Cambridge AS & A Level · Biology 9700 · Notes

Cell structure AS

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What you need to know

By the end of this topic you should be able to:

1. **Make a temporary slide** of cells (for example onion epidermis or cheek cells) that you can look at with a light microscope.
2. **Draw cells** that you see on a slide or in a photomicrograph (a photograph taken through a light microscope).
3. **Calculate magnification and actual size** from drawings, photomicrographs and electron micrographs (both scanning and transmission).
4. **Measure with an eyepiece graticule** after calibrating it against a stage micrometer, and use the right units: millimetre (mm), micrometre (μm) and nanometre (nm).
5. **Define resolution and magnification**, and explain how they differ, for light microscopes and electron microscopes.
6. **Recognise the structures in eukaryotic cells and outline their structure and function**: the cell surface membrane; the nucleus, nuclear envelope and nucleolus; rough and smooth endoplasmic reticulum; the Golgi body; mitochondria (with their small circular DNA); ribosomes (80S in the cytoplasm, 70S in mitochondria and chloroplasts); lysosomes; centrioles and microtubules; cilia; microvilli; chloroplasts (with their small circular DNA); the cell wall; plasmodesmata; and the large permanent vacuole with its tonoplast.
7. **Describe and interpret** photomicrographs, electron micrographs and drawings of typical plant and animal cells.
8. **Compare** typical plant cells with typical animal cells.
9. **State that cells use ATP from respiration** to power processes that need energy.
10. **Outline the structure of a typical prokaryotic cell** (a bacterium): a single cell, usually 1–5 μm across, with a cell wall made of peptidoglycan, circular DNA, 70S ribosomes, and no organelles surrounded by a double membrane.
11. **Compare** a typical bacterium with typical plant and animal cells.
12. **State that viruses are not cells**: every virus has a core of nucleic acid (DNA or RNA) inside a protein coat called a capsid, and some also have an outer envelope made of phospholipids.

Understand it

Units and sizes

Three small units are used:

$$1\ \text{mm} = 1000\ \mu\text{m}, \qquad 1\ \mu\text{m} = 1000\ \text{nm}, \qquad \text{so } 1\ \text{mm} = 1\,000\,000\ \text{nm}.$$

To go to a smaller unit, multiply by 1000. Rough sizes let you check that an answer makes sense:

Structure	Typical size
Plant cell	40–100 µm
Animal cell (e.g. cheek cell)	20–50 µm; a red blood cell is about 7 µm
Nucleus	about 5–10 µm
Chloroplast	about 3–10 µm long
Bacterium (prokaryotic cell)	1–5 µm
Mitochondrion	about 1 µm wide, up to a few µm long
Nucleolus	about 1–2 µm
Lysosome	about 0.5 µm
Centriole	about 0.2 µm wide
Virus	most are 20–300 nm
Ribosome	about 20–25 nm
Cell surface membrane	about 7 nm thick

So, from largest to smallest: nucleus > chloroplast > mitochondrion > nucleolus > lysosome > centriole > ribosome.

Making a temporary slide

1. Take a layer of cells thin enough for light to pass through: the inner skin of an onion scale leaf, or cells scraped from inside the cheek with a clean cotton bud.
2. Put it on a clean glass slide in a drop of water or stain. **Iodine solution** stains plant cells (nuclei go yellow-brown, starch goes blue-black); **methylene blue** stains animal cells (nuclei go darker blue).
3. Lower a coverslip at an angle with a mounted needle so no air bubbles are trapped, and blot away extra liquid.
4. Look with the low-power objective first, then high power.

Drawing what you see

- Sharp pencil, **clear continuous lines**, no shading; make it **large**.

- Keep the **proportions** you see, and draw only what is there. A cell wall is **two lines**; neighbouring cells share walls.
- Label with ruled lines (no arrowheads) that don't cross, with labels outside the drawing.

Magnification

Magnification is how many times bigger the image is than the real object:

$$\text{magnification} = \frac{\text{image size}}{\text{actual size}}$$

Both sizes must be in the **same unit**. Rearranged: actual size $= \dfrac{\text{image size}}{\text{magnification}}$ and image size $=$ actual size $\times$ magnification.

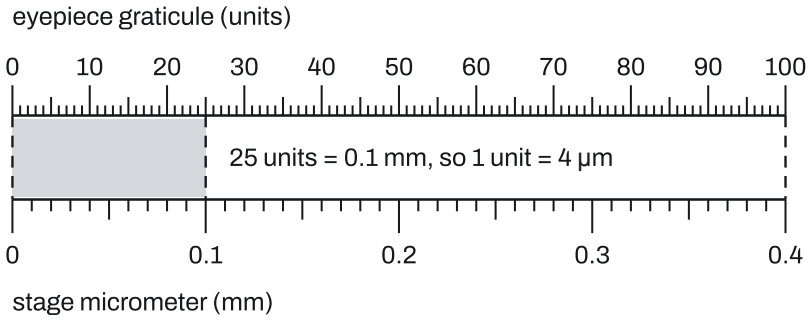
For example, a bacterium 2 µm long in a micrograph at ×10 000 has an image size of $2 \times 10\,000 = 20\,000$ µm $= 20$ mm.

A **scale bar** is a line labelled with the actual length it represents. Measure it in mm, convert, and divide: a bar 30 mm long labelled 5 µm gives magnification $= \frac{30\,000\ \mu\text{m}}{5\ \mu\text{m}} = \times 6000$.

A light microscope's own magnification is **eyepiece × objective** (×10 × ×40 = ×400). That is not the magnification of a printed photomicrograph, which has been enlarged again.

Eyepiece graticule and stage micrometer

An **eyepiece graticule** is a scale inside the eyepiece, in units with no fixed size. It stays the same size whatever the objective while the specimen is magnified, so you must find what one unit is worth at each objective: **calibration**. A **stage micrometer** is a slide with an accurate scale (often 0.1 mm divisions). Line up the two scales and see how many graticule units match a known length.



In the diagram, 25 graticule units match 0.1 mm $= 100$ µm, so

$$1 \text{ graticule unit} = \frac{100\ \mu\text{m}}{25} = 4\ \mu\text{m}.$$

Then replace the micrometer with the specimen, count the units it covers, and multiply: 17 units $\times$ 4 µm $= 68$ µm.

With an objective that magnifies 4 times more (×10 to ×40), 4 times as many graticule units fit one micrometer division, so each unit is worth **a quarter** as much: 4 µm becomes 1 µm. Recalibrate whenever you change the objective.

Resolution

Resolution is the smallest distance between two points at which they can still be seen as two separate points. The smaller that distance, the better (higher) the resolution, and the more detail you see.

Resolution is limited by the **wavelength** used: points closer than about half the wavelength can't be separated. Visible light is about 400–700 nm, so a light microscope's best is about **200 nm (0.2 µm)**. Anything smaller, such as a ribosome (25 nm) or a membrane (7 nm), can't be seen however much you magnify; extra magnification only enlarges the blur, so useful light magnification stops at about ×1500.

Electrons have a far shorter wavelength, so electron microscopes resolve about 0.5 nm and show the **ultrastructure** of cells. Changing the wavelength changes resolution, **not** magnification: blue light resolves slightly better than red.

What you can and can't see with a light microscope at ×400 (stained):

- **Visible:** cell wall, cell surface membrane (as the cell's edge), nucleus, nucleolus, chloroplasts, large vacuole, starch grains, and mitochondria (just, as small dots).
- **Not visible:** ribosomes, endoplasmic reticulum, lysosomes, centrioles, microtubules, and the inside of organelles (cristae, grana). The Golgi body is not normally made out.

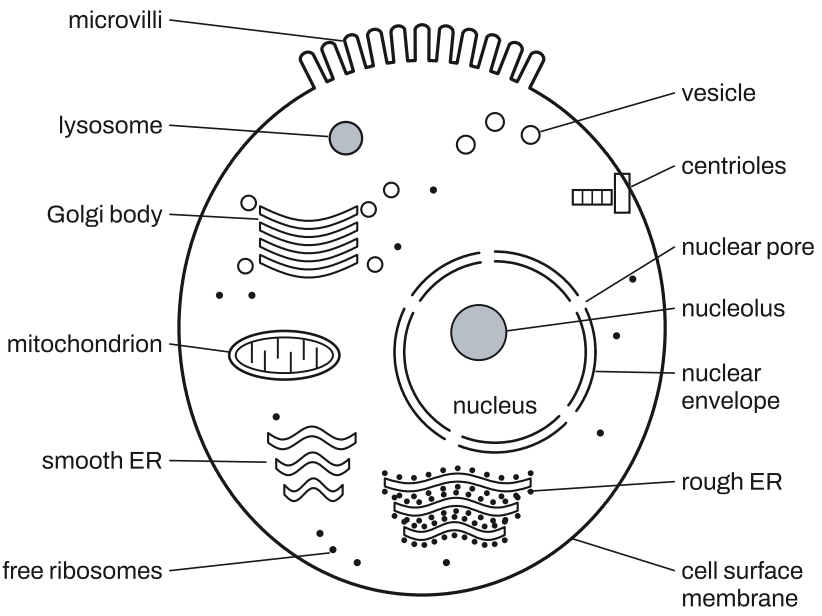
Light, transmission electron and scanning electron microscopes

	Light microscope	Transmission electron microscope (TEM)	Scanning electron microscope (SEM)
Uses	light, focused by glass lenses	electrons passing **through** a very thin section, focused by magnets	electrons **bouncing off** the surface
Image	photomicrograph, can be in colour	2D section showing internal structures, such as membranes and cristae	3D view of the **surface**
Resolution	about 200 nm	about 0.5 nm (best)	about 3–10 nm
Specimens	can be living	dead, in a vacuum, stained with heavy metals	dead, in a vacuum, coated in metal

"Black and white" is not evidence of an electron micrograph (colour can be added). The evidence is **detail too small for a light microscope**: ER membranes, cristae, ribosomes, or a magnification above ×1500.

Eukaryotic cells

Eukaryotic cells (animals, plants, fungi, protoctists) have a nucleus and membrane-bound organelles.



Cell surface membrane. A phospholipid bilayer with proteins, about 7 nm thick. It is partially permeable, controls what enters and leaves, and carries receptors for cell signalling.

Nucleus. The largest organelle. It holds the DNA as **chromatin** (DNA with histone proteins), which condenses into chromosomes when the cell divides.

- **Nuclear envelope:** a **double** membrane round the nucleus. The outer membrane is continuous with the rough ER and has ribosomes on it.
- **Nuclear pores:** gaps in the envelope that let mRNA and ribosome subunits out, and proteins (such as enzymes) in. DNA stays inside.
- **Nucleolus:** a dark, dense, round region (sometimes more than one) that makes **ribosomal RNA** and puts ribosome subunits together. It does not make mRNA.

Ribosomes. Tiny granules with no membrane, made of rRNA and protein, in two subunits. They are the site of **translation**: they join amino acids into polypeptides. Some are free in the cytoplasm; others are on the rough ER. Eukaryotic cytoplasm has larger **80S** ribosomes; mitochondria, chloroplasts and bacteria have smaller **70S** ones (S measures how fast they settle in a centrifuge).

Rough endoplasmic reticulum (RER). Flattened membrane sacs (**cisternae**) covered in ribosomes. Proteins made there enter the cisternae, fold, and are carried in **vesicles** to the Golgi body.

Smooth endoplasmic reticulum (SER). Membrane tubes and sacs **without** ribosomes. It makes **lipids**, including phospholipids and steroids.

Golgi body (Golgi apparatus, Golgi complex). A stack of curved, flattened cisternae with vesicles round it. Vesicles from the RER join one side; proteins are **modified** (for example, carbohydrate added to make **glycoproteins** such as mucin) and packaged. **Secretory vesicles** and **lysosomes** bud off the other side.

Lysosomes. Spherical vesicles with a single membrane, full of **hydrolytic enzymes**. They digest worn-out organelles, fuse with vesicles of engulfed bacteria (in phagocytes), and can release enzymes outside the cell. In mature plant cells the vacuole does this job.

Mitochondria. About 1 μm wide, with a **double membrane**; the inner one folds into **cristae** round the **matrix**. The site of **aerobic respiration**, making most of the cell's ATP, so active cells have many. They contain **small circular DNA** and **70S ribosomes**.

Centrioles and microtubules. Microtubules are hollow tubes of tubulin, about 25 nm wide. They support the cell, act as tracks for vesicles, form the **spindle** in cell division, and are inside cilia. A **centriole** is a short cylinder of 9 triplets of microtubules; animal cells have a pair at right angles near the nucleus, organising microtubules in cell division. Typical plant cells have **none**.

Cilia (one: cilium). Hair-like projections covered by the cell surface membrane, with 9 pairs of microtubules round 2 central ones (**9 + 2**) and a **basal body** at the base. They **beat**, using ATP, to move fluid: in the trachea they sweep mucus (with trapped dust and bacteria) away from the lungs.

Microvilli (one: microvillus). Finger-like folds of the cell surface membrane supported by **actin filaments**. They **don't move**; they increase the surface area for absorption (small intestine, kidney).

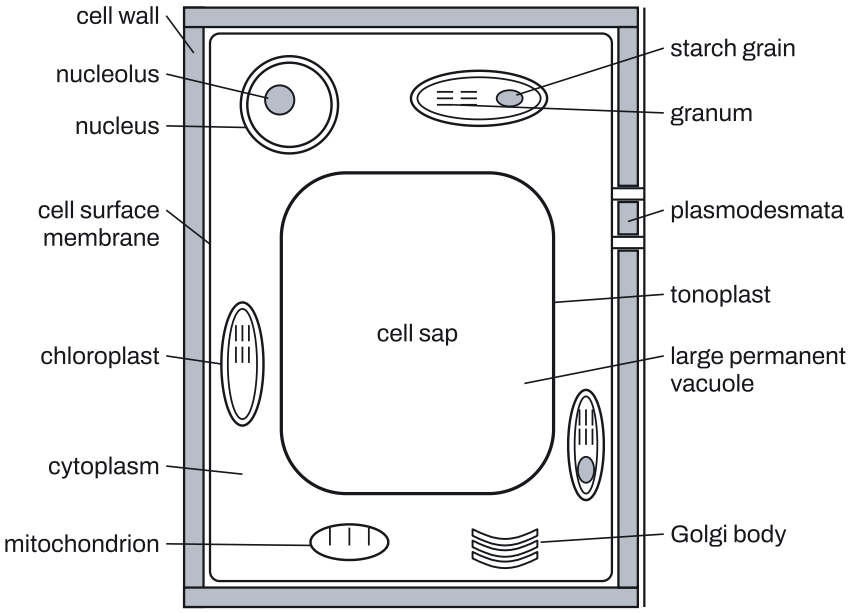
	Cilium	**Microvillus**
Inside	microtubules, 9 + 2	actin filaments
Base	basal body	none
Length	about 10 μm	about 1 μm
Moves?	yes, beats	no
Job	moves mucus or fluid along the surface	increases surface area for absorption

Chloroplasts (plants and algae only). A **double membrane**; inside, **thylakoid** membranes stacked into **grana** in the **stroma**. The site of **photosynthesis**, often with **starch grains**, and with **small circular DNA** and **70S ribosomes**. Root cells have none.

Cell wall (plants). **Cellulose** fibres; fully permeable. It gives strength and stops the cell bursting. It lies outside the cell surface membrane.

Plasmodesmata (one: plasmodesma). Channels through the walls, lined by membrane, joining the cytoplasm of neighbouring cells.

Large permanent vacuole and tonoplast (plants). A sac of **cell sap** (water, sugars, salts) inside a partially permeable membrane, the **tonoplast**. It stores substances and keeps the cell turgid.



Membranes: a summary

Surrounded by	Structures
Double membrane	nucleus (nuclear envelope), mitochondrion, chloroplast
Single membrane	RER, SER, Golgi body, lysosome, vesicles, vacuole (tonoplast)
No membrane	ribosome, centriole, microtubule, nucleolus

Every structure with a membrane has a **partially permeable** membrane (the cell wall is not a membrane, and is fully permeable). **Cisternae** are the flattened sacs of the ER and the Golgi body; the folds of a mitochondrion are called cristae instead.

Where the nucleic acids are

Structure	Nucleic acid
Nucleus	DNA (in chromatin), and RNA being made (mRNA, rRNA in the nucleolus)
Mitochondrion, chloroplast	small circular DNA, and RNA (their own mRNA and 70S ribosomes)
Ribosome	rRNA
Cytoplasm	mRNA and tRNA
Golgi body, lysosome, centriole, ER membranes, vacuole	none of their own (RER has rRNA only in its attached ribosomes)

Making and secreting a protein

The route for a secreted protein (an enzyme, antibody or mucin):

1. **Nucleus:** the gene is transcribed into mRNA, which leaves through a nuclear pore.
2. **Ribosomes on the RER:** the mRNA is translated into a polypeptide, which enters the RER cisternae and folds.
3. **Vesicle:** a vesicle buds off the RER and carries the protein to the Golgi body, fusing with it.
4. **Golgi body:** the protein is modified (for example, carbohydrate added to make a glycoprotein) and packaged.
5. **Secretory vesicle:** buds off the Golgi and moves to the cell surface along microtubules.
6. **Exocytosis:** the vesicle fuses with the **cell surface membrane** and releases its contents outside.

Mitochondria supply the ATP. Lysosome enzymes follow steps 1–4, then stay inside the cell in lysosomes.

ATP

Respiration (mostly in mitochondria) makes **ATP**, and cells use ATP for energy-requiring processes: active transport, protein synthesis, muscle contraction, exocytosis, cilia beating and cell division. Chloroplasts also make ATP in the light. ATP is a nucleotide containing ribose, a pentose sugar.

Plant and animal cells compared

Feature	Typical plant cell	Typical animal cell
Cell wall	cellulose	none
Plasmodesmata	present	none
Vacuole	large, permanent, with tonoplast	small and temporary, if any
Chloroplasts	in cells exposed to light	none
Centrioles	none	present
Microvilli, cilia	none	in some cells
Energy store	starch grains	glycogen granules

Both have a cell surface membrane, nucleus, RER, SER, Golgi body, mitochondria, 80S ribosomes (and 70S in their mitochondria) and microtubules.

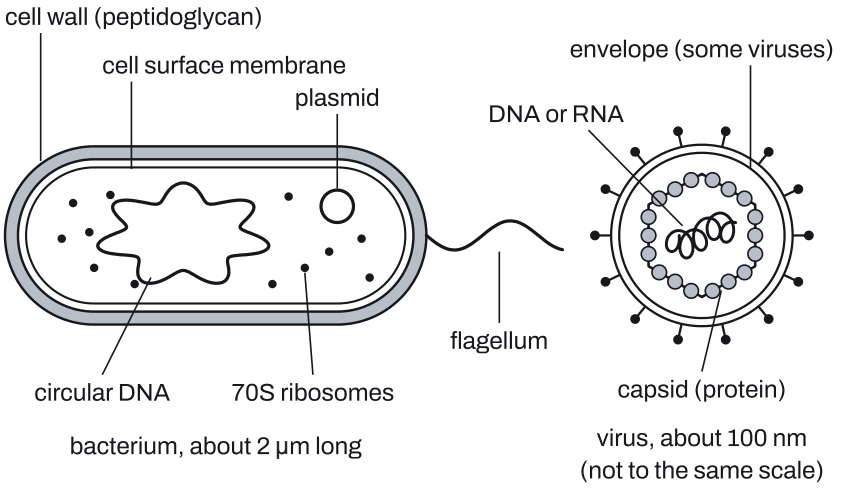
Prokaryotic cells

A typical **prokaryote** (bacterium) is a single cell with no nucleus, and has:

- a size of about **1–5 µm**;
- a **cell wall of peptidoglycan** (also called murein), not cellulose;

- one membrane round the cell, the cell surface membrane;
- **circular DNA** free in the cytoplasm, without histones, and often small loops called **plasmids**;
- **70S ribosomes**;
- **no organelles surrounded by a double membrane** (no nucleus, mitochondria or chloroplasts), and no ER, Golgi or lysosomes.

Cholera and TB are caused by bacteria; malaria by *Plasmodium*, a single-celled eukaryote.



Feature	Bacterium (prokaryote)	Plant and animal cells (eukaryotes)
Size	1–5 µm	usually 10–100 µm
Nucleus	none; DNA free in cytoplasm	DNA inside a nucleus with an envelope
DNA	circular, no histones; plasmids	linear chromosomes with histones (plus small circular DNA in mitochondria and chloroplasts)
Ribosomes	70S	80S in cytoplasm (70S in mitochondria and chloroplasts)
Membrane-bound organelles	none	nucleus, mitochondria, ER, Golgi, lysosomes (chloroplasts in plants)
Cell wall	peptidoglycan	cellulose in plants; none in animals

Mitochondria and chloroplasts look like bacteria. Their size, double membrane, small circular DNA and 70S ribosomes support the idea that they came from free-living prokaryotes taken into a larger cell long ago.

Size or a wall alone proves nothing: a few bacteria are huge, and plants and fungi have walls.

Viruses

A virus is **not a cell**: a particle, usually 20–300 nm across, made of:

- a core of **nucleic acid**: **either DNA or RNA**, never both;

- a **protein** coat, the **capsid**, built from many protein subunits;
- in some (such as HIV), an outer **envelope** of **phospholipids** from the host cell, with proteins in it.

It has no cytoplasm, ribosomes or metabolism, and can reproduce only inside a host cell, which is why cells, not viruses, are called the basic unit of life.

Key facts and formulas

None of these is in the formula list printed in the syllabus (that list is for A Level statistics and ecology), so you must learn them all.

Formula	Status
$\text{magnification} = \dfrac{\text{image size}}{\text{actual size}}$, with both sizes in the same unit	Learn it
$\text{actual size} = \dfrac{\text{image size}}{\text{magnification}}$ and $\text{image size} = \text{actual size} \times \text{magnification}$	Learn it
$1\ \text{mm} = 1000\ \mu\text{m}$ and $1\ \mu\text{m} = 1000\ \text{nm}$	Learn it
Scale bar: $\text{magnification} = \dfrac{\text{measured length of bar}}{\text{length the bar represents}}$	Learn it
Calibration: $1\ \text{graticule unit} = \dfrac{\text{length on stage micrometer}}{\text{number of graticule units that match it}}$	Learn it
$\text{actual length} = \text{number of graticule units} \times \text{value of one unit}$	Learn it
Light microscope: $\text{total magnification} = \text{eyepiece} \times \text{objective}$	Learn it
Resolution: light microscope about 200 nm; electron microscope about 0.5 nm	Learn it

The membrane, nucleic acid, plant–animal and prokaryote tables in "Understand it" are the facts to learn by heart.

How to do it

In the 263 questions we have tagged for this topic (Papers 1 and 2, 2021–2025), the types came up this often. 29 of them mix more than one type, so the counts add up to 300. Paper 1 questions are single multiple-choice marks; Paper 2 parts are often inside a longer question on another topic.

Question type	Questions
Name organelles and state their structure and function	45
Compare prokaryotic and eukaryotic cells	40
Calculate actual size or magnification	34
Resolution, magnification and microscope type	28
Organelles that contain a given molecule or feature	28

Question type	Questions
Structure of viruses	23
Eyepiece graticule and stage micrometer	19
Protein synthesis and secretion pathway	18
Mitochondria, chloroplasts and prokaryotes	17
Relate a cell's organelles to its function	14
Compare plant and animal cells	9
Cilia, microvilli, microtubules and centrioles	8
Typical sizes and unit conversion	8
Order organelles by size or density	5
Draw organelles from an electron micrograph	2
Facts about ATP	2

1. Name organelles and state their structure and function (45 questions)

1. **Identify the structure from what you see**: double membrane with pores → nuclear envelope; dark round patch in the nucleus → nucleolus; flattened sacs with dots → RER; curved stack of sacs with vesicles at the edges → Golgi body; double membrane with inner folds → mitochondrion; stacked membranes (grana) → chloroplast; tiny dots → ribosomes; small dark sphere with one membrane → lysosome; two short cylinders at right angles → centrioles.
2. **Name it precisely**: "rough endoplasmic reticulum", not just "ER".
3. **Give structure and function** with specific words: "site of aerobic respiration, producing ATP", not "makes energy".

Variations you will meet:

- **Describe the nucleus:** name each part (envelope, pores, nucleolus, chromatin) and add a detail for each, as in "Understand it". A labelled diagram can earn the same marks.
- **Match functions to descriptions in a grid** (Paper 1): use step 1.
- **A cell without a nucleolus** can't make ribosomes, so can't make proteins, and dies.

2. Compare prokaryotic and eukaryotic cells (40 questions)

1. **Tick-box tables:** check each feature against the prokaryote list and the comparison table in "Understand it".
2. **"Which features are shared"**: cell surface membrane, cytoplasm, ribosomes, DNA, and making ATP.
3. **Written comparisons:** give **both sides** in each point: "bacteria have 70S ribosomes, **whereas** eukaryotic cells have 80S ribosomes in the cytoplasm".

Variations you will meet:

- **Classify a pathogen:** cholera and TB are bacteria; malaria (*Plasmodium*) is a eukaryote; HIV, measles and influenza are viruses.
- **Explain why an organism is a eukaryote**: nucleus, membrane-bound organelles, 80S ribosomes, or linear DNA with histones.
- **Find the error** in a description, such as a bacterial wall "made of cellulose".
- **Unusual organisms:** decide on circular DNA free in the cytoplasm (prokaryote) or a nucleus (eukaryote), never on size, a wall or a vacuole.
- **Unfamiliar structures**, such as a bacterium's outer membrane: compare them with the cell surface membrane (phospholipids, proteins, bilayer) using the information given.

3. Calculate actual size or magnification (34 questions)

1. **Write the formula**: $\text{magnification} = \frac{\text{image size}}{\text{actual size}}$ (or a rearranged form). It often earns a mark.
2. **Measure the image in millimetres**, along exactly the line asked (X–Y, or the whole cell).
3. **Convert** to the same unit as the actual size: mm × 1000 for µm, mm × 1 000 000 for nm.
4. **Calculate** to the significant figures asked, with the unit (actual size) or a × sign (magnification).
5. **Check it is sensible** against the sizes table.

For example, a line X–Y across a cell measures 36 mm and the cell's actual width is 12 µm: magnification $= \frac{36\,000}{12} = \times 3000$.

Variations you will meet:

- **Scale bar:** find the magnification from the bar, then use it for another structure (Example 1).
- **Mean length:** measure several structures, find the mean, then divide by the magnification.
- **What extra information is needed?** The magnification of the **image** (not of the microscope) and the measured image length.
- **Estimate magnification** from a structure of known size, such as a red blood cell (about 7 µm).

4. Resolution, magnification and microscope type (28 questions)

1. **Define** both terms exactly (see "Understand it").
2. **Decide what is visible:** compare the size of the structure (or the gap between two structures) with the resolution, about 200 nm for light. Smaller can't be seen, however high the magnification.
3. **Explain why an electron microscope shows more:** electrons have a much shorter wavelength, so the resolution is far better.

Variations you will meet:

- **Change of wavelength:** longer (red) makes resolution worse, shorter makes it better; magnification doesn't change.

- **Which microscope made this image?** SEM: 3D surface. TEM: internal membranes, cristae, ribosomes. Name a structure as evidence.
- **Plant cells at ×400:** no centrioles at all; mitochondria and starch grains visible; ER, ribosomes and lysosomes not.
- **Total magnification** = eyepiece × objective, never added.

5. Organelles that contain a given molecule or feature (28 questions)

Test each option against the tables "Membranes: a summary" and "Where the nucleic acids are" in "Understand it". Two points catch people out:

- **Transcription** happens in the nucleus, mitochondria and chloroplasts; **translation** on ribosomes, including those inside mitochondria and chloroplasts.
- Counting questions: animal and plant cells share **two** double-membrane structures (nucleus and mitochondrion), because chloroplasts are plant only.

6. Structure of viruses (23 questions)

1. **All viruses have** nucleic acid (DNA **or** RNA) and a protein capsid. **Some** have a phospholipid envelope. **None** has ribosomes, cytoplasm, a cell wall or organelles.
2. **"What do all viruses contain?"** Protein (so peptide bonds) and a nucleic acid (so phosphodiester bonds, a pentose, and the bases A, G and C). Not necessarily thymine (DNA only), uracil or ribose (RNA only), or phospholipids.
3. **Label a diagram**: nucleic acid inside, capsid round it, envelope outside.

7. Eyepiece graticule and stage micrometer (19 questions)

1. **Find where the scales line up** and read how many graticule units match how much of the micrometer.
2. **Convert** the micrometer length to μm (0.1 mm $=$ 100 μm; 0.01 mm $=$ 10 μm).
3. **Divide** to get the value of one graticule unit.
4. **Measure the specimen** in graticule units and **multiply**.

Variations you will meet:

- **Why calibrate?** The graticule stays the same size while the specimen is magnified, so a unit is worth a different length at each objective.
- **Changing objective:** ×4 more magnification means each unit is worth a quarter as much; ×4 less, four times as much.
- **How many units cover a cell of known size?** Divide the size by the value of one unit.
- **Growth rate:** convert the change in length to μm and divide by the time.

8. Protein synthesis and secretion pathway (18 questions)

1. **Write the order** from "Making and secreting a protein", and say what happens at each stage if asked to describe.
2. **Radioactive amino acids** appear first in the RER, then the Golgi body, then vesicles, lysosomes or outside the cell.
3. **Glycoproteins** get their carbohydrate in the Golgi body; release is by **exocytosis** at the **cell surface membrane**.

9. Mitochondria, chloroplasts and prokaryotes (17 questions)

1. **Shared features:** 70S ribosomes, small circular DNA, a double membrane, bacterial size, and making some of their own proteins.
2. **These support** the idea that the organelles came from free-living prokaryotes. 80S ribosomes don't: they are only in the eukaryotic cytoplasm and on the RER.
3. **An antibiotic that binds 70S ribosomes** may also slow protein synthesis in mitochondria.

10. Relate a cell's organelles to its function (14 questions)

1. **State the visible evidence** in the micrograph.
2. **Link it to a function** with "because" or "so".

You see	It suggests
lots of RER, a large Golgi body, many vesicles	makes and secretes protein
lots of SER	makes lipids or steroids
many mitochondria	lots of ATP for active transport, contraction or synthesis
microvilli	absorption, with a larger surface area
cilia	moving mucus or fluid
many lysosomes	digesting bacteria or old organelles

A specialised cell looks different from a stem cell because it has **differentiated**: it has the organelles its job needs.

11. Compare plant and animal cells (9 questions)

Use the plant and animal table in "Understand it". A cell with a cellulose wall is a plant cell even without chloroplasts; both kinds have 70S ribosomes (in mitochondria).

12. Cilia, microvilli, microtubules and centrioles (8 questions)

1. **Cilium vs microvillus:** use the comparison table, giving both sides of each difference.

2. **Cilia vs root hairs:** one cell has many cilia; a root hair is an extension of one root cell (one per cell) and contains cytoplasm and a vacuole.
3. In the airways, **mucus traps** particles and **cilia beat** to move the mucus.

13. Typical sizes and unit conversion (8 questions)

Learn the sizes table in "Understand it". Put two sizes in the same unit before dividing: a 5 µm bacterium and a 250 nm virus give $5000\ \text{nm} \div 250\ \text{nm} = 20$, so the bacterium is 20 times wider.

14. Order organelles by size or density (5 questions)

Size order is under the sizes table. In **cell fractionation** the cells are broken open and spun: the biggest, densest structures settle first, so nuclei come out first, then chloroplasts, then mitochondria, and ribosomes last. In a density gradient the order from the top is ribosomes, mitochondria, chloroplasts, nuclei. Then state the function of the structure asked about.

15. Draw organelles from an electron micrograph (2 questions)

Draw the detail an electron microscope shows (mitochondrion with two membranes and cristae; RER with dots; SER without; nucleus with envelope, pores and nucleolus; centrioles at right angles), following the drawing rules in "Understand it".

16. Facts about ATP (2 questions)

See the ATP paragraph in "Understand it": made by respiration (mostly in mitochondria) and in chloroplasts; contains ribose; used for energy-requiring processes.

Worked examples

The bold codes show where marks are earned, as in Cambridge mark schemes. The number is how many marks.

- **M1** method mark: for a correct method, even if the numbers slip.
- **A1** accuracy mark: for a correct answer; it needs the M mark before it.
- **B1** mark for a correct result on its own, with no method needed.

Example 1

Fig. A is a transmission electron micrograph of part of a leaf cell. It has a scale bar 18 mm long labelled 3 µm.

(a) Calculate the magnification of Fig. A. Show your working. **[2]**

(b) A chloroplast in Fig. A measures 33 mm in length. Calculate its actual length in micrometres. **[2]**

(c) A mitochondrion is shown at ×24 000 in a different micrograph. Its image is 60 mm long. Calculate its actual length. **[1]**

(d) Explain why the internal structure of the chloroplast can be seen in Fig. A but not with a light microscope. **[2]**

(a) $18\ \text{mm} = 18 \times 1000 = 18\,000\ \mu\text{m}$. **M1** for converting the bar to μm and dividing by what it represents.

$$\text{magnification} = \frac{18\,000\ \mu\text{m}}{3\ \mu\text{m}} = \times 6000$$

A1

(b) $33\ \text{mm} = 33\,000\ \mu\text{m}$, so actual length $= \dfrac{33\,000}{6000} = 5.5\ \mu\text{m}$. **M1 A1** (the M1 is still earned with a wrong magnification from (a) used correctly).

(c) $\dfrac{60 \times 1000}{24\,000} = 2.5\ \mu\text{m}$. **B1**

(d) The electron microscope has a much higher resolution (about 0.5 nm, compared with about 200 nm for light), **B1** because electrons have a much shorter wavelength than light, so the thylakoid membranes, which are closer together than 200 nm, can be seen as separate. **B1**

Example 2

The first diagram in "Understand it" shows an eyepiece graticule lined up with a stage micrometer, using a ×10 objective. Each large division of the stage micrometer is 0.1 mm.

(a) Calculate the actual length of one eyepiece graticule unit. **[2]**

(b) A cheek cell viewed with the same objective covers 17 graticule units. Calculate its actual diameter. **[1]**

(c) The student changes to a ×40 objective without changing the eyepiece. State the new value of one graticule unit, and the number of graticule units the same cell would now cover. **[2]**

(a) 25 graticule units match 0.1 mm $= 100$ μm. **M1** for reading the matching lengths and converting to μm.

$$1\ \text{graticule unit} = \frac{100\ \mu\text{m}}{25} = 4\ \mu\text{m}$$

A1

(b) $17 \times 4 = 68\ \mu\text{m}$. **B1**

(c) The objective magnifies 4 times more, so each graticule unit covers a quarter of the length: $4 \div 4 = 1\ \mu\text{m}$. **B1**

The cell now covers $68 \div 1 = 68$ graticule units (4 times as many). **B1**

Example 3

(a) Copy and complete the table with ✓ (present) or ✗ (absent). **[4]**

Feature	Plant cell	Bacterium	Virus
Cell surface membrane			
70S ribosomes			
Nucleic acid			
Cell wall containing peptidoglycan			

(b) Mitochondria are thought to have come from free-living bacteria. State **two** features of mitochondria that support this idea. **[2]**

(a) One mark per correct row:

Feature	Plant cell	Bacterium	Virus
Cell surface membrane	✓	✓	✗
70S ribosomes	✓	✓	✗
Nucleic acid	✓	✓	✓
Cell wall containing peptidoglycan	✗	✓	✗

B1 B1 B1 B1. The plant cell's ✓ for 70S ribosomes comes from its mitochondria and chloroplasts. A virus's envelope, when it has one, is not a cell surface membrane.

(b) Any two: they contain small circular DNA; they have 70S ribosomes; they are about the size of a bacterium; they are surrounded by a double membrane; they make some of their own proteins. **B1 B1**

Example 4

A transmission electron micrograph of a cell from a salivary gland shows a large amount of rough endoplasmic reticulum, a well-developed Golgi body, many vesicles close to the cell surface membrane, and many mitochondria. The cell secretes amylase, an enzyme.

(a) Explain how **three** features visible in the micrograph show that the cell makes and secretes a protein. **[3]**

(b) Outline the route taken by amylase from its synthesis until it leaves the cell. **[4]**

(a) Any three, each with its explanation:

- lots of RER: its ribosomes are the site of protein (enzyme) synthesis, and the RER transports the protein; **B1**
- a large Golgi body: modifies and packages the protein into vesicles; **B1**
- many vesicles near the cell surface membrane: they carry the enzyme to the membrane for exocytosis; **B1**

- many mitochondria: supply ATP for protein synthesis and for moving vesicles. **(B1)**

(b) Any four:

- the polypeptide is made on ribosomes on the RER and enters the RER cisternae; **B1**
- it is carried in a vesicle from the RER to the Golgi body; **B1**
- it is modified in the Golgi body and packaged into secretory vesicles; **B1**
- the vesicles move to the cell surface (along microtubules); **(B1)**
- the vesicle fuses with the **cell surface membrane** and releases amylase by exocytosis. **B1**

Saying the vesicle "fuses with the membrane" without "cell surface" loses the last mark: a vesicle could fuse with any membrane.

Common mistakes

- **Converting units wrongly**, especially mm or cm to nm. Measure in **mm**, then multiply by 1000 for µm and by 1 000 000 for nm, and ask whether the answer is a sensible size.
- **Leaving out working or units.** Write the formula, the numbers used and the unit.
- **Measuring the wrong thing.** Measure exactly the line or structure named in the question.
- **Using the microscope's magnification for a printed image.** You need the magnification of **the image**.
- **Thinking wavelength changes magnification**, or that the ER, centrioles or ribosomes show at ×400.
- **Scaling the graticule the wrong way.** A higher-power objective makes each unit worth **less**.
- **Putting nucleic acid in the Golgi body or lysosomes**, or forgetting the 70S ribosomes and circular DNA inside mitochondria and chloroplasts.
- **Giving a bacterium a double membrane**, or mixing bacteria up with viruses (viruses have no ribosomes, no peptidoglycan, and DNA **or** RNA).
- **Calling malaria bacterial or viral.** *Plasmodium* is a eukaryote.
- **Saying the nucleolus makes mRNA.** It makes rRNA.
- **"Fuses with the membrane"** for exocytosis: say the **cell surface membrane**.
- **Saying cilia trap particles.** Mucus traps them; cilia move the mucus.
- **Claiming to see molecules in a micrograph**, or using "black and white" as evidence of an electron micrograph.
- **Writing 7 nm for a red blood cell.** It is about 7 µm.

How to get the marks

- **"Calculate":** show the formula, the measurement in mm, the conversion, and the answer with its unit, to the significant figures asked. A correct method usually earns a mark even if the value is wrong, and measurements get about ±1 mm tolerance.

- **"Define":** resolution is the **smallest distance at which two points are seen as separate**; "how clear the image is" is not enough.
- **"State"** is short but precise: "rough endoplasmic reticulum", "70S ribosomes", "peptidoglycan".
- **"Outline"** means the main steps in order; **"describe"** means what is there, with detail; **"explain"** needs a reason ("because", "so").
- **"Compare"** needs **both sides** in each point: "cilia contain microtubules, whereas microvilli contain actin filaments".
- **"Suggest"** means apply what you know to an unfamiliar cell, using the information given.
- **Micrographs:** name what you can see and link it to its function, such as "many vesicles" plus "exocytosis". Unexplained mentions of the nucleus earn nothing.
- **Labelled diagrams** can earn the marks in "describe" questions; **drawings** follow the drawing rules.
- **Multiple choice:** test each numbered statement on its own, then pick the matching option.

Quick check

1. A nucleus with an actual diameter of 8 μm measures 40 mm in a micrograph. Calculate the magnification of the micrograph.
2. A ribosome is about 25 nm across. Explain why ribosomes can't be seen with a light microscope, even at ×1500.
3. With a ×40 objective, one eyepiece graticule unit is worth 2.5 μm. The student changes to a ×10 objective and keeps the same eyepiece. What is one graticule unit now worth, and how long is a cell that covers 12 units?
4. Which of these contain nucleic acid: nucleus, ribosome, Golgi body, lysosome, mitochondrion, chloroplast, centriole?
5. Give three structural differences between a virus and a bacterium.

Answers

1. $40\ \text{mm} = 40\,000$ µm. Magnification $= \dfrac{40\,000}{8} = \times 5000$.
2. The best resolution of a light microscope is about 200 nm, limited by the wavelength of light. A ribosome (25 nm) is much smaller than this, so it can't be seen as a separate object; magnifying more only makes a blurred image bigger.
3. The ×10 objective magnifies 4 times less, so each unit is worth 4 times more: $2.5 \times 4 = 10$ µm. The cell is $12 \times 10 = 120$ µm long.
4. Nucleus (DNA and RNA), ribosome (rRNA), mitochondrion and chloroplast (small circular DNA and RNA). The Golgi body, lysosome and centriole do not.
5. Any three: a bacterium is a cell but a virus is not; a bacterium has cytoplasm and a cell surface membrane, a virus has neither; a bacterium has 70S ribosomes, a virus has none; a bacterium has a peptidoglycan cell wall, a virus has a protein capsid; a bacterium has DNA (circular, often with plasmids), a virus has DNA **or** RNA; bacteria are 1–5 µm, most viruses 20–300 nm.

Past questions to try

- **9700/22/O/N/25 Q1**: cilia vs microvilli, and the evidence that a cell is secretory.
- **9700/24/O/N/25 Q2**: classifying pathogens, and a magnification to 3 significant figures.
- **9700/14/O/N/25 Q2**: calibrating an eyepiece graticule and measuring a root.
- **9700/13/O/N/25 Q7**: which features viruses can have.