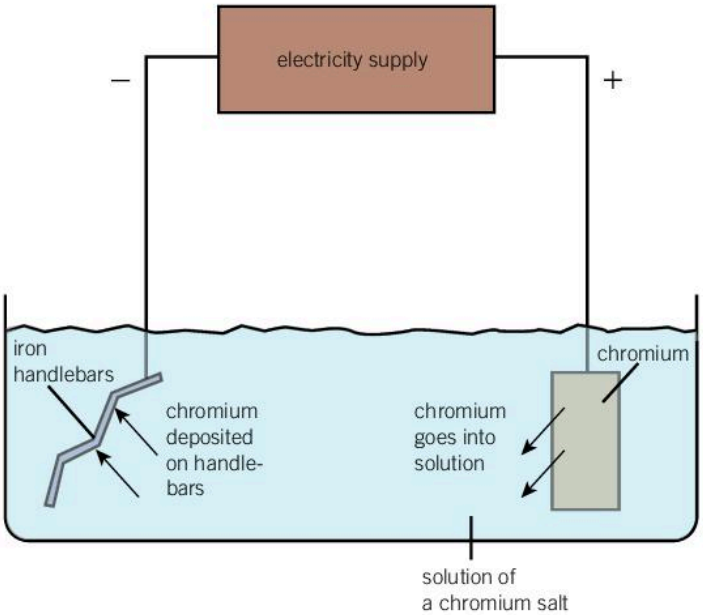
▲ **Figure 13.6.3** Chrome plating both protects iron and makes it look more attractive



▲ **Figure 13.6.4** If the layer of tin is scratched the iron is no longer protected and rust forms



▲ **Figure 13.6.5** Zinc continues to protect iron even if the layer is scratched



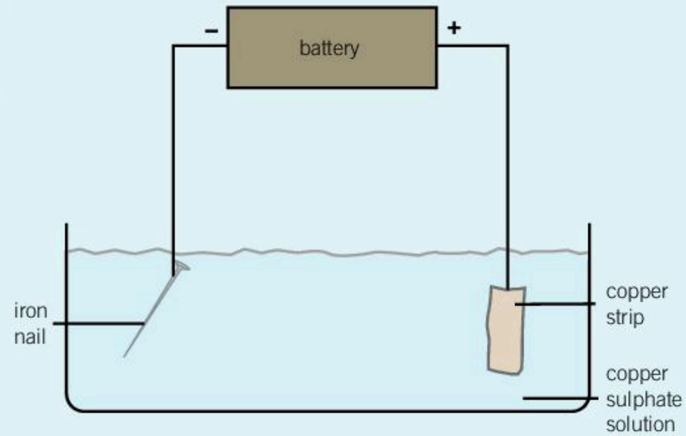
◀ **Figure 13.6.6** Electricity is used to deposit a layer of chromium on the iron

Practical Activity 13.6.2

Electroplating

Skills assessed: Observation/Recording/Reporting.

1 Suspend an iron nail and a strip of copper in a solution of copper sulphate as shown in the diagram.
2 Connect the metals to the battery as shown. The nail should be connected to the negative terminal of the battery. Leave the apparatus for 5 minutes.
3 Remove the nail and the copper strip, and examine them. How has the appearance of each one changed?
4 Replace the nail and the copper strip, and connect them to the battery in the opposite way so that the nail is connected to the positive terminal of the battery.
5 Leave the apparatus for 5 minutes and re-examine the nail and the copper strip. How has the appearance of each one changed?
6 Explain the changes that you observed to the nail and the copper strip after each 5 minute period.



Rusting and reactivity

Iron can be protected from rusting by attaching a more reactive metal to it. The more reactive metal corrodes in preference to the iron. It is for this reason that galvanising prevents rusting even when the surface is damaged and the iron is exposed.

Large ships have steel hulls. A steel hull surrounded by water will rapidly rust unless something is not done to prevent it. Painting does not provide adequate protection. In addition, zinc blocks are bolted to the underside of the ship. The zinc blocks will corrode in preference to the steel which protects the steel from rusting. This is called **sacrificial protection** as the zinc is sacrificed to protect the steel. Over a period of time these blocks wear away and must be renewed. However, it is much cheaper and more convenient to replace the blocks than to repair damage to the steel hull caused by rusting.

▲ **Figure 13.6.7** Zinc is sacrificed to prevent the iron from rusting

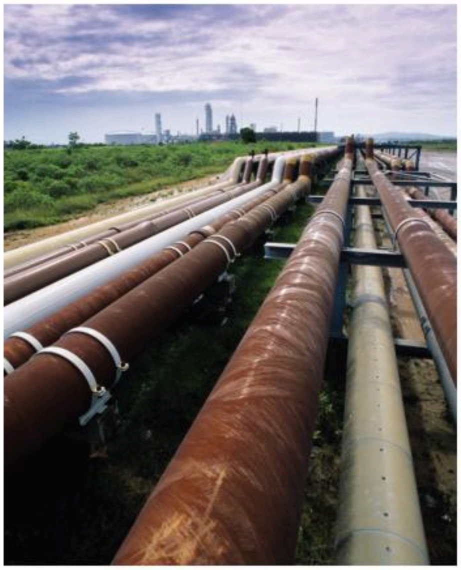
Questions

1 Name one metal other than iron that will rust.
2 What conditions are necessary for rusting?
3 How does painting prevent iron from rusting?
4 Which metal is used to galvanise iron?
5 Zinc blocks are bolted to the hull of a ship to prevent it from rusting. Why is this called sacrificial protection?

Learning outcomes

By the end of this topic you will be able to:

- state some factors that affect the rate of rusting
- describe the effect of seawater on rusting
- describe the effect of air pollution around an industrial plant on rusting.



▲ **Figure 13.7.2** Iron rusts more quickly near industrial areas

13.7 Factors that affect the rate of rusting

In Topic 13.6 you found out, that in the presence of moisture, iron or mild steel reacts with oxygen from the atmosphere to form rust or iron oxide.

Like any other chemical reaction the rate at which rusting takes place may be affected by external conditions.

▲ **Figure 13.7.1** The air in a desert is very dry

Iron rusts only in the presence of moisture. In a desert, where there is very little moisture in the air, objects take a long time to rust.

Although there is plenty of water at the North and South Poles, it is frozen as ice for much of the year. When it is liquid, the temperature is still very low. Rusting only takes place slowly when it is very cold.

Practical Activity 13.7.1

Does salt water speed up the rate of rusting?

Materials:

- Two iron nails
- Two test tubes
- Test tube rack
- Distilled water
- Seawater (5% by mass solution of sodium chloride in water can also be used)

Method:

1. Place a nail in a test tube and half-fill it with distilled water.
2. Place another nail in the second test tube and half-fill it with seawater.
3. Place the test tubes in a rack and observe them each day for a week.
4. Take a photograph of the test tubes each day if a digital camera is available.
5. Use your photographs to show how the nails rusted over the five days.
6. Which nail rusted quicker?

Seawater contains dissolved substances that assist the rusting process.

Iron and steel rust more quickly near the sea than they do inland. Objects don't have to actually be in the sea. Sufficient salt water is carried by sea breezes to affect them.

Many large industries release gases that cause atmospheric pollution, such as the acidic gases sulphur dioxide and nitrogen oxides. These atmospheric pollutants accelerate the rate at which iron rusts, so structures such as corrugated iron roofs and iron railings will rapidly rust away.

Questions

1. How would the rate of rusting of iron near a freshwater river compare to near the sea? Explain your answer.
2. Why would the iron railings around a factory need repainting more frequently than the iron railings around a school?

Exam-style questions

Multiple choice

1 Metal oxides form when:
A metals react with hydrogen
B metals react with oxygen
C metals react with an acid
D metals react with nitrogen

2 When iron and steel rust they need:
A oxygen only
B water only
C hydrogen only
D water and oxygen

3 Which of the following metals, A, B, C or D is the most reactive?

Metal	Reaction with oxygen	Reaction with water	Reaction with acid	Reaction with alkali
A	✓	✗	✓	✗
B	✓	✓	✓	✓
C	✓	✗	✗	✓
D	✓	✗	✗	✗

4 Which of the following is NOT a property of metals?
A They are shiny.
B They are good heat conductors.
C They are poor electrical conductors.
D They have low melting points.

Structured questions

5 Complete the following word equations:
a zinc + oxygen →
b zinc + steam →
c zinc + dilute hydrochloric acid →
d zinc + sodium hydroxide →

6 a Arrange the metals in the list below in their order of reactivity, starting with the most reactive.

zinc, tin, iron, copper, aluminium, silver

b Which metal forms a protective oxide layer when exposed to air?

7 a What is an alloy?
b Give one example of an alloy.
c For the alloy that you named in **b**, state which metals are used to make it.
d What are the features of this alloy that make it suitable for its uses?

8 Students noticed brown flaky spots on the school gates where the paint had come off.
a What is the brown flaky material?
b Write the word equation for the process that formed the material.
c Describe one way that the gate could be treated to prevent the process continuing.
d Design an experiment to show that steel needs oxygen and water for this process to happen.

9 The rate at which an iron object rusts depends on the climate and the location. The table below gives information about the climate and location of different cities, and the rate of rusting in them.

City	Location	Average temperature	Average level of moisture in the atmosphere	Rate of rusting
Brisbane	Coastal	Moderate	High	High
Khartoum	Inland	High	Low	Low
Manchester	Inland	Moderate	Moderate	Moderate
Quito	Inland	High	High	High
Singapore	Coastal	High	High	Very high
Vladivostock	Coastal	Low	Moderate	Moderate

a In which of the above cities is the rate of rusting slowest?
b Suggest why the rate of rusting is generally higher in cities on the coast.
c Suggest why the rate of rusting in Vladivostock is lower than in the other two coastal cities in the table.

Section B

14 Acids, bases and mixtures

Learning outcomes

By the end of this topic you will be able to:

- describe types of household chemicals and their uses
- identify some common household chemicals, their chemical names and their uses
- identify all safety symbols.

▲ **Figure 14.1.1** Soaps remove dirt from our bodies

▲ **Figure 14.1.2** Antiseptics prevent wounds from becoming infected

▲ **Figure 14.1.3** Different cleaning materials remove dirt from our homes

Our homes contain many chemicals. These are mostly found in the kitchen, the bathroom and the garage. We use these chemicals in a variety of ways to keep our homes and ourselves clean, and to improve our environment. Some of these chemicals are potentially harmful and must be handled with care.

14.1 Household chemicals

Each week, families buy a range of chemicals for use in their homes. Soaps, detergents and washing powders, disinfectants and personal hygiene products are some of the chemical substances that we use.

Water (H_2O) is the most common chemical in our homes with a wide variety of uses, which include flushing toilets, cooking food, bathing, drinking, air conditioning units, doing the laundry, in cleaning, as well as in gardening. There is more about water in Topic 14.7.

Types of household chemicals

Soaps come in the form of solid blocks or solutions. Washing powders or **detergents** are often solids or suspensions. They remove dirt and stains from our clothes. Detergents are often used in conjunction with **fabric softeners**. Washing some fabrics causes them to go hard. Fabric softener restores their original texture. The action of detergents is described in Topic 14.6.

Cleaning chemicals are solutions, or suspensions, containing detergents, and other chemicals, designed to remove stains and grease. Some contain fine particles which act as an **abrasive** when rubbed on with a cloth.

Disinfectants kill off germs in our homes. They usually come as solutions which can be rubbed over surfaces in the kitchen and bathroom with a cloth.

Antiseptics are chemicals which prevent wounds from becoming infected by killing any germs present but without damaging the skin further. Some antiseptics, such as Savlon, come as solutions. The wound is wiped over with the disinfectant on a clean cloth. Other antiseptics, such as Germolene, come as creams which are spread over the cleaned wound before a plaster or bandage is applied.

We use some chemicals each day as part of our own personal hygiene. For example, **toothpaste** usually comes as a paste which we rub on our teeth using a brush.

When we get hot, we perspire and a liquid called perspiration, or sweat, is released from the skin. Sweat is mostly water which evaporates, helping us to cool down. However, it also contains the waste product urea.

Urea has an unpleasant smell and there are bacteria on the skin which feed upon it that add to the problem. If the urea and bacteria are not removed from the skin regularly by washing, they build up on the skin, particularly in the arm pits, causing body odour.

Antiperspirants reduce the amount of perspiration so less urea is released from areas, such as the arm pits. **Deodorants** help to mask any remaining odour, so a person remains smelling fresh.

Hair shampoos contain mild detergents which remove oil from the hair and clean the scalp. Applying a **conditioner** after shampooing replaces some of the natural oils removed by shampooing, and leaves the hair looking and feeling good.

Did you know?

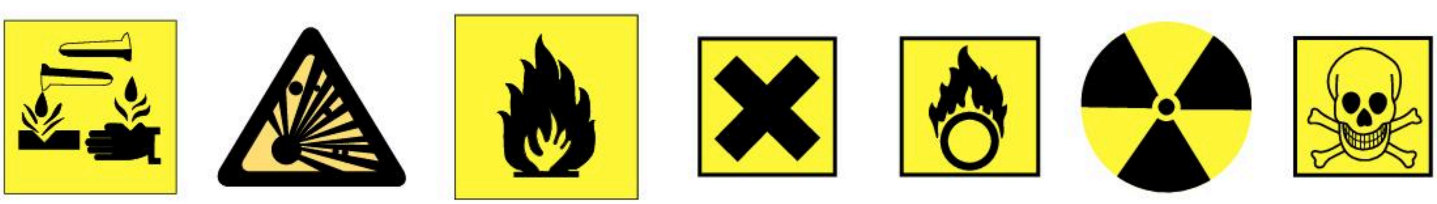
Before toothpaste was available from shops, people used to clean their teeth by rubbing them with mild abrasives, such as table salt and soot.

▼ **Table 14.1.1** Some chemical substances that we use in our homes and their functions

Household name	Chemical name	Uses
Washing soda	Sodium carbonate	Soaps, cleaners
Caustic soda	Sodium hydroxide	Drain cleaners, oil remover
Toothpaste	Sodium monofluorophosphate	Prevents tooth decay
Tums / Andrew's	Sodium hydrogencarbonate and citric acid	Treatment of indigestion
Milk of magnesia	Magnesium hydroxide	Treatment of indigestion
Vinegar	Acetic acid solution	Cooking, pickling, treating some insect stings
Baking powder	Sodium hydrogencarbonate + cream of tartar	Raising agent in baking
Epsom salts	Magnesium sulphate	Laxative
Alum	Potassium aluminium sulphate	Water purification
Baking soda	Sodium hydrogencarbonate or sodium bicarbonate	Raising agent in baking, antacid, treating some insect bites, cleaning agent
Savlon	Chlorhexidine gluconate and cetrimide	Disinfectant with antibacterial action
Scouring powders	Ash or calcite	Used for stain removal
Window cleaner	Ethanol	Used to clean glass windows

Safety symbols

A number of the chemicals used in the home are potentially harmful. To warn people about the dangers, containers often carry hazard, or safety symbols. Even if you are in a country where you cannot read the information on the container, you will be able to recognise the symbol.



▲ **Figure 14.1.4** Safety symbols

The safety symbol on hair spray warns a user that it is flammable.

Hairspray must not be used near a naked light or it could catch fire.

The safety symbol on a bottle of bleach warns people that it is either harmful or an irritant, or both. An irritant is a substance that irritates the skin if it comes into contact with it.

▲ **Figure 14.1.5** Hair spray is flammable

▲ **Figure 14.1.6** Bleach is harmful and an irritant

Bleach should not come into contact with the skin, which is why people wear rubber gloves when using it.

Questions

1. Why is fabric softener used with washing powder?
2. Why do some cleaners contain fine particles of an abrasive?
3. Name one place in your home which should be regularly disinfected.
4. What substance is excreted from the body in solution as sweat?
5. Name two household chemicals that can be used to treat insect bites.

14.2 Acids, bases and salts

Acids

Acids are chemicals that release hydrogen ions when dissolved in water. They have the following properties:

- They have a sour taste. Do NOT ever taste acids in the laboratory!
- Some are harmful and corrosive.
- They turn blue litmus paper red.
- They react with bases, or alkalis, to form salts.
- They release hydrogen ions when they are dissolved in water.

Hydrochloric acid, **nitric acid** and **sulphuric acid** are strong acids. They will damage the skin and cause holes in fabrics. Splashes with these acids must be washed immediately with lots of cold water.

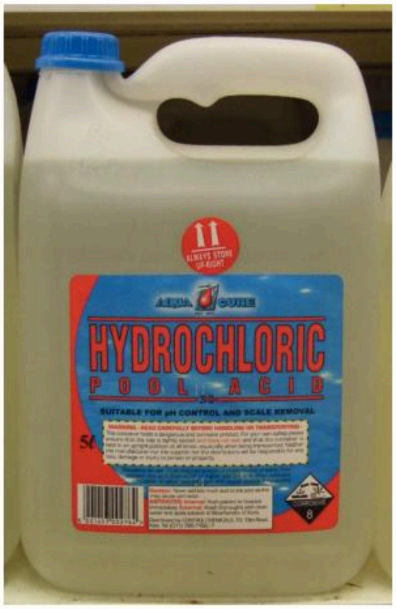


Figure 14.2.1 Hydrochloric acid is a strong acid

The foods we eat contain many weak acids, for example:

- **citric acid** is found in citrus fruits, such as oranges and limes
- **ethanoic acid** is found in vinegar
- **ascorbic acid** is another name for vitamin C; it is found in fresh fruit and leafy vegetables
- **tannic acid** is found in tea
- **tartaric acid** is found in baking powder.

Bases

A **base** reacts with an acid to form a salt. Any base that dissolves in water is called an **alkali**. Bases have the following properties:

- They are soapy when touched.
- They turn red litmus paper blue.
- They react with acids to form salts. This is called a neutralisation reaction.

Learning outcomes

By the end of this topic you will be able to:

- describe the properties of acids
- name common laboratory acids
- name common acids in food
- describe the properties of bases
- state that an alkali is a soluble base
- name common laboratory alkalis
- name common weak alkalis
- define pH
- describe the pH scale
- describe different types of indicators
- describe salts
- give examples of salts used in the home.

Did you know?

The traditional name for ethanoic acid is acetic acid.

Sodium hydroxide and **potassium hydroxide** are strong alkalis. They are both harmful and corrosive, and splashes should be treated in the same way as strong acids. Aqueous ammonia is a weaker alkali but should still be handled with great care.

Strong alkalis are found in cleaning materials. Weak alkalis, such as **calcium hydroxide** and **magnesium hydroxide**, are often found in remedies to combat indigestion.

Figure 14.2.2 We use both strong and weak alkalis in our homes

? Did you know?

Calcium hydroxide solution is the chemical name for lime water, the reagent we use to test for carbon dioxide gas.

pH

pH is a measure of how acidic or alkaline a solution is. A **pH scale** is used. On the pH scale a value of 7 is neutral so it is neither acidic nor alkaline. Values below 7 on the scale become increasingly acidic, while values above 7 become increasingly alkaline.

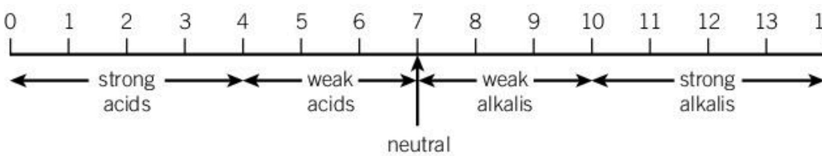


Figure 14.2.3 The pH scale measures acidity and alkalinity

! Key fact

For convenience, litmus is usually used as litmus paper.

- Blue litmus paper is used to test for acids, which turn it red.
- Red litmus paper is used to test for alkalis, which turn it blue.

Indicators

Acid–base indicators are chemicals which are different colours in acids and alkalis so they can be used to test solutions. Indicators are useful for testing whether a solution is acidic or alkaline but they do not always indicate how acidic or how alkaline it is. In order to do this we need a scale.

Table 14.2.1 The colour of some indicators commonly used in laboratories

Name of indicator	Colour of indicator in an acid	Colour of indicator in an alkali
Litmus	RED	BLUE
Phenolphthalein	COLOURLESS	PINK
Methyl orange	RED	YELLOW
Screened methyl orange	LIGHT RED	GREEN

Practical Activity 14.2.1

Investigating indicators (I)

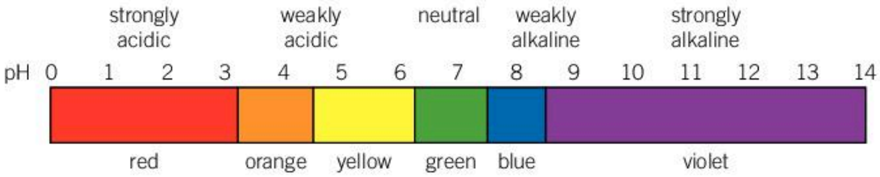
Many naturally-occurring colour pigments can be used as acid–base indicators.

Your teacher will supply you with coloured flower petals or other plant material.

1 Chop the plant material into tiny pieces, and grind these up using a mortar and pestle.
2 Add a small amount of ethanol to the ground-up plant material and stir until some of the coloured pigment has dissolved in the ethanol.
3 Carefully pour off the ethanol into a test tube.
4 Add a few drops of the pigment solution to a small amount of hydrochloric acid and to a small amount of sodium hydroxide solution.
5 What was the original colour of your pigment? What colour is the pigment in acids, and in alkalis?

Universal indicator

Universal indicator is, in fact, a mixture of several indicators. It has the advantage over other indicators of changing colour several times over the full pH scale.



▲ **Figure 14.2.4** Universal indicator has a range of colours

Universal indicator shows not only whether a solution is acidic or alkaline but also how acidic or how alkaline.

Salts

Acids react with bases to form salts and water only. This is described as a neutralisation reaction since the acid and the base react together to produce water.

$$\text{base} + \text{acid} \longrightarrow \text{salt} + \text{water}$$

Many common household chemicals are salts.

- **Sodium chloride** is the table salt we sprinkle on our food.
- **Sodium hydrogencarbonate** is the chemical name for baking powder which we use to make bread and cakes rise during baking.
- **Sodium carbonate** is the chemical name for washing soda.
- **Magnesium sulphate** is the chemical name for Epsom's salts which are used as a laxative.

Neutralisation is a type of chemical reaction in which a strong acid reacts with a strong base to produce a salt and water only.

HCl (hydrochloric acid) + $NaOH$ (sodium hydroxide) $\longrightarrow$ $NaCl$ (sodium chloride) + H_2O (water)

Practical Activity 14.2.2

Investigating indicators (II)

Skills assessed: Observation/Recording/Reporting.

Your teacher will give you some universal indicator, litmus paper, phenolphthalein and methyl orange, together with samples of the following common substances: lemon juice, salt, oven cleaner, toothpaste, milk, vinegar, milk of magnesia, washing soda, distilled water and cola.

1 Where necessary, make up a solution of the substance by adding a small amount to 1 cm^3 of water in a test tube.
2 Add a few drops of universal indicator to each solution.
3 Make a list of the substances and, alongside each one, state whether it is an acid, an alkali or neutral and write its pH value.
4 Repeat steps 2 and 3 using the other indicators. Draw a table of your results.

Key fact

The type of salt formed depends on the acid used.

- Hydrochloric acid is used to make chlorides.
- Nitric acid is used to make nitrates.
- Sulphuric acid is used to make sulphates.

Questions

1 Which acid is found in lemons?
2 What colour would you expect litmus paper to turn when dipped in a freshly cut lime?
3 What is the pH of a neutral solution?
4 What type of chemical is sodium sulphate?
5 Antacids contain weak bases which neutralise excess acidity in the stomach. An investigation was carried out by students to determine which antacid is the most effective at neutralising stomach acid. They reacted each of the antacids with dilute hydrochloric acid and tested each with universal indicator solution. Their results are shown in the table below.

Antacid	pH after addition of HCl
A	4
B	2
C	5
D	7

a Which antacid is the most effective?
b Mention one thing that the students should have done to make sure that this was a fair test.

14.3 Solutions, suspensions and colloids

Solutions

When a solid dissolves in a liquid **a solution** is formed. The solid is called the **solute** and the liquid the **solvent**. Water is the common solvent. A solution formed from water is called an **aqueous solution**. Water is used both in the laboratory and in making the products we use. However, there are many other solvents. A **non-aqueous solution** results when other solvents are used to make a solution.

Sugar water and Kool-Aid are solutions of a solid in a liquid.

Practical activity 14.3.1

Investigating solubility

Skills assessed: Observation/Recording/Reporting.

Your teacher will supply you with samples of: sodium chloride, copper(II) sulphate, calcium carbonate, magnesium hydroxide, copper(II) oxide, lead chloride, zinc sulphate and sodium carbonate.

1 Investigate which of the substances are soluble by trying to dissolve them first in cold water and then in hot water.
2 Display your results in a suitable table.

Many gases also dissolve in water (any other solvents) to give solutions. Carbonated drinks, such as lemonade, are fizzy because carbon dioxide gas is dissolved in the water.

Suspensions

If a mixture of a fine powder of an insoluble substance, such as calcium carbonate, and water is shaken the particles distribute themselves throughout the water forming **a suspension**.

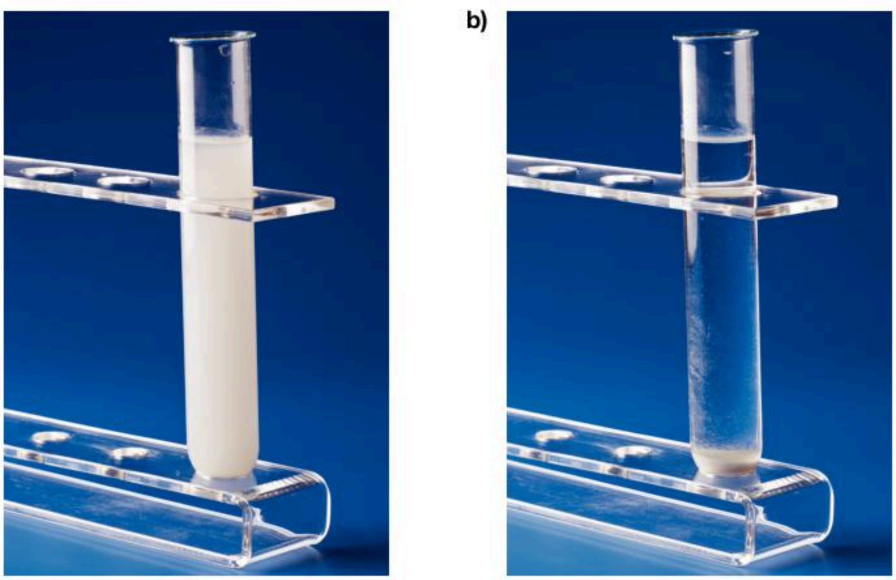
Learning outcomes

By the end of this topic you will be able to:

- explain the terms solution, solute and solvent
- describe some of the properties of a solution
- give examples of solutions
- describe how a suspension differs from a solution
- give some everyday examples of suspensions
- describe how a colloid differs from a solution and a suspension
- describe some of the properties of a colloid
- give examples of colloids.

▲ **Figure 14.3.1** Carbon dioxide is soluble in water

a)
b)



▲ **Figure 14.3.2** a) The calcium carbonate particles are suspended in the water. b) After standing for a while, the calcium carbonate particles start to settle out

Key fact

The solubility of solids in water usually rises with increasing temperature. The converse is true of gases. A gas is generally less soluble in hot water than in cold water.

▲ **Figure 14.3.3** Many sauces are suspensions of particles in vinegar

Brown sauce and tomato ketchup are suspensions. If they are left from day to day the particles begin to fall to the bottom, so we must shake them before use.

Colloids

If the particles of an insoluble substance are sufficiently small they will not fall to the bottom when shaken with water and left to stand. Instead they remain in suspension forming a **colloid**.

Colloids form when one substance becomes spread out, or dispersed, in another. The amounts of the two substances are often different.

Colloids are not just solid particles dispersed in liquids. There are a number of other types of colloids formed by solids, liquids and gases. An aerosol is a colloid in which a liquid or a solid is dispersed in a gas. When we press the top of the can, particles of the liquid or solid are carried on a stream of gas.

Practical activity 14.3.2

What is 'starch solution'?

Your teacher will give you a sample of 'starch solution' to investigate.

1. Is the solution transparent?
2. Can you shine a light through the solution?
3. Filter the solution. Does the filtrate look any different from the starting solution?
4. Test the filtrate with iodine solution. Does the filtrate contain starch?
5. Is starch solution really a solution, a suspension or a colloid?

Toothpaste is a colloid in which a solid is dispersed in a liquid.

In an **emulsion**, a colloid is formed by one liquid becoming dispersed in another. Milk is an emulsion in which oil is dispersed in water.

Cream topping is a liquid foam. This is a colloid in which a gas is dispersed in a liquid.

▼ **Table 14.3.1** The differences between a solution, a suspension and a colloid

Solution	Suspension	Colloid
The particles are too small to see.	Particles may be visible.	The particles are too small to see.
The particles cannot be removed by filtration.	The particles are large enough to be separated by filtration.	The components cannot be separated by filtration.
The particles do not settle to the bottom of the solution when left to stand.	The particles will slowly fall and settle out at the bottom of the mixture if left to stand.	The particles do not settle out if left to stand.
Transparent, since there are no particles of sufficient size to scatter light but they are often not colourless.	Not transparent because the particles will scatter light.	Not transparent because the particles are large enough to scatter light.

Questions

1. Why is it that solutions are transparent but colloids are not?
2. Why is it possible to filter off the particles in a suspension but not the particles in a solution?
3. Give an example of an everyday substance that is an emulsion.

14.4 Methods of separation

Solutions

A solution forms when a solid, liquid or gas dissolves in a liquid.

Brine is a solution of a solid called sodium chloride in water. Seawater is an impure form of brine.

Vinegar is a solution of a liquid called ethanoic acid in water.

Drinks are fizzy because they are solutions of a gas called carbon dioxide in water. Solutions are often but not always, in water. A solution in water is described as an aqueous solution.

Some of the chemicals that people use, such as nail polish, are non-aqueous solutions. They are solutions in a solvent other than water. Different solvents are used because not all substances will dissolve in water.

Some stains are caused by substances which are insoluble in water so soaking in water and detergents will have no effect. In order to remove these stains a different solvent must be used.

The dust and grime which accumulates on the outside surface of windows is often difficult to remove using water alone. Rubbing with a cloth soaked in water simply spreads any grease but does not remove it. This is because the grease is not soluble in water.

Window cleaner is a solution of ethanol in water. Grease is soluble in ethanol so the window cleaner will dissolve the grease spots leaving the window clean.

Gloss paints are colloids in which fine particles of pigment are dispersed in turpentine. Splashes of gloss paint cannot be removed by soapy water but must be rubbed with a cloth soaked in turpentine or white spirit. The paint passes into the solvent and is absorbed into the cloth.

Paint splashes must be cleaned up immediately. As the paint dries a chemical change takes place and, once dry, the paint is no longer absorbed by the solvent.

Nail polish is a colloid in which fine particles of the colour are dispersed in organic solvents, such as as propanone. Dry nail polish can be removed from finger nails by rubbing with cotton wool soaked in propanone. The nail polish is absorbed into the cotton wool.

Practical activity 14.4.1

Investigating the removal of acidic or basic stains

Skills assessed: Observation/Recording/Reporting and Analysis, and Interpretation.

Your teacher will supply you with sodium hydrogencarbonate solution, borax solution, liquid soap, turpentine and propanone. Your teacher will also supply you with four pieces of cotton each stained with (a) fruit juice, (b) tea, (c) paint and (d) nail polish.

1 Label twenty test tubes 1–20.

2 Put a second label on the test tubes as follows: 1–4 soap; 5–8 sodium hydrogencarbonate solution; 9–12 borax; 13–16 turpentine; 17–20 propanone.

Learning outcomes

By the end of this topic you will be able to:

- give examples of aqueous and non-aqueous solutions
- describe distillation
- describe filtration
- describe chromatography
- explain the importance of desalination plants.

▲ **Figure 14.4.1** Brine is a solution of a solid in water

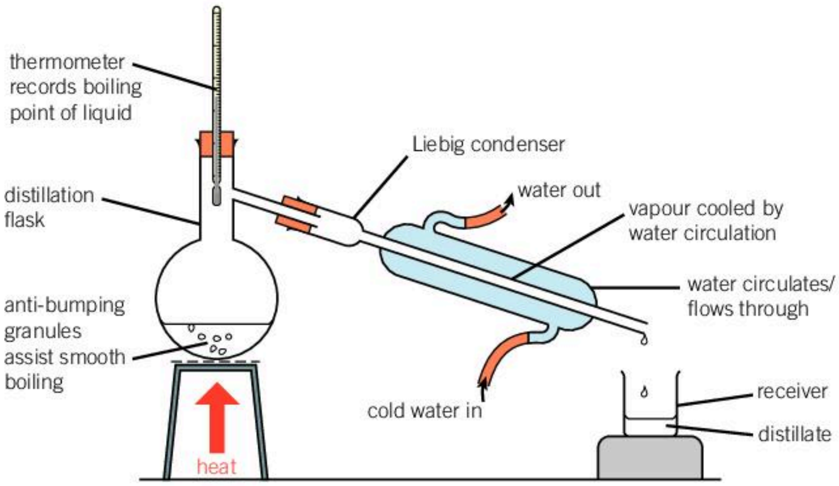
▲ **Figure 14.4.2** A fizzy drink is a solution of a gas in water

3 Half-fill test tubes 1–4 with distilled water and add a couple of drops of liquid soap to each. Place a piece of cotton stained with fruit juice in tube 1, with tea in tube 2, with paint in tube 3 and with nail polish in tube 4.
4 Half-fill test tubes 5–8 with sodium hydrogencarbonate solution. Place a piece of cotton stained with fruit juice in tube 5, tea in tube 6, paint in tube 7 and nail polish in tube 8.
5 Half-fill test tubes 9–12 with borax solution. Place a piece of cotton stained with fruit juice in tube 9, tea in tube 10, paint in tube 11 and nail polish in tube 12.
6 Half-fill test tubes 13–16 with turpentine. Place a piece of cotton stained with fruit juice in tube 13, tea in tube 14, paint in tube 15 and nail polish in tube 16.
7 Half-fill test tubes 17–20 with propanone. Place a piece of cotton stained with fruit juice in tube 17, tea in tube 18, paint in tube 19 and nail polish in tube 20.
8 Leave the stained cotton standing in the test tubes for 30 minutes. Remove the pieces of cotton taking care not to mix them up and wash them in clean cold water.
9 Compare the pieces of cotton stained with fruit juice. Which treatment worked best in removing the fruit stain?
10 Compare the pieces of cotton stained with tea. Which treatment worked best in removing the tea stain?
11 Compare the pieces of cotton stained with paint. Which treatment worked best in removing the paint stain?
12 Compare the pieces of cotton stained with nail polish. Which treatment worked best in removing the nail polish stain?

Distillation

Simple distillation is a method of separating components of a mixture. Substances are separated on the basis of how easily they become gases in a boiling mixture.

Simple distillation can be used to obtain a pure liquid and a solid from a solution (see Figure 14.4.3).



▲ **Figure 14.4.3** Distillation apparatus

When the solution in the round-bottomed flask boils, the liquid turns to vapour and passes into the condenser, while the solid remains in the flask. Cold water in the outer jacket of the condenser cools the vapour and it becomes liquid once more. The liquid then runs out of the condenser and is collected as the distillate in a beaker.

This method can be used to obtain fresh water from seawater. When seawater is distilled, the distillate is pure water and the dissolved solids remain in the flask.

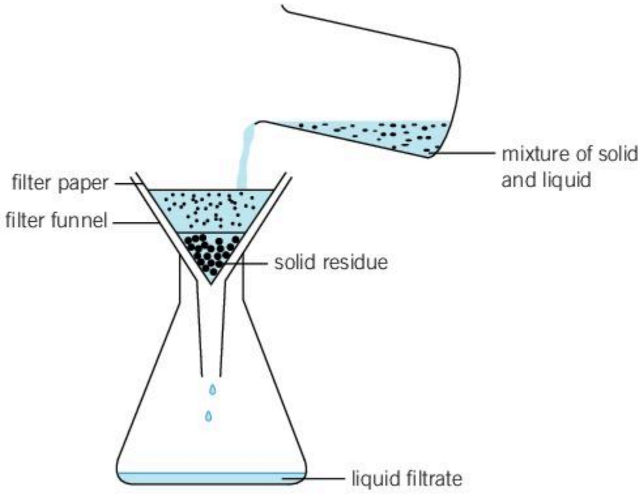
In some parts of the world distillation is used on an industrial scale to obtain fresh water from seawater. The process is called desalination because it desalinates or removes salt from the seawater.

▲ **Figure 14.4.4** Desalination plant

Filtration

Filtration is the process of separating particles of solid from a liquid or a gas. In chemistry the process is most often used to separate solids and liquids.

When solid particles are small they do not sink to the bottom of the container so they must be removed by filtration.



▲ **Figure 14.4.5** Filtering to separate a liquid from a solid

The mixture is poured through a porous filter paper supported in a filter funnel. The liquid that passes through the filter paper is called the filtrate. The solid trapped in the filter paper is called the residue.

This method can be used to separate suspensions of sand and/or chalk powder in water. It is also used in car engines, where the motor oil passes through an oil filter. This removes solid particles – such as metal dust – which could damage the engine parts.

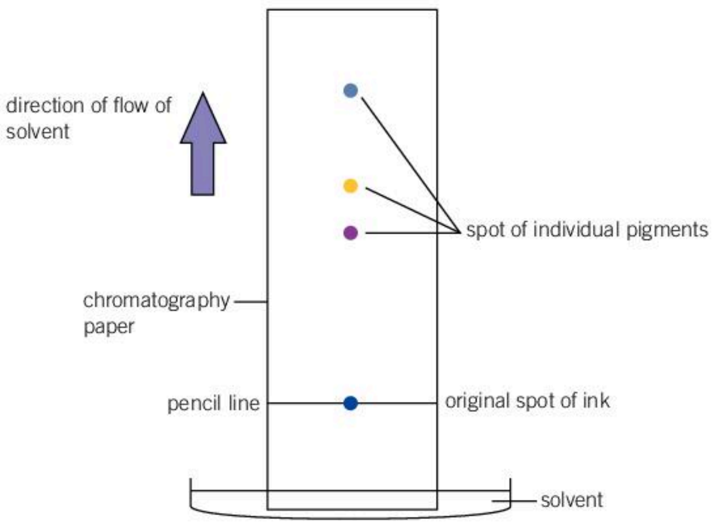
Chromatography

Paper chromatography involves placing a spot of the substance under investigation near the end of a strip of absorbent paper similar to filter paper. If the substance is a solid it must first be dissolved in a suitable solvent.

The paper is then suspended in a shallow tray containing a solvent, which is often ethanol. Ethanol is preferred to water because the substances to be separated are often more soluble in ethanol than water.

Did you know?

Chromatography techniques are used in criminal investigation of frauds. Cheques that have been used to make payments are tested for the inks used to write them.



▲ **Figure 14.4.6** Using chromatography to separate the pigments in dark blue ink

The ethanol slowly rises up the paper carrying any substances on the paper with it.

Dark blue ink is usually a solution of three or more pigments as shown in Figure 14.4.6. Each pigment will have a different solubility in ethanol. When ethanol is drawn up the chromatography paper, the pigments in the ink will move up at different rates: the more soluble a pigment is, the faster it moves. The resulting separation of pigments on the paper is called a chromatogram.

To obtain a good and clear separation by paper chromatography, the following points should be observed.

- Any base line should be drawn in pencil, and not in ink, as the pigments in the ink will separate and mix with the sample substances.
- When testing different substances, samples should be applied as small spots spaced apart on the base line to avoid them spreading into each other as they rise up the paper.
- Samples should be concentrated by applying several small spots of the same sample to the same place over a period of a couple of minutes. This ensures that the pigments can be seen when they rise up the paper.
- The level of the solvent should start below the base line where the sample spots have been placed otherwise they will simply dissolve into the solvent in the tray below.

Practical activity 14.4.2

Investigating the components of different food colourings. Your teacher may use this activity to assess the following skills: ORR and M&M

Materials:

- Glass rod
- Small paintbrush
- Shallow container
- Small clip
- Stand and clamp
- Chromatography paper approximately 20 cm × 6 cm
- Five different food colourings (such as the coloured coating from sweets)
- Water

Method:

1. In pencil, draw a line across the width of the chromatography paper about 2 cm from the bottom. Place crosses 1 cm apart along the line starting 1 cm in from the side. If you do this correctly you should have five crosses.
2. In pencil, write the colours of the food colouring that you are using below each cross.
3. Using a small clean paintbrush, place a single drop of water on the outside of a sweet and work it over the surface to obtain a concentrated solution of the colouring.
4. Transfer the coloured drop of water to the appropriate position on the chromatography paper.

5 Repeat this for the other coloured sweets ensuring that the paintbrush is clean each time.

6 Fold the opposite end of the chromatography paper around a glass rod and hold it in place with a small clip. Leave one end of the glass rod sticking out beyond the paper.

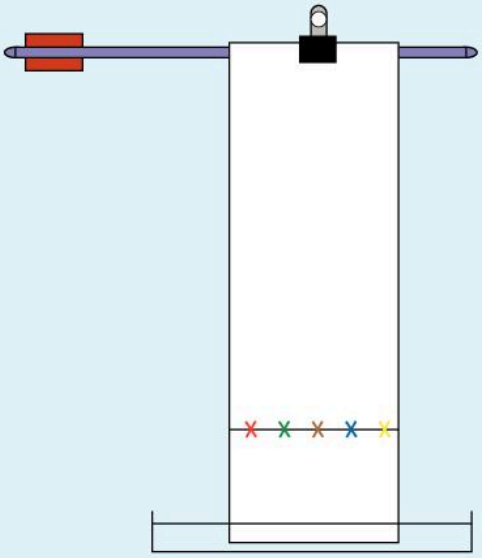
7 Place some water in a shallow tray to a depth of about 1 cm.

8 Support the chromatography paper by clamping the glass rod using a stand and clamp.

9 Stand the bottom of the chromatography paper in the shallow tray. Make sure that the spots of food colouring remain well above the water level.

10 Leave the apparatus until the water has risen to near the top of the chromatography paper.

11 Observe the numbers of different spots formed from each colouring and how far they have risen up the paper.



Questions

1 What separation process is shown in the diagram?

2 Food colourings are used to colour foods, such as icing on cakes. Each colour contains one or more dyes dissolved in water. You have samples of five different food colours.

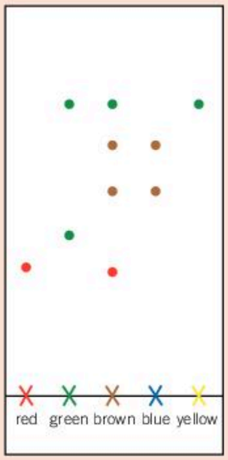
   a Write down the steps needed to separate the dyes in the food colours by chromatography.

   b The diagram below is a chromatogram obtained for five food colourings.

      i) Which food colouring(s) contains only one dye?

      ii) How many dyes are in the green food colouring?

   c Which of the other food colourings could be mixed to make brown food colouring?



14.5 The use of household chemicals

Learning outcomes

By the end of this topic you will be able to:

- describe the action of a range of household chemicals
- explain the need for precautions when using household chemicals.

▲ **Figure 14.5.1** Cleaning a hospital bed. Note the protective clothing and gloves being worn

We use a range of different chemicals in our homes. Some of the substances we use, such as soap and shampoo, we don't even think of as chemicals. In this topic we are going to consider the action of some household chemicals.

Disinfectants

A disinfectant is a chemical substance that destroys or inhibits the growth of a disease-causing micro-organism. Disinfectants are not designed for use on living tissues but can safely be used on objects and surfaces. They are used for sterilising medical equipment, such as surgical instruments, and for keeping household surfaces clean. Bleaches, Lysol and Dettol are examples of disinfectants used in the home. Chlorine-releasing compounds, such as sodium chlorate, can be used to disinfect water supplies.

Disinfectants are used to stop the spread of diseases in our homes, hospitals and on farms.

Disinfectants are useful because they are:

- readily available
- deodorisers (they remove odours)
- anti-microbial.

There are disadvantages to their use because they:

- kill all bacteria, whether useful or harmful
- do not kill the spores of micro-organisms
- are not effective against all micro-organisms
- may cause burns or irritation to the skin
- are toxic.

Care needs to be taken when using these substances in the home. The instructions should be followed and the bottles kept out of the reach of children. Medical assistance should be sought if the substances are swallowed or splashed into the eyes.

Antiseptics

Antiseptics also destroy, or inhibit, the growth of micro-organisms but they can be used on living tissue without causing harm to the tissue. Antiseptics can be applied to wounds and burns to prevent bacterial infection. Antiseptic hand sprays are used by medical staff in hospitals to reduce the transfer of disease-causing organisms from one patient to another. This reduces the risk of patients picking up an infection while they are being treated. Alcohol can be used as an antiseptic: skin is often swabbed with alcohol before an injection.

An iodine-based antiseptic, povidone-iodine, is effective against bacteria, fungi and viruses. It will also kill the spores of micro-organisms. When it is applied to the skin, it releases iodine which destroys any micro-organisms that may be present.

Antiseptics are less harsh than disinfectants, so they can be used on the surface of the body. They are not strong enough to sterilise surgical instruments or surfaces.

Deodorisers

Deodorisers are chemicals that remove unpleasant odours. We use them in lots of different ways.

Some deodorisers are able to absorb the chemicals responsible for the odour, while others contain a pleasant smelling substance that masks unpleasant odours. The substance is atomised, or released as very fine particles, when we spray it.

Bleaching

Bleach is a solution of a chemical called sodium hypochlorite in water. This chemical breaks down to release chlorine gas.

Bleach is a cheap and effective disinfectant but it leaves an unpleasant smell and may irritate the eyes. Bleach should never be used with other disinfectants because some chemicals cause bleach to decompose and give off significant quantities of poisonous chlorine gas.

Bleach can be used to remove stains but there are two problems arising from its use. Bleach is a powerful oxidising agent and, in addition to removing stains, will remove any other colour in a fabric. This means that it is not safe to be used on coloured garments. Bleach will also attack the fibres in a fabric. Holes will arise the next time it is washed.

Bleach is sometimes used in very dilute solution to improve the colour of white garments by removing any yellowing.

▲ **Figure 14.5.2** Bleach is harmful if splashed on the body or on clothing

Hydrogen peroxide

Hydrogen peroxide is an aqueous solution (a colourless liquid that looks exactly like water) with powerful oxidising properties. This allows its use as a bleaching agent, disinfectant, topical anti-infective (medicinal uses) and as a propellant in rockets. Its concentration is given as a percentage or in terms of the volume of oxygen it will release on decomposition.

For example, if the concentration is given as '20 volume' on the bottle label, then 1 cm^3 of hydrogen peroxide would release $20 \times 1 = 20\,cm^3$ of oxygen.

Hydrogen peroxide is a mild antiseptic that can be used to clean wounds and counter infection. It also has a bleaching action and can be used to add highlights to your hair. However, like bleach, it must not come into contact with clothing because it will cause discoloration.

Vinegar

Vinegar is a liquid consisting mainly of acetic acid (also called ethanoic acid) and water (5% solution of ethanoic acid in water). It can be clear (distilled /white from the oxidation fermentation of distilled alcohol) or coloured, dependent upon the source from which it is made (apples, grapes, beer, sugar cane juice, coconut, rice, sherry wine).

Vinegar is widely used in cooking and in preserving food by pickling. It can also be used to remove stains like tomato and coffee from clothing. The area of stain is soaked in vinegar before normal washing. Vinegar can also be used to remove the tarnish from silver.

Questions

1 What is the difference between an antiseptic and a disinfectant?
2 How is water disinfected?
3 Describe the safety precautions you should take when handling disinfectants.
4 What will happen if undiluted bleach is put onto a red cotton garment?

14.6 Scouring powders and detergents

Learning outcomes

By the end of this topic you will be able to:

- describe the constituents of scouring powders
- explain the cleaning action of scouring powders
- describe the structure of detergent molecules
- explain the terms hydrophilic and hydrophobic
- describe how a detergent removes dirt
- describe how to remove rust
- explain how lime scale is removed from kettles and other appliances
- describe how some different metals can be cleaned.

▲ **Figure 14.6.1** Scouring powders are rubbed onto stains

Sometimes our clothes get dirty and stained. We have to use special chemicals to remove the stains. Similarly, the objects we use around the home, such as pans, end up with stains and traces of food on them. We use scouring powders and other special chemicals to get them clean.

Scouring

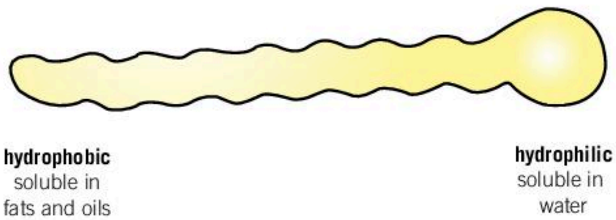
Scouring removes stains by a combination of physical and chemical action. Scouring powders contain a finely ground-up powder of insoluble ash or calcite, mixed with water to make a thick paste. When the powder is rubbed on a surface with a cloth or a brush, it acts as an **abrasive**, removing any solid matter present.

Usually scouring powders also contain detergents to help with removing dirt and grease and a bleaching agent which releases very small amounts of chlorine gas. This gas bleaches any stains and disinfects the surface.

A perfume is sometimes added to the scouring powder so a pleasant odour is left after cleaning.

Detergents

A **detergent** is a chemical we use to remove dirt and stains from clothing, surfaces and floors. Detergents are composed of long molecules with two ends. These two ends have very different structures and properties.



▲ **Figure 14.6.2** The two ends of a detergent molecule have different properties in water

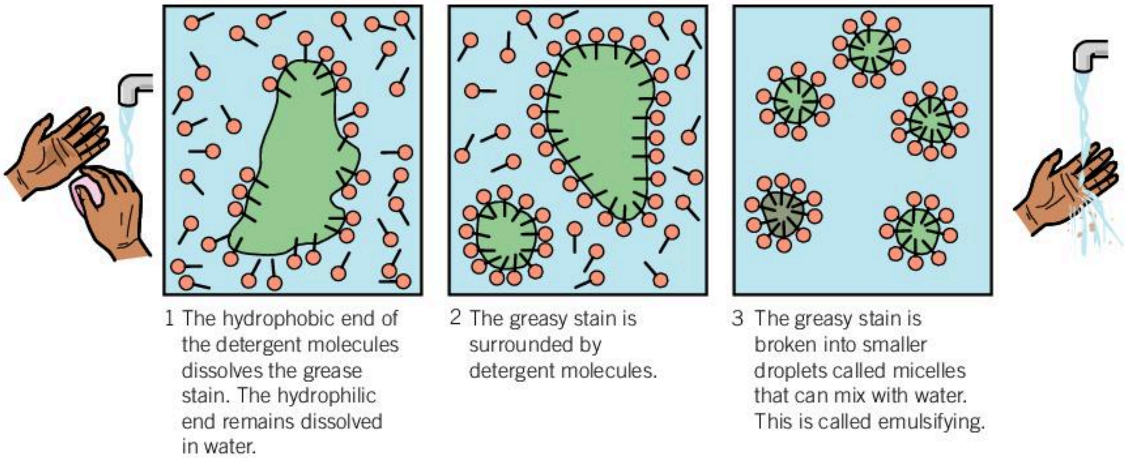
One end of the detergent molecule readily dissolves in water. We say that this end is **hydrophilic** or water-loving (so it is oil-hating).

The opposite end of the detergent molecule dissolves more readily in organic substances, such as oils and fats. We say that this end is **hydrophobic** or water-hating (so it is oil-loving).

Detergent action

Dirt and stains often consist of oily substances that do not dissolve in water. This makes them difficult to remove. Detergents assist in the removal of dirt and stains by making the oily materials mix with the water.

The diagram below shows how a grease stain can be removed by a detergent.



▲ **Figure 14.6.3** How a grease stain can be removed

Lime scale

Lime scale is a build-up of insoluble calcium carbonate in appliances, such as kettles and irons. You will learn more about this in Topic 14.7 Hard and soft water.

Calcium carbonate, like all carbonates, reacts with acids. Lime descaler is a non-toxic, non-hazardous, biodegradable acid solution (such as sulphamic acid), which converts the calcium carbonate to soluble products that can be washed away.

▲ **Figure 14.6.4** Rust remover

Rust remover

Once an iron or steel object has become badly rusted and pitted, it is impossible to reverse the damage. However, the rust can be removed using rust remover.

Rust is a form of iron oxide and is insoluble in water. Rust removers contain acids, such as phosphoric acid, that react with the iron oxide and convert it into soluble compounds that can be washed away. The rust is removed leaving bare metal.

Cleaning metals

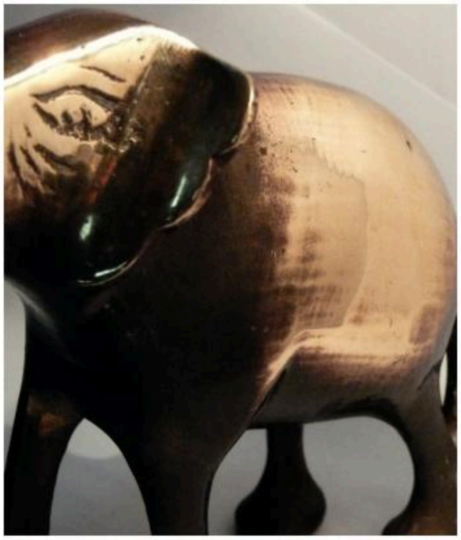
All but the most unreactive metals corrode by reacting with gases from the air. Corrosion slowly produces a layer of compounds, such as oxides and sulphides, on the surface of the metal. This spoils the metal's appearance and forms what is called 'tarnish'. The surface of metals can also become covered in dust.

The chemical reactions which bring about corrosion are difficult to reverse. This means that the metal must be cleaned by rubbing off the compound. This process is called **abrasion**.

We often value metals because they can be polished to a high lustre. Any abrasive that is used must be capable of removing the corrosion without damaging the surface of the metal underneath.

Various cleaning agents are available and they must be selected depending on the object being cleaned. Abrasive cleaners are available in powders or in liquid polishes.

Metals have different properties and therefore need to be cleaned in different ways.



▲ **Figure 14.6.5** Layers of oxide and other compounds form on the surface of metals. You can see where this brass elephant statue has been cleaned of these surface compounds

▲ **Figure 14.6.6** Oven cleaner for baked on grease

▼ **Table 14.6.1** Cleaning metals

Metal	Cleaning agent
Brass	Brasso; iron(III) chloride (jeweller's rouge)
Copper	vinegar, salt and flour mixture made into a paste; reaction with dilute hydrochloric acid
Silver	Brasso; jeweller's rouge
Iron	rubbed with oil; sprayed with lubricating oil (e.g. WD-40)

Metal polish consists of an abrasive powder either in suspension or impregnated onto an absorbent material. When a metal polish is applied to metals and alloys, such as copper, brass and silver, the abrasive removes the tarnish revealing the shiny metal beneath.

These days, the insides of the cooking pans in which we prepare food are often coated with Teflon. Pans, not coated in Teflon, can be washed in soapy water using a pan scrub to remove any food that is stuck to the metal surface.

More powerful cleaners, such as oven cleaner, can be used to remove baked on grease and food from iron, and mild steel, but they should not be used on aluminium. Oven cleaners contain sodium hydroxide that will react with aluminium.

Questions

1 Why is the abrasive in a scouring powder in the form of a very fine powder rather than in large particles?

2 Sand contains quartz which is much harder than calcite. Would a paste of sand make a good scouring powder?

3 Why are detergents added to household scouring powders?

4 In a descaler, what type of substance reacts with lime scale?

5 How does metal polish make tarnished silver shiny again?

6 Why are the insides of pots and pans today coated with Teflon?

14.7 Hard and soft water

The water that flows out of our taps comes from the sky as rain. As it soaks into the ground, and gathers in streams and rivers, it flows over different types of rock. If the rock contains soluble minerals, these will dissolve in the water causing it to become **hard**.

Hard water contains dissolved calcium and magnesium salts. It does not readily lather with soap solution but forms a precipitate called **scum**.

The dissolved salts may come out of solution in pipes and appliances which heat water, such as kettles and irons. The resulting deposits are called **lime scale**.

There are two types of hardness: temporary hardness and permanent hardness.

Temporary hardness

Carbon dioxide gas from the air dissolves in rainwater forming a very weak acid called carbonic acid. This makes rainwater slightly acidic. Typically, unpolluted rainwater has a pH of about 5.5.

carbon dioxide + water ⟶ carbonic acid

If the rainwater passes over rocks containing carbonates the following reaction takes place.

calcium carbonate + carbonic acid ⟶ calcium hydrogencarbonate
in rocks (insoluble) | in water | (soluble)

The soluble calcium hydrogencarbonate dissolves in the rainwater making it hard.

Temporary hardness is easy to remove since the above chemical reaction is reversed by heating.

calcium hydrogencarbonate (soluble) $\xrightarrow{\text{heat}}$ calcium carbonate (insoluble) + carbon dioxide + water

Unfortunately, this leaves a deposit of insoluble calcium carbonate.

Permanent hardness

Permanent hardness results when calcium sulphate (or calcium chloride) dissolves in rainwater.

Calcium sulphate is sparingly soluble in water. It is not decomposed by heating but it can be removed by adding sodium carbonate in the form of washing soda. Calcium chloride can be removed in the same way.

calcium sulphate (soluble) + sodium carbonate (soluble) ⟶ calcium carbonate (insoluble) + sodium sulphate (soluble)

Although the water now contains sodium sulphate, this does not interfere with the action of soaps and detergents because it does not form a scum.

Learning outcomes

By the end of this topic you will be able to:

- explain what hard water is
- distinguish between temporary and permanent hard water
- explain how lime scale forms
- explain how temporary hardness is removed by boiling
- explain how permanent hardness is removed using washing soda.

Key fact

Lime scale can be removed from heating elements by adding a chemical descaler. Chemical descalers contain acids that react with the lime scale converting it to a soluble compound.

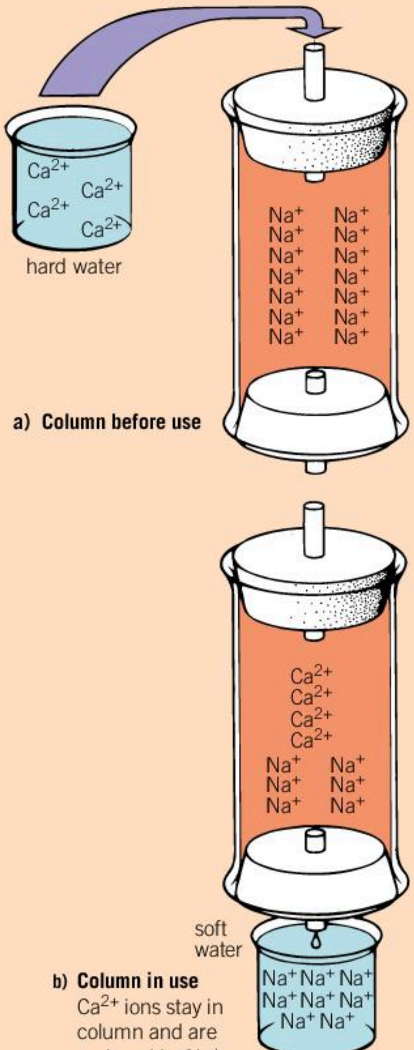
Exam tip

Notice that 'hydrogencarbonate' should be written as one word and not two.

▲ **Figure 14.7.1** Lime scale is deposited on heating elements

Key fact

Water can be softened by passing it through an ion exchange column.



a) Column before use

b) Column in use Ca^{2+} ions stay in column and are replaced by Na^+ ions

The calcium ions in the hard water are replaced by sodium ions which do not form a scum. Another method of softening water is by distillation.

Questions

1. Which gas dissolves in water to form carbonic acid?
2. How can temporary hard water be softened?
3. What type of hardness is caused by calcium sulphate?
4. Explain how scum forms.

Formation of scum

Hard water contains compounds of calcium, such as calcium hydrogencarbonate and calcium sulphate. Soap is a solution of sodium stearate. When soap is added to hard water, insoluble calcium stearate (scum) is formed.

$$\text{soap} + \text{hard water} \longrightarrow \text{scum}$$

Scum removes the soap from the solution and prevents it from doing the job of removing dirt. It is only when all of the calcium salts have been removed from the water that soap will remain to form a lather.

In hard water areas, more soap has to be added to water or the hardness has to be removed in order to make a solution that removes dirt effectively.

Practical activity 14.7.1

The hardness of water

The hardness of different samples of water can be assessed by measuring how much soap is needed to form a permanent lather.

Your teacher will supply you with a sample of distilled water, a sample of hard water, some soap solution and some crystals of washing soda.

1. Half fill a test tube with distilled water.
2. Add one drop of soap solution using a dropping pipette, cover the end of the tube with your thumb and shake the contents for a few seconds.
3. Allow the test tube to stand for a couple of minutes. If there is no permanent lather repeat step 2.
4. How many drops of soap solution were needed to form a permanent lather?
5. Is distilled water hard or soft? Explain your answer.
6. Half fill a test tube with hard water.
7. Repeat steps 2 and 3 until a permanent lather is obtained.
8. How many drops of soap solution were needed to form a permanent lather?
9. Half fill a test tube with hard water, bring it to the boil and allow it to cool.
10. Repeat steps 2 and 3 until a permanent lather is obtained.
11. How many drops of soap solution were needed to form a permanent lather?
12. Did boiling reduce the hardness of the water?
13. Half fill a test tube with hard water and add a small crystal of washing soda.
14. Repeat steps 2 and 3 until a permanent lather is obtained.
15. How many drops of soap solution were needed to form a permanent lather?
16. Did adding washing soda reduce the hardness of the water?
17. Did the hard water you were given have temporary hardness, permanent hardness or a mixture of the two? Explain your answer.

14.8 Soapy and soapless detergents

Detergents molecules may be classified as **soapy** or **soapless** depending on their structure. The two types of detergents react differently with hard water.

Soapy detergents

Soapy detergents are often just described as soaps. They are made by heating animal fats, or vegetable oils, with a strong alkali, such as sodium hydroxide or potassium hydroxide. The fats and oils are mixtures of fatty acids, such as stearic acid, which are converted into the sodium or potassium salts of the acids. For example:

sodium hydroxide + stearic acid ⟶ sodium stearate + water
(soap)

In soaps the hydrophilic end of the detergent molecule is derived from a carboxylic acid.

All soaps form a scum in hard water because the calcium salts of these acids are insoluble.

Practical activity 14.8.1

Making soap

Skills assessed: Observation/Recording/Reporting.

1. Carefully pour about 50 cm^3 of sodium hydroxide solution into a beaker and gently heat it until it nearly boils. Be very careful as this is a strong alkali.
2. Slowly add castor oil and stir continuously.
3. When the oil has disappeared, add one teaspoon of sodium chloride (salt). The soap should precipitate out. If it does not, add more salt.
4. Allow the mixture to cool down and stir it to break up the soap.
5. Filter the mixture through filter paper. Rinse the solid with cold water. This is soap.
6. Add some soap to water in a test tube and shake it.
7. What do you observe?
8. Write a word equation for the reaction.

Soapless detergents

Soapless detergents are often just called detergents or synthetic detergents. They are made from petroleum products. Some washing powders and dishwashing liquids are soapless detergents. Sulphonic acids are reacted with sodium hydroxide, or potassium hydroxide, to form sodium or potassium sulphonates.

In soapless detergents, the hydrophilic end of the detergent molecule is derived from a sulphonic acid.

Soapless detergents do not form a scum in hard water because the calcium salts of these acids are soluble.

Learning outcomes

By the end of this topic you will be able to:

- appreciate that detergents may be soapy or soapless
- describe the formation of scum using soapy detergents in hard water
- understand why soapless detergents do not form a scum in hard water
- name some of the additives in detergents and explain their function.

▲ **Figure 14.8.1** Soapy detergents are made from animal fats and vegetable oils

Table 14.8.1 Comparison between soapy and soapless detergents functions

Soapy detergents	Soapless detergents
• made by heating animal fats or vegetable oils with a strong alkali • form scum in hard water	• made from petroleum products • do not form scum in hard water
Advantages: • made from natural oils so less chance of skin irritations and allergies • environmentally friendly as they are broken down into harmless substances; they are biodegradable	**Advantages:** • more effective cleaning agents • less wastage • cheaper to make
Disadvantages: • not as efficient as soapless detergents • more wastage • more expensive to make	**Disadvantages:** • can cause allergies • non-biodegradable; form foam in water sources; can cause chemical pollution

Other additives in detergents

Oxidising agents are widely employed in laundering because of the effectiveness with which they can kill fungi and bacteria, as well as inactivate viruses. Sodium hypochlorite (NaOCl) is the main ingredient in laundry bleach. It attacks the links in the stain molecule, breaking them apart into smaller water-soluble fragments that are easily washed away.

Modern detergents often contain other chemical additives both to assist in cleaning and to make clothes nicer to wear after washing. These include:

- bleaching agents to make white clothes look white
- optical brighteners to make clothes, especially coloured fabrics, look brighter
- enzymes to remove stains, such as food, which have a protein structure
- perfumes to make clothes smell more pleasant
- fabric softeners to make washed fabrics feel soft to the touch when dry.

Questions

1. Why do soaps form a scum in hard water?
2. Give three advantages of soapless detergents.
3. Why is there less chance of skin irritations with soapy detergents?
4. Why do some detergents contain enzymes?

Exam-style questions

Multiple choice

1 Which of the following is a colloid?
  A butter
  B Epsom salts
  C milk of magnesia
  D cooking oil

2 Which of the following properties are those of an acid?
  I turns red litmus blue
  II releases hydrogen ions in solution
  III is slippery to touch
  IV is corrosive
  A I, II and III
  B II, III and IV
  C II and IV
  D I, III and IV

3 What colour would you observe if phenolphthalein is added to an alkali solution?
  A pink
  B blue
  C green
  D yellow

4 Which of the following is the pH of a weak acid?
  A pH 1
  B pH 5
  C pH 8
  D pH 11

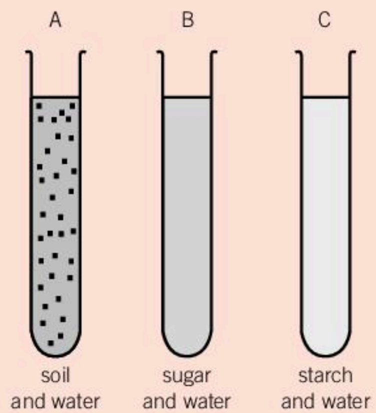
Structured questions

5 **a** List the properties of acids.
  b List the properties of bases.
  c Write a word equation to show a neutralisation reaction.

6 Different chemicals were used to remove stains from fabric. The table (top right) shows the results.
  a Which method of stain removal is best for:
    i) wine
    ii) grass?
  b What method could you use to remove fruit stains?

	Effect on stain			
	wine	**grass**	**nail polish**	**paint**
water	not removed	–	not removed	–
turpentine	–	–	–	removed
bicarbonate of soda	removed			
propanone	not removed	–	removed	–
dilute hydrogen peroxide	–	–	–	
ethanol		removed		

7 **a** **i)** Distinguish between aqueous and non-aqueous solutions.
    ii) Give one example of each.
  b Explain the difference between a colloid and a suspension.
  c The diagrams A to C show three types of mixtures.
    i) Which mixture is a suspension?
    ii) Which mixture is a solution?
    iii) Which mixture is a colloid?



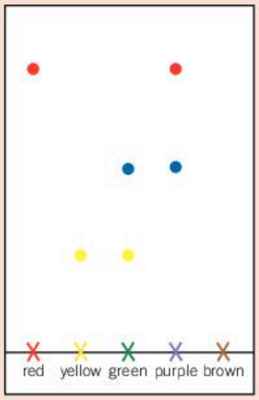
8 **a** Give one advantage of a soapy detergent and one disadvantage of a soapless detergent.
  b Explain how soap is able to remove a greasy stain. Use the terms hydrophilic, hydrophobic and micelles in your answer.
  c List three uses of household chemicals.
  d Write a word equation to show the formation of scum.

9 Maria carried out an experiment on the food colourings used to coat sweets in different colours. Here is part of the account she wrote in her laboratory book.

Using a pencil, and not a pen, I took the chromatography paper and ruled a straight line 2 cm from one edge. I marked five places on the line and under each place I wrote the name of a colour. I used a small paint brush to put a drop of water on a red sweet and removed some of the colour from it. I then put the coloured drop from the paintbrush onto one of the places I had marked on the chromatography paper to make a small spot. I repeated this twice more for the red sweet, placing the coloured drop on the same place each time. I repeated this for the other four coloured sweets.

I hung the chromatography paper from a glass rod, so that the edge was in the solvent, but the solvent level was below the coloured spots.'

Here is the chromatogram that Maria obtained.



a Explain why Maria:

i) used a pencil to mark the base line and not a pen

ii) only put a small spot on the chromatography paper

iii) spotted each food colouring three times

iv) made sure the spots of colour were above the level of the solvent.

b In terms of solubility, explain why the red spot and the yellow spot moved different heights.

c **i)** What colour dyes are in the two food colourings shown on the chromatogram?

ii) Brown food colouring is a mixture of purple and yellow. Draw a diagram to show the pattern of spots that was obtained for brown.

Section C

15 The Universe and our Solar System

All of the things that we can see in the night sky, and many that we cannot, are contained within the Universe. Galaxies are collections of stars. Many stars have planets in orbit around them. Many planets have artificial satellites, or moons, in orbit around them.

Our own Solar System consists of eight planets in orbit around the Sun. The movement of the Earth and the Moon relative to the position of the Sun is responsible for day and night, and occasionally, eclipses.

The exploration of the Universe is carried out from the Earth using powerful telescopes and also from space stations in orbit around the Earth. Exploratory devices, such as the *Mars Rover*, have landed on other planets and are able to send back detailed information about the conditions there.

Learning outcomes

By the end of this topic you will be able to:

- describe the Universe as consisting of many galaxies
- explain that galaxies have different shapes and may contain millions of stars
- describe the position of the Sun in the arm of our spiral galaxy
- state that the Solar System consists of the Sun and the bodies in orbit around it.

15.1 The Earth in the Universe

It is likely that the night sky has been a source of great interest to people since humans first populated the Earth.

You live in a Universe full of many millions of stars. The more powerful telescopes become, the more stars there appear to be.

The Ancient Greeks saw the stars as being arranged in groups which they called constellations. Each constellation seemed to them to resemble an everyday object or a character from Greek mythology. The constellations were given names like the Plough or Orion the hunter.

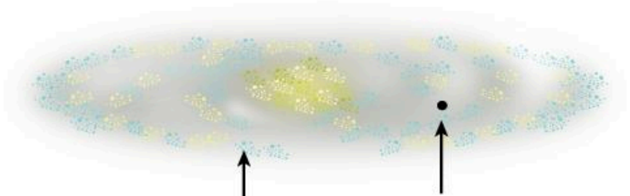
We now know that the stars in a constellation are often huge distances from each other. They only seem to make a picture because of the angle from which we view them from the Earth.

Stars exist in huge clusters called galaxies. Galaxies vary in shape and may contain millions of stars. Scientists estimate that there are between 100 to 200 billion galaxies in the Universe.

▲ **Figure 15.1.1** Orion the hunter

▲ **Figure 15.1.2** A galaxy

▲ **Figure 15.1.4** The Milky Way in the night sky



▲ **Figure 15.1.3** Milky Way galaxy

Our Sun is one star in the arm of a spiral galaxy we call the Milky Way.

When we see the band of stars that makes up the Milky Way in the night sky, we are actually looking across our galaxy.

The Ancient Greeks noticed that some of the 'stars' appeared to change position from night to night. They named these 'wandering stars' or planets. By observing the night sky, astronomers over the years were able to build up a picture of a group of planets in orbit around the Sun.

The Solar System consists of the Sun and the bodies in orbit around it. You will learn more about the Solar System in Topic 15.3.

Questions

1 Define a galaxy.

2 State the name of the galaxy containing the Sun.

3 Explain what was different about the planets compared to the stars when the Ancient Greek astronomers observed the night skies.

15.2 Satellites

Learning outcomes

By the end of this topic you will be able to:

- describe the conditions in space
- explain what is meant by a satellite
- tell the difference between a natural satellite and an artificial satellite
- explain the role of gravity in keeping satellites in orbit
- describe some uses of artificial satellites.

Space

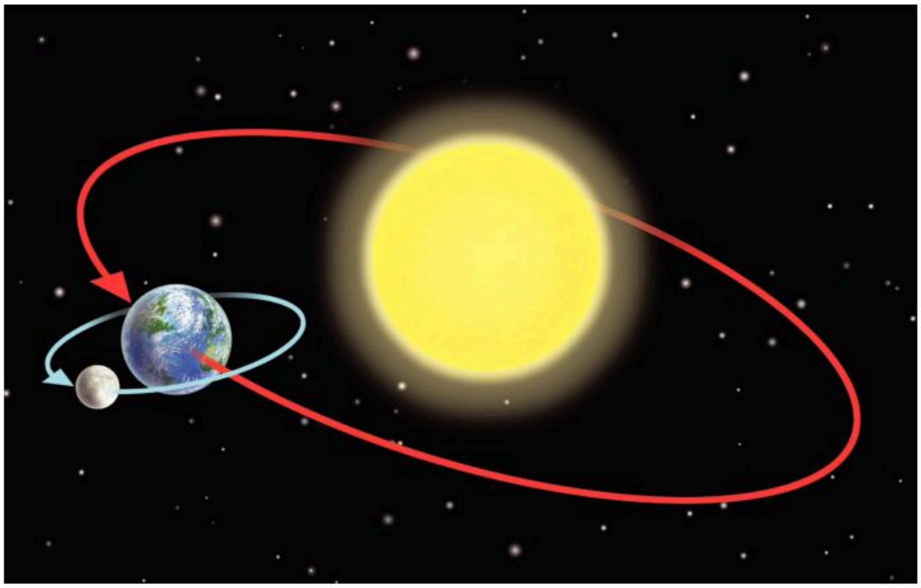
Space is defined as the regions that are beyond the gravitational pull of the Earth. In the environment of space there is:

- no atmosphere and therefore no oxygen
- extreme heat
- radiation
- meteoroids
- weightlessness.

All these features of the space environment can pose problems for humans wishing to travel in space. We cannot survive in space without taking oxygen and food. Weightlessness can cause bones to lose calcium and muscles to become weak. Simple tasks, such as eating, moving around and passing urine, can become difficult. Any person leaving a spacecraft to walk in space must be anchored in order not to drift off into space forever.

Natural satellites

In space the Moon moves in a near circular path around the Earth. We say that it is in orbit around the Earth. The planets of our Solar System are in orbit around the Sun. Any object in orbit around another object is called a **satellite**.



▲ **Figure 15.2.1** The Moon is a satellite of the Earth and the Earth is a satellite of the Sun

The Moon is described as a natural satellite of the Earth. The Earth is not the only planet that has a moon in orbit around it, as you will find out in Topic 15.3.

Satellites are held in their orbits by the force of gravity. For example, the gravitational attraction between the Moon and the Earth prevents the Moon from flying off into space.

Artificial satellites

In addition to the Moon, there are many artificial satellites in orbit around the Earth.

These are used for monitoring the weather and climate change, spying, carrying out space research, navigation and communication.

Some satellites have an orbit over the equator that takes 24 hours to complete. The Earth rotates beneath them and also takes 24 hours to complete one orbit, so the satellite stays in the same position over the surface of the Earth. We say that these satellites are in a **geostationary orbit**. They are normally used for communications.

To stay in orbit at a particular distance, a satellite must travel at a particular speed to overcome gravitational forces. The further away from the Earth the slower the satellite and the longer it takes to complete one orbit.

▲ **Figure 15.2.2** Solar panels on a telecommunications satellite

Providing energy for artificial satellites

The first artificial satellite, *Sputnik 1*, was powered by batteries. As soon as the batteries were used up, the satellite stopped working.

For a satellite to function for a long time, it must either take up a supply of fuel to provide it with energy or it must use the energy from sunlight.

Artificial satellites are powered by solar panels. Each solar panel is composed of many solar cells. These cells convert energy in sunlight into electricity. The satellites also have rechargeable batteries. Electrical energy is stored in the batteries so that when the satellite orbits in the dark on the opposite side of the Earth from the Sun, it can continue to function.

Solar panels provide an artificial satellite with all of the energy it needs to function. The Sun is a non-renewable source of energy. Provided the components in the circuits of an artificial satellite do not develop faults, it will continue to function. However, the satellite will not remain in place forever. Over time, the height of its orbit will decrease until eventually the satellite is pulled into the atmosphere by the Earth's gravitational pull.

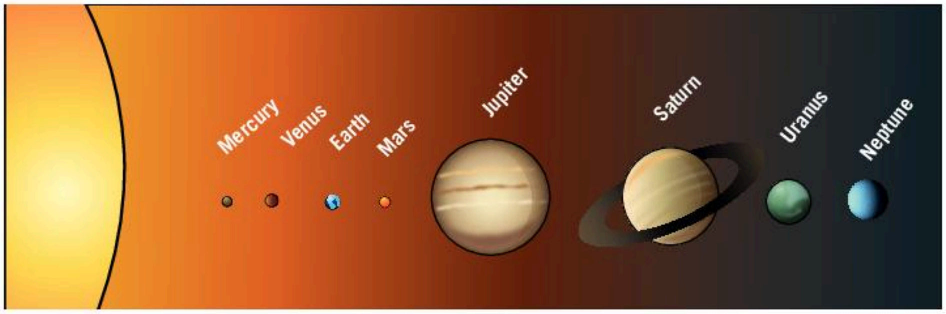
Questions

1. Define a satellite.
2. Describe the difference between a natural satellite and an artificial satellite.
3. How long does a geostationary satellite take to make one orbit around the Earth?
4. Describe one use of a geostationary satellite.

15.3 The Solar System

The Solar System consists of the Sun and all of the objects in orbit around it. These include eight planets, some minor planets and many asteroids. Some planets have natural satellites or moons in orbit around them.

There are eight planets in the Solar System.



▲ **Figure 15.3.1** The Solar System

Learning outcomes

By the end of this topic you will be able to:

- describe the structure of the Solar System
- name the eight planets in the Solar System
- describe each planet briefly
- state the number of moons in orbit around each planet.

The planets

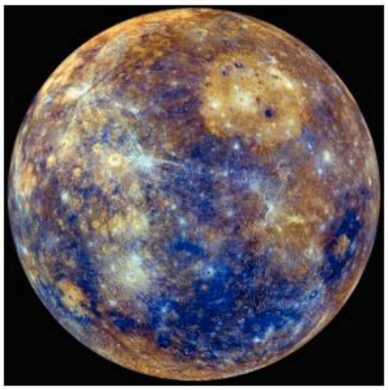
Mercury is the smallest of the planets. It is also the planet nearest the Sun.

Venus is the planet that is closest to Earth in size. It is also one of the planets closest to the Earth.

Earth is sometimes called the blue planet because so much of it is covered in water. It is the only planet where there is known life.

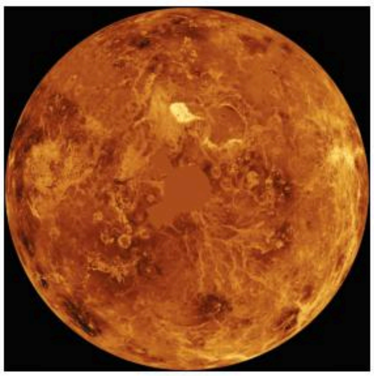
Mars is smaller than the Earth. Scientists believe that there was once water on its surface. Mars changes colour at different times of the year due to dust storms. Early astronomers thought the colour change was because there was vegetation. They compared it to the leaves on trees on Earth changing colour between summer and winter.

Jupiter is the largest of the planets. It has a large red spot that varies in size. This is thought to be the result of massive storms taking place in the planet's atmosphere.



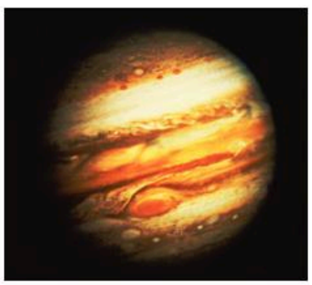
▲ **Figure 15.3.2** Mercury

▲ **Figure 15.3.4** Earth

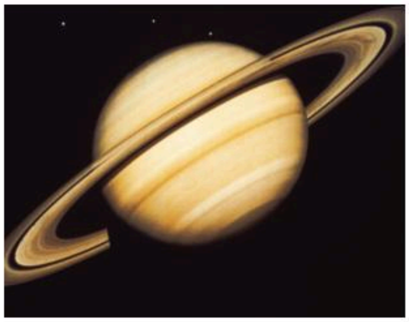


▲ **Figure 15.3.3** Venus

▲ **Figure 15.3.5** Mars



◀ **Figure 15.3.6** Jupiter



▲ **Figure 15.3.7** Saturn

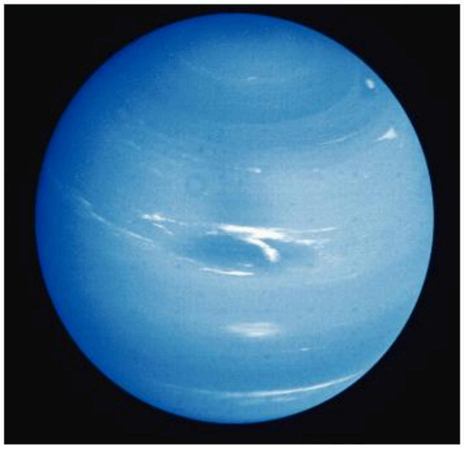
▲ **Figure 15.3.8** Uranus

Saturn is the second largest planet. It is surrounded by rings composed of countless numbers of tiny ice and rock particles.

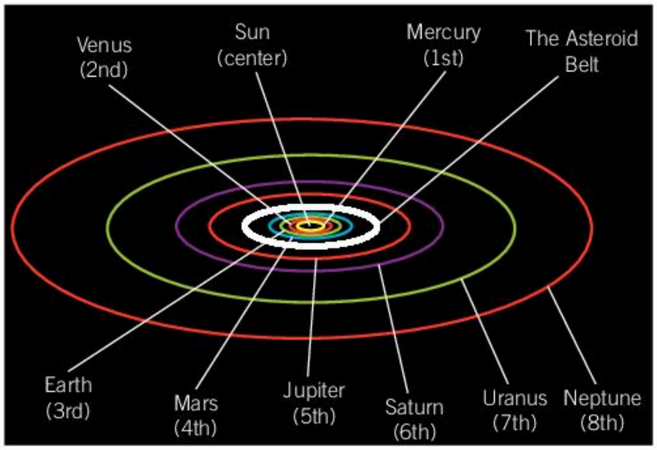
Uranus is a large planet near the far reaches of the Solar System.

Neptune is the outermost planet of the Solar System. It is very similar in size to Uranus.

The planets orbit the Sun moving in the same direction and in a similar plane.



▲ **Figure 15.3.9** Neptune



▲ **Figure 15.3.10** Planets have elliptical orbits

Although we often draw the planet orbits as circles, they are in fact slightly oval-shaped or ellipses.

Practical Activity 15.3.1

Making a scale model of the Solar System

This is a whole class activity. Your teacher will place you in groups. Each group will be responsible for making and locating one planet.

The table below compares the size of the planets and their distances from the Sun to the Earth.

For the purposes of this activity the diameter of the Earth is 10 cm and the distance from the Sun to the Earth is 10 steps.

Planet	Approximate diameter compared to the Earth	Approximate distance from the Sun compared to the Earth
Mercury	$\frac{1}{3}$	$\frac{1}{3}$
Venus	1	$\frac{2}{3}$
Earth	1	1
Mars	$\frac{1}{2}$	$1\frac{1}{2}$
Jupiter	11	5
Saturn	9	10
Uranus	4	20
Neptune	4	30

Materials:

- Materials for making a ball: paper, cardboard, polythene bags, glue, tape, ruler, paints.

Method:

1 Make your planet to scale using whatever materials are available and the information given in the table. For example, if you are making Uranus, the planet will be 4 × 10 cm = 40 cm in diameter.

2 Paint your planet the colour you think it should be.

3 When all of the groups have finished their planets, your teacher will take you outside onto the school field.

4 Place a stick in the ground to represent the Sun.

5 Pace out the distance that your planet is from the Sun using the information given in the table. For example, if your planet is Saturn you will take 10 × 10 steps = 100 steps.

6 If a digital camera is available, take a photograph of your class model of the Solar System. The best view will be from an upstairs window.

Moons

The moons which orbit some of the planets are described as natural satellites. Some planets have no moons, while others have many.

The smaller moons around the planets farthest from the Sun are impossible to see using a telescope on Earth. They have only been discovered as a result of information from space probes sent to investigate the Solar System.

▼ **Table 15.3.1**

Planet	Moons
Mercury	0
Venus	0
Earth	1
Mars	2
Jupiter	67
Saturn	62
Uranus	27
Neptune	14

Questions

1 Which planet is being described?

a It is the only planet known to have life.

b It is the largest planet in the Solar System.

c It is the farthest planet from the Sun.

d It has a large red spot.

2 The table below contains data about the planets in the Solar System.

Planet	Diameter (km)	Average surface temperature (°C)	Density (g/cm³)	Composition	Number of moons
Inner four planets					
Mercury	4900	167	5.43	rock	0
Venus	12100	457	5.24	rock	0
Earth	12800	7.2	5.52	rock	1
Mars	6800	–45	3.98	rock	2
Outer four planets					
Jupiter	143000	–153	1.33	liquid/gas	67
Saturn	120500	–139	0.70	gas	62
Uranus	51100	–197	1.30	gas	27
Neptune	49500	–200	1.76	gas	14

Using the data, describe how the following are different for the inner four planets compared to the outer four planets:

a the diameters

b the average surface temperatures

c the densities

d the number of moons.

15.4 Effect of other bodies on the Earth

Learning outcomes

By the end of this topic you will be able to:

- describe how the rotation of the Earth on its axis is responsible for day and night
- describe how the movements of the Earth and the Moon are responsible for eclipses
- draw the position of the Sun, Earth and Moon during a solar eclipse
- draw the position of the Sun, Earth and Moon during a lunar eclipse.

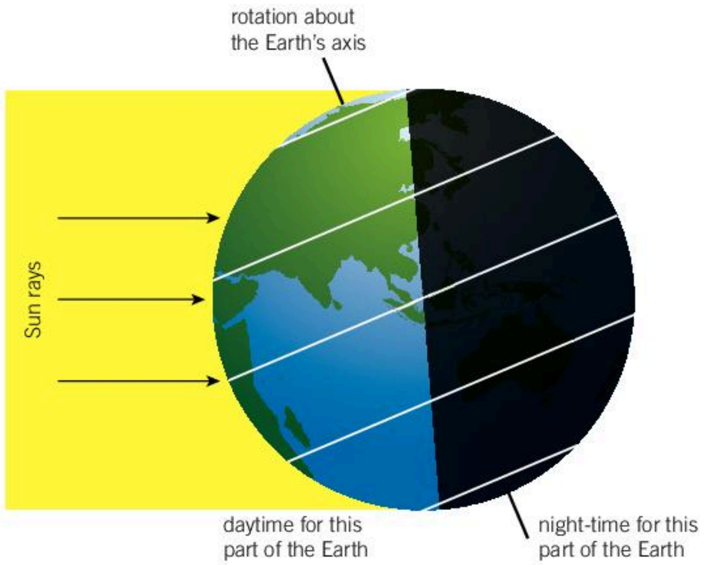
Synoptic link

See Topic 16.13 Tides.

▲ **Figure 15.4.2** Sun and Moon

Day and night

As the Earth orbits around the Sun, it also rotates or spins around an axis between the North and South Poles.



▲ **Figure 15.4.1** Daytime and night-time

The Sun seems to move position as it passes across the sky but, in reality, the Sun's position is fixed and it is the Earth that is moving. The Earth completes one full rotation about its axis every 24 hours. For any particular place on the Earth, part of the 24 hours is daytime and part is night-time.

Sizes of the Sun and Moon

When we see the Sun and the Moon in the sky, they appear to be very similar in size.

In reality the Sun is very much bigger than the Moon. So why doesn't it look much bigger?

▼ **Table 15.4.1**

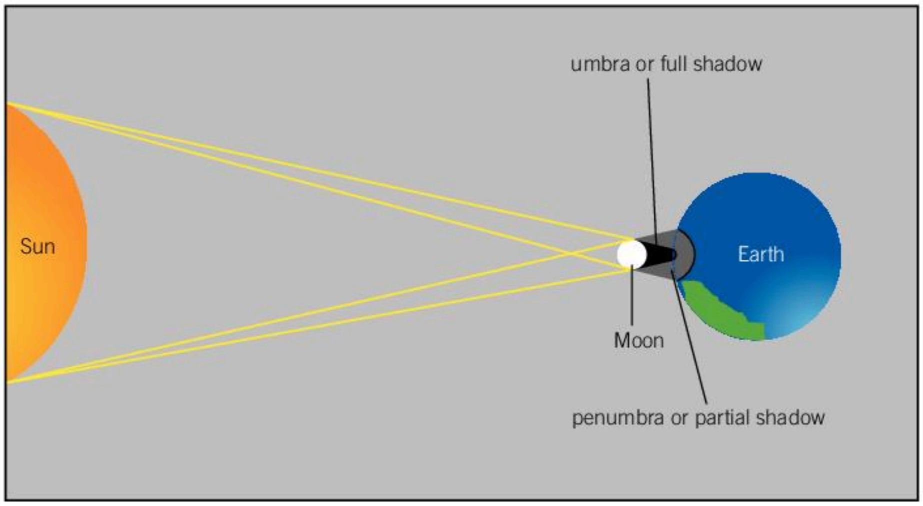
	Diameter (km)	Distance from the Earth (km)
Moon	3475	384 400
Sun	1 392 000	149 600 000

The diameter of the Sun is about 400 times that of the Moon. However, the Sun is about 400 times further away from the Earth than the Moon. This is why the two bodies appear to be a similar size.

Solar eclipse

The Earth is in orbit around the Sun and, at the same time, the Moon is in orbit around the Earth. Every now and again the three bodies lie on a straight line. This gives rise to either a solar eclipse or a lunar eclipse.

During a solar eclipse the Moon passes in front of the Sun.

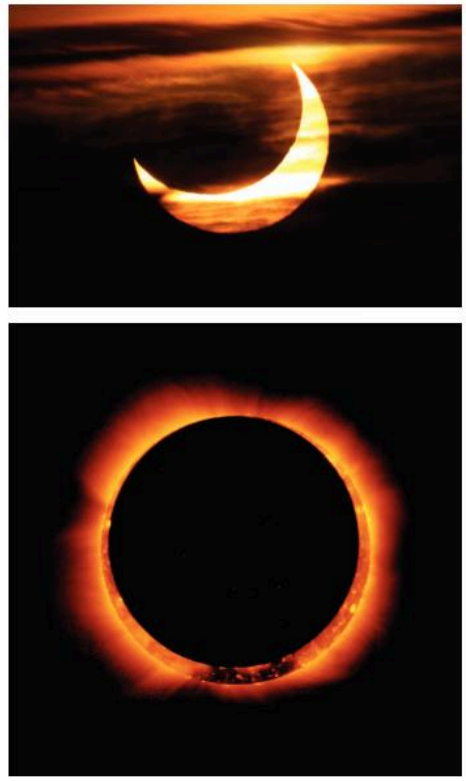


▲ **Figure 15.4.3** Solar eclipse

The Sun is so large compared to the Moon that the Moon casts a region of full shadow, called the umbra, and a region of partial shadow called the penumbra.

What observers see on Earth during a solar eclipse depends on where they are.

- People in the area covered by the umbra will see a total solar eclipse.
- People in the area covered by the penumbra will see a partial solar eclipse.
- People outside the area of the penumbra will not see any solar eclipse.



▲ **Figure 15.4.4** a) Partial and b) total eclipse of the Sun

Practical Activity 15.4.1

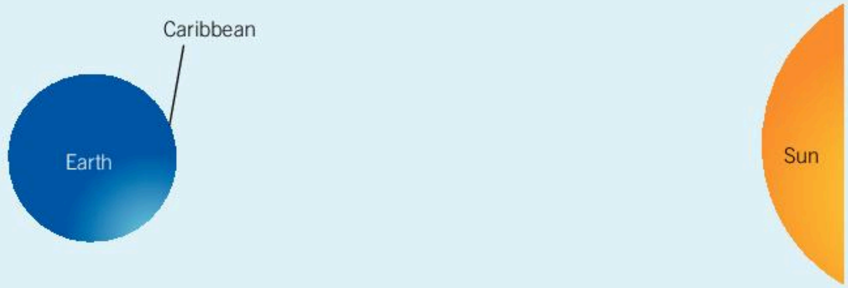
Solar eclipse

Materials:

- Torch
- Large ball
- Small ball
- Marker

Method:

1. Work in a group of three for this activity.
2. The torch represents the Sun, the large ball the Earth and the small ball the Moon. Each member of the group will be one of the heavenly bodies.
3. Draw an 'X' on the large ball to represent the position of the Caribbean.

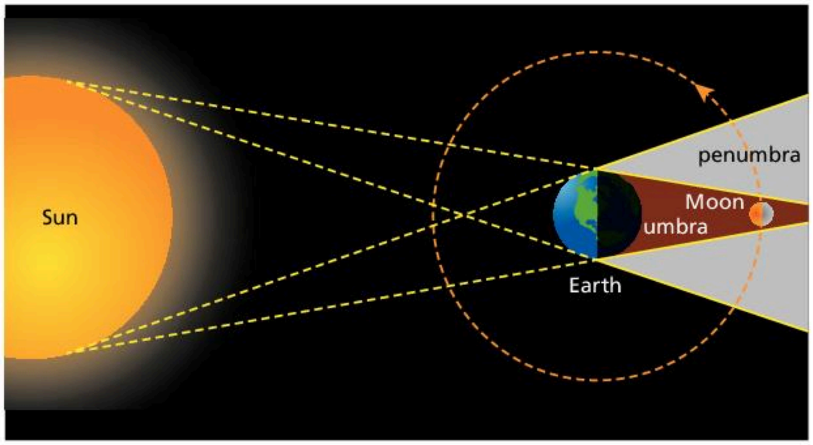


4 Place the Moon in different positions between the Earth and the Sun until you find a place where the Moon casts a shadow on the Caribbean.

5 Copy the diagram and complete it to show the position of the Moon during a solar eclipse. Remember the Moon is much nearer to the Earth than it is to the Sun.

Lunar eclipse

During a lunar eclipse the Moon passes into the Earth's shadow.



▲ **Figure 15.4.5** Lunar eclipse

The Moon may pass through a region of partial or full shadow.

▲ **Figure 15.4.6** a) Partial and b) total eclipse of the Moon

- When the Moon passes through the penumbra we see a partial lunar eclipse from the Earth.
- When the Moon passes through the umbra we see a total lunar eclipse from the Earth.

Notice that the Moon never becomes totally invisible. This is because some light is bent towards it by the Earth's atmosphere. During a total eclipse it often looks red.

Practical Activity 15.4.2

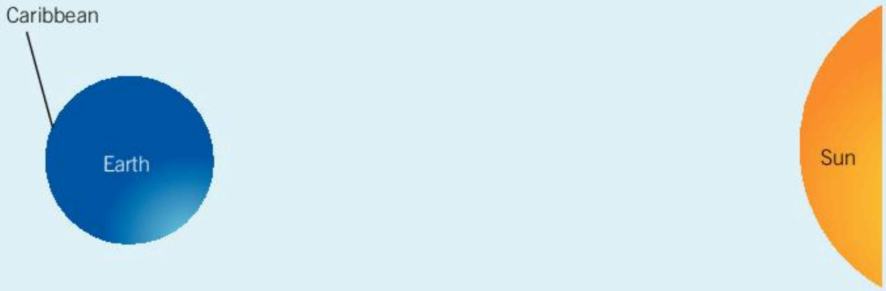
Lunar eclipse

Materials:

- Torch
- Large ball
- Small ball
- Marker

Method

1. Work in a group of three for this activity.
2. The torch represents the Sun, the large ball the Earth and the small ball the Moon. Each member of the group will be one of the heavenly bodies.
3. Draw an 'X' on the large ball to represent the position of the Caribbean.



4. Place the Moon in different positions relative to the Earth, and the Sun, until you find a place where the Moon is in the shadow of the Earth and cannot be seen from the Caribbean.
5. Copy and complete the diagram to show the position of the Moon during a lunar eclipse. Remember the Moon is smaller than the Earth.

Questions

1. Explain why the Caribbean experiences a regular cycle of day and night.
2. a Explain the difference between the terms umbra and penumbra.
   b During a solar eclipse, would everyone on that part of the Earth facing the Sun experience either a full or partial eclipse? Explain your answer.
3. Explain why the Moon does not become invisible from the Earth even when it passes into the umbra during a lunar eclipse.

15.5 Exploring the Universe

Learning outcomes

By the end of this topic you will be able to:

- explain the advantages of having telescopes in orbit above the atmosphere
- describe what a space station is
- discuss the work that goes on in a space station
- describe the exploration of Mars and how the information gained will be used to plan a manned flight to the planet in the future.

▲ **Figure 15.5.2** Hubble telescope in orbit around the Earth

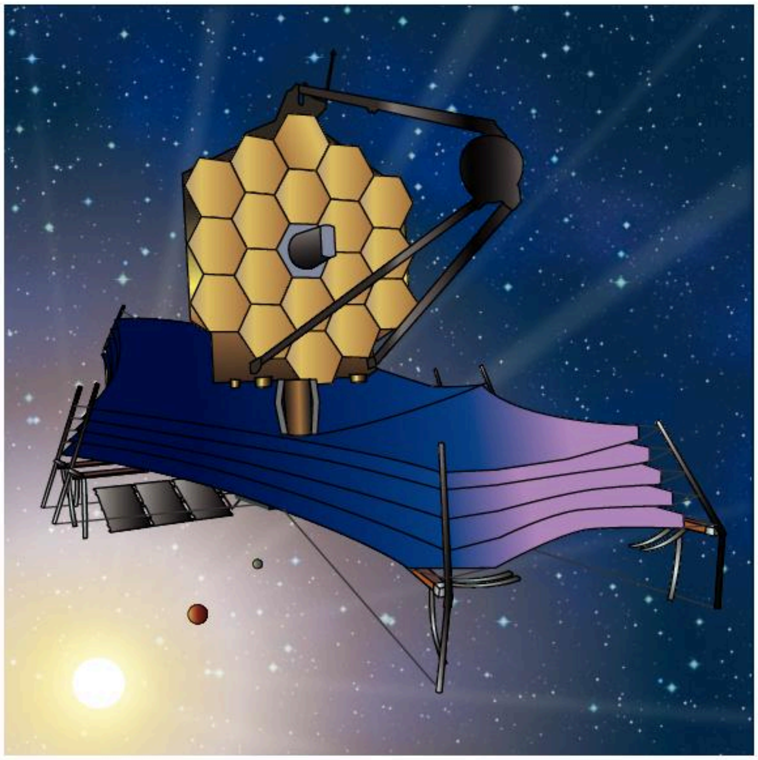
It is only within the past 50 years or so that scientists have been able to launch rockets into space. Nowadays, rockets containing sophisticated equipment are regularly launched to explore the other planets of the Solar System and beyond.

▲ **Figure 15.5.1** The Sea, Earth and Sky observatory (SEAS) at Arnos Vale, Tobago

Before the age of rockets, astronomers were limited to observing space from the Earth. Although the air looks transparent to us, the atmosphere distorts the light passing through it, so astronomers were never able to see completely clear images of bodies.

Orbiting telescopes

The Hubble telescope was launched in 1990 and is operated remotely from the Earth. It orbits the Earth above the atmosphere so it can take clear pictures of bodies and send them electronically to observatories.



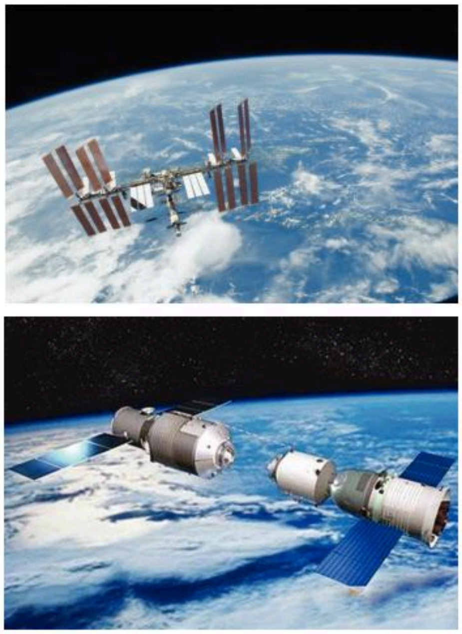
▲ **Figure 15.5.3** Artist's impression of the James Webb space telescope

The Hubble telescope is due to be replaced by the James Webb space telescope. This is under construction now and is due to be launched sometime in 2018.

Space stations

A space station is a spacecraft that is designed to remain in space and is capable of supporting a crew for a long period of time. Space stations are different to rockets, which are meant for space flights. Unlike rockets, they have no major propulsion system or landing system. There are currently two space stations in orbit that are used to carry out scientific work: the International Space Station and *Tiangong 1*.

The space stations are research platforms that are used to study the effects of spending long periods in space. The crews on the space stations also carry out many different experiments that would not be possible on Earth. For example, they have germinated seeds in the absence of gravity. In which direction do you think the roots grew? The knowledge obtained from space stations will help scientists to design space missions in the future.



▲ **Figure 15.5.4** a) International Space Station b) *Tiangong 1*

Interplanetary exploration

The first interplanetary mission took place in 1965 when the spacecraft *Venera 3* was launched towards its destination, Venus. Since then there have been many unmanned spacecraft sent to investigate different aspects of the other planets in the Solar System.

Many of these have been directed towards Venus and Mars, the two planets nearest to the Earth but there have also been missions to other planets including Mercury, Saturn and Jupiter.

One of the longest-running interplanetary projects is NASA's Mars Exploration Rover Mission (MER). This began in 2003 and has involved sending a series of rovers to explore the surface of Mars, and analysing its rocks and soils.

▲ **Figure 15.5.5** The *Curiosity* rover

The latest rover, *Curiosity*, landed on Mars in 2012. Since then it has sent back many pictures of the Martian landscape together with a wealth of information about the composition of the planet's surface and its atmosphere. Scientists are curious to find out if there is or ever was water on the planet because this may indicate whether life existed on Mars in the past.

In addition to the rovers on the surface of Mars, pictures and various measurements are currently being taken using five surveyor craft in orbit around the planet. All this information will be essential in planning a future manned flight to Mars.

Questions

1. Explain why astronomers get clearer images of the Universe from telescopes in orbit around the Earth than from those actually on the Earth.
2. State the name of the telescope that will replace the Hubble telescope and when is it due to be launched.
3. Name the two space stations currently active in orbit around the Earth.
4. State which planet is being explored by the rover *Curiosity*.

Exam-style questions

Multiple choice

1 A collection of many stars is called a:
A galaxy **B** satellite
C solar system **D** universe

2 How many natural satellites does the Earth have?
A 0 **B** 1
C 2 **D** 3

3 What provides artificial satellites with energy to continue operating for a long time?
A Fossil fuels **B** Nuclear power
C Solar power **D** Wind power

4 How many planets are in the Solar System?
A 7 **B** 8
C 9 **D** 10

5 Which is the farthest planet from the Sun?
A Jupiter **B** Neptune
C Saturn **D** Uranus

6 How long does it take the Earth to make one complete rotation about its axis?
A 1 day **B** 1 week
C 1 month **D** 1 year

7 In which of the following ways are the Earth, Moon and Sun lined up during a solar eclipse?
A Earth – Sun – Moon **B** Moon – Earth – Sun
C Sun – Moon – Earth **D** Sun – Earth – Moon

8 On which planet is the rover *Curiosity* gathering data about the surface and the atmosphere?
A Jupiter **B** Mars
C Mercury **D** Venus

Structured questions

9 a Draw a diagram to show the position of the Solar System in the Milky Way.
b Explain why we can see a dense band of stars across the sky at night.

10 a Explain the difference between a natural satellite and an artificial satellite.
b Describe the movement of a satellite in a geostationary orbit.
c Suggest a use for such a satellite.

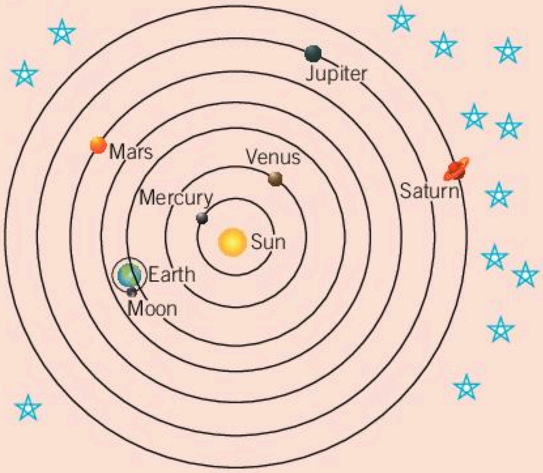
11 The following table contains data about the planets.

Planet	Distance from the Sun (1 000 000 km)	Time taken to orbit the Sun (years)
Mercury	58	0.3
Venus	108	0.6
Earth	150	1.0
Mars	228	1.9
Jupiter	778	11.9
Saturn	1427	29.4
Uranus	2871	83.8
Neptune	4500	163.7

a Use the data in the table to draw a graph of distance from the Sun against time taken to orbit the Sun.
b Draw the line of best fit through the points.
c Describe the pattern shown by the relationship of the distance from the Sun and the time taken to orbit the Sun.
d Ceres is an asteroid. It is 414 000 000 km from the Sun. Use your graph to estimate the time it takes Ceres to orbit the Sun.

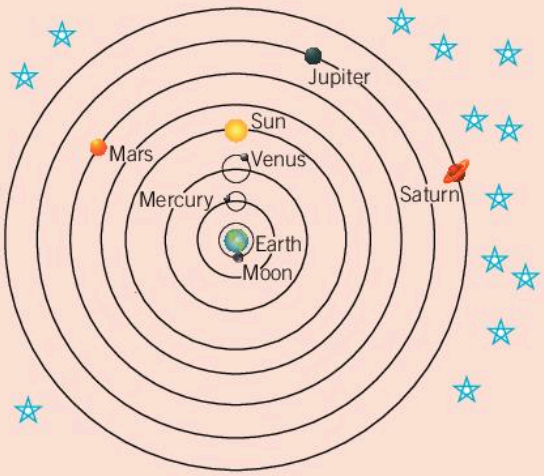
12 a Use the data given in Table 15.4.1 to show that the ratio of the diameters of the Moon and the Sun is similar to the ratio of the distances of the two bodies from the Earth.
b What implications does this have for the apparent sizes of the Sun and the Moon when viewed from the Earth?

13 In ancient times two models of the Solar System were proposed.



▲ A heliocentric model of the Solar System

- A heliocentric model in which the Sun was at the centre and the planets were in orbit around it.



▲ A geocentric model of the Solar System

- A geocentric model in which the Earth was at the centre and the Sun and other planets were in orbit around it

The heliocentric model was proposed by the ancient Greek philosopher, Aristarchus, around 200 B.C. However, the idea went against the views held by another Greek philosopher, Aristotle, who believed in a geocentric Solar System.

Aristotle put forward these arguments.

1 If the Earth spun around on its axis, then why didn't objects fly off into space?

2 If the Earth moved around the Sun, why didn't it leave behind the birds flying in the air?

3 If the Earth moved around the Sun, why didn't stars change position with respect to other stars?

Explain why Aristotle's arguments were incorrect.

Section C

16 The terrestrial environment

Learning outcomes

By the end of this topic you will be able to:

- state that soil is formed by weathering processes
- describe the physical, chemical and biological processes which bring about soil formation.

Soil is an important part of the terrestrial environment. It forms over millions of years. Soil is the essential medium in which plants grow and organisms live. Green plants are at the start of every food chain and provide animals either directly, or indirectly, with the nutrients they need to live. These nutrients are continually recycled by natural processes. The terrestrial environment is influenced by events in the atmosphere and the oceans.

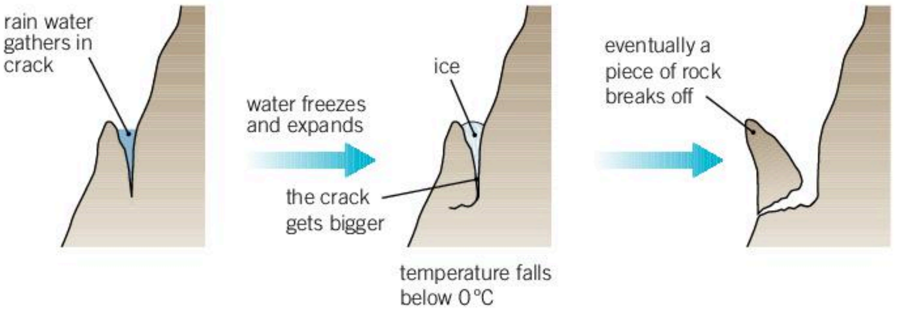
16.1 Formation of soil

Soil is an accumulation of tiny particles of rock which are formed when rocks are weathered. **Weathering** is a process in which rocks are broken up into smaller particles. This happens by physical, chemical and biological processes.

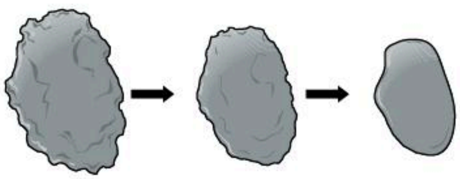
Physical processes

Physical, or mechanical, weathering involves breaking rocks into smaller pieces without any change in chemical composition. Physical weathering can take place by the action of water, ice and abrasion, and by temperature change.

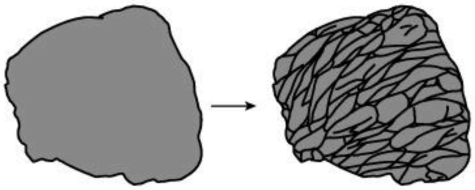
- Water expands when it freezes to form ice. If water collects in cracks in rocks and then freezes, the ice which forms will make the cracks bigger. Eventually pieces of rock will fall away (Figure 16.1.1).



▲ **Figure 16.1.1** Water expands when it freezes



▲ **Figure 16.1.2** Rocks become smaller and more rounded as a result of weathering



▲ **Figure 16.1.3** The minerals in rocks expand by different amounts when heated

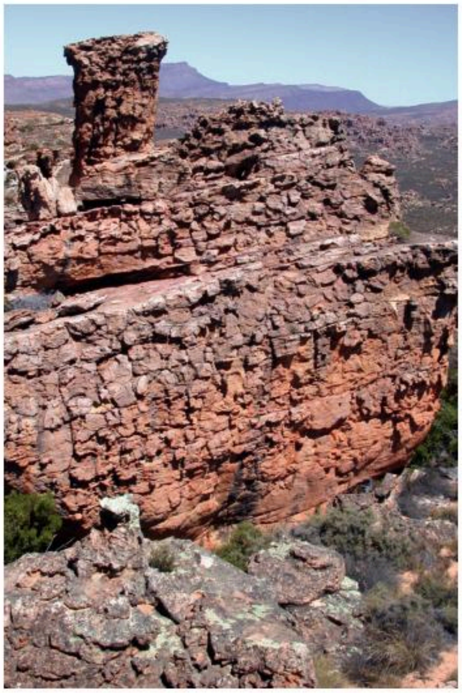
▲ **Figure 16.1.4** Sand particles blown by the wind are very abrasive

- When large rocks continually crash into each other, as on a beach or in a river, small particles of rock are chipped off. Over time the large rocks become smaller and more rounded in appearance (Figure 16.1.2).
- When rocks experience extremes of temperature, such as in a desert where the days are very hot and the nights are cold, the outer layer of a rock will crumble and fall away like the layers of an onion. This process is called **exfoliation** and is caused by the minerals in the rock expanding and contracting by different amounts as the temperature changes (Figure 16.1.3).
- Particles of rock are **abrasive**. In areas of the world where there are regularly strong winds, particles of rock carried on the wind can wear away rocks. The effect is the same as rubbing with sandpaper (Figure 16.1.4).

Chemical processes

Weathering can also be the result of chemical reactions, such as the action of carbonic acid, oxidation, dissolving and pH changes on rocks.

- Rain is a solution of a weak acid called carbonic acid which is formed when carbon dioxide dissolves in water in the atmosphere. When rain falls on rocks containing insoluble carbonates, a chemical reaction takes place and soluble hydrogencarbonate is formed. This reaction is responsible for temporary hardness in water (see Topic 14.7).
- Some minerals in rocks are oxidised by oxygen in the air into other substances which are more soluble or crumble more easily.
- As minerals dissolve in water and are lost from rocks, crevices and holes appear. The rock structure is weakened and this makes it easier for physical weathering processes to take place (Figure 16.1.5).



▲ **Figure 16.1.5** Rainwater creates crevices in rocks

Biological processes

The actions of micro-organisms, plants and animals may be responsible for biological weathering.

- Plant roots growing in rock crevices expand as the plant grows. The increase in pressure forces rocks apart.
- When dead leaves decay, organic acids are produced. These may react with the minerals in some rocks.
- Some animals, such as earthworms, consume soil particles with their food and use them to grind up the food in their gut. The particles which pass out of the worm's body have been rubbed against each other and are therefore smaller.

Questions

1. When rocks rub together they wear each other away. Is this a chemical process or a physical process?
2. Why does the earthworm consume soil with its food?
3. Explain why pebbles on a beach are rounded.
4. How do extremes of temperature contribute to the formation of soil?
5. Explain how rainwater is involved in chemical weathering processes.

Learning outcomes

By the end of this topic you will be able to:

- name the main constituents in soil
- separate the components of soil by sedimentation
- name some different types of soil
- describe some of the properties of sandy soil, clay soil and loam
- measure the air content, water content and humus content of a sample of soil.

16.2 Types and functions of soils

Structure of soil

The tiny particles of rock give soil its basic structure but there are other components. Soils also contain:

- larger pieces of rock
- micro-organisms, such as bacteria and fungi, which are called **decomposers** because they break down dead organic material in the soil
- larger animals, such as earthworms and beetles, that mix and aerate the soil as they move about, and release waste products which increase the fertility of the soil
- air providing many organisms with the oxygen they need to live
- water which is necessary for the survival of both animals and plants
- mineral salts which are absorbed in solution from the soil by plant roots
- humus, or decaying plant and animal material, which releases nutrients to the soil.

When soil is shaken with water and left to stand, the components settle out in order of mass and size. This method of separation is called **sedimentation**.

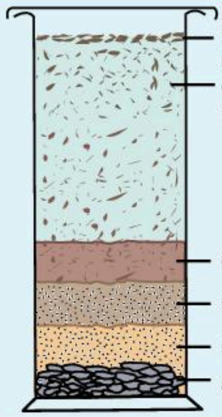
Practical Activity 16.2.1

Demonstrating sedimentation

In this activity you will separate the different components of a sample of soil by sedimentation.

1. Place four tablespoons full of soil in an empty jam jar.
2. Half fill the jar with tap water.
3. Place the lid on the jar, and shake it up and down several times.
4. Leave the contents of the jar to settle overnight.
5. Draw a labelled diagram of the contents of the jar.

You should notice that the densest particles settle first and to the bottom.



Different types of soil

All soils are not the same. Soils are classified according to the size of the particles. This determines the amount of air in the soil and how quickly water passes through it, known as **water retention** or drainage. This, in turn, determines how fertile the soil is and how well plants will grow in it.

▼ **Table 16.2.1** Comparison of soil types

Type of soil	Size of particles	Air spaces	Water retention (drainage)	Amount of organic matter	Fertility	Ease of cultivation
Sandy	High proportion of large particles	Large – good circulation of air	Water passes through easily so sandy soils are free-draining	Little	Poor – water flowing through removes nutrients from the soil	Easy, known as a 'light' soil
Clay	High proportion of small particles	Small – poor circulation of air	Water does not pass through – may become waterlogged	Little	Fairly good	Difficult – plants may rot if the soil remains waterlogged for any length of time, known as a 'heavy' soil
Loam	A mixture of large and small particles	Large – good circulation of air	Good drainage of water without drying out too quickly or becoming waterlogged	Many organisms and organic matter	Good	Easy – best growing medium for most types of plants

Practical Activity 16.2.2

Investigating the air content of soil

Skills assessed: Manipulation/Measurement.

The speed with which water passes through soil depends on the size of the air spaces.

1 Measure 50 cm^3 of soil into a 100 cm^3 measuring cylinder.
2 Measure 50 cm^3 of tap water.
3 Add the tap water to the soil in the measuring cylinder and shake the mixture.
4 Measure the combined volume of the soil and water.
5 Calculate the volume of air in the original sample of soil.
6 Express the amount of air in the original soil as a percentage.

The **water retention**, or drainage, of different soils can be compared by timing how long it takes for the same volume of water to pass through columns of different soils.

Water passes through the sandy soil quickest and through the clay soil slowest.

The water content of soil

The water content of soil is found by measuring the mass of a sample of soil before and after drying in an oven at around 100 °C. A hotter oven should not be used because, at higher temperatures, humus will start to decompose and this will invalidate the result of the process.

The humus content of soil

Humus is the collective name for organic material in the soil. It may come from dead, and decaying, animals and plants, or as a result of animal excretions or leaf fall.

Humus improves the texture of soil and increases its capacity to hold water. As humus decays, nutrients are released into the soil to be used by plants.

In order to find the humus content of soil, a known mass of previously dried soil is strongly heated on a tin lid and then reweighed when cold. Strong heating destroys the humus. This process usually produces an unpleasant odour and should be carried out by an open window or in a fume cupboard.

Questions

1 Why do you think that sandy soil is called a 'light' soil and clay is called a 'heavy' soil?
2 How could you make the comparison of the water retention of the different soils more quantitative?
3 What is humus and why is it important?
4 In which type of soil do most plants grow best?
5 When 50 cm^3 of soil and 50 cm^3 of water were mixed the volume of slurry formed was 85 cm^3. What percentage of the soil was air?

Key fact

Soils can be classified according to the size of the particles found in them.

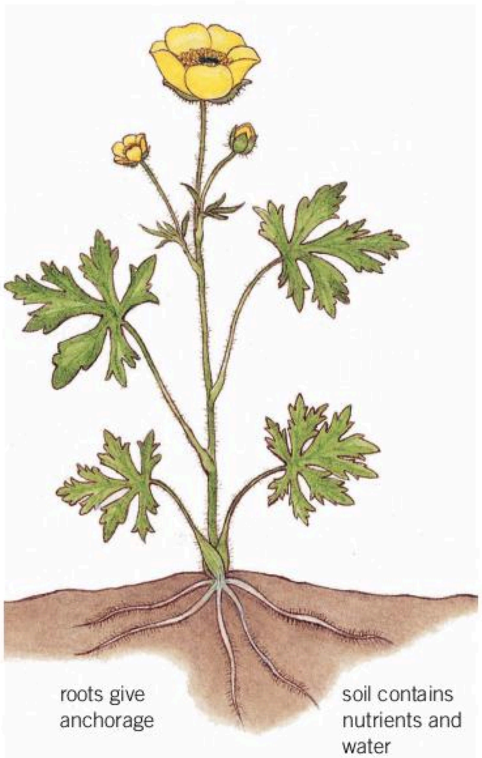
Diameter of particle (mm)	Type of soil
Less than 0.002	Clay
Between 0.002 and 0.02	Silt
Between 0.02 and 2.0	Sand
More than 2.0	Gravel

▲ **Figure 16.2.1** Testing the water content of soil using an electronic soil moisture probe

Learning outcomes

By the end of this topic you will be able to:

- describe how soil is an ideal medium for growing plants
- explain how the physical properties of soil affect its fertility
- explain how the chemical properties affect the growth of plants.



▲ **Figure 16.3.1** Most plants grow in soil

16.3 Soil fertility

Soil as a growing medium

Soil is an ideal growing medium for most plants.

- Plant roots are able to grow down into the soil providing the plant with a secure anchorage against being blown over by the wind or pushed over by passing animals. From this secure base, the plant stem can grow upright from the soil, spreading out the leaves so that they receive the maximum amount of light for photosynthesis.
- The soil also provides plants with water and mineral salts which are essential for healthy growth. The nutrients are absorbed in solution by plant roots and travel through the stem to different parts of the plant.

Effect of physical properties on soil fertility

The physical properties of the soil depend on the size of the constituent mineral particles. We have seen in Topic 16.2 that most soils will contain a mixture of clay, silt and sand particles. The proportions of these particles determine the nature of a soil. Good agricultural soils are **loams**, which are classified according to the proportions of sand, silt and clay they contain. So a sandy loam will have a higher proportion of sand particles than a silty loam or a clay loam.

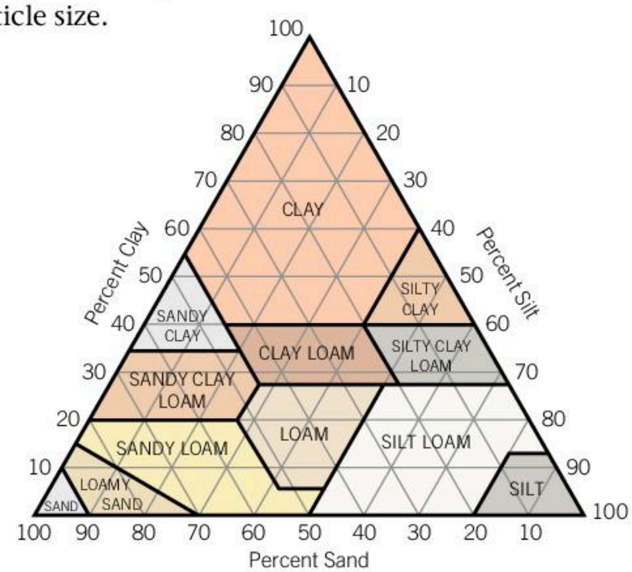
The ideal soil needs to drain fairly readily but contain enough smaller particles to retain sufficient water for plant growth. There also needs to be sufficient air to provide oxygen for root growth and for the respiration of soil organisms. Water will drain rapidly through a soil with large particles or crumbs, leaving large air spaces. Soils with a good mixture of small and larger particles will drain easily but retain some water and have enough air spaces.

Soils containing a high proportion of clay particles retain water, and become 'sticky' and difficult to cultivate. If the surface of the soil dries out, it becomes compacted and cracks, forming thick clods (Figure 16.3.2).

Very sandy soils, which drain rapidly, lose mineral ions through leaching.

The soil triangle diagram (Figure 16.3.3) shows in detail how soils are classified according to particle size.

▲ **Figure 16.3.2** Mud cracks in clay soil



▲ **Figure 16.3.3** Soil triangle diagram

Effect of chemical properties on soil fertility

Soil fertility is affected by the organic matter it contains. This organic matter consists of:

- dead remains of whole organisms
- parts of organisms, such as leaves
- animal faeces
- excretory products.

If the organic matter has not decomposed, it is called **litter**. It may be eaten by **detritivores**, such as earthworms and beetles, or broken down by **decomposers**, such as bacteria and fungi. During these processes, organic compounds are broken down releasing ammonium, phosphate and sulphate ions into the soil, and carbon dioxide into the atmosphere. Any remaining organic matter is called **humus** and this helps to stick mineral particles together to form soil crumbs, which contribute to the aeration and drainage of the soil.

Humus can stick clay particles together and its presence in a clay soil contributes to the ability of the soil to retain water and mineral ions. The soil needs to be well aerated for humus formation, so that the decomposers can break down the organic matter. If the soil is waterlogged, anaerobic conditions develop and the breakdown of the litter is restricted.

Soil fertility depends on the presence of mineral ions. Of particular importance are the bacteria involved in the nitrogen cycle, which we shall study in Topic 16.5.

The organic matter in the soil releases essential mineral ions for plant growth, so a fertile soil will contain litter and humus. Usually, such soils are a dark brown in colour and have a good crumb structure.

▲ **Figure 16.3.4** Rich soil and humus

Soil acidity

Soil fertility can be affected by how acid or alkaline a soil is. The acidity or alkalinity can be expressed as a number, the **pH** number. In a pH scale, the numbers range from 0 to 14, with a pH of 7 being neutral. A pH of less than 7 indicates an acid soil and a pH greater than 7 indicates an alkaline soil.

Most plants grow best in soils which are around neutral but there are plants that can tolerate acid or alkaline soils.

Practical Activity 16.3.1

Finding the pH of your soil

1. Put a small quantity of soil in a test tube and add about 10 cm^3 of distilled water.
2. With your thumb over the end of the tube, shake the tube vigorously for several seconds.
3. Place the tube in a rack and let the contents settle.
4. Dip a piece of pH paper into the water.
5. Observe the colour of the paper and compare it with the colour chart provided.
6. You can try this on soil samples from different areas.

Questions

1. Why is soil a good growing medium for plants?
2. Explain why good aeration of the soil is beneficial to plant growth.
3. What is a detritivore? Give two examples of detritivores.
4. How are mineral ions released into the soil from the litter?
5. Explain why soils that consist of a mixture of small and large mineral particles are more fertile than soils that have mostly large particles.

Learning outcomes

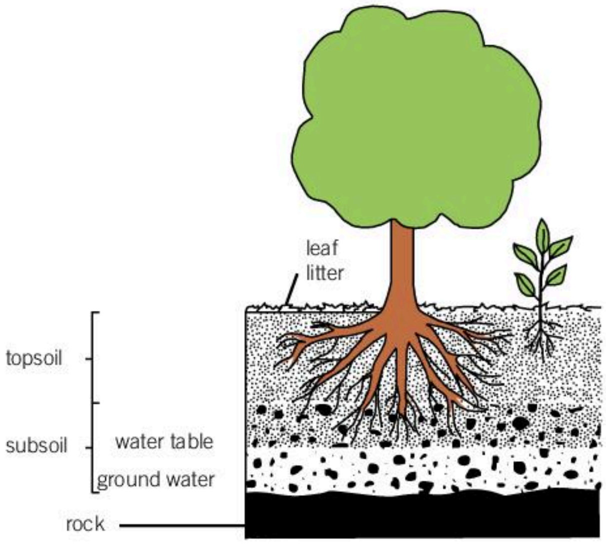
By the end of this topic you will be able to:

- state that erosion is the loss of topsoil by the action of water and wind
- appreciate the value of topsoil
- describe the importance of ground cover and ways that it may be removed
- describe types of soil erosion
- describe methods to reduce erosion
- explain how sheet erosion, rill erosion and gully erosion take place
- explain farming practices that reduce erosion.

16.4 Soil erosion

Erosion is the loss of **topsoil** due to the action of water and wind. Topsoil is the uppermost layer of soil.

The topsoil is the most fertile layer of soil since it contains the most decaying organic material and therefore the most nutrients. Topsoil is also less compacted than lower layers and therefore contains more air, drains more readily, and is easier to work. The loss of topsoil from a field greatly reduces the yield of crops that can be obtained from it.



▲ **Figure 16.4.1** The top layer of soil is the most important

When water falls onto soil as rain, or flows over soil, it loosens the soil particles and they may be carried away. Where soil has a good covering of plants, the plant roots hold the soil together and the plants slow the flow of water, so very little damage is done.

If ground-cover plants are removed, there is nothing to hold the soil together and it is easily eroded. There are a number of ways in which this can happen.

- When large areas of forest are cut down, the plants which normally live in the shade of the trees are exposed to the full strength of the Sun and are killed. This leaves the topsoil with no ground cover and erosion will occur.
- If animals, such as goats, are allowed to overgraze an area of land, all of the ground-cover plants are eaten. The topsoil will then be exposed allowing erosion to take place.

Once the topsoil is exposed, it will be eroded by flowing water in the rainy season and wind in the dry season.

Erosion is a natural process. However, it can become a serious problem if the land is poorly managed.

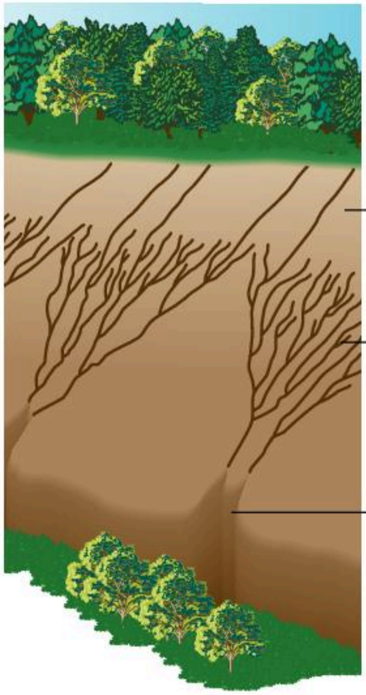
▼ **Table 16.4.1** Types of erosion

Type of erosion	Causes	Prevention methods	Farming practices
Sheet	Rain runs down through the topsoil. This is weakened and, eventually, a whole sheet of topsoil just slides down the slope	Planting trees on hillsides and controlling the amount which animals are allowed to graze	If hillsides are farmed, banks or terraces can be built across the slopes to reduce the flow of water down them
Rill	If crops are planted in rows that run down the hillside, flowing water will be channelled between the rows	Do not plant rows of crops sloping downhill	Contour ploughing around a hillside means that rows of crops grow perpendicular to the slope. This reduces the flow of water and prevents the formation of rills
Gully	Water cuts deep channels in the soil	Reduce overgrazing especially in the wet season	As for rill erosion

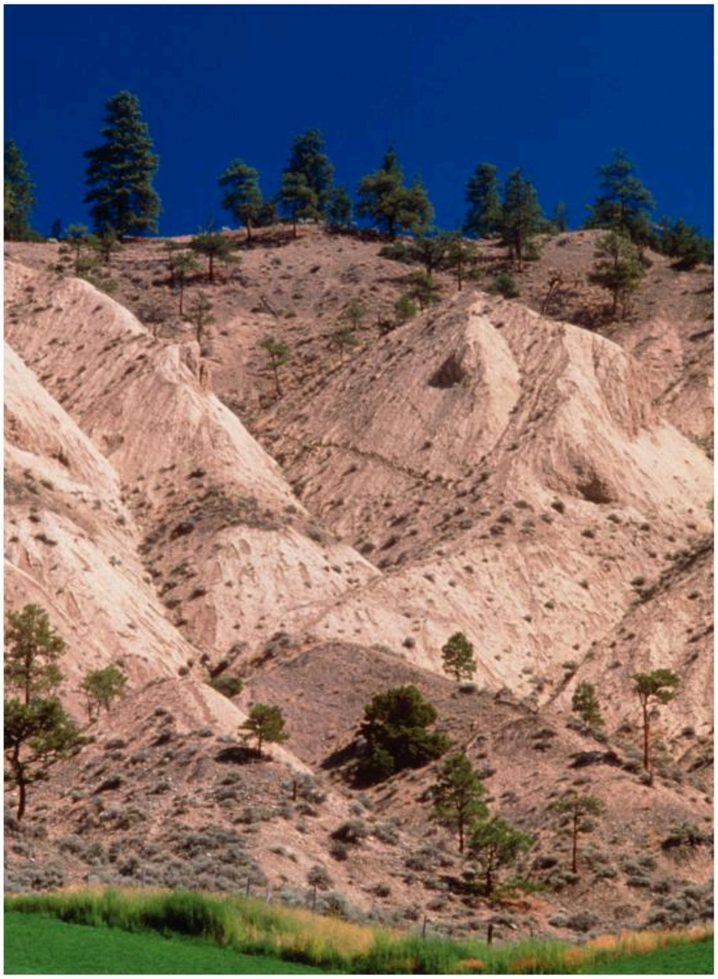
Soil conservation, nutrient loss and farming practices

Soil is a non-renewable resource. It takes a long time to replace soil that is lost by being washed into rivers and eventually into the sea. Soil erosion can be reduced by good farming practices. All farmers want to increase their crop yields and reduce nutrient loss from the soil. These practices are described in Topic 3.2.

▲ **Figure 16.4.2** Rill erosion



▲ **Figure 16.4.3** Different types of erosion



▲ **Figure 16.4.4** Hill soil erosion caused by overgrazing

Questions

1. How does the removal of trees for timber from a rainforest contribute to erosion?
2. Why is it essential to control the amount of grazing on a field?
3. Why does rill erosion occur in a ploughed field?
4. Why is the topsoil so important for plant growth?
5. How can sheet erosion be prevented?
6. How does contour ploughing help to prevent erosion?

Learning outcomes

By the end of this topic you will be able to:

- state the composition of living things
- explain the importance of all elements being recycled
- name the processes in which oxygen is used and formed
- describe the concentration of oxygen in the atmosphere
- name the processes that produce and use carbon dioxide
- name some carbon-based fuels
- describe the nitrogen cycle
- name some chemical fertilisers that add nitrogenous compounds to soil.

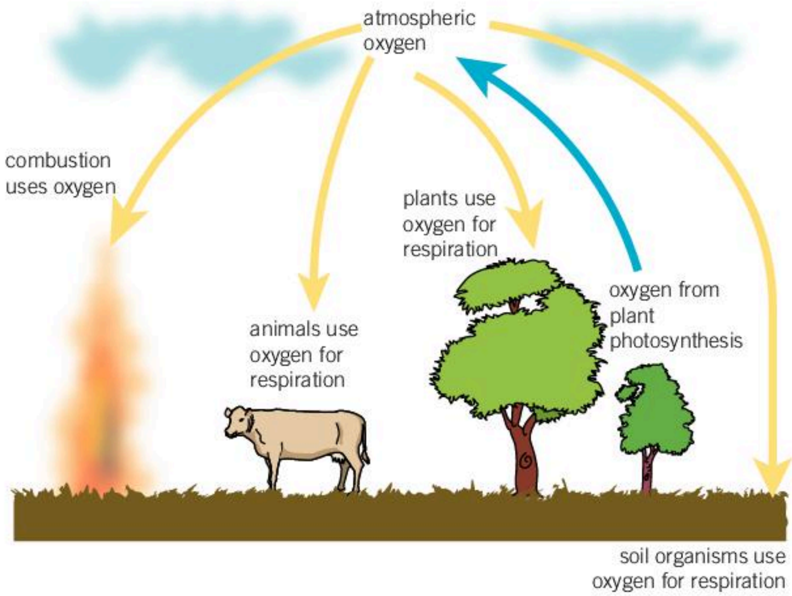
16.5 Natural cycles

All living things are composed of chemicals containing mainly carbon, hydrogen, oxygen and nitrogen. During the lifetime of an organism, chemicals containing these elements are excreted as waste materials. When the organism dies, its body decomposes and the elements are released back to nature. A series of natural cycles allow the elements needed for living things to be used over and over again.

In any natural cycle, there are processes which use an element and processes which produce it. These processes may involve the element itself or its compounds. The following cycles show how three elements which are essential for life are recycled by nature.

Oxygen cycle

The oxygen cycle is shown in Figure 16.5.1. The percentage of oxygen in the air remains more or less at around 21%, which indicates that oxygen is being used up at a similar rate to which it is being produced.



▲ **Figure 16.5.1** The oxygen cycle

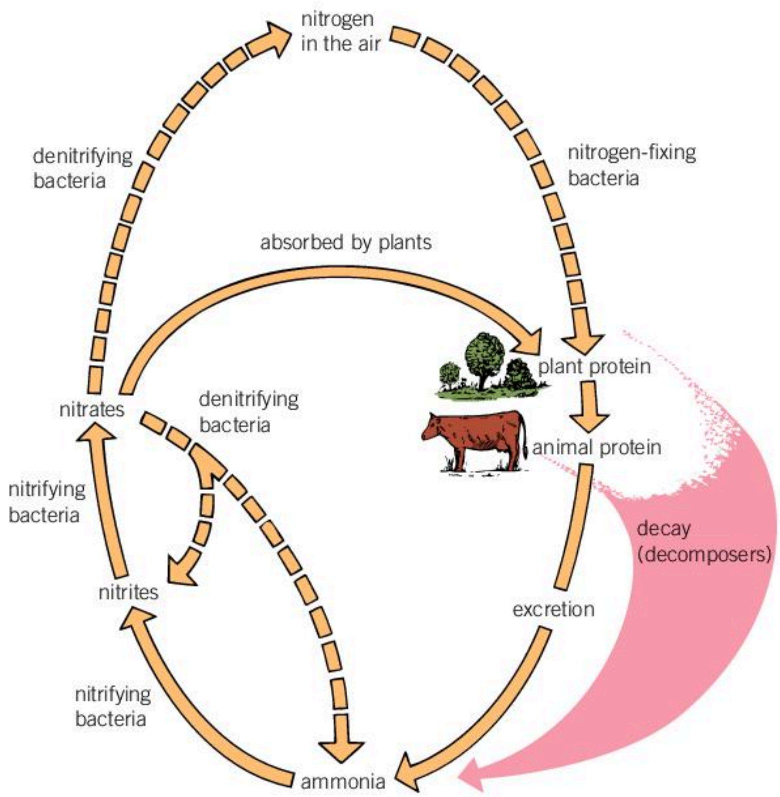
Nitrogen cycle

Although nitrogen is the most abundant gas in the atmosphere, the nitrogen cycle is really about the processes that add and remove nitrates from the soil. It is in the form of nitrates that plants obtain nitrogen from the soil.

In Topic 3.2 you learnt about the action of bacteria on the nodules of leguminous plants. These nitrogen-fixing bacteria are able to convert atmospheric nitrogen into nitrates, which are then used by the plants to make proteins.

▲ **Figure 16.5.2** Root nodules on leguminous plant. The nodules contain nitrogen-fixing bacteria

The solid waste from animals, and the bodies of dead plants and animals all contain proteins, which, in turn, contain the element nitrogen. When this organic material decomposes in the soil, the nitrogen from proteins is converted into ammonia. In well-aerated soil, nitrifying bacteria oxidise the ammonia, first into nitrites and then into nitrates. If the soil is badly aerated, other denitrifying bacteria can reduce the nitrates back to nitrites, ammonia and even atmospheric nitrogen.



▲ **Figure 16.5.3** The nitrogen cycle

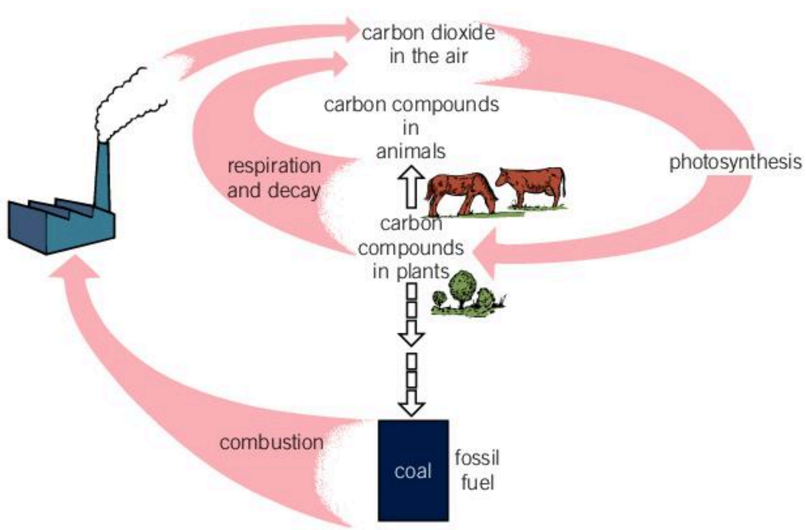
Did you know?

Atmospheric nitrogen is converted into ammonia industrially by the Haber process. The ammonia which is produced can then be oxidised into nitric acid. Ammonia and nitric acid react together to form ammonium nitrate.

Nitrogen can be introduced into soil as chemical fertilisers. Ammonium nitrate (NH_4NO_3), ammonium sulphate ($(NH_4)_2SO_4$) and urea ($CO(NH_2)_2$) are commonly used nitrogenous fertilisers. Their chemical formulae show that they all contain nitrogen.

Carbon cycle

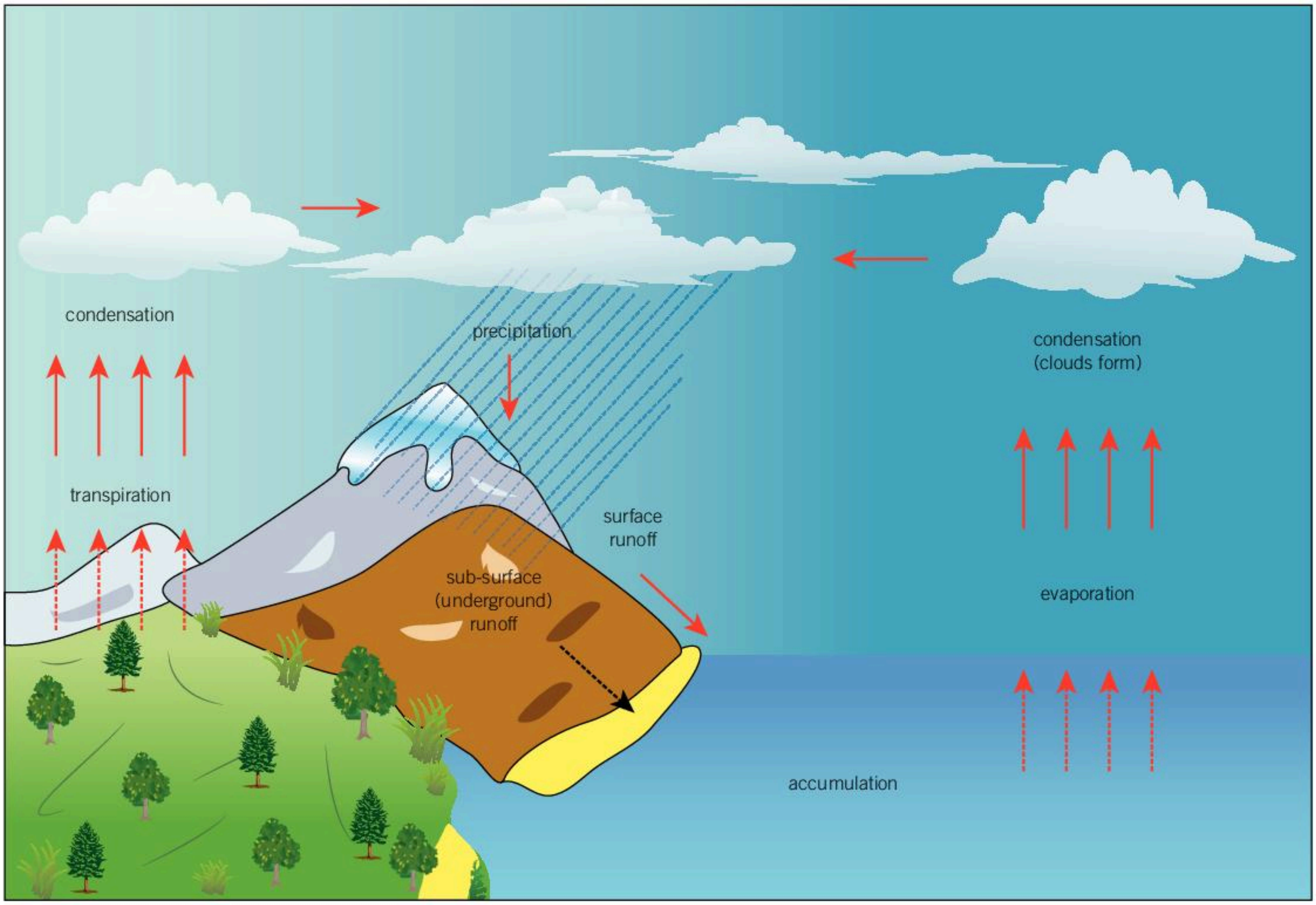
The carbon cycle is shown in Figure 16.5.4.



▲ **Figure 16.5.4** The carbon cycle

The water cycle

Water is an essential requirement for all life on Earth. Supplies of fresh water are replenished by a series of natural processes called the water cycle. The energy for this cycle is provided by the Sun.



▲ **Figure 16.5.5** The water cycle

In the warm regions of the world, heat radiation from the Sun causes massive amounts of water to evaporate from bodies of water, such as the oceans, into the atmosphere where it condenses to form clouds of tiny water droplets. The clouds are carried around the Earth by the prevailing winds. As they pass into cooler regions, the air cannot carry so much water vapour and some is lost as rain, or in very cold regions, as snow. This process is called precipitation.

Rain falling on the land flows across the soil and rocks, and eventually accumulates in lakes and rivers. Much of this water eventually finds its way back into the sea and the cycle is repeated.

Practical Activity 16.5.1

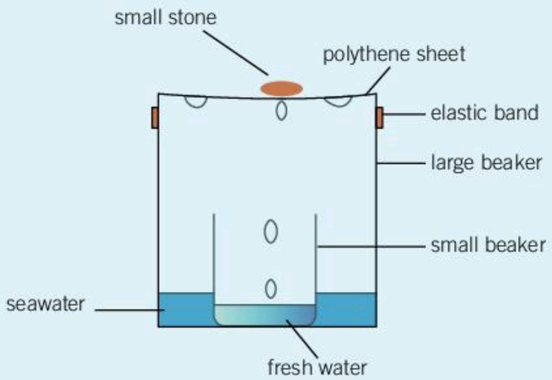
A small-scale water cycle

Materials:

- Two beakers – one large and one small
- Large elastic band
- Small stone or glass marble
- Polythene sheet
- Salt water

Method:

1. Pour salt water into a large beaker to a depth of about 2 cm.
2. Thoroughly wash and dry a small beaker. You are going to drink from this beaker later in the activity so it is essential that it is clean.
3. Place the small beaker inside at the centre of the large beaker.



4. Place the polythene sheet over the top of the large beaker and put the small stone in the centre. Allow the sheet to sag at the centre so that the small stone is directly above the small beaker.
5. Hold the polythene sheet in place with an elastic band.
6. Place the apparatus on a sunny window sill for a day.
7. After a day, remove the small beaker, wipe any salt water from the outside and taste the contents.

Questions

1. Name three elements found in all living things.
2. In which process is oxygen released into the atmosphere?
3. What provides the energy needed to drive the water cycle and in what form does it reach the Earth?
4. Where are nitrogen-fixing bacteria found?
5. Which component of decaying organic material is converted into nitrates in the soil?

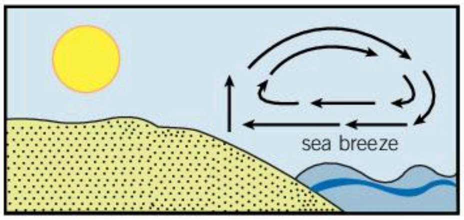
Learning outcomes

By the end of this topic you will be able to:

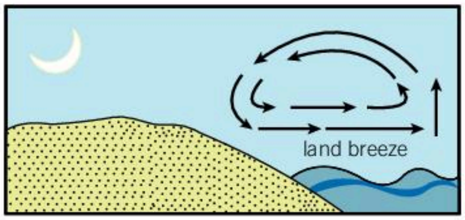
- explain the origins of wind
- explain why land breezes and sea breezes occur at different times of the day
- describe how pollutants can spread
- state that particles may be carried in the air
- describe how sand and volcanic ash may be spread by the air.

Key fact

Winds at high levels above the ground do not blow in the same direction as winds at ground level.



▲ **Figure 16.6.2** Wind blows from the sea during the day



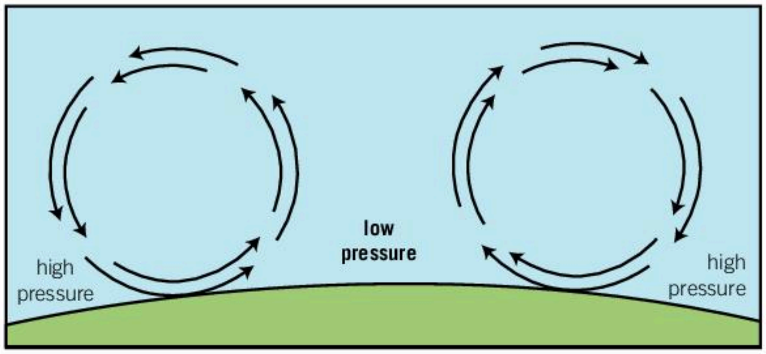
▲ **Figure 16.6.3** Wind blows from the land at night

16.6 Air movements

What is wind?

We live in a region of the Earth that we call the **atmosphere**. Winds are the result of uneven heating of the atmosphere. Energy reaches the Earth from the Sun as radiation, and passes through the atmosphere to heat the land and sea. The atmosphere is not heated directly by the Sun's radiation but receives heat energy from being in contact with warm land or warm sea.

Heat energy is transferred through the atmosphere by convection currents (see Topic 9.1). When air is warmed, it expands and becomes less dense. The warm air rises creating a region of low pressure on the Earth's surface. In turn, cooler air falls to take its place creating an area of high pressure. Winds blow from areas of high pressure towards areas of low pressure.



▲ **Figure 16.6.1** Warm air rises leaving an area of low pressure

Land and sea breezes

Land heats up and cools down more quickly than the sea. On the coast, where land meets the sea, this effect produces land breezes and sea breezes at different times of the day.

During the day the land heats up more quickly than the sea, so the air above the land rises creating an area of low pressure. Air blows from the sea to the land giving a sea breeze.

At night the sea cools down more slowly than the land, so the air above the sea rises creating an area of low pressure. Air blows from the land to the sea giving a land breeze.

Air masses

Air masses form in the lower regions of the atmosphere. Their characteristics depend on the conditions of the surface over which they form.

▼ **Table 16.6.1** Air masses and their characteristics

Air mass	Surface over which it forms	Characteristics
Maritime tropical	Tropical seas	Warm and humid
Continental tropical	Tropical land masses	Hot and dry
Maritime polar	Cold oceans	Cold and humid
Continental polar	Colder land masses	Cold and dry

Air masses move from place to place and bring about changes in weather. These are discussed in Topic 16.7.

The spread of pollutants in the air

Industrial pollutants

Many industrial processes release pollutants into the air either as gases or particles. In some cases the pollutants can travel for hundreds of kilometres assisted by the wind.

Exhaust fumes

Cars and other motor vehicles run by burning petrol or diesel. The exhaust fumes produced as a result of this combustion contain a variety of pollutants.

Radioactive fallout

The fallout from the nuclear accident that happened at Chernobyl in the Ukraine in 1986 was carried west across Europe where increased levels of radioactivity were recorded in many places.

Landfill fumes

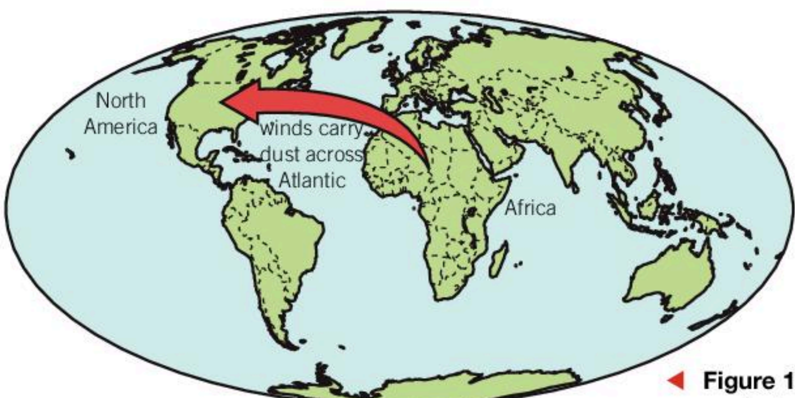
Landfill sites are used to dispose of domestic waste. As the waste decomposes, harmful gases including methane can be produced. These may result in air pollution which can spread as a result of air movement.

Sahara dust

Fine particles can be carried for long distances through the air. Every year between June and September, sand is carried to the Caribbean all the way from the Sahara Desert in North Africa.

The surface of the desert is heated by the Sun and may reach temperatures of over 50 °C. The air above the ground is heated and rises up by convection. The movement of hot air causes sand storms and may carry fine particles of sand up to heights of 5000 metres.

Winds carry the particles of sand westward across the Atlantic Ocean. Larger particles may fall out of the sky along the way and some are washed out when it rains. However, large clouds of smaller particles are deposited on the Caribbean and mainland America.



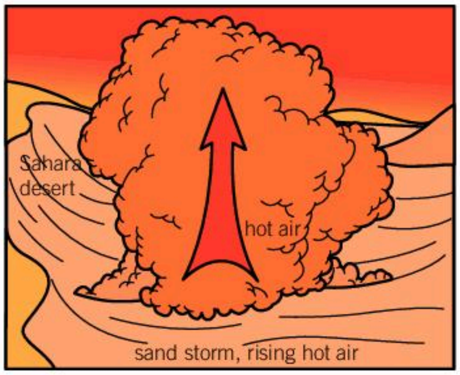
◀ **Figure 16.6.5** Sand is carried on prevailing winds

Volcanic dust

Particles are also released into the atmosphere by volcanic activity. On 22 May 2006, volcanic activity on the Soufrière Hills on Montserrat sent a cloud of volcanic ash 16 km into the air. The cloud was so dense that aircraft flights across that area of the Caribbean were cancelled due to poor visibility.

Did you know?

In the past, in order to make car engines run more smoothly, a compound called lead tetraethyl was added to petrol. After combustion in the engine particles of lead were emitted in the exhaust gases. It was found that people who lived near busy roads accumulated high levels of lead in their bodies which caused them harm so leaded fuels have been replaced by lead-free fuels.



▲ **Figure 16.6.4** Sand is drawn up in the air by convection currents

Synoptic link

See Topic 5.6 Problems caused by air pollution.

Questions

1. Which heats up faster when heated by the Sun: the sea or land?
2. In which direction do winds on the coast blow during the day?
3. What problem is caused by landfills?
4. How might large amounts of ash get into the atmosphere?
5. Explain how sand can be blown across the Atlantic to the Caribbean.

16.7 Weather fronts

Learning outcomes

By the end of this topic you will be able to:

- describe the formation of different types of fronts
- explain how the different fronts may affect the weather.

The type of weather we enjoy depends upon the movement of air in the atmosphere. When air masses meet, they do not mix. A sharp boundary forms where temperature differences occur. This boundary is called a **front**. Changes in the weather are the result of different weather fronts.

Cold fronts

A cold front is the result of a body of cold air coming into contact with a region of warm air. It is represented on a weather map by a line of blue triangles pointing in the direction that the cold front is moving. This is the most common weather front encountered in the Caribbean since the air is generally warm. Cold fronts are preceded by a rapid drop in atmospheric pressure. The warm air is displaced upwards and water vapour condenses to give rain. As the cold front passes, there is a drop in temperature of perhaps 4 °C or 5 °C and rainfall is often heavy, and may include thunderstorms.

▲ **Figure 16.7.1** A cold front is shown by a line of blue triangles

Warm fronts

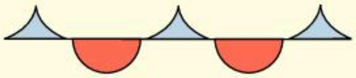
A warm front is the result of a body of warm air coming into contact with a region of cold air. It is represented on the weather map by a line of red semicircles pointing in the direction that the warm front is moving.

This type of weather front is not often encountered in the Caribbean since the air is generally already warm. Warm fronts are preceded by a gradual drop in atmospheric pressure. Water vapour in the warm air condenses to give rain and the temperature slowly rises.

▲ **Figure 16.7.2** A warm front is shown by a line of red semicircles

Stationary fronts

Under certain conditions, regions of cold air and warm air can exist side by side without moving into each other. This gives rise to a stationary front, which is represented on a weather map as a line of alternative blue triangles and red semicircles, each pointing to their own system. Stationary fronts do not alter the weather greatly, so conditions are most likely to be as they are for a warm front.

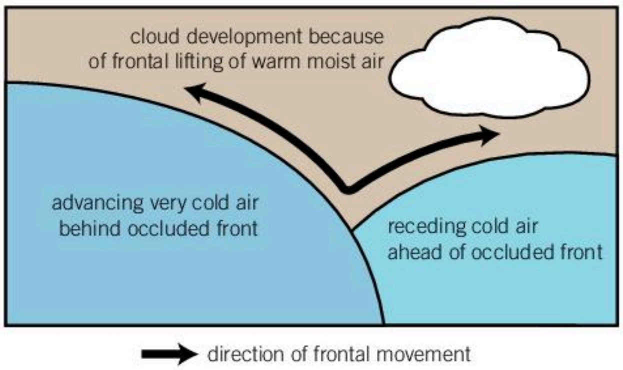


▲ **Figure 16.7.3** A stationary front is shown by a line of alternating blue triangles and red semicircles pointing in opposite directions

Occluded fronts

Cold fronts move more quickly than warm fronts. It sometimes happens that a cold front will move into a warm front forcing it upwards. An occluded front is represented on a weather map as a line of alternate blue triangles and red semicircles, both pointing in the direction that the cold and warm fronts are moving. As the warm front is forced upwards, water vapour condenses and clouds are formed. Occluded fronts are not common in the Caribbean.

▲ **Figure 16.7.4** An occluded front is shown by a line of alternating blue triangles and red semicircles pointing in the same direction



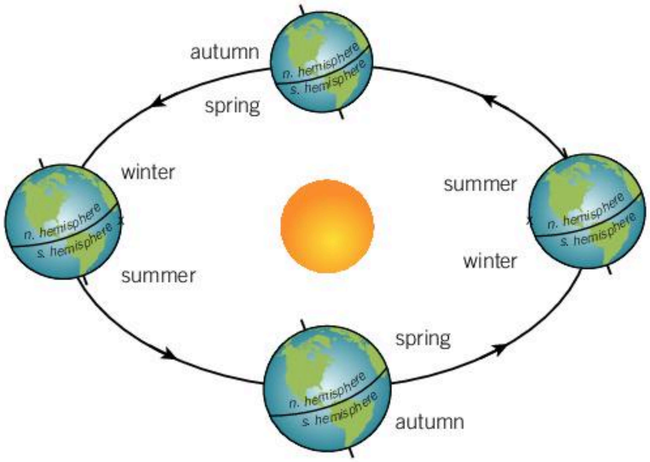
▲ **Figure 16.7.5** Clouds are formed from condensing water vapour due to an occluded front

Questions

1 How does a warm front form?
2 Describe the symbol used to show an occluded front on a weather map.
3 Which types of front affect the weather in the Caribbean?

16.8 Seasons and weather patterns

It takes the Earth one year to complete an orbit around the Sun. As the Earth's axis is slightly tilted, many countries have seasons during which the weather is different.



▲ **Figure 16.8.1** Seasons

The effect is most obvious in countries which are far north or far south of the equator. When the countries on these parts of the Earth are tilted towards the Sun, they have summer weather when is it generally warm and dry.

As the Earth continues on its orbit, the part of the Earth these countries are on is slowly tilted in the opposite direction away from the Sun. At this time they experience winter weather when temperatures are lower and it rains more frequently. In some countries it may even snow.

When countries are not tilted directly towards or away from the Sun, they have spring and autumn seasons, which are intermediate between summer and winter. Average temperatures are not as hot as the summer months nor as cold as the winter months.

Countries near the equator generally do not experience four seasons. Instead, they have a rainy season and a dry season corresponding to the amount of rainfall they receive. Sometimes, rainfall is so heavy that areas become flooded and crops may be damaged.

Just as the Earth repeats its orbit around the Sun each year, so regional weather patterns will also be repeated. The weather patterns are not *exactly* the same every year but people do know in advance what sort of weather they can expect during different seasons.

Questions

1. In what direction, relative to the Sun, is the Earth's axis tilted when countries enjoy summer?
2. Why is the average winter temperature in many countries lower than the average summer temperature?
3. Why do seasons repeat every year?

Learning outcomes

By the end of this topic you will be able to:

- appreciate that many countries have seasons in which the weather is different
- explain how the tilt of the Earth's axis contributes to seasons
- describe the effects of some adverse weather conditions.

Learning outcomes

By the end of this topic you will be able to:

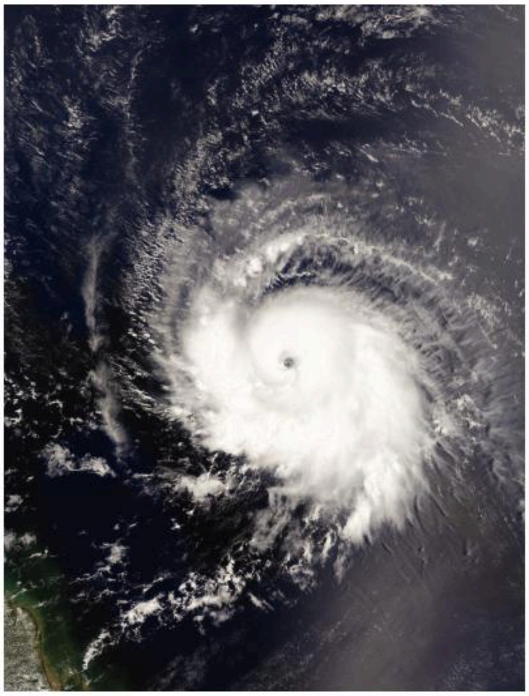
- state what is meant by a cyclone
- explain how a hurricane forms
- draw a likely track for a hurricane across the Caribbean
- state that the hurricane season in the Caribbean is from July to November
- appreciate the devastation that can be caused by a hurricane
- state some of the safety precautions that should be taken in the event of being caught in a hurricane.

16.9 Cyclones and hurricanes

A **cyclone** is a region of low pressure in the atmosphere which is accompanied by wind and rain. It is formed when warm and cold air masses meet. Cyclones can be classified according to the speed of the winds associated with them. Those which have wind speeds over 120 km/h are called **hurricanes**.

Hurricanes form over tropical seas where the water temperature is around 27–28 °C. Water evaporates from the surface of the sea and is carried into the sky by the rising air. When the moist air cools it condenses turning the water vapour into rain and in doing so releases energy which powers the hurricane.

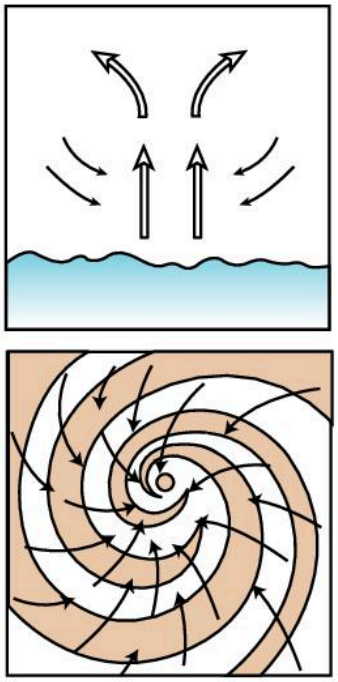
As the air rises up, more hot moist air is drawn in to replace it creating powerful winds. In the northern hemisphere, the winds blow in an anticlockwise direction around the centre (or eye) of the hurricane. In the southern hemisphere, the winds blow in a clockwise direction.



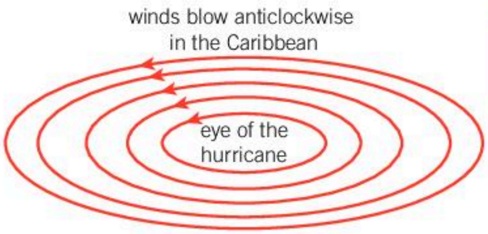
▲ **Figure 16.9.1** Satellite image of a hurricane

The eye of a hurricane remains an area of low pressure with no wind or clouds. Further away from the centre of a hurricane, pressure increases and winds build up to speeds in excess of 200 km/h.

The hurricanes which affect our part of the world form in the Atlantic Ocean and then track north-west through the Caribbean, and on to the southern states of the USA.



▲ **Figure 16.9.2** Water vapour evaporates and rises on the convection current



▲ **Figure 16.9.3** There is no wind in the eye of a hurricane

▲ **Figure 16.9.4** Hurricanes move north-west across the Caribbean

Hurricanes most often pass across the sea, missing or hardly touching land. However, when a hurricane does pass directly across land the results can be devastating.

Hurricane Gilbert passed across the Caribbean in September 1988 and is, to date, the second most intense hurricane ever seen in the Caribbean. This hurricane made its first landfall in Jamaica before passing on to affect other Caribbean Islands and mainland USA. Overall the hurricane resulted in the deaths of 318 people and caused damage costing US$9 billion to repair at today's prices. Hurricane Ivan struck the Caribbean in 2004. In 2005, hurricane Katrina formed over the Bahamas and was one of the costliest, and deadliest, hurricanes in the history of the USA with over 1800 people losing their lives when it made landfall.

▲ **Figure 16.9.5** Hurricane Ivan caused a lot of damage and suffering

Hurricane safety

A battery-powered radio is essential equipment for listening to weather forecasts about hurricanes. If a hurricane watch is announced, it suggests that there might be a hurricane heading for your area. A hurricane warning means a hurricane is on the way and there is likely to be some damage.

The safest place to be during a hurricane is probably your home, provided it is solidly built and not likely to be flooded. Here are some sensible precautions to take.

- Move any loose items from around the outside of the house, such as chairs and garbage cans, into a shed or garage.
- Board up windows with strong wood and tape around them.
- Make sure you have spare batteries for your radio and flashlights as there may be a loss of electrical power.
- Make sure you have enough food to last for a couple of weeks. This needs to be canned or dried because there may not be any power for a refrigerator.
- Make sure you have enough water for a couple of weeks in case there is any problem with your supply.
- Get a gas-powered camping stove, and a couple of spare gas cylinders, so you can boil water and make some hot meals.
- Make sure your car is full of gasoline in case you have to evacuate the area quickly.
- Keep important documents and other important personal items together in a waterproof container.

After a hurricane has passed, there may be damage that will take some time to repair. Be prepared for disrupted supplies of electricity and water. Unless you have bottled water, all drinking water should first be boiled and then stored in sealed containers after cooling. Continue to listen to news updates on the radio as these may give you information about local problems.

Questions

1. When does a cyclone become a hurricane?
2. What causes a hurricane to form?
3. Why is it sensible to have canned food rather than fresh food if you are expecting a hurricane?

Practical Activity 16.9.1

Records of hurricanes in the Caribbean

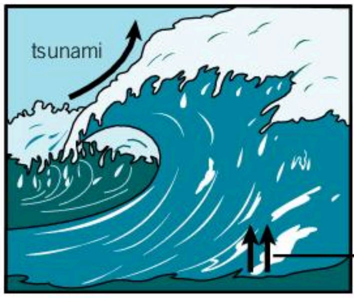
In this activity, you can use the internet, the library and newspapers to compile your records. The information you discover can then be presented as a poster, an item for a magazine or as a presentation to a group of students.

1. Choose a recent hurricane that has affected your area.
2. Find out exactly when the hurricane occurred.
3. Draw a map to show the path of the hurricane across the Caribbean.
4. Mark on your map the areas that were most seriously affected.
5. Include on your map any significant wind speeds recorded.
6. Find pictures to illustrate your report.

Learning outcomes

By the end of this topic you will be able to:

- appreciate the impact of underwater landslides
- understand how tidal waves or tsunamis occur.



▲ **Figure 16.10.1** Tsunamis occur as a result of sudden movements of the seabed

▲ **Figure 16.10.2** Tsunamis can be caused by earthquakes

Questions

1. Describe what happens during an underwater landslide.
2. Explain how a tsunami is caused.
3. What are the characteristic features of a tsunami?
4. Why might a second tsunami strike the same beach some time after the first?
5. What happens to the speed of a tsunami as it reaches shallow water?

16.10 Underwater landslides and tsunamis

Underwater landslides

During the last four million years, giant landslides surrounding the Hawaiian Islands have taken place. There is recent evidence that large blocks of land on the island of Hawaii are beginning to slide, generating large earthquakes in the process. Each landslide results in land losses to the islands, and in large waves that have carried rocks and sediment from the ocean floor on to the islands. Although these landslides do not occur often, they have the potential to bring about damage to property and resources.

Tsunamis

Sometimes the centre of an earthquake may be under the sea. These are called submarine earthquakes.

A large up or down movement of the seabed results in the formation of huge waves called **tidal waves** or **tsunamis**. Tsunamis are waves which move at fast speeds, have high amplitudes and long wavelengths.

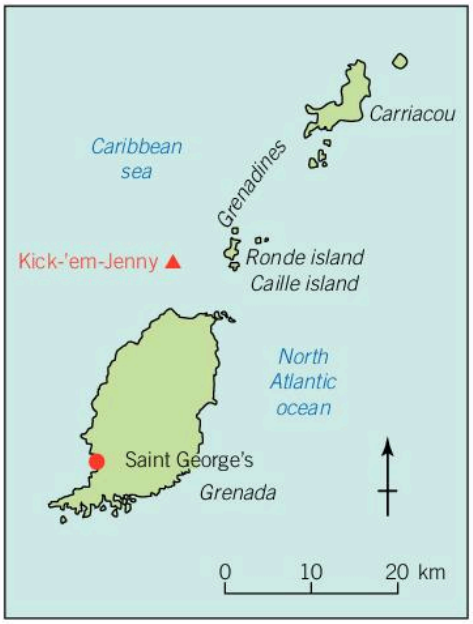
- Tsunamis can travel across the ocean at speeds of 500–1000 kilometres per hour with hardly any of their energy being lost. For this reason, a tsunami may affect regions thousands of kilometres from where it is generated.
- As a tsunami reaches shallower water near a coast, its speed decreases but its height increases and can reach 30 m or more.
- The wavelength of a tsunami can be 100 km or more, so once a tsunami hits the coast a second wave may not arrive for over an hour.

At the end of December 2004, a severe earthquake occurred in the sea off the west coast of Sumatra in Indonesia. This earthquake triggered a series of tsunamis along the coast of most countries bordering the Indian Ocean with devastating effects on anything that got in their way.

Kick-’em-Jenny

Kick-’em-Jenny is an active submarine (underwater) volcano on the Caribbean sea floor situated 8 km from Grenada. It rises 1300 km above the sea floor. Its first recorded eruption was in 1939, when it was reported that clouds of steam and debris were sent 275 m into the air. It generated a series of tsunamis that were 2 m high when they reached the coast of Grenada.

The volcano has erupted at intervals since 1939, the last eruption being recorded in 2001. Most of the eruptions are only detected by seismometers. The eruptions are heard underwater, or on land close by, as deep rumblings. In 2003, it was estimated that the summit of the volcano was 130 m below the surface of the sea.



▲ **Figure 16.10.3** The location of the underwater volcano Kick-’em-Jenny

16.11 Types of volcanic eruptions

A volcano is a gap in the Earth's crust through which a mixture of molten rock and gases called **magma** can escape. Heat and pressure build up inside the volcano until it is sufficient to cause an eruption.

Types of volcano

There are three types of volcano.

1 A **cinder cone volcano**, for example La Soufrière in St Vincent, is the familiar cone-shaped with a crater at the top. These volcanoes erupt explosively, throwing clouds of ash several kilometres into the air and belching avalanches of hot material down their sides. As this material spews out it rapidly cools and builds the cone shape.

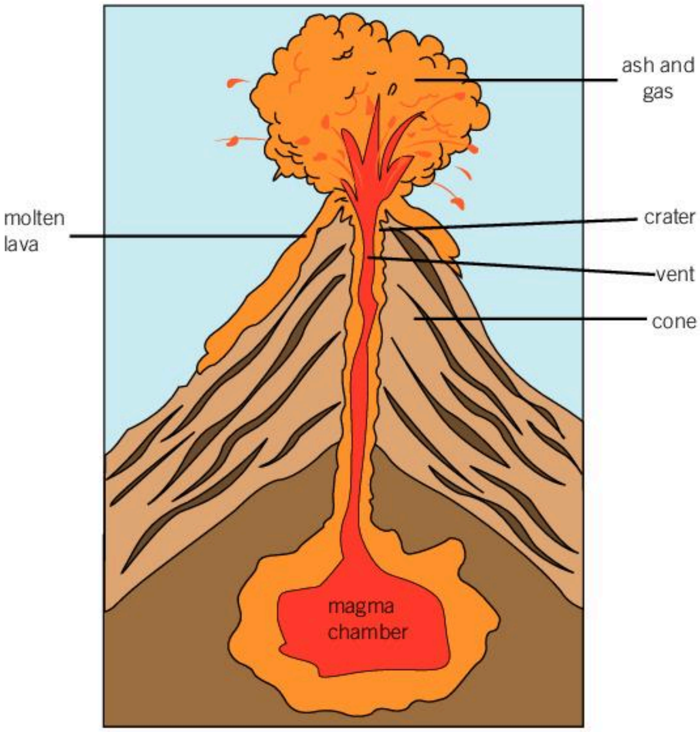
2 A **shield volcano** is wide and relatively short in height, with gentle slopes. It has this shape because it erupts in a mildly explosive way and has fluid lava that flows great distances before hardening. Shield volcanoes are common in Hawaii.

3 **Composite** or **strato-volcanoes** are steep-sided and cone-shaped. They are built from layers of lava, volcanic ash and cinders. During the eruption of Mount St Helens in the USA in 1980, a mushroom-shaped cloud of ash rose 24 km into the sky in just 15 minutes. A mixture of hot ash, pumice and gas poured out of the crater laying waste to the surroundings, and setting fire to a large area of forest.

Learning outcomes

By the end of this topic you will be able to:

- describe different types of volcano
- explain why there are volcanoes in the Caribbean
- describe some short-term and long-term consequences of volcanic eruptions.



▲ **Figure 16.11.1** The structure of a volcano

▲ **Figure 16.11.2** La Soufrière volcano, St Vincent

▲ **Figure 16.11.3** Ash plume from St Helens in 1980

Volcanoes in the Caribbean

Along its eastern and western boundaries, the adjoining plates (see 16.12) are being forced under the Caribbean Plate.

To the east, this has resulted in the formation of the volcanic islands of the Lesser Antilles. This boundary contains seventeen active volcanoes including La Soufrière on Montserrat, Mount Pelée on Martinique, La Grande Soufrière on Guadeloupe and a submarine volcano, Kick-'em-Jenny, 8 km north of Grenada.

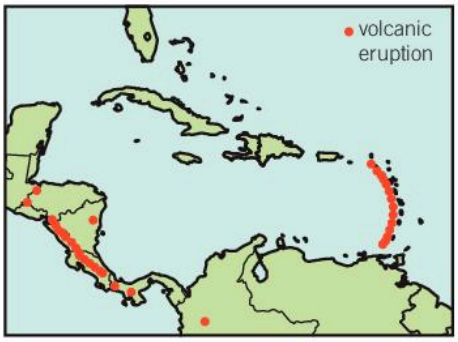
To the west, this has resulted in a string of volcanoes in Guatemala, El Salvador, Nicaragua and Costa Rica.

Ecological effects of volcanic eruptions

Volcanic dust produced during an eruption can be blown vast distances from the volcano. It can block out sunlight, damaging plants. The dust can damage dwellings and affect people who have respiratory illnesses.

In the short term, the hot magma will kill all plants and animals, including crops and livestock in the vicinity of the volcano. It may take many years for the ecosystems to recover after an eruption.

Over many years and repeated eruptions, volcanoes can change the shape of the land and the properties of the soil. In the long term, volcanic deposits can develop into rich and fertile soils that are ideal for farming. Hot springs may also form where volcanoes once erupted.



▲ **Figure 16.11.4** Lines of volcanoes are present to the east and west of the Caribbean Plate

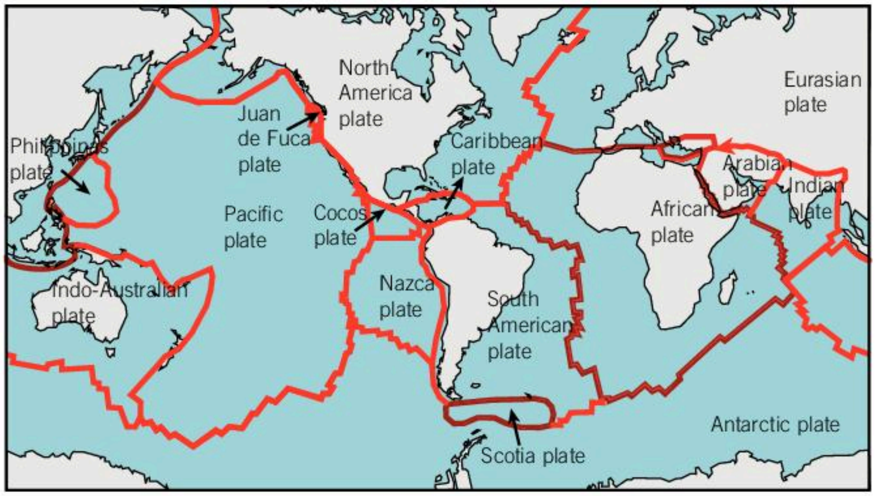
▲ **Figure 16.11.5** Lava flow from shield volcano

Questions

1. What is the mixture of molten rock and gas which escapes from a volcano?
2. Name the three types of volcanoes and give a short description of each type.
3. Explain why there are volcanoes in the Caribbean.
4. How does volcanic dust affect the environment?
5. Explain why volcanic deposits are ideal for farming.

16.12 Tectonic plates

The Earth's crust is composed of huge plates millions of square kilometres in area. These are called **tectonic plates**. You might think that these plates are not moving because the geography of the world does not change from day to day. However, there is evidence that the plates have moved large distances in the past and continue to move today, albeit very slowly.



▲ **Figure 16.12.1** The Earth's crust is composed of tectonic plates

Learning outcomes

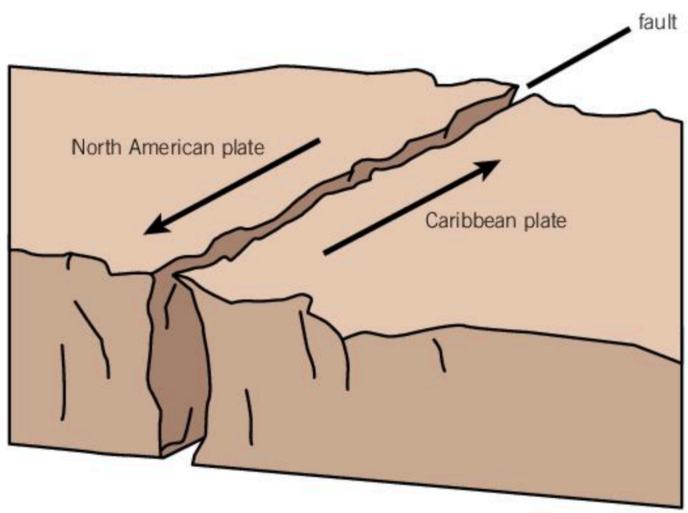
By the end of this topic you will be able to:

- describe tectonic plates
- state the position of the Caribbean Plate
- explain how earthquakes occur
- describe different types of seismic waves
- understand how seismic waves are measured and the relationship to the Richter scale
- explain why volcanoes occur along faults.

The Caribbean Plate

The Caribbean Plate underlies the Caribbean and Central America and is about 3.2 million square kilometres in area. Along the borders of the Caribbean Plate, where it meets the North American Plate, the South American Plate and the Cocos Plate, there are regions which experience frequent earthquakes, occasional tsunamis and volcanic eruptions.

Along its northern boundary, the Caribbean Plate is moving in the opposite direction to the North American Plate forming a fault.

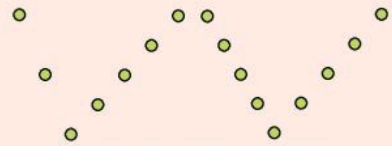


▲ **Figure 16.12.2** Earthquakes occur at strike-slip boundaries

Earthquakes

When plates meet, they may stick together creating a pressure build up. Rocks bend and buckle, and eventually snap and slip past each other resulting in an earthquake. The cracks that form when the plates slip are called **faults**. The area of a fault where the rock first slips is called the **focus**. Faults result in shock waves called **seismic waves** that spread out from the focus. If the shock waves are strong enough they will be felt as an earthquake. The **epicentre** of an earthquake is the region where the seismic waves are the strongest and where the greatest damage at the Earth's surface will occur.

▼ **Table 16.12.1** Types of seismic waves

Type of wave	Characteristics	
Pressure waves (P waves)	Result from movement of rocks. Compress the particles of ground together and then apart as occurs in sound waves (Topic 21.6). Travel through solids and liquids	 particles compressed; particles apart
Shear waves (S waves)	Result from movement of rocks. Waves move sideways, twist, shake and distort substances as they move though them. Only travel through solids	 particles are moved sideways
Surface waves (L waves)	Result when P and S waves reach the surface of the Earth. They travel along the surface of the Earth causing damage which is greatest at the epicentre	

▲ **Figure 16.12.3** A seismogram is a graph showing the type and size of waves. This seismogram shows an earthquake

Seismographs

Scientists measure the intensity of seismic waves using an instrument called a **seismograph**. The frequency and amplitude of the waves are recorded on a graph called a **seismogram**.

During an earthquake, a characteristic pattern on a seismogram appears. There are small P waves first, followed by larger S waves and then even larger L waves.

The magnitude of earthquakes is measured on the **Richter scale**. This uses the damage that occurs as a way of quantifying the magnitude of the earthquake.

! Key fact

Although Trinidad and Tobago are one country they are on different plates. Trinidad is on the South American Plate, while Tobago is on the Caribbean Plate.

▼ **Table 16.12.2** The Richter scale

Richter magnitude	Earthquake effects
< 2	Not felt
2.0–2.9	Not felt but recorded
3.0–3.9	Felt but rarely causes damage
4.0–4.9	Shaking of indoor items, rattling noise, minor damage
5.0–5.9	Poorly constructed dwellings will be badly damaged; well constructed buildings will be slightly damaged
6.0–6.9	Can be destructive in populated areas
7.0–7.9	Can cause serious damage over wide areas
8.0–8.9	Can cause serious damage over very large areas
9.0–9.9	Devastating damage to areas several thousand kilometres across
10.0+	Never recorded

Questions

1 Which plate is to the west of the Caribbean Plate?

2 Along which edge of the Caribbean Plate is there a strike-slip boundary?

3 Describe the characteristics of the three types of seismic wave.

4 How are seismic waves measured?

5 Explain the causes of earthquakes.

Volcanoes

You learnt about volcanoes in Topic 16.11. Volcanoes are similar to earthquakes in that they form at the edges of tectonic plates. This explains why there are several volcanoes in the Caribbean region. When two tectonic plates hit each other, one sometimes goes underneath the other and becomes very hot. The ground becomes molten, turns to liquid (magma) and if it finds a gap in the Earth's crust, there is a volcanic eruption.

16.13 Tides

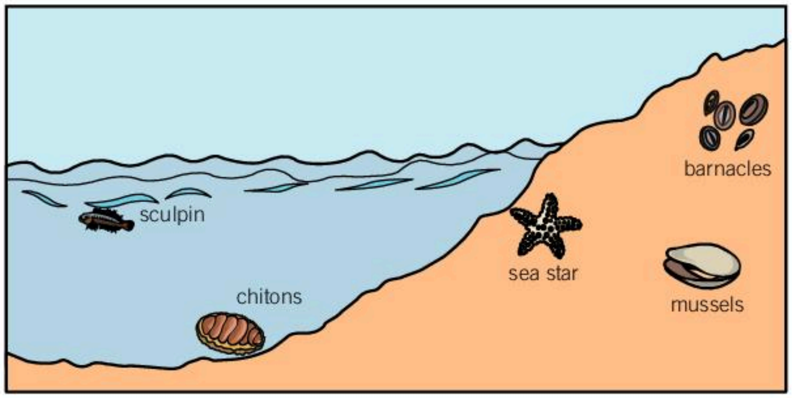
All surfaces of the Earth are pulled towards the Moon and the Sun. The effect of this, on the oceans, is to cause them to bulge on that part of the Earth facing the Moon and on the opposite side of the Earth. These bulges give rise to two regions of high tides. Between them are two regions of low tide. As the Earth spins on its axis, coastlines experiences two high tides and two low tides each day.

When the Moon, the Earth and the Sun are in line, the gravitational pull of the Sun and Moon are combined. This results in the highest high tide and lowest low tide in a particular month. These are called **spring tides**.

When the Moon, the Earth and the Sun are at right angles to each other the gravitational pulls of the Sun and Moon oppose each other. This results in the highest low tides and the lowest high tides. These are known as **neap tides**.

Life in tidal zones

Organisms that live on the sea shore, or in rivers, are adapted to the changes that occur as a result of the tides. The sea shore is mostly underwater at high tide and mostly exposed at low tide. Between the high and low tide marks is the **inter-tidal zone** where conditions continually change. Different organisms are adapted to living in different places on the shore. They must cope with changes in moisture, temperature, salinity and water turbulence. This brings about **zonation** in a shore ecosystem.



▲ **Figure 16.13.4** Different organisms are found in the inter-tidal zone

Another effect of the daily ebb and flow of the tides is the erosion of coastlines. Seawater dissolves minerals in the rocks and the kinetic energy of the moving water slowly breaks them down. As the seawater flows away from the land after high tide, it carries away tiny particles of rock.

Coastal erosion is often a very slow process but, over time, it may cause considerable changes to coastlines.

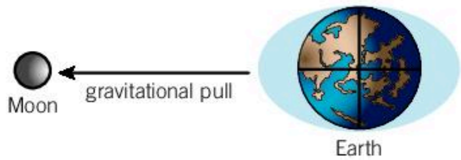
Questions

1 To which two forces are the oceans subjected?
2 Explain how high tides and low tides occur.
3 What is the frequency of high and low tides?
4 List four factors that are changing in the inter-tidal zone.

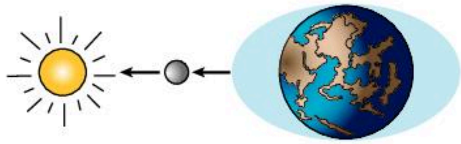
Learning outcomes

By the end of this topic you will be able to:

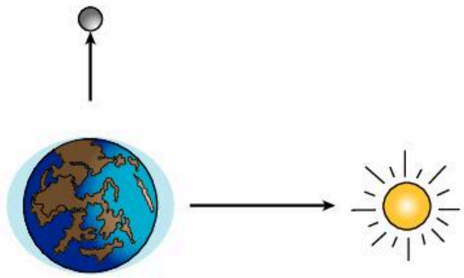
- explain how tides occur
- explain what spring and neap tides are
- explain how spring and neap tides occur.



▲ **Figure 16.13.1** The position of the Moon creates tidal bulges



▲ **Figure 16.13.2** Spring tides occur when the gravitational pull of the Sun and Moon are combined



▲ **Figure 16.13.3** Neap tides occur when the gravitational pull of the Sun and Moon are at right angles

Exam-style questions

Multiple choice

1 Nitrogen exists in the atmosphere as:

A nitrates **B** nitrous oxide
C nitrogen gas **D** nitrites

2 The table below shows the crop rotation on two farms, A and B, over a four-year period.

Year	Farm A	Farm B
1	cassava	peanuts
2	corn	beans
3	cassava	cassava
4	cassava	corn

Farm B produced high yields of crops compared to Farm A because:

A the soil in Farm B is more suitable
B the soil nutrients were replaced each year in Farm B
C Farm A had low rainfall
D the soil nutrients were leached out in Farm B

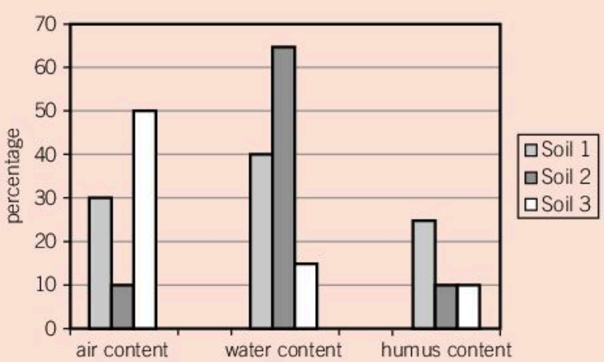
3 Loam soils are good for plant growth because:

I they have plenty of air
II they contain large quantities of humus
III they have good water retention
IV they contain mainly large particles

A II and IV
B II only
C I, II and III
D III and IV

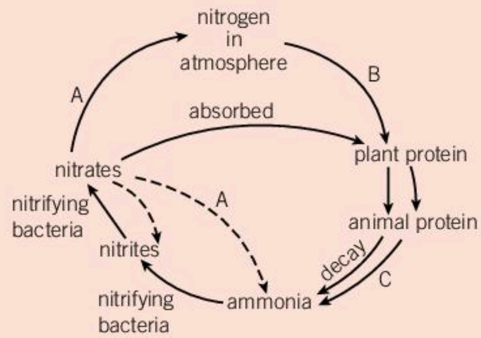
Structured questions

4 A student carried out an investigation to show the composition of three soil samples he collected from different plots in the school grounds. The bar graph below shows the results the student obtained.



a Draw a table to show the values on the graph.
b Which soil sample is most probably clay soil? Give a reason for your answer.
c Which soil will be most suitable for plant growth? Give a reason for your answer.

5 The diagram shows the nitrogen cycle.



a What are the processes A, B and C?
b Which group of bacteria is responsible for the process B?
c Where are these bacteria found?

6 a Copy and complete the table below.

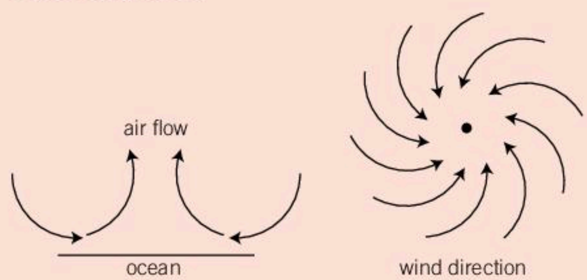
Type of erosion	Causes	Prevention methods
Sheet		
		Reduce overgrazing
Rill		

b Describe green fertilisers and give an example.
c Mention one way that the environment can be damaged by the application of too much chemical fertiliser.

7 a What is an air mass?
b What is the significance of air masses?
c Explain how a cold front forms.
d What type of weather is associated with a cold front?

8 Hurricanes frequently occur in the Caribbean.

a Use the diagrams below to explain how hurricanes form.



b **i)** What is the eye of a hurricane?
ii) Describe the conditions in the eye of a hurricane.

c **i)** Describe three safety measures that can be implemented to prepare for a hurricane.
ii) Explain why battery or gas operated appliances should be prepared.

d Name two hurricanes that have occurred in the Caribbean region in the last five years.

9 Earthquakes can result in damage to property and sometimes loss of life.

a What causes an earthquake to occur?

b **i)** What instrument is used to measure the intensity of an earthquake?

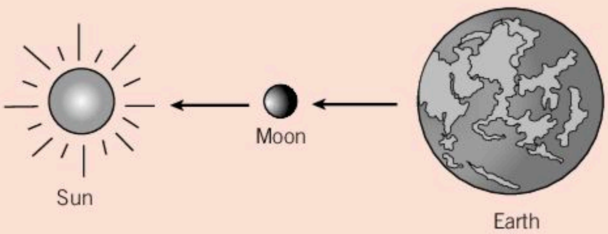
ii) What does this instrument detect during an earthquake?

iii) What scale is used to rate the severity of an earthquake?

c What is the epicentre of an earthquake?

d Name one Caribbean country that has experienced an earthquake recently.

10 **a** Use the diagram below to explain how tides occur on Earth.



b **i)** Explain how spring tides occur.

ii) How often do they occur?

11 Read the information about organisms that live in tidal zones and answer the question that follows.

The inter-tidal zone represents a transition area sandwiched between marine and terrestrial environments. In this ecosystem a purely aquatic community of organisms gives way to an air breathing community, often over a distance of no more than a few metres. The narrow strip between high and low water represents a unique habitat in its own right. Its occupants must be able to survive alternating periods of submersion in seawater and exposure to air, the latter sometimes accompanied by scorching heat. The proportion of time the shore is submerged naturally decreases the further up the shore you are and this in turn determines which species can survive at any particular point. The narrow inter-tidal habitat can be subdivided into a number of distinct zones. The range of climatic conditions experienced across each of these zones may be as great as those across the whole spectrum of terrestrial ecosystems.

Use your own words to describe the conditions that organisms must be able to withstand in the inter-tidal zone.

Section C

17 Water and the aquatic environment

Learning outcomes

By the end of this topic you will be able to:

- state that water is essential for all life
- give examples of ways in which the body receives water
- state ways in which people use water.

▲ **Figure 17.1.1** Sprinkler jets irrigating a vegetable field

Exam tip

In science we measure volume in litres (l), cubic centimetres (cm^3) or cubic decimetres (dm^3). 1 gallon is approximately 4.5 l or 4.5 dm^3.

Water is essential to all living things. People use water in lots of different ways. The water cycle provides us with a continuous supply of fresh water. However, since we use so much water, we should try to conserve it. Water provides a habitat for many plants and animals which are adapted to live in either fresh water or seawater.

17.1 The uses of water

Water – essential for life

Water is an essential substance for the survival of all living things. All chemical reactions that take place in our bodies do so in solution. When a substance is dissolved in water it forms an **aqueous** solution.

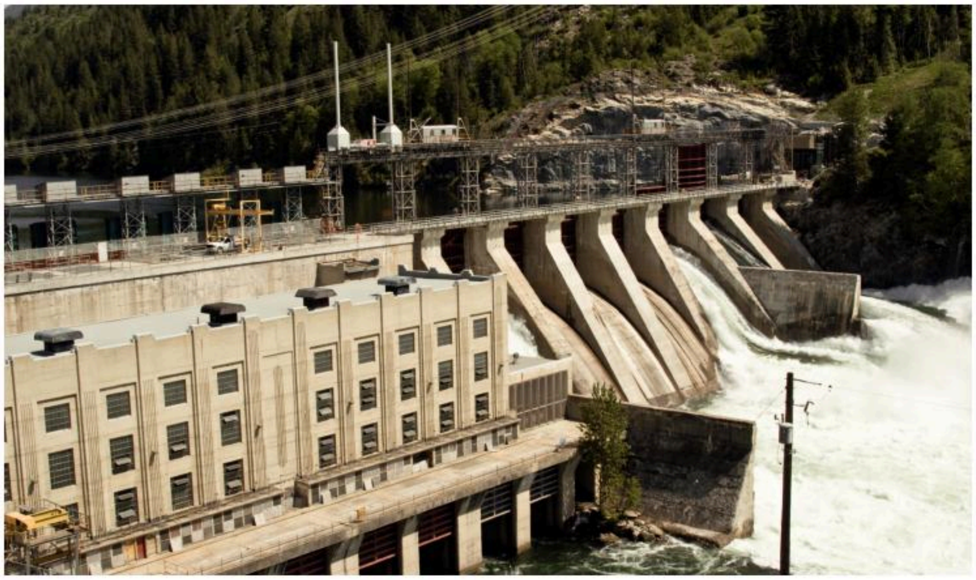
To remain healthy, an adult male needs to take in around 6000 cm^3 of water each day. Many drinks, such as cola and squash, and foods, such as fruits and fresh vegetables, contain a high proportion of water. People can survive for many days without food but only a few days without water.

Water is also essential for plants. Farmers and gardeners water, or irrigate, their crops in dry weather to prevent the plants from shrivelling and dying.

How we use water

▼ **Table 17.1.1** How we use water

Water is used in the home for:	Industrial and agricultural uses include:	Many leisure activities are based on water. These include:	Water is a habitat for large numbers of living organisms. The water provides:
• washing clothes, washing dishes and cleaning • flushing the toilet • bathing • cooking • drinking • watering gardens	• the manufacture of goods • mining • irrigation of crops • hydroponics • providing water for animals • cleaning crops before marketing • generating hydroelectric power • transport of goods and people • fire fighting	• swimming • sailing • fishing • water-skiing	• support • oxygen for respiration • submerged plants with carbon dioxide • food for aquatic animals



▲ **Figure 17.1.3** Water can be used to generate electricity

▲ **Figure 17.1.2** Water flushes waste down the toilet

Questions

1 How much water does an adult male need each day?

2 Make a list of all of the different ways in which your family use water each week. Alongside each one, say if you think it is essential or if it is something you could do without for a while if there was a shortage of water.

3 List the sources of water in your diet. From which source do you get most of your water?

Key fact

Hydroponics is the practice of growing plants in a nutrient solution without soil.

Synoptic link

See Topic 2.2 Methods of asexual reproduction in plants and animals.

Did you know?

An typical family of two adults and two children uses between 50 000 and 70 000 cm^3 of water each day for drinking, cooking, cleaning, washing, bathing and flushing the toilet.

17.2 Water treatment

Learning outcomes

By the end of this topic you will be able to:

- explain why water must be treated
- describe the different methods of water purification
- describe methods of desalination.

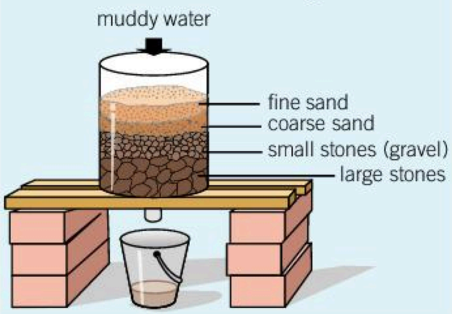
Synoptic link

See Topic 14.4 Methods of separation

Practical activity 17.2.1

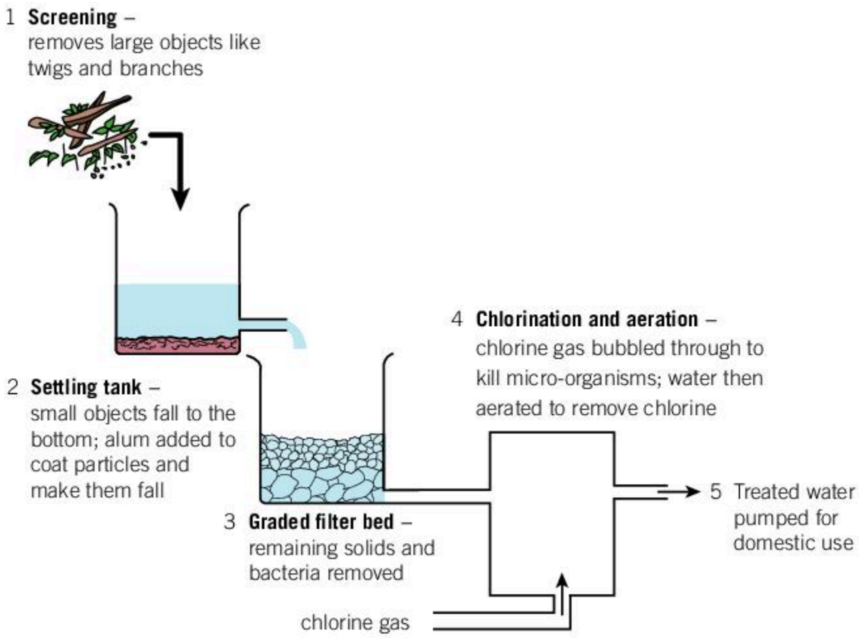
Filtering dirty water

1. Set up the apparatus as shown in the diagram.
2. Pour muddy water into the filter.
3. What colour was the muddy water after it had been filtered?
4. Do you think you could use this water for drinking?



The water that is piped to our homes comes from sources such as dams, lakes and rivers. It is sometimes cloudy and may contain harmful micro-organisms, so it must be **purified** before it is safe to use.

Large-scale water purification is needed for the provision of water for our homes. The stages in water treatment that this involves are shown in the diagram.



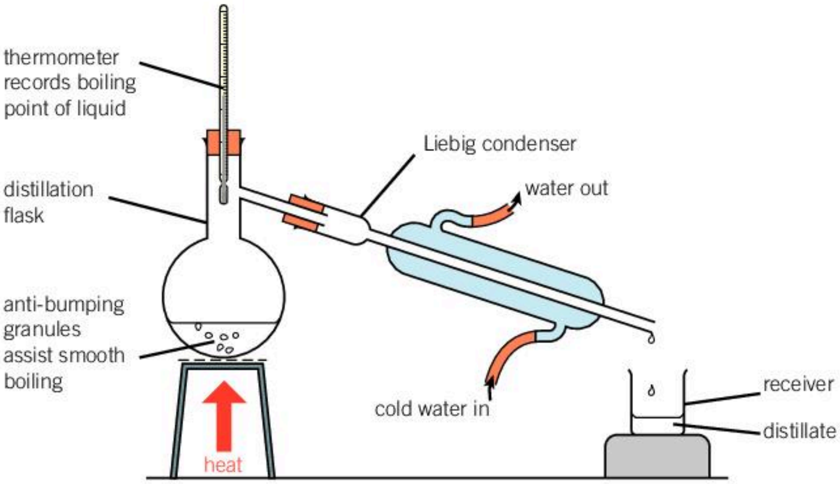
▲ **Figure 17.2.1** Stages in water treatment

Water can be purified at home by boiling, filtering, chlorinating and adding alum. Water must always be allowed to stand to allow particles to sink to the bottom. Alum powder can be used to speed up the settling process. It coats the particles, makes them heavier and they sink more quickly.

- **Boiling:** Boiling for 15 minutes kills all micro-organisms. After boiling the water should be cooled.
- **Chlorination:** Eight drops of chlorinated bleach can be added to a gallon of water. It should be stirred and then left for 30 minutes. The chlorine kills all micro-organisms.
- **Distillation:** This is a method of purifying seawater by removing the salts from it. This is discussed in the next section.

Desalination

In some countries seawater is an important raw material for making fresh water. The simplest method of separating the water from the dissolved solids is by simple **distillation**.



▲ **Figure 17.2.2** Distillation apparatus

Thermal desalination plants work on exactly the same principle but on a much bigger scale. Fossil fuels are used to heat the seawater.

▲ **Figure 17.2.3** A thermal desalination plant

Desalination is growing in importance in the Caribbean as the demand for fresh water increases every year. Since 2007, over 60 new desalination plants have been built across the region, producing more than three-quarters of a million cubic metres of purified water every day.

A major drawback to thermal desalination is the high cost of the fuels and the environmental impact of burning them. An alternative method of desalination by **reverse osmosis** does not require expensive fuels. Many think this process will replace thermal desalination in the future.

Practical activity 17.2.2

Distillation

Skills assessed: Manipulation/ Measurement.

Your teacher will supply you with a distillation apparatus like the one shown in the diagram and some seawater.

1. Half-fill the flask with seawater and add a few anti-bumping granules.
2. Connect the flask to the condenser and heat it.
3. Record the temperature at which the seawater boils.
4. Collect the distillate in a clean beaker.
5. Taste the distillate to confirm it is fresh water.

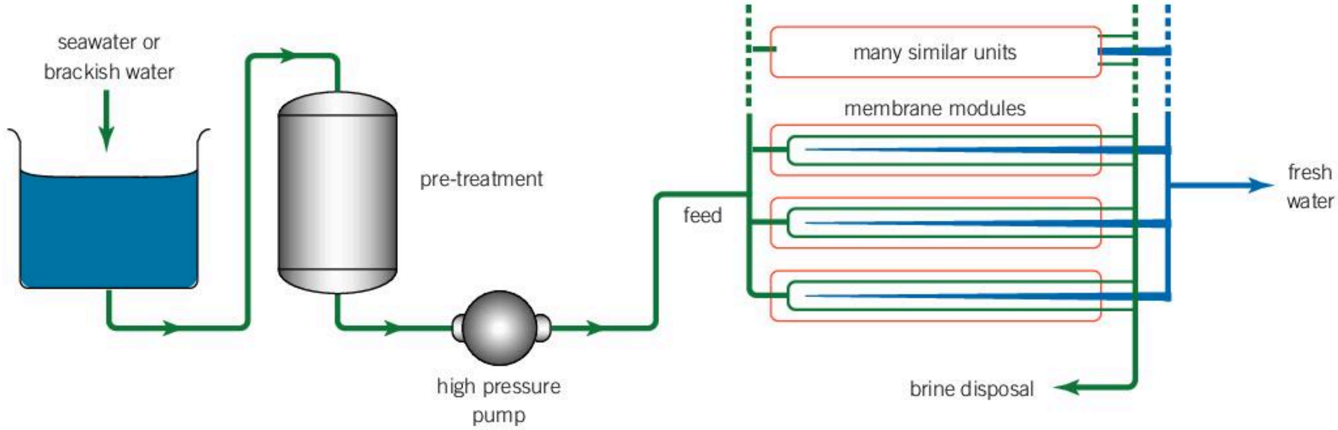


Figure 17.2.4 Reverse osmosis removes some fresh water from seawater

Desalination is the only source of fresh water for the island of Aruba.

▲ **Figure 17.2.5** Desalination plant at Aruba

A new reverse osmosis plant is being built on Aruba to replace the old thermal desalination plant. It will produce 24000 cubic metres of fresh water each day to supply the island's needs.

Questions

1 In large-scale water treatment, explain how micro-organisms are removed.

2 Why is water aerated before it is pumped into houses for domestic use?

3 What is the function of 'alum' in the purification of water?

4 Explain the principles behind the distillation process.

5 Describe how reverse osmosis is used in desalination.

17.3 The properties of water

Properties of pure water

Fresh water can be described as pure if it does not contain any impurities. Seawater contains dissolved salts.

Pure water has the following properties:

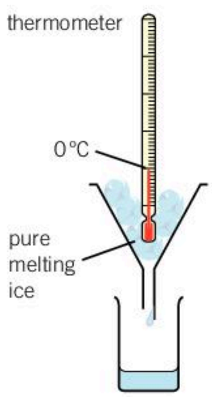
- it is a colourless, tasteless and odourless liquid
- it boils at 100 °C and freezes at 0 °C at sea level
- it has a density of 1 g/cm^3
- it has a high heat capacity
- it is a polar molecule.

Melting point and boiling point

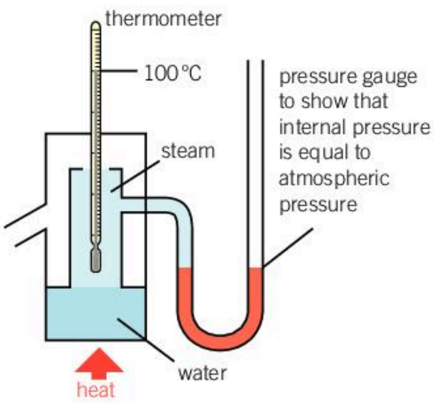
The melting point of ice and the boiling point of water are much higher than other molecules of similar size. A lot of energy is needed to overcome the forces of attraction between water molecules.

The melting point of ice is determined by measuring the temperature of melting crushed ice in a funnel. Ice melts at 0 °C.

The boiling point of water is determined by measuring the temperature of the steam above boiling water and not the boiling water itself. Water boils at 100 °C at normal atmospheric pressure.



▲ **Figure 17.3.1** Ice melts at 0 °C



▲ **Figure 17.3.2** Apparatus used to determine the boiling point of water

Exam tip

When you give the boiling point of a liquid you should state that it is at normal atmospheric pressure. The boiling point of a liquid varies with external pressure. Up a high mountain, where atmospheric pressure is less, water boils well below 100 °C.

Learning outcomes

By the end of this topic you will be able to:

- list the properties of water
- describe the melting point and boiling point of water
- describe the effect of dissolved substances on the melting point and boiling points of water
- describe how the volume of most substances decreases with decreasing temperature
- explain the unusual density of water
- explain why ice floats
- explain why fish are able to survive in a frozen pond
- appreciate that water is a common solvent
- describe a test for the presence of water
- explain the effects on blue copper sulphate of heating and then the addition of water to the residue
- state that fresh water often contains dissolved solids
- understand what the salinity of seawater is
- describe the effect of water on aquatic life.

Key fact

The water molecule is said to be polar. The attraction between the positive end of one molecule and the negative end of another has a significant effect on the physical properties of water.

Key fact

The heat capacity of a substance refers to the amount of heat needed to raise 1 g of the substance by 1 °C.

The presence of dissolved salts in a liquid causes a decrease in the temperature of its melting point and an increase in the temperature of its boiling point.

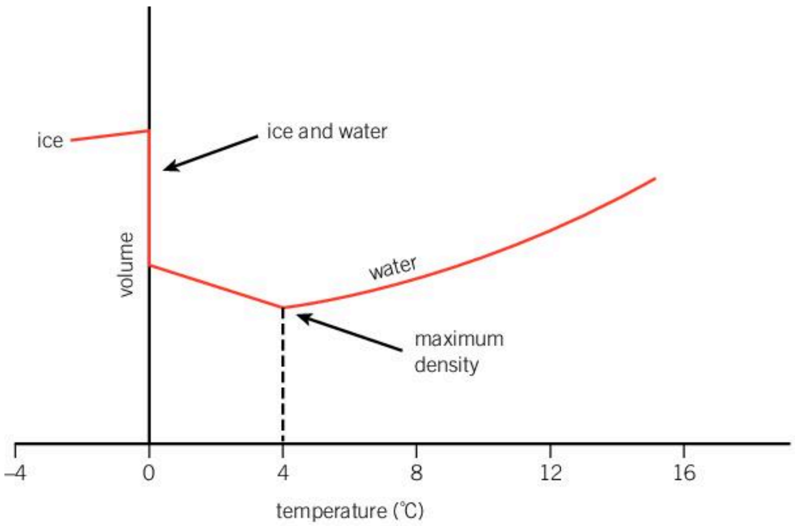
Seawater is not a chemical compound but a mixture. The composition of seawater varies from place to place but it is typically around 3.5% dissolved solids. Seawater of this composition melts at –1.8 °C and boils at 100.56 °C.

The unusual expansion of ice

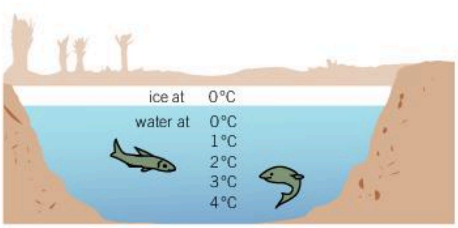
When most liquids are cooled and become solids, they contract. The volume of the solid is less than the volume of the liquid from which it forms. The solid is therefore denser than the liquid and, if it is placed in more liquid, it will sink.

When cooled, water contracts down to 4 °C but then it starts to expand. At 0 °C the volume of ice is greater than the volume of water from which it forms. This is a result of the way in which water molecules are arranged in ice. This is why ice cubes float in a cold drink.

When a pond freezes, ice covers the surface. However, the denser water remains below the ice so fish can survive under the ice.



▲ **Figure 17.3.3** The maximum density of water occurs at 4 °C



▲ **Figure 17.3.4** Fish can survive because there is water below the ice

Practical activity 17.3.1

The expansion of ice

Skills assessed: Analysis and Interpretation.

Your teacher will supply you with a small glass drink bottle and a plastic drink bottle with screw caps, and two thick polythene bags.

1. Completely fill the two bottles with water and place the caps on tightly.
2. Put the bottles in the polythene bags and secure the tops.
3. Place the bags containing the bottles into a deep freezer overnight.
4. Carefully examine the contents of the polythene bags the next morning.
5. Compare what happened to the bottles.
6. Explain why this happened.
7. What was the purpose of placing the bottles in polythene bags?

Surface tension

The attraction between water molecules results in a 'skin' on the surface of water which we call surface tension.

▲ **Figure 17.3.5** Surface tension can support these insects as their weight is spread out

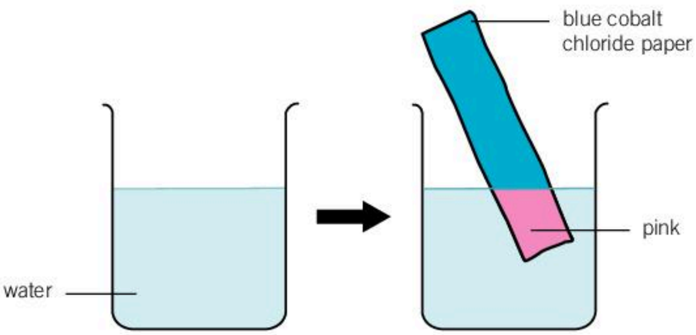
Small insects are able to walk on water because the surface tension is strong enough to support their weight.

Water as a solvent

Water is a good solvent because it is a polar molecule. Ionic and covalent polar molecules dissolve in water. The solvent properties of water make it ideal as the medium in which the chemical reactions in cells take place.

Testing for the presence of water

We can test for the presence of water using **blue cobalt chloride paper**. If water is present this paper will turn pink.



▲ **Figure 17.3.6** Water turns blue cobalt chloride paper pink

Dissolved solids in water

As fresh water flows over rocks, certain minerals dissolve in it. You have already learnt in Topic 14.7 how these dissolved solids are responsible for water hardness.

The amount of dissolved solids in water can be found by evaporating a known volume of the water to dryness and measuring the mass of solid which remains.

The label on bottled water often tells you the total amount of dissolved solids it contains.

Practical activity 17.3.2

Investigating surface tension

Your teacher will give you a beaker, a small needle, some tweezers and soap solution.

1 Make sure the beaker is clean and add clean water until it is almost full.
2 Pick up the needle lengthways with the tweezers and carefully lay it on the water. With some care and patience you can get the needle to float.
3 When the needle is floating, add a drop of soap solution to the water.
4 What force is supporting the needle when it floats?
5 What happened when you added the drop of soap solution?
6 Explain your observations.

Ingredients: Purified Water, Sodium Chloride, Magnesium Sulphate, Potassium Chloride.	
TYPICAL ANALYSIS Servings Per Container 2.5 Calories	 0
	PPM
Total Dissolved Solids	<75
Magnesium	2
Sodium	17
Sulphate	7
Potassium	2
Chloride	32
Fluoride	<0.1
Calcium	1

▲ **Figure 17.3.7** Contents label on a bottle of water

Practical activity 17.3.4

Effects of heat on blue copper sulphate

Skills assessed: Observation/Recording/Reporting.

Your teacher will supply you with some blue copper sulphate in a hard glass boiling tube and some blue cobalt chloride paper.

1 Heat the blue copper sulphate gently until no further change occurs.
2 If you see some drops of liquid at the top of the boiling tube where it is cooler test them with the blue cobalt chloride paper.
3 Leave the boiling tube to cool.
4 Once the boiling tube is cool (and not before) add a few drops of water to the contents.
5 What colour does copper sulphate turn when heated?
6 What liquid was given off?
7 What happened when water was added to the contents of the boiling tube?
8 Suggest why this is described as a reversible reaction.

Questions

1 The chemical formula for water is H_2O. What information does this give about the composition of a water molecule?
2 What observation demonstrates that the density of ice is less than the density of water?
3 How is it that some insects can walk on water?
4 How does seawater differ from fresh water?

Practical activity 17.3.3

Dissolved solids in water

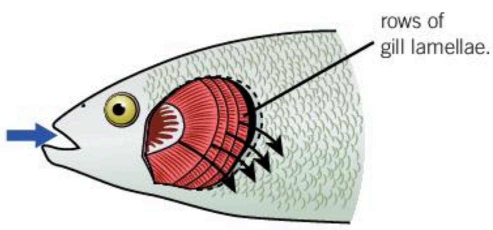
Skills assessed: Observation/Recording/Reporting.

Your teacher will supply you with three microscope slides, a dropper pipette and three different samples of water: distilled water, tap water and seawater. The samples will be labelled A, B and C. It is your task to identify each sample.

1 Wipe the microscope slides with a damp tissue to ensure they are clean.
2 Clean the dropper each time you use it.
3 Place three drops of sample A on a microscope slide taking care that none of the water runs off.
4 Place three drops of sample B on a second microscope slide.
5 Place three drops of sample C on a third microscope slide.
6 Make sure you label the slides in some way.
7 Leave the slides in the sun until all of the water has evaporated from them.
8 Draw the slides.
9 Which sample is the distilled water, which is tap water and which is seawater? Explain how you know.

Water and aquatic life

Organisms that live in an aquatic environment are continually surrounded by water. They have some features which are different to terrestrial organisms that live on land.



▲ **Figure 17.3.8** Fish have gills in place of lungs

Aquatic organisms don't have to worry about drying out, so they don't need to conserve water in their bodies like land animals and plants. They absorb the oxygen they need for respiration directly from the water.

Fish have gills rather than lungs. Gaseous exchange takes place as the water passes over the rows of gill lamellae. Gaseous exchange occurs in the gill lamellae. The gill rakers remove particles from the water before it passes over the lamellae.

Seawater contains a lot more dissolved solids than fresh water and the most common solid is salt – sodium chloride. The amount of salt in seawater is given by its salinity. The salinity of seawater varies typically from 3.5% to 4.0%. It tends to be lower in cold seas, especially in the summer when icebergs begin to melt. Conversely, salinity tends to be higher in warm seas in areas where there is little rainfall.

Most fish can only live in either fresh water or seawater, although there are some fish that live in river estuaries where the water is slightly salty.

17.4 Flotation

Upthrust

If you try to push a ball down into water, you will feel a force pushing up on you. If you lift a heavy weight in air and then put the same weight into water, you will find that it is easier to lift in the water. This is because when objects are totally, or partly, submerged in a liquid there is a force pushing upward on them. This force is called the **upthrust**.

The weight of the stone in Figure 17.4.1 is 8 N when it is weighed in air. When the same stone is immersed in water, the reading on the spring balance is only 6 N. The difference in the readings is 8 – 6 = 2 N, so the upthrust pushing on the stone is 2 N.

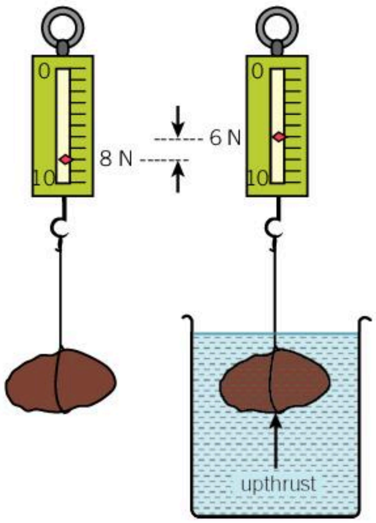


Figure 17.4.1 An object immersed in a liquid experiences an upthrust

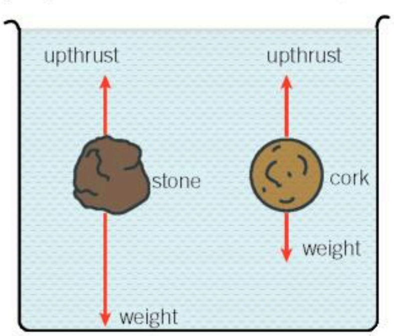
Archimedes' principle

When any object is held in a liquid, it pushes aside or displaces some of the liquid. The volume of the liquid displaced is equal to the volume of the object.

Archimedes' principle states that when a body is wholly or partially immersed in a fluid (liquid or gas) the upthrust is equal to the weight of fluid displaced.

Since the weight of an object always acts vertically downwards, the upthrust on the object always acts vertically upwards. Whether an object sinks or floats depends on its weight and the upthrust it receives.

- If the upthrust and the weight are equal, the object will stay still.
- If the weight is greater than the upthrust, the object will sink downwards.
- If the upthrust is greater than the weight, the object will float upwards.



▲ **Figure 17.4.2** Objects of the same volume experience the same upthrust when immersed in a liquid

Learning outcomes

By the end of this topic you will be able to:

- state that upthrust is an upward force that an object receives from a liquid or gas
- state Archimedes' principle
- explain the implications of Archimedes' principle for objects floating or sinking
- state a formula for density
- explain what determines whether an object will float or sink in a liquid in terms of densities
- state that the density of fresh water is less than that of seawater
- describe how the density of water varies with temperature
- explain the purpose of Plimsoll lines.

Did you know?

Archimedes was an Ancient Greek scientist who lived in Syracuse, Sicily in the 3rd century BC. He studied floating and sinking objects, and devised the principle that is named after him.

Key fact

Archimedes' principle refers to fluids. The word fluid can mean a liquid or a gas.

Key fact

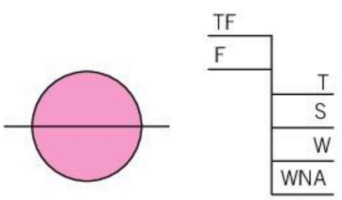
weight = mass × g
where g is the acceleration due to gravity.
g is approximately equal to 10 m/s²

Exam tip

Make sure you know the difference between mass, weight, volume and density.

Did you know?

Plimsoll lines are named after Samuel Plimsoll, a British politician who devised them in the late 19th century.



TF	fresh water in the Tropics
F	fresh water
T	salt water in the Tropics
S	salt water in the Summer
W	salt water in the Winter
WNA	winter in the North Atlantic

Figure 17.4.3 Plimsoll lines

If you hold a stone beneath the surface of some water, it will sink when you release it. This means that its weight must be greater than the upthrust acting on it. If you do the same with a cork of the same volume it will float to the surface.

The stone and the cork displace the same volume of water, and therefore the same weight of water, so they receive the same upthrust. The stone sinks because its weight is greater than the upthrust, whereas the cork rises because its weight is less than the upthrust.

Upthrust and density

A large steel ship floats on water but the same weight of steel in a block will sink. The sheets of steel that make up the ship weigh the same no matter how they are put together. The difference is in the volume (and therefore weight) of water that they displace.

The density of an object is given by the equation:

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

The steel ship will have a bigger volume than the steel block and therefore have a smaller density. The ship will sink down in the water until it has displaced enough water to create an upthrust equal to its weight. At that point the ship stays at that level in the water. The steel block cannot displace enough water to create an upthrust equal to its weight and therefore it sinks.

- If an object is more dense than the liquid in which it is placed, it will sink. The liquid displaced weighs less than the object so the upthrust is less than the weight of the object.
- If the object is less dense than the liquid in which it is placed, it will float because it can displace the weight of liquid needed to receive an upthrust equal to its weight.

From Archimedes' principle, it follows that when an object floats it displaces the weight of the fluid in which it floats equal to its own weight.

Shipping in different waters

Pure water has a density of approximately 1 g/cm³. Seawater has salts dissolved in it, making its density greater than that of pure water. This means that it is easier to float in seawater. Cold water is more dense than warm water, so it is easier to float in cold water.

If a ship moves from seawater to fresh water, or from cold water to warm water, the upthrust on it will be less so the ship will be lower in the water.

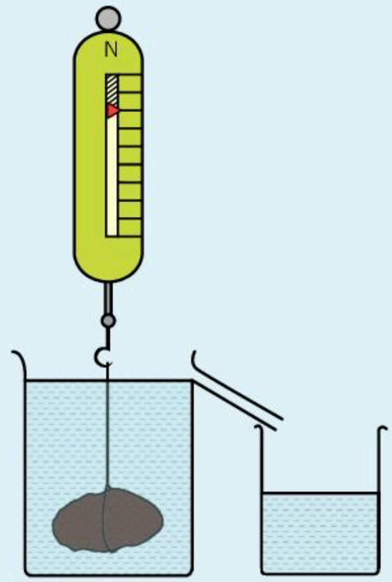
When a ship is built, calculations are made to determine the level to which it can be safely loaded in different waters at different temperatures. A series of lines, called **Plimsoll lines**, are painted on the side of the ship's hull to indicate these levels.

Practical activity 17.4.1

Upthrust and density

Skills assessed: Observation/Recording/Reporting and Manipulation/Measurement.

1 Find the mass of a dry beaker.
2 Place another beaker under the spout of a displacement can. Fill the can until water runs from the spout.
3 When the water has stopped dripping remove the beaker and replace it with the dry one.
4 Tie a string tightly around a stone and hang it from a spring balance. Record the weight of the stone in air as displayed on the spring balance.
5 Carefully lower the stone into the displacement can. When it is completely immersed record the new weight displayed on the spring balance.
6 The displaced water is caught in the beaker. When no more water drips, remove the beaker and find the mass of the beaker and water.
7 Subtract the mass of the dry beaker to find the mass of the displaced water.
8 Calculate the weight of the displaced water by multiplying the mass by g (10m/s).
9 Compare the apparent loss in weight of the stone to the weight of the water displaced. What conclusion can you make about Archimedes' principle?



Questions

1 A metal block has a mass of 60 kg and a volume of 0.05 m^3. What is the density of the metal?
2 Explain why a wooden block floats in water, while a metal block of the same size sinks.
3 A solid has a mass of 3 g and a volume of 6 cm^3. Will it sink or float in water?
4 Explain why an iron nail sinks in water but floats on mercury.
5 A loaded ship travels from cold salt water into warm fresh water. Describe what will happen to the level of the ship in the water.

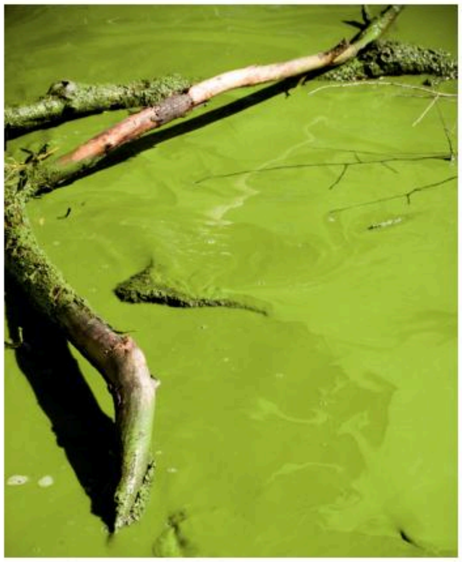
Did you know?

A cork which is less dense than water will float with most of its volume out of the water, whereas a lump of ice which has a density closer to that of water will have about nine-tenths of its volume under the water.

Learning outcomes

By the end of this topic you will be able to:

- state the causes of water pollution
- describe the steps in the process of eutrophication
- explain how pollutants may be passed along a food chain
- discuss the problems caused by a major pollution incident at sea like a large-scale spillage of crude oil.



▲ **Figure 17.5.1** Lake discoloured by algal bloom

Questions

1 What are the possible causes of water pollution?
2 How do pesticides get into water?
3 What happens to pesticides like DDT in a food chain?
4 Explain how eutrophication occurs.
5 Why are fish killed as a result of eutrophication?

17.5 Water pollution

Pollution is the contamination of a land, air or water environment with harmful or poisonous substances. Water pollution can occur for several reasons:

Eutrophication

The term **eutrophication** is used to describe the effect on fresh water rivers and lakes of the addition of large quantities of nitrates and phosphates from excessive use of fertilisers. Here is what happens:

1 The nitrates and phosphates encourage the rapid growth of algae, forming an 'algal bloom'.
2 The algae cover the surface of the water and prevent light from reaching plants growing below them.
3 The plants die and begin to decompose.
4 The decomposer (micro-organisms) need oxygen for respiration and as their numbers increase more oxygen is absorbed from the water.
5 Eventually the concentration of oxygen in the water is insufficient for fish, and they suffocate and die.

Pesticides

Pesticides applied to crops may wash off into rivers and lakes. They may poison aquatic organisms and terrestrial animals which eat them. The insecticide DDT is very effective. Its use is banned in many countries because of its toxicity once it enters a food chain.

At one time, it was spread on water to kill mosquito larvae but before the larvae died, many were eaten by small fish and the DDT was passed on to the fish to be stored in the liver. The small fish were, in turn, eaten by larger fish and the larger fish by birds, such as ospreys.

mosquito larvae ⟶ small fish ⟶ large fish ⟶ birds that eat fish

At each step, more and more DDT accumulated in the body of the animal. High concentrations of DDT in birds caused them to lay eggs with such thin shells that many cracked and few chicks were born.

Oil spillage

When crude oil from tankers spills into the sea, it floats on the surface of the water. It prevents oxygen from dissolving in the water. Organisms living on the surface, such as sea birds, rapidly become coated in crude oil and are unable to fly. When they attempt to preen their feathers, they ingest crude oil and eventually die.

As a result of wave action, the crude oil and seawater are whipped together, and form a mousse. After some time, this sinks to the seabed where it covers coral and any other organisms living there. Some oil may be washed up on beaches, where it kills plants and animals that live in the tidal margins. It leaves an unsightly sticky brown mess on sand and rocks.

Some cleaning is possible after an oil spill but in many instances there is little that can be done but leave nature to repair the mess. There are bacteria that feed off crude oil and over time they will break the crude oil down into products that can be washed away by the action of the sea.

17.6 Fishing

Fishing

Fish is an important part of people's diet in many countries, including those of the Caribbean. It is a good source of protein and has fewer lipids than meat obtained from terrestrial animals. Fish also contains essential oils and vitamins that help to keep people healthy.

Some fish are obtained from fresh water but most commercial fishing is carried out at sea. There are a number of ways in which fish are caught.

Hobby fishing

Fishing is a popular hobby and many people catch a small number of fish for their own table. Two methods are used by hobby fishermen:

- Spearing – a spear is thrown or fired from a spear gun.
- Rod and line – a bait is placed on a hook attached to a line.

Commercial fishing

Commercial fishermen must use methods that will catch a large number of fish. These methods include:

- Some fishermen put out **pots** or **traps** containing bait. They mark the position of their traps with buoys. The fish enters the trap, attracted by the bait and cannot escape back out again.
- Fishermen sometimes use very **long lines**, which have many baited hooks attached to them. This method can catch fish living at different depths in the water.
- Many fishermen use **nets** in one way or another. Drift nets are large nets suspended by floats. They hang vertically down in the water and can extend from 5 to 50 km in length. They are used to catch shoals of fish. Purse seiners are boats that detect shoals of fish and then launch their nets in a circle around the shoal. When the circle is complete, the net sinks to the correct depth and is then drawn in. The shoal is brought to the side of the boat and taken on board.
- Trawlers use nets to fish in deeper water. The net is dragged along underwater by one or two ships. Fish trapped in the **trawl net** find it difficult to swim back out.

Fish farming

Fish farming has been practised in some parts of the world for many years but has increased in importance recently due to the decrease in fish stocks in the oceans. In the Caribbean, fresh water fish, such as tilapia and silver carp, are farmed in Cuba and Jamaica. There is very little fish farming in any of the other Island States. The islands do have a favourable environment for the development of fish farming and the benefits of such systems are:

- a controlled supply of fish
- fish have an optimum growth rate
- disease-resistant fish can be reared.

Learning outcomes

By the end of this topic you will be able to:

- discuss the importance of fishing for some communities
- explain the difference between hobby fishing and commercial fishing
- describe some methods used by hobby fishermen
- describe some methods used by commercial fishermen.

Figure 17.6.1 A fishing boat

Questions

1. Which important type of nutrient is provided by fish?
2. Why would a rod and line not be a sensible way for a commercial fisherman to fish?
3. What is the difference between a trap and a baited hook?
4. What are the disadvantages of using nets to catch fish?

Learning outcomes

By the end of this topic you will be able to:

- state the need for navigation at sea
- describe the magnetic compass and how it works
- explain the use of sonar, radio and GPS in navigation.

Practical activity 17.7.1

Using a magnet to find North

Your teacher will supply you with a small bar magnet, a cork and a plastic bowl.

1. Fill the plastic bowl with water and stand it on a flat surface.
2. Place the cork in the centre of the bowl of water and place the magnet on the cork.
3. Gently turn the magnet around and then leave it to settle.
4. In which direction is the N pole of the magnet pointing?
5. Repeat the process several times.
6. What do you notice about the direction of the magnet each time?
7. Why should a galvanised iron bowl NOT be used for this experiment?

▲ **Figure 17.7.3** Radar screen on bridge of ship

17.7 Navigational devices used at sea

There are few indicators at sea to tell fishermen exactly where they are. In the past fishermen relied on a **compass** to find their way. Modern fisherman can use radar and satellite navigation to find their position far more accurately than with a compass. It prevents fishermen becoming lost at sea and may also provide them with information concerning the state of the sea or the weather.

Compass

A compass is a magnetic needle which is mounted on a pin so it is free to spin around. The point on the compass always points north. This means that the fishermen can always tell in which direction they are going. Compasses on boats are mounted on gimbals, which allow the compass to always be horizontal no matter how much the boat moves up and down.

▲ **Figure 17.7.1** Fishermen used to rely on compasses

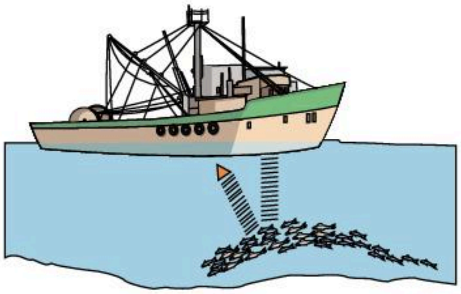


Figure 17.7.2 Fishermen use sonar to locate shoals of fish

Fishermen use echo sounders or sonar to find fish. The echo sounder sends short pulses of sound through the water surrounding a fishing boat.

If the sound waves strike a shoal of fish they are reflected back and detected by an operator in the boat.

Radar uses electromagnetic waves to detect the range, direction and speeds of objects. There is a transmitter that emits the waves, which are scattered when they come into contact with an object. A receiver detects the signal which is reflected back from the object. There is a slight change of wavelength or frequency in the returned signal if the object is moving.

GPS (Global Positioning System) is a global navigation satellite system that can be used worldwide by anybody, day or night, in all weathers and anywhere on earth. GPS satellites broadcast signals from space and a person with a GPS receiver can obtain a three-dimensional location giving the latitude, the longitude and the altitude at a certain time. It is the basis of navigation systems used on land, sea and air and is particularly useful for fishermen.

Questions

1. Explain how a compass is used to help fishermen find their way at sea.
2. As well as helping fishermen to discover shoals of fish, describe other ways in which radar is of use.
3. How is a fisherman able to detect shoals of fish using an echo sounder?

17.8 Water safety

People involved in water sports, such as sailing, rafting or canoeing, need safety devices to keep them afloat in the event of an accident. These may be in the form of inflatable tubes, life jackets or life rafts.

These devices are made of strong but light material. They can be inflated or may inflate automatically. When a person wears, or sits, on one of these devices, the density of their body is effectively reduced. This is because the total volume increases by a large amount, while the total weight only increases by a small amount. It is easier for them to stay afloat when their effective density is less.

Learning outcomes

By the end of this topic you will be able to:

- appreciate the need for safety when undertaking water sports
- name some water safety devices
- describe how buoyancy devices make it easier for a person to stay afloat.

Water safety devices

▲ **Figure 17.8.1** Water safety devices

A **life jacket** is designed to keep the wearer afloat with their nose and mouth above water. Life jackets in the form of nylon-lined foam vests are useful buoyancy aids, and are suitable for those who can swim and for children. Inflatable life jackets, or vests, are more suitable for boating, sailing and fishing. These jackets have air chambers which can be inflated by pulling a cord. The wearer is then made buoyant and will float.

A **life raft** is an inflatable boat that can be launched from a larger boat in the event of an accident. It is usually provided with paddles.

Inflatable rings provide support in the water. They may be used as aids to give non-swimmers confidence, while they are learning to swim, or they may be thrown into the water to help someone in difficulties.

Questions

1. Why is it important for people who take part in water sports to wear life jackets even if they can swim?
2. Explain why a buoyancy device helps a person to stay afloat.
3. Describe four activities for which you should wear some form of water safety device.

Learning outcomes

By the end of this topic you will be able to:

- state that the pressure exerted by water increases with depth
- describe an experiment to show that the pressure in a liquid increases with depth
- state some of the hazards associated with scuba-diving
- explain the cause of 'the bends'
- explain what happens in a decompression chamber
- explain the cause of nitrogen narcosis
- describe how the ear drums and/or lungs can be damaged when a diver ascends from depth too quickly.

Key fact

The term scuba stands for self-contained underwater breathing apparatus.

Synoptic link

See Topic 5.1 The mechanism of breathing.

Questions

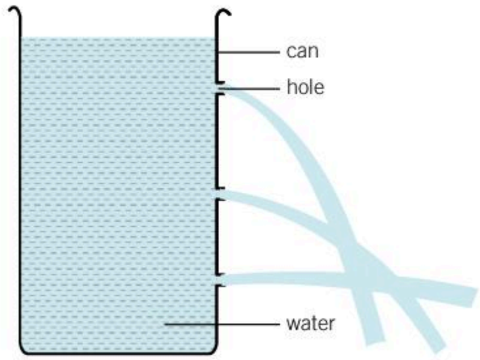
1. What does scuba stand for?
2. Describe what causes 'the bends'.
3. How does a decompression chamber prevent the bends?
4. Why does scuba-diving become more dangerous as the depth of the dive increases?
5. Why does attempting to blow your nose prevent damage to the ear drums when diving?

17.9 Scuba-diving

Pressure and depth

The apparatus in Figure 17.9.1 can be used to show that the pressure in a liquid increases with depth. When the can is filled with water, the water flows out of the three equal-sized holes drilled in its side.

The water squirts out fastest and furthest from the bottom hole, and slowest and shortest from the top hole showing that pressure increases with depth.



▲ **Figure 17.9.1** Apparatus to demonstrate that pressure increases with depth

Scuba-diving

Scuba-diving is a popular sport in the Caribbean. The diver carries a tank of compressed air on their back so they can breathe under water without needing to come to the surface for air. There are a number of hazards associated with scuba-diving; some are described below.

The bends

The pressure of water acting on a diver increases with depth. Increasing pressure causes an increase in the solubility of gases in liquids so more air dissolves in the diver's blood at greater depths. When the diver returns to the surface, the ascent must be made slowly so that the extra air has time to come out of the blood. If the diver rises too quickly, bubbles of air may form in the blood; this is known as air embolism. In the heart or brain these can be fatal. In the joints the air bubbles cause severe pain causing the body to become contorted into strange positions. It is for this reason that the condition is called 'the bends'.

Divers who return to the surface too quickly must immediately go into a special device called a **decompression chamber**. Inside the chamber, the pressure is increased to the same pressure as the diver experienced under water and then it is gradually lowered to normal atmospheric pressure.

Nitrogen narcosis

The deeper a diver goes, the more nitrogen dissolves in the blood. At a certain level this causes a condition called **nitrogen narcosis**. The diver loses control of his movements, is unable to think clearly and becomes totally disorientated.

Burst ear drums

Increased pressure may cause the ear drum to burst.

To prevent this problem, the diver should descend, or ascend, slowly, and equalise the pressure in the ear drum by pinching their nose and gently trying to breathe out through it. This forces air from the throat into the ear through a tube called the eustachian tube. This increases the internal pressure on the ear drum, thus equalising it with the outside pressure.

Ruptured lungs

Respiratory problems are caused by high pressure damaging the delicate membrane lining of the lungs. Ascending too quickly may even cause the lungs to burst.

Exam-style questions

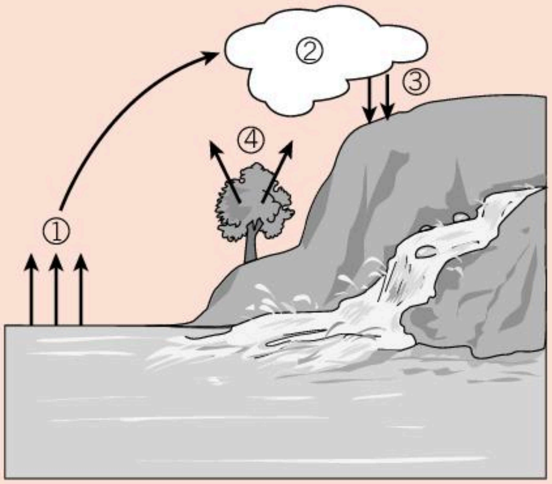
1 Which of the following methods can be used to purify water?
I boiling
II chlorination
III filtration
A I and III only **B** I and II only
C all of them **D** II and III only

2 Which of the following can be used to show the presence of water?
A pH paper **B** soda lime
C cobalt chloride paper **D** litmus paper

3 Ice floats on the surface of water because:
A ice has the same density as water
B ice is denser than water
C the volume of ice is less than the volume of water from which it forms
D the density of water is greater than ice

Structured questions

4 a Provide labels for the missing terms 1 to 4 in the flow diagram showing the water cycle.



b Eutrophication takes place in the river. Explain how this can happen.

5 The following steps are taken in water purification: chlorination, screening, settling, filtering
a Arrange the purification steps in the correct order.
b Give one reason for each step.
c What is desalination?
d Name two methods that can be used to desalinate water.

6 a Describe two methods that commercial fisherman use to catch large numbers of fish.
b **i)** Name two devices that fisherman use to help them.
ii) Explain how each device enables the fisherman to safely catch more fish.
c In the last ten years a local fisherman noticed that the number of fish that he caught was decreasing. Give one reason that would account for this.

7 a State Archimedes' principle.
b What are Plimsoll lines on ships?
c In which water will a ship sink further, fresh water or salt water? Explain your answer.

8 a What does scuba stand for?
b Describe two hazards of scuba-diving. For each, state how it can be avoided.

9 Your friends ask you to go on a sailing trip.
a Name one safety device that you would wear while on the boat.
b Explain why it is important to wear this device even if you are a good swimmer.

Section C

18 Fossil fuels and alternative sources of energy

Learning outcomes

By the end of this topic you will be able to:

- distinguish between renewable and non-renewable energy sources
- give examples of fossil fuels
- describe how fossil fuels are formed
- describe the chemical composition of crude oil and natural gas
- state where crude oil and natural gas are found
- state that methane is the main component of natural gas
- distinguish between luminous and non-luminous flames
- state that crude oil is a mixture of hydrocarbon molecules of different sizes
- explain how fractional distillation works
- describe the fractional distillation of crude oil
- state the uses of the fractions obtained from crude oil
- state some differences in the appearance and properties of different fractions obtained from crude oil.

People need energy for lots of different things. As a nation, we use energy to power the machinery in our factories, and to transport people and goods from place to place. As individuals, we use energy to heat and light our homes and cook our food. Some sources of energy are non-renewable and are gradually being used up, while others are continually renewed by natural processes.

18.1 Fossil fuels

Types of fuel

We need energy to do work. There are two ways that we can obtain this: by burning **fossil fuels** or by using alternative energy sources. The main fossil fuels, coal, crude oil and natural gas, are all examples of **non-renewable energy sources**. A non-renewable source of energy is one that is being used up far more quickly than it can be replaced by natural processes.

Alternative energy sources that can be used include solar energy, wind energy and nuclear energy. These are called **renewable energy sources** since they can be continuously replaced as they are being used.

Formation of fossil fuels

Fossil fuels take millions of years to form and are being used up at an ever-increasing rate as the population of the world increases and people look to improve their standard of living. Scientists believe that the world will run out of crude oil and natural gas by around 2070, and of coal by 2125.

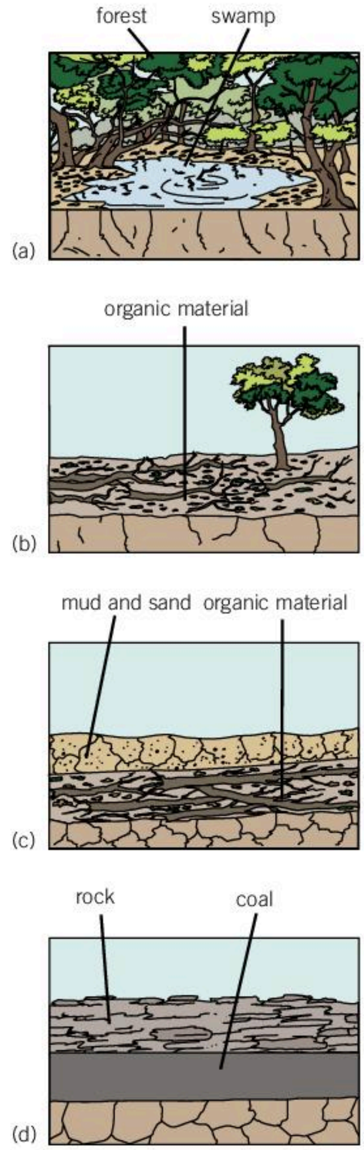
▲ **Figure 18.1.1** Angostura oil platform, Trinidad

Coal

The diagrams in Figure 18.1.2 show how coal formed.

Coal is believed to have been formed from plant material. Evidence suggests that large areas of the Earth were once covered in swampy forests. Over a long period of time, thick layers of plant material accumulated under the surface of the swamp, eventually being covered up by layers of rock-forming deposits of mud and sand.

In the absence of air, the combined effect of the pressure from the layers above, and the heat from the Earth, slowly converted the plant material to the impure form of carbon that we call coal.



▲ **Figure 18.1.2** Coal was formed from layers of plant material

Crude oil and natural gas

Crude oil and natural gas formed underground in a similar way to coal, and were absorbed into porous rock, rising towards the surface until they become trapped beneath layers of impermeable rock. They are extracted from underground by drilling wells. In a few places in the world, crude oil deposits are found on the surface. Crude oil is often found with natural gas.

The composition of crude oil and natural gas

Crude oil and natural gas are mixtures of **hydrocarbons**. These are chemicals which are composed of hydrogen and carbon only. Natural gas contains small molecules, such as methane (CH_4) and ethane (C_2H_6), while crude oil contains hydrocarbons with much bigger molecules.

Natural gas is mainly composed of methane. It requires relatively little modification before it can be used as a fuel. The gas used for a Bunsen burner is natural gas.

There are two types of flame that can be produced during combustion of fuels: **luminous** and **non-luminous**.

▼ **Table 18.1.1** The differences between luminous and non-luminous flames

Luminous flames	Non-luminous flames
Yellow colour	Blue colour
No sound produced	Sometimes called 'roaring' flames as sound is produced
Can use only some oxygen so not all the oxygen is changed to CO_2 and soot is produced	Combine all the available oxygen to CO_2 so no soot is produced
Not very efficient as less energy is produced	Very efficient as a lot of energy is produced

Fractional distillation of crude oil

Crude oil is a complex mixture of hydrocarbons. It is of no use in the form in which it comes out of the ground. **Refining** separates the hydro-carbons and modifies them to form useful products.

▲ **Figure 18.1.3** Pitch Lake Trinidad

Practical Activity 18.1.1

Investigating the Bunsen burner flame

Skills assessed: Observation/Recording/Reporting.

Your teacher will provide you with a Bunsen burner, two boiling tubes, a thermometer, a 50 cm^3 measuring cylinder and a wooden spill.

1 Light your Bunsen burner and close the air hole completely.
2 Describe the shape and colour of the flame, and say whether the gas makes a noise as it burns.
3 Measure 10 cm^3 of water into a boiling tube and measure its temperature.
4 Heat the boiling tube for 1 minute and then measure the temperature of the water again.
5 Fully open the air hole on the Bunsen burner.
6 Describe the shape and colour of the flame, and say whether the gas makes a noise as it burns.
7 Measure 10 cm^3 of water into the second boiling tube and measure its temperature.
8 Heat the second boiling tube for 1 minute. Then measure the temperature of the water again.
9 What can you say about the amount of heat produced by the different flames? Explain your answer.
10 While the air hole is fully open, place a wooden spill across the flame for a second. Remove it and blow any flame out.
11 Draw the pattern of burning you see on the wooden spill. Suggest why it appears this way.

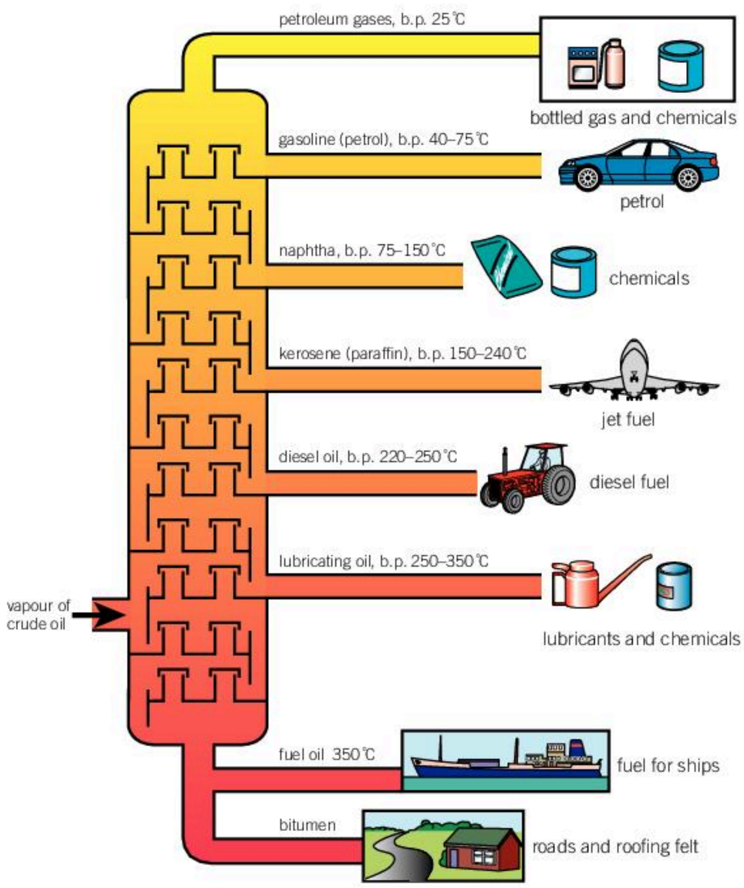


Figure 18.1.4 Fractional distillation

The hydrocarbons in crude oil have different boiling points. Most of them are liquids but some are gases and some are solids dissolved in the mixture. In order to separate them, the crude oil is first heated in a furnace up to about 360 °C. At this temperature most of the hydrocarbons become vapours and pass into a fractionating column. This is called **fractional distillation**.

The temperature of the column falls from about 360 °C at the bottom to 20 °C at the top. As the hydrocarbon vapour rises up the column it slowly cools and the gases turn back into liquids. Hydrocarbons with large molecules have higher boiling points so they condense first in the lower part of the column; hydrocarbons with small molecules have lower boiling points and condense higher up the column. Some hydrocarbons remain as gases and pass out of the top of the column.

Each fraction consists of a mixture of hydrocarbons. Some fractions are used as fuels, while others provide the raw materials for a range of chemical processes.

From the top to the bottom of the column the fractions are obtained in order of ascending boiling point. As the boiling points increase the fractions:

- become darker in colour
- are less easy to ignite
- burn with a smokier flame.

The amount of each fraction that is obtained by distillation can vary. Large hydrocarbons are less useful than smaller ones. Smaller hydrocarbons can be obtained from larger ones by the process of **cracking**.

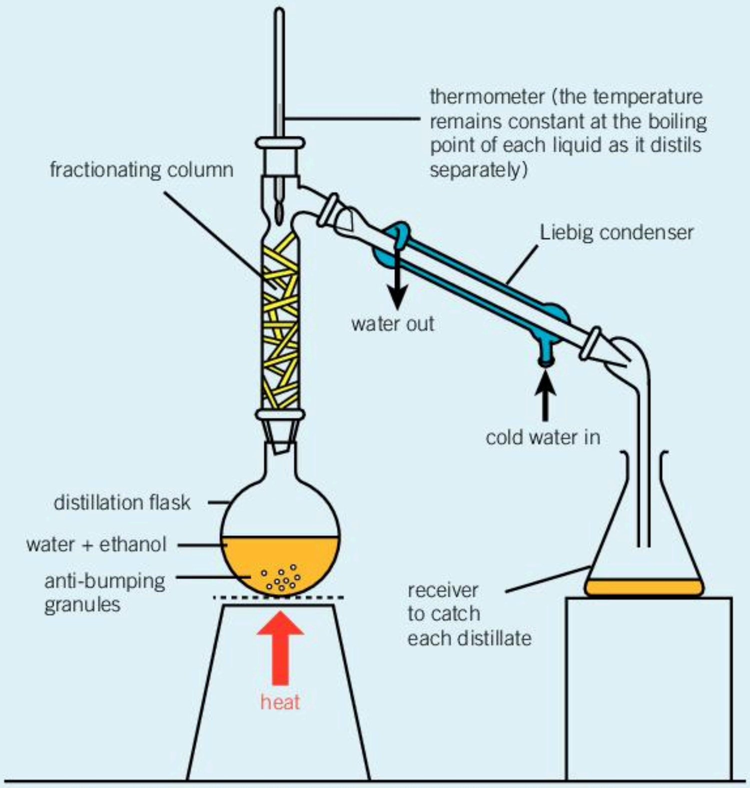
- Thermo-cracking involves heating large hydrocarbons to very high temperatures to break them up.
- Catalytic cracking involves using low temperatures and chemicals, such as aluminium oxide to break hydrocarbon chains.

Practical Activity 18.1.2

Fractional distillation

You are going to separate a mixture of water and ethanol using fractional distillation. Your teacher will give you the apparatus together with a second receiver, two watch glasses and some blue cobalt chloride paper.

1. Set up the apparatus as shown.
2. Gently heat the distillation flask until liquid starts to condense and fall into the receiver.
3. What is the temperature of the vapour from which the first fraction is forming?
4. Continue to heat the distillation flask until no more liquid is given off at that temperature.
5. Replace the receiver with a clean dry receiver.
6. Continue to heat the distillation flask until more liquid starts to condense and fall into the receiver.
7. What is the temperature of the vapour from which the second fraction is forming?
8. Continue heating until you have a few cm^3 of the second fraction.
9. Test the first and second fractions with blue cobalt chloride paper. Comment on your observations.
10. Test the first and second fractions to see if they are inflammable by placing a small amount in a watch glass and seeing if you can light it with a burning match. Comment on your observations.



Questions

1. Name three fossil fuels.
2. In the absence of which gas do fossil fuels form?
3. From what do fossil fuels form?
4. Under what type of rocks do crude oil and natural gas become trapped?
5. Which process separates the components of crude oil into fractions based on their boiling points?
6. How does the colour of the fractions obtained from crude oil change as the boiling point increases?
7. What is ‘cracking’ used for?

Learning outcomes

By the end of this topic you will be able to:

- describe how fuels contain stored energy
- explain how energy is released when a fuel burns.

▼ **Table 18.2.1**

Fuel	Amount of energy produced by burning one gram (kJ)
Hydrogen	143.0
Methane	55.6
Octane	48.0
Methanol	22.7
Ethanol	29.7

18.2 Stored energy in fuels

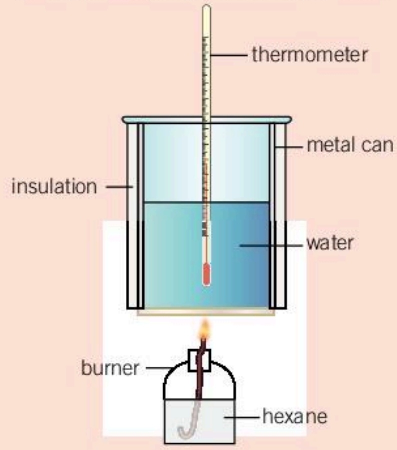
A number of the fuels that are commonly used are obtained from crude oil. These include liquid petroleum gases (LPG), gasoline, kerosene and diesel.

You should already be aware from Topic 10.2 that fuels (and foods) are a form of stored energy. When a fuel is burnt the stored energy is converted to light and heat energy. Different fuels give out different amounts of energy.

Table 18.2.1 shows the amount of energy released by burning one gram of some different fuels.

Questions

1 Hexane is a fuel, which is a liquid at room temperature. The diagram shows an experiment designed to measure the amount of heat energy released by hexane during combustion. The mass of the liquid burner was measured before and after heating the water.



Mass of water used = 100 g

Initial temperature of the water = 18 °C

Final temperature of the water = 58 °C

Mass of hexane burnt = 0.43 g

a Use the following equation to calculate the amount of heat energy produced, in kJ, when 0.43 g of hexane is burnt in air:

heat produced (kJ) = mass of water (kg) × temperature rise (°C) × 4.2 J/kg °C

b Calculate the amount of heat energy that would be given out by burning one gram of hexane in air.

18.3 Environmental problems of burning fossil fuels

Learning outcomes

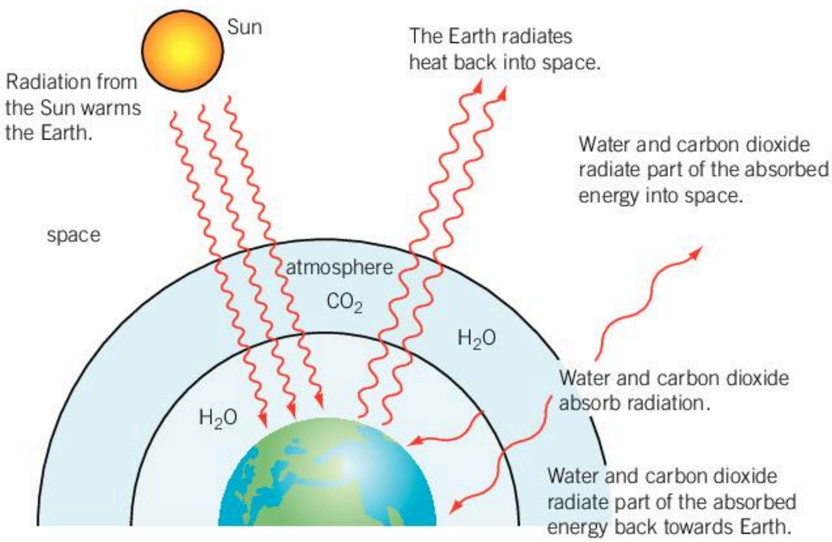
By the end of this topic you will be able to:

- understand that fossil fuels are non-renewable resources
- explain why carbon dioxide is a greenhouse gas
- explain the consequences of global warming
- describe the environmental effects of acid rain.

Carbon dioxide is produced by natural processes, such as respiration and decomposition, and used up during photosynthesis. This means that the concentration of carbon dioxide in the atmosphere remains fairly constant.

As the world has become more industrialised, more and more carbon dioxide has been released into the atmosphere from burning fossil fuels. The result has been a steady increase in the concentration of this gas in the atmosphere.

One effect of this has been to reduce the amount of heat lost by radiation from the Earth to space. Carbon dioxide is described as **a greenhouse gas** because, like glass in a greenhouse, it traps some of this heat and redirects it back to the Earth. Water also does this. The increase in the carbon dioxide in the atmosphere results in a small, but significant, increase in average temperatures around the world.



▲ **Figure 18.3.1** Global warming

Global warming is causing the North and South Poles to shrink, as the ice caps melt, and is thought to be responsible for changes in the world's weather patterns.

The burning of fossil fuels is also responsible for increasing the acidity of rainwater. This effect is commonly called **acid rain** and is the result of the formation of sulphur dioxide and nitrogen oxides.

Coal and crude oil both contain various impurities including sulphur. When the fuel is burnt the sulphur is oxidised to sulphur dioxide.

$$\text{sulphur} + \text{oxygen} \rightarrow \text{sulphur dioxide}$$

When fuels burn in furnaces or car engines, atmospheric nitrogen is oxidised to nitrogen oxides.

$$\text{nitrogen} + \text{oxygen} \rightarrow \text{nitrogen oxides}$$

All rainwater is naturally acidic because carbon dioxide dissolves in it forming carbonic acid, which is a weak acid. As a result of this, the pH value of rainwater, is typically around 5.5. When sulphur dioxide and nitrogen oxides dissolve in rainwater, the acidity increases (significantly).

Acid rain reacts with building materials, such as limestone and mortar, and increases the rate at which metals corrode. Acid rain also damages the foliage on trees, and damages the organisms in lakes and rivers. The water becomes more acidic and causes harmful metal ions to pass out of soil as water drains off the land.

Questions

1 What are the products of burning hydrocarbons?

2 What happens to water in the atmosphere when sulphur dioxide dissolves in it?

3 What is a greenhouse gas?

4 Describe the effects of acid rain on buildings.

Learning outcomes

By the end of this topic you will be able to:

- state that alternative sources of energy are sustained by natural processes
- describe biofuels
- describe how the wind, the waves and the Sun can be used as sources of energy
- understand how energy can be generated from moving water
- explain geothermal energy.

18.4 Alternative sources of energy

Biofuels

A renewable source of energy is one that is sustained or replaced by natural processes. Biofuels are renewable sources of energy which are obtained from animals and plants.

▲ **Figure 18.4.1** Sugar can be made into a fuel for cars

In some parts of the world, **wood** and other plant materials are important fuels. In theory, new trees will grow to replace those taken for firewood but, in practice, if too many trees are removed from an area, the soil may be damaged (see Unit 16.4).

Animal dung can be used in **biogas** units to produce methane for cooking, or dried and burnt as a fuel.

Sugar from sugar cane can be fermented with yeast to make **ethanol**. The sugar cane waste is burnt to provide the energy needed for distillation. In some countries the ethanol is mixed with petrol to form biofuels, such as **gasohol** and **alcool gasoline**. This uses a fuel from a renewable source (ethanol) and therefore reduces the demand on a fuel from a non-renewable source (petrol).

Biodiesel is made by reacting vegetable oil and animal fats with alcohol. The fuel produced can be used in vehicles in the same way as normal diesel and does not require any modification to the engine.

▲ **Figure 18.4.2** Wind generators at Wigton windfarm, Jamaica

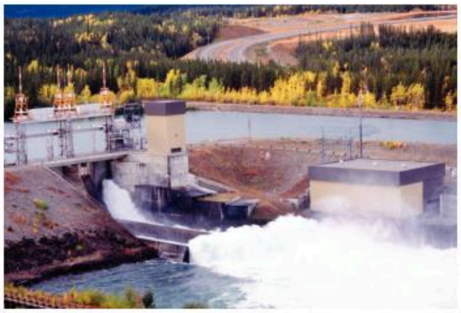
Solar energy

The Sun, either directly or indirectly, is responsible for almost all renewable sources of energy. Solar energy is an easy source of energy in countries in the Caribbean which have a tropical climate. Solar cells capture the radiation from the Sun and convert it directly into electricity.

Wind energy

Winds are the result of uneven heating of the atmosphere by the Sun. Wind energy drives wind turbines which generate electricity. Blades are used to collect the kinetic energy of the wind. The blades are connected to a drive shaft which turns an electric generator.

There are no waste gases produced, so wind power does not contribute to global warming. Wind power is abundant, safe and reliable, although the turning of the blades can be noisy.



▲ **Figure 18.4.3** Flowing water can be used to generate electricity

Energy from moving water

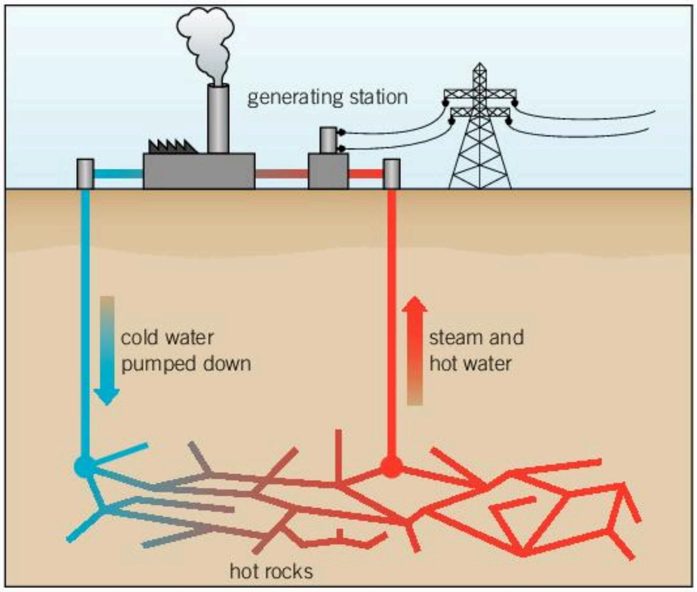
Water has been used for centuries to generate power in water mills. A swiftly flowing stream can be diverted to cause a **water wheel** to move and generate power for threshing or milling grain. Energy from the Sun drives the water cycle (Topic 16.5). In hydroelectric schemes, as water flows down from hills to the sea it can be trapped behind dams and used to drive turbo-generators to produce electricity. There have been some attempts to harness the energy of the ocean waves to generate electricity. This type of power, **wave power**, is different from **tidal power**, which uses the energy from the tides to generate electricity.

Geothermal energy

The temperature of the rocks under the ground increases at increasing depth. This is the result of heat energy, given out by the decay of radioactive materials in the Earth. In some places, hot water rises to the surface as hot water geysers.

In other places, boreholes are drilled down into the hot rocks. Cold water is pumped down one borehole and rises up the other as hot water or steam. This can be used for heating or for generating electricity.

▲ **Figure 18.4.4** Goethermal vents



▲ **Figure 18.4.5** When boreholes are drilled, the water is heated as it passes through the hot rocks

Questions

1 From what are biofuels obtained?
2 What is added to petrol to make gasohol?
3 What form of energy is obtained from a solar cell?
4 Where does the energy that causes air to flow as winds come from?
5 What causes hot water geysers?

Learning outcomes

By the end of this topic you will be able to:

- understand how a solar cell works
- describe how a solar panel heats water
- describe some other uses of solar energy
- describe how wind energy is used
- understand how a wind turbine works.

▲ **Figure 18.5.1** Solar cells make electricity

18.5 Uses of solar energy and wind energy

Solar cells

Solar cells, otherwise known as **photovoltaic cells**, convert light directly into electricity. Solar cells contain a semi-conductor, such as silicon, which has been especially treated to form an electric field. The material absorbs photons of light and releases electrons, which are captured and result in an electric current that can be used as electricity.

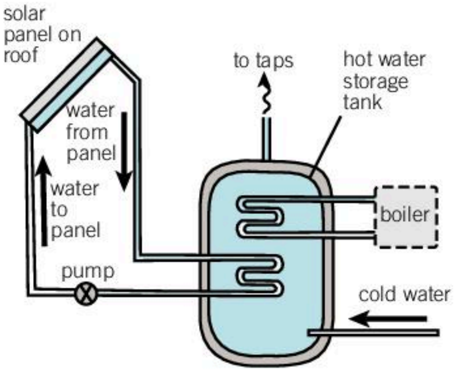
Solar cells can be used when only small amounts of electricity are needed. Small solar cells are used in calculators. Larger arrays of cells are used to power satellites. No electricity can be generated at night using solar cells.

Solar panels

Solar panels absorb heat energy from the Sun. They do not generate electricity. The heat is transferred by conduction to water which heats up. Solar water heaters are used in homes and factories.

In many water-heating systems, water is pumped through a network of pipes in the solar panel. It absorbs the heat energy and takes it to a heat exchanger, where the heat is passed on to the hot water pipes in the house. There are simpler systems for use in the home, where the solar panels are connected directly to a storage tank placed on a roof. Convection currents carry the heated water to the tank and the cold water to the solar panels. An example of this type of solar heating system is shown in Figure 18.5.3.

To reduce loss of energy, the solar water heaters are insulated. Also, the pipes and the insides of the panel are painted black to increase heat absorption. The inside of the pipes in the solar panels are shiny so that they can reflect the heat inside them. The heat energy is transferred from the metal of the pipes to the water by conduction. The heat energy is spread throughout the water in the pipes by convection currents (see Topic 9.1).



▲ **Figure 18.5.2** Solar panels can be used to heat water for the household

▲ **Figure 18.5.3** A solar water heater

Other uses of solar energy

There are many other uses of solar energy. Here are a few examples.

▲ **Figure 18.5.4** Solar-powered lamp

Solar-powered lamps absorb energy from the Sun during the day and store it as electricity. At night the electricity is used to power a lamp.

Solar dryers use energy from sunlight to evaporate water from food. Dried foods remain edible for much longer than fresh foods because the bacteria that cause food to go off need water to live.

Solar cookers focus sunlight onto a cooking pot so the food it contains gets cooked.

Artificial satellites orbiting the Earth use solar panels to recharge their batteries. This allows the satellite to operate for many years without needing any fuel.

▲ **Figure 18.5.5** Solar cooker

Wind energy

Wind is the flow of air from one place to another. Wind has movement energy that can be used to do useful work.

Sailors have used the wind to power their boats for thousands of years. Today boating enthusiasts still rely on the wind to power their dinghies.

▲ **Figure 18.5.6** Morgan Lewis Windmill

For many centuries, wind energy has been used to drive windmills. The Morgan Lewis Windmill in St Andrews, Barbados is one of the last operational wind-powered sugar mills remaining in the Caribbean.

Modern wind turbines are not so different from windmills. They use energy from the wind to generate electricity. The wind turns the blades, which are connected to a shaft. The shaft is connected to a generator. The energy from the turning shaft is used to create electricity in the generator.

Questions

1. Explain how a solar cell works.
2. Describe a simple solar water-heating system that can be used on a house.
3. What are solar dryers and why are they used?
4. How did people make use of wind energy in the past?
5. Explain how a wind turbine works.

18.6 Factors affecting solar energy and wind energy

Learning outcomes

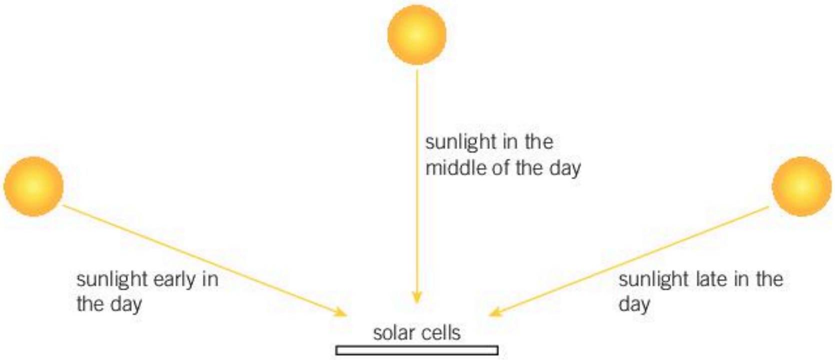
By the end of this topic you will be able to:

- discuss some of the factors affecting solar energy
- discuss some of the factors affecting wind energy.

Solar energy

The most obvious condition affecting devices, such as solar cells and solar panel heaters, is the availability of sunlight. During the night these devices do not work at all.

On cloudy days less heat radiation passes through the atmosphere so the output of solar-driven devices is reduced.



▲ **Figure 18.6.1** Angle of the Sun's radiation at different times of the day

The intensity of sunlight also changes throughout a day. The Sun's rays are most intense around the middle of the day when they shine directly onto a solar panel or water heater. They are less intense in the morning and evening when the Sun's rays are at an oblique angle. Solar energy is most useful in countries that receive lots of sunshine.

The world's largest solar furnace is at Odeillo in France. The Sun's rays are reflected by a series of mirrors onto a parabolic reflector. The parabolic reflector focuses the Sun's rays onto the same point producing temperatures of up to 3500 °C in a solar oven. The mirrors are more correctly called heliostats because they rotate as the Sun moves across the sky in order to obtain the maximum amount of solar energy.

▲ **Figure 18.6.2** Solar furnace at Odeillo in France

Wind energy

There are also factors affecting the availability of useful wind energy. Devices such as wind turbines only work when there is wind. On a still day the blades will remain motionless and no electricity will be generated.

A group of wind turbines is called a wind farm. Turbines are often placed in groups to make the best use of local conditions and to produce a worthwhile amount of electrical energy.

Wind turbines will only operate when the speed of the wind is within a certain range. If the wind speed is below the range, there is insufficient energy to drive the turbine. If the wind speed is above the range, the turbine would rotate too quickly and may be damaged as a result.

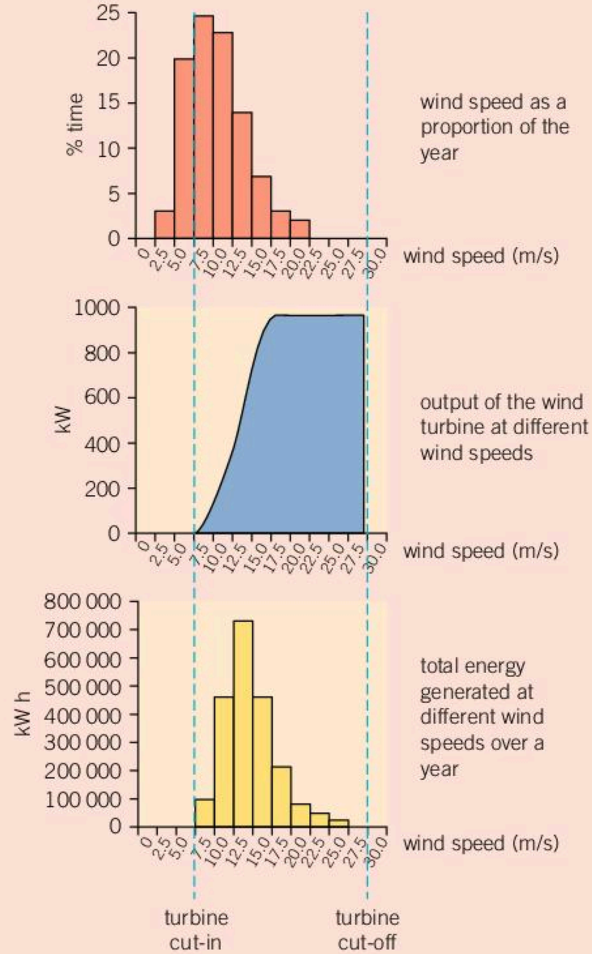
Winds don't always blow in the same direction. When yachts want to go in the opposite direction to the wind they must carry out a procedure called tacking. They zig-zag in directions at right angles to the wind.

▲ **Figure 18.6.3** Yachts tack against the wind

Wind turbines are not able to move position. However, the top section of a wind turbine is able to rotate so that the blades are always pointing towards the direction of the wind.

Questions

1 The following graphs give some information about a wind turbine that has a maximum power output of 1000 kW. This is equivalent to producing 1000 kJ of energy each second.



a Within which band of wind speed does the wind blow most often?

b What is the lowest wind speed needed to produce the maximum output of 1000 kW?

c At what wind speed is most energy produced each year?

d What percentage of the time is the power output:

i) zero (no electricity is generated)

ii) 1000 kW?

18.7 Alternative energy in the Caribbean

Learning outcomes

By the end of this topic you will be able to:

- appreciate how to determine the most suitable alternative energy sources
- describe the alternative energy sources now in use.

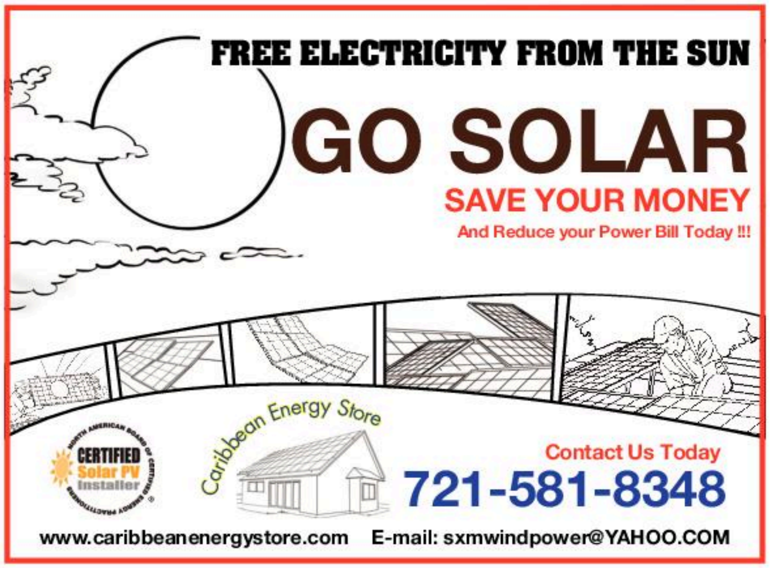
You will already be aware from Topic 18.4 that there are a number of alternative energy sources in use around the world. Alternative energy sources are energy sources other than fossil fuels. They are mainly renewable energy sources. Alternative sources of energy have both advantages and disadvantages.

Some advantages are:

- the energy is free
- the energy will never run out
- making use of renewable energy causes relatively little environmental damage
- some devices are cheap to buy and install
- some devices are better suited to satisfy the energy needs of a small community than a power station.

Some disadvantages are:

- some sources are not available all of the time, for example wind turbines only generate electricity when there is enough wind to drive them
- some sources provide relatively little energy, for example it takes a large number of wind turbines to produce the same amount of electricity as a fossil-fuelled power station
- some sources are not suitable for all countries, for example hydroelectricity is no use in a country where there are no fast-flowing rivers.



▲ **Figure 18.7.1** Solar panels

All alternative sources of energy are not suitable for every region of the world. In order to determine what alternative energy sources would be most appropriate for the Caribbean we need to consider the normal conditions in this region.

The one commodity that the Caribbean has lots of is sun. Solar panels and solar water heaters are becoming a common site on the tops and sides of buildings.

The Caribbean region receives winds coming off the Atlantic Ocean. These are ideal for driving wind turbines. At the moment there are nine wind farms in the Caribbean. They range from small installations, such as the two wind turbines on the British Virgin Islands, to large installations, such as the Los Cocos wind farm in the Barahana region of the Dominican Republic which has 40 wind turbines. This wind farm reflects the large investment made by the Dominican Republic to harnessing wind power.

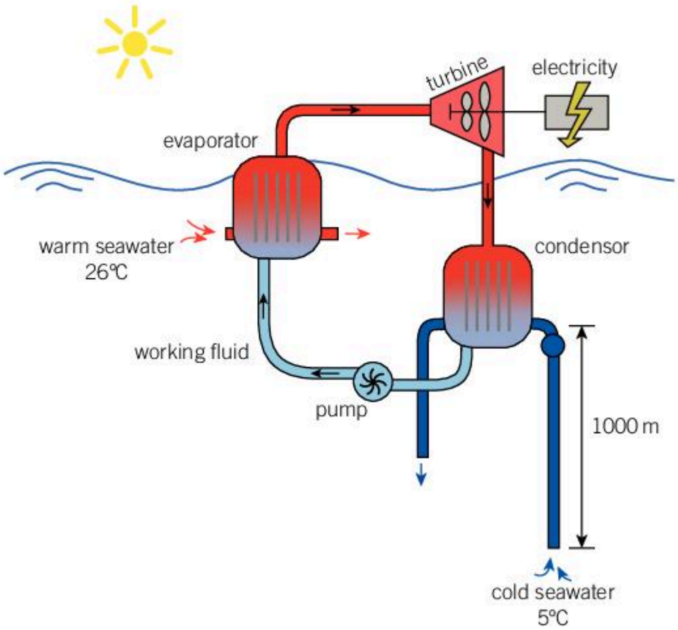
The development of other alternative energy sources, such as hydroelectricity, is less widespread in the Caribbean for a number of reasons.

▲ **Figure 18.7.2** Hydroelectricity in Costa Rica

Hydroelectricity is an option on some Caribbean islands, particularly the larger islands which have mountainous areas. Water draining from the mountains to the sea creates fast-flowing rivers. Countries such as Puerto

Rico and Costa Rica obtain a high proportion of their electricity needs from hydroelectric installations.

However, this source of energy is not an option for all countries due to the lack of suitable rivers and the cost of building the structures needed. Also, the impact that a hydroelectric plant would have on the local landscape and ecosystem is not always acceptable.



▲ **Figure 18.7.3** Ocean thermal energy conversion. Can you work out how it produces electricity?

The Caribbean islands are surrounded by sea. They are buffeted continually by waves and experience rising and falling tides each day. There are a number of potential ways of obtaining energy from waves and tides but the cost of building tidal barrages, or offshore wave farms, is prohibitively costly at the moment. This is a potential alternative energy source for the future.

Good sources of geothermal energy are most likely to be on the boundaries between tectonic plates. A number of Caribbean countries, such as Dominica, lie along such boundaries and therefore have the potential to make use of this alternative energy source. However, the cost of drilling deep into the Earth and the environmental impact of this may limit the exploitation of geothermal energy in the region.

▲ **Figure 18.7.4** Exploiting geothermal energy in Dominica

Questions

1 Why is the Caribbean a good area for harnessing solar energy?
2 Why is the Caribbean a good area for harnessing wind energy?
3 Why is hydroelectricity a useful alternative energy source in some Caribbean countries but not in others?

Exam-style questions

Multiple choice

1 Sulphur dioxide in the atmosphere can bring about:
  A global warming
  B acid rain
  C fires
  D climate change

2 Which of the following is NOT an alternative source of energy?
  A wind energy
  B solar energy
  C biofuel
  D coal

3 Crude oil can be separated into a range of products by:
  A filtration
  B fractional distillation
  C boiling
  D settling

4 Which of the following occurs during the process of cracking?
  A Small hydrocarbons are combined to form larger ones.
  B Large hydrocarbons in kerosene are broken down to form smaller gasoline molecules.
  C Molecules of iso-octane are joined with kerosene molecules.
  D Small hydrocarbons in kerosene are joined to gasoline molecules.

5 Which of the following alternative energy sources makes use of heat from the ground?
  A geothermal energy
  B hydroelectric energy
  C solar energy
  D wind energy

6 In what form is most stored energy released when a fuel is burnt?
  A chemical energy
  B electrical energy
  C heat energy
  D sound energy

Structured questions

7 State the difference between the following terms:
  a renewable and non-renewable fuels
  b acid rain and global warming.

8 **a** Give two examples of fossil fuels.
  b Name the products of the combustion of fuels.
  c Give two ways that the combustion of fossil fuels and aerobic respiration are similar.

9 **a** Explain the difference between a solar cell and a solar panel.
  b Give one advantage and one disadvantage of using solar cells to generate electricity.
  c Where does the heat energy from geothermal energy resources come from?
  d **i)** What is a biofuel?
  ii) Give two examples of substances that can be used as biofuels.

10 **a** Explain why solar power and wind power are ideal alternative energy sources for the Caribbean area.
  b The Caribbean islands are surrounded by sea. Explain why wave power and tidal power are not currently being exploited.

11 **a** With the help of suitable diagrams, explain how coal was formed.
  b Why is coal described as a non-renewable energy source?

Section C

19 Forces

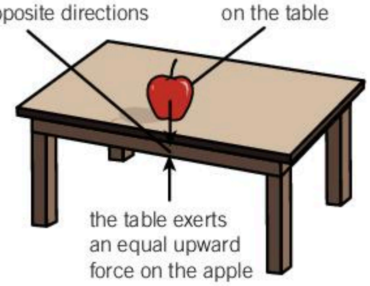
Learning outcomes

By the end of this topic you will be able to:

- describe a force as a push or a pull
- state the changes that might occur when a force is applied
- state Newton's laws
- understand Newton's third law and its applications
- explain that when two or more forces act on an object at the same time the effect is the same as for a single resultant force
- describe the forces that enable birds and aircraft to fly
- define friction
- describe the uses of friction
- list ways that friction can be overcome.

Did you know?

The unit of force is the newton. This is named after Sir Isaac Newton, an English scientist who studied forces and in 1687 proposed what we now call the three 'laws of motion'.



▲ **Figure 19.1.2** Forces always exist in pairs

Almost everything that happens in our world and Universe is the result of forces. If you look around, you will see evidence of different forces. A person sitting on a chair, a car driving down the street, the wind blowing a tree, rain droplets falling, different planets orbiting around the Sun or the Moon orbiting around the Earth are all results of forces. Forces are needed to start a stationary object, such as a car, moving, to slow it down or to make it turn a corner. Forces are needed to make things stretch, squash to twist.

19.1 Forces and motion

Forces

A **force** is a push or a pull. When we apply a force to an object it may:

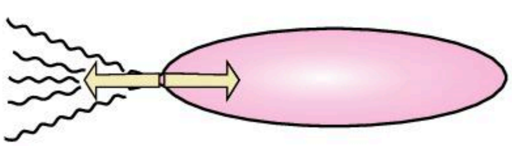
- change speed
- change direction
- change size or shape.

We can measure forces using a force meter or a newton meter. The unit of measurement for force is the newton (N).

▲ **Figure 19.1.1** Forces change speed and direction

For a force to exist, two objects have to work together or interact. Forces always exist in pairs; they cannot exist on their own. When one object exerts a force on another object, the other object pulls or pushes back. The forces between the two objects are always the same size but pull or push in the opposite direction.

We can use a balloon rocket to show how forces work in pairs. When you let go of the end of the balloon, air shoots out. The two objects interacting here are the air inside the balloon and the balloon. As the air escapes from the balloon, it exerts a pushing force on the balloon to the right. Because forces work in pairs, the balloon exerts an equal force on the air in the opposite direction, to the left. This is how a rocket lifts off and moves through the atmosphere and into space. Gases from burning fuel are released behind it producing **thrust** and the rocket moves forward.



▲ **Figure 19.1.3** Forces on a balloon rocket

Newton's laws

Newton's **first law of motion** states that an object at rest will stay at rest, or continue moving in a straight line at a constant speed, unless acted upon by an unbalanced force.

Newton's **second law of motion** is concerned with acceleration. Acceleration is the rate at which speed changes when a force is applied to an object.

Newton's **third law of motion** states that for every action there is an equal and opposite reaction. The **action–reaction** forces are pairs of forces that are always equal in size, act in the opposite direction and act on different objects.

If you push on a wall, the wall pushes back on you with an equal and opposite force. When the Earth pulls on you with a gravitational force, you pull back on the Earth with an equal and opposite force.

Applications of Newton's third law

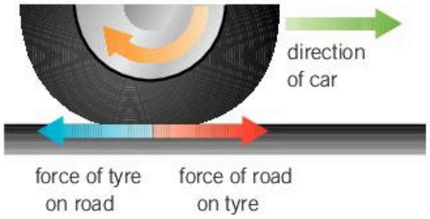
There are many applications of Newton's third law in everyday life.

1 Walking

We are only able to walk because of action and reaction forces. When you walk along the road, your feet push backwards on the ground. In turn, the ground pushes forward on you, with an equal and opposite reaction force, so you move forward.

2 Moving vehicles

When a car driver drives a car forward, the driving wheels try to turn. This causes a force that acts where the car tyre is in contact with the ground. When the tyre pushes on the road, the direction of this force is backwards. The reaction force from the road on the tyre is in the forward direction, so the car moves forward.



▲ **Figure 19.1.4** Car tyres grip the road

3 The jet engine

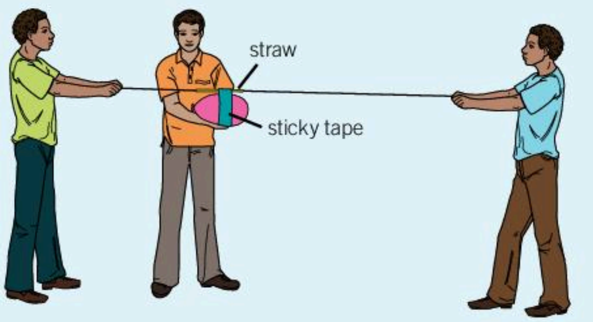
Newton's third law helps us to understand how jet engines work.

Air enters the front of the engine, is compressed, fuel is added and ignited. The expanding hot gases exit the back of the engine at high speed. The jet engine's action is accelerating a mass of gas and sending it out of the tail pipe. The equal and opposite reaction is thrust. This makes the aeroplane move forward.

Practical Activity 19.1.1

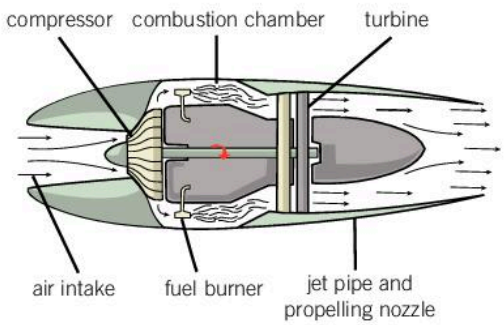
A balloon rocket

Skills assessed: Analysis and Interpretation.



Your teacher will provide you with a long sausage-shaped balloon, 10m of smooth string, a plastic straw, sticky tape, scissors and thin card.

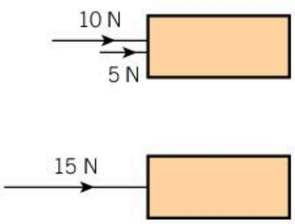
1. Thread the string through the straw.
2. Two students hold the length of string so it is pulled tight.
3. Blow the balloon up and hold the end closed. Do not tie a knot.
4. Tape the balloon to the straw, as shown in the picture.
5. Position the balloon at one end of the length of string.
6. Let go of the end of the balloon and observe what happens.
7. Use your knowledge of how forces act in pairs to explain why the balloon moves when you let go of the end.



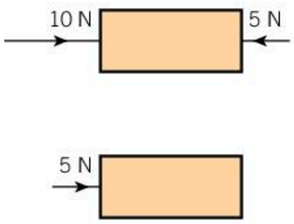
▲ **Figure 19.1.5** Air forced through a jet engine produces thrust

Exam tip

When we represent forces by lines the lengths of the lines are in proportion to the size of the forces, for example a line representing a 10 N force should be twice as long as a line representing a 5 N force.



▲ **Figure 19.1.6** If two forces act in the same direction, the resultant force is the sum of these forces so we add them together



▲ **Figure 19.1.7** If two forces act in the opposite direction, the resultant is the difference between them so we subtract one force from the other

Exam tip

When giving the resultant force it is important to also give its direction.

Resultant force

It is often the case that more than one force acts on an object at the same time. The effects of these forces can be added to give a **resultant force**.

The resultant force is the single force that has the same effect on the object as all the original forces acting together. To find the resultant force, we must remember that forces have direction, as well as size.

Forces in flight

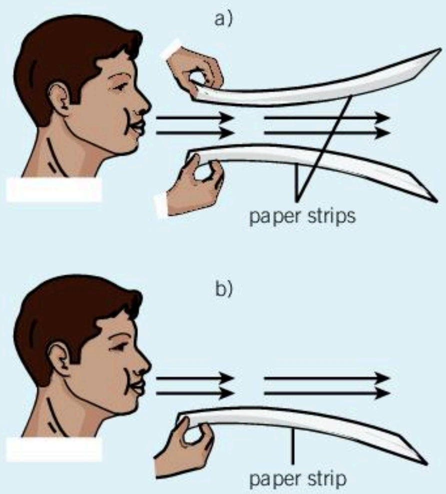
The wings of birds and aeroplanes are designed to provide **lift** for flying.

Practical Activity 19.1.2

Demonstrating lift

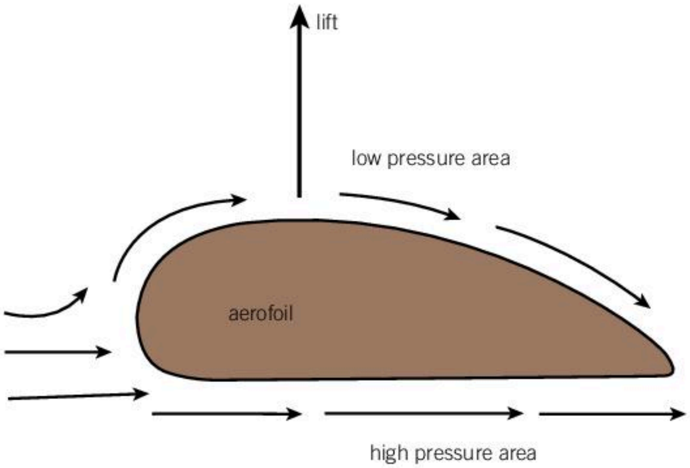
Your teacher will provide you with two strips of paper.

1 Hold the strips vertically next to each other and blow in between them. Observe what happens.
2 Hold one strip horizontally in front of you and blow over the top of it. Observe what happens.



In Practical activity 19.1.2, air was forced quickly between the two strips of paper. There will be less air pressure between the paper strips than outside them. So they are pushed together. When you used one strip, it lifted up. The air flowing over the top of the paper reached the other side at the same time as that flowing underneath it. The air at the top moved faster than that at the bottom and the airflow created lift.

Birds' wings and aeroplane wings work in a similar way to this. They are shaped like an **aerofoil**. The diagram shows that the surface at the top is more curved than below. When air strikes the aerofoil, it has a greater distance to travel over the top and so it accelerates. The pressure difference below and above the wing produces lift.



▲ **Figure 19.1.8** Air flow distribution around an aerofoil

Birds and aeroplanes move through air. This is a continuously changing medium and so they will be affected by air movements.

Friction

Friction is a force that occurs when two objects are touching each other and one moves against the other. The force of friction always acts against the direction of movement. As a result, friction slows a moving object down or causes it to stop. For example, when you roll a ball along the floor, it will slow down and eventually come to a stop. This is because the surface of the floor exerts a friction force on the ball. Friction does not only occur between two solid objects, it also occurs when a solid object interacts with a liquid or a gas. For example, when you throw a ball across a field the air will exert friction on the ball, causing the ball to slow down. Friction caused by air is called **air resistance**.

Uses of friction

Table 19.1.1 shows that friction may be useful to us and it can also be unhelpful in some instances.

▼ **Table 19.1.1** Uses of friction

Helpful effects of friction	Unhelpful effects of friction
Preventing tyres on vehicles sliding on the road surface. The vehicle can be controlled better when the brakes are applied.	It causes wear and tear on different surfaces.
	Extra force is needed to overcome frictional forces.
Making it possible for us to walk, run and play sport on different surfaces.	The friction between the moving parts of a machine slows them down and produces heat.
Allowing us to write clearly on paper surfaces.	Air resistance can slow down moving objects.
Holding objects in our hands without dropping them.	
Lighting matches and bringing about ignition.	

Practical Activity 19.1.3

Investigating friction on different surfaces

Skills assessed: Observation/Recording/Reporting and Manipulation/Measurement and Planning, and Design.

Plan an investigation to find out how friction changes with smoothness or roughness of the surface an object is moving along. Use the following questions to help you.

- How do you think friction will change when you change the roughness or smoothness of the surface the object is moving over?
- What are the independent and dependent variables?
- How can you make sure that your test is fair?
- Write down the steps you will follow to conduct the investigation.
- Make a list of the equipment you will need.
- Conduct your investigation and record your results.
- Present your results in the form of a bar chart or a line graph.
- What can you conclude from your investigation?

Key fact

Friction is a force between two objects that are moving or rubbing against each other. Friction slows things down or causes them to stop.

Overcoming friction

- Grease and oil are used as lubricants to reduce the friction in the moving parts of machinery.
- Rollers can be placed on objects so that they are not in direct contact with a surface.
- Cars and aircraft are designed with streamlined shapes to reduce the force of air friction. Designers test the shape of the car by looking at how air will flow around the car's body.

In many sports, athletes have to run across the playing surface, for example football, cricket and athletics. The athletes need to be able to change speed and direction without slipping, so there should be good friction between the surface and the athletes' feet.

The amount of friction also depends on the athlete's footwear. Spiked shoes may be used on running tracks, studded shoes on grass surfaces and rubber soled shoes to increase friction on wood or concrete surfaces.

Some surfaces are used to produce the lowest possible friction, for example ice. An ice hockey puck glides over the ice with almost no resistance.

▲ **Figure 19.1.9** Different sports use different surfaces

Questions

1. State two effects of applying a force to an object.
2. What is the unit of force?
3. An object is acted on by a force of 4 N in one direction and a force of 3 N in the opposite direction. What is the resultant of these forces?
4. How can friction be overcome in machinery with moving parts?

19.2 The force of gravity

Gravity is a non-contact force. If an object is dropped from a height it will be pulled to the ground by the force of gravity. Gravitational force exists between any objects that have mass; the greater their mass, the greater the force of attraction.

Centripetal force

Newton's first law of motion tells us that an object continues to travel at a steady speed in a straight line unless it is acted upon by an external force.

▲ **Figure 19.2.1** The centripetal force keeps the ride going in a circle

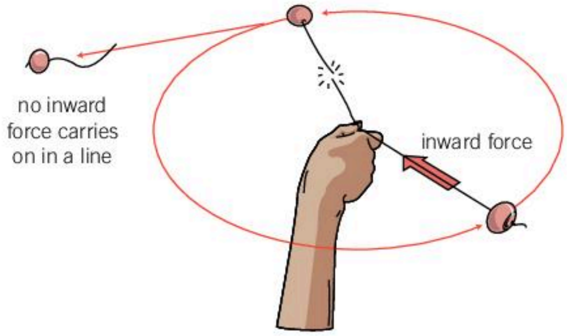
Any object that is travelling in a circular path is continuously changing direction, so it must be continuously acted upon by an external force. This force is called the **centripetal force**. It always acts towards the centre of the circle.

The size of the centripetal force on an object increases:

- as the mass of the object increases
- as the speed of the object increases.

If the centripetal force is removed the object will continue to travel in a straight line.

Examples of centripetal forces



▲ **Figure 19.2.2** If the string attached to the bead breaks, there is no inward force

- If a bead is whirled around on the end of a piece of string, the centripetal force is provided by the tension in the string.
- If the string broke, the bead would fly off in a straight line at a tangent to the circle. Due to the force of gravity acting on it, the bead would eventually fall back to the Earth.

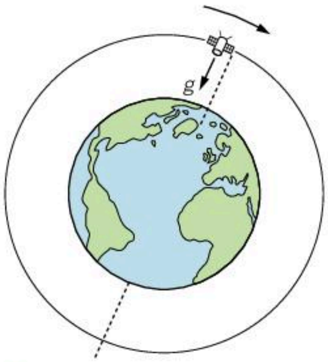
Learning outcomes

By the end of this topic you will be able to:

- define gravity
- describe the centre of gravity of a regular and an irregular shape
- explain what is meant by a centripetal force
- state the factors that affect the size of a centripetal force
- give some examples of centripetal forces
- explain how the centre of gravity affects the stability of an object.

Key fact

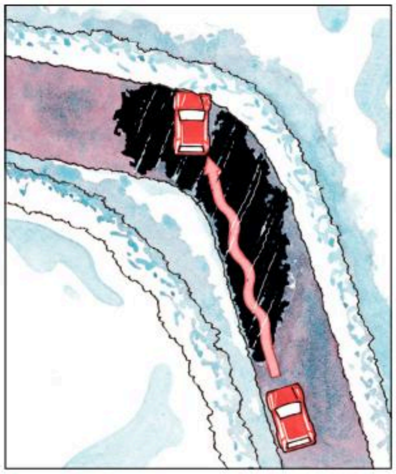
A tangent is a straight line touching a circle, which forms a right angle with a radius of the circle at the point of contact. If a centripetal force ceases to act an object moves off along a tangent.



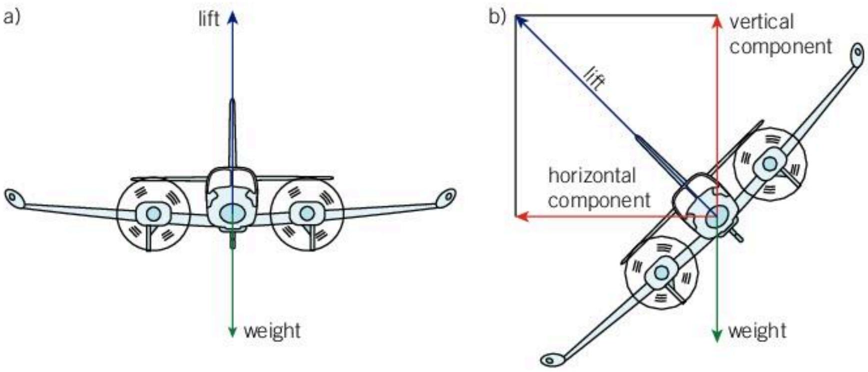
▲ **Figure 19.2.4** Gravity keeps the satellite in orbit

- If a car drives around a bend (part of a circle) the centripetal force is provided by the friction between the tyres and the road.
- If there was no friction, for example if there was ice or oil on the road, the car would be unable to turn and would skid off the road.

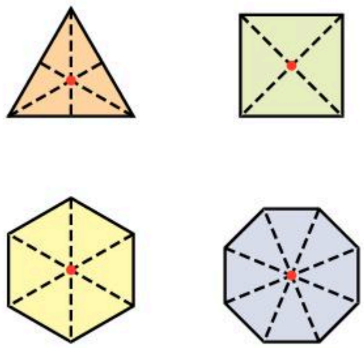
For a satellite orbiting the Earth the centripetal force is provided by the gravitational pull of the Earth on the satellite. If there was no gravitational force the satellite would travel off into space in a straight line.



▲ **Figure 19.2.3** If there is oil on the bend, the car skids off the road

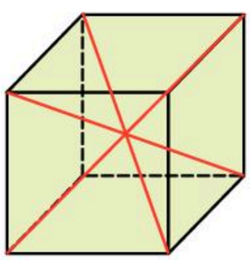


▲ **Figure 19.2.5** When an aeroplane turns, the horizontal component of lift provides the centripetal force



▲ **Figure 19.2.6** Lines of symmetry divide a regular shape into two identical halves

When an aeroplane is in a straight and level flight there are two equal forces acting on it: lift and weight (see Figure 19.2.5a) above). Lift acts perpendicularly to the wing. When the aeroplane turns the lift is divided into two parts: a vertical and a horizontal component (see Figure 19.2.5b above). To remain at the same altitude, the vertical component of the lift must be equal to the weight of the aeroplane. The horizontal component of the lift provides the centripetal force that makes the aeroplane turn.



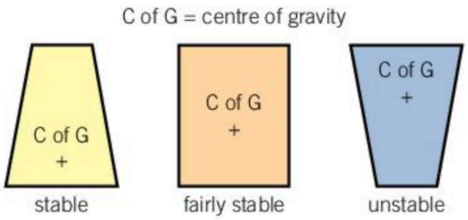
▲ **Figure 19.2.7** The centre of a cube is where lines joining opposite corners bisect

Centre of gravity

For many purposes it is useful to think of gravity as acting through a single point in an object. This is its **centre of gravity**.

The centre of gravity of a regular-shaped thin sheet is at the intersection of the lines of symmetry (see Figure 19.2.6).

The centre of gravity of a regular 3-dimensional solid is at its geometric centre (see Figure 19.2.7).

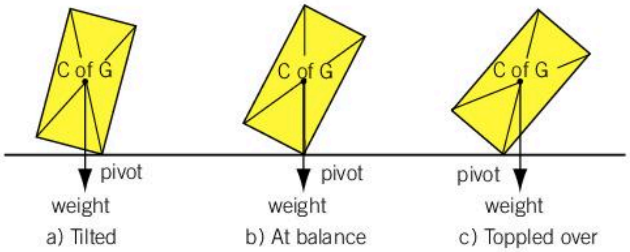


▲ **Figure 19.2.8** Stable objects have broad bases and lower centres of gravity

Stability

The position of the centre of mass of an object, in relation to its base, determines the stability of an object. The smaller the base of an object and the higher its centre of gravity, the less stable it will be.

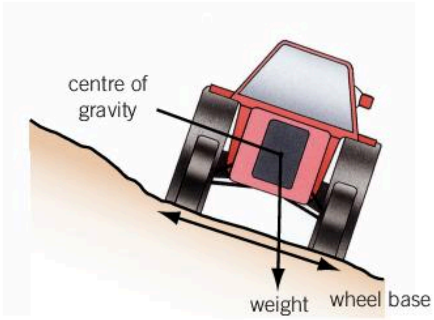
The fate of an object after it has been tilted depends on what happens to the horizontal position of the centre of gravity.



▲ **Figure 19.2.9** If an object is tilted, it will fall back to its normal position provided the horizontal position of the centre of gravity doesn't move outside its base

Provided the centre of gravity remains within the base of an object, it will tilt but it will not topple over. However, if the centre of gravity moves outside the base the object will topple onto its side.

Stability is important when designing vehicles and particularly tractors because farmland is often on steep hillsides. The tractor has a wide wheelbase and a low centre of gravity which makes it stable on slopes.



▲ **Figure 19.2.10** Tractors need to be very stable

The loading of vehicles is important as the centre of gravity should be kept low to maintain stability. For a motor bike, the panniers need to be low down so that the centre of gravity is low. Putting heavy loads on to the tops of buses and cars should also be avoided. A heavy load on top of a vehicle will raise the centre of gravity and make it unstable, especially when driving around corners. Many commercial vehicles have a maximum permitted load and undergo stability tests.

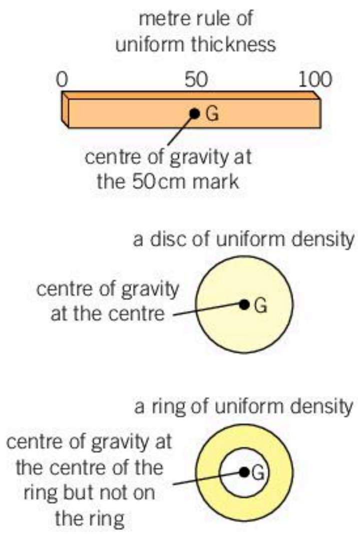
Questions

1. Which of Newton's laws states that an object continues to travel at a steady speed in a straight line unless acted on by a force?
2. What happens to the centripetal force of an object moving in a circle when its speed decreases?
3. What provides the centripetal force that keeps a car on the road as it turns around a bend?
4. What is Newton's third law?

Learning outcomes

By the end of this topic you will be able to:

- understand the relationship between gravity and weight
- explain the term 'centre of gravity'
- determine the centre of gravity of an irregular-shaped object
- describe the action of parallel forces.



▲ **Figure 19.3.1** Diagrams of some regular-shaped objects showing their centres of gravity

19.3 Centre of gravity and the conditions for equilibrium under parallel forces

Gravity and weight

The action of gravity on a mass produces a force called the weight. Weight is measured in newtons. On Earth, a mass of 1 kg has a weight of about 10 N. Objects with a larger mass have more weight than objects of smaller mass, because they exert more gravitational force.

Centre of gravity

Gravity is a force exerted by the Earth in a downwards direction. Every molecule in an object contributes to the weight of the whole object and the object behaves as if its whole weight were a single force acting through a point called its centre of gravity.

You learnt in Topic 19.2 that the centre of gravity of an object is the point through which its whole weight acts, for any direction in which the object is placed. For a symmetrical shape, such as a ball, the centre of gravity will be in the middle. For an irregularly shaped object, the centre of gravity will be closer to wherever most of its mass is. The centre of gravity stays in the same position on the object.

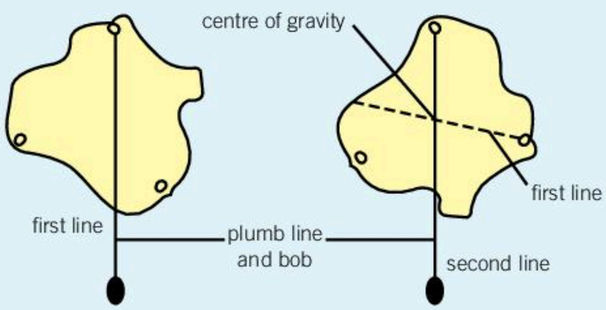
Practical Activity 19.3.1

Finding the centre of gravity of an object with an irregular shape

Skills assessed: Observation/Recording/Reporting.

Your teacher will provide you with an irregularly shaped piece of cardboard with three holes punched in it at different positions near its edge, a plumb line, and a stand and clamp. Your task is to find the centre of gravity of the cardboard.

1. Hang the cardboard by a hole from the clamp and attach the plumb line to the clamp.
2. Draw a line across the cardboard where the string hangs.
3. Repeat the process, hanging the cardboard by a second hole.
4. What is the significance of the point where the lines intersect?



5. Predict what will happen if you repeat the process hanging the cardboard by a third hole.
6. Test your prediction.

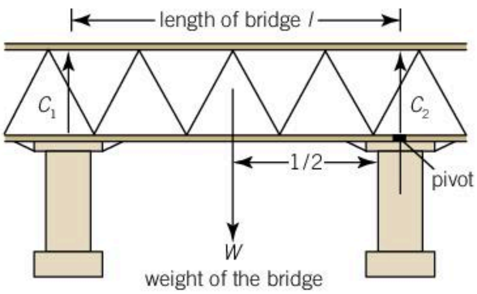
Equilibrium and parallel forces

When two or more parallel forces are acting on an object, if the object is not moving or turning it will be in equilibrium. This means that the forces are equal and are acting on the object in opposite directions but in the same line.

To be in equilibrium, the forces acting in one direction must be equal to the forces acting in the opposite direction.

Examples of parallel forces in equilibrium are:

- weights being suspended by a spring, as in a spring balance
- a bridge which is supported by pillars: the weight of the bridge acts downwards and the pillars provide the upward force.



▲ **Figure 19.3.2** Three parallel forces in equilibrium

Questions

1. Write a definition of the centre of gravity of an object.
2. Where is the centre of gravity of symmetrical objects?
3. Describe how you can determine the centre of gravity of an irregularly shaped object.
4. Explain why a mass of 1 kg will have a different weight on the Moon.

Learning outcomes

By the end of this topic you will be able to:

- explain stable, unstable and neutral equilibrium
- demonstrate the three types of equilibrium
- understand what a moment is
- use an equation to calculate the moment of a force
- understand that at equilibrium the anticlockwise moment must be equal to the clockwise moment.

19.4 Equilibrium

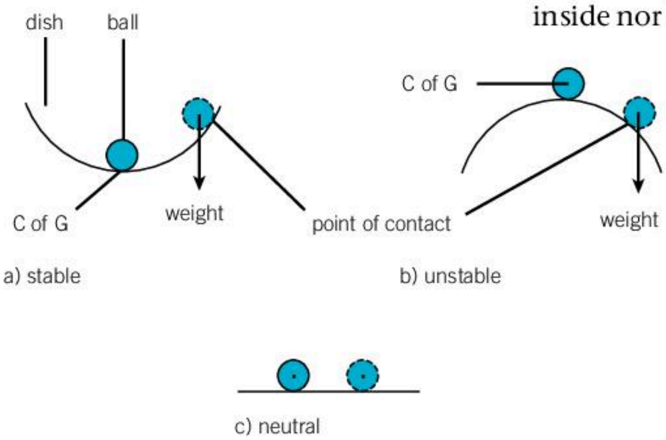
Equilibrium

The stability of objects can be viewed in terms of three **states of equilibrium**. Consider the motion of a ball in different circumstances.

1 If a ball at the bottom of a bowl is moved, it will always return to its original position. This situation is called stable equilibrium and corresponds to a situation where an object is tilted but the centre of gravity remains within its base.

2 If the bowl is inverted and the ball placed on the top, any movement will cause the ball to move further away from its original position. This is called **unstable equilibrium** and corresponds to a situation where an object is tilted so far that its centre of gravity moves outside its base.

3 If a ball on a flat surface is moved, it will stay at its new position and not move back to its original position. This is called **neutral equilibrium** and corresponds to a situation where the centre of gravity is neither inside nor outside the base of an object.



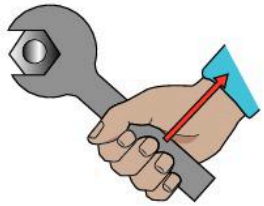
▲ **Figure 19.4.1** There are three equilibrium conditions

Moment of a force

If a force acts through the centre of gravity, it is either a push or a pull and the object moves in the direction of the force. However, a turning effect results if the force does not act through the centre of gravity. For example, when we use a spanner to slacken or tighten a nut we apply the force at the opposite end to the nut and it turns. The force created by a turning effect is called a **moment**.

The turning effect is dependent on:

- the size of the force
- the perpendicular distance between the line of action of the force and the turning or pivot point. This is called the **fulcrum**.

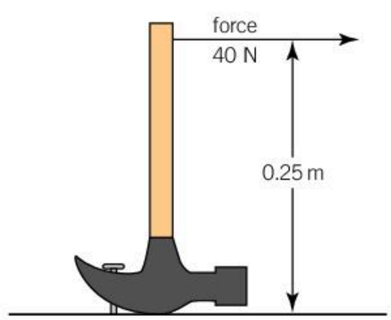


▲ **Figure 19.4.2** A moment is the turning effect of a force

We can calculate the size of the moment using the equation:

moment (in N m) = **force** (in N) × **perpendicular distance between the line of action of the force and the fulcrum** (in m)

A claw hammer is being used to remove a nail from a piece of wood. The moment of this claw hammer about the surface on which it rests (the fulcrum) is 40 N × 0.25 m = 10 N m.



▲ **Figure 19.4.3** The force is exerted at right angles to the claw hammer

Exam tip

Remember to convert mass in kilograms to force in newtons when using the equation.

Law of moments

The law of moments states that in equilibrium the anticlockwise moment must be equal to the clockwise moment.

In Figure 19.4.4, two children are sitting on a seesaw. The seesaw is horizontal and therefore in equilibrium.

The girl is heavier but she is sitting nearer to the fulcrum than the boy.

There are two forces acting on the seesaw.

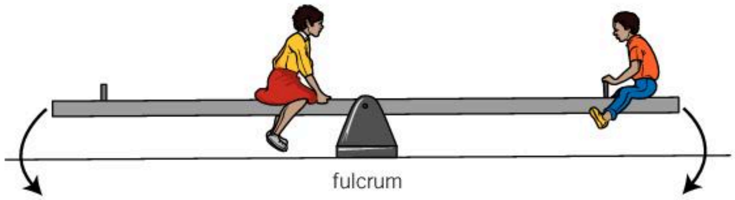
- The girl's weight is pushing the seesaw down on the left causing it to rotate **anticlockwise** about the fulcrum.
- The boy's weight is pushing the seesaw down on the right causing it to rotate **clockwise** about the fulcrum.

The seesaw is in equilibrium, therefore the anticlockwise moment must be equal to the clockwise moment.

The size of the moment depends both on the children's weights and distance they are from the centre of the seesaw.

If the girl and boy were the same weight, the moment of the weight of the boy would be greater because he is sitting further from the fulcrum. Therefore the seesaw would turn in a clockwise direction.

If the girl and boy were sitting the same distance from the fulcrum, the moment of the weight of the girl would be greater because she is heavier. Therefore the seesaw would turn in an anticlockwise direction.



▲ **Figure 19.4.4** The seesaw is in equilibrium

Questions

1. Which force pulls objects towards the Earth?
2. How can you find the centre of gravity of a rectangular lamina?
3. What happens if the vertical position of the centre of gravity of an object moves outside its base?
4. What type of equilibrium is shown by a ball on a flat surface?
5. A force of 15 N is applied at a right angle to a bottle opener 10 cm from the bottle top. What is the moment of the force?

Practical Activity 19.4.1

Investigating moments

Skills assessed: Observation/Recording/Reporting and Manipulation/Measurement.

Your teacher will supply you with the following materials to make a simple seesaw: a short piece of dowel (for the fulcrum) and a 30 cm wooden ruler or similar piece of wood. You will also receive some 0.5 N weights.

1. Experiment by placing the ruler on the fulcrum (not necessarily at the centre) and place a 0.5 N weight at the left-hand end.
2. Place one or more weights to the right of the fulcrum until the ruler is in equilibrium.
3. Measure the distances between the centre of the weight and the fulcrum on each side, and write your results in a table:

Weight on left side	Distance of weight from fulcrum	Anticlockwise moment	Weight on right side	Distance of weight from fulcrum	Clockwise moment
0.5 N					

4. Repeat steps 1 to 3 several times.
5. Comment on the size of the anticlockwise moment and clockwise moment each time.

Exam-style questions

Multiple choice

1 A mass of 20 kg has a weight of:
A 2 N **B** 200 N
C 20 N **D** 2000 N

2 A helpful effect of friction is that it:
A allows us to write clearly on paper
B slows down the moving parts of a machine
C allows tyres to slide on road surfaces
D causes wear and tear on a surface

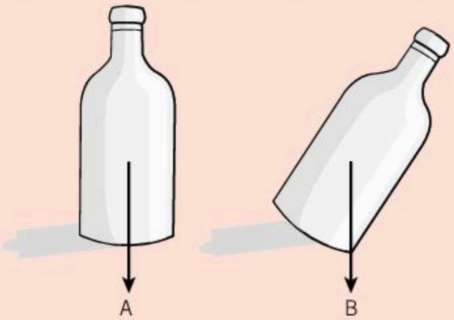
3 Which of the following describes an unstable object?
A It has a low centre of gravity.
B It has a broad base.
C It has an irregular shape.
D It has a high centre of gravity.

Structured questions

4 a What is force?
b State two effects of applying force to an object.
c Explain what is meant by action–reaction when referring to forces.
d Calculate the resultant force if two forces act on an object as shown in the diagram.

5 a What is friction?
b Give two ways that friction can be useful in our everyday lives.
c Describe two ways that friction can be overcome.

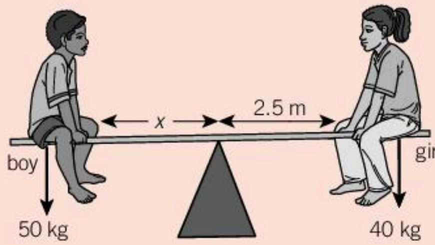
6 The diagrams show two states of equilibrium.



a Name the types of equilibrium in diagrams A and B.
b Women in the last stages of their pregnancy tend to lean backwards. Explain why they do this in terms of their centre of gravity.
c How are farm vehicles designed so that they stay upright on steep slopes?

7 a What is the moment of a force?
b A force of 20 N is applied to a ruler 20 cm from the fulcrum. What is the moment of the force?
c A boy of weight 50 kg sits on one side of a seesaw and a girl of 40 kg sits on the other side 2.5 m from the middle.

Calculate the distance, *x*, the boy should sit from the centre for the seesaw to be in equilibrium.



d A 30 g mass is suspended from a ruler 20 cm from the centre. How far should a mass of 20 g be suspended from the centre so that the ruler balances?

8 a What is centripetal force?
b The diagram below shows a stone tied to the end of a string being swung around in circular motion. Explain what will happen if the string breaks.

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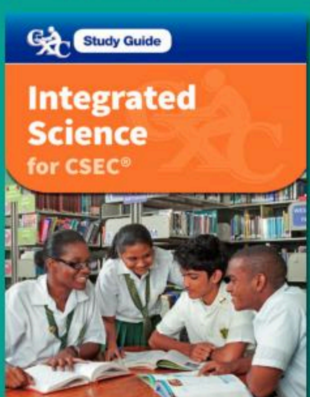

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