

Key concepts in biology revision notes

This topic covers the building blocks of biology: the structure of cells, how we study them with microscopes, how enzymes speed up reactions, and how substances move in and out of cells. Ideas from this topic come up again in almost every other topic, so it is examined on both papers.

For Edexcel GCSE Combined Science 1SC0, **Higher tier** is only on the Higher paper.

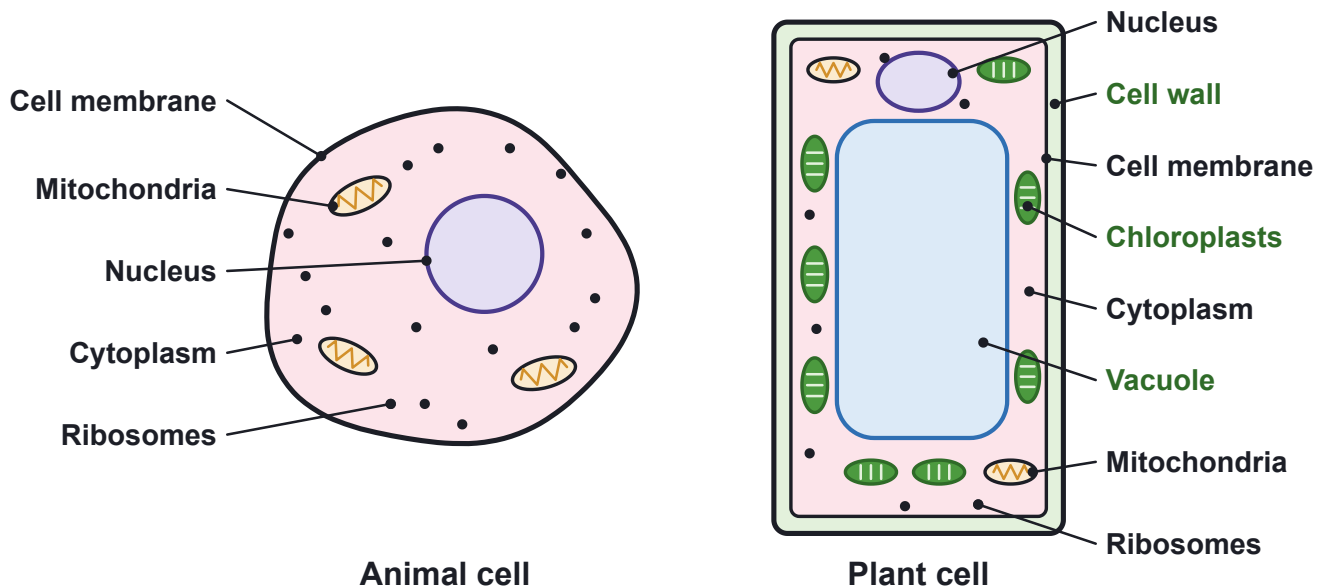
1 Cell structure and specialised cells Spec 1.1-1.2

Animal and plant cells Spec 1.1

Animal and plant cells are **eukaryotic** cells. Their genetic material is enclosed in a **nucleus**. Each structure inside a cell, called a sub-cellular structure, has a job, and you need to link each structure to its function.

Sub-cellular structures in animal and plant cells			
Structure	Function	Animal cell	Plant cell
Nucleus	Contains the genetic material (DNA) and controls the activities of the cell	Yes	Yes
Cell membrane	Controls the movement of substances into and out of the cell	Yes	Yes
Mitochondria	Where aerobic respiration takes place, releasing energy for the cell	Yes	Yes
Ribosomes	Where proteins are made (protein synthesis)	Yes	Yes
Cell wall	Made of cellulose. Strengthens the cell and supports it	No	Yes
Chloroplasts	Contain chlorophyll, which absorbs light for photosynthesis	No	Yes
Vacuole	Contains cell sap, a solution of sugars and salts, and helps keep the cell firm	No	Yes

Plant cells have three structures that animal cells do not: a **cell wall**, **chloroplasts** and a **vacuole**. Chloroplasts are only found in the green parts of a plant that photosynthesise, such as leaf cells.



☐ **Green labels: found in plant cells only, not animal cells**

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An animal cell and a plant cell. Only plant cells have a **cell wall**, **chloroplasts** and a **vacuole** (green labels).

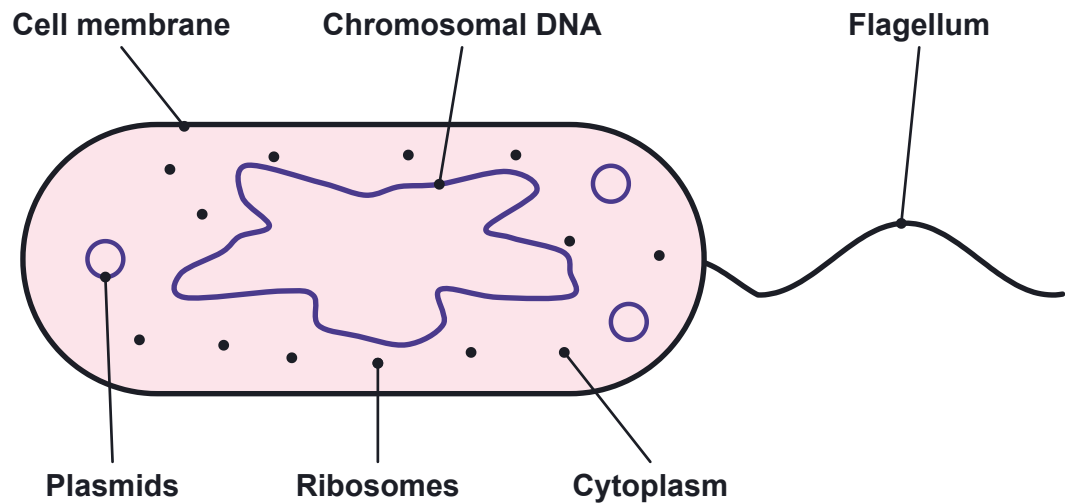
*Exam tip: Say the cell membrane **controls what enters and leaves** the cell, and that mitochondria **release energy** by respiration. Never write that the membrane 'holds the cell together' or that mitochondria 'make energy'.*

Bacterial cells Spec 1.1

Bacteria are **prokaryotic** cells. They do not have a nucleus. Their genetic material is found free in the cytoplasm.

Chromosomal DNA	A single loop of DNA found free in the cytoplasm, not enclosed in a nucleus.
Plasmid DNA	Small rings of extra DNA, separate from the chromosomal DNA.
Cell membrane	Controls the movement of substances into and out of the cell.
Ribosomes	Where proteins are made.
Flagellum	A long, whip-like structure that moves to make the bacterium swim. Some bacteria have one or more flagella.

Eukaryotic and prokaryotic cells compared		
Feature	Eukaryotic cell (animal, plant)	Prokaryotic cell (bacterium)
Nucleus	Present, contains the DNA	Absent
Where the DNA is	Inside the nucleus	Free in the cytoplasm
Plasmids	Not present	Often present
Mitochondria	Present	Absent
Flagella	Not present	Present in some



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A bacterial cell: the DNA is **not in a nucleus**. It is a single loop, plus small rings called plasmids.

Common mistake: Bacteria do have genetic material. Write that it is not in a nucleus, never that bacteria have no DNA.

Specialised cells Spec 1.2

A specialised cell has features, called adaptations, that help it do its job. You need to describe how sperm cells, egg cells and ciliated epithelial cells are adapted.

Sperm cells

The job of a sperm cell is to reach an egg cell and fuse with it at fertilisation.

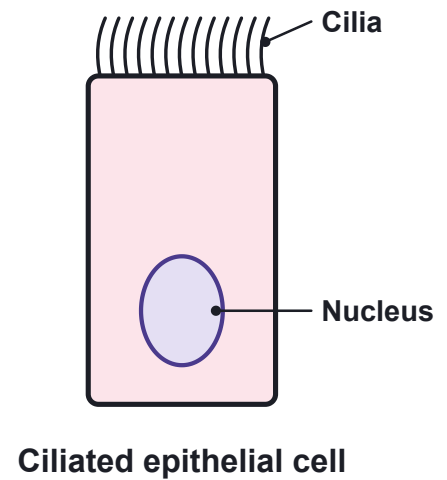
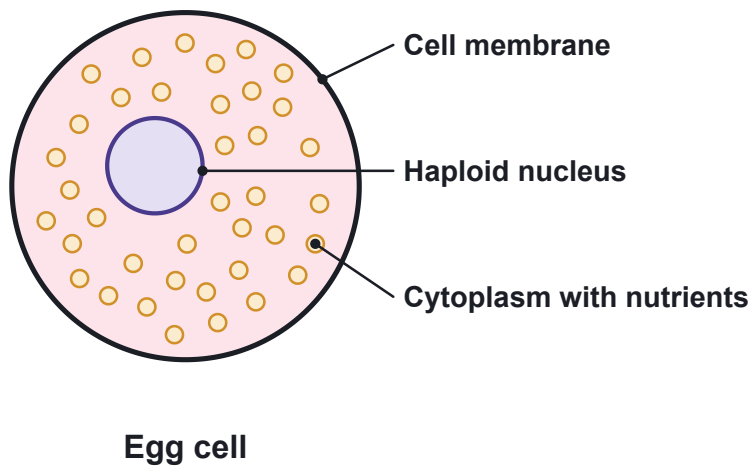
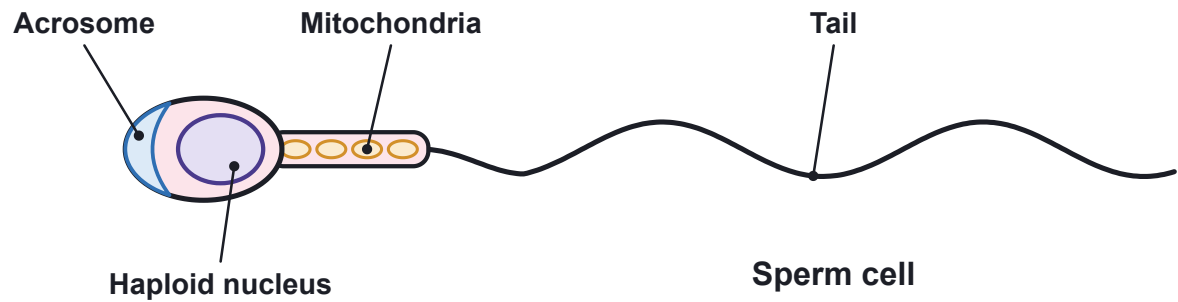
Adaptation	How it helps
Acrosome	Contains digestive enzymes that break down the outer layers of the egg cell so the sperm can get in
Haploid nucleus	Contains half the number of chromosomes of a normal body cell, so fertilisation restores the full number
Many mitochondria	Release energy by aerobic respiration for the tail to move
Tail	Moves from side to side to push the sperm along, so it can swim to the egg

Egg cells

Adaptation	How it helps
Nutrients in the cytoplasm	A food store that supplies the early embryo with nutrients and energy to grow
Haploid nucleus	Contains half the number of chromosomes, which join with the sperm nucleus at fertilisation
Changes in the cell membrane after fertilisation	The membrane changes straight after a sperm enters, so no more sperm can get in

Ciliated epithelial cells

These cells line parts of the airways. Their surface has **cilia**, tiny hair-like projections. The cilia beat together and move mucus, which has trapped dust and microorganisms, away from the lungs.



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Three specialised cells and their adaptations (not drawn to scale: the egg cell is much bigger than the sperm cell).

Exam tip: Name the adaptation, then say how it helps the cell do its job. 'It has a tail' gets no mark, but 'it has a tail to swim to the egg' does.

Quick check

1. Name the three structures found in plant cells but not in animal cells.
2. Where is the DNA in a bacterial cell?
3. What is the function of the acrosome?
4. Why does a sperm cell have a haploid nucleus?
5. What do the cilia on ciliated epithelial cells do?

2 Microscopy and measuring cells Spec 1.3-1.6

Changes in microscope technology Spec 1.3

Early light microscopes could show cells, but not much detail inside them. Two ideas matter here.

Magnification is how many times bigger the image is than the real object. **Resolution** (resolving power) is how well a microscope can show two points that are close together as separate points.

Light and electron microscopes compared		
	Light microscope	Electron microscope
Uses	Light and glass lenses	A beam of electrons
Magnification	Lower	Much higher
Resolution	Lower	Much higher
What can be seen	Cells, nucleus, and some larger structures such as chloroplasts	Fine detail, such as the internal structure of mitochondria and chloroplasts, and ribosomes

Because electron microscopes have a higher magnification and **higher resolution**, we can see **sub-cellular structures** in much more detail and with more clarity than in the past. This has increased our understanding of what each structure does, because we can now see how its structure is related to its function.

Exam tip: For a full answer to 'explain how electron microscopes have increased understanding', say three things: higher magnification and resolution, so more detail can be seen, which helps us understand the role of sub-cellular structures.

Number, size and scale: estimations Spec 1.4

Biology deals with very big and very small numbers, from the number of cells in a body to the size of a ribosome. You need to understand number, size and scale so you can compare sizes sensibly.

An **estimation** is an approximate answer, usually found by rounding numbers to one significant figure. Estimations should be used:

- to check that the answer to a calculation is sensible, for example that a cell is not 5 metres long
- when an exact value is not needed, or is impossible or too slow to find, for example estimating the number of cells in a sample by counting a few areas and scaling up
- to make quick comparisons between sizes, for example roughly how many times bigger one cell is than another

Maths skill: To check a calculation, round first: $59 \text{ mm} \div 410$ is roughly $60 \div 400 = 0.15 \text{ mm}$. If your answer is nowhere near that, look for a slip with units.

Units: milli, micro, nano and pico Spec 1.5

Cells are far too small to measure in metres, so we use smaller units. Each unit below is 1000 times smaller than the one before it.

Units used for cells

Prefix	Symbol	Power of ten	Unit of length
milli	m	10^{-3}	millimetre (mm)
micro	μ	10^{-6}	micrometre (μm)
nano	n	10^{-9}	nanometre (nm)
pico	p	10^{-12}	picometre (pm)

To go to a smaller unit, **multiply by 1000**: mm to μm , μm to nm, nm to pm. To go to a larger unit, **divide by 1000**. So 1 mm = 1000 μm , 1 μm = 1000 nm and 1 nm = 1000 pm.

Higher tier

Standard form

Higher tier

Standard form writes a number as a number between 1 and 10 multiplied by a power of ten. For example, 0.000 045 m is 4.5×10^{-5} m, and 3 200 000 is 3.2×10^6 . A negative power means a small number. You must be able to do calculations with numbers written in standard form.

Higher tier

Calculating with standard form

A cell is 2.5×10^{-5} m long. It is viewed at a magnification of $\times 400$. Calculate the length of the image in mm.

1. image size = real size $\times$ magnification
2. $2.5 \times 10^{-5} \times 400 = 1.0 \times 10^{-2}$ m
3. 1.0×10^{-2} m = 0.01 m
4. 0.01 m $\times$ 1000 = 10 mm

Answer: 10 mm

Maths skill: Convert to one unit before you calculate. Mixing mm and μm in one calculation is the most common way to lose marks.

Core practical: using a microscope Spec 1.6

In this core practical you investigate biological specimens with a light microscope, calculate magnification and make a labelled scientific drawing. A common specimen is onion epidermis, which is a thin, single layer of plant cells.

Core practical: Prepare a slide, focus from low power to high power using the fine focus, draw only what you see, then calculate the magnification from your drawing.

Method

1. Put a drop of water or stain (for example iodine solution) on a clean slide.
2. Peel a thin layer of epidermis from the onion and lay it flat on the drop with forceps.
3. Lower a coverslip on at an angle using a mounted needle, so air bubbles are not trapped.
4. Clip the slide on the stage. Select the lowest power objective lens and use the coarse focus to bring the cells into focus, then the fine focus to make them sharp.

5. Move to a higher power objective lens and focus again with the fine focus only.

6. Draw what you see and label it.

Scientific drawings

- use a sharp pencil and make clear, continuous lines, with no shading or colouring
- draw large, filling most of the space, and only draw what you can see
- label with straight lines drawn with a ruler that touch the structure they name, and do not cross the labelling lines
- give the drawing a title and write the magnification

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

Total magnification of a microscope is the eyepiece lens magnification $\times$ the objective lens magnification. For a drawing, measure the image with a ruler and use the equation above. Rearranged:
 $\text{size of real object} = \text{size of image} \div \text{magnification}.$

Finding the real size

A student draws a cell. The drawing is 54 mm wide and the magnification is $\times 300$. Calculate the real width of the cell in μm .

1. $\text{real size} = \text{image size} \div \text{magnification}$
2. $54 \div 300 = 0.18 \text{ mm}$
3. $0.18 \text{ mm} \times 1000 = 180 \mu\text{m}$

Answer: 180 μm

Finding the magnification

A cell is 90 μm long in real life. In a drawing it is 45 mm long. Calculate the magnification.

1. Convert to the same unit: $45 \text{ mm} \times 1000 = 45\,000 \mu\text{m}$
2. $\text{magnification} = \text{image size} \div \text{real size}$
3. $45\,000 \div 90 = 500$

Answer: $\times 500$

Common mistake: Do not use the coarse focus on high power, because the lens can hit and crack the slide. Handle slides and coverslips carefully and wipe up any spilt iodine, which stains skin and clothes.

Quick check

1. Why can electron microscopes show more detail than light microscopes?
2. How many nanometres are there in 1 μm ?
3. Convert 0.05 mm into μm .
4. State the equation linking magnification, image size and real size.
5. Why is a coverslip lowered at an angle?

3 Enzyme action and activity Spec 1.7-1.11

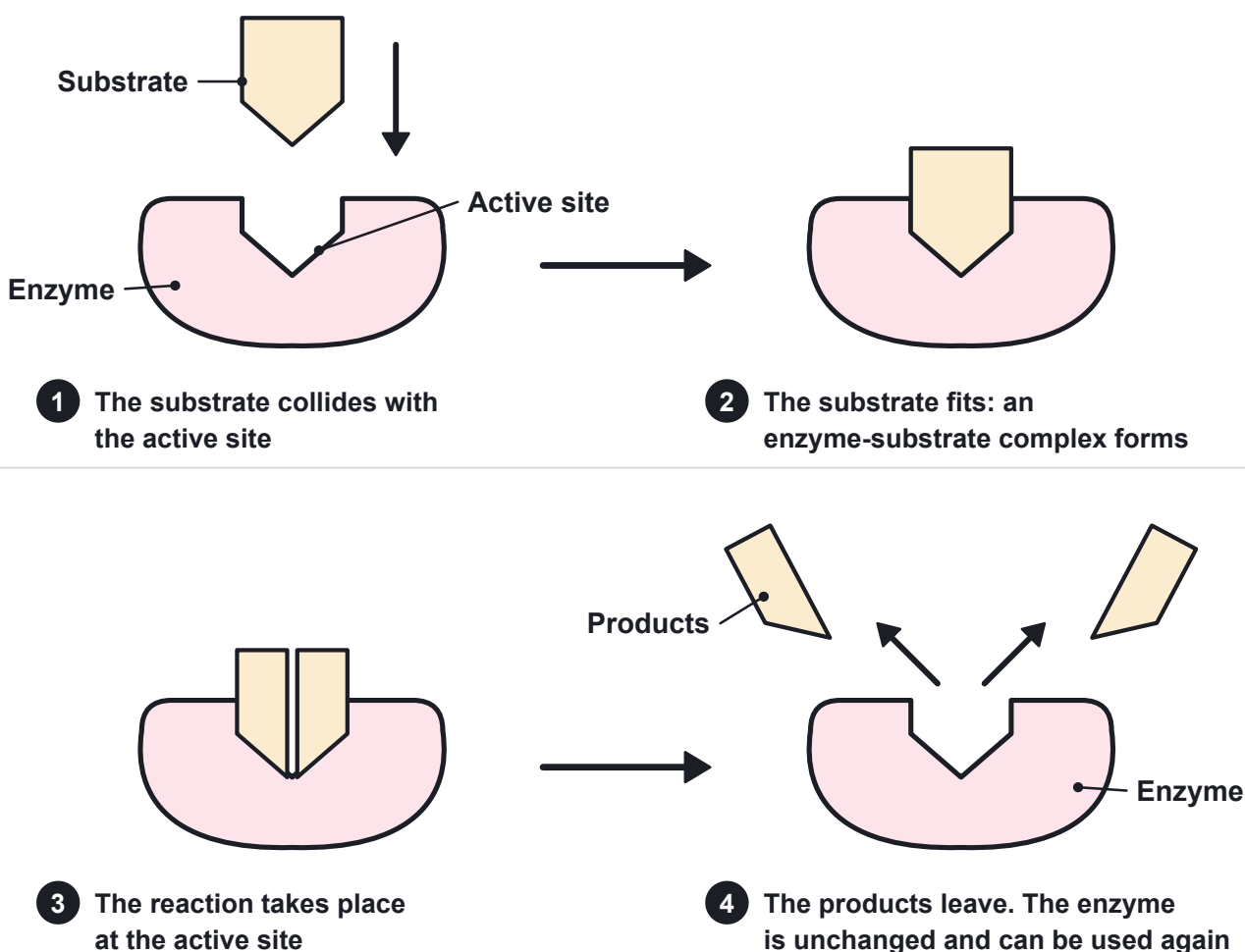
How enzymes work Spec 1.7

Enzymes are proteins that act as **biological catalysts**. A catalyst speeds up a reaction without being used up. Each enzyme has a region called the **active site**, which has a particular shape.

The molecule an enzyme acts on is called the **substrate**. The substrate has a shape that is **complementary** to the active site, so it fits in, like a key in a lock. This is called the lock and key model.

1. The substrate collides with the active site of the enzyme.
2. The substrate fits into the active site, forming an enzyme-substrate complex.
3. The reaction takes place at the active site.
4. The product or products leave the active site and the enzyme is free to be used again.

Enzymes are **specific**. Only a substrate with a shape that fits the active site can bind to it, so each enzyme catalyses only one type of reaction.



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The lock and key model. The substrate is **complementary** to the active site, and the enzyme is not used up.

Exam tip: The mark scheme word is **complementary**. Say the shape of the substrate is complementary to the shape of the active site, not that they are 'the same'.

Denaturing enzymes Spec 1.8

If the temperature is too high, or the pH is too far from the enzyme's optimum, the bonds that hold the enzyme in shape are broken. The enzyme changes shape, and so does the active site.

The substrate no longer fits the active site, so the enzyme cannot catalyse the reaction. The enzyme is **denatured**. This change is permanent.

*Common mistake: Enzymes are not 'killed' by heat, because they were never alive. Write that the enzyme is **denatured** and the **shape of the active site has changed**.*

Temperature, substrate concentration and pH Spec 1.9

Temperature

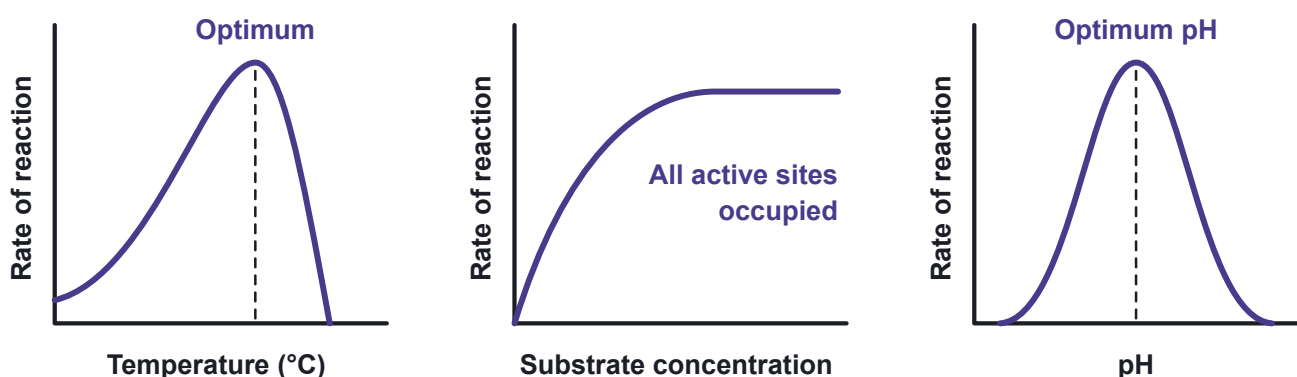
As temperature increases, the particles move faster and have more kinetic energy. Enzyme and substrate collide more often, so the rate of reaction increases. The rate is highest at the **optimum temperature**, which is around 37 °C for many human enzymes. Above the optimum, the active site changes shape, the enzyme is denatured and the rate falls quickly towards zero.

Substrate concentration

At low substrate concentration, increasing it makes the rate increase, because collisions between substrate and active sites are more frequent. Eventually all the active sites are occupied at once. Adding more substrate then has no effect, so the rate levels off. The enzyme concentration is now limiting the rate.

pH

Each enzyme has an **optimum pH** where it works fastest. If the pH is higher or lower than the optimum the rate decreases, and at extreme pH values the active site changes shape and the enzyme is denatured. Different enzymes have different optimum pH values.



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How temperature, substrate concentration and pH affect the rate of an enzyme-controlled reaction.

Summary of the effects on enzyme activity			
Factor	Below the optimum / low	At the optimum	Above the optimum / high
Temperature	Rate increases as particles move faster and collide more often	Highest rate	Enzyme denatured, rate falls
pH	Rate decreases as pH moves away from the optimum, and the enzyme is denatured at extreme pH	Highest rate	Rate decreases as pH moves away from the optimum, and the enzyme is denatured at extreme pH
Substrate concentration	Rate increases	Not applicable	Rate stops increasing when all active sites are occupied

*Exam tip: When a graph falls after a peak, always give the reason: the enzyme has been **denatured**. When a graph levels off, say all the **active sites are occupied**.*

Core practical: the effect of pH on enzyme activity Spec 1.10

A common version of this investigation uses amylase, an enzyme that breaks down starch, and iodine solution to show when the starch has gone.

Core practical: Independent variable: pH; dependent variable: time for the starch to be broken down. Keep temperature, volumes and concentrations the same each time.

1. Put drops of iodine solution into the wells of a spotting tile.
2. Add starch solution and a buffer solution of a known pH to a test tube. Put this tube, and a tube of amylase solution, in a water bath at a set temperature (for example 35 °C) for a few minutes.
3. Add the amylase solution to the starch and buffer, mix and start the stopwatch.
4. At regular intervals, for example every 30 seconds, use a dropping pipette to add a drop of the mixture to a well of iodine solution.
5. Record the time when the iodine solution stops turning blue-black and stays orange-brown. This shows all the starch has been broken down.
6. Repeat for buffer solutions of different pH values, and repeat each pH to calculate a mean.

Variable	How it is controlled
Temperature	Use a water bath
Volume and concentration of enzyme	Use the same amount of the same solution each time
Volume and concentration of starch	Use the same amount of the same solution each time

Typical results: the shortest time is at the optimum pH, where the enzyme works fastest. Times get longer at pH values further from the optimum. Plot the rate (or time) against pH on a graph and draw a smooth curve through the points. Wear eye protection, because iodine solution and some buffers are irritants, and wipe up any spills.

Rate calculations for enzyme activity Spec 1.11

The **rate of reaction** tells you how fast a reaction is happening. It is a compound measure, because it combines an amount with a time.

$$\text{rate} = \text{amount of product formed} \div \text{time taken}$$

The units depend on what you measure, for example cm³/s for a volume of gas, or g/min for a mass. If an experiment measures the time taken for a reaction to finish, such as the time for starch to disappear, the rate can be found as 1 ÷ time, with units of s⁻¹.

Calculating a rate

An enzyme produces 12 cm³ of gas in 40 seconds. Calculate the rate of reaction in cm³/s.

1. rate = amount of product ÷ time
2. 12 ÷ 40 = 0.3

Answer: 0.3 cm³/s

Maths skill: A longer time means a slower reaction. If the time doubles, the rate (1 ÷ time) halves.

Quick check

- 1 . What is the name of the part of an enzyme that the substrate fits into?
- 2 . Why does an enzyme stop working at a high temperature?
- 3 . Why does the rate level off as substrate concentration increases?
- 4 . In the pH core practical, what colour shows that starch is still present with iodine solution?
- 5 . Calculate the rate when 30 cm³ of gas is collected in 60 s.

4 Biological catalysts, food tests and energy in food Spec 1.12-1.14B

The importance of enzymes Spec 1.12

Chemical reactions in living things would be far too slow to keep us alive without enzymes. Enzymes are **biological catalysts** that speed up reactions in cells. They are needed both to build large molecules and to break them down.

Enzymes in synthesis and breakdown		
Large molecule	Made (synthesised) from	Broken down into
Carbohydrates	Sugars	Sugars
Proteins	Amino acids	Amino acids
Lipids	Fatty acids and glycerol	Fatty acids and glycerol

Different enzymes catalyse each of these reactions, because enzymes are specific. Breaking down large molecules into small ones is a vital job, and so is building the carbohydrates, proteins and lipids the body needs.

*Exam tip: If asked what a catalyst does, say it **speeds up a reaction** and is **not used up**.*

Quick check

1. What are proteins broken down into?
2. What does a catalyst do?
3. Which reagent turns purple when protein is present?
4. How can the energy in food be measured?

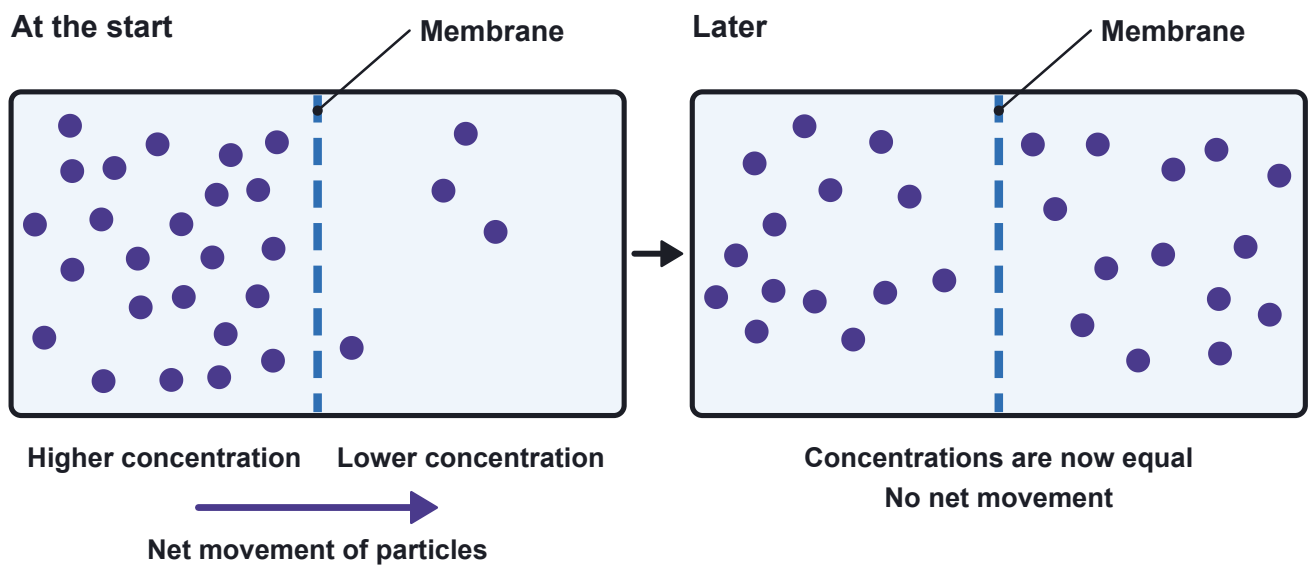
5 Transport in cells Spec 1.15-1.17

Diffusion Spec 1.15

Diffusion is the net movement of particles from an area of higher concentration to an area of lower concentration. The particles move **down a concentration gradient**. It is a passive process, so it does not need energy from respiration.

Oxygen, carbon dioxide and dissolved substances can diffuse into and out of cells through the cell membrane. The rate of diffusion is higher when:

- the concentration gradient is steeper, because there is a bigger difference in concentration
- the temperature is higher, because particles have more kinetic energy and move faster
- the surface area is larger, because more particles can cross at once



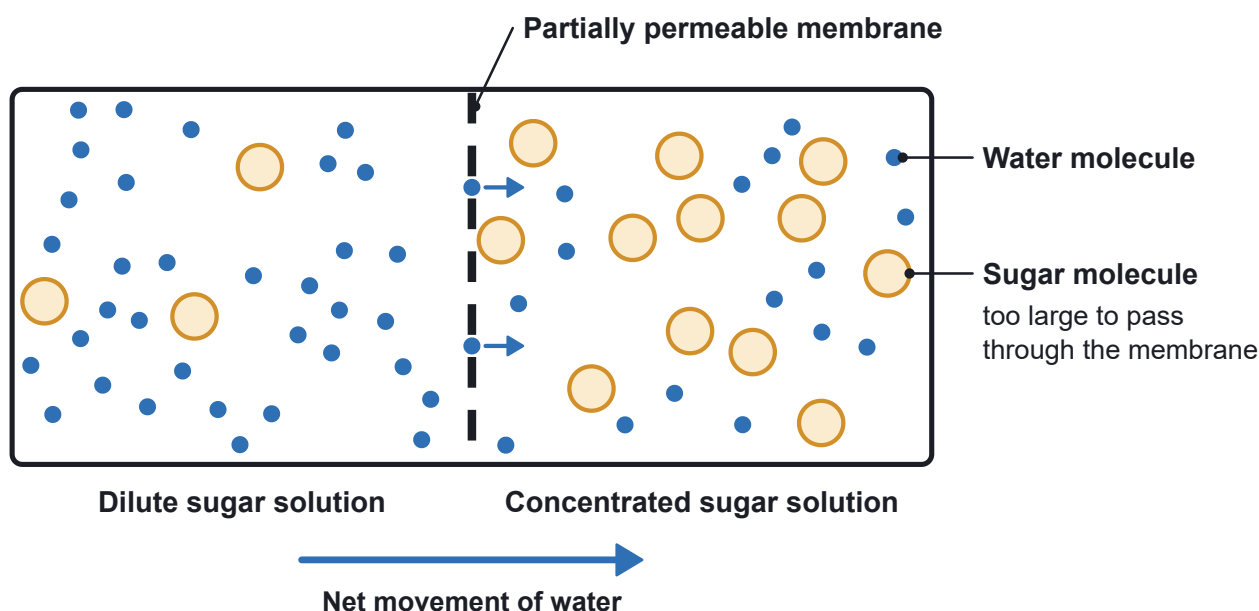
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Diffusion: net movement of particles **down a concentration gradient** until the concentrations are equal.

Osmosis Spec 1.15

Osmosis is the diffusion of water from a dilute solution to a more concentrated solution through a **partially permeable membrane**. A partially permeable membrane lets small molecules such as water through, but not larger molecules.

Osmosis is a passive process. It does not need energy from respiration.



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Osmosis: water moves from the **dilute** solution to the **concentrated** solution through a partially permeable membrane.

Common mistake: Osmosis is only about water. Do not write that 'particles' move by osmosis, and do not forget the partially permeable membrane.

Active transport Spec 1.15

Active transport is the movement of substances from a more dilute solution to a more concentrated solution, which is **against a concentration gradient**. It needs **energy from respiration**.

Active transport allows cells to take in substances they need even when they are in short supply outside the cell. For example, root hair cells take in mineral ions from the soil when the concentration of the ions is higher inside the cell than in the soil.

Three ways substances move into and out of cells

	What moves	Direction	Energy from respiration?
Diffusion	Particles, such as oxygen and carbon dioxide	High to low concentration	No
Osmosis	Water only, through a partially permeable membrane	Dilute to concentrated solution	No
Active transport	Substances such as mineral ions	Low to high concentration, against the gradient	Yes

Core practical: osmosis in potatoes Spec 1.16

Potato cells gain or lose water by osmosis depending on the concentration of the solution around them. You can measure this as a change in mass.

Core practical: Blot each cylinder dry before you weigh it. Wet cylinders have extra mass that is not from osmosis.

1. Use a cork borer to cut cylinders from one potato, and trim them to the same length.
2. Measure and record the mass of each cylinder.

- Put each cylinder in a different concentration of sugar (or salt) solution, including pure water, using the same volume of solution each time.
- Leave them for the same length of time at the same temperature.
- Remove the cylinders, blot them dry with paper towel and measure their final mass.
- Calculate the percentage change in mass for each cylinder and plot a graph of percentage change against concentration.

Result	Explanation
Mass increases	The solution is more dilute than the cell contents, so water moves into the potato by osmosis
Mass decreases	The solution is more concentrated than the cell contents, so water moves out of the potato by osmosis
No change in mass	The solution has the same concentration as the cell contents, so there is no net movement of water

Where the graph line crosses the x-axis (0% change), the concentration of the solution equals the concentration of the potato cell contents. Control the potato, the size of the cylinders, the volume of the solution, the time and the temperature. Repeat the experiment and calculate a mean. Cut on a tile away from your fingers, because cork borers and scalpels are sharp.

Percentage gain and loss of mass Spec 1.17

Different cylinders may start with slightly different masses, so you compare them using the percentage change in mass.

$$\text{percentage change} = (\text{final mass} - \text{initial mass}) \div \text{initial mass} \times 100$$

A positive answer is a percentage gain. A negative answer is a percentage loss.

Percentage change in mass

A potato cylinder has a mass of 3.00 g. After 30 minutes in a salt solution its mass is 2.55 g. Calculate the percentage change in mass.

- change in mass = $2.55 - 3.00 = -0.45$ g
- $-0.45 \div 3.00 = -0.15$
- $-0.15 \times 100 = -15\%$

Answer: -15% (a loss of 15%)

Maths skill: Divide by the initial mass, not the final mass. Keep the minus sign if the mass decreased.

Quick check

- Define diffusion.
- Define osmosis.
- What does active transport need that diffusion does not?
- A potato cylinder gains mass in a solution. What does this tell you about the solution?
- Write the equation for percentage change in mass.

Quick check answers

Cell structure and specialised cells

1. Cell wall, chloroplasts and vacuole.
2. Free in the cytoplasm, as chromosomal DNA and plasmid DNA. There is no nucleus.
3. It contains enzymes that digest the outer layers of the egg.
4. It has half the chromosomes, so fusing with the egg nucleus gives the full number.
5. They move mucus containing trapped dust and microorganisms away from the lungs.

Microscopy and measuring cells

1. They have a higher magnification and higher resolution.
2. 1000 nm.
3. 50 μm (0.05×1000).
4. $\text{magnification} = \text{size of image} \div \text{size of real object}$.
5. To avoid trapping air bubbles.

Enzyme action and activity

1. The active site.
2. The shape of the active site changes, so the substrate no longer fits. The enzyme is denatured.
3. All the active sites are occupied.
4. Blue-black.
5. 0.5 cm^3/s .

Biological catalysts, food tests and energy in food

1. Amino acids.
2. It speeds up a reaction and is not used up.
3. Biuret reagent (Triple only).
4. By burning it to heat water and using the temperature change (calorimetry) (Triple only).

Transport in cells

1. The net movement of particles from a region of higher concentration to a region of lower concentration.
2. The diffusion of water from a dilute solution to a more concentrated solution through a partially permeable membrane.
3. Energy from respiration.
4. It is more dilute than the cell contents.
5. $(\text{final mass} - \text{initial mass}) \div \text{initial mass} \times 100$.