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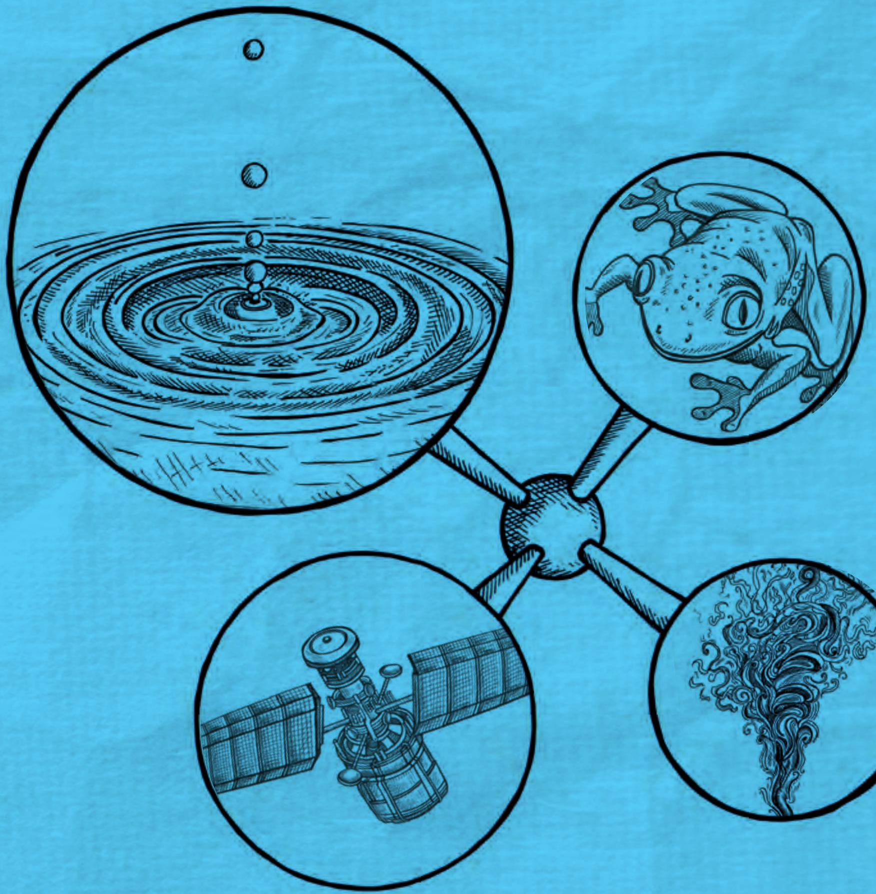

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REVISE AQA GCSE (9–1)

Combined Science: Trilogy

REVISION GUIDE

Higher

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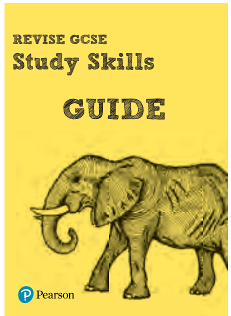

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Contents

1-to-1 page match with the Combined Science Higher Revision Workbook

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A small bit of small print:
AQA publishes Sample Assessment Material and the Specification on its website. This is the official content and this book should be used in conjunction with it. The questions in Now try this have been written to help you practise every topic in the book. Remember: the real exam questions may not look like this.

Microscopes and magnification

Elements

The **light microscope** was invented about 350 years ago. It uses light to form magnified images of cells and other tiny objects.

The best light microscope can produce magnifications of about 2000 times: ×2000.

The **electron microscope** was invented in the last century. It uses electrons to produce magnifications of up to 2 million times.

The higher magnification and resolving power of electron microscopes allow scientists to see and understand sub-cellular structures.

Resolving power

A microscope with a high **resolution** allows you to distinguish between two objects that are very close together.

Microscope	Resolution (nm)
light microscope	200
electron microscope (scanning)	10
electron microscope (transmission)	0.1

Maths skills: Magnification

You can calculate **magnification** using:

$$\text{magnification} = \frac{\text{size of image}}{\text{size of real image}}$$

You can rearrange the equation to find the size of the real object, if you know the magnification and the size of the image:

$$\text{size of real object} = \frac{\text{size of image}}{\text{magnification}}$$

Worked example

A light microscope has a ×10 eyepiece lens and a ×40 objective lens. The image of an onion cell viewed using this microscope is 0.2 mm long.

(a) Calculate the total magnification of the microscope. **(1 mark)**

total magnification = 10 × 40 = ×400

(b) Use your answer to (a) to calculate the real length of the cell. **(1 mark)**

$$\frac{\text{size of image}}{\text{magnification}} = \frac{0.2\text{ mm}}{400} = 0.0005\text{ mm}$$

1 mm = 1000 µm

0.0005 × 1000 = 0.5 µm

Scale bars

Diagrams and photos of microscope images often have a scale bar on them.

A scale bar lets you:

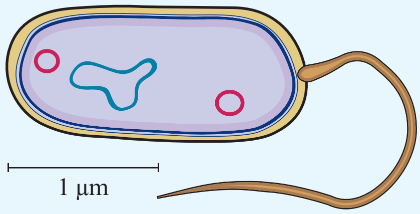
- easily see the real sizes of the different objects in the diagram or photo
- calculate the magnification, if you do not know what this is.

If you want to calculate the magnification, you need to use a ruler to measure the real length of the scale bar.

It is better to make your measurements in millimetres, mm (rather than in centimetres, cm).

Worked example

The diagram shows a cell with a scale bar.



Calculate the magnification of this image. **(2 marks)**

length of scale bar on diagram = 20 mm

= 20 × 1000 = 20 000 µm

real length (from scale bar) = 1 µm

$$\text{magnification} = \frac{20\,000}{1} = \times 20\,000$$

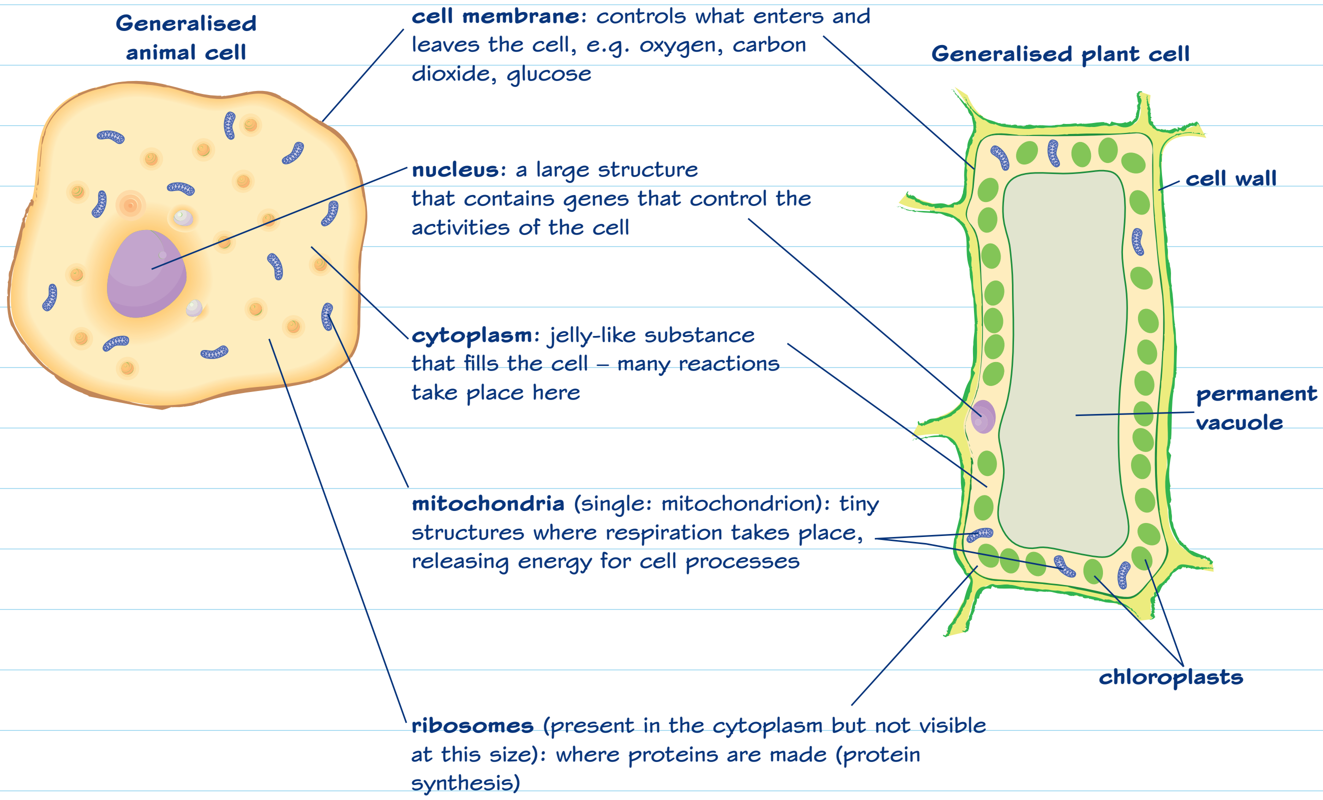
Now try this

A light microscope has a ×5 eyepiece lens and a ×20 objective lens. The image of a cell is 15 mm long. Calculate the actual length of the cell. Give your final answer in µm. **(3 marks)**

Animal and plant cells

Animal **cells** and plant cells contain smaller structures which have different functions.

Structures of animal cells and plant cells



Worked example

Name the three structures that are present in most plant and algal cells, but are not present in animal cells. Describe the function of each structure. **(3 marks)**

Plant and algal cells contain a permanent **vacuole**. This is filled with cell sap and helps to keep the cell rigid.

They have a **cell wall** made of cellulose, which strengthens the cell.

They also contain **chloroplasts**. These are the structures where photosynthesis takes place to make food for the cell.

Algae are simple aquatic organisms. Their cells have a similar structure to plant cells, so algae used to be classified as plants. They are now classified as protists (see pages 34 and 74).

Take care not to confuse the cell wall with the cell membrane.

Bacterial cells also have cell walls, but these are not made from cellulose.

Now try this

1 Name the cell structures that are found in both animal cells and plant cells. **(5 marks)**

2 Muscle cells contain more mitochondria than skin cells. Suggest an explanation for this. **(2 marks)**

3 Cells found in plant roots do not usually contain chloroplasts. Suggest an explanation for this. **(2 marks)**

Eukaryotes and prokaryotes

Animal cells and plant cells are **eukaryotic** cells, but bacterial cells are **prokaryotic** cells.

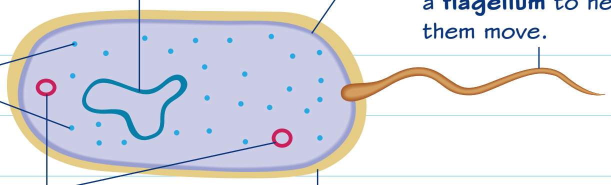
Bacterial cells

Eukaryotic cells and prokaryotic cells have:

- a cell membrane
- cytoplasm.

But prokaryotic cells:

- are surrounded by a cell wall
- do not have a nucleus.



Standard form

Numbers in standard form have two parts.

$$7.3 \times 10^{-6}$$

This part is a number greater than or equal to 1 and less than 10.

This part is a power of 10.

You can use standard form to write very large or very small numbers.

$$920\,000 = 9.2 \times 10^{5}$$

Numbers greater than 10 have a positive power of 10.

$$0.007\,03 = 7.03 \times 10^{-3}$$

Numbers less than 1 have a negative power of 10.

Maths skills: Finding a power

You can count decimal places to convert between numbers in standard form and ordinary numbers.

3 jumps

$$7900 = 7.9 \times 10^{3}$$

7900 > 10 so the power is positive

4 jumps

$$0.000\,35 = 3.5 \times 10^{-4}$$

0.000 35 < 1 so the power is negative

Be careful!

Don't just count zeros to work out the power.

Worked example

An animal cell is 0.01 mm long and a bacterial cell is 1 µm long.

(a) Give these lengths in metres, m, in standard form. **(2 marks)**

$0.01\text{ mm} = 0.01 \times 10^{-3}\text{ m} = 1 \times 10^{-5}\text{ m}$

$1\,\mu\text{m} = 1 \times 10^{-6}\text{ m}$

(b) How many orders of magnitude greater is the size of the animal cell? **(1 mark)**

$0.01\text{ mm} = 0.01 \times 10^{3}\,\mu\text{m} = 10\,\mu\text{m}$

So the animal cell is $\frac{10}{1} = 10$ times larger. This is one order of magnitude.

These units use the prefixes milli, m, and micro, µ. They refer to powers of 10:

milli-	micro-	nano-
10^{-3}	10^{-6}	10^{-9}

1 nm (nanometre) is 1×10^{-9} m.

You can also work this out using the powers of 10 in the lengths given in standard form.

The difference between 5 and 6 is 1, showing one order of magnitude difference.

Now try this

(a) Give these lengths in metres, m, in standard form:
(i) 75 µm (the diameter of a plant cell); (ii) 750 nm (the diameter of a mitochondrion). **(2 marks)**

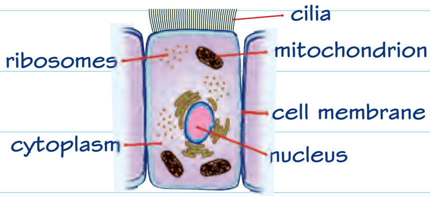
(b) Determine how many orders of magnitude greater a plant cell is than a mitochondrion. **(1 mark)**

Specialised animal cells

Animal cells may be specialised to carry out a particular function.

Ciliated cells

Cilia are tiny hair-like structures on the surface of some cells. They can move in organised ways to push substances past the surface of the cell.



Ciliated cells line the **trachea** or windpipe. These sweep mucus away from the lungs, carrying away dirt and bacteria.

Differentiation

As an organism develops, cells **differentiate** to form different specialised cells:

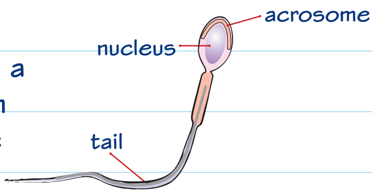
- Most types of animal cell differentiate at an early stage.
- Cells acquire different structures so they can carry out a particular function.
- Cell division in mature animals is mainly for repair and replacement.

You can revise the structures in generalised animal cells on page 2 and stem cells on page 8.

Sperm cells

Sperm cells carry the male parent's genetic information to the female parent's egg cell.

They may have to travel a relatively long way, then get through the surface of the egg cell.

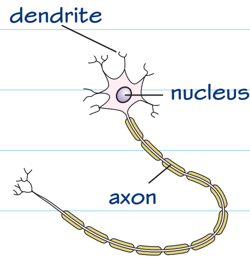


A sperm cell has:

- a tail, and many mitochondria to release the energy needed for the tail to move
- enzymes in its acrosome to digest the outer layers of an egg cell.

Nerve cells

Nerve cells carry electrical impulses from one part of the body to another, which may be a long way apart. Nerve cells often connect with one another.

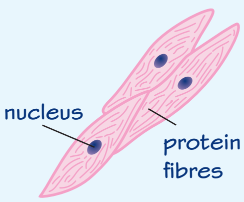


A typical nerve cell has:

- a long axon to connect distant parts
- tiny finger-like dendrites that make connections with other nerve cells.

Worked example

The diagram shows muscle cells. Describe, using information shown, how they are specialised for their function. **(2 marks)**



The protein fibres slide over each other, making the muscle cells contract.

Muscle cells also contain many mitochondria. These supply the energy needed to keep the muscles working.

Now try this

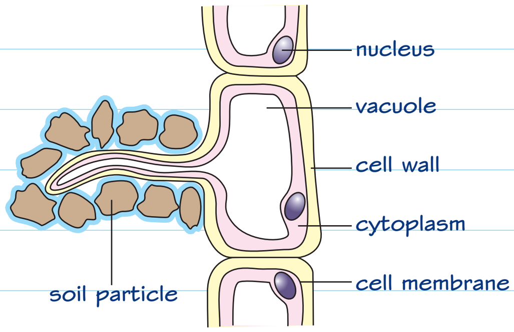
Different specialised cells have different shapes. Explain how the shapes of ciliated cells in the trachea and sperm cells are related to their functions. **(4 marks)**

Specialised plant cells

Plant cells may be **specialised** to carry out a particular function.

Root hair cells

Root hair cells are found on the surface of plant roots. They absorb water and mineral ions.



A root hair cell has:

- a large vacuole to increase the rate of absorption of water by **osmosis**
- many mitochondria to release the energy needed for the **active transport** of mineral ions.

You can revise diffusion on page 9, osmosis on page 11 and active transport on page 13.

Differentiation

As an organism develops, cells **differentiate** to form different specialised cells:

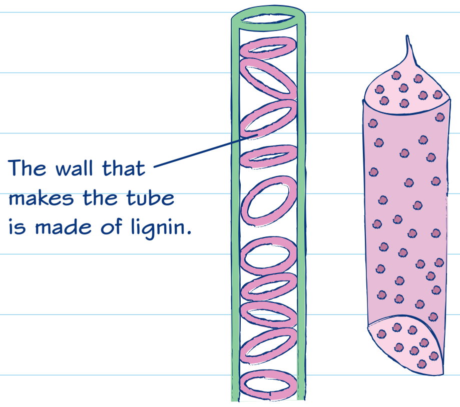
- Meristem cells in the tips of roots and shoots are undifferentiated cells.
- Cells acquire different structures so they can carry out a particular function.

Unlike most types of animal cells, many types of plant cells keep the ability to differentiate through their life.

You can revise the structures in generalised plant cells on page 2 and stem cells on page 8.

Xylem cells

Xylem cells form the **transport tissue** that carries water and mineral ions from roots to the rest of the plant. Lignin builds up in xylem cells. These die and form hollow tubes.

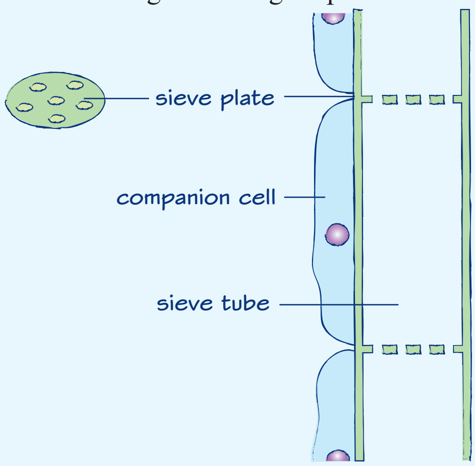


Xylem cells have:

- **lignin** to provide strength and support
- no end walls, so water and mineral ions can flow easily through the plant
- **pits** that let water and ions move out.

Worked example

Phloem cells form the transport tissue that carries dissolved sugars through a plant.



Explain two ways in which phloem cells are specialised for their function. **(4 marks)**

The cell walls between cells form sieve plates, which let solutions move from cell to cell. They have companion cells which contain lots of mitochondria. These release the energy needed for the active transport of sugars.

Now try this

Root hair cells have large surface areas to increase the rate of absorption of water and mineral ions. Describe the structure that provides this feature. **(2 marks)**

Mention the shape of this structure and where it grows.

Using a light microscope

Practical skills You can use a **light microscope** to observe, draw and label a selection of plant and animal cells.

Required practical

Observing cells

Aim

to make a slide with onion cells, then use a microscope to observe, draw and label these and other cells

Apparatus

- small piece of onion
- forceps
- microscope slide with coverslip
- iodine solution
- prepared slides of animal and plant cells
- light microscope

Method: Preparing a specimen

1 Use the forceps to peel a thin layer of epidermal tissue from the onion.
2 Carefully lay the thin layer on the slide.
3 Add one or two drops of iodine solution.
4 Lower the coverslip over the onion layer. Remove excess liquid with tissue paper.

Method: Observing a specimen

5 Place a slide on the microscope stage.
6 Turn the turret to the lowest power objective lens.
7 Looking from the side, use the coarse wheel to lower the lens so it almost touches the slide.
8 Looking through the eyepiece, use the coarse wheel to raise the objective lens until the image is focused.
9 Turn the turret to select a higher power objective lens. Use the fine wheel to focus the image again.
10 Repeat steps 5–9 with other slides.

Results

Make a pencil drawing of one or more cells:

- Draw outlines of what you see.
- Use shading only to distinguish between structures.
- Identify structures using labels with straight lines.
- Write the magnification on your drawing.

You can revise calculating magnification on page 1.

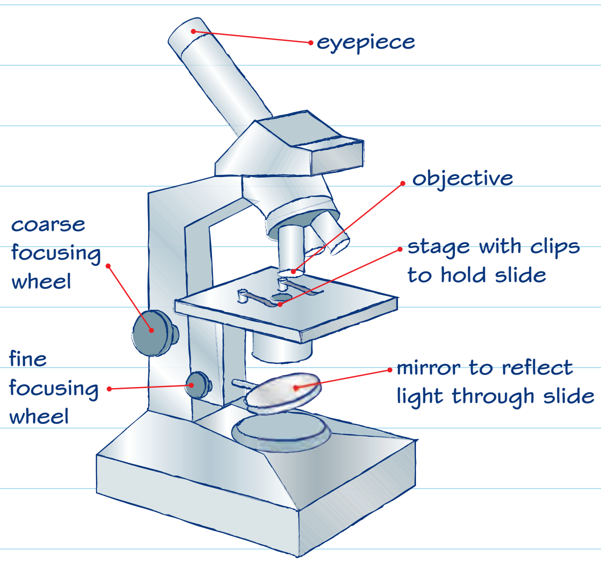
Onion skin is easily peeled away in single layers of cells.

Wear eye protection when you handle the iodine solution. Wash off spills straight away because it will stain skin and clothes.

You may find it easier to position the layer of onion if you put a drop of water on the slide first. Don't let the tissue curl over on itself.

Place one edge of the coverslip on the slide at 45°. Gently lower the other edge so that liquid and bubbles are pushed out.

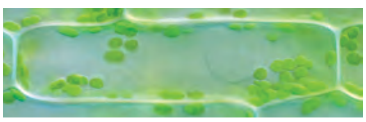
The light microscope



Some modern microscopes have a lamp rather than a mirror.

Now try this

Make a labelled drawing of the onion epidermal cells.
Identify the cell wall, nucleus, cytoplasm and a chloroplast. **(5 marks)**



Mitosis

The nucleus of a cell contains **chromosomes** made of **DNA** molecules which carry a large number of **genes**. The chromosomes are normally found in pairs in body cells.

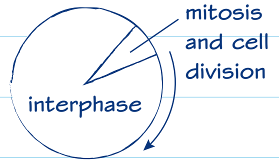
The cell cycle

There are three main stages in the **cell cycle**:

1. **interphase**, the stage where the cell:
   - grows
   - increases the numbers of structures such as ribosomes and mitochondria
   - **replicates** its DNA to form two copies of each chromosome.
2. **mitosis**, the stage where:
   - one set of chromosomes is pulled to each end of the cell
   - the nucleus divides.
3. **cell division**, the stage immediately after mitosis where:
   - cell membranes and cytoplasm divide
   - two identical cells form.

Interphase

A cell spends most of its life in interphase.



Three things to remember

- mi-To-sis makes Two cells
- mI-tosis makes cells that are genetically Identical to the parent cell
- Diploid means Double (two sets of) chromosomes

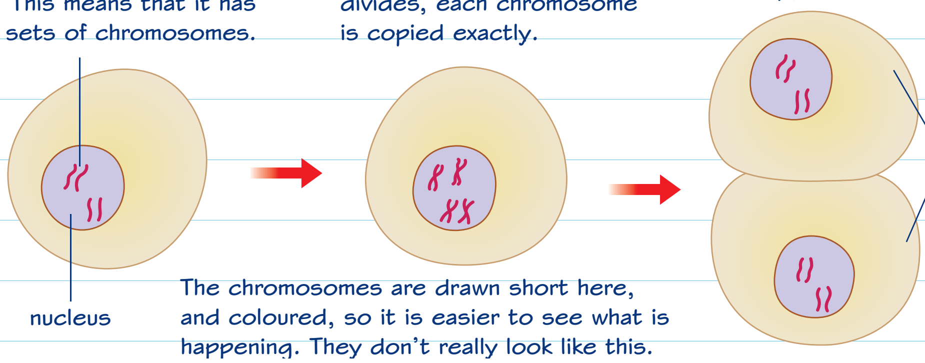
Parent cell and two daughter cells

The cell that divides is called the **parent cell**. → The parent cell divides to form two **daughter cells**.

The parent cell is a **diploid** cell. This means that it has two sets of chromosomes.

Before the parent cell divides, each chromosome is copied exactly.

When the cell divides in two, each cell gets one copy of each chromosome.



nucleus

The chromosomes are drawn short here, and coloured, so it is easier to see what is happening. They don't really look like this.

The daughter cells are genetically identical to each other and the parent cells. They are also diploid cells.

Worked example

Give **three** situations in which mitosis is used to produce new cells. **(3 marks)**

Mitosis produces new body cells for:

- growth
- repair to damaged parts of the body.

It also produces new individuals by asexual reproduction.

Cell division by mitosis is important in the growth and development of multicellular organisms.

You can revise asexual reproduction on page 61.

Now try this

Explain why daughter cells produced by mitosis are genetically identical to each other and to the parent cell. **(3 marks)**

Stem cells

Stem cells are undifferentiated cells in an organism. They can produce many more cells of the same type, and specialised cells by **differentiation**.

Stem cells in animals

A zygote is a single cell formed when an egg cell and sperm cell join together. This divides to form a ball of cells called an **embryo**:

- the embryo contains **embryonic stem cells**, which differentiate to form many different specialised cell types.

Adult animals retain some stem cells. The bone marrow contains **adult stem cells**. These form many cell types, including blood cells.

Stem cells in plants

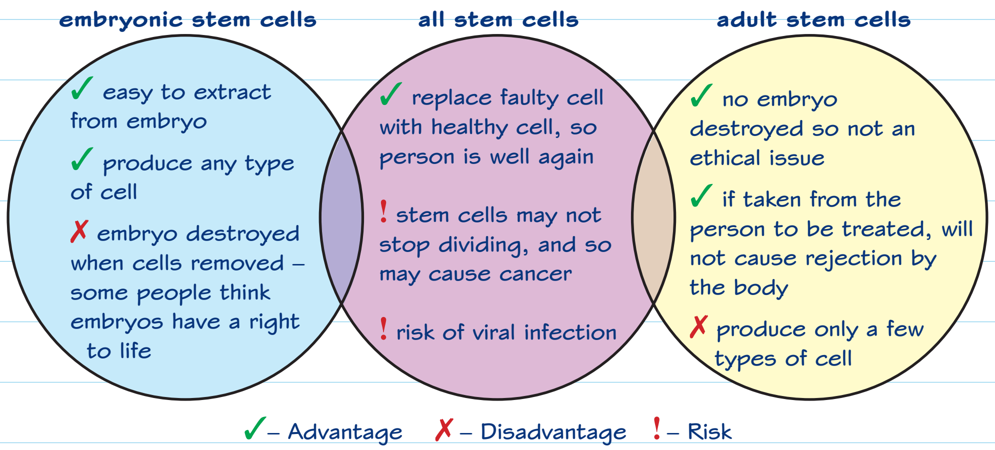
The **meristems** in plants contain stem cells.

Meristem tissue is found at the tips of roots and shoots. It differentiates throughout the life of the plant:

- in roots to form root hair cells, xylem, phloem and other cells in the root
- in shoots to form mesophyll cells, xylem, phloem and other cells in the stems and leaves.

Stem cell treatment

Stem cells may be able to help to treat conditions such as diabetes and paralysis. Injected stem cells may be able to replace damaged or missing cells in the pancreas or nervous system.



Worked example

Stem cells from meristems in plants can be used to produce clones rapidly and economically. Explain **one** possible use of producing plants this way. **(2 marks)**

If a crop plant has a useful feature, such as resistance to disease, it could be cloned. This would provide large numbers of these plants for farmers to grow.

Clones are genetically identical individuals.

Cloning could also save rare plant species from extinction by producing large numbers of these plants.

Now try this

Therapeutic cloning is a way to produce an embryo using a cell from a patient. It involves replacing the nucleus in an egg cell with the nucleus from one of the patient's cells. The egg cell is then stimulated to make it divide to form an embryo.

Explain an advantage and a disadvantage of treating a patient with stem cells produced in this way. **(4 marks)**

Diffusion

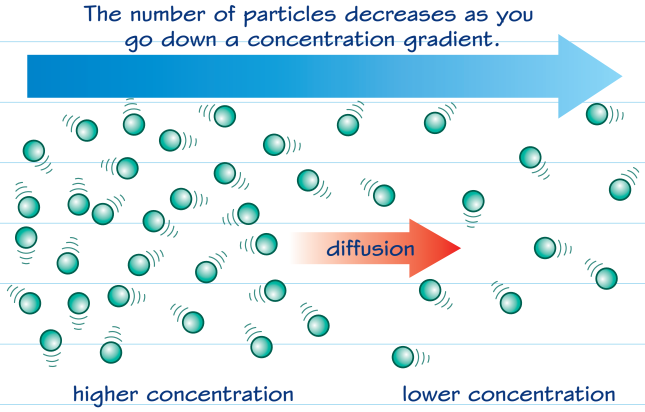
Substances may move into and out of cells by **diffusion** across cell membranes.

Net movement of particles

Diffusion is the spreading out of:
- the particles of a gas, or
- the particles of any substance in solution.

Diffusion results in an overall movement of particles down a **concentration gradient**:
- from an area of higher concentration to an area of lower concentration.

The rate of diffusion increases when:
- the difference in concentration increases, so the concentration gradient increases
- the temperature increases, so the particles move more quickly.

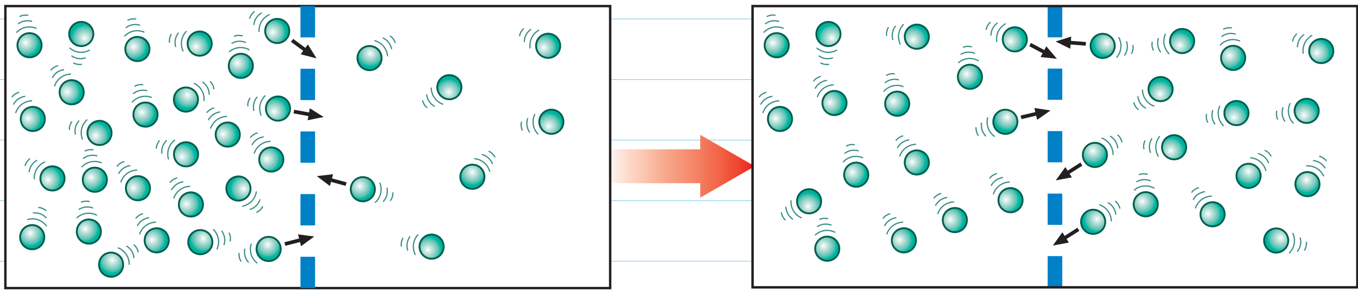


Diffusion explains why you can smell cooking from the next room, and why ink spreads through a glass of water without stirring.

Diffusion across membranes

Diffusion also happens across membranes.

In addition to the two factors above, the rate of diffusion increases when:
- the **surface area** of the membrane **increases**
- the **thickness** of the membrane **decreases**.



Molecules pass through the membrane in both directions. The rate of movement from left to right is greater than the rate of movement from right to left.

There is a net movement of particles from left to right until their concentration is the same on both sides.

Particles remain in random and continuous motion before, during and after diffusion.

Worked example

Describe three examples of the movement of substances into or out of animal cells by diffusion. **(3 marks)**

During gas exchange, oxygen moves into cells by diffusion, and carbon dioxide moves out of the cells by diffusion.

Urea is a waste product. It moves out of cells into the blood plasma by diffusion.

Diffusion also happens in plants, such as gas exchange in the leaves during photosynthesis.

You can revise gas exchange in the lungs on page 22.

Now try this

1 Explain diffusion in terms of the particles involved. **(3 marks)**
2 Explain how the rate of diffusion changes as the temperature increases. **(2 marks)**

Exchange surfaces

Multicellular organisms have adaptations to allow effective exchange of materials.

Surface area to volume ratio

Single-celled organisms have high **surface area to volume ratios**. This means that:

- there is a relatively large surface area of cell membrane for diffusion to occur
- the distances from the cell membrane to the interior of the cell are small.

Molecules move in and out of a single-celled organism well enough to meet its needs.

However, multicellular organisms need:

- **exchange surfaces** to provide large surface area to volume ratios
- **transport systems** to maintain high concentration gradients.

Maths skills: Calculating surface area to volume ratio

Imagine a cube-shaped cell with sides 1 µm long. It has six equal square sides:

- surface area = $6 \times (1 \times 1) = 6\ \mu m^2$
- volume = $1 \times 1 \times 1 = 1\ \mu m^3$

The cell's surface area to volume ratio is: $\frac{6}{1} = 6$

Surface area to volume ratio decreases with increasing size. For example, for cubes:

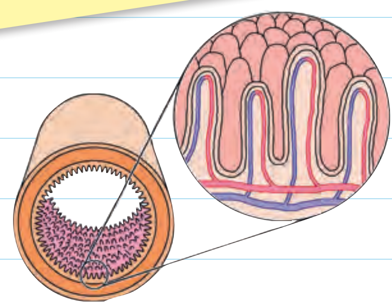
Length of side (µm)	Surface area to volume ratio
10	0.6
100	0.06

Increasing the effectiveness of an exchange surface

The effectiveness of an exchange surface increases with:

- increase in surface area → e.g. alveoli in lungs, or villi in small intestine
- a shorter distance for diffusion → e.g. surfaces are one cell thick
- maintenance of a high concentration gradient → e.g. animals have an efficient blood supply, lungs are ventilated

The fast removal of substances maintains a steep concentration gradient so diffusion is faster.

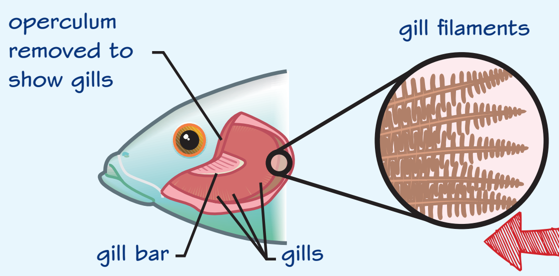


For example, the lining of the small intestine is folded into many tiny finger-like structures called villi. These provide:

- a large surface area for diffusion
- a single layer of cells for a short diffusion path
- a network of capillaries to carry food molecules away.

Worked example

The diagram shows the gills in a fish. Describe how they are adapted for gas exchange. **(2 marks)**



The gills have tiny finger-like gill filaments. These greatly increase the surface area available for gas exchange.

You can revise the adaptations of the lungs on page 22, and of leaves on page 27.

Now try this

1 Describe **two** ways in which a high concentration gradient can be maintained. **(2 marks)**

2 Explain why multicellular organisms need exchange surfaces but single-celled organisms do not. **(4 marks)**

Osmosis

Water may move across cell membranes by **osmosis**.

Explaining osmosis

Osmosis is the diffusion of water:

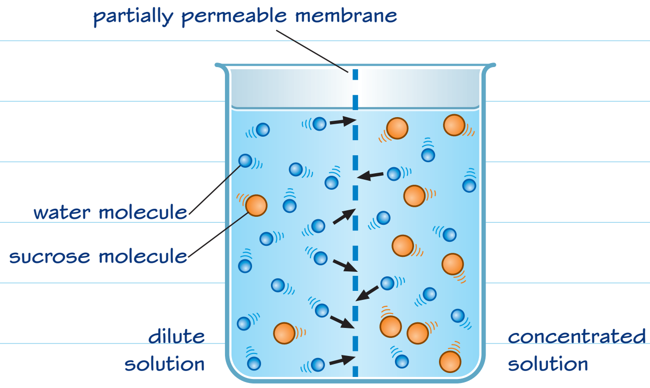
- from a dilute solution
- to a concentrated solution
- through a **partially permeable membrane**.

A partially permeable membrane:

- allows small molecules such as water molecules to pass through it
- does not allow ions or larger molecules such as sucrose to pass through it.

Cell membranes are partially permeable. Water can diffuse across them but sugars cannot.

This diagram shows how there is a net movement of water from a dilute sucrose solution to a concentrated sucrose solution.



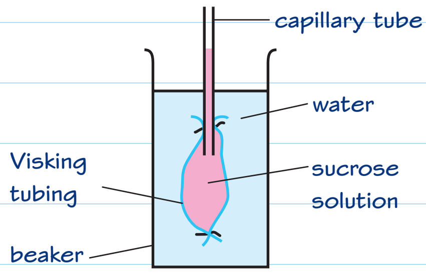
Investigating osmosis

Visking tubing is an artificial, partially permeable membrane. It is supplied dry and is soaked in water to soften it before use.

The diagram on the right shows a typical osmosis experiment. The Visking tubing is:

- tied at the bottom with cotton thread
- filled with sucrose solution
- tightly fitted around a narrow glass capillary tube and tied with thread
- placed in a beaker of water.

There is a net movement of water from the beaker into the sucrose solution.



Over time, the volume of liquid inside the Visking tube increases. The level of liquid in the capillary tube rises.

Worked example

Red blood cells are placed on a microscope slide. A few drops of concentrated sucrose solution are added, and the red blood cells are observed using a microscope. They decrease in size. Explain these observations. **(2 marks)**

The sucrose solution is more concentrated than the cytoplasm in the red blood cells. Water moves across the cell membrane from the cytoplasm into the sucrose solution, causing the red blood cells to shrink.

You see similar results with other types of cell. Cells increase in size, and may even burst, if placed in water or very dilute solutions.

This is an example of osmosis, with the cell membrane acting as a partially permeable membrane.

You may see the term 'semi-permeable membrane' instead of 'partially permeable membrane'.

Now try this

1 Describe what is meant by osmosis. **(3 marks)**

2 Sugar is sprinkled over some cut pieces of fruit. A liquid gradually appears on the cut surfaces of the fruit. Explain this observation. **(3 marks)**

The sugar dissolves to form a concentrated solution.

Investigating osmosis

Practical skills

You can investigate the effect of **osmosis** on the mass of plant tissue.

Required practical

Concentration and osmosis

Aim

to investigate the effect of different sucrose concentrations on the mass of potato tissue

You could use different concentrations of sodium chloride instead.

Apparatus

- potato
- cork borer, cutting board and knife
- ruler with 1-mm scale divisions
- balance, precise to ±0.01 g
- different concentrations of sucrose
- boiling tubes with bungs and labels

A suitable range is 0–1.0 mol/dm³ sucrose solution. Distilled water provides the 0 mol/dm³ solution. If you use sodium chloride, use 0–0.5 mol/dm³ (0–1.0 mol/dm³ dissolved ions).

You could use labelled Petri dishes instead.

Method

1 Use the cork borer to make potato cylinders. Trim them to about 30 mm.
2 Two-thirds fill each boiling tube with a different sucrose solution.
3 Dry the outside of a potato cylinder with a paper towel, then measure and record its mass. Add it to one of the solutions.
4 Repeat step 3 for each different solution.
5 After about 30 minutes, remove each potato cylinder. Dry them and record their mass.

Make sure all the potato cylinders are the same length.

You could also measure and record the new lengths, and then analyse those results.

You could wait for up to 24 hours instead.

Results

Make a suitable table to record your results. This one has some example results in it.

Sucrose conc. (mol/dm³)	Start mass (g)	End mass (g)	Change (g)	% change
0	2.00	2.53	+0.53	+26.5
0.25	2.15	2.23		
0.50	2.05	1.80		
0.75	1.96	1.53		
1.00	2.08	1.45	−0.63	−30.3

Analysis

1 Calculate the change in mass and percentage change in mass for each potato cylinder.
2 Plot a graph with:
   - percentage change in mass on the vertical axis
   - concentration of sucrose on the horizontal axis.

Maths skills: Calculating percentage change

percentage change in mass =

$$\frac{\text{(final mass} - \text{initial mass)}}{\text{initial mass}} \times 100$$

A negative value means the mass decreased.

Now try this

(a) Calculate the percentage change in mass for the results in the table. **(3 marks)**
(b) Plot a suitable graph using all the percentage changes in mass. **(3 marks)**
(c) Use your graph to estimate the concentration of the potato tissue. **(1 mark)**

This is when the percentage change in mass is zero.

Active transport

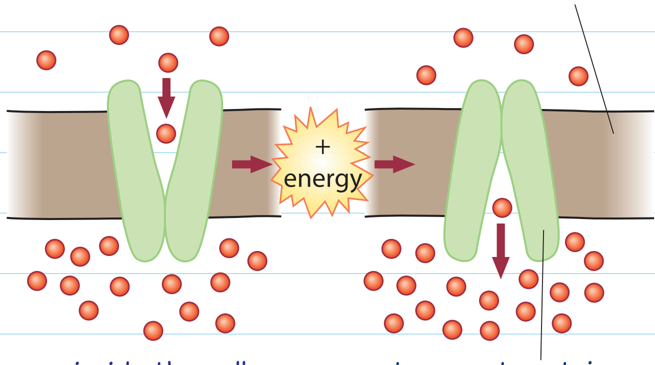
Unlike diffusion and osmosis, **active transport** requires **energy** from respiration to happen.

Explaining active transport

Active transport moves substances:
- from a more dilute solution
- to a more concentrated solution, and
- this requires energy from **respiration**.

Active transport lets substances move against a **concentration gradient**.

Cell membranes contain 'transport proteins'. The diagram shows how energy allows one of these molecules to change shape, which moves a solute particle into a cell.



Active transport in the gut

Glucose is provided by the food we eat. It must be absorbed across the wall of the **small intestine** into the bloodstream. Active transport of glucose molecules means:
- glucose can be absorbed, even if its concentration in the blood is higher than its concentration in the small intestine.

It is important because cells need glucose for respiration. This happens in the mitochondria (you can revise cell structure on page 2).

Active transport in roots

Plants need **mineral ions** such as nitrate ions, NO_3^-, for healthy growth. The **root hair cells** absorb mineral ions from soil water. The concentration of ions in soil water is very low. Active transport of mineral ions means:
- plants can absorb mineral ions, even from very dilute solutions.

Transport processes

Process	Features
diffusion	• Substances move from high concentration of substance to low concentration. • Membranes are not needed. • No energy is needed.
osmosis	• Water moves from a dilute solution to a concentrated solution. • Partially permeable membrane is needed. • No energy is needed.
active transport	• Substances move from low concentration of substance to high concentration. • Membranes are needed. • Energy is needed.

Worked example

A farmer's field becomes flooded with water after heavy rain. Explain why the plants growing there are unable to absorb enough nitrate ions for healthy growth. **(4 marks)**

Plants absorb nitrate ions from the soil by active transport. This needs energy from cell respiration. Water-logged soil contains very little air. There is not sufficient oxygen for enough active transport by root hair cells.

Plants need nitrate ions so they can make proteins. Nitrate deficiency causes stunted growth in plants.

Some substances are toxic to cells because they prevent respiration. Active transport will also stop in the presence of these substances.

Now try this

Explain why cells involved in active transport contain many mitochondria. **(2 marks)**

Extended response – Cell biology

There will be at least one 6-mark question on your exam paper. For these questions, you will need to think scientifically and structure your answer logically, showing how the points you make are related to each other.

For the questions on this page, you can revise cells and transport on pages 2 and 9–13.

Worked example

Substances are transported into and out of cells by diffusion, osmosis and active transport. Compare these three processes. In your answer, you should include a suitable example of each process in living organisms. **(6 marks)**

Diffusion is the spreading out of particles, producing a net movement from an area of higher concentration to an area of lower concentration. It is important for gas exchange in the lungs and gills.

Osmosis also involves diffusion, but only of water. It is important for water absorption by root hair cells. Unlike diffusion, which can take place in gases or in solutions, osmosis only involves solutions.

In addition, although diffusion can happen across cell membranes but does not have to, osmosis only happens across partially permeable membranes such as cell membranes.

Active transport is important for the absorption of mineral ions by plant root hair cells. During active transport, substances move from a more dilute solution to a more concentrated solution. This is against a concentration gradient, whereas diffusion happens down a concentration gradient.

Diffusion and osmosis are passive processes that do not need energy from respiration. However, active transport does need energy from respiration and cannot happen without it.

Command word: Compare

When you are asked to **compare** something, you must describe the similarities and/or differences between two or more things. It is not enough just to write about one of the things.

This part of the answer defines diffusion and gives suitable examples, but does not yet compare it with the other two processes. Carbon dioxide and oxygen could be named as the gases involved.

The answer should have stated that osmosis involves the net movement of water from a dilute to a more concentrated solution.

The use of the connective 'in addition' signals that a related idea is about to follow.

The use of the connective 'whereas' signals that an opposite idea is about to follow.

The use of the connective 'however' also signals that an opposite idea follows.

You need to show comprehensive knowledge and understanding, using relevant scientific ideas, to support your answer. The three transport processes are defined, and suitable examples of each one are given. Their similarities and differences are identified in a logical way.

Now try this

Cells are the basic unit of all animals and plants. Compare the structure of a typical animal cell with the structure of a typical plant cell. In your answer, you should name the main sub-cellular structures and describe their functions. **(6 marks)**

You must provide a written answer, but a labelled diagram can help to make some points clearer.

The digestive system

An **enzyme** is a biological catalyst: a protein that can speed up or control a specific reaction.

Digestive enzymes

Digestive enzymes convert larger food molecules into smaller, soluble molecules that can be absorbed into the bloodstream:

1. **Carbohydrase** enzymes

   carbohydrates → simple sugars

   Amylase is produced by the salivary glands, pancreas and small intestine. It breaks down **starch** in the mouth and small intestine.

2. **Protease** enzymes

   proteins → amino acids

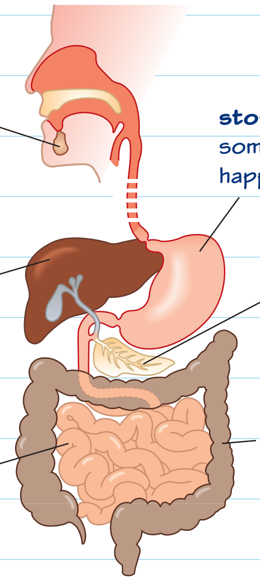
   Produced by the stomach, pancreas and small intestine. Breakdown of **proteins** occurs in the stomach and small intestine.

3. **Lipase** enzymes

   lipids → fatty acids + glycerol

   Produced by the pancreas and small intestine. Breakdown of **lipids** (fats and oils) occurs in the small intestine.

The digestive system



The **digestive system** is an organ system in which several organs work together to digest and absorb food.

Worked example

Describe **two** uses of the products of digestion by the body. **(2 marks)**

Simple sugars can be used to build new carbohydrates.

Some of the glucose produced by digestion of carbohydrates is used in respiration.

Other products of digestion can be used to build other new substances:

- amino acids for new proteins
- fatty acids and glycerol for new lipids.

You can revise the role of enzymes in metabolism (all the reactions in a cell or body) on page 46.

Principles of organisation

The bodies of large multicellular organisms are organised into different **organ systems**.

Cell	Tissue	Organ	Organ system
basic building block of all living organisms	group of cells with a similar structure and function	combination of tissues, each with specific functions	two or more organs working together
e.g. muscle cell, secretory cell	e.g. muscular tissue, glandular tissue, epithelial tissue	e.g. heart, stomach, lungs, kidney	e.g. digestive system, circulatory system, respiratory system

Now try this

Make a table to summarise the features of amylase, proteases and lipases. In your table, show their sites of production and action, the substances they break down and the products formed. **(6 marks)**

Food testing

Practical skills

You can use **qualitative reagents** to test for a range of carbohydrates, lipids and proteins.

Required practical

Chemical tests for food

These are **qualitative tests**. They show if a substance is present but not how much.

Aim

to investigate different types of food to identify the substances they contain

Apparatus

- eye protection
- test tubes and test-tube rack
- hot water bath
- distilled water
- Benedict's solution
- iodine solution
- Sudan III stain in ethanol solution
- Biuret reagent
- food samples

Make a hot water bath by half filling a beaker with hot (not boiling) water from a kettle.

Wash spills off clothing or skin immediately.

Ethanol is highly flammable.

Methods

Before each test, mix a small food sample with about 2 cm^3 of distilled water in a test tube.

If you are given larger pieces of food, cut them into small pieces or grind them with a pestle and mortar.

Test for reducing sugars: Add a few drops of Benedict's solution and heat in the hot water bath for 5 minutes. Record any colour change.

Glucose and fructose are **reducing sugars**, but sucrose (table sugar) is not.

Test for starch: Add a few drops of iodine solution. Record any colour change.

Test for lipids: Add a few drops of Sudan III stain solution and shake to mix. Record whether a red upper layer forms.

You could just use ethanol instead, and look for a cloudy upper layer.

Test for proteins: Add an equal volume of Biuret reagent and shake to mix. Record any colour change.

Results

Make a table to record your results. This one shows the expected results for each substance.

Test reagent	Substance detected	Colour of reagent or negative result	Colour or result if substance present
Benedict's solution	reducing sugars	blue	green → orange → red (depending on amount of sugar)
iodine solution	starch	orange–brown	blue–black
Sudan III stain in ethanol	lipids	colourless upper layer	red upper layer
Biuret reagent	proteins	blue	pink or purple

Now try this

Suggest **two** reasons to explain why a hot water bath is safer to use in this investigation, rather than a Bunsen burner. **(3 marks)**

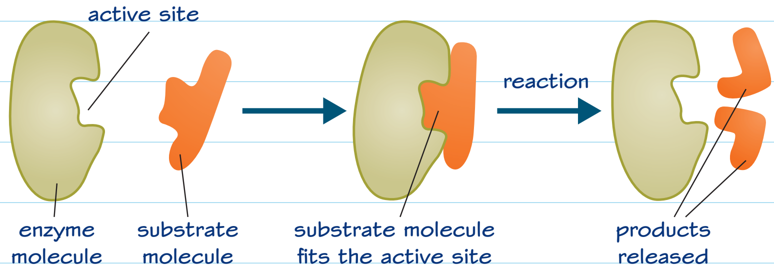
Think about how the test for reducing sugars is carried out, and the nature of the substance used in the test for lipids.

Enzymes

The **lock-and-key theory** is a simple model to explain the action of enzymes.

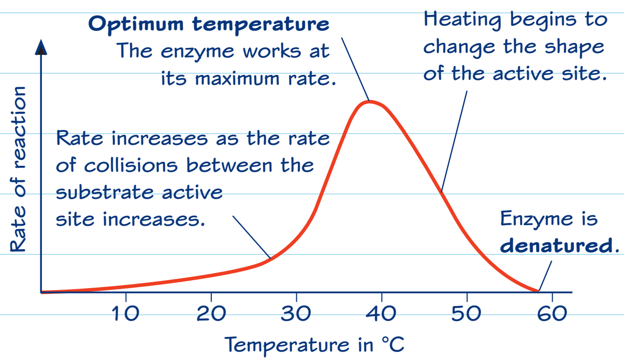
Lock-and-key theory

Enzymes are protein molecules, with complex shapes which are important for their activity:
- Part of an enzyme molecule is its **active site**.
- A **substrate** molecule fits into the active site, like a key fits into a lock.
- Other substances do not fit, so are not substrates for the enzyme.
- If the shape of an active site changes, the enzyme is **denatured** and no longer works.



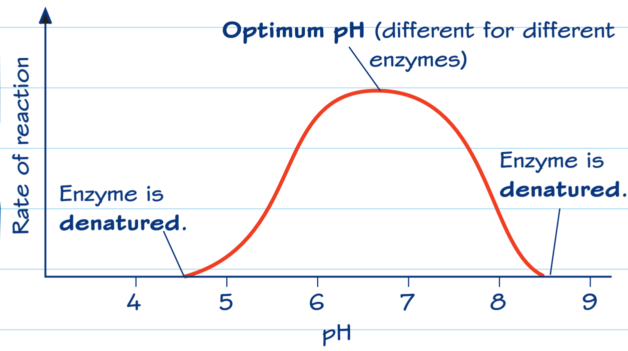
Effect of temperature

The rate of chemical reactions increases as the **temperature** increases. This happens with enzyme-catalysed reactions, but:
- There is an **optimum temperature** at which there is a maximum reaction rate.
- At higher temperatures the active site changes shape, reducing the reaction rate.



Effect of pH

The **pH** of an enzyme's surroundings affects the shape of the active site. This means that:
- Enzymes have an **optimum pH** at which there is a maximum reaction rate.
- Below and above the optimum pH, the bonds in the enzyme are affected, so the shape of the active site changes.



Worked example

Bile is made in the liver, stored in the gall bladder and released into the small intestine. Explain its role in the digestion of fats. **(3 marks)**

Bile is alkaline, so it neutralises hydrochloric acid made by the stomach. It also emulsifies fat, breaking it into small droplets. This increases the surface area of the fat. The alkaline conditions and the large surface area increase the rate at which lipases break down fat.

Partly digested food is acidic as it reaches the small intestine. The optimum pH for the lipase is pH 7.5–8.0 (alkaline conditions).

Now try this

1 Proteases digest proteins in the stomach. Suggest the optimum pH of these proteases, and justify your answer. **(2 marks)**

2 Explain the importance of the active site for enzyme activity at different temperatures and pH values. **(4 marks)**

Had a look ☐ Nearly there ☐ Nailed it! ☐

Investigating enzymes

Practical skills You can use **continuous sampling** to find the time taken to digest starch at different pH values.

Required practical

Investigating the effect of pH

Aim

to investigate the effect of pH on amylase activity

Apparatus and Method

1 Add one drop of iodine solution to each well in a spotting tile.
2 Add the following to a test tube: 2 cm^3 of a pH buffer solution, 2 cm^3 of amylase solution and 2 cm^3 of starch solution.
3 Mix with a glass rod and start a stop clock.
4 After 30 seconds, use a glass rod to transfer one drop to a well in the spotting tile. Rinse the glass rod with water.
5 Repeat step 4 until there is no change in the colour of the iodine solution. Stop the stop clock and record the time.
6 Repeat steps 1 to 5 using different pH buffer solutions.

Results

Record your results in a suitable table. This one shows some sample results.

pH of buffer	Time taken to digest starch (s)	Rate of reaction (/s)
4	169	0.0059
5	125	
6	100	
7	118	
8	260	

Analysis

1 Calculate the rate of reaction that corresponds to each reaction time.
2 Plot a graph with:
- rate of reaction on the vertical axis
- pH of buffer solution on the horizontal axis.

3 Use your results to identify the **optimum pH** for amylase activity.

Amylase is an enzyme that breaks down starch into simple sugars.

All the solutions should be kept at the same temperature. You can achieve this by keeping the bottles of solution in a water bath maintained at 25 °C.

When the iodine in a well no longer changes colour, there is no starch present – it has all been digested to form simple sugars.

A **buffer solution** is a mixture that resists changes to its pH.

Maths skills **Rate of reaction**

The rate of a reaction is proportional to the time taken for it to finish. This means that you can convert reaction times to reaction rates:

$$\text{rate (/s)} = \frac{1}{\text{time (s)}}$$

For example, if reaction time is 200 s:
- reaction rate = 1/200 = 0.005/s

Choose sensible scales that allow the plotted points to occupy at least 50% of the area of the graph. Draw a curve of best fit.

The optimum pH is the pH that gives the greatest rate of reaction.

Now try this

1 Calculate the rates of reaction for the reaction times shown in the table. Give your answers to 2 significant figures. **(2 marks)**
2 Draw a suitable graph to show the rates of reaction between pH 4 and 8. **(3 marks)**
3 Use your graph drawn for question 2, or the table of results, to identify the optimum pH for amylase. Explain your answer. **(2 marks)**
4 Explain why the temperature is controlled in this investigation. **(2 marks)**

The blood

Blood is a tissue with red blood cells, white blood cells and platelets suspended in plasma.

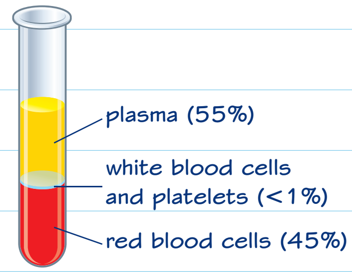
Plasma

Blood **plasma** is a yellow liquid. It transports cells and platelets around the body through the **blood vessels**. It also transports dissolved substances, including:

- carbon dioxide from respiring cells
- soluble products of digestion, such as glucose and amino acids
- urea – a waste product formed when the liver breaks down excess proteins.

Centrifuging blood

The different parts in blood settle out quickly when blood is spun in a centrifuge.



Red blood cells

Most of the cells in blood are **red blood cells**. These cells transport oxygen around the body through the blood vessels. They have several adaptations for this function.

Adaptation	Reason
contain **haemoglobin**	red pigment which binds reversibly to oxygen
no nucleus	provides more space to contain more haemoglobin
biconcave disc shape	increases the surface area to volume ratio for diffusion

White blood cells

White blood cells are larger than red blood cells and have a **nucleus**. They are part of the body's **immune system**. There are different types of white blood cell, including:

- **phagocytes**, which engulf and destroy **pathogens** (disease-causing organisms)
- **lymphocytes**, which produce antibodies – proteins that bind to pathogens and lead to their destruction.

Platelets

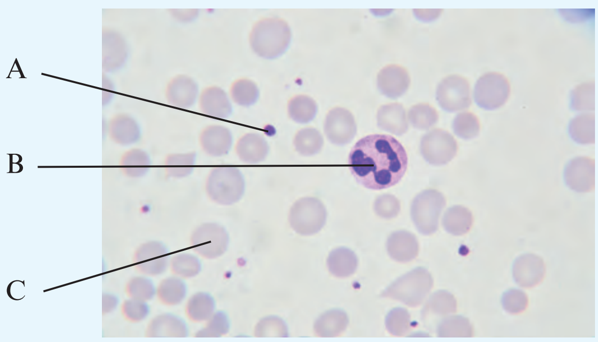
Platelets are fragments of cells with no nucleus. They are involved in forming a blood clot at a cut or wound. Platelets are trapped when a meshwork of fibrin protein forms.

Worked example

The photo shows a thin smear of blood, viewed through a light microscope.
Identify A, B and C. **(3 marks)**

A is a platelet, B is a white blood cell and C is a red blood cell.

Platelets are much smaller than red cells or white cells. White cells have a nucleus (the dark area inside) but red cells do not. Blood contains more red cells than white cells.



A blood smear stained with a dye.

Now try this

Compare the structure of red blood cells with the structure of white blood cells. **(4 marks)**

Blood vessels

The body contains three different types of **blood vessel**, called arteries, veins and capillaries.

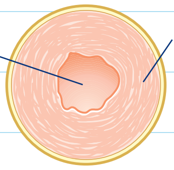
Arteries

Arteries carry blood **A**way from the heart. The blood in arteries is under high pressure:

- this increases each time the heart beats.

Arteries have thick walls containing muscle and elastic fibres. These allow arteries to:

- stretch, without bursting, as blood is pushed through them
- regain their shape afterwards.



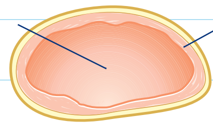
Artery (cross-section)

Veins

Veins carry blood towards the heart. The blood in veins is under the lowest pressure, and is not pumped by the heart. Veins have:

- thinner walls than arteries
- a large **lumen** (space inside)
- **valves** to prevent blood flowing backwards.

Blood is squeezed through the veins by the contractions of surrounding skeletal muscle.



Vein (cross-section)

Capillaries

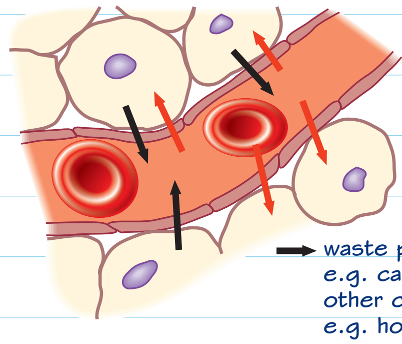
The **capillaries** are the smallest blood vessels, and contain blood at low pressure.

They form capillary beds – networks that supply blood to the body's tissues and organs.

Substances are exchanged between the blood in the capillaries and the cells around them.

Capillaries:

- are typically one blood cell wide
- have thin walls, one cell thick, allowing substances to diffuse easily through them.



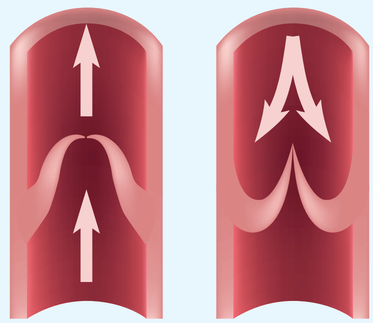
Worked example

The diagrams show part of a blood vessel in long section. The arrows indicate the direction of blood flow.

Identify the type of blood vessel, giving a reason for your answer. **(2 marks)**

It shows a vein because there are valves, which are found in veins.

Blood can only flow one way between the flaps in the valve.



Now try this

1 List the **three** types of blood vessel, in order of decreasing blood pressure. **(1 mark)**

2 Explain why almost every body cell is very close to a capillary. **(3 marks)**

3 The inner wall of an artery is smooth. Suggest a reason for this adaptation. **(1 mark)**