

Cell structure

Revision notes • Eukaryotic and prokaryotic cells, sub-cellular structures, specialised cells, differentiation, microscopy and culturing microorganisms.

For AQA GCSE Biology 8461 and Combined Science: Trilogy 8464. **Triple only** is not in Combined Science. **Higher tier** is only on the Higher paper.

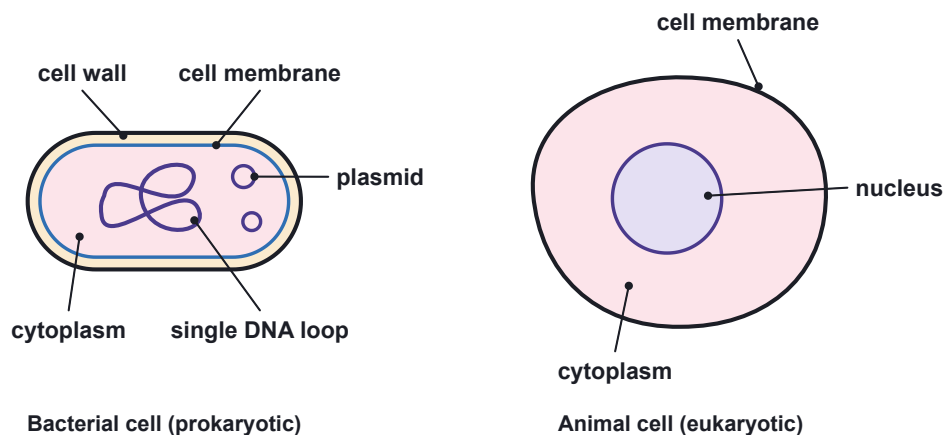
Cell structure Spec 4.1.1

Eukaryotes and prokaryotes Spec 4.1.1.1

Plant and animal cells are **eukaryotic cells**. They have a cell membrane, cytoplasm and genetic material enclosed in a nucleus.

Bacterial cells are **prokaryotic cells**. They are much smaller in comparison. They have cytoplasm and a cell membrane surrounded by a cell wall. The genetic material is **not** enclosed in a nucleus. It is a **single DNA loop**, and there may be one or more small rings of DNA called **plasmids**.

Eukaryotic and prokaryotic cells compared		
	Eukaryotic cell (plant, animal)	Prokaryotic cell (bacterium)
Size	Larger	Much smaller
Genetic material	Enclosed in a nucleus	Single DNA loop, not enclosed in a nucleus
Plasmids	No	One or more may be present
Cell membrane and cytoplasm	Yes	Yes
Cell wall	Plant and algal cells (made of cellulose); not animal cells	Yes



A bacterial (prokaryotic) cell has a **single DNA loop** and plasmids, but **no nucleus**. Not to scale: bacteria are much smaller.

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

Scale and size of cells

You need to understand the scale and size of cells and be able to make **order of magnitude** calculations. An order of magnitude is a power of ten. A cell that is 100 times wider than another is two orders of magnitude bigger, because $100 = 10^2$.

Prefixes and units of length			
Prefix	Symbol	Standard form (compared with 1 m)	Example
centi	c	$\times 10^{-2}$	1 cm = 0.01 m
milli	m	$\times 10^{-3}$	1 mm = 0.001 m
micro	μ	$\times 10^{-6}$	1 μ m = 0.000 001 m
nano	n	$\times 10^{-9}$	1 nm = 0.000 000 001 m

To change units: 1 mm = 1000 μ m and 1 μ m = 1000 nm. **Standard form** is a number between 1 and 10 multiplied by a power of ten, for example $0.000\ 004\ \text{m} = 4 \times 10^{-6}\ \text{m}$.

Order of magnitude

A plant cell is 100 μ m long. A bacterium is 1 μ m long. How many orders of magnitude longer is the plant cell?

1. Divide the larger length by the smaller: $100 \div 1 = 100$.
2. Write the answer as a power of ten: $100 = 10^2$.

Answer: The plant cell is 10^2 (100) times longer, which is two orders of magnitude.

Standard form

A cell is 0.000 025 m wide. Write this in standard form, then in μ m.

1. Move the decimal point to give a number between 1 and 10: 2.5.
2. Count the places moved: 5. Because the number is small, the power is negative: $2.5 \times 10^{-5}\ \text{m}$.
3. To convert to μ m, multiply metres by 1 000 000: $0.000\ 025 \times 1\ 000\ 000 = 25$.

Answer: $2.5 \times 10^{-5}\ \text{m}$, which is 25 μ m.

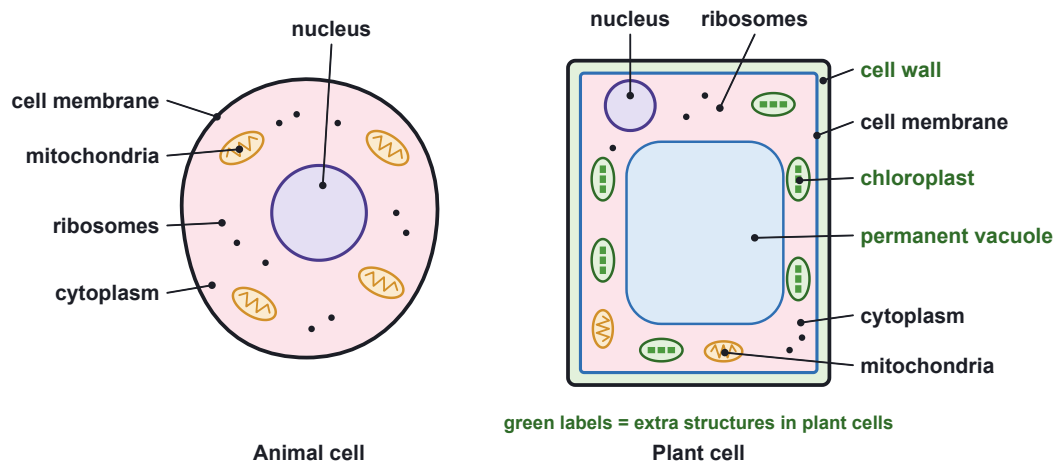
Maths skill: A negative power of ten means a number smaller than 1. Check the sign of your power by asking whether the number you started with was big or small.

Animal and plant cells Spec 4.1.1.2

Most animal cells have: a nucleus, cytoplasm, a cell membrane, mitochondria and ribosomes. In addition, plant cells often have: chloroplasts and a **permanent vacuole** filled with **cell sap**. Plant and algal cells also have a **cell wall made of cellulose**, which strengthens the cell.

Sub-cellular structures and their functions

Structure	Function	Animal cell	Plant cell	Bacterial cell
Nucleus	Contains the genetic material (DNA) and controls the activities of the cell	Yes	Yes	No
Cytoplasm	Where most chemical reactions happen	Yes	Yes	Yes
Cell membrane	Controls the movement of substances into and out of the cell	Yes	Yes	Yes
Mitochondria	Where aerobic respiration takes place, releasing energy for the cell	Yes	Yes	No
Ribosomes	Where proteins are made (protein synthesis)	Yes	Yes	Yes
Cell wall	Strengthens the cell; made of cellulose in plant and algal cells	No	Yes	Yes (not cellulose)
Chloroplasts	Contain chlorophyll, which absorbs light energy for photosynthesis	No	Yes (often)	No
Permanent vacuole	Filled with cell sap; helps keep the cell firm	No	Yes	No
Plasmid	Small ring of extra DNA	No	No	Possibly



Plant cells have the same structures as animal cells, plus a **cell wall**, **chloroplasts** and a **permanent vacuole**.

Exam tip: When asked to explain how a structure is related to its function, name the structure, state what it does, then link that to the job of the cell. Chloroplasts absorb light for photosynthesis, so they are found in cells that make food.

Estimating size and area

You should be able to use **estimations** to judge the relative size or area of sub-cellular structures. Round the measurements to easy numbers and compare them. Use an estimate when you only need to know roughly how much bigger one structure is than another, or to check that a calculated answer is sensible.

Estimating relative size

In a micrograph, a cell is 62 mm across and its nucleus is 19 mm across. Estimate how many times wider the cell is than the nucleus.

1. Round the numbers: 62 mm is about 60 mm and 19 mm is about 20 mm.
2. Divide: $60 \div 20 = 3$.

Answer: The cell is roughly 3 times wider than the nucleus.

Required practical 1: using a light microscope Spec 4.1.1.2

Required practical: Use a light microscope to observe, draw and label a selection of plant and animal cells. A magnification scale must be included.

1. Place a thin piece of tissue (for example onion epidermis, or cheek cells) on a clean microscope slide. Add a drop of water or a stain such as iodine solution.
2. Lower a cover slip onto the specimen at an angle, using a mounting needle, so that no air bubbles are trapped.
3. Clip the slide onto the stage. Select the lowest-power objective lens and turn the coarse focusing knob until the specimen is roughly in focus.
4. Use the fine focusing knob to get a sharp image. Then switch to a higher-power objective lens and refocus with the fine focusing knob only.
5. Draw what you see using a sharp pencil. Use clear, unbroken lines, no shading, and make the drawing large. Draw only a few cells accurately rather than many badly.
6. Label the sub-cellular structures with straight label lines that do not cross. Add a title and the magnification.

To find the total magnification of a light microscope, multiply the magnification of the eyepiece lens by the magnification of the objective lens. The magnification of your drawing is found with the equation $\text{magnification} = \text{size of image} \div \text{size of real object}$, using the width of your drawing and the real width of the cell.

Safety: carry the microscope with two hands, handle glass slides and cover slips carefully, and take care with the stain, which can mark skin and clothes. Start with the lowest-power lens so that the objective lens does not hit the slide.

Exam tip: A scale or magnification must be included on a drawing. Always write the magnification next to the title, for example 'Onion cells, $\times 400$ '.

Cell specialisation Spec 4.1.1.3

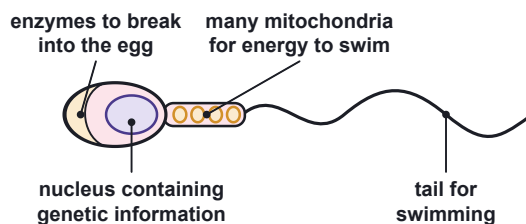
Cells may be specialised to carry out a particular function. You should be able to explain how the structure of different types of cell relate to their function in a tissue, an organ or organ system, or the whole organism, when you are given appropriate information.

Specialised cells in animals and plants

Cell	Function	How its structure helps
Sperm cell	Carries the male genetic information to the egg	Tail for swimming; many mitochondria to release the energy needed to swim; streamlined head; enzymes in the head to break into the egg; nucleus containing genetic information
Nerve cell	Carries electrical impulses around the body	Long (extended) so it can carry impulses over long distances; branched connections at the ends to connect with other nerve cells and organs
Muscle cell	Contracts (shortens) to cause movement	Contains protein fibres that can slide to make the cell shorten; many mitochondria to release energy for contraction; may store glycogen as an energy source
Root hair cell	Absorbs water and mineral ions from the soil	Long hair-like projection gives a large surface area; thin cell wall; many mitochondria to release energy for active transport of mineral ions
Xylem cell	Carries water and mineral ions up the plant	Joined end to end to form a hollow tube with no end walls and no cytoplasm; walls strengthened (by lignin)
Phloem cell	Carries dissolved sugars around the plant	Elongated cells joined end to end to form tubes; pores in the end walls let cell sap containing dissolved sugars move from one phloem cell to the next

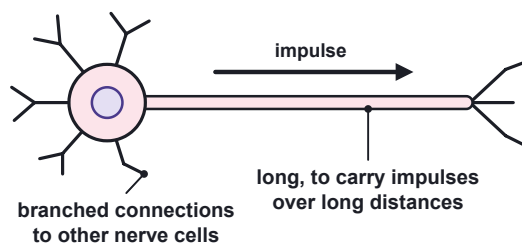
Sperm cell

Carries the male genetic information to the egg



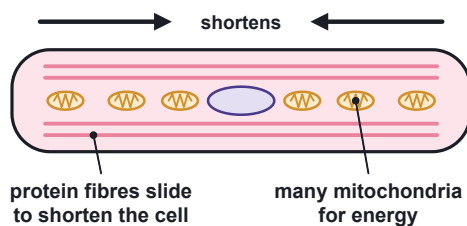
Nerve cell

Carries electrical impulses around the body



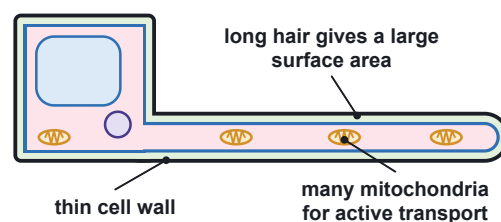
Muscle cell

Contracts (shortens) to cause movement



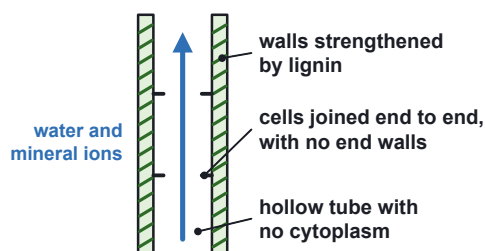
Root hair cell

Absorbs water and mineral ions from the soil



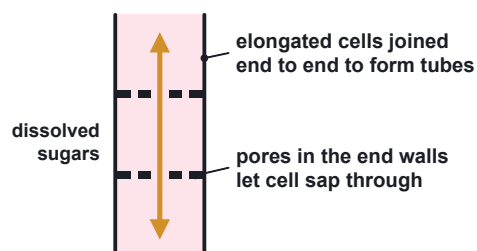
Xylem cell

Carries water and mineral ions up the plant



Phloem cell

Carries dissolved sugars around the plant



Each specialised cell has features that suit its **function**.

Exam tip: For an unfamiliar cell, pick out each feature in the information, say what it does and link it to the cell's function. 'Many mitochondria' means more energy released by respiration.

Cell differentiation Spec 4.1.1.4

As an organism develops, cells **differentiate** to form different types of cells. As a cell differentiates it acquires different sub-cellular structures to enable it to carry out a certain function. It has become a **specialised cell**.

- Most types of animal cell differentiate at an early stage.
- Many types of plant cell retain the ability to differentiate throughout life.
- In mature animals, cell division is mainly restricted to repair and replacement.

Differentiation is important because it allows cells to become specialised, with the sub-cellular structures they need for a particular job. A multicellular organism made of specialised cells can carry out many different functions efficiently, as the specialised cells work together in tissues, organs and organ systems.

Exam tip: To explain the importance of differentiation, say that cells gain different sub-cellular structures so that they can carry out specific functions. Do not just say that cells 'change'.

Microscopy Spec 4.1.1.5

Microscopy techniques have developed over time. The first microscopes used light and lenses to magnify a specimen, and these **light microscopes** were improved with better lenses and the use of stains. Later, **electron microscopes** were developed. These use electrons instead of light.

An electron microscope has much higher **magnification** and **resolving power** than a light microscope. This means that it can be used to study cells in much finer detail. This has enabled biologists to see and understand many more sub-cellular structures.

Light and electron microscopes		
	Light microscope	Electron microscope
Magnification	Lower	Much higher
Resolving power (resolution)	Lower	Much higher
Detail seen	Cells and larger sub-cellular structures such as the nucleus	Much finer detail, including the internal structure of mitochondria and chloroplasts, and ribosomes

Magnification	How many times larger the image is than the real object.
Resolving power	The ability to distinguish between two points that are close together as separate points. Higher resolving power gives a sharper, more detailed image.

Common mistake: Magnification and resolution are not the same: making an image bigger does not add detail. Electron microscopes show more because their resolving power is higher.

Magnification calculations

magnification = size of image ÷ size of real object

Rearranged: real size = image size $\div$ magnification, and image size = real size $\times$ magnification. Make sure the image and real object are in the same units before you divide, then convert at the end. Give the answer in **standard form** if appropriate.

Calculating magnification

A drawing of a cell is 45 mm wide. The real cell is 0.15 mm wide. Calculate the magnification.

1. Both sizes are in mm, so no conversion is needed.
2. magnification = $45 \div 0.15 = 300$.

Answer: $\times 300$

Calculating real size

A cell appears 12 mm wide in an image magnified $\times 400$. Calculate the real width in μm .

1. real size = image size $\div$ magnification = $12 \div 400 = 0.03$ mm.
2. Convert to μm : $0.03 \times 1000 = 30$ μm .

Answer: 30 μm

Maths skill: Use the triangle trick: put image size on top, and real size and magnification below. Cover the one you want and you can see the calculation.

Culturing microorganisms Spec 4.1.1.6 Triple only

Bacteria multiply by simple cell division called **binary fission**, as often as once every 20 minutes if they have enough nutrients and a suitable temperature.

Bacteria can be grown in a **nutrient broth solution** or as colonies on an **agar gel plate**. **Uncontaminated cultures** of microorganisms are required for investigating the action of disinfectants and antibiotics, so that the only microorganisms present are the ones being tested.

Preparing an uncontaminated culture using aseptic technique

1. Sterilise the Petri dish and the agar culture medium before use (for example by heating), to kill any unwanted microorganisms.
2. Sterilise the inoculating loop by passing it through a flame.
3. Use the sterile loop to transfer the microorganisms to the agar. Keep the lid of the Petri dish open for as short a time as possible.
4. Secure the lid of the Petri dish with adhesive tape and store it upside down.
5. Incubate the plate at 25 °C.

Explaining the steps

Step	Reason
Sterilise Petri dishes and culture media	Kills unwanted microorganisms that could contaminate the culture
Pass the inoculating loop through a flame	Kills microorganisms already on the loop, so that only the intended microorganisms are transferred
Secure the lid with adhesive tape	Stops microorganisms from the air getting in, and stops the cultured microorganisms escaping
Store the dish upside down	Condensation drips onto the lid rather than onto the agar surface
Incubate at 25 °C in school laboratories	Reduces the chance of growing pathogens that are harmful to humans, which grow best at higher temperatures such as body temperature

Exam tip: Answers on aseptic technique must say what the step prevents. 'To keep it sterile' earns less than 'to stop microorganisms from the air contaminating the culture'.

Culture calculations Spec 4.1.1.6 Triple only

Number of bacteria after a certain time

You should be able to calculate the number of bacteria in a population after a certain time if you are given the mean division time. Each division doubles the population.

1. Work out the number of divisions: total time $\div$ mean division time (use the same units).
2. Number of bacteria = starting number $\times 2$ to the power of the number of divisions.

Bacterial population

A single bacterium divides every 20 minutes. How many bacteria are there after 2 hours?

1. 2 hours = 120 minutes. Number of divisions = $120 \div 20 = 6$.
2. Number of bacteria = $1 \times 2^6 = 64$.

Answer: 64 bacteria

Higher tier

Standard form

A single bacterium divides every 20 minutes. How many bacteria are there after 8 hours? Give your answer in standard form to 2 significant figures.

1. 8 hours = 480 minutes. Number of divisions = $480 \div 20 = 24$.
2. Number of bacteria = $2^{24} = 16\,777\,216$.
3. Move the decimal point 7 places: 1.6777216×10^7 . To 2 significant figures: 1.7×10^7 .

Answer: 1.7×10^7 bacteria

Areas of colonies and clear areas

You should be able to calculate the cross-sectional area of colonies, or of clear areas around colonies, using πr^2 . The radius is half of the diameter.

$$\text{area} = \pi \times r^2$$

Area of a clear zone

The clear zone around an antibiotic disc has a diameter of 14 mm. Calculate its cross-sectional area. Use $\pi = 3.14$.

1. Radius = $14 \div 2 = 7$ mm.
2. Area = $\pi \times r^2 = 3.14 \times 7 \times 7 = 3.14 \times 49 = 153.86 \text{ mm}^2$.

Answer: About 154 mm^2

Common mistake: Using the diameter as the radius is the most common error. Halve the diameter first, then square the radius.

Required practical 2: antiseptics and antibiotics Spec 4.1.1.6 Triple only

Required practical: Investigate the effect of antiseptics or antibiotics on bacterial growth using agar plates and measuring zones of inhibition.

1. Using aseptic technique, spread a sample of bacteria evenly over the surface of a sterile agar plate to make a bacterial 'lawn'.
2. Using sterile forceps, place sterile paper discs soaked in different antiseptics or antibiotics (or different concentrations of one) onto the agar. Include a control disc soaked in sterile water.
3. Secure the lid with adhesive tape, label the base, store the plate upside down and incubate at 25°C for about two days.
4. Measure the diameter of the clear area (zone of inhibition) around each disc and calculate its area using πr^2 .

Where the antiseptic or antibiotic has killed or stopped the growth of the bacteria, there is a clear zone around the disc. The **larger the zone of inhibition**, the more effective the substance is against that bacterium. The control disc should have no clear zone, which shows that the water itself does not kill the bacteria.

- Independent variable: the type or concentration of antiseptic or antibiotic.
- Dependent variable: the size (diameter or area) of the zone of inhibition.
- Control variables: type and amount of bacteria, type and depth of agar, size of disc, volume of solution on the disc, temperature, incubation time.

Safety: the cultures may contain harmful microorganisms. Use aseptic technique, wash hands, keep the plate taped shut, never open it after incubation, and disinfect the work area and dispose of plates safely.

Quick check

1. How is the genetic material of a bacterial cell arranged?
2. Which sub-cellular structure is the site of aerobic respiration?
3. What is the formula for magnification?
4. Why does an electron microscope show more detail than a light microscope?
5. Triple only: why are inoculating loops passed through a flame?

Quick check answers

Cell structure

1. As a single DNA loop that is not enclosed in a nucleus. There may also be plasmids.
2. Mitochondria.
3. Magnification = size of image $\div$ size of real object.
4. It has much higher magnification and resolving power.
5. To sterilise them and kill unwanted microorganisms.