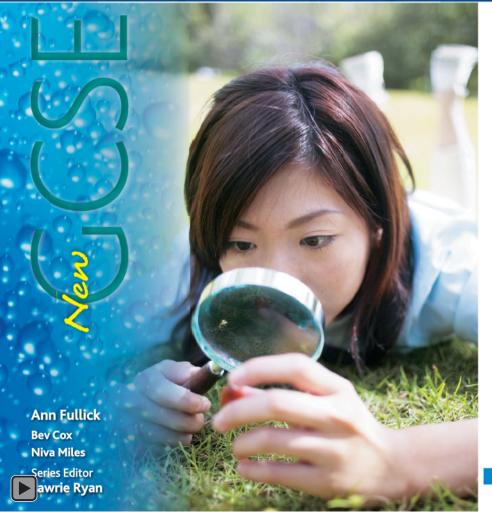
AQA Science Biology



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AQA Science Biology



Ann Fullick

Bev Cox

Niva Miles

Series Editor

Lawrie Ryan





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Biology

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Welcome to AQA GCSE Biology!

Learning objectives

Each topic begins with key questions that you should be able to answer by the end of the lesson.



Hints from the examiners who will mark your exams, giving you important advice on things to remember and what to watch out for.

Did you know ...?

There are lots of interesting, and often strange, facts about science. This feature tells you about many of them.

O links

Links will tell you where you can find more information about what you are learning.

Activity

An activity is linked to a main lesson and could be a discussion or task in pairs, groups or by yourself.



Maths skills

This feature highlights the maths skills that you will need for your GCSE Biology exams with short, visual explanations.

This book has been written for you by the people who will be marking your exams, very experienced teachers and subject experts. It covers everything you need to know for your exams and is packed full of features to help you achieve the very best that you can.

Questions in yellow boxes check that you understand what you are learning as you go along. The answers are all within the text so if you don't know the answer, you can go back and reread the relevant section.

Figure 1 Many diagrams are as important for you to learn as the text, so make sure you revise them carefully.

Key words are highlighted in the text. You can look them up in the glossary at the back of the book if you are not sure what they mean.

Where you see this icon, you will know that this part of the topic involves How Science Works – a really important part of your GCSE and an interesting way to understand 'how science works' in real life.



Where you see this icon, there are supporting electronic resources in our Kerboodle online service.

Practical

This feature helps you become familiar with key practicals. It may be a simple introduction, a reminder or the basis for a practical in the classroom.

Anything in the Higher Tier boxes must be learned by those sitting the Higher Tier exam. If you'll be sitting the Foundation Tier, these boxes can be missed out.

The same is true for any other places which are marked Higher or [H].

Summary questions

These questions give you the chance to test whether you have learned and understood everything in the topic. If you get any wrong, go back and have another look.

And at the end of each chapter you will find ...

Summary questions

These will test you on what you have learned throughout the whole chapter, helping you to work out what you have understood and where you need to go back and revise.



These questions are examples of the types of questions you will answer in your actual GCSE exam, so you can get lots of practice during your course.

Key points

At the end of the topic are the important points that you must remember. They can be used to help with revision and summarising your knowledge.



Learning objectives

- What is meant by 'How Science Works'?
- · What is a hypothesis?
- What is a prediction and why should you make one?
- How can you investigate a problem scientifically?

O links

You can find out more about your ISA by looking at H10 The ISA at the end of this chapter.



Figure 1 Albert Einstein was a genius, but he worked through scientific problems in the same way as you will in your GCSE

How does science work? (k)

This first chapter looks at 'How Science Works'. It is an important part of your GCSE because the ideas introduced here will crop up throughout your course. You will be expected to collect scientific **evidence** and to understand how we use evidence. These concepts will be assessed as the major part of your internal school assessment.

You will take one or more 45-minute tests. These tests are based on **data** you have collected previously plus data supplied for you in the test. They are called Investigative Skills Assignments (ISA). The ideas in 'How Science Works' will also be assessed in your examinations.

How science works for us

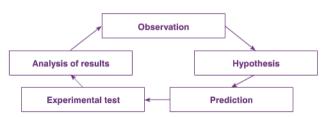
Science works for us all day, every day. You do not need to know how a mobile phone works to enjoy sending text messages. But, think about how you started to use your mobile phone or your television remote control. Did you work through pages of instructions? Probably not!

You knew that pressing the buttons would change something on the screen (knowledge). You played around with the buttons, to see what would happen (observation). You had a guess based on your knowledge and observations at what you thought might be happening (prediction) and then tested your idea (experiment).

Perhaps 'How Science Works' should really be called 'How Scientists Work'.

Science moves forward by slow, steady steps. When a genius such as Einstein comes along, it takes a giant leap. Those small steps build on knowledge and experience that we already have.

The steps don't always lead in a straight line, starting with an observation and ending with a conclusion. More often than not you find yourself going round in circles, but each time you go around the loop you gain more knowledge and so can make better predictions.



Each small step is important in its own way. It builds on the body of knowledge that we have, but observation is usually the starting point. In 1796, Edward Jenner observed that people who worked with cows did not catch smallpox but did catch a very similar disease called cowpox. This observation led him to develop a system of inoculating people with cowpox to prevent them from catching smallpox. Jenner called this process vaccination, from the Latin word for cow, vacca.

Activity

Coconut seeds

Once you have got the idea of holidays out of your mind, look at the photograph in Figure 2 with your scientific brain.

Work in groups to *observe* the beach and the plants growing on it. Then you can start to think about why the plants can grow (*knowledge*) so close to the beach.

One idea could be that the seeds can float for a long while in the sea, without taking in any water.

You can use the following headings to discuss your investigation. One person should be writing your ideas down, so that you can discuss them with the rest of your class.

- What prediction can you make about the mass of the coconut seed and the time it spends in the sea water?
- How could you test your prediction?
- What would you have to control?
- Write a plan for your investigation.
- How could you make sure your results were repeatable?



Figure 2 Tropical beach

Summary questions



Did you know ...?

The Greeks were arguably the first true scientists. They challenged traditional myths about life. They put forward ideas that they knew would be challenged. They were keen to argue the point and come to a reasoned conclusion.

Other cultures relied on long-established myths and argument was seen as heresy.

- Observations are often the starting point for an investigation.
- A hypothesis is a proposal intended to explain certain facts or observations.
- A prediction is an intelligent guess, based on some knowledge.
- An experiment is a way of testing your prediction.



How Science Works

H2

Learning objectives

- How do you spot when an opinion is not based on good science?
- What is the importance of continuous and categoric variables?
- What does it mean to say that evidence is valid?
- What is the difference between a result being repeatable and a result being reproducible?
- How can two sets of data be linked?

AQA Examiner's tip

Read a newspaper article or watch the news on TV. Ask yourself whether any research presented is valid. Ask yourself whether you can trust that person's opinion and why.

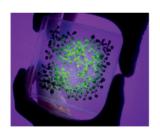


Figure 1 Cress seedlings growing in a Petri dish

Science is too important for us to get it wrong

Sometimes it is easy to spot when people try to use science poorly. Sometimes it can be funny. You might have seen adverts claiming to give your hair 'body' or sprays that give your feet 'lift'!

On the other hand, poor scientific practice can cost lives.

Fundamental ideas about

how science works

Some years ago a company sold the drug thalidomide to people as a sleeping pill. Research was carried out on animals to see if it was safe. The research did not include work on pregnant animals. The **opinion** of the people in charge was that the animal research showed the drug could be used safely with humans.

Then the drug was also found to help ease morning sickness in pregnant women. Unfortunately, doctors prescribed it to many women, resulting in thousands of babies being born with deformed limbs. It was far from safe.

These are very difficult decisions to make. You need to be absolutely certain of what the science is telling you.

a Why was the opinion of the people in charge of developing thalidomide based on poor science?

Deciding on what to measure: variables

Variables are physical, chemical or biological quantities or characteristics.

In an investigation, you normally choose one thing to change or vary. This is called the **independent variable**.

When you change the independent variable, it may cause something else to change. This is called the **dependent variable**.

A **control variable** is one that is kept the same and is not changed during the investigation.

You need to know about two different types of these variables:

- A categoric variable is one that is best described by a label (usually a word). The 'colour of eyes' is a categoric variable, e.g. blue or brown eyes.
- A continuous variable is one that we measure, so its value could be any number. Temperature (as measured by a thermometer or temperature sensor) is a continuous variable, e.g. 37.6°C, 45.2°C. Continuous variables can have values (called quantities) that can be found by making measurements (e.g. light intensity, flow rate, etc.).
 - b Imagine you were growing seedlings in different volumes of water. Would it be better to say that some were tall and some were short, or some were taller than others, or to measure the heights of all the seedlings?

Making your evidence repeatable, reproducible and valid

When you are designing an investigation you must make sure that other people can get the same results as you. This makes the evidence you collect **reproducible**.

A measurement is **repeatable** if the original experimenter repeats the investigation using the same method and equipment and obtains the same results.

A measurement is reproducible if the investigation is repeated by another person, or by using different equipment or techniques, and the same results are obtained.

You must also make sure you are measuring the actual thing you want to measure. If you don't, your data can't be used to answer your original question. This seems very obvious but it is not always quite so easy. You need to make sure that you have controlled as many other variables as you can, so that no one can say that your investigation is not valid. A measurement is valid if it measures what it is supposed to measure with an appropriate level of performance.

c State one way in which you can show that your results are repeatable.

How might an independent variable be linked to a dependent variable?

Looking for a link between your independent and dependent variables is very important. The pattern of your graph or bar chart can often help you to see if there is a link.

But beware! There may not be a link! If your results seem to show that there is no link, don't be afraid to say so. Look at Figure 2.

The points on the top graph show a clear pattern, but the bottom graph shows random scatter.

Summary questions

- 2 A researcher claimed that the metal tungsten 'alters the growth of leukaemia cells' in laboratory tests. A newspaper wrote that they would 'wait until other scientists had reviewed the research before giving their opinion'. Why is this a good idea?

Examiner's tip

When designing your investigation you should always try to measure continuous data whenever you can. This is not always possible, so then you have to use a label (categoric variable). You might still be able to put the variables in an order so that you can spot a pattern. For example, you could describe flow rate as 'fast flowing', 'steady flow' or 'slow flowing'.

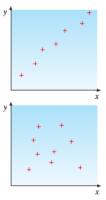


Figure 2 Which graph shows that there might be a link between x and y?

?? Did you know ...?

Aristotle, a brilliant Greek scientist, once proclaimed that men had more teeth than women! Do you think that his data collection was reproducible?

- Be on the lookout for nonscientific opinions.
- Continuous data give more information than other types of data.
- Check that evidence is reproducible and valid.



Learning objectives

- How can you use your scientific knowledge to observe the world around you?
- How can you use your observations to make a hypothesis?
- How can you make predictions and start to design an investigation?



Figure 1 Plant showing positive phototropism

Did you know ...?

Some biologists think that we still have about one hundred millions species of insects to discover – plenty to go for then! Of course, observing one is the easy part – knowing that it is undiscovered is the difficult bit!

Starting an investigation

Observation

As humans we are sensitive to the world around us. We can use our many senses to detect what is happening. As scientists we use observations to ask questions. We can only ask useful questions if we know something about the observed event. We will not have all of the answers, but we know enough to start asking relevant questions.

If we observe that the weather has been hot today, we would not ask whether it was due to global warming. If the weather was hotter than normal for several years, we could ask that question. We know that global warming takes many years to show its effect.

When you are designing an investigation you have to observe carefully which variables are likely to have an effect.

a Would it be reasonable to ask whether the plant in Figure 1 is 'growing towards the glass'? Explain your answer.

A farmer noticed that her corn was much smaller at the edge of the field than in the middle (observation). She noticed that the trees were quite large on that side of the field. She came up with the following ideas that might explain why this is happening:

- The trees at the edge of the field were blocking out the light.
- The trees were taking too many nutrients out of the soil.
- The leaves from the tree had covered the young corn plants in the spring.
- The trees had taken too much water out of the soil.
- The seeds at the edge of the field were genetically small plants.
- The drill had planted fewer seeds on that side of the field.
- The fertiliser spray had not reached the side of the field.
- The wind had been too strong over winter and had moved the roots of the plants.
- The plants at the edge of the field had a disease.
 - b Discuss each of these ideas and use your knowledge of science to decide which four are the most likely to have caused the poor growth of the corn.

Observations, backed up by really creative thinking and good scientific knowledge, can lead to a **hypothesis**.

Testing scientific ideas

Scientists always try to think of ways to explain how things work or why they behave in the way that they do.

After their observations, they use their understanding of science to come up with an idea that could explain what is going on. This idea is sometimes called a hypothesis. They use this idea to make a prediction. A prediction is like a guess, but it is not just a wild guess – it is based on previous understanding.



A scientist will say, 'if it works the way I think it does, I should be able to change **this** (the independent variable) and **that** will happen (the dependent variable).'

Predictions are what make science so powerful. They mean that we can work out rules that tell us what will happen in the future. For example, electricians can predict how much current will flow through a wire when an electric cooker is connected. Knowing this, they can choose the right thickness of cable to use.

Knowledge of energy transfer could lead to an idea that the insides of chips cook by energy being conducted from the outside. You might predict that small, thinly sliced chips will cook faster than large, fat chips.

c Look at the photograph of a frog in Figure 2. Note down anything you find interesting. Use your knowledge and some creative thought to suggest a hypothesis based on your observations.

Not all predictions are correct. If scientists find that the prediction doesn't work, it's back to the drawing board! They either amend their original idea or think of a completely new one.



Figure 2 A frog

Starting to design a valid investigation

observation + knowledge → hypothesis → prediction → investigation

We can test a prediction by carrying out an **investigation**. You, as the scientist, predict that there is a relationship between two variables.

The independent variable is one that is selected and changed by you, the investigator. The dependent variable is measured for each change in your independent variable. Then all other variables become control variables, kept constant so that your investigation is a fair test.

If your measurements are going to be accepted by other people, they must be valid. Part of this is making sure that you are really measuring the effect of changing your chosen variable. For example, if other variables aren't controlled properly, they might be affecting the data collected.

d Look at Figure 3. When investigating his heart rate before and after exercise, Darren got his girlfriend to measure his pulse. Would Darren's investigation be valid? Explain your answer.



Figure 3 Measuring a pulse

Summary questions

- 2 What is the difference between a prediction and a guess?
- 3 Imagine you were testing how an enzyme affects the rate of reaction. The reaction might cause the solution to get hot.
 - a How could you monitor the temperature?

variables need to be

b What other control variables can you think of that might affect the results?

- Observation is often the starting point for an investigation.
- Testing predictions can lead to new scientific understanding.
- You must design investigations that produce valid results if you are to be believed.



Learning objectives

- How do you design a fair test?
- How do you set up a survey?
- How do you set up a control group or control experiment?
- How do you reduce risks in hazardous situations?

A Examiner's tip

If you are asked about why it is important to keep control variables constant, you need to give a detailed explanation. Don't just answer, 'To make it a fair test.'

When you are asked to write a plan for your investigation, make sure that you give all the details. Ask yourself, 'Would' someone else be able to follow my written plan and use it to do the investigation?'

Planning an investigation

Fair testing

A fair test is one in which only the independent variable affects the dependent variable. All other variables (called control variables) should be kept the same. If the test is not fair, the results of your investigation will not be valid

Sometimes it is very difficult to keep control variables the same. However, at least you can monitor them, so that you know whether they have changed or not.



Figure 1 Corn being examined

a Imagine you were testing how close together you could plant corn to get the most cobs. You would plant five different plots, with different numbers of plants in each plot. List some of the variables that you could not control.

Surveys

Not all scientific investigations involve deliberately changing the independent

Imagine you were investigating the effect of diet on diabetes. You might conduct a survey. You would have to choose people of the same age and same family history to test. The larger the sample size you test, the better your results will be.

Control group

Control groups are used in investigations to try to make sure that you are measuring the variable that you intend to measure. When investigating the effects of a new drug, the control group will be given a placebo. This is a 'pretend' drug that actually has no effect on the patient at all. The control group think they are taking a drug but the placebo does not contain the drug. This way you can control the variable of 'thinking that the drug is working' and separate out the effect of the actual drug.

Usually neither the patient nor the doctor knows until after the trials have been completed which of the patients were given the placebo. This is known as a double-blind trial.



Risks and hazards

One of the first things you must do is to think about any potential **hazards** and then assess the **risk**.

Everything you do in life presents a hazard. What you have to do is to identify the hazard and then decide the degree of risk that it gives. If the risk is very high, you must do something to reduce it.

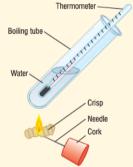
For example, if you decide to go out in the pouring rain, lightning is a possible hazard. However, you decide that the risk is so small that you will ignore it and go out anyway.

If you decide to cross a busy road, the cars travelling along it at high speed represent a hazard. You decide to reduce the risk by crossing at a pedestrian crossing.

Activity

Burning foods

Imagine you were testing crisps to see how much energy they give out when burned.



- What are the hazards that are present?
- What could you do to reduce the risk from these hazards?

Summary questions

sure that the are as small as possible.

- 2 Explain the difference between a control group and a control variable.
- 3 Briefly describe how you would go about setting up a fair test in a laboratory investigation. Give your answer as general advice.



Figure 2 The hazard is the busy road. We reduce the risk by using a pedestrian crossing.

A()A Examiner's tip

Before you start your practical work you must make sure that it is safe. What are the likely hazards? How could you reduce the risk caused by these hazards? This is known as a risk assessment. You may well be asked questions like this on your ISA paper.

- Care must be taken to ensure fair testing – as far as is possible.
- Control variables must be kept the same during an investigation.
- Surveys are often used when it is impossible to carry out an experiment in which the independent variable is changed.
- Control groups allow you to make a comparison.
- A risk assessment must be made when planning a practical investigation.



Learning objectives

- How do you make sure that you choose the best values for your variables?
- How do you decide on a suitable range?
- How do you decide on a suitable interval?
- How do you ensure accuracy and precision?

Designing an investigation

Choosing values of a variable

Trial runs will tell you a lot about how your early thoughts are going to work out.

Do you have the correct conditions?

A photosynthesis investigation that produces tiny amounts of oxygen might not have enough light, pondweed or carbon dioxide. Alternatively, the temperature might not be high enough.

Have you chosen a sensible range?

Range means the maximum and minimum values of the independent or dependent variables. It is important to choose a suitable range for the independent variable, otherwise you may not be able to see any change in the dependent variable.

For example, if the results are all very similar, you might not have chosen a wide enough range of light intensities.

Have you got enough readings that are close together?

The gap between the readings is known as the interval.

For example, you might alter the light intensity by moving a lamp to different distances from the pondweed. A set of 11 readings equally spaced over a distance of 1 metre would give an interval of 10 centimetres.

If the results are very different from each other, you might not see a pattern if you have large gaps between readings over the important part of the range.

Accuracy

Accurate measurements are very close to the true value.

Your investigation should provide data that is accurate enough to answer your original question.

However, it is not always possible to know what that the true value is.

How do you get accurate data?

- You can repeat your measurements and your mean is more likely to be accurate.
- Try repeating your measurements with a different instrument and see whether you get the same readings.
- Use high-quality instruments that measure accurately.
- The more carefully you use the measuring instruments, the more accuracy you will get.



Precision, resolution, repeatability and reproducibility

A precise measurement is one in which there is very little spread about the mean value.

If your repeated measurements are closely grouped together, you have precision. Your measurements must be made with an instrument that has a suitable **resolution**. Resolution of a measuring instrument is the smallest change in the quantity being measured (input) that gives a perceptible change in the reading.

It's no use measuring the time for a fast reaction to finish using the seconds hand on a clock! If there are big differences within sets of repeat readings, you will not be able to make a valid conclusion. You won't be able to trust your data!

How do you get precise data?

- You have to use measuring instruments with sufficiently small scale divisions.
- You have to repeat your tests as often as necessary.
- You have to repeat your tests in exactly the same way each time.

If you repeat your investigation using the same method and equipment and obtain the same results, your results are said to be **repeatable**.

If someone else repeats your investigation in the same way, or if you repeat it by using different equipment or techniques, and the same results are obtained, it is said to be **reproducible**.

You may be asked to compare your results with those of others in your group, or with data from other scientists. Research like this is a good way of checking your results.

A word of caution!

Precision depends only on the extent of random errors – it gives no indication of how close results are to the true value. Just because your results show precision does not mean they are accurate.

a Draw a thermometer scale reading 49.5 °C, showing four results that are both accurate and precise.

Summary questions

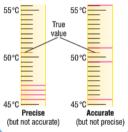
- 2 Use an example to explain how a set of repeat measurements could be accurate, but not precise.
- 3 Explain the difference between a set of results that are reproducible and a set of results that are repeatable.

Examiner's tip

You must know the difference between accurate and precise results.

Imagine measuring the temperature after a set time when a fuel is used to heat a fixed volume of water.
Two students repeated this experiment, four times each.
Their results are marked on the thermometer scales below:

- A precise set of repeat readings will be grouped closely together.
- An accurate set of repeat readings will have a mean (average) close to the true value.



- You can use a trial run to make sure that you choose the best values for your variables.
- The range states the maximum and minimum values of a variable.
- The interval is the gap between the values of a variable.
- Careful use of the correct equipment can improve accuracy and precision.
- You should try to reproduce your results carefully.



Learning objectives

- Why do results always vary?
- How do you choose instruments that will give you accurate results?
- What do we mean by the resolution of an instrument?
- What is the difference between a systematic error and a random error?
- How does human error affect results and what do you do with anomalies?



Figure 1 Student testing the rate at which oxygen is produced using an enzyme

Making measurements

Using instruments

Try measuring the temperature of a beaker of water using a digital thermometer. Do you always get the same result? Probably not! So can we say that any measurement is absolutely correct?

In any experiment there will be doubts about actual measurements.

a Look at Figure 1. Suppose, like this student, you tested the rate at which oxygen was produced using an enzyme. It is unlikely that you would get two readings exactly the same. Discuss all the possible reasons why.

When you choose an instrument you need to know that it will give you the accuracy that you want. You need to be confident that it is giving a true reading.

If you have used an electric water bath, would you trust the temperature on the dial? How do you know it is the true temperature? You could use a very expensive thermometer to calibrate your water bath. The expensive thermometer is more likely to show the true temperature. But can you really be sure it is accurate?

You also need to be able to use an instrument properly.

b In Figure 1 the student is reading the amount of gas in the measuring cylinder. Why is the student unlikely to get a true measurement?

Instruments that measure the same thing can have different sensitivities. The **resolution** of an instrument refers to the smallest change in a value that can be detected. This is one factor that determines the precision of your measurements.

Choosing the wrong scale can cause you to miss important data or make silly conclusions. We would not measure the weight of a prescription drug in kilograms, we would use milligrams.

c Match the following scales to their best use:

Used to measure	Resolution of scale
Size of a cell	millimetres
Human height	metres
Length of a running race to test fitness	micrometres
Growth of seedlings	centimetres

Errors

Even when an instrument is used correctly, the results can still show differences.

Results may differ because of **random error**. This is most likely to be due to a poor measurement being made. It could be due to not carrying out the method consistently.

If you repeat your measurements several times and then calculate a mean, you will reduce the effect of random errors.



The error might be a systematic error. This means that the method was carried out consistently but an error was being repeated. A systematic error will make your readings be spread about some value other than the true value. This is because your results will differ from the true value by a consistent amount each time a measurement is made.

No number of repeats can do anything about systematic errors. If you think that you have a systematic error, you need to repeat using a different set of equipment or a different technique. Then compare your results and spot the difference!

A zero error is one kind of systematic error. Suppose that you were trying to measure the length of your desk with a metre rule, but you hadn't noticed that someone had sawn off half a centimetre from the end of the ruler. It wouldn't matter how many times you repeated the measurement, you would never get any nearer to the true value.

Look at the table. It shows the two sets of data that were taken from the investigation that Sara did. She tested five different volumes of enzyme.

Sara's investigation into the volumes of enzymes

Amount of enzyme used (cm³)	1	2	3	4	5
Oxygen produced (cm³)	3.2	8.9	9.5	12.7	75.9
Volume of oxygen expected (cm³)	3.1	6.4	9.7	12.5	76.1
Calculated oxygen production (cm³)	4.2	8.4	12.5	16.6	20.7

- d Discuss whether there is any evidence of random error in these results.
- e Discuss whether there is any evidence of systematic error in these results.

Anomalies

Anomalous results are clearly out of line. They are not those that are due to the natural variation you get from any measurement. These should be looked at carefully. There might be a very interesting reason why they are so different. You should always look for anomalous results and discard them before you calculate a mean, if necessary.

- If anomalies can be identified while you are doing an investigation, it is best to repeat that part of the investigation.
- If you find anomalies after you have finished collecting data for an investigation, they must be discarded.

Summary questions

- 1 Copy and complete this paragraph using the following words: accurate discarded random resolution systematic use variation
 - There will always be some in results. You should always choose the best instruments that you can in order to get the mostresults. You must know how to the instrument properly. The of an instrument refers to the smallest change that can be detected. There are two types of error - and Anomalies due to random error should be
- 2 What kind of error will most likely occur in the following situations?
 - a Asking everyone in the class to measure the length of the bench.
 - b Using a ruler that has a piece missing from the zero end.

A Examiner's tip

If you are asked what may have caused an error, never answer simply 'human error' - you won't get any marks for this.

You need to say what the experimenter may have done to cause the error, or give more detail, e.g. 'Human reaction time might have caused an error in the timing when using a stopwatch.'

Did you know ...?

Sir Alexander Fleming had grown bacteria on agar plates. He noticed an anomaly. There was some mould growing on one of the plates and around it there were no bacteria. He decided to investigate further and grew more of the mould. Only because Fleming checked out his anomaly did it lead to the discovery of penicillin.

- Results will nearly always vary.
- Better quality instruments give more accurate results.
- The resolution of an instrument refers to the smallest change that it can detect.
- Human error can produce random and/or systematic errors.
- We examine anomalies; they might give us some interesting ideas. If they are due to a random error, we repeat the measurements. If there is no time to repeat them, we discard them.



Learning objectives

- How do you calculate the mean from a set of data?
- How do you use tables of results?
- What is the range of the data?
- How do vou display vour data?



Figure 1 Petri dish with discs showing growth inhibition of bacteria

Presenting data

For this section you will be working with data from this investigation:

Mel spread some bacteria onto a dish containing nutrient jelly. She also placed some discs onto the jelly. The discs contained different concentrations of an antibiotic. The dish was sealed and then left for a couple of days.

Then she measured the diameter of the clear part around each disc. The clear part is where the bacteria have not been able to grow. The bacteria grew all over the rest of the dish.

Tables (k



Tables are really good for getting your results down guickly and clearly. You should design your table before you start your investigation.

Your table should be constructed to fit in all the data to be collected. It should be fully labelled, including units.

You may want to have extra columns for repeats, calculations of means or calculated values.

Checking for anomalies

While filling in your table of results you should be constantly looking for anomalies.

- . Check to see whether any reading in a set of repeat readings is significantly different from the others.
- Check to see whether the pattern you are getting as you change the independent variable is what you expected.

Remember, a result that looks anomalous should be checked out to see if it really is a poor reading.

Planning your table

Mel had decided on the values for her independent variable. We always put these in the first column of a table. The dependent variable goes in the second column. Mel will find its values as she carries out the investigation.

So she could plan a table like this:

Concentration of antibiotic (µg/ml)	Size of clear zone (mm)
4	
8	
16	
32	
64	

Or like this:

Concentration of antibiotic (µg/ml)	4	8	16	32	64
Size of clear zone (mm)					

All she had to do in the investigation was to write the correct numbers in the second column to complete the top table.



Mel's results are shown in the alternative format in the table below:

Concentration of antibiotic (µg/ml)	4	8	16	32	64
Size of clear zone (mm)	4	16	22	26	28

The range of the data

Pick out the maximum and the minimum values and you have the range of a variable. You should always quote these two numbers when asked for a range. For example, the range of the dependent variable is between 4 mm (the lowest value) and 28 mm (the highest value) – and don't forget to include the units!

a What is the range for the independent variable and for the dependent variable in Mel's set of data?



Maths skills

The mean of the data

Often you have to find the **mean** of each repeated set of measurements. The first thing you should do is to look for any anomalous results. If you find any, miss these out of the calculation. Then add together the remaining measurements and divide by how many there are.

For example:

- Mel takes four readings, 15 mm, 18 mm, 29 mm, 15 mm
- 29 mm is an anomalous result and so is missed out. So 15 + 18 + 15 = 48
- 48 divided by three (the number of valid results) = 16 mm

The repeat values and mean can be recorded as shown below:

Concentration of antibiotic	otic Size of clear zone (mm)				
(μg/ml)	First test	Second test	Third test	Mean	
8	15	18	15	16	

Displaying your results

Bar charts

If one of your variables is categoric, you should use a bar chart.

Line graphs

If you have a continuous independent and a continuous dependent variable, a **line graph** should be used. Plot the points as small 'plus' signs (+).

Summary questions

- Copy and complete this paragraph using the following words:
 categoric continuous mean range
 - The maximum and minimum values show the of the data. The sum of the values in a set of repeat readings divided by the total number of these repeat values gives the Bar charts are used when you have aindependent variable and a continuous dependent variable. Line graphs are used when you haveindependent and dependent variables.
- 2 Draw a graph of Mel's results from the top of this page.

AQA Examiner's tip

When you make a table for your results, remember to include:

- · headings, including the units
- a title.

When you draw a line graph or bar chart, remember to:

- use a sensible scale that is easy to work out
- use as much of the graph paper as possible; your data should occupy at least a third of each axis
- label both axes
- draw a line of best fit if it is a line graph
- label each bar if it is a bar chart.

AQA Examiner's tip

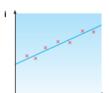
Marks are often dropped in the ISA by candidates plotting points incorrectly. Also use a line of best fit where appropriate – don't just join the points 'dot-to-dot'!

- The range states the maximum and the minimum values.
- The mean is the sum of the values divided by how many values there are.
- Tables are best used during an investigation to record results.
- Bar charts are used when you have a categoric variable.
- Line graphs are used to display data that are continuous.



Learning objectives

- How do you best use charts and graphs to identify patterns?
- What are the possible relationships you can identify from charts and graphs?
- How do you draw conclusions from relationships?
- How can you decide whether your conclusions are valid?



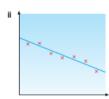


Figure 1 Graphs showing linear relationships



Figure 2 Graph showing a directly proportional relationship

Using data to draw conclusions

Identifying patterns and relationships

Now that you have a bar chart or a line graph of your results you can begin to look for patterns. You must have an open mind at this point.

First, there could still be some anomalous results. You might not have picked these out earlier. How do you spot an anomaly? It must be a significant distance away from the pattern, not just within normal variation. If you do have any anomalous results plotted on your graph, circle these and ignore them when drawing the line of best fit.

Now look at your graph. Is there a pattern that you can see? When you have decided, draw a line of best fit that shows this pattern.

A line of best fit is a kind of visual averaging process. You should draw the line so that it leaves as many points slightly above the line as there are points below. In other words it is a line that steers a middle course through the field of points.

The vast majority of results that you get from continuous data require a line of best fit.

Remember, a line of best fit can be a straight line or it can be a curve – you have to decide from your results.

You need to consider whether your graph shows a **linear relationship**. This simply means, can you be confident about drawing a straight line of best fit on your graph? If the answer is yes – is this line positive or negative?

a Say whether graphs i and ii in Figure 1 show a positive or a negative linear relationship.

Look at the graph in Figure 2. It shows a positive linear relationship. It also goes through the origin (0,0). We call this a **directly proportional** relationship.

Your results might also show a curved line of best fit. These can be predictable, complex or very complex! Look at Figure 3 below.

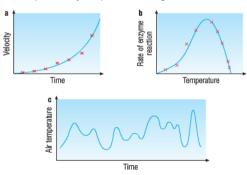


Figure 3 a Graph showing predictable results ${\bf b}$ Graph showing complex results ${\bf c}$ Graph showing very complex results

Drawing conclusions

If there is a pattern to be seen (for example as one variable gets bigger the other also gets bigger), it may be that:

- . changing one has caused the other to change
- the two are related, but one is not necessarily the cause of the other.

Your conclusion must go no further than the evidence that you have.

Activity

Looking at relationships

Some people think that watching too much television can cause an increase in violence.

The table shows the number of television sets in the UK for four different years, and the number of murders committed in those years.

Year	Number of televisions (millions)	Number of murders
1970	15	310
1980	25	500
1990	42	550
2000	60	750

Plot a graph to show the relationship. Do you think this proves that watching television causes violence? Explain your answer.

Poor science can often happen if a wrong decision is made here. Newspapers have said that living near electricity substations can cause cancer. All that scientists would say is that there is possibly an association.

Evaluation

You will often be asked to evaluate either the method of the investigation or the conclusion that has been reached. Ask yourself: Could the method have been improved? Is the conclusion that has been made a valid one?

Summary questions

- 2 Nasma knew about the possible link between cancer and living near to electricity substations. She found a quote from a National Grid Company survey of substations:

Measurements of the magnetic field were taken at 0.5 metres above ground level within 1 metre of fences and revealed 1.9 microteslas. After 5 metres this dropped to the normal levels measured in any house.

Discuss the type of experiment and the data you would expect to see to support a conclusion that it is safe to build houses over 5 metres from an electricity substation.



When you read scientific claims, think carefully about the evidence that should be there to back up the claim.

- Drawing lines of best fit helps us to study the relationship between variables.
- The possible relationships are linear, positive and negative, directly proportional, predictable and complex curves.
- Conclusions must go no further than the data available.
- The reproducibility of data can be checked by looking at other similar work done by others, perhaps on the internet. It can also be checked by using a different method or by others checking your method.



Learning objectives

- How can science encourage people to trust its research?
- How might bias affect people's judgement of science?
- Can politics influence judgements about science?
- Do you have to be a professor to be believed?



Pid you know ...?

A scientist who rejected the idea of a causal link between smoking and lung cancer was later found to be being paid by a tobacco company.

*(QA Examiner's tip

If you are asked about bias in scientific evidence, there are two types:

- the measuring instruments may have introduced a bias because they were not calibrated correctly
- the scientists themselves may have a biased opinion (e.g. if they are paid by a company to promote their product).

Scientific evidence and society

Now you have reached a conclusion about a piece of scientific research. So what is next? If it is pure research, your fellow scientists will want to look at it very carefully. If it affects the lives of ordinary people, society will also want to examine it closely.

You can help your cause by giving a balanced account of what you have found out. It is much the same as any argument you might have. If you make ridiculous claims, nobody will believe anything you have to say.

Be open and honest. If you only tell part of the story, someone will want to know why! Equally, if somebody is only telling you part of the truth, you cannot be confident about anything they say.

a A disinfectant claims that it kills 99.9% of germs on surfaces that you come in contact with every day. What is missing? Is it important?

You must be on the lookout for people who might be biased when presenting scientific evidence. Some scientists are paid by companies to do research. When you are told that a certain product is harmless, just check out who is telling you.

b Bottles of perfume spray contain this advice: 'This finished product has not been tested on animals.' Why might you mistrust this statement?

Suppose you wanted to know about how to slim. Who would you be more likely to believe? Would it be a scientist working for 'Slim Kwik', or an independent scientist? Sometimes the differences are not quite so obvious.



We also have to be very careful in reaching judgements according to who is presenting scientific evidence to us. For example, if the evidence might provoke public or political problems, it might be played down.

Equally, others might want to exaggerate the findings. They might make more of the results than the evidence suggests. Take as an example the data available on animal research. Animal liberation followers may well present the same evidence completely differently to pharmaceutical companies wishing to develop new drugs.

c Check out some websites on smoking and lung cancer. Do a balanced review looking at tobacco manufacturers as well as anti-smoking lobbies such as ASH. You might also check out government websites.



The status of the experimenter may place more weight on evidence. Suppose a lawyer wants to convince a jury enquiry that a particular piece of scientific evidence is valid. The lawyer will choose the most eminent scientist in that field who is likely to support them. Cot deaths are a particularly difficult problem for the police. If the medical evidence suggests that the baby might have been murdered, the prosecution and the defence get the most eminent scientists to argue the validity of the evidence. Who does the jury believe?

EXPERT WITNESS IN COT DEATH COURT CASE MISLED THE JURY

A child abuse expert was struck off as a doctor today for giving seriously misleading evidence in a court case. The court case led to a woman being wrongly convicted of murdering her two children.

The limitations of science

Science can help us in many ways but it cannot supply all the answers. We are still finding out about things and developing our scientific knowledge. For example, the Hubble telescope has helped us to revise our ideas about the beginnings of the universe.

There are some questions that we cannot answer, maybe because we do not have enough reproducible, repeatable and valid evidence. For example, research into the causes of cancer still needs much work to be done to provide data.

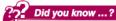
There are some questions that science cannot answer at all. These tend to be questions where beliefs, opinions and ethics are important. For example, science can suggest what the universe was like when it was first formed, but cannot answer the question of why it was formed.

Summary questions

- Copy and complete this paragraph using the following words:
 status balanced bias political
- 2 Collect some newspaper articles to show how scientific evidence is used. Discuss in groups whether these articles are honest and fair representations of the science. Consider whether they carry any bias.
- 3 This is the opening paragraph from a review of GM foods.

The UK government has been promoting ... a review of the science of GM, led by Sir David King (the Government's Chief Scientific Adviser) working with Professor Howard Dalton (the Chief Scientific Adviser to the Secretary of State for the Environment, Food and Rural Affairs), with independent advice from the Food Standards Agency.

Discuss this paragraph and decide which parts of it make you want to believe the evidence they might give. Next, consider which parts make you mistrust any conclusions they might reach.



Science can often lead to the development of new materials or techniques. Sometimes these cause a problem for society where hard choices have to be made.

Scientists can give us the answers to many questions, but not to every question. Scientists have a contribution to make to a debate, but so do others such as environmentalists, economists and politicians.



Figure 1 The Hubble space telescope can look deep into space and tell us things about the Universe's beginning from the formations of early galaxies

- Scientific evidence must be presented in a balanced way that points out clearly how valid the evidence is.
- The evidence must not contain any bias from the experimenter.
- The evidence must be checked to appreciate whether there has been any political influence.
- The status of the experimenter can influence the weight placed on the evidence.



H₁₀

Learning objectives

- How do you write a plan?
- How do you make a risk assessment?
- · What is a hypothesis?
- How do you arrive at a conclusion?

(QA Examiner's tip

When you are making a blank table or drawing a graph or bar chart, make sure that you use full headings, e.g.

- the length of the leaf', not just 'length'
- the time taken for the reaction', not just 'time'
- the height from which the ball was dropped', not just 'height'

and don't forget to include any units.

The ISA

There are several different stages to the ISA (Investigate Skills Assignment) that you will complete for your Controlled Assessment. This will make up 25% of your GCSE marks.

Stage 1

Your teacher will tell you the problem that you are going to investigate, and you will have to develop your own hypothesis. They will also set the problem in a context - in other words, where in real life your investigation could be useful. You should have a discussion about it, and talk about different ways in which you might solve the problem. Your teacher should show you the equipment that you can use, and you should research one or two possible methods for carrying out an experiment to test the hypothesis. You should also research the context and do a risk assessment for your practical work. You will be allowed to make one side of notes on this research, which you can take into the written part of the ISA.



Figure 1 Doing practical work allows you to develop the skills needed to do well in the ISA

You should be allowed to handle the equipment and you may be allowed to carry out a preliminary experiment.

Make sure that you understand what you have to do – now is the time to ask questions if you are not sure.

<u>o</u>

How Science Works

Section 1 of the ISA

At the end of this stage, you will answer Section 1 of the ISA. You will need to:

- develop a hypothesis
- identify one or more variables that you need to control
- describe how you would carry out the main experiment
- identify possible hazards and say what you would do to reduce any risk
- make a blank table ready for your results.
- a What features should you include in your written plan?
- b What should you include in your blank table?



Stage 2

This is where you carry out the experiment and get some results. Don't worry too much about spending a long time getting fantastically accurate results – it is more important to get some results that you can analyse.

After you have got results, you will have to compare your results with those of others. You will also have to draw a graph or a bar chart.

c How do you decide whether you should draw a bar chart or a line graph?

Stage 3

This is where you answer Section 2 of the ISA. Section 2 of the ISA is all about your own results, so make sure that you look at your table and graph when you are answering this section. To get the best marks you will need to quote some data from your results.



Section 2 of the ISA

In this section you will need to:

How Science Works

- · say what you were trying to find out
- compare your results with those of others, saying whether you think they are similar or different
- analyse data that is given in the paper. This data will be in the same topic area as your investigation
- use ideas from your own investigation to answer questions about this data
- write a conclusion
- compare your conclusion with the hypothesis you have tested.

You may need to change or even reject your hypothesis in response to your findings.

Summary questions

Copy and complete the paragraph using the words below:
 control independent dependent

When writing a plan you need to state the variable that you

When writing a plan, you need to state the variable that you are deliberately going to change, called the variable. You also need to say what you expect will change because of this; this is called the variable. You must also say what variables you will keep constant in order to make it a fair test.

ACA Examiner's tip

When you are comparing your conclusion with the hypothesis, make sure that you also talk about the **extent** to which your results support the hypothesis. Which of these answers do you think would score the most marks?

- My results support the hypothesis.
- In my results, as x got bigger, y got bigger, as stated in the hypothesis.
- In my results, as x got bigger, y got bigger, as stated in the hypothesis, but unlike the hypothesis, y stopped increasing after a while.

- When you are writing the plan make sure that you include details about:
 - the range and interval of the independent variable
 the control variables
 - the number of repeats.
- Try to put down at least two possible hazards, and say how you are going to minimise the risk from them.
- Look carefully at the hypothesis that you are given - this should give you a good clue about how to do the experiment.
- Always refer back to the hypothesis when you are writing your conclusion.



Summary questions

- 1 a Put these words into order. They should be in the order that you might use them in an investigation. design; prediction; conclusion; method; repeat; controls; graph; results; table; improve; safety; hypothesis
- 2 a How would you tell the difference between an opinion that was scientific and a biased or prejudiced opinion?



- b Suppose you were describing the height of plants for some fieldwork. What type of variable would you choose and why?
- 3 You might have observed that lichens do not grow where there is air pollution. You ask the question why. You use some theory to answer the question.





- a Explain what you understand by the term 'hypothesis'.
- b Sulfur dioxide in the air forms acids that attack the lichens. This is a hypothesis. Develop this into a prediction.
- c Explain why a prediction is more useful than a hypothesis.
- d Suppose you have tested your prediction and have some data. What might this do for your hypothesis?
- e Suppose the data does not support the hypothesis. What should you do to the theory that gave you the hypothesis?

- 4 a What do you understand by a 'fair test'?
 - b Explain why setting up a fair test in fieldwork is difficult.
 - c Describe how you can make your results valid in fieldwork.
 - d Suppose you were carrying out an investigation into how pulse rates vary with exercise. You would need to carry out a trial. Describe what a trial would tell you about how to plan your method.
- 5 Suppose you were watching a friend carry out an investigation measuring the carbon dioxide produced by yeast cells. You have to mark your friend on how accurately she is making her measurements. Make a list of points that you would be looking for.

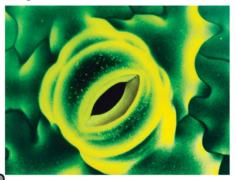


- 6 a How do you decide on the range of a set of data?
 - b How do you calculate the mean?
 - c When should you use a bar chart?
 - d When should you use a line graph?
- 7 a What should happen to anomalous results?
 - b What does a line of best fit allow you to do?
 - c When making a conclusion, what must you take into consideration?
 - d How can you check on the repeatability and reproducibility of your results?

- 8 a Why is it important when reporting science to 'tell the truth, the whole truth and nothing but the truth'?
 - b Why might some people be tempted not to be completely fair when reporting their opinions on scientific data?



- 9 a 'Science can advance technology and technology can advance science.' What do you think is meant by this statement?
 - **b** Who should answer the questions that start with 'Should we...'?
- 10 Look at the electron micrograph image below. Stomata are very small holes in the leaves of plants. They allow carbon dioxide to diffuse into the leaf cells for photosynthesis. The size of the hole is controlled by guard cells. It was suggested that the size of the hole might affect the rate at which carbon dioxide diffused through the hole.



Stomata are very small holes (when fully open they are 10–20 μ m in diameter). The question was:

Are small holes better than large holes? This would seem reasonable as plants have very small stomata. The hypothesis was that small holes would allow more carbon dioxide to pass through than large holes.

It was decided to use much larger holes than the stomata because it would be easier to get accurate measurements. The investigation was carried out and the results were as follows.

Diameter of hole (mm)	Volume of CO ₂ diffusing per hour (cm³)
22.7	0.24
12.1	0.10
6.0	0.06
3.2	0.04
2.0	0.02

- a What was the observation on which this investigation was based?
- b What was the original hypothesis?
- c What was the likely prediction?
- d What was the independent variable?
- e What was the dependent variable?
- f What is the range for the diameter of the hole?
- **g** Why was the temperature kept the same during the investigation?
- h Was this a sensible range of size of holes to use? Explain your answer.
- i How could the investigation be made more repeatable and reproducible?
- j Was the sensitivity of the instrument measuring volumes of CO₂ satisfactory? Provide some evidence for your answer from the data in the table.
- k Draw a graph of the results in the table above.
- I Describe the pattern in these results.
- m What conclusion can you make?
- n Does your conclusion support the prediction?



Keeping healthy

B1 1.1

Learning objectives

- What does a healthy diet contain?
- Why can some people eat lots of food without getting
- How does an athlete's diet differ from yours?

Did you know ...?

Whether you prefer sushi, dahl, or roast chicken, you need to eat a varied diet that includes everything you need to keep your body healthy.



Figure 2 Athletes have a great deal of muscle tissue so they have to eat a lot of od to supply the energy they need

Diet and exercise

What makes a healthy diet? (K)



A balanced diet contains the correct amounts of:

- carbohydrates
- proteins
- fats
- vitamins
- minerals
- fibre
- water.

Your body uses carbohydrates, proteins and fats to release the energy you need to live and to build new cells. You need small amounts of vitamins and minerals for your body to work healthily. Without them vou will suffer deficiency diseases. If you don't have a balanced diet then you will end up malnourished.



Figure 1 A balanced diet provides everything you need to survive, including plenty of energy

Fortunately, in countries like the UK, most of us take in all the minerals and vitamins we need from the food we eat. However, our diet can easily be unbalanced in terms of the amount of energy we take in. If we take in too much energy we put on weight. If we don't take in enough we become underweight.

It isn't always easy to get it right because different people need different amounts of energy. Even if you eat a lot, you can still lack vitamins and minerals if you don't eat the right food.

a Why do you need to eat food?

How much energy do you need?

The amount of energy you need to live depends on lots of different things. Some of these things you can change and some you can't.

Males need to take in more energy than a female of the same age - unless she is pregnant.

If you are a teenager, you will need more energy than if you are in your 70s.

b Why does a pregnant woman need more energy than a woman who isn't pregnant?

Your food supplies energy to your muscles as they work. So the amount of exercise you do affects the amount of energy you need. If you do very little exercise, then you don't need as much food. The more you exercise the more food you need to take in.

People who exercise regularly are usually much fitter than people who take little exercise. They make bigger muscles – up to 40% of their body mass. Muscle tissue transfers much more energy than fat. But exercise doesn't always mean time spent training or 'working out' in the gym. Walking to school, running around the house looking after small children or doing a physically active job all count as exercise too.

c Why do athletes need to eat more food than the average person?

The temperature where you live affects how much energy you need as well. In warmer countries you need to eat less food. This is because you use less energy keeping your body temperature at a steady level.

The metabolic rate

Think of a friend who is very similar in age, gender and size to you. Despite these similarities, you may need quite different amounts of energy in your diet. This is because the rate of chemical reactions in your cells (the **metabolic rate**) varies from person to person.

Men generally have a higher metabolic rate than women. The proportion of muscle to fat in your body affects your metabolic rate. Men often have a higher proportion of muscle to fat than women. You can change the proportion of muscle to fat in your body by exercising. This will build up more muscle.

Your metabolic rate is also affected by the amount of activity you do. Exercise increases your metabolic rate for a time even after you stop exercising.

Scientists think that your basic metabolic rate may be affected by genetic factors you inherit from your parents. This is an example of how **inherited** factors can affect our health.



Figure 3 If you work somewhere really cold your metabolic rate will go up to keep you warm. You will need lots of fat in your diet to supply the energy you need.

? ☐ Did you know ...?

Between 60–75% of your daily energy needs are used up in the basic reactions needed to keep you alive. About 10% is needed to digest your food – and only the final 15–30% is affected by your physical activity!

Examiner's tip

'Metabolic rate' refers to the chemical reactions which take place in cells.

Key points

- Most people eat a varied diet, which includes everything needed to keep the body healthy.
- Different people need different amounts of energy.
- The metabolic rate varies from person to person.
- The more exercise you take, the more food you need.

Summary questions

- 1 What is 'a balanced diet'?
- 2 a Why do you need more energy in your diet when you are 18 than when you are 80?
 - b Why does a top athlete need more energy in their diet than you do? Where does the energy in the diet come from?
- 3 a What is the 'metabolic rate'?
 - b Explain why some people put on weight more easily than others.



Keeping healthy

Weight problems

B1 1.2

Learning objectives

- What health problems are linked to being overweight?
- Why is it unhealthy to be too thin?
- Why are people who do exercise usually healthier than those who do not?



Figure 1 In spite of some of the media hype, most people are not obese – but the amount of weight people carry varies a great deal!



Figure 2 Fitness instructors can help with improving health and fitness

Obesity

If you take in more energy than you use, the excess is stored as fat. You need some body fat to cushion your internal organs. Your fat also acts as an energy store for when you don't feel like eating. But if someone eats a lot more food than they need, this is a form of malnourishment. Over time they could become overweight or even obese.

Carrying too much weight is often inconvenient and uncomfortable. Obesity can also lead to serious health problems such as arthritis, type 2 diabetes (high blood sugar levels which are hard to control), high blood pressure and heart disease. Obese people are more likely to die at an earlier age than non-obese people.

a What health problems are linked to obesity?

Losing weight

Many people want to be thinner. This might be for their health or just to look better. You gain fat by taking in more energy than you need. You lose **mass** when the energy content of your food is less than the energy you use in your daily life. There are three main ways you can lose mass.

- You can reduce the amount of energy you take in by cutting back the amount of food you eat. In particular, you can cut down on energy-rich foods like biscuits, crisps and chips.
- You can increase the amount of energy you use by doing more exercise.
- The best way to lose weight is to do both reduce your energy intake and exercise more!

Scientists talk about 'mass', but most people talk about losing weight. Many people find it easier to lose weight by attending slimming groups. At these weekly meetings they get lots of advice and support from other slimmers. All slimming programmes involve eating fewer energy-rich foods and/or taking more exercise.

Exercise can make you healthier by helping to control your weight. It increases the amount of energy used by your body and increases the proportion of muscle to fat. It can make your heart healthier too. However, you need to take care. If you suddenly start taking vigorous exercise, you can cause other health problems.

Fitness instructors can measure the proportion of your body that is made up of fat. They can advise on the right food to eat and the exercise you need to become thinner, fitter, or both.

Different slimming programmes approach weight loss in different ways. Many simply give advice on healthy living. They advise lots of fruit and vegetables, avoiding too much fat or too many calories and plenty of exercise. Some are more extreme and suggest that you cut out almost all of the fat or the carbohydrates from your diet.

b What must you do to lose weight?



How Science Works

You can find lots of slimming products in the supermarket. Used in the right way, they can help you to lose weight. Some people claim that 'slimming teas' or 'herbal pills' will enable you to eat what you like and still lose weight.

 What sort of evidence would you look for to decide which approaches to losing weight work best?



Figure 3 Slimming products can help you lose weight, but only if you control the total amount of energy you take in

Did you know ...?

The number of obese and overweight people is growing. The WHO (World Health Organisation) says over 1 billion adults worldwide are now overweight or obese.

Lack of food

In some parts of the world many people are underweight and malnourished because there is not enough food to eat. Civil wars, droughts and pests can all destroy local crops.

Deficiency diseases, due to lack of mineral ions and vitamins, are common in both children and adults when they never have enough food. Deficiency diseases can also occur if you do not have a balanced diet.

Examiner's tip

The word 'malnourished' can be used to describe people who do not have a balanced diet. They may have too little food or too much food, or take in the wrong combination of foods.

Summary questions

- 1 Copy and complete using the words below: energy fat less more obese If you take in more than you use, the excess is stored as If you eat too much over a long period of time, you will eventually become
- 2 Why do people who are very thin, and some people who are obese, suffer from deficiency diseases?
- 3 One slimming programme controls your food intake. Another controls your food intake but also has an exercise programme. Which do you think would be the most effective? Explain your answer.

- If you take in more energy than you use, you will store the excess as fat.
- Obese people have more health problems than others.
- People who do not have enough to eat can develop serious health problems.
- Exercise helps reduce weight and maintain health.



Keeping healthy

B1 1.3

Learning objectives

- How can inherited factors affect your health?
- Why does your cholesterol level matter?
- Does exercise make you healthier?

O links

For information on metabolic rate, look back at B1 1.1 Diet and exercise.

?? Did you know ...?

The maximum healthy blood cholesterol is given as 6 mmol/l, 5 mmol/l and 4 mmol/l on different medical websites.

Scientists don't always agree!

Inheriting health

Inherited factors from your parents affect your appearance, such as the colour of your eyes. They also have a big effect on your health. They affect your metabolic rate, which affects how easily you lose and gain mass. Being overweight has a bad effect on your health. Inherited factors affect the proportion of muscle to fat in your body. They also affect your risk of heart disease, partly because they influence the levels of cholesterol in your blood.



Figure 1 Lots of things affect your health

your diet, how much exercise you take
and what you inherit from your parents

Controlling cholesterol

The way your body balances cholesterol is an example of how an inherited factor can affect your health. You need cholesterol for your cell membranes and to make vital hormones. There are two forms of cholesterol carried around your body in your blood. One form is healthy but the other can cause health problems. If the balance of your cholesterol levels is wrong, your risk of getting heart disease increases.

Inheritance, exercise and health

a Why do you need cholesterol in your body?

The way your liver deals with the fat in your diet and makes the different types of cholesterol is inherited from your parents. For most people, eating a balanced diet means your liver can keep the balance of cholesterol right.

Eating lots of high-fat food means you are likely to have raised levels of harmful cholesterol and an increased risk of heart disease. But 1 in every 500 people inherit factors which mean they will have high levels of harmful cholesterol and an increased risk of heart disease whatever they eat. This is an example of how an inherited factor can affect your health.



Figure 2 Next time you eat a burger and fries, think about all the fat you are taking in. Will your body be able to deal with it, or are your blood cholesterol levels about go up?

Exercise and health

Scientists have collected lots of evidence about exercise and health. It shows that people who exercise regularly are generally healthier than people who don't do much exercise. The graph in Figure 3 shows the results of an American study published in the journal *Circulation*. 6213 men were studied. The least active men were 4.5 times more likely to die early than the fittest, most active men

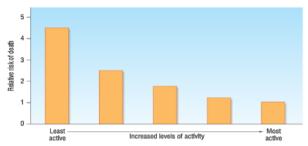


Figure 3 The effect of exercise on risk of death (Source: Jonathan Myers, Circulation, 2003)

These are some of the scientific explanations why exercise helps to keep you healthy.

- You are less likely to be overweight if you exercise regularly. This is partly because you will be using more energy.
- You will have more muscle tissue, which will increase your metabolic rate. If you can control your weight, you are less likely to be affected by problems such as arthritis, diabetes and high blood pressure.
- Your cholesterol levels are affected by exercise. Regular exercise lowers
 your blood cholesterol levels. It also helps the balance of the different types
 of cholesterol. When you exercise, your good cholesterol level goes up
 and the harmful cholesterol level goes down. This lowers your risk of heart
 disease and other health problems.
 - b How could you change your cholesterol levels?

Summary questions

- Copy and complete using the words below:
 heart metabolic inherited cholesterol balance
 There are factors such as your rate that can affect your
 - health. The way your liver makes is inherited and if the of cholesterol is wrong it can increase your risk of disease.
- 2 Why are people who exercise regularly usually healthier than people who take little exercise?
- 3 Using the data in Figure 3, which group of people do you think are most at risk of death? Why do you think this might be? What could they do to reduce the risk?

- Inherited factors affect our health. These include our metabolic rate and cholesterol level.
- People who exercise regularly are usually healthier than people who take little exercise.



Keeping healthy

B1 1.4

Learning objectives

- What are pathogens?
- How do pathogens cause disease?
- How did Ignaz Semmelweis change the way we look at disease?

Infectious diseases are found all over the world, in every country, Some diseases are fairly mild ones, such as the common cold and tonsillitis. Other diseases are known killers, such as tetanus, influenza and HIV/Aids.

Pathogens and disease

An infectious disease is caused by a microorganism entering and attacking your body. People can pass these microorganisms from one person to another. This is what we mean by infectious.



Figure 1 Many bacteria are very useful but some, like these E. coli, can cause

Microorganisms which cause disease are called pathogens. Common pathogens are bacteria and viruses.

a What causes infectious diseases?

The differences between bacteria and viruses

Bacteria are single-celled living organisms that are much smaller than animal and plant cells.

Although some bacteria cause disease, many are harmless and some are really useful to us. We use them to make food like yoghurt and cheese, to treat sewage and to make medicines.

Viruses are even smaller than bacteria. They usually have regular shapes. Viruses cause diseases in every type of living organism from people to bacteria.

b How do viruses differ from bacteria?

Figure 2 These tobacco mosaic viruses cause disease in plants

How pathogens cause disease (k)



Once bacteria and viruses are inside your body they reproduce rapidly. This is how they make you ill. Bacteria simply split in two - they often produce toxins (poisons) which affect your body. Sometimes they directly damage your cells. Viruses take over the cells of your body as they reproduce, damaging and destroying the cells. They very rarely produce toxins.

Common disease symptoms are a high temperature, headaches and rashes. These are caused by the damage and toxins produced by the pathogens. The symptoms also appear as a result of the way your body responds to the damage and toxins.

You catch an infectious disease when you pick up a pathogen from someone else who is infected with the disease.

c How do pathogens make you feel ill?

O links

For more information on bacteria that are resistant to antibiotics, see B1 1.8 Changing pathogens.





How Science Works

The work of Ignaz Semmelweis

Ignaz Philipp Semmelweis was a doctor in the mid-1850s. At the time. many women in hospital died from childbed fever a few days after giving birth. However, no one knew what caused it.

Semmelweis noticed something about his medical students. They went straight from dissecting a dead body to delivering a baby without washing their hands. He wondered if they were carrying the cause of disease from the corpses to their patients.

Then another doctor cut himself while working on a body. He died from symptoms which were identical to childbed fever. Semmelweis was sure that the fever was caused by something that could be passed on - some kind of infectious agent.

He insisted that his medical students wash their hands before delivering babies. Immediately, fewer mothers died from the fever.

Getting his ideas accepted

Semmelweis talked to other doctors. He thought his evidence would prove to them that childbed fever was spread by doctors. But his ideas were mocked.

Many doctors thought that childbed fever was God's punishment to women. No one had ever seen bacteria or viruses. So it was hard to believe that disease was caused by something invisible passed from person to person. Doctors didn't like the idea that they might have been spreading disease. They were being told that their actions had killed patients instead of curing them.

In hospitals today, bacteria such as MRSA, which are resistant to antibiotics, are causing lots of problems. Getting doctors, nurses and visitors to wash their hands more often is part of the answer - just as it was in Semmelweis's time!

Summary questions

- 1 Copy and complete using the words below: toxins viruses microorganisms reproduce pathogens damage symptoms bacteria
 - and get inside your body they rapidly. They your tissues and may producewhich cause the of disease.
- 2 Give five examples of things we now know we can do to reduce the spread of pathogens to lower the risk of disease, e.g. hand-washing in hospitals.
- 3 Write a letter by Ignaz Semmelweis to a friend explaining how he formed his ideas and the struggle to get them accepted.

Did you know ...?

Semmelweis couldn't bear to think of the thousands of women who died because other doctors ignored his findings. By the 1860s he suffered a major breakdown and in 1865, aged only 47, he died – from an infection picked up from a patient during an operation.



Figure 3 Ignaz Semmelweis - his battle to get medical staff to wash their hands to prevent infections is still going on today

- Infectious diseases are caused by microorganisms called pathogens, such as bacteria and viruses.
- Bacteria and viruses reproduce rapidly inside your body. Bacteria can produce toxins which make you feel ill.
- Viruses damage your cells as they reproduce. This can also make you feel ill.
- Semmelweis recognised the importance of hand-washing in preventing the spread of infectious diseases in hospital.



Keeping healthy

B1 1.5

Learning objectives

- How does your body stop pathogens getting in?
- How do white blood cells protect us from disease?

Figure 2 When you get a cut, the platelets in your blood set up a chain of events to form a clot that dries to a scab. This stops pathogens from getting into your body. It also stops you bleeding to cath!

Defence mechanisms

There are a number of ways in which pathogens spread from one person to another. The more pathogens that get into your body, the more likely it is that you will get an infectious disease.

Droplet infection: When you cough, sneeze or talk you expel tiny droplets full of pathogens from your breathing system. Other people breathe in the droplets,



Figure 1 Droplets carrying millions of pathogens fly out of your mouth and nose at up to 100 miles an hour when you sneeze

along with the pathogens they contain. So they pick up the infection, e.g. flu (influenza), tuberculosis or the common cold.

Direct contact: Some diseases are spread by direct contact of the skin, e.g. impetigo and some sexually transmitted diseases like genital herpes.

Contaminated food and drink: Eating raw or undercooked food, or drinking water containing sewage can spread disease, e.g. diarrhoea or salmonellosis. You get these by taking large numbers of microorganisms straight into your gut.

Through a break in your skin: Pathogens can enter your body through cuts, scratches and needle punctures, e.g. HIV/Aids or hepatitis.

When people live in crowded conditions, with no sewage treatment, infectious diseases can spread very rapidly.

a What are the four main ways in which infectious diseases are spread?

Preventing microbes getting into your body

Each day you come across millions of disease-causing microorganisms. Fortunately your body has several ways of stopping these pathogens getting inside.

Your skin covers your body and acts as a barrier. It prevents bacteria and viruses from reaching the tissues beneath that can be infected.

If you damage or cut your skin you bleed. Your blood quickly forms a clot which dries into a scab. The scab forms a seal over the cut, stopping pathogens getting in through the wound.

Your breathing system could be a weak link in your body defences. Every time you breathe you draw air full of pathogens inside your body. However, your breathing system produces sticky liquid, called mucus. This mucus covers the lining of your lungs and tubes. It traps the pathogens. The mucus is then moved out of your body or swallowed down into your gut. Then the acid in your stomach destroys the microorganisms. In the same way, the stomach acid destroys most of the pathogens you take in through your mouth.

b What are the three main ways in which your body prevents pathogens from getting in?

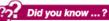
How white blood cells protect you from disease

In spite of your body's defence mechanisms, some pathogens still get inside your body. Once there, they will meet your second line of defence – the **white blood cells** of your **immune system**.

The white blood cells help to defend your body against pathogens in several ways.

Table 1 Ways in which your white blood cells destroy pathogens and protect you against disease

disease		
Role of white blood cell	How it protects you against disease	
Ingesting microorganisms	Some white blood cells ingest (take in) pathogens, destroying them so they can't make you ill.	
Producing antibodies Antibody Antigen Bacterium White blood cell Antibody attached to antigen	Some white blood cells produce special chemicals called antibodies. These target particular bacteria or viruses and destroy them. You need a unique antibody for each type of pathogen. Once your white blood cells have produced antibodies once against a particular pathogen, they can be made very quickly if that pathogen gets into the body again.	
Producing antitoxins Antitoxin molecule Toxin and antitoxin joined together Toxin molecule	Some white blood cells produce antitoxins. These counteract (cancel out) the toxins (poisons) released by pathogens.	



Mucus produced from your nose turns green when you have a cold. This happens because some white blood cells contain green-coloured enzymes. These white blood cells destroy the cold viruses and any bacteria in the mucus of your nose when you have a cold. The dead white blood cells along with the dead bacteria and viruses are removed in the mucus, making it look green.

O links

For more information about the blood, see B3 2.3 Transport in the blood.

Summary questions

- 1 Explain how diseases are spread by:
 - a droplet infection

Bacterium

c contaminated food and drink

b direct contact

- d entry through a cut in the skin.
- 2 Certain diseases mean you cannot fight infections very well. Explain why the following symptoms would make you less able to cope with pathogens.
 - a Your blood won't clot properly.
 - **b** The number of white cells in your blood falls.
- 3 Here are three common things we do. Explain carefully how each one helps to prevent the spread of disease.
 - a Washing your hands before preparing a salad.
 - b Throwing away tissues after you have blown your nose.
 - c Making sure that sewage does not get into drinking water.
- 4 Explain in detail how the white blood cells in your body work.

- Your body has several methods of defending itself against the entry of pathogens using the skin, the mucus of the breathing system and the clotting of the blood.
- Your white blood cells help to defend you against pathogens by ingesting them, making antibodies and making antitoxins.



Keeping healthy

B1 1.6

Learning objectives

- What is a medicine?
- How do medicines work?
- Why can't we use antibiotics to treat diseases caused by viruses?

Using drugs to treat disease

When you have an infectious disease, you generally take medicines which contain useful drugs. Often the medicine doesn't affect the pathogen that is causing the problems. It just eases the symptoms and makes you feel better.

Drugs like aspirin and paracetamol are very useful as painkillers. When you have a cold they will help relieve your headache and sore throat. On the other hand, they will have no effect on the viruses which have entered your tissues and made you feel ill.

Many of the medicines you can buy at a chemist's or supermarket are like this. They relieve your symptoms but do not kill the pathogens. They do not cure you any faster. You have to wait for your immune system to overcome the pathogens.



Figure 1 Taking paracetamol will make this child feel better, but she will not actually get well any faster as a result

a Why don't medicines like aspirin actually cure your illness?

Antibiotics (k



Drugs that make us feel better are useful but what we really need are drugs that can cure us. We use antiseptics and disinfectants to kill bacteria outside the body. But they are far too poisonous to use inside your body. They would kill you and your pathogens at the same time!

The drugs that have really changed the way we treat infectious diseases are antibiotics. These are medicines that can work inside your body to kill the bacteria that cause diseases.

b What is an antibiotic?



Figure 2 Penicillin was the first antibiotic. Now we have many different ones which kill different types of bacterium. Scientists are always on the look out for new antibiotics to keep us ahead in the battle gainst pathogens.

How antibiotics work (13)



Antibiotics like penicillin work by killing the bacteria that cause disease while they are inside your body. They damage the bacterial cells without harming your own cells. They have had an enormous effect on our society. We can now cure bacterial diseases that killed millions of people in the past.

Unfortunately antibiotics are not the complete answer to the problem of infectious diseases. They have no effect on diseases caused by viruses.

The problem with viral pathogens is that they reproduce inside the cells of your body. It is extremely difficult to develop drugs that kill the viruses without damaging the cells and tissues of your body at the same time.

c How do antibiotics work?



How Science Works

Discovering penicillin

Alexander Fleming was a scientist who studied bacteria and wanted to find ways of killing them. In 1928, he was growing lots of bacteria on agar plates. Alexander was rather careless, and his lab was quite untidy. He often left the lids off his plates for a long time and forgot about experiments he had set up!

After one holiday, Fleming saw that lots of his culture plates had mould growing on them. He noticed a clear ring in the jelly around some of the spots of mould. Something had killed the bacteria covering the jelly.

Fleming saw how important this was. He called the mould 'penicillin'. He worked hard to



Figure 3 Alexander Fleming was on the lookout for something that would kill bacteria. As a result of him noticing the effect of this mould on his cultures, millions of lives have been saved around the world.

extract a juice from the mould. But he couldn't get much penicillin and he couldn't make it survive, even in a fridge. So Fleming couldn't prove it would actually kill bacteria and make people better. By 1934 he gave up on penicillin and went on to do different work.

About 10 years after penicillin was first discovered, Ernst Chain and Howard Florey set about trying to use it on people. They gave some penicillin they extracted to Albert Alexander, who was dying of a blood infection. The effect was amazing and Albert recovered. But then the penicillin ran out. Florey and Chain even tried to collect unused penicillin from Albert's urine, but it was no good. The infection came back and sadly Albert died.

They kept working and eventually they managed to make penicillin on an industrial scale. The process was able to produce enough penicillin to supply the demands of the Second World War. We have used it as a medicine ever since.

d Who was the first person to discover penicillin?

Summary questions

- 1 What is the main difference between drugs such as paracetamol and drugs such as penicillin?
- 2 a How did Alexander Fleming discover penicillin?
 - b Why was it so difficult to make a medicine out of penicillin?
 - c Who developed the industrial process which made it possible to mass-produce penicillin?
- 3 Explain why it is so much more difficult to develop medicines against viruses than it has been to develop antibacterial drugs.

A()A Examiner's tip

Remember:

- Antibiotics are drugs which kill bacteria.
- Antibodies are produced by white blood cells to kill bacteria.

- Some medicines relieve the symptoms of disease but do not kill the pathogens which cause it.
- Antibiotics cure bacterial diseases by killing the bacteria inside your body.
- Antibiotics do not destroy viruses because viruses reproduce inside the cells. It is difficult to develop drugs that can destroy viruses without damaging your body cells.



Keeping healthy

B1 1.7

Learning objectives

- How can we grow an uncontaminated culture of bacteria in the lab?
- Why do we need uncontaminated cultures?
- Why do we incubate bacteria at no more than 25°C in schools and colleges?

Did vou know ...?

You are surrounded by disease-causing bacteria all the time. If you cultured bacteria at 37°C - human body temperature - there would be a very high risk of growing some dangerous pathogens.



Figure 2 When working with the most dangerous pathogens, scientists need to be very careful. Sensible safety precautions are needed when working ith microorganisms.

Growing and investigating bacteria

To find out more about microorganisms we need to culture them. This means we grow very large numbers of them so that we can see all of the bacteria (the colony) as a whole. Many microorganisms can be grown in the laboratory. This helps us to learn more about them. We can find out what nutrients they need to grow and investigate which chemicals are best at killing them. Bacteria are the most commonly cultured microorganisms.

Growing microorganisms in the lab



To culture (grow) microorganisms you must provide them with everything they need. This means giving them a liquid or gel containing nutrients - a culture medium. It contains carbohydrate as an energy source along with various minerals and sometimes other chemicals. Most microorganisms also need warmth and oxygen to grow.

You usually provide the nutrients in agar jelly. Hot agar containing all the nutrients your bacteria will need is poured into a Petri dish. It is then left to cool and set before you add the microorganisms.

You must take great care when you are culturing microorganisms. The bacteria you want to grow may be harmless. However, there is always the risk that a mutation (a change in the DNA) will take place and produce a new and dangerous pathogen.

You also want to keep the pure strains of bacteria you are culturing free from any other microorganisms. Such contamination might come from your skin, the air, the soil or the water around you. Investigations need uncontaminated cultures of microorganism. Whenever you



Figure 1 Culturing microorganisms like bacteria makes it possible for us to observe them and see how different chemicals affect them

are culturing microorganisms you must carry out strict health and safety procedures to protect yourself and others.

a What is agar jelly?

Growing useful organisms

You can prepare an uncontaminated culture of microorganisms in the laboratory by following a number of steps.

The Petri dishes on which you will grow your microorganisms must be sterilised before using them. The nutrient agar, which will provide their food, must also be sterilised. This kills off any unwanted microorganisms. You can use heat to sterilise glass dishes. A special oven called an autoclave is often used. It sterilises by using steam at high pressure. Plastic Petri dishes are often bought ready-sterilised. UV light or gamma radiation is used to kill the bacteria.

b Why must everything be sterilised before you start a culture?

The next step is to inoculate the sterile agar with the microorganisms you want to grow.



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



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



Seal the lid of the Petri dish with adhesive tape to prevent microorganisms from the air contaminating the culture - or microorganisms from the culture escaping. Do not seal all the way around the edge so oxygen can get into the dish and harmful anaerobic bacteria do not grow.

Figure 3 Culturing microorganisms safely in the laboratory

Once you have inoculated your plates, the sealed Petri dishes need to be incubated (kept warm) for several days so the microorganisms can grow. In school and college laboratories the maximum temperature at which cultures are incubated is 25 °C. This greatly reduces the likelihood that you will grow pathogens that might be harmful to people. In industrial conditions. bacterial cultures are often grown at higher temperatures, which allow the microorganisms to grow more rapidly.



Practical

Investigating the action of disinfectants and antibiotics



You can use cultures you set up yourself or pre-inoculated agar to investigate the effect of disinfectants and antibiotics on the growth of bacteria. An area of clear jelly indicates that the bacteria have been killed or cannot grow.

 What are the safety issues in this investigation and how will you manage any risks?

Summary questions

- 1 Why do we culture microorganisms in the laboratory?
- 2 Why don't we culture bacteria at 37°C in the school lab?
- 3 When you set up a culture of bacteria in a Petri dish (see Figure 3) you give the bacteria everything they need to grow as fast as possible. However these ideal conditions do not last forever. What might limit the growth of the bacteria in a culture on a Petri dish?



Make sure you understand why we sterilise. We boil solutions and heat-treat apparatus in an autoclave to kill bacteria already in them. This is sterilisina.

- An uncontaminated culture of microorganisms can be grown using sterilised Petri dishes and agar. You sterilise the inoculating loop before use and seal the lid of the Petri dish to prevent unwanted microorganisms getting in. The culture is left at about 25°C for a few days.
- Uncontaminated cultures are needed so we can investigate the effect of chemicals such as disinfectants and antibiotics on microorganisms.
- Cultures should be incubated at a maximum temperature of 25°C in schools and colleges to reduce the likelihood of harmful pathogens growing.



- What is antibiotic resistance?
- How can we prevent antibiotic resistance developing?
- Why is mutation in bacteria and viruses such a problem?

If you are given an antibiotic and use it properly, the bacteria that have made you ill are killed off. However some bacteria develop resistance to antibiotics. They have a natural mutation (change in the genetic material) that means they are not affected by the antibiotic. These mutations happen by chance and they produce new strains of bacteria by natural selection.

More types of bacteria are becoming resistant to more antibiotics. Diseases caused by bacteria are becoming more difficult to treat. Over the years antibiotics have been overused and used when they are not really needed. This increases the rate at which antibiotic-resistant strains have developed.

Antibiotic-resistant bacteria

Normally an antibiotic kills the bacteria of a non-resistant strain. However individual resistant bacteria survive and reproduce, so the population of **resistant** bacteria increases.

IHI

Antibiotics are no longer used to treat non-serious infections such as mild throat infections, which are often caused by viruses. Hopefully this will slow down the rate of development of resistant strains.

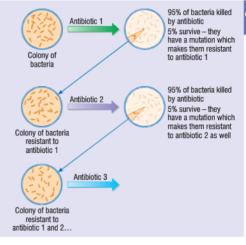


Figure 1 Bacteria can develop resistance to many different antibiotics in a process of natural selection as this simple model shows

To prevent more resistant strains of bacteria appearing it is important not to overuse antibiotics. It's best to only use them when you really need them. Antibiotics don't affect viruses so people should not demand antibiotics to treat an illness which the doctor thinks is viral.

Some antibiotics treat very specific bacteria. Others treat many different types of bacteria. The right type of antibiotic must be used to treat each bacterial infection to prevent further antibiotic resistance developing. It is also important that people finish their course of medicine every time.

a Why is it important not to use antibiotics too frequently?

AQA Examiner's tip

Washing hands removes the pathogens on them, but it may not kill the pathogens.

The MRSA story

Hospitals use a lot of antibiotics to treat infections. As a result of natural selection, some of the bacteria in hospitals are resistant to many antibiotics. This is what has happened with MRSA (the bacterium methicillin-resistant Staphylococcus aureus).



As doctors and nurses move from patient to patient, these antibiotic-resistant bacteria are spread easily. MRSA alone now contributes to around 1000 deaths every year in UK hospitals.

There are a number of simple steps which can reduce the spread of microorganisms such as MRSA. We have known some of them since the time of Semmelweis, but they sometimes get forgotten!

- Antibiotics should only be used when they are really needed.
- Specific bacteria should be treated with specific antibiotics.
- Medical staff should wash their hands with soap and water or alcohol gel between patients. They should wear disposable clothing or clothing that is regularly sterilised.
- Visitors should wash their hands as they enter and leave the hospital.
- Patients infected with antibiotic-resistant bacteria should be looked after in isolation from other patients.
- Hospitals should be kept clean there should be high standards of hygiene.
 - b Is MRSA a bacterium or a virus?

Mutation and pandemics

Another problem caused by the mutation of pathogens is that new forms of diseases can appear. These new strains can spread quickly and cause widespread illness because no one is immune to them and there is no effective treatment. For example the flu virus mutates easily. Every year there are new strains of the virus that your immune system doesn't recognise. There is no effective treatment against viruses at all. The existing flu vaccine is not effective against new strains of the virus, and it takes time to develop a new vaccine.

There may be a flu **epidemic** (in one country) or even a **pandemic** (across several countries). In 1918–19, a new strain of flu virus killed over 40 million people around the world.

With modern international travel, a new strain of pathogen can spread very quickly. In 2009 there was a pandemic of a new strain of flu, known as swine flu, which spread very fast. Internationally, countries worked to stop it spreading and the death toll was kept relatively low.

Summary questions

- 1 Copy and complete using the words below: antibiotics bacterium (virus) better disease mutation mutate resistant virus (bacterium)
 - If bacteria change or they may become to to This means the medicine no longer makes you A in a or can also lead to a new form of
- 2 Make a flow chart to show how bacteria develop resistance to antibiotics.
- 3 Use Figure 2 to help you answer these questions.
 - a How could you explain the increase in deaths linked to MRSA?
 - b How could you explain the fall in deaths linked to MRSA, which still continues?

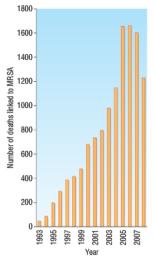


Figure 2 Data that show how the number of deaths in which MRSA played a part from 1993 (Source: National Statistics Office)

O links

For more information on the work of Semmelweis, look back at B1 1.4 Pathogens and disease.

- Many types of bacterium have developed antibiotic resistance as a result of natural selection. To prevent the problem getting worse we must not overuse antibiotics.
- If bacteria or viruses mutate, new strains of the pathogen can appear causing disease.
- New strains of disease which spread rapidly can cause epidemics and pandemics.
 Antibiotics and vaccinations may not be effective against the new strain.



Keeping healthy

B1 1.9

Learning objectives

- How does your immune system work?
- How does vaccination protect you against disease?



Figure 1 No one likes having a vaccination very much – but they save millions of lives!

Immunity

Every cell has unique proteins on its surface called **antigens**. The antigens on the microorganisms that get into your body are different to the ones on your own cells. Your immune system recognises they are different.

Your white blood cells then make antibodies which join up with the antigens. This destroys the pathogens.

Your white blood cells 'remember' the right antibody needed to tackle a particular pathogen. If you meet that pathogen again, they can make the same antibody very quickly. So you become immune to that disease.

The first time you meet a new pathogen you get ill. That's because there is a delay while your body sorts out the right antibody needed. The next time, you completely destroy the invaders before they have time to make you feel unwell.

a What is an antigen?

Vaccination 🚯

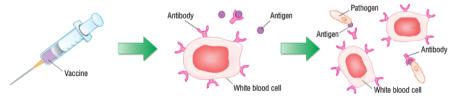
Some pathogens can make you seriously ill very quickly. In fact you can die before your body manages to make the right antibodies. Fortunately, you can be protected against many of these serious diseases by **immunisation** (also known as **vaccination**).

Immunisation involves giving you a **vaccine**. A vaccine is usually made of a dead or weakened form of the disease-causing microorganism. It works by triggering your body's natural immune response to invading pathogens.

A small amount of dead or inactive pathogen is introduced into your body. This gives your white blood cells the chance to develop the right antibodies against the pathogen without you getting ill.

Then, if you meet the live pathogens, your white blood cells can respond rapidly. They can make the right antibodies just as if you had already had the disease, so you are protected against it.

b What is an antibody?



Small amounts of dead or inactive pathogen are put into your body, often by injection.

The antigens in the vaccine stimulate your white blood cells into making antibodies. The antibodies destroy the antigens without any risk of you getting the disease.

You are immune to future infections by the pathogen. That's because your body can respond rapidly and make the correct antibody as if you had already had the disease.

gure 2 This is how vaccines protect you against dangerous infectious diseases

We use vaccines to protect us against both bacterial diseases (e.g. tetanus and diphtheria) and viral diseases (e.g. polio, measles and mumps). For example, the MMR vaccine protects against measles, mumps and rubella. Vaccines have saved millions of lives around the world. If a large proportion of the population is immune to a disease, the spread of the pathogen is very much reduced. One disease – smallpox – has been completely wiped out by vaccinations. Doctors hope polio will also disappear in the next few years.

c Give an example of one bacterial and one viral disease which you can be immunised against.

AQA Examiner's tip

High levels of antibodies do not stay in your blood forever – immunity is the ability of your white blood cells to produce the right antibodies quickly if you are reinfected by a disease.



How Science Works

The vaccine debate (K)



No medicine is completely risk free. Very rarely, a child will react badly to a vaccine with tragic results. Making the decision to have your baby immunised can be difficult.

Society needs as many people as possible to be immunised against as many diseases as possible. This keeps the pool of infection in the population very low. On the other hand, you know there is a remote chance that something may go wrong with a vaccination.

Because vaccines are so successful, we rarely see the terrible diseases they protect us against. A hundred years ago nearly 50% of all deaths of children and young people were caused by infectious diseases. The development of antibiotics and vaccines means that now only 0.5% of all deaths in the same age group are due to infectious disease. Many children were also left permanently damaged by serious infections. Parents today are often aware of the very small risks from vaccination – but sometimes forget about the terrible dangers of the diseases we vaccinate against.

If you are a parent it can be difficult to find unbiased advice to help you make a decision. The media highlight scare stories which make good headlines. The pharmaceutical companies want to sell vaccines. Doctors and health visitors can weigh up all the information, but they have vaccination targets set by the government.

Summary questions

1	Copy	and	complete	using th	e words	below:

antibodies pathogen immunised dead immune inactive white

People can beagainst a disease by introducing small quantities
of or forms of a into your body. They stimulate
the blood cells to produce to destroy the pathogen. This
makes you to the disease in future.

- 2 Explain carefully, using diagrams if they help you:
 - a how the immune system of your body works
 - b how vaccines use your natural immune system to protect you against serious diseases.
- 3 Explain why vaccines can be used against both bacterial and viral diseases but antibiotics only work against bacteria.

O links

For more information on antibiotics, look back at B1 1.8 Changing pathogens.

- Your white blood cells produce antibodies to destroy the pathogens.
 Then your body will respond rapidly to future infections by the same pathogen, by making the correct antibody.
 You become immune to the disease.
- You can be immunised against a disease by introducing small amounts of dead or inactive pathogens into your body.
- We can use vaccinations to protect against both bacterial and viral pathogens.





B1 1.10

Learning objectives

- What are the advantages and disadvantages of being vaccinated?
- How has the treatment of disease changed over time?

Activity

Design a webpage for parents that answers the sort of questions they might ask about their child having the normal varcines. Make it user-friendly, i.e. the sort of thing a health worker could use to help reassure worried parents.

OR

Produce a PowerPoint presentation on the importance of responsible media reporting of science and medicine, using the whooping cough case as one of your main examples.

How do we deal with disease?

The whooping cough story

In the 1970s, Dr John Wilson, a UK specialist in treating children, published a report suggesting that the pertussis (whooping cough) vaccine might cause brain damage in some children. The report was based on his study of a small group of 36 patients.

The media publicised the story and parents began to panic. The number of children being vaccinated against whooping cough fell from over 80% to around 30%. This was too low to protect the population from the disease.

People were so worried about the vaccine that they forgot that whooping cough itself can cause brain damage and death. In Scotland about 100 000 children suffered from whooping cough between 1977 and 1991. About 75 of them died. A similar pattern was seen across the whole of the UK.

An investigation into the original research discovered that it had serious flaws. Identical twin girls who were included in the study, and later died of a rare genetic disorder, had never actually had the whooping cough vaccine. It was a small study and only 12 of the children investigated had shown any symptoms close to the time of their whooping cough vaccination. Their parents were involved in claims for compensation from the vaccine manufacturers.

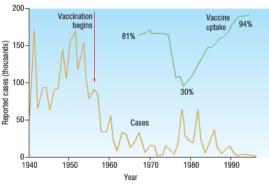


Figure 1 Graph showing the effect of the whooping cough scare on both uptake of the vaccine and the number of cases of the disease (Source: Open University)

No medical treatment (including vaccinations) is completely safe, but when the claims for compensation came to court, the whole study was questioned. After hearing all the evidence, the judge decided that the risks of whooping cough were far worse than any possible damage caused by the vaccine itself.

However, this judgement on the study got much less media coverage than the original scare story. Parents still felt there was 'no smoke without fire'. It was 20 years before vaccination levels, and the levels of whooping cough, returned to the levels before the scare. The number of people having vaccinations now is over 90%, and deaths from whooping cough are almost unknown in the UK.



Medicines for the future

Overuse of antibiotics has lead to spreading antibiotic resistance in many different bacteria. In recent years doctors have found strains of bacteria that are resistant to even the strongest antibiotics. When that happens, there is nothing more that antibiotics can do for a patient and he or she may well die.

The development of antibiotic-resistant strains of bacteria means scientitists are constantly looking for new antibiotics. It isn't easy to find chemicals which kill bacteria without damaging human cells.

Penicillin and several other antibiotics are made by moulds. Scientists are collecting soil samples from all over the world to try and find another mould to produce a new antibiotic that will kill antibiotic-resistant bacteria such as MRSA.

Crocodiles have teeth full of rotting meat. They live in dirty water and fight a lot. But scientists noticed that although crocodiles often give each other terrible bites, the bites do not become infected. They have extracted a chemical known as 'crocodillin' from crocodile blood and it seems to be a powerful antibiotic.

Now the race is on to try and turn these amazing chemicals into antibiotics we can use.



Fish such as this plaice are covered with a slime which helps to protect them from damage and infection. Scientists have analysed this slime and found it contains proteins which have antibiotic properties. The proteins have been isolated from the slime and they still kill bacteria. So maybe fish will provide us with an antibiotic for the future.



Honey has been used since the time of the Ancient Egyptians to help heal wounds. Scientists in Germany and Australia have found that certain types of honey have antibiotic properties. They kill many bacteria, including MRSA. Doctors are using manuka honey dressings more and more to treat infected wounds.

Figure 2 Where will the next antibiotic be found?

Activity

Produce a poster on antibiotic resistance in bacteria and the search for new antibiotics. Make sure you explain how antibiotic resistance has developed and why we need more antibiotics. Use the ideas given here and, if possible, look for more examples of possible sources of new antibiotics.

Summary questions

- 1 Give one advantage and one disadvantage of being vaccinated.
- 2 List three examples of bad science from the story of the whooping cough vaccine and explain why the story should never have been published.

- Vaccination protects individuals and society from the effects of a disease.
- The treatment of disease has changed as our understanding of how antibiotics and immunity has increased.



Keeping healthy: B1 1.1-B1 1.10

Summary questions (1)



- a Define the term 'balanced diet'.
 - b A top athlete needs to eat a lot of food each day. This includes protein and carbohydrate. Explain how they can eat so much without putting on weight.
- 2 Two young people have written to a lifestyle magazine problem page for advice about their diet and lifestyle. Produce an 'answer page' for the next edition of the magazine.
 - a Melanie: I'm 16 and I worry about my weight a lot. I'm not really overweight but I want to be thinner. I've tried to diet but I just feel so tired when I do - and then I buy chocolate bars on the way home from school when my friends can't see me! What can I do?
 - b Jaz: I'm nearly 17 and I've grown so fast in the last year that I look like a stick! So my clothes look pretty silly. I'm also really good at football, but I don't seem as strong as I was and my legs get really tired by the end of a match. I want to build up a bit more muscle and stamina - but I don't just want to eat so much I end up getting really heavy. What can I do about it?
- 3 a What factors affect the cholesterol levels in your blood?
 - b What can you do to help reduce your blood cholesterol levels?
 - c Cholesterol is one inherited factor which affects your health. Give one other example of an inherited factor which affects your health and explain how it does this.

- 4 How do tiny organisms such as bacteria and viruses make a person ill?
- 5 There is going to be a campaign to try and stop the spread of colds in Year 7 of your school. There is going to be a poster and a simple PowerPoint presentation. Make a list of all the important things that the Year 7 children need to know about how diseases are spread. Also cover how the spread of infectious diseases from one person to another can be reduced.
- 6 a Vancomycin is an antibiotic which doctors used for patients infected with MRSA and other antibioticresistant bacteria. Now they are finding some infections are resistant to vancomycin. Explain how this may have happened.
 - **b** What can we do to prevent the problem of antibiotic resistance getting worse? [H]
- a How would you set up a culture of bacteria in a school lab?
 - b Describe how you would test to find out the right strength of disinfectant to use to wash the school floors.

A()A/Examination-style questions (A)

1 It is possible to grow microorganisms in the laboratory. List A shows some temperatures.

List B shows situations for which these temperatures might be suitable.

Match each temperature to the correct situation.

List A
25°C
35°C
100°C

List B
Used in industrial laboratories to grow
microorganisms quickly
Used in school laboratory to grow
microorganisms safely
Used to stop microorganisms growing
without killing them
Used to kill microorganisms

In this question you will be assessed on using good English, organising information clearly and using specialist terms where appropriate.

We need a balanced diet to keep us healthy. Explain the ways in which an unbalanced diet can affect the body. (6)

- 3 A person's metabolic rate varies with the amount of activity they do.
 - Choose one answer.

the breathing rate

the rate of chemical reactions in cells the heart rate (1)

- b Suggest one other factor which can change a person's metabolic rate. (1)
- Polio is a disease caused by a virus. In the UK, children are given polio vaccine to protect them against the disease.
 - a Choose the correct words from each list to complete the sentences below.
 - i It is difficult to kill the polio virus inside the body because the virus (1)is not affected by drugs lives inside cells produces antitoxins
 - ii The vaccine contains an form of the polio virus. (1)

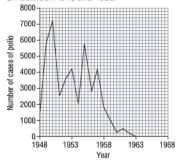
active infective inactive

iii The vaccine stimulates the white blood cells to produce which destroy the virus. (1)antibiotics antibodies drugs



(3)

b The graph shows the number of cases of polio in the UK between 1948 and 1968.



- i In which year was the number of cases of polio (1)
- ii Polio vaccination was first used in the UK in 1955. How many years did it take for the number of cases of polio to fall to zero?
- iii There have been no cases of polio in the UK for many years. But children are still vaccinated against the disease.

Suggest one reason for this.

AQA, 2006

- 5 Controlling infections in hospitals has become much more difficult in recent years.
 - a Suggest two reasons why MRSA is causing problems in many hospitals.
 - b The pioneer in methods of treating infections in hospitals was Ignaz Semmelweis. He observed that women whose babies were delivered by doctors in hospital had a death rate of 18% from infections caught in the hospital. Women whose babies were delivered by midwives in the hospital had a death rate of 2%. He observed that doctors often came straight from examining dead bodies to the delivery ward.
 - i In a controlled experiment, Semmelweis made doctors wash their hands in chloride of lime solution before delivering the babies. The death rate fell to about 2% - down to the same level as the death rate in mothers whose babies were delivered by midwives.

Explain why the death rate fell.

ii Explain how Semmelweis's results could be used to reduce the spread of MRSA in a modern hospital.

AQA, 2005



(1)

Coordination and control

B1 2.1

Learning objectives

- Why do you need a nervous system?
- What is a receptor?
- How do you respond to changes in your surroundings?



Figure 1 Your body is made up of millions of cells which have to work together. Whatever you do with your body – whether it's walking to school or playing on the computer – your movements need to be coordinated.

?? Did you know ...?

Some male moths have receptors so sensitive they can detect the scent of a female several kilometres away and follow the scent trail to find her!

Responding to change

You need to know what is going on in the world around you. Your nervous system makes this possible. It enables you to react to your surroundings and coordinate your behaviour.

Your nervous system carries electrical signals (impulses) that travel fast – from 1 to 120 metres per second. This means you can react to changes in your surroundings very quickly.

a What is the main job of the nervous system?

The nervous system

Like all living things, you need to avoid danger, find food and, eventually, find a mate! This is where your nervous system comes into its own. Your body is particularly sensitive to changes in the world around you. Any changes (known as **stimuli**) are picked up by cells called **receptors**.

Receptor cells (e.g. the light receptor cells in your eyes) are like most animal cells. They have a nucleus, cytoplasm and a cell membrane. These receptors are usually found clustered together in special sense organs, such as your eyes and your skin. You have many different types of sensory receptor (see Figure 2).

- **b** Where would you find receptors that respond to:
 - i a loud noise
 - ii touching a hot oven
 - iii a strong perfume?



Figure 2 This cat relies on its sensory receptors to detect changes in the environment



How your nervous system works (R)



Once a sensory receptor detects a stimulus, the information (sent as an electrical impulse) passes along special cells called neurons. These are usually found in bundles of hundreds or even thousands of neurons known as nerves.

The impulse travels along the neuron until it reaches the central nervous system or CNS. The CNS is made up of the brain and the spinal cord. The cells which carry impulses from your sense organs to your central nervous system are called sensory neurons.

c What is the difference between a neuron and a nerve?

Your brain gets huge amounts of information from all the sensory receptors in your body. It coordinates the information and sends impulses out along special cells. These cells carry information from the CNS to the rest of your body. The cells are called motor neurons. They carry impulses to make the right bits of your body - the effector organs - respond.

Effector organs are muscles or glands. Your muscles respond to the arrival of impulses by contracting. Your glands respond by releasing (secreting) chemical substances.

The way your nervous system works can be summed up as:

 $receptor \rightarrow sensory \ neuron \rightarrow coordinator \ (CNS) \rightarrow motor \ neuron \rightarrow effector$

d What is the difference between a sensory neuron and a motor neuron?

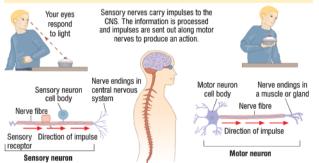


Figure 3 The rapid responses of our nervous system allow us to respond to our surroundings quickly - and in the right way!

Summary questions

- 1 Copy and complete using the words below: neurons receptors electrical CNS environment nervous Your _____ system carries fast _____ impulses. Changes in the _____ are picked up by your and impulses travel along your to your
- 2 Make a table to show the different types of sense receptor. For each one, give an example of the sort of things it responds to, e.g. touch receptors respond to an insect crawling on your skin.
- 3 Explain what happens in your nervous system when you see a piece of chocolate, pick it up and eat it.

()A/Examiner's tip

Make sure you are clear that 'motor' means movement. 'Motor neurons' stimulate the muscles to contract.

Examiner's tip

Be careful to use the terms neuron and nerve correctly.

Talk about impulses (not messages) travelling along a neuron.

- The nervous system uses electrical impulses to enable you to react quickly to your surroundings and coordinate what you do.
- Cells called receptors detect stimuli (changes in the environment).
- Like all animal cells, light receptor cells and other receptors have a nucleus. cytoplasm and cell membrane.
- Impulses from receptors pass along sensory neurons to the brain or spinal cord (CNS), Impulses are sent along motor neurons from the brain (CNS) to the effector organs.



Coordination and control

B1 2.2

Learning objectives

- What is a reflex?
- Why are reflexes so important?

Practical

The stick-drop test

You can investigate how quickly nerve impulses travel in your body using metre rules, and either stop clocks or ICT to measure how quickly you catch the ruler OR by standing in a circle holding hands with your eyes closed and measuring how long it takes a hand squeeze to pass around the circle.

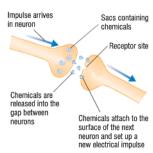


Figure 1 When an impulse arrives at the junction between two neurons, chemicals are released which cross the synapse and arrive at receptor sites on the next neuron. This starts up an electrical inpulse in the next neuron.

Reflex actions

Your nervous system lets you take in information from your surroundings and respond in the right way. However, some of your responses are so fast that they happen without giving you time to think.

When you touch something hot, or sharp, you pull your hand back before you feel the pain. If something comes near your face, you blink. Automatic responses like these are known as **reflexes**.

What are reflexes for?

Reflexes are very important both for human beings and for other animals. They help you to avoid danger or harm because they happen so fast. There are also lots of reflexes that take care of your basic body functions. These functions include breathing and moving food through your gut.

It would make life very difficult if you had to think consciously about those things all the time – and would be fatal if you forgot to breathel

a Why are reflexes important?

How do reflexes work?



- sensory neurons
- motor neurons
- relay neurons these connect a sensory neuron and a motor neuron. Your relay neurons are in the CNS.

An electrical impulse passes from the sensory receptor along the sensory neuron to the CNS. It then passes along a relay neuron (usually in the spinal cord) and straight back along a motor neuron. From there the impulse arrives at the effector organ. The effector organ will be a muscle or a gland. We call this a reflex arc.

The key point in a reflex arc is that the impulse bypasses the conscious areas of your brain. The result is that the time between the stimulus and the reflex action is as short as possible.

b Why is it important that the impulses in a reflex arc do not go to the conscious brain?

How synapses work (

Your nerves are not joined up directly to each other. There are junctions between them called **synapses**. The electrical impulses travelling along your neurons have to cross these synapses. They cannot leap the gap. Look at Figure 1 to see what happens next.

The reflex arc in detail

Look at Figure 2. It shows what would happen if you touched a hot object. When you touch it, a receptor in your skin is stimulated. An electrical impulse passes along a sensory neuron to the central nervous system – in this case the spinal cord.

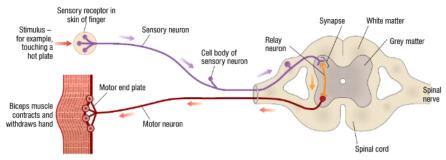


Figure 2 The reflex action which moves your hand away from something hot can save you from being burned. Reflex actions are quick and automatic; you do not think about them.

When an impulse from the sensory neuron arrives in the synapse with a relay neuron, a chemical messenger is released. This chemical crosses the synapse to the relay neuron. There it sets off an electrical impulse that travels along the relay neuron.

When the impulse reaches the synapse between the relay neuron and a motor neuron returning to the arm, another chemical is released.

This chemical crosses the synapse and starts an electrical impulse travelling down the motor neuron. When the impulse reaches the effector organ, it is stimulated to respond.

In this example the impulses arrive in the muscles of the arm, causing them to contract. This action moves the hand rapidly away from the source of pain. If the effector organ is a gland, it will respond by releasing (secreting) chemicals.

Most reflex actions can be shown as follows:

$stimulus \rightarrow receptor \rightarrow coordinator \rightarrow effector \rightarrow response$

This is not very different from a normal conscious action. However, in a reflex action the coordinator is a relay neuron either in the spinal cord or in the unconscious areas of the brain. The whole reflex is very fast indeed.

An impulse also travels up the spinal cord to the conscious areas of your brain. You know about the reflex action, but only after it has happened.

Summary questions

- 1 Copy and complete using the words below:

 conscious motor reflex relay response sensory stimulus

 In a ______ arc the electrical impulse bypasses the ______ areas of
 your brain. The time between the _____ and the _____ is as short as
 possible. Only _____ neurons, _____ neurons and _____ neurons are
 involved.
- 2 Explain why some actions, such as breathing and swallowing, are reflex actions, while others such as speaking and eating are under your conscious control.
- 3 Draw a flow chart to explain what happens when you step on a pin. Make sure you include an explanation of how a synapse works.

ACA Examiner's tip

Make sure you know the correct sequence of links from the receptor to the effector.



Figure 3 Newborn babies have a number of special reflexes which disappear as they grow. This gripping reflex is one of them.

- Some responses to stimuli are automatic and rapid and are called 'reflex actions'.
- Reflex actions run everyday bodily functions and help you to avoid danger.



B₁ 2.3

Learning objectives

- How is the menstrual cycle controlled?
- When is a woman most likely to conceive?

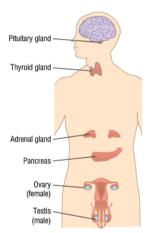


Figure 1 Hormones act as chemical messages. They are made in glands in one part of the body but have an effect somewhere else.

Did you know ...?

A baby girl is born with ovaries full of immature eggs, but they do nothing until she has gone through the changes of puberty.

Hormones and the menstrual cycle

Hormones are chemical substances that coordinate many processes within your body. Special glands make and release (secrete) these hormones into your body. Then the hormones are carried around your body to their target organs in the bloodstream. Hormones regulate the functions of many organs and cells. They can act very quickly, but often their effects are quite slow and long lasting.

A woman's menstrual cycle is a good example of control by hormones. Hormones are made in a woman's pituitary gland and her ovaries control her menstrual cycle. The levels of the different hormones rise and fall in a regular pattern. This affects the way her body works.

What is the menstrual cycle?

The average length of the menstrual cycle is about 28 days. Each month the lining of the womb thickens ready to support a developing baby. At the same time an egg starts maturing in the ovary.

About 14 days after the egg starts maturing it is released from the ovary. This is known as ovulation. The lining of the womb stays thick for several days after the egg has been released.

If the egg is fertilised by a sperm, then pregnancy may take place. The lining of the womb provides protection and food for the developing embryo, If the egg is not fertilised, the lining of the womb and the dead egg are shed from the body. This is the monthly bleed or period.

All of these changes are brought about by hormones. These are made and released by the pituitary gland (a pea-sized gland in the brain) and the

- a What controls the menstrual cycle?
- b Why does the lining of the womb build up each month?

How the menstrual cycle works (K)



Once a month, a surge of hormones from the pituitary gland in the brain starts eggs maturing in the ovaries. The hormones also stimulate the ovaries to produce the female sex hormone **oestrogen**.

- Follicle stimulating hormone (FSH) is secreted by the pituitary gland. It makes eggs mature in the ovaries. FSH also stimulates the ovaries to produce oestrogen.
- Oestrogen is made and secreted by the ovaries. It stimulates the lining of the womb to build up ready for pregnancy. It inhibits (slows down) the production of more FSH.
- Other hormones involved in the menstrual cycle are luteinising hormone (LH) and progesterone.

The hormones produced by the pituitary gland and the ovary act together to control what happens in the menstrual cycle. As the oestrogen levels rise they inhibit the production of FSH and encourage the production of LH by the pituitary gland. When LH levels reach a peak in the middle of the cycle, they stimulate the release of a mature egg.



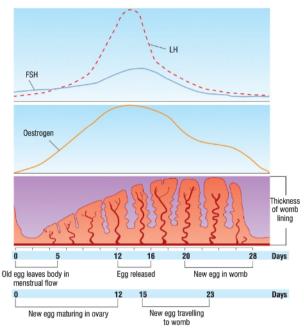


Figure 2 The changing levels of the female sex hormones control the different stages of the menstrual cycle

AQA Examiner's tip

Be clear on the difference between FSH and oestrogen.

FSH

- causes eggs to mature
- stimulates the ovary to produce oestrogen.

Oestrogen

- causes the lining of the womb to develop
- inhibits FSH production
- stimulates the release of a mature egg.

AQA Examiner's tip

Make sure you know the difference between eggs maturing and eggs being released.

Summary questions

- 1 Copy and complete using the words below:
- 2 Look at Figure 2 above:
 - a Explain what happens to FSH.
 - b On which days is the female having a menstrual period?
 - **c** Which hormone controls the build-up of the lining of the womb?
- 3 Produce a poster to explain the events of the menstrual cycle to women who are hoping to start a family. You will need to explain the graphs at the top of this page and show when a woman is most likely to get pregnant. Remember sperm can live for up to three days inside the woman's body.

- Hormones control the release of an egg from the ovary and the build-up of the lining of the womb in the menstrual cycle.
- Some of the hormones involved are FSH from the pituitary gland and oestrogen from the ovary.



Coordination and control

B1 2.4

Learning objectives

- How can hormones be used to stop pregnancy?
- How can hormones help to solve the problems of infertility?



Figure 1 The contraceptive pill contains a mixture of hormones which effectively trick the body into thinking it is already pregnant, so no more eggs are released

Examiner's tip

FSH and LH are used in IVF to stimulate the eggs to mature.

Did you know ...?

In the early days of using fertility drugs there were big problems with the doses used. In 1971 an Italian doctor removed 15 four-month-old fetuses (ten girls and five boys) from the womb of a 35-yearold woman after treatment with fertility drugs. Not one of them survived.

The artificial control of fertility

Contraceptive chemicals (R)



In the 21st century it is possible to choose when to have children - and when not to have them. One of the most important and widely used ways of controlling fertility is to use oral contraceptives (the contraceptive pill).

The pill contains female hormones, particularly oestrogen. The hormones affect women's ovaries, preventing the release of any eggs. The pill inhibits the production of FSH so no eggs mature in the ovaries. Without mature eggs. women can't get pregnant.

Anyone who uses the pill as a contraceptive has to take it very regularly. If they forget to take it, the artificial hormone levels drop. Then their body's own hormones can take over very quickly. This can lead to the unexpected release of an egg - and an unexpected baby.

a What is a contraceptive?

The first birth control pills contained very large amounts of oestrogen. They caused serious side effects such as high blood pressure and headaches in some women. Modern contraceptive pills contain much lower doses of oestrogen along with some progesterone. They cause fewer side effects. Some contraceptive pills only contain progesterone. These cause even fewer side effects. However, they are not quite so good at preventing pregnancy because they don't stop the eggs from maturing.

b What is the difference between the mixed pill and the progesterone-only pill?

Fertility treatments (K)



In the UK as many as one couple in six have problems having a family when they want one. There are many possible reasons for this infertility. It may be linked to a lack of female hormones. Some women want children but do not make enough FSH to stimulate the eggs in their ovaries. Fortunately, artificial FSH can be used as a fertility drug. It stimulates the eggs in the ovary to mature and also triggers oestrogen production.





Figure 2 Most people who take fertility drugs end up with one or two babies. But in 1983 the Walton family from Liverpool had six baby girls who all survived.

Fertility drugs are also used in **IVF** (in vitro fertilisation). Conception usually takes place in the fallopian tube. This is the tube between the ovary and the womb that the egg travels along. If the fallopian tubes are damaged, the eggs cannot reach the womb so women cannot get pregnant naturally.

Fortunately doctors can now help. They collect eggs from the ovary of the mother and fertilise them with sperm from the father outside the body. The fertilised eggs develop into tiny embryos. The embryos are inserted into the womb of the mother. In this way they bypass the faulty tubes.

During IVF the woman is given FSH to make sure as many eggs as possible mature in her ovaries. LH is also given at the end of the cycle to make sure all the mature eggs are released. IVF is expensive and not always successful.



- Fertility drugs are used to make lots of eggs mature at the same time for collection.
- 2 The eggs are collected and placed in a special solution in a Petri dish.





- 3 A sample of semen is collected and the sperm and eggs are mixed in the Petri dish.
- 4 The eggs are checked to make sure they have been fertilised and the early embryos are developing properly.





5 When the fertilised eggs have formed tiny balls of cells, 1 or 2 of the tiny embryos are placed in the womb of the mother. Then, if all goes well, at least one baby will grow and develop successfully.

Figure 3 New reproductive technology using hormones and IVF has helped thousands of infertile couples to have habies

a woman using fertility drugs may be

Key points

- Hormones can be used to control fertility.
- Oral contraceptives contain hormones, which stop FSH production so no eggs mature.
- FSH can be used as a fertility drug for women, to stimulate eggs to mature in their ovaries. These eggs may be used in IVF treatments.

How S

How Science Works

The advantages and disadvantages of fertility treatment

The use of hormones to control fertility has been a major scientific breakthrough. But like most things, there are advantages and disadvantages! Here are some points to think about:

In the developed world, using the pill has helped make families much smaller than they used to be. There is less poverty because with fewer children being born there are fewer mouths to feed and more money to go round.

The pill has also helped to control population growth in countries such as China, where they find it difficult to feed all their people. In many other countries of the developing world the pill is not available because of a lack of money, education and doctors.

The pill can cause health problems so a doctor always oversees its use.

The use of fertility drugs can also have some health risks for the mother and it can be expensive for society and parents. A large multiple birth can be tragic for the parents if some or all of the babies die. It also costs hospitals a lot of money to keep very small premature babies alive.

Controlling fertility artificially also raises many ethical issues for society and individuals. For example, some religious groups think that preventing conception is denying life and ban the use of the pill.

The mature eggs produced by a woman using fertility drugs may be collected and stored, or fertilised and stored, until she wants to get pregnant later. But what happens if the woman dies, or does not want the eggs or embryos any more?

 What, in your opinion, are the main advantages and disadvantages of using artificial hormones to control female fertility?

Summary questions

- 1 Explain the meaning of the following terms: oral contraceptive, fallopian tube, fertility drug, in vitro fertilisation.
- 2 Explain how artificial female hormones can be used to:
 - a prevent unwanted pregnancies
 - b help people overcome infertility.



Coordination and control

B₁ 2.5

Learning objectives

- How are conditions inside your body controlled?
- Why is it so important to control your internal environment?



Figure 1 Everything you do affects your internal environment

∕Examiner's tip

Sweating causes the body to cool. Energy from the body is used to evaporate the water in sweat.



Figure 2 You can change your behaviour to help control your temperature, for example by adding extra clothing or turning up the heating when it's really

Controlling conditions

The conditions inside your body are known as its internal environment. Your organs cannot work properly if this keeps changing. Many of the processes which go on inside your body aim to keep everything as constant as possible. This balancing act is called homeostasis.

It involves your nervous system, your hormone systems and many of your body organs.

a Why is homeostasis important?

Controlling water and ions (R)



Water can move in and out of your body cells. How much it moves depends on the concentration of mineral ions (such as salt) and the amount of water in your body. If too much water moves into or out of your cells, they can be damaged or destroyed.

You take water and minerals into your body as you eat and drink. You lose water as you breathe out, and also in your sweat. You lose salt in your sweat as well. You also lose water and salt in your urine, which is made in your kidnevs.

Your kidneys can change the amount of salt and water lost in your urine, depending on your body conditions. They help to control the balance of water and mineral ions in your body. The concentration of the urine produced by your kidneys is controlled by both nerves and hormones.

So, for example, imagine drinking a lot of water all in one go. Your kidneys will remove the extra water from your blood and you will produce lots of very pale urine

b What do your kidneys control?

Controlling temperature

It is vital that your deep core body temperature is kept at 37°C. At this temperature your enzymes work best. At only a few degrees above or below normal body temperature the reactions in your cells stop and you will die.

Your body controls your temperature in several ways. For example, you can sweat to cool down and shiver to warm up. Your nervous system is very important in coordinating the way your body responds to changes in temperature.

Once your body temperature drops below 35°C you are at risk of dying from hypothermia. Several hundred old people die from the effects of cold each year. So do a number of young people who get lost on mountains or try to walk home in the snow after a night out.

If your body temperature goes above about 40-42°C your enzymes and cells don't work properly. This means that you may die of heat stroke or heat exhaustion.

c What is the ideal body temperature?

Controlling blood sugar

When you digest a meal, lots of sugar (glucose) passes into your blood. Left alone, your blood glucose levels would keep changing. The levels would be very high straight after a meal, but very low again a few hours later. This would cause chaos in your body.

However, the concentration of glucose in your blood is kept constant by hormones made in your **pancreas**. This means your body cells are provided with the constant supply of energy that they need.

d What would happen to your blood sugar level if you ate a packet of sweets?



Figure 3 Sweets like this are almost all sugar. When you eat them your body has to deal with the effect on your blood.

Summary questions

- Copy and complete using the words below:
 body constant homeostasis hormones internal nervous
 Conditions in the ______ environment of your _____ must be kept _____.
 This is called _____ . The control is given by both your _____ and your _____ system.
- 2 Why is it important to control:
 - a water levels in the body
 - b the body temperature
 - c sugar (glucose) levels in the blood?
- 3 a Look at the marathon runners in Figure 1. List the ways in which the running is affecting their:
 - i water balance
 - ii ion balance
 - iii temperature.
 - b It is much harder to run a marathon in a costume than in running clothes. Explain why this is.

O links

For more information about the control of blood sugar, see B3 3.7 Controlling blood glucose.

- Humans need to maintain a constant internal environment, controlling levels of water, ions and blood sugar, as well as temperature.
- Homeostasis is the result of the coordination of your nervous system, your hormones and your body organs.



B1 2.6

Learning objectives

- What stimuli do plants respond to?
- How do plants respond to their environment?
- Why do farmers and gardeners use plant hormones?



Figure 1 Seedlings like this radish show you clearly how plant shoots respond to light - they grow towards it

Did vou know ...?

The first scientists to show the way the shoot of a plant responds to light from one direction were Charles Darwin and his son Francis.



Practical

The effect of light on the growth of seedlings

You can investigate the effect of one-sided light on the growth of seedlings using a simple box with a hole cut in it and cress seedling growing in a Petri dish.

Coordination and control

Hormones and the control of plant growth

It is easy to see how animals, such as ourselves, take in information about the surroundings and then react to it. But plants also need to be coordinated. They are sensitive to light, water and gravity.

Plants are sensitive (R)



When seeds are spread they may fall any way up in the soil. It is very important that when the seed starts to grow (germinate) the roots grow downwards into the soil. Then they can anchor the seedling and keep it stable. They can also take up the water and minerals needed for healthy growth.

At the same time the shoots need to grow upwards towards the light so they can photosynthesise as much as possible.

Plant roots are sensitive to gravity and water. The roots grow towards moisture and in the direction of the force of gravity. Plant shoots are sensitive to gravity and light. The shoots grow towards light and against the force of gravity. This means that whichever way up the seed lands, the plant always grows the right way up!

Plant responses (K



Plant responses happen as a result of plant hormones which coordinate and control growth. These responses are easy to see in young seedlings, but they also happen in adult plants. For example, the stems of a houseplant left on a windowsill will soon bend towards the light. The response of a plant to light is known as phototropism. The response of a plant to gravity is called gravitropism (also known as geotropism).

The responses of plant roots and shoots to light, gravity and moisture are controlled by a hormone called auxin. The response happens because of an uneven distribution of this hormone in the growing shoot or root. This causes an unequal growth rate. As a result the root or shoot bends in the right direction.

Phototropism can clearly be seen when a young shoot responds to light from one side only. The shoot will bend so it is growing towards the light. Auxin moves from the side of the shoot where the light is falling to the unlit side of the shoot. The cells on that side respond to the hormone by growing more and so the shoot bends towards the light. Once light falls evenly on the shoot, the levels of auxin will be equal on all sides and so the shoot grows straight again.

Gravitropisms can be seen in roots and shoots. Auxin has different effects on root and shoot cells. High levels of auxin make shoot cells grow more but inhibit growth of root cells. This is why roots and shoots respond differently to gravity.

a What is the name of the plant hormone which controls phototropism and gravitropism?



The shoot grows more on the side with most auxin, making it bend and grow up

away from the force of gravity. When it has grown up, the auxin becomes evenly spread again.

3 The root grows more on the side with least auxin.

evenly spread again.

making it bend and grow down towards the force of

gravity. When it has grown down, the auxin becomes

1 A normal young bean plant is laid on its side in the dark. Auxin is equally spread through the tissues.



2 In the root, more auxin gathers on the lower side.

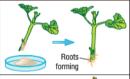


Figure 2 Gravitropism (or geotropism) in shoots and roots. The uneven distribution of the hormone auxin causes unequal growth rates so the roots grow down and the shoots grow up.

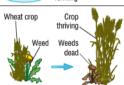




Plant hormones can be used to manage plants grown in the garden or home. Farmers also use them to grow better crops.



Gardeners and horticulturists rely on taking cuttings to produce lots of identical plants. Plant growth hormones are used as rooting powder. A little placed on the end of a cutting stimulates the growth of new roots and helps the cutting to grow into a new plant.



You can use high doses of plant hormones as weed killers. Most weeds are broad-leaved plants which absorb a lot of hormone weed killer. This makes them go into rapid, uncontrolled growth which kills them. Narrow-leaved plants such as grasses and cereal are not affected, so the crop or lawn keeps growing well.

Figure 3 Some human uses of plant hormones

Summary questions

- 2 Why are the responses of shoots and roots so important in the life of plants?
- 3 Explain carefully, using diagrams, how a plant shoot responds to light shining at it from one side only.



- Plants are sensitive to light, moisture and gravity.
- Plant responses are brought about by plant hormones (auxin).
- The responses of roots and shoots to stimuli such as light and gravity are the result of the unequal distribution of plant hormones.
- We can use plant growth hormones as weed killers and as rooting hormones on cuttings.





B1 2.7

Learning objectives

- What are some of the issues associated with the use of hormones to control human fertility?
- How much should we use plant hormones to produce our food?



Figure 1 Using hormones to control fertility has made it possible for women in their 50s and 60s to become pregnant and have a baby – but not everyone thinks this is a good idea

Using hormones

People can control human fertility. Infertile women can have treatment and have babies, while fertile women can choose not to have children. We can make thousands of identical plants and we can kill weeds as they grow. We do these things using hormones. But not everyone agrees with what is being done.

Woman 1

'I married late – I was 40 – and we wanted a family but my periods stopped when I was 41. Now we have a chance again. I haven't got any eggs so doctors will use FSH as a fertility drug to help them take lots of eggs from my donor, a younger woman. We want this child SO much!'

Woman 2

'We've got three lovely children. I decided to donate some of my eggs to help couples who aren't as lucky as we are. I don't mind the age of the woman who gets my eggs as long as she manages to have a baby and loves it!'

Man 1

'I think it is disgraceful and unnatural for women to have babies when they are older. We are interfering with nature and with God's will and no good will come of it. The mother might die before the child is an adult.'

Doctor

'All our evidence shows that infertility treatment can be just as successful in older women as it is in younger ones. We have to use artificial hormones to get the womb ready and use donor eggs, but once the women are pregnant their own hormones take over.'

Man 2

'I can't see anything wrong with older women having babies as long as they are fit and well. I know some people object to it, but some women have babies in their fifties naturally – and lots of men father children in their 60s and even their 70s and no one objects to that, do they?'

a Which hormone would doctors use to stimulate the ovaries of an egg donor?

Activity

Make your mind up!

There is a lot of debate about older mothers. Use what you have learned in this spread to help you write a 2-3-minute report for your school radio. Use the title: 'Older mothers - should science help?'

It will go out in a regular slot called 'Science issues', so students will be expecting some science as well as opinions.

O links

For information on plant growth hormones, look back at B1 2.6 Hormones and the control of plant arowth.

Plant hormones, plant killers (K)



Scientists have discovered that plant hormones such as auxin make effective weed killers. The hormones used in commercial weed killers are not natural hormones extracted from plants. They are made in chemical factories. These weed killers seem effective and safe. People use them on their lawns because the grass is not affected, but the weeds like dandelions and daisies are killed. Golf courses are kept weed-free in the same way.

Farmers around the world use hormone weed killers to kill off the weeds in cereal crops. They are one of the reasons why the yield of cereal crops is now so much bigger all across Europe. That means more food is available at cheaper prices.

But chemicals based on plant hormones (synthetic plant hormones) can cause serious problems. In the Vietnam War, one of these chemicals (Agent Orange) was sprayed on the forests. It works in the same way as natural plant hormones and in high doses it strips all the leaves off the trees. This made it easier for the US soldiers to find enemy fighters. It caused terrible damage to the forests. Not only that, hundreds of thousands of people were badly affected by the powerful chemicals.

b What is Agent Orange?

Practical

The effect of rooting compounds and weed killers on the growth of plants

You can investigate the effect of rooting hormone by taking some cuttings and growing half of them with rooting powder and half without.

Did you know ...?

Agent Orange has been used to destroy areas of the Amazon rainforest, particularly for the building of the Tucurui dam in Brazil.

Activity

Is it worth it?

Synthetic plant hormones, like many scientific discoveries, can be used both to benefit people and to cause great harm. Some people have suggested that synthetic plant hormones should all be banned. Plan a short speech EITHER supporting this idea OR disagreeing with it.

Use evidence and persuasive writing in your speech.

Key points

- There are benefits and problems associated with the use of hormones to control fertility and these must be evaluated carefully.
- Plant hormones are very useful as weed killers but their use can damage the environment.

Summary guestions

- 1 Make a table to summarise the main points for and against allowing older women to use hormones such as FSH to help them have a baby.
- 2 How can plant hormones be used to kill plants?



Summary questions (1)



1 This question is about animal responses. Match up the following parts of sentences:

A effector organs.
B secreted by glands.
C to react to your surroundings and coordinate your behaviour.
D are found in the eyes.
E are known as nerves.
F are controlled by hormones.

- 2 a What is the job of your nervous system?
 - b Where in your body would you find nervous receptors which respond to:
 - i liaht
 - ii sound
 - iii heat
 - iv touch?
 - c Draw and label a simple diagram of a reflex arc. Explain carefully how a reflex arc works and why it allows you to respond quickly to danger.
- 3 a What is the menstrual cycle?
 - b What is the role of the following hormones in the menstrual cycle:
 - i FSH
 - ii oestrogen?
- 4 a Explain carefully the difference between nervous and hormone control of your body.
 - b What are synapses and why are they important in your nervous system?
 - c How can hormones be used to control the fertility of a woman?

5 The table shows four ways in which water leaves your body, and the amounts lost on a cool day:

Source of water loss	Cool day (water loss in cm³)	Hot day (loss in cm³)
Breath	400	The same
Skin	500	Α
Urine	1500	В
Faeces	150	С

- a On a hot day, would the amount of water lost in A, B and C be less, the same or more than the amount of water lost on a cool day?
- b Name the process by which we lose water from the
- c On a cool day the body gained 2550 cm³ of water. 1750 cm3 came directly from drinking. Where did the rest come from?
- 6 It is very important to keep the conditions inside the body stable. Taking part in school sports on a hot day without a drink for the afternoon would be difficult for your body. Explain how your body would keep the internal environment as stable as possible.
- 7 a What is gravitropism (geotropism)?
 - b Explain carefully how the following respond to gravity, including the part played by plant hormones. Diagrams may help in your explanations.
 - i a root
 - ii a shoot
- You are provided with some very young single shoots. Devise an experiment which would demonstrate that shoots grow towards the light.

A()A/Examination-style questions (A)



(1)

A dog responds to stimuli.



- a Link the receptor descriptions to the correct part of the animal by choosing the correct letter (A. B. C or D).
 - i Contains receptors to detect chemicals
 - ii Contains receptors to detect light (1)
 - iii Contains receptors to detect movement of the head and sound.
- b The skin of a human contains receptors which are sensitive to touch.
 - Give one other stimulus which is detected by human skin.
 - ii Suggest why there are many touch receptors in a person's fingertips.
- 2 a When a person touches a hot surface they move their hand away guickly.

Choose the correct word to complete the sentence.

This is called a _____ action. learned reflex thoughtful

- b What is the importance of this type of action? (1)
- 3 This picture shows a Venus flytrap.



a The Venus flytrap catches flies for food. When a fly lands on the leaf the trap closes.

Choose the correct word to complete the sentence.

The shutting of the trap is called a (1)detector stimulus response

b Suggest one receptor the Venus flytrap has to detect the flv. (1)

- 4 Hormones are important chemicals which help to control conditions inside living organisms.
- a List A shows three hormones

List B shows where some hormones are produced.

Match each hormone with where it is produced.

List A	List B
Hormone	Where produced
auxin	pituitary gland
oestrogen	kidney
FSH	plant stems and roots
	ovary

b Choose the correct answer to complete each of the following sentences.

The hormone which causes eggs to mature is (1) auxin oestrogen FSH

- ii The hormone which causes growth of the uterus(womb) lining is (1) auxin oestrogen FSH
- 5 When light is shone in a person's eyes they blink. When a plant is placed near a lamp the stem bends towards the light.
 - a Choose the correct answer to complete each of the following sentences.

i The response of the eve to bright light is called a action. (1)

learned reflex stimulated

ii The response of the plant to light is called

gravitropism hydrotropism phototropism

b In this question you will be assessed on using good English, organising information clearly and using specialist terms where appropriate.

Plants respond to light and gravity. Describe how plant hormones control the growth of roots and shoots. (6)



(1)

(3)

Medicine and drugs

B1 3.1

Learning objectives

- What are the stages in testing and trialling a new drug?
- Why is testing new drugs so important?



Figure 1 The development of a new medicine takes millions of pounds, involves many people and lots of equipment

AN Examiner's tip

Make sure you are clear that a medical drug is tested to establish:

- its effectiveness
- its toxicity
- the most appropriate dose.

AN Examiner's tip

Remember, the cells, tissues and animals act as models to predict how the drug may behave in humans.

Developing new medicines

We are developing new medicines all the time, as scientists and doctors try to find ways of curing more diseases. We test new medicines in the laboratory. Every new medical treatment has to be extensively tested and trialled before it is used. This process makes sure that it works well and is as safe as possible.

A good medicine is:

- Effective it must prevent or cure a disease or at least make you feel better.
- Safe the drug must not be too toxic (poisonous) or have unacceptable side effects for the patient.
- Stable you must be able to use the medicine under normal conditions and store it for some time.
- Successfully taken into and removed from your body it must reach its target and be cleared from your system once it has done its work.

Developing and testing a new drug

When scientists research a new medicine they have to make sure all these conditions are met. It can take up to 12 years to bring a new medicine into your doctor's surgery. It can also cost a lot of money; up to about £350 million!

Researchers target a disease and make lots of possible new drugs. These are tested in the laboratory to find out if they are toxic and if they seem to do their job. They are tested on cells, tissues and even whole organs. Many chemicals fail at this stage.

The small numbers of chemicals which pass the earlier tests are now tested on animals. This is done to find out how they work in a whole living organism. It also gives information about possible doses and side effects. The tissues and animals are used as models to predict how the drugs may behave in humans.

Drugs that pass animal testing will be tested on human volunteers in clinical trials. First very low doses are given to healthy people to check for side effects. Then it is tried on a small number of patients to see if it treats the disease. If it seems to be safe and effective, bigger clinical trials take place to find the optimum dose for the drug.

If the medicine passes all the legal tests it is licensed so your doctor can prescribe it. Its safety will be monitored for as long as it is used.

a What are the important properties of a good new medicine?

Double-blind trials

In human trials, scientists use a **double-blind trial** to see just how effective the new medicine is. Some patients with the target disease agree to take part in the trials. They are either given a **placebo** that does not contain the drug or the new medicine. Neither the doctor nor the patients know who has received the real drug and who has received the placebo until the trial is complete. The patients' health is monitored carefully.

Often the placebo will contain a different drug that is already used to treat the disease. That is so the patient is not deprived of treatment by taking part in the trial.



Why do we test new medicines so thoroughly?

Thalidomide is a medicine which was developed in the 1950s as a sleeping pill. This was before there were agreed standards for testing new medicines. In particular, tests on pregnant animals, which we now know to be essential, were not carried out.

Then it was discovered that thalidomide stopped morning sickness during pregnancy. Because thalidomide seemed very safe for adults, it was assumed to be safe for unborn children. Doctors gave it to pregnant women to relieve their sickness.

Tragically, thalidomide was **not** safe for developing fetuses. It affected the fetuses of many women who took the drug in the early stages of pregnancy. They went on to give birth to babies with severe limb deformities.

The thalidomide tragedy led to a new law being passed. It set standards for the testing of all new medicines. Since the Medicines Act 1968, new medicines must be tested on animals to see if they have an effect on developing fetuses.

There is another twist in the thalidomide story. Doctors discovered it can treat leprosy. They started to use the drug against leprosy in the developing world but again children were born with abnormalities. Its use for leprosy has now been banned by the World Health Organisation (WHO).

However doctors are finding more uses for the drug. It can treat some autoimmune diseases (where the body attacks its own cells) and even some cancers. It is now used very carefully and never given to anyone who is or might become pregnant.



Figure 2 This woman has limb deformities because her mother took thalidomide during her pregnancy. She was just one of thousands of people affected by the thalidomide tragedy, many of whom have gone on to live full and active lives

b Why was thalidomide prescribed to pregnant women?

Summary questions

- 2 a Testing a new medicine costs a lot of money and can take up to 12 years. Make a flow chart to show the main stages in testing new drugs.
 - b Why is an active drug often used as the control in a clinical trial instead of a sugar pill placebo which does nothing?
- 3 a What were the flaws in the original development of thalidomide?
 - b Why do you think that the World Health Organisation has stopped the use of thalidomide to treat leprosy but the drug is still being used in the developed world to treat certain rare conditions?

- When we develop new medicines they have to be tested and trialled extensively before we can use them.
- Drugs are tested to see if they work well. We also make sure they are not too toxic and have no unacceptable side effects.
- Thalidomide was developed as a sleeping pill and was found to prevent morning sickness in early pregnancy.
 It had not been fully tested and it caused birth defects.





B₁ 3.2

How effective are medicines?

Learning objectives

- What are statins?
- How good are statins at preventing cardiovascular disease?
- Can drugs you buy over the counter be as good as the drugs that your doctor prescribes?

The statin revolution (L)



As you have seen, high blood cholesterol levels are linked to a higher than average risk of cardiovascular disease. In other words, you are more likely to have a heart attack or a stroke if your blood cholesterol is high.

Doctors now have an amazing weapon against high cholesterol levels and the problems they can cause. They can use a group of drugs called statins. Statins are drugs that lower the amount of cholesterol in your blood. They stop your liver producing too much cholesterol. Patients need to keep to a relatively low fat diet as well for the best effects.

a What are statins?

Here are some different opinions about these exciting new drugs:

A GP

'Some people just can't get their cholesterol level right by changing their diet. It doesn't matter how hard they try. I've been very pleased with the results using statins. Almost all my patients have now got healthy cholesterol levels. What's more, we have lost far fewer people to strokes and heart attacks since we started using the drugs."



A Member of NICE (National Institute for Health and Clinical Excellence)

'We have looked at data from lots of really large, powerful research trials involving over 30 000 patients. The trials all show similar results. Using a statin drug can lower your chances of having a heart attack or stroke by 25 to 40%, and we didn't find too many side effects."

'I'm so pleased with my new medicine, the pills have brought my cholesterol levels right down and I'm feeling really well."

Patient 2

'The great thing about these new statins that the doctor has given me is that they control my cholesterol for me. It's back to the cream cakes and chips for me, and I won't have to worry about my heart!'

Patient 3

Patient 1

'I'm very worried about possible side effects with these new tablets - the leaflet said they can cause liver damage. I know my cholesterol levels were very high without the tablets, but I'm not sure about taking these tablets. I don't want my liver to be damaged!'

Examiner's tip

Statins are medical drugs which are used to reduce cholesterol levels in the blood. This reduces the risk of heart disease.

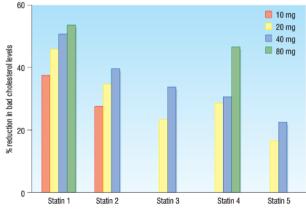


Figure 1 This graph shows the effects of different doses of different statins on the 'bad' cholesterol in the blood

Prescribed drugs v. non-prescribed

The medicines your doctor prescribes for you have been thoroughly tested and trialled. However some people choose to use non-prescribed medicines they buy for themselves. Some of these medicines are little more than sugar, flavouring and water. They will not hurt you – but they won't make you better either.

Some non-prescribed medicines can be dangerous. They are made from herbs and 'natural products' but can contain potentially dangerous chemicals.

Remember that many of our effective prescribed medicines come from living organisms.

You can only tell if a non-prescribed medicine is as effective as a prescribed medicine if it undergoes double-blind clinical trials. Very few of them are ever evaluated in this way because of the expense.

One example of a non-prescribed medicine which seems to work well is the herb St John's Wort. If you suffer from depression your doctor may prescribe Prozac (fluoxetine). Some people prefer to use non-prescribed St John's Wort (hypericum). It is a herbal remedy which has been used as an antidepressant for around 2000 years.

There have now been some scientific studies carried out. They compare the effectiveness of St John's Wort to the most commonly used antidepressant medicines. The evidence so far suggests that the herbal treatment is as effective as the most common medicines used to treat depression. It also seems more effective than placebos and it has fewer side effects than the prescribed medicines.

b Look at Figure 2. How much improvement in depression scores was seen over 12 weeks of using Prozac and St John's Wort?

Activity

There are lots of food products which claim to lower blood cholesterol. Investigate one of these claims.

- See how much evidence you can discover.
- Plan an investigation to help show whether this dietary supplement or alternative food can really lower blood cholesterol levels.

Summary questions

- Copy and complete using the words below:
 statins cholesterol lower cardiovascular risk
 If your blood levels are high you have an increased of disease. Drugs called can your risk and help to keep you healthy.
- 2 Explain why is it unwise to think that non-prescribed drugs cannot cause harmful side effects.

Activity

Write a short report on statins for the health page of your local paper.

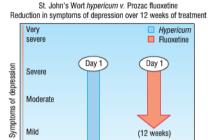


Figure 2 Data from one of a number of studies which show that hypericum (St John's Wort) is at least as effective as commonly prescribed drugs in treating decression

O links

(12 weeks)

Remission

For more information on cholesterol levels, see B1 1.3 Inheritance, exercise and health.

- Statins lower the amount of cholesterol in the blood and can reduce the risk of cardiovascular disease by up to 40%.
- The effectiveness of both prescribed and nonprescribed drugs can only be measured in proper double-blind trials.



Medicine and drugs

B1 3.3

Learning objectives

- What is a drug?
- What is addiction?
- Why are drugs such as cannabis, cocaine and heroin such a problem?

A Examiner's tip

Drugs are chemicals which alter the body's chemistry.

Many drugs are used as medicines to treat disease.

Drugs

A **drug** is a substance that alters the way in which your body works. It can affect your mind, your body or both. In every society there are certain drugs which people use for medicine, and other drugs which they use for pleasure.

Many of the drugs that are used both for medicine and for recreation come originally from natural substances, often plants. Many of them have been known to and used by indigenous (long-term inhabitants of an area) peoples for many years. Usually some of the drugs that are used for pleasure are socially acceptable and legal, while others are illegal.



Figure 1 Millions of pounds worth of illegal drugs are brought into the UK every year. It is a constant battle for the police to find and destroy drugs like these.

a What do we mean by 'indigenous peoples'?

Drugs are everywhere in our society. People drink coffee and tea, smoke cigarettes and have a beer, an alcopop or a glass of wine. They think nothing of it. Yet all of these things contain drugs – caffeine, nicotine and alcohol (the chemical ethanol). These drugs are all legal.

Other drugs, such as cocaine, ecstasy and heroin are illegal. Which drugs are legal and which are not varies from country to country. Alcohol is legal in the UK as long as you are over 18, but it is illegal in many Arab states. Heroin is illegal almost everywhere.

b Give an example of one drug which is legal and one which is illegal in the UK.

Because drugs affect the chemistry of your body, they can cause great harm. This is even true of drugs we use as medicines. However, because medical drugs make you better, it is usually worth taking the risk.

But legal recreational drugs, such as alcohol and tobacco, and illegal substances, such as solvents, cannabis and cocaine, can cause terrible damage to your body. Yet they offer no long-term benefits to you at all.

O links

For more information on the mental health problems that can be caused by cannabis, see B1 3.5

Does cannabis lead to hard drugs?

What is addiction?



Some drugs change the chemical processes in your body so that you may become addicted to them. You can become dependent on them. If you are addicted to a drug, you cannot manage properly without it. Some drugs, for example heroin and cocaine, are very addictive.

Once addicted, you generally need more and more of the drug to keep you feeling normal. When addicts try to stop using drugs they usually feel very unwell. They often have aches and pains, sweating, shaking, headaches and cravings for their drug. We call these withdrawal symptoms.

c What do we mean by 'addiction'?

The problems of drug abuse

People take drugs for a reason. Drugs can make you feel very good about yourself. They can make you feel happy and they can make you feel as if your problems no longer matter. Unfortunately, because most recreational drugs are addictive, they can soon become a problem themselves.

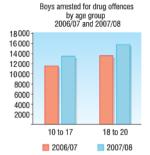
No drugs are without a risk. Cannabis is often thought of as a relatively 'soft' and therefore safe - drug. But evidence is growing which shows that cannabis smoke contains chemicals which can cause mental illness to develop in some people.

Hard drugs, such as cocaine and heroin, are extremely addictive. Using them often leads to very severe health problems. Some of these come from the drugs themselves. Others come from the lifestyle that often goes with drugs.

Because these drugs are illegal, they are expensive. Young people often end up turning to crime to pay for their drug habit. They don't eat properly or look after themselves. They can also contract serious illnesses, such as hepatitis. STDs (sexually transmitted diseases) and HIV/Aids especially if drugs are taken intravenously (via a needle).

Summary questions

- 1 Copy and complete using the words below: mind cocaine ecstasy legal alcohol drug body A alters the way in which your body works. It can affect the the or both. Some drugs are e.g. caffeine and Other drugs, such as and heroin are illegal.
- 2 a Why do people often need more and more of a drug?
 - b What happens if you stop taking a drug when you are addicted to it?
- 3 a Why do people take drugs?
 - b Explain some of the problems linked with using cannabis, cocaine and heroin.
 - c Look at Figure 2. What does this tell you about the difference in drug use between boys and girls?
 - d What does Figure 2 tell you about the trend in drug use in young
 - e Why do you think young people continue to take these drugs when they are well aware of the dangers?



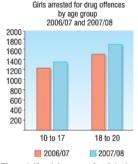


Figure 2 Illegal drugs are often linked with crime. In the UK more and more young people are being arrested for drug offences - using or selling illegal drugs.

- Drugs change the chemical processes in your body, so you may become addicted to them.
- Addiction is when you become physically or mentally dependent on a drug.
- Smoking cannabis may cause mental health problems.
- Hard drugs, such as cocaine and heroin, are very addictive and can cause serious health problems.



Medicine and drugs

B₁ 3.4

Learning objectives

- How do drugs like caffeine and heroin affect your nervous system?
- Which has the bigger overall impact on health – legal or illegal drugs?



Legal and illegal drugs

What is the most widely used drug in the world? It is probably one that most of you will have used at least once today, yet no one really thinks about. The caffeine in your cup of tea, mug of coffee or can of cola is a drug.

Many people find it hard to get going in the morning without a mug of coffee. They are probably addicted to the drug caffeine. It stimulates your brain and increases your heart rate and blood pressure.



Figure 1 NASA scientists have shown that common house spiders spin their webs very differently when given some commonly used legal and illegal drugs. The effect of caffeine on the nervous system of a spider is particularly dramatic!

a What drug is in a can of cola?

How do drugs affect you?

Many of the drugs used for medical treatments have little or no effect on your nervous system. However, all of the recreational drugs that people use for pleasure affect the way your nervous system works, particularly your brain. It is these changes that people enjoy when they use the drugs. The same changes can cause addiction. Once addicted, your body doesn't work properly without the drug.

Some drugs like caffeine, nicotine and cocaine speed up the activity of your brain. They make you feel more alert and energetic.

Others, like alcohol and cannabis, slow down the responses of your brain. They make you feel calm and better able to cope. Heroin actually stops impulses travelling in your nervous system. Therefore you don't feel any pain or discomfort. Cannabis produces vivid waking dreams. It can make you see or hear things that are not really there.

Why do people use drugs?

People use drugs for a variety of reasons. They feel that caffeine, nicotine and alcohol help them cope with everyday life. Few people who use these legal drugs would think of themselves as addicts. Yet the chemicals they take can have a big physical and psychological impact (see Figure 1).

As for the illegal recreational drugs – people who try them may be looking for excitement or escape. They might want to be part of the crowd or just want to see what happens. Yet many drugs are addictive and your body needs increasingly more to feel the effects.

Examiner's tip

Drugs may be:

- legal or illegal
- addictive or non-addictive.

Learn examples of all of these.



Impact of drugs on health

Some recreational drugs are more harmful than others. Most media reports on the dangers of drugs focus on illegal drugs. But in fact the impact of legal drugs on health is much greater than the impact of illegal drugs. That's because far more people take them. Millions of people in the UK take medicines such as statins, or smoke or drink alcohol. Only a few thousand take heroin.

A recent case history shows you how emotions and politics can be more important than scientific evidence in the way society reacts to drugs. In 2010, several young people died after apparently taking a relatively new legal drug known as 'meow-meow'. The drug was made illegal even though at least one of the 'victims' had not taken meow-meow.

In fact, in the UK, there are around 2000 deaths linked to using illegal drugs each year.

But every year in the UK around 9000 people die as a result of alcohol-abuse. About 90000 people die from smoking-related diseases. Yet alcohol and nicotine remain completely legal drugs.

Everyone can see the dangers to health of non-prescribed, illegal drugs. However, choosing which drugs to make illegal does not appear to be based on the scientific evidence of health damage alone.

b Why do legal drugs cause many more health problems than illegal drugs?



Figure 2 Drugs can seem appealing, exciting and fun. Many people use them briefly and then leave them behind. But the risks of addiction are high, and no one can predict whom drugs will affect most

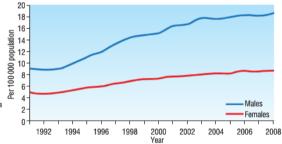


Figure 3 This graph shows how alcohol-related deaths almost doubled between 1990 and 2008 (Source: National Statistics Office)

Summary questions

- 2 Use data from Figure 3 to help you answer these:

than illegal ones.

- a How many men and women died of alcohol-related diseases per 100000 of the population in 1992?
- b How many men and women died of alcohol-related diseases per 100 000 of the population in 2008?
- c Suggest reasons for this increase in alcohol-related deaths.
- d Why do you think alcohol remains a legal drug when it causes so many deaths?
- 3 Compare the overall impact of legal and illegal drugs on the nation's health.

- Many recreational drugs affect the nervous system, particularly the brain. Some are more harmful than others.
- Some recreational drugs are legal and others are illegal.
- The overall impact of legal drugs on health is much greater than illegal drugs because more people use them.





B1 3.5

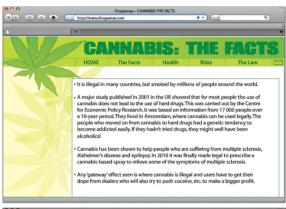
Learning objectives

- How do people move from using recreational drugs to hard drugs?
- Is cannabis harmful?



Figure 2 In the minds of many people parents, teachers and politicians – cannabis is a 'gateway' drug. It opens the door to the use of other much harder drugs such as cocaine and heroin. Your health – and indeed your life itself – is at isk. How accurate is this picture?

Cannabis - the facts?



Does cannabis lead to hard drugs?



Figure 1 How can you find out the truth about cannabis and the effect it might have on you, your friend or – if you are a parent – your child?

a What diseases are helped by the chemicals in cannabis?

Cannabis - where do you stand?

A lot of scientific research has been done into the effects of cannabis on our health. The links between cannabis use and addiction to hard drugs has also been investigated.

Unfortunately many of the studies have been quite small. They have not used large sample sizes, so the evidence is not strong.

The UK Government downgraded cannabis to a Class C drug in 2004. Then stronger negative evidence emerged. It found that cannabis use can trigger mental health problems in people who are vulnerable to such problems. In 2009 the decision to downgrade was reversed and cannabis is now a Class B drug again.

What the doctors say

- The evidence is clear that for some people cannabis use can trigger mental illness. This may be serious and permanent. It is particularly the case for people who have a genetic tendency to mental health problems.
- A study has been carried out on 1600 14- to 15-year-old students in Australia. It showed that the youngsters who use cannabis regularly have a significantly higher risk of depression. However it doesn't work the other way round. Children who are already suffering depression are no more likely than anyone else to use cannabis.
- All the evidence suggests that teenagers are particularly vulnerable to mental health problems triggered by cannabis. Consider a teenager who starts smoking cannabis before



Figure 3 The doctors at the Royal College of Psychiatrists are the people who deal with mental health problems of all kinds. They have some real concerns about cannabis-use.

they are 15. They are four times more likely to develop schizophrenia or another psychotic illness by the time they are 26 than a non-user.

Untangling the evidence

The evidence shows that almost all heroin users were originally cannabis users. This is not necessarily a case of cannabis use causing heroin addiction. Almost all cannabis users are originally smokers – but we don't claim that smoking cigarettes leads to cannabis usel In fact the vast majority of smokers do not go on to use cannabis. Just as the vast majority of cannabis users do not move on to hard drugs like heroin. Most studies suggest that cannabis can act as a 'gateway' to other drugs. However, that is **not** because it makes people want a stronger drug but because it puts them in touch with illegal drug dealers.

b How much does using cannabis before you are 15 appear to increase your risk of developing serious mental illness?

Summary questions

- 1 a What is meant by a 'gateway' drug?
 - **b** Why is cannabis considered a gateway drug?
- 2 Cannabis is linked to some mental health problems, but tobacco is known to cause hundreds of thousands of deaths each year through heart disease and lung cancer. Why do you think cannabis is illegal and tobacco is legal?

Activity

You are going to set up a classroom debate. The subject is:

'We believe that cannabis should be made a legal drug.'

You are going to prepare two short speeches – one for the idea of legalising cannabis and one against.

You can use the information on these pages and also look elsewhere for information. Try books and leaflets and on the internet.

In both of your speeches you must base your arguments on scientific evidence as well as considering the social, moral and ethical implications of any change in the law. You have to be prepared to argue your case (both for and against) and answer any questions – so do your research well!

- People can progress from using recreational drugs such as cannabis to addiction to hard drugs because cannabis is illegal and has to be obtained from a drug dealer.
- Cannabis smoke contains chemicals which may cause mental illness in some people. Teenagers are particularly vulnerable to this effect.



Medicine and drugs

B13.6

Learning objectives

- Can drugs make you better at sport?
- Is it ethical to use drugs to win?

Drugs in sport

The world of sport has a big problem with the illegal use of drugs. In theory, the only difference between competitors should be their natural ability and the amount they train. However, there are many performance-enhancing drugs that allow athletes to improve on their natural ability. The people who do this get labelled as cheats if they are caught.



Figure 1 Weightlifters need a lot of muscle so it can be tempting to cheat. Eleven Bulgarian weightlifters tested positive for anabolic steroids and were disqualified from the 2008 Olympics.

Performance-enhancing drugs

Different sports need different things from the competitors.

Anabolic **steroids** are drugs that help build up muscle mass. They are used by athletes who need to be very strong, such as weightlifters. Athletes who need lots of muscle to be very fast, such as sprinters, also sometimes use anabolic steroids. Taking anabolic steroids and careful training means you can make much more muscle and build it where you want it.

Strong painkilling drugs can allow an athlete to train and compete with an injury, causing further and perhaps permanent damage. These drugs are illegal for use by people involved in sport.

Different sports need great stamina – marathons and long distance cycling races are two examples. Some cyclists (and other athletes) use a drug to stimulate their body to make more red blood cells. This means they can carry more oxygen to their muscles. The drug is a compound found naturally in the body so drug-testers are looking for abnormally high levels of it.

Fast reactions are vital in many sports, and there are drugs that will make you very alert and on edge. On the other hand, in sports such as darts and shooting, you need very steady hands. Some athletes take drugs to slow down their heart and reduce any shaking in their hands to try and win medals.

a What are anabolic steroids and why do athletes use them?

Catching the cheats

Athletes found using illegal drugs are banned from competing. The sports authorities keep producing new tests for drugs and run random drugs tests to try and identify the cheats. But some competitors are always looking for new ways to cheat without being found out. So the illegal use of drugs in sport continues. Some medicines contain banned drugs which can enhance performance, so athletes need to be very careful so they don't end up 'cheating' by accident.



Figure 2 The Tour de France has had many drug problems. Cyclists have died after using illegal drugs to help them go faster. Floyd Landis, the winner in 2006, as disqualified for using steroids.

The ethics of using drugs in sport

There are lots of ways an athlete can improve their performance. Where does wanting to win end and cheating begin? Is the use of performance-enhancing substances ever acceptable in sport? These are questions scientists cannot answer – society has to decide

For example, if an athlete lives and trains at high altitude for several weeks, their body makes a hormone which increases their red blood cell count. This is legal. But it is illegal to buy the hormone and inject it to make more red blood cells.

Here are some of the arguments that athletes use to justify the use of substances that are banned and could do them harm:



- They feel that other athletes are using these substances, and unless they take them they will be left behind.
- They think the health risks are just scare stories.
- Some athletes claim that they did not know they were taking drugs their coaches supply them hidden in 'supplements'.

There are a number of ethical points that society needs to consider. Top athletes compete for the satisfaction of winning and millions of people enjoy watching them. Most performance-enhancing drugs risk the health of the athlete at the high doses used in training. They can even cause death. Even if the individual is prepared to take the risk, is this ethically acceptable? At the moment most people say 'no'.

Often the substances used by cheats are so expensive, or new, that most competitors can't afford them. This gives the richest competitors an unfair advantage. For example, most athletes could afford anabolic steroids if they wanted to use them, but not the most recent versions that are not detected by the drug-testing process.

There are some people who think that athletes should be able to do what they like with their bodies. At the moment most of society does not agree with this view – what do you think?

b Why do athletes use drugs which could cause them harm?

Summary questions

- 2 Suggest the advantages and disadvantages to an athlete of using banned performance-enhancing drugs to help win a competition.
- 3 It has been suggested that athletes be allowed to use any drugs to improve their performance. Suggest arguments for and against this proposal.



Figure 3 Athletes can be asked to produce a urine sample for a drug test at any time, whether they are competing, training or resting

AQA Examiner's tip

Make sure you understand why athletes are banned from using some medical drugs.

- Anabolic steroids and other banned performanceenhancing drugs are used by some athletes.
- The use of performanceenhancing drugs is considered unethical by most people.



Medicine and drugs: B1 3.1-B1 3.6

Summary questions (2)



- 1 a Why do new medicines need to be tested and trialled before doctors can use them to treat their patients?
 - b Why is the development of a new medicine so expensive?
 - c Do you think it would ever be acceptable to use a new medicine before all the trials had been completed?
- a What is a statin?
 - b How do statins help reduce the number of people who suffer from cardiovascular disease?
 - c Which of the statins in Figure 1, B1 3.2 is most effective?
 - d The most effective drug is not always the one used. Why do you think other statins might be prescribed?
- Some students decided to test whether drinking coffee could affect heart rate. They asked the class to help them with their investigation. They divided the class into two groups. Both groups had their pulses taken. They gave one group a drink of coffee. They waited for 10 minutes and then took their pulses again. They then followed the same procedure with the second group.
 - a What do you think the second group were asked to drink?
 - b State a control variable that should have been used.
 - c Explain why it would have been a good idea not to tell the two groups exactly what they were drinking.
 - d Study this table of results that they produced.

Group	Increase in pulse rate (beats per minute)
With caffeine	12, 15, 13, 10, 15, 16, 10, 15, 16, 21, 14, 13, 16
Without caffeine	4, 3, 4, 5, 7, 5, 7, 4, 2, 6, 5, 4, 7

Can you detect any evidence for systematic error in these results? If so, describe this evidence.

- e Is there any evidence for a random error in these results? If so, describe this evidence.
- f What is the range for the increase in pulse rates without caffeine?
- g What is the mean (or average) increase in pulse rate:
 - i with caffeine?
 - ii without caffeine?

- Look at Figure 3, B1 3.4, Compare the data in that graph to Figure 2, B1 3.3. Both show impact of drug taking on individuals in society.
 - a What are the similarities between the two data sets?
 - b Explain the relative impact of legal and illegal drugs on individuals and on society.
 - 5 a Why do some athletes use illegal drugs, such as anabolic steroids, when they are training or competing?
 - b What are the arguments for and against the use of these performance-enhancing drugs?
 - c People sometimes use illegal performance-enhancing drugs on horses. They use pain killers, stimulants and substances which make the skin on their legs very sensitive. Sometimes they are given sedatives so they run slowly. Discuss the ethical aspects of giving performance-changing drugs to animals.

AQA Examination-style questions (L)

People take drugs for many different reasons.
 alcohol heroin penicillin statin steroid thalidomide

Choose a word from above to match the following sentences.

- a an illegal drug which is highly addictive (1
- **b** a drug used by athletes to make them perform better
- c a medical drug which is used to reduce cholesterol levels (1
- 2 A drug company wants to test a new painkiller called PainGo2. The company hope that the new drug will cure headaches quicker than PainGo1.

PainGo2 has to be tested in clinical trials. PainGo2 is twice as strong as PainGo1.

Phase 1 trial – a few healthy people will be given one or two tablets of PainGo2.

Phase 2 trial – a small group (200–300) of patients with headaches will be given PainGo2.

Phase 3 trial – 3 large groups (2000 in each group) of patients with headaches will be given either PainGo2 or PainGo1 or a placebo.

- a What is the purpose of the Phase 1 trial? (1)
- **b** Suggest why in Phase 2 the patients were asked to record how they felt after taking the PainGo2.

Suggest why. (1)

- c What is a placebo? (1)
- d Phase 3 was done as a double-blind trial by doctors who had patients with headaches.

In a double-blind trial who will know who is given the new drug?

Choose your answer from the choices below.

- A the patient only
- B the doctor only
- C both the doctor and the patient
- D neither the doctor nor the patient (1)
- e Why is it important to use the placebo in the Phase 3 trial? (1)
- f Why are some patients given PainGo1 in Phase 3? (1)
- 3 a Give one example of:
 - i a legal recreational drug (1)
 - ii an illegal recreational drug. (1)

- b Some recreational drugs are addictive.
 - i Give one example of a recreational drug that is very addictive.
 - Explain how the action of a drug makes a person become addicted to it.
- c Some doctors think that smoking cannabis causes depression. Doctors investigated the cannabis smoking habits of 1500 young adults.

The table shows the percentage of cannabis smokers in the investigation who became depressed.

How many times the men or women had smoked cannabis in the last 12 months	Percentage of men who became depressed	Percentage of women who became depressed
Less than 5 times	9	16
More than 5 times, but less than once per week	10	17
1-4 times per week	12	31
Every day	15	68

From the data, give **two** conclusions that can be drawn about the relationship between cannabis and depression.

AQA, 2007

4 In this question you will be assessed on using good English, organising information clearly and using specialist terms where appropriate.

Read the description of an investigation into the link between smoking cannabis and heroin addiction.

Six 'teenage' rats were given a small dose of THC – the active chemical in cannabis – every three days between the ages of 28 and 49 days. This is the equivalent of human ages 12 to 18.

The amount of THC given was roughly equivalent to a human smoking one cannabis 'joint' every three days.

A control group of six 'teenage' rats did not receive THC. After 56 days catheters (narrow tubes) were inserted in

After 56 days catheters (narrow tubes) were inserted in all twelve of the now adult rats and they were able to selfadminister heroin by pushing a lever.

All the rats began to self-administer heroin frequently. After a while, they stabilised their daily intake at a certain level.

The ones that had been on THC as 'teenagers' stabilised their heroin intake at a much higher level than the others. They appeared to be less sensitive to the effects of heroin. This pattern continued throughout their lives.

Reduced sensitivity to the heroin means that the rats take larger doses. This has been shown to increase the risk of addiction.

Evaluate this investigation with respect to establishing a link between cannabis smoking and heroin addiction in humans. Remember to include a conclusion to your evaluation.

AQA, 2007



Adaptation for survival

B₁ 4.1

Learning objectives

- What do organisms need to live?
- How do organisms survive in many different conditions?

O links

For more information on plant adaptation, see B1 4.3 Adaptation in plants.

A()A Examiner's tip

Practise recognising plant and animal adaptations and try to work out where they might live from the adaptation. This will help in your examination where you may be asked to do the same.

O links

For more information on animal adaptation, see B1 4.2 Adaptation in animals.

Adapt and survive

The variety of conditions on the surface of the Earth is huge. It ranges from hot, dry deserts to permanent ice and snow. There are deep, saltwater oceans and tiny freshwater pools. Whatever the conditions, almost everywhere on Earth you will find living organisms able to survive and reproduce.

Survive and reproduce

Living organisms need a supply of materials from their surroundings and from other living organisms so they can survive and reproduce successfully. What they need depends on the type of organism.

- Plants need light, carbon dioxide, water, oxygen and nutrients to produce glucose energy in order to survive.
- Animals need food from other living organisms, water and oxygen.
- Microorganisms need a range of things. Some are like plants, some are like animals and some don't need oxygen or light to survive.

Living organisms have special features known as **adaptations**. These features make it possible for them to survive in their particular habitat, even when the conditions are very extreme.

Plant adaptations

Plants need to photosynthesise to produce the glucose needed for energy and growth. They also need to have enough water to maintain their cells and tissues. They have adaptations that enable them to live in many different places. For example, most plants get water and nutrients from the soil through their roots. Epiphytes are found in rainforests. They have adaptations which allow them to live high above the ground attached to other plants. They collect water and nutrients from the air and in their specially adapted leaves.



Figure 1 Mangroves are trees that live in soil with very little oxygen, often with their roots covered by salty water. They have special adaptations to get rid of the salt through their leaves, and roots which grow in the air to get oxygen.

Some plant adaptations are all about reproduction. *Rafflesia arnoldii* produces flowers which are 1 m across, weigh about 11 kg and smell of a rotting corpse. The plants are rare so the dramatic and very smelly flower increases the chances of flies visiting and carrying pollen from one plant to another.

a Why do plants need to photosynthesise?

Animal adaptations

Animals cannot make their own food. They have to eat plants or other animals. Many of the adaptations of animals help them to get the food they need. So you can tell what a mammal eats by looking at its teeth. Herbivores have teeth for grinding up plant cells. Carnivores have teeth adapted for tearing flesh or crushing bones. Animals also often have adaptations to help them find and attract a mate.

Adapting to the environment



Some of the adaptations seen in animals and plants help them to survive in a particular environment. Some sea birds get rid of all the extra salt they take in from the sea water by 'crying' very salty tears from a special salt gland. Animals that need to survive extreme winter temperatures often produce a chemical in their cells which acts as antifreeze. It stops the water in the cells from freezing and destroying the cell. Plants such as water lilies have lots of big air spaces in their leaves. This adaptation enables them to float on top of their watery environment and make food by photosynthesis.

Organisms that survive and reproduce in the most difficult conditions are known as extremophiles.

Living in extreme environments

Microorganisms are found in more places in the world than any other living thing. These places range from ice packs to hot springs and gevsers. Microorganisms have a range of adaptations which make this possible. Many extremophiles are microorganisms.

Some extremophiles live at very high temperatures. Bacteria known as thermophiles can survive at temperatures of over 45 °C and often up to 80 °C or higher. In most organisms the enzymes stop working at around 40°C. These extremophiles have specially adapted enzymes that do not denature and so work at these high temperatures. In fact, many of these organisms cannot survive and reproduce at lower temperatures.

Other bacteria have adaptations so they can grow and reproduce at very low temperatures, down to -15°C. They are found in ice packs and glaciers around the world.

Most living organisms struggle to survive in a very salty environment because of the problems it causes with water balance. However, there are species of extremophile bacteria that can only live in extremely salty environments such as the Dead Sea and salt flats. They have adaptations to their cytoplasm so that water does not move out of their cells into their salty environment. But in ordinary sea water, they would swell up and burst!

b What is a thermophile?

Summary questions

- 1 Copy and complete using the words below: adaptations organisms materials survive extreme To and reproduce, organisms need a supply of from their surroundings and the living in their habitat. They have that enable them to survive in their particular habitat, even when the conditions are very
- 2 Make a list of what plants and animals need from their surroundings to survive and reproduce.
- 3 a What is an extremophile?
 - **b** Give two examples of adaptations found in different extremophiles.



Figure 2 Animals from the deep oceans are adapted to cope with enormous pressure, no light and very cold, salty water. If these extremophiles are brought to the surface too quickly, they explode because of the rapid change in pressure.



Figure 3 Black smoker bacteria live in deep ocean vents, 2500 m down, at temperatures of well over 100°C, with enormous pressure, no light and an acid pH of about 2.8. They have adaptations to cope with some of the most extreme conditions on Earth.

- Organisms need a supply of materials from their surroundings and from other living organisms to survive and reproduce.
- Organisms have features (adaptations) that enable them to survive in the conditions in which they normally live.
- Extremophiles have adaptations enabling them to live in extreme conditions of salt, temperature or pressure.



Adaptation for survival

B₁ 4.2

Learning objectives

- How can hair help animals survive in very cold climates?
- What are the advantages and disadvantages - of lots of body fat?
- How do animals adapt to hot. dry climates?

Examiner's tip

Remember, the larger the animal, the smaller the surface area:volume (SA:V) ratio.

Animals often have increased surface areas in hot climates. and decreased surface areas in cold climates.

O links

For more information about other implications of surface area: volume ratios, see B3 1.4 Exchanging materials - the lungs.



Figure 1 The Arctic is a cold and bleak environment. However, the animals that live there are well adapted for survival. Notice the large size, small ears, thick coat and white camouflage of this polar

Adaptation in animals

Animals have adaptations that help them to get the food and mates they need to survive and reproduce. They also have adaptations for survival in the conditions where they normally live.

Animals in cold climates (K)



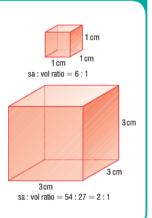
To survive in a cold environment you must be able to keep yourself warm. Animals which live in very cold places, such as the Arctic, are adapted to reduce the energy they lose from their bodies. You lose body heat through your body surface (mainly your skin). The amount of energy you lose is closely linked to your surface area: volume (SA:V) ratio.

Maths skills

Surface area: volume ratio (K

The surface area: volume ratio is very important when you look at the adaptations of animals that live in cold climates. It explains why so many Arctic mammals, such as seals, walruses, whales and polar bears, are relatively large.

The ratio of surface area to volume falls as objects get bigger. You can see this clearly in the diagram. The larger the surface area: volume ratio. the larger the rate of energy loss. So mammals in a cold climate grow to a large size. This keeps their surface area: volume ratio as small as possible and so helps them hold on to their body heat.



a Why are so many Arctic animals large?

Animals in very cold climates often have other adaptations too. The surface area of the thinly skinned areas of their bodies, like their ears, is usually very small. This reduces their energy loss.

Many Arctic mammals have plenty of insulation, both inside and out. Inside they have blubber (a thick layer of fat that builds up under the skin). On the outside a thick fur coat will insulate an animal very effectively. These adaptations really reduce the amount of energy lost through their skin.

The fat layer also provides a food supply. Animals often build up their fat in the summer. Then they can live off their body fat through the winter when there is almost no food.

b List three ways in which Arctic animals keep warm in winter.

Camouflage

Camouflage is important both to predators (so their prey doesn't see them coming) and to prey (so they can't be seen). The colours that would camouflage an Arctic animal in summer against plants would stand out against the snow in winter. Many Arctic animals, including the Arctic fox, the Arctic hare and the stoat, have grey or brown summer coats that change to pure white in the winter. Polar bears don't change colour. They have no natural predators on the land. They hunt seals all year round in the sea, where their white colour makes them less visible among the ice.

The colour of the coat of a lioness is another example of effective camouflage. The sandy brown colour matches perfectly with the dried grasses of the African savannah. Her colour hides the lioness from the grazing animals which are her prey.

Surviving in dry climates

Dry climates are often also hot climates – like deserts. Deserts are very difficult places for animals to live. There is scorching heat during the day, followed by bitter cold at night. Water is also in short supply.

The biggest challenges if you live in a desert are:

- · coping with the lack of water
- stopping body temperature from getting too high.

Many desert animals are adapted to need little or nothing to drink. They get the water they need from the food they eat.

Mammals keep their body temperature the same all the time. So as the environment gets hotter, they have to find ways of keeping cool. Sweating means they lose water, which is not easy to replace in the desert.

c Why do mammals try to cool down without sweating in hot, dry conditions?

Animals that live in hot conditions adapt their behaviour to keep cool. They are often most active in the early morning and late evening, when it is not so hot. During the cold nights and the heat of the day they rest in burrows where the temperature doesn't change much.

Many desert animals are quite small, so their surface area is large compared to their volume. This helps them to lose heat through their skin. They often have large, thin ears to increase their surface area for losing energy.

Another adaptation of many desert animals is to have thin fur. Any fur they do have is fine and silky. They also have relatively little body fat stored under the skin. These features make it easier for them to lose energy through the surface of the skin.

Summary questions

- 1 a List the main problems that face animals living in cold conditions like the Arctic.
 - b List the main problems that face animals living in the desert.
- 2 Animals that live in the Arctic are adapted to keep warm through the winter. Describe three of these adaptations and explain how they work.
- 3 a Using Figure 2, describe the visible adaptations of a jerboa and an elephant to keeping cool in hot conditions.
 - b Suggest other ways in which animals might be adapted to survive in hot, dry conditions.





Figure 2 Jerboas are very small and elephants are very big. They both show clear adaptations that help them survive in the hot, dry places where they live.

- All living things have adaptations that help them to survive in the conditions where they live.
- Animals that are adapted for cold environments are often large, with a small surface area:volume (SA:V) ratio.
 They have thick insulating layers of fat and fur.
- Changing coat colour in the different seasons gives animals year-round camouflage.
- Adaptations for hot, dry environments include a large SA: V ratio, thin fur, little body fat and behaviour patterns that avoid the heat of the day.



Adaptation for survival

B₁ 4.3

Learning objectives

- How do plants lose water?
- How are plants adapted to live in dry conditions?

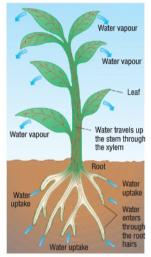


Figure 1 Plants lose water vapour from the surface of their leaves. When the conditions are hot and dry, they may lose water very quickly.

O links

For information on surface area: volume ratio, look back at B1 4.2 Adaptation in animals.



Figure 2 Marram grass grows on sand dunes. It has tightly curled leaves to reduce the surface area for water loss so can survive the dry conditions.

Adaptation in plants

Plants need light, water, space and nutrients to survive. There are some places where plants cannot grow. In deep oceans no light penetrates and so plants cannot photosynthesise. In the icy wastes of the Antarctic it is simply too cold for plants to grow.

Almost everywhere else, including the hot, dry areas of the world, you find plants growing. Without them there would be no food for the animals. But plants need water for photosynthesis and to keep their tissues supported. If a plant does not get the water it needs, it wilts and eventually dies.

a Why do plants need water?

Plants take in water from the soil through their roots. It moves up through the plant and into the leaves. There are small openings called **stomata** in the leaves of a plant. These open to allow gases in and out for photosynthesis and **respiration**. At the same time water vapour is lost through the stomata by evaporation.

The rate at which a plant loses water is linked to the conditions it is growing in. When it is hot and dry, photosynthesis and respiration take place quickly. As a result, plants also lose water vapour very quickly. Plants that live in very hot, dry conditions need special adaptations to survive. Most of them either reduce their surface area so they lose less water or store water in their tissues. Some do both!

b How do plants lose water from their leaves?

Changing surface area

When it comes to stopping water loss through the leaves, the surface area:volume ratio is very important to plants. A few desert plants have broad leaves with a large surface area. These leaves collect the dew that forms in the cold evenings. They then funnel the water towards their shallow roots.

Some plants in dry environments have curled leaves. This reduces the surface area of the leaf. It also traps a layer of moist air around the leaf. This reduces the amount of water the plant loses by evaporation.

Most plants that live in dry conditions have leaves with a very small surface area. This adaptation cuts down the area from which water can be lost. Some desert plants have small fleshy leaves with a thick cuticle to keep water loss down. The cuticle is a waxy covering on the leaf that stops water evaporating.

The best-known desert plants are the cacti. Their leaves have been reduced to spines with a very small surface area indeed. This means the cactus only loses a tiny amount of water. Not only that, its sharp spines also put animals off eating the cactus.

Why do plants often reduce the surface area of their leaves?

Collecting water

Many plants that live in very dry conditions have specially adapted and very big root systems. They may have extensive root systems that spread over a very wide area, roots that go down a very long way, or both. These adaptations allow the plant to take up as much water as possible from the soil. The mesquite tree has roots that grow as far as 50 m down into the soil.

Storing water

Some plants cope with dry conditions by storing water in their tissues. When there is plenty of water after a period of rain, the plant stores it. Some plants use their fleshy leaves to store water. Others use their stems or roots.

For example, cacti don't just rely on their spiny leaves to help them survive in dry conditions. The fat green body of a cactus is its stem, which is full of water-storing tissue. These adaptations make cacti the most successful plants in a hot, dry climate.



Figure 3 A large saguaro cactus in the desert loses less than one class of water a day. A UK apple tree can lose a whole bath of water in the same amount of time!

d In which parts can a plant store its water?

Summary questions

- 1 Copy and complete using the words below: adaptations desert plants spines stems water Cacti are that live in the They have two main to help them survive. Their leaves have become and they storein their
- 2 a Explain why plants lose water through their leaves all the time. b Why does this make living in a dry place such a problem?
- 3 Plants living in dry conditions have adaptations to reduce water loss from their leaves. Give three of these and explain how they work.

O links

For more information about water loss in plants, see B3 1.9 Transpiration.

(()A Examiner's tip

Remember that plants need their stomata open for photosynthesis and respiration. This is why they lose water by evaporation from their leaves.

- Plants lose water vapour from the surface of their leaves.
- Plant adaptations for surviving in dry conditions include reducing the surface area of the leaves, having water-storage tissues and having extensive root systems.



Adaptation for survival

B1 4.4

Learning objectives

- What is competition?
- What makes an animal a good competitor?



Figure 1 Some herbivores only feed on one particular plant. Pandas only eat bamboo, so they are open to competition from other animals or to diseases that damage bamboo.





Figure 2 The coral snake (top) is poisonous but the milk snake (bottom) is not. The milk snake is a mimic - it looks like the coral snake. As long as the two species live in the same area the milk snake is protected. Other animals and people leave it alone thinking it is a oisonous coral snake!

Competition in animals

Animals and plants grow alongside lots of other living things. Some will be from the same species and others will be completely different. In any area there is only a limited amount of food, water and space, and a limited number of mates. As a result, living organisms have to compete for the things they

The best adapted organisms are most likely to win the competition for resources. They will be most likely to survive and produce healthy offspring.

a Why do living organisms compete?

What do animals compete for? (13)



Animals compete for many things, including:

- food
- territory
- mates.

Competition for food

Competition for food is very common. Herbivores sometimes feed on many types of plant, and sometimes on only one or two different sorts. Many different species of herbivores will all eat the same plants. Just think how many types of animals eat grass!

The animals that eat a wide range of plants are most likely to be successful. If you are a picky eater, you risk dying out if anything happens to your only food source. An animal with wider tastes will just eat something else for a while!

Competition is common among carnivores. They compete for prey. Small mammals like mice are eaten by animals like foxes, owls, hawks and domestic cats. The different types of animals all hunt the same mice. So the animals which are best adapted to the area will be most successful.

Carnivores have to compete with their own species for their prey as well as with different species. Some successful predators are adapted to have long legs for running fast and sharp eyes to spot prev. These features will be passed on to their offspring.

Animals often avoid direct competition with members of other species when they can. It is the competition between members of the same species which is most intense.

Prev animals compete with each other too - to be the one that isn't caught! Their adaptations help prevent them becoming a meal for a predator. Some animals contain poisons which make anything that eats them sick or even kills them. Very often these animals also have bright warning colours so that predators quickly learn which animals to avoid. Poison arrow frogs are a good example.

b Give one useful adaptation for a herbivore and one for a carnivore.

Competition for territory

For many animals, setting up and defending a territory is vital. A territory may simply be a place to build a nest. It could be all the space needed for an animal to find food and reproduce. Most animals cannot reproduce successfully if they have no territory. So they will compete for the best spaces. This helps to make sure they will be able to find enough food for themselves and for their young.

Competition for a mate

Competition for mates can be fierce. In many species the male animals put a lot of effort into impressing the females. The males compete in different ways to win the privilege of mating with a female.

In some species – like deer and lions – the males fight between themselves. Then the winner gets the females.

Many male animals display to the females to get their attention. Some birds have spectacular adaptations to help them stand out. Male peacocks have the most amazing tail feathers. They use them for displaying to other males (to warn them off) and to females (to attract them).

What makes a successful competitor?

A successful competitor is an animal that is adapted to be better at finding food or a mate than the other members of its own species. It also needs to be better at finding food than the members of other local species. It must be able to breed successfully.

Many animals are successful because they avoid competition with other species as much as possible. They feed in a way that no other local animals do, or they eat a type of food that other animals avoid. For example, one plant can feed many animals without direct competition. While caterpillars eat the leaves, greenfly drink the sap, butterflies suck nectar from the flowers and beetles feed on pollen.



Figure 3 The territory of a gannet pair may be small but without a space they cannot build a nest and reproduce



Figure 4 The spectacular display of a male peacock attracts females. Unlike deer and lions he doesn't need to fight and risk injury.

Examiner's tip

Learn to look at an animal and spot the adaptations that make it a successful competitor.

Summary questions

- 1 a Give an example of animals competing with members of the same species for food.
 - b Give an example of animals competing with members of other species for food.
 - c Animals that rely on a single type of food can easily become extinct. Explain why.
- 2 a Give two ways in which animals compete for mates.
 - b Suggest the advantages and disadvantages of the methods chosen in part a.
- 3 Explain the adaptations you would expect to find in:
 - a an animal that hunts mice
 - b an animal that eats grass
 - c an animal that hunts and eats other animals
 - d an animal that feeds on the tender leaves at the top of trees.

- Animals often compete with each other for food, territories and mates.
- Animals have adaptations that make them good competitors.



Adaptation for survival

B₁ 4.5

Learning objectives

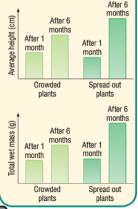
- What do plants compete for?
- How do plants compete?



Practical

Investigating competition in plants

Carry out an investigation to look at the effect of competition on plants. Set up two trays of seeds - one crowded and one spread out. Then monitor the plants' height and wet mass (mass after watering). Keep all of the conditions - light level, the amount of water and nutrients available and the temperature - exactly the same for both sets of plants. The differences in their growth will be the result of overcrowding and competition for resources in one of the groups. The data show growth of tree seedlings. You can get results in days rather than months by using cress seeds.



Competition in plants

Plants compete fiercely with each other. They compete for:

- light for photosynthesis, to make food using energy from sunlight
- water for photosynthesis and to keep their tissues rigid and supported
- nutrients (minerals) so they can make all the chemicals they need in their cells
- space to grow, allowing their roots to take in water and nutrients, and their leaves to capture light.
 - a What do plants compete with each other for?

Why do plants compete? (K)



Just like animals, plants are in competition both with other species of plants and with their own species. Big, tall plants such as trees take up a lot of water and nutrients from the soil. They also prevent light from reaching the plants beneath them. So the plants around them need adaptations to help them to survive.

When a plant sheds its seeds they might land nearby. Then the parent plant will be in direct competition with its own seedlings. Because the parent plant is large and settled, it will take most of the water, nutrients and light. So the plant will deprive its own offspring of everything they need to grow successfully. The roots of some desert plants even produce a chemical that stops seeds from germinating, killing the competition even before it begins to grow!

Sometimes the seeds from a plant will all land close together, a long way from their parent. They will then compete with each other as they grow.

b Why is it important that seeds are spread as far as possible from the parent plant?

Coping with competition

Plants that grow close to other species often have adaptations which help them to avoid competition.

Small plants found in woodlands often grow and flower very early in the year. This is when plenty of light gets through the bare branches of the trees. The dormant trees take very little water out of the soil. The leaves shed the previous autumn have rotted down to provide nutrients in the soil. Plants like snowdrops, anemones and bluebells are all adapted to take advantage of these things. They flower, set seeds and die back again before the trees are in full leaf.

Another way plants compete successfully is by having different types of roots. Some plants have shallow roots taking water and nutrients from near the surface of the soil. Others have long, deep roots, which go far underground. Both compete successfully for what they need without affecting the other.

If one plant is growing in the shade of another, it may grow taller to reach the light. It may also grow leaves with a bigger surface area to take advantage of all the light it does get.

Some plants are adapted to prevent animals from eating them. They may have thorns, like the African acacia or the blackberry. They may make poisons that mean they taste very bitter or make the animals that eat them ill. Either way they compete successfully because they are less likely to be eaten than other plants.

c How can short roots help a plant to compete successfully?

Spreading the seeds (R)



To reproduce successfully, a plant has to avoid competition with its own seedlings. Many plants use the wind to help them spread their seeds as far as possible. They produce fruits or seeds with special adaptations for flight to carry their seeds away. Examples of this are the parachutes of the dandelion 'clock' and the winged seeds of the sycamore tree.

d How do the fluffy parachutes of dandelion seeds help the seeds to spread out?

Some plants use mini-explosions to spread their seeds. The pods dry out, twist and pop, flinging the seeds out and away.

Juicy berries, fruits and nuts are adaptations to tempt animals to eat them. The fruit is digested and the tough seeds are deposited well away from the parent plant in their own little pile of fertiliser!

Fruits that are sticky or covered in hooks get caught up in the fur or feathers of a passing animal. They are carried around until they fall off hours or even days later.

Sometimes the seeds of several different plants land on the soil and start to grow together. The plants that grow fastest will compete successfully against the slower-growing plants. For example:

- The plants that get their roots into the soil first will get most of the available water and nutrients.
- The plants that open their leaves fastest will be able to photosynthesise and grow faster still, depriving the competition of light.

Summary questions

- 1 a How can plants overcome the problems of growing in the shade of another plant?
 - b How do bluebell plants grow and flower successfully in spite of living under large trees in a wood?
- 2 a Why is it so important that plants spread their seeds successfully?
- b Give three examples of successful adaptations for spreading seeds.
- 3 The dandelion is a successful weed. Carry out some research and evaluate the adaptations that make it a better competitor than other plants on a school field.



Figure 1 Plants have different types of roots to compete for water and nutrients in the soil



Figure 2 The winged seeds of the sycamore tree



Figure 3 Coconuts will float for weeks or even months on ocean currents, which can carry them hundreds of miles from their parents - and any other coconuts!

- Plants often compete with each other for light, for water and for nutrients (minerals) from the soil.
- Plants have many adaptations that make them good competitors.





B14.6

Learning objectives

- How do organisms survive in very unusual conditions?
- What factors are organisms competing for in a habitat?



Figure 1 A fig tree

How do you survive?

So far in this chapter we have looked at lots of different ways in which living organisms are adapted. This helps them to survive and reproduce wherever they live. We have looked at why they need to compete successfully against their own species and others. Now we are going to consider three case studies of adaption in living organisms.

Figs and fig wasps

There are about 700 different species of fig trees. Each one has its own species of pollinating wasps, without which the trees will die. The fig flowers of the trees are specially adapted so that they attract the right species of wasp.

Female fig wasps have specially shaped heads for getting into fig flowers. They also have **ovipositors** that allow them to place their eggs deep in the flowers of the fig tree.

Male fig wasps vary. Some species can fly but others are adapted to live in a fig fruit all their life. If they are lucky, a female wasp will arrive in the flower and the male will fertilise her. After this he digs an escape tunnel for the female through the fruit and dies himself! The male wasp has special adaptations (such as the loss of his wings and very small eyes) which help him move around inside the fig fruit to find a female.



Figure 2 A female (top) and male (bottom) fig wasp

If a fig tree cannot attract the right species of wasp, it will never be able to reproduce. In fact in some areas the trees are in danger of extinction because the wasp populations are being wiped out.



The fastest predator in the world?

It takes you about 650 milliseconds to react to a crisis. But the star-nosed mole takes only 230 milliseconds from the moment it first touches its prey to gulping it down. That's faster than the human eye can see!

What makes this even more amazing is that star-nosed moles live underground and are almost totally blind. Their main sense organ is a crown of fleshy tendrils around the nose – incredibly sensitive to touch and smell but very odd to look at. The ultra-sensitive tendrils can try out 13 possible targets every second.

It seems likely that they have adapted to react so quickly because they can't see what is going on. They need to grab their prey as soon as possible after they touch it. If they don't it might move away or try to avoid them, and they wouldn't know where it had gone.



Figure 3 The star-nosed mole

A carnivorous plant

Venus flytraps are plants that grow on bogs. Bogs are wet and their peaty soil has very few nutrients in it. This makes it a difficult place for plants to live.

The Venus flytrap has special 'traps' that contain sweet smelling nectar. They sit wide open showing their red insides. Insects are attracted to the colour and the smell. Inside the trap are many small, sensitive hairs. As the insect moves about to find the nectar, it will brush against these hairs. Once the hairs have been touched, the trap is triggered. It snaps shut and traps the insect inside.

Special enzymes then digest the insect inside the trap. The Venus flytrap uses the nutrients from the digested bodies of its victims. This is in place of the nutrients that it cannot get from the poor bog soil. After the insect has been digested, the trap reopens ready to try again.



Figure 4 The Venus flytrap – an insect-eating plant

Activity

Case studies

- For each of these three case studies, list how the organisms are adapted for their habitat and how these adaptations help them to compete successfully against both their own species and other species.
- Choose three organisms that you know something about or find out about three organisms which interest you. Make your own fact file on their adaptations and how these adaptations help them to compete successfully. Include at least one plant.

Summary questions

- 1 Explain how both of the animals featured compete successfully for food.
- 2 Why could any species of fig tree or fig wasp easily die out? Give a reason for each.
- 3 Carry out research to explain the adaptations of a giraffe and why they help it to compete successfully with other animals living in the same area.

- Organisms have adaptations which enable them to survive in the conditions in which they normally live.
- Plants often compete with each other for light, water and nutrients from the soil.
- Animals often compete with each other for food, mates and territory.



Adaptation for survival

B₁ 4.7

Learning objectives

- What affects the distribution of living things?
- What causes environmental changes?
- How can we measure environmental changes?



Figure 1 The distribution of bullhorn acacia ants depends on where the swollen-thorn acacia trees grow

O links

For more information about how environmental changes affect organisms, see B3 chapter 4 How humans can affect the environment.

Measuring environmental change

Have you noticed different types of animals and plants when you travel to different places? The distribution of living organisms depends on the environmental conditions and varies around the world

Factors affecting the distribution of organisms

Non-living factors have a big effect on where organisms live. The average temperature or average rainfall will have a big impact on what can survive. You don't find polar bears in countries where the average temperature is over 20°C, for example! The amount of rainfall affects the distribution of both plants and animals. Light, pH and the local climate all influence where living organisms are found.

The distribution of different species of animals in water is closely linked to the oxygen levels. Salmon can only live in water with lots of dissolved oxygen, but bloodworms can survive in very low oxygen levels.

Living organisms also affect the distribution of other living organisms. So, for example, koala bears are only found where eucalyptus trees grow. Parasites only live where they can find a host.

One species of ant eats nectar produced by the flowers of the swollen-thorn acacia tree. The ants hollow out the vicious thorns and live in them. So any animal biting the tree not only gets the sharp thorns, they get a mouth full of angry ants as well. The distribution of the ants depends on the trees.

a Which non-living environmental factor affects the distribution of polar bears?

Environmental changes

When the environment changes, it can cause a change in the distribution of living organisms in the area. Non-living factors often cause these changes in an environment.

The average temperature may rise or fall. The oxygen concentration in water may change. A change in the amount of sunlight, the strength of the wind or the average rainfall may affect an environment. Any of these factors can affect the distribution of living organisms.

Living factors can also cause a change in the environment where an organism lives, affecting distribution. A new type of predator may move into an area. A new disease-causing pathogen may appear and wipe out a species of animal or plant. Different plants may appear and provide food or a home for a whole range of different species.

b Give an example of a living and a non-living factor that can change an environment.



Measuring environmental change (



When an environment changes, the living organisms in it are affected. If the change is big enough, the distribution of animals or plants in an area may change.

You can measure environmental change using non-living indicators. You can measure factors such as average rainfall, temperature, oxygen levels, pH and pollutant levels in water or the air, and much more. All sorts of different instruments are available to do these measurements. These range from simple rain gauges and thermometers to oxygen meters and dataloggers used in schools.

You can also use the changing distribution of living organisms as an indicator of environmental change. Living organisms are particularly good as indicators of pollution.

Lichens grow on places like rocks, roofs and the bark of trees. They are very sensitive to air pollution, particularly levels of sulfur dioxide in the atmosphere. When the air is clean, many different types of lichen grow. The more polluted the air, the fewer lichen species there will be. So a field survey on the numbers and types of lichen can be used to give an indication of air pollution. The data can be used to study local sites or to compare different areas of the country.

In the same way you can use invertebrate animals as water pollution indicators. The cleaner the water, the more species you will find. Some species of invertebrates are only found in the cleanest waters. Others can be found even in very polluted waters. Counting the different types of species gives a good indication of pollution levels, and can be used to monitor any changes.



Summary questions

- 1 Copy and complete these sentences using the words below: indicators distribution pollution organisms Changes in the environment affect the of living This means living organisms can be used as of
- 2 Give three different methods you could use to collect environmental data. For each method, comment on its reliability and usefulness as a source of evidence of environmental change.

Practical

Indicators of pollution levels

Investigate both the variety of lichens in your local area and the number of invertebrate species in your local pond or stream. This will give you an idea of pollution levels in your area if you compare them to national figures.

Figure 2 Lichens grow well where the air is clean. In an area polluted with sulfur dioxide there would be fewer species. Lichens are good indicators of pollution.

- Animals and plants may be adapted to cope with specific features of their environment, e.g. thorns, poisons and warning colours.
- Environmental changes may be caused by living or nonliving factors.
- Environmental changes can be measured using nonliving indicators.
- Living organisms can be used as indicators of pollution.





B14.8

The impact of change

Learning objectives

- How do changes in the environment affect the distribution of living organisms?
- How reproducible are the data about the effect of environmental change on living organisms?



Figure 1 The Dartford warbler

Changing birds of Britain

Temperatures in the UK seem to be rising. Many people like the idea – summer barbeques and low heating bills. But rising temperatures will have a big impact on many living organisms. We could see changes in the distribution of many species. Food plants and animals might become more common, or die out, in different conditions.

The Dartford warbler is small brown bird that breeds mainly in southern Europe. A small population lived in Dorset and Hampshire. By 1963, two very cold winters left just 11 breeding pairs in the UK. But temperatures have increased steadily since. Dartford warblers are now found in Wales, the Midlands and East Anglia. If climate change continues, Dartford warblers could spread through most of England and Ireland. However, in Spain the numbers are dropping rapidly – 25% in the last 10 years – as it becomes too warm. Scientists can simulate the distribution of birds as the climate changes. They predict that by the end of the century Spain could lose most of its millions of Dartford warblers.

Scientists predict that by the end of this century, if climate change continues at its present rate, the range of the average bird species will move nearly 550km north-east. About 75% of all the birds that nest in Europe are likely to have smaller ranges as a result and many species will be lost for good.

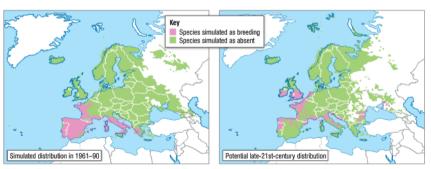


Figure 2 The maps show how scientists think the distribution of these birds might change in the future

Table 1 Numbers of breeding pairs of Dartford warblers in the UK

Year	Number of breeding	
	pairs	
1961	450	
1963	11	
1974	560	
1984	420	
1994	1890	
2010	3208	

Activity

- Plot a bar graph to show the change in population of the Dartford warbler from 1961 to the present day. Draw an extra bar to show what you would expect the population to be in 2030 if climate change continues in the same way.
- Investigate the effect of climate change on the way birds migrate from one country to another and write a report for a wildlife programme or magazine.



Where are all the bees?



All around the world honey bees are disappearing. In the UK alone, around one in five bee hives has been lost in the last few years. In the United States. around 2 million colonies of bees were lost in 3 years. The bees had been struck down by a new, mystery disease called Colony Collapse Disorder or CCD. The bees either die, or simply fail to return to the hive. Without the mass of worker bees, those bees left in the hive quickly die.

Members of the British Beekeepers Association are alarmed. They say that if hives continue to be lost at the same rate there will be no honey bees left in Britain by 2018. You might think that having fewer bees doesn't really matter. It also means honey is more expensive to buy.

In fact, bees are vitally important in plant ecology. Honey bees pollinate flowers as they collect the nectar. Without them, flowers are not pollinated and fruit does not form. Without bees as pollinators we would have no apples, raspberries. cucumbers, strawberries, peaches ... the list goes on and on. There would be cereal crops, because they are pollinated by the wind, but not much else.

No one yet fully understands what is happening to the bees and what is changing their distribution. Scientists think that viral diseases, possibly spread by a parasitic mite, are a major cause. So living factors - the agents of disease - are causing a major change in the environment of the honey bee. This in turn is affecting their distribution.

Other living and non-living factors affecting the environment have also been suggested. Flowering patterns are changing as temperatures vary with climate change. This may affect the food supply of the bees. Farmers spray chemicals that may build up in the bees. Some people have even suggested that mobile phones affect the navigation system of the bees.

Research is continuing all over the world. Disease-resistant strains of bees are being bred. Collecting the evidence to show exactly what environmental change is affecting the honey bee population is proving to be difficult. But until we can find out, the decline of the honey bee looks as if it will continue. There is a little good news - UK numbers have recovered slightly as more people have started keeping bees, probably as a result of all the publicity.

Activity

- List the main suggested causes for the decline of the honey bee. Use secondary sources to investigate the current state of the research findings for each cause.
- Produce a slide show to justify the investment of research funds into the loss of honey bees. Show what is happening to the bees, the main theories about what is causing the problem and how the problem is being tackled.

Summary questions

- 1 Using the information on this spread, what aspect of climate change seems to be linked to a change in the distribution of British birds?
- 2 a Why is the loss of honey bees so important?
 - b Why is it important to find out whether the environmental cause of the problem is a living or non-living factor?



Figure 3 Honey bees are vital pollinators. Bee-pollinated fruits are worth about £50 billion of trade every year.

- Both living and non-living factors can cause changes in the environment that affect the distribution of living organisms.
- Reproducible data on the effect of environmental change are not always easy to collect or interpret.



Summary questions (A)



Match the following words to their definitions:

а	competition	Α	an animal that eats plants
b	carnivore	В	an area where an animal lives and feeds
С	herbivore	С	an animal that eats meat
d	territory	D	the way animals compete with each other for food, water, space and mates

- 2 Cold-blooded animals like reptiles and snakes absorb heat from their surroundings and cannot move until they
 - a Why do you think that there are no reptiles and snakes in the Arctic?
 - b What problems do you think reptiles face in desert conditions and what adaptations could they have to cope with them?
 - c Most desert animals are quite small. How does this help them survive in the heat?
- 3 a What are the main problems for plants living in a hot. dry climate?
 - b Why does reducing the surface area of their leaves help plants to reduce water loss?
 - c Describe two ways in which the surface area of the leaves of some desert plants is reduced.
 - d How else are some plants adapted to cope with hot, dry conditions?
 - e Why are cacti such perfect desert plants?
- 4 a How does marking out and defending a territory help. an animal to compete successfully?
 - b Bamboo plants all tend to flower and die at the same time. Why is this such bad news for pandas, but doesn't affect most other animals?
- 5 Why is competition between animals of the same species so much more intense than the competition between different species?
- 6 Use the bar charts from the practical activity on B1 4.5 to answer these questions.
 - a Describe what happens to the height of both sets of seedlings over the first six months and explain why the changes take place.
 - b The total wet mass of the seedlings after one month was the same whether or not they were crowded. After six months there was a big difference.

- i Why do you think both types of seedling had the same mass after one month?
- ii Explain why the seedlings that were more spread out each had more wet mass after six months.
- c When scientists carry out experiments such as the one described, they try to use large sample sizes. Why?
- d i Name a control variable mentioned in the practical. ii Why were the other variables kept constant?
- 7 a Give three living factors that can change the environment and affect the distribution of living organisms.
 - b Give three non-living factors that can change the environment and affect the distribution of living organisms.
- Maize is a very important crop plant. It has many uses it is made into cornflakes and it is also grown for animal feed. The most important part of the plant is the cob, which fetches the most money. In an experiment to find the best growing conditions, three plots of land were used. The young maize plants were grown in different densities in the three plots.

The results were as follows:

	Planting density (plants/m²)		lants/m²)
	10	15	20
Dry mass of shoots (kg/m²)	9.7	11.6	13.5
Dry mass of cobs (kg/m²)	6.1	4.4	2.8

- a What was the independent variable in this investigation?
- b Draw a graph to show the effect of the planting density on the mass of the cobs grown.
- c What is the pattern shown in your graph?
- d This was a fieldwork investigation. What would the experimenter have taken into account when choosing the location of the three plots?
- e Did the experimenter choose enough plots? Explain vour answer.
- f What is the relationship between the mass of cobs and the mass of shoots at different planting densities?
- g The experimenter concluded that the best density for planting the maize is 10 plants per m2. Do you agree with this as a conclusion? Explain your answer.

A()A Examination-style questions (



The picture shows a solenodon.



Solenodons have lived on Earth since the Age of the Dinosaurs. They are only found in forests in Haiti and are the only mammals which have a poisonous bite. They are rarely seen because they feed at night. They mainly eat insects and spiders.

- a The solenodon has adaptations which help it to
 - Match the adaptation to the correct letter (A,B, C, D or E) for the following:
 - i This helps the solenodon to dig its burrow. (1)
 - ii This helps the solenodon to detect its food. (1)
- b The solenodon is at risk of dying out since new animals have been taken to the islands. Use the information and the picture to help answer the following questions.
 - i The solenodon is not adapted to flee from predators. Suggest why. (1)
 - ii If the solenodon is caught by a predator it can defend itself. Suggest how. (1)
- 2 Trees that live in the rainforests are very tall and often have broad leaves. This is a problem for young trees, which do not get much light.
 - a Choose the correct answer to complete the sentence. light nutrients space Rainforest trees have broad leaves so they can compete for (1)
 - b Choose the correct answer to complete the sentence. larger trees large seeds with stored food Trees in the rainforest have adapted to lack of light near the ground by having (1)

3 The gemsbok is a large herbivore living in dry desert regions of South Africa. It feeds on grasses that are adapted to the dry conditions by obtaining moisture from the air as it cools at night. The table below shows the water content of these grasses and the feeding activity of the gemsbok over a 24-hour period.

Time of day	% water content of grasses	% of gemsboks feeding
03.00	18	40
06.00	23	60
09.00	25	20
12.00	08	17
15.00	06	16
18.00	05	19
21.00	07	30
24.00	14	50

- Name the independent variable investigated.
 - ii Is this a categoric, ordered, discrete or continuous variable?
- b How does the water content of the grasses change throughout the 24-hour period?
- c Between which recorded times are more than 30% of the aemsboks feeding?
- d Suggest three reasons why the gemsboks benefit from feeding at this time.

AQA, 2008



Energy in biomass

B₁ 5.1

Learning objectives

- Where does biomass come from?
- What is a pyramid of biomass?



Did you know ...?

Only about 1% of all the light energy falling on the Earth is used by plants and algae for photosynthesis.

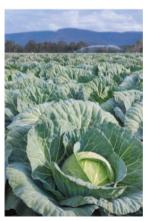


Figure 1 Plants can produce a huge mass of biological material in just one growing season

Pyramids of biomass

Radiation from the Sun (solar or light energy) is the source of energy for all groups of living organisms on Earth.

Light (solar) energy pours out continually on to the surface of the Earth. Green plants and algae absorb some of this light energy using chlorophyll for photosynthesis. During photosynthesis some of the light energy is transferred to chemical energy. This energy is stored in the substances that make up the cells of the plants and algae. This new material adds to the **biomass**.

Biomass is the mass of material in living organisms. Ultimately all biomass is built up using energy from the Sun. Biomass is often measured as the dry mass of biological material in grams.

a What is the source of all the energy in the living things on Earth?

The biomass made by plants is passed on through food chains or food webs. It goes into the animals that eat the plants. It then passes into the animals that eat other animals. No matter how long the food chain or complex the food web, the original source of all the biomass involved is the Sun.

In a food chain, there are usually more producers (plants) than primary consumers (herbivores). There are also more primary consumers than secondary consumers (carnivores). If you count the number of organisms at each level you can compare them. However, the number of organisms often does not accurately reflect what is happening to the biomass.

Pyramids of biomass

The amount of biomass at each stage of a food chain is less than it was at the previous stage. We can draw the total amount of biomass in the living organisms at each stage of the food chain. When this biomass is drawn to scale, we can show it as a **pyramid of biomass**.

b What is a pyramid of biomass?

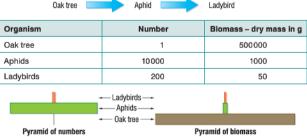


Figure 2 Using a pyramid of biomass shows us the amount of biological material involved at each level of this food chain much more effectively than a pyramid of numbers



Interpreting pyramids of biomass

The amount of material and energy contained in the biomass of organisms at each stage of a food chain is less than it was at the previous stage.

This is because:

- not all organisms at one stage are eaten by the stage above
- some material and energy taken in is passed out as waste by the organism
- when a herbivore eats a plant, lots of the plant biomass is used in respiration by the animal cells to release energy. Only a relatively small proportion of the plant material is used to build new herbivore biomass by making new cells, building muscle tissue etc. This means that very little of the plant biomass eaten by the herbivore in its lifetime is available to be passed on to any carnivore that eats it.

So, at each stage of a food chain the amount of energy in the biomass that is passed on gets less. A large amount of plant biomass supports a smaller amount of herbivore biomass. This in turn supports an even smaller amount of carnivore biomass.

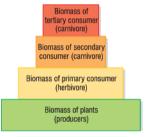


Figure 3 Any food chain can be turned into a pyramid of biomass like this

Summary questions

- 1 a What is biomass?
 - b Why is a pyramid of biomass more useful for showing what is happening in a food chain than a pyramid of numbers?

2	Organism	anism Biomass, dry mass (g)	
	grass	100 000	
	sheep	5000	
	sheep ticks	30	

Draw a pyramid of biomass for this grassland ecosystem.

- 3 Using the data in Figure 2, calculate the percentage biomass passed on from:
 - a the producers to the primary consumers
 - **b** the primary consumers to the secondary consumers.

Examiner's tip

Make sure you can draw pyramids of biomass when you are given the data.

- Radiation from the Sun (solar or light energy) is the main source of energy for all living things. The Sun's light energy is captured and used by green plants and algae during photosynthesis, to make new biomass.
- Biomass is the dry mass of living material in an animal or plant.
- The mass of living material at each stage of a food chain is less than at the previous stage. The biomass at each stage can be drawn to scale and shown as a pyramid of biomass.



Energy in biomass

B₁ 5.2

Learning objectives

- What happens to the material and energy in the biomass of organisms at each stage of a food chain?
- How is some energy transferred to the environment?

Examiner's tip

Make sure you can explain the different ways in which energy is lost between the stages of a food chain.



Figure 2 Animals such as horses produce very large quantities of dung made up of all the biomass they can't digest



Figure 3 These sea anemones don't move much so they don't need to eat much

Energy transfers

The amounts of biomass and energy contained in living things get less as you progress up a food chain. Only a small amount of the biomass taken in gets turned into new animal material. What happens to the rest?



Figure 1 The amount of biomass in a lion is a lot less than the amount of biomass in the grass that feeds the zebra it preys on. But where does all the biomass go?

Energy loss in waste

The biomass that an animal eats is a source of energy, but not all of the energy can be used. Firstly, herbivores cannot digest all of the plant material they eat. The material they can't digest is passed out of the body in faeces.

The meat that carnivores eat is easier to digest than plants. This means that carnivores need to eat less often and produce less waste. But like herbivores, most carnivores cannot digest all of their prey, such as hooves, claws, bones and teeth. Therefore some of the biomass that they eat is lost in their faeces.

When an animal eats more protein than it needs, the excess is broken down. It gets passed out as **urea** in the urine. This is another way biomass – and energy – are transferred from the body to the surroundings.

a Why is biomass lost in faeces?

Energy loss due to movement

Part of the biomass eaten by an animal is used for respiration in its cells. This supplies all the energy needs for the living processes taking place within the body, including movement.

Movement uses a great deal of energy. The muscles use energy to contract and also get hot. So the more an animal moves about the more energy (and biomass) it uses from its food.

b Why do animals that move around a lot use up more of the biomass they eat than animals that don't move much?

Keeping a constant body temperature

Much of the energy animals release from their food in cellular respiration is eventually transferred heating their surroundings. Some of this heat is produced by the muscles as the animals move.

Energy transfers to the surroundings are particularly large in mammals and birds. That is because they use energy to keep their bodies at a constant temperature. They use energy all the time, to keep warm when it's cold or to cool down when it's hot. So mammals and birds need to eat far more food than animals such as fish and amphibians to get the same increase in biomass.

Practical

Investigating the energy released by respiration

Even plants transfer energy by heating their surroundings in cellular respiration. You can investigate this using germinating peas in a vacuum flask.

- What would be the best way to monitor the temperature continuously?
- Plan the investigation.

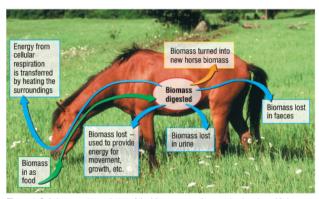


Figure 4 Only between 2% and 10% of the biomass eaten by an animal such as this horse will get turned into new horse. The rest of the stored energy will be used for movement or transferred, heating the surroundings, or lost in waste materials.

Summary questions

- 1 Copy and complete using the words below:

 biomass temperature energy chain growth movement
 producers respiration waste

 The amounts of ______ and _____ contained in living things always get
 less at each stage of a food _____ from ____ onwards. Biomass is lost
 as _____ products and used to release energy in _____ . This is used
 for _____ and to control body _____ . Only a small amount is used for
- 2 Explain why so much of the energy from the Sun that lands on the surface of the Earth is not turned into biomass in animals.

- The amounts of biomass and energy get less at each successive stage in a food chain.
- This is because some material and energy are always lost in waste materials, and some are used for respiration to supply energy for living processes, including movement. Much of the energy is eventually transferred by heating to the surroundings.



Energy in biomass

B₁ 5.3

Learning objectives

- Why do things decay?
- Why are decay processes so important?
- How are materials cycled in a stable community?

Examiner's tip

You need to know the type of organisms that cause decay. the conditions needed for decay and the importance of decay in recycling nutrients.



Figure 1 This tomato is slowly being broken down by the action of decomposers. You can see the fungi clearly but the bacteria are too small to be seen.

Did you know ...?

The 'Body Farm' is a US research site where scientists have buried human bodies in many different conditions. They are studying every stage of human decay to help police forces all over the world work out when someone died and if they were murdered.

Decay processes

Plants take nutrients from the soil all the time. These nutrients are passed on into animals through food chains and food webs. If this was a one-way process the resources of the Earth would have been exhausted long ago.

Fortunately all these materials are recycled. Many trees shed their leaves each year, and most animals produce droppings at least once a day. Animals and plants eventually die as well. A group of organisms known as the decomposers then break down the waste and the dead animals and plants. In this process decomposers return the nutrients and other materials to the environment. The same material is recycled over and over again. This often leads to very stable communities of organisms.

a Which group of organisms take materials out of the soil?

The decay process

Decomposers are a group of microorganisms that include bacteria and fungi. They feed on waste droppings and dead organisms.

Detritus feeders, such as maggots and some types of worms, often start the process of decay. They eat dead animals and produce waste material. The bacteria and fungi then digest everything - dead animals, plants and detritus feeders plus their waste. They use some of the nutrients to grow and reproduce. They also release waste products.

The waste products of decomposers are carbon dioxide, water, and nutrients that plants can use. When we say that things decay, they are actually being broken down and digested by microorganisms.

The recycling of materials through the process of decay makes sure that the soil contains the mineral ions that plants need to grow. The decomposers also 'clean up' the environment, removing the bodies of all the dead organisms.

b What type of organisms are decomposers?

Conditions for decay (



The speed at which things decay depends partly on the temperature. Chemical reactions in microorganisms, like those in most living things, work faster in warm conditions. They slow down and might even stop if conditions are too cold. Decay also stops if it gets too hot. The enzymes in the decomposers change shape and stop working.

Most microorganisms also grow better in moist conditions. The moisture makes it easier for them to dissolve their food and also prevents them from drying out. So the decay of dead plants and animals - as well as leaves and dung - takes place far more rapidly in warm, moist conditions than it does in cold, dry ones.

Although some microbes survive without oxygen, most decomposers respire like any other organism. This means they need oxygen to release energy, grow and reproduce. This is why decay takes place more rapidly when there is plenty of oxygen available.

c Why are water, warmth and oxygen needed for the process of decay?





Figure 2 The decomposers cannot function at low temperatures so if an organism – such as this 4000-year-old man – is frozen as it dies, it will be preserved with very little decay

\odot

Practical

Investigating decay

Plan an investigation into the effect of temperature on how quickly things decay.

- Write a question that can be used as the title of this investigation.
- Identify the independent variable in the investigation.

The importance of decay in recycling

Decomposers are vital for recycling resources in the natural world. What's more, we can take advantage of the process of decay to help us recycle our waste.

In sewage treatment plants we use microorganisms to break down the bodily waste we produce. This makes it safe to release into rivers or the sea. These sewage works have been designed to provide the bacteria and other microorganisms with the conditions they need. That includes a good supply of oxygen.

Another place where the decomposers are useful is in the garden. Many gardeners have a compost heap. Grass cuttings, vegetable peelings and weeds are put onto the compost heap. It is then left to allow decomposing microorganisms break all the plant material down. It forms a brown, crumbly substance known as compost which can be used as a fertiliser.

Summary questions

- 2 Explain why the processes of decay are so important in keeping the soil fertile.

- Living things remove materials from the environment as they grow.
 They return them when they die through the action of the decomposers.
- Materials decay because they are broken down (digested) by microorganisms.
 Microorganisms digest materials faster in warm, moist conditions. Many of them also need oxygen.
- The decay process releases substances that plants need to grow.
- In a stable community the processes that remove materials (particularly plant growth) are balanced by the processes that return materials.



Energy in biomass

B₁ 5.4

Learning objectives

- What is the carbon cycle in nature?
- Which processes remove carbon dioxide from the atmosphere – and which processes return it?



Figure 1 Within the natural cycle of life and death in the living world, mineral nutrients are cycled between living organisms and the physical environment

?? Did you know ...?

Every year about 166 gigatonnes of carbon are cycled through the living world. That's 16600000000 tonnes – an awful lot of carbonl

The carbon cycle

Imagine a stable community of plants and animals. The processes that remove materials from the environment are balanced by processes that return materials. Materials are constantly cycled through the environment. One of the most important of these is carbon.

All of the main **molecules** that make up our bodies (carbohydrates, proteins, fats and DNA) are based on carbon atoms combined with other **elements**.

The amount of carbon on the Earth is fixed. Some of the carbon is 'locked up' in **fossil fuels** like coal, oil and gas. It is only released when we burn them.

Huge amounts of carbon are combined with other elements in carbonate rocks like limestone and chalk. There is a pool of carbon in the form of carbon dioxide in the air. It is also found dissolved in the water of rivers, lakes and oceans. All the time a relatively small amount of available carbon is cycled between living things and the environment. We call this the **carbon cycle**.

a What are the main sources of carbon on Earth?

Photosynthesis

Green plants and algae remove carbon dioxide from the atmosphere for photosynthesis. They use the carbon from carbon dioxide to make carbohydrates, proteins and fats. These make up biomass of the plants and algae. The carbon is passed on to animals that eat the plants. The carbon goes on to become part of the carbohydrates, proteins and fats in these animal bodies.

This is how carbon is taken out of the environment. But how is it returned?

b What effect does photosynthesis have on the distribution of carbon levels in the environment?

Respiration

Living organisms respire all the time. They use oxygen to break down glucose, providing energy for their cells. Carbon dioxide is produced as a waste product. This is how carbon is returned to the atmosphere.

When plants, algae and animals die their bodies are broken down by decomposers. These are animals and microorganisms such as blowflies, moulds and bacteria that feed on the dead bodies. The animals which feed on dead bodies and waste are called *detritus feeders*. They include animals such as worms, centipedes and many insects.

Carbon is released into the atmosphere as carbon dioxide when these organisms respire. All of the carbon (in the form of carbon dioxide) released by the various living organisms is then available again. It is ready to be taken up by plants and algae in photosynthesis.



Combustion

Fossil fuels contain carbon, which was locked away by photosynthesising organisms millions of years ago. When we burn fossil fuels, carbon dioxide is produced, so we release some of that carbon back into the atmosphere:

Photosynthesis: carbon dioxide + water (+ light energy) → glucose+ oxygen

Respiration: glucose + oxygen → carbon dioxide + water (+ energy)

Combustion: fossil fuel or wood + oxygen → carbon dioxide + water (+ energy)

The constant cycling of carbon is summarised in Figure 2.

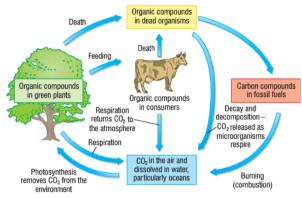


Figure 2 The carbon cycle in nature

Energy transfers

When plants and algae photosynthesise, they transfer light energy into chemical energy in the food they make. This chemical energy is transferred from one organism to another through the carbon cycle. Some of the energy can be used for movement or transferred as energy to the organisms and their surroundings at each stage. The decomposers break down all the waste and dead organisms and cycle the materials as plant nutrients. By this time all of the energy originally absorbed by green plants and algae during photosynthesis has been transferred elsewhere.

For millions of years the carbon cycle has regulated itself. However, as we burn more fossil fuels we are pouring increasing amounts of carbon dioxide into the atmosphere. Scientists fear that the carbon cycle may not cope. If the levels of carbon dioxide in our atmosphere increase it may lead to global warming.

Summary questions

- 1 a What is the carbon cycle?
 - **b** What are the main processes involved in the carbon cycle?
 - c Why is the carbon cycle so important for life on Earth?
- 2 a Where does the carbon come from that is used in photosynthesis?
 - b Explain carefully how carbon is transferred through an ecosystem.

ACA Examiner's tip

Make sure you can label the processes in a diagram of the carbon cycle.



Figure 3 Fossil fuels such as coal contain large amounts of carbon

- The constant cycling of carbon in nature is known as the carbon cycle.
- Carbon dioxide is removed from the atmosphere by photosynthesis. It is returned to the atmosphere through respiration and combustion.





B₁ 5.5

Learning objectives

- Why should we recycle organic kitchen and garden waste?
- How can we investigate the most effective way to recycle this organic waste?

Figure 1 Some landfill sites now collect the methane that is produced as organic material decays and use it to generate electricity. But if everyone recycled their own organic waste, we would need far fewer landfill sites and there would be no problem.

22

Did you know ...?

One tonne of organic kitchen and garden waste produces 200 to 400 m³ of gas. Around 27% of the methane produced in the UK each year comes from landfill sites.

Activity

Plan an assembly to be used with students in Years 7–9 suggesting that the school introduces a scheme to recycle all the organic waste from the kitchens and the school grounds to make compost. The compost could then be sold to the local community for charity. Remember, you need to explain why and how this should be done as well as recruit volunteers to help run the compost bins.

Recycling organic waste

The problem of waste

People produce lots of waste – and getting rid of it is a big problem. Whenever we prepare food we produce **organic waste** to throw away, such as vegetable peelings. Gardening produces lots of organic waste too, including the grass cuttings when we mow the lawn. We put about 100 million tonnes of waste a year into landfill sites and about two thirds of that is organic matter. By recycling our organic waste we can reduce this mountain of waste material.



The kitchen and garden waste we put into landfill sites doesn't rot easily in the conditions there. It forms a smelly liquid which soaks into the ground and can pollute local rivers and streams. In these conditions the microorganisms that break down the plant and animal material produce mainly methane gas. This is a greenhouse gas that adds to the problem of global warming.

 a Give two examples of the organic waste you might put into a compost bin.

The simplest way to recycle kitchen and garden waste is to make compost. Natural decomposing organisms break down all the plant material to make a brown, crumbly substance. This compost is full of the nutrients that have been released by the decomposers. The process takes from a few months to over a year. The compost forms a really good, natural fertiliser. It also greatly reduces the amount of rubbish you need to send to the landfill site.

b Which greenhouse gas, other than carbon dioxide, is given off as organic material decays in landfill sites?

Making compost

Composting can be done on a small scale or on a large scale. There are several different factors which are important in making successful compost:

- Compost can be made with or without oxygen mixing your compost regularly helps air get in. If the microorganisms have oxygen they generate energy, which kills off weed seeds and speeds up the process. Without oxygen the process releases little energy and is slower.
- The warmer the compost mixture, the faster the compost will be made (up to about 70°C, at which point the microorganisms stop working properly).
- The decay process is faster in moist conditions than in dry ones. (In fact, decay does not take place at all in perfectly dry conditions.)





Practical

Investigating the decay of organic matter

We have seen that the presence of oxygen and moisture, as well as the temperature, affect the rate of decay. Choose one of these factors to investigate. Carry out any tests on the sort of materials that might go into a garden compost bin.

- Plan to find out what effect your chosen factor has on the rate at which the material decays.
- Pool the conclusions of each group to decide on the ideal conditions for composting organic waste.
- Comment on the limitations of the conclusions you can draw.

O links

For more information about waste management and pollution, see B3 4.1 The effects of the population explosion and B3 4.2 Land and water pollution.

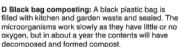


A Compost heap: The simplest and cheapest method. Kitchen and garden waste is put in a pile, with new material added to the top, and left to rot down.



B Compost bin: Bins are often made of plastic and may be sold cheaply by local councils to encourage people to recycle their organic waste. Instructions

include watering the bin in dry weather and mixing the contents from time to time.





C Council composting: Local councils may collect garden or kitchen waste and use large-scale bins to recycle the material to make compost. They may shred the material before adding it to the bins to increase the surface area. You can buy the compost from the schemes to put on your garden.



Summary questions

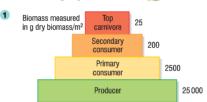
- 1 Why is it important to recycle organic kitchen and garden waste?
- 2 Evaluate each of the four methods of making compost shown in Figure 2, giving advantages and disadvantages of each.
- 3 How do mixing the compost regularly, adding a variety of different types of organic waste and watering in dry weather improve the composting process?

- Recycling organic kitchen and garden waste is necessary to reduce landfill, reduce the production of methane and to recycle the minerals and nutrients in the organic material.
- Composting organic waste can be done in a variety of different ways.



Energy in biomas: B1 5.1-B1 5.5

Summary questions

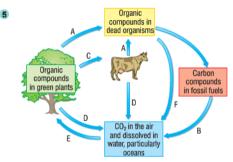


- a From this diagram, calculate the percentage biomass passed on:
 - i from producers to primary consumers
 - ii from primary to secondary consumers
 - iii from secondary consumers to top carnivores.
- b In any food chain or food web the biomass of the producers is much larger than that of any other level of the pyramid. Why is this?
- c In any food chain or food web there are only small numbers of top carnivores. Use your calculations to help you explain why.
- d All of the animals in the pyramid of biomass shown here are cold blooded. What difference would it have made to the average percentage of biomass passed on between the levels if mammals and birds had been involved? Explain the difference.
- 2 The world population is increasing and there are food shortages in many parts of the world. Explain, using pyramids of biomass to help you, why it would make a better use of resources if people everywhere ate much less meat and more plant material.
- to provide meat as cheaply as possible. The birds arrive in the broiler house as 1-day-old chicks. They are slaughtered at 42 days of age when they weigh about 2 kg. The temperature, amount of food and water and light levels are carefully controlled. About 20000 chickens are reared together in one house. The table below shows their weight gain.

Age (days)	1	7	14	21	28	35	42
Mass (g)	36	141	404	795	1180	1657	1998

- a Plot a graph to show the growth rate of one of these chickens.
- b Explain why the temperature is so carefully controlled in the broiler house.
- c Explain why so many birds are reared together in a relatively small area.
- d Why are birds for eating reared like this?

- 4 Microorganisms decompose organic waste and dead bodies. We preserve food to stop this decomposition taking place. Use your knowledge of decomposition to explain how each method stops the food going bad:
 - a Food may be frozen.
 - b Food may be cooked cooked food keeps longer than fresh food.
 - c Food may be stored in a vacuum pack with all the air sucked out.
 - **d** Food may be tinned it is heated and sealed in an airtight container.



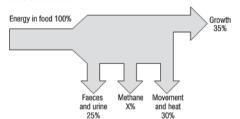
- a How is carbon dioxide removed from the atmosphere in the carbon cycle?
- b How does carbon dioxide get into the atmosphere?
- c Where is most of the carbon stored?
- d Why is the carbon cycle so important and what could happen if the balance of the reactions was disturbed?
- 6 a The temperature in the middle of a compost heap will be quite warm. Heat is produced as microbes respire. How does this help the compost to be broken down more quickly?
 - b In sewage works oxygen is bubbled through the tanks containing sewage and microorganisms. How does this help make sure the human waste is broken down completely?

A()A Examination-style questions (A)



(2)

- Rabbits eat very large amounts of grass. A single hawk eats a few rabbits.
 - a Draw a pyramid of biomass for the rabbits, grass and the hawk.
 - b Much of the energy from the grass is not transferred to the hawk.
 - Suggest two reasons why. (2)
- 2 Choose words from below to complete each sentence. carbon dioxide cool dry insects microorganisms moist nitrogen oxygen rats warm
 - a Plant waste in a compost heap is decayed by (1)
 - b The plant waste decays faster in conditions which are and
 - c The plant waste will also decay faster when the air contains plenty of
- 3 The diagram shows what happens to the energy in the food a calf eats.



In the calculations show clearly how you work out your answer.

- a Calculate the percentage of energy lost in methane (X).
- b The energy in the food the calf eats in one day is 10 megajoules.
 - Calculate the amount of this energy that would be lost in faeces and urine.
- c Name the process which transfers the energy from the food into movement.
- d The farmer decides to move his calf indoors so that it will grow guicker.
 - Suggest two reasons why.

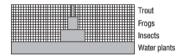
In this guestion you will be assessed on using good English, organising information clearly and using specialist terms where appropriate.

The constant cycling of carbon in nature is called 'The carbon cycle'.

Each autumn, trees lose their leaves.

Describe how the carbon in the leaves is recycled so that the trees can use it again.

5 The diagram shows a pyramid of biomass drawn to scale.



- a What is the source of energy for the water plants?
- **b** The ratio of the biomass of water plants to the biomass of insects is 5:1.

Calculate the ratio of the biomass of insects to the biomass of frogs.

Show clearly how you work out your answer.

- c Give two reasons why the biomass of the frog population is smaller than the biomass of the insect population.
- d Some insects die. Describe how the carbon in the dead insect bodies may be recycled.

AQA, 2006

(2)

Variation, reproduction and new technology

B₁ 6.1

Learning objectives

- How do parents pass on genetic information to their offspring?
- In which part of a cell is the genetic information found?

A Examiner's tip

Make sure you know the difference between chromosomes, genes and DNA.

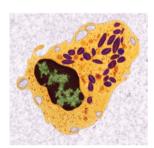


Figure 2 The nucleus of each of your cells contains your chromosomes. The chromosomes carry the genes, which control the characteristics of your whole body.

Inheritance

Young animals and plants resemble their parents. Horses have foals and people have babies. Chestnut trees produce conkers that grow into little chestnut trees. Many of the smallest organisms that live in the world around us are actually identical to their parents. So what makes us the way we are?



Figure 1 This mother cat and her kittens are not identical, but they are obviously related

Why do we resemble our parents?

Most families have characteristics that we can see clearly from generation to generation. People like to comment when one member of a family looks very much like another. Characteristics like nose shape, eye colour and dimples are inherited. They are passed on to you from your parents.

Your resemblance to your parents is the result of information carried by **genes**. These are passed on to you in the sex cells (**gametes**) from which you developed. This genetic information determines what you will be like.

a Why do you look like your parents?

Chromosomes and genes

The genetic information is carried in the nucleus of your cells. It is passed from generation to generation during reproduction. The nucleus contains all the plans for making and organising a new cell. What's more, the nucleus contains the plans for a whole new you!

b In which part of a cell is the genetic information found?

Inside the nucleus of all your cells there are thread-like structures called **chromosomes**. The chromosomes are made up of a special chemical called **DNA** (deoxyribonucleic acid). This is where the genetic information is actually stored.

DNA is a long molecule made up of two strands that are twisted together to make a spiral. This is known as a double helix – imagine a ladder that has been twisted round.

Each different type of organism has a different number of chromosomes in its body cells. Humans have 46 chromosomes while turkeys have 82. You inherit half your chromosomes from your mother and half from your father, so chromosomes come in pairs. You have 23 pairs of chromosomes in all your normal body cells.

Each of your chromosomes contains thousands of genes joined together. These are the units of inheritance.

Each gene is a small section of the long DNA molecule. Genes control what an organism is like. They determine its size, its shape and its colour. Genes work at the level of the molecules in your body to control the development of all the different characteristics you can see. They do this by controlling all the different enzymes and other proteins made in your body.

Your chromosomes are organised so that both of the chromosomes in a pair carry genes controlling the same things. This means your genes also come in pairs – one from your father and one from your mother.

c Where would you find your genes?

Some of your characteristics are decided by a single pair of genes. For example, there is one pair of genes which decides whether or not you will have dimples when you smile. However, most of your characteristics are the result of several different genes working together. For example, your hair and eye colour are both the result of several different genes.

Did you know that scientists are still not sure exactly how many genes we have? At the moment they think it is between 20000 to 25000.

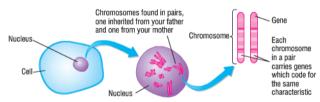


Figure 3 The nucleus of your cell contains the chromosomes that carry the genes which control the characteristics of your whole body

Summary questions

- 2 a What is the basic unit of inheritance?
 - b Offspring inherit information from their parents, but do not look exactly like them. Why not?
- 3 a Why do chromosomes come in pairs?
 - b Why do genes come in pairs?
 - c How many genes do scientists think humans have?

- Parents pass on genetic information to their offspring in the sex cells (gametes).
- The genetic information is found in the nucleus of your cells. The nucleus contains chromosomes, and chromosomes carry the genes that control the characteristics of your body.
- Different genes control the development of different characteristics.



Variation, reproduction and new technology

B1 6.2

Learning objectives

- What is a clone?
- Why does asexual reproduction result in offspring that are identical to their parents?
- How does sexual reproduction produce variety?

Figure 1 A mass of daffodils like this can contain hundreds of identical flowers. This is because they come from bulbs that reproduce asexually. They also reproduce sexually using their flowers.

₹QA Examiner's tip

- asexual reproduction one parent → clones
- sexual reproduction two parents → variety

Types of reproduction

Reproduction is very important to living things. It is during reproduction that genetic information is passed on from parents to their offspring. There are two very different ways of reproducing – asexual reproduction and sexual reproduction.

Asexual reproduction (kg)



Asexual reproduction only involves one parent. There is no joining of special sex cells and there is no variety in the offspring.

Asexual reproduction gives rise to identical offspring known as **clones**. Their genetic material is identical both to the parent and to each other.

a Why is there no variety in offspring from asexual reproduction?

Asexual reproduction is very common in the smallest animals and plants and in bacteria. However, many bigger plants like daffodils, strawberries and brambles do it too. The cells of your body reproduce asexually all the time. They divide into two identical cells for growth and to replace worn-out tissues.



Sexual reproduction

Sexual reproduction involves a male sex cell and a female sex cell from two parents. These two special sex cells (gametes) join together to form a new individual.

The offspring that result from sexual reproduction inherit genetic information from both parents. This means you will have some characteristics from both of your parents, but won't be exactly like either of them. This introduces variety. The offspring of sexual reproduction show much more variation than the offspring from asexual reproduction. In plants the gametes involved in sexual reproduction are found within ovules and pollen. In animals they are called ova (eggs) and sperm.

Sexual reproduction is risky because it relies on the sex cells from two individuals meeting but it also introduces variety. That's why we find sexual reproduction in organisms ranging from bacteria to people.

b How does sexual reproduction cause variety in the offspring?



Figure 2 Although these young people

have some family likenesses, the variety caused by the mixing of their parents'

genetic information is clear

Variation

Why is sexual reproduction so important? The variety it produces is a great advantage in making sure a species survives. Variety makes it more likely that at least a few of the offspring will have the ability to survive difficult conditions.

If you take a closer look at how sexual reproduction works, you can see how variation appears in the offspring.

Different genes control the development of different characteristics about you. Most things about you, such as your hair and eye colour, are controlled by several different pairs of genes. A few of your characteristics are controlled by one single pair of genes. For example, there are genes that decide whether:

- · your earlobes are attached closely to the side of your head or hang freely
- your thumb is straight or curved
- vou have dimples when you smile
- you have hair on the second segment of your ring finger.

We can use these genes to help us understand how inheritance works.

c Why is variety important?



Straight thumb

Attached ear lobe



Unattached ear lobe



Dimples



No dimples

Figure 3 These are all human characteristics that are controlled by a single pair of genes. They can help us to understand how sexual reproduction introduces variety and how inheritance works.

You will get a random mixture of genetic information from your parents, which is why you don't look exactly like either of them!

Summary questions

- 1 Define the following words:
 - a asexual reproduction
- c gamete
- b sexual reproduction
- d variation.
- 2 Compare the advantages and disadvantages of sexual reproduction with asexual reproduction.
- 3 A daffodil reproduces asexually using bulbs and sexually using flowers.
 - a How does this help to make them very successful plants?
 - b Explain the genetic differences between a daffodils's sexually and asexually produced offspring.

- In asexual reproduction there is no joining of gametes and only one parent. There is no genetic variety in the offspring.
- The genetically identical offspring of asexual reproduction are known as clones.
- In sexual reproduction male and female gametes join. The mixture of genetic information from two parents leads to genetic variety in the offspring.



Variation, reproduction and new technology

differences

Genetic and environmental

Have a look at the ends of your fingers and notice the pattern of your

fingerprints. No one else in the world will have exactly the same fingerprints as you. Even identical twins have different fingerprints. What factors make you so different from other people?

Nature – genetic variety

The genes you inherit determine a lot about you. An apple tree seed will never grow into an oak tree. Environmental factors, such as the weather or soil conditions do not matter. The basic characteristics of every species are determined by the genes they inherit.

Certain human characteristics are clearly inherited. Features such as eye colour, the shape of your nose and earlobes, your sex and dimples are the result of genetic information inherited from your parents. But your genes are only part of the story.

a Where do the genes you inherit come from?

Nurture – environmental variety (K)

Some differences between you and other people are completely due to the environment you live in. For example, if a woman drinks heavily when she is pregnant, her baby may be very small when it is born and have learning difficulties. These characteristics are a direct result of the alcohol the fetus has to deal with as it develops. You may have a scar as a result of an accident or an operation. These characteristics are all environmental, not genetic.

Genes certainly play a major part in deciding how an organism will look. However, the conditions in which it develops are important too. Genetically identical plants can be grown under different conditions of light or soil nutrients. The resulting plants do not look identical. Plants deprived of light, carbon dioxide or nutrients do not make as much food as plants with plenty of everything. The deprived plants will be smaller and weaker. They have not been able to fulfil their 'genetic potential'.

b Why are genetically identical plants so useful for showing the effect of the environment on appearance?

Combined causes of variety

Many of the differences between individuals of the same species are the result of both their genes and the environment. For example, you inherit your hair colour and skin colour from your parents. However, whatever your inherited skin colour, it will be darker if you live in a sunny environment. If your hair is brown or blonde, it will be lighter if you live in a sunny country.

Your height and weight are also affected by both your genes and the conditions in which you grow up. You may have a genetic tendency to be overweight. However, if you never have enough to eat you will be underweight.

B₁ 6.3

Learning objectives

- What makes you different from the rest of your family?
- Why aren't identical twins exactly the same in every wav?



Figure 1 However much this Falabella eats, it will never be as tall as the Shire. It just isn't in the genes.



Figure 2 The differences in these cows are partly genetic and partly down to their environment, from the milk they drank as calves to the quality of the grass they eat ach day

Investigating variety

It is quite easy to produce genetically identical plants to investigate variety. You can then put them in different situations to see how the environment affects their appearance. Scientists also use groups of animals that are genetically very similar to investigate variety. You cannot easily do this in a school laboratory.

The only genetically identical humans are identical twins who come from the same fertilised egg. Scientists are very interested in identical twins, to find out how similar they are as adults.

It would be unethical to take identical twins away from their parents and have them brought up differently just to investigate environmental effect. But there are cases of identical twins who have been adopted by different families. Some scientists have researched these separated identical twins.

Often identical twins look and act in a remarkably similar way. Scientists measure features such as height, weight and IQ (a measure of intelligence). The evidence shows that human beings are just like other organisms. Some of the differences between us are mainly due to genetics and some are largely due to our environment.

In one study, scientists compared four groups of adults:

- separated identical twins
- identical twins brought up together
- non-identical, same sex twins brought up together
- same sex, non-twin siblings brought up together.

The differences between the pairs were measured. A small difference means the individuals in a pair are very alike. If there was a big difference between the identical twins the scientists could see that their environment had more effect than their genes.

O links

For more information on producing genetically identical plants, see B1 6.4 Cloning.



Figure 3 Whether identical twins are brought up together or apart, they are often very similar as adults

Table 1
Table 1

Measured difference in:	sured difference Identical twins brought up together		Non-identical twins	Non-twin siblings	
height (cm)	1.7	1.8	4.4	4.5	
mass (kg)	1.9	4.5	4.6	4.7	
IQ	5.9	8.2	9.9	9.8	

Summary questions

- 1 Copy and complete using the words below. combination identical developed genes
- 2 a Using the data from Table 1, explain which human characteristic appears to be mostly controlled by genes and which appears to be most affected by the environment.
 - b Why do you think non-twin siblings reared together were included in the study as well as twins reared together and apart?
- 3 You are given 20 pots containing identical cloned seedlings, all the same height and colour. Explain how you would investigate the effect of temperature on the growth of these seedlings compared to the impact of their genes.

AQA Examiner's tip

- Genes control the development of characteristics.
- Characteristics may be changed by the environment.

Key points

 The different characteristics between individuals of a family or species may be due to genetic causes, environmental causes or a combination of both.



Variation, reproduction and new technology

B₁ 6.4

Learning objectives

- How do we clone plants?
- How do we clone animals?
- Why do we want to create clones?

O links

For information on taking plant cuttings, look back at B1 2.6 Hormones and the control of plant growth.



Figure 1 Simple cloning by taking cuttings is a technique used by gardeners and nurserymen all around the world



Figure 2 Tissue culture makes it possible to produce thousands of identical plants wickly and easily

Cloning

A clone is an individual that has been produced asexually and is genetically identical to the parent. Many plants reproduce naturally by cloning and this has been used by farmers and gardeners for many years.

Cloning plants

Gardeners can produce new plants by taking cuttings from older plants. How do you take a cutting? First you remove a small piece of a plant. This is often part of the stem or sometimes just part of the leaf. If you keep it in the right conditions, new roots and shoots will form. It will grow to give you a small, complete new plant.

Using this method you can produce new plants quickly and cheaply from old plants. The cuttings will be genetically identical to the parent plants.

Many growers now use hormone rooting powders to encourage cuttings to grow. Cuttings are most likely to develop successfully if you keep them in a moist atmosphere until their roots develop. We produce plants such as orchids and many conifer trees commercially by cloning in this way.

a Why does a cutting look the same as its parent plant?

Cloning tissue

Taking cuttings is a form of artificial asexual reproduction. It has been carried out for hundreds of years. In recent years scientists have come up with a more modern way of cloning plants called **tissue culture**. It is more expensive but it allows you to make thousands of new plants from one tiny piece of plant tissue.

The first step is to use a mixture of plant hormones to make a small group of cells from the plant you want to clone produce a big mass of identical plant cells.

Then, using a different mixture of hormones and conditions, you can stimulate each of these cells to form a tiny new plant. This type of cloning guarantees that you can produce thousands of offspring with the characteristics you want from one individual plant.

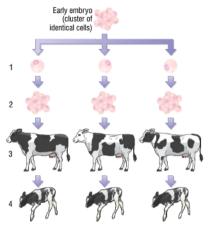
b What is the advantage of tissue culture over taking cuttings?

Cloning animals

In recent years cloning animals has become quite common in farming, particularly transplanting cloned cattle embryos. Cows normally produce only one or two calves at a time. If you use embryo cloning, your best cows can produce many more top-quality calves each year.

How does embryo cloning work? You give a top-quality cow fertility hormones so that it produces a lot of eggs. You fertilise these eggs using sperm from a really good bull. Often this is done inside the cow and the embryos that are produced are then gently washed out of her womb. Sometimes the eggs are collected and you add sperm in a laboratory to produce the embryos.

At this very early stage of development every cell of the embryo can still form all of the cells needed for a new cow. They have not become specialised.



- 1 Divide each embryo into several individual cells.
- 2 Each cell grows into an identical embryo in the lab.
- 3 Transfer embryos into their host mothers, which have been given hormones to get them ready for pregnancy.
- 4 Identical cloned calves are born. They are not biologically related to their mothers.

Figure 3 Cloning cattle embryos

Cloning cattle embryos and transferring them to host cattle is skilled and expensive work. It is worth it because using normal reproduction, a top cow might produce 8–10 calves during her working life. Using embryo cloning she can produce more calves than that in a single year.

Cloning embryos means we can transport high-quality embryos all around the world. They can be carried to places where cattle with a high milk yield or lots of meat are badly needed for breeding with poor local stock. Embryo cloning is also used to make lots of identical copies of embryos that have been **genetically modified** to produce medically useful compounds.

Examiner's tip

- Remember clones have identical genetic information.
- Make sure you are clear about the difference between a tissue and an embryo.

O links

For more information on cloning embryos, see B1 6.5 Adult cell cloning.

Summary questions

- 1 Define the following words:
 - a cuttings
 - b tissue cloning
 - c asexual reproduction
 - d embryo cloning.
- 2 Make a table to compare the similarities and differences between tissue cloning and taking cuttings.
- 3 a Cloning cattle embryos is very useful. Why?
 - **b** Draw a flow chart to show the stages in the embryo cloning of cattle.
 - c Suggest some of the economic and ethical issues raised by embryo cloning in cattle.

- New plant clones can be produced quickly and cheaply by taking cuttings from mature plants. The new plants are genetically identical to the older ones.
- A modern technique for cloning plants is tissue culture using cells from a small part of the original plant.
- Transplanting cloned embryos is one way in which animals are cloned.



Variation, reproduction and new technology

B₁ 6.5

Learning objectives

- How did scientists clone a sheep?
- What are the steps in the techniques of adult cell cloning?



Figure 1 Dolly the sheep was the first large mammal to be cloned from another adult mammal. She went on to have lambs of her own in the normal way.

Adult cell cloning

True cloning of animals, without sexual reproduction involved at all, has been a major scientific breakthrough. It is the most complicated form of asexual reproduction you can find.

Adult cell cloning

To clone a cell from an adult animal is easy. The cells of your body reproduce asexually all the time to produce millions of identical cells. However, to take a cell from an adult animal and make an embryo or even a complete identical animal is a very different thing.

When a new whole animal is produced from the cell of another adult animal, it is known as adult cell cloning. This is still relatively rare. You place the nucleus of one cell into the empty egg cell of another animal of the same species. Then you place the resulting embryo into the womb of another adult female where it develops until it is born.

Here are the steps involved:

- The nucleus is removed from an unfertilised egg cell.
- At the same time the nucleus is taken from an adult body cell, e.g. a skin cell of another animal of the same species.
- The nucleus from the adult cell is inserted (placed) in the empty egg cell.
- The new cell is given a tiny electric shock that makes it start dividing to form embryo cells. These contain the same genetic information as the original adult cell and the original adult animal.
- When the embryo has developed into a ball of cells it is inserted into the womb of an adult female to continue its development.

Adult cell cloning has been used to produce a number of whole animal clones. The first large mammal ever to be cloned from the cell of another adult animal was Dolly the sheep, born in 1997.

a What is the name of the technique that produced Dolly the sheep?

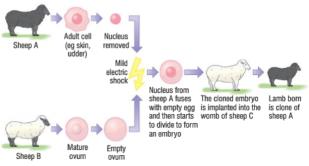


Figure 2 Adult cell cloning is still a very difficult technique – but scientists hope it may bring benefits in the future

Examiner's tip

Animals can be cloned by using embryo transplants or by adult cell cloning.



When Dolly was produced she was the only success from hundreds of attempts. The technique is still difficult and unreliable, but scientists hope that it will become easier in future.

How Science Works

The benefits and disadvantages of adult cell cloning

One big hope for adult cell cloning is that animals that have been genetically engineered to produce useful proteins in their milk can be cloned. This would give us a good way of producing large numbers of cloned, medically useful animals.

This technique could also be used to help save animals from extinction, or even bring back species of animals that died out years ago. The technique could be used to clone pets or prized animals so that they continue even after the original has died. However, some people are not happy about this idea.

There are some disadvantages to this exciting science as well. Many people fear that the technique could lead to the cloning of human babies. This could be used to help infertile couples, but it could also be abused. At the moment this is not possible, but who knows what might be possible in the future?

Another problem is that modern cloning techniques produce lots of plants or animals with identical genes. In other words, cloning reduces variety in a population. This means the population is less able to survive any changes in the environment that might happen in the future. That's because if one of them does not contain a useful characteristic, none of them will.

In a more natural population, at least one or two individuals can usually survive change. They go on to reproduce and restock. This could be a problem in the future for cloned crop plants or for cloned farm animals.

b How might adult cell cloning be used to help people?

Summary questions

- 1 Copy and complete using the words below: mammal adult technique genetic Dolly In cell cloning an animal is produced that is an exact copy of another adult animal. the sheep was the first large to be produced using this modern cloning
- 2 Produce a flow chart to show how adult cell cloning works.
- 3 What are the main advantages and disadvantages of the development of adult cell cloning techniques?

O links

For more information on adult cell clonina, see B1 6,7 Makina choices about technology.

Did you know ...?

The only human clones alive at the moment are natural ones known as identical twins! But the ability to clone mammals such as Dolly the sheep has led to fears that some people may want to have a clone of themselves produced whatever the cost.

- Scientists cloned Dollv the sheep using adult cell cloning.
- In adult cell cloning the nucleus of a cell from an adult animal is transferred to an empty egg cell from another animal. A small electric shock causes the egg cell to begin to divide and starts embryo development. The embryo is placed in the womb of a third animal to develop. The animal that is born is genetically identical to the animal that donated the original adult cell.



B₁ 6.6

Learning objectives

- What is genetic engineering?
- How are genes transferred from one organism to another?
- What are the issues involved in genetic engineering?

Genetic engineering

What is genetic engineering? (13)



Genetic engineering involves changing the genetic material of an organism. You take a gene from one organism and transfer it to the genetic material of a completely different organism. So, for example, genes from the chromosomes of a human cell can be 'cut out' using enzymes and transferred to the cell of a bacterium. The gene carries on making a human protein, even though it is now in a bacterium.

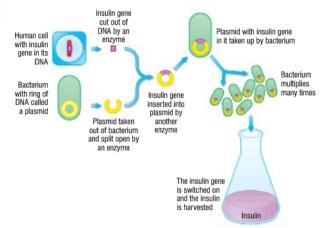


Figure 1 The principles of genetic engineering. A bacterial cell receives a gene from a human being so it makes the human hormone insulin.

a How is a gene taken out of one organism to be put into another?

If genetically engineered bacteria are cultured on a large scale they will make huge quantities of protein from other organisms. We now use them to make a number of drugs and hormones used as medicines.

Transferring genes to animal and plant cells

There is a limit to the types of proteins that bacteria are capable of making. As a result, genetic engineering has moved on. Scientists have found that genes from one organism can be transferred to the cells of another type of animal or plant at an early stage of their development. As the animal or plant grows it develops with the new desired characteristics from the other organism. For example, glowing genes from jellyfish have been used to produce crop plants which give off a blue light when they are attacked by insects. Then the farmer knows when they need spraying.

b Why are genes inserted into animals and plants as well as into bacteria?



The benefits of genetic engineering

Genetically engineered bacteria can make exactly the proteins we need, in exactly the amounts needed and in a very pure form. For example, people with diabetes need supplies of the hormone insulin. In the past people used animal insulin extracted from the pancreases of pigs and cattle. Now they can use pure human insulin produced by genetically engineered bacteria (see Figure 1).

We can use engineered genes to improve the growth rates of plants and animals. They can be used to improve the food value of crops as genetically modified (GM) crops usually have much bigger yields than ordinary crops. They can also be designed to grow well in dry, hot or cold parts of the world so could help to solve the problems of world hunger. Crops can be engineered to produce plants which make their own pesticide or are resistant to herbicides used to control weeds.

Human engineering

If there is a mistake in your genetic material, you may have a genetic disease. These can be very serious. Many people hope that genetic engineering can solve the problem.

It might become possible to put 'healthy' genes into the affected cells by genetic engineering, so they work properly. Perhaps the cells of an early embryo can be engineered so that the individual develops into a healthy person. If these treatments become possible, many people would have new hope of a normal life for themselves or their children.

c What do we mean by a 'genetic disease'?

The disadvantages of genetic engineering

Genetic engineering is still a very new science. No one knows what all of the long-term effects might be. For example, insects may become pesticide-resistant if they eat a constant diet of pesticide-forming plants.

Some people are concerned about the effect of eating GM food on human health. Genes from genetically modified plants and animals might spread into the wildlife of the countryside. GM crops are often made infertile, which means farmers in poor countries have to buy new seed each year.

People might want to manipulate the genes of their future children. This may be to make sure they are born healthy, but there are concerns that people might want to use it to have 'designer' children with particular characteristics such as high intelligence. Genetic engineering raises issues for us all to think about.

Summary questions

- 2 a Make a flow chart that explains the stages of genetic engineering.
 - b Make two lists, one to show the possible advantages of genetic engineering and the other to show the possible disadvantages.



Figure 2 You can't tell that food is genetically modified just by looking at it! In the UK, few GM foods are sold and they have to be clearly labelled. Many other countries, including the USA, are less worried and use GM food widely.

- Genes can be transferred to the cells of animals and plants at an early stage of their development so they develop desired characteristics. This is genetic engineering.
- In genetic engineering, genes from the chromosomes of humans and other organisms can be 'cut out' using enzymes and transferred to the cells of bacteria and other organisms.
- There are advantages and disadvantages associated with genetic engineering.





B₁6.7

Learning objectives

 What sort of economic. social and ethical issues are there about new techniques such as cloning and genetic engineering?

Making choices about technology

Cloning pets (R)



Cc, or Copycat, was the first cloned cat to be produced. Most of the research into cloning had been focused on farm and research animals - but cats are thought of first and foremost as pets.

Much of the funding for cat cloning in the US comes from companies who are hoping to be able to clone people's dying or dead pets for them. It has already been shown that a successful clone can be produced from a dead animal. Cells from beef from a slaughter house were used to create a live cloned calf.

It took one hundred and eighty-eight attempts to make Cc, producing 87 cloned embryos, only one of which resulted in a kitten. Cloning your pet won't be easy or cheap. The issue is, should people be cloning their dead cats, or would it be better to give a home to one of the thousands of unwanted cats already in existence? Even if a favourite pet cat is cloned, it may look nothing like the original because the coat colour of many cats is the result of genes switching on and off at random in the skin cells. The clone will develop and grow in a different environment to the original cat as well. This means other characteristics that are affected by the environment will probably be different too.



Did you know ...?

Dogs have also been cloned. In 2009, an American couple paid more than £100,000 to have a clone of their much-loved pet Labrador. The new dog is called Lancelot encore (encore means 'again').



Figure 2 Lancelot encore, a clone of a much-loved pet, and a portrait of the original dog





Figure 1 The cat on the left is Rainbow. The cat on the right is Cc, Rainbow's clone. Rainbow and Cc share the same DNA - but they don't look the same.

To some people these are exciting events. To others they are a waste of time, money and the lives of all the embryos that don't make it. What do you think?

Activity

In B1 6.4 and B1 6.5 there is information about cloning animals and plants for farming. Here you have two different stories about cloning animals for money (Cc and Lancelot encore).

There is talk of a local company setting up a laboratory to clone cats, dogs and horses for anyone in the country who wants to do this.

Write a letter or post a blog either for the application or against it. Make sure you use clear, sensible arguments and put the science of the situation across clearly.

The debate about GM foods

Ever since genetically modified foods were first introduced there has been controversy and discussion about them. For example, varieties of GM rice known as 'golden rice' and 'golden rice 2' have been developed. These varieties of rice produce large amounts of vitamin A. Up to 500 000 children go blind each year as a result of lack of vitamin A in their diets. In theory golden rice offers a solution to this problem. In fact, many people objected to the way trials of the rice were run and the cost of the product. No golden rice is yet being grown in countries affected by vitamin A blindness.

There is a lot of discussion about genetically modified crops. Here are some commonly expressed opinions.



Figure 3 The amount of beta carotene in golden rice and golden rice 2 is reflected in the depth of colour of the rice

John, 49, plumber, UK

'I'm very concerned about GM foods. Who knows what we're all eating nowadays. I don't want strange genes inside me, thank you very much. We've got plenty of fruit and vegetables as it is – why do we need more?'

Ali, 26, shop assistant, UK

'I think GM food is such a good idea. If the scientists can modify crops so they don't go off so quickly, food should get cheaper, and there will be more to go around. And what about these plants that produce pesticides? That'll stop a lot of crop spraying, so that should make our food cleaner and cheaper. It's typical of us in the UK that we moan and panic about it all.'

Tilahun, 35, farmer, Ethiopia

'I have some real worries about the GM crops that don't form fertile seeds. In the past, farmers in poorer countries just kept seeds from the previous year's crops, so it was cheap and easy. With the GM crops we have to buy new seeds every year – although I hear that won't be the case with golden rice. On the other hand, these GM crops don't need spraying very much. They grow well in our dry conditions, they give a much bigger crop yield and keep well too – so there are some advantages.'

Summary questions

- 1 People get very concerned about cloning. Do you think these fears are justified? Explain your answer.
- 2 Summarise the main advantages and disadvantages of genetic engineering expressed here.

Activity

You are going to produce a 5-minute slot for a daytime television show on 'Genetic engineering – a good thing or not?' Using the information here and on B1 6.6 Genetic engineering (and extra research if you have time), plan out a script for your time on air, remembering that you have to inform the public about genetic engineering, entertain them and make them think about the issues involved.

Key points

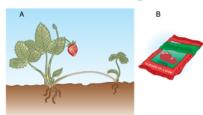
 There are a number of economic, social and ethical issues concerning cloning and genetic engineering which need to be considered when making judgements about the use of this science.



Variation, reproduction and new technology: B1 6.1-B1 6.7

Summary questions (1)





- a How has the small plant shown in diagram A been produced?
- b What sort of reproduction is this?
- c How were the seeds in B produced?
- d How are the new plants that you would grow from the packet of seeds shown in B different from the new plants shown in A?
- 2 a What is a gene?
 - b Where do you find genes?
 - c What is a gamete?
- 3 Tissue culture techniques mean that 50 000 new raspberry plants can be grown from one old one instead of two or three by taking cuttings. Cloning embryos from the best bred cows means that they can be genetically responsible for 30 or more calves each year instead of two or three.
 - a How does tissue culture differ from taking cuttings?
 - b How can one cow produce 30 or more calves in a vear?
 - c What are the similarities between cloning plants and cloning animals in this way?
 - d What are the differences in the techniques for cloning animals and plants?
 - e Why do you think there is so much interest in finding different ways to make the breeding of farm animals and plants increasingly efficient?
- 4 a Describe the process of adult cell cloning.
 - b There has been a great deal of media interest and concern about cloning animals but very little about cloning plants. Why do you think there is such a difference in the way people react to these two different technologies?

- 5 Human growth is usually controlled by growth hormones produced by the pituitary gland in your brain. If you don't make enough hormones, you don't grow properly and remain very small. This condition affects 1 in every 5000 children. Until recently the only way to get growth hormone was from the pituitary glands of dead bodies. Genetically engineered bacteria can now make plenty of pure growth hormone.
 - a Draw and label a diagram to explain how a healthy human gene for making growth hormone can be taken from a human chromosome and put into a working bacterial cell.
 - b What are the advantages of producing substances like growth hormone using genetic engineering?
- 6 In 2003 two mules called Idaho Gem and Idaho Star were born in America. They were clones of a famous racing mule. They both seem very healthy. They were separated and sent to different stables to be reared and trained for racing. So far Idaho Gem has been more successful than his cloned brother, winning several races against ordinary racing mules. There is a third clone, Utah Pioneer, which has not been raced.
 - a The mules are genetically identical. How do you explain the fact that Idaho Gem has beaten Idaho Star in several races?
 - b Why do you think one of the clones is not being
 - c Their progress is being carefully monitored by scientists. What type of data do you think will be available from these animals?
- One concern people have about GM crops is that they might cross pollinate with wild plants. Scientists need to find out how far pollen from a GM crop can travel to be able to answer these concerns.

Describe how a trial to investigate this might be set up.

A()A/Examination-style questions (A)

Strawberries are able to reproduce many plants from one parent plant.

Choose the correct answer to complete each sentence.

- a Producing new plants with one parent is called. asexual reproduction genetic engineering sexual reproduction
- b The advantage of this is that all the strawberry fruits (1)

be bigger all taste better all taste the same

- c A disadvantage of this to the strawberry plants is that there is more variation they are genetically identical they cannot mate
- 2 Read the passage. Use the information and your own knowledge to answer the questions.

At one time, the boll weevil destroyed cotton crops. Farmers sprayed the crops with a pesticide.

The weevil died out but another insect, the bollworm moth, became resistant to this pesticide.

In the 1990s large crops of the cotton plant were destroyed by the bollworm moth. The pesticides then used to kill the moth were expensive and very poisonous, resulting in deaths to humans.

Scientists investigated alternative ways to control the bollworm moth. They found out that a type of bacterium produced a poison which killed bollworm larvae (grubs).

A GM cotton crop plant was developed which produced the poison to kill bollworms. This proved to be very effective and farmers were able to stop using pesticide sprays.

Now farmers have another problem. Large numbers of other insects have multiplied because they were not killed when the farmers stopped using pesticides. Some of these insects have started to destroy the GM cotton and farmers are beginning to use pesticides again!

- Give one advantage of spraying crops with pesticides.
 - ii Give two disadvantages of spraying crops with pesticides.
 - iii Give one economic advantage of using GM cotton.
 - iv Some people object to using GM crops. Suggest
- b In this question you will be assessed on using good English, organising information clearly and using specialist terms where appropriate.

one reason why.

The GM cotton was genetically engineered to produce the same poison as the bacterium. Describe fully how this is done. (6) 3 The use of cloned animals in food production is controversial.

It is now possible to clone 'champion' cows.

Champion cows produce large quantities of milk.

- a Describe how adult cell cloning could be used to produce a clone of a 'champion' cow.
- **b** Read the passage about cloning cattle.

The Government has been accused of 'inexcusable behaviour' because a calf of a cloned American 'champion' cow has been born on a British farm. Campaigners say it will undermine trust in British food because the cloned cow's milk could enter the human food chain.

But supporters of cloning say that milk from clones and their offspring is as safe as the milk we drink every day.

Those in favour of cloning say that an animal clone is a genetic copy. It is not the same as a genetically engineered animal. Opponents of cloning say that consumers will be uneasy about drinking milk from cloned animals.

Use the information in the passage and your own knowledge and understanding to evaluate whether the government should allow the production of milk from cloned 'champion' cows.

Remember to give a conclusion to your evaluation. AQA, 2006



Evolution

B1 7.1

Learning objectives

- What is the theory of evolution?
- What is the evidence that evolution has taken place?

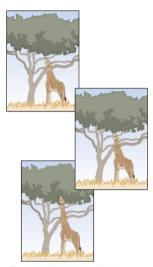


Figure 1 In Lamarck's model of evolution, giraffes have long necks because each generation stretched up to reach the highest leaves. So each new generation had a slightly longer neck.

Theories of evolution

We are surrounded by an amazing variety of life on planet Earth. Questions such as 'Where has it all come from?' and 'When did life on Earth begin?' have puzzled people for many generations.

The theory of evolution tells us that all the species of living things alive today have evolved from the first simple life forms. Scientists think these early forms of life developed on Earth more than 3 billion years ago. Most of us take these ideas for granted – but they are really quite new.

Up to the 18th century most people in Europe believed that the world had been created by God. They thought it was made, as described in the Christian Bible, a few thousand years ago. However, by the beginning of the 19th century scientists were beginning to come up with new ideas.

Lamarck's theory of evolution

Jean-Baptiste Lamarck was a French biologist. He thought that all organisms were linked by what he called a 'fountain of life'. He made the great step forward of suggesting that individual animals adapted and evolved to suit their environment. His idea was that every type of animal evolved from primitive worms. The change from worms to other organisms was caused by the inheritance of acquired characteristics.

Lamarck's theory was that the way organisms behaved affected the features of their body – a case of 'use it or lose it'. If animals used something a lot over a lifetime he thought it would grow and develop. Any useful changes that took place in an organism during its lifetime would be passed from a parent to its offspring. The neck of the giraffe is a good example. If a feature wasn't used, Lamarck thought it would shrink and be lost.

Lamarck's theory influenced the way **Charles Darwin** thought. However, there were several problems with Lamarck's ideas. There was no evidence for his 'fountain of life' and people didn't like the idea of being descended from worms. People could also see quite clearly that changes in their bodies – such as big muscles, for example – were not passed on to their children.

We now know that in the great majority of cases Lamarck's idea of inheritance cannot happen. However, scientists have discovered that in a few cases the way an animal behaves actually changes its genes. This results in the next generation behaving in the same way.

a What do you think is meant by the phrase 'inheritance of acquired characteristics'?

Charles Darwin and the origin of species

Our modern ideas about evolution began with the work of one of the most famous scientists of all time – Charles Darwin. Darwin set out in 1831 as the ship's naturalist on *HMS Beagle*. He was only 22 years old at the start of the voyage to South America and the South Sea Islands.

Darwin planned to study geology on the trip. But as the voyage went on he became as excited by his collection of animals and plants as by his rock samples.

b What was the name of the ship that Darwin sailed on?



Remember the basic key stages in natural selection: survive → breed → pass on genes



In South America, Darwin discovered a new form of the common rhea, an ostrich-like bird. Two different types of the same bird living in slightly different areas set Darwin thinking.

On the Galapagos Islands he was amazed by the variety of species. He noticed that they differed from island to island. Darwin found strong similarities between types of finches, iguanas and tortoises on the different islands. Yet each was different and adapted to make the most of local conditions.

Darwin collected huge numbers of specimens of animals and plants during the voyage. He also made detailed drawings and kept written observations. The long journey home gave him plenty



Figure 2 Darwin was very impressed by the giant tortoises he found on the Galapagos Islands. The tortoises on each island had different-shaped shells and a slightly different way of life. Darwin made detailed drawings of them all.

of time to think about what he had seen. Charles Darwin returned home after five years with some new and different ideas forming in his mind.

c What is the name of the famous islands where Darwin found so many interesting species?

After returning to England, Darwin spent the next 20 years working on his ideas. Darwin's theory of evolution by natural selection is that all living organisms have evolved from simpler life forms. This evolution has come about by a process of natural selection.

Reproduction always gives more offspring than the environment can support. Only those that have inherited features most suited to their environment – the 'fittest' – will survive. When they breed, they pass on the genes for those useful inherited characteristics to their offspring. This is natural selection.

When Darwin suggested how evolution took place, no one knew about genes. He simply observed that useful inherited characteristics were passed on. Today, we know it is useful genes which are passed from parents to their offspring in natural selection.



Figure 3 Darwin worked here in his study for around 20 years, carrying out experiments and organising his ideas on evolution by natural selection

AQA Examiner's tip

Avoid confusion between:

- the theory of evolution and
- the process of natural selection.

Summary questions

- 1 Explain what is meant by the following terms:
 - a evolution
 - b natural selection
- 2 What was the importance of the following in the development of Darwin's ideas?
 - a South American rheas
 - b Galapagos tortoises, iguanas and finches
 - c the long voyage of HMS Beagle
 - d the 20 years from his return to the publication of his book The Origin of Species.

- The theory of evolution states that all the species which are alive today – and many more which are now extinct – evolved from simple life forms that first developed more than 3 billion years ago.
- Darwin's theory is that evolution takes place through natural selection.





B₁ 7.2

Learning Objectives

 Why was Darwin's theory of evolution only gradually accepted?

Accepting Darwin's ideas

Charles Darwin came back from his trip on *HMS Beagle* with new ideas about the variety of life on Earth. He read many books and thought about the ideas of many other people such as Lamarck, Lovell and Malthus. He gradually built up his theory of evolution by natural selection.

He knew his ideas would be controversial. He expected a lot of opposition both from fellow scientists and from religious leaders.

Building up the evidence

Darwin realised he would need lots of evidence to support his theories. This is one of the reasons why it took him so long to publish his ideas. He spent years trying to put his evidence together in order to convince other scientists.

He used the amazing animals and plants he had seen on his journeys as part of that evidence. They showed that organisms on different islands had adapted to their environments by natural selection. So they had evolved to be different from each other.

Darwin carried out breeding experiments with pigeons at his home. He wanted to show how features could be artificially selected. Darwin also studied different types of barnacles (small invertebrates found on seashore rocks) and where they lived. This gave him more evidence of organisms adapting and forming different species.

Darwin built up a network of friends, fellow scientists and pigeon breeders. He didn't travel far from home (he was often unwell) but he spent a lot of time discussing his ideas with this group of friends. They helped him get together the evidence he needed and he trusted them as he talked about his ideas.

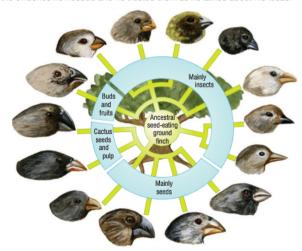


Figure 1 The finches found on the different Galapagos islands look very different but all evolved from the same original type of finch by natural selection



Why did people object?

In 1859, Darwin published his famous book *On the Origin of Species by means of Natural Selection* (often known as *The Origin of Species*). The book caused a sensation. Many people were very excited by his ideas and defended them enthusiastically. Others were deeply offended, or simply did not accept them.

There were many different reasons why it took some scientists a long time to accept Darwin's theory of natural selection. They include:

- The theory of evolution by natural selection challenged the belief that God made all of the animals and plants that live on Earth. This religious view was the generally accepted belief among most people in early Victorian England.
- In spite of all Darwin's efforts, many scientists felt there was not enough evidence to convince them of his theory.
- There was no way to explain how variety and inheritance happened. The mechanism of how inheritance happens by genes and genetics was not known until 50 years after Darwin published his ideas. Because there was no mechanism to explain how characteristics could be inherited, it was much harder for people to accept and understand.

The arguments raged and it took some time before the majority of scientists accepted Darwin's ideas. However, by the time of his death in 1882 he was widely regarded as one of the world's great scientists. He is buried in Westminster Abbey along with other great people like Sir Isaac Newton.

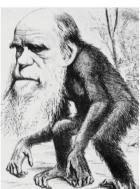


Figure 3 It wasn't just scientists who were interested in Darwin's ideas. Cartoonists loved the idea of evolution too

Summary questions

- 1 a Darwin set out in HMS Beagle in 1831. How many years later did he publish The Origin of Species?
 - b What was Darwin's big idea?
- 2 What type of evidence did Darwin put together to convince other scientists his ideas were right?
- 3 Why did it take some time before most people accepted Darwin's ideas?



Figure 2 Darwin's famous book – it sold out on the first day of publication!

?p? Did you know ...?

Darwin let his children use the back of his original manuscript of *The Origin of Species* as drawing paper. Not many of these original pages exist. Darwin kept the ones that remain because of his children's drawings rather than his own writing!

- Darwin's theory of evolution by natural selection was only gradually accepted for a number of reasons. These include:
 - a conflict with the widely held belief that God made all the animals and plants on the Earth
 - insufficient evidence
 - no mechanism for explaining variety and inheritance – genetics were not understood for another 50 years.



Evolution

B₁ 7.3

Learning objectives

- How does natural selection work?
- What is mutation?

O links

For more information on the competition between plants and animals in the natural world, look back at B1 4.4 Competition in animals and B1 4.5 Competition in plants.



Figure 1 The natural world is often brutal. Only the best adapted predators capture prey - and only the best adapted prey animals escape.

Did you know ...?

Fruit flies can produce 200 offspring every two weeks. The vellow star thistle, an American weed, produces around 150000 seeds per plant per year. If all those offspring survived we'd be overrun with fruit flies and yellow star thistles!

Iinks

For information on genes, see B1 § 1 Inheritance.

Natural selection (R)

Scientists explain the variety of life today as the result of a process called natural selection. The idea was first suggested about 150 years ago by Charles Darwin.

Animals and plants are always in competition with each other. Sometimes an animal or plant gains an advantage in the competition. This might be against other species or against other members of its own species. That individual is more likely to survive and breed. This is known as natural selection.

a Who first suggested the idea of natural selection?

Survival of the fittest (K



Charles Darwin was the first person to describe natural selection as the 'survival of the fittest'. Reproduction is a very wasteful process. Animals and plants always produce more offspring than the environment can support.

The individual organisms in any species show lots of variation. This is because of differences in the genes they inherit. Only the offspring with the genes best suited to their habitat manage to stay alive and breed successfully. This is natural selection at work.

Think about rabbits. The rabbits with the best all-round eyesight, the sharpest hearing and the longest legs will be the ones that are most likely to escape being eaten by a fox. They will be the ones most likely to live long enough to breed. What's more, they will pass those useful genes on to their babies. The slower, less alert rabbits will get eaten and their genes are less likely to be passed on.

b Why would a rabbit with good hearing be more likely to survive than one with less keen hearing?

The part played by mutation

New forms of genes result from changes in existing genes. These changes are known as mutations. They are tiny changes in the long strands of DNA.

Mutations occur quite naturally through mistakes made in copying DNA when the cells divide. Mutations introduce more variety into the genes of a species. In terms of survival, this is very important.

c What is a mutation?

Many mutations have no effect on the characteristics of an organism, and some mutations are harmful. However, just occasionally a mutation has a good effect. It produces an adaptation that makes an organism better suited to its environment. This makes it more likely to survive and breed.

Whatever the adaptation, if it helps an organism survive and reproduce it will get passed on to the next generation. The mutant gene will gradually become more common in the population. It will cause the species to evolve.

When new forms of a gene arise from mutation, there may be a relatively more rapid change in a species. This is particularly true if the environment changes. If the mutation gives the organism an advantage in the changed environment, it will soon become common.

Natural selection in action

Malpeque Bay in Canada has some very large oyster beds. In 1915, the oyster fishermen noticed a few small, flabby oysters with pus-filled blisters among their healthy catch.

By 1922 the oyster beds were almost empty. The oysters had been wiped out by a destructive new disease (soon known as Malpeque disease).

Fortunately a few of the oysters had a mutation which made them resistant to the disease. These were the only ones to survive and breed. The oyster beds filled up again and by 1940 they were producing more oysters than ever.

A new population of oysters had evolved. As a result of natural selection, almost every oyster in Malpeque Bay now carries a gene that makes them resistant to Malpeque disease. So the disease is no longer a problem.

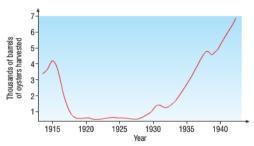


Figure 3 Oyster yields from Malpeque Bay 1915–40. As you can see, disease devastated the oyster beds. However, thanks to the process of natural selection, a healthy population of oysters managed to survive and reproduce again.

d What is Malpegue disease?

Summary questions

- 1 Copy and complete using the words below:

 adaptation breed environment generation

 mutation selection organism survive

 When a ______ has a good effect it produces an ______ that makes an _____ better suited to its ______. This makes it more likely to ______.

 and ______. The mutation then gets passed on to the next ______. This is natural.
- 2 Many features that help animals and plants survive are the result of natural selection. Give three examples, e.g. all-round eyesight in rabbits.
- 3 Explain how the following characteristics of animals and plants have come about in terms of natural selection.
 - a Male red deer have large sets of antiers.
 - b Cacti have spines instead of leaves.
 - c Camels can tolerate their body temperature rising far higher than most other mammals.



Figure 2 The tiny number of dandelion seeds that survive and grow into plants have a combination of genes that gives them an edge over all the others

- Natural selection works by selecting the organisms best adapted to a particular habitat.
- Different organisms in a species show a wide range of variation because of differences in their genes.
- The individuals with the characteristics most suited to their environment are most likely to survive and breed successfully.
- The genes that have produced these successful characteristics are then passed on to the next generation.
- Mutation is a change in the genetic material (DNA) which results in a new form of a gene.



Evolution

B₁ 7.4

Learning objectives

- What is classification?
- How does classification help us understand evolution?



Did you know ...?

The most widely accepted kingdoms of microorganisms are Monera, Protista and Fungi. However, there is still a lot of argument between scientists as to exactly which organisms fit into each kingdom.







Figure 1 Animals, plants and microorganisms are identified by the differences between them rather than the minitarities

Classification and evolution

How are organisms classified?

Classification is the organisation of living things into groups according to their similarities.

There are millions of different types of living organisms. Biologists classify living things to make it easier to study them. Classification allows us to make sense of the living world. It also helps us to understand how life began and how the different groups of living things are related to each other.

Living things are classified by studying their similarities and differences. By looking at similarities and differences between organisms we can decide which should be grouped together.

The system we use for classifying living things is known as the **natural** classification system. The biggest groups are the **kingdoms**, and the best known are the animal kingdom and the plant kingdom. The microorganisms are then split between three different kingdoms.

Kingdoms contain lots of organisms with many differences but a few important similarities. For example, all animals move their whole bodies about during at least part of their life cycle, and their cells do not have cell walls. Plants on the other hand do not move their whole bodies about, and their cells have cell walls. Also some plant cells contain chloroplasts full of chlorophyll for photosynthesis.

The smallest group is a **species**. Members of the same species are very similar. Any differences are small variations of the same feature. A species is a group of organisms that can breed together and produce fertile offspring. Orang-utans, dandelions and brown trout are all examples of species of living organisms.

a What is classification?

Classification and evolutionary relationships

In the past, we relied on careful observation of organisms to decide which group they belonged to. Out in the field, this is still the main way we identify an organism. However, scientists develop models to suggest relationships between living organisms.

Since Darwin's time, scientists have used classification to show the evolutionary links between different organisms. These models are called **evolutionary trees**. They are built up by looking at the similarities and differences between different groups of organisms. One of the most famous evolutionary trees was produced by Darwin himself. It was found in one of the notebooks that he used to plan his book *The Origin of Species*. It starts off with the words 'I think'. Then it shows how Darwin was beginning to see relationships between different groups of living organisms (see Figure 2).

However, observation may not tell you the whole story. Some organisms look very different but are closely related. Others look very similar but come from very different groups. Now scientists are increasingly using DNA evidence to decide what species an animal belongs to. They look for differences as well as similarities in the DNA. This allows them to work out the **evolutionary relationships** between organisms. It also means they can see how long ago different organisms had a common ancestor.

b What is an evolutionary tree?

Evolutionary and ecological relationships (

Classifying organisms helps us to understand how they evolved. It can also help us understand how species have evolved together in an environment. We call this their ecological relationships and it is another way of modelling relationships between organisms.

For example, pandas have a thumb which they use to grip bamboo. However it is not like a human thumb – it has evolved from specialised wrist bones. The only other animals to have a similar 'wrist thumb' are the red pandas. Both red pandas and giant pandas eat bamboo. Based on their modern ecological feeding relationships, it looks as if they are closely related in evolution. However, based on their anatomy and DNA, giant pandas are closely related to other species of bears. Red pandas are much more closely related to raccons.

Recently scientists found a fossil ancestor of red pandas which also had a 'wrist thumb'. There is also evidence from the ecological relationships of this fossil animal. This suggests the thumb evolved as an adaptation for a quick escape into trees carrying prey stolen from sabre-toothed tigers. This is rather different from the giant panda evolving to feed on bamboo.

Now the ecological models and the evolutionary models match – the two species had a common ancestor a very long time ago, but the special 'wrist thumb' evolved separately as adaptations to solve two different ecological problems.

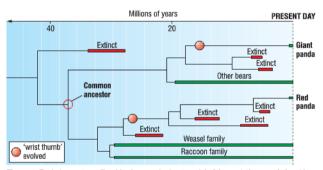


Figure 3 Evolutionary trees like this show us the best model of the evolutionary relationships between organisms



Figure 2 This evolutionary tree was found in one of the notebooks that Darwin used to plan his book *The Origin of Species*





Figure 4 Both the giant panda and the red panda use the 'wrist thumb' to eat bamboo

Summary questions

- 1 Copy and complete using the words below:
 - kingdoms animals organisms species classify microorganisms similarities
- 2 What observations can be made to compare living organisms?
- 3 How are evolutionary trees useful to us?

- Studying the similarities and differences between organisms allows us to classify them into animals, plants and microorganisms.
- Classification also helps us to understand evolutionary and ecological relationships.



Summary questions (A)

- What was Jean-Baptiste Lamarck's theory of evolution?
- 2 a What started Charles Darwin thinking about the variety of life and how it has come about?
 - b Explain Darwin's theory of evolution.
- 3 a Summarise the similarities and differences between. Darwin's and Lamarck's theories of evolution.
 - b Why do you think Lamarck's theory was so important to the way Darwin's theory was subsequently received?

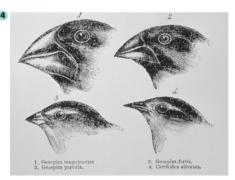


Figure 1 Darwin's finches - more evidence for evolution

Look at the birds in Figure 1. They are known as Darwin's finches. They live on the Galapagos Islands. Each one has a slightly different beak and eats a different type of food.

Explain carefully how natural selection can result in so many different beak shapes from one original type of founder finch.

5 Alfred Russel Wallace came from a poor family but he was a gifted naturalist. He went on a collecting expedition to Borneo, an island in South East Asia that has a rich variety of unique animal and plant life. While he was there. Wallace became ill with a fever and while he was unwell he developed his theory. He had the idea that if species exist in various forms, the organisms that are not well adapted to change are likely to die out. This would leave only the better-adapted forms to survive and breed. Wallace put his ideas down in a paper and sent it to Charles Darwin for advice. Darwin and Wallace both published papers together on their ideas in London at the same time. It was Wallace's work that shocked Darwin into finally writing The Origin of Species. Wallace's ideas were not as well thought out as Darwin's and he did not have the evidence to back them up, which is why it is largely Darwin who is remembered for the theory of evolution by natural selection.

- a What was Wallace's theory?
- b What are the similarities between Borneo and the Galapagos and how would this have helped Wallace develop his theory?
- c Why do you think the arrival of Wallace's letter and paper was such a shock to Darwin?
- d Wallace's theories were not strongly supported by evidence. What sort of evidence did Darwin bring forward to support his ideas in The Origin of Species?
- 6 a What is classification?
 - b Explain two alternative ways of deciding how to classify an organism.
 - c What are the differences and similarities between an evolutionary relationship and an ecological relationship between organisms?
- 👬 It is difficult to gather data that illustrate evolution. It is possible to gather data to show natural selection, but this usually takes a long time. Simulations are useful because, while they are not factually correct, they do show how natural selection might work.

A class decided to simulate natural selection, using different tools to pick up seeds.

Four students each chose a particular tool to pick up seeds. The teacher then scattered hundreds of seeds onto a patch of grass outside the lab. The four students were given 5 minutes to pick up as many seeds as they could.

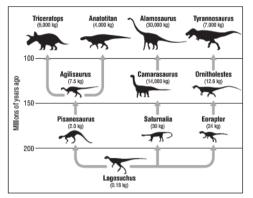
James, who was using a spoon, picked up 23 seeds, whilst Farzana, using a fork, could only pick up two. Claire managed seven seeds with the spatula, but Jenny struggled to pick up her two seeds with a pair of scissors.

- a Put the essential data into a table.
- b How would the data be best presented? Explain your choice.
- c Was this a fair test? Explain your answer.
- d What conclusion can you draw from this simulation?
- e How does this simulation model the situation with the finches on the Galapagos Islands, which evolved into many different species?

A()A/Examination-style questions (L)

 a This diagram shows a timeline for the evolution of some dinosaurs. The mass of each dinosaur is shown in the brackets by its name.

Choose the correct answer to complete each sentence.



Dinosaur evolution timeline

	JSa	iur evolution timenne	
	i	A dinosaur which lived between 100 and 150 million years ago is	(1)
		, ,	(1)
		Agilisaurus Saturnalia Tyrannosaurus	
	ii	Camarasaurus evolved from	(1)
		Agilisaurus Alamosaurus Saturnalia	
	iii	The difference in mass between Agilisaurus and	413
		the smallest dinosaur iskg.	(1)
		1.82 5.5 7.32	
b	i	The earliest life forms developed on Earth more	
		than 3 years ago.	(1)
		billion million thousand	
	ii	The earliest life forms can be described as	
			(1)
		bony complex simple	
С		arwin suggested a theory of evolution. His theory is scribed as evolution by	s (1)
	ac	quired characteristics a god natural selection	

2 Giraffes have developed their long necks over millions of years.

> Two scientists tried to explain why the giraffes have long necks. They are called Darwin and Lamarck.



Match the name in List A to the correct statement in List B.

present at birth

List B

Name
Darwin only
Lamark only
Both Lamark
and Darwin

List A

Statement
Noticed that the neck of the giraffe changed over time
Had enough evidence to prove why the giraffe's neck got longer
Thought that natural selection worked on variations in neck length

Thought the giraffe stretched its neck while eating leaves in trees. Then its young inherited the longer neck

3 The photograph shows a snake eating a toad.



Cane toads were first introduced into Australia in 1935. The toads contain toxins and most species of Australian snake die after eating the toad. The cane toad toxin does not affect all snakes the same way. Longer snakes are less affected by toad toxin. Scientists investigated how red-bellied black snakes had changed in the 70 years since cane toads were introduced into their area. They found that red-bellied black snakes had become longer by around 3–5%.

Suggest an explanation for the change in the body length of the red-bellied black snakes since the introduction of the cane toads.

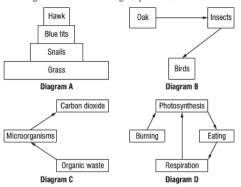
AQA, 2005



(3)

Examination-style questions

The diagrams show some biological processes.



- a Write one letter, A, B, C or D to complete each sentence
 - The diagram which shows the process of decay is (1)
 - ii The diagram which shows a pyramid of biomass is
 (1)
 - iii The diagram which shows the carbon cycle is (1)
- b The grass and the oak tree can photosynthesise.

What is the source of energy for photosynthesis? (1)

c In Diagram A, the bar for grass is bigger than the bar for the hawk.

Suggest two reasons why. (2)

Read the passage.

Some microorganisms live in very unusual environments.

Scientists have discovered bacteria that can survive in temperatures between $80\,^\circ\!C$ and $105\,^\circ\!C$ and at pressures 1000 times higher than atmospheric pressure.

Other bacteria, called halophiles live in super salty conditions.

Some bacteria need large amounts of iron in quantities that would kill most other organisms.

These unusual environments may be similar to early times on Earth, when the first life forms lived in very extreme conditions, such as very hot water containing high concentrations of salt, iron and other minerals.

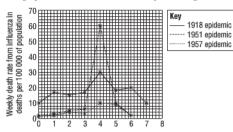
- a What is the name given to all the bacteria which live in these unusual environments?
- b Which chemical in human cells would not work at temperatures between 80°C and 105°C?
- e How long ago did early life forms appear on Earth? (1)
- d Halophiles breed in very salty conditions. The offspring of halophiles can also live in very salty conditions.

Choose the correct answer to complete the sentence.

genes iron salt

- 3 Influenza is a disease caused by a virus.
 - a Suggest two reasons why it is difficult to treat diseases caused by viruses.
 - b In some years there are influenza epidemics.

The graph shows the death rate in Liverpool during three influenza epidemics.



Time in weeks from start of epidemic

- i The population of Liverpool in 1951 was approximately 700 000. Calculate the approximate number of deaths from influenza in week 4 of the 1951 epidemic.
 - Show clearly how you work out your answer.
- ii In most years, the number of deaths from influenza in Liverpool is very low. Suggest, in terms of the influenza virus and the body's immune system, three reasons why there were large numbers of deaths in years such as 1918 and 1951.
- 4 In this question you will be assessed on using good English, organising information clearly and using specialist terms where appropriate.

Hormones are used in contraceptive pills.

Read the information about the trialling of the first contraceptive pill.

The Pill was developed by a team of scientists led by Gregory Pincus. The team needed to carry out large-scale trials on humans.

In the summer of 1955, Pincus visited the island of Puerto Rico. Puerto Rico is one of the most densely populated areas in the world. Officials supported birth control as a form of population control. Pincus knew that if he could demonstrate that the poor, uneducated women of Puerto Rico could use the Pill correctly then so could women anywhere in the world.

The scientists selected a pill with a high dose of hormones to ensure that no pregnancies would occur while test subjects were taking the drug. The Pill was found to be 100% effective when taken properly. But 17% of the women in the study complained of side effects. Pincus ignored these side effects.

The women in the trial had been told only that they were taking a drug that prevented pregnancy. They had not been told that the Pill was experimental or that there was a chance of dangerous side effects.

Evaluate the methods used by Pincus in trialling the contraceptive pill. (6)

A()A Examiner's tip

(2)

(2)

Before answering a graph question be sure to read all the information before the graph and then read the axis labels. When a graph has several lines, as in 3b, check the key before you take any readings.

Next, read the question instructions. Why has the examiner told you the population is 700 000? You need this information because the numbers of deaths is given per 100000.

Before doing the calculation, check again that you are reading the point on the correct graph line.

$\P(A)$ Examiner's tip

When you see the following instruction

In this question you will be assessed on using good English, organising information clearly and using specialist terms where appropriate.

Be aware that you will lose marks if you do not:

- write in a logical order
- use the correct scientific terms and spell them correctly
- PLAN before you WRITE.



Cells, tissues and organs

B2 1.1

Learning objectives

- What do the different parts of your cells do?
- Are human cells the same as other animal cells?
- How do plant and algal cells differ from animal cells?



Figure 1 Diagrams of cells are much easier to understand than the real thing seen under a microscope. This picture shows a magnified animal cell.

*(QA Examiner's tip

Remember that not all plant cells have chloroplasts. Don't confuse chloroplasts and chlorophyll.

O links

For more information on photosynthesis, look at B2 2.1 Photosynthesis.

Animal and plant cells (8)

The Earth is covered with a great variety of living things. However, they all have one thing in common – they are all made up of cells. Most cells are very small. You can only see them using a microscope.

The **light microscopes** in schools may magnify things several hundred times. Scientists have found out even more about cells using **electron microscopes**. These can magnify things more than a hundred thousand times!

Animal cells – structure and function

All cells have some features in common. We can see these clearly in animal cells. The cells of your body have these features, just like the cells of every other living thing.

- The nucleus controls all the activities of the cell. It contains the genes on the chromosomes. They carry the instructions for making new cells or new organisms.
- The cytoplasm a liquid gel in which most of the chemical reactions needed for life take place.
- The cell membrane controls the passage of substances into and out of the cell.
- The mitochondria structures in the cytoplasm where oxygen is used and most of the energy is released during respiration.
- Ribosomes where protein synthesis takes place. All the proteins needed in the cell are made here.

Plant cells - structure and function

Plants are very different organisms from animals. They make their own food by photosynthesis. They stay in one place, and do not move their whole bodies about from one place to another.

Plant cells have all the features of a typical animal cell, but they also contain features that are needed for their very different way of life. Algae are simple aquatic organisms. They also make their own food and have many similar features to plant cells.

All plant and algal cells have:

• a cell wall made of cellulose that strengthens the cell and gives it support.

Many (but not all) plant cells also have these other features:

- Chloroplasts are found in all the green parts of the plant. They are green because they contain the green substance chlorophyll. Chlorophyll absorbs light energy to make food by photosynthesis. Root cells do not have chloroplast because they are underground and do not photosynthesise.
- A permanent vacuole is a space in the cytoplasm filled with cell sap. This is important for keeping the cells rigid to support the plant.
 - a What are the main features found in all living cells?
 - **b** How do plant cells differ from animal cells?

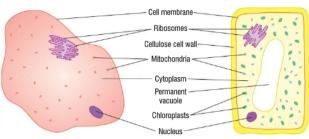


Figure 2 A simple animal cell like this shows the features which are common to all living cells – including human cells

Figure 3 A plant cell has many features in common with an animal cell, but others that are unique to plants

Did you know ...?

Animal cells vary in size but we can only see most of them using a microscope. Eggs are the biggest animal cells. Unfertilised ostrich eggs are the biggest of all – they have a mass of around 1.35 kgl

Practical

Looking at cells K

Set up a microscope to look at plant cells, e.g. from onions and *Elodea*. You should see the cell wall, the cytoplasm and sometimes a vacuole but you won't see chloroplasts in the onion cells.

• Why won't you see any chloroplasts in the onion cells?



Figure 4 Microscopes can be used to look at the features of a plant cell

Summary questions

- 1 a List the main structures you would expect to find in an animal cell.
 - b You would find all the things we have in animal cells also in a plant or algal cell. There are three extra features that are found in plant cells but not animal cells. What are they?
 - c What are the main functions of these three extra structures?
- 2 Why are the nucleus and the mitochondria so important in all cells?
- 3 Chloroplasts are found in many plant cells but not all of them. Give an example of plant cells without chloroplasts and explain why they have none.

A()A Examiner's tip

Practise labelling an animal cell and a plant cell. You need to know the functions of each part of a cell. For example, chloroplasts contain chlorophyll, which absorbs light energy for photosynthesis. Write the functions of the parts on the diagram.

- Most human cells are like most other animal cells and contain a nucleus, cytoplasm, cell membrane, mitochondria and ribosomes.
- Plant and algal cells contain all the structures seen in animal cells as well as a cell wall. Many plant cells also contain chloroplasts and a permanent vacuole filled with sap.



Cells, tissues and organs

B2 1.2

Learning objectives

- What are bacterial cells like?
- How are yeast cells different from bacterial, plant and animal cells?





Figure 2 Bacteria come in several different shapes and sizes. This helps us to identify them under the microscope. Streptococcus causes sore throats and coli live in your gut.

Bacteria and yeast (6)

Bacteria are single-celled living organisms that are much smaller than animal and plant cells. Most bacteria are less than 1 μ m in length. You could fit hundreds of thousands of bacteria on to the full stop at the end of this sentence. You can't see individual bacteria without a powerful microscope.

When you culture bacteria on an agar plate you grow many millions of bacteria. This enables you to see the **bacterial colony** with your naked eye.

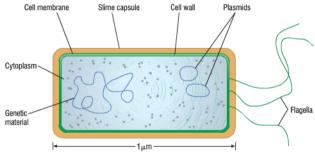


Figure 1 Bacteria come in a variety of shapes, but they all have the same basic structure

Bacterial cells

Each bacterium is a single cell. It is made up of cytoplasm surrounded by a membrane and a cell wall. Inside the bacterial cell is the **genetic material**. Unlike animal, plant and algal cells, the genes are not contained in a nucleus. The long strand of DNA (the bacterial chromosome) is usually circular and found free in the cytoplasm.

Many bacterial cells also contain **plasmids**, which are small circular bits of DNA. These carry extra genetic information. Bacteria may have a slime capsule around the outside of the cell wall. Some types of bacterium have at least one flagellum (plural: flagella), a long protein strand that lashes about. These bacteria use their flagella to move themselves around.

Although some bacteria cause disease, many are harmless. Some are actually really useful to us. We use them to make food like yoghurt and cheese. Others are used in sewage treatment and to make medicines.

a How are bacteria different from animal and plant cells?

Veast

Another type of microorganism that is very useful to people is yeast. Yeasts are single-celled organisms. Each yeast cell has a nucleus containing the genetic material, cytoplasm, and a membrane surrounded by a cell wall.

The cells vary in size but most are about $3-4\mu m$. This makes them bigger than bacteria but still very small.

The main way in which yeasts reproduce is by **asexual budding**. This involves a new yeast cell growing out from the original cell to form a new separate yeast organism.

b How do yeast cells differ from bacterial cells?

Yeast cells are specialised to be able to survive for a long time even when there is very little oxygen available. When yeast cells have plenty of oxygen they use aerobic respiration. They use oxygen to break down sugar to provide energy for the cell. During this process they produce water and carbon dioxide as waste products.

However, when there isn't much oxygen, yeast can use **anaerobic respiration**. When yeast cells break down sugar in the absence of oxygen, they produce **ethanol** and carbon dioxide.

Ethanol is commonly referred to as alcohol. The anaerobic respiration of yeast is sometimes called **fermentation**.

We have used yeast for making bread and alcoholic drinks almost as far back as human records go. We know yeast was used to make bread in Egypt 6000 years ago. Not only that, some ancient wine found in Iran is over 7000 years old.

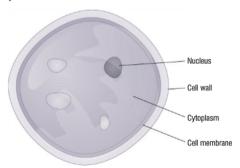


Figure 3 Yeast cells - these microscopic organisms have been useful to us for centuries

???

Did you know ...?

In Ethiopia, natural yeast from the air is enough to make injera, the traditional bread. The dough is left for a couple of days before it is cooked for the yeast to produce carbon dioxide bubbles, which give injera its texture.



Be clear about the similarities and differences between animal, plant, algal, bacterial and yeast cells.



Figure 4 Brewers use the ethanol produced by yeast in their alcoholic drinks

Summary questions

- 2 a What is unusual about the genetic material in bacterial cells?
 - **b** Which are bigger, bacterial cells or yeast cells?
 - c What are flagella and what are they used for?
- 3 Make a table to compare the structures in animal, plant and algal, bacterial and yeast cells.

- A bacterial cell consists of cytoplasm and a membrane surrounded by a cell wall.
 The genes are not in a distinct nucleus.
- Yeast is a single-celled organism. Each cell has a nucleus, cytoplasm and a membrane surrounded by a cell wall.





B2 1.3

Learning objectives

- What different types of cell are there?
- How is the structure of a specialised cell related to its function?

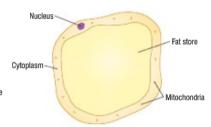
Specialised cells

The smallest living organisms are single cells. They can carry out all of the functions of life. These range from feeding and respiration to excretion and reproduction. Most organisms are bigger and are made up of lots of cells. Some of these cells become **specialised** in order to carry out particular jobs.

When a cell becomes specialised its structure is adapted to suit the particular job it does. As a result, specialised cells often look very different to the 'typical' plant or animal cell. Sometimes cells become so specialised that they only have one function within the body. Examples of this include sperm, eggs, red blood cells and nerve cells.

Fat cells

If you eat more food than you need, your body makes fat and stores it in fat cells. These cells help animals, including us, to survive when food is in short supply. Fat cells have three main adaptations:



- They have a small amount of cytoplasm and large amounts of fat.
- They have few mitochondria as the cell needs very little energy.
- They can expand a fat cell can end up 1000 times its original size as it fills up with fat.

Cone cells from human eye

Cone cells are in the light-sensitive layer of your eye (the retina). They make it possible for you to see in colour. Cone cells have three main adaptations:

- The outer segment contains a special chemical (a visual pigment). This changes chemically in coloured light. It needs energy to change it back to its original form.
- The middle segment is packed full of mitochondria. The mitochondria release the energy needed to reform the visual pigment. This lets you see continually in colour.
- Outer segment
 containing
 visual pigment

 Middle section
 many mitochondria

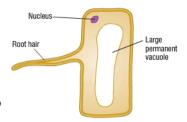
 Nucleus

 Synapses —
 connections to
 nerve cells in
 optic nerve
- The final part of the cone cell is a specialised synapse that connects to the optic nerve. When coloured light makes your visual pigment change, an impulse is triggered. The impulse crosses the synapse and travels along the optic nerve to your brain.
 - a In which part of the cone cell do we find mitochondria?



Root hair cells

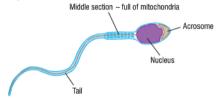
You find root hair cells close to the tips of growing roots. Plants need to take in lots of water (and dissolved mineral ions). The root hair cells help them to take up water more efficiently. Root hair cells are always close to the xylem tissue. The xylem tissue carries water and mineral ions up into the rest of the plant.



Root hair cells have two main adaptations:

- The root hairs increase the surface area for water to move into the cell.
- The root hair cells have a large permanent vacuole that speeds up the movement of water by osmosis from the soil across the root hair cell.

Sperm cells



Sperm cells are usually released a long way from the egg they are going to fertilise. They contain the genetic information from the male parent. Depending on the type of animal, they need to move through water or through the female reproductive system to reach an egg. Then they have to break into the egg. Sperm cells have several adaptations to make all this possible:

- Long tail whips from side to side and helps move the sperm towards the egg.
- The middle section is full of mitochondria, which provide the energy for the tail to work.
- The acrosome stores digestive enzymes for breaking down the outer layers of the egg.
- A large nucleus contains the genetic information to be passed on.
 - **b** Why do sperm contain digestive enzymes?

Summary questions

- 1 Make a table to explain how the structure of each cell on this spread is adapted to its function.
- 2 Think back to two other types of specialised cells you have met in biology, e.g. motor neurons, photosynthetic cells in plants, red or white blood cells.
 - Draw the cells you have chosen. Label them fully to show how the structures you can see are related to the function of the cells.



Practical

Observing specialised cells

Try looking at different specialised cells under a microscope.

When you look at a specialised cell there are two useful questions you can ask yourself:

- How is this cell different in structure from a generalised cell?
- How does the difference in structure help it to carry out its function?

- Cells may be specialised to carry out a particular function.
- Examples of specialised cells are fat cells, cone cells, root hair cells and sperm cells.



Cells, tissues and organs

B2 1.4

Learning objectives

- What is diffusion?
- What affects the rate of diffusion?

O links

For more information about a specialised form of diffusion known as osmosis, see B3 1.1 Osmosis.

Diffusion

Your cells need to take in substances such as glucose and oxygen for respiration. Dissolved substances and gases can move into and out of your cells across the cell membrane. One of the main ways in which they move is by diffusion. Cells also need to get rid of waste products and chemicals that are needed elsewhere in your body.

Diffusion

Diffusion is the spreading out of the particles of a gas, or of any substance in solution (a solute). This results in the **net movement** (overall movement) of particles. The net movement is from an area of high concentration to an area of lower concentration. It takes place because of the random movement of the particles. All the particles are moving and bumping into each other and this moves them all around.

a What is diffusion?

Imagine a room containing a group of boys and a group of girls. If everyone closes their eyes and moves around briskly but randomly, children will bump into each other. They will scatter until the room contains a mixture of boys and girls. This gives you a good model of diffusion.



At the moment, when the blue particles are added to the red particles they are not mixed at all



As the particles move randomly, the blue ones begin to mix with the red ones



As the particles move and spread out, they bump into each other. This helps them to keep spreading randomly



Eventually, the particles are completely mixed and diffusion is complete

Figure 1 The random movement of particles results in substances spreading out or diffusing from an area of higher concentration to an area of lower concentration

Rates of diffusion

If there is a big difference in concentration between two areas, diffusion will take place quickly. Many particles will move randomly towards the area of low concentration. Only a few will move randomly in the other direction. However, if there is only a small difference in concentration between two areas, the net movement by diffusion will be quite slow. The number of particles moving into the area of lower concentration by random movement will only be slightly bigger than the number of particles that are leaving the area.

The net movement = particles moving in - particles moving out.

In general, the greater the difference in concentration, the faster the rate of diffusion. This difference between two areas of concentration is called the **concentration gradient**. The bigger the difference, the steeper the concentration gradient. The steeper the concentration gradient, the faster diffusion will take place. Diffusion occurs down a concentration gradient.

b What is meant by the net movement of particles?



Particles diffuse randomly but the net movement is from a region of high concentration to a region of low concentration.



Both types of particles can pass through this membrane - it is freely permeable

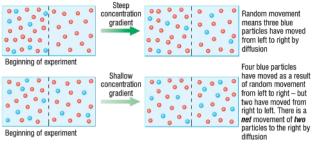


Figure 2 This diagram shows the effect of concentration on the rate of diffusion. This is why so many body systems are adapted to maintain steep concentration gradients.

Temperature also affects the rate of diffusion. An increase in temperature means the particles in a gas or a solution move more quickly. Diffusion takes place more rapidly as the random movement of the particles speeds up.

Diffusion in living organisms

Many important substances can move across your cell membranes by diffusion. Water is one, as well as simple sugars, such as glucose. The amino acids from the breakdown of proteins in your gut can also pass through cell membranes by diffusion.

The oxygen you need for respiration passes from the air into your lungs. From there it gets into your red blood cells through the cell membranes by diffusion. The oxygen moves along a concentration gradient from a region of high to low oxygen concentration.

Individual cells may be adapted to make diffusion easier and more rapid. The most common adaptation is to increase the surface area of the cell membrane. Increasing the surface area means there is more room for diffusion to take place. By folding up the membrane of a cell, or the tissue lining an organ, the area over which diffusion can take place is greatly increased. Therefore the rate of diffusion is also greatly increased. This means much more of a substance moves in a given time.

Summary questions

- Copy and complete using the words below:
 diffusion gas high lower random solute
 ______ is the net movement of particles of a ______ or a _____ from an area of ______ concentration to an area of ______ concentration as a result of the ______ movement of the particles.
- 2 a Explain why diffusion takes place faster when there is an increase in temperature.
 - b Explain in terms of diffusion why so many cells have folded membranes along at least one surface.

AQA Examiner's tip

Do not refer to movement along a gradient – this does not tell us whether it is from high to low or the other way!





Infoldings of the cell membrane form microvilli, which increase the surface area of the cell

Figure 3 An increase in the surface area of a cell membrane means diffusion can take place more quickly. This is an intestinal cell.

- Dissolved substances and gases such as oxygen move in and out of cells by diffusion.
- Diffusion is the net movement of particles from an area where they are at a high concentration to an area where they are at a lower concentration.
- The greater the difference in concentration, the faster the rate of diffusion.



Cells, tissues and organs

B2 1.5

Learning objectives

- What is a tissue?
- What is an organ?

O links

For more information on specialised cells, look back at B2 1.3 Specialised cells.



Figure 1 Muscle tissue like this contracts to move your skeleton around

Tissues and organs

Large multicellular organisms have to overcome the problems linked to their size. They develop different ways of exchanging materials. During the development of a multicellular organism, cells differentiate. They become specialised to carry out particular jobs. For example, in animals, muscle cells have a different structure to blood and nerve cells. In plants the cells where photosynthesis takes place are very different to root hair cells.

However, the adaptations of multicellular organisms go beyond specialised cells. Similar specialised cells are often found grouped together to form a tissue.

Tissues

A **tissue** is a group of cells with similar structure and function working together. **Muscular tissue** can contract to bring about movement. **Glandular tissue** contains secretory cells that can produce substances such as enzymes and hormones. **Epithelial tissue** covers the outside of your body as well as your internal organs.

Plants have tissues too. **Epidermal tissues** cover the surfaces and protect them. **Mesophyll tissues** contain lots of chloroplasts and can carry out photosynthesis. **Xylem** and **phloem** are the transport tissues in plants. They carry water and dissolved mineral ions from the roots up to the leaves and dissolved food from the leaves around the plant.

a What is a tissue?

Organs

Organs are made up of tissues. One organ can contain several tissues, all working together. For example, the stomach is an organ involved in the digestion of your food. It contains:

- muscular tissue to churn the food and digestive juices of the stomach together
- glandular tissue, to produce the digestive juices that break down food
- epithelial tissue, which covers the inside and the outside of the organ.

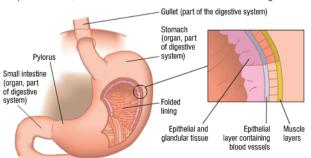


Figure 2 The stomach contains several different tissues, each with a different function in the organ



The pancreas is an organ that has two important functions. It makes hormones to control our blood sugar. It also makes some of the enzymes that digest our food. It contains two very different types of tissue to produce these different secretions.

To summarise, an organ is a collection of different tissues working together to carry out important functions in your body.

b What is an organ?

Different organs are combined in **organ systems** to carry out major functions in the body. These functions include transporting the blood or digesting food. The organ systems together make up your body.

Adaptations for exchange

Many of the organs of the body have developed to enable exchange to take place. For example:

- there is an exchange of gases in the lungs
- . digested food moves from the small intestine into the blood
- many different dissolved substances are filtered out of the blood into the kidney tubules. Some of them then move back from the tubules into the blood.

These organs have adaptations that make the exchange of materials easier and more efficient.

Many of these adaptations increase the surface area over which materials are exchanged. The bigger the surface area, the more quickly diffusion can take place.

Other adaptations increase the concentration gradient across the membranes. The steeper the concentration gradient, the faster diffusion takes place. Many organs have a good blood supply, bringing substances in and taking them out. This helps to maintain the steep concentration gradient needed for diffusion to take place more rapidly.

Did you know ...?

A human liver cell is about $10\mu m$ (1 × $10^{-6}m$) in diameter. A human liver is about 22.5cm ($2.5 \times 10^{-1}m$) across. It contains a lot of liver cells!

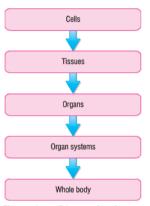


Figure 3 Larger living organisms have many levels of organisation

Summary guestions

- 1 Copy and complete using the words below:
- 2 For each of the following, state whether they are a specialised cell, a tissue or an organ. Explain your answer.
 - a sperm
 - **b** kidney
 - c stomach
- 3 Find out and explain how the small intestine and the lungs are adapted to provide the biggest possible surface area for the exchange of materials within the organs.

- A tissue is a group of cells with similar structure and function.
- Organs are made of tissues.
 One organ may contain several types of tissue.



Cells, tissues and organs

B2 1.6

Learning objectives

- What are organ systems?
- What organs form the digestive system?
- What are plant organs?

?? Did you know ...?

The digestive system is 6–9 m long. That is about 9 × 10⁶ times longer than an average human cell!

Organ systems

Organ systems are groups of organs that all work together to perform a particular function. The way one organ functions often depends on others in the system. The human digestive system is a good example of an organ system.

The digestive system

The digestive system of humans and other mammals exchanges substances with the environment. The food you take in and eat is made up of large insoluble molecules. Your body cannot absorb and use these molecules. They need to be broken down or digested to form smaller, soluble molecules. These can then be absorbed and used by your cells. This process of digestion takes place in your digestive system.

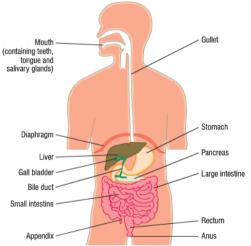


Figure 1 The main organs of the human digestive system

The digestive system is a **muscular tube** that squeezes your food through it. It starts at one end with your mouth, and finishes at the other with your anus. The digestive system contains many different organs. There are glands such as the pancreas and **salivary glands**. These glands make and release digestive juices containing enzymes to break down your food.

The stomach and the small intestine are the main organs where food is digested. Enzymes break down the large insoluble food molecules into smaller, soluble ones.

Your small intestine is also where the soluble food molecules are absorbed into your blood. Once there they get transported in the bloodstream around your body. The small intestine is adapted to have a very large surface area. This increases diffusion from the gut to the blood.



The muscular walls of the gut squeeze the undigested food onwards into your large intestine. This is where water is absorbed from the undigested food into your blood. The material left forms the faeces. Faeces are stored and then pass out of your body through the rectum and anus back into the environment.

a What is the digestive system and what does it do?

Plant organs

Animals are not the only organisms to have organs and organ systems – plants do too.

Plants have differentiated cells that form specialised tissues. These include mesophyll, xylem and phloem. Within the body of a plant, tissues such as these are arranged to form organs. Each organ carries out its own particular functions.

Plant organs include the leaves, stems and roots, each of which has a very specific job to do.

b What are the main organs in a plant?

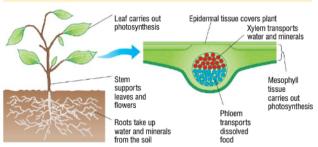


Figure 2 Plant organs and tissues

C small intestine for absorption

Did you know ...?

Some trees, like giant redwoods, have trunks over 40m tall. A plant cell is about 100 µm long. So the plant organ is 4 × 10^s times bigger than the individual cells.

Learn the sequence for multicellular organisms: organism organ systems organs tissues cells

Summary questions

- Match each of the following organs to its correct function.
 - A stem

B root

D leaf

- i breaking down large insoluble molecules into smaller soluble
- molecules
 - ii photosynthesising in plants
 - iii providing support in plants
 - iv anchoring plants and obtaining water and minerals from soil
- 2 Explain the difference between organs and organ systems, giving two examples.
- 3 Using the human digestive system as an example, explain how the organs in an organ system rely on each other to function properly.

- Organ systems are groups of organs that perform a particular function.
- The digestive system in a mammal is an example of a system where substances are exchanged with the environment.
- Plant organs include stems, roots and leaves.



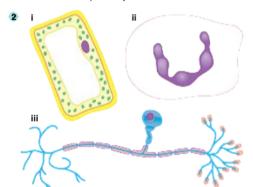
Cells, tissues and organs: B2 1.1-B2 1.6

Summary questions (3)



Flagellum

- Chlamydomonas is a single-celled organism that lives under water. light to photosynthesise. and stores excess food as starch.
 - It can move itself to the Chloroplast Red eye spot Site of starch a What features does it formation Starch grains
 - have in common with most plant cells?
 - b What features are not like plant cells and what are they used for?
 - c Would you class Chlamydomonas as a plant cell or an animal cell? Explain why.



Each of these cells is specialised for a particular function in your body.

- a Copy each of these diagrams and label the cells carefully. Carry out some research if necessary.
- b Describe what you think is the function of each of these cells.
- c Explain how the structure of the cell is related to its function.
- 3 a Draw and label a bacterial cell and a yeast cell.
 - b What are the common structures in all plant, algal and animal cells? Describe their functions.
- 4 a What is diffusion?
 - b If you cut your hand and then put it in a bowl of water, it looks as if there is a lot of blood. Explain why this happens.

- c The scent of flowers in a garden is much more noticeable on a warm, still day than it is on a cold, still day. Explain this in terms of diffusion.
- S a What effect does surface area have on diffusion?
 - b Describe one way in which the following can be adapted to increase the surface area available for diffusion:
 - individual cells
 - ii body organs.
- 6 Plants have specialised cells, tissues and organs just as animals do.
 - a Give three examples of plant tissues.
 - b What are the main plant organs and what do they do?
 - c Which plant tissues are found in all of the main plant organs and why?
- It is possible to separate the different parts of a cell using a centrifuge which spins around rather like a very fast spin dryer. They are used to separate structures that might be mixed together in a liquid. One of their uses is to separate the different parts of a cell.

The cells are first broken open so that the contents spill out into the liquid. The mixture is then put into the centrifuge. The centrifuge starts to spin slowly and a pellet forms at the bottom of the tube. This is removed. The rest is put back into the centrifuge at a higher speed and the next pellet removed and so on.

Here are some results:

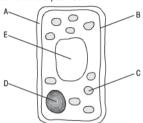
Centrifuge speed (rpm*)	Part of cell in pellet
3000	nuclei
10 000	mitochondria
12000	ribosomes

*rpm = revolutions per minute

- a From these observations can you suggest a link between the speed of the centrifuge and the size of the part of the cell found in the pellet?
- b What apparatus would you need to test your suggestion?
- c If your suggestion is correct, what results would you expect?
- d What would be the easiest measurement to make to show the size of the mitochondria?
- e Suggest how many mitochondria you might measure.
- f How would you calculate the mean for the measurements you have taken?

AQA Examination-style questions

1 The diagram shows a plant cell.



a Identify the structures listed. Choose the correct letter A, B, C, D or E for each structure.

i	nucleus	(1)
ii	chloroplast	(1)
iii	cell wall	(1)

- b Animal cells are different from plant cells.
 Give the letters of the two parts that are also found in animal cells.
- c What is a tissue? (2)
- 2 The parts of plant cells have important functions. List A contains names of cell parts. List B lists some functions of cell parts.

Match each cell part to its correct function.

List A
nucleus
mitochondria
chloroplasts
ribosomes

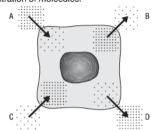
List B
controls entry of materials into cell
produce protein
release energy
controls cell activities
absorb light for photosynthesis

(4)

(1)

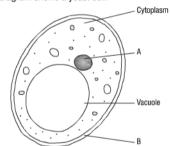
- 3 Plant and animal organs contain tissues.
 - Name one example of a plant tissue and describe its function.
 - b i Name one example of an animal tissue. (1)
 - ii Give an example of an organ where this tissue would be found. (1
 - iii What is the function of the tissue you have named?

 The diagram shows four ways in which molecules may move into and out of a cell. The dots show the concentration of molecules.



- Name the cell structure that controls the movement of materials into or out of cells.

 (1)
- **b** i Name the process illustrated by A and B. (1)
 - ii Explain the direction of the arrows in A and B.
- 5 The diagram shows a yeast cell.



- a Identify the parts labelled A and B.
- **b** The cytoplasm also contains mitochondria and ribosomes.
 - What is the function of these structures? (2)
- c Suggest what is found in the vacuole. (1)
- 6 In this question you will be assessed on using good English, organising information clearly and using specialist terms where appropriate.

The digestive system is a group of organs which changes food from insoluble into soluble molecules. Soluble molecules can be absorbed into the blood stream. Some food cannot be digested.

Describe the functions (jobs) of the organs in the digestive system.



(6)

(2)

Organisms in the environment

B2 2.1

Learning objectives

- What is photosynthesis?
- What are the raw materials for photosynthesis?
- Where does the energy for photosynthesis come from and how do plants absorb it?

Practical

Producing oxygen

You can show that a plant is photosynthesising by the oxygen given off as a by-product. Oxygen is a colourless gas, but if you use water plants you can see and collect the bubbles of gas they give off when they are photosynthesising. The gas will relight a glowing splint, showing that it is oxygen.





Figure 1 These variegated leaves came from a plant which has been kept in the light for several hours. The one on the right has been tested for starch, using indire solution.

Photosynthesis

Like all living organisms, plants and algae need food. It provides them with the energy for respiration, growth and reproduction. But plants don't need to eat – they can make their own food. They do it by photosynthesis. This takes place in the green parts of plants (especially the leaves) when it is light. Algae can also carry out photosynthesis.

The process of photosynthesis



Photosynthesis can be summed up in the following equation:

(+ light energy)

→ glucose + oxygen

The cells in algae and the leaves of a plant are full of small green parts called chloroplasts. They contain a green substance called chlorophyll.

During photosynthesis, light energy is absorbed by the chlorophyll in the chloroplasts. This energy is then used to convert carbon dioxide from the air plus water from the soil into a simple sugar called **glucose**. The chemical reaction also produces oxygen gas as a by-product. The gas is released into the air, which we can then use when we breathe it in.

a Write the word equation for photosynthesis.

Some of the glucose produced during photosynthesis is used immediately by the cells of the plant. However, a lot of the glucose made is converted into insoluble starch and stored.

lodine solution is a yellowy-brown liquid. It turns dark blue when it reacts with starch. You can use this iodine test for starch to show that photosynthesis has taken place in a plant.

Practical

Testing for starch

To show that light is vital for photosynthesis to take place:

Take a leaf from a plant kept in the light and a plant kept in the dark for at least 24 hours. Leaves have to be specially prepared so the iodine solution can reach the cells. Just adding iodine to a leaf is not enough, because the waterproof cuticle keeps the iodine out so it can't react with the starch. The green chlorophyll would mask any colour changes if the iodine did react with the starch. You need to treat the leaves by boiling them in ethanol first to destroy the waxy cuticle and remove the colour. The leaves are then rinsed in hot water to soften them. After treating the leaves, use iodine solution to show how important light is (see Figure 1).

What happens in the test? Explain your observations.

Safety: Take care when using ethanol. It is volatile, flammable, and harmful. Always wear eye protection.

b What is chlorophyll?

Leaf adaptations

The leaves of plants are perfectly adapted because:

- most leaves are broad, giving them a big surface area for light to fall on
- they contain chlorophyll in the chloroplasts to absorb the light energy
- they have air spaces that allow carbon dioxide to get to the cells, and oxygen to leave them by diffusion
- they have veins, which bring plenty of water to the cells of the leaves.

These adaptations mean the plant can photosynthesise as much as possible whenever there is light available.

Algae are aquatic so they are adapted to photosynthesising in water. They absorb carbon dioxide dissolved in the water around them.

c How does the broad shape of leaves help photosynthesis to take place?

AQA Examiner's tip

- Learn the word equation for photosynthesis.
- Be able to explain the results of experiments on photosynthesis.

?? Did you know ...?

Every year plants produce about 368 000 000 000 tonnes of oxygen, so there is plenty to go round!

Practical

Observing leaves

oxygen water

Look at a whole plant leaf and then a section of a leaf under a microscope. You can see how well adapted it is. Compare what you can see with Figure 2.

What magnification did you use?

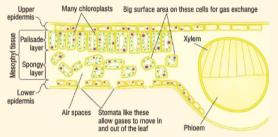


Figure 2 A section (slice) through a leaf showing the different tissues

Summary questions

1 Copy and complete using the words below: carbon dioxide chlorophyll energy gas glucose light

During photosynthesis energy is absorbed by, a substance found in the chloroplasts. This is then used to convert from the air and from the soil into a simple sugar called is also produced and released as a

- 2 a Where does a plant get the carbon dioxide and water that it needs for photosynthesis, and how does it get the light it needs?
 - b Where do algae get the same things from?
 - c Work out the path taken by a carbon atom as it moves from being part of the carbon dioxide in the air to being part of a starch molecule in a plant.

- Photosynthesis can be summed up by the equation:
 (+ light energy)
 carbon dioxide + water
- During photosynthesis light energy is absorbed by chlorophyll in the chloroplasts of the green parts of the plant. It is used to convert carbon dioxide and water into sugar (glucose).
 Oxygen is released as a by-product.
- Leaves are well adapted to allow the maximum amount of photosynthesis to take place.



Organisms in the environment

B2 2.2

Limiting factors (B)

Learning objectives

- What factors limit the rate of photosynthesis in plants?
- How can we use what we know about limiting factors to grow more food?

You may have noticed that plants grow quickly in the summer, yet they hardly grow at all in the winter. Plants need certain things to grow quickly. They need light, warmth and carbon dioxide if they are going to photosynthesise as fast as they can.

Sometimes any one or more of these things can be in short supply. Then they may limit the amount of photosynthesis a plant can manage. This is why they are known as **limiting factors**.

a Why do you think plants grow faster in the summer than in the winter?

()A Examiner's tip

Make sure you can explain limiting factors.

Learn to interpret graphs that show the effect of limiting factors on photosynthesis.

Light (R)

The most obvious factor affecting the rate of photosynthesis is light. If there is plenty of light, lots of photosynthesis can take place. If there is very little or no light, photosynthesis will stop. It doesn't matter what other conditions are like around the plant. For most plants, the brighter the light, the faster the rate of photosynthesis.

Practical

How does the intensity of light affect the rate of photosynthesis?

We can look at this experimentally (see Figure 1). At the start, the rate of photosynthesis goes up as the light intensity increases. This tells us that light intensity is a limiting factor.

When the light is moved away from this water plant, the rate of photosynthesis falls – shown by a slowing in the stream of oxygen bubbles being produced. If the light is moved closer (keeping the water temperature constant) the stream of bubbles becomes faster, showing an increased rate of photosynthesis.

However, we reach a point when no matter how bright the light, the rate of photosynthesis stays the same. At this point, light is no longer limiting the rate of photosynthesis. Something else has become the limiting factor.

The results can be plotted on a graph, which shows the effect of light intensity on the rate of photosynthesis.

- Why is light a limiting factor for photosynthesis?
- Name the independent and the dependent variables in this investigation.



Bubbles of

oxygen-rich gas

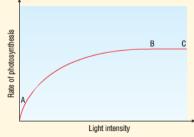


Figure 1 Investigating the effect of light intensity on the rate of photosynthesis



Temperature 🕟

Temperature affects all chemical reactions, including photosynthesis. As the temperature rises, the rate of photosynthesis increases as the reaction speeds up. However, photosynthesis is controlled by enzymes. Most enzymes are destroyed (denatured) once the temperature rises to around 40–50 °C. So if the temperature gets too high, the enzymes controlling photosynthesis are denatured. Therefore the rate of photosynthesis will fall (see Figure 2).

b Why does temperature affect photosynthesis?

Carbon dioxide levels

Plants need carbon dioxide to make glucose. The atmosphere only contains about 0.04% carbon dioxide. This means that carbon dioxide levels often limit the rate of photosynthesis. Increasing the carbon dioxide levels will increase the rate of photosynthesis.

On a sunny day, carbon dioxide levels are the most common limiting factor for plants. The carbon dioxide levels around a plant tend to rise at night. That's because in the dark a plant respires but doesn't photosynthesise. Then, as the light and temperature levels increase in the morning, the carbon dioxide all gets used up.

However, in a science lab or greenhouse the levels of carbon dioxide can be increased artificially. This means they are no longer limiting. Then the rate of photosynthesis increases with the rise in carbon dioxide.

In a garden, woodland or field rather than a lab, light, temperature and carbon dioxide levels interact and any one of them might be the factor that limits photosynthesis.

Summary questions

- 1 a What is photosynthesis?
 - b What are the three main limiting factors that affect the rate of photosynthesis in a plant?
- 2 a In each of these situations one factor in particular is most likely to be limiting photosynthesis. In each case listed below, suggest which factor this is and explain why the rate of photosynthesis is limited.
 - i a wheat field first thing in the morning
 - ii the same field later on in the day
 - iii plants growing on a woodland floor in winter
 - iv plants growing on a woodland floor in summer.
 - b Why is it impossible to be certain which factor is involved in each of these cases?
- 3 Look at the graph in Figure 1.
 - a Explain what is happening between points A and B on the graph.
 - **b** Explain what is happening between points B and C on the graph.
 - c Look at Figure 2. Explain why it is a different shape to the other two graphs shown in Figures 1 and 3.

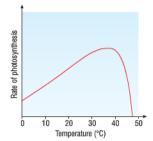


Figure 2 The effect of increasing temperature on the rate of photosynthesis

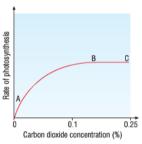


Figure 3 This graph shows the effect of increasing carbon dioxide levels on the rate of photosynthesis at a given light level and temperature

- The rate of photosynthesis may be limited by shortage of light, low temperature and shortage of carbon dioxide.
- We can manipulate the levels of light, temperature and carbon dioxide artificially to increase the rate of photosynthesis in food crops.



Organisms in the environment

B₂ 2.3

Learning objectives

- What do plants do with the glucose they make?
- How do plants store food?
- What other materials do plant and algal cells need to produce proteins?

A Examiner's tip

Two important points to remember:

- Plants respire 24 hours a day to release energy.
- Glucose is soluble in water, but starch is insoluble.



Figure 2 Algal cells contain a nucleus and chloroplasts so they can photosynthesise

O links

For more information about the transport of sugars in plants, see B3 2.5 Transport systems in plants.

How plants use glucose

Plants and algae make glucose when they photosynthesise. This glucose is vital for their survival.

Some of the glucose produced during photosynthesis is used immediately by the cells. They use it for respiration to provide energy for cell functions such as growth and reproduction.

Figure 1 Worldwide, algae produce more oxygen and biomass by photosynthesis than plants do – but we often forget all about them

Using glucose

Plants cells and algal cells, like any other living cells, respire all the time. They use some of the glucose produced during photosynthesis as

they respire. The glucose is broken down using oxygen to provide energy for the cells. Carbon dioxide and water are the waste products of the reaction.

The energy released in respiration is used to build up smaller molecules into bigger molecules. Some of the glucose is changed into starch for storage. Plants and algae also build up glucose into more complex carbohydrates like cellulose. They use this to strengthen the cell walls.

Plants use some of the glucose from photosynthesis to make amino acids. They do this by combining sugars with **nitrate ions** and other **mineral ions** from the soil. These amino acids are then built up into proteins to be used in the cells. This uses energy from respiration.

Algae also make amino acids. They do this by taking the nitrate ions and other materials they need from the water they live in.

Plants and algae also use glucose from photosynthesis and energy from respiration to build up fats and oils. These may be used in the cells as an energy store. They are sometimes used in the cell walls to make them stronger. In addition, plants often use fats or oils as an energy store in their seeds. They provide lots of energy for the new plant as it germinates.

Some algal cells are very rich in oils. They are even being considered as a possible source of biofuels for the future.

a Why do plants respire?

Starch for storage

Plants make food by photosynthesis in their leaves and other green parts. However, the food is needed all over the plant. It is moved around the plant in the phloem.

Plants convert some of the glucose produced in photosynthesis into starch to be stored. Glucose is soluble in water. If it were stored in plant cells it could affect the way water moves into and out of the cells. Lots of glucose stored in plant cells could affect the water balance of the whole plant.





Figure 3 Oilseed rape plants use energy from respiration and glucose from photosynthesis to produce oil to store in their seeds. We use this to make oil for cooking and as a source of biofuels.

Starch is insoluble in water. It will have no effect on the water balance of the plant. This means that plants can store large amounts of starch in their cells.

So, the main energy store in plants is starch and it is found all over a plant. It is stored in the cells of the leaves. The starch provides an energy store for when it is dark or when light levels are low.

Insoluble starch is also kept in special storage areas of a plant. Many plants produce **tubers** and bulbs. These help them to survive through the winter. They are full of stored starch. We often take advantage of these starch stores and eat them ourselves. Potatoes and onions are all full of starch to keep a plant going until spring comes again.

b What is the main storage substance in plants?

Summary questions

- 1 Copy and complete using the words below:
 - energy glucose growth photosynthesise respiration reproduction starch storage 24
- 2 List as many ways as possible in which a plant uses the glucose produced by photosynthesis.
- 3 a Why is some of the glucose made by photosynthesis converted to starch to be stored in the plant?
 - **b** Where might you find starch in a plant?
 - c How could you show that a potato is a store of starch?

Practical

Making starch

The presence of starch in a leaf is evidence that photosynthesis has taken place. You can test for starch using the iodine test. See B2 2.1 Photosynthesis for details of how to treat the leaves so they will absorb the iodine. After this treatment, adding iodine will show you clearly if the leaf has been photosynthesising or not.





Figure 4 The leaf on the right has been kept in the dark. Its starch stores have been used for respiration or moved to other parts of the plant. The leaf on the left has been in the light and been able to photosynthesise. The glucose has been converted to starch, which is clearly visible when it reacts with iodine and turns blue-black.

- Plant and algal cells use the soluble glucose they produce during photosynthesis in several different ways:
 - for respiration
 - to convert into insoluble starch for storage
 - to produce fats or oils for storage
 - to produce fats, proteins or cellulose for use in the cells and cell walls.
- Plants and algal cells need other materials including nitrate ions to make the amino acids which make up proteins.



B2 2.4

2.4 Making the most of photosynthesis (8)

Learning objectives

- How can we control the environment in which plants are grown?
- What are the advantages and disadvantages of growing plants in an artificial environment?

?? Did you know ...?

The first recorded greenhouse was built in about 30 AD for Tiberius Caesar, a Roman emperor who wanted to eat cucumbers out of season.

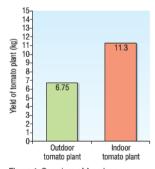


Figure 1 One piece of American research showed that the crop yield inside a greenhouse was almost double that of crops grown outdoors

The more a plant photosynthesises, the more biomass it makes and the faster it grows. It's not surprising that farmers want their plants to grow as fast and as big as possible. It helps them to make a profit.

In theory, if you give plants a warm environment with plenty of light, carbon dioxide and water, they should grow as fast as possible. Out in the fields it is almost impossible to influence any of these factors. However, people have found ways in which they can artificially control the environment of their plants.

The garden greenhouse

Lots of people have glass or perspex greenhouses in their gardens. Farmers use the same idea in huge plastic 'polytunnels'. They are used for growing crops ranging from tomatoes to strawberries and potatoes.

So how does a greenhouse affect the rate of photosynthesis? Within the glass or plastic structure the environment is much more controllable than outside. Most importantly, the atmosphere is warmer inside than out. This affects the rate of photosynthesis, speeding it up so plants grow faster. They will flower and fruit earlier and produce higher yields. We can also use greenhouses to grow fruit like peaches, lemons and oranges, which don't normally grow well outside in the UK.



Figure 2 Tomatoes certainly grow better in a greenhouse

a Why do plants grow faster in a greenhouse than outside?



Controlling a crop's environment

In a science lab you can change one factor at a time while keeping the others constant. Then you can judge how each one limits the rate of photosynthesis.

Outside, most plants are affected by a mixture of these factors. Early in the morning, light levels and temperature may limit the rate of photosynthesis. As light levels and temperature rise, carbon dioxide levels become limiting. On a bright, cold day, temperature might be the limiting factor. So there is a continuous interaction between the different factors.

Control through technology

Companies using big commercial greenhouses take advantage of what we know about limiting factors. They control the temperature and the levels of light and carbon dioxide. The levels are varied to get the fastest possible rates of photosynthesis. As a result the plants grow increasingly quickly.

The plants can even be grown in water with a perfect balance of mineral ions instead of soil, so nothing slows down their growth. This type of system is known as **hydroponics**.

The greenhouses are huge and conditions are controlled using computer software. It costs a lot of money but controlling the environment has many benefits. Turnover is fast, which means profits can be high. The crops are clean and unspoilt. There is no ploughing or preparing the land and in these systems crops can be grown where the land is poor.

b What are hydroponics?

It takes a lot of energy to keep conditions in the greenhouses just right – but fewer staff are needed. Monitoring systems and alarms are vital in case things go wrong, but for plants grown hydroponically, limiting factors are a thing of the past!



Figure 3 By controlling the temperature, light and carbon dioxide levels in a greenhouse like this you can produce the biggest possible crops – fast!

Summary questions

- 1 What are the main differences between a garden greenhouse and a hydroponics growing system?
- 2 What are the main benefits of artificially controlling the environment in which we grow our food plants?

Activity

The National Farmer's Union (NFU) wants to produce a resource to explain to people how hydroponic farming works. Your job is to produce either a presentation or a poster series that can be sent out to schools around the country, explaining how it works and the biology behind the technology.

- Factors such as light levels, low temperature and carbon dioxide levels affect the rate of photosynthesis.
- The environment can be artificially controlled to make sure these factors do not limit growth, which has a number of benefits.



Organisms in the environment

B₂ 2.5

Organisms in their environment 🕟

In any habitat you will find different distributions of living organisms. These

organisms form communities, with the different animals and plants often

Learning objectives

- What factors affect the distribution of organisms in their natural environment?
- Are animals as well as plants affected by physical factors?

Factors affecting living organisms

A number of factors affect how living organisms are distributed in the environment. They include the following.

?? Did you know ...?

Reindeer live in cold environments where most of the plants are small because temperature limits growth. They eat grass, moss and lichen. Reindeer travel thousands of miles as they feed. They cannot get enough food to survive in just one area.

Temperature

dependent on each other.

You have seen that temperature is a limiting factor on photosynthesis and therefore growth in plants. In cold climates temperature is always a limiting factor. For example, Arctic plants are all small. This in turn affects the numbers of berbivores that can survive in the area.



Figure 1 Reindeer distribution depends on temperature, which affects the rate of photosynthesis and growth of their food



Figure 2 The distribution of plants like these Venus flytraps depends heavily on autrient levels

Nutrients

The level of mineral ions (e.g. nitrate ions) available has a big impact on the distribution of plants. Carnivorous plants such as Venus flytraps thrive where nitrate levels are very low because they can trap and digest animal prey. The nitrates they need are provided when they break down the animal protein. Most other plants struggle to grow in these areas with low levels of mineral ions.

a How do nutrient levels affect the distribution of plants like the Venus fly trap?

Amount of light

Light limits photosynthesis, so it also affects the distribution of plants and animals. Some plants are adapted to living in low light levels. They may have more chlorophyll or bigger leaves. However, most plants need plenty of light to grow well.

The breeding cycles of many animal and plant species are linked to the day length. They only live and breed in regions where day length and light intensity are right for them.

Availability of water

The availability of water is important in the distribution of plants and animals in a desert. As a rule plants and animals are relatively rare in a desert. However, the distribution changes after it rains. A large number of plants grow, flower and set seeds very quickly while the water is available. These plants are eaten by many animals that move into the area to take advantage of them. If there is no water, there will be little or no life.

Availability of oxygen and carbon dioxide

The availability of oxygen has a big impact on water-living organisms. Some invertebrates can survive in water with very low oxygen levels. However, most fish need a high level of dissolved oxygen. The distribution of land organisms is not affected by oxygen levels as there is plenty of oxygen in the air and levels vary very little.

Carbon dioxide levels act as a limiting factor on photosynthesis and plant growth. They can also affect the distribution of organisms. For example, mosquitoes are attracted to the animals on whose blood they feed by high carbon dioxide levels. Plants are also more vulnerable to insect attacks in an area with high carbon dioxide levels.

b How do carbon dioxide levels affect the distribution of plants?

The physical factors that affect the distribution of living organisms do not work in isolation. They interact to create unique environments where different animals and plants can live.

Summary questions

- 1 What are the physical factors most likely to affect living organisms?
- 2 How do carnivorous plants survive in areas with very low levels of nitrate ions whilst other plants cannot grow there?
- 3 Explain how the limiting factors for photosynthesis light, temperature and carbon dioxide levels – also affect the distribution of animals directly and indirectly.

?? Did you know ...?

Scientists thought that all organisms, apart from specialised microorganisms, needed oxygen to live. Then in 2010, multicellular organisms that do not need oxygen were discovered living deep under the Mediterranean seas. If more of these amazing organisms are found, our ideas of how oxygen affects the distribution of organisms will have to chance.



Figure 3 One of the first known multicellular organisms that do not need oxygen to respire



Figure 4 Mosquitoes are attracted to us by the carbon dioxide we breathe out

- Physical factors that may affect the distribution of living organisms include:
 - temperature
 - nutrients
 - the amount of light
 - the availability of water
 - the availability oxygen and carbon dioxide.



Organisms in the environment

Measuring the distribution of organisms 🚯

B₂ 2.6

Learning objectives

- How can you measure the distribution of living things in their natural environment?
- What are mean, median and mode? How do they help you understand your data?



Figure 1 Using a quadrat to measure barnacles on a rocky shore

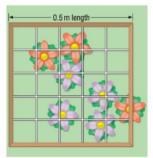


Figure 2 It doesn't matter if organisms partly covered by a quadrat are counted as in or out as long as you decide and stick to it. In this diagram of a quadrat, you have six or seven plants per 0.25 m2 (that's 24 or 28 plants per square metre). epending on the way you count

It is often important to show how a physical factor (or changes in a physical factor) affects the distribution of living organisms. To do this you must be able to measure how those organisms are distributed in the first place.

Quadrats

The simplest way to sample an area (to count the number of organisms there) is to use a quadrat. A quadrat is usually a square frame made of wood or metal that you lay on the ground. This outlines your sample area.

A quadrat with sides 0.5 m long gives you a 0.25 m² sample area. Quadrats are used to investigate the size of a population of plants. They can also be used for animals that move very slowly, e.g. snails, sea anemones.

a What is a quadrat?

You use the same size quadrat every time and sample as many areas as you can. This makes your results as valid as possible. Sample size is very important. You must choose your sample areas at random. This ensures that your results reflect the true distribution of the organisms. So any findings you make will be valid. There are a number of ways to make sure that the samples you take are random. For example, the person with the quadrat closes their eyes, spins round, opens their eyes and walks 10 paces before dropping the quadrat. A random number generator is a more scientific way of deciding where to drop your quadrat.

You need to take a number of random readings and then find the mean number of organisms per m2. This technique is known as quantitative sampling. You can use quantitative sampling to compare the distribution of the same organism in different habitats. You can use it to compare the variety of organisms in a number of different habitats.

Maths skills

Finding the range, the mean, the median and the mode

A student takes 10 random 1 m² quadrat readings looking at the number of snails in a garden. The results are:

	4	4	3	4	5	2	6	5	4	3
--	---	---	---	---	---	---	---	---	---	---

The range of the data is the range between the minimum and maximum values - in this case from 2-6 snails per m2.

To find the mean distribution of snails in the garden, add all the readings together and divide by 10:

$$4+4+3+4+5+2+6+5+4+3/10=40/10=4$$
 snails per m²

The **median** is the middle value when the numbers are put in order – in this case, the range is 2-6 snails per m² so the median is 4 snails per m².

The mode is the most frequently occurring value - in this case, 4 snails per m2.

Sampling is also used to measure changes in the distribution of organisms over time. You do this by repeating your measurements at regular time intervals. Finding the **range** of distribution and the **median** and **mode** of your data can also give you useful information (see Examiner's tip).

Counting along a transect

Sampling along a **transect** is another useful way of measuring the distribution of organisms. There are different types of transect. A line transect is most commonly used.

Transects are not random. You stretch a tape between two points. You sample the organisms along that line at regular intervals using a quadrat. This shows you how the distribution of organisms changes along that line. You can also measure some of the physical factors, such as, light levels and soil pH, that might affect the growth of the plants along the transect.

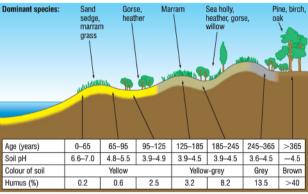


Figure 3 In this transect of some sand dunes at Gibraltar Point you can clearly see the effect of changes in the physical factors on the distribution of the plants

ACA Examiner's tip

Make sure you know the difference between:

- mean (the sum of the values divided by the number of the values)
- median (the middle value of the range)
- mode (the most frequently occurring value).



Figure 4 Carrying out a transect of a rocky shore

Summary questions

- 2 a How can you make sure your sampling with a quadrat is random?
 - **b** Why is it so important for samples to be random?
 - c In a series of 10 random 1 m² quadrats, a class found the following numbers of dandelions: 6, 3, 7, 8, 4, 6, 5, 7, 9, 8. What is the mean density of dandelions per m² on the school field?
- 3 Explain the ways in which the information you get from quadrats and transects is similar and how it differs.

- You can get quantitative data on the distribution of organisms in the environment using:
 - random sampling with quadrats
 - sampling along a transect.
- You can determine the range, mean, median and mode of your data.



Organisms in the environment

σ

B₂ 2.7

Learning objectives

- Will the method used answer the question that has been asked?
- Have all the variables been controlled?
- Does the size of your sample matter?



Figure 1 If you are trying to find evidence of environmental change in an area as big as this, it is important to use a method that is as valid as possible

How valid is the data?

Environments are changing naturally all the time. But people also have an effect on the environment. This can be locally, e.g. dropping litter or building a new road, or on a worldwide scale with possible global warming and climate change. A change in the distribution of living organisms can be evidence of a change in the environment. However, if you want to use this type of data as evidence for environmental change it is important to use reproducible and valid methods to collect your results.

Reproducible, valid data

When you measure the distribution of living organisms you want your investigation to be reproducible and valid. In a reproducible investigation, other people can do the same investigation and get results that are very similar or the same as yours. And for the investigation to be valid it must answer the question you are asking. For example: What is the population density of snails in this garden?

One important factor is the size of your sample. If you do 10 quadrats, your data will not be as reproducible or as valid as if you carry out 100 quadrats.

Your method of sampling must be appropriate. If you want to measure the distribution of plants in an area, random quadrats work well. If you want to measure change in distribution over a range of habitats, a transect is a better technique to use.

If you are trying to measure change over time, you must be able to replicate your method every time you repeat your readings.

Changes in the distribution of a species are often used as evidence of environmental change. You must use a method of measuring that works regardless of who is collecting the data.

Controlling variables

When you are working in a lab you can control as many of the variables as possible. Then other scientists can carry out the investigation under the same conditions. This increases the likelihood that your results will be reproducible.

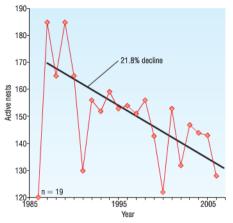
In fieldwork, it is not possible to control all the variables of the natural environment, but you can control some. For example, you can always measure at the same time of day. However, you cannot control the weather or the arrival of different organisms.

You must be clear about the problems of collecting data if you want to use them as evidence of environmental change.

A penguin case study

In the early 1980s Dee Boersma noticed that the numbers of penguins in a breeding colony in Argentina were falling. In 1987 she set up a research project making a transect of the colony with 47 permanent stakes, 100 metres apart.





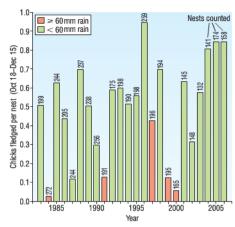


Figure 2 Patagonian penguins reflect environmental change in a very sensitive way. This graph shows clearly the effect of heavy rain on chick survival.

Every year Dee counted the active nests within a 100 m² circle around 19 of the stakes. She surveyed the remaining sites less regularly. However, Dee found the same pattern everywhere – numbers were falling.

What is causing these changes? Climate change seems to be significant:

- There have been several breeding seasons where unusually heavy rainfall
 has occurred. This has destroyed many nests and killed many chicks (see
 Figure 2).
- There have been changes in the numbers of small fish that the penguins eat. This is in response to changes in the water temperature. So there has been less food available in some years.

However, in biology things are rarely simple. The penguins are also affected by oil and waste from nearby shipping lanes. Around 20000 penguins were killed by one major oil spill in 1991 alone. People catch the same small fish that the penguins feed on. Thousands of tourists visit the colony every year. They trample the area and cause stress to the birds.

Many factors, probably including climate change, are involved in the distribution changes of the penguins.

Summary questions

- 1 What is meant by the terms: a reproducible and b valid, when you are talking about scientific data?
- 2 Look at Figure 2 and Figure 3 and the text above to help you answer this question.
 - a When was the penguin population at Punta Tombo at its peak?
 - **b** When was the population at its lowest? Suggest a reason for this.
 - c How could Professor Boersma's data be used as evidence for environmental change?
- 3 Professor Boersma is widely respected in the scientific community. In what ways can you see that her data are both reproducible and valid?



Figure 3 The penguin population at Punta Tombo fell by almost 22% between 1987 and 2006

- Different methods can be used to collect environmental data.
- Validity and reproducibility must be considered carefully as it is difficult to control variables in fieldwork.
- Sample size is an important factor in both reproducibility and validity of data.



Organisms in the environment: B2 2.1-B2 2.7

Summary questions (A)



- 1 a Write the word equation for photosynthesis.
 - b Much of the glucose made in photosynthesis is turned into an insoluble storage compound. What is this compound?
- The figures in the table show the mean growth of two sets of oak seedlings. One set was grown in 85% full sunlight, the other set in only 35% full sunlight.

Year	Mean height of seedlings grown in 85% full sunlight (cm)	Mean height of seedlings grown in 35% full sunlight (cm)			
2005	12	10			
2006	16	12.5			
2007	18	14			
2008	21	17			
2009	28	20			
2010	35	21			
2011	36	23			

The figures in the table show the mean growth of two sets of oak seedlings. One set was grown in 85% full sunlight, the other set in only 35% full sunlight.

- a Plot a graph to show the growth of both sets of oak seedlings.
- b Using what you know about photosynthesis and limiting factors, explain the difference in the growth of the two sets of seedlings.
- 3 More of the biomass and oxygen produced by photosynthesis comes from algae than from plants.
 - a Where do you find most algae?
 - b How do algal cells use the products of photosynthesis?
- Palm oil is made from the fruit of oil palms. Large areas of tropical rainforests have been destroyed to make space to plant these oil palms, which grow rapidly.
 - a Why do you think that oil palms grow rapidly in the conditions that support a tropical rainforest?
 - b Where does the oil in the oil palm fruit come from?
 - c What is it used for in the plant?
 - d How else is glucose used in the plant?

Here are the yields of some different plants grown in Bengal, India. The yields per acre when grown normally in the field and when grown hydroponically are compared.

Name of crop	Hydroponic crop per acre (kg)	Ordinary soil crop per acre (kg)
wheat	3629	2540
rice	5443	408
potatoes	70760	8164
cabbage	8164	5896
peas	63 503	11 340
tomatoes	181 437	9072
lettuce	9525	4080
cucumber	12700	3175

- a Why are yields always higher when the crops are grown hydroponically?
- b Which crops would it be most economically sensible to grow hydroponically? Explain your choice.
- c Which crops would it be least sensible to grow hydroponically? Explain your choice.
- d What are the benefits and problems of growing crops:
 - i in their natural environment
 - ii in an artificially manipulated environment?

A()A Examination-style questions (



The picture shows a snail. Snails feed on plants.



Some students wanted to investigate the distribution of snails in the hedges on two sides of their school field. All the hedges were trimmed to a height of 1.5 metres. One side of the field was very open but the opposite side was shaded by trees. The students thought there would be more snails in the hedges on the open side because birds living in the trees would eat the snails. In the investigation they:

- measured a transect of 50 metres along the hedge on the open side of the field
- leaned a 1 m² guadrat against the hedge every 5
- counted all the snails they could see in the quadrat
- recorded the data in a table
- repeated the investigation with the hedge that was shaded by trees.
- a Choose the correct answer to complete each sentence.
 - The idea that birds in the trees eat the snails is a

conclusion hypothesis test

ii A transect is a. (1)

line square triangle

iii One thing that was controlled in this investigation was the

light intensity number of trees size of quadrat

b The data recorded by the students can be seen in the table.

	Number of snails									
Quadrat number	1	2	3	4	5	6	7	8	9	10
Open hedge	3	3	5	3	2	3	6	3	6	2
Hedge shaded by trees	2	3	4	3	5	2	1	4	1	5

Use the data to answer the questions. Choose the correct answer.

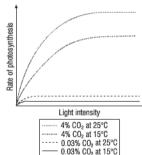
- i The mean for the number of snails in the open hedge is [3 / 3.6 / 5].
- ii The median for the number of snails in the shaded hedge is [2 / 3 / 4].
- c One student said he didn't think the results would be valid. Suggest one reason why.
- 2 A farmer has decided to grow strawberry plants in polytunnels, similar to the one shown in the diagram.



(1)

The tunnels are enclosed spaces with walls made of plastic sheeting. The farmer decides to set up several small polytunnels, as models, so he can work out the best conditions for the strawberry plants to grow. He needs help from a plant biologist who provides some data.

The data is shown in the graph.



a In this question you will be assessed on using good English, organising information clearly and using specialist terms where appropriate.

You are advising the farmer.

Using all the information given, describe the factors the farmer should consider when building his model tunnels so he can calculate the optimal conditions for growing strawberry plants.

b Biologists often use models in their research. Suggest one reason why.

AQA, 2007



B2 3.1

Learning objectives

- What is a protein?
- What do proteins do?
- What is an enzyme and how do they work?



Did vou know ...?

15-16% of your body mass is protein - second only to water, unless you are overweight. Protein is found in tissues ranging from your hair and nails to the muscles that move you around and the enzymes that control your body chemistry.

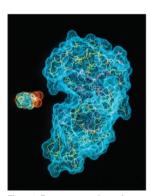


Figure 1 Enzymes are made up of chains of amino acids folded together, as you can see in this computer-generated image

Examiner's tip

Remember that the way an enzyme works depends on the shape of the active site that allows it to bind with the substrate.

Proteins, catalysts and enzymes

Protein molecules are very important in your body. A protein molecule is made up of long chains of small units called amino acids. Different arrangements of amino acids give you different proteins.

Proteins carry out many different functions in your body. They act as:

- structural components such as muscles and tendons
- hormones such as insulin
- antibodies, which destroy pathogens
- catalysts in the form of enzymes.
 - a What is an amino acid?

Controlling the rate of reactions

In everyday life we control the rates of chemical reactions all the time. You increase the temperature of your oven to speed up chemical reactions when you cook. You lower the temperature in your fridge to slow down reactions in stored food. Sometimes we use special chemicals known as catalysts to speed up reactions for us. A catalyst speeds up a chemical reaction, but it is not used up in the reaction. You can use a catalyst over and over again.

b What is a catalyst?

Enzymes – biological catalysts (K)



In your body, chemical reaction rates are controlled by enzymes. These are special biological catalysts that speed up reactions.

Enzymes are large protein molecules. The long chains of amino acids are folded to produce a molecule with a specific shape. This special shape allows other molecules (substrates) to fit into the enzyme protein. We call this the active site. The shape of an enzyme is vital for the way it works.

Enzymes are involved in:

- building large molecules from lots of smaller ones
- changing one molecule into another
- breaking down large molecules into smaller ones.

Enzymes do not change a reaction in any way - they just make it happen faster. Different enzymes catalyse (speed up) specific types of reaction. In your body you need to build large molecules from smaller ones, e.g. making glycogen from glucose or proteins from amino acids. You need to change certain molecules into different ones, e.g. one sugar into another, such as glucose to fructose, and to break down large molecules into smaller ones, e.g. breaking down insoluble food molecules into small soluble molecules, such as glucose. All these reactions are speeded up using enzymes.



Practical

Breaking down hydrogen peroxide

Investigate the effect of:

- a manganese(iv) oxide, and b raw liver.
- on the breakdown of hydrogen peroxide solution.
- Describe your observations and interpret the graph (see Figure 2).

Safety: Wear eye protection.



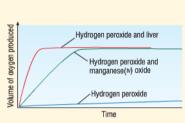


Figure 2 The decomposition of hydrogen peroxide to oxygen and water goes much faster using a catalyst like manganese(v) oxide. Raw liver contains the enzyme catalase, which speeds up the same reaction.

How do enzymes work?

The substrate (reactant) of the reaction fits into the active site of the enzyme. You can think of it like a lock and key. Once it is in place the enzyme and the substrate bind together.

The reaction then takes place rapidly and the products are released from the surface of the enzyme (see Figure 3). Remember that enzymes can join small molecules together as well as break up large ones.

Summary questions

1 Match each word with its correct definition:

A catalyst	I the special part in the structure of an enzyme where the substrate binds
B enzyme	a substance that speeds up a chemical reaction without being changed itself
C active site	iii a biological catalyst made of protein

- 2 a What is a protein?
 - b How are proteins used in the body?
- 3 a What is an enzyme?
 - b What are enzymes made of?
 - c How do enzymes act to speed up reactions in your body?

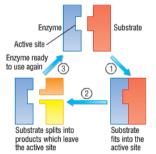


Figure 3 Enzymes act as catalysts using the 'lock-and-key' mechanism shown here

- Protein molecules are made up of long chains of amino acids.
- Proteins act as structural components of tissues, as hormones, as antibodies and as catalysts.
- Catalysts increase the rate of chemical reactions without changing themselves.
 Enzymes are biological catalysts.
- Enzymes are proteins. The amino acid chains are folded to form the active site.



Enzymes

B₂ 3.2

Learning objectives

- How does increasing the temperature affect your enzymes?
- Why does a change in pH affect your enzymes?

O links

For more information about how body temperature is maintained at a constant level for optimum enzyme activity, see B3 3.5 Controlling body temperature.

Practical

Investigating the effect of temperature on enzymes

You can show the effect of temperature on the rate of enzyme action using simple practical procedures.

The enzyme amylase (found in your saliva) breaks down starch into simple sugars. You can mix starch solution and amylase together and keep them at different temperatures. Then you test samples from each temperature with iodine solution at regular intervals.

- How does iodine solution show you if starch is present?
- Why do we test starch solution without any amylase
- What conclusion can you draw from the results?

Factors affecting enzyme action

A container of milk left at the back of your fridge for a week or two will be disgusting. The milk will go off as enzymes in bacteria break down the protein structure.

Leave your milk in the sun for a day and the same thing happens - but much faster. Temperature affects the rate at which chemical reactions take place even when they are controlled by biological catalysts.

Biological reactions are affected by the same factors as any other chemical reactions. Factors such as concentration, temperature and surface area all affect them. However, in living organisms an increase in temperature only works up to a certain point.

a Why does milk left in the sun go off quickly?

The effect of temperature on enzyme action (k)



The reactions that take place in cells happen at relatively low temperatures. Like other reactions, the rate of enzyme-controlled reactions increases as the temperature increases.

However, this is only true up to temperatures of about 40 °C. After this the protein structure of the enzyme is affected by the high temperature. The long amino acid chains begin to unravel. As a result, the shape of the active site changes. We say the enzyme has been denatured. It can no longer act as a catalyst, so the rate of the reaction drops dramatically. Most human enzymes work best at 37°C.

b What does it mean if an enzyme is denatured?

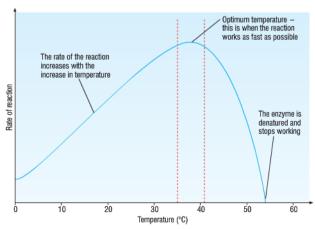


Figure 1 The rate of an enzyme-controlled reaction increases as the temperature rises - but only until the protein structure of the enzyme breaks down



Effect of pH on enzyme action (I)

The shape of the active site of an enzyme comes from forces between the different parts of the protein molecule. These forces hold the folded chains in place. A change in the pH affects these forces. That's why it changes the shape of the molecule. As a result, the active site is lost, so the enzyme no longer acts as a catalyst.

Different enzymes have different pH levels at which they work best. A change in the pH can stop them working completely.

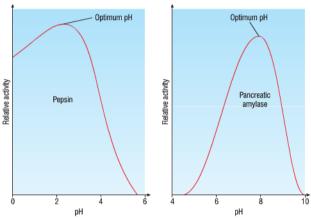


Figure 2 These two digestive enzymes need very different pH levels to work at their maximum rate. Pepsin is found in the stomach, along with hydrochloric acid, while pancreatic amylase is in the small intestine along with alkaline bile.

Without enzymes, none of the reactions in your body would happen fast enough to keep you alive. This is why it is so dangerous if your temperature goes too high when you are ill. Once your body temperature reaches about 41 °C, your enzymes start to be denatured and you will soon die.

Summary questions

- 1 Copy and complete using the words below:

 active site cells denatured enzyme increase protein
 reactions shape temperatures 40°C

 The chemical _______ that take place in living ______ happen at relatively
 low ______. The rate of these ______controlled reactions ______ with an increase in temperature. However, this is only true up to temperatures of about _____. After this the ______ structure of the enzyme is affected and the _____ of the _____ is changed. The enzyme has been _____.
- 2 Look at Figure 2.
 - a At which pH does pepsin work best?
 - b At which pH does amylase work best?
 - c What happens to the activity of the enzymes as the pH increases?
 - d Explain why this change in activity happens.



Not all enzymes work best at around 40°C. Bacteria living in hot springs survive at temperatures up to 80°C and higher. On the other hand, some bacteria that live in the very cold, deep seas have enzymes that work effectively at 0°C and below.



Figure 3 The magical light display of a firefly is caused by the action of an enzyme called luciferase

AQA Examiner's tip

Enzymes aren't killed (they are molecules, not living things themselves) – use the term 'denatured'.

- Enzyme activity is affected by temperature and pH.
- High temperatures and the wrong pH can affect the shape of the active site of an enzyme and stop it working.



B₂ 3.3

Learning objectives

- Where are your digestive enzymes made?
- How are enzymes involved in the digestion of your food?

Enzymes in digestion

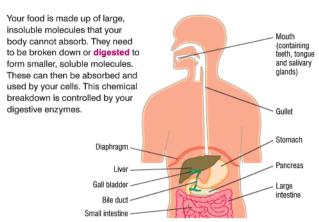


Figure 1 The human digestive system is a collection of organs all working together to digest your food

\PQA Examiner's tip

Learn the different types of digestive enzyme and the end products of the breakdown of your food.

Make sure you know where the different digestive enzymes are made.

Most of your enzymes work *inside* the cells of your body, controlling the rate of the chemical reactions. Your digestive enzymes are different. They work *outside* your cells. They are produced by specialised cells in glands (like your salivary glands and your pancreas), and in the lining of your gut.

The enzymes then pass out of these cells into the gut itself. Your gut is a hollow, muscular tube that squeezes your food. It helps to break up your food into small pieces with a large surface area for your enzymes to work on. It mixes your food with your digestive juices so that the enzymes come into contact with as much of the food as possible. The muscles of the gut move your food along from one area to the next.

a How do your digestive enzymes differ from most of your other enzymes?

Digesting carbohydrates

Enzymes that break down carbohydrates are called **carbohydrases**. Starch is one of the most common carbohydrates that you eat. It is broken down into sugars in your mouth and small intestine. This reaction is catalysed by an enzyme called **amylase**.

Amylase is produced in your salivary glands. So the digestion of starch starts in your mouth. Amylase is also made in your pancreas and your small intestine. No digestion takes place inside the pancreas. All the enzymes made there flow into your small intestine, where most of the starch you eat is digested.

b What is the name of the enzyme that breaks down starch in your gut?



Digesting proteins (



The breakdown of protein food like meat, fish and cheese into amino acids is catalysed by protease enzymes. Proteases are produced by your stomach. your pancreas and your small intestine. The breakdown of proteins into amino acids takes place in your stomach and small intestine.

c Which enzymes break down protein in your gut?

Digesting fats

The lipids (fats and oils) that you eat are broken down into fatty acids and glycerol in your small intestine. The reaction is catalysed by lipase enzymes. These are made in your pancreas and your small intestine. Again, the enzymes made in the pancreas are passed into the small intestine.

Once your food molecules have been completely digested into soluble glucose, amino acids, fatty acids and glycerol, they leave your small intestine. They pass into your bloodstream to be carried around the body to the cells that need them.

d Which enzymes break down fats in your gut?

Did you know ...?

When Alexis St Martin suffered a terrible gunshot wound in 1822, Dr William Beaumont managed to save his life. However, Alexis was left with a hole (or fistula) from his stomach to the outside world. Dr Beaumont then used this hole to find out what happened in Alexis' stomach as he digested food!

Practical

Investigating digestion

You can make a model gut using a special bag containing starch and amylase enzymes. When the enzyme has catalysed the breakdown of the starch, you can no longer detect the presence of starch inside the 'gut'.

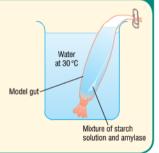
How can you test for starch?

Smaller molecules of sugar diffuse out of the gut. Test the water in the beaker for (reducing) sugar.

1 Copy and complete using the words below:

• How can you test for this?

Figure 2 This apparatus provides you with a model of the gut. You can use it to investigate the effects of factors like temperature and pH on how the gut enzymes work.



Summary questions

- absorbed broken down cells digestive food insoluble soluble The _____ you eat is made up of large ____ molecules that need to be to form smaller, molecules. These can be by your by your enzymes.
- 2 Make a table that describes amylase, protease and lipase. For each enzyme show where it is made, which reaction it catalyses and where it
- 3 Why is digestion of your food so important? Explain your answer in terms of the molecules involved.

- Digestive enzymes are produced by specialised cells in glands and in the lining of the gut. They work outside of the body cells in the gut itself.
- Different enzymes catalyse the breakdown of carbohydrates, proteins and fats into smaller, soluble molecules during digestion.



Enzymes

B23.4

Learning objectives

- Why does your stomach contain hydrochloric acid?
- What is bile and why is it so important in digestion?

O links

For information on the sensitivity of enzymes to temperature and pH, look back at B2 3.2 Factors affecting enzyme action.

Speeding up digestion

Your digestive system produces many enzymes that speed up the breakdown of the food you eat. As your body is kept at a fairly steady 37 °C, your enzymes have an ideal temperature that allows them to work as fast as possible.

Keeping the pH in your gut at ideal levels isn't that easy because different enzymes work best at different pH levels. For example, the protease enzyme found in your stomach works best in acidic conditions.

On the other hand, the proteases made in your pancreas need alkaline conditions to work at their best.

So, your body makes a variety of different chemicals that help to keep conditions ideal for your enzymes all the way through your gut.

a Why do your enzymes almost always have the right temperature to work at their best?

Changing pH in the gut

You have around 35 million glands in the lining of your stomach. These secrete protease enzymes to digest the protein you eat. The enzymes work best in an acid pH. So your stomach also produces a concentrated solution of hydrochloric acid from the same glands. In fact, your stomach produces around 3 litres of acid a day! This acid allows your stomach protease enzymes to work very effectively. It also kills most of the bacteria that you take in with your food.

Finally, your stomach also produces a thick layer of mucus. This coats your stomach walls and protects them from being digested by the acid and the enzymes.

b How does your stomach avoid digesting itself?

O.

Practical

Breaking down protein

You can see the effect of acid on pepsin, the protease found in the stomach, quite simply. Set up three test tubes: one containing pepsin, one containing hydrochloric acid and one containing a mixture of the two. Keep them at body temperature in a water bath. Add a similar-sized chunk of meat to all three of them. Set up a webcam and watch for a few hours to see what happens.

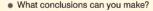




Figure 1 These test tubes show clearly the importance of protein-digesting enzymes and hydrochloric acid in your stomach. Meat was added to each tube at the same time.



After a few hours – depending on the size and type of the meal you have eaten – your food leaves your stomach. It moves on into your small intestine. Some of the enzymes that catalyse digestion in your small intestine are made in your pancreas. Some are also made in the small intestine itself. They all work best in an alkaline environment.

The acidic liquid coming from your stomach needs to become an alkaline mix in your small intestine. So how does it happen?

Your liver makes a greenish-yellow alkaline liquid called **bile**. Bile is stored in your gall bladder until it is needed.

As food comes into the small intestine from the stomach, bile is squirted onto it. The bile neutralises the acid from the stomach and then makes the semi-digested food alkaline. This provides the ideal conditions needed for the enzymes in the small intestine.

c Why does the food coming into your small intestine need neutralising?

Altering the surface area

It is very important for the enzymes of the gut to have the largest possible surface area of food to work on. This is not a problem with carbohydrates and proteins. However, the fats that you eat do not mix with all the watery liquids in your gut. They stay as large globules (like oil in water) that make it difficult for the lipase enzymes to act.

This is the second important function of the bile. It **emulsifies** the fats in your food. This means bile physically breaks up large drops of fat into smaller droplets. This provides a much bigger surface area for the lipase enzymes to act on. The larger surface area helps the lipase chemically break down the fats more quickly into fatty acids and glycerol.

Summary questions

- 2 Look at Figure 1.
 - a In what conditions does the protease from the stomach work best?
 - b How does your body create the right pH in the stomach for this enzyme?
 - c In what conditions does the proteases in the small intestine work best?
 - d How does your body create the right pH in the small intestine for this enzyme?
- 3 Draw a diagram to explain how bile produces a big surface area for lipase to work on and explain why this is important.



Sometimes gall stones block the gall bladder and bile duct. The stones can range from a few millimetres to several centimetres long and can cause terrible pain.



Figure 2 Gall stones

A()A Examiner's tip

Remember, food is not digested in the liver or the pancreas.

Bile is *not* an enzyme and it does *not* break down fat molecules.

Bile emulsifies fat droplets to increase the surface area, which in turn increases the rate of fat digestion by lipase.

- The enzymes of the stomach work best in acid conditions.
- The enzymes made in the pancreas and the small intestine work best in alkaline conditions.
- Bile produced by the liver neutralises acid and emulsifies fats.



Enzymes

B23.5

Learning objectives

- How do biological detergents work?
- How are enzymes used in the food industry?



Figure 1 Many people now have a dishwasher. Dishwasher detergents contain enzymes that digest cooked-on proteins like eggs, which are often hard to remove.



Figure 2 Learning to eat solid food isn't easy. Having some of it predigested by protease enzymes can make it easier to et the amino acids you need to grow.

Making use of enzymes

Enzymes were first isolated from living cells in the 19th century. Ever since then, we have found more and more ways of using them in industry. Some microorganisms produce enzymes that pass out of the cells and are easy for us to use. In other cases we use the whole microorganism.

Enzymes in the home

In the past, people boiled and scrubbed their clothes to get them clean - by hand! Now we have washing machines and enzymes ready and waiting to digest the stains.

Many people use biological detergents to remove stains such as grass, sweat and food from their clothes. Biological washing powders contain proteases and lipases. These enzymes break down the proteins and fats in the stains. They help to give you a cleaner wash. Biological detergents work better than non-biological detergents at lower temperatures. This is because the enzymes work best at lower temperatures - they are denatured if the water is too hot. This means you use less electricity too.

a What is a biological washing powder?



Practical

Investigating biological washing powder

Weigh a chunk of cooked egg white and leave it in a strong solution of biological washing powder.

- What do you think will happen to the egg white?
- How can you measure just how effective the protease enzymes are?
- How could you investigate the effect of surface area on enzyme action?

Enzymes in industry (K)



Pure enzymes have many uses in industry.

Proteases are used to make baby foods. They 'predigest' some of the protein in the food. When babies first begin to eat solid foods they are not very good at digesting it. Treating the food with protease enzymes makes it easier for a baby's digestive system to cope with it. It is easier for them to get the amino acids they need from their food.

Carbohydrases are used to convert starch into sugar (glucose) syrup. We use huge quantities of sugar syrup in food production. You will see it on the ingredients labels on all sorts of foods.

Starch is made by plants like corn and it is very cheap. Using enzymes to convert this plant starch into sweet sugar provides a cheap source of sweetness for food manufacturers.

It is also important for the process of making fuel (ethanol) from plants.

b Why does starch need to be converted to sugar before it is used to make ethanol?

Sometimes the glucose syrup made from starch is passed through another process that uses a different set of enzymes. The enzyme **isomerase** is used to change glucose syrup into **fructose syrup**.

Glucose and fructose contain exactly the same amount of energy (1700 kJ or 400 kcal per 100 g). However, fructose is much sweeter than glucose. Much smaller amounts are needed to make food taste sweet. Fructose is widely used in 'slimming' foods – the food tastes sweet but contains fewer calories.

The advantages and disadvantages of using enzymes

In industrial processes, many of the reactions need high temperatures and pressures to make them go fast enough to produce the products needed. This needs expensive equipment and requires a lot of energy.

Enzymes can solve industrial problems like these. They catalyse reactions at relatively low temperatures and normal pressures. Enzyme-based processes are therefore often fairly cheap to run.

One problem with enzymes is that they are denatured at high temperatures, so the temperature must be kept down (usually below 45°C). The pH also needs to be kept within carefully controlled limits that suit the enzyme. It costs money to control these conditions.

Many enzymes are also expensive to produce. Whole microorganisms are relatively cheap, but need to be supplied with food and oxygen and their waste products removed. They use some of the substrate to grow more microorganisms. Pure enzymes use the substrate more efficiently, but they are also more expensive to produce.



Figure 3 Some people are always trying to lose weight. Enzyme technology is used to convert more and more glucose syrup into fructose syrup to make so-called 'slimming' foods.

ACA Examiner's tip

Remember that most enzyme names end in '-ase'.

Some enzymes used in industry work at quite high temperatures – so don't be put off if a graph shows an optimum temperature well above 45°C!

Summary questions

- 1 List three enzymes and the ways in which we use them in the food industry.
- 2 Biological washing powders contain enzymes in tiny capsules. Explain why:
 - a they are more effective than non-biological powders at lower temperatures
 - b they are not more effective at high temperatures.
- 3 Make a table to show the advantages and disadvantages of using enzymes in industry.

- Some microorganisms produce enzymes that pass out of the cells and can be used in different ways.
- Biological detergents may contain proteases and lipases.
- Proteases, carbohydrases and isomerase are all used in the food industry.





B23.6

Learning objectives

- What are the advantages and disadvantages of using enzymes in detergents?
- Can doctors use enzymes to help keep you healthy?

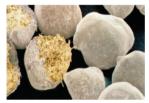


Figure 2 The enzymes in biological detergents are held in tiny capsules – these are seen under an electron microscope



Practical

Plan and carry out an investigation to compare the effectiveness of a biological detergent with a non-biological detergent at 40 °C.

High-tech enzymes

The pros and cons of biological detergents (



For many people, biological washing powders have lots of benefits. Children can be messy eaters and their clothes get lots of mud and grass stains as well. Many of the stains that adults get on their clothes – sweat, food and drink – are biological too. So these enzyme-based washing powders are effective and therefore widely used.

Biological powders have another advantage. They are very effective at cleaning at low temperatures. Therefore they use a lot less electricity than non-biological detergents. That's good for the environment and cheaper for the consumer.



Figure 1 Biological detergents come in many different forms

However, when biological detergent was first manufactured many factory staff developed allergies. They were reacting to enzyme dust in the air – proteins often trigger allergies. Some people using the powders were affected in the same way. But there was a solution – the enzymes were put in tiny capsules and then most of the allergy problems stopped.

Unfortunately, it got bad publicity, which some people still remember. However, research (based on 44 different studies) was published by the British Journal of Dermatology in 2008. This showed that biological detergents do not seem to be a major cause of skin problems.

Some people worry about all the enzymes going into our rivers and seas from biological detergents. The waste water from washing machines goes into the sewage system. Also, the low temperatures used to wash with biological detergents may not be as good at killing pathogens on the clothes.

Enzymes and medicine

Some of the ways in which enzymes are used in medicine

TO DIAGNOSE DISEASE

If your liver is damaged or diseased, some of your liver enzymes may leak out into your bloodstream. If your symptoms suggest your liver isn't working properly, doctors can test your blood for these enzymes. This will tell them if your liver really is damaged.

TO DIAGNOSE AND CONTROL DISEASE

People who have diabetes have too much glucose in their blood. As a result, they also get glucose in their urine. One commonly used test for sugar in the urine relies on a colour change on a test strip. The test strip contains a chemical indicator and an enzyme. It is placed in a urine sample. The enzyme catalyses the breakdown of any glucose found in the urine. The strip changes colour if the products of this reaction are present. This shows that glucose was present in the original sample.

TO CURE DISEASE

- If your pancreas is damaged or diseased it cannot make enzymes. So, you have to take extra enzymes – particularly lipase – to allow you to digest your food. The enzymes are in special capsules to stop them being digested in your stomach.
- If you have a heart attack, an enzyme called streptokinase will be injected into your blood as soon as possible. It dissolves clots in the arteries of the heart wall and reduces the amount of damage done to your heart muscle.
- An enzyme is being used to treat a type of blood cancer in children. The cancer cells cannot make one particular amino acid. They need to take it from your body fluids. The enzyme speeds up the breakdown of this amino acid. The cancer cells cannot get any and they die. Your normal cells can make the amino acid so they are not affected.

Summary questions

- 1 Some people think that biological detergents are better for the environment than non-biological detergents. Why is this?
- 2 Write a short report in the use of one enzyme in industry or medicine. Explain things such as where the enzyme comes from, what it does, why it is an advantage to use it and what disadvantages there might be.



Figure 3 Enzymes are vital in the human body, so it is not surprising that they are widely used in the world of medicine as

Activity

Make a poster with the title 'Enzymes in medicine' which could be displayed on the walls of the science department to inform and interest students in KS3 and/or KS4. Use this material as a starting point and do some more research about the way enzymes are used, to help you make your poster as interesting as possible.

- e Enzymes in detergents break down biological stains such as sweat. They work at low temperatures so use less electricity, which is cheaper and environmentally friendly. They originally caused problems with allergies, but this has been solved now. The lower-temperature washes are less good at killing pathogens; but higher temperatures can denature the enzymes.
- Enzymes can be produced industrially, both to diagnose and to treat disease.



Summary questions (A)



1 a Copy and complete the following sentences, matching each beginning with its correct ending.

Α	A catalyst will speed up a reaction	i	could not occur without enzymes.
В	Living organisms make very efficient catalysts	II	made of protein.
С	All enzymes are	III	binds to the active site.
D	The reactions that keep you alive	iv	known as enzymes.
Е	The substrate of an enzyme	v	a specific type of molecule.
F	Each type of enzyme affects	vi	but is not changed itself.

- b Explain how an enzyme catalyses a reaction. Use diagrams if they make your explanation clearer.
- 2 The table gives some data about the relative activity levels of an enzyme at different pH levels.

pH	Relative activity
4	0
6	3
8	10
10	1

- a Plot a graph of this data.
- b Does this enzyme work best in an acid or an alkaline environment?
- c This is a protein-digesting enzyme. Where in the gut do you think it might be found? Explain your answer.

The results in these tables come from a student who was investigating the breakdown of hydrogen peroxide using manganese(IV) oxide and mashed raw potato.

Table 1 Manganese(IV) oxide

Temperature (°C)	Time taken (s)
20	106
30	51
40	26
50	12

Table 2 Raw mashed potato

Temperature (°C)	Time taken (s)
20	114
30	96
40	80
50	120
60	no reaction

- a Draw a graph of the results using manganese(iv)
- b What do these results tell you about the effect of temperature on a catalysed reaction? Explain your observation.
- c Draw a graph of the results when raw mashed potato was added to the hydrogen peroxide.
- d What is the name of the enzyme found in living cells that catalyses the breakdown of hydrogen peroxide?
- e What does this graph tell you about the effect of temperature on an enzyme-catalysed reaction?
- f Why does temperature have this effect on the enzymecatalysed reaction but not on the reaction catalysed by manganese(IV) oxide?
- g How could you change the second investigation to find the temperature at which the enzyme works best?

A()A/Examination-style questions (A)



- Enzymes are chemicals produced in living cells.
 - a Copy and complete the following sentences, using some of the words below.

amylase bile catalysts fats lipase protease protein sugars

	Enzymes are described as biological	(1)
ii	Enzyme molecules are made of	(1)
iii	The enzyme that digests starch is called	(1)

- iv The substance that neutralises stomach acid is
- v Glycerol is one of the products of the digestion of
- b An enzyme works well in pH 7.
 - i What happens to this enzyme when it is placed in an acid solution?
 - ii Give one other factor that will affect the activity of the enzyme.
- c Explain what happens to starch when it is digested. (2) AQA, 2002
- 2 Enzymes have many uses in the home and in industry.
 - a Which type of organisms are used to produce these enzymes?

Choose the correct answer from the following options: mammals microorganisms plants

b Babies may have difficulty digesting proteins in their food. Baby-food manufacturers use enzymes to 'predigest' the protein in baby food to overcome this difficulty.

Copy and complete the following sentences, using some of the words below.

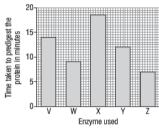
amino acids amylases proteases sugars

- Proteins are 'predigested' using enzymes called (1)
- (1)

c A baby-food manufacturer uses enzyme V to predigest

He tries four new enzymes, W. X. Y and Z. to see if he can reduce the time taken to predigest the protein. The graph shows the time taken for the enzymes to completely predigest the protein.

The manufacturer uses the same concentration of enzyme and the same mass of protein in each experiment.



- How long did it take enzyme V to predigest the protein? (1)
- ii Which enzyme would you advise the baby food manufacturer to use?

Choose the correct answer from the following options:

enzyme V enzyme W enzyme X enzyme Y enzyme Z

Give a reason for your answer.

iii Give two factors which should be controlled in the baby-food manufacturer's investigations. Choose the correct answer from the following options:

oxygen concentration temperature light intensity pH

(2)

3 In this guestion you will be assessed on using good English, organising information clearly and using specialist terms where appropriate.

Describe the roles of the liver and pancreas in the digestion of fats.





Energy from respiration

B2 4.1

Learning objectives

- What is aerobic respiration?
- Where in your cells does respiration take place?



Did you know ...?

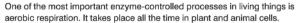
The average energy needs of a teenage boy are 11510kJ of energy every day – but teenage girls only need 8830kJ a day. This is partly because on average girls are smaller than boys, but also because boys have more muscle cells, which means more mitochondria demanding fuel for aerobic respiration.



Folded inner membrane gives a large surface area where the enzymes which release cellular respiration are found

Figure 1 Mitochrondria are the powerhouses that provide energy for all the functions of your cells

Aerobic respiration



Your digestive system, lungs and circulation all work to provide your cells with the glucose and oxygen they need for respiration.

During aerobic respiration, glucose reacts with oxygen. This reaction releases energy that your cells can use. This energy is vital for everything that goes on in your body.

Carbon dioxide and water are produced as waste products of the reaction. We call the process aerobic respiration because it uses oxygen from the air.

Aerobic respiration can be summed up by the equation:

a Why is aerobic respiration so important?



Practical

Investigating respiration

Animals, plants and microorganisms all respire. It is possible to show that cellular respiration is taking place. You can either deprive a living organism of the things it needs to respire, or show that waste products are produced from the reaction.

Depriving a living thing of food and/or oxygen would kill it. This would be unethical. So we concentrate on the products of respiration. Carbon dioxide is the easiest to identify. We can also measure the energy released to the surroundings.

Limewater goes cloudy when carbon dioxide bubbles through it. The higher the concentration of carbon dioxide, the quicker the limewater goes cloudy. This gives us an easy way of showing that carbon dioxide has been produced. We can also look for a rise in temperature to show that energy is being released during respiration.

 Plan an ethical investigation into aerobic respiration in living organisms.

Mitochondria - the site of respiration

Aerobic respiration involves lots of chemical reactions. Each reaction is controlled by a different enzyme. Most of these reactions take place in the mitochondria of your cells.

Mitochondria are tiny rod-shaped parts (organelles) that are found in almost all plant and animal cells. They have a folded inner membrane. This provides a large surface area for the enzymes involved in aerobic respiration.

The number of mitochondria in a cell shows you how active the cell is.

b Why do mitochondria have folded inner membranes?



Reasons for respiration

Respiration releases energy from the food we eat so that our cells can use it.

- Living cells need energy to carry out the basic functions of life. They build up large molecules from smaller ones to make new cell material. Much of the energy released in respiration is used for these 'building' activities (synthesis reactions). For example, in plants the sugars, nitrates and other nutrients are built up into amino acids. The amino acids are then built up into proteins.
- In animals, energy from respiration is used to make muscles contract.
 Muscles are working all the time in your body. Even when you sleep your heart beats, you breathe and your gut churns. All muscular activities use energy.
- Finally, mammals and birds keep their bodies at a constant temperature inside almost regardless of the temperature of their surroundings. So on cold days you will use energy to keep warm, while on hot days you use energy to sweat and keep your body cool.



Figure 2 When the weather is cold, birds like this robin use up a lot of energy from respiration just to keep warm. Giving them extra food supplies can mean the difference between life and death.

Summary questions

- 2 Why do muscle cells have many mitochondria but fat cells very few?
- 3 You need a regular supply of food to provide energy for your cells. If you don't get enough to eat you become thin and stop growing. You don't want to move around and you start to feel cold.
 - a What are the three main uses of the energy released in your body during aerobic respiration?
 - **b** How does this explain the symptoms of starvation described above?
- 4 Suggest an experiment to show that: a oxygen is taken up, and b carbon dioxide is released, during aerobic respiration.

AQA Examiner's tip

Make sure you know the word equation for aerobic respiration.

Remember that aerobic respiration takes place in the mitochondria.

Key points

- Aerobic respiration involves chemical reactions that use oxygen and sugar and release energy. The reaction is summed up as: glucose + oxygen → carbon
- Most of the reactions in aerobic respiration take place inside the mitochondria.

dioxide + water (+ energy)

 The energy released during respiration is used to build large molecules from smaller ones and allows muscles to contract. In mammals and birds, it enables them to maintain a steady body temperature.



B₂ 4₋₂

Learning objectives

- How does your body respond to the increased demands for oxygen during exercise?
- What is glycogen and how is it used in the body?



Figure 1 All the work done by the muscles is based on these special protein fibres, which contract when they work and relax afterwards

Energy from respiration

The effect of exercise on the body B

Your muscles use a lot of energy. They move you around and help support your body against gravity. Your heart is made of muscle and pumps blood around your body. The movement of food along your gut depends on muscles too.

Muscle tissue is made up of protein fibres. These contract when they are supplied with energy from respiration. Muscle fibres need a lot of energy to contract. They contain many mitochondria to carry out aerobic respiration and supply the energy needed.

Muscle fibres usually occur in big blocks or groups known as muscles, which contract to cause movement. They then relax, which allows other muscles to work.

Your muscles also store glucose as the carbohydrate glycogen. Glycogen can be converted rapidly back to glucose to use during exercise. The glucose is used in aerobic respiration to provide the energy to make your muscles contract:

glucose + oxygen → carbon dioxide + water (+ energy)

a What is aerobic respiration?

The response to exercise (



Even when you are not moving about your muscles use up a certain amount of oxygen and glucose. However, when you begin to exercise, many muscles start contracting harder and faster. As a result they need more glucose and oxygen to supply their energy needs. During exercise the muscles also produce increased amounts of carbon dioxide. This needs to be removed for muscles to keep working effectively.

b Why do you need more energy when you exercise?

So during exercise, when muscular activity increases, several changes take place in your body:

- Your heart rate increases and the arteries supplying blood to your muscles dilate (widen). These changes increase the blood flow to your exercising muscles. This in turn increases the supply of oxygen and glucose to the muscles. It also increases the rate that carbon dioxide is removed from the muscles.
- Your breathing rate increases and you breathe more deeply. So you breathe more often and also bring more air into your lungs each time you breathe in. More oxygen is brought into your body and picked up by your red blood cells. This oxygen is carried to your exercising muscles. It also means that more carbon dioxide can be removed from the blood in the lungs and breathed out.
 - c Why do you produce more carbon dioxide when you are exercising hard?

Anaerobic respiration

Learning objectives

- Why do muscles use anaerobic respiration to obtain energy?
- Why is less energy released by anaerobic respiration than aerobic respiration? (H)
- What is an oxygen debt? [H]



Figure 1 Training hard is the simplest way to avoid anaerobic respiration. When you are fit you can get oxygen to your muscles and remove carbon dioxide more efficiently.

Your everyday muscle movements use energy released by aerobic respiration. However, when you exercise hard your muscle cells may become short of oxygen. Although you increase your heart and breathing rates, sometimes the blood cannot supply oxygen to the muscles fast enough. When this happens the muscle cells can still get energy from glucose. They use anaerobic respiration, which takes place without oxygen.

In anaerobic respiration the glucose is not broken down completely. It produces lactic acid instead of carbon dioxide and water.

If you are fit, your heart and lungs will be able to keep a good supply of oxygen going to your muscles while you exercise. If you are unfit, your muscles will run short of oxygen much sooner.

a How does anaerobic respiration differ from aerobic respiration?

Muscle fatigue (R)



Using your muscle fibres vigorously for a long time can make them become fatigued. This means they stop contracting efficiently. One cause of muscle fatigue is the build up of lactic acid. It is made by anaerobic respiration in the muscle cells. Blood flowing through the muscles removes the lactic acid.



Figure 2 Repeated movements can soon lead to anaerobic respiration in your muscles particularly if you're not used to it

Anaerobic respiration is not as efficient as aerobic respiration. This is because the glucose molecules are not broken down completely. So far less energy is released than during aerobic respiration.

The end product of anaerobic respiration is lactic acid and this leads to the release of a small amount of energy, instead of the carbon dioxide and water plus lots of energy released by aerobic respiration.

Anaerobic respiration:

glucose → lactic acid (+ energy)



The benefits of exercise

Your heart and lungs benefit from regular exercise. Both the heart and the lungs become larger. They both develop a bigger and more efficient blood supply. This means they function as effectively as possible, whether you are exercising or not. Look at the table below.

Table 1 A comparison of heart and lung functions before and after getting fit

	Before getting fit	After getting fit
Amount of blood pumped out of the heart during each beat at rest (cm³)	64	80
Volume of the heart at rest (cm³)	120	140
Resting breathing rate at rest (breaths/min)	14	12
Resting pulse rate (beats/min)	72	63
Maximum lung volume (cm³)	1000	1200

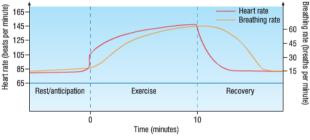


Figure 2 During exercise the heart rate and breathing rate increase to supply the muscles with what they need and remove the extra waste produced. The maximum rate to which you should push your heart is usually calculated as approximately 220 beats per minute minus your age. When you exercise, you should ideally get your heart rate into the range between 60 per cent and 90 per cent of your maximum.

Practical

Testing fitness

A good way of telling how fit you are is to measure your resting heart rate and breathing rate. The fitter you are, the lower they will be. Then see what happens when you exercise. The increase in your heart rate and breathing rate and how fast they return to normal is another way of finding out how fit you are – or aren't!

Summary questions

- 1 Using Figure 2, describe the effect of exercise on the heart rate and the breathing rate of a fit person and explain why these changes happen.
- 2 Plan an investigation into the fitness levels of your classmates. Describe how you might carry out this investigation and explain what you would expect the results to be.

A()A Examiner's tip

- Be clear about the difference between the rate and the depth of breathing.
- Be clear about the difference between the breathing rate and the rate of respiration.

- The energy that is released during respiration is used to enable muscles to contract.
- When you use your muscles you need more glucose and oxygen and produce more carbon dioxide.
- Body responses to exercise include:
 - an increase in heart rate, in breathing rate and in depth of breathing
 - glycogen stores in the muscle are converted to glucose for cellular respiration
 - the blood flow to the muscles increases.
- These act to increase the supply of glucose and oxygen to the muscle and remove more carbon dioxide.



Oxygen debt

If you have been exercising hard, you often carry on puffing and panting for some time after you stop. The length of time you remain out of breath depends on how fit you are. But why do you keeping breathing faster and more deeply when you have stopped using your muscles?

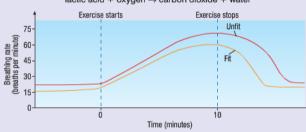
The waste lactic acid you produce during anaerobic respiration is a problem. You cannot simply get rid of lactic acid by breathing it out as you can with carbon dioxide. As a result, when the exercise is over lactic acid has to be broken down to produce carbon dioxide and water. This needs oxygen.

The amount of oxygen needed to break down the lactic acid to carbon dioxide and water is known as the **oxygen debt**.

After a race, your heart rate and breathing rate stay high to supply the extra oxygen needed to pay off the oxygen debt. The bigger the debt (the larger the amount of lactic acid), the longer you will puff and pant!

Oxygen debt repayment:

lactic acid + oxygen → carbon dioxide + water



b What is an oxygen debt?

? Did you know ...?

In a 100m sprint some athletes do not breathe at all. This means that the muscles use the oxygen taken in before the start of the race and then don't get any more oxygen until the race is over. Although the race only takes a few seconds, a tremendous amount of energy is used up so a big oxygen debt can develop, even though the athletes are very fit.

Figure 3 Everyone gets an oxygen debt if they exercise hard, but if you are fit you can pay it off faster

Practical

Making lactic acid

Carry out a single repetitive action such as stepping up and down or lifting a weight or a book from the bench to your shoulder time after time or even just clenching and unclenching your fist. You will soon feel the effect of a build up of lactic acid in your muscles.

 How can you tell when your muscles have started to respire anaerobically?

Summary questions

- Define the following terms:
 aerobic respiration anaerobic respiration lactic acid
- 2 If you exercise very hard or for a long time, your muscles begin to ache and do not work so effectively. Explain why.
- If you exercise very hard, you often puff and pant for some time after you stop. Explain what is happening.

 [H]

- If muscles work hard for a long time they become fatigued and don't contract efficiently. If they don't get enough oxygen they will respire anaerobically.
- Anaerobic respiration is respiration without oxygen.
 Glucose is incompletely broken down to form lactic acid.
- The anaerobic breakdown of glucose releases less energy than aerobic respiration. [H]
- After exercise, oxygen is still needed to break down the lactic acid which has built up. The amount of oxygen needed is known as the oxygen debt.



Summary questions (A)



Edward and Jess wanted to investigate the process of cellular respiration. They set up three vacuum flasks. One contained live, soaked peas. One contained dry peas. One contained peas which had been soaked and then boiled. They took daily observations of the temperature in each flask for a week. The results are shown in the table.

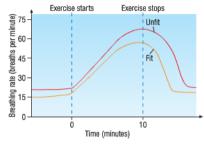
Day	Room temperature (°C)	Temperature in flask A containing live, soaked peas (°C)	Temperature in flask B containing dry peas (°C)	Temperature in flask C containing soaked, boiled peas (°C)
1	20.0	20.0	20.0	20.0
2	20.0	20.5	20.0	20.0
3	20.0	21.0	20.0	20.0
4	20.0	21.5	20.0	20.0
5	20.0	22.0	20.0	20.0
6	20.0	22.2	20.0	20.5
7	20.0	22.5	20.0	21.0

- a Plot a graph to show these results.
- b Explain the results in flask A containing the live, soaked peas.
- c Why were the results in flask B the same as the room temperature readings?
- d Why did Edward and Jess record room temperature in the lab every day?
- e How would you explain the results seen in flask C? Why is the temperature at 20°C for the first five days? Give two possible explanations why the temperature then increases.
- It is often said that taking regular exercise and getting fit is good for your heart and your lungs.

	Before getting fit	After getting fit
Amount of blood pumped out of the heart during each beat (cm³)	64	80
Heart volume (cm³)	120	140
Breathing rate (breaths/ min)	14	12
Pulse rate (beats/min)	72	63

- a The table shows the effect of getting fit on the heart and lungs of one person. Display this data in four bar charts.
- b Use the information on your bar charts to explain exactly what effect increased fitness has on:
 - vour heart
 - ii your lungs.

Section 1 is a second state of the contract fit and unfit person and the time taken to repay oxygen debt.



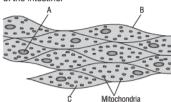
- a Explain what is happening to both people.
- b Why is the graph for the unfit person different from the graph for the fit person?
- c What could the unfit person do to change their body responses to be more like those of the fit person? [H]
- 4 Athletes want to be able to use their muscles aerobically for as long as possible when they compete. They train to develop their heart and lungs. Many athletes also train at altitude. There is less oxygen in the air so your body makes more red blood cells, which helps to avoid oxygen debt. Sometimes athletes remove some of their own blood, store it and then just before a competition transfuse it back into their system. This is called blood doping and it is illegal. Other athletes use hormones to stimulate the growth of extra red blood cells. This is also illegal.
 - a What is aerobic respiration?
 - b Why do athletes want to be able to use their muscles aerobically for as long as possible?
 - c How does developing more red blood cells by training at altitude help athletic performance?
 - d How does blood doping help performance?
 - e Explain in detail what happens to the muscles if the body cannot supply enough glucose and oxygen when they are working hard. TH1
 - f It is legal to train at altitude but illegal to carry out blood doping or to take hormones that stimulate the development of red blood cells. What do you think about this situation?

A()A Examination-style questions (



(1)

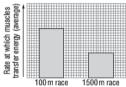
1 The diagram shows a group of muscle cells from the wall of the intestine.

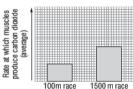


- a Choose the correct words to name the structures labelled A. B and C. cell membrane cell wall chloroplast cytoplasm nucleus
- b Suggest two ways that these muscle cells are adapted to release a lot of energy?
- Respiration is a chemical process.
 - a Where does respiration take place? Choose the correct answer.
 - chloroplasts mitochondria nuclei ribosomes (1)
 - b Which food material is used in respiration?
 - c Name the two waste materials that are produced in respiration.
 - d Respiration is important in muscle contraction. Explain why.
- 3 a Copy and complete the word equation for aerobic respiration.
 - $oxygen + \rightarrow water + (+ energy)$ (2)
 - b i Which substance is missing in anaerobic respiration? (1)
 - ii What is made during anaerobic respiration?
 - (1)iii Muscles get tired during anaerobic respiration. Explain why. (1)

- 4 An athlete started a fitness programme. He was advised to eat a diet containing 18000kJ per day.
 - a The athlete was told that 80% of this energy was needed to keep his body temperature at normal levels. Calculate the remaining number of kilojoules available to the athlete. Show your working.
 - b The athlete decided to double his amount of exercise and assumed he should increase the number of kilojoules in his diet. Using only the information available to the athlete,
 - calculate the extra energy is he likely to need. (1)
 - c The energy supplied in the diet must be transferred to the muscles.
 - Explain in detail this process of energy transfer to the muscles. (4)
- 5 In this question you will be assessed on using good English, organising information clearly and using specialist terms where appropriate.

The bar charts show what happens in an athlete's muscles when running in two races of different distances.





The equations show two processes that occur in muscle cells.

aerobic glucose + oxygen → carbon dioxide + respiration water anaerobic glucose → lactic acid respiration

Use all the information to explain what happens in the athlete's muscles when running in the two races.

Simple inheritance in animals and plants

B25.1

Learning objectives

- How are chromosomes arranged in body cells?
- What is mitosis?
- What is cell differentiation and how does it differ in animals and plants?

O links

For more information on alleles, look at B2 5.5 Inheritance in action.

Cell division and growth (£)

New cells are needed for an organism, or part of an organism, to grow. They are also needed to replace cells which become worn out and to repair damaged tissue. However, the new cells must have the same genetic information as the originals. Then they can do the same job.

Each of your cells has a nucleus containing the instructions for making both new cells and all the tissues and organs needed to make an entire new you. These instructions are carried in the form of genes.

A gene is a small packet of information that controls a characteristic or part of a characteristic, of your body. It is a section of DNA. Different forms of the same gene are known as **alleles**. The genes are grouped together on chromosomes. A chromosome may carry several hundred or even thousands of genes.

You have 46 chromosomes in the nucleus of your body cells. They are arranged in 23 pairs. One of each pair is inherited from your father and one from your mother. Your sex cells (gametes) have only one of each pair of chromosomes.

a Why are new cells needed?

Mitosis



The cell division in normal body cells produces two identical cells and is called **mitosis**. As a result of mitosis all your body cells have the same chromosomes. This means they have the same genetic information.

In asexual reproduction, the cells of the offspring are produced by mitosis from the cells of their parent. This is why they contain exactly the same alleles as their parent with no genetic variation.

How does mitosis work? Before a cell divides it produces new copies of the chromosomes in the nucleus. Then the cell divides once to form two genetically identical cells.

In some parts of an animal or plant, cell division like this carries on rapidly all the time. Your skin is a good example. You constantly lose cells from the skin's surface, and make new cells to replace them. In fact about 300 million body cells die every minute so mitosis is very important.

This normal body cell has four chromosomes in two pairs As cell division starts, a copy of each chromosome is made

The cell divides in two to form two daughter cells. Each daughter cell has a nucleus containing four chromosomes identical to the ones in the original parent cell.

Figure 1 Two identical cells are formed by the simple division that takes place during mitosis. For simplicity this cell is shown with only two pairs (not 23).

Practical

Observing mitosis

View a special preparation of a growing root tip under a microscope. You should be able to see the different stages of mitosis as they are taking place. Use Figure 2 for reference.

- Describe your observations of mitosis.
- b What is mitosis?

Differentiation

In the early development of animal and plant embryos the cells are unspecialised. Each one of them (known as a **stem cell**) can become any type of cell that is needed.

In many animals, the cells become specialised very early in life. By the time a human baby is born most of its cells are specialised. They will all do a particular job, such as liver cells, skin cells or muscle cells. They have differentiated. Some of their genes have been switched on and others have been switched off.

This means that when, for example, a muscle cell divides by mitosis it can only form more muscle cells. So in a mature (adult) animal, cell division is mainly restricted. It is needed for the repair of damaged tissue and to replace worn out cells. This is because in most adult cells differentiation has already occurred. Specialised cells can divide by mitosis, but they only form the same sort of cell. Therefore growth stops once the animal is mature.

In contrast, most plant cells are able to differentiate all through their life. Undifferentiated cells are formed at active regions of the stems and roots. In these areas mitosis takes place almost continuously.

Plants keep growing all through their lives at these 'growing points'. The plant cells produced don't differentiate until they are in their final position in the plant. Even then the differentiation isn't permanent. You can move a plant cell from one part of a plant to another. There it can redifferentiate and become a completely different type of cell. You can't do that with animal cells – once a muscle cell, always a muscle cell.

We can produce huge numbers of identical plant clones from a tiny piece of leaf tissue. This is because in the right conditions, a plant cell will become unspecialised and undergo mitosis many times. Each of these undifferentiated cells will produce more cells by mitosis. Given different conditions, these will then differentiate to form a tiny new plant. The new plant will be identical to the original parent.

It is difficult to clone animals because animal cells differentiate permanently, early in embryo development. The cells can't change back. Animal clones can only be made by cloning embryos in one way or another, although adult cells can be used to make an embryo.

Summary questions

1 Copy and complete using the words below:

chromosomes genetic information genes growth mitosis nucleus replace

- 2 a Explain why the chromosome number must stay the same when the cells divide to make other normal body cells.
 - **b** Why is mitosis so important?
- 3 a What is differentiation?
 - **b** How does differentiation differ in animal and plant cells?
 - c How does this difference affect the cloning of plants and animals?



For information on cell differentiation, look back to B2 1.5 Tissues and organs.

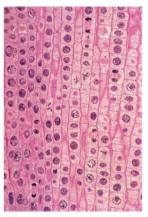


Figure 2 The undifferentiated cells in this onion root tip are dividing rapidly. You can see mitosis taking place, with the chromosomes in different positions as the cells divide.

A Examiner's tip

Cells produced by mitosis are genetically identical.

- In body cells, chromosomes are found in pairs.
- Body cells divide by mitosis to produce more identical cells for growth, repair and replacement, or in some cases asexual reproduction.
- Most types of animal cell differentiate at an early stage of development. Many plant cells can differentiate throughout their life.



B₂ 5.2

Learning objectives

- What is meiosis?
- What happens to your chromosomes when your gametes are formed? THI
- How does sexual reproduction give rise to variation?

Did you know ...?

The testes can produce around 400 million sperm by meiosis every 24 hours between them. Only one sperm is needed to fertilise an egg but each sperm needs to travel 100 000 times its own length to reach the ovum and less than one in a million make it!

Cell division in sexual reproduction

Mitosis is taking place all the time, in tissues all over your body. But there is another type of cell division that takes place only in the reproductive organs of animals and plants. In humans this is the ovaries and the testes. Meiosis results in sex cells, called gametes, with only half the original number of chromosomes.

Meiosis (L)

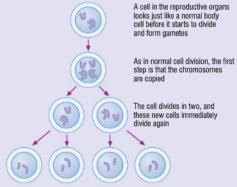


The female gametes or ova are made in the ovaries. The male gametes or sperm are made in the testes.

The gametes are formed by meiosis - cell division where the chromosome number is reduced by half. When a cell divides to form gametes, the chromosomes (the genetic information) are copied so there are four sets of chromosomes. The cell then divides twice in quick succession to form four gametes, each with a single set of chromosomes.

Each gamete that is produced is slightly different from all the others. They contain random mixtures of the original chromosomes pairs. This introduces variety.

What are the names of the male and female gametes in animals? How do they differ from normal body cells?



This gives four sex cells, each with a single set of chromosomes - in this case two instead of the original four

Figure 1 The formation of sex cells in the ovaries and testes involves meiosis to halve the chromosome number. The original cell is shown with only two pairs of chromosomes to make it easier to follow what is happening.

b What type of cell division is needed to produce the gametes?



Fertilisation

More variety is added when fertilisation takes place. Each sex cell has a single set of chromosomes. When two sex cells join during fertilisation the single new cell formed has a full set of chromosomes. In humans, the egg cell (ovum) has 23 chromosomes and so does the sperm. When they join together they produce a single new body cell with the body human number of 46 chromosomes in 23 pairs.

The combination of genes on the chromosomes of every newly fertilised ovum is unique. Once fertilisation is complete, the unique new cell begins to divide by mitosis to form a new individual. This will continue long after the fetus is fully developed and the baby is born.

In fact about 80% of fertilised eggs never make it to become a live baby – about 50% never even implant into the lining of the womb.

Variation

The differences between asexual and sexual reproduction are reflected in the different types of cell division involved.

In asexual reproduction the offspring are produced as a result of mitosis from the parent cells. So they contain exactly the same chromosomes and the same genes as their parents. There is no variation in the genetic material.

In sexual reproduction the gametes are produced by meiosis in the sex organs of the parents. This introduces variety as each gamete is different. Then when the gametes fuse, one of each pair of chromosomes, and so one of each pair of genes, comes from each parent.

The combination of genes in the new pair of chromosomes will contain alleles from each parent. This also helps to produce variation in the characteristics of the offspring.

Summary questions

- 1 a How many pairs of chromosomes are there in a normal human body cell?
 - **b** How many chromosomes are there in a human sperm cell?
 - c How many chromosomes are there in a fertilised human egg cell?
- 2 Sexual reproduction results in variety. Explain how.
- 3 a What is the name of the special type of cell division that produces gametes from ordinary body cells? Describe what happens to the chromosomes in this process.
 - **b** Where in your body would this type of cell division take place?
 - c Why is this type of cell division so important in sexual reproduction?

Figure 2 At the moment of fertilisation the chromosomes in the two gametes are combined. The new cell has a complete set of chromosomes, like any other body cell. This new cell will then grow and reproduce by mitosis to form a new individual.

A()A Examiner's tip

Learn to spell mitosis and meiosis.

Remember their meanings: Mitosis – making identical two. Meiosis – making eggs (and sperm).

Key points

- Cells in the reproductive organs divide by meiosis to form the gametes (sex cells).
- Body cells have two sets of chromosomes; gametes have only one set.
- In meiosis the genetic material is copied and then the cell divides twice to form four gametes, each with a single set of chromosomes.

 Sexual reproduction gives rise to variety because genetic information from two parents is combined.



Simple inheritance in animals and plants

B₂ 5.3

Learning objectives

- What is special about stem cells?
- How can we use stem cells to cure people?

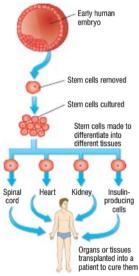


Figure 1 This shows how scientists hope embryonic stem cells might be formed into adult cells and used as human treatments in the future

Stem cells

The function of stem cells

An egg and sperm cell fuse to form a zygote, a single new cell. That cell divides and becomes a hollow ball of cells - the embryo. The inner cells of this ball are the stem cells. Stem cells differentiate to form the specialised cells of your body that make up your various tissues and organs. They will eventually produce every type of cell in your body.

Even when you are an adult, some of your stem cells remain. Your bone marrow is a good source of stem cells. Scientists now think there may be a tiny number of stem cells in most of the different tissues in your body. This includes your blood, brain, muscle and liver.

The stem cells can stay in the different tissues for many years. They are only needed if your tissues are injured or affected by disease. Then they start dividing to replace the different types of damaged cell.

a What are stem cells?

Using stem cells (13)



Many people suffer and even die because parts of their body stop working properly. For example, spinal injuries can cause paralysis. That's because the spinal nerves do not repair themselves. Millions of people would benefit if we could replace damaged body parts.

In 1998, there was a breakthrough, Two American scientists managed to culture human embryonic stem cells. These were capable of forming other types of cell.

Scientists hope that the embryonic stem cells can be encouraged to grow into almost any different type of cell needed in the body. For example, scientists in the US have grown nerve cells from embryonic stem cells. In rats, these have been used to reconnect damaged spinal nerves. The rats regained some movement of their legs. In 2010 the first trials using nerve cells grown from embryonic stem cells in humans were carried out. The nerve cells were injected into the spinal cords of patients with new, severe spinal cord injuries. These first trials were to make sure that the technique is safe. The scientists and doctors hope it will not be long before they can use stem cells to help people who have been paralysed walk again.

We might also be able to grow whole new organs from embryonic stem cells. These organs could be used in transplant surgery. Conditions from infertility to dementia could eventually be treated using stem cells. Doctors in the UK hope to begin using embryonic stem cells to treat a common cause of blindness in 2011.

b What was the big scientific breakthrough by American scientists in 1998?



Problems with stem cells (A)



Many embryonic stem cells come from aborted embryos. Others come from spare embryos in fertility treatment. This raises ethical issues. There are people, including many religious groups, who feel this is wrong. They question the use of a potential human being as a source of cells, even to cure others.

Some people feel that as the embryo cannot give permission, using it is a violation of its human rights. As well as this, progress with stem cells is slow. There is some concern that embryonic stem cells might cause cancer if they are used to treat sick people. This has certainly been seen in mice. Making stem cells is slow, difficult, expensive and hard to control.

c What is the biggest ethical concern with the use of embryonic stem cells?

The future of stem cell research

Scientists have found embryonic stem cells in the umbilical cord blood of newborn babies. These may help to overcome some of the ethical concerns.

Scientists are also finding ways of growing the adult stem cells found in bone marrow and some other tissues. So far they can only develop into a limited range of cell types. However, this is another possible way of avoiding the controversial use of embryonic tissue. Adult stem cells have been used successfully to treat some forms of heart disease and to grow some new organs such as tracheas (windpipes).

The area of stem cell research known as therapeutic cloning could be very useful. However, it is proving very difficult. It involves using cells from an adult to produce a cloned early embryo of themselves. This would provide a source of perfectly matched embryonic stem cells. In theory these could then be used to grow new organs for the original donor. The new organs would not be rejected by the body because they have been made from the body's own cells.

Most people remain excited by the possibilities of embryonic stem cell use in treating many diseases. At the moment, after years of relatively slow progress. hopes are high again that stem cells will change the future of medicine. We don't know how many of these hopes will be fulfilled; only time will tell.



Figure 2 For years, funding for stem cell research in the US was blocked by the government. In 2009 President Obama changed that ruling so US research could move forward. However, the battle continues in the courts.



Figure 3 In 2010 Ciaran Finn-Lynch was the first child to be given a life-saving new windpipe grown using his own stem cells

Summary questions

- 1 Copy and complete using the words below: bone marrow differentiate embryos hollow inner stem cells Unspecialised cells known as can (divide and change) into many different types of cell when they are needed. Human stem cells are found in and in adult The embryo forms a ball of cells and the cells of this ball are the stem cells.
- 2 a What are the advantages of using stem cells to treat diseases?
 - b What are the difficulties with stem cell research?
 - c How are scientists hoping to overcome the ethical objections to using embryonic stem cells in their research?

- Embryonic stem cells (from human embryos) and adult stem cells (from adult bone marrow) can be made to differentiate into many different types of cell.
- Stem cells have the potential to treat previously incurable conditions. We may be able to grow nerve cells or whole new organs for people who need them.



Simple inheritance in animals and plants

B₂ 5.4

Learning objectives

- What did Mendel's experiments teach us about inheritance?
- What is DNA?
- How are specific proteins made in the body? [H]



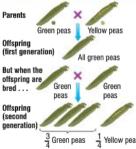


Figure 1 Gregor Mendel, the father of modern genetics. His work was not recognised in his lifetime but now we know just how right he was!

From Mendel to DNA

Until about 150 years ago people had no idea how information was passed from one generation to the next. Today we can identify people by the genetic information in their cells.

Mendel's discoveries

time.

Gregor Mendel was born in 1822 in Austrian Silesia. He was clever but poor, so he became a monk to get an education.

He worked in the monastery gardens and became fascinated by the peas growing there. He carried out some breeding experiments using peas. He used smooth peas, wrinkled peas, green peas and yellow peas for his work. Mendel cross-bred the peas and counted the different offspring carefully. He found that characteristics were inherited in clear and predictable patterns. Mendel explained his results by suggesting there were separate units of inherited material. He realised that some characteristics were dominant over others and that they never mixed together. This was an amazing idea for the

a Why did Gregor Mendel become a monk?

Mendel kept records of everything he did, and analysed his results. This was almost unheard of in those days. Eventually in 1866 Mendel published his findings.

He had never seen chromosomes nor heard of genes. Yet he explained some of the basic laws of genetics using mathematical models in ways that we still use today.

Mendel was ahead of his time. As no one knew about genes or chromosomes, people simply didn't understand his theories. He died 20 years later with his ideas still ignored – but convinced that he was right.

b What was unusual about Mendel's scientific technique at the time?

Sixteen years after Mendel's death, his work was finally recognised. By 1900, people had seen chromosomes through a microscope. Other scientists discovered Mendel's papers and repeated his experiments. When they published their results, they gave Mendel the credit for what they observed.

From then on ideas about genetics developed rapidly. It was suggested that Mendel's units of inheritance might be carried on the chromosomes seen under the microscope. And so the science of genetics as we know it today was born.

DNA - the molecule of inheritance

The work of Gregor Mendel was just the start of our understanding of inheritance. Today, we know that our features are inherited on genes carried on the chromosomes found in the nuclei of our cells.

These chromosomes are made up of long molecules of a chemical known as DNA (deoxyribonucleic acid). This has a double helix structure. Your genes are small sections of this DNA. The DNA carries the instructions to make the proteins that form most of your cell structures. These proteins also include the enzymes that control your cell chemistry. This is how the relationship



between the genes and the whole organism builds up. The genes make up the chromosomes in the nucleus of the cell. They control the proteins, which make up the different specialised cells that form tissues. These tissues then form organs and organ systems that make up the whole body.

Herhor

The genetic code

The long strands of your DNA are made up of combinations of four different chemical bases (see Figure 2). These are grouped into threes and each group of three codes for an amino acid.

Each gene is made up of hundreds or thousands of these bases. The order of the bases controls the order in which the amino acids are put together so that they make a particular protein for use in your body cells. Each

disrupt the whole protein structure and the way it works.

make a particular protein for use in your body cells. Each gene codes for a particular combination of amino acids, which make a specific protein.

A change or mutation in a single group of bases can be enough to change or

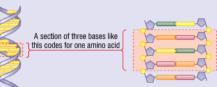


Figure 2 DNA codes for the amino acids that make up the proteins that make up the enzymes that make each individual

DNA fingerprinting K



Unless you have an identical twin, your DNA is unique to you. Other members of your family will have strong similarities in their DNA. However, each individual has their own unique pattern. Only identical twins have the same DNA. That's because they have both developed from the same original cell.

The unique patterns in your DNA can be used to identify you. A technique known as 'DNA fingerprinting' can be applied to make the patterns known as DNA fingerprints.

These patterns are more similar between people who are related than between total strangers. They can

be produced from very tiny samples of DNA from body fluids such as blood, saliva and semen.

The likelihood of two identical samples coming from different people (apart from identical twins) is millions to one. As a result, DNA fingerprinting is very useful in solving crimes. It can also be used to find the biological father of a child when there is doubt.

Summary questions

- 1 a How did Mendel's experiments with peas convince him that there were distinct 'units of inheritance' that were not blended together in offspring?
 - b Why didn't people accept his ideas?
 - c The development of the microscope played an important part in helping to convince people that Mendel was right. How?
- 2 Two men claim to be the father of the same child. Explain how DNA fingerprinting could be used to find out which one is the real father.
- 3 Explain the saying 'One gene, one protein'.

Did you know ...?

The first time DNA fingerprinting was used to solve a crime, it identified Colin Pitchfork as the murderer of two teenage girls and cleared an innocent man of the same crimes.

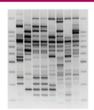


Figure 3 A DNA fingerprint

- Gregor Mendel was the first person to suggest separately inherited factors, which we now call genes.
- Chromosomes are made up of large molecules of DNA.
- A gene is a small section of DNA that codes for a particular combination of amino acids, which make a specific protein.
- Everyone (except identical twins) has unique DNA that can be used to identify them using DNA fingerprinting.



Simple inheritance in animals and plants

B25.5

Learning objectives

- How is sex determined in humans?
- How do we predict what features a child might inherit?
- Can you construct a genetic diagram?

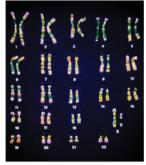


Figure 1 This special photo shows the 23 pairs of human chromosomes. You can see the XY chromosomes, which tell you they are from a male.

Inheritance in action

The way features are passed from one generation to another follows some clear patterns. We can use these to predict what may be passed on.

How inheritance works

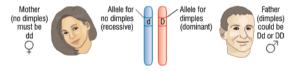
Scientists have built on the work of Gregor Mendel. We now understand how genetic information is passed from parent to offspring.

Humans have 23 pairs of chromosomes. In 22 cases, each chromosome in the pair is a similar shape. Each one has genes carrying information about the same things. One pair of chromosomes is different – these are the **sex chromosomes**. Two X chromosomes mean you are female; one X chromosome and a much smaller one, known as the Y chromosome, mean you are male.

a Twins are born. Twin A is XY and twin B is XX. What sex are the two babies?

The chromosomes we inherit carry our genetic information in the form of genes. Many of these genes have different forms or alleles. Each allele will result in a different protein.

Picture a gene as a position on a chromosome. An allele is the particular form of information in that position on an individual chromosome. For example, the gene for dimples may have the dimple (D) or the no-dimple (d) allele in place.



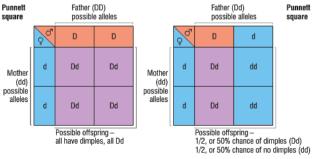


Figure 2 The different forms of genes, known as alleles, can result in the development of quite different characteristics. Genetic diagrams like these Punnett squares help you explain what is happening and predict what the offspring might be like.



Some alleles control the development of a characteristic even when they are only present on one of your chromosomes. These alleles are **dominant**, e.g. dimples and dangly earlobes. We use a capital letter to represent them, e.g. D.

Some alleles only control the development of a characteristic if they are present on both chromosomes – in other words, no dominant allele is present. These alleles are **recessive**, e.g. no dimples and attached earlobes. We use a lower case letter to represent them, e.g. d.

AN Examiner's tip

When you choose a letter as a genetic symbol, try and use a letter that looks different in upper and lower case. Whatever you choose, be very careful to make the upper and lower case symbols clear. [H]

Igher

Genetic terms

Some words are useful when you are working with biological models such as Punnett squares or family trees:

- Homozygous an individual with two identical alleles for a characteristic, e.g. DD, dd.
- Heterozygous an individual with different alleles for a characteristic, e.g. Dd.
- Genotype this describes the genetic makeup of an individual regarding a particular characteristic, e.g. Dd, dd.
- Phenotype this describes the physical appearance of an individual regarding a particular characteristic, e.g. dimples, no dimples.

Dimples male Dimples female No dimples female

Figure 3 A family tree to show the inheritance of dimples

Family trees

You can trace genetic characteristics through a family by drawing a family tree. Family trees show males and females and can be useful for tracing family likenesses. They can also be used for tracking inherited diseases, showing a physical characteristic or showing the different alleles people have inherited.

Summary questions

- 2 a What is meant by the term 'dominant allele'?
 - b What is meant by the term 'recessive allele'?
 - c Try and discover as many human characteristics as you can that are inherited on a single gene. Which alleles are dominant and which are recessive?
- 3 Draw a Punnett square like the ones in Figure 2 to show the possible offspring from a cross between two people who both have dimples and the genotype Dd.
 [H]

- In human body cells the sex chromosomes determine whether you are female (XX) or male (XY).
- Some features are controlled by a single gene.
- Genes can have different forms called alleles.
- Some alleles are dominant and some are recessive.
- We can construct genetic diagrams to predict characteristics.



B2 5.6

Learning objectives

- How are human genetic disorders inherited?
- How can we use a genetic diagram to predict whether a child will inherit a genetic disorder?
- Can you construct a genetic diagram to make predictions about the likelihood of inheriting a genetic disorder? THI

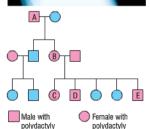


Figure 1 Polydactyly is passed through a amily tree by a dominant allele

Unaffected female

Unaffected male

Inherited conditions in humans

Not all diseases are infectious. Sometimes diseases are the result of a problem in our genes and can be passed on from parent to child. They are known as genetic or inherited disorders.

We can use our knowledge of dominant and recessive alleles to work out the risk of inheriting a genetic disorder.

a How is an inherited disorder different from an infectious disease?

Polydactyly

Sometimes babies are born with extra fingers or toes. This is called polydactyly. The most common form of polydactyly is caused by a dominant allele. It can be inherited from one parent who has the condition. People often have their extra digit removed, but some live guite happily with them.

If one of your parents has polydactyly and is heterozygous, you have a 50% chance of inheriting the disorder. That's because half of their gametes will contain the faulty allele. If they are homozygous, you will definitely have the condition.

Cystic fibrosis (K)



Cystic fibrosis is a genetic disorder that affects many organs of the body, particularly the lungs and the pancreas. Over 8500 people in the UK have cystic fibrosis.

Organs become clogged up by thick, sticky mucus, which stops them working properly. The reproductive system is also affected, so many people with cystic fibrosis are infertile.

Treatment for cystic fibrosis includes physiotherapy and antibiotics. These help keep the lungs clear of mucus and infections. Enzymes are used to replace the ones the pancreas cannot produce and to thin the mucus.

However, although treatments are getting better all the time, there is still no cure.

Cystic fibrosis is caused by a recessive allele so it must be inherited from both parents. Children affected by cystic fibrosis are usually born to parents who do not suffer from the disorder. They have a dominant healthy allele, which means their bodies work normally. However, they also carry the recessive cystic fibrosis allele. Because it gives them no symptoms, they have no idea it is there. They are known as carriers.

In the UK, one person in 25 carries the cystic fibrosis allele. Most of them will never be aware of it. They only realise when they have children with a partner who also carries the allele. Then there is a 25% (one in four) chance that any child they have will be affected.

b You will only inherit cystic fibrosis if you get the cystic fibrosis allele from both parents. Why?

The genetic lottery

When the genes from parents are combined, it is called a genetic cross. We can show this using a genetic diagram (see Figures 2 and 3). A genetic diagram shows us:

- the alleles for a characteristic carried by the parents (the genotype of the parents)
- the possible gametes which can be formed from these
- how these could combine to form the characteristic in their offspring. The genotype of the offspring allows you to work out the possible phenotypes too.

When looking at the possibility of inheriting genetic disorders, it is important to remember that every time an egg and a sperm fuse it is down to chance which alleles combine. So if two parents who are heterozygous for the cystic fibrosis allele have four children, there is a 25% chance (one in four) that each child might have the disorder.

But in fact all four children could have cystic fibrosis, or none of them might be affected. They might all be carriers, or none of them might inherit the faulty alleles at all. It's all down to chancel

Figure 3 A genetic diagram for cystic fibrosis



50% chance polydactyly, PP or Pp, 50% chance normal pp

Pp = Parent with polydactyly pp = Normal parent

Figure 2 A genetic diagram for polydactyly

Both parents are carriers, so Cc

\setminus	C	С	ı
С	CC	Сс	1
С	Сс	CC	

Genotype: 25% normal (CC) 50% carriers (Cc) 25% affected by cystic fibrosis (cc)

Phenotype:

3/4, or 75% chance normal 1/4, or 25% chance cystic fibrosis

Curing genetic diseases

So far we have no way of curing genetic disorders. Scientists hope that genetic engineering could be the answer. It should be possible to cut out faulty alleles and replace them with healthy ones. They have tried this in people affected by cystic fibrosis. Unfortunately, so far they have not managed to cure anyone.

Genetic tests are available that can show people if they carry the faulty allele. This allows them to make choices such as whether or not to have a family. It is possible to screen fetuses or embryos during pregnancy for the alleles which cause inherited disorders. You can also screen embryos before they are implanted in the mother during IVF treatment. These tests are very useful but raise many ethical issues.

Summary questions

- 1 a What is polydactyly?
 - b Why can one parent with the allele for polydactyly pass the condition on to their children even though the other parent is not affected?
 - c Look at the family tree in Figure 1. For each of the five people labelled A to E affected by polydactyly, give their possible alleles and explain your answers.
- 2 a Why are carriers of cystic fibrosis not affected by the disorder themselves?
 - b Why must both of your parents be carriers of the allele for cystic fibrosis before you can inherit the disease?
- 3 A couple have a baby who has cystic fibrosis. Neither the couple, nor their parents, have any signs of the disorder.
- Draw genetic diagrams showing the possible genotypes of the grandparents and the parents to show how this could happen.

- Some disorders are inherited.
- Polydactyly is caused by a dominant allele of a gene and can be inherited from only one parent.
- Cystic fibrosis is caused by a recessive allele of a gene and so must be inherited from both parents.
- You can use genetic diagrams to predict how genetic disorders might be inherited.
- You can construct genetic diagrams to predict the inheritance of genetic disease.



B₂ 5.7

Stem cells and embryos – science and ethics

Learning objectives

- Does everyone agree with the use of embryonic stem cells?
- Are there any problems related to embryo screening?

The stem cell dilemma

Doctors have treated people with adult stem cells for many years by giving bone marrow transplants. Now scientists are moving ever closer to treating very ill people using embryonic stem cells. This area of medicine raises many issues. People have strong opinions about using embryonic stem cells – here are some of them:

In favour of using embryonic stem cells in medical research and possible treatments



- Embryonic stem cells offer one of the best chances of finding treatments for many different and often very serious conditions, including paralysis from spinal injury, Alzheimer's and diabetes.
- The embryos used are generally spare embryos from infertility treatment which would be destroyed anyway.
- Embryos are being created from adult cells for use in research and therapy – they would never become babies.
- It may be possible to use embryonic stem cells from the umbilical cord of newborn bables, so that no embryos need to be destroyed for the research and treatments to go ahead.
- Embryonic stem cells could be used to grow new tissues and organs for transplants.

Against using embryonic stem cells in medical research and possible treatments



- Embryonic stem cell treatments are very experimental and there is a risk that they may cause further problems such as the development of cancers.
- All embryos have the potential to become babies. It is therefore wrong to experiment on them or destroy them.
- Embryos cannot give permission to be used in experiments or treatments, so it is unethical.
- It is taking a long time to develop any therapy that works

 the money and research time would be better spent on other possible treatments such as new drugs or using adult stem cells.

Activity 1

Your class is going to produce a large wall display covered with articles both for and against stem cell research. Your display is aimed at students in Years 10–11. Make sure the level of content is right for your target group.

Try and carry out a survey or a vote with your target group before the display is put up to assess attitudes to the use of embryonic stem cells. Record your findings.

Work on your own or in a small group to produce one piece of display material either in favour of stem cell research or against it. Use a variety of resources to help you – the material in this chapter is a good starting point. Make sure that your ideas are backed up with as much scientific evidence as possible.

Once the material has been displayed for a week or two, repeat your initial survey or vote. Analyse the data to see if easy access to information has changed people's views.

The ethics of screening

Today we not only understand the causes of many genetic disorders, we can also test for them. However, being able to test for a genetic disorder doesn't necessarily mean we should always do it.

- Huntington's disease is inherited through a dominant allele. It causes death
 in middle age. People in affected families can take a genetic test for the
 faulty allele. Some people in affected families take the test and use it to help
 them decide whether to marry or have a family. Others prefer not to know.
- Some couples with an inherited disorder in their family have any developing embryos tested during pregnancy. Cells from the embryo are checked. If it is affected, the parents have a choice. They may decide to keep the baby, knowing that it will have a genetic disorder when it is born. On the other hand, they may decide to have an abortion. This prevents the birth of a child with serious problems. Then they can try again to have a healthy baby.
- Some couples with an inherited disorder in the family have their embryos screened before they are implanted in the mother. Embryos are produced by IVF (in vitro fertilisation). Doctors remove a single cell from each embryo and screen it for inherited disorders. Only healthy embryos free from genetic disorders are implanted back into their mother, so only babies without that disorder are born.



H = dominant, Huntington's disease h = recessive, no Huntington's disease Offspring genotype: 50% Hh, 50% hh Phenotype: 50% Huntington's disease 50% healthy

Figure 1 A genetic diagram for Huntington's disease

Activity 2

Genetic counsellors help families affected by particular genetic disorders to understand the problems and the choices available. Plan a role play of an interview between a genetic counsellor and a couple who already have one child with cystic fibrosis, and would like to have another child.

Either: Plan the role of the counsellor. Make sure you have all the information you need to be able to explain the chances of another child being affected and the choices that are open to the parents.

Or: Plan the role of a parent or work in pairs to give the views of a couple. Think carefully about the factors that will affect your decision, e.g. can you cope with another sick child? Are you prepared to have an abortion? Do you have religious views on the matter? What is fairest to the unborn child, and the child you already have? Is it ethical to choose embryos to implant?

Key points

- It is important that people make informed judgements about the use of embryonic stem cells in medical research and treatment.
- There are a number of economic, social and ethical issues surrounding the screening of embryos.

Summary questions

- 1 What are the main ethical issues associated with the use of embryonic stem cells?
- 2 It would cost a lot of money to screen all embryos for genetic conditions. Put forward two arguments for, and two against, this process.



Simple inheritance in animals and plants: B2 5.1-B2 5.7

Summary questions

- 1 a What is mitosis?
 - b Explain, using diagrams, what takes place when a cell divides by mitosis.
 - c Mitosis is very important during the development of a baby from a fertilised egg. It is also important all through life, Why?
- What is meiosis and where does it take place?
- 3 a Why is meiosis so important?
 - b Explain, using labelled diagrams, what takes place when a cell divides by meiosis. [H]
- 4 a What are stem cells?
 - b It is hoped that many different medical problems may be cured using stem cells. Explain how this might
 - c There are some ethical issues associated with the use of embryonic stem cells. Explain the arguments both for and against their use.
- 5 Hugo de Vries is one of the scientists who made the same discoveries as Mendel several years after Mendel's death. Write a letter from Hugo to one of his friends after he has found Mendel's writings. Explain what Mendel did, why no one took any notice of him and how the situation has changed so that you (Hugo) can come up with a clear explanation for the results of your own experiments, Explain your attitude to Mendel.
- 6 Whether you have a straight thumb or a curved one is decided by a single gene with two alleles. The allele for a straight thumb, S, is dominant to the curved allele, s. Use this information to help you answer these questions. Josh has straight thumbs but Sami has curved thumbs. They are expecting a baby.
 - a We know exactly what Sami's thumb alleles are. What are they and how do you know?
 - b If the baby has curved thumbs, what does this tell you about Josh's thumb alleles? Draw and complete a Punnett square to show the genetics of your explanation.
 - c If the baby has straight thumbs, what does this tell us about Josh's thumb alleles? Draw and complete a Punnett square to show the genetics of your explanation. TH1

Amjid grew some purple flowering pea plants from seeds he had bought at the garden centre. He planted them in his garden.



Here are his results.

Seeds planted	247
Purple-flowered plants	242
White-flowered plants	1
Seeds not growing	4

- a Is the white-flowered plant an anomaly? Why?
- **b** Are the seeds that did not grow anomalies? Why?
- c Suggest other investigations Amiid could carry out into the cause of the colour of the white-flowered plant.

Amiid was interested in these plants, so he collected the seed from some of the purple-flowered plants and used them in the garden the following year. He made a careful note of what happened.

Here are his results:

Seeds planted	406
Purple-flowered plants	295
White-flowered plants	102
Seeds not growing	6

Amjid was slightly surprised. He did not expect to find that a third of his flowers would be white.

- d i The purple allele (P) is dominant and the allele for white flowers (p) is recessive. Draw a genetic diagram that explains Amjid's numbers of purple and white flowers.
 - ii How accurate were Amjid's results compared with the expected ratio?
- e How could Amjid have improved his method of growing the peas to make his results more valid? [H]

A()A/Examination-style questions (A)

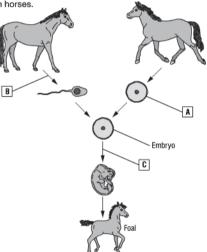
1 Copy and complete the following sentences using the words or symbols below:

characteristics cytoplasm fitness genes nucleus proteins tissue

2 23 46 X XX XY Y

In the body cells of a boy there arechromosomes that are found in the The boy's cells can be identified as male by the chromosome. On all the chromosomes there are sections called that determine the of the boy.

2 The drawing shows some of the stages of reproduction in horses.



- a i Name this type of reproduction (1)ii Name the type of cell labelled A. (1)
- b Name the type of cell division taking place at the stages labelled:

i B (1)

- ii C. (1)
- c How does the number of chromosomes in each cell of the embryo compare with the number of chromosomes in cell A? (1)
- d When the foal grows up it will look similar to its parents but it will not be identical to either parent.
 - Explain why it will look similar to its parents.
 - ii Suggest two reasons why it will not be identical to either of its parents.

AQA, 2001

- 3 When an embryo is formed, the cells divide and start to differentiate. Some adult cells are still able to differentiate.
 - a What is meant by the term differentiation? (1)
 - b What name do we give to cells which have not differentiated? (1)
 - c Give an example of adult cells that can differentiate. (1)
 - d Some of the embryo cells may be used in the future to treat conditions such as paralysis. There are people who do not think we should use embryos in this way. What is an ethical reason for objecting to the use of embryos? (1)
- 4 In this guestion you will be assessed on using good English, organising information clearly and using specialist terms where appropriate.

Doctors all over the world are investigating the use of stem cells to treat a wide variety of disorders.

Many doctors use adult stem cells but some use embryonic stem cells. There is evidence that adult stem cells do not cause cancer tumours if they are transferred soon after being removed from the body. Embryonic stem cells multiply very quickly and there is a risk of cancer developing after treatment with them.

Bone marrow cells are stem cells which continually replace your blood cells every day of your life.

Adult stem cells from bone marrow have been used successfully to treat leukaemia for over 40 years. Many patients with damage to the nervous system have reported improvements in movement following treatment with adult stem cells, but more research is needed before widespread use of the treatment.

One doctor said, 'It is safer to use adult stem cells. Using embryonic stem cells is not ethical.'

Using the information and your own knowledge explain the statement made by the doctor.



Old and new species

B2 6.1

Learning objectives

- What is the evidence for the origins of life on Earth?
- What are fossils?
- What can we learn from fossils?

The origins of life on Earth 18

There is no record of the origins of life on Earth. It is a puzzle that can never be completely solved. There is not much valid evidence for what happened – no one was there to see it! We don't even know exactly when life on Earth began. However, most scientists think it was somewhere between 3 to 4 billion years ago.

There are some interesting ideas and well-respected theories that explain most of what you can see around you. The biggest problem we have is finding the evidence to support the ideas.

a When do scientists think life on Earth began?

What can we learn from fossils?

Some of the best evidence we have about the history of life on Earth comes from **fossils**. Fossils are the remains of organisms from many thousands or millions of years ago that are found preserved in rocks, ice and other places. For example, fossils have revealed the world of the dinosaurs. These lizards dominated the Earth at one stage and died out millions of years before humans came to dominate the Earth.



Maths skills

Time scales for the evolution of life are big:

- A thousand years is 10³ years.
- A million years is 10⁶ years.
- A billion years is 109 years.

You have probably seen a fossil in a museum or on TV, or maybe even found one yourself. Fossils can be formed in a number of ways:

- They may be formed from the hard parts of an animal. These are the bits that do not decay easily, such as the bones, teeth, claws or shells.
- Another type of fossil is formed when an animal or plant does not decay after it has died. This happens when one or more of the conditions needed for decay are not there. This may be because there is little or no oxygen present. It could be because poisonous gases kill off the bacteria that cause decay. Sometimes the temperature is too low for decay to take place. Then the animals and plants are preserved in ice. These ice fossils are rare, but they give a clear insight into what an animal looked like. They can also tell us what an animal had been eating or the colour of a long-extinct flower. We can even extract the DNA and compare it to modern organisms.
- Many fossils are formed when harder parts of the animal or plant are replaced by other minerals. This takes place over long periods of time. These are the most common fossils (see Figure 3).
- Some of the fossils we find are not of actual animals or plants, but of traces they have left behind. Fossil footprints, burrows, rootlet traces and droppings are all formed. These help us to build up a picture of life on Earth long ago.
 - **b** Which is the most common type of fossil?



Did you know ...?

The biggest herbivore found so far is Argentinosaurus huinculensis. It was nearly 40 metres long and probably weighed about 80–100 tonnes! The biggest carnivore found, Giganotosaurus, was about 14 metres long. It had a brain the size of a banana and 20 cm long serrated teeth. By comparison, the biggest modern lizard, the Komodo dragon, is about 3 metres long and weighs around 140kg.



Figure 1 A fossil of Tyrannosaurus rex

An incomplete record

The fossil record is not complete for several reasons. Many of the very earliest forms of life were soft-bodied organisms. This means they have left little fossil trace. It is partly why there is so little valid evidence of how life began. There is no fossil record of the earliest life forms on Earth.

Most organisms that died did not become fossilised – the right conditions for fossil formation were rare. Also, many of the fossils that were formed in the rocks have been destroyed by geological activity. Huge amounts of rock have been broken down, worn away, buried or melted over the years. As this happens the fossil record is lost too. Finally, there are many fossils that are still to be found.

In spite of all these limitations, the fossils we have found can still give us a 'snapshot' of life millions of years ago.



2 The flesh rots, leaving the skeleton to be covered in sand or soil and clay before it is damaged



3 Protected, over millions of years, the skeleton becomes mineralised and turns to rock. The rocks shift in the earth with the fossil trapped inside.





Figure 2 This baby mammoth was preserved in ice for at least 10000 years. Examining this kind of evidence helps scientists check the accuracy of ideas based on fossil skeletons alone.

4 Eventually, the fossil emerges as the rocks move and erosion takes place



Figure 3 It takes a very long time for fossils to form, but they provide us with invaluable evidence of how life on Earth has developed

Summary questions

- 2 There are several theories about how life on Earth began.
 - a Why is it impossible to know for sure?
 - b Why are fossils such important evidence for the way life has developed?
- 3 How do ice fossils help scientists check the evidence provided by the main fossil record?

- Fossils are the remains of organisms from many years ago that are found in rocks.
- Fossils may be formed in different ways.
- Fossils give us information about organisms that lived millions of years ago.
- It is very difficult for scientists to know exactly how life on Earth began because there is little evidence that is valid.



B26.2

Learning objectives

- How much have organisms changed over time?
- What is extinction?
- How do living organisms cause extinction?

O links

For information on fossil records, look back at B2 6.1 The origins of life on Earth.

Figure 1 The evolutionary history of the horse based on the fossil record

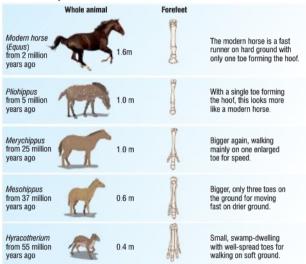
- a What is extinction?
- b How many species of living organisms are thought to have existed on Earth over the years?

Exploring the fossil evidence

Using the fossil record

The fossil record helps us to understand how much organisms have changed since life developed on Earth. However, this understanding is often limited. Only small bits of skeletons or little bits of shells have been found. Luckily we have a very complete fossil record for a few animals, including the horse. These relatively complete fossil records can show us how some organisms have changed and developed over time.

Fossils also show us that not all animals have changed very much. For example, fossil sharks from millions of years ago look very like modern sharks. They evolved early into a form that was almost perfectly adapted for their environment and their way of life. Their environment has not changed much for millions of years so sharks have also remained the same.



Extinction

Throughout the history of life on Earth, scientists estimate that about 4 billion different species have existed. Yet only a few million species of living organisms are alive today. The rest have become extinct. **Extinction** is the permanent loss of all the members of a species.

As conditions change, new species evolve that are better suited to survive the new conditions. The older species that cannot cope with the changes gradually die out. This is because they are not able to compete so well for food and other resources. This is how evolution takes place and the number of species on Earth slowly changes. Some of the species that have become extinct are lost forever or only exist in the fossil record. Others have left living relatives.



There are many different causes of extinction. They always involve a change in the environment such as new **predators**, new diseases or new, more successful competitors.

The gradual change of the climate over millions of years has also caused changes in the species that are adapted for a particular area. This is still happening today.

Organisms that cause extinction

Living organisms can change an environment and cause extinction in several different ways:

- New predators can wipe out unsuspecting prey animals very quickly. This is because the prey animals do not have adaptations to avoid them. New predators may evolve, or an existing species might simply move into new territory. Sometimes this can be due to human intervention. People accidentally brought the brown tree snake from Australia to the island of Guam after World War II. This caused the rapid extinction of many bird species on Guam. They were being eaten by the snakes. The birds had no time to evolve a defence against this new predator.
- New diseases (caused by microorganisms) can bring a species to the point of extinction. They are most likely to cause extinctions on islands, where the whole population of an animal or plant are close together. The Australian Tasmanian devil is one example of this. These rare animals are dying from a new form of infectious cancer. It attacks and kills them very quickly.
- Finally, one species can cause another to become extinct by successful competition. New mutations can give one type of organism a real advantage over another. Sometimes new species are introduced into an environment by mistake. This means that a new, more successful competitor can take over from the original animal or plant and make it extinct. In Australia, the introduction of rabbits has caused severe problems. They eat so much and breed so fast that the other native Australian animals are dying out because they cannot compete.

Summary questions

- 1 Copy and complete using the words below: climate competitors diseases Earth environment extinction predators species
- 2 Look at the evolution of the horse shown in Figure 1. Explain how the fossil evidence of the legs helps us to understand what the animals were like and how they lived.
- 3 Explain how each of the following situations might cause a species of animal or plant to become extinct.
 - a Mouse Island has a rare species of black-tailed mice. They are preyed on by hawks and owls, but there are no mammals that eat them. A new family bring their pregnant pet cat to the island.
 - b English primroses have quite small leaves. Several people bring home packets of seeds from a European primrose, which has bigger leaves and flowers very early in the spring.



The Scottish island of North Uist has a similar problem to Guam. Hedgehogs were brought to the island to combat the problem of garden slugs. Unfortunately, the hedgehogs bred rapidly and are eating the eggs and chicks of the many rare sea birds that breed on the island. Now people are trying to kill or remove the hedgehogs to save the birds.



A Examiner's tip

Always mention a *change* when you suggest reasons for extinction.

- We can learn from fossils how much or how little organisms have changed as life has developed on Earth.
- Extinction may be caused by new predators, new diseases or new, more successful competitors.



Old and new species

B₂ 6.3

Learning objectives

- How does environmental change over long time scales affect living organisms?
- What caused the mass extinctions of the past?

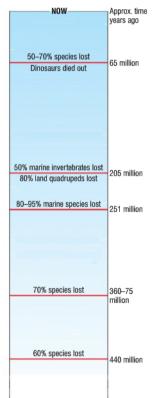


Figure 2 The five main extinction events so far in the evolutionary history of the Farth

ORIGINS OF LIFE

3500 million

years ago

More about extinction

It isn't just changes in living organisms that bring about extinctions. The biggest influences on survival are changes in the environment.

Environmental changes

Throughout history, the climate and environment of the Earth has been changing. At times the Earth has been very hot. At other times, temperatures have fallen and the Earth has been in the grip of an Ice Age. These changes take place over millions and even billions of years.

Organisms that do well in the heat of a tropical climate won't do well in the icy conditions of an Ice Age. Many of them will become extinct through lack of food or being too cold to breed. However, species that cope well in cold climates will evolve and thrive by natural selection.

Changes to the climate or the environment have been the main cause of extinction throughout history. There have been five occasions during the history of the Earth when big climate changes have led to extinction on an enormous scale (see Figure 2).



Figure 1 The dinosaurs ruled the Earth for millions of years, but when the whole environment changed, they could not adapt and most of them died out. Mammals, which could control their own body temperature, had an advantage and became dominant.

a Why are Ice Ages often linked to extinctions?

Extinction on a large scale

Fossil evidence shows that at times there have been mass extinctions on a global scale. During these events many (or even most) of the species on Earth die out. This usually happens over a relatively short time period of several million years. Huge numbers of species disappear from the fossil record.

The evidence suggests that a single catastrophic event is often the cause of these mass extinctions. This could be a massive volcanic eruption or the collision of giant asteroids with the surface of the Earth.

b What is a mass extinction?

What destroyed the dinosaurs?



The most recent mass extinction was when the dinosaurs became extinct around 65 million years ago. In 2010 an international team of scientists published a review of all the evidence put together over the last 20 years. They agreed that around 65 million years ago a giant asteroid collided with the Earth in Chicxulub in Mexico.

We can see a huge crater (180km in diameter) there. Scientists have identified a layer of rock formed from crater debris in countries across the world. The further you move away from the crater, the thinner the layer of crater debris in the rock. Also, deep below the crater, scientists found lots of a mineral only formed when a rock is hit with a massive force such as an asteroid strike.



Figure 3 This layer of debris from the asteroid crater appears in rocks that are 65 million years old - the time the dinosaurs died out

The asteroid impact would have caused huge fires, earthquakes, landslides and tsunamis. Enormous amounts of material would have been blasted into the atmosphere. The accepted theory is that the dust in the atmosphere made everywhere almost dark. Plants struggled to survive and the drop in temperatures caused a global winter. Between 50-70% of all living species. including the dinosaurs, became extinct.

No sooner had this work been published than a group of UK scientists published different ideas and evidence. They suggest that the extinction of the dinosaurs started sooner (137 million years ago) and was much slower than previously thought.

Their idea is that the melting of the sea ice (caused by global warming) flooded the seas and oceans with very cold water. A drop in the sea temperature of about 9°C triggered the mass extinction. Their evidence is based on an unexpected change in fossils and minerals that they found in areas of Norway.

As you can see, building up a valid, evidence-based history of events so long ago is not easy to do. Events can always be interpreted in different ways.

O links

For more information about the way people are changing the environment and bringing about extinction, see B3 chapter 4 How humans can affect the environment.

Examiner's tip

Remember that the time scales in forming new species and mass extinctions are huge.

Try to develop an understanding of time in millions and billions of years.

Summary questions

- 1 a Give four causes of extinction in species of living organisms. b Give two possible causes of mass extinction events.
- 2 Why do you think extinction is an important part of evolution?
- 3 a Summarise the evidence for a giant asteroid impact as the cause of the mass extinction event that resulted in the death of the dinosaurs.
 - b Explain why scientists think that low light levels and low temperatures would have followed a massive asteroid strike. Why would these have caused mass extinctions?

- Extinction can be caused by environmental change over geological time.
- Mass extinctions may be caused by single catastrophic events such as volcanoes or asteroid strikes.



B₂ 6.4

Learning objectives

- How do new species arise?
- How do populations become isolated?
- Do new species always form at the same rate?
- How does speciation take place in an isolated population?

(H)

Did you know ...?

Sometimes the organisms are separated by environmental isolation. This is when the climate changes in one area where an organism lives but not in others. For example, if the climate becomes warmer in one area plants will flower at a different time of year. The breeding times of the plants and the animals linked with them will change and new species emerge.



Figure 1 Both the marsupial koala and the eucalyptus tree have evolved in geographical isolation in Australia

Old and new species

Isolation and the evolution of new species

After a mass extinction, scientists have noticed that huge numbers of new species appear in the fossil record. This is evolution in action. Natural selection takes place and new organisms adapted to the different conditions evolve. But evolution is happening all the time. There is a natural cycle of new species appearing and others becoming extinct.

Isolation and evolution

You have already learnt about the role of genetic variation and natural selection in evolution. Any population of living organisms contains genetic variety. If one population becomes isolated from another, the conditions they are living in are likely to be different. This means that different characteristics will be selected for. The two populations might change so much over time that they cannot interbreed successfully. Then a new species evolves.

How do populations become isolated?

The most common way is by geographical isolation. This is when two populations become physically isolated by a geographical feature. This might be a new mountain range, a new river or an area of land becoming an island.

There are some well-known examples of this. Australia separated from the other continents over 5 million years ago. That's when the Australian populations of marsupial mammals that carry their babies in pouches became geographically isolated.

As a result of natural selection, many different species of marsupials evolved. Organisms as varied as kangaroos and koala bears appeared. Across the rest of the world, competition resulted in the evolution of other mammals with more efficient reproductive systems. In Australia, marsupials remain dominant.

a What is geographical isolation?

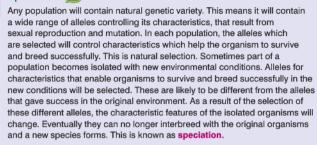
Organisms in isolation

Organisms on islands are geographically isolated from the rest of the world. The closely related but very different species on the Galapagos Islands helped Darwin form his ideas about evolution.

When a species evolves in isolation and is found in only one place in the world, it is said to be endemic to that area. An area where scientists are finding many new endemic species is Borneo. It is one of the largest islands in the world. Borneo still contains huge areas of tropical rainforest.

Between 1994 and 2006 scientists discovered over 400 new species in the Borneo rainforest. There are more than 25 species of mammals found only on the island. All of these organisms have evolved through geographical isolation.

Speciation (K



This is what has happened on the island of Borneo, in Australia and on the Galapagos Islands. If conditions in these isolated places are changed or the habitat is lost, the species that have evolved to survive within it could easily become extinct.

b What is an endemic organism?

Geographical isolation may involve very large areas like Borneo or very small regions. Mount Bosavi is the crater of an extinct volcano in Papua New Guinea. It is only 4km wide and the walls of the crater are 1km high. The animals and plants trapped within the crater have evolved in different ways to those outside.

Very few people have been inside the crater. During a 3-week expedition in 2009 scientists discovered around 40 new species. These included mammals, fish, birds, reptiles, amphibians, insects and plants. All of these species are the result of natural selection caused by the specialised environment of the isolated crater. They include an enormous 82cm long rat that weighs 1.5 kgl

Summary questions

- 1 Copy and complete using the words below: geographically interbreeding populations evolution species selection
 - When two ______ become _____ isolated _____ may take place. Natural _____ in each area means the populations become so different that successful ____ can no longer take place. New _____ have evolved.
- 2 a How might populations become isolated?
 - b Why does this isolation lead to the evolution of new species?
- 3 Explain how genetic variation and natural selection result in the formation of new species in isolated populations.



Figure 2 Orang-utans like these are just one example of the many endemic species that have evolved in isolation in Borneo



Figure 3 Mount Bosavi in Papua New Guinea – a small, geographically isolated environment where many new species have evolved

Key points

- New species arise when two populations become isolated.
- Populations become isolated when they are separated geographically, e.g. on islands.
- There are natural cycles linked to environmental change when species form and when species die out.
- In an isolated population alleles are selected that increase successful breeding in the new environment. [H]
- Speciation takes place when an isolated population becomes so different from the original population that successful interbreeding can no long take place.

[H]



Summary questions (A)



Look at Figure 1 and answer the questions that follow.

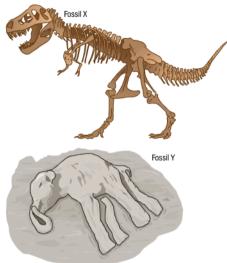


Figure 1

- a What is a fossil?
- **b** Explain fully how fossil X and fossil Y were formed.
- c How can fossils like these be used as evidence for the development of life on Earth and what are their limitations?
- d Why are fossils of little use in helping us understand how life on Earth began?
- 2 a What is extinction?
 - b How does mass extinction differ from species extinction?
 - c What is the evidence for the occurrence of mass extinctions throughout the history of life on Earth?
 - d Suggest at least two theories about the possible causes of mass extinctions and explain the sort of evidence that is used to support these ideas.
 - e What important part have mass extinctions played in the evolution of life on Earth and why?

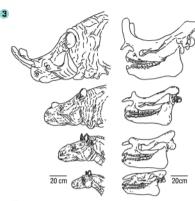


Figure 2

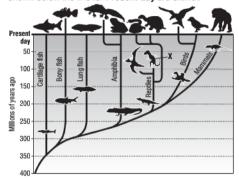
- a This sequence of skulls comes from the fossil record of a group of animals known as perissodactyls. Suggest a possible living relative of these animals.
- **b** How do you think these organisms changed as they evolved, based on the evidence of the diagram above?
- c What are the limitations of this type of evidence?
- d What other fossil remains would you want to see to understand more about the lives of these extinct organisms?
- 4 How does evolution take place?
- 5 Describe how evolution takes place in terms of speciation. Explain the roles of isolation and genetic variation in the process of speciation. Use as many examples and as much evidence as you can in your answer.

TH1

A()A/Examination-style questions (R)



1 The diagram shows a timeline for the evolution of some groups of animals. The earliest forms of the animals shown below the line for Present day are extinct.



Use information from the diagram to answer these auestions.

- a Name the four groups of animals that developed legs.
- b Which group of animals shown in the diagram evolved first? (1)
- c The animal labelled X has been extinct for over 50 million years.

How do scientists know that it once lived? (1)

d Copy and complete the sentence by choosing the correct words from below.

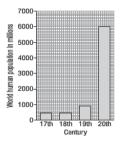
diseases enzymes hormones plants predators rocks

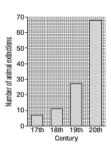
Animals may become extinct because of new and new AQA, 2003

- 2 a What is meant by the term 'extinction'?
 - **b** The bar charts show the population of the world from the 17th to the 20th century and the number of animal extinctions that have taken place over the same period.

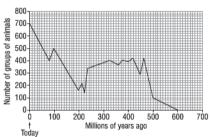
Use the information, in the bar charts to answer the

- i What was the world population in the 19th century?
- ii How many animals became extinct in the 18th century?
- iii What is the relationship between the population of humans and the number of animal extinctions?





- c Between 1900 and 1960 (20th century) 64 animals became extinct.
 - i How many animals became extinct from 1960– 2000? Show your working.
 - ii Suggest a reason for the difference in numbers between the beginning and the end of the 20th century.
- 3 The diagram shows how the number of groups of animals has changed during the history of life on Earth.



- a i How long ago did the first living animals appear on Earth? Give your answer in millions of years.
 - ii How long did it take for the number of groups to rise to 400? Give your answer in millions of years.
- b i Calculate the proportion of groups that disappeared between 100 million years and 80 million years ago. Show your working.
 - ii Give two reasons why some groups of animals disappeared during the history of life on Earth AQA, 2008
- In this question you will be assessed on using good English, organising information clearly and using specialist terms where appropriate.

Describe how new species may arise by isolation. [H] (6)



Examination-style questions

1 a i Put the following structures into the correct order from the smallest to the

cell chromosome gene nucleus smallest

largest

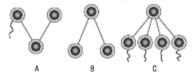
ii What is the function of the nucleus?

b Plant cells contain chloroplasts.

What is the role of chloroplasts in photosynthesis?

ii Name the gas produced in photosynthesis. (1)

2 The diagrams show three processes. Match the correct letter to the process.



Process	Letter
Fertilisation	
Meiosis	
Mitosis	

(1)

(1)

(1)

(4)

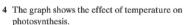
(3)

3 The diagram shows two villi in the small intestine of a healthy person.

The small intestine is an organ in the digestive system.

- a i Name another organ in the digestive system.
 - ii Name tissue X.
- b The villi are surrounded by digested food materials which must enter the blood capillaries.

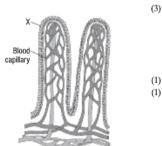
Explain how these materials enter the blood.

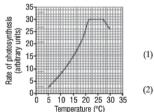


- a i Between which temperatures is the rate of photosynthesis fastest?
 - ii Suggest why the rate of photosynthesis stays the same between these two temperatures.
- A greenhouse owner wants to grow lettuces as quickly and cheaply as possible in winter.

At what temperature should he keep his greenhouse in order to grow the lettuces as quickly and cheaply as possible?.....°C

Explain your answer.





AQA Examiner's tip

When reading graphs (see Q4)

Do not be put off by the term 'arbitrary units' just look at the numbers. Sometimes examiners use this term to avoid writing very complex numbers or unit names.

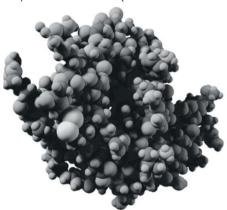
AQA Examiner's tip

Photosynthesis questions often ask about limiting factors.

If raising the temperature does not increase the rate of photosynthesis any further, some other factor must be preventing this. Ask yourself 'What do plants need for photosynthesis?'



5 The picture shows a model of a protein.



Some proteins are enzymes but proteins also have other functions.

a i Give two other functions of proteins.

1.....

2

- ii What is the function of an enzyme? (1)
- b This protein is normally found in neutral conditions. What would happen to the protein if it was placed in acid conditions?
- c When the model protein is put together the scientists use smaller molecules to make the specific shape.
 - i Choose the correct answer to complete the sentence.

amino acids fatty acids lactic acid

- ii Cells are able to put the smaller molecules together in the correct order.
 Explain how the cell does this.
- 6 Some cattle are affected by an inherited condition called glycogen storage disease.
 - i Where is glycogen stored?
 - ii Cattle with this disease become tired easily.

 Explain why. (2)
 - b Glycogen storage disease can be inherited by a calf whose parents do not have the disease.
 - i Use the symbols G and g and a genetic diagram to explain how this is possible. (4)
 - ii If the same parents have another calf, what is the probability that it will not have glycogen storage disease? (1)
- 7 In this question you will be assessed on using good English, organising information clearly and using specialist terms where appropriate.

Describe the changes which take place in the human body during exercise to ensure that the muscles receive enough oxygen and what happens if oxygen is in short supply.

(QA Examiner's tip

(2)

(1)

(6)

Q7 requires a description in a logical order. Think about your answer before writing. Make a brief list of the key words and number them in the correct sequence. Rehearse your answer in your head and change the numbers if necessary. Now write your answer using the numbered words as a quide.

Do not forget to cross out any notes which are not intended for marking.



Exchange of materials

B3 1.1

Osmosis (R)

Learning objectives

- What is osmosis?
- How is osmosis different from diffusion?
- Why is osmosis so important?

Diffusion takes place when particles can spread freely from one place to another. However, the solutions inside cells are separated from those outside by the cell membrane. This membrane does not let all types of particles through. Membranes which only let some types of particles through are called partially permeable.

Osmosis (R)



Partially permeable cell membranes let water move across them. Remember that a dilute solution of sugar contains a high concentration of water (the solvent). It has a low concentration of sugar (the solute). A concentrated sugar solution contains a relatively low concentration of water and a high concentration of sugar.

The cytoplasm of a cell is made up of chemicals dissolved in water inside a partially permeable bag of cell membrane. The cytoplasm contains a fairly concentrated solution of salts and sugars. Water moves from a high concentration of water molecules (in a dilute solution) to a less concentrated solution of water molecules (in a concentrated solution) across the membrane of the cell.

This special type of diffusion, where only water moves across a partially permeable membrane, is called osmosis.

a What is the difference between diffusion and osmosis?

Examiner's tip

Remember, diffusion refers to movement of any particles from a region of high concentration to a region of low concentration.

Osmosis only refers to movement of water molecules.

Practical Investigating osmosis Sugar molecules Water molecules You can make model cells Glass tubes Final level using bags made of partially Initial level permeable membrane (see Concentrated Figure 1). You can see what sugar solution Water moves happens to them if the into the bag concentrations of the solutions Water by osmosis inside or outside the 'cell' Partially permeable change. membrane bags Concentrated sugar solution Water moves Figure 1 A model of osmosis in a out of the bag Water cell. In a the 'cell' contents are more by osmosis concentrated than the surrounding solution. In b the 'cell' contents Partially permeable are less concentrated than the membrane bags

surrounding solution.

The concentration inside your cells needs to stay the same for them to work properly. However, the concentration of the solutions outside your cells may be very different to the concentration inside them. This can cause water to move into or out of the cells by osmosis.



Osmosis in animals

If a cell uses up water in its chemical reactions, the cytoplasm becomes more concentrated. More water immediately moves in by osmosis. If the cytoplasm becomes too dilute because more water is made in chemical reactions, water leaves the cell by osmosis. So osmosis restores the balance in both cases.

However, osmosis can also cause big problems in animal cells. If the solution outside the cell is more dilute than the cell contents, water will move into the cell by osmosis. The cell will swell and may burst.

If the solution outside the cell is more concentrated than the cell contents, water will move out of the cell by osmosis. The cytoplasm will become too concentrated and the cell will shrivel up. Then it can no longer survive. Once you understand the effect osmosis can have on cells, the importance of maintaining constant internal conditions becomes clear.

b How does osmosis help maintain body cells at a specific concentration?

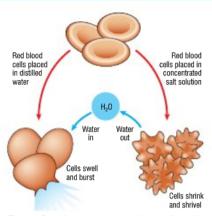


Figure 2 Osmosis can destroy your red blood cells, so it is important to keep your body fluids at the right concentration

Osmosis in plants ([[]

Plants rely on osmosis to support their stems and leaves. Water moves into plant cells by osmosis. This causes the vacuole to swell and press the cytoplasm against the plant cell walls. The pressure builds up until no more water can physically enter the cell. This makes the cell hard and rigid.

This swollen state keeps the leaves and stems of the plant rigid and firm. So plants need the fluid surrounding the cells to always have a higher concentration of water (to be a more dilute solution of chemicals) than the cytoplasm of the cells. This keeps water moving by osmosis in the right direction. If the solution surrounding the plant cells is more concentrated than the cell contents, water will leave the cells by osmosis. The cells will not support the plant tissues. Osmosis is important in all living organisms.



Figure 3 Plant cells in a concentrated sugar solution

Summary questions

- 1 Define the following words: diffusion, osmosis, partially permeable membrane.
- 2 a Explain, using a diagram, what has happened to the plant cells in Figure 3.
 - b Explain, using a diagram, what would happen to these cells if you put them in distilled water.
- 3 Animals that live in fresh water have a constant problem with their water balance. The single-celled organism called Amoeba has a special vacuole in its cell. It fills with water and then moves to the outside of the cell and bursts. A new vacuole starts forming straight away. Explain in terms of osmosis why the Amoeba needs one of these vacuoles.

- Osmosis is a special case of diffusion.
- Osmosis is the diffusion/ movement of water from a dilute to a more concentrated solution through a partially permeable membrane that allows water to pass through.
- Differences in the concentrations of solutions inside and outside a cell cause water to move into or out of the cell by osmosis.

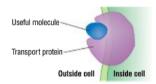


Exchange of materials

B3 1.2

Learning objectives

- What is active transport?
- Why is active transport so important?



Transport protein rotates and releases molecule inside cell (using energy)



Transport protein rotates back again (often using energy)



Figure 1 Active transport uses energy to move substances against a concentration gradient

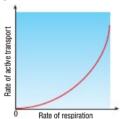


Figure 2 The rate of active transport epends on the rate of respiration

Cells need to move substances in and out. Water often moves across the cell boundaries by osmosis. Dissolved substances also need to move in and out of cells. There are two main ways in which this happens. Substances move by diffusion, along a concentration gradient. This must be in the right direction to be useful to the cells. However, sometimes the substances needed by a cell have to be moved against a concentration gradient, or across a partially permeable membrane. This needs a special process called active transport.

Moving substances by active transport

Active transport allows cells to move substances from an area of low concentration to an area of high concentration. This movement is *against* the concentration gradient. As a result, cells can absorb ions from very dilute solutions. It also enables them to move substances, such as sugars and ions, from one place to another through the cell membranes.

a How does active transport differ from diffusion and osmosis?

It takes energy for the active transport system to carry a molecule across the membrane and then return to its original position (see Figure 1). The energy for active transport comes from cellular respiration. Scientists have shown in a number of different cells that the rate of respiration and the rate of active transport are closely linked (see Figure 2).

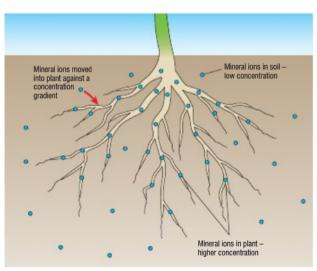


Figure 3 Plants use energy from respiration in active transport to move mineral ions from the soil into the roots against a concentration gradient

In other words, if a cell is making lots of energy, it can carry out lots of active transport. Examples include root hair cells and the cells lining your gut. Cells involved in a lot of active transport usually have lots of mitochondria to provide the energy they need.

b Why do cells that carry out a lot of active transport have lots of mitochondria?

AOA Examiner's tip

Remember, active transport requires energy. Particles are moved from a region of low concentration against the concentration gradient.

The importance of active transport

Active transport is widely used in cells. There are some situations where it is particularly important. For example, the mineral ions in the soil are usually found in very dilute solutions. These solutions are more dilute than the solution within the plant cells. By using active transport, plants can absorb these mineral ions, even though it is against a concentration gradient (see Figure 3).

Sugar such as glucose is always actively absorbed out of your gut and kidney tubules into your blood. This is often done against a large concentration gradient.



Figure 4 Crocodiles have special salt glands in their tongues. These remove excess salt from the body against the concentration gradient by active transport. That's why crocodiles can live in estuaries and even the sea.

?? Did you know ...?

People with cystic fibrosis (see B2 5.6 Inherited conditions in humans) have thick, sticky mucus in their lungs, gut and reproductive systems. This is the result of a mutation affecting a protein involved in the active transport system of the mucus-producing cells.

Summary questions

- 2 Explain how active transport works in a cell.

....., which uses produced by

- 3 Diffusion and osmosis do not need energy. Why is energy needed for active transport and where does it come from?
- 4 Why is active transport so important to:
 - a marine birds such as albatrosses, which have special salt glands producing very salty liquid?
 - b plants?

- Substances are sometimes absorbed against a concentration gradient by active transport.
- Active transport uses energy from respiration.
- Cells can absorb ions from very dilute solutions, and actively absorb substances such as sugar and salt against a concentration gradient using active transport.



Exchange of materials

B3 1.3

Learning objectives

- How do sports drinks differ from ordinary soft drinks?
- Do sports drinks live up to their claims?



Figure 1 The runners in the London marathon certainly use plenty of sports drinks

The sports drink dilemma 🕟

People love soft drinks. In the UK we spend £8–9 billion every year on them. Most of these soft drinks contain mainly water. Colouring, flavouring and some sugar or sweeteners are added, along with tiny amounts of mineral ions. Sometimes carbon dioxide gas is added for fizz.

Professional athletes and people who just enjoy sport often buy special sports drinks. They think these help their performance and recovery after exercise.

Nearly £250 million worth of sports drinks were used last year.

What happens when you exercise?

When you exercise you release energy by respiration to make your muscles contract and move your body, using up sugar. You also sweat to keep your body temperature stable. Sweat contains water and mineral ions. The more you sweat, the more water and mineral ions you lose. This can affect the concentration of your body fluids. If the body fluids become concentrated, water will leave your cells by osmosis. The cells will become dehydrated.

If the water and mineral ions you lose in sweating are not replaced, the mineral ion/water balance of your body will be disturbed. Then your cells will not work as efficiently as usual. To keep exercising at your best, you need to replace the sugar used in respiration and the water and mineral ions lost through sweating. This also applies to recovering properly after exercise. Here is where manufacturers of sports drinks claim to help.

a How do you lose water and mineral ions when you exercise?

What is a sports drink?

A sports drink is mainly water. It also contains sugar (often glucose). It contains more mineral ions than most normal soft drinks. It also has colourings and flavourings added to make it pleasant to drink. Most sports drinks claim to aid hydration of the tissues, help replace lost energy and replace lost electrolytes (the mineral ions you lose when you sweat). But how good are they at doing this?

b What is a sports drink?



How Science Works

Evaluating sports drinks

Sports drinks are usually more expensive than normal soft drinks. There is plenty of evidence to show that sports drinks do what they claim. They contain lots of water so they dilute the body fluids. This allows water to move back into the cells and **rehydrate** them by osmosis. They contain salt, which raises your ion levels, so ions move back into your cells by diffusion. They raise the blood sugar levels so sugar moves back into your cells by diffusion and active transport.



However, sports drinks are expensive. Are they worth the money? There is a lot of evidence which shows that using sports drinks, particularly for normal short-term exercise rather than endurance sports such as marathon running, is not needed. Jeanette Crosland is consultant nutritionist to the British Olympic team. She has examined a lot of evidence and says 'Isotonic sports drinks are not really necessary in activities lasting less than 1 hour, when plain water will suffice'.

So, simply drinking tap water will keep your cells hydrated. Ordinary orange squash will replace the sugar. If you make dilute orange squash and add a pinch of salt it will replace the most important mineral ions. This gives you a 'sports' drink as effective as most commercial products. Evidence is also building



Figure 2 Sports drinks are a growing market as more and more people try to improve their performance

that milk drinks are one of the most effective ways of rehydrating your cells and replacing the sugars and salts used during exercise. Milk provides your muscles with extra protein and gives you vitamins as well.

Table 1 Data on sports drinks compared to milky drinks from the Journal of the International Society of Sports Nutrition

Nutrient value	250 cm ³ skimmed milk (0.1% fat)	250 cm³ semi- skimmed chocolate milk (2% fat)	250 cm ³ sports drink 1	250 cm³ sports drink 2
Energy (kJ)	90	189	52	53
Protein (g)	9	8	0	0
Carbohydrate (g)	13	27	15	15
Sodium ions (mg)	133	159	115	211
Potassium ions (mg)	431	446	31	95

Summary questions

- 1 Copy and complete using the words below:

 salt respiration energy water ions exercise

 When you you release energy from in your muscles. You lose and such as salt in your sweat as you cool down. You need to replace the as well as the and water you have lost through sweat.
- 2 a How do sports drinks differ from ordinary soft drinks?
 - b Some people claim that drinking an ordinary soft drink during exercise is as effective as a sports drink. How could you investigate that claim?
- 3 a How would you display the data given in Table 1? Explain your answer.
 - b What do you think are the advantages and disadvantages of using water, orange squash or milk drinks over special sports drinks, both from the data given here and your wider knowledge?

- Most soft drinks contain water, sugar and mineral ions.
- Sports drinks contain sugars to replace the sugar used in energy release during activity. They also contain water and ions to replace the water and mineral ions lost during sweating.
- Evidence suggests that for normal levels of exercise water is at least as effective as a sports drink.



Exchange of materials

B3 1.4

Learning objectives

- What makes an organ efficient when it comes to exchanging gases or solutes?
- What are your alveoli?
- How are your lungs adapted to make gas exchange as efficient as possible?

O links

For information on surface area: volume ratio, look back to B2 4.2 The effect of exercise on the body.



Figure 1 The common musk turtle has a very unusual tongue, adapted for aseous exchange

Exchanging materials – the lungs 🕟



As living organisms get bigger and more complex, their surface area: volume ratio gets smaller. This makes it increasingly difficult to exchange materials quickly enough with the outside world. Gases and food molecules can no longer reach every cell inside the organism by simple diffusion. So in many larger organisms there are special surfaces where gas and solute exchange take place. They are adapted to be as effective as possible. You can find them in people, in other animals and in plants.

a Why do gas and solute exchange get more difficult as organisms get bigger and more complex?

Adaptations for exchanging materials

There are various adaptations to make the process of exchange more efficient. The effectiveness of an exchange surface can be increased by:

- having a large surface area
- being thin, which provides a short diffusion path
- having an efficient blood supply, in animals. This moves the diffusing substances away and maintains a concentration (diffusion) gradient
- being ventilated, in animals, to make gaseous exchange more efficient by maintaining steep concentration gradients.

Different organisms have very different adaptations for the exchange of materials, such as the leaves of a plant, the gills of a fish and the kidneys of a desert rat. For example, scientists have recently discovered that the common musk turtle has a specially adapted tongue. It is covered in tiny buds that greatly increase the surface area. The tongue also has a good blood supply. These turtles don't just use their tongue for eating - they use it for gaseous exchange too. The buds on the tongue absorb oxygen from the water that passes over them. Most turtles have to surface regularly for air. However, the musk turtle's tongue is so effective at gaseous exchange that it can stay underwater for months at a time.

b How is the tongue of a common musk turtle adapted for gaseous exchange?

Many of your own organ systems are specialised for exchanging materials. One of them is your breathing system, particularly your lungs.

Exchange of gases in the lungs

Your lungs are specially adapted to make gas exchange more efficient. They are made up of clusters of alveoli. These tiny air sacs give the lungs a very large surface area. This is important for the most effective diffusion of the oxygen and carbon dioxide.

The alveoli also have a rich blood supply. This maintains a concentration gradient in both directions. Oxygen is constantly moved from the air in the lungs into the blood and carbon dioxide is constantly delivered into the lungs from the blood.

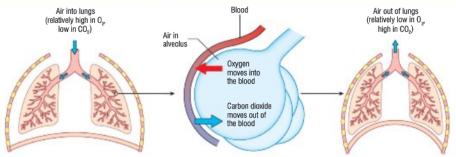


Figure 2 An exchange of gases between the air and the blood takes place in the alveoli of the lungs

As a result, gas exchange takes place along the steepest concentration gradients possible. This makes the exchange rapid and effective. The layer of cells between the air in the lungs and the blood in the **capillaries** is also very thin. This allows diffusion to take place over the shortest possible distance.

c What is the function of the alveoli?

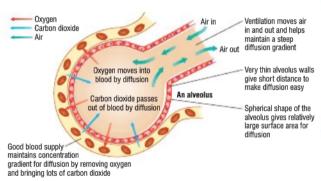


Figure 3 The alveoli are adapted so that gas exchange can take place as efficiently as possible in the lungs

Summary questions

- 1 a Why are gas and solute exchange surfaces so important in larger organisms?
 - **b** Give four common adaptations of exchange surfaces.
- 2 What is meant by the term 'gaseous exchange' and why is it so important in your body?
- 3 How are the lungs adapted to allow gas exchange to take place?

?? Did you know ...?

If all the alveoli in your lungs were spread out flat, they would have a surface area about the size of a tennis court!

- Certain features such as a large surface area, short diffusion paths and steep concentration gradients increase the effectiveness of an exchange surface.
- The alveoli are the air sacs in the lungs.
- The lungs are adapted to make gaseous exchange as efficient as possible. They have many alveoli, which provide a large surface area with a good blood supply and short diffusion distances.
 The lungs are ventilated to maintain steep diffusion gradients.





B3 1.6

Learning objectives

- What happens if the surface area of the gas exchange surface in the lungs is reduced, or you can't use your muscles to ventilate your lungs?
- Can a machine breathe for you?
- How good are artificial lungs?

Artificial breathing aids

There are many different reasons why people sometimes struggle to breathe and get enough oxygen into their lungs. For example:

- The tubes leading to the lungs may be very narrow so less air gets through them.
- The structure of the alveoli can break down. This results in a few big air sacs that have a smaller surface area for gas exchange than healthy alveoli.
- Some people are paralysed in an accident or by disease so they can't breathe.

There are a number of artificial aids for supporting or taking over breathing that have saved countless lives. They work in two main ways – **negative pressure** and **positive pressure**.

a Why might someone need an artificial breathing aid?

The 'iron lung' - negative pressure

Polio is a disease that can leave people paralysed and unable to breathe. To keep polio sufferers alive until their bodies recovered, an external negative-pressure ventilator was developed. This was commonly known as the iron lung. Nowadays we are all vaccinated against polio and it has almost been wiped out worldwide.

The patient lay in a metal cylinder with their head sticking out and a tight seal around the neck. Air was pumped out of the chamber, lowering the pressure inside to form a vacuum. As a result, the chest wall of the patient moved up. This increased the volume and decreased the pressure inside the chest. So air from the outside was drawn into the lungs, just like normal breathing.

The vacuum then switched off automatically and air moved back into the chamber, increasing the pressure. The ribs moved down, lowering the volume and increasing the pressure inside the thorax. This forced air out of the lungs.



Figure 1 Without a negative pressure iron lung to ventilate its lungs this baby would have died



B3 1.5

Ventilating the lungs



Learning objectives

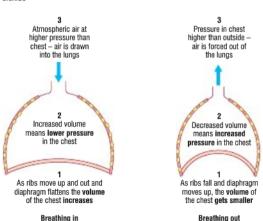
- What are the main parts of your breathing system?
- How do you move air into and out of your lungs?

For a gas exchange system to work efficiently you need a steep concentration gradient. Humans, like many big, complex mammals, move air in and out of the lungs regularly. They maintain a steep concentration gradient of both oxygen in and carbon dioxide out. This is known as ventilating the lungs or breathing. It takes place in your specially adapted breathing system.

a What is meant by 'ventilating the lungs'?

Nose Mouth Muscles between the ribs Rih Luna Trachea Thorax (windpipe) Heart Alveoli (air sacs) Bronchi Abdomen Diaphragm

Figure 1 The breathing system supplies your body with vital oxygen and removes waste carbon dioxide



The breathing system

Your lungs are found in your chest or thorax and are protected by your bony ribcage. They are separated from the digestive organs beneath (in your abdomen) by the diaphragm. The diaphragm is a strong sheet of muscle. The job of your breathing system is to move air in and out of your lungs. The lungs provide an efficient surface for gas exchange (in the alveoli).

b What is the thorax?

Moving air in and out of the lungs

Ventilation of the lungs is brought about by movements of your ribcage and diaphragm. You can see and feel movements of the ribcage, but not of the diaphragm. When you breathe in, oxygen-rich air moves into your lungs. This maintains a steep concentration gradient with the blood. As a result oxygen continually diffuses into your bloodstream through the gas exchange surfaces of your alveoli. Breathing out removes carbon dioxide-rich air from the lungs. This maintains a diffusion gradient so carbon dioxide can continually diffuse out of the bloodstream into the air in the lungs.

Figure 2 Ventilation of the lungs



Practical

Comparing air breathed in and breathed out

This simple investigation (see Figure 3) allows you to demonstrate that the air you breathe in (tube A) is different from the air you breathe out (tube B). You can use limewater as an indicator of the presence of carbon dioxide. It is a colourless solution that turns cloudy when carbon dioxide is bubbled through it. The higher the concentration of carbon dioxide, the faster it turns cloudy.

Using sensors, scientists have measured the changes in the levels of oxygen and carbon dioxide in the air that goes into and comes out of your lungs (see Table 1).

Table 1 The composition of inhaled and exhaled air (~ means approximately)

Atmospheric gas	% of air breathed in	% of air breathed out	
nitrogen	~80	~80	
oxygen	20	~16	
carbon dioxide	0.04	~4	

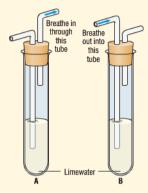


Figure 3 Comparing the level of carbon dioxide in air you breathe in and breathe out

When you breathe in, your **intercostal muscles** contract, pulling your ribs upwards and outwards. At the same time your diaphragm muscles contract. This flattens your diaphragm from its normal, **domed** shape. These two movements *increase* the volume of your thorax. Because the same amount of gas is now inside a much bigger space, the pressure inside your thorax drops. Pressure inside the thorax is now lower than the pressure of air outside your body. As a result, air moves into your lungs.

When the intercostal muscles relax, your ribs drop down and in again. When the diaphragm relaxes it curves back up into your thorax. As a result the volume of your thorax gets smaller again. This increases the pressure inside the chest so the air is squeezed and forced out of the lungs. That's how you breathe out.

c Which muscles bring about ventilation of the lungs?

Summary questions

- 2 Explain clearly how air is moved into and out of your lungs.
- 3 a Draw a bar chart to show the difference in composition between the air you breathe in and the air you breathe out (use Table 1 above).
 - b People often say we breathe in oxygen and breathe out carbon dioxide. Use your bar chart to explain why this is wrong.
 - c How is your breathing system adapted to make these gas exchanges as efficient as possible?

()A Examiner's tip

Remember the sequence for breathing in:

- muscles contract
- volume of thorax increases
- pressure in thorax decreases
- air enters lungs.

- The lungs are in your thorax protected by your ribcage and separated from your abdomen by the diaphragm.
- The intercostal muscles contract to move your ribs up and out and flatten the diaphragm, increasing the volume of your thorax. The pressure decreases and air moves in.
- The intercostal muscles relax and the ribs move down and in, and the diaphragm domes up, decreasing the volume of your thorax. The pressure increases and air is forced out.



A more modern version, the 'shell', is a mini-cylinder that fits just around the chest so it is much easier for the patient to use. It was used mainly with paralysed patients. However, negative pressure ventilation is not used much anymore. It has been overtaken by positive pressure systems.

b What is an iron lung?

Positive pressure breathing

A positive pressure ventilator forces a carefully measured 'breath' of air into your lungs under a positive pressure. It's a bit like blowing up a balloon. Once the lungs have been inflated the air pressure stops. The lungs then deflate as the ribs move down again, forcing the air back out of the lungs.

Positive pressure ventilation can be used in patients with many different problems. It can be given using a simple face mask or by a tube going into the **trachea**. Positive pressure bag ventilators are held and squeezed by doctors or nurses in emergency treatments. They are very simple and temporary but can save lives. Full-scale positive pressure ventilating machines can keep patients alive through major surgery. They can help people who are paralysed to survive for years.

One of the big benefits of positive pressure ventilation is that patients do not have to be placed inside in an iron lung machine. The equipment can be used at home and the patient can even move about. Another benefit is that patients can have some control over the machine. Modern systems can link a ventilator with computer systems, which help patients manage their own breathing much more easily.

Activity

Artificial aids to breathing

Use the content of this page and your own research to help you put together a presentation evaluating three different types of artificial aids to breathing. There are long-term machines and short-term solutions, systems used in surgery and systems that can be used at home. Decide which you are interested in and evaluate:

- a how they work
- b how effective they are at replacing the normal breathing system of the patient
- c the advantages and disadvantages of each system.

Summary questions

•	Copy and t	complete u	sing the w	oras be	iow.		
	negative	breathing	positive	body	aids	breathe	
	Artificial		take over	or help	out a	patient when their o	own
	is st	truggling or	they cann	ot	Old	der machines used	
	external	pressu	ire but mo	st mode	ern ma	chines use a	
	pressure s	ystem.					

- 2 a Explain the difference between the way an external negative pressure aid to breathing works and an internal positive pressure aid to breathing works.
 - b Which is most similar to the natural pattern of breathing of the body?



Figure 2 Using a positive pressure bag ventilator

- Different types of artificial breathing aids have been developed over the years to help people when their lungs or breathing systems don't function properly.
- The different methods have advantages and disadvantages.



Exchange of materials

B3 1.7

Learning objectives

- What are the adaptations in your small intestine that allow you to absorb food efficiently?
- Why are your villi so important?

O links

For information on glucose, amino acids, fatty acids and glycerol, look back to B2 3.3 Enzymes in digestion.

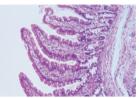




Figure 1 The villi of the small intestine increase the surface area available for diffusion many times so we can absorb enough digested food to survive





Exchange in the gut

The food you eat is broken down in your gut. Food molecules get turned into simple sugars, such as glucose, amino acids, fatty acids and glycerol. Your body cells need these products of digestion to provide fuel for respiration and the building blocks for growth and repair. A successful exchange surface is very important.

Absorption in the small intestine

For the digested food molecules to reach your cells they must move from inside your small intestine into your bloodstream. They do this by a combination of diffusion and active transport.

a Why must the products of digestion get into your bloodstream?

The digested food molecules are small enough to pass freely through the walls of the small intestine into the blood vessels. They move in this direction because there is a very high concentration of food molecules in the gut and a much lower concentration in the blood. They move into the blood down a steep concentration gradient.

The lining of the small intestine is folded into thousands of tiny finger-like projections known as villi (singular: villus). These greatly increase the uptake of digested food by diffusion (see Figure 1). Only a certain number of digested food molecules can diffuse over a given surface area of gut lining at any one time. Increasing the surface area means there is more room for diffusion to take place (see Figure 2).

Each individual villus is itself covered in many microscopic microvilli. This increases the surface area available for diffusion even more.

b What is a villus?

Like the alveoli of the lungs, the lining of the small intestine has an excellent blood supply. This carries away the digested food molecules as soon as they have diffused from one side to the other. So a steep concentration gradient is maintained all the time, from the inside of the intestine to the blood (see Figure 3). This in turn makes sure diffusion is as rapid and efficient as possible down the concentration gradient.

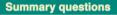
c Why is it so important that the villi have a rich blood supply?

Active transport in the small intestine

Diffusion isn't the only way in which dissolved products of digestion move from the gut into the blood. As the time since your last meal gets longer you can have more dissolved food molecules in your blood than in your digestive system. Glucose and other dissolved food molecules are then moved from the small intestine into the blood by active transport. The digested food molecules have to move against the concentration gradient. This makes sure that none of the digested food is wasted and lost in your faeces.

?? Did you know ...?

Although your gut is only around 7 metres long and a few centimetres wide, the way it is folded into your body along with the villi and microvilli give you a surface area for the absorption of digested products of 200–300 m²!



1 In the following sentences, match each beginning (A, B, C or D) to its correct ending (1 to 4).

Α	Food needs to be broken down into small soluble molecules	1	by diffusion and active transport.
В	The villi are	2	carry away the digested food to the cells and maintain a steep concentration gradient.
С	Food molecules move from the small intestine into the bloodstream	3	so diffusion across the gut lining can take place.
D	The small intestine has a rich blood supply to	4	finger-like projections in the lining of the small intestine which increase the surface area for diffusion.

- 2 Explain why a folded gut wall can absorb more nutrients than a flat one.
- 3 Coeliac disease is caused by gluten, a protein found in wheat, oats and rye. The villi become flattened and the lining of the small intestine becomes damaged.
 - a Why do you think people with untreated coeliac disease are often quite thin?
 - b If someone with coeliac disease stops eating any food containing gluten, they will gradually gain weight and no longer suffer malnutrition. Suggest why this might be.

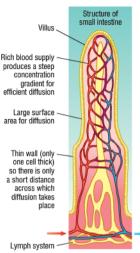


Figure 3 Thousands of finger-like projections in the wall of the small intestine – the villi – make it possible for all the digested food molecules to be transferred from your small intestine into your blood by diffusion and active transport

- The villi in the small intestine provide a large surface area with an extensive network of blood capillaries.
- This makes villi well adapted to absorb the products of digestion by diffusion and active transport.



Exchange of materials

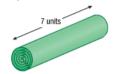
B3 1.8

Learning objectives

- How are the leaves of plants adapted for gaseous exchange?
- How are roots adapted for the efficient uptake of water and mineral ions?

O links

For information on photosynthesis, look back to B2 2.1 Photosynthesis.



Surface area = 22 units²

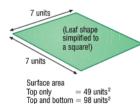


Figure 1 The wide, flat shape of most leaves greatly increases the surface area for collecting light and exchanging gases, compared with more cylindrical leaves

Exchange in plants

Animals aren't the only living organisms that need to exchange materials. Plants rely heavily on diffusion to get the carbon dioxide they need for photosynthesis. They use osmosis to take water from the soil and active transport to obtain mineral ions from the soil. Plants have adaptations that make these exchanges as efficient as possible.

Gas exchange in plants (K



Plants need carbon dioxide and water for photosynthesis to take place. They get the carbon dioxide they need by diffusion through their leaves. The flattened shape of the leaves increases the surface area for diffusion. Most plants have thin leaves. This means the distance the carbon dioxide has to diffuse from the outside air to the photosynthesising cells is kept as short as possible.

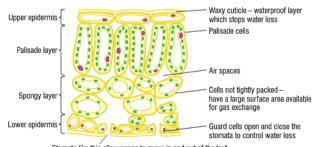
What's more, leaves have many air spaces in their structure. These allow carbon dioxide to come into contact with lots of cells and give a large surface area for diffusion.

a How are leaves adapted for efficient diffusion of carbon dioxide?

However, there is a problem. Leaf cells constantly lose water by evaporation. If carbon dioxide could diffuse freely in and out of the leaves, water vapour would also be lost very quickly. Then the leaves - and the plant - would die.

The leaf cells do not need carbon dioxide all the time. When it is dark. they don't need carbon dioxide because they are not photosynthesising. Sometimes light is a limiting factor on the rate of photosynthesis. Then the carbon dioxide produced by respiration can be used for photosynthesis. But on bright, warm, sunny days a lot of carbon dioxide needs to come into the leaves by diffusion.

Leaves are adapted to allow carbon dioxide in only when it is needed. They are covered with a waxy cuticle. This is a waterproof and gasproof layer.



Stomata like this allow gases to move in and out of the leaf

Figure 2 This cross-section of a leaf shows the arrangement of the cells inside, with plenty of air spaces and short diffusion distances. This means that the carbon dioxide needed for photosynthesis reaches the cells as efficiently as possible.



All over the leaf surface are small openings known as stomata. The stomata can be opened when the plant needs to allow air into the leaves. Carbon dioxide from the atmosphere diffuses into the air spaces and then into the cells along a concentration gradient. At the same time oxygen produced by photosynthesis is removed from the leaf by diffusion into the surrounding air. This maintains a concentration gradient for oxygen from the cells into the air spaces of the leaf. The stomata can be closed the rest of the time to limit the loss of water. The opening and closing of the stomata is controlled by the guard cells. Water is also lost from the leaves by diffusion when the stomata are open.

b Why don't leaves need carbon dioxide all the time?





Open stomata

Closed stomata

Figure 3 Guards cells open and close the stomata to control the carbon dioxide going into the leaf and water vapour leaving it

Uptake of water and mineral ions in plants

Plant roots are adapted to take water and mineral ions from the soil as efficiently as possible. The roots themselves are thin, divided tubes with a large surface area. The cells on the outside of the roots near the growing tips have special adaptations that increase the surface area. These **root hair cells** have tiny projections from the cells which push out between the soil particles.

Water moves into the root hair cells by osmosis across the partially permeable root cell membrane. It then has only a short distance to move across the root to the xylem, where it is moved up and around the plant.

Plant roots are also adapted to take in mineral ions using active transport. They have plenty of mitochondria to supply the energy they need. They also have all the advantages of a large surface area and the short pathways needed for the movement of water.

Summary questions

- 1 a What are stomata?
 - **b** Describe their role in the plant.
 - c How are they controlled?
- 2 a How are plant roots adapted for the absorption of water and mineral ions?
 - b How do the adaptations of plants for the exchange of materials compare with human adaptations in the lungs and the gut?

O links

For information on stomata, look back to B1 4.3 Adaptation in plants.

? Did you know ...?

Root hairs have an amazing effect – a 1 m² area of lawn grass has 350 m² of root surface areal

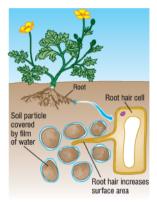


Figure 4 Many small roots, and the presence of microscopic root hairs on the individual root cells, increase diffusion of substances from the soil into the plant

O links

For information on xylem, look back to B2 1.5 Tissues and organs.

- Plants have stomata that allow them to obtain carbon dioxide from the atmosphere.
- Carbon dioxide enters the leaf by diffusion. Leaves have a flat, thin shape and internal air spaces to increase the surface area available for diffusion.
- Most of the water and mineral ions needed by a plant are absorbed by the root hair cells, which increase the surface area of the roots.



Exchange of materials

B3 1.9

Learning objectives

- What is transpiration?
- When do plants transpire fastest?



Figure 1 The transpiration stream in trees like these redwoods can pull many litres of water metres above the ground

Transpiration 🕟

The top of a tree may be many metres from the ground. Yet the leaves at the top need water just as much as the lower branches. So how do they get the water they need?

Water loss from the leaves

The stomata on the surface of plant leaves can be opened and closed by the guard cells that surround them. Plants open their stomata to take in carbon dioxide for photosynthesis. However, when the stomata are open, plants lose water vapour through them as well. This loss of water vapour is called evaporation.

As water evaporates from the surface of the leaves, more water is pulled up through the xylem to take its place. This constant movement of water molecules through the xylem from the roots to the leaves is known as the **transpiration stream**. It is driven by the evaporation of water from the leaves. So anything that affects the rate of evaporation will affect **transpiration**.

a What is the transpiration stream?

The effect of the environment on transpiration

Anything that increases the rate of photosynthesis will increase the rate of transpiration. This happens because more stomata are opened up to let carbon dioxide in. In turn, more water is lost by evaporation through the open stomata. So warm, sunny conditions increase the rate of transpiration.

Conditions that increase the rate of evaporation of water when the stomata are open will also make transpiration happen more rapidly. Hot, dry, windy conditions increase the rate of transpiration.

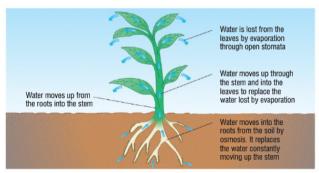


Figure 2 The transpiration stream

b Give three conditions that will increase the rate of evaporation from a leaf.



Controlling water loss

Most plants have a variety of adaptations which help them to photosynthesise as much as possible, while losing as little water as possible.

Most leaves have a waxy, waterproof layer (the cuticle) to prevent uncontrolled water loss. In very hot environments the cuticle may be very thick and shiny. Most of the stomata are found on the underside of the leaves. This protects them from the direct light and energy from the Sun, and reduces the time they are open.

If a plant begins to lose water faster than it is replaced by the roots, it can take some drastic measures. The whole plant may wilt. **Wilting** is a protection mechanism against further water loss. The leaves all collapse and hang down. So the surface area available for water loss by evaporation is greatly reduced.

The stomata close, which stops photosynthesis and risks overheating. But this prevents most water loss and any further wilting. The plant will remain wilted until the temperature drops, the sun goes in or it rains.

ACA Examiner's tip

Remember, water is lost from leaves as water vapour.

Potometers measure the uptake of water not transpiration.

Evidence for transpiration

There are a number of experiments which can be done to investigate the movement of water in plants by transpiration. Many of them use a piece of apparatus known as a potometer.

A potometer can be used to show how the uptake of water by the plant changes with different conditions. This gives you a good idea of the amount of water lost by the plant in transpiration.

Practical

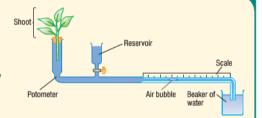


Figure 3 A potometer is used to show the water uptake of a plant under different conditions

Summary questions

- 1 a What is transpiration?
 - **b** Describe how water moves up a plant in the transpiration stream.
- 2 a What part of the leaves helps the plant to reduce water loss under normal conditions?
 - b How will transpiration in a plant be affected if the top leaf surfaces are coated in petroleum jelly?
 - c How will transpiration in a plant be affected if the bottom leaf surfaces are coated in petroleum jelly?
 - d Explain the effect on transpiration of turning a fan onto the leaves of the plant.
 - e What does a potometer actually measure?
- 3 Water lilies have their stomata on the tops of their leaves.
 - a How will this affect transpiration in water lilies?
 - **b** How will the plants cope with this situation?

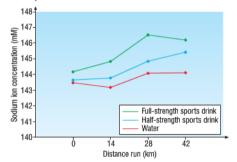
- The loss of water vapour from the surface of plant leaves is known as transpiration.
- Water is lost through the stomata, which are opened and closed to let in carbon dioxide for photosynthesis.
- Transpiration is more rapid in hot, dry, windy or bright conditions.



Summary questions (1)

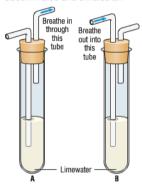


- a Produce a table to compare diffusion, osmosis and active transport. Write a brief explanation of the advantages and disadvantages of all three processes in cells.
 - b Josh thinks that an increase in temperature would increase the rate of osmosis. Abi isn't so sure. Planand describe an investigation that you could carry out to see if temperature has any effect on the rate of osmosis. Explain the results you would expect to get and why.
- This graph was produced by someone who was involved in the development of a particular brand of sports drink. It shows the blood sodium ion concentrations of groups of marathon runners. Seven drank full-strength sports drink, eight drank half-strength sports drink and six drank plain water.



- a Describe what has happened to the blood sodium levels of each group of runners.
- b How could you use this evidence to support the idea that drinking a sports drink while exercising is a good idea?
- c How could you use this evidence to support the idea that sports drinks are not really necessary and are a waste of money?
- d What are the limitations of this research from the data you have been given and how could you improve the repeatability, reproducibility and validity of the results?

- 3 a How are the lungs adapted to allow the exchange of oxygen and carbon dioxide between the air and the blood?
 - b Explain what the experiment shown below tells us about inhaled and exhaled air.



- 4 Some people stop breathing in their sleep, which disturbs them and can be dangerous. A nasal intermittent positive pressure ventilation system forces air into their lungs under pressure at regular intervals through a small facial mask they wear all night. The air enters the lungs, expanding the chest and is then squeezed out again as the chest falls.
 - a Explain how this differs from normal breathing.
 - **b** Explain the advantages of a system like this over an iron luna.
- Compare the adaptations of plant leaves for the exchange of carbon dioxide, oxygen and water vapour with the adaptations of the roots for the absorption of water and mineral ions.

AQA Examination-style questions

 During marathon races, athletes are advised to drink sports drinks.

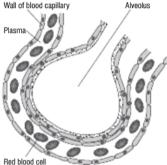
Choose the correct words from the list below to complete the sentences.

alcohol fat ions protein starch sugar water While running the athletes sweat.

The sports drink replaces the _____ and ____ lost in sweat.

The drinks are also a source of energy because they

2 The diagram shows an alveolus and a blood capillary.



The alveolus and the blood capillary are gas exchange

- a i Where in the body would these structures be found?
 - Give two features visible in the diagram that allow efficient gas exchange to take place.
- b i Name the gas that moves from the alveolus into the blood. (1)
 - ii Choose the correct word to complete the sentence.diffusion osmosis ventilation

iii Describe two changes that take place in the body to draw gases into the alveolus. (2 3 Substances move in and out of plants.

List A shows some processes.

List B shows descriptions for these processes. Match each process with its correct description.

List A	
active transport	
osmosis	
evaporation	

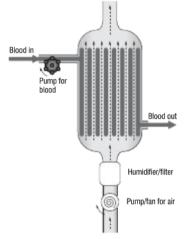
List B
how water is lost through stomata
enables root cells to absorb ions from very dilute soil water
transport of sugar through the plant

movement of water from cell to cell

(3)

In this question you will be assessed on using good English, organising information clearly and using specialist terms where appropriate.

The diagram shows a design for an artificial lung.



Many people with lung disease are confined to a wheelchair or are unable to do much exercise. Scientists hope that a portable artificial lung, the size of a spectacle case, can be developed. This device might replace the need for lung transplants and allow patients to live a normal life.

When scientists design an artificial lung, what features of a normal lung must they copy? Suggest the advantages of the artificial lung compared with a lung transplant. (6)



B3 2.1

Learning objectives

- What is your circulatory system?
- How does your heart work?

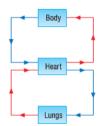


Figure 1 The two separate circulation systems supply the lungs and the rest of the body

Transporting materials

The circulatory system and the heart

You are made up of billions of cells and most of them are far from a direct source of food or oxygen. A **transport system** is vital to supply the needs of your body cells and remove the waste material they produce. This is the function of your **blood circulation system**. It has three parts – the pipes (**blood vessels**), the pump (the **heart**) and the liquid (the **blood**).

a What are the main parts of your circulatory system?

A double circulation

You have two transport systems, called a **double circulation**. One carries blood from your heart to your lungs and back. This allows oxygen and carbon dioxide to be exchanged with the air in the lungs. The other carries blood around the rest of your body and back again to the heart.

A double circulation like this is vital in warm-blooded, active animals like humans. It makes our circulatory system very efficient. Fully **oxygenated** blood returns to the heart from the lungs. This blood can then be sent off to different parts of the body at high pressure. So more areas of your body can receive fully oxygenated blood quickly.

In your circulatory system arteries carry blood away from your heart to the organs of the body. Blood returns to your heart in the veins.

b Why do we need a blood circulation system?

The heart as a pump

Your heart is the organ that pumps blood around your body. It is made up of two pumps (for the double circulation) that beat together about 70 times each minute. The walls of your heart are almost entirely muscle. This muscle is supplied with oxygen by the **coronary arteries**.

c What do your coronary arteries do?

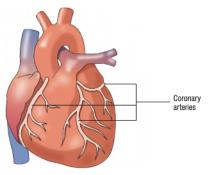


Figure 2 The muscles of the heart work hard so they need a good supply of oxygen and glucose. This is supplied by the blood in the coronary arteries.



The structure of the human heart is perfectly adapted for pumping blood to your lungs and your body. The two sides of the heart fill and empty at the same time. This gives a strong, coordinated heart beat.

Blood enters the top chambers of your heart (the atria). The blood coming into the right atrium from the vena cava is deoxygenated blood from your body. The blood coming into the left atrium in the pulmonary vein is oxygenated blood from your lungs. The atria contract together and force blood down into the ventricles. Valves close to stop the blood flowing backwards out of the heart

- The ventricles contract and force blood out of the heart.
- The right ventricle forces deoxygenated blood to the lungs in the pulmonary artery.
- The left ventricle pumps oxygenated blood around the body in a big artery called the aorta.

As the blood is pumped into these two big vessels, valves close to make sure the blood flows in the right direction.

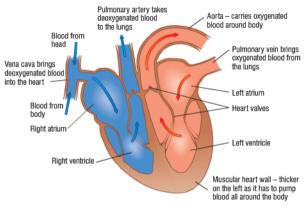


Figure 3 The structure of the heart

Summary questions

- 2 Make a flowchart showing the route of a unit of blood as it passes through the heart and the lungs.
- 3 Blood in the arteries is usually bright red because it is full of oxygen. This is not true of the arteries leading from the heart to the lungs. Why not?

?? Did you know ...?

The noise of the heartbeat that you can hear through a stethoscope is actually the sound of the valves of the heart closing to prevent the blood from flowing backwards.

ACA Examiner's tip

Remember:

- The heart has four chambers.
- Ventricles pump blood out of the heart.

- The circulation system consists of the blood vessels, the heart and the blood.
- Human beings have a double circulation.
- The heart is an organ that pumps blood around the body.
- The valves make sure blood flows in the right direction through the heart.



Transporting materials

B3 2.2

Learning objectives

- Where do substances enter and leave the blood?
- What happens if the veins close up or the valves fail?



Did you know ...?

No cell in your body is more than 0.05 mm away from a capillary!

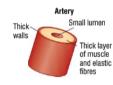






Figure 1 The three main types of blood vessels

Practical

Blood flow

 You can practise finding your pulse and look for the valves in the veins in your hands and wrist.

Keeping the blood flowing

Blood is carried around your body in three main types of blood vessels, each adapted for a different function.

The blood vessels

Your arteries carry blood away from your heart to the organs of your body. This blood is usually bright red oxygenated blood. The arteries stretch as the blood is forced through them and go back into shape afterwards. You can feel this as a pulse where the arteries run close to the surface (like your wrist). Because the blood in the arteries is under pressure, it is very dangerous if an artery is cut. That's because the blood spurts out rapidly every time the heart beats.

The **veins** carry blood towards your heart. It is usually low in oxygen and so is a deep purply-red colour. Veins do not have a pulse. They often have **valves** to prevent the backflow of blood as it moves back to the heart.

The capillaries form a huge network of tiny vessels linking the arteries and the veins. Capillaries are narrow with very thin walls. This enables substances, such as oxygen and glucose, to diffuse easily out of your blood and into your cells. Similarly the substances produced by your cells, such as carbon dioxide, pass into the blood through the walls of the capillaries.

a Substances can only enter and leave the blood in the capillaries. Why is this?

Problems with blood flow through the heart

If the supply of oxygen to your heart is interrupted it can cause pain, a heart attack and even death. The coronary arteries that supply blood to the heart muscle can become narrow as you age. They also get narrower when fatty deposits form on the lining of the vessel. Doctors often solve the problem with stents. A stent is a metal mesh that is placed in the artery. A tiny balloon is inflated to open up the blood vessel and the stent at the same time. As soon as this is done the blood flows freely. Doctors can put a stent in place without a general anaesthetic.

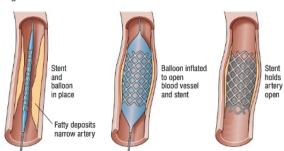


Figure 2 A stent being positioned in an artery





How Science Works

Using stents and artificial valves (K



It isn't only coronary arteries that can narrow and cause problems. Stents can be used to open up an artery almost anywhere in the body. Many stents now also release drugs to prevent the blood from clotting. However, there are some questions about the costs and benefits of this treatment.

Doctors can also carry out bypass surgery. In this operation they replace the narrow or blocked coronary arteries with bits of veins from other parts of the body. This works for badly blocked arteries where stents cannot help. However, the surgery is expensive and involves a general anaesthetic.

b What is a stent?

Leaky valves

The heart valves keep the blood flowing in the right direction. These valves have to withstand a lot of pressure. They may weaken and start to leak. so the heart does not work so well. The person affected can become very breathless. They will eventually die if the problem is not solved.

Doctors can operate on the heart and replace the faulty valve. Mechanical valves are made of materials such as titanium and polymers. They last for a very long time. However, with a mechanical valve you have to take medicine for the rest of your life. This medicine prevents your blood from clotting. Biological valves are based on valves taken from animals such as pigs or cattle. These work extremely well and the patient does not need any medication. However, they only last for about 15 years.





Figure 3 Both biological and mechanical heart valves work very well. They both have advantages and disadvantages for the patient.

Summary questions

- 1 Describe the following blood vessels:
 - a artery
 - **b** vein
 - c capillary.
- 2 a Draw a diagram that explains the way the arteries, veins and capillaries are linked to each other and to the heart.
 - b Label the diagram and explain what is happening in the capillaries.
- 3 Make a table to show the advantages and disadvantages of:
 - a using a stent to improve the blood flow through the coronary arteries and carrying out bypass surgery
 - b mechanical and biological replacement heart valves.

(C)A Examiner's tip

Don't be confused by the names:

- arteries carry blood away from the heart
- veins carry blood to the heart
- valves prevent backflow.

(()A/Examiner's tip

Learn the sequence: veins → atria → ventricles →

 $V \rightarrow A \rightarrow V \rightarrow A$

arteries

- The main types of blood vessels are arteries, veins and capillaries.
- Substances diffuse in and out of the blood in the capillaries.
- Stents can be used to keep narrowed or blocked arteries open.
- Damaged heart valves can be replaced.



Transporting materials

B3 2.3

Learning objectives

- What is blood made up of?
- How are red blood cells adapted to carry oxygen around your body?

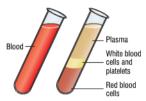


Figure 1 The main components of blood



Figure 2 Blood plasma is a yellow liquid that transports everything you need – and need to get rid of – around your body

Transport in the blood

Your blood is a tissue that consists of a fluid called **plasma**. Plasma carries **red blood cells**, **white blood cells** and **platelets** suspended in it. It also carries many dissolved substances around your body. The average person has between 4.7 and 5.0 litres of blood.

a What types of cells are suspended in the plasma?

The blood plasma as a transport medium

Your blood plasma is a yellow liquid. The red colour of your blood comes from the red blood cells. The plasma transports all of your blood cells and some other things around your body. Carbon dioxide produced in the organs of the body is carried back to the lungs in the plasma.

Similarly, **urea** is carried to your kidneys in the plasma. Urea is a waste product formed in your liver from the breakdown of proteins. In the kidneys the urea is removed from your blood to form **urine**.

All the small, soluble products of digestion pass into the blood from your small intestine. These food molecules are carried in the plasma around your body to the other organs and individual cells.

b What is transported in your blood plasma?

Red blood cells

The red blood cells pick up oxygen from your lungs. They carry the oxygen to the tissues and cells where it is needed. These blood cells have adaptations that make them very efficient at their job:

They have a very unusual shape – they are biconcave discs. That means
they are concave (pushed in) on both sides. This gives them an increased
surface area to volume ratio over which the diffusion of oxygen can take
place.

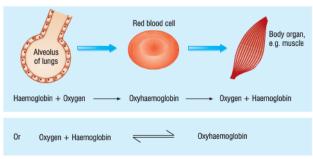


Figure 3 The reversible reaction between oxygen and haemoglobin makes life as we know it possible by carrying oxygen to all the places where it is needed

One red blood cell contains

about 250 million molecules of

haemoglobin, which allow it to

carry 1000 million molecules of

Did you know ...?

- They are packed full of a special red pigment called haemoglobin that can carry oxygen.
- They do not have a nucleus. This makes more space to pack in molecules of haemoglobin.

In a high concentration of oxygen, haemoglobin reacts with oxygen to form bright red oxyhaemoglobin. In other organs where the concentration of oxygen is lower, the oxyhaemoglobin splits up. It forms purply-red haemoglobin and oxygen, which diffuses into the cells where it is needed.

White blood cells are much bigger than the red cells and there are fewer of them. They have a nucleus and form part of the body's defence system against harmful microorganisms. Some white blood cells form antibodies against microorganisms. Others digest invading bacteria and viruses.

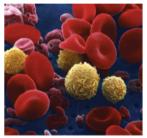
Platelets are small fragments of cells that have no nucleus. They are very important in helping the blood to clot at the site of a wound. They help produce a network of protein threads. The threads then capture lots of red blood cells and more platelets to form a jelly-like clot. This stops you bleeding to death. The clot dries and hardens to form a scab. The scab protects the new skin as it grows and stops bacteria getting into your body through the wound.



oxvaen!

Did you know ...?

There are more red blood cells than any other type of blood cell in your body about 5 million in each cubic millimetre of your blood.



White blood cells



cell

Figure 4 Red blood cells, white blood cells and platelets are suspended in the plasma to make up our blood

Summary questions

cell

- 1 Copy and complete using the words below: transported glucose red blood cells urea blood lungs plasma oxygen Substances are around your body in your Dissolved food
 - molecules such as and waste substances such as are carried in the while is carried from the to the cells by your
- 2 a Why is it not accurate to describe the blood as a red liquid?
 - b What actually makes the blood red?
 - c Give three important functions of blood plasma.
- 3 Explain the main ways in which the blood helps you to avoid infection. including a description of the parts of the blood involved.

- Your blood plasma transports dissolved food molecules, carbon dioxide and urea and has the blood cells suspended in it.
- Your red blood cells carry oxygen from your lungs to the organs of the body.
- Red blood cells are adapted to carry oxygen by being biconcave, giving them a bigger surface area, by containing haemoglobin and by having no nucleus so more haemoglobin can fit in.
- White blood cells are part of the defence system of the body.
- Platelets are cell fragments involved in the clotting of the blood.





B3 2.4

Artificial or real? (R)

Learning objectives

- What is artificial blood?
- How well does artificial blood work?
- Is an artificial heart as good as a real one?

Artificial blood

Blood is vital to life – lose too much and you die. You can be given a blood **transfusion** to replace the blood you have lost. People have different blood groups that must be matched for a successful transfusion.

Blood can only be stored for a limited time and there is often a shortage of blood **donors**. Some people will not accept blood transfusions for religious reasons. Doctors and scientists have been trying to develop artificial blood to solve these problems for years.

Plasma or saline

The simplest way to replace blood in an emergency is with donated plasma or even saline (salt water). Plasma carries a little dissolved oxygen. However, saline does not carry oxygen or food. It just replaces the lost blood volume to keep your blood pressure as normal as possible. This can buy time for your body to make more blood, or for a matched blood transfusion to be found.

Perfluorocarbons (PFCs)

Activity 1

Perfluorocarbons are a more sophisticated form of artificial blood. These are very non-reactive chemicals that can carry dissolved gases around your body. Oxygen dissolves readily in PFCs. After accidents or surgery, capillaries may be squashed almost shut and red blood cells cannot get through. Because PFCs do not contain cells, they can carry oxygen into the most swollen tissues of a damaged body. They can be kept for a long time and they do not carry disease.

However, PFCs do not dissolve in water so getting them into the blood is difficult. They do not carry as much oxygen as real whole blood so large amounts are needed to supply the body. PFCs are also broken down very quickly and can cause severe side-effects.

Artificial blood

- Use these data to help you explain why there is so much interest in developing artificial blood products.
- 2 Make a poster encouraging people to give blood. Give information about the need for blood and the advantages and limitations of artificial bloods developed so far. This should aim to encourage as many people as possible to donate blood.

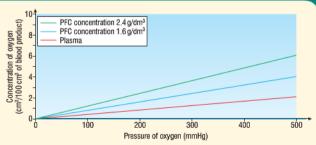


Figure 1 This graph shows how much oxygen dissolves in normal blood plasma (that can be used as a blood substitute) and in two different concentrations of PFCs

Look up information about the amounts of blood needed each year etc. The NHS Blood and Transplant website is a good source of information.



Haemoglobin-based products

The other main type of artificial blood being developed is based on haemoglobin. A solution is made that does not contain any red blood cells. The haemoglobin is often taken from human or animal blood. However, it can be made synthetically or by genetically engineered bacteria. The haemoglobin in the solution carries even more oxygen than normal blood. Another advantage is that it does not always need to be kept in a fridge.

However, this type of artificial blood is broken down very quickly in the body. It only lasts for 20 to 30 hours and does not clot or fight disease. It has also caused severe problems in patients in trials.

So far, artificial blood has not been very successful. However, in the future it may yet save many lives.

a Name two types of artificial blood.

Artificial hearts



When people need a heart transplant they have to wait for a donor heart that is a tissue match. However, there are never enough hearts to go around. Many people die before they get a chance to have a new heart.

For years scientists have been trying to develop an artificial heart. They have developed temporary hearts that can support your natural heart until it can be replaced. However, replacing your heart permanently with a machine is still a long way off.



Figure 2 This amazing artificial heart uses air pressure to pump blood around the body

Since 2004 about 1000 people worldwide have been fitted with a completely artificial heart. These artificial hearts need a lot of machinery to keep them working. Most patients have to stay in hospital until they have their transplant.

However, in 2010, a 43-year-old American man became the first person to leave hospital and go home with a completely artificial heart. He carried the machine working the heart in a backpack! There is always a risk of the blood clotting in the artificial heart, which can kill the patient. But this new technology gives people a chance to live a relatively normal life while they wait for a heart transplant.

b When did the first person successfully go home from hospital with an artificial heart?

Summary questions

- 1 Make a table to show the advantages and disadvantages of artificial blood products over normal blood transfusions.
- 2 Suggest both scientific and social arguments for and against the continued development of artificial hearts.

Activity 2

The story of transplants and artificial hearts

Make a presentation on the history of heart transplants and the use of artificial hearts. Look for evidence for the benefits of artificial hearts in the heart transplant programme.

- Artificial blood is a solution which can be used to replace real blood that is lost.
- The advantages of artificial blood: it is always available; it doesn't always need to be kept in a fridge; it doesn't contain cells so it can get into any tissue and no blood group matching is needed.
- The disadvantages: it is expensive; it doesn't carry as much oxygen as whole blood; some artificial blood does not dissolve in water so doesn't mix easily with the blood; most artificial bloods are broken down very quickly in the body; some artificial bloods can cause unpleasant side-effects.
- Advantages of artificial hearts: no wait for a donor; no need to match tissue; no need for immunosuppressant drugs.
- Disadvantages: size; problems with blood clotting; until recently always involved staying in hospital; expense.



Transporting materials

B3 2.5

Learning objectives

- What substances are transported in plants?
- How does transport in the xylem and the phloem differ?

O links

For information on phloem, look back to B2 1.5 Tissues and organs.

Transport systems in plants 🕟

Plants make sugar by photosynthesis in the leaves and other green parts. This sugar is needed all over the plant. Similarly, water and mineral ions move into the plant from the soil through the roots, but they are needed by every cell of the plant. Plants have two separate transport systems to move substances around their bodies.

Phloem - moving food

The phloem transports the sugars made by photosynthesis from the leaves to the rest of the plant. This includes the growing areas of the stems and roots. Here the sugars are needed for making new plant cells. Food is also transported to the storage organs where it is needed to provide an energy store for the winter. Phloem is a living tissue.

Greenfly and other aphids are plant pests. They stick their sharp mouthparts right into the phloem and feed on the sugary fluid. If too many of them attack a plant they can kill it by taking all of the food.

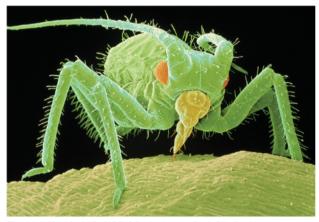


Figure 1 Aphids take the liquid full of dissolved sugars directly from the phloem

Xylem – moving water and mineral ions

The xylem is the other transport tissue in plants. It carries water and mineral ions from the soil around the plant. Mature xylem cells are dead. In woody plants like trees, the xylem makes up the bulk of the wood and the phloem is found in a ring just underneath the bark. This makes young trees in particular very vulnerable to damage by animals. That's because if a complete ring of bark is eaten, transport in the phloem stops. Then the tree will die.

- a Which plant transport tissue is living?
- **b** What is transported in the xylem?



For information on xylem, look back B2 1.5 Tissues and organs.

Why is transport so important?

It is very important to move the food made by photosynthesis around the plant. All the cells need sugars for respiration as well as to provide materials for growth. The movement of water and mineral ions from the roots is equally important. The mineral ions are needed for the production of proteins and other molecules within the cells

The water is needed for several reasons. One is for photosynthesis, where carbon dioxide and water are combined to make sugar. Another is that water is needed to hold the plant upright. When a cell has plenty of water inside it the vacuole presses the cytoplasm against the cell walls. This pressure of the cytoplasm against the cell walls gives support for young plants and for the structure of the leaves. For young plants and soft-stemmed plants – although not trees – this is the main method of support.



Figure 2 The phloem and xylem are arranged in vascular bundles in the stem



Figure 3 A simple way of demonstrating that water moves up the xylem

AOA Examiner's tip

Don't confuse xylem and phloem:

- For phloem think 'food' (sugar) transport.
- For xylem think 'transports water'.

Summary questions

- 2 a Why does a plant need a transport system?
 - **b** Explain why a constant supply of sugar and water are so important to the cells of a plant.
- 3 A local woodland trust has set up a scheme to put protective plastic covers around the trunks of young trees. Some local residents are objecting to this, saying it spoils the look of the woodland. Write a letter to your local paper explaining exactly why this protection is necessary.

- Flowering plants have separate transport systems.
- Xylem tissue transports water and mineral ions from the roots to the stems and leaves.
- Phloem tissue transports dissolved sugars from the leaves to the rest of the plant, including the growing regions and storage organs.



Summary questions (1)



- Here are descriptions of two heart problems. In each case use what you know about the heart and the circulatory system to explain the problems caused by the condition.
 - a Sometimes babies are born with a 'hole in the heart' there is a gap in the central dividing wall of the heart. They may look blue in colour and have very little energy.
 - b The coronary arteries supplying blood to the heart muscle itself may become clogged with fatty material. The person affected may get chest pain when they exercise or even have a heart attack.
- 2 In each of the following examples, explain the effect on the blood and what this will mean to the person involved:
 - a an athlete running a race after acting as a blood donor and giving blood
 - b someone who eats a diet low in iron.
- a How are the red blood cells adapted for the carriage of oxygen?
 - b The graph shows the effect of an increased carbon dioxide concentration on the way haemoglobin carries oxygen.

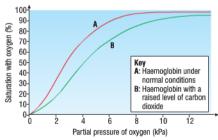


Figure 1 Graph to show the effect of carbon dioxide concentration on the reaction between haemoglobin and oxygen

- i What is the percentage saturation of haemoglobin under normal conditions when the partial pressure of oxygen is 2 and 6?
- ii What is the percentage saturation of haemoglobin when the partial pressure of oxygen is 2 and 6 and the concentration of carbon dioxide is raised?
- iii What does this tell you about events in the blood capillaries in the lungs?

- iv How does the concentration of carbon dioxide in the tissues affect gaseous exchange between the cells and the blood?
- Why do these data suggest that haemoglobinbased oxygen-carrying artificial blood would be effective?
- If a patient has a blocked blood vessel, doctors may be able to open up the blocked vessels with a stent or replace the clogged up blood vessels with bits of healthy blood vessels taken from other parts of the patient's

Figure 2 shows you the results of these procedures in one group of patients after one year.

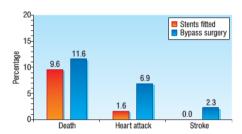


Figure 2 Results after 1 year

- a What is a stent and how does it work?
- b Which technique does the evidence suggest is the most successful for treating blocked coronary arteries? Explain your answer.
- c What additional information would you need to decide whether this evidence was repeatable, reproducible and valid?
- 5 Arteries, veins, xylem and phloem are all transport vessels in living organisms.
 - a Make a table to compare arteries and veins.
 - b Make a table to compare xylem and phloem tissue.
 - c Comment on the two different systems.

A()A/Examination-style questions (A)



1 a Platelets are found in the blood plasma. Some sick people need platelets as part of their treatment.

What is the function of platelets? (1)

b Some people donate whole blood, but the National Blood Service also needs platelet donations.

Read the facts about blood donation and platelet donation in the table below.

Use information from the table and your own knowledge to answer the questions.

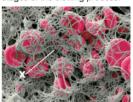
i The National Blood Service needs more platelet donors.

Whv? (1)

- ii Give two reasons why doctors prefer platelet donation for seriously ill patients who require platelets.
- iii Give one disadvantage of platelet donation for the National Blood Service.
- iv Blood platelet donors choose to donate because they know the benefits to patients but there are disadvantages to donating platelets instead of whole blood.

Give two disadvantages for the donor of platelets. (2)

v Give one advantage to the donor for platelet donation over whole blood donation. (1) 2 The photograph shows a red blood cell in part of a blood clot. The fibres labelled X are produced in the early stages of the clotting process.



- a Suggest how the fibres labelled X help in blood-clot formation.
- b The average diameter of a real red blood cell is 0.008 millimetres.

On the photograph, the diameter of the red blood cell is 100 millimetres.

Use the formula to calculate the magnification of the photograph.

diameter on photograph = real diameter × magnification Magnification =

- c Some blood capillaries have an internal diameter of approximately 0.01 millimetres.
 - i Use information given in part b to explain why only one red blood cell at a time can pass through a
 - ii Explain the advantages of red blood cells passing through a capillary one at a time.

	Blood donation	Platelet donation	
Age of donors	17+	17+	
Number of possible donations per year	2–3	8–12	
Diet before donating	normal diet	a few days of low fat food, no aspirin or	
		other 'blood-thinning drugs'	
Volume removed	470 cm³ blood	400-600 cm3 of straw coloured liquid	
Time to test blood before donation	time for confidential questionnaire plus a	often a previous blood donor; extra blood	
	few minutes for a finger-prick test to find	tests take about 8 weeks to check platelet	
	out haemoglobin levels	levels	
Usual time to donate	10 minutes to donate blood plus resting	90 minutes to donate platelets plus resting	
	time; about 1 hour in total	time; about 2 hours in total	
Time for blood to get back to normal	about 16 weeks	a few days	
Keeping time	depends on treatment - blood is separated	5 days	
	into different parts such as red cells or		
	plasma; some is frozen		
Number of people to benefit from a	blood is often split into components,	three adults or up to 12 children	
single donation	including platelets; 3-7 people may benefit	_	
Benefit to person receiving platelets	may require platelets from several donors	platelets received from one donor	

Keeping internal conditions constant

B3 3.1

Learning objectives

- What body conditions need to be controlled?
- How do you get rid of the waste products from your cells?

O links

For information on homeostasis, look back to B1 2.5 Controlling conditions.

Controlling internal conditions

For your body to work properly the conditions surrounding your millions of cells must stay as constant as possible. On the other hand, almost everything you do tends to change things. For example:

- as you move you produce energy that warms the body
- as you respire you produce waste
- when you digest food you take millions of molecules into your body.

Yet somehow you keep your internal conditions constant within a very narrow range. How do you manage this? The answer is through homeostasis. Many of the functions in your body help to keep your internal environment as constant as possible. Now you are going to find out more about some of them.

a What is homeostasis?





Figure 1 Whatever you choose to do in life, the conditions inside your body will stay more or less exactly the same

Removing waste products

No matter what you are doing, the cells of your body are constantly producing waste products. These are products of the chemical reactions that take place in the cells. The more extreme the conditions you put yourself in, the more waste products your cells make.

There are two main poisonous waste products – carbon dioxide and urea. They cause major problems for your body if their levels are allowed to build up.

Carbon dioxide

Carbon dioxide is produced during respiration. Every cell in your body respires, and so every cell produces carbon dioxide. It is vital that you remove this carbon dioxide because dissolved carbon dioxide produces an acidic solution. This would affect the working of all the enzymes in your cells.

The carbon dioxide moves out of the cells into your blood. Your bloodstream carries it back to your lungs. Almost all of the carbon dioxide is removed from your body via your lungs when you breathe out. The air you breathe in contains only 0.04% carbon dioxide. However, the air you breathe out contains about 4% carbon dioxide.

b How do you remove carbon dioxide from your body?

Examiner's tip

Don't confuse *urea* and *urine*. Urea is made in the liver; urine is produced by the kidney. Urine contains urea.



Urea

The other main waste product of your body is urea.

When you eat more protein than you need, or when body tissues are worn out, the extra protein has to be broken down. Amino acids cannot be used as fuel for your body. Your liver removes the amino group and converts it into urea.

The rest of the amino acid molecule can then be used in respiration or to make other molecules. The urea passes from the liver cells into your blood.

Urea is poisonous and if the levels build up in your blood it will cause a lot of damage. Fortunately the urea is filtered out of your blood by your kidneys. It is then passed out of your body in your urine, along with any excess water and salt.

c Where is urea made?

Maintaining body balance

Water and ions enter your body when you eat or drink. The water and ion content of your body are carefully controlled, preventing damage to your cells. Water is lost through breathing, through sweating and in urine. The ions are lost in sweat and urine.

If the concentrations of your body fluids change, water will move into or out of your cells by osmosis. This could damage or destroy the cells. You saw this when you looked at the importance of keeping hydrated when you exercise. So water balance is vital.

It is also very important to control your body temperature. If it goes too high or too low it can be fatal. Finally, it is very important to control the levels of sugar in your blood. The amount of sugar coming into your body and the energy needed by your cells are always changing and a balance must always be maintained. So homeostasis plays a very important role in your body.

Summary questions

blood carbon dioxide constant controlled environment enzymes homeostasis sugar temperature urea water

The internal of your body is kept relatively by a whole range of processes that together are known as

1 Copy and complete using the words below:

- 2 There are two main waste products that have to be removed from the human body – carbon dioxide and urea. For each waste product, describe:
 - a how it is formed
 - b why it has to be removed
 - c where it is removed from the body.
- 3 Draw a spider diagram with the word 'homeostasis' in the centre and make as many links in the diagram as you can. Label the links made.



Figure 2 The average person produces up to 900 litres of urine a year!

O links

For information on osmosis, look back to B3 1.1 Osmosis.

For information on keeping hydrated, look back to B3 1.3 The sports drink dilemma.

For information on body temperature, see B3 3.5 Controlling body temperature.

For information on controlling glucose levels, see B3 3.7 Controlling blood glucose.

- The internal conditions of your body have to be controlled to maintain a constant internal environment.
 These include your body temperature, your water and ion balance and your blood sugar levels.
- Carbon dioxide is produced during respiration and leaves the body via the lungs when you breathe out.
- Urea is produced by your liver as excess amino acids are broken down, and is removed by your kidneys in the urine.



Keeping internal conditions constant

B3 3.2

Learning objectives

- Why are your kidneys so important?
- How do your kidneys work?

?? Did you know ...?

All the blood in your body passes through your kidneys about once every 5 minutes. Your kidneys filter about 180 litres of water out of your blood during the day. About 99% of it is returned straight back into your blood. So on average you produce about 1800 ml of urine a day. Urine trickles into your bladder where it is stored. When the bladder is full you will feel the need to empty it.

AQA Examiner's tip

Remember that kidneys filter water and soluble substances then reabsorb useful substances such as sugar and ions. Large molecules such as protein cannot be filtered.

The human kidney

Your kidneys are one of the main organs that help to maintain homeostasis. They keep the conditions inside your body as constant as possible.

What are the functions of your kidney?

Your kidneys are very important in your body for homeostasis. They are involved in excretion – the removal of waste products. For example, you produce urea in your liver when you break down excess amino acids. Urea is poisonous, but your kidneys **filter** it out of your blood. Then you get rid of it in your urine, which is produced constantly by your kidneys and stored temporarily in your **bladder**.

a What is urea?

Your kidneys are also vital in the water balance of your body. You gain water when you drink and eat. You lose water constantly from your lungs. The water evaporates into the air in your lungs and is breathed out. Whenever you exercise or get hot you sweat more and lose more water.

So how do your kidneys balance all these changes? If you are short of water your kidneys conserve it. You produce very little urine and most of the water is saved for use in your body. If you drink too much water then your kidneys produce lots of urine to get rid of the excess.

The ion concentration of your body is very important. You take in mineral ions with your food. The amount you take in varies. Sometimes you take in very little.

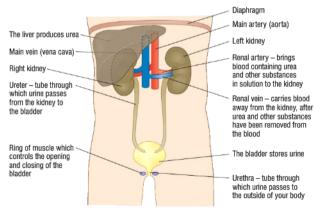


Figure 1 The kidney is a very important organ of homeostasis. It controls the balance of water and mineral ions in the body and gets rid of urea.



However, if you eat processed food which is high in salt, you take in a lot of mineral ions. Some are lost through your skin when you sweat. Again, your kidneys are most important in keeping a mineral ion balance. They remove excess mineral ions (particularly sodium and chloride ions from salt). These are passed out in the urine.

b Why do your kidneys work hard after you have eaten a lot of processed food?

How do your kidneys work?

Your kidneys filter your blood. Then they take back (reabsorb) everything your body needs. They have a rich blood supply. Sugar (glucose), amino acids, mineral ions, urea and water all move out of your blood into the kidney tubules. They move by diffusion along a concentration gradient. The blood cells and large molecules such as proteins are left behind. They are too big to pass through the membrane of the tubule.

All of the sugar is reabsorbed back into the blood by active transport. However, the amount of water and dissolved mineral ions that are reabsorbed varies. It depends on what is needed by your body. This is known as **selective reabsorption**. The amount of water reabsorbed into the blood is controlled by a very sensitive feedback mechanism.

Urea is lost in your urine. However, some of it leaves the kidney tubules and moves back into your blood. The urea moves back into the blood by diffusion along a concentration gradient.

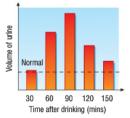
What does urine contain?

Your urine contains the waste urea along with excess mineral ions and water not needed by your body. The exact quantities vary depending on what you have taken in and given out. For example, on a hot day if you drink little and exercise a lot you will produce very little urine. This will be concentrated and relatively dark yellow. On a cool day if you drink a lot of liquid and do very little you will produce a lot of dilute, almost colourless urine.

Water, glucose, urea and salt are all colourless, but your urine is yellow. This is the result of **urobilins**, yellow pigments that come from the breakdown of haemoglobin in your liver. They are excreted by your kidneys in the urine along with everything else, making it yellow.

Summary questions

- 1 a What do the kidneys do in your body?
 - **b** How do the kidneys carry out their job?
- 2 Explain how your kidneys would maintain the water and mineral balance of your blood on:
 - a a cool day when you stayed inside and drank lots of cups of tea
 - b a hot sports day when you ran three races and had forgotten your drink bottle.



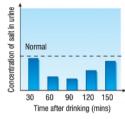


Figure 2 These data show how your kidneys respond when you drink a lot. They show the volume of urine produced and the concentration of salt in the urine after a student drank a large volume of water.

- The kidneys are important for exretion and homeostasis.
- A healthy kidney produces urine by filtering the blood. It then reabsorbs all of the sugar, plus any mineral ions and water needed by your body.
- Excess mineral ions and water, along with urea, are removed in the urine.



Keeping internal conditions constant

B3 3.3

Learning objectives

- What is dialysis and why is it needed?
- How does dialysis work?



Figure 1 A dialysis machine. These 'artificial kidneys' not only save lots of lives, but allow sufferers from kidney failure to lead relatively full, active lives

Dialysis – an artificial kidney 🗈

Your kidneys can be damaged and destroyed by infections. Some people have a genetic problem that means their kidneys fail. In others, the kidneys are damaged during an accident. Whatever the cause, untreated failure of both your kidneys can lead to death. Toxins, such as urea, build up in the body, and the salt and water balance of your body is upset.

Dialysis

For centuries kidney failure meant certain death, but we now have two effective methods of treating this problem:

- We can carry out the function of the kidney artificially using dialysis.
- We can replace the failed kidneys with a healthy one in a kidney transplant.
 - a Why is kidney failure such a threat to life?

The machine that carries out the functions of the kidney is known as a **dialysis** machine. It relies on the process of dialysis to clean the blood. In a dialysis machine a person's blood leaves their body and flows between partially permeable membranes. On the other side of these membranes is the dialysis fluid. The dialysis fluid contains the same concentration of useful substances as the blood.

If your kidneys don't work, the concentrations of urea and mineral ions build up in the blood. Treatment by dialysis restores the concentrations of these dissolved substances to normal levels. Then as you carry on with normal life, urea and other substances build up again. So dialysis has to be repeated at regular intervals.

It takes around eight hours for dialysis to be complete. So people with kidney failure have to remain attached to a dialysis machine for hours several times a week. They also have to manage their diets carefully. This helps keep their blood chemistry as stable as possible so that they can lead a normal life between sessions.

b What process does dialysis depend on?

How dialysis works

During dialysis, it is vital that patients lose the excess urea and mineral ions that have built up in the blood. It is equally important that they do not lose useful substances from their blood. These include glucose and useful mineral ions.

The loss of these substances is prevented by the careful control of the dialysis fluid. The dialysis fluid contains the same concentration of glucose and mineral ions as the blood. So there is *no net* movement of glucose and useful mineral ions out of the blood. This makes sure that glucose and useful mineral ions are not lost. Because the dialysis fluid contains normal plasma levels of mineral ions, any excess ions are removed from the blood. The excess ions move out by diffusion along a concentration gradient.



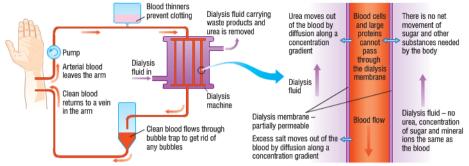


Figure 2 A dialysis machine relies on simple diffusion to clean the blood, removing the waste products which would damage the body as they build up

In contrast, the dialysis fluid contains no urea. This makes a steep concentration gradient from the blood to the fluid. So, much of the urea leaves the blood. The whole process of dialysis depends on diffusion along concentration gradients, which have to be maintained by the flow of fluid. There is no active transport.

Many people go to hospital to receive dialysis. However, in 1964 home dialysis machines were made available for the first time. They are big and expensive but at least some people can have dialysis at home. Even with all our modern technology, dialysis machines are still quite large. They are certainly much bigger than the kidneys they replace! There is even a form of dialysis which takes place inside the body cavity!

Dialysis has some disadvantages. You have to follow a very carefully controlled diet. You also have to spend regular, long sessions connected to a dialysis machine. Over many years, the balance of substances in the blood can become more difficult to control, no matter how careful the dialysis. Even so, for many people with kidney failure, dialysis keeps them alive. Fortunately, in dialysis we have successfully copied the action of the kidney in the body.

Summary questions

- 1 Produce a flowchart to explain how a dialysis machine works.
- 2 a Why do people with kidney failure have to control their intake of protein and salt?
 - b Why can patients with kidney failure eat and drink what they like during the first few hours of dialysis?
- 3 a Explain the importance of dialysis fluid containing no urea and normal plasma levels of salt, glucose and minerals.
 - b Both blood and dialysis fluid are constantly circulated through the dialysis machine. Explain why the constant circulation of dialysis fluid is so important.

AQA Examiner's tip

Look at as many different examples of dialysis diagrams as you can. Identify the membrane. Be clear about what diffuses through the membrane. What is in the dialysis fluid?

- People suffering from kidney failure may be treated by regular sessions on a kidney dialysis machine or by having a kidney transplant.
- In a dialysis machine, the concentration of dissolved substances in the blood is restored to normal levels.
- The levels of useful substances in the blood are maintained, while urea and excess mineral ions pass out from the blood into the dialysis fluid.



Keeping internal conditions constant

B3 3.4

Learning objectives

- What is a kidney transplant?
- How can we stop the body rejecting a transplanted kidney?

O links

For information on antigens, look back to B1 1.9 Immunity.

Diseased kidneys can be replaced in a kidney transplant using a single healthy kidney from a donor. The donor kidney is joined to the blood vessels in the groin of the patient (the recipient). If all goes well, it will function normally to clean and balance the blood. One kidney can balance your blood chemistry and remove your waste urea for a lifetime.

The rejection problem

The main problem with transplanting a kidney is that the new kidney comes from a different person. The antigens (proteins on the cell surface) of the donor organ will be different to those of the recipient (person who needs the new kidney). There is a risk that the antibodies of the immune system of the recipient will attack the antigens on the donor organ. This results in rejection and destruction of the donated kidney.

a There is one situation where there is no risk of a new kidney being rejected. What do you think that might be?

There are a number of ways of reducing the risk of rejection. The match between the antigens of the donor and the recipient is made as close as possible. For example, we can use a donor kidney with a 'tissue type' very similar to the recipient (from people with the same blood group).

The recipient is given drugs to suppress their immune response (immunosuppressant drugs) for the rest of their lives. This helps to prevent the rejection of their new organ. Immunosuppressant drugs are improving all the time. Nowadays the need for a really close tissue match is getting less important.

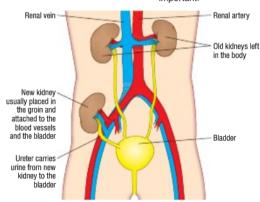


Figure 1 A donor kidney takes over the functions of failed kidneys, which are usually left in place

The disadvantage of taking immunosuppressant drugs is that they prevent the patients from dealing effectively with infectious diseases. They have to take great care if they become ill in any way. However, most people feel this is a small price to pay for a new, working kidney.

Transplanted organs don't last forever. The average transplanted kidney works for around 9 years although some last much longer. Once the organ starts to fail the patient has to return to dialysis. Then they have to wait until another suitable kidney is found.





How Science Works

Dialysis v. transplants

The great advantage of receiving a kidney transplant is that you are free from the restrictions which come with regular dialysis sessions. You can also eat what you want. An almost completely normal life is the dream of everyone waiting for a kidney transplant.

The disadvantages are mainly to do with the risk of rejection. You have to take medicine every day of your life in case the kidney is rejected. You also need regular check-ups to see if your body has started to reject the new organ. However, the biggest disadvantage is that you may never get the chance of a transplant at all.

Dialysis is much more readily available than donor organs, so it is there whenever kidneys fail. It enables you to lead a relatively normal life. However, you are tied to a special diet and regular sessions on the machine. Long term dialysis is much more expensive than a transplant.

Finding the donors

The main source of kidneys is from people who die suddenly. The deaths are often from road accidents or from strokes and heart attacks. In the UK, organs can be taken from people if they carry an organ donor card or are on the online donor register. Alternatively, a relative of someone who has died suddenly can give their consent.

There are never enough donor kidneys to go around. Many of us do not register as donors. What's more, as cars become safer, fewer people die in traffic accidents. This is very good news, but it means there are fewer potential donors. At any one time there are thousands of people having kidney dialysis. Most would love to have a kidney transplant but never get the opportunity. In 2008–9, 2497 people in the UK had kidney transplants. However, by the end of 2009 there were still almost 7000 people on dialysis waiting for a kidney.

Some scientists are working on **xenotransplantation**, producing genetically engineered pigs with organs that could be used for human transplants. Other scientists hope that stem cell research will produce a way of growing new kidneys on demand, so no one dies waiting for a suitable organ to become available.



Figure 2 This young woman has been given a new lease of life by a kidney transplant. A lack of donors means not everyone who suffers from kidney failure is so lucky. For more information on kidney treatment, see B3 3.6 Treatment and temperature issues.

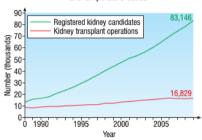


Figure 3 This graph shows how the gap between people needing a kidney and available organs is getting bigger in the US. The same pattern is seen in most other countries, including the UK.

O links

For information on stem cell research, look back to B2 5.3 Stem cells.

Summary questions

- 1 How does someone with a kidney transplant overcome the problems of kidney failure?
- 2 Sometimes a live donor usually a close family member will donate a kidney. These transplants have a higher rate of success than normal transplants from dead, unrelated donors.
 - a Suggest two reasons why live transplants from a close family member have a higher success rate than normal transplants.
 - **b** Why do you think that live donor transplants are relatively rare?
- 3 Produce a table to compare the advantages and disadvantages of treating kidney failure with dialysis or with a kidney transplant. Which treatment do you think is preferable and why?

- In a kidney transplant, diseased or damaged kidneys are replaced with a healthy kidney from a donor.
- To try and prevent rejection of the donor kidney, the tissue types of the donor and the recipient are matched as closely as possible. Immunosuppressant drugs are also used.



Controlling body temperature

Learning objectives

- How does your body monitor its temperature?
- How does your body stop you getting too hot?
- How does your body keep you warm?





Figure 1 People in different parts of the world live in conditions of extreme heat and extreme cold and still maintain a constant internal body temperature

\QA Examiner's tip

Remember that the thermoregulatory centre is in the brain and it monitors the temperature of the blood.

Wherever you go and whatever you do, your body temperature needs to stay around 37 °C. This is the temperature at which your enzymes work best. Your skin temperature can vary enormously without problems. It is the temperature deep inside your body, known as the **core body temperature**, which must be kept stable.

At only a few degrees above or below normal body temperature your enzymes don't function properly. All sorts of things can affect your internal body temperature, including:

- energy produced in your muscles during exercise
- · fevers caused by disease
- the external temperature rising or falling.

Basic temperature control

You can change your clothing, light a fire, and turn on the heating or airconditioning to help control your body temperature. However, it is your internal control mechanisms that are most important.

a Why is control of your body temperature so important?

Control of your core body temperature relies on the **thermoregulatory centre** in your brain. This centre contains receptors that are sensitive to temperature changes. They monitor the temperature of the blood flowing through the brain itself

Extra information comes from the temperature receptors in the skin. These send impulses to the thermoregulatory centre, giving information about the skin temperature. The receptors are so sensitive they can detect a difference in temperature of as little as 0.5 °Cl

If your temperature starts to go up, your sweat glands release more sweat, which cools the body down. Sweating also makes you lose water and mineral ions. Therefore you need to take in more drink to replace the water and ions you have lost.

Your skin also looks redder as more blood flows through it, cooling you down. If your temperature starts to go down you will look pale as less blood flows through your skin. This means you lose less energy.

Cooling the body down

If you get too hot, your enzymes denature and can no longer catalyse the reactions in your cells. When your core body temperature begins to rise, impulses are sent from the thermoregulatory centre to the body so more energy is released:

- The blood vessels that supply your skin capillaries dilate (open wider). This
 lets more blood flow through the capillaries. Your skin flushes, so you lose
 more energy by radiation.
- Your rate of sweating goes up. This extra sweat cools your body down as it evaporates. In humid weather when the sweat does not evaporate it is much harder to keep cool.



Reducing energy loss

It is just as dangerous for your core temperature to drop as it is for it to rise. If you get very cold, the rate of the enzyme-controlled reactions in your cells falls too low. You don't release enough energy and your cells begin to die. If your core body temperature starts to fall, impulses are sent from your thermoregulatory centre to the body to conserve and even release more energy:

- The blood vessels that supply your skin capillaries constrict (close up) to reduce the flow of blood through the capillaries. This reduces the energy released by radiation through the surface of the skin.
- Sweat production is reduced. Less sweat evaporates so less energy is released.
- You may shiver your muscles contract and relax rapidly. These muscle contractions need lots of respiration, which releases more energy. This raises your body temperature. As you warm up, the shivering stops.
 - b Why is a fall in your core body temperature so dangerous?

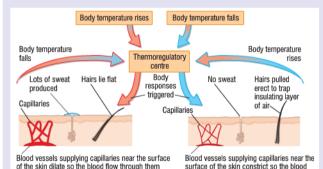


Figure 2 Changes in your core body temperature set off automatic responses to oppose the changes and maintain a steady internal environment

flow through the capillaries decreases

Summary questions

1 Copy and complete using the words below:

increases and more energy is lost to the environment

- 2 a Why is it so important to maintain a body temperature of about 37 °C?
 - b Explain the role of:
 - i the thermoregulatory centre in the brain, and
 - ii the temperature sensors in the skin in maintaining a constant core body temperature.
- 3 Explain how the body responds to both an increase and a decrease in core temperature to return its temperature to normal levels.
 [H]



Practical

Body temperature

Use a temperature sensor and datalogger to record your skin and core body temperature on one hand as you plunge the other into icv water.

Explain your observations.



Figure 3 A student using a temperature sensor and data logger

Key points

- Your body temperature is monitored and controlled by the thermoregulatory centre in your brain.
- Your body temperature must be kept at the level at which enzymes work best.
- Your body responds to cool you down or warm you up if your core body temperature changes.
- The blood vessels that supply the capillaries in the skin dilate and constrict to control the blood flow to the surface.
- Energy is released through the evaporation of sweat from the surface of the skin to cool the body down.
- Shivering involves contraction of the muscles that produces energy from respiration to warm the body.

ш





B3 3.6

Treatment and temperature issues

Learning objectives

- What are the advantages of a kidney transplant over dialysis?
- What happens when your body gets too cold - or too hot? THI

Treating kidney failure

Many different issues are linked to the treatment of kidney failure, particularly to kidney transplants. Some of these issues are explored here:

- In some developing countries people will sell one of their kidneys. They need the money to pay for food, medicine or education for their families. In the United States they are very short of organ donors. It is being suggested that people could be paid to go on the organ donor register. Some families become increasingly desperate when they see a much loved child, partner or parent struggling with kidney failure. They may even be prepared to buy a kidney, though it is illegal.
- Many families who lose a loved one give their consent for organ donation. Knowing that their loss has given other people a chance of life is a real comfort at a terrible time.
- Both transplants and dialysis cost a lot of money. In the UK, 3% of the whole NHS budget is spent on dealing with kidney failure. The average cost of dialysis for one patient for one year is £30800. The cost of a kidney transplant is around £17000, and the immunosuppressant drugs then cost about £5000 a year for each patient.

There are over 23000 people in the UK who have had kidney transplants. This has given them a much improved quality of life. It also saves the NHS over £512 million each year compared to keeping the patients on dialysis. Yet in 2008-9 only 2497 kidney transplants were carried out, leaving 6920 patients waiting for a new kidney at the end of the year.

Activity 1



Figure 1 It takes very little time to fill in a donor card - yet it could save several lives

At the moment in the UK you have to sign up to be an organ donor. Many people don't, even though every new driver has the chance to do so when they get their first driver's licence. Often people can't be bothered - or they don't like to think about dying.

In some countries everyone is automatically an organ donor unless they opt out. This provides many more organs for transplantation. Some people are suggesting this method should be used in the UK. What do you think - should things stay as they are or should they change?

Write a brief paragraph explaining your personal point of view. Then design a poster, leaflet or webpage supporting kidney transplants and encouraging people to sign up as donors. Decide whether your target audience is young people or adults and design your resource to appeal to them.

B3 3.7

Controlling blood glucose

Learning objectives

- How is your blood glucose level controlled?
- What is type 1 diabetes and how is it treated?

()A/Examiner's tip

Make sure you understand the difference between:

- glucose a sugar found in the blood
- glycogen a storage carbohydrate found in the liver and muscles
- glucagon a hormone. [H] Take care with the different spellings - errors often lead to marks being lost in exams.

O links

250

For information on glycogen, look back to B2 4.2 The effect of exercise on the body.

Night-time

It is very important that your cells have a constant supply of the glucose they need for respiration. You have a system in your body that controls your blood sugar levels to within very narrow limits.

a Why are the levels of glucose in your blood so important?

Insulin and the control of blood glucose levels

When you digest a meal, large amounts of glucose pass into your blood. Without a control mechanism your blood glucose levels would vary significantly. They would range from very high after a meal to very low several hours later - so low that cells would not have enough glucose to respire.

This situation is prevented by your pancreas. The pancreas is a small pink organ found under your stomach. It constantly monitors and controls your blood alucose concentration using two hormones. The best known of these is insulin.

When your blood glucose concentration rises after you have eaten a meal. insulin is released. Insulin allows glucose to move from the blood into your cells where it is used. Soluble glucose is also converted to an insoluble carbohydrate called glycogen. Insulin controls the storage of glycogen in your liver. This glycogen can be converted back into glucose when it is needed. Your blood glucose stays stable within a narrow range of concentrations.

b Name one hormone involved in the control of your blood sugar levels.

Glucose levels mmol/1 200 150 100 50 0 Breakfast Lunch Supper 8 nsulin levels pmol/1

Figure 1 Insulin is secreted from the pancreas after meals to keep your lood glucose stable within narrow limits

Blood glucose Natural insulin secretion

Normal (non-diabetic) blood glucose and insulin levels over 24 hours

What causes diabetes?

If your pancreas does not make enough (or any) insulin, your blood sugar concentration is not controlled. You have type 1 diabetes.

Without insulin your blood glucose levels get very high after you eat. Eventually your kidneys excrete glucose in your urine. You produce lots of urine and feel thirsty all the time. Without insulin, glucose cannot get into the cells of your body, so you lack energy and feel tired. You break down fat and protein to use as fuel instead, so you lose weight. Type 1 diabetes usually starts in young children and teenagers.

Before there was any treatment for diabetes, people would waste away. Eventually they would fall into a coma and die. Fortunately there are now some very effective ways of treating diabetes.

c Why do people with untreated diabetes feel very tired and lack energy?

Too cold or too hot!

If your core body temperature falls below 35 °C you are suffering from **hypothermia** and the normal working of your body is affected. Old people, very young children and people exposed to bad weather conditions are most at risk.

The first signs of hypothermia are extreme tiredness and not wanting to move. You may not even realise how cold you are. Your skin feels cold to the touch and your face goes greyishblue and puffy, with blue lips. You become drowsy and your speech becomes slurred. Eventually you actually stop shivering as your enzymes stop working. If your body temperature becomes too low you will become unconscious and may die.

About 30000 people die of hypothermia every year in the UK alone, mainly during the winter months. This contributes to what is known as the excess winter mortality (EWM).



Figure 2 Most people who die of hypothermia are elderly. Even if you are fit and active, you are more vulnerable to the cold as you get older.

Excess heat is also bad for people. Heat stroke happens when your body gets too hot. The most common cause is very hot, humid weather, often combined with exercise. Exercise releases energy. When it is very hot and humid, your sweat cannot evaporate to cool you down. If you don't drink enough in very hot weather you can't make sweat so you can't lose energy. Your body temperature keeps going up. You stop sweating and your skin is red and flushed. You can become confused, see things that aren't there (hallucinations) and eventually go into a coma and die. The very old and the very young are at risk – and so are fit, active young people.

Activity 2

Climate change may well result in colder winters and hotter summers. Write an article for the lifestyle pages of a newspaper/news website on:

- how your body normally copes with changes in temperature
- the dangers to health of hot summers and cold winters
- the best ways to avoid any problems for you and your family.

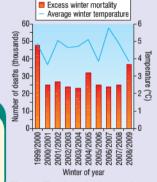


Figure 3 The relationship between the excess winter mortality and the average winter temperature is not straightforward

Summary questions

- 1 Calculate the difference in cost between a patient with kidney failure who has 10 years of dialysis compared to a patient who has a kidney transplant followed by treatment with immunosuppressant drugs for 10 years.
- 2 Look at Figure 3.
 - a Give an example of a year that supports the idea that a high death rate is linked to low average winter temperatures.

 [H]
 - b Give an example of a year that does not support that hypothesis and explain why.
 [H]
 - c Put forward a hypothesis (theory) that would explain years when the excess winter mortality is high even though average temperatures are high as well.
 [H]

- A kidney transplant allows someone to live a normal life apart from taking immunosupressant drugs.
 It costs less than dialysis in the long term.
- Control of the body temperature in different conditions involves several different processes which cannot always cope in extreme conditions.



Treating diabetes

If you have type 1 diabetes you need replacement insulin before meals. Insulin is a protein, which would be digested in your stomach. So it is usually given as an injection to get it into your blood.

This injected insulin allows glucose to be taken into your body cells and converted into glycogen in the liver. This stops the concentration of glucose in your blood from getting too high. Then, as the blood glucose levels fall, the glycogen is converted back to glucose. As a result your blood glucose levels are kept as stable as possible.

If you have type 1 diabetes you also need to be careful about the levels of carbohydrate you eat. You need to have regular meals. Like everyone else, you need to exercise to keep your heart and blood vessels healthy. This needs careful planning to keep your blood sugar levels steady and your cells supplied with glucose.

Insulin injections treat diabetes successfully but they do not cure it. Until a cure is developed, someone with type 1 diabetes has to inject insulin every day of their life.

Glucagon and control of blood glucose levels

The control of blood sugar doesn't just involve insulin. When your blood glucose concentration falls below the ideal range, the pancreas secretes **glucagon**. Glucagon makes your liver break down glycogen, converting it back into glucose. In this way the stored sugar is released back into the blood.

By using two hormones and the glycogen store in your liver, your pancreas keeps your blood glucose concentration fairly constant.

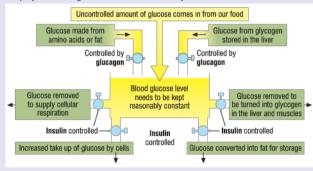


Figure 3 This model of your blood glucose control system shows the blood glucose as a tank. It has both controlled and uncontrolled inlets and outlets. In every case the control is given by the hormones insulin and glucagon.

Summary questions

- 1 Define the following words: hormone, insulin, diabetes, glycogen.
- 2 a Explain how your pancreas keeps the blood glucose levels of your body constant.
 - **b** Why is it so important to control the level of glucose in your blood?
- 3 What is type 1 diabetes and how can it be treated?



Figure 2 The treatment of type 1 diabetes involves regular blood sugar tests and insulin injections

AQA Examiner's tip

The pancreas produces two hormones:

- Insulin reduces blood glucose concentration.
- Glucagon increases blood glucose concentration. [H]

- Your blood glucose concentration is monitored and controlled by your pancreas.
- The pancreas produces the hormone insulin, which allows glucose to move from the blood into the cells.
- In type 1 diabetes, the blood glucose may rise to fatally high levels because the pancreas does not secrete enough insulin. It can be treated by injections of insulin before meals.
- Glucagon allows glycogen to be converted back into glucose and released into the blood.





B3 3.8

Learning objectives

- How has the treatment of diabetes developed over the years?
- How is type 2 diabetes treated?



Figure 1 Treatments like this human insulin allow a person to manage type 1 diabetes and live with it but they do not cure the condition

Treating diabetes

The treatment of diabetes has changed a great deal over the years.

Using insulin from other organisms

In the early 1920s Frederick Banting and Charles Best made some dogs diabetic by removing their pancreases. Then they gave them extracts of pancreas taken from other dogs. We now know these extracts contained insulin. Banting and Best realised that extracts of animal pancreas could keep people with diabetes alive. Many dogs died in the search for a successful treatment. However, the lives of millions of people have been saved over the years.

For years, insulin from pigs and cows was used to treat affected people although there were problems. Animal insulin is not identical to human insulin and the supply depended on how many animals were killed for meat. So sometimes there was not enough insulin to go round.

In recent years genetic engineering has been used to develop bacteria that can produce pure human insulin. This is genetically identical to natural human insulin and the supply is constant. This is now used by most people with type 1 diabetes. However, some people do not think this type of interference with genetic material is ethical.

Curing type 1 diabetes

Scientists and doctors want to find a treatment that means people with diabetes never have to take insulin again. However, so far none of them is widely available.

- Doctors can transplant a pancreas successfully. However, the operations
 are quite difficult and rather risky. These transplants are still only carried out
 on a few hundred people each year in the UK. There are 250000 people
 in the UK with type 1 diabetes and there are simply not enough donors
 available. What's more, the patient exchanges one sort of medicine (insulin)
 for another (immunosuppressants).
- Transplanting the pancreatic cells that make insulin from both dead and living donors has been tried, with very limited success so far.

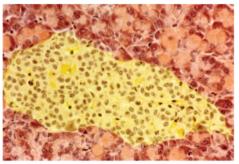


Figure 2 Part of the pancreas. The tissue stained red makes digestive enzymes while the central yellow area contains the cells that make insulin.



In 2005, scientists produced insulin-secreting cells from embryonic stem cells and used them to cure diabetes in mice. In 2008, UK scientists discovered a completely new technique. Using genetic engineering they turned mouse pancreas cells, which normally make enzymes, into insulin-producing cells. Other groups are using adult stem cells from diabetic patients.

Scientists hope that eventually they will be able to genetically engineer human pancreatic cells so they work properly. Then they will be able to return them to the patient with no rejection issues. It still seems likely that the easiest cure will be to use stem cells from human embryos that have been specially created for the process. But, for some people, this is not ethically acceptable.

Much more research is needed. However, scientists hope that before too long type 1 diabetes will be an illness we can cure rather than simply treat and manage.

Treating type 2 diabetes

Type 2 diabetes is another, more common type of diabetes that is often a result of obesity, lack of exercise or both. In this type of diabetes the pancreas still makes insulin, although it may make less. Most importantly, your cells stop responding to insulin properly.

If you develop type 2 diabetes you can often deal with it without needing to inject insulin. Many people can restore their normal blood glucose balance by taking three simple steps:

- eating a balanced diet with carefully controlled amounts of carbohydrates
- losing weight
- doing regular exercise.

If this doesn't work there are drugs that:

- help insulin work better on the body cells
- help your pancreas make more insulin
- reduce the amount of glucose you absorb from your gut.

Only if none of these treatment options work will you end up having insulin injections. This sort of diabetes usually affects older people. However, it is becoming more and more common in young people.

Summary questions

- 2 a Compare modern insulin treatment with the original insulin used to treat diabetics and evaluate the two treatments.
 - b Transplanting a pancreas to replace natural insulin production seems to be the ideal treatment for type 1 diabetes. Compare this treatment with insulin injections and explain why it is not more widely used.



For information on embryonic stem cells, look back to B2 5.3 Stem cells.



Figure 3 Losing weight and taking exercise, like these young people, seem simple ways to overcome type 2 diabetes. However, some people object to being given this advice and ignore it until they need medication to control the diabetes.

O links

For information on type 2 diabetes, look back to B1 1.2 Weight problems.

Activity

Much of the research into treatments for diabetes, both past and present, have involved ethical issues. Evaluate the main ethical issues associated with each of the treatment methods described in this spread.

- A variety of different methods are being used or developed to treat diabetes using genetic engineering and stem cell techniques.
- Type 2 diabetes is treated by careful attention to diet and taking more exercise alone. If this doesn't work, drugs may be needed.



Keeping internal conditions constant: B3 3.1-B3 3.8

Summary questions (1)

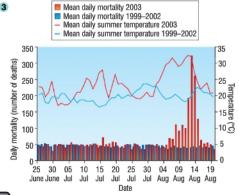


- 1 a Draw and annotate a diagram explaining the basic principles of homeostasis.
 - b Write a paragraph explaining why control of the conditions inside your body is so important.
- A patient with kidney failure has dialysis three times a week. Every month the blood is checked to ensure that the machine is working properly. The blood is tested for its urea content (URR test), which should be above 64%. Also the amount of blood being filtered compared with the amount of fluid in the body (Kt/V test) should be more than 1.1.

Look at this chart and answer the questions below.

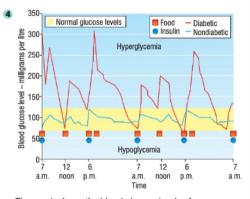
Test	Target	Jan	Feb	Mar	April	May	June	July	Aug
Kt/V	≥1.2	1.1	1.15	1.2	1.23	1.24	1.2	1.2	1.2
URR	≥65	60	62	64	65	66	65	65	65

- a What was the range for the Kt/V test?
- b What was the pattern for the Kt/V test?
- c How do the Kt/V test results compare to those for the URR test?
- d Can you say that there is a causal link between the two sets of test results?
- e For how many months were both tests satisfactory?
- f Urologists say that the two tests really measure the same thing. Why then is it a good idea to do both tests?
- What are the economic issues related to kidney
- h What are the social issues related to kidney dialysis?



In August 2003 a heat wave hit Europe. The graph shows the effect it had on the number of deaths in Paris.

- a What effect did the Paris heat wave have on deaths in the city?
- **b** From the data, what temperature begins to have an effect on the death rate?
- c Explain why more people die when conditions are very hot.



The graph shows the blood glucose levels of a nondiabetic person and someone with type 1 diabetes managed with regular insulin injections. They both eat at the same times. Use this graph to help you answer the questions below:

- a What happens to the blood glucose levels in both individuals after eating?
- b What is the range of blood glucose concentration of the normal subject?
- c What is the range of blood glucose concentration of the person with diabetes?
- d The graph shows the effect of regular insulin injections on the blood glucose level of someone with diabetes. Why are the insulin injections so important to their health and wellbeing? What does this data suggest are the limitations of insulin injections?
- e People with diabetes have to monitor the amount of carbohydrate in their diet. Explain why.

AQA Examination-style questions 🕟

a The human body must keep internal conditions
 constant

List A shows some conditions.

List B shows some monitoring or control centres.

Match each condition with its correct monitoring or control centre.

List A			
blood glucose level			
body temperature			
blood water content			

List B
kidneys
pancreas
thermoregulatory centre
skin

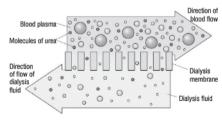
b Choose the correct words from the list below to complete the sentence.

2 a Which two of the following substances are found in the urine of a healthy person?

glucose mineral ions proteins water (2)

b A person with kidney disease can be treated by dialysis.

The diagram shows how dialysis works. The circles represent molecules of different substances.



Choose the correct word or phrase to complete each sentence.

iv	 To allow the movement of urea, the dialysis membrane is		
	impermeable partially permeable thick		
v	The urea can pass through the membrane becauthe urea molecules are	se (1)	
	large round small		

c For most patients, a kidney transplant is better than continued dialysis treatment.

drug treatment is needed to suppress the immune system

hospital visits are needed three times a week yearly costs are higher than for dialysis

AQA, 2002

When a person has a kidney transplant, the donor kidney must be matched to their tissue type.

Choose the correct words from the list below to complete the sentences.

antibodies antiseptics aspirin immunosuppressants protein urea

On the surface of the kidney cells are antigens.

Antigens are made of

The antigens may be attacked by the person's

When a person gets too cold, the organs cannot function properly. Below 35 °C the person could die. Alcohol causes blood vessels to stay dilated.

A person found collapsed on a cold mountain should not be given an alcoholic drink. Explain why.

[H] (4)

In this question you will be assessed on using good English, organising information clearly and using specialist terms where appropriate.

A person with type 1 diabetes cannot produce enough of the hormone insulin.

Some diabetics use an insulin pump that is attached to the body. They can increase or decrease the amount of insulin which is injected, depending on their lifestyle.

Describe how insulin controls blood glucose levels and explain why a diabetic may need to change their insulin levels at certain times.

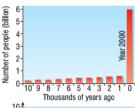
B3 4.1

Learning objective

 What effect is the growth in human population having on the Earth and its resources?



Figure 1 The Earth – as the human population grows, our impact on the planet gets bigger every day



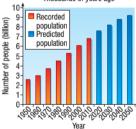


Figure 2 This record of human population growth shows the massive increase during the past 60 years – and predicts more to come

Did you know ...?

Current UN predictions suggest that the world population will soar to 244 billion by 2150 and 134 trillion by 2300!

How humans can affect the environment

The effects of the population explosion

Humans have been on Earth for less than a million years. Yet our activity has changed the balance of nature on the planet enormously. Several of the changes we have made seem to be driving many other species to extinction. Some people worry that we may even be threatening our own survival.

Human population growth

For many thousands of years people lived on the Earth in quite small numbers. There were only a few hundred million of us. We were scattered all over the world, and the effects of our activity were usually small and local. Any changes could easily be absorbed by the environment where we lived.

However, in the past 200 years or so the human population has grown very quickly. By 2010 the human population was almost 7 billion people, and it is still growing.

If the population of any other species of animal or plant suddenly increased like this, nature would tend to restore the balance. Predators, lack of food, build-up of waste products or diseases would reduce the population again. But we have discovered how to grow more food than we could ever gather from the wild. We can cure or prevent many killer diseases. We have no natural predators. This helps to explain why the human population has grown so fast.

In many parts of the world our standard of living has also improved enormously. In the UK, we use vast amounts of electricity and fuel to provide energy for our homes and places of work. We use fossil fuels like oil to produce this electricity. We also use oil and oil-based fuels to move about in cars, planes, trains and boats at high speed and to make materials like plastics. We have more than enough to eat and if we are ill we can often be made better.

a Approximately how many people were living on the Earth in 2010?

The effect on land and resources

The increase in the numbers of people has had a big effect on our environment. All these billions of people need land to live on. More and more land is used for the building of houses, shops, industrial sites and roads. Some of these building projects destroy the habitats of other living organisms.

We use billions of acres of land around the world for farming. Wherever people farm, the natural animal and plant populations are destroyed.

In quarrying, we dig up great areas of land for the resources it holds, such as rocks and metal ores. This also reduces the land available for other organisms.

b How do people reduce the amount of land available for other animals and plants?

The huge human population drains the resources of the Earth. Raw materials are rapidly being used up. This includes **non-renewable** energy resources such as oil and natural gas. Also, once metal ores are processed they cannot be replaced.



Managing waste

The growing human population also means vastly increased amounts of waste. This includes human bodily waste and the rubbish from packaging, uneaten food and disposable goods. The dumping of this waste is another way in which we reduce the amount of land available for any other life apart from scavengers.

There has also been an increase in manufacturing and industry to produce the goods we want. This in turn has led to **industrial waste**.

The waste we produce presents us with some very difficult problems. If it is not handled properly it can cause serious pollution. Our water may be polluted by **sewage**, by fertilisers from farms and by toxic chemicals from industry. The air we breathe may be polluted with smoke and poisonous gases such as sulfur dioxide.

The land itself can be polluted with toxic chemicals from farming such as pesticides and herbicides. It can also be contaminated with industrial waste, such as heavy metals. These chemicals in turn can be washed from the land into waterways.



Figure 3 In the UK alone hundreds of thousands of new houses and miles of new road systems are continuously being built. Every time we clear land like this, the homes of countless animals and plants are destroyed.

If our ever-growing population continues to affect the **ecology** of the Earth, everyone will pay the price.

- c What substances commonly pollute:
 - i water
 - ii air
 - iii land?

AQA Examiner's tip

Look for examples in the media of how humans pollute the environment and methods of controlling the pollution. These can be useful to refer to in your examination.

Summary questions

1	Copy and	complete	these	sentences	using the wo	rds below:
	diseases	farming	food	increase	population	predators
	treat 200	0				

- 2 a List examples of how the standard of living has increased over the past 100 years?
 - b Give three examples of resources that humans are using up.
- 3 Write a paragraph clearly explaining how the ever-increasing human population causes pollution in a number of different ways.

- The human population is growing rapidly and the standard of living is increasing.
- More waste is being produced. If it is not handled properly it can pollute the water, the air and the land.
- The activities of humans reduce the amount of land available for other animals and plants.
- Raw materials, including nonrenewable resources, are being used up rapidly.



B3 4.2

Learning objectives

- How do people pollute the land?
- How do people pollute the water?

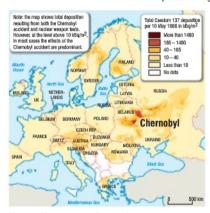


Figure 1 The accident at Chemobyl nuclear power plant polluted the land a long way away



Figure 2 Welsh sheep

Land and water pollution

As the human population grows, more waste is produced. If it is not handled carefully, it may pollute the land, the water or the air.

Polluting the land

People pollute the land in many different ways. The more people there are, the more bodily waste and waste water from our homes (sewage) is produced. If the human waste is not treated properly, the soil becomes polluted with unpleasant chemicals and gut parasites. In the developed world people produce huge amounts of household waste and hazardous (dangerous)

industrial waste. The household waste goes into landfill sites, which take up a lot of room and destroy natural habitats. Toxic chemicals also spread from the waste into the soil.

Toxic chemicals are also a problem in industrial waste. They can poison the soil for miles around. For example, after the Chernobyl nuclear accident in 1986 the soil was contaminated thousands of miles away from the original accident. Almost 30 years on, sheep from some farms in North Wales still cannot be sold for food because the radioactivity levels are too high.

a What is human bodily waste mixed with waste water known as?

Land can also be polluted as a side effect of farming. Weeds compete with crop plants for light, water and mineral ions. Animal and fungal pests attack crops and eat them. Farmers increasingly use chemicals to protect their crops. Weedkillers (or herbicides) kill weeds but leave the crop unharmed. Pesticides kill the insects that might otherwise attack and

destroy the crop. The problem is that these chemicals are poisons. When they are sprayed onto crops they also get into the soil. From there they can be washed out into streams and rivers (see next page). They can also become part of food chains. The toxins get into organisms that feed on the plants or live in the soil. This can lead to dangerous levels of poisons building up in the top predators (see Figure 3).

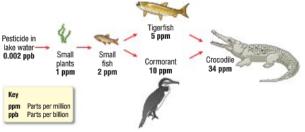


Figure 3 The feeding relationships between different organisms can lead to dangerous levels of toxins building up in the top predators



Polluting the water

A growing human population means a growing need for food. Farmers add fertilisers to the soil to make sure it stays **fertile** year after year. The minerals in these fertilisers, particularly the nitrates, are easily washed from the soil into local streams, ponds and rivers. Untreated sewage that is washed into waterways or pumped out into the sea also causes high levels of nitrates in the water.

The nitrates and other minerals fertilise the water plants, which grow rapidly. Some plants die naturally. Others die because there is so much competition for light. There is a big increase in microorganisms feeding on the dead plants. These microorganisms use up a lot of oxygen. This increase in decomposers leads to a fall in oxygen levels dissolved in the water. This means there isn't enough oxygen to support some of the fish and other animals living in it. They die – and are decomposed by yet more microorganisms. This uses up even more oxygen.

Eventually, the oxygen levels in the water fall so low that all aquatic animals die, and the pond or stream becomes 'dead'. This is called **eutrophication**.

b Name a mineral in fertilisers and sewage that causes eutrophication.

Toxic chemicals such as pesticides and herbicides or poisonous chemicals from landfill sites can also be washed into waterways. These chemicals can have the same effect on aquatic food webs as they do to life on land. The largest carnivorous fish die or fail to breed because of the build up of toxic chemicals in their bodies.

In many countries, including the UK, there are now strict controls on the use of chemicals on farms. The same applies to the treatment of sewage and to landfill sites, to help avoid these problems arising.

Pollution levels in water can be measured in many different ways. Oxygen and pH levels are measured using instruments. The water can be analysed to show the levels of polluting chemicals such as pesticides or industrial waste. Bioindicators – species which can

only be found in very clean or very polluted water – are also used to monitor pollution levels in our waterways.

AQA Examiner's tip

Don't get herbicides and pesticides mixed up! Remember: herbicides are used to kill weed plants while pesticides kill insect pests.



Figure 4 This stream may look green and healthy but all the animal life it once supported is dead as a result of eutrophication

Summary questions

- 2 Farming can cause pollution of both the land and the water. Explain how this pollution comes about, and how they are linked.

- Toxic chemicals such as pesticides and herbicides can pollute the land.
- If sewage is not properly handled and treated it can pollute the water.
- Fertilisers and toxic chemicals can be washed from the land into the water and pollute it.



How humans can affect the environment

B3 4.3

Learning objectives

- How is acid rain formed?
- What are the effects of acid rain on living organisms?



Figure 1 In some parts of Europe and America, huge areas of woodland are dying as a result of acid rain

Air pollution

When the air you breathe is polluted, no one escapes the effects. A major source of air pollution is burning fossil fuels. As the human population grows and living standards increase we are using more oil, coal and natural gas. We also burn huge amounts of petrol, diesel and aviation (aeroplane) fuel made from oil. Fossil fuels are a non-renewable resource – eventually they will all be used up.

a Name three fossil fuels.

The formation of acid rain

When fossil fuels are burned, carbon dioxide is released into the atmosphere as a waste product. In addition, fossil fuels often contain sulfur impurities. These react with oxygen when they burn to form sulfur dioxide gas. At high temperatures, for example in car engines, nitrogen oxides are also released into the atmosphere.

Sulfur dioxide and nitrogen oxides can cause serious breathing problems for people if the concentrations get too high.

The sulfur dioxide and nitrogen oxides also dissolve in rainwater and react with oxygen in the air to form dilute sulfuric acid and nitric acid. This produces acid rain, which has been measured with a pH of 2.0 – more acidic than vinegar!

b What are the main gases involved in the formation of acid rain?

The effects of acid rain

Acid rain directly damages the environment. If it falls onto trees it may kill the leaves and, as it soaks into the soil, it can destroy the roots as well. Whole ecosystems can be destroyed.

Acid rain also has an indirect effect on our environment. As acid rain falls into lakes, rivers and streams the water in them becomes slightly acidic. If the concentration of acid gets too high, plants and animals can no longer survive. Many lakes and streams have become 'dead' – no longer able to support life.

c How does acid rain kill trees?

Acid rain is difficult to control. It is formed by pollution from factories. It also comes from the cars and other vehicles we use every day. The worst effects of acid rain are often not felt by the country that produced the pollution (see Figure 2). The sulfur dioxide and nitrogen oxides are carried high in the air by the winds. As a result, it is often relatively 'clean' countries that get the acid rain from their dirtier neighbours. Their own clean air goes on to benefit someone else.

The UK and other countries have worked hard to stop their vehicles, factories and power stations producing the polluting gases. They have introduced measures to reduce the levels of sulfur dioxide and nitrogen oxides in the air. Low-sulfur petrol and diesel are now used in vehicles. More and more cars are fitted with catalytic converters. Once hot, these remove the acidic nitrogen oxides before they are released into the air. There are strict rules about the levels of sulfur dioxide and nitrogen oxides in the exhaust furnes of new cars.



In the UK we have introduced cleaner, low-sulfur fuels such as gas in power stations and started generating more electricity from nuclear power. We have also put systems in power station chimneys to clean the flue gases before they are released into the atmosphere.

As a result, the levels of sulfur dioxide in the air, and of acid rain, have fallen steadily over the past 40 years. Many European countries have done the same (see Figure 3). Unfortunately there are still many countries around the world that do not have controls in place.

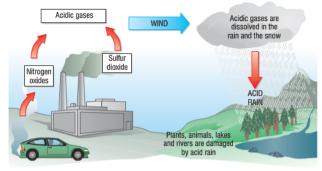


Figure 2 Air pollution in one place can cause acid rain – and serious pollution problems – somewhere else entirely, even in another country

Global dimming

One form of air pollution involves an increase in the number of tiny solid particles in the air. The sulfur products from the burning of fossil fuels are part of this problem. So is smoke from any type of burning. These particles reflect sunlight so less light hits the surface of the Earth. This causes a dimming effect. Global dimming could lead to a cooling of the temperatures at the surface of the Earth.

In Europe, where sulfur emissions and smoke are being controlled, dimming is being reversed. In many developing countries, dimming continues to get worse as air pollution grows.

Summary questions

- 1 Copy and complete using the words below:
 - acid rain carbon dioxide fossil nitric nitrogen oxides sulfur sulfuric

- 2 a Explain how pollution from cars and factories burning fossil fuels pollute:
 - i the air
 - ii the water
 - iii the land.
 - b In order to get rid of acid rain it is important that all countries in an area control their production of sulfur dioxide and nitrogen oxides. Explain why this is.
- 3 a What is global dimming?
 - b From Figure 3, what was the percentage reduction in sulfur emissions in Europe between 1980 and 2002?
 - c Dimming has been reversed over Europe between 1980 and the present day. Suggest an explanation for this.

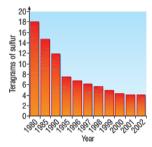


Figure 3 Bar chart to show the reductions in sulfur emissions made by European countries in recent years

- When we burn fossil fuels, carbon dioxide is released into the atmosphere.
- Sulfur dioxide and nitrogen oxides can be released when fossil fuels are burnt. These gases dissolve in rainwater and make it more acidic.
- Acid rain may damage trees directly. It can make lakes and rivers too acidic so plants and animals cannot live in them.
- Air pollution can cause global dimming as tiny solid particles in the air reflect away the sunlight.



Deforestation and peat destruction (6)

Learning objectives

- What is deforestation?
- Why does loss of biodiversity matter?
- What is the link between cows and methane?
- · What is the effect of destroying peat bogs?

As the world population grows we need more land, more food and more fuel. One solution to this has been to cut down huge areas of forests. The loss of our forests may have many long-term effects on the environment and ecology of the Earth.

The effects of deforestation

All around the world, large-scale deforestation is taking place for timber and to clear the land for farming. When the land is to be used for farming, the tress are often felled and burned in what



Figure 1 Tropical rainforests are being destroyed by slash-and-burn clearance to provide cheap food for countries like ours

is known as 'slash-and-burn' clearance. The wood isn't used, it is just burned. The land produced is only fertile for a short time, after which more forest is destroyed. No trees are planted to replace those cut down.

Deforestation increases the amount of carbon dioxide released into the atmosphere. Burning the trees leads to an increase in carbon dioxide levels from combustion. The dead vegetation left behind decays. It is attacked by decomposing microorganisms, which release more carbon dioxide.

Normally, trees and other plants use carbon dioxide in photosynthesis. They take it from the air and it gets locked up for years in plant material like wood. So when we destroy trees we lose a vital carbon dioxide 'sink'. Dead trees don't take carbon dioxide out of the atmosphere. In fact they add to the carbon dioxide levels as they are burned or decay.

a What is deforestation?

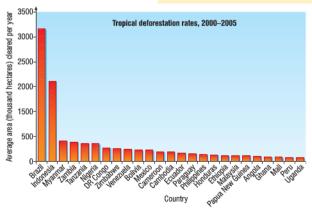




Figure 2 The rate of deforestation is devastating. For an animal like the orang-utan, which eats ound 300 different plant species, losing the forest habitat is driving the species to extinction

Loss of biodiversity

Tropical rainforests contain more diversity of living organisms than any other land environment. When we lose these forests, we also lose **biodiversity** as many species of animals and plants die out. Many of these species have not yet been identified or studied. We could be destroying sources of new medicines or food for the future.

Deforestation is taking place at a tremendous rate. In Brazil alone an area about a quarter the size of England is lost each year. When the forests are cleared, they are often replaced by a monoculture (single species) such as oil palms. This process also greatly reduces biodiversity.

Cows, rice and methane

It isn't just carbon dioxide levels that are increasing in the atmosphere as a result of deforestation.

Much of the deforested land is used to produce food for the ever-increasing world population. One of these foods is rice. As rice grows in swampy conditions, known as paddy fields, **methane** is released. Methane is another gas that affects global warming.

Another food – and another source of methane – is from cattle. Cows produce methane during their digestive processes and release it at regular intervals. In recent years the number of cattle raised to produce cheap meat for fast food, such as burgers, has grown enormously. So the levels of methane are rising. Many of these cattle are raised on farms created by deforestation.

b Where does the methane that is building up in the atmosphere come from?

Peat bog destruction

Peat bogs are another resource that is being widely destroyed. Peat bogs form over thousands of years, usually in marshy areas. They are made of plant material that cannot decay completely because the conditions are very acidic and lack oxygen. Peat acts as a massive carbon store.

Peat can be burned as a fuel and is also widely used by gardeners because it helps to improve the properties of the soil. When peat is burned or used in gardens, carbon dioxide is released into the atmosphere and the carbon store is lost. Peat is formed very slowly so it is being destroyed faster than it is made. In the UK, the government is trying to persuade gardeners to use alternative 'peat-free' composts to reduce carbon dioxide emissions. Compost can be made from bark, from garden waste, from coconut husks and other sources – the problem is persuading gardeners to use them.

Summary questions

- 1 Define the following words: deforestation slash-and-burn biodiversity peat
- 2 Give three reasons why deforestation increases the amount of carbon dioxide in the atmosphere.
- 3 a Why are the numbers of:
 - i rice fields and cattle in the world increasing
 - ii peat bogs in the world decreasing?
 - b Why is this cause for concern?

A Examiner's tip

Remember that trees, plants in peat bogs and algae in the sea all use carbon dioxide for photosynthesis. Carbon compounds are then 'locked up' in these plants.



Figure 3 Peat-free compost effectively replaces peat-based compost – protecting peat bogs and reducing carbon dioxide emissions

- Deforestation is the destruction or removal of areas of forest or woodland.
- Large-scale deforestation has led to an increase in the amount of carbon dioxide released into the atmosphere (from burning and the actions of microorganisms). It has also reduced the rate at which carbon dioxide is removed from the air by plants.
- More rice fields and cattle have led to increased levels of methane in the atmosphere because rice and cattle both produce methane as they grow.
- The destruction of peat bogs releases carbon dioxide into the atmosphere.



B3 4.5

Learning objectives

- What is global warming?
- How will global warming affect life on Earth?

O links

For information on photosynthesis, look back to B2 2.1 Photosynthesis.

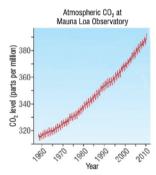


Figure 1 The atmospheric carbon dioxide readings for this graph are taken monthly on a mountain-top in Hawaii. There is a clear upward trend, which shows no sign of slowing down.

Global warming 16

Many scientists are very worried that the climate of the Earth is getting warmer. This is often called **global warming**.

Changing conditions

For millions of years there has been a natural balance in the levels of carbon dioxide in the atmosphere. The carbon dioxide released by living things into the atmosphere from respiration has been matched by the amount removed. Carbon dioxide is removed by plants for photosynthesis and huge amounts are dissolved in the oceans, lakes and rivers. We say that the carbon dioxide is sequestered in plants and water, or that plants and water act as carbon dioxide sinks.

As a result, carbon dioxide levels in the air stayed about the same for a long period. However now, as a result of human activities, the levels of carbon dioxide are increasing. Unfortunately, the numbers of plants available to absorb it are decreasing. The speed of these changes means that the natural sinks cannot cope. So the levels of carbon dioxide in the atmosphere are building up. At the same time, the levels of methane are increasing too.

a Give two reasons for the observed increase in atmospheric carbon dioxide levels.

The greenhouse effect

Energy from the Sun reaches the Earth and much of it is radiated back out into space. However, gases such as carbon dioxide and methane absorb some of this energy so it can't escape. As a result, the Earth and its surrounding atmosphere are kept warm and ideal for life. Because carbon dioxide and methane act like a greenhouse around the Earth they are known as greenhouse gases. The way they keep the surface of the Earth warm is known as the greenhouse effect and it is vital for life on Earth.

b Name two greenhouse gases.

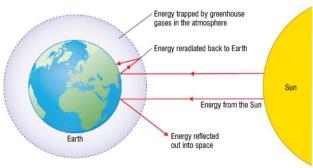


Figure 2 The greenhouse effect - vital for life on Earth



Global warming

However, as the levels of carbon dioxide and methane go up, the greenhouse effect is increasing. There are more greenhouse gases in the atmosphere to trap the energy of the Sun and the temperature at the Earth's surface is going up. The change is very small – only about 0.55 °C from the 1970s to the present day. This is not much – but an increase of only a few degrees Celsius may cause:

- big changes in the Earth's climate: As the climate changes due to global warming, many scientists think that we will see an increase in severe and unpredictable weather conditions. Some people think the very high winds and extensive flooding seen around the world in the 21st century are early examples of the effects of global warming.
- a rise in sea levels: If the Earth warms up, the ice caps at the north and south poles and many glaciers will melt. This will cause sea levels to rise.
 There is evidence that this is already happening. It will mean more flooding for low-lying shores and eventually parts of countries, or even whole countries, may disappear beneath the seas.
- reduced biodiversity: As the climate changes, many organisms will be unable to survive and will become extinct, e.g. the loss of polar bears as the ice melts.
- changes in migration patterns: As climates become colder or hotter, and the seasons change, the migration patterns of birds, insects and mammals may change.
- changes in distribution: Some animals may extend their range as climate change makes conditions more favourable. Others may find their range shrinks. Some will disappear completely from an area or a country.

What's more, as sea temperatures rise less carbon dioxide can be held in the water, which makes the problem worse. Global warming is a big problem for us all.



Figure 3 Puffin populations in Northem Scotland failed to rear their chicks because a rise in sea temperatures reduced the numbers of small fish that puffins feed on. They may need to move to new breeding sites if they are to survive.

Summary questions

- Copy and complete these sentences using the words below:
 climate carbon dioxide temperature atmosphere biodiversity
 methane global warming
- 2 a Use the data in Figure 1 to produce a bar chart showing the maximum recorded level of carbon dioxide in the atmosphere every tenth year from 1970 to the year 2010.
 - **b** Explain the trend you can see on your chart.
 - c Describe and explain the greenhouse effect. How might it affect the conditions on Earth?
- 3 Research one possible result of global warming and write a report, giving examples of organisms that have been or might be affected.

- Increasing levels of carbon dioxide and methane in the atmosphere give an increased greenhouse effect, leading to global warming – an increase in the temperature of the surface of the Earth.
- Global warming may cause a number of changes including climate change, a rise in sea level, loss of biodiversity and changes in migration patterns and distribution of species.



How humans can affect the environment

B3 4.6

Learning objectives

- How can yeast produce fuel for your car?
- What is the environmental impact of biofuels?

O links

For information on ethanol, look back to B2 1.2 Bacteria and yeast.

O links

For information on deforestation, look back to B3 4.4 Deforestation and peat destruction.



Figure 1 In tropical regions plants grow fast, an important factor when they are grown for fuel

Biofuels

Everyone needs fuel of some sort but there is only a finite amount of fossil fuels to use. Around the world, we all need other, renewable forms of fuel. The production of **biofuels** has become increasingly important in both the developing and the developed world.

Biofuels are made from natural products by fermentation using yeast or bacteria. There are two main types of biofuels – ethanol-based fuels and biogas.

Ethanol-based fuels

Some of the land that is deforested is used for crops that grow very fast. The crops can then be used to produce biofuels. Sugarcane grows about 4 to 5 metres in a year and maize (sweetcorn) is another fast grower. The sugarrich products from cane and maize are fermented anaerobically with yeast. The products are ethanol and carbon dioxide. You can extract the ethanol by distillation, and then use it in cars as a fuel.

Car engines need special modification to be able to use pure ethanol as a fuel, but it is not a major job. Many cars can run on a mixture of petrol and ethanol without any problems at all.

a Why are sugarcane and maize used as crops for the production of ethanol?

The advantages and disadvantages of ethanol as a fuel

In many ways ethanol is an ideal fuel. It is efficient and it does not produce toxic gases when you burn it. It is much less polluting than conventional fuels, which produce carbon monoxide, sulfur dioxide and nitrogen oxides. In addition, you can mix ethanol with conventional petrol to make a fuel known as gasohol, which reduces pollution levels considerably.

Using ethanol as a fuel is known as a **carbon neutral** process. This means that in theory there is no overall increase in carbon dioxide in the atmosphere when you burn ethanol. The original plants remove carbon dioxide from the air during photosynthesis. When you burn the ethanol, you simply return the same amount of carbon dioxide into the atmosphere.

The biggest difficulty with using plant-based fuels for our cars is that it takes a lot of plant material to produce the ethanol. As a result, the use of ethanol as a fuel has largely been limited to countries with enough space and a suitable climate to grow lots of plant material as fast as possible. Scientists are attempting to find ways of producing economically viable quantities of ethanol from plants that grow fast and well in Europe. They have tried pine trees and beet but have not yet been very successful. Now they are looking at fast-growing grasses.

b What is meant by the term 'carbon neutral'?



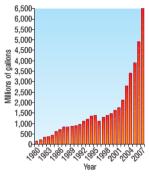




Figure 2 Increasing demand for gasohol in the US has lead to increasing production of ethanol from maize, as this data clearly shows

The latest biofuels

People around the world are worried about environmental problems such as global warming linked to burning fossil fuels. Interest in clean alternatives such as ethanol is soaring.

The main problem is finding enough ethanol. If Europeans added 5% ethanol to their fuel it would contribute to some reduction in Europe's carbon dioxide emissions. However, we would need 7.5 billion litres of ethanol a year, which would use a lot of plants.

The main methods of ethanol production use the edible parts of plants and leave large quantities of unused plant material. Many people are concerned about using plants for fuel that could feed hungry people. The aim is to make ethanol production work ethically and financially in the long term. To do this we need to find a way to use the waste, cellulose-rich biomass rather than the edible parts of plants.

The latest biofuel technologies use bacteria, enzymes and steam or chemical treatments to break down the cellulose in biomass. They use straw and woodchips as raw materials. The end-products of this breakdown are sugars. These can be respired by yeast to make more ethanol. We don't know exactly what the future will hold, but it seems likely that ethanol-based fuel will be part of it.

(()A Examiner's tip

Be clear about the advantages and disadvantages of using land for growing 'biofuel crops'.



Figure 3 The latest biofuel plants like Longannet in Fife make ethanol from waste biomass

Summary questions

- 1 Make a table to summarise the advantages and disadvantages of ethanol as a fuel for cars.
- 2 Use the data in Figure 2 to help you answer the following questions:
 - a What was the increase in ethanol production from maize in the USA between:
 - i 1980 and 1990
 - ii 1990 and 2000
 - iii 2000 and 2007?
- b Graphs showing worldwide production of fuel ethanol follow a similar pattern. Explain what this suggests about the use of ethanol as a fuel.

- Some land has been deforested so that crops can be grown, from which biofuels based on ethanol can be produced.
- Biofuels can be made from natural products using fermentation by yeast.



How humans can affect the environment

B3 4.7

Learning objectives

- What is biogas?
- How is biogas produced?



In the days before electricity, biogas was taken from the London sewers and used as fuel for the gas lamps that lit the streets.



Figure 1 Biogas generators have made an enormous difference to many families and communities by producing cheap and readily available fuel

Biogas 🗷

Biogas is a biofuel that is becoming more and more important. Biogas is produced naturally in sewers and rubbish dumps. Today, it is becoming increasingly used as a fuel around the world.

What is biogas?

Biogas is a flammable mixture of gases. It is formed when bacteria break down plant material or the waste products of animals in anaerobic conditions. Biogas is mainly methane but the composition of the mixture varies. It depends on what is put into the generator and which bacteria are present (Table 1).

Table 1 Components of biogas

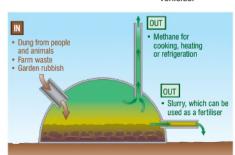
Component	Percentage in the mixture by volume			
methane	50-80			
carbon dioxide	15-45			
water vapour	5			
other gases including: hydrogen hydrogen sulfide	0-1 0-3			

a What is the main component of biogas?

Biogas generators

Around the world, millions of tonnes of faeces and urine are made by animals like cows, pigs, sheep and chickens. We produce our fair share of waste materials tool Also, in many places, plant material grows very rapidly. Both the plant material and the animal waste contain carbohydrates. They make up a potentially enormous energy resource – but how can we use it?

When bacteria decompose waste material in anaerobic conditions they produce methane. Methane is a flammable gas that can be used as a fuel for heating and cooking. We can also use it to produce electricity or as a fuel for vehicles.



The bacteria involved in biogas production work best at a temperature of around 30 °C. So biogas generators tend to work best in hot countries. However, the process releases energy (the reactions are **exothermic**). This means that if you put some energy in at the beginning to start things off, and have your generator well insulated to prevent energy loss, biogas generators will work anywhere.

b What is an exothermic reaction?

Figure 2 Biogas generators take in body waste or plants, and biogas and useful fertilisers come out at the other end



How Science Works

Scaling up the process

At the moment most biogas generators around the world operate on a relatively small scale. They supply the energy needs of one family, a farm or at most a village.

What you put into your small generator has a big effect on what comes out. There are well over 7 million biogas units in China. These produce as much energy as 22 million tonnes of coal. Waste vegetables, animal dung and human waste are the main raw materials. These Chinese generators produce excellent fertiliser but relatively low-quality biogas.

In India, there are religious and social taboos against using human waste in biogas generators. As a result only cattle and buffalo dung is put into the generators. This produces very high quality biogas.

but much less fertiliser.

The sizes and design of biogas generators will depend on local conditions. Many generators are sunk into the ground, which provides very good insulation. Others are built above ground, and are easier and cheaper to build. However, this offers less insulation so low night-time temperatures can cause problems.

Many countries are now looking at biogas generators and experimenting with using them on a larger scale. The waste material we produce from sugar factories, sewage farms and rubbish tips can be used to produce biogas. However, in the UK we have been relatively slow at starting to use biogas generators but a number of projects are now in place.

Vast herds of dairy cattle, containing several thousand cows, produce large amounts of slurry. This can be used to produce biogas which in turn can be used to generate electricity. This is already done in the US, Saudi Arabia and other countries, and may soon be set up in the UK.

Biogas could well be an important fuel of the future for all of us. It would help us to get rid of much of the waste we produce as well as providing a clean and renewable energy supply.

Examiner's tip

Do not be put off by unfamiliar diagrams of biogas generators in the examination.

Remember, they all function in a similar way:

 anaerobic fermentation of waste carbohydrate, by microorganisms, to produce methane.



Figure 3 This commercial biogas plant in Texas uses the slurry from 10000 cows as well as other agricultural waste as its raw material

Summary questions

- 1 Explain simply what biogas is and how it can be made.
- 2 Some types of biogas generators are set up with a large amount of plant material like straw and a starter mixture of bacteria, and left to produce gas. These batch digesters produce biogas very efficiently. Once gas generation begins to drop, the generator is emptied and cleaned out and the process starts again.
 - a Using a generator like this, how could you be sure of a continuous supply of gas for cooking?
 - **b** What are the advantages and disadvantages of a batch-type digester over the types shown in Figure 2, where dung and plant waste is fed in continuously?

- Biogas mainly methane - can be produced by anaerobic fermentation of a wide range of plant products and waste materials that contain carbohydrates.
- Biogas generators can be small, to supply a single family, or large, to deal with the sewage from an entire city.



How humans can affect the environment

B3 4.8

Learning objectives

- Why do short food chains make food production more efficient?
- How can we manage food production to reduce energy losses?

O links

For information on pyramids of biomass, look back to B1 5.1 Pvramids of biomass.



Figure 1 Reducing the number of stages in food chains could dramatically increase the efficiency of our food production. Eating less meat would mean more food for everyone.

O links

For information on energy losses between trophic levels, look back to B1 5.2 Energy transfers.

Making food production efficient

Pyramids of biomass show us that the organisms at each successive stage of a food chain contain less material and therefore less energy. This has major implications for the way we produce food.

Food chains in food production

In the developed world much of our diet consists of meat or other animal products such as eggs, cheese and milk. The cows, goats, pigs and sheep that we use to produce our food eat plants. By the time it reaches us, much of the energy from the plant has been used up.

In some cases we even feed animals to animals. Ground up fish, for example, is often part of commercial pig and chicken feed. This means we have put another extra stage into the food chain. It goes from plant to fish, fish to pig, pig to people, making it even less efficient.

a Name three animals that we use for food.

There is a limited amount of the Earth's surface that we can use to grow food. The most energy-efficient way to use this food is to grow plants and eat them directly. If we only ate plants, then in theory there would be plenty of food for everyone on the Earth. Biomass produced by plants would be used to feed people and produce human biomass.

However, every extra stage we introduce results in less energy getting to us at the end of the chain. An example is feeding plants to animals before we eat the food ourselves. In turn this means less food to go around the human population.

b Why would there be more food for everyone if we all ate only plants?

Artificially managed food production (K)



As you saw in B1 5.2, animals don't turn all of the food they eat into new animal. Some of the food can't be digested and is lost as waste. Energy is also used in moving around and maintaining a constant body temperature.

Farmers apply these ideas to food production to make it more efficient. People want meat, eggs and milk - but they want them as cheaply as possible. So farmers want to get the maximum possible increase in biomass from animals without feeding them extra food. There are two ways of doing this:

- Limiting the movement of food animals: then they don't use much energy in moving their muscles and so have more biomass available from their food for growth.
- Controlling the temperature of their surroundings: then the animals will not have to use much energy keeping warm or cooling down. Again, this leaves more biomass spare for growth.



Controlling these factors means keeping the animals inside with restricted space to move, and a constant ideal temperature. This is what happens in the massive poultry rearing sheds where the majority of the chickens that we eat are produced.

Birds kept in these sheds can be ready to eat in a matter of weeks. They always have plenty of food but there is not much room to move. There is a risk of disease spreading quickly through the animals as they are so close together. They need constant monitoring, which costs money, but they can be sold for meat very quickly. Animals reared in this way can appear more like factory products than farm animals. That's why these intensive methods are sometimes referred to as factory farming.

Intensive farming methods are used because there has been a steady increase in demand for cheap meat and animal products. This is the only way farmers can meet these demands from consumers.

On the other hand, these animals live very unnatural and restricted lives. In comparison, birds reared outside grow more slowly but have a better quality of life. It takes more space, the weather can be a problem and it is a slower process but there is no heating or lighting to pay for.

More people are now aware of how our cheap meat and eggs are produced. As a result there has been a backlash against the conditions in which intensively reared animals live. Increasingly, intensive systems are being developed with far greater awareness of animal welfare issues. Contented animals gain biomass more quickly than stressed ones, so everyone benefits.

Food miles

Another aspect of efficiency in food production is how far the food travels. Food produced around the world can travel thousands of miles to reach your plate. This uses fuel, which increases the amount of carbon dioxide in the atmosphere. People are more aware of these 'food miles' now and many people try to buy meat, fruit and vegetables which have been grown relatively locally.

Summary questions

1 Copy and complete using the words below: movement food chain biomass material temperature

energy efficiency

- At each stage in a ______less _____ and less _____ are contained in the _____ of the organisms. Farmers improve the _____ of food production by limiting _____ and controlling the _____.
- 2 Why are animals prevented from moving much and kept indoors in intensive farming?
- 3 a What are the advantages and disadvantages for a farmer of rearing animals intensively?
 - b What are the advantages and disadvantages of less intensive rearing methods?





Figure 2 Intensively reared chickens versus free-range chickens



Did you know ...?

The biggest herd of dairy cows in the world is in Saudi Arabia, where 37000 cows are all kept inside water-cooled buildings.

AQA Examiner's tip

Be clear about the ways in which the efficiency of food production can be improved to meet the needs of a growing human population. Make sure you have considered the advantages and disadvantages of each method before your examination.

- Biomass and energy are reduced at each stage of a food chain. The efficiency of food production is improved by reducing the number of stages in our food chains.
- If you stop animals moving about and keep them warm, they waste less energy, making food production more efficient.



B3 4.9

Learning objectives

- What is sustainable food production?
- Can we use fungi to make sustainable food?

Sustainable food production

As the human population keeps increasing, we are becoming more aware of the need for sustainable food production. This means producing food in ways that can continue for many years. It involves maintaining the health of the soil so plant crops grow well year after year. It also involves taking care of the fish stocks in our oceans so they do not run out.

Managing the oceans

People have fished for food throughout human history. However, in the past 60 years or so commercial fishing fleets of large factory ships have built up. These are capable of taking huge quantities of fish on a regular basis. The result of this uncontrolled overfishing is that stocks of edible fish are falling. In some areas, such as the North Sea, they are becoming dangerously low. That's because almost all of the breeding fish have been caught.



Figure 1 Many scientists think that only a complete fishing ban can save the bluefin tuna. It has been overfished almost to extinction in spite of net size control and fishing quotas.

It is important to maintain fish stocks at a level where breeding continues successfully. Otherwise certain species, such as cod and bluefin tuna, may disappear completely in some areas (Figure 1). People have been warning about the problems of overfishing for years. Numbers of some fish are so low they could disappear altogether. Finally, serious restrictions on fishing are being put in place.

Ways in which we can conserve fish populations include controlling the size of the holes in the nets. Then only the biggest fish are caught. There can also be bans on fishing in the breeding season and very strict quotas imposed on fishermen. This means they have a strictly enforced limit on the amount and type of fish they are allowed to catch.

Only with protection like this will we be able to conserve the fish stocks. Then we will be able to fish them sustainably for years to come.

a What is a fishing quota?

Mycoprotein production

Almost 30 years ago a completely new food based on fungi was developed. It is known as **mycoprotein**, which means 'protein from fungus'. It is produced using the fungus *Fusarium*. This grows and reproduces rapidly on a relatively cheap sugar syrup (made from waste starch) in large specialised containers called **fermenters**. *Fusarium* needs aerobic conditions to grow successfully. In optimum conditions it can double its mass every five hours! Because the fungi use cheap food and reproduce rapidly this is a very sustainable food source.



The fermenter is designed to react to changes, keeping the conditions as stable as possible (Figure 2). This means we can get the maximum yield. The fermenters have:

- an air supply to provide oxygen for respiration of the fungi
- a stirrer to keep the microorganisms in suspension. This
 maintains an even temperature and makes sure that oxygen
 and food are evenly spread throughout the mixture
- a water-cooled jacket, which removes the excess energy released by the respiring fungi. Any rise in temperature is used to heat the water, which is constantly removed and replaced with more cold water
- measuring instruments that constantly monitor factors such as the pH and temperature so that changes can be made if necessary.
 - b How quickly can Fusarium double its mass when conditions are right?

The fungal biomass is harvested and purified. Then it is dried and processed to make mycoprotein. This is a pale yellow solid with a faint taste of mushrooms. On its own it has very little flavour.

However, mycoprotein is given a range of textures and flavours to make it similar to many familiar foods (Figure 3). It is a high-protein, low-fat meat substitute. The protein content of mycoprotein is similar to that of prime beef. So it is used by vegetarians and people who want to reduce the fat in their diet.

When mycoprotein was first developed people thought a world food shortage was on its way. They were looking for new ways to make protein cheaply and efficiently. The food shortage never happened, but the fungus-based food



Figure 3 Mycoprotein can be made to look like meat, chicken, fish or burgers. It is very versatile.

continued. It is versatile, high in protein and fibre, low in fat and calories and very sustainable, so is widely used in the developed world.

Summary questions

- 2 a How has the fishing industry reached crisis point?
 - b How can fish stocks be protected?
 - c Why do you think these measures were not put in place a long time ago?
- 3 Mycoprotein is an example of sustainable food production. Explain how it is similar to and how it differs from intensive farming.

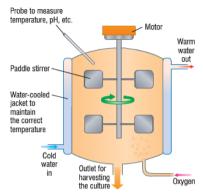


Figure 2 Conditions inside the fermenters used to culture microorganisms such as Fusarium are kept as stable as possible

AQA Examiner's tip

Make sure you understand the meaning of 'sustainable food production'. Humans need food now but also need to plan for feeding the next generation.

- Sustainable food production means producing food in a way which can continue for many years.
- It is important to control net size and impose fishing quotas to conserve fish stocks, so breeding continues and the decline in numbers is hatted.
- The fungus Fusarium is grown on sugar syrup in aerobic conditions to produce mycoprotein foods.



B3 4.10

Learning objectives

- How do we affect the global environment?
- What sort of data have we got about environmental issues?
- How strong is the evidence for environmental change?



Figure 1 When the Aswan dam was built in Egypt, 60 000 people lost their homes as Lake Nasser was formed

Activity 1

Find out about the environmental impact of a single dam and reservoir. Then make a list of all the benefits and problems caused by that single project and decide if you think the dam was a good idea.

O links

For information on hard evidence for the build-up of greenhouse gases, look back to B3 4.5 Global warming.

Environmental issues

Food and water - a vicious circle?

As the world population grows, we need ever more food and water. However, the way in which we get that food and water can affect the environment both locally and globally. You have already seen how food production can affect the environment. One example is deforestation. Others are the growth of crops, such as rice, and the rearing of livestock, such as cattle. These last two increase the production of the greenhouse gas methane.

Yet people need water as much as food. It isn't just people either – crops and animals also need water. One way of supplying water is to build a dam. A dam creates a reservoir, which can be used as a source of clean water for drinking and irrigating crops. Unfortunately there can be many environmental problems as a result:

- Dams destroy river ecosystems, particularly below the dam, where the rivers may be lost completely. This can cause huge areas to dry out.
- Flood plains with their fertile soil disappear, so people can no longer grow the crops they need.
- Environments are destroyed as the reservoir forms and animals, plants and people lose their homes (Figure 1).
- Reservoirs act as breeding grounds for the mosquitoes that carry diseases such as malaria.
- Dams and reservoirs may even add to methane in the atmosphere as eutrophication can occur.

How can we be sure?

The build-up of greenhouse gases cannot be denied, because there is hard evidence for it. The great majority of scientists now think the evidence shows that global warming is at least partly linked to human activities such as the burning of fossil fuels and deforestation, but not everyone agrees.

Some extreme weather patterns have been recorded in recent years. Yet throughout history there is evidence of other, equally violent, weather patterns. These occurred long before fossil fuels were used so heavily and deforestation was happening. Also, weather is not the same as climate. Weather can change from day to day but climate is the weather in an area over a long period of time.

How valid, reproducible and repeatable are the data on which the ideas are based? Scientists measure the daily temperatures in many different places. They also look at how the temperature of the Earth has changed over time (Figure 2). They collect many different types of evidence. For example, they use cores of ice that are thousands of years old (Figure 3), the rings in the trunks of trees and the type of pollen found in peat bogs.

Much of the evidence is published in well-respected journals, but there are some controversies. In 2009, it emerged that some scientists in the UK had hidden data that showed that global temperatures were falling slightly rather than rising. The scientists support the idea that human activities are causing global warming and did not want to publish data which might challenge that idea.



The evidence continues to be collected. At the moment, most people and governments are convinced that we need to change the way we live if we are to reduce the damage that global warming might do.

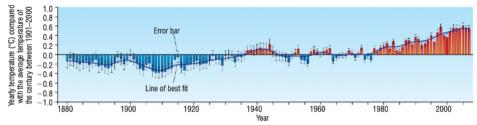


Figure 2 This graph shows how global surface temperatures have varied from the 1901–2000 mean over 130 years. These data are widely regarded as very reproducible and repeatable.

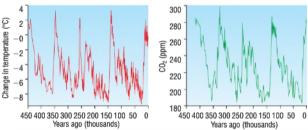


Figure 3 These graphs show data from the Vostok ice cores in Antarctica, giving evidence about temperature, carbon dioxide and dust levels over 420000 years

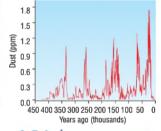
Activity 2

Problems like greenhouse gas emissions, global warming and the management of food and water supplies for the world population can seem overwhelming. However, you can make a difference by the choices you make in everyday life.

- Research material on environmental problems.
- Carefully evaluate the evidence you find.
- Develop some web pages to be used by your school on environmental issues.
- Suggest ways in which individuals as well as governments can conserve resources and change attitudes.

Summary questions

- 1 Develop a spider diagram or flowchart to show how building a dam to produce water for people to drink can damage the environment.
- 2 Summarise the evidence shown on the graphs in Figures 2 and 3. Explain what they appear to show and how these data might be used as evidence for a human influence on global warming. What other data might you need to help confirm that conclusion?



AQA Examiner's tip

Media reports on environmental issues can be very confusing. If you are going to quote any in your examination, make sure that it is backed up by scientific evidence and not just an opinion.

Key points

- Methods used to produce food and water for people can have short- and long-term effects on the environment.
- There are a lot of data on environmental change.
 The validity, reproducibility and repeatability of all data must be evaluated before conclusions can be drawn.



How humans can affect the environment: B3 4.1-B3 4.10

Summary questions (A)



- 1 a List the main ways in which humans reduce the amount of land available for other living things.
 - b Explain why each of these land uses is necessary.
 - c Suggest ways in which two of these different types of land use might be reduced.
- 2 a Draw a flowchart showing acid rain formation.
 - b Look at Figure 3 in B3 4.3 Air pollution.
 - i What was the level of sulfur emissions in 1980?
 - ii What was the approximate level of sulfur in the air in the year that you were born? (Make sure you give your birth year.)
 - iii What was the level of sulfur emissions in 2002?
 - c What do these data tell you about trends in the levels of sulfur emissions since 1980. Suggest explanations for the trends you have observed.
- in Figure 1 in B3 4.5 Global warming, you can see clearly annual variations in the levels of carbon dioxide recorded each year. These fluctuations are thought to be due to seasonal changes in the way plants are growing and photosynthesising through the year.
 - a Explain how changes in plant growth and rate of photosynthesis might affect carbon dioxide levels.
 - b How could you use the evidence of this data to argue against deforestation?
 - c How is the ever-increasing human population affecting the build-up of greenhouse gases?
 - d What type of evidence is used to investigate the effect of this build-up of greenhouse gases on the climate of the Earth? Which types of evidence are most valid, repeatable and reproducible?
 - 4 a Suggest ways in which people might improve the quality of the biogas produced in their generators.
 - b Suggest reasons for and against the use of biogas generators and biogas in the UK.
 - Write a letter to your local authority, explaining why you think they should look into the idea of running all their vehicles - buses, emergency vehicles, etc. - on ethanol or gasohol. Explain the potential value of ethanol in helping to prevent the greenhouse effect and global warming.

Chicks grown for food arrive in the broiler house as 1-day-old chicks. They are slaughtered at 42 days of age when their mass is about 2 kg. The temperature, amount of food and water, and light levels are carefully controlled. About 20000 chickens are reared together in one house. The table below shows their average mass:

Age (days)	1	7	14	21	28	35	42	
Mass (g)	36	141	404	795	1180	1657	1998	

- a Plot a graph to show the average growth rate (gain in mass) per chicken.
- b Explain why the temperature is so carefully controlled. in the broiler house.
- c Explain why so many birds are reared together in a relatively small area.
- d Why are birds for eating reared like this?
- e Draw a second line to show how you would expect a chicken reared outside in a free-range system to gain in mass, and explain the difference.
- Human cells cannot make some of the amino acids that we need. We must obtain these amino acids from our diet.

The table shows the amounts of four of these amino acids present in mycoprotein, in beef and in wheat.

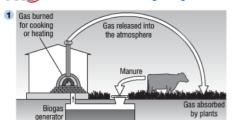
Name of amino acid		Amount of amino acid per 100 g in mg						
	Mycoprotein	Beef	Wheat					
lysine	910	1600	300	840				
methionine	230	500	220	910				
phenylalanine	540	60	680	980				
threonine	610	840	370	490				

A diet book states that mycoprotein is the best source of amino acids for the human diet.

Evaluate this statement. It may help to calculate the percentage of the daily amount of each amino acid found in the different foods. If there is obviously more than 100%, simply state that.

A()A/Examination-style questions (A)





The diagram shows how the manure from a cow can be recycled.

- a Choose the correct word to complete the sentences.
 - i The gas used for cooking is .. (1)carbon dioxide methane nitrogen ii The gas released into the atmosphere is (1)
 - carbon dioxide methane nitrogen
 - iii The gas absorbed by the plants is (1) carbon dioxide methane nitrogen
- b i Name the biological process that occurs in the biogas generator.
 - ii Name the organisms that are active in the biogas generator.
- c The biogas generator is built underground. Suggest two reasons for this.

- 2 Humans need food, water and shelter. Large areas of land must be cleared to grow food or to build houses. Sometimes valleys are flooded in order to store water in reservoirs.
 - a Land is usually cleared by cutting trees down. Give two disadvantages to the environment of removing
 - b The cleared land may be used for rearing cattle or growing rice.
 - i Name the two gases which increase in the atmosphere due to these activities.
 - ii Choose the correct answer to complete the sentence.

These gases may contribute to (1)alobal warming food production deforestation

- c Water in reservoirs can sometimes be polluted by human farming activities. Explain how. (2)
- 3 In this guestion you will be assessed on using good English, organising information clearly and using specialist terms where appropriate.

Producing food efficiently to feed an increasing human population is a challenge for farmers.

Describe how farmers increase the efficiency of food production.

You should refer to food chains and reducing energy loss in your answer. (6)



(2)

Examination-style questions

1 Changes occur in the human body.

List A shows some causes.

List B shows some effects.

Match each cause with its correct effect.

List A	List B
blood is filtered	blood clots
platelets are released	glucose is reabsorbed
blood gets hot	skin looks red
	heart rate decreases

(3)

(1)

(1)

(1)

(1)

(2)

f Dialysis fluid contains sugar and ions so that the concentration in the blood will

.....(1)

3 Flowering plants have transport systems.

a much warmer climate than the UK.

Complete the following sentences.

a The tissue which transports water in a plant is (1)

c The organ which absorbs water from the soil is a (1)

4 Humans need food.

a Fishermen are not allowed to use nets that catch very small fish. Explain why.

b Some farmers keep their chickens in sheds.

Explain why. (2)
c Some people object to cutting down trees to clear land for food crops.

Give a reason why. (1

5 Read the passage below about biogas production in Sri Lanka, which is a country with

Mr Ratnayake is a farmer. Using nothing more than cow dung, he has enough power to cook and provide heat and light for his home without using a single piece of wood. He collects the manure from his cows in their cattle shed. He then mixes the manure with water and leaves it to ferment in a large concrete pit. The gas produced is collected in a simple storage tank and is piped into his house for use. The dried manure left after this biogas is generated is richer than ordinary manure. It makes a good organic fertiliser for Mr Ratnayake's crops. He can then sell his crops at a higher price as they are organic produce.

http://www.i-sis.org.uk

- What is the fuel gas present in biogas? (1)ii Name the process that produces biogas. (1)
- Give two ways in which Mr Ratnayake benefits from making biogas as described in the passage.
 - ii This design of biogas generator works well in Sri Lanka. It would not work so well in the UK. Explain why.

AOA, 2009

- 6 Microorganisms are often used in the industrial production of useful substances. The fungus, Penicillium chrysogenum, can be used to make an enzyme that digests the sugar sucrose. When it is growing in a medium containing sucrose, the fungus releases this enzyme into the surrounding solution.
 - a Explain why it is useful to the fungus to release the enzyme into the surrounding solution.
 - b Before setting up an industrial fermenter, laboratory-scale investigations are carried out to find the best conditions to use.

A manufacturer investigated the effect of changing several factors on the amount of enzyme produced by the fungus. The results are shown in the table.

Condition	Concentration of enzyme produced in arbitrary units								
	24 hours	72 hours	120 hours						
Amount of fungus added as %									
1	9.0	28.8	44.4						
5	7.2	54.0	60.0						
25	6.0	66.0	62.4						
Aeration rate in arbitrary units									
0.5	9.0	36.0	45.8						
1.0	7.2	54.0	60.0						
2.0	10.8	43.2	52.8						
Sucrose concentration at start as %		•							
4	7.2	54.0	60.0						
8	3.0	29.7	48.3						
12	0	54.0	21.6						

The manufacturer decided to use the following conditions:

- amount of fungus = 5%
- aeration rate = 1.0 arbitrary units
- time = 72 hours.

Suggest an explanation for each of the following.

- The manufacturer decided to add 5% fungus rather than 25%.
- ii The concentration of enzyme produced at an aeration rate of 2.0 arbitrary units was less than the concentration at an aeration rate of 1.0 arbitrary units. (2)

AOA, 2006



Glossary

Α

- Abdomen The lower region of the body. In humans it contains the digestive organs, kidneys, etc.
- Accurate A measurement is considered accurate if it is judged to be close to the true value.
- Acld rain Rain that is acidic due to dissolved gases, such as sulfur dioxide, produced by the burning of fossil fuels.
- Active site The site on an enzyme where the reactants bind.
- Active transport The movement of substances against a concentration gradient and/or across a cell membrane, using energy.
- Adaptation Special feature that makes an organism particularly well suited to the environment where it lives.
- Adult cell cloning Process in which the nucleus of an adult cell of one animal is fused with an empty egg from another animal. The embryo which results is placed inside the uterus of a third animal to develop.
- Aerobic respiration Breaking down food using oxygen to release energy for the cells
- Agar The nutrient jelly on which many microorganisms are cultured.
- Algal cells The cells of algae, singlecelled or simple multicellular organisms, which can
- photosynthesise but are not plants.

 Allele A version of a particular gene.
- Alveoli The tiny air sacs in the lungs which increase the surface area for gaseous exchange.
- Amino acids The building blocks of protein.
- Amylase The enzyme made in the salivary glands and the pancreas which speeds up the breakdown of starch into simple sugars.
- Anaerobic respiration Breaking down food without oxygen to release energy for the cells.
- Anomalous result Result that does not match the pattern seen in the other data collected or is well outside the range of other repeat readings. It should be retested and if necessary discarded.

- Antibiotic Drug that destroys bacteria inside the body without damaging human cells.
- Antigen The unique protein on the surface of a cell. It is recognised by the immune system as 'self' or 'non-self'.
- Aorta The main artery leaving the left ventricle carrying oxygenated blood to the body.
- Artery Blood vessel which carries blood away from the heart. It usually carries oxygenated blood and it has a pulse.
- Asexual budding A form of asexual reproduction where a complete new individual forms as a bud on the parent organism e.g. yeast, hydra.
- Asexual reproduction Reproduction that involves only one individual with no fusing of gametes to produce the offspring. The offspring are identical to the parent.
- Atria The small upper chambers of the heart. The right atrium receives blood from the body and the left atrium receives blood from the lungs.
- Auxin A plant hormone that controls the responses of plants to light (phototropism) and to gravity (gravitropism).

В

- Bacteria Single-celled microorganisms that can reproduce very rapidly. Many bacteria are useful, e.g. gut bacteria and decomposing bacteria, but some cause disease.
- Bacterial colony A population of billions of bacteria grown in culture.
- Bar chart A chart with rectangular bars with lengths proportional to the values that they represent. The bars should be of equal width and are usually plotted horizontally or vertically. Also called a bar graph.
- Biconcave disc The shape of the red blood cells – a disc which is dimpled inwards on both sides.
- Bile Yellowy-green liquid made in the liver and stored in the gall bladder. It is released into the small intestine and emulsifies fats.

- Blodiversity The number and variety of different organisms found in a specified area.
- Blofuel Fuel produced from biological material which is renewable and sustainable.
- Blogas Methane produced by the fermentation of biological materials.
- Biological detergent Washing detergent that contains enzymes.
- Blomass Biological material from living or recently living organisms.
- Bladder The organ where urine is stored until it is released from the body
- Blood The liquid which is pumped around the body by the heart. It contains blood cells, dissolved food, oxygen, waste products, mineral ions, hormones and other substances needed in the body or needing to be removed from the body
- Blood circulation system The system by which blood is pumped around the body.
- Blood vessel A tube which carries blood around the body, i.e. arteries, veins and capillaries.
- Breathing The physical movement of air into and out of the lungs. In humans this is brought about by the action of the intercostal muscles on the ribs and the diaphragm.
- Breathing system The stems involved in breathing: the ribs, intercostal muscles, diaphragm as well as the lungs and the tubes which bring air into the body from the outside.

С

- Capillaries The smallest blood vessels which run between individual cells. They have a wall which is only one cell thick.
- Carbohydrase Enzyme which speeds up the breakdown of carbohydrates.
- Carbon cycle The cycling of carbon through the living and non-living world.
- Carbon neutral A process which uses as much carbon dioxide as it produces.
- Carnivore Animal that eats other animals
- Carrier Individual who is heterozygous



- for a faulty allele that causes a genetic disease in the homozygous form.
- Catalyst A substance which speeds up a chemical reaction. At the end of the reaction the catalyst remains chemically unchanged.
- Categoric variable See Variable categoric.
- Cell membrane The membrane around the contents of a cell which controls what moves in and out of the cell.
- Cell wall A rigid structure which surrounds the cells of living organisms apart from animals.
- Cellulose A big carbohydrate molecule which makes up plant and algal cell walls.
- Central nervous system (CNS) The central nervous system is made up of the brain and spinal cord where information is processed.
- Charles Darwin The Victorian scientist who developed the theory of evolution by a process of natural selection.
- Chlorophyll The green pigment contained in the chloroplasts.
- Chloroplasts The organelles in which photosynthesis takes place.
- Chromosome Thread-like structure carrying the genetic information found in the nucleus of a cell.
- Clone Offspring produced by asexual reproduction which is identical to its parent organism.
- Combustion The process of burning.
 Competition The process by which
 living organisms compete with each
 other for limited resources such as
 food, light or reproductive partners.
- Compost heap A site where garden rubbish and kitchen waste are decomposed by microorganisms.
- Concentration gradient The gradient between an area where a substance is at a high concentration and an area where it is at a low concentration.
- Continuous variable See Variable continuous.
- Contraceptive pill A pill containing female sex hormones which is used to prevent conception.
- Control group If an experiment is to determine the effect of changing a single variable, a control is often set up in which the independent variable is not changed, thus enabling a comparison to be made. If the investigation is of the survey

- type (q.v.) a control group is usually established to serve the same purpose.
- Control variable See Variable –
- Core body temperature The internal temperature of the body.
- Coronary artery An artery which carries oxygenated blood to the muscle of the heart.
- Culture medium A substance containing the nutrients needed for microorganisms to grow.
- Cuticle The waxy covering of a leaf (or an insect) which reduces water loss from the surface.
- Cystic fibrosis A genetic disease that affects the lungs, digestive and reproductive systems. It is inherited through a recessive allele.
- Cytoplasm The water-based gel in which the organelles of all living cells are suspended.

D

- Data Information, either qualitative or quantitative, that have been collected.
- Decomposer Microorganism that breaks down waste products and dead bodies
- **Deforestation** Removal of forests by felling, burning, etc.
- Dehydrated Lacking in water.
 Denature Change the shape of an enzyme so that it can no longer speed up a reaction.
- Denatured Change the shape of an enzyme so that it can no longer speed up a reaction.
- Deoxygenated Lacking in oxygen.

 Dependent variable See Variable –

 dependent.
- Depression A mental illness that involves feelings of great sadness that interfere with everyday life.
- Detritus feeder See decomposer.
 Diabetes A condition in which it
 becomes difficult or impossible for
 your body to control the levels of
 sugar in your blood.
- Dialysis The process of cleansing the blood through a dialysis machine when the kidneys have failed.
- Dialysis machine The machine used to remove urea and excess mineral ions from the blood when the kidneys fail.
- Dlaphragm A strong sheet of muscle that separates the thorax from the digestive organs, used to change

- the volume of the chest during ventilation of the lungs.
- Differentiated Specialised for a particular function.
- Diffusion The net movement of particles of a gas or a solute from an area of high concentration to an area of low concentration (along a concentration gradient).
- Digested Broken down into small molecules by the digestive enzymes.
- Digestive juices The mixture of enzymes and other chemiocals produced by the digestive system.
- Digestive system The organ system running from the mouth to the anus where food is digested.
- Direct contact A way of spreading infectious diseases by skin contact between two people.
- Directly proportional A relationship that, when drawn on a line graph, shows a positive linear relationship that crosses through the origin.
- Distillation A process which separates the components of a mixture on the basis of their different boiling points.
- DNA Deoxyribonucleic acid, the material of inheritance.
- DNA fingerprints Patterns produced by analysing the DNA which can be used to identify an individual.
- Domed A curved, dome shape.

 Dominant The characteristic that
 will show up in the offspring even if
 only one of the alleles is inherited.
- Donor The person who gives material from their body to another person who needs healthy tissues or organs, e.g. blood, kidneys. Donors may be alive or dead.
- Double-blind trial A drug trial in which neither the patient nor the doctor knows if the patient is receiving the new drug or a placebo.
- Double circulation The separate circulation of the blood from the heart to the lungs and then back to the heart and on to the body.
- Droplet Infection A way of spreading infectious diseases through the tiny droplets full of pathogens, which are expelled from your body when you cough, sneeze or talk.
- Drug A chemical which causes changes in the body. Medical drugs cure disease or relieve symptoms. Recreational drugs after the state of your mind and/or body.



F

- Ecology The scientific study of the relationships between living organisms and their environment
- Effective medicine A medicine that cures the disease it is targeting.
- Effector organs Muscles and glands which respond to impulses from the nervous system.
- Electron microscope An instrument used to magnify specimens using a beam of electrons.
- Element A substance made up of only one type of atom. An element cannot be broken down chemically into any simpler substance.
- Embryonic stem cell Stem cell with the potential to form a number of different specialised cell types, which is taken from an early embryo.
- Emulsifies Breaks down into tiny droplets which will form an emulsion.
- Endemic When a species evolves in isolation and is found in only one place in the world; it is said to be endemic (particular) to that area.
- Environmental isolation This is when the climate changes in one area where an organism lives but not in others.
- Enzyme Protein molecule which acts as a biological catalyst. It changes the rate of chemical reactions without being affected itself at the end of the reaction.
- Epidemic When more cases of an infectious disease are recorded than would normally be expected.
- Epidermal tissue The tissue of the epidermis the outer layer of an organism.
- Epithelial tissue Tissue made up of relatively unspecialised cells which line the tubes and organs of the body
- Error human Often present in the collection of data, and may be random or systematic. For example, the effect of human reaction time when recording short time intervals with a stopwatch.
- Error random Cause readings to be spread about the true value, due to results varying in an unpredictable way from one measurement to the next. Random errors are present when any measurement is made, and cannot be corrected. The effect of random errors can be reduced by

- making more measurements and calculating a new mean.
- Error systematic Cause readings to be spread about some value other than the true value, due to results differing from the true value by a consistent amount each time a measurement is made. Sources of systematic error can include the environment, methods of observation or instruments used. Systematic errors cannot be dealt with by simple repeats. If a systematic error is suspected, the data collection should be repeated using a different technique or a different set of equipment, and the results compared.
- Error zero Any indication that a measuring system gives a false reading when the true value of a measured quantity is zero, e.g. the needle on an ammeter failing to return to zero when no current flows. Ethanol Chemical found in alcoholic drinks and biofuels such as gasohol, its chemical formula: C, H,OH
- Errors Sometimes called uncertainties.
 Eutrophication The process by which
 excessive nutrients in water lead
 to very fast plant growth. When the
 plants die they are decomposed and
 this uses up a lot of oxygen so the
 water can no longer sustain animal
 life.
- Evaporation The change of a liquid to a vapour at a temperature below its boiling point.
- Evidence Data which has been shown to be valid.
- Evolution The process of slow change in living organisms over long periods of time as those best adapted to survive breed successfully.
- Evolutionary relationship Model of the relationships between organisms, often based on DNA evidence, which suggests how long ago they evolved away from each other and how closely related they are in evolutionary terms.
- Evolutionary tree Model of the evolutionary relationships between different organisms based on their appearance, and increasingly, on DNA evidence.
- Exchange surface A surface where materials are exchanged.
- Exothermic Releases heat energy.

 Extinction Extinction is the permanent loss of all the members of a species.

Extremophile Organism which lives in environments that are very extreme, e.g. very high or very low temperatures, high salt levels or high pressures.

F

- Fair test A fair test is one in which only the independent variable has been allowed to affect the dependent variable.
- Fatty acids Building blocks of lipids.
 Fermentation The reaction in which the enzymes in yeast turn glucose into ethanol and carbon dioxide.
- Fertile A fertile soil contains enough minerals e.g. nitrates, to supply the crop plants with the all nutrients needed for healthy growth.
- Fertiliser A substance provided for plants that supplies them with essential nutrients for healthy growth.
- Fossil fuel Fuel obtained from longdead biological material.
- Fructose syrup A sugar syrup.
 FSH Follicle stimulating hormone, a female hormone that stimulates the eggs to mature in the ovaries, and the ovaries to produce hormones, including oestrogen.

G

- Gamete Sex cell which has half the chromosome number of an ordinary
- Gaseous exchange The exchange of gases, e.g. the exchange of oxygen and carbon dioxide which occurs between the air in the lungs and the blood
- Gene A short section of DNA carrying genetic information.
- Genetic disorder Disease which is inherited.
- Genetic engineering/modification A technique for changing the genetic information of a cell.
- Genetic material The DNA which carries the instructions for making a new cell or a new individual.
- Geographical Isolation This is when two populations become physically isolated by a geographical feature.
- Glandular tissue The tissue which makes up the glands and secretes chemicals, e.g. enzymes, hormones.
- Global warming Warming of the Earth due to greenhouse gases in the atmosphere trapping infrared radiation from the surface.



Glucagon A hormone involved in the control of blood sugar levels.

Glucose A simple sugar.

Glycerol Building block of lipids.

Glycogen Carbohydrate store in animals, including the muscles, liver and brain of the human body.

Gravitropism Response of a plant to the force of gravity controlled by auxin.

Greenhouse effect The trapping of infrared radiation from the Sun as a result of greenhouse gases, such as carbon dioxide and methane, in the Earth's atmosphere. The greenhouse effect maintains the surface of the Earth at a temperature suitable for life.

Greenhouse gas Gases, such as carbon dioxide and methane, which absorb infrared radiated from the Earth, and result in warming up the atmosphere.

Guard cells The cells which surround stomata in the leaves of plants and control their opening and closing.

н

Haemoglobin The red pigment which carries oxygen around the body.

Hazard A hazard is something (e.g. an object, a property of a substance or

an activity) that can cause harm.

Heart The muscular organ which
pumps blood around the body.

Herbicide Chemical that kills plants.
Herbivore Animal that feeds on plants.
Homeostasis The maintenance

of constant internal body conditions.

Hydrated With plenty of water.

Hydroponics Growing plants in water enriched by mineral ions rather than soil.

Hypothermia The state when the core body temperature falls below the normal range.

Hypothesis A proposal intended to explain certain facts or observations.

ı

Immune response The response of the immune system to cells carrying foreign antigens. It results in the production of antibodies against the foreign cells and the destruction of those cells.

Immune system The body system which recognises and destroys foreign cells or proteins such as invading pathogens.

Immunisation Giving a vaccine that allows immunity to develop without exposure to the disease itself.

Immunosuppressant drugs Drugs which suppress the immune system of the recipient of a transplanted organ to prevent rejection.

Impulse Electrical signal carried along the neurons.

Independent variables See Variables – independent.

Indicator species Lichens or insects that are particularly sensitive to pollution and so can be used to indicate changes in the environmental pollution levels.

Industrial waste Waste produced by industrial processes.

Infectious Capable of causing infection.

Infectious disease Disease which can be passed from one individual to another

Inheritance of acquired

characteristics Jean-Baptiste Lamarck's theory of how evolution took place.

Inherited Passed on from parents to their offspring through genes.

Inoculate To make someone immune to a disease by injecting them with a vaccine which stimulates the immune system to make antibodies against the disease.

Insoluble molecule Molecule which will not dissolve in a particular solvent such as water.

Insulin A hormone involved in the control of blood sugar levels.

Intercostal muscles The muscles between the ribs which raise and lower them during breathing movements

Internal environment The conditions inside the body.

Interval The quantity between readings, e.g. a set of 11 readings equally spaced over a distance of 1 m would give an interval of 10 cm.

Ion A charged particle produced by the loss or gain of electrons.

Isomerase An enzyme which converts one form of a molecule into another.
Isotonic Having the same concentration of solutes as another solution.

J

Jean-Baptiste Lamarck French biologist who developed a theory of evolution based on the inheritance of acquired characteristics.

K

Kidney Organ which filters the blood and removes urea, excess salts and water.

Kidney transplant Replacing failed kidneys with a healthy kidney from a donor

Kidney tubule A structure in the kidney where substances are reabsorbed back into the blood.

Kingdom The highest group in the classification system e.g. animals, plants.

L

Lactic acid One product of anaerobic respiration. It builds up in muscles with exercise. Important in yoghurt and cheese making processes.

Light energy Energy in the form of light.

Light microscope An instrument used to magnify specimens using lenses and light.

Limiting factor Factor which limits the rate of a reaction, e.g. temperature, pH, light levels (photosynthesis).

Line graph Used when both variables are continuous. The line should normally be a line of best fit, and may be straight or a smooth curve. (Exceptionally, in some (mainly biological) investigations, the line may be a 'point-to-point' line.)

Linear relationship The relationship between two continuous variables that can be represented by a straight line on a graph.

Lipase Enzyme which breaks down fats and oils into fatty acids and glycerol.

Lipid An oil or fat.

Liver A large organ in the abdomen which carries out a wide range of functions in the body.

М

Malnourished The condition when the body does not get a balanced diet.

Mean The arithmetical average of a series of numbers.

Median The middle value in a list of

Melosis The two-stage process of cell division which reduces the chromosome number of the daughter cells. It is involved in making the gametes for sexual reproduction.



- Menstrual cycle The reproductive cycle in women controlled by hormones.
- Mesophyll tissue The tissue in a green plant where photosynthesis takes place.
- Metabolic rate The rate at which the reactions of your body take place, particularly cellular respiration.
- Methane A hydrocarbon gas with the chemical formula CH₂. It makes up the main flammable component of biogas.
- Microorganism Bacteria, viruses and other organisms that can only be seen using a microscope.
- Mineral ion Chemical needed in small amounts as part of a balanced diet to keep the body healthy.
- Mitochondria The site of aerobic cellular respiration in a cell.
- Mitosis Asexual cell division where two identical cells are formed.
- Mode The number which occurs most often in a set of data.
- Molecule A particle made up of two or more atoms bonded together.
- Monitor Observations made over a period of time.
- Motor neuron Neuron that carries impulses from the central nervous system to the effector organs.
- system to the effector organs.

 MRSA Methicillin-resistant

 Staphylococus aureus. An
- antibiotic-resistant bacterium.

 Multicellular organism An organism which is made up of many different cells which work together. Some of the cells are specialised for different functions in the organism.
- Muscular tissue The tissue which makes up the muscles. It can contract and relax.
- Mutation A change in the genetic material of an organism.
- Mycoprotein A food based on the fungus Fusarium that grows and reproduces rapidly. It means 'protein from fungus'.

N

Natural classification system

Classification system based on the similarities between different living organisms.

Natural selection The process by which evolution takes place. Organisms produce more offspring than the environment can support so only those which are most suited to their environment – the 'fittest' – will

- survive to breed and pass on their useful characteristics.
- Negative pressure A system when the external pressure is lower than the internal pressure.
- Nerve Bundles of hundreds or even thousands of neurons
- Nervous system See Central nervous system.
- Net movement The overall movement of ...
- Neuron(s) Basic cell of the nervous system which carries minute
- electrical impulses around the body.

 Nitrate Ion Ion which is needed by plants to make proteins.
- Non-renewable Something which cannot be replaced once it is used
- Nucleus (of a cell) An organelle found in many living cells containing the genetic information.

0

- Obese Very overweight, with a BMI of over 30
- Oestrogen Female sex hormone which stimulates the lining of the womb to build up in preparation for a pregnancy.
- Opinion A belief not backed up by facts or evidence.
- Optic nerve The nerve carrying impulses from the retina of the eye to the brain.
- Oral contraceptive Hormone contraceptive that is taken by mouth.
- Organ A group of different tissues working together to carry out a particular function.
- Organ system A group of organs working together to carry out a particular function.
- Organic waste Waste material from living organisms, e.g. garden waste.
- Osmosis The net movement of water from an area of high concentration (of water) to an area of low concentration (of water) along a concentration gradient.
- Ova The female sex cells, eggs.
- Ovary Female sex organ which contains the eggs and produces sex hormones during the menstrual cycle.
- Overweight A person is overweight if their body carries excess fat and their BMI is between 25 and 30.
- Ovipositor A pointed tube found in many female insects which is used to lay eggs.

- Ovulation The release of a mature egg from the ovary in the middle of the menstrual cycle.
- Oxygen debt The extra oxygen that must be taken into the body after exercise has stopped to complete the aerobic respiration of lactic acid.
- Oxygenated Containing oxygen.

 Oxyhaemoglobin The molecule formed when haemoglobin binds to oxygen molecules.

P

- Pancreas An organ that produces the hormone insulin and many digestive enzymes.
- Pandemic When more cases of a disease are recorded than normal in a number of different countries.
- Parasite Organism which lives in or on other living organisms and gets some or all of its nourishment from this host organism.
- Partially permeable Allowing only certain substances to pass through.
- Pathogen Microorganism which causes disease.
- Perfluorocarbon Chemical which can be used as artificial blood.
- Period The stage in the menstrual cycle when the lining of the womb is lost
- Permanent vacuole A space in the cytoplasm filled with cell sap which is there all the time.
- Pesticide Chemical that kills animals.

 Phloem tissue The living transport
 tissue in plants which carries sugars
 around the plant.
- Photosynthesis The process by which plants make food using carbon dioxide, water and light energy.
- Phototropism The response of a plant to light, controlled by auxin.
- Pigment A coloured molecule.

 Pitultary gland Small gland in the brain which produces a range of hormones controlling body

functions

- Placebo A substance used in clinical trials which does not contain any drug at all.
- Plasma The clear, yellow liquid part of the blood which carries dissolved substances and blood cells around the body.
- Plasmid Extra circle of DNA found in bacterial cytoplasm.
- Platelet Fragment of cell in the blood which is vital for the clotting mechanism to work.



- Polydactyly A genetic condition inherited through a dominant allele which results in extra fingers and toes.
- Polytunnel Large greenhouse made of plastic.
- Positive pressure A system where the external pressure is higher than the internal pressure.
- Precise A precise measurement is one in which there is very little spread about the mean value. Precision depends only on the extent of random errors it gives no indication of how close results are to the true value.
- Predator An animal which preys on other animals for food.
- Prediction A forecast or statement about the way something will happen in the future. In science it is not just a simple guess, because it is based on some prior knowledge or on a hypothesis.
- Progesterone Female sex hormone used in the contraceptive pill.
- Protease An enzyme which breaks down proteins.
- Protein synthesis The process by which proteins are made on the ribosomes based on information from the genes in the nucleus.
- Puberty The stage of development when the sexual organs and the body become adult.
- Pulmonary artery The large blood vessel taking deoxygenated blood from the right ventricle of the heart to the lungs.
- Pulmonary vein The large blood vessel bringing blood into the left atrium of the heart from the lungs.
- Pyramid of blomass A model of the mass of biological material in the organisms at each level of a food chain.

Q

- Quadrat A piece of apparatus for sampling organisms in the field.
- Quantitative sampling Sampling which records the numbers of organisms rather than just the type.

R

Range The maximum and minimum values of the independent or dependent variables; important in ensuring that any pattern is detected.

- Receptor Special sensory cell that detects changes in the environment.
- Recessive The characteristic that will show up in the offspring only if both of the alleles are inherited.
- Recipient The person who receives a donor organ.
- Red blood cell Blood cell which contains the red pigment haemoglobin. It is biconcave discs in shape and gives the blood its red colour.
- Reflex arc The sense organ, sensory neuron, relay neuron, motor neuron and effector organ which bring about a reflex action.
- Reflex Rapid automatic response of the nervous system that does not involve conscious thought.
- Rehydrate To restore water to a system.
- Repeatable A measurement is repeatable if the original experimenter repeats the investigation using same method and equipment and obtains the same results.
- Reproducible A measurement is reproducible if the investigation is repeated by another person, or by using different equipment or techniques, and the same results are obtained.
- Resolution This is the smallest change in the quantity being measured (input) of a measuring instrument that gives a perceptible change in the reading.
- Respiration The process by which food molecules are broken down to release energy for the cells.
- Ribosome The site of protein synthesis in a cell
- Risk The likelihood that a hazard will actually cause harm. We can reduce risk by identifying the hazard and doing something to protect against that hazard
- Root hair cell Cell on the root of a plant with microscopic hairs which increases the surface area for the absorption of water from the soil.

S

- Safe medicine A medicine that does not cause any unreasonable side effects while curing a disease.
- Salivary gland Gland in the mouth which produces saliva containing the enzyme amylase.

- Sample size The size of a sample in an investigation.
- Secreting Releasing chemicals such as hormones or enzymes.
- Selective reabsorption The varying amount of water and dissolved mineral ions that are taken back into the blood in the kidney, depending on what is needed by the body.
- Sense organ Collection of special cells known as receptors which responds to changes in the surroundings (e.g. eye, ear).
- Sensory neuron Neuron which carries impulses from the sensory organs to the central nervous system.
- Sewage A combination of bodily waste, waste water from homes and rainfall overflow from street drains.
- Sewage treatment plant A site where human waste is broken down using microorganisms.
- Sex chromosome A chromosome which carries the information about the sex of an individual.
- Sexual reproduction Reproduction which involves the joining (fusion) of male and female gametes producing genetic variety in the offspring.
- Small intestine The region of the digestive system where most of the digestion of the food takes place.
- Solar energy (light energy) Energy from the Sun or other light source.
- Solute The solid which dissolves in a solvent to form a solution.
- Specialised Adapted for a particular function.
- Speciation The formation of a new species.
- Species A group of organisms with many features in common which can breed successfully producing fertile offspring.
- Stable medicine A medicine which does not break down under normal conditions.
- Statin Drug which lowers the blood cholesterol levels and improves the balance of HDLs to LDL.
- Stem cell Undifferentiated cell with the potential to form a wide variety of different cell types.
- Stent A metal mesh placed in the artery which is used to open up the blood vessel by the inflation of a tiny balloon.
- Steroid Drug that is used illegally by some athletes to build muscles and improve performance.



- Stimuli A change in the environment that is detected by sensory receptors.
- Stomata Openings in the leaves of plants (particularly the underside) which allow gases to enter and leave the leaf. They are opened and closed by the quard cells.

Sustainable food production

Methods of producing food which can be sustained over time without destroying the fertility of the land or ocean.

Synapse A gap between neurons where the transmission of information is chemical rather than electrical

Т

- Territory An area where an animal lives and feeds, which it may mark out or defend against other animals.
- Thalldomide A drug that caused deformities in the fetus when given to pregnant women to prevent morning sickness.
- Therapeutic cloning Cloning by transferring the nucleus of an adult cell to an empty egg to produce tissues or organs which could be used in medicine.
- Thermoregulatory centre The area of the brain which is sensitive to the temperature of the blood.
- Thorax The upper (chest) region of the body. In humans it includes the ribcage, heart and lungs.
- Tissue A group of specialised cells all carrying out the same function.
- Tissue culture Using small groups of cells from a plant to make new plants.
- Trachea The main tube lined with cartilage rings which carries air from the nose and mouth down towards the lungs.
- Transect A measured line or area along which ecological measurements (e.g. quadrats) are made.
- **Transfusion** The transfer of blood from one person to another.
- Transpiration The loss of water vapour from the leaves of plants through the stomata when they are opened to allow gas exchange for photosynthesis.
- Transpiration stream The movement of water through a plant from the roots to the leaves as a result of the loss of water by evaporation from the surface of the leaves.

- Transport system A system for transporting substances around a multicellular living organism.
- Trial run Preliminary work that is often done to establish a suitable range or interval for the main investigation.
- **Tuber** Modified part of a plant which is used to store food in the form of starch.
- Type 1 diabetes Diabetes which is caused when the pancreas cannot make insulin. It usually occurs in children and young adults and can be treated by regular insulin injections.

u

- Urea The waste product formed by the breakdown of excess amino acids in the liver
- Urine The liquid produced by the kidneys containing the metabolic waste product urea along with excess water and salts from the body.
- Urobilin Yellow pigment that come from the breakdown of haemoglobin in the liver.

V

- Vaccination Introducing small quantities of dead or inactive pathogens into the body to stimulate the white blood cells to produce antibodies that destroy the pathogens. This makes the person immune to future infection.
- Vaccine The dead or inactive pathogen material used in vaccination.
- Vacuum An area with little or no gas pressure.
- Valid Suitability of the investigative procedure to answer the question being asked.
- Valve Structure which prevents the backflow of liquid, e.g. the valves of the heart or the veins.
- Variable Physical, chemical or biological quantity or characteristic.
- Variable categoric Categoric variables have values that are labels. For example, names of plants or types of material.
- Variable continuous Can have values (called a quantity) that can be given by measurement (e.g. light intensity, flow rate, etc.).
- Variable control A variable which may, in addition to the independent

- variable, affect the outcome of the investigation and therefore has to be kept constant or at least monitored.
- Variable dependent The variable for which the value is measured for each and every change in the independent variable.
- Variable Independent The variable for which values are changed or selected by the investigator.
- Variegated Having different colours, e.g. a green and white leaf.
- VeIn Blood vessel which carries blood away from the heart. It usually carries deoxygenated blood and has valves to prevent the backflow of blood.
- Vena cava The large vein going into the right atrium of the heart carrying deoxygenated blood from the body.
- Ventilated Movement of air into and out of the lungs.
- Ventricles The large chambers at the bottom of the heart. The right ventricle pumps blood to the lungs, the left ventricle pumps blood around the body.
- VIIII The finger-like projections from the lining of the small intestine which increase the surface area for the absorption of digested food into the blood.
- Virus Microorganism which takes over body cells and reproduces rapidly, causing disease.

W

- White blood cell Blood cell which is involved in the immune system of the body, engulfing bacteria, making antibodies and making antitoxins.
- Wilting The process by which plants droop when they are short of water or too hot. This reduces further water loss and prevents cell damage.
- Withdrawal symptom The symptom experienced by a drug addict when they do not get the drug to which they are addicted.

X

- Xenotransplantation Transplanting tissues or organs from one species to another, e.g. pig organs into people.
- Xylem tissue The non-living transport tissue in plants, which transports water around the plant.



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The Periodic Table of Elements

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^{*} The Lanthanides (atomic numbers 58 – 71) and the Actinides (atomic numbers 90 – 103) have been omitted.

Cu and CI have not been rounded to the nearest whole number.



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