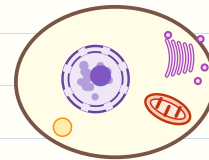


AS & A Level · Biology (9700) · Chapter 1

Cell Structure



Syllabus topic 1: 1.1 The microscope in cell studies · 1.2 Cells as the basic units of living organisms

For the Cambridge International AS & A Level Biology 9700 syllabus, exams in 2025, 2026 and 2027 (AS Level content)

Syllabus statements covered in this chapter

Syllabus ref.	What you must be able to do	Level
1.1.1–1.1.5	Temporary preparations; drawing cells; magnification and actual size from drawings, photomicrographs and electron micrographs; eyepiece graticule and stage micrometer (mm, μm , nm); resolution and magnification	AS
1.2.1–1.2.4	Eukaryotic organelles: structure and function; interpreting micrographs and drawings; comparing plant and animal cells; cells use ATP from respiration	AS
1.2.5–1.2.7	Prokaryotic cells and their comparison with eukaryotic cells; viruses as non-cellular structures	AS

What is inside

1. Concept notes, 8 worked examples
2. Practical skills (Paper 3); common mistakes from examiner reports
3. 20 MCQs (Paper 1 style), explained
4. 3 structured questions (Paper 2 style) with full mark schemes
5. Quick-reference sheet, "I can" checklist

How to read these notes

AS = AS Level content (Papers 1, 2 and 3)

A = A Level only (Papers 4 and 5)

red = key term **green** = definition

1 = one mark in the mark scheme

★ **Exam tip:** 1 mm = 1000 μm and 1 μm = 1000 nm. Always put the image size and the actual size into the **same unit** before dividing.

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1.1 The microscope in cell studies

Temporary preparations (light microscope)

- Take a **thin** layer of tissue (one cell thick, e.g. onion bulb epidermis peeled with forceps, or cheek cells scraped with a clean cotton bud) so that light can pass through it.
- Place it in a drop of water or **stain** on a clean slide: **iodine in potassium iodide solution** for plant cells (stains starch blue-black, makes nuclei visible), **methylene blue** for animal cells (stains nuclei).
- Lower a **coverslip** at an angle with a mounted needle to avoid trapping **air bubbles**; blot off excess liquid. The coverslip keeps the specimen flat and stops it drying out.
- Focus with the **low-power** objective first (coarse focus), then change to high power and use only the fine focus.

Drawing cells from slides and photomicrographs

- Use a sharp HB pencil: **thin, continuous lines that join up; no shading; use most of the space; keep the correct proportions.**
- **Low-power plan diagram:** outlines of the **tissues** (layers) only, **no individual cells**. **High-power drawing:** a few **individual cells**, with cell walls drawn as **double lines**.
- Label lines: ruled, ending exactly on the structure, no arrowheads, not crossing each other; labels outside the drawing.

Units and magnification

1 mm = 1000 μm (micrometres) · 1 μm = 1000 nm (nanometres) · 1 mm = 1 000 000 nm

magnification = $\frac{\text{image size}}{\text{actual size}}$ or $M = \frac{I}{A}$ so $A = \frac{I}{M}$ and $I = A \times M$

I and **A** must be in the **same unit**. Magnification has **no unit**; write it as $\times 8000$.

- A **scale bar** on a micrograph gives a known actual length. Measure the bar with a ruler (in mm), convert to μm , then $M = \frac{\text{bar length on image}}{\text{length the bar represents}}$.
- Typical sizes: bacterium 1–5 μm ; red blood cell about 7 μm ; mitochondrion about 1 μm wide; chloroplast 3–10 μm long; 80S ribosome about 25 nm; virus about 20–300 nm.

Worked example 1: magnification of a drawing

A student's drawing of a mitochondrion is 48 mm long. The mitochondrion is actually 4 μm long. Calculate the magnification.

Same units: 48 mm = $48 \times 1000 = 48\,000\ \mu\text{m}$. $M = \frac{48\,000}{4} = \times 12\,000$.

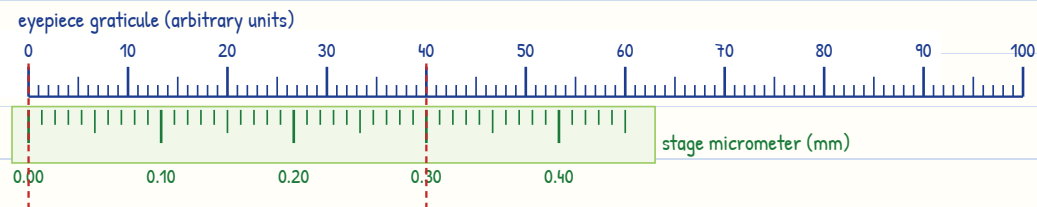
Worked example 2: actual size using a scale bar

On an electron micrograph a scale bar labelled 2 μm is 16 mm long. A chloroplast on the same micrograph is 52 mm long. Find the magnification and the actual length of the chloroplast.

$M = \frac{16\,000\ \mu\text{m}}{2\ \mu\text{m}} = \times 8000$. $A = \frac{I}{M} = \frac{52\,000\ \mu\text{m}}{8000} = 6.5\ \mu\text{m}$.

Eyepiece graticule and stage micrometer

- An **eyepiece graticule** is a scale in the eyepiece with **arbitrary divisions (eyepiece units)**; it appears over the specimen at every magnification, so its units have no fixed size.
- A **stage micrometer** is a slide with an **accurately ruled scale of known length** (often 1 mm divided into 100 divisions of $0.01 \text{ mm} = 10 \mu\text{m}$).
- Calibrate:** line up the two scales, find a point further along where lines coincide again, and calculate the length of one eyepiece unit. Then remove the micrometer, put the specimen on the stage and measure in eyepiece units.
- Recalibrate for each objective lens:** with a $\times 4$ more powerful objective, each eyepiece unit covers $\frac{1}{4}$ of the length.



40 eyepiece units = 30 stage divisions = 0.30 mm
 so 1 eyepiece unit = $300 \mu\text{m} \div 40 = 7.5 \mu\text{m}$ (at this objective only)

Calibration: lines coincide at 0 and at 40 eyepiece units.

Worked example 3: calibrating the graticule

In the figure, 40 eyepiece units line up with 30 stage divisions of 0.01 mm . Calculate the length of one eyepiece unit.

$$30 \times 0.01 \text{ mm} = 0.30 \text{ mm} = 300 \mu\text{m}. \text{ One eyepiece unit} = \frac{300}{40} = 7.5 \mu\text{m}.$$

Worked example 4: measuring a cell

With the same objective, a cheek cell is 18 eyepiece units across. (a) Find its diameter. (b) The $\times 10$ objective is changed for the $\times 40$ objective. What is one eyepiece unit worth now?

(a) $18 \times 7.5 = 135 \mu\text{m}$. (b) The image is 4 times larger, so one unit covers $\frac{7.5}{4} = 1.875 \mu\text{m}$ ($1.9 \mu\text{m}$). In the exam, recalibrate rather than assume this.

Magnification and resolution

Definition **Magnification:** the number of times larger an image is than the real size of the object.

Definition **Resolution:** the ability to distinguish between two separate points (objects) that are close together; the smallest distance between two points that can still be seen as separate.

- Resolution is limited by the **wavelength** of the radiation: two points closer than about half the wavelength appear as one. Light has wavelengths $400\text{--}700 \text{ nm}$, so the light microscope cannot resolve points closer than about **200 nm** .
- Electrons have a **much shorter wavelength**, so electron microscopes have a much higher resolution. Increasing magnification **without** increasing resolution only gives a bigger blur ("empty magnification").

Feature	Light microscope	Transmission EM (TEM)	Scanning EM (SEM)
radiation	light, focused by glass lenses	electron beam, focused by electromagnets	electron beam, focused by electromagnets
resolution	about 200 nm	about 0.5 nm	about $3\text{--}10 \text{ nm}$

maximum useful magnification	about $\times 1500$	about $\times 500\,000$	about $\times 100\,000$
image	colour; living or dead specimens	thin section, 2-D, internal ultrastructure; black and white (false colour may be added)	surface, 3-D appearance; black and white
specimen	can be living	dead, in a vacuum, stained with heavy metals	dead, in a vacuum, coated with metal

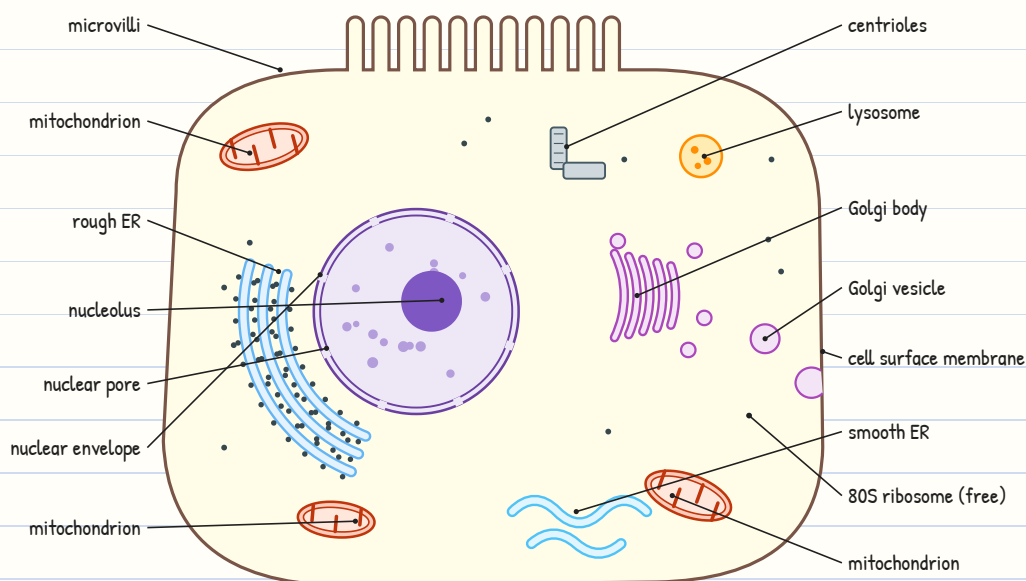
Worked example 5: what can be resolved?

Two ribosomes on rough ER are 50 nm apart. Explain why they cannot be seen as separate with a light microscope at $\times 1500$ but can with a TEM.

The resolution of the light microscope is about 200 nm, so points 50 nm apart appear as one; magnifying more only enlarges the blur. Electrons have a much shorter wavelength, giving a TEM resolution of about 0.5 nm, which is far smaller than 50 nm, so **the two ribosomes are resolved by the TEM.**

1.2 Cells as the basic units of living organisms

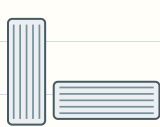
Eukaryotic cells (animals, plants, fungi, protocists) have a **nucleus** and membrane-bound organelles. The structures below are seen with the electron microscope (the **ultrastructure** of the cell).



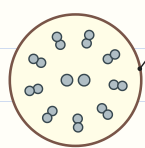
Animal cell (e.g. an intestinal epithelial cell) as seen with a TEM, drawn.

Structure	Structure (outline)	Function
cell surface membrane	phospholipid bilayer with proteins, about 7 nm thick	partially permeable barrier; controls entry and exit; cell signalling and recognition (Chapter 4)
nucleus	largest organelle; contains chromosomes made of chromatin (DNA + histone proteins)	contains the genetic information; controls the cell's activities through protein synthesis; DNA replication

nuclear envelope	two membranes with nuclear pores ; outer membrane continuous with rough ER	separates nucleus from cytoplasm; pores let mRNA and ribosome subunits out, and nucleotides and proteins in
nucleolus	dense, darkly staining region in the nucleus	makes ribosomes (ribosomal RNA, rRNA, and assembly of subunits)
rough endoplasmic reticulum (RER)	network of flattened membrane sacs (cisternae) with ribosomes on the outer surface	proteins made on its ribosomes enter the cisternae, fold, and are transported (e.g. to the Golgi body) in vesicles
smooth endoplasmic reticulum (SER)	tubular membranes without ribosomes	synthesis of lipids and steroids (e.g. cholesterol, steroid hormones); stores calcium ions in muscle; detoxification
Golgi body (Golgi apparatus, Golgi complex)	stack of curved, flattened membrane sacs; vesicles bud off	modifies proteins and lipids (e.g. adds carbohydrate to make glycoproteins); packages them into Golgi vesicles for secretion (exocytosis) or for use in the cell; makes lysosomes
mitochondria	double membrane ; inner membrane folded into cristae ; matrix containing small circular DNA and 70S ribosomes	site of aerobic respiration (Krebs cycle in the matrix, ATP synthesis on the inner membrane); produce most of the cell's ATP
ribosomes	two subunits of rRNA and protein, no membrane; 80S (about 25 nm) free in the cytoplasm or on RER; 70S (smaller) in chloroplasts and mitochondria	site of protein synthesis (translation)
lysosomes	spherical sacs bounded by a single membrane , 0.1–0.5 μm , made by the Golgi body	contain hydrolytic (digestive) enzymes : digest worn-out organelles, and material taken in by endocytosis/phagocytosis (fuse with the vesicle); can destroy the whole cell
centrioles and microtubules	microtubules : hollow tubes of the protein tubulin , about 25 nm wide. Centrioles : a pair of short cylinders at right angles, each of 9 triplets of microtubules, in the centrosome (animal cells only)	microtubules form the cytoskeleton, move organelles and vesicles, and form the spindle ; centrioles organise the spindle in animal cell division and form the bases (basal bodies) of cilia
cilia	hair-like extensions of the cell surface, with a "9 + 2" arrangement of microtubules	beat to move fluid or mucus over the cell surface (e.g. ciliated epithelium of the trachea) or to move the cell
microvilli	finger-like folds of the cell surface membrane , about 1 μm long	increase the surface area for absorption (e.g. small intestine, kidney tubule)

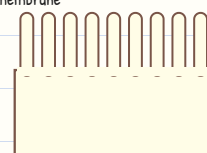


centrioles: two at right angles; each is 9 triplets of microtubules

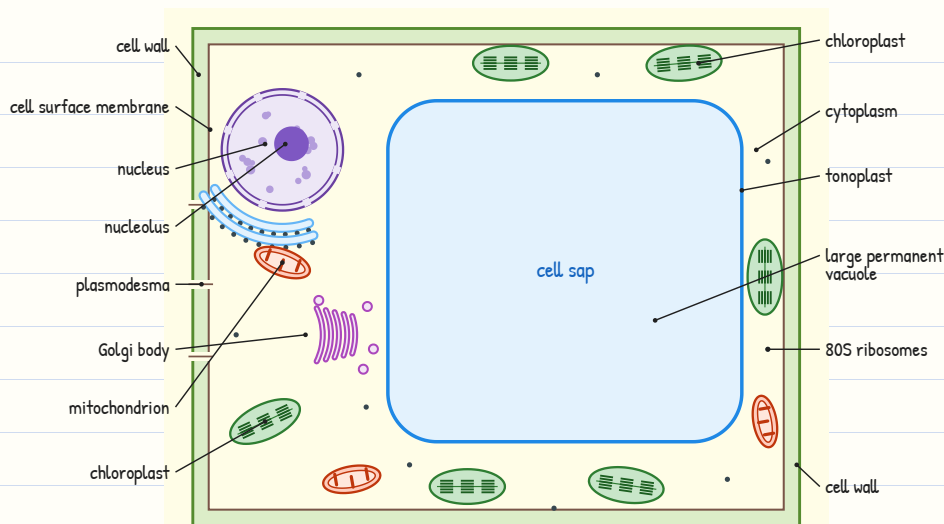


cilium (cross-section): "9 + 2"
9 pairs + 2 central microtubules

cell surface membrane

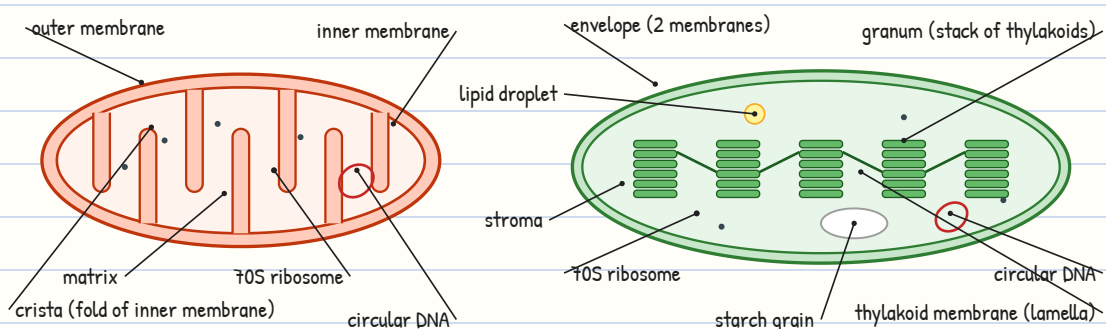


microvilli: folds of the cell surface membrane ($\approx 1 \mu\text{m}$ long)



Plant cell (e.g. a palisade mesophyll cell) as seen with a TEM, drawn.

Structure	Structure (outline)	Function
chloroplasts	double membrane (envelope); thylakoids stacked in grana; stroma containing small circular DNA, 70S ribosomes, starch grains and lipid droplets	site of photosynthesis : light-dependent stage on the thylakoid membranes, light-independent stage in the stroma
cell wall	layers of cellulose microfibrils (plants); freely permeable	strength and support; prevents the cell bursting when water enters by osmosis; keeps the shape of the cell
plasmodesmata (singular plasmodesma)	narrow channels through the cell walls , lined by cell surface membrane, with a strand of ER through the middle	connect the cytoplasm of neighbouring cells, so water and solutes move from cell to cell (and allow communication)
large permanent vacuole and tonoplast	large sac of cell sap (water, sugars, ions, pigments) surrounded by a single membrane, the tonoplast	stores solutes; gives turgor (pressure on the wall) that supports the plant; the tonoplast is partially permeable and controls what enters and leaves the vacuole



Mitochondrion (left, about 1 μm wide) and chloroplast (right, 3–10 μm long). Both have two membranes, circular DNA and 70S ribosomes.

Comparing plant and animal cells

Feature	Typical plant cell	Typical animal cell
cell wall	present (cellulose), with plasmodesmata	absent

chloroplasts	present in green tissues (absent in roots)	absent
vacuole	large, permanent, central, with tonoplast	small and temporary (e.g. food vacuoles) if any
centrioles	absent (in flowering plants)	present
shape	regular, often rectangular (fixed by the wall)	variable, often rounded
carbohydrate store	starch grains	glycogen granules
cilia, microvilli	absent	present in some cells

Both have: cell surface membrane, nucleus with nuclear envelope and nucleolus, RER, SER, Golgi body, mitochondria, 80S ribosomes, microtubules and cytoplasm. Lysosome-like vesicles occur in plant cells but are not usually shown.

ATP: the energy currency

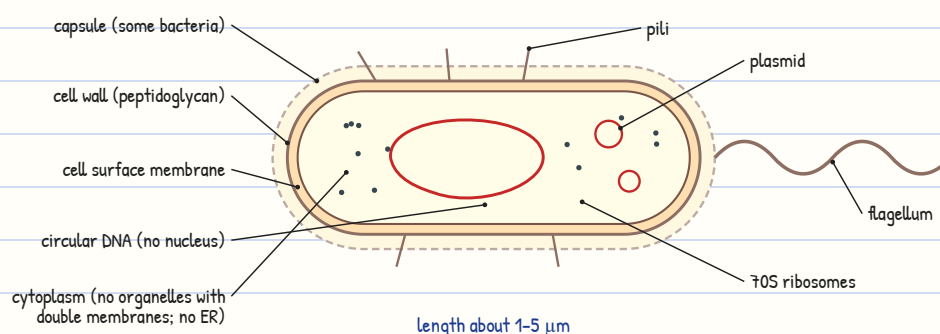
- Cells use **ATP** (adenosine triphosphate) made in **respiration** (mostly in mitochondria) for **energy-requiring processes**. Hydrolysis of ATP to ADP and phosphate releases energy in small, usable amounts, exactly where it is needed.
- Examples: **active transport**, **protein synthesis** and other anabolic reactions, **muscle contraction**, movement of cilia, **endocytosis and exocytosis**, DNA replication and **cell division**.
- Cells that do a lot of active transport or secretion (e.g. kidney tubule cells, gland cells) have **many mitochondria**.

Worked example 6: the route of a secreted enzyme

A pancreatic cell secretes the extracellular enzyme amylase. Outline the roles of organelles in producing and secreting it.

Nucleus: the gene is transcribed to **mRNA**, which leaves through a **nuclear pore** → **ribosomes on the RER** translate it; the polypeptide enters the RER cisternae and folds → carried in a **vesicle** to the **Golgi body**, where it is modified and packaged → **Golgi (secretory) vesicle** moves along microtubules to the cell surface membrane → fuses with it and releases amylase by **exocytosis**. **Mitochondria** supply ATP for protein synthesis, vesicle movement and exocytosis.

Prokaryotic cells (a typical bacterium)

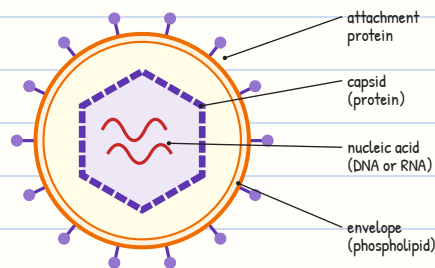


A typical bacterium. Capsule, flagellum, pili and plasmids are present in some bacteria only.

- A **prokaryote** is **unicellular**, generally **1-5 μm** in diameter, with a **peptidoglycan** (murein) cell wall, **circular DNA** lying free in the cytoplasm (no nucleus), **70S ribosomes** and **no organelles surrounded by double membranes** (no mitochondria, chloroplasts or nucleus), and no ER or Golgi body.

Feature	Prokaryotic cell (bacterium)	Eukaryotic cell (plant / animal)
size	usually 1-5 μm diameter	usually 10-100 μm

nucleus	none; circular DNA free in cytoplasm (+ plasmids)	nucleus with nuclear envelope; linear DNA with histones in chromosomes
ribosomes	70S only	80S in cytoplasm; 70S in mitochondria and chloroplasts
cell wall	always present; peptidoglycan	plant: cellulose; animal: none
double-membrane organelles	none	nucleus, mitochondria (and chloroplasts in plants)
ER, Golgi body, lysosomes	absent	present
flagellum	some; simple, no microtubules	some (e.g. sperm), "9 + 2" microtubules



An enveloped virus in section (about 100 nm across).

Viruses

- All viruses are **non-cellular**: no cytoplasm, no ribosomes, no metabolism of their own; they reproduce only inside a host cell.
- Structure: a **nucleic acid core, either DNA or RNA** (never both), inside a **capsid** made of **protein** (subunits called capsomeres).
- **Some** viruses (e.g. HIV, influenza) have an outer **envelope made of phospholipids**, taken from the host cell surface membrane, with glycoprotein attachment proteins.
- Size: about 20–300 nm, so they are seen only with the electron microscope.

Worked example 7: classifying a structure from an electron micrograph

A cell 2 μm long has a cell wall, 70S ribosomes and a circular DNA molecule, and has no nucleus. A second cell 40 μm long has a cell wall, 80S ribosomes, a nucleus and mitochondria but no chloroplasts. Identify each.

First: no nucleus, 70S ribosomes, 1–5 μm → **prokaryote (bacterium)**. Second: nucleus and 80S ribosomes → eukaryote; cell wall → **plant cell** (e.g. a root cell, which has no chloroplasts). A cell wall alone does not show that a cell is a plant cell, because bacteria have walls too.

Worked example 8: actual size from a micrograph without a scale bar

A transmission electron micrograph at $\times 20\,000$ shows a virus with a diameter of 2.4 mm on the page. Calculate its actual diameter in nm and explain why it could not be seen with a light microscope.

2.4 mm = 2 400 000 nm. $A = \frac{2\,400\,000}{20\,000} = 120 \text{ nm}$. This is smaller than the 200 nm resolution of the light microscope, so it cannot be resolved however much the image is magnified.

Practical skills for Paper 3

Microscopy, drawing and measurement

- **Slide preparation:** thin specimen, suitable stain, coverslip lowered at an angle, excess stain blotted; start on low power.
- **Plan diagram** (low power): draw only tissue boundaries, no cells, in correct proportion; show, for example, the layers of a root or the vascular bundles of a stem.
- **High-power drawing:** draw only the number of cells asked for (e.g. "four adjacent cells"); each cell touching its neighbours; walls as double lines; different cells with different shapes and sizes as seen, not identical circles.
- **Measuring a scale bar:** measure the bar in mm, convert to μm , divide; show every step: " $500 \mu\text{m} \div 25 \text{ mm}$, then $\times$ length of A-B".
- **Graticule:** state how many eyepiece units match a stated stage length, divide, give the answer with a unit (μm); then multiply the specimen's eyepiece units by this value.
- **Observable differences** between a slide and a photomicrograph: compare only what you can see (e.g. "thicker epidermis on the slide", "no trichomes in the figure"), giving exactly the number asked for.
- Give calculated sizes to a sensible number of significant figures (usually 2 or 3) and check the answer is **credible** (a cell of 7 nm or a magnification of $\times 0.5$ for an EM is wrong).

Common mistakes that lose marks

- **Wrong units:** red blood cells are about 7 μm , not 7 nm. Convert both measurements to the same unit before dividing.
- **Not measuring the scale bar** (or measuring it in the wrong unit), so the actual size cannot be calculated.
- **Ribosome size:** ribosomes are about 25 nm; a structure about 100 nm across in a micrograph is not a ribosome.
- **"Cell membrane"** is ambiguous: write **cell surface membrane**. Write **tonoplast** (or vacuolar membrane), not just "vacuole".
- **Nucleolus vs nucleus:** the nucleolus makes ribosomes; naming it "nucleus" loses the mark. Spell nucleolus correctly.
- **Lysosomes contain enzymes;** they are not enzymes and they do not engulf pathogens themselves (they fuse with phagocytic vesicles).
- **Prokaryotes** do not have cellulose cell walls, chloroplasts, ER or a nucleus; circular DNA is also found in mitochondria and chloroplasts, so it does not by itself identify a prokaryote.
- **Viruses** contain DNA **or** RNA, and their capsid is protein, not polysaccharide.
- **Plasmodesma** is one channel; plasmodesmata is the plural. **Centrioles** are not the same as centrosomes.
- Saying a cell has "few" chloroplasts when it has **none**: be precise about what the micrograph shows.

Exam-style multiple-choice questions (Paper 1 style)

20 questions, 1 mark each. Choose one answer, A, B, C or D. Answers with explanations follow the questions.

1. Which equation is correct?

- A actual size = image size $\div$ magnification
- B actual size = magnification $\div$ image size
- C actual size = image size $\times$ magnification
- D magnification = actual size $\div$ image size

2. Which conversion is correct?

- | | |
|-----------------------------|-----------------------------|
| A 1 mm = 100 μm | B 1 μm = 100 nm |
| C 1 μm = 1000 nm | D 1 nm = 1000 μm |

3. On a photomicrograph, a scale bar representing 5 μm is 20 mm long. What is the magnification?

- | | |
|--------------------|-----------------|
| A $\times 400$ | B $\times 4000$ |
| C $\times 40\,000$ | D $\times 250$ |

4. Which structure is present in both a bacterium and a palisade mesophyll cell?

- | | |
|--------------------|-----------------|
| A nuclear envelope | B mitochondrion |
| C Golgi body | D ribosomes |

5. What is meant by the resolution of a microscope?

- A the number of times the image is larger than the specimen
- B the ability to distinguish between two points that are close together
- C the greatest magnification the microscope can produce
- D the wavelength of the radiation used to form the image

6. Which organelle contains both small circular DNA and 70S ribosomes?

- | | |
|---------------|--------------|
| A chloroplast | B Golgi body |
| C lysosome | D nucleolus |

7. Which features are found in **all** viruses?

1 a nucleic acid core 2 a protein capsid 3 a phospholipid envelope

- | | |
|----------------|----------------|
| A 1 only | B 1 and 3 only |
| C 2 and 3 only | D 1 and 2 only |

8. Which structure is the site of production of ribosomal RNA and assembly of ribosomes?

- | | |
|--------------------|-------------------------------|
| A nuclear envelope | B rough endoplasmic reticulum |
| C nucleolus | D Golgi body |

9. 25 eyepiece units line up with 0.1 mm on a stage micrometer. A cell is 30 eyepiece units long. What is its actual length?

- | | |
|---------------------|---------------------|
| A 120 μm | B 12 μm |
| C 75 μm | D 7.5 μm |

10. Which structure is found in a typical animal cell but not in a typical leaf palisade cell?

- | | |
|-----------------|-------------------------------|
| A Golgi body | B centriole |
| C mitochondrion | D rough endoplasmic reticulum |

11. Which structure could **not** be seen as a separate structure with a light microscope at $\times 1500$?

- | | |
|------------|---------------|
| A nucleus | B chloroplast |
| C ribosome | D cell wall |

12. What is the main component of the cell wall of a bacterium?

- | | |
|----------------|-----------------|
| A cellulose | B chitin |
| C phospholipid | D peptidoglycan |

13. Which statement describes microvilli?

- A folds of the cell surface membrane that increase the surface area for absorption
- B extensions with a 9 + 2 arrangement of microtubules that beat to move mucus
- C hollow tubes of tubulin that form the spindle
- D channels through cell walls that link the cytoplasm of neighbouring cells

14. Which sequence shows the route taken by a protein that is secreted from a cell?

- A Golgi body → rough ER → vesicle → cell surface membrane
- B rough ER → vesicle → Golgi body → Golgi vesicle → cell surface membrane
- C smooth ER → Golgi body → lysosome → cell surface membrane
- D nucleolus → rough ER → lysosome → cell surface membrane

15. Which processes in a cell require ATP from respiration?

1 active transport of ions 2 synthesis of proteins 3 diffusion of oxygen into the cell

- A 1 only
- B 3 only
- C 2 and 3 only
- D 1 and 2 only

16. On a transmission electron micrograph at $\times 12\,000$, a mitochondrion is 36 mm long. What is its actual length?

- A $0.3\ \mu\text{m}$
- B $30\ \mu\text{m}$
- C $3\ \mu\text{m}$
- D $0.003\ \mu\text{m}$

17. Why does a transmission electron microscope have a higher resolution than a light microscope?

- A Electrons have a much shorter wavelength than light.
- B The specimen is stained with heavy metals.
- C Electromagnets give a greater magnification than glass lenses.
- D The specimen is placed in a vacuum.

18. Which structure is found in a plant cell but not in an animal cell?

- A 80S ribosomes
- B nucleolus
- C smooth ER
- D tonoplast

19. What is the function of lysosomes?

- A synthesis of lipids and steroids
- B digestion of worn-out organelles and engulfed material by hydrolytic enzymes
- C production of ATP by aerobic respiration
- D adding carbohydrate to proteins to form glycoproteins

20. Which row describes a typical bacterium?

	<i>diameter</i>	<i>ribosomes</i>	<i>DNA</i>
A	10–100 μm	80S	linear, in a nucleus
B	1–5 μm	80S	circular
C	1–5 μm	70S	circular
D	1–5 μm	70S	linear, in a nucleus

Answers and explanations

1 A · 2 C · 3 B · 4 D · 5 B · 6 A · 7 D · 8 C · 9 A · 10 B · 11 C · 12 D · 13 A · 14 B · 15 D · 16 C · 17 A · 18 D · 19 B · 20 C

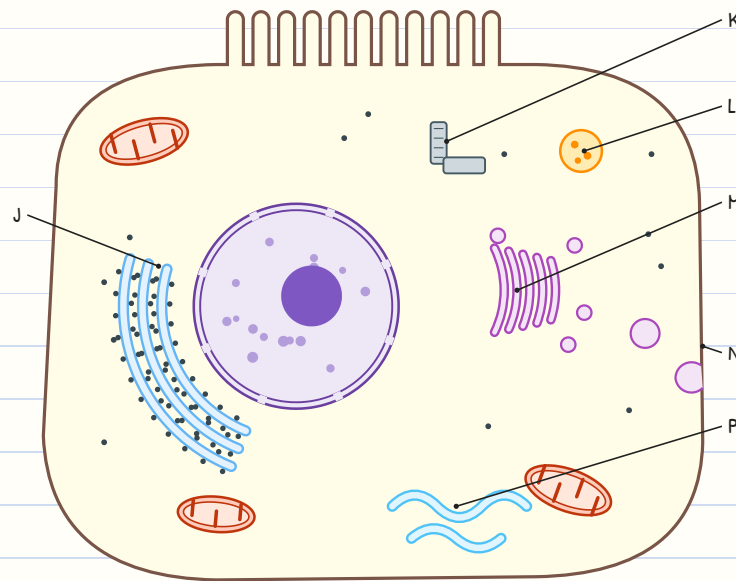
1. **A.** $M = I/A$, so $A = I/M$.
2. **C.** Each step ($\text{mm} \rightarrow \mu\text{m} \rightarrow \text{nm}$) is $\times 1000$.
3. **B.** $20 \text{ mm} = 20\,000 \mu\text{m}$; $20\,000 \div 5 = 4000$.
4. **D.** Both have ribosomes (70S in the bacterium, 80S in the plant cytoplasm); bacteria have no membrane-bound organelles.
5. **B.** A is magnification; resolution is about separating close points.
6. **A.** Chloroplasts (and mitochondria) contain circular DNA and 70S ribosomes.
7. **D.** Only some viruses have an envelope.
8. **C.** The nucleolus makes ribosomes.
9. **A.** $100 \mu\text{m} \div 25 = 4 \mu\text{m}$ per unit; $30 \times 4 = 120 \mu\text{m}$.
10. **B.** Flowering plant cells have no centrioles.
11. **C.** A ribosome (about 25 nm) is far below the 200 nm resolution of the light microscope.
12. **D.** Bacterial walls are peptidoglycan; cellulose is in plants and chitin in fungi.
13. **A.** B describes cilia, C microtubules, D plasmodesmata.
14. **B.** Proteins made on the RER go by vesicle to the Golgi body, then by Golgi vesicle to the surface for exocytosis.
15. **D.** Diffusion is passive and needs no ATP.
16. **C.** $36 \text{ mm} = 36\,000 \mu\text{m}$; $36\,000 \div 12\,000 = 3 \mu\text{m}$.
17. **A.** Resolution depends on wavelength, not on staining or the vacuum.
18. **D.** The tonoplast surrounds the large permanent vacuole of plant cells.
19. **B.** A is smooth ER, C mitochondria, D the Golgi body.
20. **C.** Bacteria are $1\text{--}5 \mu\text{m}$ with 70S ribosomes and circular DNA, and have no nucleus.

Exam-style structured questions (Paper 2 style)

Answer all parts. Show your working. Total: 24 marks.

Question 1 [9 marks]

The diagram is drawn from a transmission electron micrograph of a cell from the lining of the small intestine.



- (a) Name the structures labelled J, K and L. [3]
- (b) State one function of structure M. [1]
- (c) The cell secretes a digestive enzyme. Outline how structures in the cell are involved in its production and release. [3]
- (d) On the original micrograph the nucleus is 60 mm across. Its actual diameter is $7.5 \mu\text{m}$. Calculate the magnification. [2]

Mark scheme

- (a) J: rough endoplasmic reticulum 1; K: centriole(s) 1; L: lysosome 1
- (b) M (Golgi body): modifies proteins, e.g. adds carbohydrate to form glycoproteins / packages proteins into vesicles / makes lysosomes 1
- (c) any three: protein synthesised on ribosomes of the RER (J) 1; transported in vesicles to the Golgi body (M), where it is modified and packaged into vesicles 1; vesicles move to the cell surface membrane and fuse with it, releasing the enzyme by exocytosis 1; mitochondria provide ATP / mRNA from the nucleus leaves through nuclear pores
- (d) $60 \text{ mm} = 60\,000 \mu\text{m}$; $M = 60\,000 \div 7.5$ 1; $= \times 8000$ 1

Question 2 [8 marks]

A student uses a light microscope with an eyepiece graticule to measure root hair cells.

- (a) Define the terms magnification and resolution. [2]
- (b) With the $\times 10$ objective, 32 eyepiece units line up exactly with 4 divisions of the stage micrometer. Each division is 0.1 mm . Calculate the length of one eyepiece unit in μm . [2]
- (c) A root hair cell is 22 eyepiece units long. Calculate its length. [1]
- (d) Explain why the student must recalibrate the graticule after changing to the $\times 40$ objective. [1]

(e) Explain why the student cannot see the ribosomes in the root hair cell, however much the image is magnified. [2]

Mark scheme

- (a) magnification: how many times larger the image is than the actual object 1; resolution: the ability to distinguish two points close together as separate 1
- (b) $4 \times 0.1 \text{ mm} = 0.4 \text{ mm} = 400 \mu\text{m}$ 1; $400 \div 32 = 12.5 \mu\text{m}$ 1
- (c) $22 \times 12.5 = 275 \mu\text{m}$ 1
- (d) the graticule stays the same size but the specimen image is magnified more, so each eyepiece unit represents a smaller (different) actual length 1
- (e) ribosomes are about 25 nm, smaller than the resolution of the light microscope (about 200 nm) 1; resolution is limited by the wavelength of light, so extra magnification only enlarges a blur 1

Question 3 [7 marks]

Streptococcus is a bacterium that causes throat infections. Influenza is caused by an enveloped RNA virus.

- (a) State four structural differences between a *Streptococcus* cell and a palisade mesophyll cell. [4]
- (b) Describe the structure of an influenza virus particle and explain why viruses are described as non-cellular. [3]

Mark scheme

- (a) any four, each as a pair: bacterium has no nucleus / DNA free in cytoplasm; plant cell has a nucleus with nuclear envelope 1; bacterium has circular DNA; plant has linear DNA in chromosomes 1; bacterium 70S ribosomes only; plant 80S in cytoplasm 1; bacterium wall of peptidoglycan; plant wall of cellulose 1; bacterium has no mitochondria / chloroplasts / ER / Golgi body; bacterium 1–5 μm , plant cell much larger; plasmids only in bacterium
- (b) RNA (nucleic acid) core 1; surrounded by a protein capsid, inside a phospholipid envelope with attachment proteins 1; non-cellular: no cytoplasm / ribosomes / cell surface membrane of its own, cannot carry out metabolism or reproduce outside a host cell 1

Quick-reference sheet

Item	Key facts
units	1 mm = 1000 μm ; 1 μm = 1000 nm
magnification	$M = I/A$, same units, no unit for M ; scale bar: bar length $\div$ length it represents
graticule	calibrate with stage micrometer for each objective: one unit = stage length $\div$ number of eyepiece units
resolution	LM about 200 nm ($\times 1500$); TEM about 0.5 nm; SEM 3–10 nm (3-D surface)
organelles	nucleolus $\rightarrow$ ribosomes; RER $\rightarrow$ proteins; SER $\rightarrow$ lipids; Golgi $\rightarrow$ modify and package, lysosomes; mitochondria $\rightarrow$ aerobic respiration, ATP; lysosomes $\rightarrow$ hydrolytic enzymes
70S vs 80S	80S in eukaryotic cytoplasm; 70S in prokaryotes, mitochondria and chloroplasts (which also have circular DNA)

prokaryote	unicellular, 1–5 μm , peptidoglycan wall, circular DNA, 70S ribosomes, no double-membrane organelles
virus	non-cellular; DNA or RNA core; protein capsid; some have phospholipid envelope

"I can" checklist

- ☐ make a temporary slide and draw plan diagrams and high-power drawings correctly
- ☐ calculate magnification and actual size from drawings, photomicrographs and electron micrographs
- ☐ calibrate an eyepiece graticule with a stage micrometer and measure in μm
- ☐ define magnification and resolution and compare light, TEM and SEM
- ☐ recognise each organelle on an electron micrograph and state its structure and function
- ☐ compare plant and animal cells, and prokaryotic and eukaryotic cells
- ☐ state that cells use ATP from respiration for energy-requiring processes
- ☐ describe the structure of viruses and explain why they are non-cellular