OCR A Level Biology

Your notes

Cell Structure

Contents

- Studying Cells
- Using a Microscope
- Drawing Cells
- Magnification & Resolution
- Eukaryotic Cells
- Eukaryotic Cells Under the Microscope
- Organelles & the Production of Proteins
- The Cytoskeleton
- Prokaryotic & Eukaryotic Cells

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Your notes

Use of microscopy

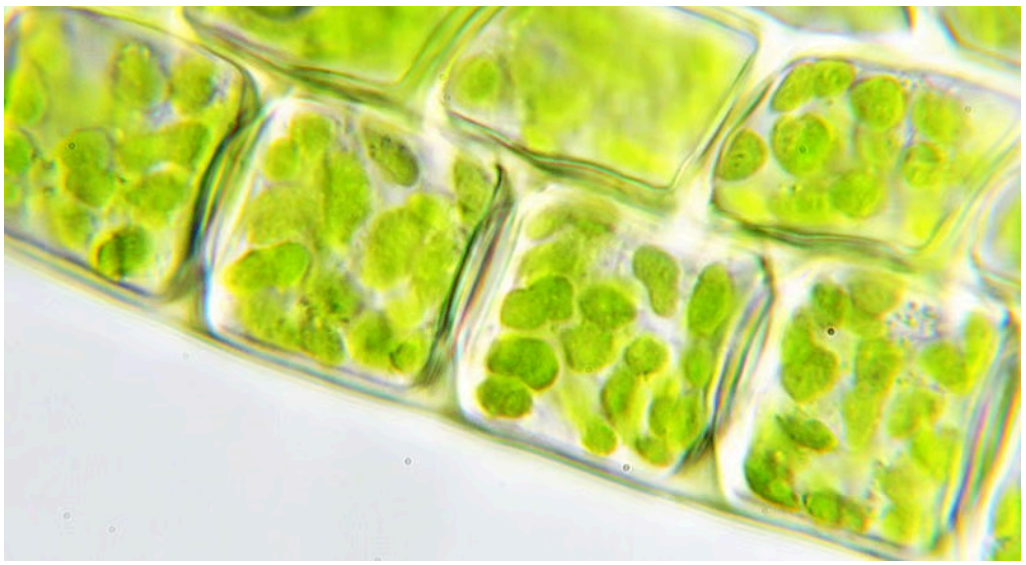
- Microscopes can be used to **observe** and **investigate** cell structure
- Different types of microscope can be used to study cells at different levels of detail, e.g.
  - **light** microscopes
  - **electron** microscopes
- The images generated by the different types of microscope differ significantly

Light microscopes

- Light, or optical, microscopes use **light** to form an image
- The maximum resolution of a light microscope is around **0.2 micrometres (µm)**, meaning that the maximum useful magnification of optical microscopes is about **×1500**
- Light microscopes can only be used to observe **larger structures**, e.g.:
  - entire cells
  - nuclei
  - mitochondria and chloroplasts
- While light microscopes have limited resolution, they do have advantages, such as:
  - they are **small** and relatively **cheap**
  - **specimen preparation can be straightforward** enough to perform in a school laboratory
  - they can be used to produce **colour images**
  - they allow the observation of **living specimens**

Light microscope image

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Your notes

Light microscope images allow the observation of cell shape, as well as larger internal structures, e.g, here chloroplasts can be seen within a series of plant cells

Kelvinsong, via Wikimedia Commons

Electron microscopes

- Electron microscopes use **electrons** to form an image
- Electron microscopes have a maximum resolution of around **0.0002 µm,** or **0.2 nm**, and a maximum magnification that range from around **×1,000,000** up to **many millions**
- Electron microscopes can be used to observe **small structures inside cells**, such as:
  - cell membranes
  - ribosomes
  - the endoplasmic reticulum
  - lysosomes
- While electron microscopes are essential tools in the study of cell biology, they do have some limitations
  - They are very **large** and **expensive**
  - Specimens must be prepared using a highly **complex** process
  - Specimens must be viewed in a **vacuum**, meaning that live specimens cannot be observed
  - Images are always **black and white**, though they can be artificially coloured during processing
- There are two types of electron microscope:
  - transmission electron microscopes (TEMs)

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- scanning electron microscopes (SEMs)



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Transmission electron microscopes

- TEMs use electromagnets to **transmit** a beam of electrons **through** a specimen; denser parts of the specimen absorb more electrons, meaning that denser parts appear darker on the final image
- TEMs produce images that:
  - are **high-resolution**
  - allow the **internal structures** within cells, and within organelles to be seen
  - are **two-dimensional**

TEM image



TEM images allow the internal structures within cells and organelles to be studied

Klingm01, via Wikimedia Commons

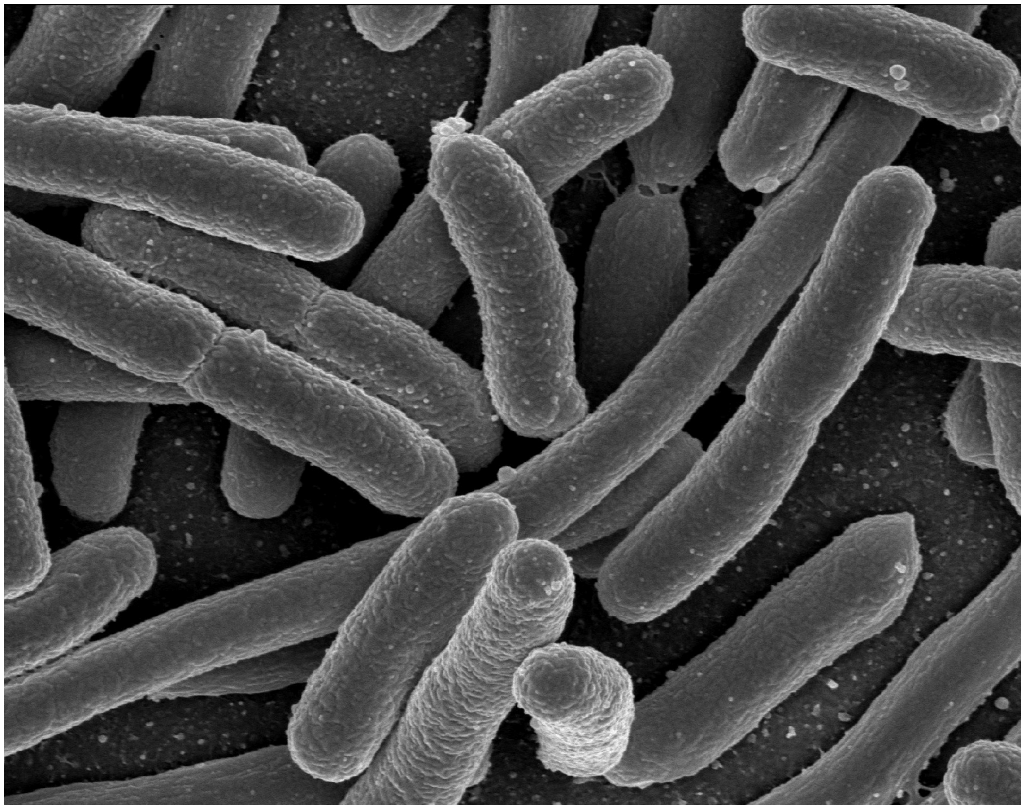
Scanning electron microscopes

- SEMs pass a beam of electrons **across the surface** of a specimen and then detect the rate at which the electrons **bounce back**
- This means that SEMs produce images that:
  - are **three-dimensional**

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- show the **surface** of specimens
- SEMs have a lower maximum resolution than TEMs

SEM image



SEM images are three-dimensional and show the surface of objects, e.g. here E. coli bacteria can be seen

NIAID, via Flickr

Examiner Tips and Tricks

In an exam you could be shown an image and asked to identify the microscope used to produce it, so make sure that you understand the differences between the images produced by the different types of microscope.

Your notes

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Your notes

Preparation of Microscope Slides

- Many biological structures are too small to be seen by the naked eye
- Optical microscopes are an invaluable tool for scientists as they allow for tissues, cells and organelles to be seen and studied
- For example, the movement of chromosomes during mitosis can be observed using a microscope

How optical microscopes work

- Light is directed through the thin layer of biological material that is supported on a glass slide
- This light is focused through several lenses so that an image is visible through the eyepiece
- The magnifying power of the microscope can be increased by rotating the higher power objective lens into place

Apparatus

- The key components of an optical microscope are:
  - The eyepiece lens
  - The objective lenses
  - The stage
  - The light source
  - The coarse and fine focus
- Other tools used:
  - Forceps
  - Scissors
  - Scalpel
  - Coverslip
  - Slides
  - Pipette
  - Staining solution

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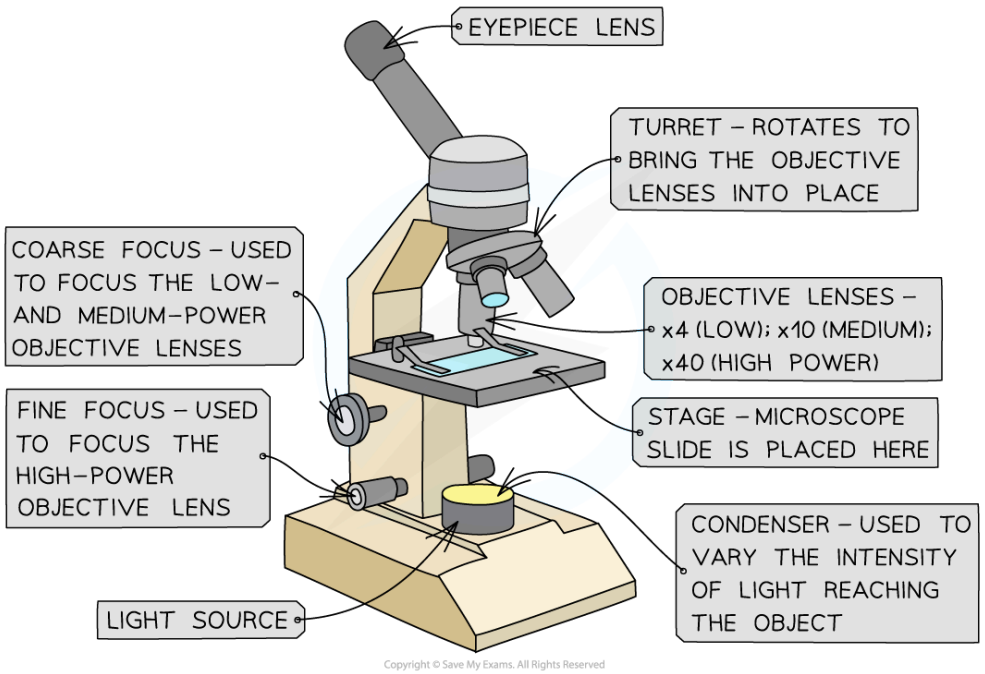


Image showing all the components of an optical microscope

Method

- Preparing a slide using a **liquid specimen**:
  - Add a few drops of the sample to the slide using a pipette
  - Cover the liquid/smear with a coverslip and gently press down to **remove air bubbles**
  - **Wear gloves** to ensure there is no cross-contamination of foreign cells
- Methods of preparing a microscope slide using a **solid specimen**:
  - Take care when using sharp objects and wear gloves to prevent the stain from dying your skin
  - Use scissors to cut a small sample of the tissue
  - Peel away or cut a **very thin layer** of cells from the tissue sample to be placed on the slide (using a scalpel or forceps)
    - The tissue needs to be thin so that the **light** from the microscope can pass through
  - Apply a stain
  - Gently place a coverslip on top and press down to remove any air bubbles

Or

- Some tissue samples need to be treated with chemicals to kill/make the tissue rigid

Your notes

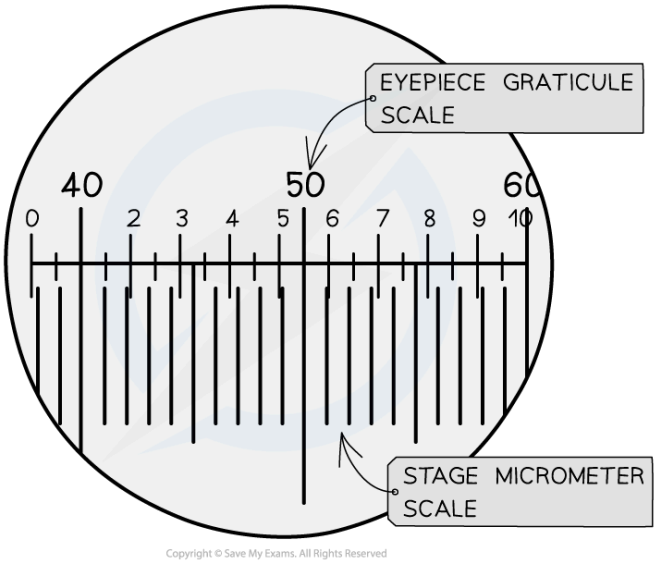

Your notes

- This involves **fixing the specimen** using formaldehyde (preservative), dehydrating it using a series of ethanol solutions, impregnating it in paraffin/resin for support then cutting thin slices from the specimen using a **microtome**
- The paraffin is removed from the slices/specimen, a stain is applied and the specimen is mounted using a resin and a coverslip is applied

Or

- **Freeze** the specimen in carbon dioxide or liquid nitrogen
  - Cut the specimen into thin slices using a **cryostat**
  - Place the specimen on the slide and add a stain
  - Gently place a coverslip on top and press down to remove any air bubbles
- When using an optical microscope always **start with the low power objective lens**:
  - It is **easier to find** what you are looking for in the field of view
  - This helps to **prevent damage** to the lens or coverslip in case the stage has been raised too high
- Preventing the dehydration of tissue:
  - The thin layers of material placed on slides can **dry up rapidly**
  - Adding a drop of water to the specimen (beneath the coverslip) can prevent the cells from being damaged by dehydration
- Unclear or blurry images:
  - Switch to the lower power objective lens and try using the **coarse focus** to get a clearer image
  - Consider whether the specimen sample is **thin enough** for light to pass through to see the structures clearly
  - There could be **cross-contamination** with foreign cells or bodies
- Using a graticule to take measurements of cells:
  - A **graticule** is a small disc that has an **engraved ruler**
  - It can be placed into the eyepiece of a microscope to act as a ruler in the field of view
  - As a graticule has no fixed units it must be **calibrated** for the objective lens that is in use. This is done by using a scale engraved on a microscope slide (**a stage micrometer**)
  - By using the two scales together the number of micrometers each graticule unit is worth can be worked out
  - After this is known the graticule can be used as a **ruler** in the field of view

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The stage micrometer scale is used to find out how many micrometers each graticule unit represents

Limitations

- The size of cells or structures of tissues may appear inconsistent in different specimen slides
  - Cell structures are 3D and the different tissue samples will have been **cut at different planes** resulting in this inconsistencies when viewed on a 2D slide
- Optical microscopes do not have the same magnification power as other types of microscopes and so there are some structures that can not be seen
- The treatment of specimens when preparing slides could alter the structure of cells

Examiner Tips and Tricks

Remember the importance of **calibration** when using a **graticule**. If it is not calibrated then the measurements taken will be completely arbitrary!

Staining in Light Microscopy

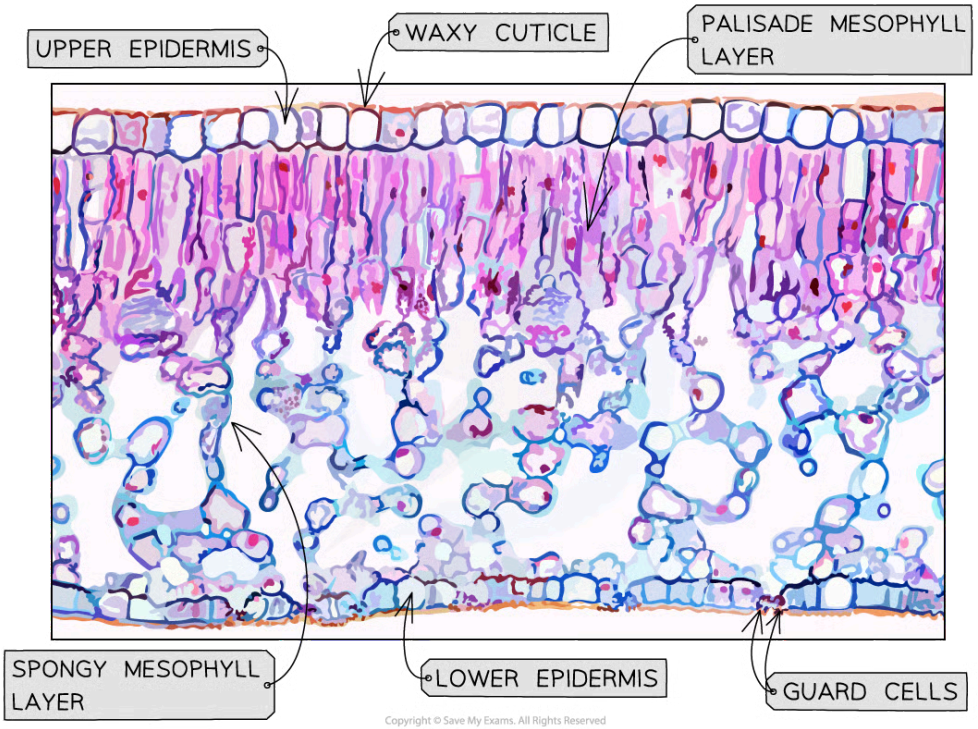
- Many tissues that are used in microscopy are naturally **transparent**, they let both light and electrons pass through them
- This makes it very difficult to see any detail in the tissue when using a microscope
- Stains are often used to make the tissue coloured/visible

Staining for light microscopy

- Coloured dyes are used when staining specimens

Your notes

- The dyes used **absorb specific colours of light while reflecting others**; this makes the structures within the specimen that have absorbed the dye visible
- **Certain tissues absorb certain dyes**, which dye they absorb depends on their chemical nature
- Specimens or sections are sometimes **stained with multiple dyes** to ensure the different tissues within the specimen show up - this is known as **differential staining**
- It is important to remember that most of the **colours** seen in photomicrographs (image taken using a light microscope) are **not natural**
  - Chloroplasts don't need stains as they show up green, which is their natural colour
- **Toluidine blue and phloroglucinol** are common stains used
  - Toluidine blue turns cells blue
  - Phloroglucinol turns cells red/pink



Toluidine blue and phloroglucinol have been used to stain this tissue specimen taken from a leaf

Staining for electron microscopy

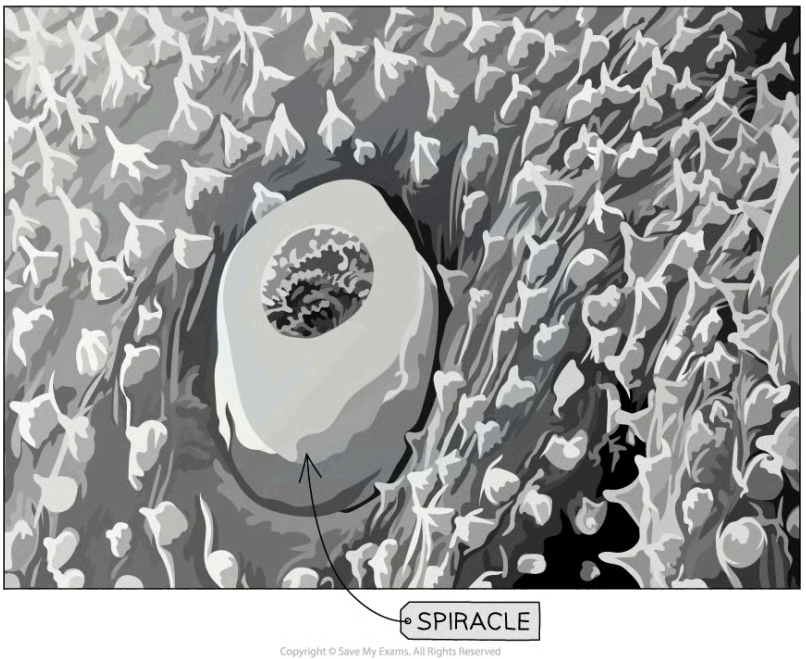
- When using Transmission electron microscopes (TEMs) the specimen must be stained in order to **absorb the electrons**
- Unlike light, electrons have **no colour**
  - The dyes used for staining cause the tissues to show up **black or different shades of grey**

Your notes

- **Heavy-metal compounds** are commonly used as dyes because they absorb electrons well
  - Osmium tetroxide and ruthenium tetroxide are examples
- Any of the colour present in electron micrographs is not natural and it is also not a result of the staining
- **Colours are added to the image** using an image-processing software


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The internal structure of the mitochondrion can be seen using a TEM and staining



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A spiracle found on the exoskeleton of an insect. No colours have been added to this image using image-processing software.

Your notes



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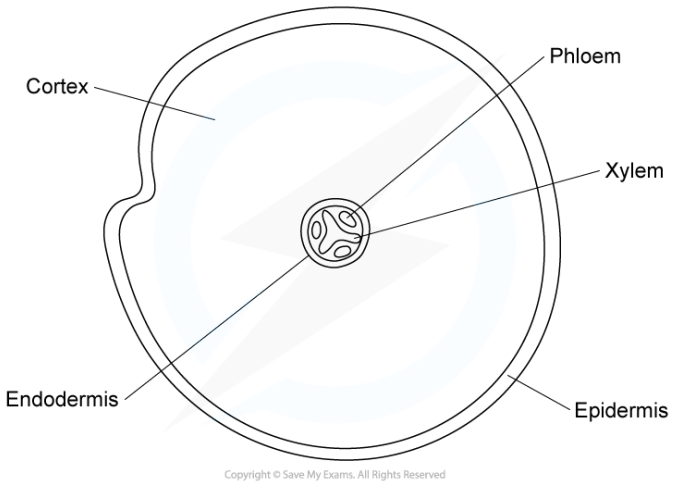
Drawing Cells

- To record the observations seen under the microscope (or from photomicrographs taken) a labelled biological drawing is often made
- **Biological drawings** are line pictures which show specific features that have been observed when the specimen was viewed
- There are a number of rules/conventions that are followed when making a biological drawing

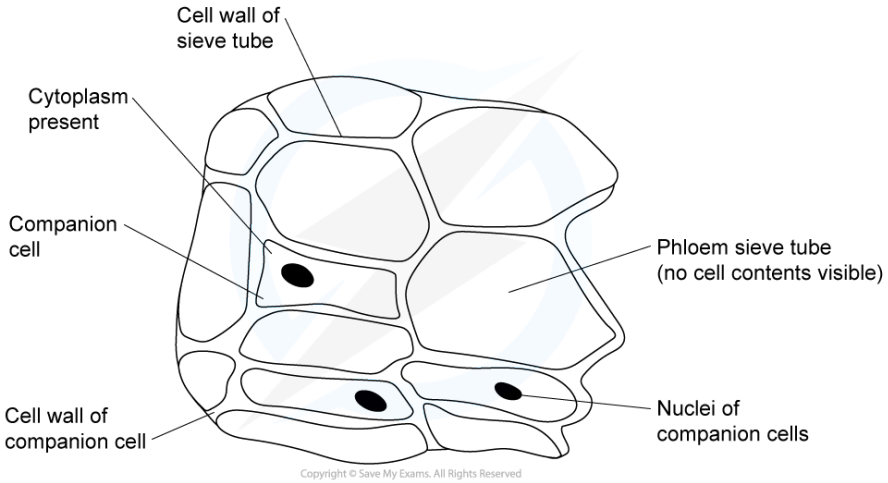
Guidelines for microscope drawings

- The conventions are:
  - The drawing must have a title
  - The **magnification** under which the observations shown by the drawing are made must be recorded
  - A **sharp HB pencil** should be used (and a good eraser!)
  - Drawings should be on plain white paper
  - Lines should be **clear**, **single lines** (no thick shading)
  - **No shading**
  - The drawing should take up as much of the space on the page as possible
  - Well-defined structures should be drawn
  - The drawing should be made with **proper proportions**
  - **Label lines** should not cross or have arrowheads and should **connect directly** to the part of the drawing being labelled
  - Label lines should be kept to one side of the drawing (in parallel to the top of the page) and drawn with a **ruler**
- Drawings of cells are typically made when visualizing cells at a higher magnification power, whereas plan drawings are typically made of tissues viewed under lower magnifications (individual cells are never drawn in a plan diagram)

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An example of a tissue plan drawn from a low-power image of a transverse section of a root. There is no cell detail present.



An example of a cellular drawing taken from a high-power image of phloem tissue.

Examiner Tips and Tricks

When producing a biological drawing, it is vital that you only ever draw what you see and not what you think you see.To accurately reflect the size and proportions of structures you see under the microscope, you should get used to using the eyepiece graticule.You should be able to describe and interpret photomicrographs, electron micrographs and drawings of typical animal cells.

Your notes

Your notes

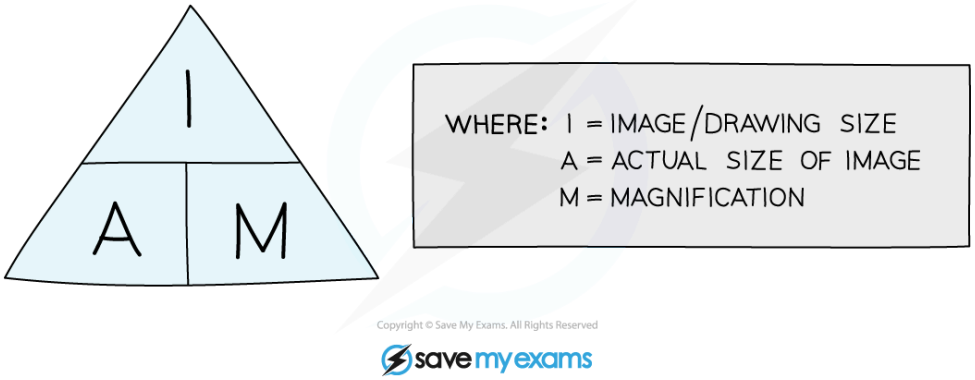
Magnification formula

- The **magnification** of an object can be calculated using the formula:

magnification = size of image ÷ size of real object

- The magnification formula can be rearranged to allow the calculation of:
  - **m**agnification (**m**)
  - size of **i**mage (**i**)
  - size of real object, often referred to as **a**ctual size (**a**)

Magnification equation triangle



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An equation triangle allows the magnification formula to be rearranged easily

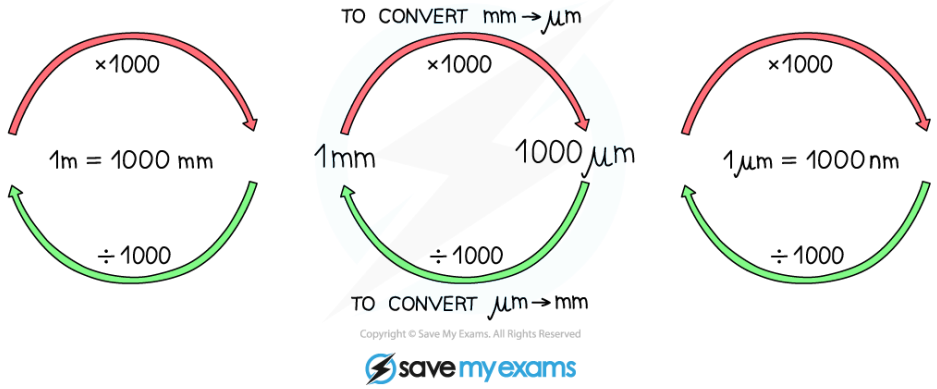
Converting units during magnification calculations

- Different units of measurement are used to measure different objects:
  - The actual size of cells is typically measured using the micrometre (**µm**) scale
  - Internal cellular structures are sometimes measured in nanometers (**nm**)
  - The size of images is usually measured in centimetres (**cm**) or millimetres (**mm**)
- Units of measurement relate to each other as follows:
  - 1000 nm = 1 µm
  - 1000 µm = 1 mm
  - 1000 mm = 1 m
  - 10 mm = 1 cm

- When carrying out magnification calculations it is essential that all measurements have the **same units**, so **unit conversions** are often required
- Units can be converted by **multiplying or dividing** by the relevant factor
  - Converting larger units to smaller units = multiply
  - Converting smaller units to larger units = divide
- Note that **magnification does not have units**

Your notes

Converting units diagram

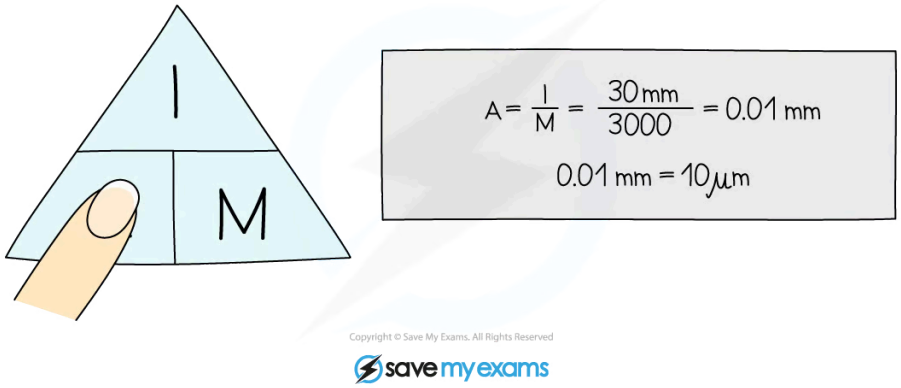


Units of measurement can be converted by multiplying or dividing by the relevant factor

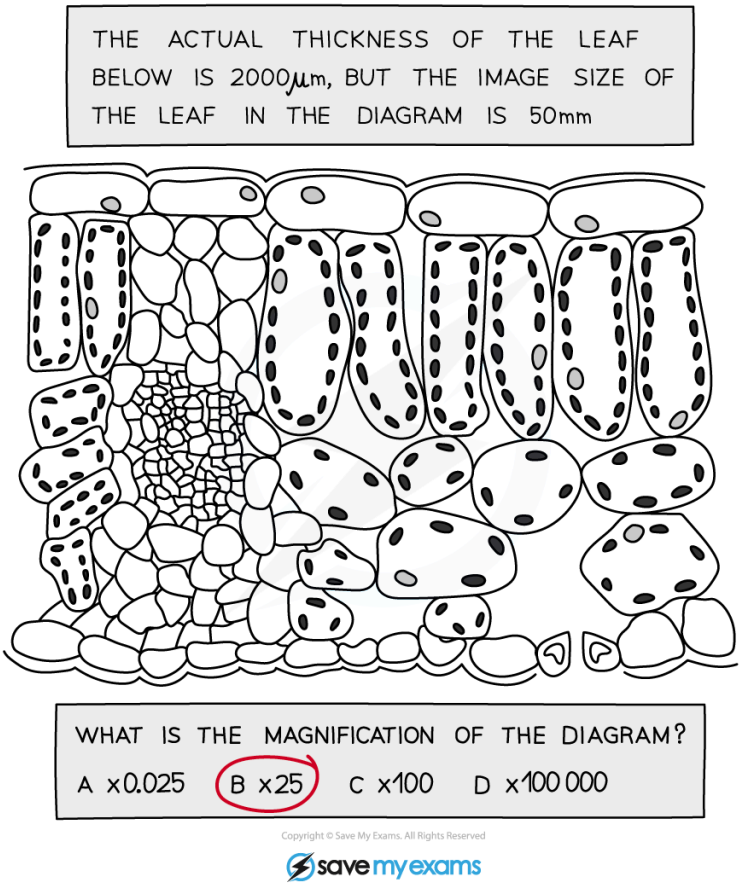
Worked Example

An **image** of an animal cell is 30 mm in size and it has been **magnified** by a factor of ×3000.

What is the **actual** size of the cell?



Worked Example



Step 1: Convert all units to µm

1 mm = 1000 µm, so converting mm to µm involves multiplying by 1000

50 × 1000 = 50 000

The **a**ctual thickness of the leaf is 2000 µm and the **i**mage size is 50 000 µm

Step 2: Calculate magnification using the formula

magnification = image size ÷ actual size

= 50 000 / 2000

= 25

So the magnification is **×25**

Your notes

Magnification & Resolution

Magnification

- Magnification can be defined as:

The number of times larger an image is than the actual object

- The ability of a microscope to magnify an object depends on the type of microscope, and on the features of the microscope itself
  - E.g. for a light **microscope** the magnification can be calculated by **multiplying** together the magnification of the **eyepiece lens** and the **objective lens**

Resolution

- Resolution can be defined as:

The ability to distinguish separate points on an image as two separate objects

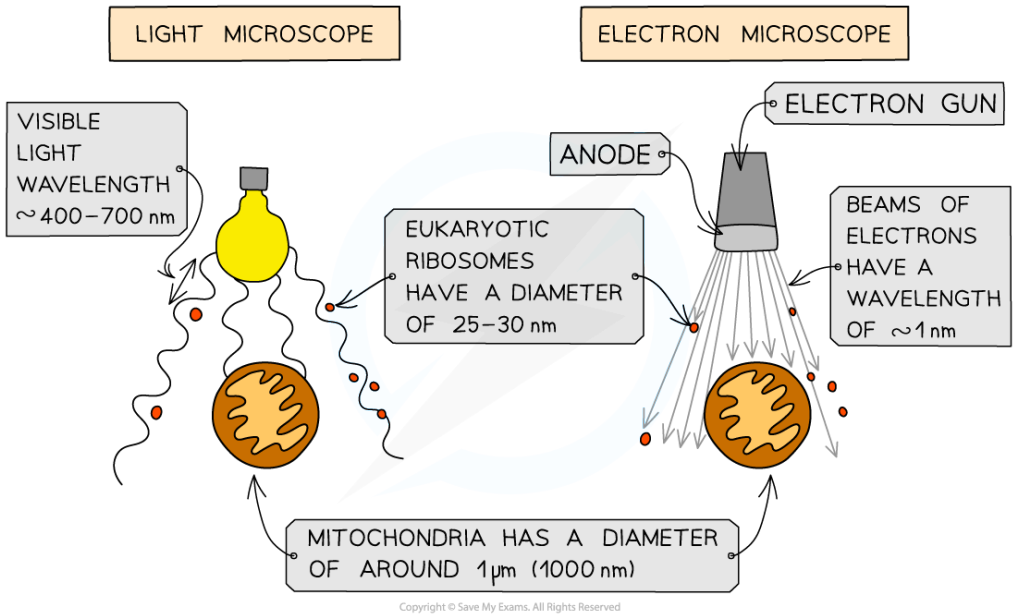
- The higher the resolution, the shorter the distance at which the two objects can be clearly distinguished
- The ability of a microscope to resolve two objects as separate points is dependent on the method of image generation:
  - **Light microscopes**: the resolution is limited by the **wavelength of light**
    - As light passes close to physical structures it is **diffracted**, meaning that light waves spread out
    - The closer the structures are to each other, the more the **light waves overlap** each other as they are diffracted
    - Points that are closer together than half the wavelength of visible light cannot be clearly distinguished from each other
  - **Electron microscopes**: the resolution is much higher because **electrons have a smaller wavelength** than visible light
    - The objects past which the electrons travel can therefore be much closer together before the diffracted beams overlap

Resolution diagram



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The resolving power of an electron microscope is much greater than that of a light microscope; this is because electrons have a smaller wavelength than visible light

Comparing light and electron microscopes

- **Light microscopes**:
  - have a maximum resolution of **200 nm**
  - have a maximum useful magnification of around **×1500–2000**
  - can be used for viewing **living** or **dead** specimens
  - are useful for looking at **whole cells**, small **organisms** and **tissues** within organs such as in leaves or skin
- **Electron microscopes**:
  - have a maximum resolution of 0.5 nm (TEM) or 3–10 nm (SEM)
  - are capable of generating images with a magnification of **more than ×500 000**
    - TEMs are capable of higher magnification than SEMs due to their higher resolution
  - can only be used for viewing **dead** specimens
  - are useful for looking at **organelles** and **viruses**, as well as looking at whole cells in more detail

Light and electron microscopes comparison table



Your notes

ELECTRON MICROSCOPE	LIGHT MICROSCOPE
LARGE AND INSTALLATION MEANS IT CAN'T BE MOVED	SMALL AND EASY TO CARRY
VACUUM NEEDED	NO VACUUM NEEDED
COMPLICATED SAMPLE PREPARATION	EASY SAMPLE PREPARATION
OVER x 500 000 MAGNIFICATION	UP TO x 2000 MAGNIFICATION
RESOLUTION 0.5 nm	RESOLUTION 200 nm
SPECIMENS ARE DEAD	SPECIMENS CAN BE LIVING OR DEAD



Examiner Tips and Tricks

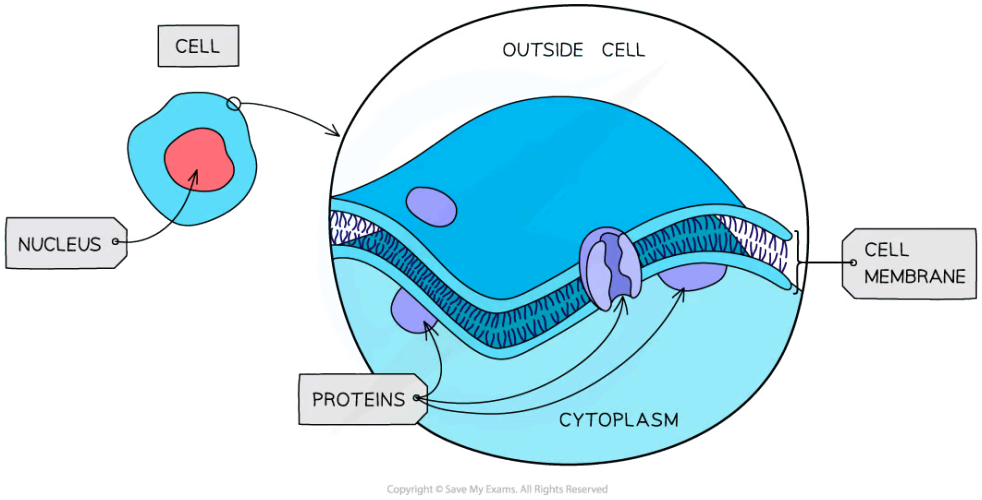
You do not need to be able to recall the exact numbers for resolution and magnification in different types of microscope, but you must have an appreciation of **how the values differ** between **light microscopes**, **TEMs** and **SEMs**.

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Your notes

Eukaryotic Cell Structure

Cell surface membrane

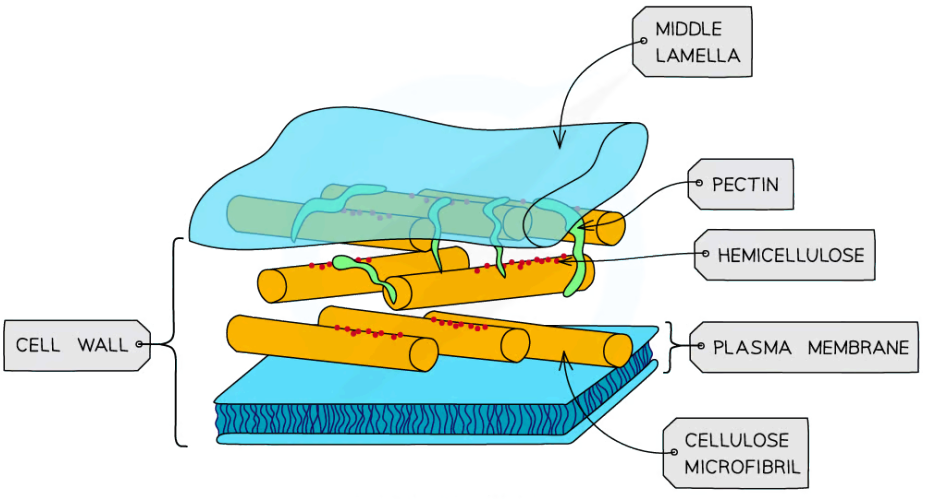


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The structure of the cell surface membrane – although the structure looks static the phospholipids and proteins forming the bilayer are constantly in motion

- **All cells** are surrounded by a cell surface membrane which controls the exchange of materials between the internal cell environment and the external environment
  - The membrane is described as being 'partially permeable'
- The cell membrane is formed from a **phospholipid bilayer** of phospholipids spanning a diameter of around 10 nm

Cell wall



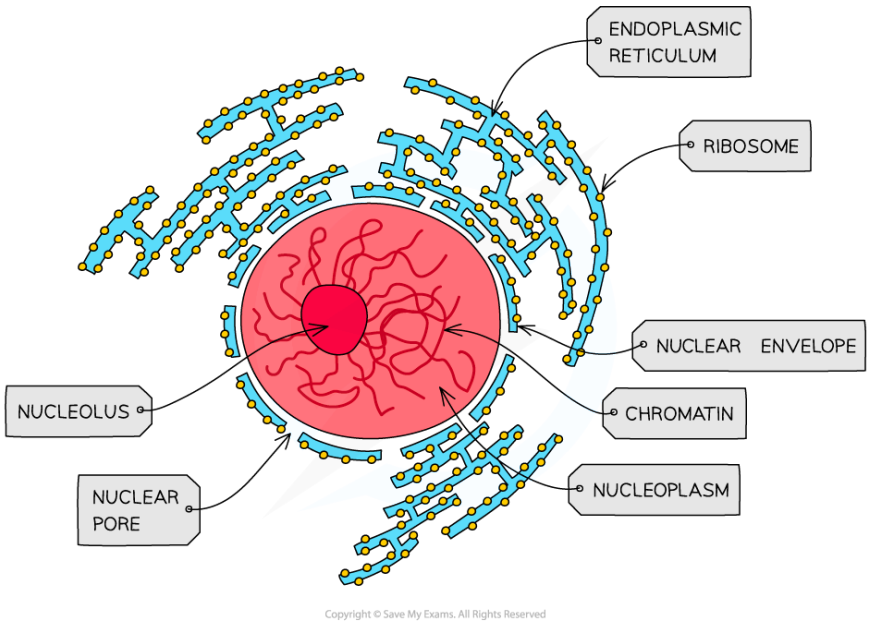
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The cell wall is freely permeable to most substances (unlike the plasma membrane)

- Found in plant cells but **not in animal cells**
- Cell walls are formed outside of the cell membrane and offer structural support to cell
- Structural support is provided by the polysaccharide cellulose in plants, and peptidoglycan in most bacterial cells
- Narrow threads of cytoplasm (surrounded by a cell membrane) called **plasmodesmata** connect the cytoplasm of neighbouring plant cells

Your notes

Nucleus

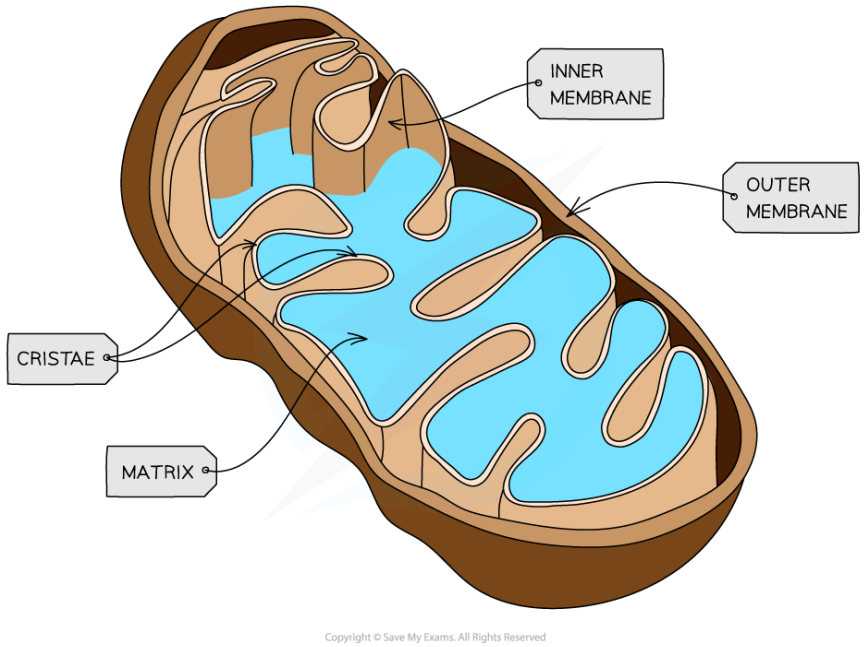


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The nucleus of a cell contains chromatin (a complex of DNA and histone proteins) which is the genetic material of the cell

- Present **in all eukaryotic cells** (except red blood cells), the nucleus is relatively large and separated from the cytoplasm by a double membrane (the **nuclear envelope)** which has many pores
- Nuclear pores are important channels for allowing mRNA and ribosomes to travel out of the nucleus, as well as allowing enzymes (eg. DNA polymerases) and signalling molecules to travel in
- The nucleus contains **chromatin** (the material from which chromosomes are made)
  - Chromosomes are made of sections of **linear DNA** tightly wound around proteins called **histones**
- Usually, at least one or more darkly stained regions can be observed – these regions are individually termed '**nucleolus**' (plural: nucleoli) and are the sites of **ribosome production**

Mitochondria



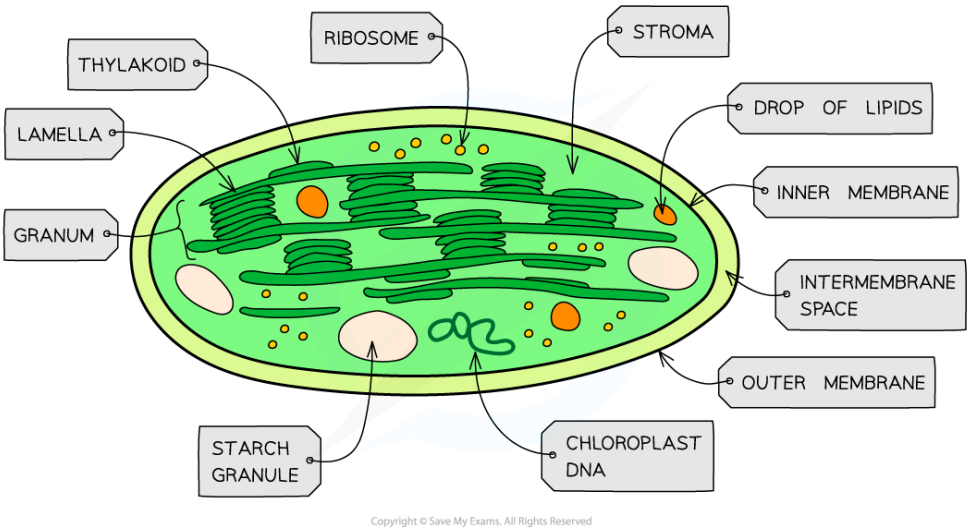
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A single mitochondrion is shown – the inner membrane has protein complexes vital for the later stages of aerobic respiration embedded within it

- The site of aerobic respiration within **all eukaryotic cells**, mitochondria are just visible with a light microscope
- Surrounded by double-membrane with the inner membrane folded to form **cristae**
- The matrix formed by the cristae contains enzymes needed for **aerobic respiration**, producing **ATP**
- Small circular pieces of **DNA** (mitochondrial DNA) and ribosomes are also found in the matrix (needed for replication)

Chloroplasts

Your notes



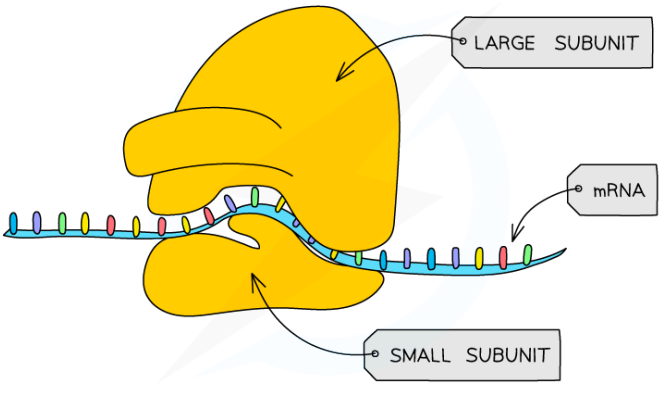
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Chloroplasts are found in the green parts of a plant – the green colour a result of the photosynthetic pigment chlorophyll

- Found in **plant cells**
- Larger than mitochondria, also surrounded by a **double-membrane**
- Membrane-bound compartments called **thylakoids** containing chlorophyll stack to form structures called **grana**
- Grana are joined together by **lamellae** (thin and flat thylakoid membranes)
- Chloroplasts are the site of **photosynthesis**:
  - The **light-dependent stage** takes place in the thylakoids
  - The **light-independent stage** (Calvin Cycle) takes place in the **stroma**
- Also contain small circular pieces of **DNA** and ribosomes used to synthesise proteins needed in chloroplast replication and photosynthesis

Ribosomes

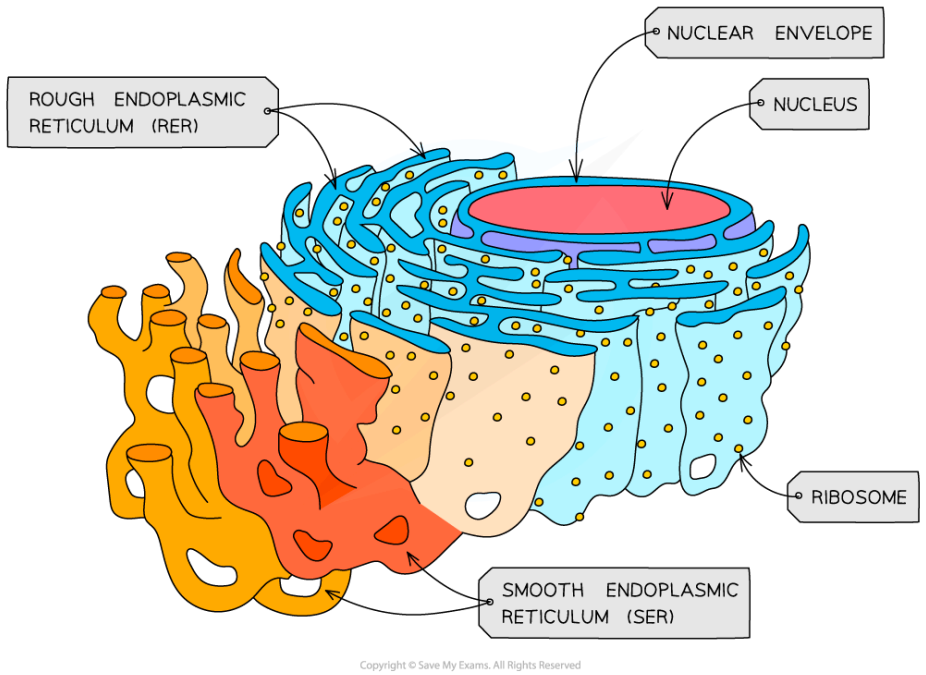


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Ribosomes are formed in the nucleolus and are composed of almost equal amounts of RNA and protein

- Found in **all cells**
- Found freely in the cytoplasm of all cells or as part of the **rough endoplasmic reticulum** in eukaryotic cells
- Each ribosome is a complex of **ribosomal RNA (rRNA)** and proteins
- 80S ribosomes (composed of 60S and 40S subunits) are found in eukaryotic cells
- 70S ribosomes (composed of 50S and 30S subunits) in prokaryotes, mitochondria and chloroplasts
- Site of translation (**protein synthesis)**

Endoplasmic reticulum



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The RER and ER are visible under the electron microscope – the presence or absence of ribosomes helps to distinguish between them

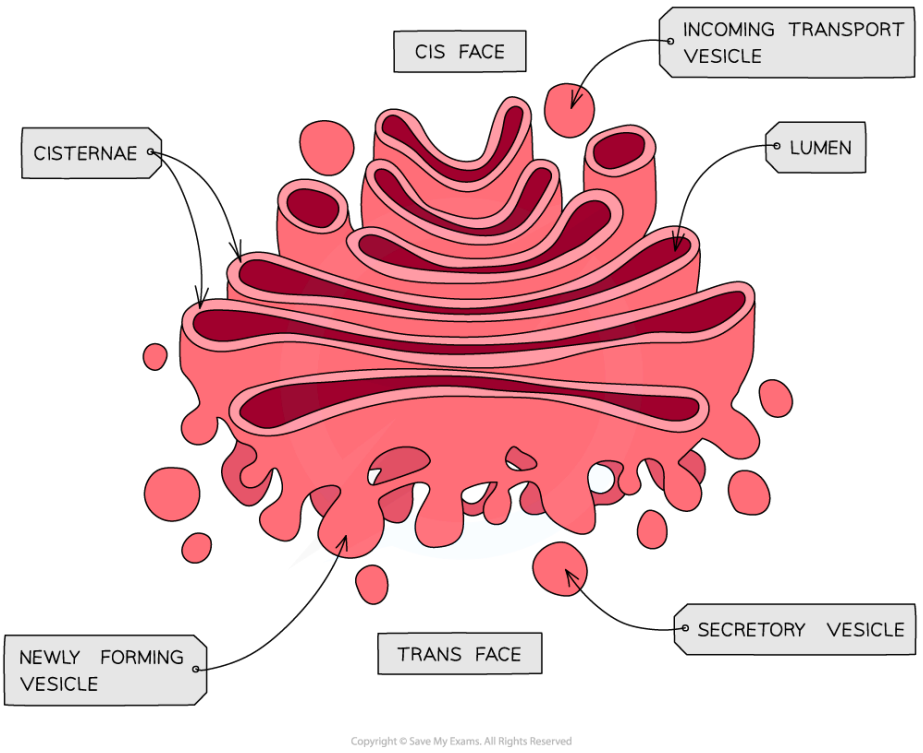
Rough Endoplasmic Reticulum (RER)

- Found in plant and animal cells
- Surface covered in **ribosomes**
- Formed from continuous folds of membrane continuous with the **nuclear envelope**
- Processes proteins made by the **ribosomes**

Smooth Endoplasmic Reticulum (ER)

Your notes

- Found in plant and animal cells
- Does not have ribosomes on the surface, its function is distinct to the RER
- Involved in the production, processing and storage of **lipids, carbohydrates** and **steroids**

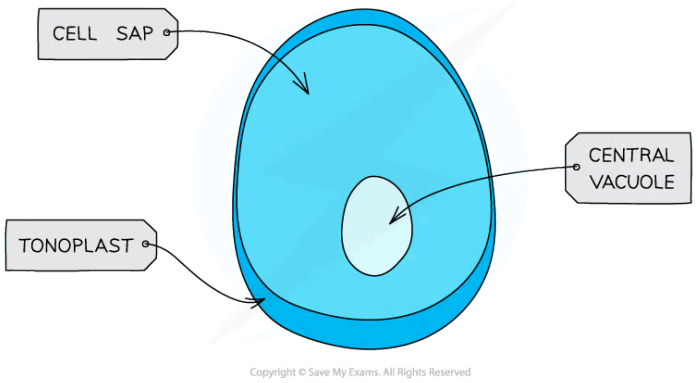


Golgi apparatus (golgi complex)

The structure of the Golgi apparatus

- Found in plant and animal cells
- Flattened sacs of membrane similar to the smooth endoplasmic reticulum
- **Modifies** proteins and lipids before **packaging** them into **Golgi vesicles**
  - The vesicles then **transport the proteins and lipids** to their required destination
  - Proteins that go through the Golgi apparatus are usually exported (e.g. hormones such as insulin), put into lysosomes (such as hydrolytic enzymes) or delivered to membrane-bound organelles

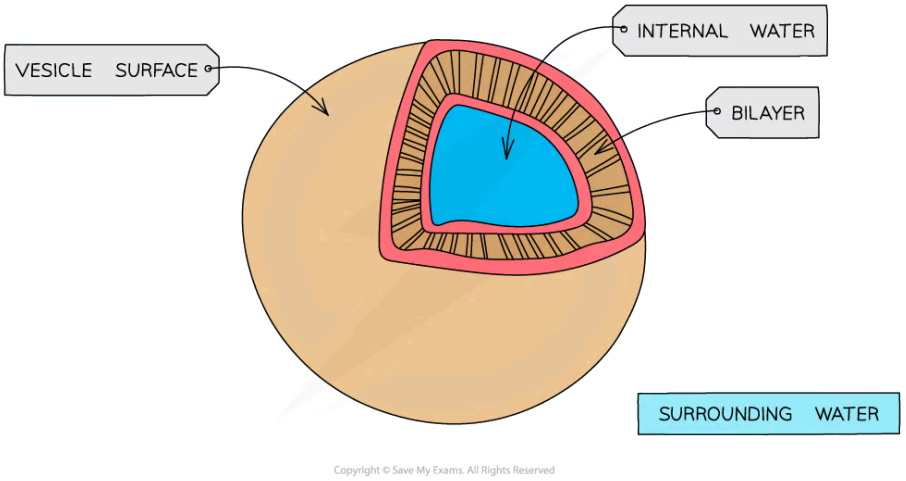
Large permanent vacuoles



The structure of the vacuole

- A sac in **plant cells** surrounded by the **tonoplast**, selectively permeable membrane
- Vacuoles in animal cells are not permanent and small

Vesicles

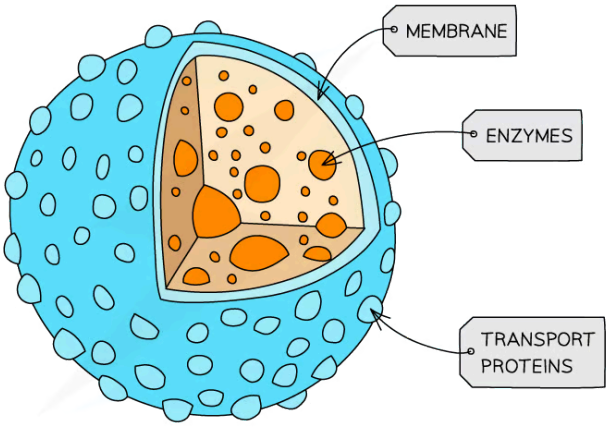


The structure of the vesicle

- Found in plant and animal cells
- A membrane-bound sac for transport and storage

Lysosomes

Your notes

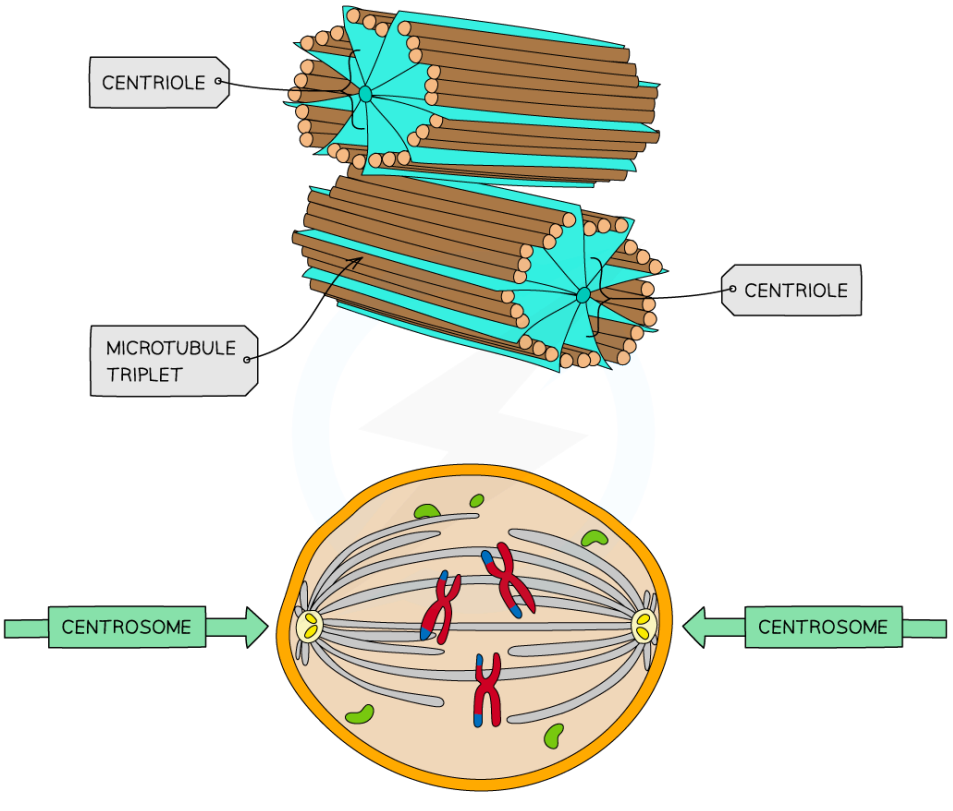


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The structure of the lysosome

- Specialist forms of vesicles which contain **hydrolytic enzymes** (enzymes that break biological molecules down)
- Break down waste materials such as worn-out organelles
- Used extensively by cells of the **immune system** and in **apoptosis** (programmed cell death)

Centrioles



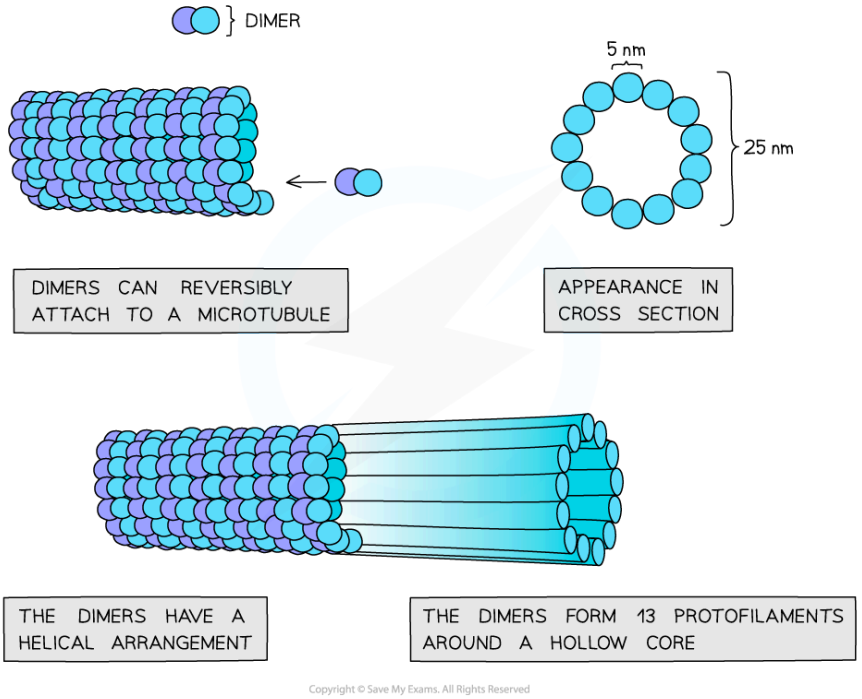
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Your notes

The structure of the centriole

- Hollow fibres made of **microtubules**
- Two centrioles at right angles to each other form a **centrosome**, which organises the **spindle fibres** during cell division
- Not found in flowering plants and fungi

Microtubules



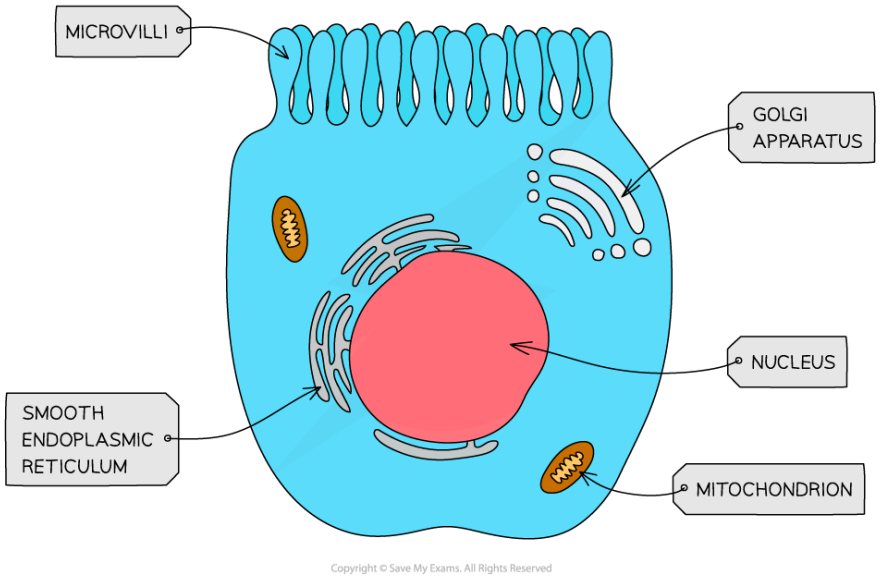
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The structure of the microtubule

- Found in all eukaryotic cells
- Makes up the cytoskeleton of the cell about 25 nm in diameter
- Made of α and β tubulin combined to form dimers, the dimers are then joined into protofilaments
  - Thirteen protofilaments in a cylinder make a microtubule
- The cytoskeleton is used to provide support and movement of the cell

Microvilli

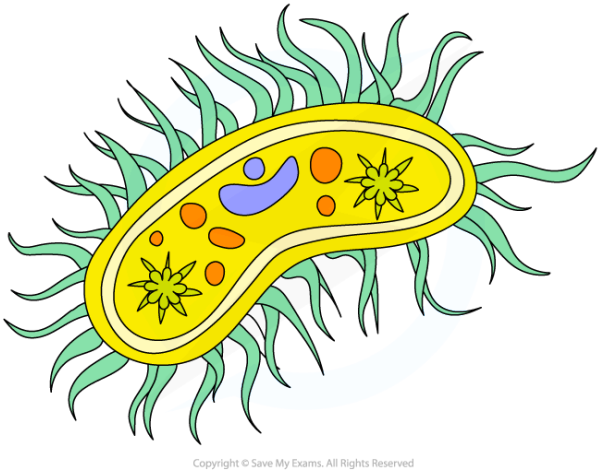
Your notes



The structure of the microvilli

- Found in specialised animal cells
- Cell membrane projections
- Used to **increase the surface area** of the cell surface membrane in order to increase the rate of exchange of substances

Cilia

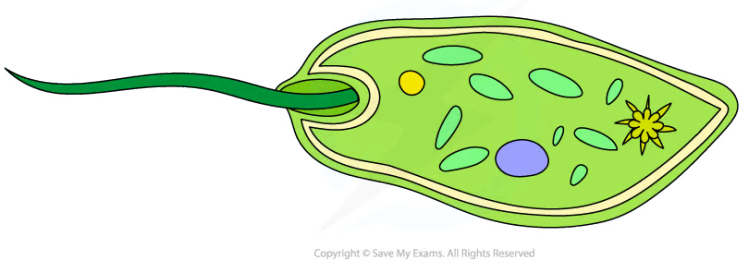


The structure of the cilia

- Hair-like projections made from **microtubules**
- Allows the movement of substances over the cell surface

Your notes

Flagella


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The structure of the flagella

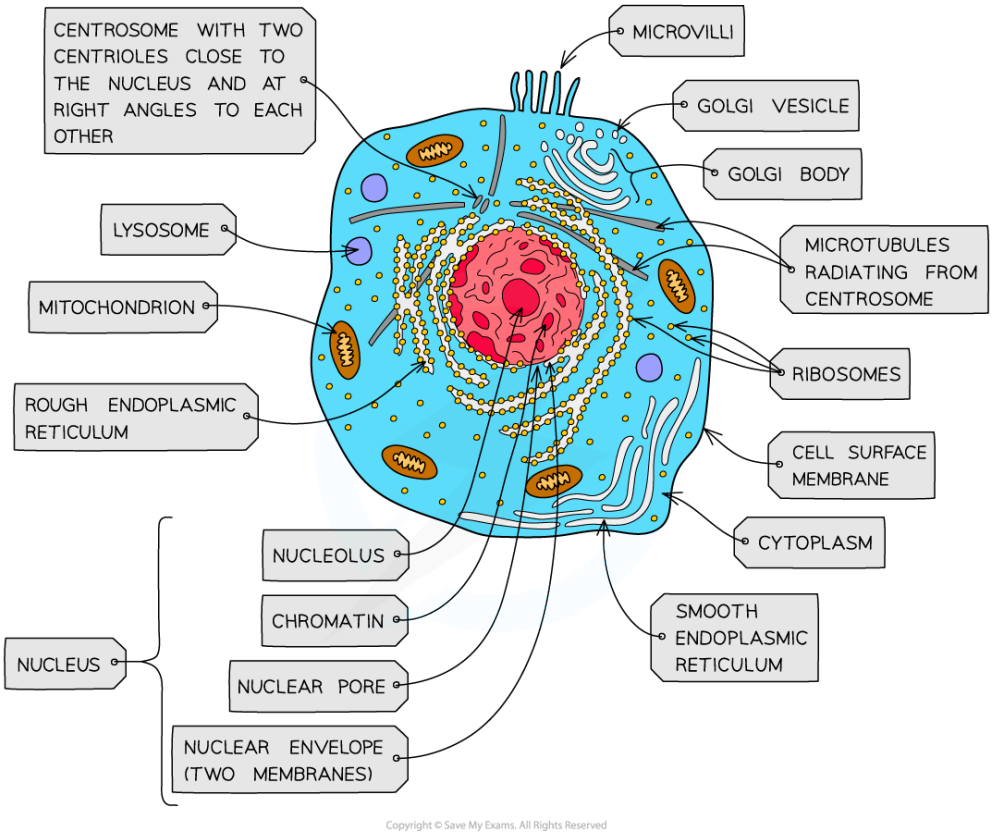
- Found in specialised cells
- Similar in structure to **cilia**, made of longer **microtubules**
- Contract to provide cell movement for example in **sperm cells**

Your notes

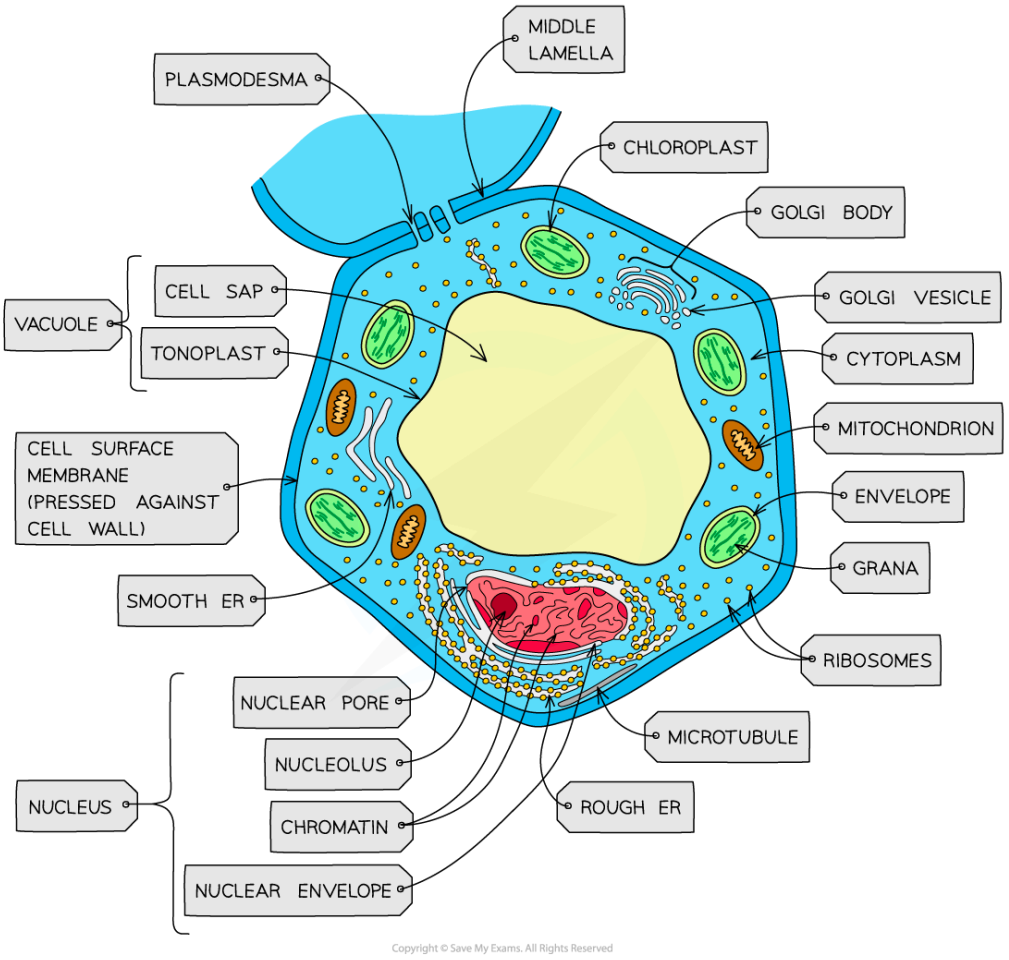
Your notes

Photomicrographs of Eukaryotic Cells

- There are some features or structures that can help to identify whether a cell shown in an image is a plant cell or animal cell
  - Structures found only in **animal** cells: **centrioles** and **microvilli**
  - Structures found only in **plant** cells: the **cellulose cell wall**, large permanent **vacuoles** and **chloroplasts**



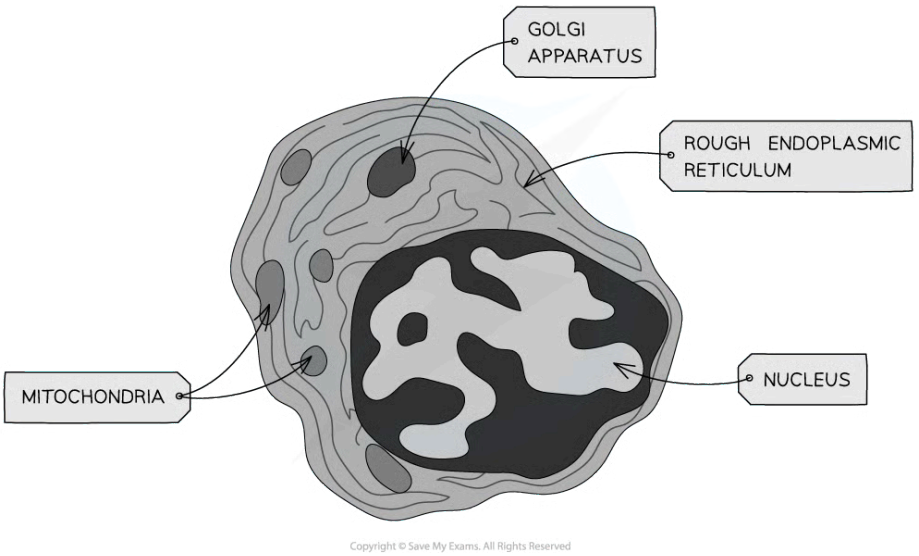
The ultrastructure of an animal cell shows a densely packed cell – the ER and RER and ribosomes form extensive networks throughout the cell in reality.



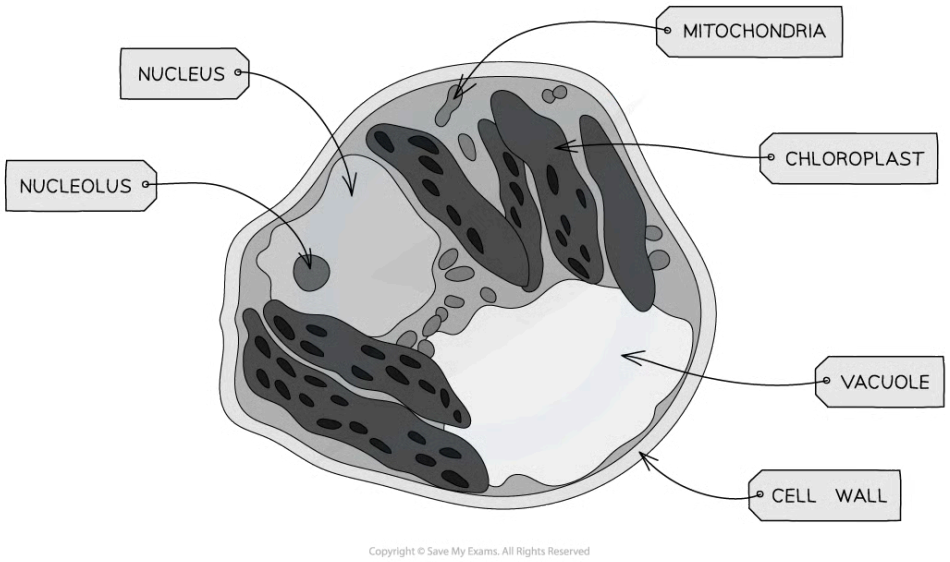
Plant cells have a larger, more regular structure in comparison to animal cells.

- Describing and interpreting photomicrographs, electron micrographs and drawings of typical animal/plant cells is an important skill
- The organelles and structures within cells have a characteristic shape and size which can be helpful when having to identify and label them in an exam

Your notes



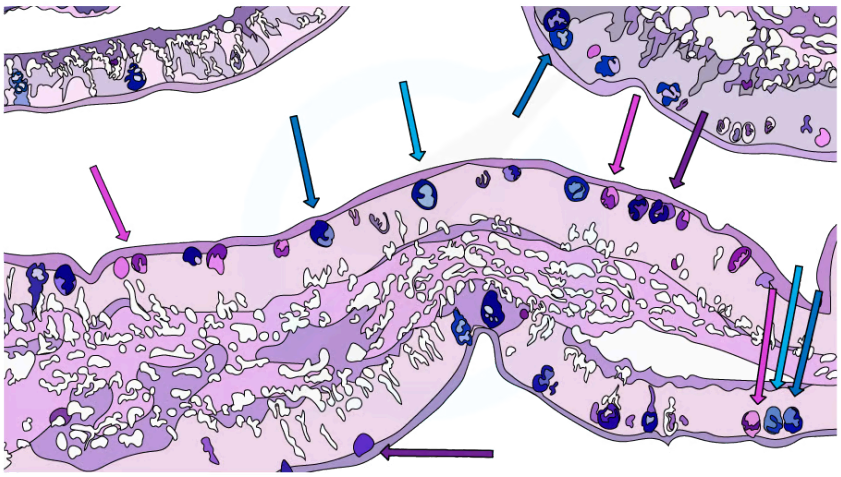
TEM electron micrograph of an animal cell showing key features. Notice the lack of a cell wall.



TEM electron micrograph of a plant cell showing key features. Notice the presence of a cell wall and vacuole.

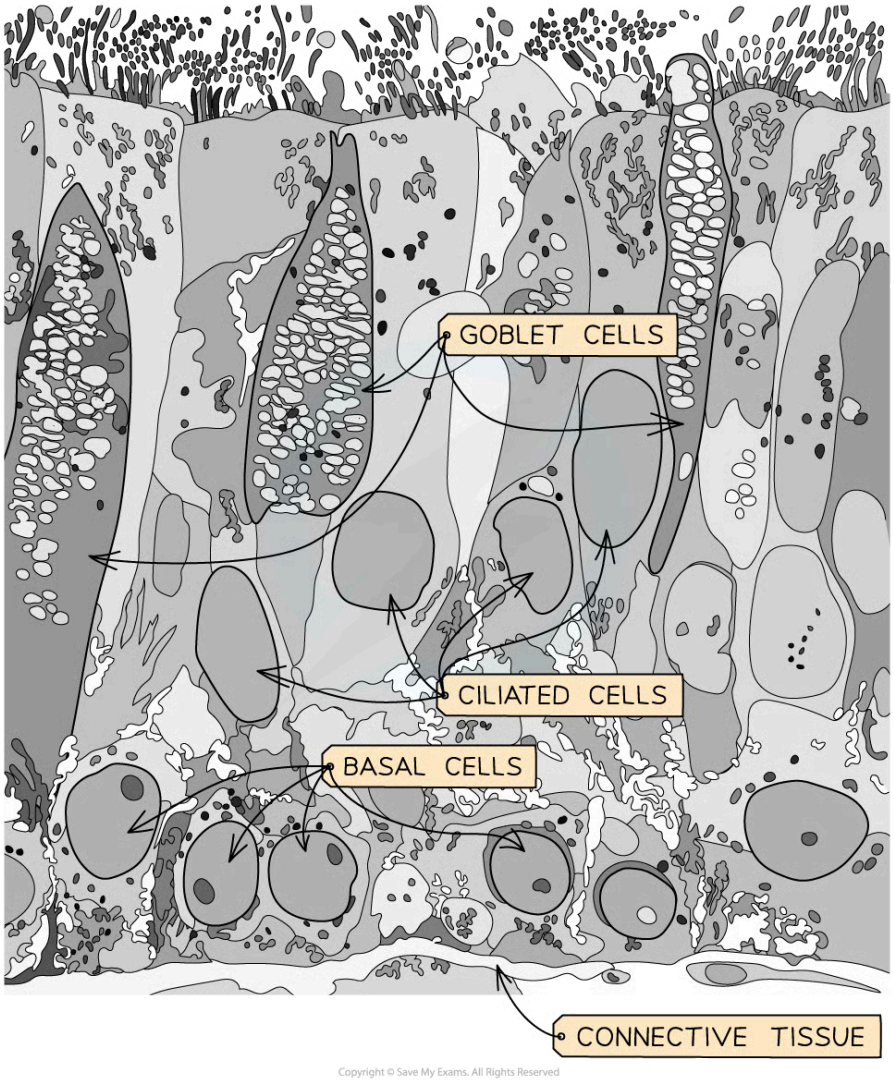
- More detailed structures can be seen and identified in electron micrographs compared to photomicrographs
- This is because electron microscopes have greater maximum magnification and resolution than light (optical) microscopes

Your notes



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Mucus producing goblet cells (found in the lining of trachea, bronchi and larger bronchioles) are shown in a photomicrograph



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Details of the structures inside the goblet cell can be seen in an electron micrograph

Your notes

Examiner Tips and Tricks

Make sure to learn the key identifying features of animal cells vs plant cells! It might also help to familiarise yourself with the shapes and sizes of important structures and organelles found in cells by finding some more photomicrographs and electron micrographs.

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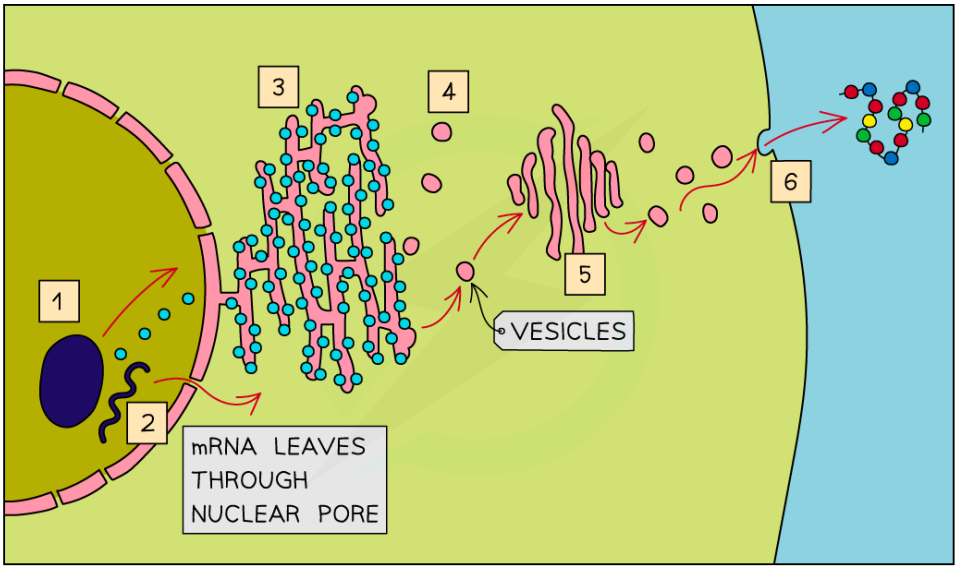
Your notes

Organelles & the production of proteins

- Inside cells multiple organelles are involved in the **production** and **secretion** of proteins
- Organelles involved in protein production, and their roles, include:
  - **nucleus**
    - **DNA** is stored
    - The **nucleolus** manufactures **ribosomes**
    - Transcription occurs, during which an **mRNA copy of DNA** is produced
  - **ribosomes**
    - mRNA leaves the nucleus and attaches to a ribosome
    - Translation occurs, during which a **chain of amino acids** is produced; this chain is known as a **polypeptide**
  - **rough endoplasmic reticulum** (**RER**)
    - Many ribosomes are attached to the surface of this organelle
    - After translation the polypeptides are **folded** and **processed** to produce **proteins**
  - **Golgi apparatus**
    - Proteins are **modified** and **prepared for secretion**
  - **vesicles**
    - Proteins are **transported** from the RER to the Golgi apparatus, and from the Golgi apparatus to the cell surface membrane inside vesicles
    - Vesicles fuse with the cell surface membrane to secrete proteins, e.g. hormones, from the cell by **exocytosis**
- Cells that produce many proteins, e.g. within hormone-producing glands, or in the enzyme-producing cells of the digestive system, will have many of the organelles that are involved with protein production

Organelles in protein production diagram

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1	THE **NUCLEOLUS** MANUFACTURES **RIBOSOMES** FOR PROTEIN SYNTHESIS IN THE **RER** (ROUGH ENDOPLASMIC RETICULUM)
2	THE **NUCLEUS** MANUFACTURES mRNA, WHICH IS NEEDED BY **RIBOSOMES** TO MAKE PROTEINS
3	THE **RIBOSOMES** IN THE **RER** MAKE PROTEINS
4	THE **RER** PROCESSES THE PROTEINS WHICH ARE THEN SENT IN VESICLES TO THE GOLGI BODY
5	THE **GOLGI BODY** FURTHER PROCESSES THE PROTEINS AND SENDS THEM IN VESICLES TO THE **PLASMA MEMBRANE**
6	THE VESICLES FUSE WITH THE **PLASMA MEMBRANE** TO SECRETE THE FINISHED PROTEIN PRODUCT

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Multiple cellular structures are involved in the production and secretion of proteins

Your notes

Your notes

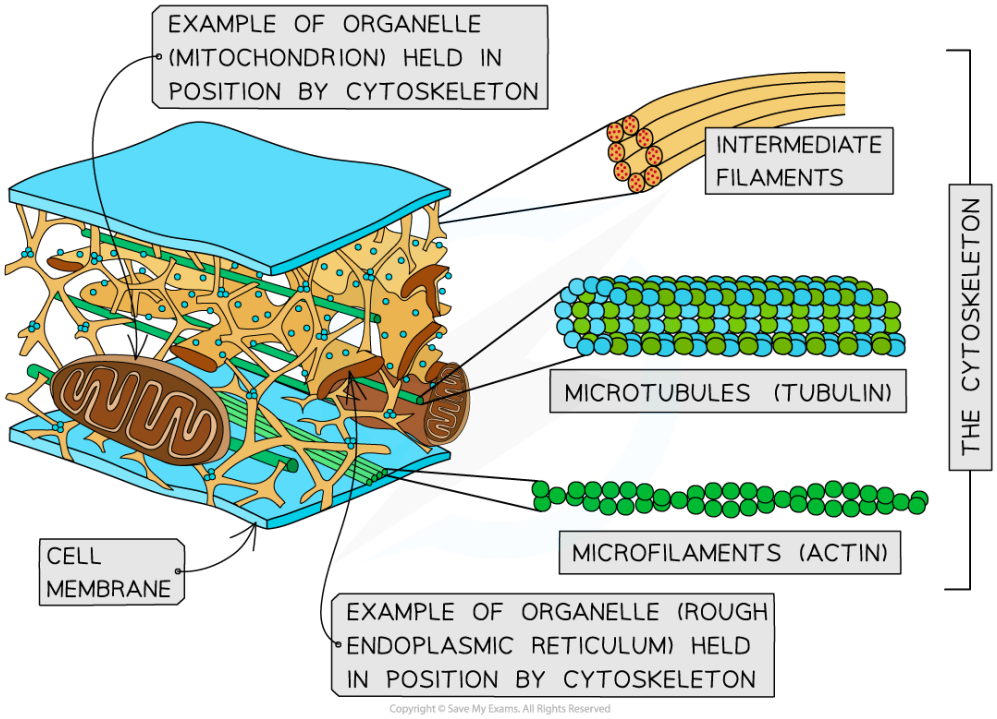
The Cytoskeleton

- Within the **cytoplasm** of cells, there is an extensive **network** of **protein fibres**
  - This is known as the **cytoskeleton**
- The cytoskeleton is made up of **two** main types of protein fibres: **microfilaments** and **microtubules**
  - Microfilaments are **solid strands** that are mostly made of the protein **actin**. These fibres can cause some **cell movement** and the movement of some **organelles** within cells by **moving against each other**
  - Microtubules are **tubular (hollow) strands** that are mostly made of the protein **tubulin**. Organelles and other cell contents are moved along these fibres using **ATP** to drive this movement
- Intermediate filaments (a third type of fibre) are also found within the cytoskeleton

The importance of the cytoskeleton

- The cytoskeleton is **important** as it has several different **functions**, including:
- Strengthening and support:
  - The cytoskeleton provides the cell with **mechanical strength**, forming a kind of '**scaffolding**' that helps to maintain the **shape** of the cell
  - It also supports the organelles, keeping them in **position**
- Intracellular (within cell) movement:
  - The cytoskeleton aids **transport** within cells by forming 'tracks' along which **organelles** can **move**
  - Examples of this include the movement of vesicles and the movement of chromosomes to opposite ends of a cell during cell division
- Cellular movement:
  - The cytoskeleton enables **cell movement** via **cilia** and **flagella**
  - These structures are both hair-like extensions that protrude from the cell surface and contain **microtubules** that are responsible for moving them

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The cytoskeleton provides mechanical strength to cells, aids transport within cells and enables cell movement

Examiner Tips and Tricks

For the exam, you only need to be aware of the two main types of protein fibres within the cytoskeleton: microfilaments and microtubules. The third type (intermediate filaments) are shown here to give extra detail on the composition of the cytoskeleton.

Your notes

Your notes

Comparison of Prokaryotic & Eukaryotic Cells

- Animal and plant cells are types of **eukaryotic** cells, whereas bacteria are a type of **prokaryote**
- Prokaryotic cells are much **smaller** than eukaryotic cells (between 100 - 1000 times smaller)
- Prokaryotic cells also differ from eukaryotic cells in having:
  - A **cytoplasm** that **lacks membrane-bound organelles**
  - Their **ribosomes** are structurally smaller (70 S) in comparison to those found in eukaryotic cells (80 S)
  - **No nucleus** (instead they have a **single circular DNA molecule** that is free in the cytoplasm and is **not associated with proteins**)
  - A cell wall that contains **murein** (a glycoprotein)
- In addition, many prokaryotic cells have a few other structures that differentiate them from others and act as a selective advantage, examples of these are:
  - Plasmids
  - Capsules
  - Flagellum
- Plasmids are small **loops of DNA** that are separate from the main circular DNA molecule
  - Plasmids contain **genes** that can be passed between prokaryotes (e.g. genes for **antibiotic resistance**)
- Some prokaryotes (e.g. bacteria) are surrounded by a final outer layer known as a **capsule**. This is sometimes called the **slime** capsule
  - It helps to **protect bacteria** from drying out and from attack by cells of the immune system of the host organism
- Flagellum (plural = flagella) are **long, tail-like structure** that **rotate**, enabling the prokaryote to **move** (a bit like a propeller)
  - Some prokaryotes have **more than one**

Structures unique to prokaryotic cells

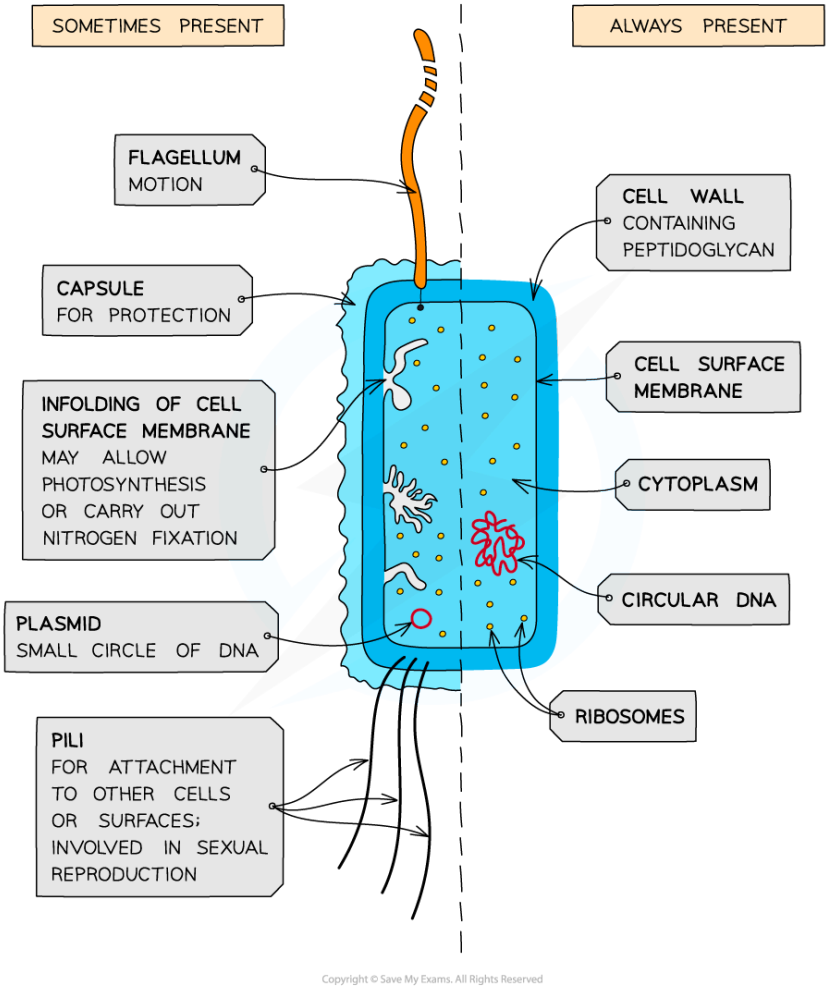
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Prokaryotic cell structure	Purpose of structure
Plasmids	Small **loops of DNA** that are separate from the main circular DNA molecule. Plasmids contain **genes** that can be passed between prokaryotes (e.g. genes for **antibiotic resistance**). Not present in all prokaryotes.
Capsule	Some prokaryotes (e.g. bacteria) are surrounded by a final outer layer known as a **capsule**. This is sometimes called the **slime** capsule. It helps to **protect bacteria** from drying out and from attack by cells of the immune system of the host organism. Not present in all prokaryotes.
Flagellum (plural = flagella)	A **long, hair-like structure** that **rotates**, enabling the prokaryote to **move** (a bit like a propeller). Some prokaryotes have **more than one**. Not present in all prokaryotes.

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Your notes



Your notes

Prokaryotic cells are often described as being 'simpler' than eukaryotic cells, and they are believed to have emerged as the first living organisms on Earth.

- There are a number of important structural and physiological differences between prokaryotic and eukaryotic cells
  - These differences affect their metabolic processes and how they reproduce

Prokaryotic & Eukaryotic Cells Comparison Table

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FEATURE	PROKARYOTES	EUKARYOTES
SIZE	0.5–5 μm DIAMETER	UP TO 100 μm DIAMETER
GENOME	DNA CIRCULAR WITH NO PROTEINS, IN THE CYTOPLASM	DNA IS ASSOCIATED WITH HISTONES (PROTEINS) FORMED INTO CHROMOSOMES
CELL DIVISION	OCCURS BY BINARY FISSION, NO SPINDLE INVOLVED	OCCURS BY MITOSIS OR MEIOSIS AND INVOLVES A SPINDLE TO SEPARATE CHROMOSOMES
RIBOSOMES	70S RIBOSOMES	80S RIBOSOMES
ORGANELLES	VERY FEW NO MEMBRANE–BOUND ORGANELLES.	NUMEROUS TYPES OF ORGANELLES MEMBRANE–BOUND SINGLE MEMBRANES: LYSOSOMES, GOLGI COMPLEX, VACUOLES DOUBLE MEMBRANES: NUCLEUS, MITOCHONDRIA, CHLOROPLAST NO MEMBRANE: RIBOSOMES, CENTRIOLES, MICROTUBULES
CELL WALL	MADE OF PEPTIDOGLYCAN (POLYSACCHARIDE AND AMINO ACIDS) AND MUREIN	PRESENT IN PLANTS (MADE OF CELLULOSE OR LIGNIN) AND FUNGI (MADE OF CHITIN, SIMILAR TO CELLULOSE BUT CONTAINS NITROGEN)

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Your notes

Examiner Tips and Tricks

You will need to know all the **differences** between prokaryotic and eukaryotic cells. Remember - the features in the table above are not present in all prokaryotes so keep this in mind when answering exam questions. Also, **size is not a structural feature** so if you are asked for a structural difference between a prokaryotic and eukaryotic cell don't include size in your answer.