EXAM PAPERS PRACTICE

AQA A Level Biology

Topic 2 Cells

Topic	Sub-topic	Understand	Memorise	Practise
2.1 Cell structure	2.1.1 Structure of eukaryotic cells			
	2.1.2 Structure of prokaryotic cells and of viruses			
	2.1.3 Methods of studying cells			
2.2 All cells arise from other cells	2.2 All cells arise from other cells			
	Required practical 2			
2.3 Transport across cell membranes	2.3 Transport across cell membranes			
	Required practical 3			
	Required practical 4			
2.4 Cell recognition & the immune system	2.4 Cell recognition and the immune system			

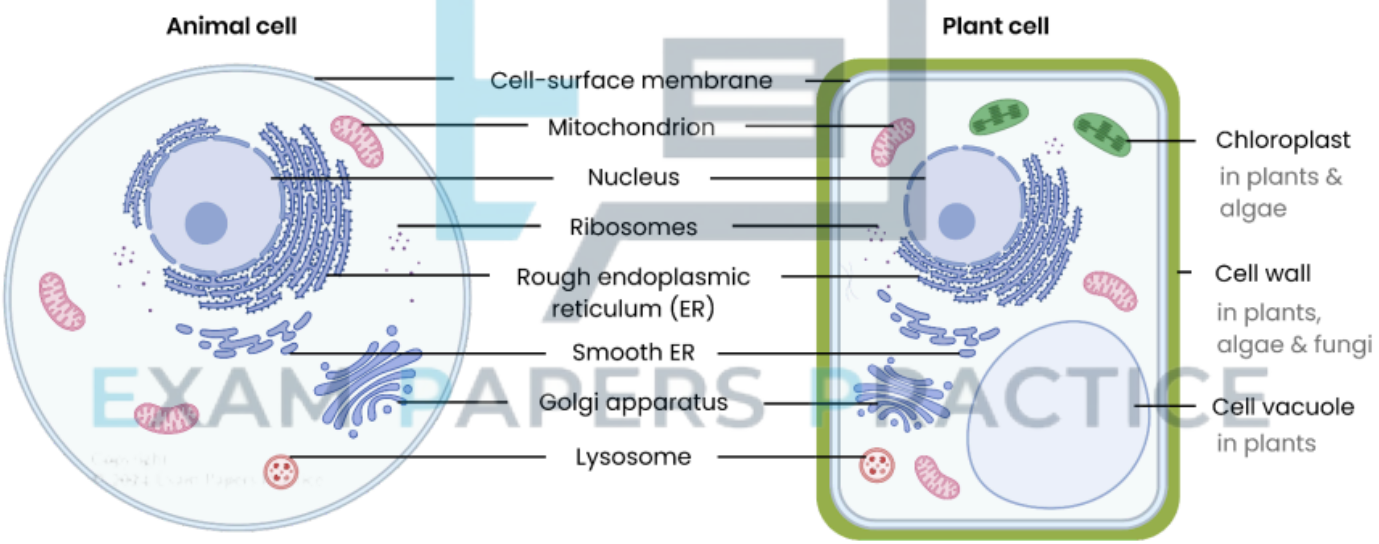
2.1 Cell structure

2.1.1 Structure of eukaryotic cells

What are the distinguishing features of eukaryotic cells?

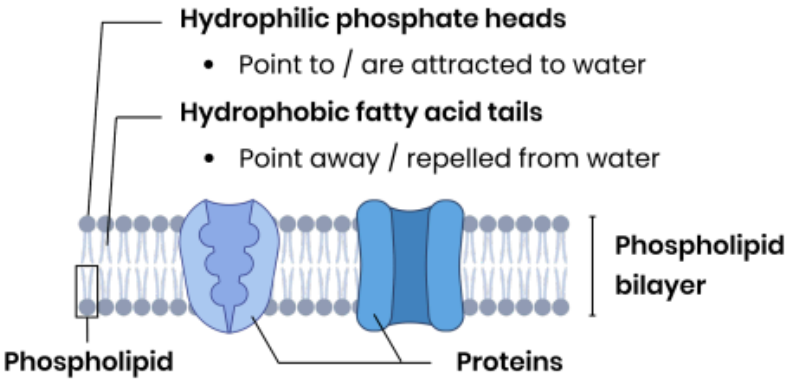
- Cytoplasm containing **membrane-bound** organelles
- So DNA enclosed in a **nucleus**

Describe the general structure of eukaryotic cells



Algal and **fungal cells** are similar to plant cells. See differences above.

Describe the structure of the cell-surface membrane

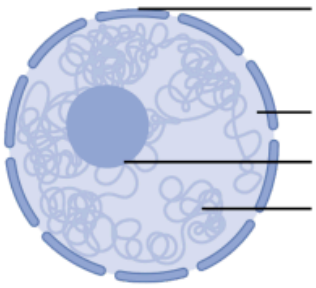


More detail covered in 2.3 Transport across cell membranes.

Describe the function of the cell-surface membrane

- **Selectively permeable** → enables control of **passage of substances** in / out of cell
- **Molecules / receptors / antigens** on surface → allow cell **recognition / signalling**

Describe the structure of the nucleus



Nuclear envelope
- Double membrane
- Has nuclear pores

Nucleoplasm

Nucleolus (dense region)

Protein/histone-bound, linear DNA
- Chromatin = condensed
- Chromosome = highly condensed

Describe the function of the nucleus

- Holds / stores **genetic information** which codes for **polypeptides** (proteins)
- Site of **DNA replication**
- Site of **transcription** (part of protein synthesis), producing **mRNA**
- **Nucleolus** makes **ribosomes** / rRNA

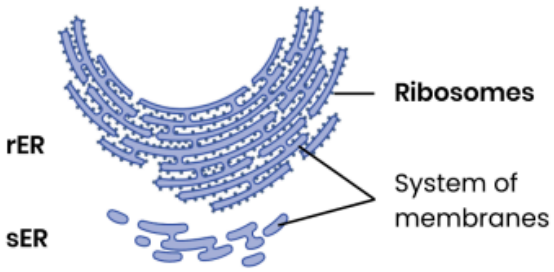
Describe the structure of a ribosome

- Made of **ribosomal RNA** and **protein** (two subunits)
- **Not** a membrane-bound organelle

Describe the function of a ribosome

Site of **protein synthesis** (translation)

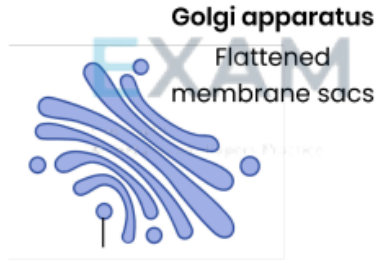
Describe the structure of rough (rER) & smooth endoplasmic reticulum (sER)



Describe the function of rER and sER

rER	• Ribosomes on surface **synthesise proteins** • Proteins processed / folded / **transported** inside rER • Proteins packaged into **vesicles** for transport eg. to Golgi apparatus
sER	• Synthesises and processes **lipids** • Eg. cholesterol and steroid hormones

Describe the structure of Golgi apparatus and Golgi vesicles

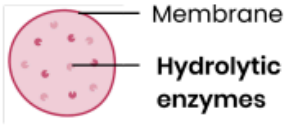


Golgi vesicle
Small membrane sac

Describe the function of Golgi apparatus and Golgi vesicles

Golgi apparatus	• **Modifies protein**, eg. adds carbohydrates to produce **glycoproteins** • **Modifies lipids,** eg. adds carbohydrates to make **glycolipids** • **Packages** proteins / lipids into **Golgi vesicles** • Produces **lysosomes** (a type of Golgi vesicle)
Golgi vesicles	• **Transports** proteins / lipids to their required destination • Eg. moves to and **fuses** with **cell-surface membrane**

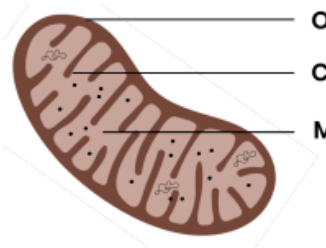
Describe the structure of lysosomes



Describe the function of lysosomes

- Release **hydrolytic enzymes** (lysozymes)
- To break down / hydrolyse **pathogens** or **worn-out** cell components

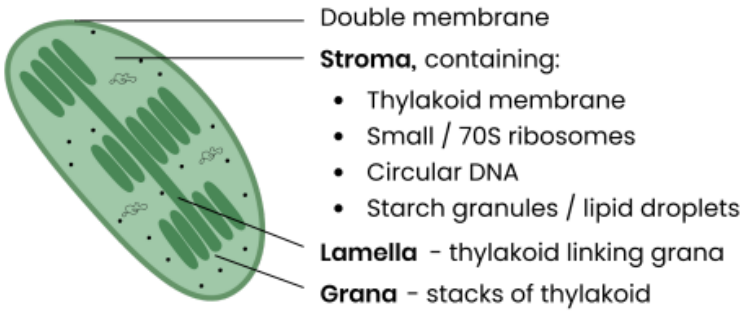
Describe the structure of mitochondria



Describe the function of mitochondria

- Site of **aerobic respiration**
- To produce **ATP** for energy release
- Eg. for protein synthesis / vesicle movement / active transport

Describe the structure of chloroplasts in plants and algae



Describe the function of chloroplasts in plants and algae

- Absorbs **light** energy for **photosynthesis**
- To produce **organic substances** eg. carbohydrates / lipids

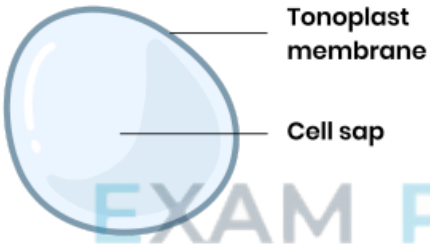
Describe the structure of the cell wall in plants, algae and fungi

- Composed mainly of **cellulose** (a polysaccharide) in plants / algae
- Composed of **chitin** (a nitrogen-containing polysaccharide) in fungi

Describe the function of the cell wall in plants, algae and fungi

- Provides **mechanical strength** to cell
- So prevents cell changing shape or **bursting** under pressure due to osmosis

Describe the structure of the cell vacuole in plants



Describe the function of the cell vacuole in plants

- Maintains **turgor pressure** in cell (stopping plant wilting)
- Contains **cell sap** → stores **sugars, amino acids,** pigments and any waste chemicals

Describe how eukaryotic cells are organised in complex multicellular organisms

In complex multicellular organisms, eukaryotic cells become **specialised** for **specific functions.**

Tissue	**Group of specialised cells** with a similar structure working together to perform a specific function, often with the same origin.
Organ	**Aggregations of tissues** performing specific functions.
Organ system	**Group of organs** working together to perform specific functions.

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Describe how you can apply your knowledge of cell features / organelles to explain adaptations of eukaryotic cells

General answer format:

- [Named cell] has **many** [named organelle, eg. ribosomes]
- **To** [link organelle function to cell function eg. increase rate of protein synthesis, making many antibodies]

Exam insight: common mistakes ❌

Mistake	Explanation
"Mitochondria **make energy** in respiration."	Energy can't be made, only **released**. You also need to specify that **ATP** (the 'energy currency' of cells) is made, which **releases energy**.
"The nucleus **controls cell activities.**"	This is low-level **GCSE** standard. Instead, refer to processes related to the DNA it stores, such as **DNA replication** or **transcription**.
"A cell is adapted for protein synthesis by **having ribosomes**."	Almost all cells have ribosomes, so this is not an adaptation. If a cell has a high rate of protein synthesis, it will have **more** ribosomes.
"[Named cells] have many vesicles for transport."	This is often too vague. Use the information in the question to identify **where** the vesicles are transporting molecules to.
"The **rER...**"	The **full name** of the **rough endoplasmic reticulum** is given in the specification with no abbreviation offered as an alternative, so 'rER' alone is normally not enough to get a mark.
*Not being able to label an **electron micrograph** of an organelle.*	Students find this difficult. Practise labelling **chloroplast** and **mitochondria** electron micrographs, as these are common.

2.1.2 Structure of prokaryotic cells and of viruses

What are the distinguishing features of prokaryotic cells?

- **Cytoplasm lacking** membrane-bound organelles
- So genetic material **not** enclosed in a nucleus

Examples of prokaryotic organisms:
bacteria and archaea (always unicellular)

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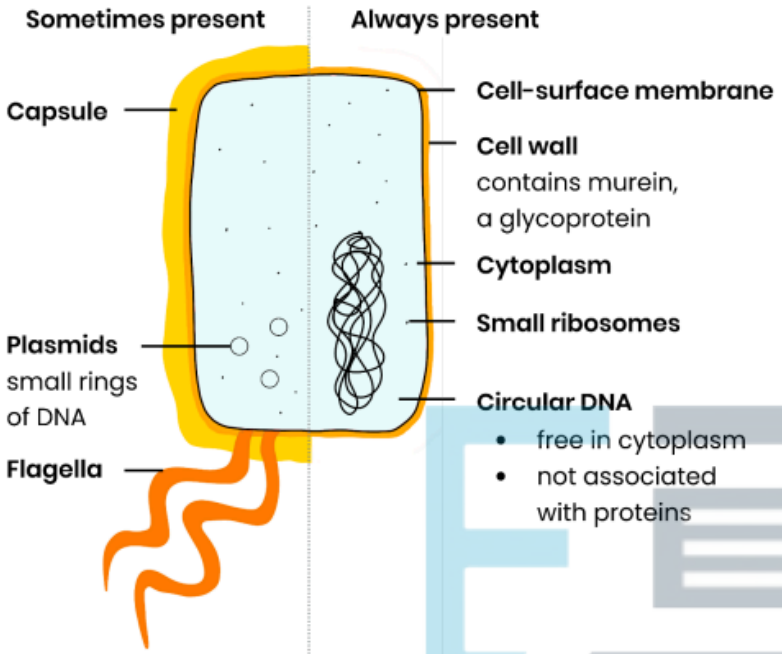
Describe the general structure of prokaryotic cells



Compare and contrast the structure of eukaryotic and prokaryotic cells

Eukaryotic cell	Prokaryotic cell
Has **membrane-bound organelles** eg. mitochondria, endoplasmic reticulum	**No** membrane-bound organelles eg. no mitochondria, endoplasmic reticulum
Has a **nucleus** Containing DNA	**No** nucleus DNA is is free in cytoplasm
DNA is long & **linear** & associated with histone **proteins**	DNA is short & **circular** & **not** associated with proteins
Larger (80S) ribosomes (in cytoplasm)	**Smaller** (70S) ribosomes
Cell wall only in plants, algae and fungi Containing **cellulose** or chitin	Cell wall in all prokaryotic cells Containing **murein,** a glycoprotein
Plasmids / capsule never present (sometimes flagella)	Plasmids, flagella and a capsule sometimes present
Larger overall size	Much **smaller** overall size

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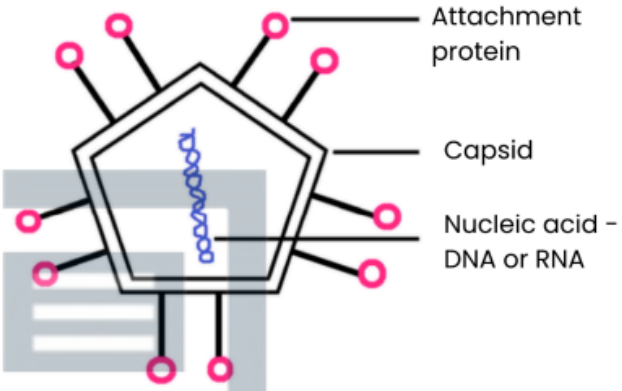
Explain why viruses are described as acellular and non-living

- **Acellular** - not made of **cells**, no cell membrane / cytoplasm / organelles
- **Non-living** - have no metabolism, cannot independently move / respire / replicate / excrete

Describe the general structure of a virus particle

1. **Nucleic acids** surrounded by a **capsid** (protein coat)
2. **Attachment proteins** allow attachment to specific host cells
3. **No** cytoplasm, ribosomes, cell wall, cell-surface membrane etc.
4. Some also surrounded by a lipid envelope eg. HIV



Exam insight: common mistakes ❌

Mistake	Explanation
"**All** prokaryotes have plasmids, a capsule and flagella."	These **aren't present in all** prokaryotic cells, so be careful when using them in comparison questions.
"**Bacteria** have a **capsid** and **viruses** have a **capsule**."	**Bacterial** ('slime') **capsules** provide protection and help with adhesion. **Viral capsids** ('protein coat') protect genetic material.
"Prokaryotic cells have **mitochondria** to make ATP."	Prokaryotic cells have **no membrane-bound organelles**, so no mitochondria. They still perform respiration to make ATP.
*Not making direct **comparisons** between cell types.*	Statements in compare / contrast questions need to reference **both sides,** eg. 'A prokaryotic cell has... whereas a eukaryotic cell has...'
"Prokaryotic cells have small / 70S ribosomes; **eukaryotic cells don't.**"	Small/70S ribosomes are found in both prokaryotic cells and the **mitochondria** and **chloroplasts** of eukaryotic cells.
"Viruses are acellular because they cannot reproduce on their own."	This relates to viruses being **non-living**. Viruses are acellular as they are not made of cells and don't have cell organelles.
"**All** viruses have a **lipid envelope**."	**HIV** has a lipid envelope, but **not all** viruses do.

2.1.3 Methods of studying cells

Describe the difference between magnification and resolution

- **Magnification** = number of times **greater** image is than size of the real (actual) object
  - Magnification = size of **image** / size of **real object**
- **Resolution =** minimum distance apart 2 objects can be to be **distinguished** as separate objects

Compare the principles and limitations of optical microscopes, transmission electron microscopes and scanning electron microscopes

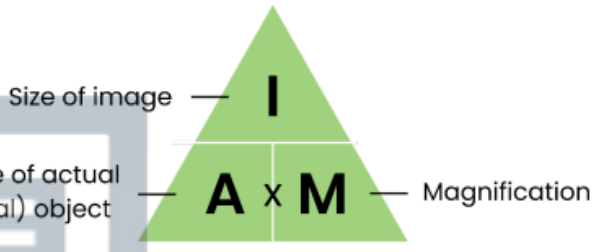
Optical microscope	Transmission electron microscope (TEM)	Scanning electron microscope (SEM)
Light focused using glass **lenses**	**Electrons** focused using **electromagnets**	**Electrons** focused using **electromagnets**
Light **passes through** specimen, different structures absorb different amounts & wavelengths	Electrons **pass through** specimen, denser parts **absorb more** and appear **darker**	Electrons **deflected** / **bounce off** specimen surface
Generates a **2D** image of a **cross-section**	Generates a **2D** image of a **cross-section**	Generates a **3D** image of **surface**
Low resolution due to **long wavelength** of light	**Very high** resolution due to **short wavelength** of electrons	**High** resolution due to **short wavelength** of electrons
Can't see **internal structure** of organelles or ribosomes	**Can** see **internal structures** of organelles and ribosomes	**Can't** see internal structures
Specimen = **thin**	Specimen = **very thin**	Specimen does not need to be thin
Low magnification (x 1500)	**High** magnification (x 1,000,000)	**High** magnification (x 1,000,000)
Can view **living** organisms	Can only view **dead / dehydrated** specimens as uses a **vacuum**	Can only view **dead / dehydrated** specimens as uses a **vacuum**
Simple preparation	Complex **preparation** so **artefacts** often present	Complex **preparation** so **artefacts** often present
Can show **colour**	Does **not** show colour	Does **not** show colour

Students should be able to appreciate that there was a considerable period of time during which the scientific community distinguished between **artefacts** (eg. dust, air bubbles occurring during preparation) and **cell organelles.**

To overcome this, scientists prepared specimens in different ways. If an object was seen with one technique but not another, it was more likely to be an artefact than an organelle.

List the steps in calculations involving magnification, real size & image size

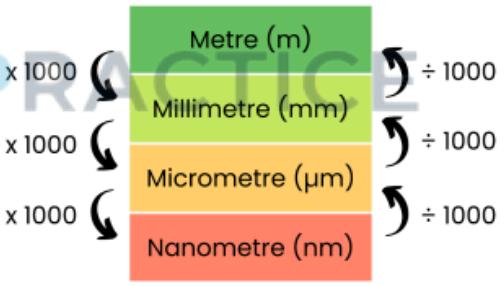
1	Note **formula** / **rearrange** if necessary (I = AM)
2	Convert **units** if necessary - image and actual size must be in **same** unit
3	**Calculate** answer and **check units** required or if **standard form** etc. is required



Note - a **scale bar** may also be used.

Describe how to convert between different units

Unit	Equivalent number of metres		
Centimetre (cm)	1/100 m	0.01 m	10^{-2} m
Millimetre (mm)	1/1000 m	0.001 m	10^{-3} m
Micrometre (µm)	1/1000000 m	0.000001 m	10^{-6} m
Nanometre (nm)	1/1000000000 m	0.000000001 m	10^{-9} m

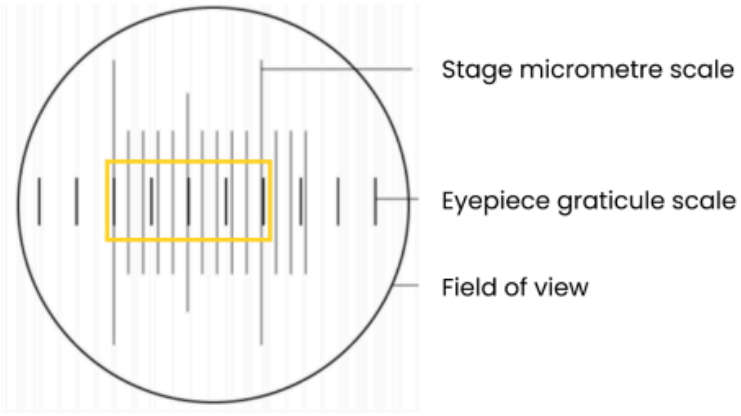


Describe how the size of an object viewed with an optical microscope can be measured

1. **Line up** (scale of) eyepiece graticule with (scale of) **stage micrometre**
2. **Calibrate** eyepiece graticule - use **stage micrometre** to calculate **size of divisions** on **eyepiece graticule**
3. Take micrometre away and use graticule to measure **how many divisions** make up the object
4. Calculate size of object by **multiplying** number of divisions by size of division
5. **Recalibrate** eyepiece graticule at different magnifications

Eg. using the stage micrometre to calculate the size of divisions on the eyepiece graticule.

- 4 eyepiece graticule divisions = 10 stage micrometre divisions
- In this stage micrometre, 1 subdivision = 10 µm
- So 4 eyepiece graticule divisions = 10 µm x 10 = 100 µm
- So 1 eyepiece graticule division = 100 µm/4 = 25 µm



Describe and explain the principles of cell fractionation and ultracentrifugation as used to separate cell components

1. **Homogenise** tissue / use a blender
   - Disrupts **cell membrane**, **breaking open** cells and releasing contents / organelles
2. Place in a **cold, isotonic, buffered** solution
   - Cold to **reduce enzyme activity** → so organelles not broken down / damaged
   - Isotonic so water doesn't move in or out of organelles by **osmosis** → so they don't **burst**
   - Buffered to keep **pH constant** → so **enzymes** don't **denature**
3. **Filter homogenate**
   - Remove large, unwanted **debris** eg. whole cells, connective tissue
4. **Ultracentrifugation** - separates organelles in order of **density / mass**
   - Centrifuge homogenate in a tube at a **high speed**
   - Remove **pellet** of **heaviest** organelle and **respin supernatant** at a **higher speed**
   - Repeat at **increasing speeds** until separated out, each time pellet made of **lighter** organelles (nuclei → chloroplasts / mitochondria → lysosomes → ER → ribosomes)

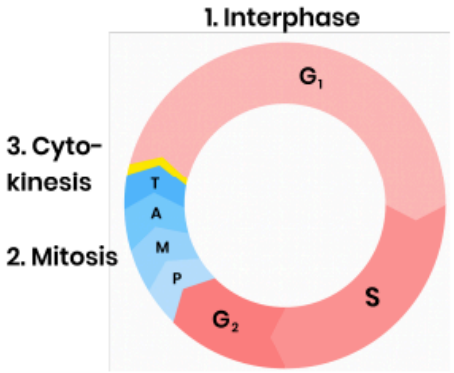
Exam insight: common mistakes ❌

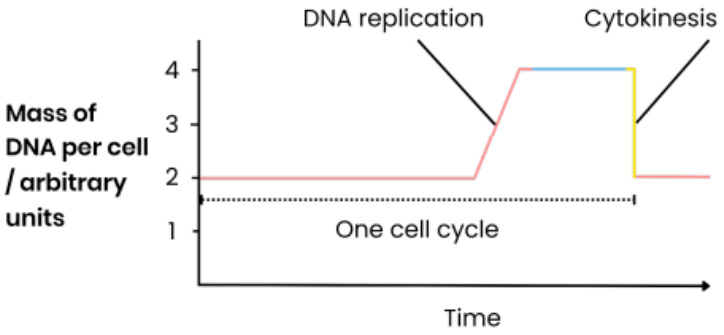
Mistake	Explanation
"**Cost** is a limitation of electron microscopes."	This is too basic and won't achieve a mark.
"Electron microscopes produce **clearer** images."	This is too vague. They have a **higher resolution**.
*Not relating resolution to **wavelength**.*	Explaining resolution in terms of **long / short wavelength of light / electrons** almost always achieves a mark.
"**Light microscopes** have a long wavelength."	Be careful with your wording. It's the **light** with the long wavelength, not the microscope.
"A **black & white** image proves a scanning electron microscope was used."	All electron microscope images are B&W. However, only a SEM produces **3D images**.
"[Named organelle eg. nucleus] is not visible in the TEM / optical microscope image because it is **not present** in the cell."	Not all features may be present in an image as it is only a **section / slice**; the organelle could be in **another part** of the cell. It may also have not been **stained**.
*Mixing up the role of an **eyepiece graticule** and the role of a **stage micrometer**.*	The **eyepiece graticule** spans the full **field of view**. With **no fixed units**, it requires **calibration** at different magnifications using a **micrometre** (has **units**) on the **stage**.

2.2 All cells arise from other cells

Describe the stages of the cell cycle in eukaryotic cells

1. Interphase	• (S phase) **DNA replicates** semi-conservatively ○ Leading to **2 chromatids (identical copies)** joined at a **centromere** • (G1/G2) number of **organelles** & volume of **cytoplasm** increases, protein synthesis
2. Mitosis	• **Nucleus divides** • To produce 2 nuclei with **identical** copies of DNA produced by parent cell
3. Cytokinesis	• **Cytoplasm** and **cell membrane** (normally) divide • To form 2 new genetically identical daughter cells



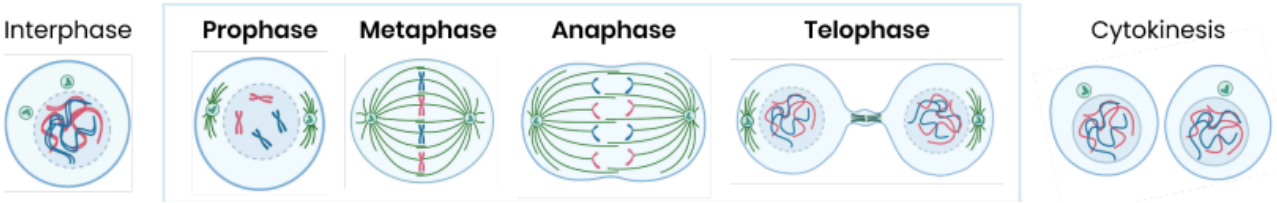


Describe the behaviour of chromosomes & role of spindle fibres in mitosis

Stage 1 Prophase	• Chromosomes **condense**, becoming **shorter / thicker** (so visible) ○ Appear as **2 sister chromatids** joined by a **centromere** • Nuclear envelope breaks down • **Centrioles** move to opposite poles forming **spindle network**
Stage 2 Metaphase	• Spindle fibres **attach** to chromosomes by their **centromeres** • Chromosomes align along **equator**
Stage 3 Anaphase	• Spindle fibres **shorten / contract** • **Centromere divides** • Pulling chromatids (from each pair) to opposite **poles** of cell
Stage 4 Telophase	• Chromosomes **uncoil**, becoming **longer / thinner** • Nuclear envelopes reform = **2 nuclei** • Spindle fibres / centrioles break down

Students should be able to **recognise** the stages of the cell cycle and **explain** the appearance of cells in each stage of mitosis.

This is covered under **required practical 2**.



Why do some eukaryotic cells not undergo the cell cycle?

- Within **multicellular organisms, not all cells** retain the ability to divide (eg. neurons)
- Only cells that do retain this ability go through a **cell cycle**

Explain the importance of mitosis in the life of an organism

Parent cell divides to produce 2 **genetically identical** daughter cells for...

- **Growth** of multicellular organisms by increasing cell number
- **Replacing** cells to repair damaged tissues
- **Asexual** reproduction

Describe how tumours and cancers form

Mitosis is a **controlled** process.

- Mutations in DNA / genes **controlling mitosis** can lead to **uncontrolled cell division**
- **Tumour** formed if this results in **mass of abnormal cells**
  - **Malignant** tumour = **cancerous**, can **spread** (metastasis)
  - **Benign** tumour = **non-cancerous**

Suggest how cancer treatments control rate of cell division

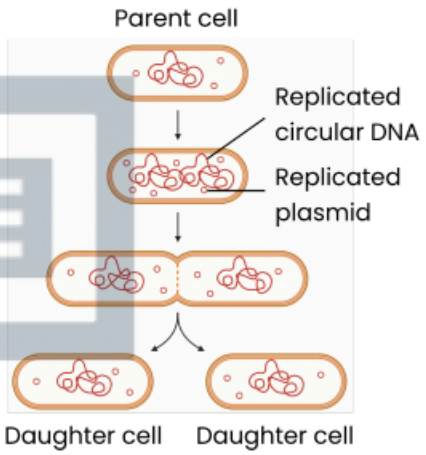
- Some disrupt **spindle fibre activity / formation**
  - So chromosomes can't attach to spindle by their **centromere**
  - So chromatids can't be **separated** to opposite poles (no **anaphase**)
  - So prevents / slows **mitosis**
- Some prevent **DNA replication** during interphase
  - So can't make 2 **copies** of each chromosome (**chromatids**)
  - So prevents / slows **mitosis**

More effective against cancer cells due to uncontrolled cell division but also disrupts cell cycle of rapidly dividing healthy cells.

Describe how prokaryotic cells replicate

Binary fission:

1. **Replication** of circular **DNA**
2. **Replication** of **plasmids**
3. **Division** of **cytoplasm** to produce 2 daughter cells
   - **Single** copy of circular DNA
   - **Variable** number of copies of plasmids



Describe how viruses replicate

Being **non-living**, viruses **do not undergo cell division**.

1. **Attachment proteins** attach to complementary **receptors** on host cell
2. Inject viral **nucleic acid** (DNA/RNA) into host cell
3. Infected **host cell replicates** virus particles:
   a. **Nucleic acid** replicated
   b. Cell produces viral **protein / capsid / enzymes**
   c. Virus **assembled** then **released**

Exam insight: common mistakes ❌

Mistake	Explanation
"Mitosis **repairs** cells."	Mitosis creates **new cells** to **replace** damaged or dead ones, therefore **repairing the tissue** but not the cells themselves.
"DNA replication happens **in mitosis**."	DNA replication happens in **interphase**, which is **before mitosis**.
"**Chromosomes** and **chromatids** are the same thing."	A chromatid is one of the **two identical** halves of a chromosome that has been replicated. These are held together by a centromere.
*Mixing up **centromeres** and **centrioles**.*	**Centromeres** join **sister chromatids**, while **centrioles** are organelles involved in **spindle formation**.
*Forgetting to mention that **centromeres divide** in anaphase.*	This mark is commonly missed. When **sister chromatids are pulled apart**, the centromere holding them together divides.
"Cytokinesis **always** happens."	Some cells (eg. muscle cells) undergo mitosis (nuclear division) **without cytokinesis** (cytoplasmic division), so have **multiple nuclei**.
"Tumours and cancers form due to **rapid** cell division."	Many other cells divide rapidly, but cell division has to be **uncontrolled** for cancers and tumours to form.
"In binary fission in prokaryotic cells, bacterial **chromosomes** replicate."	Chromosomes consist of **linear DNA associated with histones** and are only found in **eukaryotic** cells. Bacteria have **circular DNA** (no histones).

Required practical 2

Preparation of **stained squashes** of cells from **plant root tips**;
set-up and **use** of an **optical microscope** to identify the **stages of mitosis** in these stained squashes and calculation of a **mitotic index.**

Students should measure the **apparent size** of cells in the root tip and calculate their **actual size** using the formula: **actual size = size of image / magnification**

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Describe how to prepare squashes of cells from plant root tips

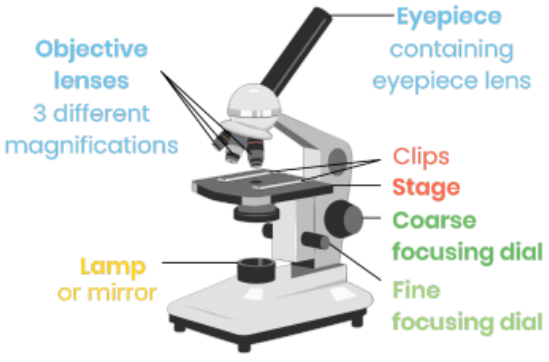
1. Cut a **thin** slice of **root tip** (5mm from end) using scalpel and mount onto a slide
2. Soak root tip in **hydrochloric acid** then rinse
3. **Stain** for **DNA** eg. with toluidine blue
4. **Lower coverslip** using a mounted needle at 45° without trapping air bubbles
5. **Squash** by firmly pressing down on glass slip but do not push sideways

Common questions

1. **Why are root tips used?**	• Where dividing cells are found / **mitosis** occurs
2. **Why is a stain used?**	• To **distinguish chromosomes** • Chromosomes not visible without stain
3. **Why squash / press down on cover slip?**	• (Spreads out cells) to create a **single layer of cells** • So **light passes** through to make chromosomes visible
4. **Why not push cover slip sideways?**	• Avoid rolling cells together / **breaking chromosomes**
5. **Why soak roots in acid?**	• **Separate** cells / cell walls • To allow **stain** to diffuse into cells • To allow cells to be more easily **squashed** • To **stop mitosis**

Describe how to set-up and use an optical microscope

1	Clip slide onto **stage** and turn on **light**
2	Select **lowest power objective lens** (usually x 4)
3	a. Use **coarse focusing** dial to **move stage** close to lens b. Turn **coarse focusing** dial to move stage away from lens until image comes into focus
4	Adjust **fine focusing** dial to get clear image
5	Swap to **higher power objective lens**, then **refocus**



What are the rules of scientific drawing?

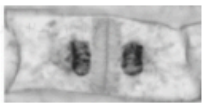
- ✓ Look **similar** to specimen / image
- ✓ **No sketching / shading** - only **clear, continuous** lines
- ✓ Include a **magnification scale** (eg. x 400)
- ✓ **Label** with straight, **uncrossed lines**

Onion cells

Cheek cells

Explain how the stages of mitosis can be identified

In **interphase** (not mitosis), chromosomes aren't visible but nuclei are. In mitosis, chromosomes are visible.

Stage	Appearance	Explanation
Prophase		• Chromosomes **visible / distinct** → because **condensing** • But **randomly arranged** → because no spindle activity / not attached to **spindle fibre**
Metaphase		• Chromosomes lined up on **equator** → because attaching to spindle
Anaphase		• Chromatids (in two groups) at **poles** of spindle • Chromatids **V shaped** → because being **pulled apart** at their centromeres by spindle fibres
Telophase		• Chromosomes in **two sets**, one at each pole

What is a mitotic index?

- **Proportion** of cells undergoing mitosis (with **visible chromosomes**)
- **Mitotic index** = number of cells undergoing **mitosis / total** number of cells in sample

Explain how to determine a reliable MI from observed squashes

- Count cells in **mitosis** in field of view
- Count only **whole cells** / only cells on top and right edges → **standardise** counting
- Divide this by **total** number of cells in **field of view**
- **Repeat** with **many / at least 5 fields of view** selected **randomly** → **representative** sample
- Calculate a reliable **mean**

Suggest how to calculate the time cells are in a certain phase of mitosis

1. Identify **proportion** of cells in named phase at any one time
    - Number of cells in that phase / total number of cells observed
2. **Multiply** by **length of cell cycle**

2.3 Transport across cell membranes

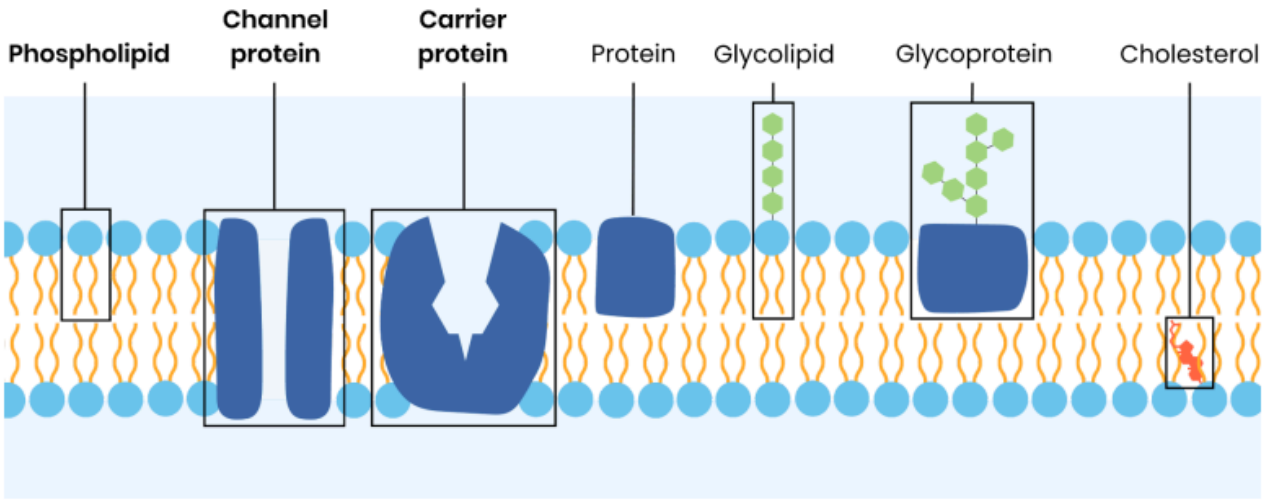
Describe the fluid-mosaic model of membrane structure

- Molecules free to **move laterally** in phospholipid bilayer
- Many components - **phospholipids, proteins,** glycoproteins and glycolipids

The basic structure of all cell membranes (cell-surface membranes & membranes around eukaryotic organelles) is the same.

Describe the arrangement of the components of a cell membrane

- **Phospholipids** form a **bilayer** - fatty acid tails face inwards, phosphate heads face outwards
- **Proteins**
    - **Intrinsic / integral** proteins span bilayer eg. channel and carrier proteins
    - **Extrinsic / peripheral** proteins on surface of membrane
- **Glycolipids** (lipids with polysaccharide chains attached) found on exterior surface
- **Glycoproteins** (proteins with polysaccharide chains attached) found on exterior surface
- **Cholesterol** (sometimes present) bonds to phospholipid hydrophobic fatty acid tails



Explain the arrangement of phospholipids in a cell membrane

- **Bilayer**, with **water** present on either side
- **Hydrophobic** fatty acid tails **repelled** from water so point away from water / to interior
- **Hydrophilic** phosphate heads **attracted** to water so point to water

Explain the role of cholesterol (sometimes present) in cell membranes

- **Restricts movement** of other molecules making up membrane
- So **decreases fluidity** (and permeability) / increases rigidity

Suggest how cell membranes are adapted for other functions

- Phospholipid bilayer is **fluid** → membrane can bend for **vesicle** formation / **phagocytosis**
- Glycoproteins / glycolipids act as **receptors / antigens** → involved in cell **signalling / recognition**

Describe how movement across membranes occurs by simple diffusion

- **Lipid-soluble (non-polar)** or very small substances eg. O_2, steroid hormones
- Move from an area of **higher** conc. to an area of **lower** conc. **down** a conc. gradient
- Across **phospholipid bilayer**
- **Passive - doesn't** require energy from **ATP / respiration** (only **kinetic energy** of substances)

Explain the limitations imposed by the nature of the phospholipid bilayer

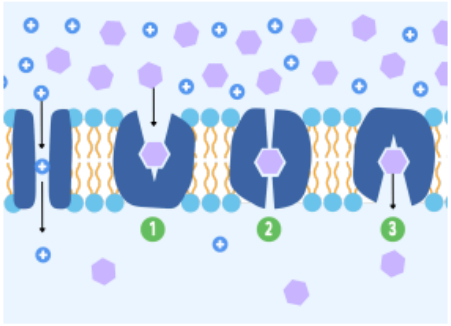
- Restricts movement of **water soluble (polar) & larger** substances eg. Na^+ / glucose
- Due to **hydrophobic fatty acid tails** in interior of bilayer

Describe how movement across membranes occurs by facilitated diffusion

- **Water-soluble (polar)** / slightly larger substances
- Move **down** a **concentration gradient**
- Through **specific channel / carrier proteins**
- **Passive - doesn't** require energy from **ATP / respiration** (only **kinetic energy** of substances)

Explain the role of carrier and channel proteins in facilitated diffusion

- **Shape / charge** of protein determines which substances move
- **Channel** proteins facilitate diffusion of **water-soluble** substances
  - **Hydrophilic pore** filled with **water**
  - May be **gated** - can open / close
- **Carrier** proteins facilitate diffusion of (slightly larger) substances
  - **Complementary** substance attaches to **binding site**
  - Protein changes **shape** to transport substance



Describe how movement across membranes occurs by osmosis

- **Water** diffuses / moves
- From an area of **high to low water potential (ψ)** / **down** a water potential gradient
- Through a **partially permeable membrane**
- **Passive - doesn't** require energy from **ATP** / **respiration** (only **kinetic energy** of substances)

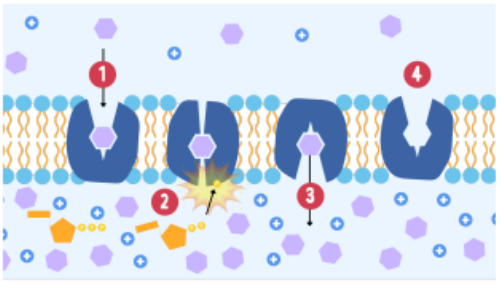
Water potential is a measure of how **likely** water molecules are to move **out** of a solution. **Pure (distilled) water** has the **maximum** possible ψ (0 kPA), **increasing solute concentration decreases ψ.**

Describe how movement across membranes occurs by active transport

- Substances move from area of **lower** to **higher** concentration / **against** a concentration gradient
- Requiring **hydrolysis** of **ATP** and specific **carrier proteins**

Describe the role of carrier proteins and the importance of the hydrolysis of ATP in active transport

1. **Complementary** substance **binds** to **specific carrier** protein
2. **ATP** binds, hydrolysed into **ADP + Pi**, releasing energy
3. Carrier protein **changes shape,** releasing substance on side of higher concentration
4. Pi released → protein returns to **original shape**



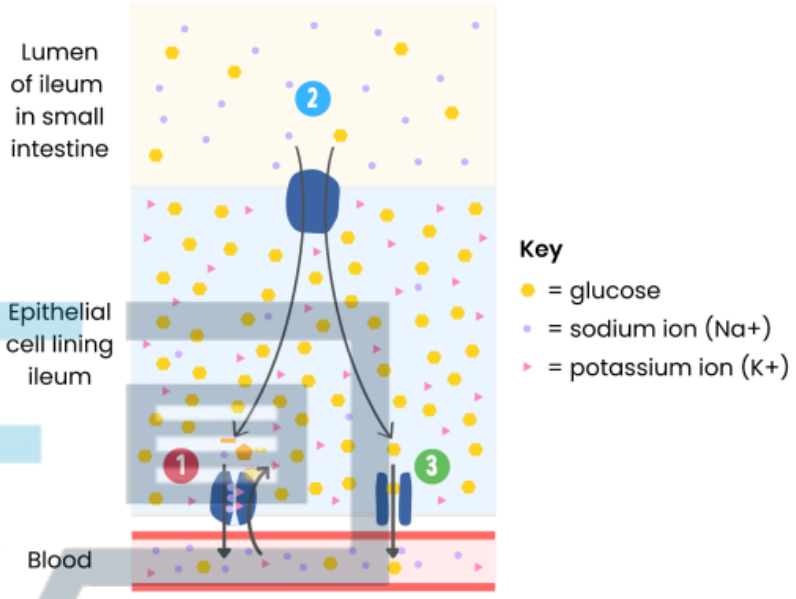
Describe how movement across membranes occurs by co-transport

- **Two different** substances **bind** to and move **simultaneously** via a **co-transporter protein** (type of **carrier** protein)
- Movement of one substance **against** its concentration gradient is often coupled with the movement of another **down** its concentration gradient

Describe an example that illustrates co-transport

Absorption of sodium ions and glucose (or amino acids) by cells lining the mammalian ileum:

1	• **Na^+ actively transported** from epithelial cells to blood (by Na^+/K^+ pump) • Establishing a **conc. gradient** of Na^+ (higher in lumen than epithelial cell)
2	• **Na^+** enters epithelial cell **down** its concentration gradient with **glucose against** its concentration gradient • Via a **co-transporter protein**
3	• **Glucose** moves **down** a conc. gradient into blood via **facilitated diffusion**



The movement of sodium can be considered **indirect / secondary** active transport, as it is reliant on a **concentration gradient** established by active transport.

Describe how surface area, number of channel or carrier proteins and differences in gradients of concentration or water potential affect the rate of movement across cell membranes

- Increasing surface area of membrane **increases** rate of movement
- Increasing number of channel / carrier proteins **increases** rate of **facilitated diffusion / active transport**
- Increasing concentration gradient **increases** rate of **simple / facilitated diffusion** and **osmosis**
- Increasing concentration gradient **increases** rate of **facilitated diffusion**
  - Until number of **channel / carrier proteins** becomes a **limiting factor** as **all in use / saturated**
- Increasing water potential gradient **increases** rate of **osmosis**

Explain the adaptations of some specialised cells in relation to the rate of transport across their internal and external membranes

- Membrane **folded** eg. microvilli in ileum → increase in **surface area**
- More **protein** channels / carriers → for **facilitated diffusion** (or active transport - carrier proteins only)
- **Large number** of **mitochondria** → make more **ATP** by aerobic respiration for **active transport**

Exam insight: common mistakes ❌

Mistake	Explanation
"**Thin** cell membranes increase the rate of diffusion."	Cell membranes are less than 5nm wide and **vary very little** in thickness. A thin **layer of cells** increases the rate.
"Only **small molecules** move by simple diffusion."	The key marking point here is that these molecules are **lipid-soluble / non-polar**.
"Active transport uses carrier or **channel** proteins."	Active transport only uses **carrier** proteins.
"Cholesterol increases membrane **strength**."	Cholesterol **decreases fluidity** / increases rigidity, but this is not the same as increasing strength.
"Osmosis is movement of water from a **dilute to a more concentrated** solution."	This is a GCSE answer. Osmosis at A Level should be described in terms of **water potential**.
"Diffusion is movement of substances from a **high gradient to low gradient**."	Diffusion is movement from **high concentration to low concentration**, not gradient to gradient.
"Having carrier / channel proteins is an adaptation for fast facilitated diffusion."	For a membrane to be adapted for rapid transport, it must have **more** of these proteins, rather than them just being present.

Required practical 3

Production of a **dilution series** of a solute
to produce a **calibration curve**
with which to identify the **water potential** of **plant tissue.**

Describe how to calculate dilutions

Use the formula: **C1 x V1 = C2 x V2**

- **C1** = concentration of stock solution
- **V1** = volume of stock solution used to make new concentration
- **C2** = concentration of solution you are making
- **V2** = volume of new solution you are making

V2 = V1 + volume of distilled water to dilute with

Worked example: describe how you would use a 0.5 mol dm^{-3} solution of sucrose (stock solution) to produce 30 cm^3 of a 0.15 mol dm^{-3} sucrose solution.

1. Volume of **stock solution** required, V1 = **(C2/C1) x V2**
   (0.15 ÷ 0.5) x 30 = 9 cm^3
2. Volume of **distilled water** to top up with = V2 - V1
   30 - 9 = 21 cm^3 distilled water

Describe a method to produce of a calibration curve with which to identify the water potential of plant tissue (eg. potato)

Part 1: collecting data

Step	Control variables
1. Create a **series of dilutions** using a 1 mol dm^{-3} sucrose solution (0.0, 0.2, 0.4, 0.6, 0.8, 1.0 mol dm^{-3})	• **Volume** of solution, eg. 20 cm^3
2. Use scalpel / cork borer to cut potato into **identical** cylinders	• **Size, shape** and **surface area** of plant tissue • **Source** of plant tissue ie variety or age
3. Blot dry with a paper towel and measure / record **initial mass** of each piece	• **Blot dry** to remove excess water before weighing
4. **Immerse** one chip in each solution and leave for a **set time** (20-30 mins) in a water **bath** at 30°C	• Length of **time** in solution • **Temperature** • Regularly **stir / shake** to ensure all surfaces exposed
5. Blot dry with a paper towel and measure / record **final mass** of each piece	• **Blot dry** to remove excess water before weighing

Repeat (3 or more times) at each concentration.

Part 2: processing data

6. Calculate **% change** in mass = **(final - initial mass)/ initial mass**
7. Plot a graph with **concentration** on x axis and **percentage change in mass** on y axis **(calibration curve)**
    - Must show **positive** and **negative** regions
8. Identify concentration where line of best fit intercepts **x axis** (**0% change**)
    - Water potential of sucrose solution = water potential of potato cells
9. Use a table in a textbook to find the **water potential** of that solution

Common questions

Why calculate % change in mass?	• Enables **comparison** / shows **proportional** change • As plant tissue samples had **different initial masses**
Why blot dry before weighing?	• Solution on surface will **add** to mass (only want to measure water taken up or lost) • Amount of solution on cube **varies** (so ensure same amount of solution on outside)

Explain the changes in plant tissue mass when placed in different concentrations of solute

Increase in mass	• Water moved **into** cells by **osmosis** • As **water potential** of **solution higher** than inside cells
Decrease in mass	• Water moved **out** of cells by **osmosis** • As **water potential** of solution **lower** than inside cells
No change	• No **net** gain/loss of water by osmosis • As water potential of solution **=** water potential of cells

Required practical 4

Investigation into the effect of a **named variable** on the **permeability** of **cell-surface membranes.**

Describe a method to investigate the effect of a named variable (eg. temperature) on the permeability of cell-surface membranes

1. **Cut equal sized / identical cubes** of plant tissue (eg. beetroot) of **same age / type** using a scalpel
2. **Rinse** to remove pigment released during cutting or **blot** on paper towel
3. Add **same number of cubes** to 5 different test tubes containing **same volume of water** (eg. 5cm^3)
4. Place each test tube in a water bath at a **different temperature** (eg. 10, 20, 30, 40, 50 °C)
5. Leave for **same amount of time** (eg. 20 mins)
6. Remove beetroot and measure **intensity of colour of surrounding solution:**
    - **Semi-quantitatively**
        - Use a known conc. of extract & distilled water to prepare a **dilution series** (colour standards)
        - **Compare** results with colour standards to **estimate** conc.
    - **Quantitatively**
        - Measure **absorbance** (of light) of known concentrations using a **colorimeter**
        - Draw a **calibration curve** → plot a graph of absorbance (y) against conc. of extract (x) and draw a **line / curve of best fit**
        - **Absorbance value for sample** read off calibration curve to find **associated extract conc.**

EXAM PAPERS PRACTICE

Common questions

What are the issues with comparing to a colour standard?	• Matching to colour standards is **subjective** • Colour obtained may **not match any** of colour standards
Why wash the beetroot before placing it in water?	• Wash off any **pigment** on **surface** • To show that release is only due to **[named variable]**
Why regularly shake each test tube containing cubes of plant tissue?	• To ensure all **surfaces** of cubes remain in contact with liquid • To maintain a **concentration gradient** for diffusion
Why control the volume of water?	• Too much water **would** dilute the pigment so solution will appear **lighter** / more light passes through in colorimeter than expected • So results are **comparable**
How could you ensure beetroot cylinders were kept at the same temperature throughout the experiment?	• Take readings in **intervals** throughout experiment of temperature in tube using a **digital thermometer / temperature sensor** • Use **corrective measure** if temperature has fluctuated

What does a high absorbance suggest about the cell-membrane?

- More **permeable** / damaged
- As more **pigment leaks** out making surrounding solution more **concentrated** (darker)

Explain how temperature affects permeability of cell-surface membranes

- As temperature increases, permeability **increases**
  - Phospholipids gain **kinetic energy** and **fluidity** increases
  - **Transport proteins denature** at high temperatures as **H bonds break,** changing **tertiary** structure
- At very low temperatures, permeability **increases**
  - Ice crystals can form which pierce the cell membrane and increase permeability

Explain how pH affects permeability of cell-surface membranes

- High or low pH **increases** permeability
  - **Transport proteins denature** as **H / ionic bonds break**, changing **tertiary** structure

Explain how lipid-soluble solvents eg. alcohol affect permeability of cell-surface membranes

- As concentration increases, permeability **increases**
- Ethanol (a lipid-soluble solvent) may **dissolve phospholipid bilayer** (gaps form)

2.4 Cell recognition and the immune system

What is an antigen?

- **Foreign molecule / protein** / glycoprotein / glycolipid
- That stimulates an **immune response** leading to production of **antibody**

How are cells identified by the immune system?

- Each type of cell has **specific molecules** on its **surface** (cell-surface membrane / cell wall) that identify it
- Often **proteins** → have a **specific tertiary structure** (or glycoproteins / glycolipids)

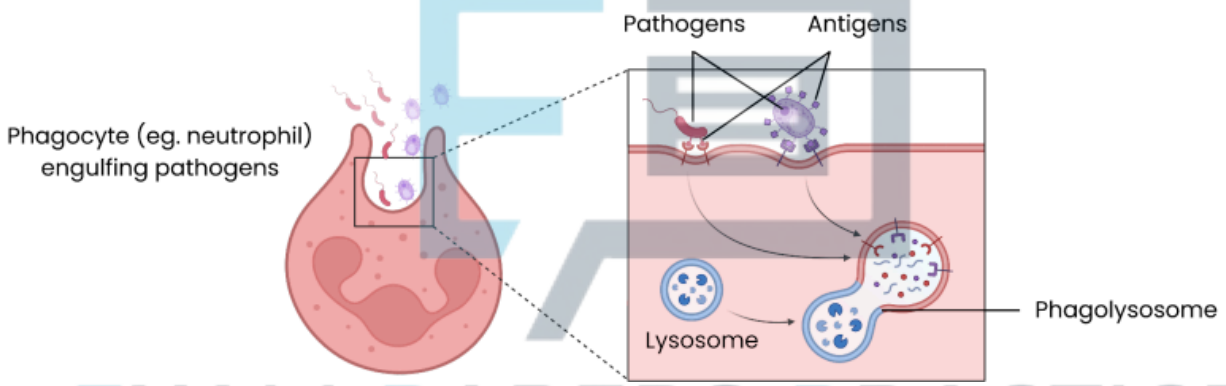
What types of cells and molecules can the immune system identify?

1. **Pathogens** (disease causing microorganisms) eg. viruses, fungi, bacteria
2. **Cells from other organisms** of the same species (eg. organ transplants)
3. **Abnormal body cells** eg. tumour cells or virus-infected cells
4. **Toxins** (poisons) released by some bacteria

Describe phagocytosis of pathogens (non-specific immune response)

1	Phagocyte attracted by chemicals / recognises (foreign) antigens on pathogen
2	Phagocyte **engulfs** pathogen by surrounding it with its cell membrane
3	Pathogen contained in **vesicle / phagosome** in cytoplasm of phagocyte
4	**Lysosome** fuses with phagosome and releases **lysozymes** (hydrolytic **enzymes**)
5	Lysozymes **hydrolyse / digest** pathogen

Phagocytosis leads to **presentation of antigens** where antigens are displayed on the phagocyte **cell-surface membrane**, stimulating the **specific** immune response (cellular and humoral response).

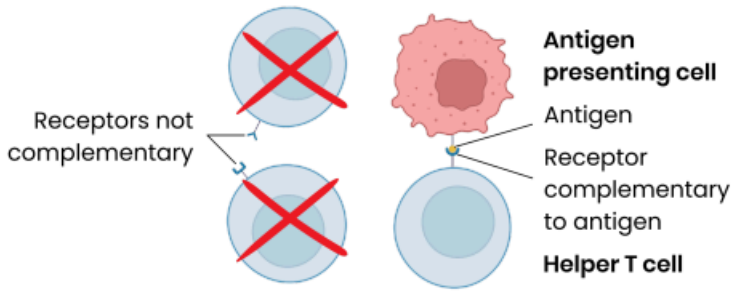


Describe the response of T lymphocytes to a foreign antigen (the cellular response)

T lymphocytes recognise (antigens on surface of) **antigen presenting cells** eg. infected cells, phagocytes presenting antigens, transplanted cells, tumour cells etc.

Specific **helper T cells with complementary receptors** (on cell surface) bind to antigen on **antigen-presenting cell** → activated and divide by mitosis to form clones which **stimulate**:

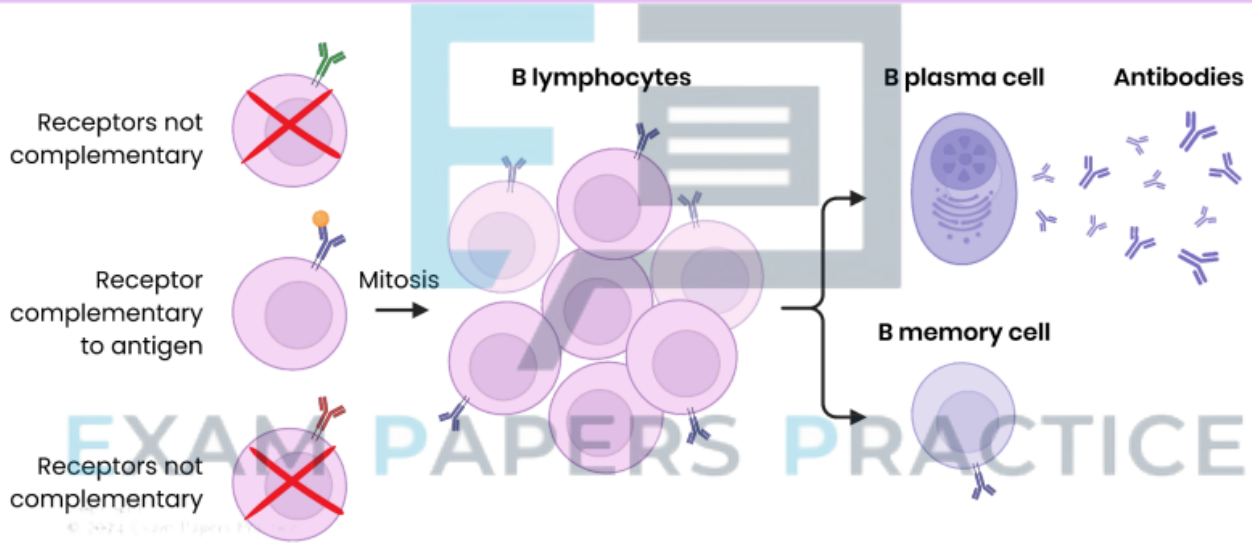
- **Cytotoxic T cells** → kill infected cells / tumour cells (by producing perforin)
- Specific **B cells** (humoral response - see below)
- **Phagocytes** → engulf pathogens by phagocytosis



Describe the response of B lymphocytes to a foreign antigen (the humoral response)

B lymphocytes can recognise **free** antigens eg. in blood or tissues, not just antigen presenting cells.

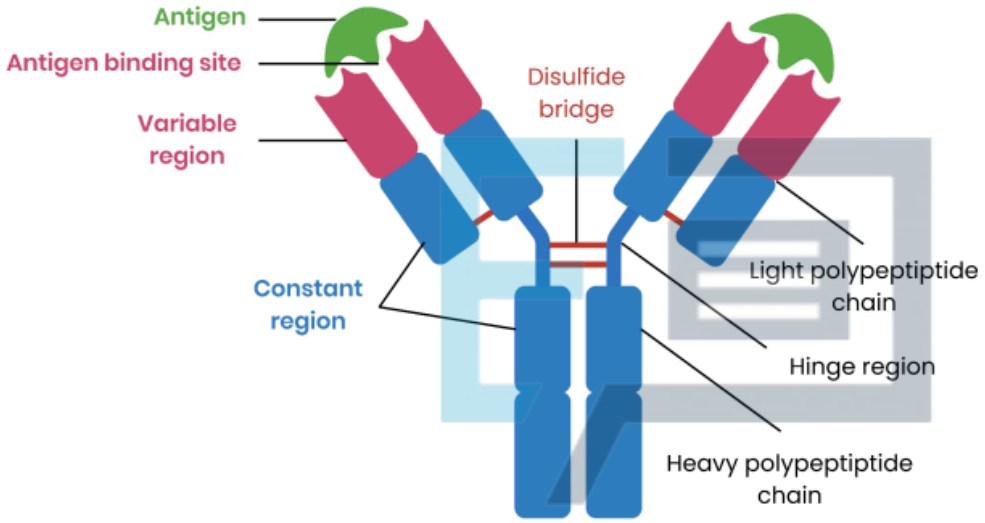
1. **Clonal selection:**
   - **Specific B lymphocyte** with **complementary receptor** (antibody on cell surface) binds to **antigen**
   - This is then stimulated by **helper T cells** (which releases cytokines)
   - So divides (rapidly) by **mitosis** to form **clones**
2. Some differentiate into **B plasma cells** → secrete large amounts of (monoclonal) **antibody**
3. Some differentiate into **B memory cells** → remain in blood for secondary immune response



What are antibodies?

- **Quaternary structure proteins** (4 polypeptide chains)
- Secreted by **B lymphocytes** eg. plasma cells in response to **specific** antigens
- Bind **specifically** to antigens forming **antigen-antibody complexes**

Describe the structure of an antibody

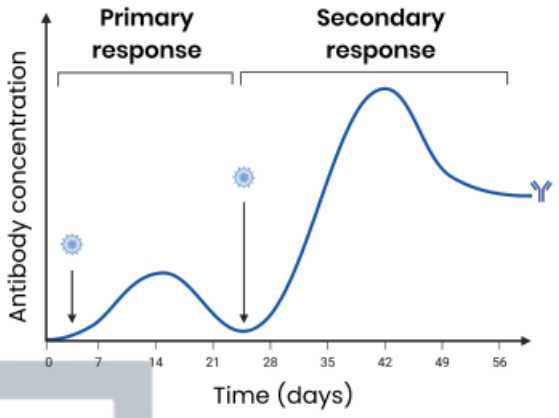


Explain how antibodies lead to the destruction of pathogens

- Antibodies **bind to antigens** on pathogens forming an **antigen-antibody complex**
  - Specific **tertiary structure** so **binding site / variable region binds** to **complementary antigen**
- Each antibody binds to **2 pathogens** at a time causing **agglutination** (clumping) of pathogens
- Antibodies **attract phagocytes**
- Phagocytes bind to the antibodies and **phagocytose many pathogens at once**

Explain the differences between the primary & secondary immune response

- **Primary** - first exposure to antigen
  - Antibodies produced **slowly** & at a **lower conc.**
  - Takes time for specific **B plasma cells** to be stimulated to produce specific antibodies
  - Memory cells produced
- **Secondary** - second exposure to antigen
  - Antibodies produced **faster** & at a **higher conc.**
  - **B memory cells** rapidly undergo mitosis to produce many **plasma cells** which produce specific antibodies



What is a vaccine?

- Injection of **antigens** from **attenuated** (dead or weakened) pathogens
- Stimulating formation of **memory cells**

Explain how vaccines provide protection to individuals against disease

1. Specific **B lymphocyte** with complementary receptor binds to **antigen**
2. Specific **T helper cell** binds to **antigen-presenting** cell and **stimulates** B cell
3. B lymphocyte divides by **mitosis** to form clones
4. Some differentiate into **B plasma cells** which release **antibodies**
5. Some differentiate into **B memory cells**
6. On **secondary exposure** to antigen, **B memory cells** rapidly divide by mitosis to produce **B plasma cells**
7. These release **antibodies faster** and at a **higher concentration**

Explain how vaccines provide protections for populations against disease

- **Herd immunity** - **large proportion** of population vaccinated, reducing **spread** of pathogen
  - Large proportion of population **immune** so **do not become ill** from infection
  - **Fewer infected** people to pass **pathogen** on / **unvaccinated** people **less likely** to come in **contact** with someone with disease

Describe the differences between active and passive immunity

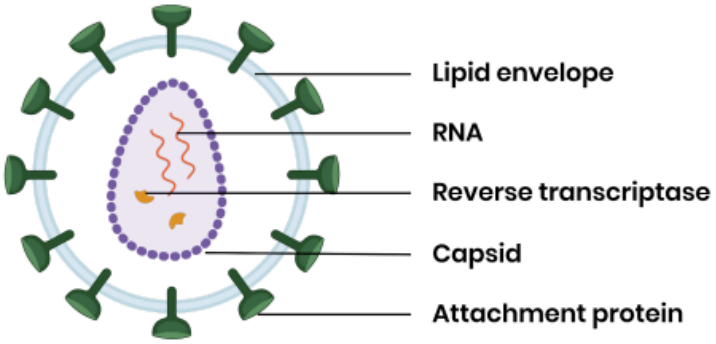
Active immunity	Passive immunity
Initial exposure to **antigen** eg. vaccine or primary infection	**No** exposure to antigen
Memory cells involved	**No** memory cells involved
Antibody produced and secreted by **B plasma cells**	Antibody introduced from **another organism** eg. breast milk / across placenta from mother
Slow; takes **longer** to develop	**Faster acting**
Long term immunity as antibody can be produced in response to a specific antigen **again**	**Short term** immunity as antibody hydrolysed (endo/exo/dipeptidases)

Explain the effect of antigen variability on disease and disease prevention

- Antigens on pathogens **change shape / tertiary structure** due to **gene mutations** (creating new strains)
- So **no longer immune** (from vaccine or prior infection)
  - **B memory cell** receptors cannot bind to / recognise changed antigen on secondary exposure
  - Specific antibodies **not complementary / cannot bind** to changed antigen

Examples: *yearly new flu vaccines, no vaccine for HIV, catch a cold many times*

Describe the structure of a HIV particle



Describe the replication of HIV in helper T cells

1. **HIV attachment proteins** attach to **receptors** on **helper T cell**
2. **Lipid envelope fuses** with cell-surface membrane, releasing **capsid** into cell
3. Capsid uncoats, **releasing RNA** and **reverse transcriptase**
4. **Reverse transcriptase** converts viral **RNA to DNA**
5. Viral DNA **inserted / incorporated** into helper T cell **DNA** (may remain latent)
6. **Viral protein / capsid / enzymes** are produced
    a. DNA **transcribed** into HIV mRNA
    b. HIV mRNA **translated** into new HIV proteins
7. Virus particles **assembled** and **released** from cell (via budding)

Explain how HIV causes the symptoms of acquired immune deficiency syndrome (AIDS)

- HIV infects and **kills helper T cells** (host cell) as it multiplies rapidly
    - So T helper cells can't stimulate **cytotoxic T cells**, **B cells** and **phagocytes**
    - So B plasma cells can't release as many **antibodies** for agglutination & destruction of pathogens
- **Immune system deteriorates** → more susceptible to (opportunistic) infections
- Pathogens reproduce, release toxins and damage cells

Explain why antibiotics are ineffective against viruses

Viruses do not have structures / processes that antibiotics inhibit:

- Viruses do not have **metabolic processes** (eg. do not make protein) / **ribosomes**
- Viruses do not have **bacterial enzymes / murein cell wall**

What is a monoclonal antibody?

- Antibody produced from **genetically identical / cloned B lymphocytes / plasma cells**
- So have **same tertiary structure**

Explain how monoclonal antibodies can be used in medical treatments

- Monoclonal antibody has a **specific tertiary structure / binding site / variable region**
- **Complementary** to **receptor / protein / antigen** found only on a **specific cell type** (eg. cancer cell)
- **Therapeutic drug** attached to antibody
- Antibody **binds** to specific cell, forming **antigen-antibody complex**, delivering drug

Some monoclonal antibodies are also designed to **block antigens / receptors** on cells.

Explain how monoclonal antibodies can be used in medical diagnosis

- Monoclonal antibody has a **specific tertiary structure / binding site / variable region**
- **Complementary** to specific **receptor / protein / antigen** associated with diagnosis
- **Dye / stain / fluorescent marker** attached to antibody
- Antibody **binds** to receptor / protein / antigen, forming **antigen-antibody complex**

Examples vary, eg. pregnancy tests. You'll need to interpret information in the question on how these work.

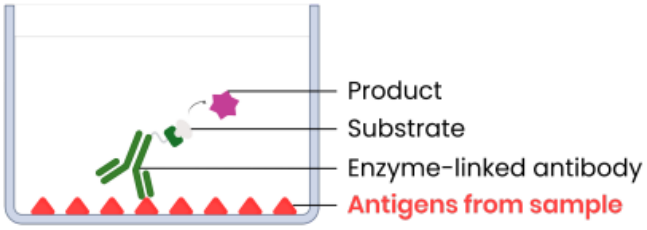
Explain the use of antibodies in the ELISA (enzyme-linked immunosorbent assay) test to detect antigens

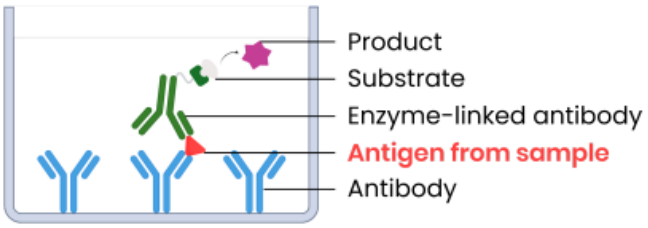
Direct ELISA

1. Attach **sample** with **potential antigens** to well
2. Add **complementary monoclonal antibodies** with **enzymes** attached → **bind** to antigens if present
3. **Wash** well → **remove unbound antibodies** (to prevent false positive)
4. Add **substrate** → enzymes create products that cause a **colour change** (positive result)

OR sandwich ELISA

1. Attach **specific monoclonal antibodies** to well
2. Add **sample** with **potential antigens,** then wash well
3. Add **complementary monoclonal antibodies** with **enzymes** attached → **bind** to antigens if present
4. **Wash** well → **remove unbound antibodies** (to prevent false positive)
5. Add **substrate** → enzymes create products that cause a **colour change** (positive result)

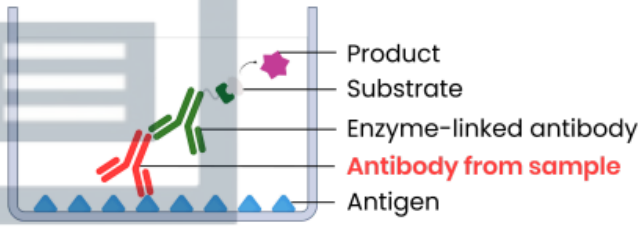




Explain the use of antibodies in the ELISA test to detect antibodies

Indirect ELISA

1. Attach **specific antigens** to well
2. Add **sample** with **potential antibodies**, wash well
3. Add **complementary monoclonal antibodies** with **enzymes** attached → **bind** to antibodies if present
4. **Wash** well → **remove unbound antibodies**
5. Add **substrate** → enzymes create products that cause a **colour change** (positive result)



Suggest the purpose of a control well in the ELISA test

- Compare to test to show only **enzyme** causes **colour change**
- Compare to test to show all unbound antibodies have been **washed** away

Discuss some general ethical issues associated with the use of vaccines and monoclonal antibodies

- Pre-clinical testing on / use of **animals** - potential **stress / harm / mistreatment**
  - But animals **not killed** & helps produce new drugs to reduce **human suffering**
- Clinical trials on **humans** - potential **harm / side-effects**
- Vaccines - may continue **high risk activities** and still **develop / pass on pathogen**
- Use of drug - potentially dangerous **side effects**

Suggest some points to consider when evaluating methodology relating to the use of vaccines and monoclonal antibodies

- Was the **sample size** large enough to be representative?
- Were participants **diverse** in terms of age, sex, ethnicity and health status?
- Were **placebo / control groups** used for comparison?
- Was the **duration** of the study long enough to show long-term effects?
- Was the trial **double-blind** (neither doctor / patient knew who was given drug or placebo) to reduce **bias**?

Suggest some points to consider when evaluating evidence and data relating to the use of vaccines and monoclonal antibodies

- What **side effects** were observed, and how frequently did they occur?
- Was a **statistical test** used to see if there was a significant difference between start & final results?
- Was the **standard deviation** of final results large, showing some people did not benefit?
- Did **standard deviations** of start & final results **overlap**, showing there may not be a significant difference?
- What **dosage** was optimum? Does increasing dose increase effectiveness enough to justify extra cost?
- Was the **cost of production & distribution** low enough?

Exam insight: common mistakes ❌

Mistake	Explanation
Confusing lysosomes & lysozymes	**Lysozymes** are **enzymes** found in lysosomes.
"Pathogens are contained in a **vacuole** during phagocytosis."	Sometimes mark schemes only allow the terms **vesicle** or **phagosome**, so use these to be safe.
"Lysosomes fuse with **pathogens**."	Lysosomes fuse with the **phagosome** that contains the pathogen.
*Not mentioning the idea of **specificity** in B / T lymphocytes.*	B and T lymphocytes are highly specific due to the wide range of **receptors** found on their cell-surface membranes. The cellular and humoral response are classed as the **specific immune response**.
"An antibody has an **active site**."	An **enzyme** has an active site. An antibody has a **binding site**.
*Describing the **full** immune response for every immune system question.*	Pay close attention to the wording of the question, as they normally tend to focus on a specific aspect of the immune response.
"Antibiotics are ineffective against viruses as **viruses live inside host human cells** and so are **inaccessible**."	This is not wrong, but was considered to be GCSE level. Instead, mention the **structures** and **processes** that antibiotics inhibit, that viruses don't have.
"HIV replicates using the T helper cells' **machinery**."	This is too vague. Refer to specific processes, such as **transcription** and **translation**.
"A monoclonal antibody is a **clone of an antibody**."	A monoclonal antibody by definition is produced by a **clone of a plasma cell.** The antibody itself can't be considered a clone.