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Objectives

- Describe the structure of plants from the roots to the leaves
- Know that photosynthesis is the process by which plants make carbohydrates
- Describe trends and patterns in results
- Make conclusions by interpreting results

stem

Fig 9.1 A: The main structures of a plant.

What do we know about plants?

Plants are everywhere – they are even visible on the Earth from space. Plant biology is one of the most important areas of scientific study today.

Why are plants important?

Think of what you already know about plants.

- Plants make carbohydrates using energy from the Sun and carbon dioxide from the atmosphere.
- Plants are the producers for food chains and food webs all over the world.
- Plant crops are the source of most human food, both directly and as animal feed.
- Plants are part of the water cycle (see Unit 4.2).
- Materials from plants are used for medicines, clothing, building, biofuels and more.

Why do we study plants?

Biologists study plants for many different reasons. They want to find out about the world around them. Understanding plants also helps us make better use of them. Scientists look at plant structures, plant breeding and the genetic material of plants. They use this knowledge to develop plants with useful characteristics such as big leaves or large fruits. They study the nutrients plants need to grow as fast and as large as possible, so they can help farmers get the best crops (Fig 9.1 B). Scientists also investigate plant pests and diseases, to develop ways of protecting our plants from attack.

The structure of a plant

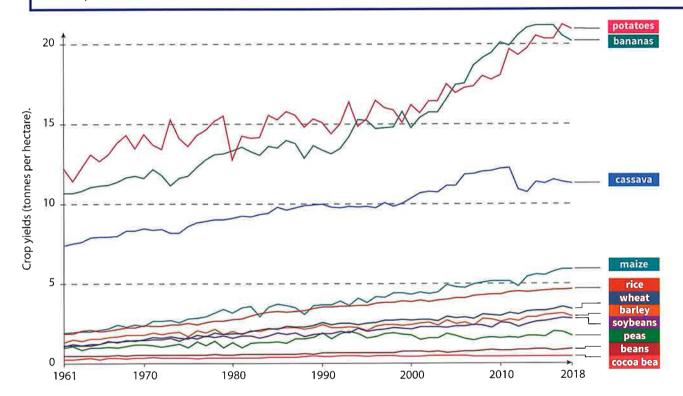
Before you look in detail at plants, remind yourself of the main structures you will be learning about.

- **Roots:** the roots anchor the plant in the ground and supply it with water and mineral nutrients from the soil.
- **Stems:** stems support the leaves, holding them out to capture the sunlight they need for photosynthesis. They also support the flowers and fruit.
- Leaves: leaves capture energy from the Sun using the green colour chlorophyll. They use this for photosynthesis to make carbohydrates.
- **Flowers:** flowers are the reproductive structures of plants, and they form the seeds and fruit. They only appear at certain times in the life cycle of the plant.

Thinking and working scientifically

Crop yields over time

The data in Fig 9.1 B show the **yield** of different plant crops over the last 57 years. The graph shows clear patterns in the data. Each crop produces more now than it did in 1961. The yield of some crops, such as maize and wheat, has more than doubled. All of this extra food is the result of scientists learning more about plants.



Questions

- 1. State 3 reasons why plants are important to people.
- 2. Draw a diagram of a plant and label the roots, stem, leaves and flowers. Describe the function of each structure you label.
- **3.** Use the data in Fig 9.1 B to answer these questions.



- **a.** What trend do these data show in crop production?
- **b. i.** Which is the highest yielding crop shown in Fig 9.1 B?
 - ii. What was the yield of this crop in 1970 and in 2017?
 - iii. Calculate the percentage increase in the yield of this crop. Show your working.
- **c.** Look at the data for cassava, rice and maize. Calculate the increase in yield for all three of these crops between 1970 and 2017. Show your working.
- d. Describe the type of the scientific work which has given us these changes in crop yields and explain why it is so important.

▲ Fig 9.1 B: Global crop yields over 57 years, 1961-2018, measured in tonnes per hectare.



Key points

- The main structures in plants are the roots, stems, leaves and flowers.
- Graphs allow you to see trends in a series of results.
- Interpreting results from a graph makes it possible to draw evidence-based conclusions.



Objectives

- Know that photosynthesis is the process by which plants make carbohydrates, using the energy from light
- Know that photosynthesis occurs in the chloroplasts
- Know and use the summary word equation for photosynthesis

Photosynthesis

For many people, plants are just a green background to their lives, in the countryside or in their homes. To biologists, plants are important organisms. The health of our planet, our own food and wellbeing, and the great diversity of life on Earth all depend on plants. In fact, they all depend on one vital process – photosynthesis.

What is photosynthesis?

Biomass is the material living organisms are made of, and much of the biomass on Earth comes from plants. Animals have to eat plants to get the biomass they need. Plants do not need to feed. They make their own biomass using sunlight, air and water in a process called photosynthesis.







▲ Fig 9.2 A: From wood to cereal crops to flowers – all of the biomass in plants comes from photosynthesis.

light energy IN water IN glucose OUT oxygen IN OUT

▲ **Fig 9.2 C**: This section through a leaf shows you the movements into and out of a leaf during photosynthesis.

The process of photosynthesis

Plants need two small molecules to make carbohydrates in photosynthesis:

- carbon dioxide, which they get from the air, and also make during aerobic respiration
- water, which they get from the soil (see Unit 9.5).

They also need energy from light, usually the Sun. Plants capture light energy using the green pigment chlorophyll. They use it in a reaction between carbon dioxide and water to make a molecule of glucose, a simple carbohydrate. Oxygen is also produced in the reaction. The oxygen made by plants during photosynthesis is used for aerobic respiration in the cells of most living things.

Photosynthesis involves many different reactions, but we represent the process as a simple summary word equation:

▲ **Fig 9.2 B**: Photosynthesis in plants uses energy from the Sun to combine carbon dioxide and water to make glucose and oxygen.

Why are chloroplasts important?

As you know, chloroplasts contain the green chlorophyll needed to capture light energy for photosynthesis. Most of the reactions of photosynthesis also take place inside the chloroplasts. If a plant cell does not have any chloroplasts, it cannot carry out photosynthesis. The number of chloroplasts in a plant cell tells you about the amount of photosynthesis it carries out.

How do plants use the glucose they make in photosynthesis?

Plants use the glucose they make during photosynthesis in several ways:

- For aerobic respiration: about half of the glucose a plant makes is used in cellular respiration, making energy available for all the other reactions going on in the cells.
- As a starch store: small, soluble glucose molecules cannot be stored but plant cells need glucose to respire in the dark, when photosynthesis stops. Glucose molecules join together to form big molecules of starch, which are stored in the leaves. A leaf stores enough starch to last several days without any light. Starch is also stored in special areas such as root tubers for example, potatoes are full of plant starch.
- To make other molecules: plant cells need other carbohydrates, proteins, lipids and molecules like chlorophyll. Glucose molecules made during photosynthesis are the building blocks for all of these other compounds.

Questions

- 1. a. What is photosynthesis?
 - **b.** Give the summary equation for the process of photosynthesis.
- 2. Describe the function of chloroplasts in photosynthesis.
- **3.** Describe three ways in which plants use the glucose made during photosynthesis.
- **4.** 'Most of the biomass on Earth has come from photosynthesis'. Discuss this statement.

(Rey points

- Photosynthesis is the process by which plants make carbohydrates, using the energy from light.
- Chloroplasts contain chlorophyll which traps the light energy needed for photosynthesis.
- The reactions of photosynthesis take place in the chloroplasts.
- The summary word equation for photosynthesis is:

 $\begin{array}{c} \text{light} \\ \text{carbon dioxide + water} & \longrightarrow & \text{glucose + oxygen} \\ \text{chlorophyll} & \text{(products)} \end{array}$



▲ Fig 9.2 D: Photosynthesis takes place in the chloroplasts in plant cells.

Thinking and working scientifically

9.3

Objectives

- Know that photosynthesis occurs in the chloroplasts, and is the process by which plants make carbohydrates, using the energy from light
- Plan a range of investigations of different types to obtain appropriate evidence when testing hypotheses

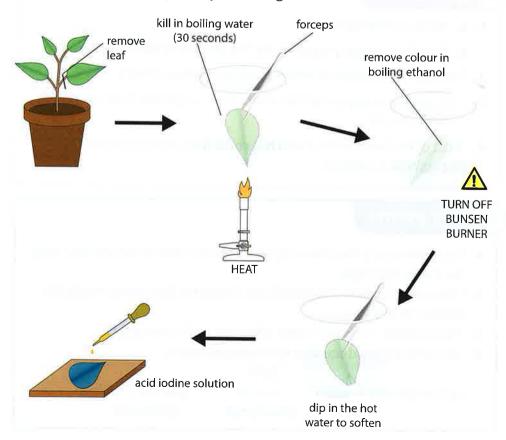
Evidence for photosynthesis: testing for starch

Salma, Dina and Abdul know that some of the glucose made in a leaf by photosynthesis is turned into starch to be stored. Their teacher describes a method of showing there is starch in a leaf using iodine solution, a yellow-brown liquid which turns blue-black in starch.

How do you test a leaf for starch?

Leaves are covered in a waxy, waterproof layer and leaf cells have tough cell walls, so iodine cannot reach the starch in a living leaf. You must prepare a leaf carefully before testing it for starch. Look at Fig 9.3 A:

- **1.** Take a leaf from a plant. To demonstrate photosynthesis it must have been in the light for at least 12 hours.
- 2. Drop the leaf into boiling water to remove the waterproof layer and break open the cells. Turn off the Bunsen burner. Use forceps to take the leaf from the boiling water.
- 3. Place the leaf in a test tube of ethanol and put the test tube into the hot water. The ethanol will boil and the green colour will come out of the leaf.
- **4.** Remove the white leaf from the ethanol. It will be stiff. Dip it into the hot water to soften it.
- **5.** Spread the leaf on a white tile and add a few drops of iodine solution. If starch is present, the leaf will turn blue–black. This shows it contains starch and has been photosynthesising.



▶ **Fig 9.3 A**: Using iodine to test a leaf for starch. Take care with hot water and hot ethanol.

Investigating photosynthesis

Now Salma, Dina and Abdul must use the iodine test to investigate photosynthesis. Their teacher reminds them that a leaf uses its starch stores for respiration when it is in the dark. It has enough starch to keep respiring for 2–3 days. If you are going to investigate photosynthesis by looking for starch, always start with a plant that has been in the dark for at least 3 days, so that you know it has not got any starch left.

Here are their plans:

Abdul Dina Salma Do plants need carbon dioxide to Do plants need chlorophyll to Do plants need light for photosynthesise? photosynthesise? photosynthesis? Take a plant that has been in a Take a plant with two-coloured Take a plant that has been in a dark cupboard for at least 3 days. leaves that has been in a dark dark cupboard for at least 3 days. Place a bag containing a chemical cupboard for at least 3 days. Place Make a foil cover and put it on a that absorbs carbon dioxide it in the light for 24 hours. Test leaf of a plant. Make sure the foil around one leaf. Leave the plant a leaf from the plant for starch, blocks the light. Leave the plant in the light for 24 hours. Take the using the iodine test we have in the light for 24 hours. Use the leaf out of the bag and test it for learned. iodine test to test the foil-covered starch, using the iodine test. Test leaf for starch. a leaf that was in the air for a control.

before

light blocked

with silver foil

after

Q Questions

before

- 1. Make a flow diagram showing how to test a leaf for starch.
- 2. a. Explain why the students use plants kept in the dark for three days in their planned investigations.
 - **b.** For each investigation:
 - i. State what they are investigating.

after

- ii. State the conclusion you can draw from their results.
- iii. Give two examples of good science in their plan.
- iv. Suggest one way the investigation could be made better.

(Rey points)

after

before

carbon dioxide

removed from air

around leaf

- Photosynthesis occurs in the chloroplasts, and is the process by which plants make carbohydrates, using light.
- A range of investigations can test different hypotheses about the requirements for photosynthesis.

Thinking and working scientifically

9.4

Objectives

- Know that photosynthesis occurs in the chloroplasts, and is the process by which plants make carbohydrates, using the energy from light
- Decide when to increase the range of measurements taken to give reliable data
- Describe trends and patterns in results
- Make conclusions by interpreting results and explain the limitations of your conclusions



▲ **Fig 9.4 A**: Bubbles of oxygen-rich gas produced by waterweed as it photosynthesises.

Evidence of photosynthesis: oxygen bubbles

Evidence for photosynthesis

Recall the summary equation for photosynthesis:

light

carbon dioxide + water

 \rightarrow

glucose + oxygen.

(reactants)

chlorophyll

(products)

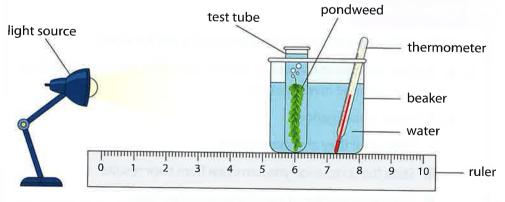
Some of the glucose made during photosynthesis is turned into starch to be stored. You know how to use the starch made in leaves as evidence that photosynthesis has taken place (Unit 9.3).

Oxygen is also produced during photosynthesis. Some of the oxygen is used by plant cells for aerobic respiration. Some of it is lost from the leaves. It is difficult to use the oxygen produced from the leaves of land plants as evidence for photosynthesis because it diffuses into the air. Plants that live in water are different. The oxygen they make when they photosynthesise is released from the leaves and from cut stems as bubbles in the water. Shining a light on a water plant allows you to:

- collect the gas and show that it is oxygen, as evidence of photosynthesis taking place
- count the number of bubbles produced in a given amount of time to show how quickly photosynthesis is taking place.

Does light intensity affect the rate of photosynthesis?

David and Iona set out to investigate the effect of **light intensity** on the rate of photosynthesis of a water plant using the apparatus shown in Fig 9.4 B. What do you predict will happen as the plant is moved further away from the lamp?



▲ **Fig 9.4 B**: Apparatus used to measure the effect of light intensity on photosynthesis.

Method

- 1. Place a piece of pondweed in a tube, cut end up, and cover with water.
- 2. Place the tube in a beaker of water and position it on a ruler so the plant is 0 cm from the lamp.
- 3. Give the plant a few minutes to adjust to the light intensity.
- **4.** Count the number of bubbles escaping from the cut end per minute and record your data.
- 5. Repeat your count at least once more.
- **6.** Repeat the experiment, moving the plant 2 cm further away from the lamp each time.

Results

David and Iona recorded their results in a table:

Lamp distance	Number of bubbles per minute		
from plant (cm)	Test I	Test 2	Average
0	110	104	107
2	92	94	93
4	86	84	85
6	75	69	72
8	62	58	60
10	50	46	48

Their teacher noticed that the second reading was often lower than the first.

David suggests that the plant is still adjusting to the lower light intensity. Perhaps they should give it longer to adjust each time.

Iona thinks that the cut end of the plant might be healing over, so fewer bubbles escape. Perhaps they should cut the stem after every measurement to keep it open.

What do you think?

Questions

- 1. Plot a graph of David and Iona's results.
- 2. Describe what you see on the graph.
- **3.** Give the conclusions you draw from this investigation.
- **4.** Suggest a reason for the thermometer in the beaker of water shown on the diagram and explain why it is important.
- 5. Evaluate this investigation.
 - **a.** Describe two examples of good science in this investigation.
 - **b.** Suggest three ways in which the investigation could be made better.



- Photosynthesis occurs in the chloroplasts. It is the process by which plants make carbohydrates, using the energy from light. Oxygen is also produced during photosynthesis.
- The reliability of the results of these investigations would be improved using a wider range of measurements and by repeating each reading more often.
- The results show a clear trend which can be described both from the table and from a graph of the data.
- We can draw
 conclusions from
 these results about the
 relationship between
 the light intensity
 and the amount of
 photosynthesis that
 takes place, although
 the conclusions are
 limited by the quantity
 and reliability of
 the data.

Objective

 Plants need minerals to maintain healthy growth and life processes





▲ Fig 9.5 A: Photosynthesis is amazing – but plants need more than light, water and carbon dioxide to grow, and to produce flowers and fruits.

The need for minerals

If you put a plant in a jar of water and leave it in the air and sun, will it live? For a time, it will do well. It has light, water and carbon dioxide – everything it needs for photosynthesis.

Sadly, in time your plant will look sickly and eventually it will die. What goes wrong?

The need for minerals

In Chapter 6, you learned that humans need a balanced diet to stay healthy. A balanced diet for people includes small amounts of **minerals** such as calcium and iron.

Photosynthesis provides plants with glucose, which they use in aerobic respiration or build into bigger carbohydrate molecules like starch or cellulose for their cell walls. Plant cells also use carbohydrates to make lipid molecules. But there are some substances which cannot be made from carbohydrates alone.

Plants need minerals too. Minerals are water-soluble substances that cells can absorb. Two of the most important minerals for plants are:

- Nitrates: Nitrates contain nitrogen. They are produced by decomposers breaking down the waste material and dead bodies from other plants and animals.
 - Plants must have nitrates to make the proteins they need. Proteins control many reactions in plant cells, including photosynthesis. They are also part of the structure of the plant cell itself. Without nitrates to make proteins, a plant cannot survive for long.
- Magnesium: Chlorophyll, the green molecule which traps light in photosynthesis, contains magnesium. Plants must have enough magnesium to make chlorophyll for the chloroplasts of new cells, and to replace the chlorophyll when chloroplasts get worn out or damaged.

Mineral deficiencies in plants

If a plant does not get the minerals it needs, it does not grow well. This is called a **mineral deficiency**. Different mineral deficiencies in plants have different symptoms. We can recognise which mineral is missing by the appearance of the plant – very like mineral deficiency diseases in people.

Mineral deficiency	Symptoms	
Nitrate	Poor growth, and older leaves turn yellow	
Magnesium	Plant leaves are pale or yellow	



Plants get most of the minerals they need, such as magnesium, from the soil. The minerals are dissolved in the water in the soil. They are taken into the plant with water through the plant roots and carried around in the plant transport systems (see Unit 9.7).

Most plants get all the nitrates they need from the soil, just like the other minerals. Some plants, called **legumes** (peas, beans and clover), do not get their nitrates from the soil. They have root nodules full of special bacteria that make nitrates from the nitrogen in the air. The plants get some of these nitrates in return for sugar from photosynthesis. Legumes grow very well in nitrate-poor soil. They even add nitrates to the soil and make it more fertile. Farmers often grow them to improve the soil for other crops that need lots of nitrogen.





▲ Fig 9.5 B: Peas and beans are successful because of their root nodules. The nodules are full of bacteria that make nitrates for the plant.

Questions

- 1. Plants need minerals to grow well. What are minerals?
- 2. Name two minerals that plants need for healthy growth. For each, explain the importance of the mineral in the plant.
- **3.** A gardener grows fruit and vegetables in her garden to help feed her family. This year, many of her crops do not grow well. As the plants get bigger, the older leaves turn yellow. In one part of the garden the plants are doing well. Her peas and beans are growing strongly.
 - **a.** Suggest why many of the plants are not growing well and explain how you know this.
 - **b.** Explain why the peas and beans are growing well when the other plants are not.
 - c. Suggest how the gardener could improve her crops next year without buying fertiliser.

(III) Key points

- Plants need minerals to maintain healthy growth and life processes.
- Minerals are watersoluble substances that plants can absorb from the soil.
- Plants need nitrates to make proteins.
- Plants need magnesium to make chlorophyll for photosynthesis.

Science in context

9.6

Objectives

- Plants need minerals to maintain healthy growth and life processes
- Describe how science is applied across industries



▲ **Fig 9.6 A**: Natural fertilisers include manure.



▲ Fig 9.6 B: Nitrate fertilisers help us grow the food we need.

The use of fertilisers

In a wild ecosystem, plants grow, flower, fruit and eventually die. They are broken down by decomposers returning nutrients to the soil, for the next generation of plants.

On a farm the plants also grow, flower and fruit, taking minerals from the soil. Then we harvest the crop and grow more plants in the same soil the next year. Each crop takes more minerals from the soil. How can we keep our soil fertile?

What are fertilisers?

Fertilisers are substances that replace minerals such as nitrates in the soil. Using fertilisers increases the yield of crops. There are two main types of fertilisers.

- For thousands of years people have used natural fertilisers such as manure, made from decomposed animal droppings, and compost, from decomposed plant material (see Chapter 3 and Fig 9.6 A). These fertilisers are cheap and improve the structure of the soil but they release their nutrients slowly and there is a limited supply.
- We have only had artificial fertilisers for around 100 years. They are
 made in huge quantities in industrial processes (see Fig 9.6 B and C).
 They work fast and are always available. Farmers control the amount of
 nitrate added to the soil. But artificial fertilisers are also expensive, and
 they do not improve the structure of the soil.

Scientists estimate that almost 50% of the world population now rely on food grown with the help of artificial fertilisers!

Nitrate fertilisers - applying science to industry

The air is 80% nitrogen, but most plants can't use it. They have to get their nitrates from the soil.

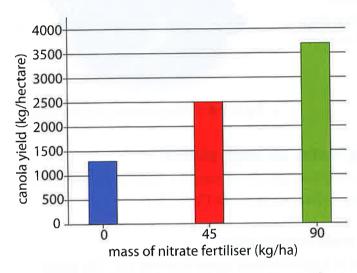
By applying science to industry, we have developed artificial nitrate fertilisers. This has saved billions of lives by helping us grow the food we need to feed the increasing world population.

In the early 20th century, a German chemist called Fritz Haber developed a way of making a compound called ammonia from the nitrogen in the air. Ammonia acts as a nitrate-rich fertiliser. Haber's laboratory method only made small amounts of ammonia, so it was not much use to farmers!

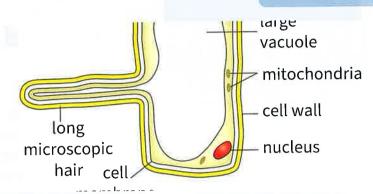
Then Carl Bosch, a chemist and engineer, developed a way to use Haber's reaction on an industrial scale. This Haber–Bosch process is still used today to produce around 120 million tonnes of nitrate fertiliser for farmers all over the world (see Fig 9.6 C).

Through the industrial production of nitrate fertilisers, science has changed the world. More people have enough food to live and to raise children – nitrate fertilisers have saved billions of lives.

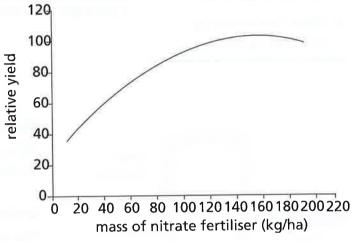
Figs 9.6 D and 9.6 E show examples of the impact of nitrate fertilisers on the yield of two important crops. Canola oil is widely used for cooking and wheat is one of the staple food crops of the world.



▲ Fig 9.6 D: Effect of nitrate fertiliser on the yield of canola.



▲ Fig 9.6 C: A fertiliser factory – science applied to industry.



▲ Fig 9.6 E: Effect of nitrate fertiliser on the yield of wheat.

Questions

- 1. a. Define a fertiliser.
 - **b.** Explain why we need fertilisers to grow our food.
- **2.** Give two advantages and two disadvantages of improving crop yield by using:
 - a. natural fertilisers
 - b. artificial fertilisers.
- **3.** The use of artificial fertilisers is an example of the impact of science applied to industry. Explain this statement.
- **4. a.** Use Fig 9.6 D to calculate the percentage increase in yield of canola using
 - i. 45 kg/hectare nitrate fertiliser
 - ii. 90 kg/hectare nitrate fertiliser.
 - **b.** Use Figs 9.6 D and 9.6 E to make a table to compare the impact of nitrate fertiliser on canola and wheat crops.

(Rey points

- Plants need minerals to maintain healthy growth and life processes.
- Scientific understanding is applied to industrial processes in the production of nitrate fertilisers. This has had a big impact on global society, saving billions of lives.



Objective

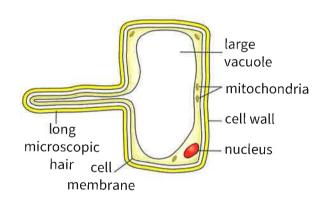
- Describe the pathway of water and mineral salts from the roots to the leaves in flowering plants
- Make conclusions by interpreting results

Water and mineral transport in plants

Plants need water for photosynthesis, for support and to carry substances to the different parts of the plant body. If a plant doesn't get enough water, its stems and leaves droop (see Fig 9.7 A). How does a plant get the water it needs?



▲ Fig 9.7 A: Without water, a plant wilts.



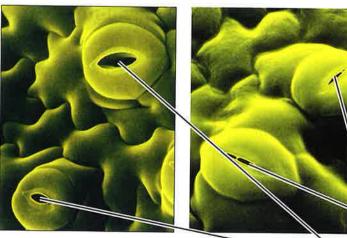
▲ Fig 9.7 B: Root hair cells are specialised for the absorption of water and minerals from the soil.

Moving water through plants

Water moves through plants from the roots to the leaves in the **transpiration stream** (see Fig 9.7 E).

Getting water into the plant

The roots of a plant absorb water from the soil. The water moves from the soil into the root hair cells by diffusion. As you know, plants have specialised root hair cells on the outside of their roots. Root hair cells have long, microscopic hairs that give them a big surface area. This allows a lot of water to move by diffusion through the surface into the root of the plant. Remind yourself of their structure in Fig 9.7 B. Minerals such as nitrates are also absorbed into plant roots through the root hair cells. They are transported dissolved in the water.



▲ Fig 9.7 C: Stomata on the bottom of a leaf, magnified 1000 times

Transporting water and minerals around the plant

Xylem is a specialised plant tissue (see Unit 9.8). Xylem tubes run up through the stems of a plant from the roots to the leaves. They are part of the plant transport system. Water moves up the plant in the xylem, carrying dissolved minerals to the cells where they are needed.

stomata closed

stomata open

Leaving the plant

The leaves are very important plant organs. This is where most photosynthesis takes place. The leaves are also where gas exchange takes place in a plant. On the underside of leaves there are lots of tiny holes called **stomata** (singular = stoma). Each stoma is surrounded by special cells which open and close it (as you can see in Fig 9.7 C). The carbon dioxide the plant needs for photosynthesis moves in through the stomata; any spare oxygen made during photosynthesis moves out. Whenever the stomata are open, water evaporates from the cells of the leaves, and moves out through the stomata by diffusion. This process is called **transpiration**. As water vapour evaporates from the leaves, more water is pulled up through the plant – rather like sucking on a drinking straw. When it is hot or windy, more transpiration takes place because more water evaporates from the leaves.

Thinking and working scientifically

Does water move up the xylem?

Amir and Jamillah plan to show that water moves up the xylem in plant stems. They get some celery stems. Celery stems have many xylem tubes. The students stand their stems in water mixed with food colourings and leave them for several hours. You can see their results in Fig 9.7 D. Describe what you see. What conclusions can you draw from these results?

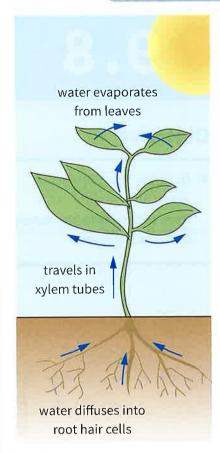


▲ Fig 9.7 D: Amir and Jamillah are pleased with their results. What do they show you?

Jamilla dips the end of a celery stem in wax and repeats the experiment. She puts the wax-covered end in the coloured water. What useful information does this give the students?

Questions

- 1. Explain how water moves into the roots of a plant.
- 2. Describe how the mineral salts that plants need reach the cells of the leaves.
- 3. a. What are the stomata?
 - **b.** Why are the stomata important in transpiration?
- **4.** Students observe that, on hot days, a pot plant in the classroom often wilts. On cooler days, it does not. Using what you know about transpiration, suggest an explanation for these observations.



▲ Fig 9.7 E: Water enters the plant through the roots, moves up the xylem in the stem and evaporates out through the leaves.

(III) Key points

- The pathway of water and mineral salts from the roots to the leaves in flowering plants involves absorption in root hair cells, transport through the xylem and transpiration from the surface of the leaves.
- Looking at the results of investigations enables you to apply your scientific understanding and draw conclusions.

Extension

Objective

 Describe the pathway of water and mineral salts from the roots to the leaves in flowering plants

Xylem, phloem and plant pests

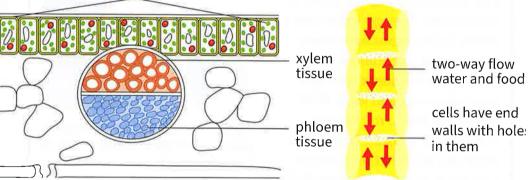
Plant pests cost people huge amounts of money and can result in food shortages around the world. When plants get attacked, it is often their transport systems that are affected.

Sugar transport in plants

The xylem that transports water and minerals from the soil up to the cells of the leaves, flowers and fruit of a plant is dead tissue. The water and dissolved mineral salts flow in one direction, from the roots upwards.

Plants have another transport system too. They make glucose in their leaves by photosynthesis. This glucose is needed by cells all over the plant. Plants transport water and dissolved sugars in the phloem, a living tissue. Phloem cells use energy to move the water and dissolved sugars both up to the buds and flowers and down to the roots.

photosynthetic / palisade tissue



▶ Fig 9.8 A: Living phloem tubes carry dissolved sugars all around the plant.



▲ Fig 9.8 B: Shield bugs are found all over the world. Many of them feed from the phloem of plants.

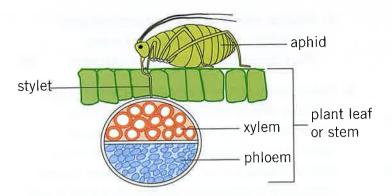
Targeting transport

Every plant has phloem tubes full of sugar-rich liquid in their stems, leaves and roots. Many different insects target this sugary water as easy food. This is good for the insect but bad for the plant.

Insect pests

Insects that attack the phloem are some of the most damaging plant pests. They include aphids, plant hoppers, leafhoppers, cicadas, spittlebugs, scale insects and shield bugs (see Fig 9.8 B). Each insect is small, but there are enormous numbers of them. They destroy billions of plants every year.

These insect pests have specialised mouth parts called stylets to get the sugary liquid they want. Stylets are sharp, pointed, hollow tubes. The insect sticks its stylet into the phloem of a plant and feeds on the sugary liquid inside. Aphids are a common example of phloem feeders. Fig 9.8 C shows a single aphid – but there can be thousands of them on one plant.



▲ Fig 9.8 C: An aphid sticks its pointed mouthparts deep into the phloem to feed on the sugary contents.

Unwelcome visitors

Insect pests weaken plants. Some steal sugars from the phloem, others eat parts of the plant itself. They reduce crop yields and ruin garden plants. However, it is the visitors they bring with them that cause the biggest problems.

Plant pests often carry plant pathogens. These are viruses, bacteria or fungi that cause diseases in plants. When phloem-feeders stick their mouthparts deep into the transport tissues of the plant they may also carry pathogens into the xylem or phloem. Once these pathogens are in the transport system, they are carried all over the plant. Some pathogens spread into all of the cells of the plant. Some stay in the transport tissues. For example, if pathogens block the xylem tissue of a plant, water cannot reach the stems and leaves. The plant will wilt and die.



▲ Fig 9.8 D: This beet plant is infected with a virus that attacks the xylem tissue and turns the veins yellow.

Questions

- 1. Describe the main differences between xylem and phloem in a plant.
- 2. a. What is an aphid?
 - **b.** Describe two different ways in which aphids damage plants.
- **3.** One rose bush in a garden is covered in aphids. Another has none. The rose bush infected with aphids produces fewer, smaller flowers. Suggest a hypothesis to explain this observation.
- **4.** The xylem and phloem of trees grows in a layer just under the bark. In young trees the bark is soft. Some mammals, such as deer, eat the bark of young trees.
 - **a.** If a complete ring of bark is eaten, the young tree dies. Explain why this happens.
 - **b.** Suggest a way of protecting young trees from attack by animals such as deer.

(Rey points

- The pathway of water and mineral salts from the roots to the leaves in flowering plants involves transport through the xylem from the roots to the leaves.
- Water also moves around the plant in the phloem, carrying dissolved sugars from the leaves to the cells that need them.

Review

9.9

- 1. a. What is photosynthesis?
 - **b.** Give a summary word equation for the process of photosynthesis.
 - c. Explain how the reactants of photosynthesis get into the leaf cells and what happens to the products once they are made.
 - **d.** State and explain whether or not photosynthesis would take place:
 - i. in a root hair cell

[3]

[2]

[3]

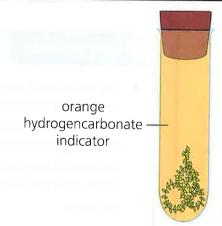
[10]

[2]

[3]

- ii. in a plant on a bright, sunny day
- [2]
- **iii.** in the same plant in the middle of the night.
- **2.** Hydrogen carbonate indicator is orange. When carbon dioxide is added or removed, it changes colour.

Carbon dioxide	Colour of indicator
added	yellow
removed	purple



a. When some pond weed was left in a tube of hydrogencarbonate indicator for a day by a window, the solution went purple. Explain why.

b. Another tube of pondweed and indicator was left in a dark cupboard for a day. The indicator went yellow. Explain why.

[4]

[5]

3. Rahul carries out an investigation to see if light intensity affects the rate of photosynthesis in pondweed. He sets up 5 identical sets of apparatus (see diagram) and puts each one a different distance from a sunny window. He will measure and record the volume of oxygen in each set of apparatus at the end of the day.

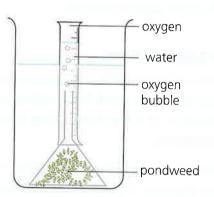


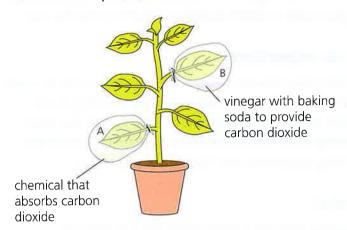
Table of results:

Volume of oxygen collected (cm³/day)	Distance from window (m)
4.5	0
4.0	1
1.5	2
0.5	3
0.25	4

- a. Describe how Rahul measures the amount of oxygen produced by the pondweed in his apparatus.
- **b.** Sketch a graph of Rahul's results.
- c. Explain what these results show you about the effect of light intensity on photosynthesis. [3]
- d. Suggest two variables which Rahul must control to make sure that his comparison of the light intensities is a fair test.

[1]

4. A plant was left in the dark for two days. Then two of its leaves were treated as shown in the figure. At the end of a day in the sun, leaves A and B were tested for the presence of starch.



- **a.** Suggest what question this experiment is designed to answer.
- b. Why is the plant left in the dark for two days before the investigation begins?[2]

[1]

- c. Describe how to carry out the iodine test for starch on these leaves. [6]
- d. Predict which leaf would turn blue–black with iodine and explain why.[5]
- **5.** Identical seedlings were placed in pure water or water mixed with soil.



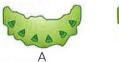
A pure water

B water mixed with soil

The table compares their appearance after 2 weeks.

Plant	Height of plant (cm)	Observations
Α	9	Yellow leaves
В	15	Green leaves

- a. Suggest a reason for these differences.
- **b.** Explain how a plant absorbs minerals and transports them to its different parts. [4]
- c. Plants that lack magnesium have yellow leaves.
 - i. Explain why a lack of magnesium affects the colour of the leaves. [2]
 - ii. Suggest why plants that lack magnesium do not grow as quickly as plants that have plenty of magnesium. [5]
- 6. This diagram shows sections taken from two celery stems that have been used in an investigation. Stem B was placed in ink for 24 hours.





- **a.** Identify the part of the stem B that has turned black. [1]
- b. Describe this tissue and its function in the plant.[3]
- **c.** Suggest two possible explanations for the appearance of stem A. [2]

Objective

 Describe the structure of the human excretory system

What is excretion?

You take food and oxygen into your body every day. You also breathe out and pass urine from your body to get rid of waste products. The removal of waste products from your cells is called excretion – and it is vital for life!

Why is excretion so important?

The waste products from your cells are **toxic**. If the amounts of these waste products build up in your body, they damage your cells and stop them working healthily. This is why it is so important that we excrete our toxic waste products, removing them from our bodies. Excretion is one of the characteristics of all living organisms (see Figs 10.1 A and 10.1B).

What do we excrete?

You remove carbon dioxide from your lungs when you breathe out.

Urea is the other main waste product of your body. Where does this urea come from? If you eat a lot of carbohydrates or lipids, your body breaks them down and stores them as fat – but your body cannot store excess protein. When you eat more protein-rich food than you need, the extra protein is broken down in your liver. This gives your body some useful molecules, and the waste product urea.

Urea is very toxic. If the concentration of urea in your blood gets too high, it damages other organs including your brain. It can make you very ill and even kill you. The good news is that you have special organs to remove the urea. These organs are your **kidneys**. They remove urea from your blood and pass it out of your body as part of your **urine**.



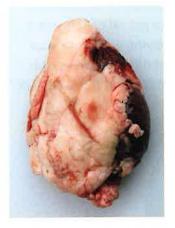
▲ Fig 10.1 A: Plants like these palms excrete oxygen into the air.



▼ **Fig 10.1 B**: This lion eats a lot of protein, so he makes a lot of toxic urea which he must excrete.

What do kidneys look like?

A human kidney is a reddish-brown organ about 10 cm long. If you put your hands on your waist with the thumbs facing back, the end of your thumbs will be about where your kidneys are positioned against your back. Inside your body, your kidneys have a thick layer of fat around them to protect their delicate structures from damage (see Fig 10.1C).





▲ Fig 10.1 C: The kidneys are well protected because they do a very important job in your body.

Why is urine yellow?

Pure urea forms white crystals (Fig 10.1D). It dissolves in water. It is carried to your kidneys dissolved in your blood plasma, which is mainly water.

As you know, urine is yellow, but the yellow colour does not come from urea. It comes from yellow substances which are also excreted in the urine along with the urea and the water.

▲ Fig 10.1 D: Urea – the white crystals make a colourless solution when they are dissolved in water.

Excretion or egestion?

Excretion means getting rid of waste products made in the body itself, such as carbon dioxide and urea. When an animal eats food, it cannot digest everything it eats. The undigested food passes out of the digestive system as **faeces**. Faeces are made of materials which have been taken into the body but have not been absorbed into the blood, such as plant fibre from fruit and vegetables. This process is called **egestion**. It is *not* excretion.

Questions

- 1. Define the term excretion.
- 2. Describe what is meant by egestion.
- 3. State which organ of the body excretes urea.
- **4.** Describe where urea comes from and explain why is it important to excrete it.
- 5. Explain why your kidneys are covered in a layer of fat.

(III) Key points

- Excretion means getting rid of waste products made in the cells of the body.
- Humans excrete carbon dioxide from their lungs and urea though their kidneys.
- Urea is produced in the liver from the breakdown of excess protein.
- Urea is excreted in the urine.

Objective

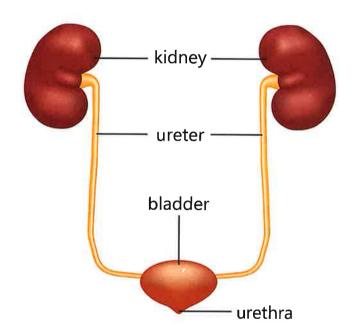
 Describe the structure of the human excretory system and its function

The human excretory system

The urea made in your liver is deadly. Your kidneys remove this toxic substance from your body.

How do we remove urea?

The urea made when your body breaks down extra protein is dissolved in water, along with other substances the body needs to get rid of. It forms a yellow liquid called urine. The whole system for removing urea from your body involves your kidneys, your bladder and several different tubes. It is called the human excretory system or the human renal system. You can see the main parts of this system in Fig 10.2 A.



▲ Fig 10.2 A: The human renal system.

Making and storing urine

Your kidneys have a rich blood supply. The blood which goes into your kidneys contains many different things. It carries dissolved food molecules, oxygen, salt and many other useful substances. It also contains the waste product urea. Your kidneys work by filtering your blood. Toxic waste products such as urea pass through the filters and are removed from your blood. Blood cells and big molecules which your body needs stay in the blood. Unfortunately, some useful substances, like glucose, are also small enough to pass through the filters in the kidneys. The good news is that they get taken back into your blood, because your body needs them. Some water is also filtered out of your blood, along with other substances which your body does not need, such as excess salt from your food. The yellow liquid formed is called urine.

▼ Fig 10.2 B: Doctors check urine samples to make sure their patients have healthy kidneys.



Each kidney has a tube called a ureter which connects it to the bladder. Urine travels away from your kidneys down the ureters and collects in your bladder. Your bladder is a muscular bag which stretches as it fills with urine. Eventually, when it gets full, the bladder is emptied. The urine passes down another tube called the urethra and out of your body.

Balancing your blood

Do you know how much urine your kidneys make? Make an estimate, and then see if you are right. An average adult human being produces about 1500 cm³ of urine every day! Your kidneys filter out enough urea to keep the levels in your blood safe – along with lots of water.

The colour of urine varies. Sometimes it is very pale, almost colourless, but at other times it is deep yellow. These differences are because your kidneys work hard both to get rid of urea and to make sure your blood stays at the right concentration. If you drink a lot, your kidneys will filter a lot of water out of your blood, and you will produce lots of very dilute urine. If you don't get much to drink, if it is very hot, or if you do a lot of exercise, your kidneys save water to keep your blood at the right concentration. You will produce a much smaller volume of very concentrated (darker coloured) urine.

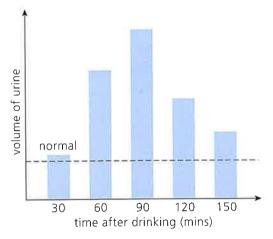


Fig 10.2 C: This bar graph shows how the amount of urine made changes after someone has a big drink of water.

Ouestions

- 1. Describe what urine is.
- 2. Describe how your kidneys work to remove toxic urea from your
- 3. Describe the difference between the ureter and the urethra in the human excretory system.
- 4. Give one similarity and one difference between the kidneys and the bladder in the human excretory system.



rws 5. Use the data shown in the bar chart in Fig 10.2 C to explain how the kidneys change the amount of urine they produce to help to keep your blood at the right concentration when you drink a lot of water.

Key points

- The human excretory system is also known as the renal system.
- The kidneys filter the blood, removing the toxic urea.
- The kidneys also remove water and other chemicals not needed by the body.
- Urine passes from the kidneys down the ureters to the bladder where it is stored until it passes out of the body down the urethra.

Thinking and working scientifically

10.3

Objective

 Describe some important models and discuss their strengths and limitations

Who made the best model?

The kidney is a very interesting and important organ. It is also a complicated organ. Some students find it hard to understand how the kidney removes urea from the blood without also removing the blood cells and all the useful substances the body needs.

Ejaz and Fatima have each produced a physical model to help their classmates understand the kidney more clearly. Have a look at their models.

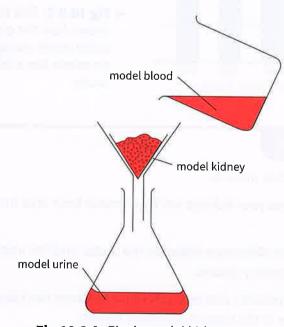
Filtering fun

Ejaz listened carefully to his teacher when she explained how the kidney works. He understands that the kidney filters urea out of the blood.

Ejaz makes a demonstration of filtration for his classmates. He gets a funnel, lines it with filter paper, and balances it on a flask. He mixes together some water, salt (to represent urea), sand, and red food colouring.

Ejaz explains his model like this:

- The mixture of sand, salt (safer than using toxic urea), food colouring, and water models the blood.
- The funnel and filter paper model the kidney.
- The liquid which passes through the filter models the urine.
- The sand which stays in the filter paper models the blood cells and large, useful molecules which are not filtered out by the kidney.



Sieving cells

Fatima also listened carefully when her teacher described the kidney. Fatima made a model of how the kidney works based on things she found in the kitchen at home, and things from the science room at school. She borrowed a sieve used to strain vegetables, and a mixture of different substances. Fatima mixed together dried peas and beans, salt crystals, and sand. She poured her mixture

mixture of peas, beans, salt, and sand

sieve peas + beans salt + sand

▲ Fig 10.3 B: Fatima's model kidney.

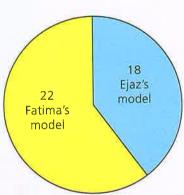
into the sieve and used what happened as her model of the kidney.

Fatima explains her model like this:

- The sieve models the kidney and the holes in the sieve are where the different substances move out of the blood.
- The peas and beans represent blood cells and large molecules that your body needs.
- The salt crystals represent urea salt is safer to use.
- The sand represents water.
- When the mixture is poured into the sieve, the salt and sand pass through the holes in the sieve – this is the urea and the water being filtered out of the blood. The dried beans and peas are too big to go through the holes in the sieve, so they stay in the blood where they are needed.

Which model works best?

Everyone in the class listened to Ejaz and Fatima and looked carefully at their models. They discussed the strengths of each model, thinking how each one made it easier to understand what happens inside a kidney. Then they discussed the limitations of the models – the things they did not show and any ideas that were wrong. The class voted to decide which model was most useful. The results are shown in Fig 10.3 C.



▲ Fig 10.3 C: This pie chart shows how many students voted for each model.

Questions

- 1. Explain what a physical model in science is.
- 2. Look at Ejaz's model of the kidney. List what you think are the strengths and limitations of his model.
- **3.** Look at Fatima's model of the kidney. List what you think are the strengths and limitations of her model.
- 4. Suggest one way in which each model could be made better.
- **5.** Using the data in Fig 10.3 C, what percentage of the students voted for Fatima's model?

(Rey points)

- A physical model is a way to help predict or explain something which cannot easily be seen.
- Different models have strengths and limitations, which can be evaluated.

Science in context

10.4

Objective

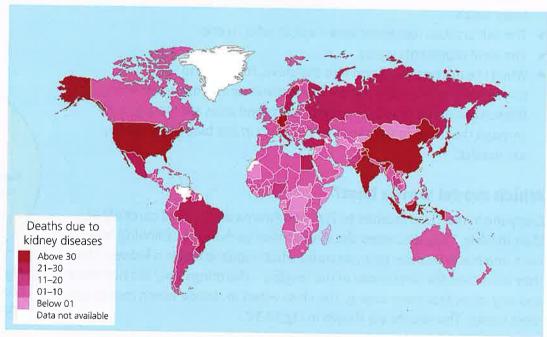
Evaluate issues which involve and/or require scientific understanding

When kidneys go wrong

Mohammed has been feeling very unwell for a long time. He has lost weight, but his ankles, feet and hands keep swelling. He is tired and breathless all the time, and he has lost his appetite. His parents take him to see doctors who run some blood tests to find out what is going wrong. They discover Mohammed's kidneys are failing.

Life without kidneys

Why do kidneys fail? They may be damaged by an infection, in an accident, or as a result of inherited problems. If your kidneys stop working, toxic urea builds up in your blood. You feel unwell. If nothing is done, you will die. Kidney disease is a huge problem all over the world. A big international study showed that, in 2017, kidney disease cause 4.6% of all deaths. Around 1.2 million people died just from one form of kidney disease.



▲ Fig 10.4 A: Deaths from kidney disease per 1000 people around the world.



Life without kidneys: a kidney machine

Failing kidneys do not always mean death. Scientists and doctors have developed ways of replacing failed kidneys. Mohammed is given dialysis, where a special machine acts as an artificial kidney. The machine filters Mohammed's blood, removing the urea and other waste products just as healthy kidneys do.

► Fig 10.4 B: A dialysis machine does the work of diseased or damaged kidneys. filtering the blood and removing waste products such as

Mohammed feels much better after each session of dialysis, but he has to spend many hours on the machine several times a week. He feels ill before his blood is filtered, and he is missing school and time with his friends. Dialysis machines are very expensive and there are not enough of them to go around. Doctors want to help Mohammed feel well all the time.

A new kidney for life

Doctors can replace failed organs and give people like Mohammed a new working kidney. There are two ways of doing this. Both of them offer Mohammed and patients like him a chance of a new healthy life. But both ways mean we have to make ethical choices – it isn't just about the science.

- Living donors: We all have two kidneys but we only need one. If someone is willing to donate one of their own kidneys, doctors will operate and give it to Mohammed. This is called a kidney transplant. The donor must be a close tissue match for Mohammed or his body will reject and destroy the new kidney. Living donors are often close family members, but sometimes a stranger will offer a kidney that is a good match.
- **Deceased donors:** Around the world, most kidney transplants are carried out using deceased donors. Deceased donors are usually healthy people who die in an accident. If they agreed to be an organ donor when they were alive, their kidneys, liver, heart, and lungs can be used to give life to other people. This is often a comfort to their family.

After Mohammed's transplant operation, his new kidney started working immediately, removing urea and excess water from his blood. He takes medicine every day to protect his new kidney, but otherwise he now lives a normal life. Mohammed knows that transplants mean that people have to make some difficult decisions, but he is very happy that he has this new chance of life.



▲ Fig 10.4 C: Patients recover fast after having a kidney transplant.

Questions

- 1. Explain why kidney failure causes people to become so ill.
- **2.** Use the map in Fig 10.4.A to find your own country and discover the rate of deaths from kidney disease per 1000 people.
- **3.** Kidney failure can be treated using dialysis or by carrying out transplants. Evaluate these ways of treating the problem, using your scientific understanding to explain your ideas.



Key point

 There are many medical issues where scientific understanding helps us to make difficult choices.

Extension 10.5

Objectives

- Describe the structure of the human excretory (renal) system and its function
- Links to IGCSE Adaptive features



▲ Fig 10.5 A: The kidneys of a camel help it to survive in extreme environments with little water.



Fig 10.5 B: The kidneys of a kangaroo rat produce tiny amounts of very concentrated urine.

Kidneys work everywhere!

People survive in very cold places, and in very hot ones. But we humans can keep ourselves cool when it is hot, and warm when the climate is cold. Most importantly, we can transport water, so that we always have water to drink, and our kidneys are not put under stress. But what about the animals which live all over our planet?

Hot and dry

Large areas of the world are hot and dry. Water is not easy to find. Desert mammals, like all other mammals, produce toxic urea when they break down the excess protein from their food. They must excrete this urea but they need water to make urine. How do they do it?

Camel kidneys

Camels have specially adapted kidneys which enable them to survive and remove the toxic urea from their bodies without wasting precious water. Camel kidneys filter less water from the blood than the kidneys of domestic animals such as cows. They also reabsorb much more water back into the blood. When camels are short of water, they produce only 500–1000 cm³ of thick, syrupy urine per day. This urine is much more concentrated than human urine, so camels get rid of their toxic urea and other waste products without losing much water.

Kangaroo rat kidneys

Kangaroo rats are very small mammals which survive in some of the most extreme dry environments. They have highly adapted kidneys which can produce very concentrated urine – much more concentrated than camel urine. Kangaroo rats do not even need to drink – they produce enough water from digesting the seeds they eat.

Water everywhere

Not all mammals live on land. When mammals live in the water, their kidneys have very different challenges.

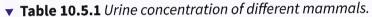
Fresh water kidneys

Beavers are mammals which live in fresh water – they feed on twigs and leaves and cut down trees to build dams in rivers. Beaver kidneys produce large amounts of very dilute urine. They do not use energy resources to concentrate their urine and conserve water, because there is plenty of water all around them.

Salt water kidneys

Porpoises live in the sea. This gives them a problem. They have as much water as they want - but it is very salty. If the levels of salt in the body get too high, it is very dangerous. The more salty water they take in, the more salt they must get rid of. They have no problems getting rid of urea, but they have to remove a lot of salt as well, and this also means removing a lot of water.

Porpoise kidneys are adapted to produce large quantities of urine – but it is also very concentrated. Table 10.5.1 compares the urine concentration of five different types of mammals, including ourselves.



Mammal	Urine concentration (arbitrary units)	
beaver	5.2	
camel	28.0	
human	14.0	
kangaroo rat	55.0	
porpoise	18.0	

Marine birds, such as penguins, pelicans, gulls and albatrosses, also drink salty seawater but their kidneys cannot produce highly concentrated urine to remove the excess salt. Instead, many marine birds have specialised salt glands connected to their bills. These glands remove excess salt from the blood, so the birds drink sea water without any problems. In one study of black backed gulls, their salt glands removed 10 times more salt from the blood than their kidneys.



▲ Fig 10.5 C: Porpoises live in salt water and produce lots of concentrated urine.



Marine birds like these brown pelicans have special salt glands draining into their bills.

Questions

- 1. Describe how the volume of urine produced by a camel per day compares with human urine production and explain the difference.
- 2. Give two ways in which kangaroo rats and camels differ in their adaptation to hot, dry conditions.
- rws3. a. Display the data in Table 10.5.1 as a bar chart.
 - b. Give one advantage and one disadvantage of displaying the data in this way.
 - 4. Compare the water challenges faced by kangaroo rats and porpoises.



Key points

The structure and functions of the kidneys of different mammals are adapted for removing urea from the body in very different environmental conditions.

Review

10.6

- 1. a. Define excretion.
 - b. Name two substances excreted by human beings.
 - c. Explain why excretion so important.
- 2. a. What is urea?
 - **b.** State where urea is formed in the body.
 - c. State which organs remove urea from the body.
 - d. Explain why these organs are surrounded by a thick layer of fat in the body.
 - e. Explain what the term 'toxic' means.
- 3. Using the following list of terms, copy and complete the following paragraph. You may use words more than once:

urine blood filter kidneys deathis very toxic. If the concentration in your gets too high, it damages other organs including your brain. It can make you very ill and may lead to It is removed from your body by special organs called the They the toxic molecules from your and pass it out of your body as part of your [7] 4.

[2]

[2]

[3]

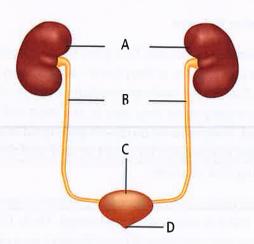
[2]

[1]

[1]

[2]

[1]



- a. Name the body system shown in the diagram. [1]
- **b.** Give an alternative name for this system. [1]
- c. State the function of this system in the body. [2]
- d. Copy and complete this table to describe the function of each of the labelled parts.

Part of the system	Function

5. The average urine production of a 70 kg patient is 70 cm³ in 30 minutes. In an investigation into kidney function, the urine output of a patient was measured every 30 minutes for 3 hours. The patient then drank 500 cm³ of water. His urine volume was again measured every 30 minutes for 3 hours. The table below shows you the results of this investigation.

Time interval (mins)	Normal urine production (cm³)	Urine production after drinking 500 cm³ of water (cm³)
30	70	75
60	72	200
90	68	280
120	70	190
150	71	105
180	70	70

a. Plot a bar chart to compare normal urine production with urine production after drinking 500 cm³ water.
 [7]

[7]

b. Calculate how much extra urine was produced in total.

6. a. Explain how the kidneys work to remove urea from the blood. [5]

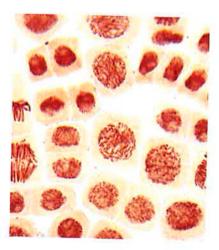
b. Give two other functions of the kidney. [2]

c. Explain why it is so dangerous if the kidneys fail. [3]

d. If the kidneys stop working, we use a machine to take over their function. A patient has to use the machine several times each week to remove urea and other substances that are not needed from the blood. Suggest two ways in which a machine is not as good as working kidneys. [3]

Objectives

- Reproduction is one of the seven characteristics of living things
- Know that chromosomes contain genes made of DNA



▲ **Fig 11.1 B:** Stained chromosomes under a light microscope.



▲ Fig 11.1 C: The big and small spider plants are identical, with the same DNA.

Reproduction: a characteristic of life

As you saw in Chapter 1, all living things carry out reproduction and make more of themselves (see Fig 11.1 A). When organisms reproduce, they pass on some of their **genetic material** to their offspring. **DNA** is the genetic material. It is an enormous molecule and it contains the instructions for making a new life.





▲ Fig 11.1 A: A mother goose and her offspring. You can see the offspring are not identical to each other.

DNA, chromosomes and genes

When you look at a cell under a microscope, you will see the cell nucleus (see Unit 2.3). The nucleus contains the DNA. When a cell is about to divide, the DNA forms long threads called **chromosomes** (see Fig 11.1 B). Human body cells have 46 chromosomes. Other species have different numbers – for example garlic cells have 16 chromosomes, potato cells have 48 and elephant cells have 56 chromosomes.

In human cells, our 46 chromosomes form 23 pairs. Each pair carries information about the same characteristics. Garlic cells have 8 pairs, potato cells have 24 pairs and elephant cells have 28 pairs of chromosomes.

What are genes?

The sections of DNA in the chromosomes that carry information are called **genes**. You will learn more about genes in the rest of this chapter.

Asexual reproduction

Many microscopic organisms, and some plants and animals, need only one parent organism. Bacteria, for example, simply split in two to reproduce. This is called **asexual reproduction**. The offspring produced during asexual reproduction are identical to their parent. They have exactly the same DNA (see Fig 11.1 C).

Sexual reproduction

Many plants and animals need two parents to produce offspring in a process called sexual reproduction. In sexual reproduction the offspring get some DNA from each parent. As a result, they are similar to but different from both of their parents.

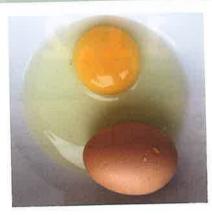
What are gametes?

Sexual reproduction involves special reproductive cells called gametes. Each gamete contains half the number of chromosomes as the parent cells. Human body cells contain 46 chromosomes, so human gametes each contain just 23 chromosomes.





▲ Fig 11.1 D: Both this baby elephant and the seeds in the cocoa pods are produced by sexual reproduction, so the offspring are not identical to their parents.



▲ Fig 11.1 E: The cells of a hen each contain 78 chromosomes. A hen's egg is a very large gamete. Each egg contains 39 chromosomes.

Questions

- 1. Define reproduction.
- 2. a. What is DNA?
 - **b.** Name the long threads of DNA that form when a cell divides.
- 3. a. State the number of chromosomes in a human body cell.
 - **b.** State the number of chromosomes in a human gamete.
- 4. Describe the main differences between asexual and sexual reproduction.



ťWŠ

- 5. a. A great white shark has 82 chromosomes in its body cells. Calculate the number of chromosomes in its gametes.
 - **b.** A giant panda has 21 chromosomes in its gametes. Calculate the number of chromosomes in a giant panda body cell.

(Religion) Key points

- Reproduction is one of the seven characteristics of living things.
- Asexual reproduction involves one parent and results in identical offspring.
- Sexual reproduction involves two parents and the formation of special reproductive cells called gametes.
- DNA is the genetic material in the nucleus of a cell. It forms chromosomes as a cell divides.
- Chromosomes contain genes made of DNA.

Objectives

- Know that chromosomes contain genes, made of DNA
- Know that genes contribute to the characteristics of an organism
- Describe the fusion of gametes to produce a fertilised egg with a new combination of DNA

Fertilisation: new life begins

In Unit 11.1 you learned that the genetic material in the nucleus of a cell is arranged into long threads called chromosomes. Each chromosome contains many genes, and each gene carries information about particular characteristics in the organism. Organisms that use sexual reproduction make special reproductive cells called gametes which contain half of the chromosomes of the normal body cells.

This is all very scientific, but what really happens? How is a new human being made?

Making the gametes

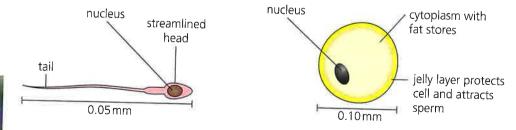
In sexual reproduction, the gametes **fuse** (join together) to create a new organism.

Egg cells

Female gametes in animals are called **eggs**, and they are much bigger than the male gametes. They contain a store of food. When the egg cell fuses with a male gamete, this store is used to feed a growing embryo. Relatively few egg cells are made. Human egg cells are formed and stored in special organs called the **ovaries**. All the egg cells are already there in the ovaries when a baby girl is born. A few eggs mature and one is released every month once she becomes a teenager. Egg cells cannot move themselves.

Sperm cells

Male gametes in animals are called **sperm**. They are very small and specialised. Their function is to swim through the female reproductive system, find an egg and fuse with it. Each sperm has a long tail for swimming (see Fig 11.2 A). Sperm are formed in the testes, and boys make millions of sperm every day once they become teenagers.



▲ Fig 11.2 A: Egg and sperm cells are specialised for their functions in reproduction.

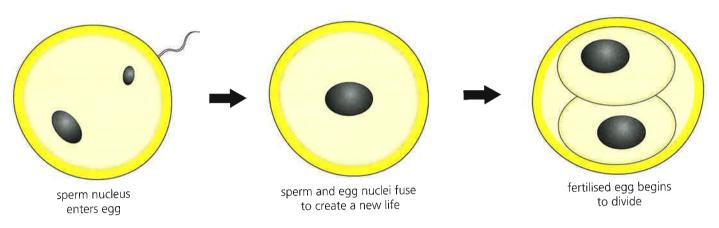
The fusing of the gametes

Once millions of male sperm are released inside the body of the female, they swim towards the egg. As soon as one sperm enters the egg cell, the egg cell forms a protective layer so that no other sperm can get in.



▲ **Fig 11.2 B**: This male butterfly is transferring sperm to the female to fertilise her eggs.

To make a new organism, the nucleus of a sperm cell and the nucleus of an egg cell must fuse together. This is **fertilisation** (see Figs 11.2 C and 11.2 D). The fertilised egg has a new combination of DNA, as half of the chromosomes are from the father and half from the mother. In humans, each gamete has 23 chromosomes and the newly fertilised egg cell has 46 chromosomes.



▲ Fig 11.2 C: Fertilisation.

The new cell formed when the egg and sperm fuse, divides several times to form a tiny ball of cells called the **embryo**. This embryo implants into the uterus of the mother and continues to grow. Eventually it forms a fully grown baby, and then it is born.

The importance of the genes

As soon as the fertilised egg begins to grow and form an embryo, the genes it has inherited from its parents when the gametes fuse begin to determine its characteristics. The genes control many features of the developing baby, from the colour of its skin and eyes to the way the heart forms and the length of the arms and legs. The chromosomes also also affect whether the new individual is a boy or a girl, as you will see in Unit 11.3.

▼ Fig 11.2 D: A magnified image of a sperm fertilising an egg.



Questions

- **1.** Draw and complete a table comparing the structure of human eggs and sperm, and how they are produced.
- **2.** Produce a flow chart for the events before and immediately after the fertilisation of a human egg.
- 3. a. Describe how gametes differ from normal body cells.
 - **b.** Explain why this is important.

(III) Key points

- Chromosomes
 contain genes, made
 of DNA, and these
 determine some of the
 characteristics of an
 individual organism.
- The fusion of male and female gametes produces a fertilised egg with a new combination of DNA.

Objectives

- Describe the fusion of the gametes to produce a fertilised egg with a new combination of DNA
- Sex in humans is inherited through the X and Y chromosomes

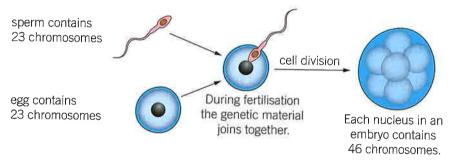
Boy or girl? Sex inheritance in humans

People always want to know if a new baby is a boy or a girl. The sex of a baby is determined at the moment the egg is fertilised by a sperm. Like so many of your characteristics, your sex is determined by your DNA.

Passing on characteristics

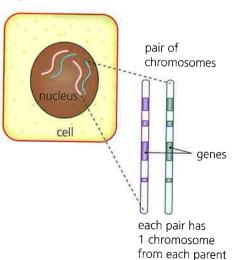
When fertilisation takes place, an embryo gets half of its chromosomes from the egg (its mother) and half from the sperm (its father).

How is the information about sex passed on? Each gamete contains 23 chromosomes, and each new embryo contains 46 chromosomes in every cell (see Fig 11.3 A). These chromosomes are in pairs. They carry the genes, so you get one copy from your mother and one from your father.



▲ Fig 11.3 A: Half of your genetic material comes from your father, and half from your mother.

▼ Fig 11.3 B: You inherit matching pairs of chromosomes and matching pairs of genes from your parents.



The genes on the paired chromosomes both control the same features. Fig 11.3 B shows you a simplified cell with two pairs of chromosomes, each with four genes. You have 46 chromosomes, each carrying around 1000 genes, so they are too complicated to draw!

The sex chromosomes

You have 23 pairs of chromosomes. Twenty-two of them are in pairs where each of the pair is the same size and shape, with matching pairs of genes. The 23rd pair of chromosomes are the sex chromosomes and there are two different types. The X chromosome is relatively large. The Y chromosome is smaller, with just a few genes on it. These chromosomes carry the genes that determine whether you are female or male. Your pair of sex chromosomes may be the same size and shape, like your other chromosome pairs, or they may be very different.

- Females have two similar-sized X chromosomes they are XX.
- Males have an X chromosome and a Y chromosome they are XY (see Fig 11.3 C).

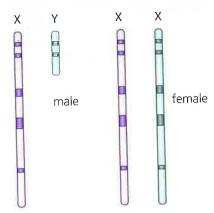
The sex chromosomes

Remember – you inherit one of each pair of chromosomes from your mother and one from your father.

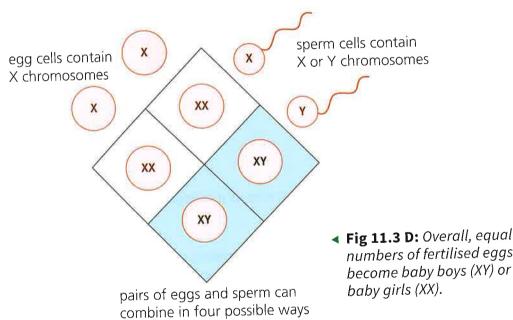
Women's cells are XX, so all eggs contain an X chromosome. You will always get an X chromosome from your mother.

Men's cells are XY, so men make two types of sperm. Half of them carry an X chromosome, and half of them carry a Y chromosome.

All of the sperm have an equal chance of fertilising the egg. If a sperm containing an X chromosome fertilises the egg, the new cell will have two X chromosomes (XX) so the child will be a girl. If a sperm carrying a Y chromosome fertilises the egg, the new cell will have an X and a Y chromosome (XY) so the child will be a boy. As you can see in Fig 11.3 D, for every pregnancy, the chances of a baby boy being born are 1 in 2, or 50%. The chances of having a baby girl are exactly the same.



▲ Fig 11.3 C: The pair of sex chromosomes you inherit determines whether you are female or male.



Questions

- **1.** Arrange these objects in size order, starting with the largest: nucleus chromosome gene cell DNA
- **2.** Explain as fully as you can why you share some characteristics with your mother and some with your father.
- 3. a. State the number of pairs of chromosomes in a normal body cell.
 - **b.** Describe how the sex chromosomes differ from all the other chromosome pairs.
- **4.** Khalil is one of three boys. His parents are expecting another child and they are certain it will be a girl. Explain fully why they are wrong.

Rey points

- When the gametes fuse they produce a
- Sex in humans is inherited through the X and Y chromosomes.
 Females are XX and males are XY.

fertilised egg with a new

combination of DNA.

Objectives

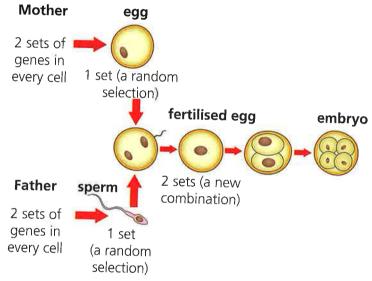
- Describe genetic differences between individuals
- Know that genes contribute to the determination of an organism's characteristics

Variation between individuals

Take a look in the mirror. Your appearance is affected by two things – the genes you inherited from your parents and the environment you live in.

Genetic differences

You inherited a random selection of genes from your mother and father. So did any brothers or sisters you may have (see Fig 11.4 A). The characteristics you inherit make you different from every other person (unless you have an identical twin).



▲ Fig 11.4 A: Each fertilised egg contains a random selection of genes from each parent.

Because the selection of genes in each gamete is random, you may have many genes in common with your siblings and all look very similar. It is just as likely that you all received a very different selection of genes, and don't look similar at all. Many families have characteristics clearly seen in several generations, such as being very tall, having eyes of an unusual colour, or

Some characteristics, like your eye colour or blood group, are determined by the genes you inherit and nothing will change them. This is **inherited variation**.

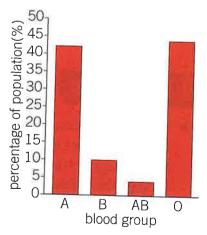
More than just our genes

having small ears.

Many characteristics are affected both by your genes and by the world you live in. For example, what you eat affects your body mass, and your exercise levels affect your muscles and strength. Everyone has a different environment, and these differences cause **environmental variation**.

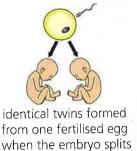
Your genes and environment work together to determine characteristics such as height, body mass and intelligence.

 Fig 11.4 B: Nothing changes the blood group you are born with.



Identical twins

Sometimes an embryo splits in two as it grows and forms two babies who are genetically exactly the same. These are identical twins. All of the characteristics completely determined by their genes, like their blood groups, will be the same. But, even though they have exactly the same genes, some of their characteristics are also affected by factors such as diet, health, and exercise levels. The older they become, the less identical they look, as their different environments affect them more.





▲ Fig 11.4 D: Identical twins show us the effect of their environment and their genes.

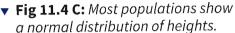
(A) Thinking and working scientifically

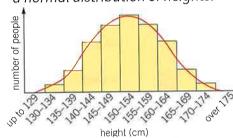
Looking at height

Each population includes tall people, short people and people in the middle (see Fig 11.4 C). Your maximum height is determined by your genes. If most people in your family are short, you will probably be short. If most are tall, you will probably be above average height.

Height is partly determined by your genes and partly by your environment. Without the right balance of food when you are growing, you cannot reach your full potential height.

Scientists observe that, over time, the standard of living has improved all over the world. Although many individuals still lack food, overall, whole populations have more to eat. This affects the average height of populations everywhere (see Table 11.4.1).





▼ Table 11.4.1: Increase in height between 1896 and 1996, rounded to the nearest cm

Area	1896	1996
North America	168	176
Europe and central Asia	166	177
Sub-Saharan Africa	162	167
East Asia and Pacific	161	169
Middle east and North Africa	160	171
South Asia	160	165

Questions

- 1. Explain why children in a family look different.
- 2. Explain why identical twins often look exactly the same when they are young, but their appearances differ more as they get older.
- rws 3. a. Display the data in Table 11.4.1 as a bar chart, and then answer the following:
 - **b. i.** Which area showed the greatest percentage increase in average height, and which showed the smallest between 1896 and 1996?
 - ii. Suggest reasons for these observations.
 - c. i. Calculate the difference in height between the areas with the tallest and shortest populations in 1896 and in 1996.
 - ii. Suggest reasons for the differences in both cases.



(Rey points)

- Genetic differences between individuals. even in a family, result from the genetic information they inherit.
- Some characteristics are determined entirely by the genes, but some are also affected by the environment.



Objective

 Describe healthy fetal development

The development of a fetus

When an egg and a sperm meet and fuse, a new life begins. This fertilised egg cell must divide and grow to produce the billions of cells that make up a new baby.

How long does it take to grow a baby?

Women, like all female mammals, have an organ called the **uterus** where their babies develop. The time it takes for the baby to develop from a fertilised egg is called the **gestation period** or **pregnancy**. It takes 40 weeks, or about 9 months, for a human baby to develop from a fertilised egg.

Just a dot

0

1 week – cells beginning to specialise

3 mm long



4 weeks – spine and brain forming, heart beating

3 cm long



9 weeks – tiny movements, lips and cheeks sense touch, eyes and ears forming

7 cm long



12 weeks – fetus uses its muscles to kick, suck, swallow, and practise breathing The early stages of human development

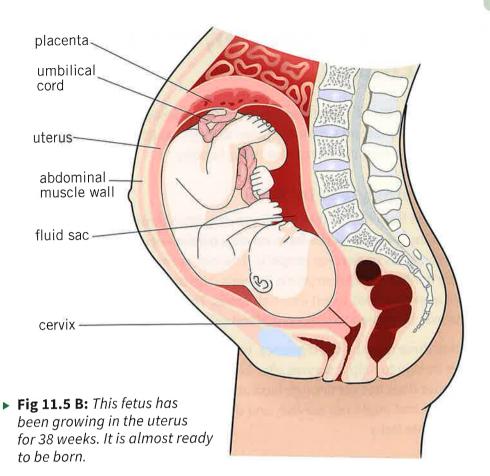
The fertilised egg settles into the wall of the uterus. During the early stages of a pregnancy, the cells grow and divide. They begin to specialise and form tissues and organs. After 8 weeks the embryo is called a **fetus**. By 12 weeks after fertilisation, most of the organ systems are formed, but they need to grow and develop for many more weeks before the fetus can survive on its own (see Fig 11.5 A).

Protected, warm and fed

Three important structures must form if the baby is to get everything it needs throughout the whole pregnancy (see Fig 11.5 B).

- ▲ Fig 11.5 A: The early stages of human development.
- The **placenta** allows substances to move between the blood of the mother and the blood of the fetus. The blood of the mother and the blood of the fetus flow very close together but they do not mix. Dissolved food molecules and oxygen move by diffusion from the mother's blood to the fetus. Waste carbon dioxide and urea pass by diffusion from the fetus to the mother, to be removed. The placenta also acts as a protective barrier. It stops most infections and harmful substances from reaching the baby.
- The **umbilical cord** joins the fetus to the placenta. It carries blood full of dissolved food and oxygen from the placenta to the fetus. It also carries blood loaded with waste products from the fetus to the placenta, where the waste is removed.
- The **fluid sac** is full of fluid that supports the baby as it grows and moves. The fluid in the fluid sac also acts as a shock absorber, protecting the fetus from any bumps as it grows inside its mother.

Human genetics and development



▼ Fig 11.5 C: After the birth, mother and father get to know their new baby.



How is a baby born?

After around 40 weeks of pregnancy, the growing baby has developed enough to survive on its own.

It can no longer get enough food and oxygen through the placenta – it must be born. The cervix relaxes and the muscles in the walls of the uterus contract to push the baby out into the world. As soon as the baby is born it must breathe for itself. There is still a lot of growing to do before it is an adult human being.

Questions

- **1. a.** If a fertilised egg cell just kept dividing, it would make a big round blob of identical cells. Describe what else must happen as the embryo develops and becomes a fetus.
 - b. At what stage of development does the heart start beating?
- **2.** State two functions of the bag of fluid that forms around the fetus in the uterus.
- **3.** Produce a flow diagram showing the stages of human development from the fertilised egg to birth.
- **4.** Explain how the uterus and placenta support the development of a baby throughout pregnancy.

(Rey points

- It takes approximately 40 weeks (9 months) of pregnancy for a fertilised human egg to become a fully developed baby
- A developing fetus needs a good supply of dissolved food and oxygen supplied by the placenta through the umbilical cord. It also needs its waste products removed through the placenta, and to be protected from infections and harmful substances. It is supported and protected from physical harm by fluid in the fluid sac.

Objective

 Discuss how fetal development is affected by the health of the mother, including the effects of diet, smoking and drugs



▲ Fig 11.6 A: The main tissues and organs of a fetus form during the first three months of pregnancy.

Fig 11.6 B: There is lots of helpful advice about diet for pregnant women.

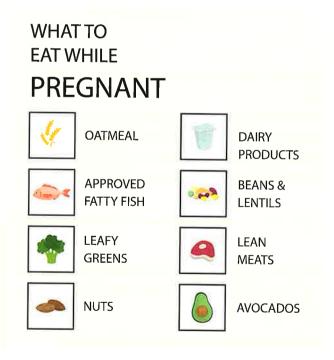
Health of the mother, health of the child

For the nine months of a human pregnancy, the developing baby depends on its mother. It is important for a mother to be as healthy as possible, to give her baby the best chance of also being healthy.

Food for mother, food for baby

Nutrients pass from the mother to her growing fetus through the placenta. All through the pregnancy, the fetus needs a balance of nutrients for its tissues and organs to develop properly. The mother must eat a healthy diet to provide her fetus with everything it needs (see Unit 11.7). For example, a pregnant woman needs to eat iron-rich foods. This gives both her and her fetus the iron they need to make red blood cells.

In the final three months of pregnancy, the fetus grows rapidly. It stores fat under its skin to help it survive after birth until it gets plenty of milk. If the mother does not get enough food at this stage, her baby may be underweight and might not survive, and the mother may not make enough milk to feed her baby.



Drugs and baby

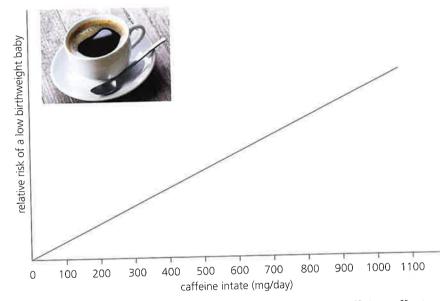
Some substances can cross the placenta and affect the growing fetus. Pregnant women must be very careful about the drugs they use. Drugs are substances that affect the way your body works, changing chemical reactions inside your cells. There are two types of drugs:

- Medicines make us feel better when we are ill. The medicines and doses that a doctor gives you will have been thoroughly tested to be sure they are safe. If a pregnant woman is unwell, it is important that she gets better, but she must take care because some medicines may harm her developing fetus, especially in the first 12 weeks. For example, some drugs stop the arms and legs of the fetus growing, or damage the structure of the heart as it forms. Health workers must be told if a woman is pregnant, so that they give drugs that will make her better and are safe for her fetus.
- Recreational drugs are substances that people use for enjoyment, to change the way they feel. The caffeine in a cup of coffee or tea is an example of a legal drug. So is the nicotine found in tobacco.
 Other drugs, including cannabis, heroin and cocaine, are illegal in most countries. All of these drugs cross the placenta and reach the fetus.

For example, scientists have shown that babies born to mothers who take in caffeine while they are pregnant have a lower birth weight than those who do not. A single cup of coffee contains about 95 mg of caffeine. The more coffee the mother drinks, the smaller the baby is likely to be – see Fig 11.6 D. Smaller babies are more likely to have health problems, or to die soon after birth. If a pregnant woman uses drugs such as cocaine or heroin, her baby may be born addicted to the drug. These babies have a very difficult start in life.

▼ Fig 11.6 C: Doctors check carefully before giving medicines like these antibiotics to pregnant women.





▲ Fig 11.6 D: Caffeine affects your heart and your nervous system. If you are pregnant, it may also affect the growth of your fetus.

Questions

- 1. Describe how a fetus gets the nutrients it needs to grow and develop.
- 2. Give two reasons why a pregnant woman needs to take in plenty of iron in her diet.
- 3. a. Describe 3 differences between medicinal and recreational drugs.
 - **b.** Suggest why doctors and nurses are very careful about the medicines they give to pregnant women.
 - c. A friend of your mother is pregnant. She drinks 5 cups of coffee each day. Explain how you could use the evidence in Fig 11.6 D to suggest that she drinks less coffee until the baby is born.

(Key point

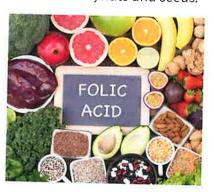
 The development of a fetus is affected by the health of the mother, including her diet, smoking, and any drugs she takes.

Science in context 11.7

Objectives

- Discuss how fetal development is affected by the diet of the mother
- Evaluate issues which involve or require scientific understanding
- Describe how people develop and use scientific understanding both as individuals and through collaboration
- ▶ Fig 11.7 A: Spina bifida may be mild or very serious.

▼ Fig 11.7 B: Foods rich in folic acid, like avocados, citrus fruits, nuts and seeds.



Understanding science, saving lives

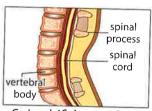
People sometimes think that science does not really affect their lives. In fact, there are many times when understanding science helps us make healthy choices. In this example, developing scientific knowledge has improved the health of millions of babics.

Developing and using scientific understanding: the importance of folic acid

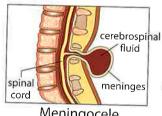
The spine and spinal cord develop very early in the embryo, and sometimes this process goes wrong. It may result in spina bifida, where the spinal cord does not form properly (see Fig 11.7 A). Spina bifida may be very mild, but it may cause serious problems such as paralysis throughout life. For centuries no-one knew why babies were born with spina bifida, but modern scientists understand some of the reasons. Spina bifida cannot always be prevented, but scientists discovered one cause that we can do something about.



Spina bifida A birth defect that happens when a baby'sbackbone (spine) does not form normally

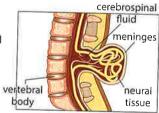


Spina bifida occulta



Types of spina bifida

Meningocele



Myelomeningocele

Folic acid deficiencies

In the late 20th century, scientists discovered that women who lack folic acid (vitamin B9) in their diet have a raised risk of having a baby with spina bifida. The scientists also showed that giving women folic acid before and during pregnancy greatly reduces this risk. The research was published in peer reviewed papers and was quickly accepted by scientists and doctors around the world.

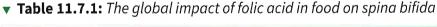
People use this scientific understanding in many ways.

Individual women choose to eat diets high in folic acid, or take folic acid supplements, before they get pregnant. This protects their fetus from the moment of fertilisation (see Fig 11.7B).

- In many countries doctors and nurses advise women to take folic acid supplements and give supplements to pregnant patients. This is nonmandatory fortification – people choose whether to take the folic acid.
- Some countries now add folic acid to staple foods such as cereals and bread, giving everyone vitamin B9 in their diet. This makes sure all women have the folic acid they need before they get pregnant, and reduces the number of babies born with spina bifida. It is called mandatory fortification, because people

do not have a choice about taking folic acid (see Fig 11.7 C).

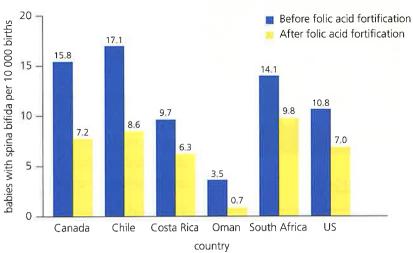
Understanding the science and sharing that knowledge is helping mothers have babies with healthy spinal cords, all over the world (see Table 17.1).



Population	No mandatory fortification	Mandatory fortification
Live births affected by spina bifida per 100 000 births	48.4	33.9
Live births + still births affected by spina bifida per 100 000 births	47.7	30.4

Questions

- 1. a. What is spina bifida?
 - **b.** Explain why it is important for women to have folic acid in their diets or take folic acid supplements before they become pregnant.
- 2. Explain how scientific work linking folic acid levels and spina bifida in babies can be used both by individual women and by societies.
- TWS 3. Use the data in Fig 11.7 C to calculate the percentage reduction in spina bifida births in each country. Put your results in a table.
 - 4. a. Display the data in Table 11.7.1 as a bar chart.
 - **b.** Write a paragraph to go with your bar chart using it as an example of the way that developing and using scientific understanding has a major impact on people's lives.



▲ Fig 11.7 C: Evidence for the impact of folic acid fortification on the numbers of babies born with spina bifida in several countries

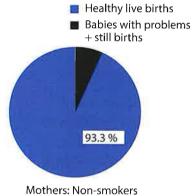
Key points

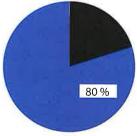
- Many organ systems, including the spine and spinal cord, are formed during the first 12 weeks of pregnancy.
- This development is affected by the health of the mother and deficiencies in her diet may cause problems in the development of the fetus.
- Issues which require scientific understanding can have a major effect on people's lives.
- People are using scientific understanding both as individuals and as societies to increase the intake of folic acid and reduce the numbers of babies born with spina bifida.

Thinking and working scientifically 11.8

Objectives

- Discuss how fetal development is affected if the mother smokes
- Make conclusions by interpreting results
- Evaluate the strength of evidence collected





Mothers: Smokers

Fig 11.8 A: The percentage of healthy live births in each group of mothers.

Smoking and pregnancy: the evidence

A cigarette for baby?

If a pregnant woman smokes a cigarette, up to 10% of her blood carries carbon monoxide, starving the fetus of the oxygen it needs. There is an increased risk that the baby will fail to grow properly, be born very small or die before or soon after birth.

Two students are making presentations about the risks of smoking during pregnancy, based on evidence they have collected. Evaluate what they have done.

Aleena's family history

Aleena has lots of older cousins, sisters and aunts. She has carried out a survey of her family, recording who smoked and who did not, and what happened to their babies. This is her presentation.

In the last five years, 30 babies have been born in my family. I did some research to see who smoked when they were pregnant and who did not. Here is my data:

▼ Table 11.8.1: Analysis of Aleena's family births.

	Mother does not smoke	Mother smokes
Total number of births	15	15
Healthy live births	14	12
Stillborn babies	0	1
Very small babies	1	1
Babies with a cleft palate	0	1

A still birth is when a baby is born dead. If the roof of the mouth and the lips do not form properly when the embryo is developing, the baby has a cleft palate.

My evidence shows that the babies born to mothers who smoke when they are pregnant are more likely to have problems than babies born to mothers who do not smoke. I know that smoker's babies don't get enough oxygen. Perhaps this is why they are more likely to die.

I found out that a cleft palate is more common when the mother smokes when she is pregnant. Perhaps some of the toxic substances in cigarette smoke damage the cells of the embryo.

To end my presentation: DON'T SMOKE WHEN YOU ARE PREGNANT!

Yousuf's online research

Yousuf spends time online to find information about the links between smoking during pregnancy and birth problems. This is his presentation.

I have found lots of evidence that smoking during pregnancy is linked to increased risks for the baby. My data come from evidence based on large samples involving hundreds of thousands of pregnant women:

I found another study where scientists looked at 841228 mothers to see the effect of smoking on the risk of stillbirth (see Fig 11.8 C). Shockingly, even when a mother does not smoke, her baby may be harmed before it is born by second-hand smoke, if her husband smokes or she works in a smoky atmosphere (Table 11.8.3).

Table 11.8.2: Relative risk of stillbirth in mothers globally.

Group of mothers	Stillbirth rate per 1000 births
All mothers	4.2
Non-smokers	3.8
Smokers	5.8

	Maternal smoking	Second-hand smoke exposure
Low birthweight	200 g or more lower than non-	30–45 g lower than non-smokers
	smokers	
Heart defects	9% more likely than in non-smokers	Increased risk
Stillbirth	47% more likely than in non-	Possible increase
	smokers	
Early birth	27% more likely than in non-	Increased risk
	smokers	
Cleft palate	60%+ more likely than in non-	14% more likely than in non-
	smokers	smokers

The conclusion I draw from all this evidence is:

If you are a woman: DON'T SMOKE WHEN YOU ARE PREGNANT!
If you are a man: DON'T SMOKE WHEN YOUR WIFE IS PREGNANT!

▲ **Table 11.8.3:** Relative risk of problems in babies, based on their mother's exposure to tobacco smoke.

Questions

- 1. a. Draw a bar chart of the data in Table 11.8.1.
 - **b.** Draw a bar chart of the data in Table 11.8.2.
- 2. Write a clear evaluation of the work done by Aleena and Yousuf. Highlight strengths and weakness in both of their presentations.
- **3.** Using as much of the evidence presented here as possible, summarise the effect of smoking on the chances of a woman having a healthy live baby.

(Rey points

- If a mother smokes, the development of her fetus may be affected in many ways.
- The evidence from many studies allows us to make conclusions about the effects of smoking on pregnancy.
- The strength of the evidence depends on the size of the samples and how it is analysed.

Review



[2]

b. Describe a chromosome.

c. What is a gene?

[2]

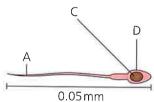
[2]

d. Copy and complete this table:

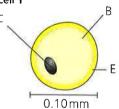
	Asexual reproduction	Sexual reproduction
How many		
parent cells are		
involved?		
Are the		
offspring		
identical to		
their parents?		

2. This diagram shows two specialised cells.

Cell X



Cell Y



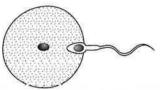
a. Name cell X and cell Y.

[2]

[4]

- **b.** Cell X and Cell Y are gametes. Give one difference between a gamete and a normal body cell. [1]
- c. Name the parts of these gametes labelled A-E. [5]
- **d.** Describe the functions of the parts labelled A-E [6]
- e. State one similarity and two differences between the two different types of gamete. [3]

3. This diagram shows part of human reproduction.



a. Name the process taking place in this diagram.

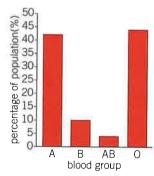
[1]

- **b.** The egg only fuses (joins) with one sperm. Write the letters in order to describe how this happens.
 - A The fertilised egg begins to divide to form an embryo.
 - **B** The egg stops any more sperm cells getting in.
 - **C** Many thousands of sperm swim to the egg.
 - **D** The nucleus of the successful sperm fuses with the nucleus of the egg cell.
 - **E** One sperm gets into the egg cell. [5]
- c. Each adult human cell has 46 chromosomes. How many chromosomes would there be in:
 - i. the egg cell

[1]

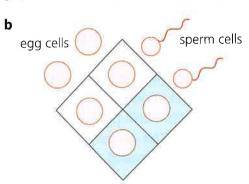
ii. the sperm cell?

[1]



- a. Your blood group is the result of genetic variation. Use the data in the diagram to help you explain what this means. [3]
- **b.** Identical twin boys grew up with different families. When they met up as young men, they both had the same shaped earlobes, and the same blood group but one twin was 2 cm taller than the other, and also heavier. Explain these similarities and differences. [5]

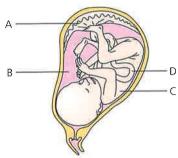
5. a What are the sex chromosomes?



Copy and complete this diagram to show how the sex of a baby is inherited. [8]

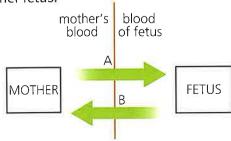
[1]

6.



This diagram shows a fetus inside the uterus of its mother.

- a. Write the correct letter for each of these parts: [4]
 - i. fluid sac
 - ii. fetus
 - iii. umbilical cord
 - iv. placenta.
- **b.** Describe the function of part D. [2]
- **c.** Describe the function of part B. [2]
- 7. The placenta allows small molecules to move between the blood of a mother and the blood of her fetus.



Write the letter of the correct arrow to show which way each of these substances move.

- a. Food molecules [1]
- **b.** Carbon dioxide [1]
- **c.** Urea [1]
- d. Oxygen [1]
- **8.** Pregnant women must be very careful about what they take in to their bodies.
 - **a.** Explain why it is so important for a pregnant woman to eat a balanced diet. [4]
 - **b.** Explain why a pregnant woman needs to eat more food in the last three months of her pregnancy.
 - c. If a pregnant woman becomes ill, doctors take extra care when they decide what medicine to give her. Explain why they are so careful. [3]
 - **d.** Doctors compared babies whose mother smoked with babies whose mothers did not. These are the lines of best fit from their graphs.



- i. Many of the babies were born early.Describe how the mass of a baby changes as the pregnancy gets longer. [1]
- ii. Scientists think that cigarette smoke can damage a growing fetus. Does this evidence support that idea? Explain why. [3]
- iii. Suggest how a mother who smokes might damage her fetus.[5]

[3]

Objective

 Describe the carbon cycle in nature





▲ Fig 12.1 A: From mangrove swamps to deserts, the carbon cycle is vital for life.

The carbon cycle

As you saw in Chapter 4, water cycles continuously between the air and the seas, passing through living organisms as it goes. Water is not the only substance which cycles in nature. **Carbon** is an important element in the carbohydrate, protein, and lipid molecules that make up the cells of your body, and of all living things. Carbon is part of the DNA passed from parents to offspring. Carbon is essential to life on Earth. The **carbon cycle** in nature makes sure that we always have the carbon that we need.

The carbon cycle

The carbon cycle in nature is a series of processes that move carbon between living organisms and the physical environment. It returns carbon dioxide from organisms to the atmosphere, to be taken up and used again in photosynthesis. It involves several processes, some of which you have already met. Carbon is removed from the atmosphere by photosynthesis. It passes into other organisms through feeding. It is returned to the atmosphere through respiration, **decomposition**, and **combustion**.

Respiration

Respiration takes place in all living organisms. Glucose molecules are broken down using oxygen, producing carbon dioxide (CO₂) and water. This releases energy to be used by cells. You discovered respiration in Units 8.2, 8.3 and 8.4.

Photosynthesis

Photosynthesis takes place in the green parts of plants and in algae. It uses energy from light, trapped by chlorophyll in the chloroplasts. Carbon dioxide is taken in from the air and combined with water to produce glucose and oxygen. This in turn is used to build the biomass of plants. You explored photosynthesis in Units 9.1, 9.2 and 9.3.

Feeding

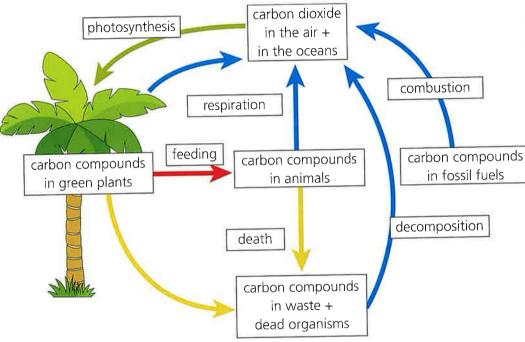
Animals feed. They eat plants or other animals. They take in the biomass of plants, break it down, and build it back up into animal biomass. Carbon is passed from one organism to another in this way. Some is released into the environment through respiration at the same time. You looked at feeding and feeding relationships in Units 3.7, 6.1, 6.2, 6.3, 6.4 and 7.3.

Decomposition

Decomposition is the process carried out by the decomposers you investigated in Units 3.5, 3.6 and 3.7. Microorganisms such as bacteria and fungi feed on the waste materials produced by animals, the dead leaves produced by plants, and the dead bodies of animals and plants. They break them down, releasing carbon dioxide back into the atmosphere.

Combustion

Combustion is the scientific word for burning. When a substance burns, it reacts with oxygen in the air. In combustion, the energy transferred heats the surroundings and produces light – see Fig 12.1 B. Many fuels, from wood to fossil fuels, are carbon compounds. When these fuels burn, they produce carbon dioxide and water which are released into the atmosphere.



Mark

▲ Fig 12.1 B: The combustion of wood releases carbon dioxide into the atmosphere.

Fig 12.1 C: The carbon cycle in nature.

Questions

- 1. a. Define the carbon cycle.
 - **b.** Explain why the carbon cycle is so important for life on Earth.
- 2. a. List the main processes involved in the carbon cycle in nature.
 - **b.** Describe how each process affects the amount of carbon dioxide in the atmosphere.
- 3. Draw and label a diagram to show the carbon cycle in nature.

(Rey points

- The carbon cycle returns carbon dioxide from organisms to the atmosphere, to be taken up and used again in photosynthesis.
- The carbon cycle involves photosynthesis, respiration, feeding, decomposition, and combustion.

Science in context

12.2

Objectives

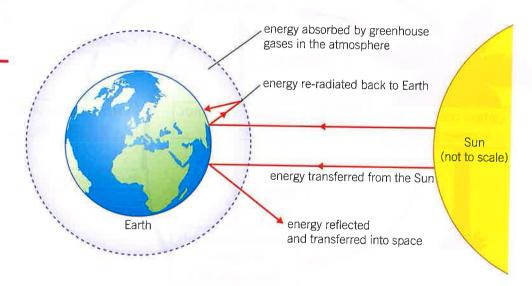
- Describe the impact of the carbon cycle on Earth
- Understand how using science can have a global environmental impact

► **Fig 12.2 A**: The greenhouse effect keeps us all alive.

People and the carbon cycle

A perfect planet

Conditions on Earth are perfect for life. We have carbon, oxygen and water, and the temperature at the surface of the Earth is just right for organisms to live and grow. The reason for this is the carbon dioxide and other **greenhouse gases** in our atmosphere. They are called greenhouse gases because they trap energy from the Sun, like the glass in a greenhouse. They trap enough to keep the Earth's surface warm, but not too much so we don't overheat – see Fig 12.2 A. This is called the **greenhouse effect**.



If the concentration of carbon dioxide in the atmosphere increases, more energy is trapped and temperatures at the surface of the Earth increase. Many ecosystems are finely balanced. A change in temperature may affect whether a type of organism lives or dies.

Global carbon dioxide emissions 2017



▲ Fig 12.2 B: 36.2 billion tonnes of carbon dioxide were produced in 2017 – which parts of the world emitted the most?

People and carbon dioxide

Over the last two centuries, scientists and engineers have made discoveries and developments we use every day but many of them affect carbon dioxide levels in the atmosphere. Some add carbon dioxide to the atmosphere. Others interfere with **carbon sinks** – such as forests, coral reefs and oceans – that naturally absorb and store carbon.

Here are three examples:

- Cars, lorries, boats and planes all work by combustion. Their engines burn fossil fuels, made from oil. They release about 6.7 gigatonnes (Gt) of carbon dioxide into the atmosphere each year. One gigatonne is one thousand million tonnes!
- A lot of the electricity generated around the world is produced by burning the fossil fuels coal, oil or gas. Electricity generation adds around 33 Gt of carbon dioxide into the atmosphere each year.
- Deforestation means cutting down forests. Forests take up carbon

dioxide for photosynthesis and turn it into biomass. We stop them taking up carbon dioxide when we cut them down. We also often burn the trees we cut down, producing even more carbon dioxide. Globally, forests absorb 33% less carbon dioxide than they did 30 years ago.

Who produces most?

Different parts of the world produce different amounts of carbon dioxide. The pattern has changed over time, as the use of science and technology changes in different countries. Wealth also affects the amount of carbon dioxide produced. As people get richer, they use more transport. They use more electricity to pump clean water and to provide electric lighting, refrigeration, heating, and air conditioning. Table 12.2.1 shows the impact of changes in societies, by analysing where carbon dioxide has been produced both historically and today.

Table 12.2.1: Global carbon dioxide emissions

Region	Percentage of global carbon dioxide emissions in 1751–2017	Percentage of global carbon dioxide emissions in 2017
Asia	29	53
North America	29	18
Europe	33	17
Africa	3	3.7
South America	3	3.2
Oceania	1.2	1.3
International aviation and shipping	n/a	3.2

Questions

- 1. a. What is the greenhouse effect?
 - **b.** Explain how an increase in carbon dioxide in the atmosphere makes the surface of the Earth warmer.
- 2. Describe how human transport systems and electricity generation affect the levels of carbon dioxide in the atmosphere and suggest two more ways in which humans affect the levels of CO₂ in the atmosphere.
- TWS 3.a. Draw a pie chart to show the carbon dioxide produced in different areas from 1751-2017.
 - **b.** Describe the differences between this and data for 2017.
 - c. Explain why there is no data for International aviation and shipping in the data from 1751–2017.
 - **d.** Suggest two other reasons for the differences you observe.



- Carbon dioxide in the atmosphere traps energy and maintains the surface of the Earth at a temperature suitable for life.
- Using science has enabled us to develop engines and produce electricity by burning fossil fuels. This has increased atmospheric CO₂ levels causing global warming.

Objective

 Describe the historical impacts of climate change



▲ Fig 12.3 A: In the Ice Ages, glaciers carved out valleys from the rocks around them.



▲ Fig 12.3 B: This fossil shark's tooth from Europe is evidence that tropical sharks once swam in countries that are now very cold and dry.

Historical impacts of climate change

For many years, scientists have studied the levels of carbon dioxide in the atmosphere, looking for evidence of climate changes both millions of years ago and in recent history.

Climate change: ancient history

Scientists have gathered many different types of evidence to show that the Earth has had periods of both very high and very low temperatures.

Glaciation

At times, the surface of the Earth was very cold, covered in ice and snow. Huge frozen rivers of ice called **glaciers** carved out the landscape. However hot your home country, it was probably covered in ice during the history of the Earth! Theories about the causes of these cold periods include:

- huge volcanoes erupting, filling the atmosphere with ash and blocking the sunlight
- giant meteorites striking Earth, causing dust that blocked out the Sun
- changes in the orbit of the Earth
- changes in the activity of the Sun.

Global warming

The climate of the Earth has changed several times from Ice Ages to tropical forests and desert heat. Evidence shows us that global warming events are always linked to increases in greenhouse gases such as carbon dioxide in the atmosphere, for example, from massive volcanic eruptions.

Climate change: recent history

Almost every country produces greenhouse gases, and every country is affected by global warming and climate change. Here are some of its impacts in the last 150 years:

- **Flooding**: global warming and climate change are linked to an increase in torrential rain and severe flooding on a scale not seen before. For example, in 2010, in Pakistan, massive flooding killed at least 2000 people and affected the lives of 20 million others.
- Drought: in some parts of the world, climate change is leading to extreme heat and a lack of rain. Over the last 30 years, Africa has become hotter and drier, with crops failing and lakes drying up. Many people can no longer grow enough to eat. The whole ecosystem is affected. Droughts in Australia resulted in huge bush fires which threatened to wipe out many species such as koala bears.

• Extreme weather events: around the world, we are seeing more extreme weather events such as hurricanes, tornados, blizzards, heavy rain, and very high temperatures. Scientists link many of these events to global warming changing the airflows in the atmosphere, which affects the climate everywhere.

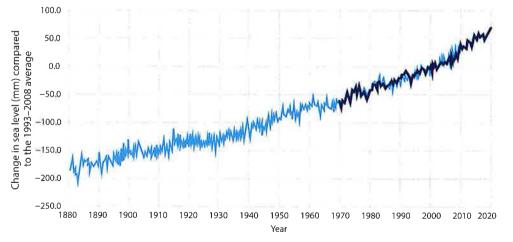
180 recorded 160 140 120 major named storms 100 80 60 40 20 0 1900-10 1950-60 2000-10 vears

Fig 12.3 C: Major storms are becoming more common as the climate changes.

Table 12.3.1 Number of major named storms and hurricanes in 10 year periods

	1900-1910	1950-1960	2000-2010
Major named storms	89	127	170
Hurricanes	45	72	94

Sea levels rising: Global warming is melting land ice, and mean sea level has risen around 21–24 cm since 1880. Rises in sea level increase coastal erosion and change ocean currents. This has an impact on the movements of the tiny organisms supporting all the ocean food chains.



▲ Fig 12.3 D: Scientists have been monitoring sea levels for many years.



▲ Fig 12.3 E: The steady rise in sea levels has affected people's homes and the lives of many ocean animals.

Questions

- **1. a.** Give one example of climate change seen millions of years ago.
 - **b.** Suggest a possible reason for this type of climate change.
- 2. Describe 4 impacts of climate change seen over the last 150 years.



ŕws

- TWS 3. a. Using Fig 12.3 D, describe the global trend in major named storms since 1900.
 - **b.** Use the data from Table 12.3.1 to draw a bar chart showing the trend in hurricanes since 1900.
 - c. Compare the trend in hurricane numbers to the trend in major storms and suggest a reason for these observations.



- Climate change has affected life on Earth both in ancient and recent history.
- In the last 150 years, climate change has caused sea level changes, flooding, droughts, and other extreme weather events.

Objective

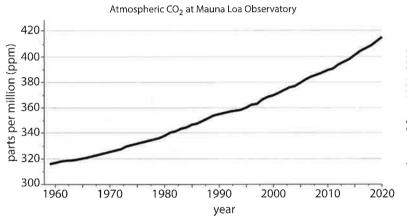
- Describe predicted future impacts of climate change
- Fig 12.4 A: Carbon dioxide levels in the atmosphere and mean global surface temperature.

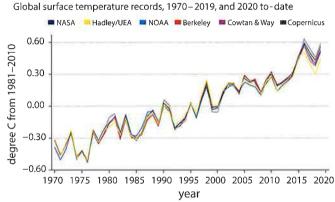
12.4 Predicting the future

In the 1890s, a scientist called Svante Arrhenius calculated that doubling the amount of carbon dioxide in the atmosphere would make it 5 °C warmer at the surface of the Earth, seriously affecting the climate. In the 21st century, Arrhenius's predictions are coming true.

How hot will it get?

The Intergovernmental Panel on Climate Change (IPCC) studies evidence from thousands of scientists all over the world (see Fig 12.4 A) and advises governments globally. The IPCC states that global warming is happening as a result of human activities, such as burning fossil fuels and deforestation, causing an increase in carbon dioxide and other greenhouse gases in the atmosphere.





Future impacts

The IPCC predicts that, by the middle of the 21st century, global temperatures will increase by another 1.3–1.8 °C. What impact will this have?

Sea level rises

As oceans get warmer, and glaciers and land ice melts, some scientists predict a rise in sea levels of between 26–82 cm by the end of the 21st century. Low lying countries like Tuvalu, and areas of many other countries, will disappear beneath the sea (see Fig 12.4 B).

Droughts and heat waves

As temperatures rise and rainfall patterns change, huge areas will become infertile. Plants and animal species will die out if there is no water to support life. People will starve. Scientists predict that climate change will play a part in a global expansion of dry and arid lands. Drought also leads to fires, destroying whole ecosystems across large areas (see Fig 12.4 C).



▶ Fig 12.4 B: Rising sea levels will remove land important to wildlife, such as this Costa Rican beach where turtles lay their eggs.

Increased rainfall and flooding

In contrast, many parts of the world will get more rainfall and snowfall than ever before, often as extreme storms or blizzards (snow storms). This will lead to floods, washing away fertile soil and causing the loss of homes and lives.

Colder or warmer temperatures

Some countries will get hotter, so new pests such as mosquitoes, ticks and crop pests will survive, affecting our health and agriculture. Some will get colder. Ecosystems are often very temperature dependent, so plant life, migration patterns of animals and the species you see around every day will change in the future. Many species will become **extinct**.

More extreme weather events

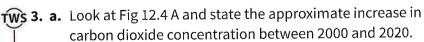
If climate change continues, extreme weather events such as hurricanes and storms will happen more often and affect more of our lives. A single storm can cause huge damage to infrastructure such as power supplies, buildings, roads and railways.

Hope for the future

The good news is that only a third of the temperature increases predicted by the IPCC for the next half century will happen for certain. If we make the right choices and change the way we live, we may stop this climate change before it cannot be undone (see Fig 12.4 D). Only time will tell.

Questions

- 1. a. State what IPCC stands for.
 - **b.** Describe the role of the IPCC.
 - **c.** State the IPCC's maximum predicted increase in global temperature by the middle of the 21st century.
- **2. a.** Describe what scientists predict the future impact of climate change on sea levels will be.
 - **b.** Describe two different problems this will cause.



- **b.** State the approximate increase in global surface temperature over the same time period.
- **c.** Predict **i.** carbon dioxide levels and **ii.** increase in global surface temperature by the year 2100 if carbon dioxide levels continue to rise at the same rate.



Fig 12.4 C: Without regular rainfall, once-fertile land dies.



Fig 12.4 D: Using wind or sunlight to generate electricity adds no carbon dioxide to the atmosphere.

(Rey point

Scientists predict
 that if climate change
 continues at the
 current rate, future
 impacts will include the
 loss of countries and
 land to rising sea levels,
 catastrophic flooding
 in some places,
 severe drought and
 starvation in others
 and an increase in
 severe weather events
 globally.

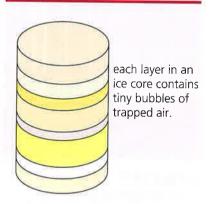


Extension

12.5

Objectives

- Describe the historical and future impacts of climate change
- Evaluate the strength of evidence collected
- Evaluate issues that require scientific understanding



▲ **Fig 12.5 A**: The deepest layers of ice are the oldest, giving scientists information about carbon dioxide concentrations thousands of years ago.



▲ Fig 12.5 B: The growth rings in this tree are clear to see.

Evaluating evidence for climate change

The IPCC is convinced that increases in atmospheric carbon dioxide levels resulting from human activities are causing global warming and climate change, which is affecting all of our lives. What sort of evidence is this based on?

Mauna Loa Observatory

The graph in Fig 12.4 A (see page 218) is a very important source of evidence for increases in carbon dioxide concentration in the atmosphere. The data comes from the Mauna Loa Observatory, sitting high on a volcano in Hawai'i. The air there is clean and there is little human activity or plant life. Scientists have collected data about the composition of the air there since the 1950s.

Looking back in time

To build a picture of the impact of increasing carbon dioxide levels on the Earth's climate, scientists must look back in time and see what happened in the past. How is this done?

Ice cores

Scientists collect cores of ice from the Antarctic. The ice builds up in layers over time. Bubbles of air are trapped in the ice – air that is thousands of years old. Scientists analyse the bubbles of gas and discover the carbon dioxide concentration of the atmosphere up to 10000 years ago (Fig 12.5 A).

Tree rings

When a tree is cut down, you can see the growth rings in the trunk (Fig 12.5 B). Each ring represents a year of growth for the tree. In warm, wet years, the rings will be wider than in cooler, drier years. Some types of tree live for hundreds or even thousands of years, so scientists combine evidence from tree rings with evidence from ice cores, relating atmospheric carbon dioxide concentrations to the growing conditions of the tree.

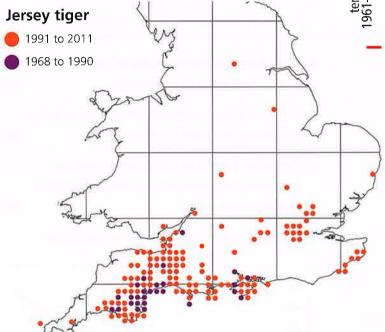
Bog cores and pollen

The plants which formed peat bogs grew many thousands of years ago, so cores taken from peat bogs give scientists another way of looking back in time, up to 12 000 years ago. Pollen is preserved in the peat, giving scientists a record of plants growing at different times.

Scientists put together evidence from different sources. They use it to build up a picture of the changes in carbon dioxide concentration in the atmosphere and global temperatures over time. They can identify trends and link them to possible causes (see Fig 12.5 C).

Predicting the future

Scientists look at patterns of carbon dioxide concentrations, human activities, global temperatures and the impact of climate change on where different organisms live (Fig 12.5 D). They use this evidence to predict the future impact of climate change, including rising sea levels and extreme weather.



temperatures measured — temperatures estimated from with thermometers — tree rings and ice cores etc.

▲ **Fig 12.5 C**: A combination of evidence shows temperature changes over time.



Fig 12.5 D: The beautiful Jersey tiger moth is spreading north in the UK as global temperatures rise.

Questions

TWS

- **1.** Evaluate the five different types of evidence for climate change described here, giving one strength and one weakness for each.
- 2. a. Work out the approximate age of the tree in Fig 12.5 B.
 - **b.** Describe the weather when the tree was 15 years old. Explain how you know this.
- TWS 3. a. Use Fig 12.5 D to describe the effect of climate change on the Jersey tiger moth.
 - **b.** Predict what will happen to the population of the moth if
 - i. the climate remains stableii. the climate continues to get warmer.
 - **4.** The evidence is very strong that levels of carbon dioxide in the atmosphere are increasing, causing global warming and climate change. The evidence is also strong that the rise in carbon dioxide is the result of human activities. Explain why it is so important to have strong evidence for this.



Key points

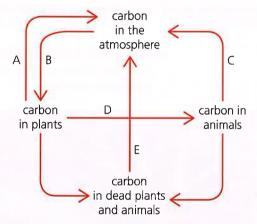
- Climate change is impacting sea levels, droughts, flooding, and extreme weather events.
- Putting together evidence from a number of different sources increases the validity.
- It is important that the science around climate change is clear so that people understand it and accept that action is needed to prevent further global warming.

Review questions

12.6

- 1. a What is the carbon cycle?
 - **b.** The diagram below shows how carbon is recycled by living things.

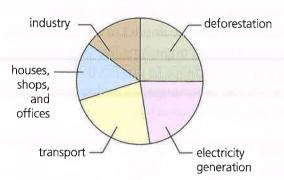
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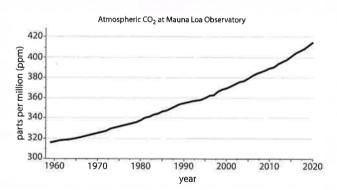
Choose the correct arrow to represent each of the following:

- i. photosynthesis [1]
- ii. animal respiration [1]
- iii.feeding [1]
- iv. decomposition. [1]
- 2. Write a short paragraph explaining the role of each of the following processes in the carbon cycle in nature:
 - **a.** photosynthesis [3]
 - **b.** animal respiration [3]
 - c. combustion [3]
 - d. decomposition. [3]

3. Scientists estimate how much carbon dioxide different human activities produce.



- **a.** Calculate what percentage of carbon dioxide emissions come from industry. [4]
- **b.** From this data, state which human activity produces the most carbon dioxide. [1]
- c. Describe 2 ways in which deforestation increases the amount of carbon dioxide in the atmosphere.[4]
- 4. This graph shows you the Mauna Loa curve.



- a. State what the Mauna Loa curve measures. [2]
- **b.** Describe where this data is collected. [4]
- **c.** From this graph, state when the first data was collected. [2]
- d. Describe the trend in the data on the Mauna Loa curve. [3]

5. The table below summarises some of the data from the Mauna Loa curve.

Date	CO ₂ concentration (ppm)
1960	315
1970	325
1980	338
1990	355
2000	373
2010	395
2020	420

- **a.** Display these data on a bar chart.
- **b.** Describe the trends in your data. [3]

[5]

- **c.** Suggest reasons for the trend you have observed. **[4]**
- **6.** Global climates have changed many times through the history of the Earth.
 - **a.** State two different types of climate change seen over millions of years. [2]
 - **b.** Suggest one possible cause for each type of climate change in your answer to part **a**. [2]

7.	a	What is the IPCC?	[1]
	b.	State the IPCC's position on global warming and climate change.	[2]
	c.	List four measured impacts of climate change over the last 50 years.	[4]
	d.	Explain how each of these impacts affects life on Earth.	[8]
8.	а	Describe the greenhouse effect using a diagram.	[5]
	b.	Explain briefly why the greenhouse effect is so important for life on Earth.	[2]
	c.	Using the idea of the greenhouse effect, exp how rising carbon dioxide concentrations in the atmosphere cause rising temperatures a the surface of the Earth.	1
	d	What is the predicted increase in the Earth's surface temperature by the middle of the 21st century?	[2]
	e	 Write a paragraph describing and explainin the future impacts of a rise in global 	g

temperatures.

[10]

Objectives

- Describe the variation in a species
- Relate this variation to genetic differences between individuals





Fig 13.1 A: You don't have to be a biologist to see the differences between a butterfly and a lizard.

Variation in animals and plants

It is easy to tell the difference between a palm tree and a sunflower plant. They are different species, and they have many different characteristics. There is a lot of genetic variation between them. It is not always so easy to see the differences between two animals or two plants of the same species.

Variation in animals

In Chapter 11 you learned that variation has two causes:

- inherited or genetic variation, carried in the genes passed on from parents to offspring
- environmental variation, resulting from the world in which an organism lives.

Animals of the same species have many shared genetic characteristics. This is why they breed successfully. They also have differences, which is why you do not look the same as your parents, your siblings or your cousins. The variation you observe between members of a species may be the result of genetic differences, environmental differences or the interaction of the two.

Within a species, some differences are easy to identify. For example, some horses have longer legs than others and some butterflies have longer tongues than their relatives. Look at the puffins in Fig 13.1 B. The similarities are clear – but what variation can you see?









▲ **Fig 13.1 B**: At first sight these puffins all look the same. Can you find some variation in their beaks, their eye markings or their feet?

If you look carefully, you will observe that some puffins have paler feet than the others, and the shape and pattern of each beak is slightly different. This variation lets us identify each bird.

Some variation is less easy to see, involving characteristics that only appear some of the time, or systems inside an animal. For example, some frogs call louder than others in the breeding season, and some people have lower blood pressure than others.



▲ Fig 13.1 C: Early spider orchids show clear similarities and variations in their flowers.

Human blood groups

One clear example of genetic variation in humans is the inheritance of blood groups. If you hurt yourself and bleed, your blood will look like anyone else's, but it may be a completely different ABO group to any of your friends. Everyone inherits an ABO blood group from their parents and this remains the same throughout your life. The four possible blood groups are A, B, AB, and O. It is very important that you get the right type of blood if you need a blood transfusion. If you are given the wrong blood group, it will make you very ill.

Variation in plants

Like animals, plants of the same species inherit many characteristics that are the same, but they also have differences. Olive trees produce olives, date palms have dates, but the fruit of some trees will be bigger, sweeter, and tastier than others, even when they grow in the same conditions.

All the flowers of a species of plant will have the same basic shape and pattern but, like the puffins, there will be some variation. See what variation you can observe in the early spider orchids in Fig 13.1 D. The features that members of the same species have in common show how they are adapted to the environment in which they live. The differences between them show the variation that will allow the species to adapt when the environment changes.

Questions

- 1. Describe the causes of variation between
 - a. different species
 - **b.** individuals within a species.
- 2. a. Describe the general appearance of the puffins in Fig 13.1 B.
 - **b.** List three ways in which the appearance of the birds shows variation.
- 3. a. State the type of variation seen in human blood groups.
 - **b.** Explain how you are sure of the type of variation involved.
- **4. a.** List three ways in which the early spider orchids in Fig 13.1 C show variation.
 - **b.** Discuss how features of a plant might be affected by genetic variation only, or by a combination of genetic and environmental variation.

(Record

Key points

- Members of the same species share many genetic characteristics and have many features in common, but they do not all look the same.
- Variation within a species is the result of both genetic and environmental variation.

Objectives

- Describe the scientific theory of natural selection
- Relate natural selection to genetic changes over time
- Fig 13.2 A: Wildebeest on their great migration – imagine the variation in this herd.

Natural selection

Organisms in a species show variation – this is caused by differences in their genes.



The organisms with the characteristics that are best adapted to the environment survive and reproduce. Less well adapted organisms die. This process is known as 'survival of the fittest'.



Genes from successful organisms are passed to the offspring in the next generation. This means that the offspring are likely to possess the characteristics that made their parents successful.



This process is then repeated many times. Over a period of time, this may lead to the development of a new species.

▲ Fig 13.2 B: The process of natural selection.

Natural selection in action

Look at the enormous herd of wildebeest in Fig 13.2 A. Millions of these animals migrate across Africa every year. When the young are born, they each get a different combination of genes from their parents. Some of them have slightly longer legs. Others have stronger hearts or bigger muscles or better teeth. They each have slightly different markings. Some have bigger horns or higher nostrils or better eyesight. Some of the females will make more milk than others.

Does any of this variation matter?



Natural selection

Living organisms produce many offspring. Think of the seeds in a pomegranate or the baby birds in a nest. Most of these offspring do not survive. What affects which organisms live, and which die?

The answer is **natural selection**. Natural selection is the result of variation between individuals. It is the process by which the organisms with the characteristics best adapted to their environment live and reproduce, passing on the useful characteristics to their offspring. There are several steps in the process of natural selection:

- Each individual inherits genetic variation from their parents and is different from all other members of their species.
- The individuals with characteristics that give them an advantage are the ones most likely to survive. Think again about the wildebeest. The animals with the longest legs, strongest hearts and muscles or best eyesight are most likely to escape being eaten by hungry lions or hyenas. The females who make the most milk increase the chances that their calves will survive. The animals with the best teeth will eat more efficiently and get more food.
- The successful individuals survive long enough to reproduce and pass on their useful characteristics.
- This process is repeated many times until these characteristics become more common in the population. Over a long period of time, it may lead to the development of a new species.

This is natural selection in action. It is sometimes called 'survival of the fittest'.

Examples of natural selection

Natural selection does *not* change individuals. Whole populations or even species change as a result of natural selection. Think about the puffins in Fig 13.1 B. The birds with the brightest colours are most likely to attract a mate. The puffins with the biggest beaks catch more fish to feed their offspring, so they are most likely to survive. Eventually all puffins will have bigger beaks or brighter colours. In Fig 13.1 D, the early spider orchid which attracts the most insects to pollinate it has the best chance of producing lots of fertile seeds. Gradually most of the population will have these successful characteristics. Table 13.2.1 shows some more examples of natural selection.

Table 13.2.1

Organism	Example of natural selection	
Rats	Since 1950, warfarin has been used to poison rats. As part of the natural variation in the rat population, some rats inherit a gene that makes them resistant to the poison. Whenever the poison is used, only the resistant rats survive and breed. In some rat populations, all the rats are resistant to the poison.	
Pitcher plants	Several variations allowed the ancestors of these pitcher plants to collect water, trap insects, and make use of the digested bodies. This gave them a huge advantage in the mineral-poor ecosystems where they live. Now all pitcher plants get added nitrates from insect prey in the same way.	
Lizards	The variation that makes this lizard the same colour as his environment makes it very difficult for predators to find him. This is a big survival advantage and as a result of natural selection, lizards of this species are now all leaf green in colour.	

Questions

- 1. Plants and animals keep producing offspring but the total number of each species stays approximately the same. Suggest a reason for this.
- 2. a. State what the term 'natural selection' means.
 - **b.** Explain how the process of natural selection takes place.
- **3.** Give two examples of the effects of natural selection in animal species local to your country.
- **4.** Give two examples of the effects of natural selection in plant species local to your country.

(Key points

- Natural selection is the result of variation between individuals. It is the natural process by which the organisms best able to survive are the ones which live and reproduce, passing on advantageous characteristics to their offspring.
- Living organisms produce many offspring, many of which don't survive. Some of the offspring have genes that give them useful characteristics that increase their chances of surviving and reproducing successfully. These genes and the variations they produce will become common in the population. Over a long period of time, a new species may develop.

Objective

 Describe what happens to the population of a species when there is an environmental change





- ▲ Fig 13.3 A: A cactus grows better in a desert than in a UK garden.
 - ▶ **Fig 13.3 B**: The effect of natural selection on a population when the environment changes.

Environmental change and natural selection

Natural selection results in **adaptation**, producing populations that survive successfully in their environment. Changes in that environment will affect the organisms living there. Date palms and olive trees may survive in low temperatures, but they will not bear fruit.

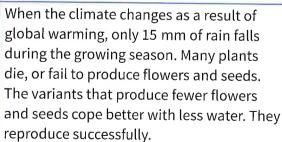
What happens when the environment changes?

In Chapter 12 you looked at how the climate is changing, affecting environments all over the world. Many are getting hotter and drier, while some get wetter. Winters may be colder or end sooner. Rains are failing. Environmental changes mean that organisms are no longer well adapted to their environment.

Every population contains variation. The individuals which are different may struggle to survive and breed. But if conditions change, they are there with characteristics more suited to the new conditions, so their population can survive (see Fig 13.3 B).

Living organisms must adapt to changes in their environment or they will not survive. Natural selection changes populations to fit their environment.

A population of plants grow, flower and set seeds successfully every year with 25 mm of rain every growing season. Most plants produce 7 flowers and an average of 28 seeds, but there are variations. Some produce 5 flowers with an average of 15 seeds, others produce 3 flowers with an average of 6 seeds.



As the dry conditions continue, natural selection takes place until most of the population are the drought-adapted variation. They produce fewer flowers and seeds but survive and reproduce successfully in the changed environment.



Rainfall in growing season:

15 mm

Rainfall in growing season: 15 mm

Natural selection, environment change and interdependence

Environmental changes also impact the interdependence of organisms in an ecosystem. Plant and animal life cycles are often linked through feeding relationships. If the environment changes, patterns of reproduction change, and the food supply fails. For example, many organisms in hot, dry regions depend on the rains to reproduce. If the rains are delayed or fail, whole populations are threatened. If one population or species changes over time by natural selection in response to a change in the environment, other interdependent species must also adapt to the new conditions or die out.



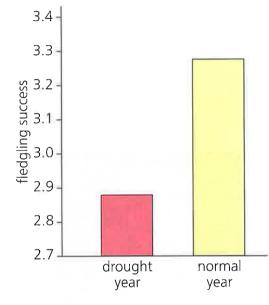
▲ Fig 13.3 C: A young kestrel.

Gradual change v. extreme events

Kestrels are small birds of prey (see Fig 13.3 C), widespread in Africa, Asia and Europe. Their diet varies depending on where they live and the time of year.

Scientists observe that kestrels reproduce successfully even when the average environmental temperature increases due to climate change, but kestrel populations are damaged by extreme weather events such as droughts (see Fig 13.3 D). Natural selection means that the birds best able to cope with rising temperatures will breed successfully, which reduces the impact of environmental warming. There are no adaptations which prepare kestrels for severe, unpredictable droughts.

Natural selection has always allowed species to adapt to new environmental conditions. The problem is that climate change is now happening very fast and causing many extreme weather events. Will natural selection keep up with the changes?



▲ Fig 13.3 D: Kestrel breeding success per nest over different seasons.

Questions

- 1. Explain how environmental changes drive natural selection and affect populations.
- 2. Use information from Fig 13.3 B to answer these questions.
 - a. Explain why 7-flowered plants are most common in the original environment.
 - b. Suggest reasons why 5-flowered plants, not 3-flowered plants, become more common when the climate becomes drier.
 - c. Predict, giving an example, how the population might change if the climate changes again.



- **3. a.** Describe using Fig 13.3 D how kestrels are affected by changes in their environment.
 - **b.** How do you know this data is the average from many nests?
 - c. Explain the role of natural selection in the adaptation of kestrels to changes in their environment.



Key point

When there is an environmental change, populations change and become better adapted to their new environment as a result of natural selection.



Objective

- Describe how populations and species become extinct as a result of environmental change
- Fig 13.4A: All we have left of the dinosaurs are fossil remains.



▼ Fig 13.4 C: Amphibian species around the world are threatened with extinction by a deadly new fungal disease.



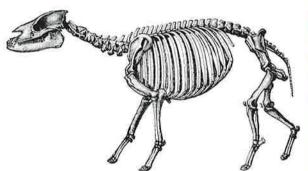
Extinction!

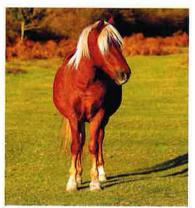
Millions of years ago, our planet was home to dinosaurs such as *Stegosaurus* (see Fig 13.4 A). Where are they all now?

What is extinction?

A species becomes **extinct** when there are no more individuals of that species alive. Extinction may be local, involving a population in a particular place, or it may be global, so that an organism no longer exists anywhere on Earth – like the dinosaurs.

Once a species becomes globally extinct, it has gone forever. This is not always a bad thing. Some extinct species only exist as fossils. Others have descendants living today, better adapted to their environment (see Fig 13.4B). Extinction is part of life on Earth, and is needed to make resources available for better adapted organisms.





▲ Fig 13.4 B: This extinct fossil mammal is a relative of modern horses.

Why do species go extinct?

Species go extinct because their environment changes, and the climate of the earth has changed many times through history, as you learned in Unit 8.3. For example, tropical organisms become extinct in an ice age through lack of food, or being too cold.

A new species moving into an environment also changes it. The newcomers may be predators, like the brown tree snakes on Guam, or competitors better adapted to the environment, for example invasive plants like Himalayan balsam or water hyacinth. You learned about this in chapter 7.

Environmental changes also produce the conditions for new diseases to appear, sometimes wiping out whole species (see Fig 13.4 C).

Changes in land use are driving many animals and plants to extinction – for example draining land for agriculture destroys ecosystems such as mangroves, marshes, and bogs.

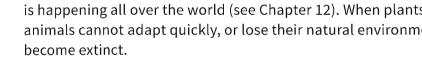
So far, there have been five mass extinctions on a global scale, when many species died out over a relatively short time period. In the past, these extinctions were the result of huge environmental changes, often coming from a single catastrophic event such as a massive volcanic eruption or a giant meteorite strike.

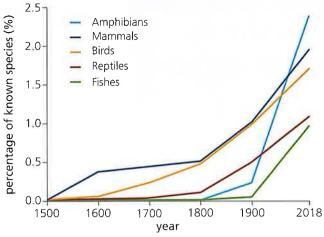
Humans and extinction

In the last 150 years, the rate of extinctions has been increasing. Species of animals and plants are dying out faster than ever before (see Fig 13.4 D).

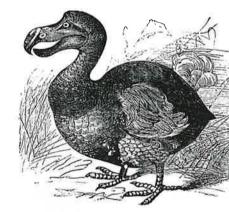
We are living in the sixth mass extinction and the evidence suggests many of these extinctions are the result of our human actions on the environment. These include:

- Hunting/fishing: the human population has grown enormously and we have guns. From mammoths to dodos and whales, human hunters have killed and eaten many species to extinction. We have also overfished the seas.
- Habitat destruction: humans are destroying habitats such as rainforests for farmland, at a rate of about 8000 km² per year. Climate change from our actions is also destroying coral reefs, and pollution from our factories and our sewage is destroying rivers and ocean environments – 16 species of freshwater fish became extinct in 2020 alone.
- Climate change: climate change resulting from human activities is happening all over the world (see Chapter 12). When plants and animals cannot adapt quickly, or lose their natural environment, they become extinct.





▲ Fig 13.4 D: The impact of human activities on extinction rates begins in the Industrial Age.



▲ Fig 13.4 E: Dodos were big, flightless birds on the island of Mauritius. They had no predators until people arrived in the 17th century. *In less than 100 years, dodos* were extinct.

Questions

- 1. a. What is extinction?
 - **b.** Explain why some extinction is important for life on earth.
- **2. a.** Describe four different changes in the environment that may result in the extinction of a population or species.
 - **b.** Explain how extinction happens.



- **3.** Use the data in Fig 13.4 D to answer these questions.
 - a. In which year did extinction rates begin to speed up?
 - **b.** Which type of animals are becoming extinct most rapidly? Suggest two reasons for this.
 - c. Explain how the data in Fig 13.4 D suggests that environmental changes are leading to the extinction of many species.



Populations and species may become extinct as a result of environmental changes such as temperature, habitat loss, new diseases or competitors moving in, hunting by humans, etc.



Thinking and working scientifically

13.5

Objectives

- Describe a model for natural selection
- Describe examples where scientists' unexpected results have led to improved scientific understanding
- Describe how people develop and use scientific understanding



▲ Fig 13.5 A: Light and dark coloured peppered moths on a clean tree.

 Fig 13.5 B: The changing populations of light and dark coloured peppered moths in industrial areas.

Investigating the peppered moth: past and present

Scientists thought natural selection took place over long periods of time. Some unexpected observations of British moths made them change their minds.

Natural selection in action: the peppered moth

Peppered moths (*Biston betularia*) are found in countries from China, Russia and Kazakhstan to Europe and North America. They vary in colour from almost white to almost black. Some well-known studies on these moths were carried out in the 1950s by Professor Kettlewell of Oxford University, UK.

Kettlewell's theory

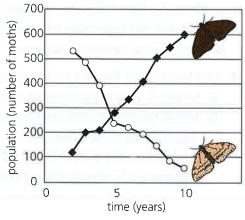
If natural selection causes changes in moth populations, clean woodlands will contain mainly pale moths. Pale moths are more likely to survive and reproduce, camouflaged against the tree trunks where they rest. Darker moths produced by natural variation will be more easily seen and eaten by birds (Fig 13.5 A).

After the Industrial Revolution, many UK trees were blackened by factory pollution. Kettlewell suggested this made it easy for birds to find pale moths, so moths with genes for lighter colours would be eaten. In polluted woodlands, he predicted there would be many more dark moths than light ones in the population, as a result of natural selection.

Kettlewell's findings

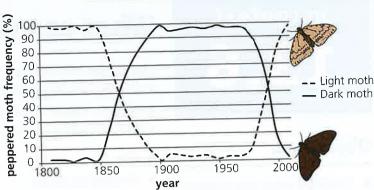
Professor Kettlewell analysed specimens of peppered moths from old collections made before the Industrial Revolution and observations from amateur moth collectors all over the country. He carried out field experiments, placing light and dark moths on different coloured tree trunks and observing which were eaten by birds. The evidence he collected supported his theory (Fig 13.5 B). This was natural selection in action – fast.





Moving forwards

Environments keep changing. From 1970, factories in the UK became cleaner, followed by the air and the trees. Birds could easily see the dark moths again. The changing environment caused more natural selection. Most peppered moths in the UK and northern Europe are now the pale form again.



▲ Fig 13.5 C: Changes in the colours of peppered moths in the UK over time.

Proving the point

At one stage, some people questioned Professor Kettlewell's original experiments. They said that moths did not rest on tree trunks. They doubted whether birds ate the moths. They even accused him of cheating.

Between 2001 and 2008, Professor Michael Majerus from Cambridge University set out to verify the story of the peppered moth. He observed them in their natural habitat. He released 4864 moths over six years at an unpolluted site and recorded where they rested, what ate them, and which colours were eaten. He found the original work was correct. Birds see and eat dark moths more easily on clean trees, so natural selection favours the pale moths.

Professor Majerus's results

- 35% of the moths rested on tree trunks. Most of the rest were on branches.
- The moths were eaten by nine different bird species including, robins, great tits, blue tits, blackbirds, starlings, and wrens.
- Over a 6-year period, a greater percentage of the dark moths released were seen and eaten by birds than light moths.

▼ Table	13.5.1
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Year	% of released pale moths eaten	% of released dark moths eaten
2001	23	31
2002	28	29
2003	17	32
2004	22	31
2005	19	18
2006	20	29

Questions

- 1. a. Describe Professor Kettlewell's theory about peppered moths.
 - **b.** Describe three ways in which he proved his theory correct.
 - c. Explain how each of these methods supported his theory.
- 2. a. Describe what the data in Fig 13.5 C shows you.
 - **b.** Explain these observations in terms of natural selection.
- a. Display the data in Table 13.5.1 as a bar chart.b. Discuss the work of Professor Majerus and explain how it supports Kettlewell's original findings about natural selection and peppered moths.

(Rey points

- An investigation into the effect of environmental change on peppered moths led to improved scientific understanding of natural selection.
- People develop scientific understanding through investigations, analysing evidence and building models that can be tested.

Science in context

13.6

Objectives

- Describe what can happen to a species when there is an environmental change
- Describe how people develop and use scientific understanding
- Discuss how the uses of science can have a global impact



▲ **Fig 13.6 A**: The world at night is lit up by electric lights.



Fig 13.6 B: Hydroelectric power produces clean electricity.

What can we do?

The global environment is changing fast. Species are becoming extinct at an alarming rate. Scientists and citizens around the world want to solve these problems. Some of the ideas are simple, cheap, and effective. Often there is a human price to be paid. In every case we must ask:

- Can we do it?
- Should we do it?

Sometimes a solution to one problem produces another. The advantages and disadvantages must be weighed in the balance. These reports were written by IGCSE students. Read them carefully.

Article 1: Stop global warming now!

Global warming and the climate change it causes are accepted scientific facts. They are happening as a result of human activities and climate change is driving the extinction of organisms of all sorts (see Unit 13.4).

People all over the world want cheap electricity. Electricity lights our homes, powers our technology, refrigerates our food and our medicines, gives us warmth or air conditioning in our buildings, powers our factories Unfortunately, about two thirds of all the electricity used around the world is generated by burning fossil fuels, adding carbon dioxide to our atmosphere, increasing global warming and affecting climate change.

There is another way. We can produce electricity without producing carbon dioxide using the energy in the Sun, in the wind and in our mighty rivers. Hydroelectric power uses water, a natural renewable resource, trapping it behind huge dams so it can be used. Four hydroelectric dams on the Mekong river in China produce more than 8800 megawatts of electricity each day, or around 3 million megawatts per year. That's equivalent to burning over 7 million barrels of oil. Hydroelectric power does not produce greenhouse gases. and provides people with relatively cheap electricity. In Latin America, 70% of the electricity is now generated by hydroelectric power. Many scientists and governments see hydroelectric power as part of the solution to global warming for the future. We can use the power of water to generate electricity and help prevent climate change at the same time.

Article 2: Saving our freshwater fish

Humans have lived by rivers and lakes and eaten freshwater fish since the earliest times. But times are changing. A recent scientific report called *The World's Forgotten Fishes* shows that fresh water fish are threatened all over the world. Here are some of the statistics:

- Nearly one third of all freshwater fish species are threatened by extinction.
- 16 freshwater fish species became globally extinct in 2020 alone.

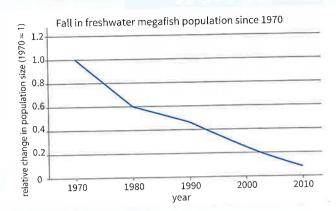
- Populations of migratory fish like salmon and eels have fallen by 75% in the last 50 years.
- Megafish enormous freshwater fish that weigh over 30 kg and live for many years, for example, the Mekong giant catfish – are seriously threatened.



Human activities are affecting the survival of freshwater fish around the world. Where fish go extinct, other species are threatened as well. Many of the changes to the environment that threaten freshwater fish are linked to human activities. They include:

- Hydroelectric dams: producing electricity for people and industry changes river flows and may cause drought in some areas. It floods land in the reservoirs created by the dam which can remove indigenous people and destroys ecosystems. Hydroelectric power stations prevent fish moving up and down rivers to breed.
- Pollution of rivers by human sewage, farming and industry: this may destroy all life, including plants, invertebrates and fish, or it may result in bioaccumulation.
- <u>Draining rivers and wetlands</u>: done to make farmland or build housing, it removes the river habitat and may deprive people downstream of water.
- Overfishing: depletes the populations of fish which may never recover. This deprives people of a long-term food source and source of income.

We must put a stop to the decline in our freshwater fish before it is too late!



▲ Fig 13.6 C: The fall in populations of megafish since 1970 is catastrophic.



▲ Fig 13.6 D: The Mekong giant catfish is considered critically endangered.

Questions

- **1. a.** Make a table to compare the advantages and any disadvantages of hydroelectric power mentioned in Article 1.
 - **b.** Make a table to compare the advantages and disadvantages of hydroelectric power mentioned in Article 2.
- **c.** Use the data from Fig 13.6 C to help you to explain why scientists are so concerned about global freshwater fish.
 - **2. a.** Discuss the specific issues of hydroelectric power highlighted in both these articles.
 - **b.** Suggest how people could have as many of the benefits of hydroelectric power as possible whilst minimising the damage.

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Key points

- When there is an environmental change, it may reduce the numbers of one or more species or threaten them with extinction.
- People develop and use scientific understanding to try to solve global problems such as climate change and extinctions.
- The uses of science can have global impacts.

Review

13.7

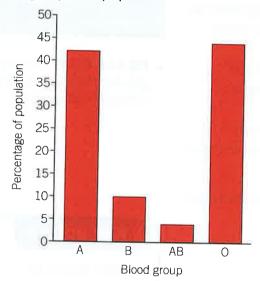
- **1.** Zarah is a scientist. She is investigating the variation in the weights of a herd of goats.
 - a. What is meant by variation?
 - **b.** Zarah found that every goat had a different body mass. Name the type of graph Zarah should use to display her results.

[1]

[1]

[3]

- **c.** Suggest two different explanations for the differences in the body masses of the goats that Zarah observed.
- **2.** This graph shows you the distribution of human blood groups in a population.



- **a.** Which blood group is most common? [1]
- **b.** Which blood group is least common? [1]
- c. Abdul has lost weight by eating healthily. He has changed his body mass. Now he wants to give blood to help others. Abdul is blood group A. He plans to eat different food to change his blood group to a rarer one. His doctor says this will not work. His blood group will always be the same.

Explain to Abdul why he could change his body mass but cannot change his blood group. [6]

are the fastest land animals. They have very long legs, which use a lot of energy. Animals with short legs do not run as fast, but they use less energy. Animals with extra long legs easily break their bones. Scientists measured the length of the front legs of 10 female cheetahs in Namibia.

Cheetah number	Length of front leg (cm)
1	73
2	73
3	73
4	69
5	72
6	77
7	70
8	74
9	74
10	72

- **a.** What is natural selection? [2]
- **b.** Draw a bar chart of the variation in the front legs of the cheetahs. [5]
- **c.** Describe the type of variation seen. [2]
- d. Explain how the process of natural selection
 has affected the leg length of the female
 cheetahs.
 [6]
- e. A new type of plant-eating animal moves into the environment of the cheetahs. It is relatively slow moving, but it breeds very fast. Discuss the changes you might expect to see in the cheetah population in future. [6]
- **4. a** Draw a flow diagram of the process of natural selection. **[6]**
 - b. Explain how the process of natural selection helps a species overcome the problems of climate change.[6]

5. Peppered moths rest on tree trunks during the day. Their main predators are birds. The moths come in two forms – light and dark. The light forms are well camouflaged on light tree trunks.





[5]

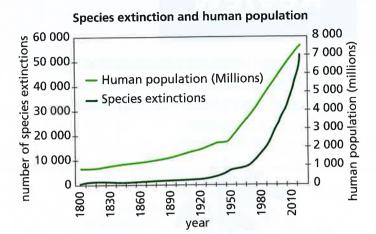
The percentages of dark and light moths were measured in the years 1700, 1840 and 1980.

Moth colour	% of total moth population		
	1700	1840	1980
dark	1	90	5
light	99	10	95

- a. Draw a bar chart of these results.
- b. Briefly describe how the populations of moths changed between 1700 and 1840.[2]
- c. Between these dates the use of coal increased.

 Smoke from the burning coal turned tree
 trunks black. Which type of moth would birds
 see more clearly on the dark tree trunks? [1]
- **d.** Describe the change in the moth populations between 1840 and 1980. [3]
- e. Explain how and why these changes in the colour of the peppered moth population happened.[12]

6. a. State what is meant by extinction and give an example of an organism that is extinct. **[4]**



- **b.** Describe the data in this graph.
- **c.** Suggest an explanation for the pattern in the data.
- **d.** Describe and explain four ways in which humans impact the rate of extinction of other organisms.

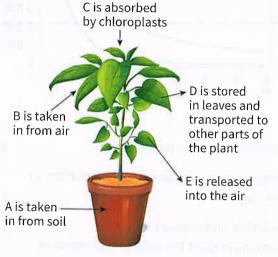
[4]

[3]

[8]

Stage 9 Review

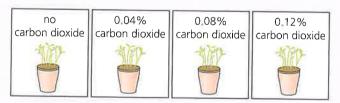
1. This diagram shows the substances that plants absorb, make and release when their cells are photosynthesising faster than they respire.



Identify A-E.

[5]

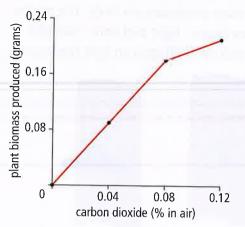
2. Zain grew seeds in glass boxes containing different amounts of carbon dioxide.



He dried the plants from each box and measured their mass. Then he subtracted the mass of the original seeds to see how much new biomass they had made.

Carbon dioxide (% in air)	Plant biomass produced (g)
0.00	0.00
0.04	0.09
0.08	0.18
0.21	0.21

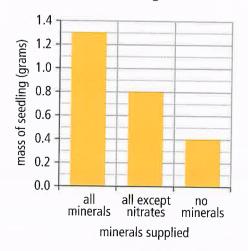
Zain plotted a graph of his results.



- **a.** State the conclusion you can draw from Zain's graph.
- b. Write the summary equation for photosynthesis. [3]

[1]

- c. Use your knowledge of photosynthesis to explain Zain's results. [4]
- d. Zain's data for the box with no carbon dioxide is not correct. He assumed there would be no new biomass. Explain why this assumption was wrong.
- e. Suggest three other variables that need to be controlled to make Zain's results more reliable and explain why they should be controlled.
 [6]
- 3. Mariam wants to know which minerals are important for plant growth. She takes three samples of pure water and adds different minerals to each of them. Then she puts a seedling in each sample of water. After 2 weeks she compares the masses of the seedlings



[6]

a. Suggest one other thing she could have measured apart from the mass of the seedlings.

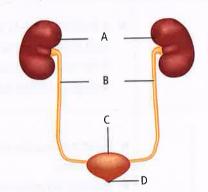
b. What effect does a lack of nitrates have on

[1]

[2]

- the growth of the seedling? c. What is this mineral used for in the plant? [1]
- d. Suggest what would happen to the colour of the leaves if the plant was grown with all the minerals it needs apart from magnesium, [3] and explain your answer.

4.



- a. State what is meant by excretion. [1]
- b. State the substance excreted by the system [1] shown in the figure.
- c. Name the parts labelled A–D and describe [8] what each part does in the body.

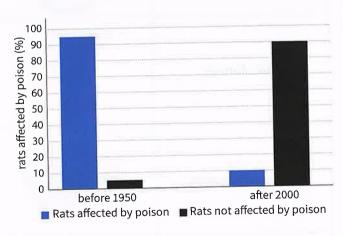
5.





- a. Identify and name the male cell and give two ways in which it is adapted to its function.
- b. Identify and name the female cell and give two ways in which it is adapted for its [3] function.
- c. Describe what happens to these cells at [3] fertilisation.

- d. State what sex chromosomes you might find in:
 - [1] i. Cell B
 - [1] ii. Cell A.
- e. Draw a diagram to explain how the sex of a baby is decided at fertilisation and why there is a 50:50 chance that the new baby [4] will be a boy or a girl.
- 6. Draw and label a diagram of the carbon cycle. [11]
- 7. a. Describe the greenhouse effect and explain why it is so important for life on Earth. [5]
 - b. Describe two different types of evidence that scientists use to show that the climate has [4] changed in the past.
 - Give two ways in which human activities are affecting the carbon cycle. Explain how this is affecting life on Earth.
- 8. a. Give two sources of variation in animals [2] and plants.
 - **b.** A new rat poison was introduced in 1950. At first it was very effective. By the year 2000 the population of rats was as big as ever and the poison had little effect. Use natural selection to explain the changes in the rat [8] population shown in the bar graph.



Reference

Choosing apparatus

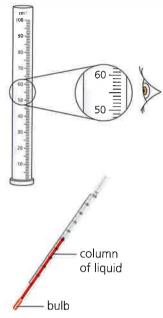
There are many different types of scientific apparatus. The table below shows what they look like, how to draw them, and what you can use them for.

Apparatus name	What it looks like	Diagram	What you can use it for
test tube			 heating solids and liquids mixing substances small-scale chemical reactions
boiling tube			 a boiling tube is a big test tube; you can use it for doing the same things as a test tube
beaker	400 mil 5 mil 6 mil 7 mi		heating liquids and solutionsmixing substances
conical flask			heating liquids and solutionsmixing substances
filter funnel			 to separate solids from liquids, using filter paper
evaporating dish			• to evaporate a liquid from a solution
condenser			to cool a substance in the gas state, so that it condenses to the liquid state

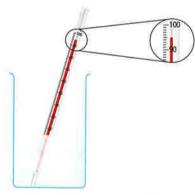
stand, clamp, and boss			to hold apparatus safely in place
Bunsen burner			to heat the contents of beakers or test tubesto heat solids
tripod			 to support apparatus above a Bunsen burner
gauze			 to spread out thermal energy from a Bunsen burner to support apparatus, such as beakers, over a Bunsen burner
pipette			 to transfer liquids or solutions from one container to another
syringe			 to transfer liquids and solutions to measure volumes of liquids or solutions
spatula	Was a second		 to transfer solids from one container to another
tongs and test tube holders	a de de	7	 to hold hot apparatus, or to hold a test tube in a hot flame

Reference

2



▲ The different parts of a thermometer.



▲ The temperature of the liquid is 95 °C.



▲ The balance measures mass.

Working accurately and safely

You need to make accurate measurements in science practicals. You will need to choose the correct measuring instrument, and use it properly.

Measuring cylinder

Measuring cylinders measure volumes of liquids or solutions. A measuring cylinder is better for this job than a beaker because it measures smaller differences in volume.

To measure volume:

- 1. Place the measuring cylinder on a flat surface.
- 2. Bend down so that your eyes are level with the surface of liquid.
- **3.** Use the scale to read the volume. You need to look at the bottom of the curved surface of the liquid. The curved surface is called the **meniscus**.

Measuring cylinders measure volume in cubic centimetres, cm³, or millilitres, ml. One cm³ is the same as one ml.

Thermometer

The diagram to the left shows an alcohol thermometer. The liquid expands when the bulb is in a hot liquid and moves up the column. The liquid contracts when the bulb is in a cold liquid.

To measure temperature:

- **1.** Look at the scale on the thermometer. Work out the temperature difference represented by each small division.
- 2. Place the bulb of the thermometer in the liquid.
- **3.** Bend down so that your eyes are level with the liquid in the thermometer.
- **4.** Use the scale to read the temperature.

Most thermometers measure temperature in degrees Celsius, °C.

Balance

A **balance** is used to measure mass. Sometimes you need to find the mass of something that you can only measure in a container, like liquid in a beaker. To use a balance to find the mass of liquid in a beaker:

- 1. Place the empty beaker on the pan. Read its mass.
- 2. Pour the liquid into the beaker. Read the new mass.
- 3. Calculate the mass of the liquid like this:

(mass of liquid) = (mass of beaker + liquid) – (mass of beaker)

Balances normally measure mass in grams, g, or kilograms, kg.

Working safely

Hazard symbols

Hazards are the possible dangers linked to using substances or doing experiments. Hazardous substances display **hazard symbols**. The table shows some hazard symbols. It also shows how to reduce risks from each hazard.

Hazard symbol	What it means	Reduce risks from this hazard by
	Corrosive – the substance attacks and destroys living tissue, such as skin and eyes.	wearing eye protectionavoiding contact with the skin
×	Irritant – the substance is not corrosive, but will make the skin go red or form blisters.	wearing eye protectionavoiding contact with the skin
	Toxic – can cause death, for example, if it is swallowed or breathed in.	 wearing eye protection wearing gloves wearing a mask, or using the substance in a fume cupboard
	Flammable – catches fire easily.	wearing eye protectionkeeping away from flames and sparks
	Explosive – the substance may explode if it comes into contact with a flame or heat.	wearing eye protectionkeeping away from flames and sparks
*	Dangerous to the environment – the substance may pollute the environment.	taking care with disposal

Other hazards

The table does not list all the hazards of doing practical work in science. You need to follow the guidance below to work safely. Always follow your teacher's safety advice, too.

- Take care not to touch hot apparatus, even if it does not look hot.
- Take care not to break glass apparatus leave it in a safe place on the table, where it cannot roll off.
- Support apparatus safely. For example, you might need to weigh down a clamp stand if you are hanging heavy loads from the clamp.
- If you are using an electrical circuit, switch it off before making any change to the circuit.
- Remember that wires may get hot, even with a low voltage.
- Never connect wires across the terminals of a battery.
- Do not look directly at the Sun, or at a laser beam.
- Wear eye protection whatever you are doing in the laboratory!

Glossary

Abiotic Describes something that is non-living.

Adaptation A physical characteristic or behaviour that makes animals or plants particularly suited to their environment. Useful adaptations are the result of natural selection.

Aerobic respiration The controlled release of energy from food that takes place in the mitochondria of the cells, using oxygen.

Alveolus (pl. Alveoli) Tiny air sacs at the end of the tubes leading into the lungs providing a big surface area for gas exchange to take place.

Amino acids Small molecules that are the building blocks of proteins.

Amphibians Vertebrates that live on land and in water at different stages of their life cycle. They have smooth, moist skin, four legs and breathe through skin and lungs when adult.

Anaemia Deficiency Disease that results from lack of iron in the diet.

Anaerobic respiration The controlled release of energy from food in cells without using oxygen. It produces much less available energy than aerobic respiration.

Antagonistic muscles Muscles which pull in opposite directions e.g. biceps and triceps.

Antibiotic A substance that kills bacteria or stops them growing so it can cure bacterial infections.

Antibodies Special proteins made by the white blood cells in response to pathogens. They stick to microorganisms so they cannot cause disease.

Arachnid A group of arthropods including spiders and scorpions which all have 8 legs.

Arthritis Painful joints, often as a result of wear and tear.

Arthropod Invertebrates with a hard outer skeleton and jointed legs.

Artificial fertilisers Fertilisers that are compounds made by industrial processes.

Asexual reproduction Reproduction involving only one parent, that results in offspring that are identical to their parent.

Bacteria (sing. Bacterium) Some of the smallest living organisms, between 0.2 and 2.0 µm in diameter. They are all single celled and reproduce by splitting in two.

Balanced diet A diet that contains all of the foods needed for health in the right amounts.

Ball-and-socket joints Joints that give all round movement.

Biceps The muscle at the front of the upper arm that contracts to bend the arm at the elbow.

Biconcave To have a dimple on both sides.

Bioaccumulation The increase in the concentration of a substance along a food chain, often a toxin that reaches levels where it affects the top predator in the food chain.

Biodiversity The number and variety of living organisms.

Biological pest control The control of a pest species using another species of organism.

Biologist A scientist who studies living organisms (biology).

Biology The study of living organisms.

Biomass The material living organisms are made of.

Biosphere The environment of the Earth and all the living organisms on it.

Biotic Describes something that is living or associated with living organisms.

Birds Vertebrates that live on land, and most can fly. They have feathers, wings and beaks, breathe air using lungs and lay hard shelled eggs on land. They control their own body temperature.

Bladder Organ that stores urine produced by the kidneys before it is released from the body.

Blood The liquid which flows around the body in the blood vessels transporting substances to and from the tissues and cells.

Body mass index (BMI) A measure of obesity. To calculate the BMI, divide the body mass in kg by the height in metres squared.

Bone marrow Soft tissue inside some of the bones which makes red and white blood cells.

Breathing The movements of the rib cage and diaphragm which cause air to move in and out of the lungs, due to pressure changes inside the chest.

Bronchus (pl. bronchi) Tubes leading from the trachea into the lungs.

Caffeine The drug found in coffee, which is a stimulant.

Calcium Mineral needed for making strong, healthy bones and teeth.

Cancer A group of diseases where the cells divide uncontrollably.

Capillaries Very small blood vessels.

Carbohydrate Molecules that contain a lot of energy. Food rich in carbohydrates include sugar, flour, cassava, rice and maize.

Carbon An element that is part of many molecules in living things.

Carbon cycle A series of processes that move carbon between living organisms and the physical environment.

Carbon dioxide (CO2) A gas produced during aerobic respiration in cells and needed by plants for photosynthesis. It is a greenhouse gas which maintains the surface of the Earth at the right temperature for life.

Carbon monoxide A poisonous gas that reduces the amount of oxygen the red blood cells can carry.

Carbon sink Natural systems that absorb or store carbon.

Carcinogen Something that causes cancer.

Carnivore Animals that eat other animals (meat).

Cartilage Tissue that cushions the bones and reduces friction so they do not wear away.

Causal link A clear connection between a cause and an effect.

Cell membrane The outer layer of the cell that controls what moves into and out of the cell.

Cell sap Fluid found in the vacuole of a plant cell.

Cell theory The concept that the cell is the basic unit of the structure of all living things.

Cell wall Tough outer layer of a plant cell that gives it shape and strength. In plants, the cell wall is made of cellulose.

Cell(s) The single units or building blocks of living things.

Cellulose The indigestible substance that makes up the cell walls of plants.

Characteristics Features of living organisms that can be observed and measured.

Chlorophyll The green coloured pigment which traps light energy for photosynthesis in the chloroplasts of plant cells.

Chloroplast Small structures in the cytoplasm of some plant cells that contain chlorophyll. This is where photosynthesis takes place.

Chromosomes Long DNA structures found in the cell nucleus.

Chronic Obstructive Pulmonary
Disease (COPD) a lung disease
affecting the structure of the alveoli in
the lungs.

Cilia Tiny hair-like structures found on some cells.

Ciliated cells Specialised cells with cilia which beat to cause movement.

Classification Sorting organisms into groups based on their similarities and differences.

Climate The long term weather patterns in an area.

Cnidaria Invertebrates that all live in the sea, and have no legs and stinging tentacles around their mouths.

Combustion The scientific word for burning. The process where substances react with oxygen in the air, transferring light and heating the surroundings.

Compost Brown substance full of nutrients for the garden, produced by the decomposition of garden and kitchen waste by microorganisms.

Concentration gradient The gradient in concentration between an area with a high concentration of a substance and an area with a lower concentration of the same substance.

Condensation The process by which a gas changes state to become a liquid as it cools.

Conifer (gymnosperm) Flowering plant with narrow, needle-like leaves that reproduces using seeds in cones.

Contracts When a muscle shortens.

Controlled variable Variable that is not changed during an investigation.

Crustacean A group of arthropods with at least 10 legs.

Culture A method of growing microorganisms.

Cytoplasm The jelly-like substance where many of the chemical reactions of the cell take place.

Decomposer Microorganisms that feed on dead bodies, droppings, fruits and other food.

Decomposition The process of microorganisms decomposing waste material from organisms, including dead bodies.

Deficiency disease A disease which results if a diet is lacking a certain element long term.

Diabetes A condition where the body cannot control the levels of sugar in the blood. It may be inherited or a result of obesity.

Dialysis A process of cleaning the blood using a special machine if the kidneys have failed and no longer work.

Diaphragm Sheet of muscle and other tissues that divides the chest cavity from the rest of the organs.

Dichotomous key A key used to identify organisms through a series of questions.

Diet The mixture of foods eaten over a period of time.

Diffusion The net (overall) movement of particles from an area where there are lots of them (a high concentration) to an area where there are fewer of them (a lower concentration) in a liquid or a gas as a result of the random movement of particles.

Distribution A measure of where particular organisms occur in an environment.

DNA The genetic material, that makes up the chromosomes in the nucleus of a cell.

Donor An individual who gives an organ to save the life of another person whose organs have failed.

Droplet infection The spread of pathogens by airborne droplets from coughs, sneezes, etc.

Echinoderms Invertebrate group with spiny skins, that are often star or ball-shaped.

Ecosystem An environment that supports life.

Egestion The removal of undigested material from the body in the form of faeces.

Eggs Female gametes in animals.

Electron microscope Big, expensive instrument using electron beams to magnify very small objects.

Embryo The early stages of development after fertilisation.

Environmental variation External, environmental factors that affect our inherited characteristics.

Estimate Approximate calculation or judgement of an answer based on knowledge and understanding.

Evaluate Work out what is good and what is not so good.

Evaporate The process by which a liquid changes state to become a gas as it warms up.

Excretion The removal of waste products from the cells or body of an organism.

Exhale Breathe out.

Extinct When no more individuals of a species remain alive, either locally or globally.

Faeces The undigested material passed out of the body during egestion.

Fat A solid lipid used as an energy store in the cells.

Fern Relatively large non-flowering plants that reproduce using spores.

Fertilisation The point at which the nucleus of the egg and sperm fuse to make a new cell with a full set of chromosomes.

Fetus The developing baby after the initial stages of pregnancy.

Fibre An important part of the diet made up of large molecules the body can't digest that helps everything move steadily through the digestive system.

Fish Vertebrate group that live and reproduce in water, breathe through gills, have scales, fins and a tail and their body temperature varies with the surroundings.

Flower The reproductive organs of a plant.

Flowering plant (seed plant) Plants that reproduce using flowers and making seeds.

Fluid sac The fluid filled structure that surrounds a developing fetus to support and protect it.

Food web A model of the feeding relationships in an ecosystem.

Fossil The preserved remains of ancient organisms.

Function Job or role in a cell or organism.

Fungi A group of living organisms that can be single cells like yeast or may be very large. They have chitin cell walls. All fungi digest their food outside their bodies and they reproduce by splitting in two (yeasts) or producing spores.

Fuse Join together

Fused joints Joints that have grown together so they do not allow movement.

Gametes Special reproductive cells that contain half the number of chromosomes as the normal body cells of the parent.

Gas exchange The exchange of one gas for another – in living organisms, the gases exchanged are usually oxygen and carbon dioxide.

Gas exchange system Body system where gas exchange takes place.

Genes The sections of the DNA in the chromosomes that control the development of inherited characteristics.

Genetic material The material of inheritance, passed from parents to offspring.

Germ theory of disease The idea that infectious diseases are caused by microorganisms (germs) passed from one organism to another.

Gestation period (pregnancy) The time it takes a baby to develop from a fertilised egg to birth.

Glacier A huge frozen river of ice.

Glucose A simple sugar produced by plants in photosynthesis.

Glycogen A short term energy store in mammalian muscles and liver.

Greenhouse effect The effect of greenhouse gases trapping energy and warming the surface of the earth.

Greenhouse gases Gases that reflect energy back to the surface of the Earth, warming it and maintaining a temperature suitable for life.

Groundwater Water held in the soil and stored underground

Growth Getting bigger by gaining more cells or more biomass.

Habitat The area where an organism lives – its home.

Haemoglobin Iron-based red molecule found in the red blood cells, that carries oxygen around the body

Heart attack When an area of the heart is deprived of blood due to a blocked blood vessel.

Heart disease Disease of the heart, often caused by problems in the blood supply to the heart muscle.

Herbivore An animal that eats plants.

High blood pressure A condition where the pressure of the blood in the blood vessels is too high, risking major health problems.

Hinge joints Joints that allow forwards and backwards movement

Hybrids The offspring of two different species. They are usually infertile.

Hyphae A major part of the structure of large, multicellular fungi

Ice age A long period of very low temperatures at the surface of the Earth, when ice and glaciers cover much of the land surface.

Identical twins Twins formed from a single fertilised egg, who are genetically identical.

Inequality of access When different people have different abilities to access things that are needed.

Inhale Breathe in

Inhaler Apparatus that delivers medicines directly into the breathing system.

Inherited variation Characteristics determined solely by your genes

Insect A group of arthropods with 3 body segments, six legs and a pair of antennae. Many of them have wings.

Insulation Material which minimises the transfer of energy from one place to another.

Intercostal muscles Muscles between the ribs which contract or relax to change the shape and therefore the pressure of the chest cavity for breathing in or out.

Interdependence of life The concept that all the organisms in an ecosystem depend on each other.

Intergovernmental panel on climate change (IPCC) International body that studies evidence on global warming and climate change from thousands of scientists all over the world and advises governments.

Introduced species (non-native species) Species that are brought into a country or an ecosystem by human activity.

Invasive species A species introduced into an ecosystem by human activity, which then damages the ecosystem.

Invertebrates Animals without backbones.

Iron Mineral needed to make the haemoglobin that carries oxygen around the body.

Joint The structures where two bones meet.

Kidney transplant A procedure where a kidney from either a deceased or a living donor is placed in the body of an individual to replace their own, failed kidneys.

Kidneys The organs that remove toxic urea from the blood and excrete it in the urine.

Lactic acid The compound made by anaerobic respiration in animal cells.

Leaves Plant organs that make food by photosynthesis.

Legumes Plants belonging to the pea bean and clover family that have root nodules full of nitrating bacteria.

Ligaments Slightly stretchy, strong tissues that hold the bones in joints in place.

Light intensity Measure of the amount of light falling on an object.

Light microscope Instrument using light and lenses to magnify very small objects.

Lipid Fats and oils, needed to supply energy, used as an energy store in the body and needed for cell membranes. Butter, cheese and meat are fat-rich foods.

Liverworts Small non-flowering plants with no true stems, roots or leaves that reproduce using spores.

Lung cancers Cancers which form in the lungs, often as a result of smoking tobacco.

Mammals Vertebrates that must breathe air using lungs, have fur and 4 limbs, and give birth to live young, producing milk to feed their offspring. They all control their own body temperature. **Manure** The waste from domestic animals used as fertiliser.

Micron (μm) 1/1 000 000 of a metre

Microorganisms Very small single-celled organisms.

Mineral deficiency A lack of a mineral compound needed for health and/or growth.

Mineral salts/minerals Dissolved compounds needed by plant and animal cells to grow and remain healthy.

Misconception A wrong or inaccurate idea based on a lack of understanding.

Mitochondria Tiny structures in the cytoplasm of a cell where respiration takes place.

Mosses Small non-flowering plants with no true stems, roots or leaves that reproduce using spores.

Mould A type of fungus that feeds on many different materials. Some moulds produce antibiotics like penicillin.

Movement The moving of all or part of the body or an organism.

Multicellular Made up of many cells.

Myoglobin A substance similar to haemoglobin that stores oxygen in the muscles.

Myriapod A group of arthropods with long, segmented bodies and 1 or 2 pairs of legs on each segment.

Native species Species that are a natural part of an ecosystem.

Natural fertilisers Fertilisers made from natural materials that have been decomposed eg compost, manure.

Natural selection The process by which organisms with the characteristics best adapted to their environment live and reproduce, passing on the useful characteristics to their offspring.

Net Overall, when everything is taken into consideration.

Neurones (nerve cells) Specialised cells that carry electrical messages around the body.

Niche The role of an organism in its habitat.

Nicotine The addictive drug in tobacco smoke.

Night-blindness Deficiency disease that results from lack of vitamin A.

Non-flowering plant Plant that reproduces using spores. They do not produce flowers.

Nucleus The part of the cell that contains the genetic material and controls the activity of the cell

Nutrition The food needed for the survival of an organism.

Obese Very overweight, with a BMI of over 30.

Oil Liquid lipid.

Open water Oceans, lakes and rivers.

Organ A group of several different tissues all working together to carry out a particular function.

Organ system A group of specialised organs all working together to carry out a particular function.

Organism A group of many organs and organ systems all working together to make a whole individual.

Ovaries The organs that produce female gametes (eggs).

Oxygen One of the gases in the atmosphere, needed for aerobic respiration in cells.

Parasite An organism that lives in or on another organism and causes it harm.

Palisade cells Specialised plant cells found near the top surface of leaves which contain many chloroplasts for photosynthesis.

Peer review The process by which scientists check the work of other scientists before it is published, to make sure it is reliable and can be repeated.

Penicillin An antibiotic – a substance that kills bacteria or stops them growing.

Persistent pesticide A pesticide that does not break down over time but remains in the environment.

Pesticide A substance that kills pests.

Phloem Specialised living plant tissue that transports dissolved food from the leaves around the plant.

Photosynthesis The process by which plants make their own food from carbon dioxide and water, using light energy.

Photosynthetic system The green parts of a plant, mainly the leaves, that carry out photosynthesis.

Placenta The structure that allows substances to pass between the mother and the fetus throughout pregnancy, providing the fetus with food and oxygen and removing waste products produced by the fetus.

Plasma The yellow, liquid part of the blood that carries cells and many dissolved substances around the body.

Platelets Tiny pieces of cells that help the blood clot.

Pleura Tough, slippery membranes surrounding the lungs.

Population The number of animals or plants of a particular type that live in an area.

Precipitation Water droplets that become too heavy to remain in a cloud falling to Earth. Precipitation includes rain, snow, hail and sleet.

Predator An animal which catches, kills and eats other animals.

Pregnancy (gestation period) The time it takes a baby to develop from a fertilised egg to birth.

Prey Animals that are eaten by other animals.

Producer An organism that traps energy from the sun and makes food by photosynthesis e.g. plants.

Protein Substance needed to build new tissues, replace old tissues and repair damaged tissues; found in meat, fish, eggs, peas, beans and nuts.

Quadrat An area used to study the numbers and distribution of organisms in the field.

Red blood cells Tiny, flexible cells with a biconcave shape and no nucleus when they are mature. They are filled with haemoglobin and carry oxygen around the body.

Reproduction The process by which living organisms make more of themselves (produce offspring).

Reptile A vertebrate with dry, scaly skin that breathes air using lungs. All but snakes have 4 legs. Reptiles reproduce by laying leathery-shelled eggs on land.

Respiration The controlled release of the energy in food for use by the cells of an organism.

Respiratory system The organ system that moves air into and out of the lungs and makes gas exchange possible.

Respire Carry out cellular respiration.

Rickets Deficiency disease that results from lack of vitamin D or lack of calcium in the diet.

Root hair cells Specialised cells found on the roots of plants. They have long, microscopic hairs adapted for the uptake of water and mineral salts

Root system The part of the plant below the ground that anchors the plant in the soil and takes in the water and mineral salts the plant needs.

Roots Plant structures that grow below the ground and carry out a number of functions including anchoring the plant, absorbing water and mineral salts and sometimes storing food.

Run-off Water that cannot be absorbed by the ground but runs off the surface into rivers and streams.

Scurvy Deficiency disease that results from lack of vitamin C.

Sensitivity The ability of organisms to be aware of and respond to their surroundings.

Sexual reproduction Reproduction involving two gametes and usually two parents. It results in offspring that are similar to but different from both parents.

Shoot system (see photosynthetic system) The parts of the plant above ground that carry out photosynthesis and make food.

Single-celled organisms Organisms made up of only one cell that carries out all the functions of life.

Skeleton All of the bones of the body.

Solvent A substance that other substances will dissolve in.

Specialised cells Cells adapted to carry out particular functions in the body.

Species A group of organisms with similar characteristics that reproduce to give fertile offspring.

Specimen Object being observed e.g. the organism or part of an organism looked at through a microscope.

Sperm The male gamete in animals.

Spores The reproductive cells of non-flowering plants and fungi.

Stain Substances used to colour specimens to be seen under the microscope.

Starch A carbohydrate made of many sugar molecules, used as an energy store in plants.

Stems Plant organs that support the leaves, flowers and fruit.

Stomata (singular = stoma) Tiny holes in the surface of a leaf, surrounded by cells which open and close them to allow gas exchange and the evaporation of water from the surface.

Sugar A sweet, easily digested carbohydrate.

Surface area The area of the surface of an organism or organ.

Tar The sticky black substance in tobacco smoke that causes cancer.

Tendons Strong tissue that does not stretch and joins the muscles to the bones.

Testes The organs that make the male gametes (sperm).

Tissue A group of specialised cells all working together to carry out a particular function.

Toxic Poisonous

Toxin Poison

Trachea The tube carrying air from your nose down into your chest and carrying air back from the lungs out of the body.

Transpiration The evaporation of water from the surface of leaves.

Transpiration stream The movement of water from the roots of a plant through the xylem up to the leaves and out into the air by evaporation.

Triceps Muscle up the back of the upper arm that contracts to lower the arm from the elbow.

Umbilical cord Structure that joins the fetus to the placenta. It carries blood loaded with waste products from the fetus to the placenta, and returns it with the waste removed, full of dissolved food and oxygen.

Urea Toxic waste product made in the liver from the breakdown of excess proteins; it is excreted by the kidney.

Ureter Tube that carries urine from the kidney to the bladder.

Urethra Tube that carries urine from the bladder to the outside world.

Urine The liquid waste containing urea, water and excess salt that is produced by the kidney.

Uterus The organ where a developing baby grows during pregnancy.

Vacuole A membrane-lined, fluid filled space in the cytoplasm of a plant cell.

Vaccine Material given to develop an immune response to protect against infection by a specific pathogen e.g. polio, COVID-19.

Vertebrae The small bones that make up your backbone, supporting your body mass, making you flexible and protecting your spinal cord.

Vertebrate Animals with backbones.

Vitamins Substances needed in tiny amounts in the diet to help chemical reactions take place in cells.

Vitamin A Vitamin needed for healthy eyes.

Vitamin C Vitamin needed to help the cells of the body stick together, and which takes part in the reactions of aerobic respiration.

Vitamin D Vitamin needed to help the bones absorb calcium needed to be hard and strong.

Virus Extremely tiny structures about 0.1– $0.01~\mu m$ or 1/1000 the size of a human cell, made of genetic material inside a protein coat. They can only reproduce inside other living cells.

Water cycle The process by which fresh water moves constantly through the environment over time.

Weather The mix of atmospheric events taking place in a particular place at a particular time.

White blood cells Large blood cells with a nucleus that protect the body against pathogens by producing antibodies or by digesting microorganisms.

Worms Invertebrate group with no legs and long bodies, which may be round, flat or segmented.

Xylem Specialised dead tissue that transports water and dissolved mineral salts from the soil up to the leaves and flowers of the plant.

Yield A measure of the amount of a particular product produced, particularly applied to crops.

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