SL IB Biology

Your notes

Cell Structure

Contents

Cell Theory

Your notes

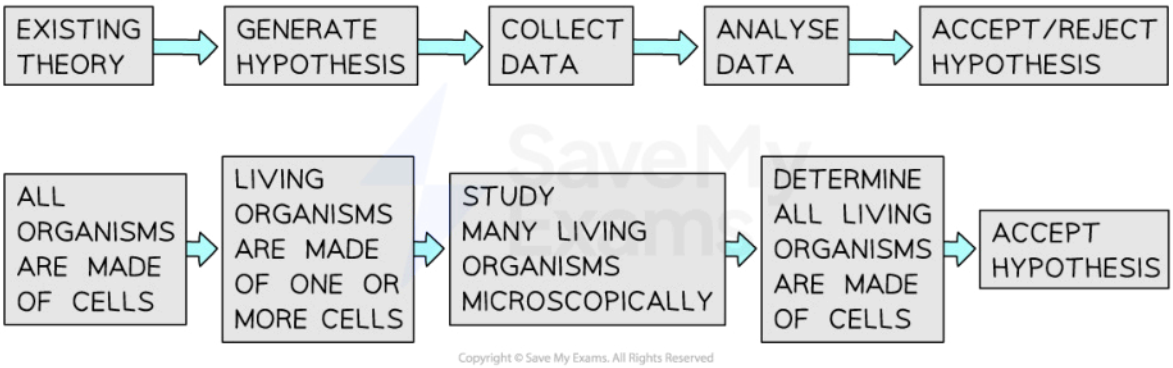
Cell Theory

- Cells are the **basic structural unit of all living organisms**
- Until microscopes became powerful enough to view individual cells, no-one knew for certain what living organisms were made from
- A scientist called **Robert Hooke** came up with the term "cells" in the 1660's after examining the structure of cork
- Matthias **Schleiden** and Theodor **Schwann** were two scientists who studied animal and plant cells
  - In 1837, they came up with the idea that **all living organisms are made of cells**
  - This idea is known as **'cell theory'**
  - The cell theory is a **unifying concept** in biology (meaning it is **universally accepted**)
- The cell theory includes three main ideas:
  1. **All living organisms** are made up of **one or more cells**
  2. Cells are the **basic functional unit** (i.e. the basic unit of structure and organisation) in living organisms
  3. **New cells** are produced from **pre-existing cells**
- Although cells vary in size and shape they all
  - Are surrounded by a **membrane**
  - Contain **genetic material**
  - Have **chemical reactions** occurring within the cell that are catalysed by **enzymes**

NOS: Deductive reasoning can be used to generate predictions from theories. Based on cell theory, a newly discovered organism can be predicted to consist of one or more cells.

- **Deductive** reasoning is an approach where one progresses from **general ideas** to **hypothesis testing** to **specific conclusions**
  - This is in contrast with **inductive** reasoning where one starts with **specific observations** and then **develops theories**
- **Cytology,** the branch of biology which focuses on cell theory, can be used to demonstrate deductive reasoning
  - Cell **theory** states that all living organisms are made of at least one cell
  - We can **hypothesise** that any newly discovered living organisms on Earth will also be made up of at least one cell
  - We can **observe** living organisms to **test this hypothesis**

Deductive reasoning flow diagram



Deductive reasoning can be used to develop specific hypothesis from existing theories

Your notes

Cell Theory: Skills

Your notes

Skills in Microscopy

- Many biological structures are too small to be seen by the naked eye
- Optical (light) 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 (light) 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 (light) microscope are:

- The eyepiece lens
- The objective lenses
- The stage
- The light source
- The coarse and fine focus
- Other tools that may be used:
  - Forceps
  - Scissors
  - Scalpel
  - Coverslip
  - Slides
  - Pipette

A diagram of an optical microscope

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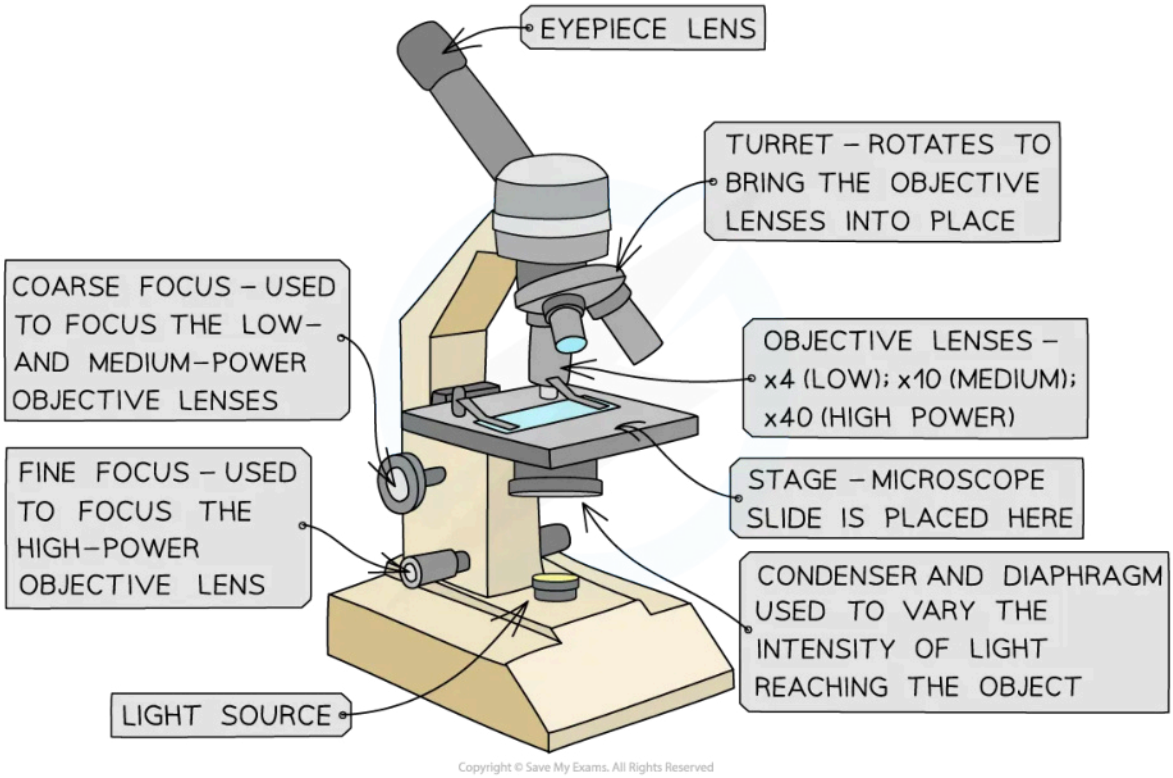


Image showing all the components of an optical (light) microscope

Method

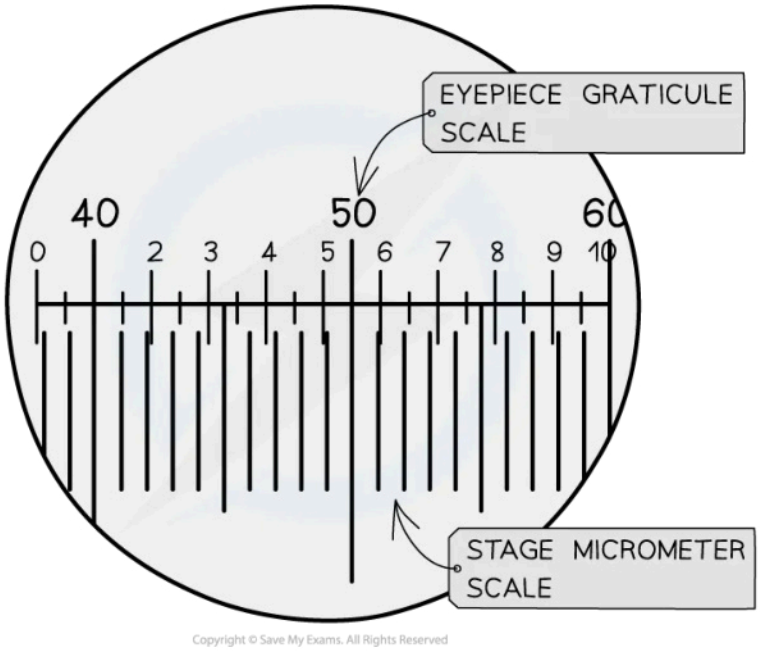
- Preparing a **temporary mount** slide using a **liquid specimen**:
  - Add a few drops of the sample to the slide using a pipette
  - Cover the liquid/smear with a coverslip and gently press down to **remove air bubbles**
  - **Wear gloves** to ensure there is no cross-contamination of foreign cells
- Preparing a **temporary mount** slide using a **solid specimen**:
  - 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)
  - Some tissue samples need be treated with chemicals to kill / make the tissue rigid
  - A **stain** may be required to make the structures visible depending on the type of tissue being examined
  - Gently place a coverslip on top and press down to remove any air bubbles
  - Take care when using sharp objects and wear gloves to prevent the stain from dying your skin
- Place the microscope slide on the **stage**, fix in place using the stage clips (ensure the microscope is plugged in and on)
- 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 incase the stage has been raised too high

- Whilst looking through the **eyepiece lens** move the **coarse focusing knob** until the specimen comes into **focus**. The **fine focusing knob** should be used to sharpen the focus on particular parts (and at higher objective lens only)
- To examine the whole slide, move it carefully with your hands (or if using a binocular microscope use the stage adjusting knobs)
- **Once** you have **focused** on the object/structure then carefully **move** to a **higher objective lens** (10X and 40X). If resistance is felt do not continue to move the turret
  - At the **higher objective** powers **only** use the **fine focusing knob**
  - **Do not move** the **stage down** when moving to higher objective lens
- 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
- Use a **calibrated graticule** to take measurements of cells
  - A **graticule** is a small disc that has an engraved **scale.** 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
  - The measurements made using these microscope apparatus are a form of **quantitative** observations

Diagram of an eyepiece graticule and stage micrometer


Your notes

Your notes

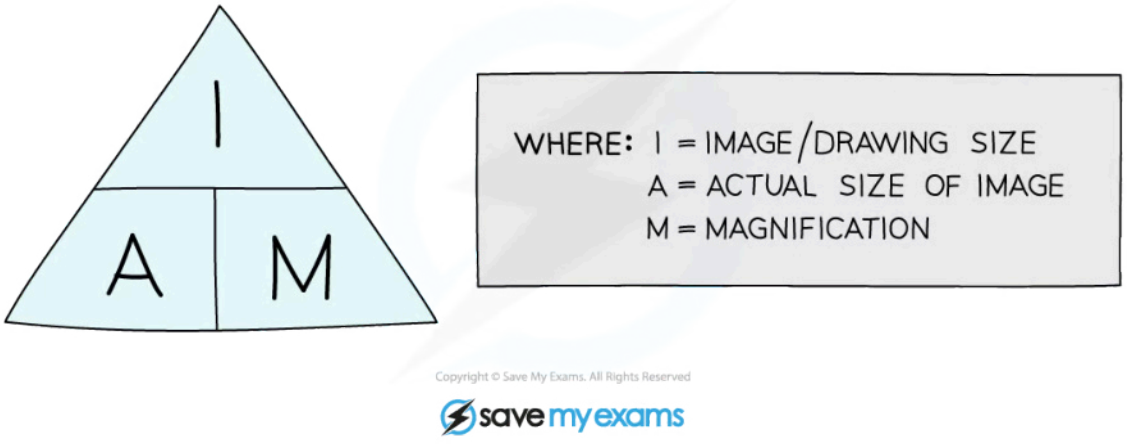


The stage micrometer scale is used to find out how many micrometers each graticule unit represents

Magnification calculations

- **Magnification** is **how many times bigger** the image of a specimen observed is in comparison to the actual (real-life) size of the specimen
- The **magnification** (*M*) of an object can be calculated if both the size of the image (*I*), and the actual size of the specimen (*A*), is known

The magnification equation triangle



An equation triangle for calculating magnification

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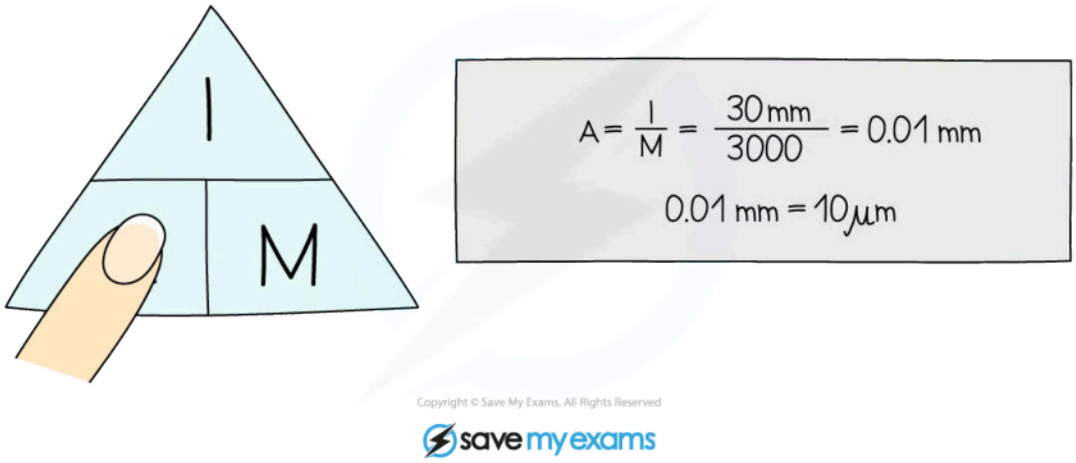
Worked example

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

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

Answer:

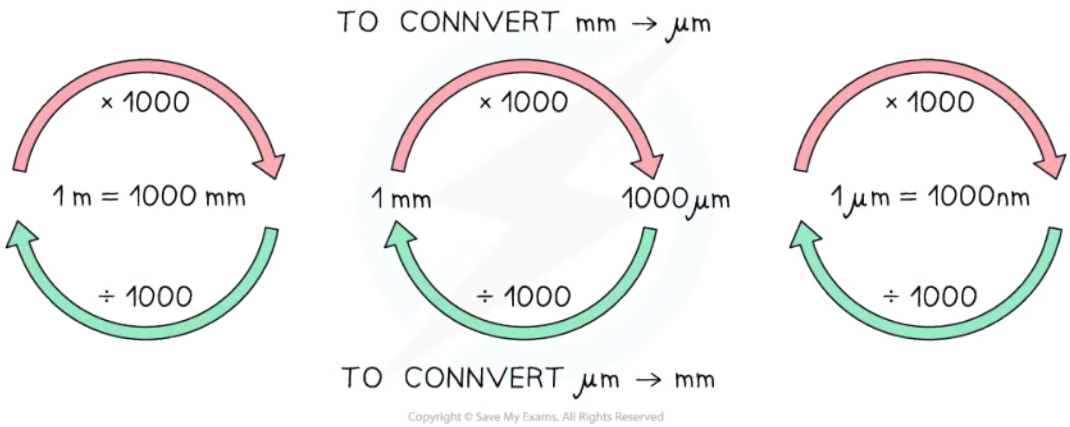
To find the **actual** size of the cell:



Using the appropriate units

- The size of cells is typically measured using the **micrometer** (μm) scale, with cellular structures measured in either **micrometers** (μm) or **nanometers** (nm)
- When doing calculations all measurements must be in the **same units**. It is best to use the **smallest unit** of measurement shown in the question
- To convert units, multiply or divide depending if the units are **increasing or decreasing**
- Magnification does **not** have units

Diagram to show conversion of units



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- There are 1000 nanometers (nm) in a micrometre (μm)
- There are 1000 micrometres (μm) in a millimetre (mm)
- There are 1000 millimetres (mm) in a metre (m)

Producing a scale bar

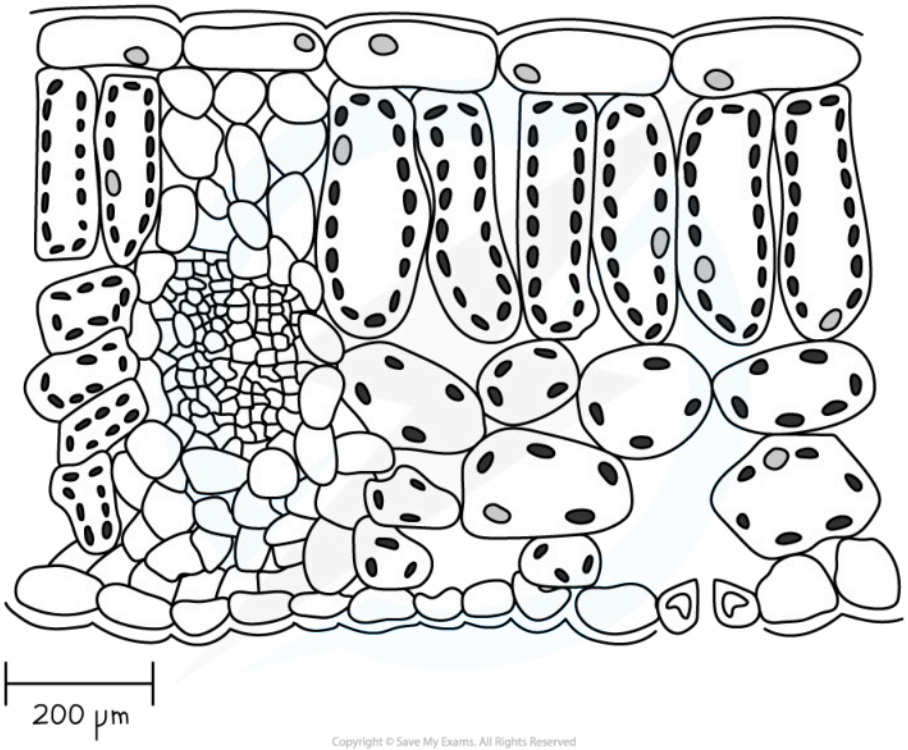
- A scale bar is a straight line on the drawing or micrograph that represents the actual size before the image was enlarged
- It can be used to calculate magnification from biological drawings and images
- To add a scale bar to a biological drawing of a microscope specimen:
  1. Use the eyepiece graticule and stage micrometer to calculate the distance between two markings on the eyepiece graticule; this is the graticule unit
  2. Remove the stage micrometer and add the specimen to the microscope stage
  3. Measure the length of the specimen using the eyepiece graticule which will be in graticule units
  4. Determine the length of the specimen in micrometers by multiplying the number of graticule units by the length of each unit (calculated in step 1)
- Your scale bar should represent 20% of the actual length of your specimen. If you specimen is 300μm then your scale bar would represent 60μm
  1. Draw your specimen as directed and measure the length of your drawing in mm; your scale bar should be 20% of the length of your specimen drawing; if your drawing is 150mm then your scale bar should be 30mm long
  2. Add the actual length your scale bar represents underneath your scale bar e.g. 60μm

Using a scale bar

- If the calculation required includes a scale bar on the micrograph or drawing then follow these steps:
  1. Use a ruler to measure the length of the scale bar in millimetres (mm)
  2. Convert this measurement into the same units as the number on the scale bar
  3. Insert these numbers into the magnification formula above (note: the size of the image is the measured length of the scale bar and the actual size is the number on the scale bar)

Worked example

Calculate the magnification of the transverse section of the leaf blade.



Transverse section of the leaf blade

Answer:

Step 1: Use a ruler to measure the length of the scale bar in millimetres

Using a ruler the length of the scale bar is equal to 20 mm

Step 2: Convert this measurement into the same units as the number on the scale bar

The units on the scale bar are µm, remember that 1mm = 1000 µm

therefore 20 mm = 20 x 1000 = 20 000 µm

Step 3: Insert these numbers into the magnification formula

$$\text{Magnification} = \frac{\text{measured length of scale bar}}{\text{scale bar label}}$$

Your notes

Note: the size of the image is the measured length of the scale bar and the actual size is the number on the scale bar

$$\text{Magnification} = \frac{20\,000\mu m}{200\mu m}$$

therefore Magnification = x 100

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Examiner Tip

Before doing any calculations make sure that all the measurements have the same units. When doing the calculations it is easier to write the formula, then rearrange it, before you add any measurements, as this helps avoid any possible errors. Note that when you do calculations using a scale bar, the number on the scale bar is informing you how many mm/µm or nm the line actually represents (e.g. if the scale bar has 20 nm above it and the line is 10 mm, then every 10 mm on the diagram is **actually** 20 nm).

NOS: Measurement using instruments is a form of quantitative observation

- Microscopy can give us accurate **quantitative observations** about cells
  - Quantitative observations are a collection of data which are focused on **numbers** and **values** such as measurements of length, height, volume, or values of quantity and frequency
- Using instruments such as eyepiece graticules and stage micrometers allow us to take **measurements** on a small scale such as in micrometers (µm) and nanometers (nm) (using electron microscopes)
  - Data can be collected about cell and organelle sizes
- **Qualitative data** is non-numerical data such as colour and presence of structures which can also be determined using microscopes
- Making observations and taking measurements form the basis for developing **new hypotheses** in Biology

Microscopes

Your notes

Microscopy: Developments

- **Microscopes** can be used to analyse **cell components** and observe **organelles**
- **Magnification** and **resolution** are two scientific terms that are very important to understand and **distinguish** between when answering questions about microscopy (the use of microscopes):
  - **Magnification** tells you how many times bigger the **image** produced by the microscope is than the **real-life object** you are viewing
  - **Resolution** is the ability to **distinguish between objects** that are close together (i.e. the ability to see two structures that are very close together as two separate structures)
- There are two main types of microscopes:
  - **Optical** microscopes (sometimes known as light microscopes)
  - **Electron** microscopes

Optical (light) microscopes

- Optical microscopes use **light** to form an image
- This **limits the resolution** of optical microscopes
  - Using light, it is impossible to resolve (distinguish between) two objects that are closer than half the wavelength of light
  - The wavelength of visible light is between 500–650 nanometres (nm), so an optical microscope cannot be used to distinguish between objects closer than half of this value
- This means optical microscopes have a **maximum resolution of around 0.2 micrometres (µm) or 200 nm**
  - Optical microscopes **can be used** to observe **eukaryotic cells**, their **nuclei** and possibly mitochondria and chloroplasts
  - They **cannot be used** to observe **smaller organelles** such as **ribosomes**, the **endoplasmic reticulum** or **lysosomes**
- The **maximum useful magnification** of optical microscopes is about **×1500**

Electron microscopes

- Electron microscopes use **electrons** to form an image
- This **greatly increases the resolution** of electron microscopes compared to optical microscopes, giving a **more detailed image**
  - A beam of electrons has a much smaller wavelength than light, so an electron microscope can resolve (distinguish between) two objects that are extremely close together
- This means electron microscopes have a **maximum resolution of around 0.0002 µm or 0.2 nm** (i.e. around 1000 times greater than that of optical microscopes)
  - This means electron microscopes can be used to observe **small organelles** such as **ribosomes**, the **endoplasmic reticulum** or **lysosomes**
- The **maximum useful magnification** of electron microscopes is about **×1,500,000**

- There are two types of electron microscopes:
  - **Transmission** electron microscopes (TEMs)
  - **Scanning** electron microscopes (SEMs)


Your notes

Transmission electron microscopes (TEMs)

- TEMs use electromagnets to focus a **beam of electrons**
- This beam of electrons is **transmitted through** the specimen
- Denser parts of the specimen absorb more electrons
  - This makes these denser parts appear darker on the final image produced (produces contrast between different parts of the object being observed)
- **Advantages** of TEMs:
  - They give **high-resolution** images (more detail)
  - This allows the **internal structures** within cells (or even within organelles) to be seen
- **Disadvantages** of TEMs:
  - They can only be used with **very thin specimens** or **thin sections** of the object being observed
  - They **cannot be used to observe live specimens**
    - As there is a vacuum inside a TEM, all the water must be removed from the specimen and so living cells cannot be observed, meaning that specimens must be dead. Optical microscopes can be used to observe live specimens
  - The **lengthy treatment required to prepare specimens** means that **artefacts can be introduced**
    - Artefacts look like real structures but are actually the results of preserving and staining
  - They **do not produce a colour image**
    - Unlike optical microscopes that produce a colour image

Scanning electron microscopes (SEMs)

- SEMs scan a beam of electrons across the specimen
- This beam **bounces off the surface of the specimen** and the electrons are detected, forming an image
  - This means SEMs can produce **three-dimensional images** that show the **surface** of specimens
- **Advantages** of SEMs:
  - They can be used on **thick** or **3-D** specimens
  - They allow the **external**, **3-D structure** of specimens to be observed
- **Disadvantages** of SEMs:
  - They give **lower resolution** images (less detail) than TEMs
  - They **cannot be used to observe live specimens**
  - They **do not produce a colour image**

Comparison of the electron microscope & light microscope

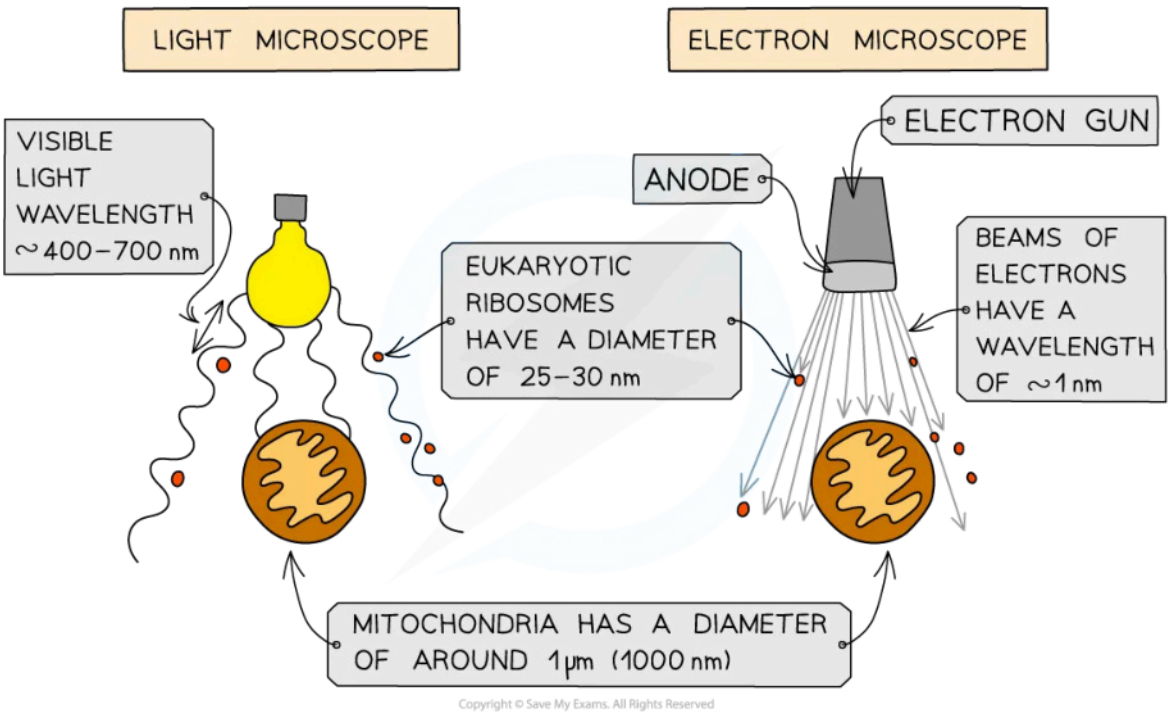
- **Light microscopes** are used for specimens **above 200 nm**
  - Light microscopes shine **light** through the specimen, this light is then passed through an **objective lens** (which can be changed) and an **eyepiece lens** (x10) which magnify the specimen to give an image that can be seen by the naked eye
  - The specimens can be **living** (and therefore can be moving), **or dead**

Your notes

- Light microscopes are useful for looking at **whole cells**, small plant and animal **organisms**, **tissues within organs** such as in leaves or skin

- **Electron microscopes**, both scanning and transmission, are used for specimens **above 0.5 nm**
  - Electron microscopes fire a **beam of electrons** at the specimen either a broad static beam (transmission) or a small beam that moves across the specimen (scanning)
  - Due to the **higher frequency of electron waves** (a much shorter wavelength) compared to visible light, the magnification and resolution of an electron microscope is much higher than a light microscope
  - Electron microscopes are useful for looking at **organelles, viruses** and **DNA** as well as looking at whole cells in more detail
  - Electron microscopy requires the specimen to be **dead** however this can provide a **snapshot** in time of what is occurring in a cell e.g. DNA can be seen replicating and chromosome position within the stages of mitosis are visible

Diagram of the comparison of resolution of microscopes



The resolving power of an electron microscope is much greater than that of the light microscope, as structures much smaller than the wavelength of light will interfere with a beam of electrons

Light Microscope vs Electron Microscope Table

Electron Microscope	Light Microscope

Large and installation means it cannot be moved	Small and easy to carry
Vacuum needed	No vacuum needed
Complicated sample preparation	Simple sample preparation
Over x500000 magnification	Up to x2000 magnification
Resolution 0.5nm	Resolution 200nm
Specimens need to be dead	Specimens can be living or dead


Your notes

Examiner Tip

Learn the difference between resolution and magnification! Also, learn how the light and electron microscope differ in terms of resolution and magnification.

Microscopy: Developments


Your notes

- The microscope has undergone many developments since the first one used in the 1600s by Robert Hooke
- Every advancement in microscopy technologies has improved our understanding of cells and their structures

Optical (light) microscopes

- **Optical (light) microscopes** have made advancements in their ability to to **view living cells** and their **internal structures**
- **Condenser** lenses have been developed to direct light from the light source through the specimen
  - Light rays pass from the specimen through the objective lens to the eyepiece
  - Different types of condensers give different features to the microscope
- The use of **fluorescent stains** and **immunofluorescence** can be used in optical microscopes which have made it possible to view cellular structures such as RNA
  - **Fluorescent dyes** and stains are used to combine with specific cell structures and organelles which, when exposed to UV rays, gives a more detailed view of the specimen
  - **Immunofluorescence** involves the use of **antibodies** that have been prepared with fluorescent dyes which can bind with target molecules complimentary to the antibody. This allows specific molecules to be detected such as virus proteins

Electron microscopes

- Electron microscopes bring us many **advantages** to studying cells
  - **High magnification and resolution** meaning that great detail can be seen in a range of cells and structures within cells, and including viruses
  - **3D images** can be produced using a scanning electron microscope
- **Electron microscopes** have also undergone developments in their abilities
  - **Cryogenic electron microscopy**
    - This involves flash-freezing solutions containing proteins or other biological molecules
    - The frozen solution is then exposed to electrons to produce images of individual molecules
    - Computer software is used to reconstruct a **3D representation of a cell's proteins** using the images of individual molecules
    - Our understanding of virus structure and composition, cell membrane arrangement and protein synthesis have improved thanks to this technique
  - **Freeze fracture**
    - A sample is **rapidly frozen** using liquid nitrogen and then physically broken apart (**fractured**) in a vacuum
    - It can be used to provide a unique planar view of the internal organisation of cell membranes

General Cell Structure


Your notes

General Cell Structure

- All living organisms are comprised of cells
- These cells all have some **common unifying features**, including
  - **DNA** as genetic material
  - **Cytoplasm**
  - A **plasma membrane**

DNA

- All living cells contain some sort of DNA, this **varies between eukaryotic cells and prokaryotic cells**
- The presence of DNA means that a **new cell can be formed from an old cell**, as genetic material is able to be stored and transferred
- DNA also controls the **production of enzymes** and other vital proteins within the cell

Cytoplasm

- Cytoplasm is found within the boundary of a cell
- It is composed of **mainly water** with dissolved substances, such as ions
- The fluid is known as **cytosol**
- Many of the cell's important reactions take place within the cytoplasm

Plasma membrane

- The plasma membrane **surrounds the cell** and encloses all the cell contents
- In all cell types, the plasma membrane has two layers and this is called a **bilayer**
- The bilayer consists of **lipids**; these vary depending on the type of organism
- The membrane is responsible for controlling the interactions of the cell's **interior** with the **exterior**
  - Materials required by the cell are transported into the cell interior
  - Waste substances are exported out of the cell to the surrounding environment
- The membrane is studded with **proteins** which have varying functions including:
  - Cell recognition
  - Cell communication
  - Transport into and out of the cell

Prokaryotic Cell Structure


Your notes

Prokaryotic Cell Structure

- The cell structure of organisms determines whether they are **prokaryotic** or eukaryotic
- Prokaryotes have the **simplest cell structure**, being the first organisms to evolve on Earth and have been classified into two domains:
  - **Bacteria** or Eubacteria - 'true' bacteria, includes commonly known bacteria such as *E.coli* and *Helicobacter*
  - **Archaebacteria** or Archaea - typically found in extreme environments such as high temperatures and salt concentrations and include methanogens (organisms that exist in anaerobic conditions and produce methane gas)
- Prokaryotic cells are **small**, ranging from 0.1μm to 5.0μm
- Prokaryotes have cells that **lack a nucleus** (the Greek roots of prokaryote are 'pro' = before and 'karuon' = nut or kernel, relating to 'before the nucleus')

Structure of prokaryotic cells

- The cytoplasm of prokaryotic cells is **not divided** into **compartments**, it **lacks membrane-bound organelles**
- Structures that are common to most prokaryotes include:
  - 70S ribosomes
  - DNA in a loop
  - Cytoplasm
  - Plasma membrane
  - Cell wall

Ribosomes

- Prokaryotic **ribosomes** are structurally smaller (70S) in comparison to those found in eukaryotic cells (80S)
- The function of these ribosomes is the binding and reading of mRNA during **translation** to **produce proteins**

DNA

- Prokaryotes do not have a nucleus, but they **do have genetic material**. This is generally in the form of a "naked" **single circular DNA molecule** (**not associated with proteins**) located in the nucleoid and in smaller loops called **plasmids**
- 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**)

Cytoplasm

- Prokaryotic **cytoplasm** is very similar to the cytoplasm of any other cell
- It is the site of many **cellular reactions**

- This is where the 70S ribosomes are found
- A major component of the cytoplasm is a gel-like **cytosol**, a water-based solution that contains ions, small molecules, and macromolecules

Your notes

Cell membrane

- The cell membrane of prokaryotes is composed of a **lipid bilayer**
- A group of prokaryotes, known as archaea, have their plasma membrane formed as a monolayer as opposed to a bilayer
- The role of the plasma membrane is to control substances entering and exiting the cell

Cell wall

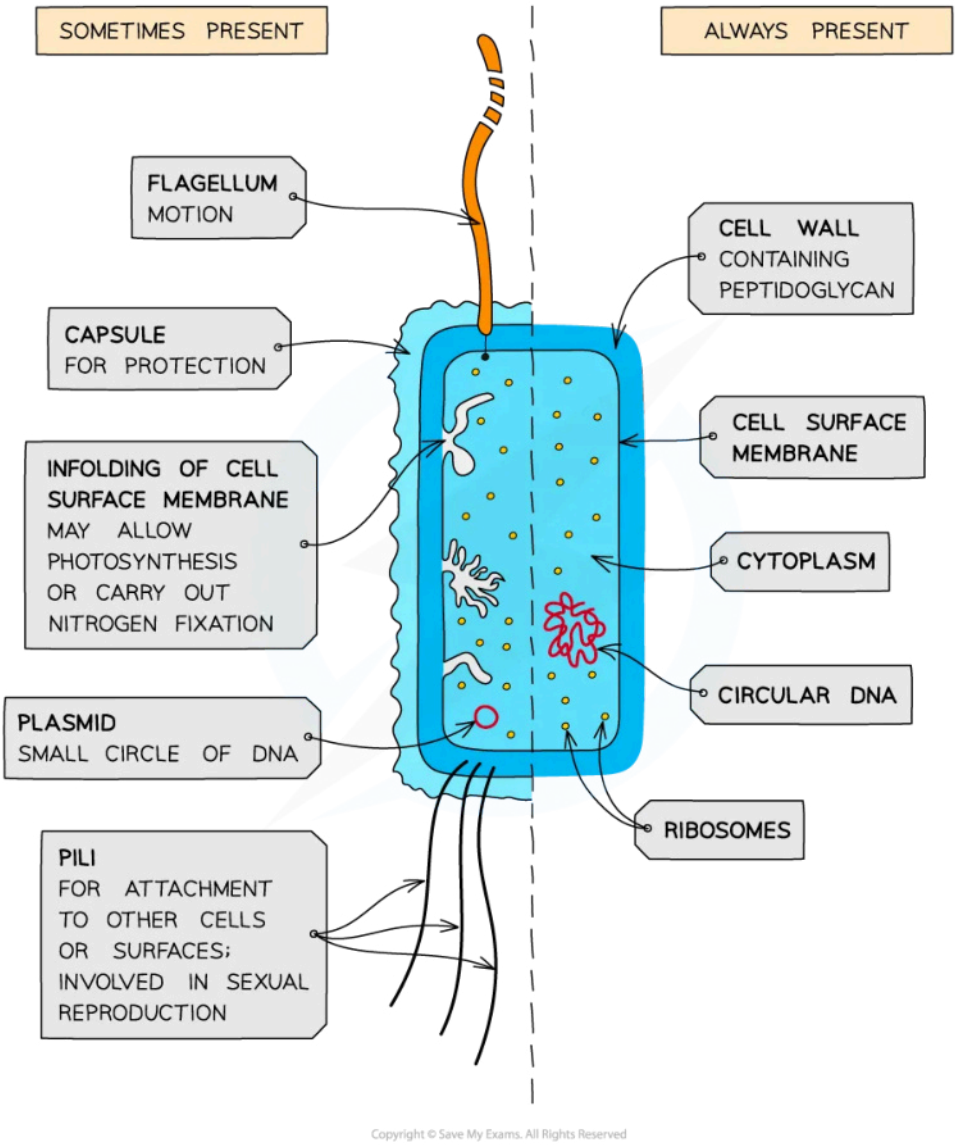
- Most prokaryotes have a **cell wall** containing **murein/peptidoglycan** (a glycoprotein)
- The cell wall acts as **protection**, maintains the **shape** of the cell and prevents the cell from **bursting**
- Some bacteria are able to be **classified** because of their cell wall structure
  - Their ability to retain a dye called crystal violet classifies a group of bacteria as **Gram positive**, they appear blue/violet after exposure to the dye
  - Examples of gram positive bacteria are *Bacillus* and *Staphylococcus*
  - Bacteria that do not react with the dye are referred to as Gram negative bacteria

Additional structures

- In addition, many prokaryotic cells have a few other structures that differentiate the species from others and act as a selective advantage, examples of these are:
  - Plasmids
  - Capsules
  - Flagellum
  - Pili
- 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 structures** that **rotate**, enabling the prokaryote to **move** (a bit like a propeller)
  - Some prokaryotes have **more than one**
- **Pili** are shorter and thinner structures than flagella
  - They assist with movement, avoidance of attack by white blood cells, conjugation (the sexual mode for bacteria) and are commonly used to allow bacteria to **adhere to cell surfaces**

A diagram of the structure of prokaryotic cells

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

Examiner Tip

Make sure you learn the typical **structures** and **organelles** found in prokaryotic cells, as well as their **functions**.

Eukaryotic Cell Structure

Your notes

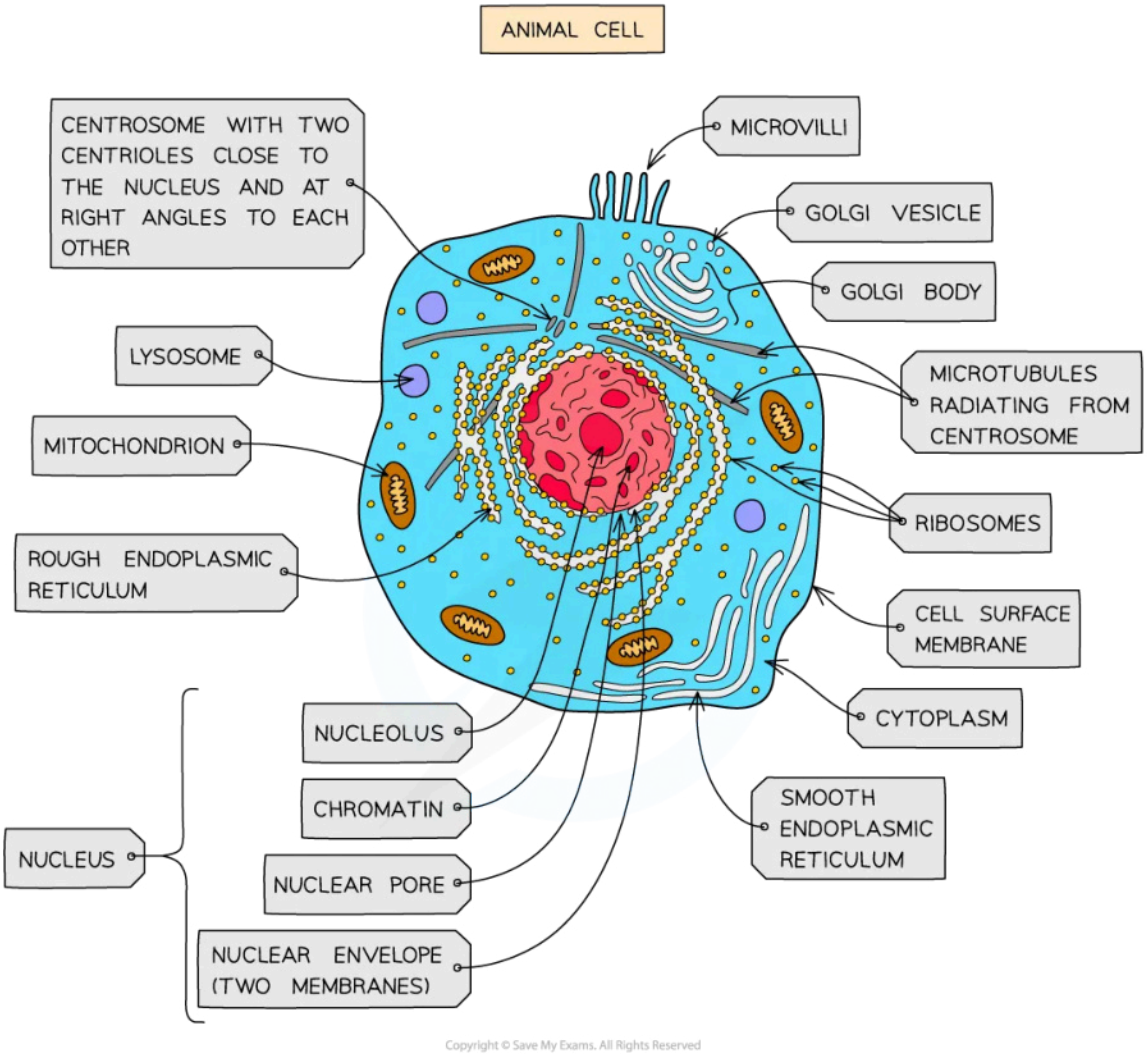
Eukaryotic Cell Structure

Structure of eukaryotic cells

- Eukaryotic cells have a more **complex ultrastructure** than prokaryotic cells
- The cytoplasm of eukaryotic cells is divided up into **membrane-bound** compartments called **organelles**
- The **compartmentalisation** of the cell is **advantageous** as it allows:
  - enzymes and substrates to be available at higher concentrations
  - damaging substances to be kept separated, e.g. digestive enzymes are stored in lysosomes so they do not digest the cell
  - optimal conditions to be maintained for certain processes, e.g. optimal pH for digestive enzymes
  - the numbers and locations of organelles to be altered depending on requirements of the cell

Animal cell diagram

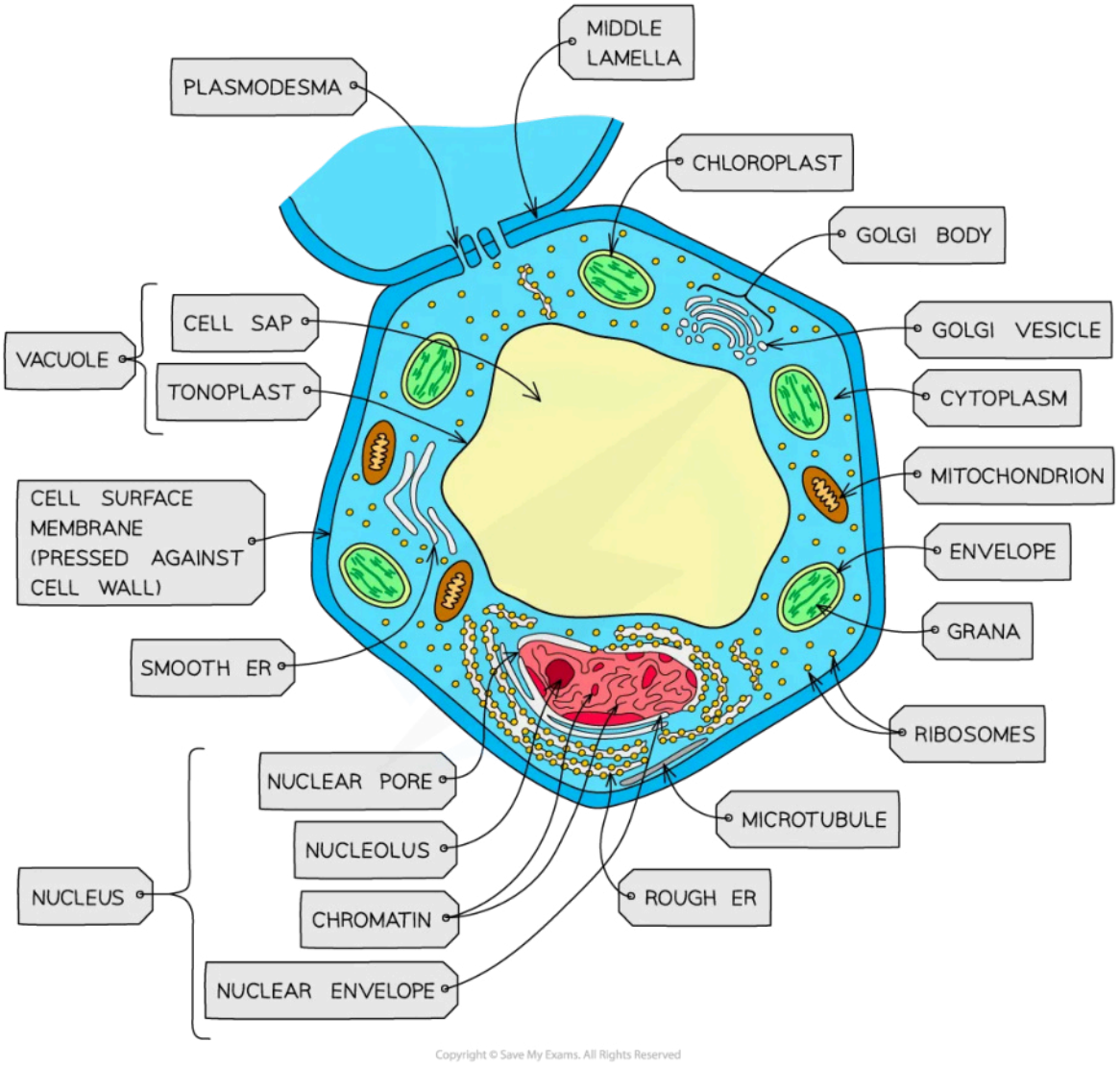
Your notes



Animal cells contain membrane-bound compartments, e.g. the nucleus and mitochondria

Plant cell diagram

Your notes

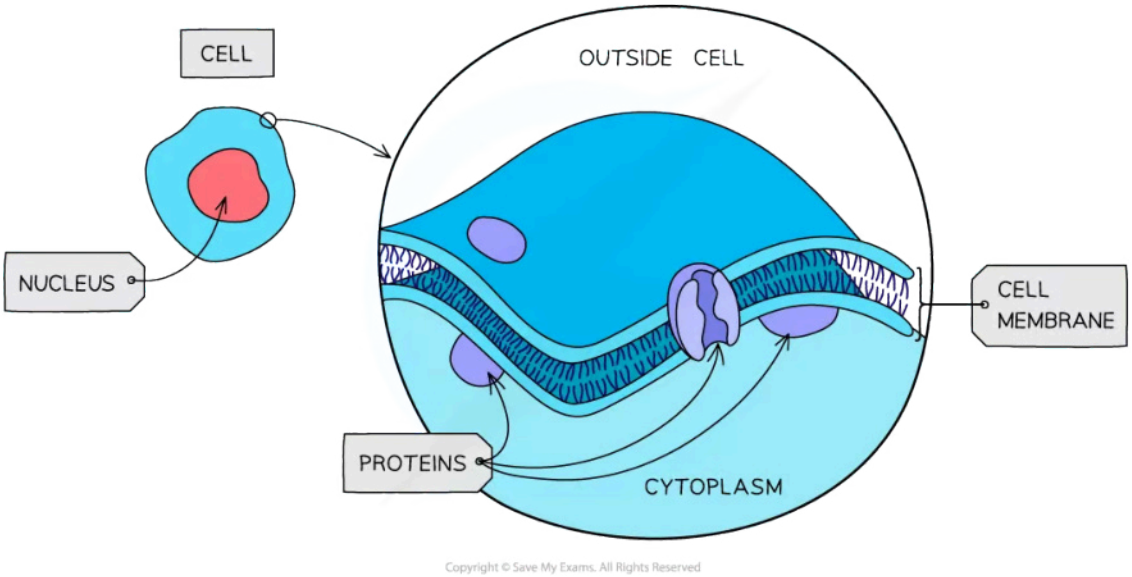


Plant cells are also eukaryotic cells, and have additional features when compared to animal cells, e.g. a cell wall and chroroplasts

Organelles

Plasma membrane

- **All cells** are surrounded by a plasma 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 plasma membrane is formed from a **bilayer of phospholipids** spanning a diameter of around 10 nm



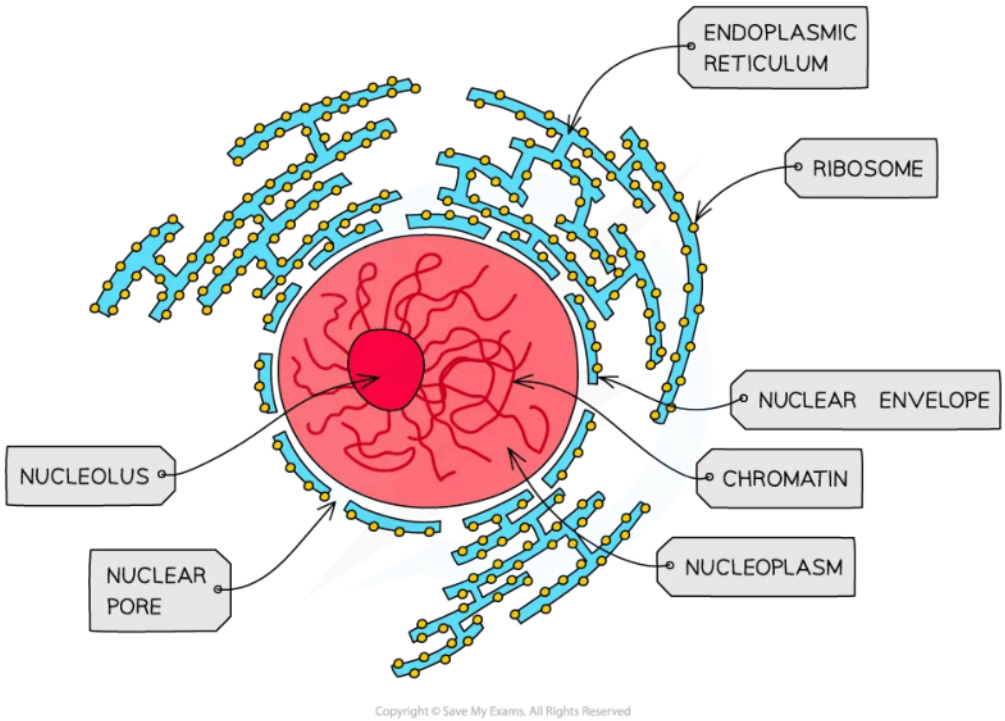
The cell surface membrane, or plasma membrane, controls the passage of substances into and out of cells

Nucleus

- Present **in all eukaryotic cells** (except red blood cells), the nucleus is a large organelle that is 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 (e.g. 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 within the nucleus; these regions are individually termed the '**nucleolus**' (plural: nucleoli) and are the sites of **ribosome production**

Your notes

Your notes

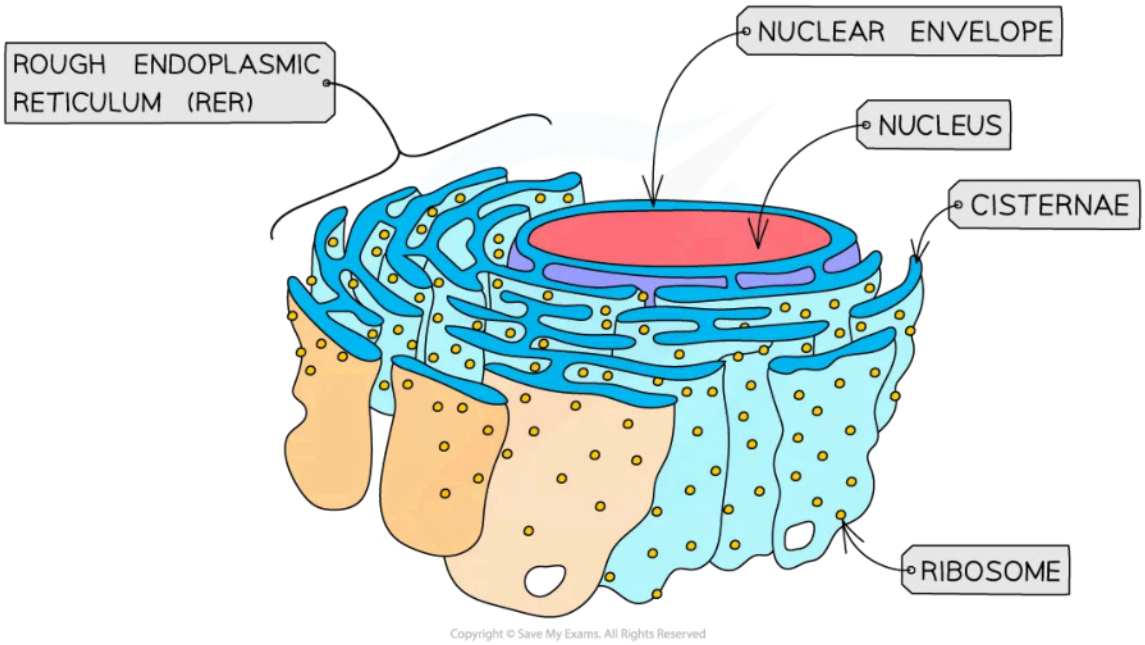


The nucleus of a cell contains chromatin (a complex of DNA and histone proteins) which is the genetic material of the cell

Rough endoplasmic reticulum

- Found in plant and animal cells
- Surface covered in **ribosomes** (80S)
- Formed from folds of membrane continuous with the **nuclear envelope**; these flattened membrane sacs are called **cisternae**
- **Processes proteins** made by the ribosomes
- The **proteins** synthesised by the ribosomes move to the cisternae, bud off into vesicles that carry the proteins to Golgi apparatus before being **secreted out** of the cell

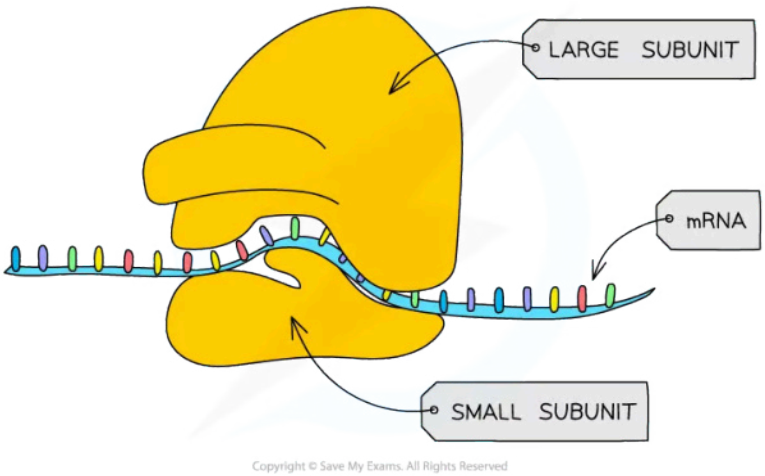
Your notes



The rough endoplasmic reticulum (RER) has ribosomes on its surface

Ribosomes

- 80S ribosomes are found freely in the cytoplasm or as part of the **rough endoplasmic reticulum** in eukaryotic cells
- Each ribosome is a complex of **ribosomal RNA (rRNA)** and proteins
- Constructed in the nucleolus
- Site of translation (which is part of **protein synthesis**)

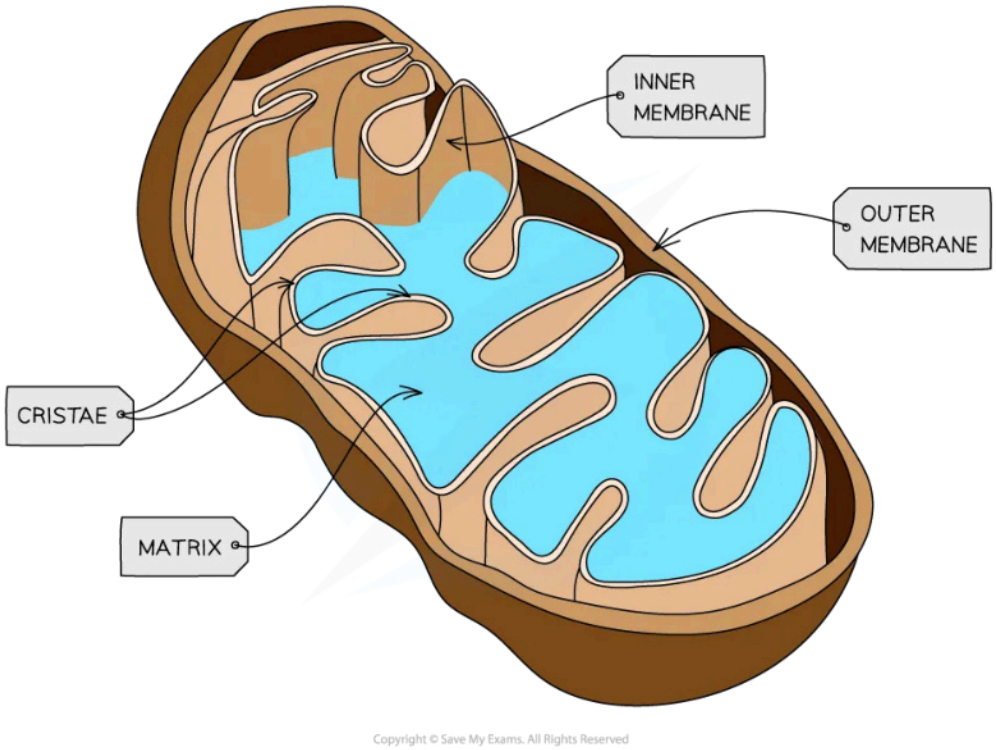


Ribosomes are formed in the nucleolus and are composed of almost equal amounts of RNA and protein

Mitochondria

Your notes

- The site of aerobic respiration within **all eukaryotic cells**, mitochondria (singular mitochondrion) are just visible with a light microscope
- Surrounded by a **double-membrane** with the inner membrane folded to form **cristae**
- The matrix 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)

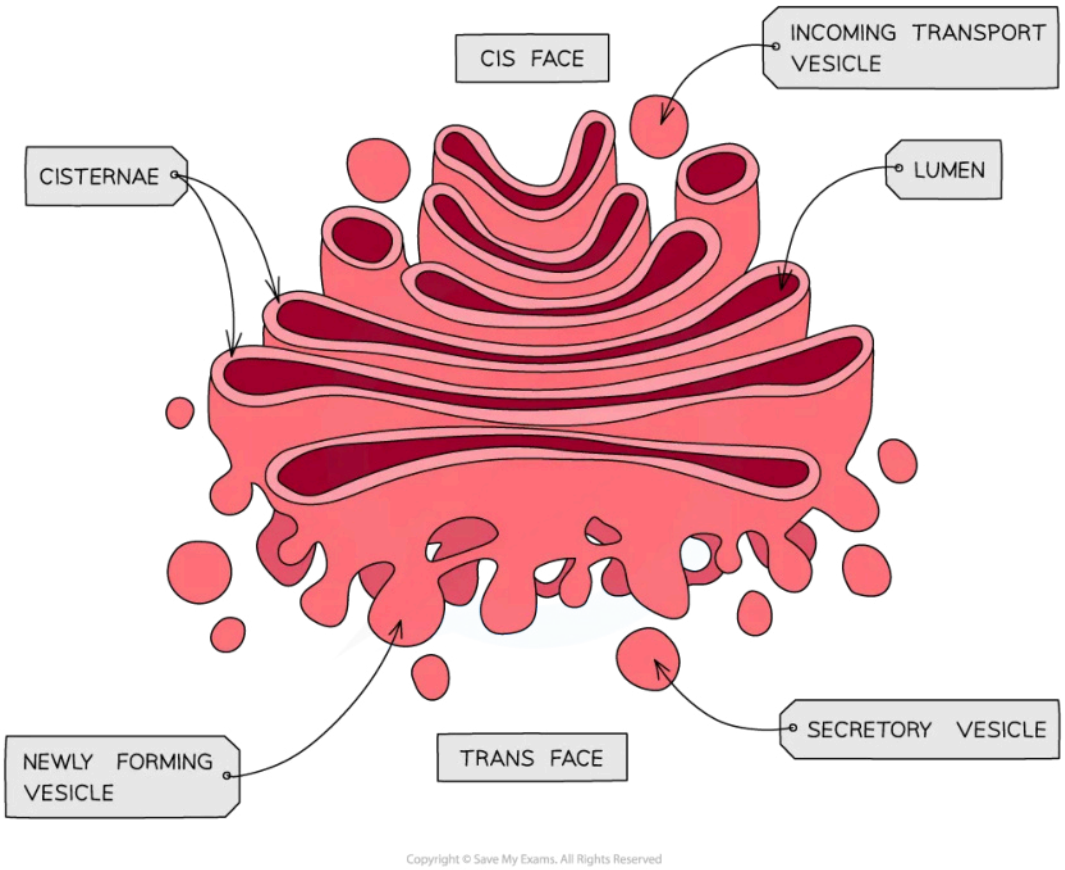


The inner mitochondrial membrane has protein complexes vital for the later stages of aerobic respiration embedded within it

Golgi apparatus

- Flattened sacs of membrane called cisternae
- **Modifies** proteins and lipids before **packaging** them into **Golgi vesicles**
- The vesicles then **transport the proteins and lipids** to their required destination
- Proteins that pass through the Golgi apparatus are usually:
  - exported, e.g. hormones such as insulin
  - put into lysosomes, such as hydrolytic enzymes
  - delivered to membrane-bound organelles

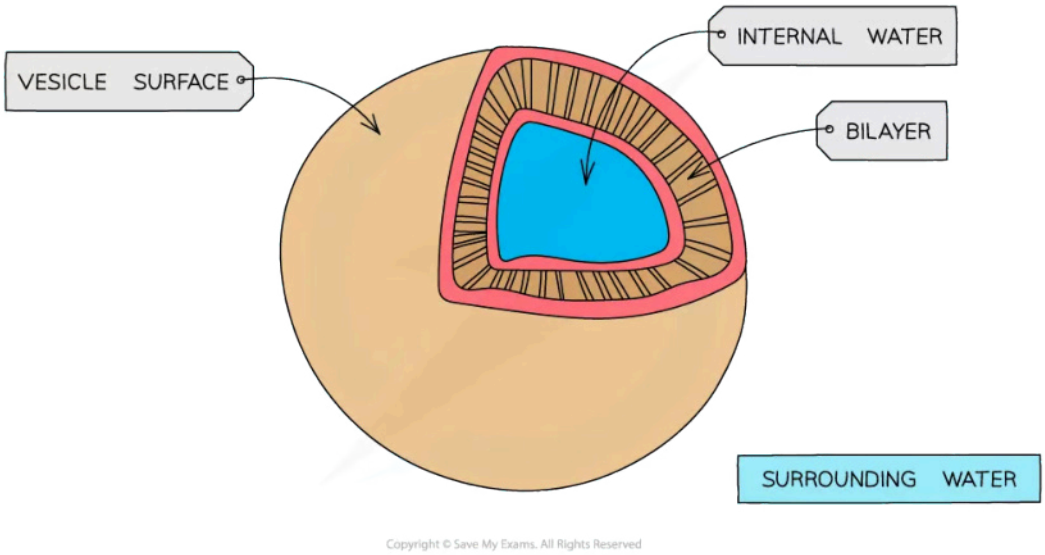
Your notes



The Golgi apparatus has a distinctive appearance due to the arrangement of cisternae from which it is formed

Vesicles

- Membrane-bound sacs for transport and storage, e.g. Golgi vesicles transport proteins from the Golgi apparatus around the cell
- **Lysosomes** are specialised vesicles that contain hydrolytic enzymes
  - The role of lysosomes is to break down waste materials such as worn-out organelles
  - Lysosomes are used extensively by cells of the **immune system** and in **apoptosis** (programmed cell death)



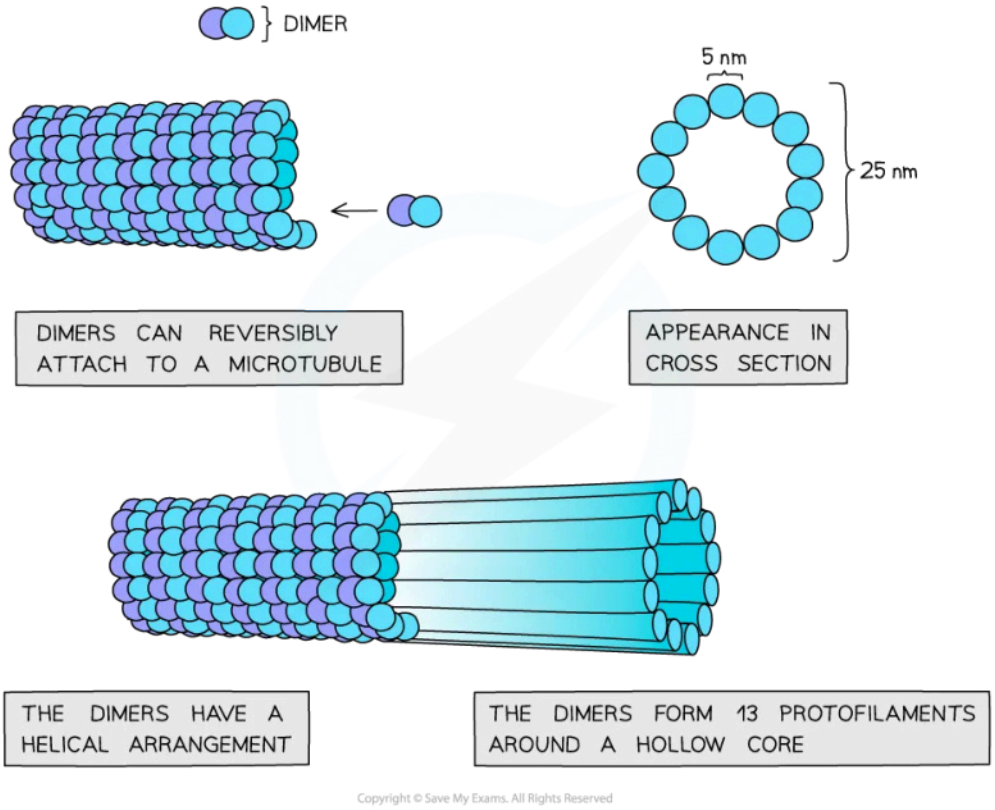
The structure of the vesicle

Your notes

Microtubules

- Make up the **cytoskeleton** of the cell and are about 25 nm in diameter
- The cytoskeleton is used to provide support and movement to the cell
- Made of α and β tubulin proteins combined to form dimers, the dimers are then joined into protofilaments

Your notes



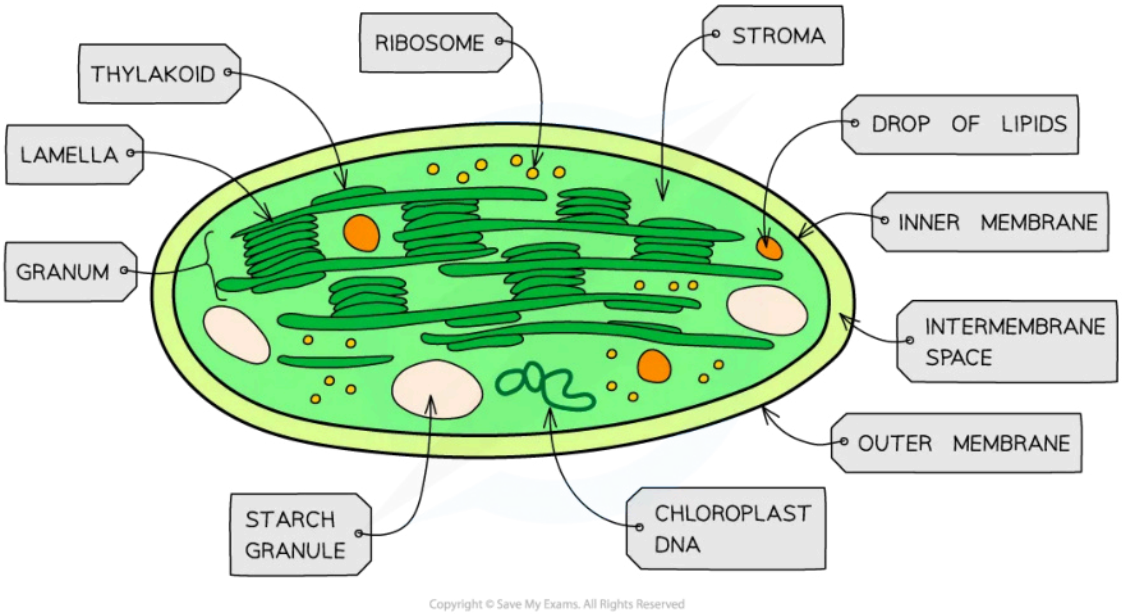
Microtubules make up the cell cytoskeleton

Plant cell structures

Chloroplasts

- Larger than mitochondria
- 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

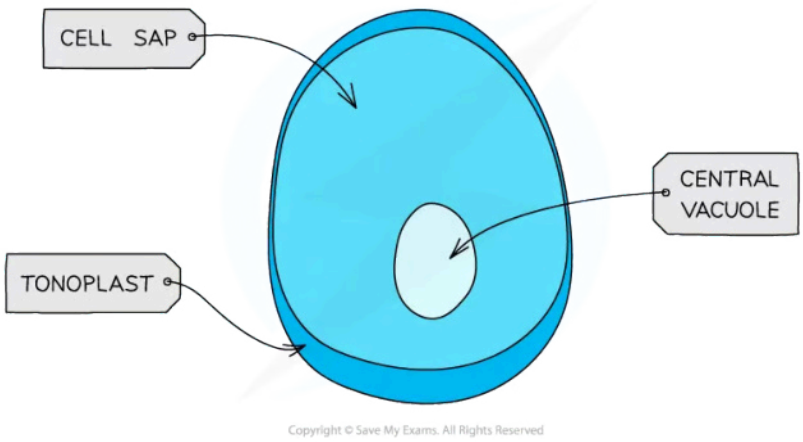
Your notes



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

Large permanent vacuole

- A sac in **plant cells** surrounded by the **tonoplast**, which is a selectively permeable membrane
- Animal cells can contain vacuoles, but they are temporary and small



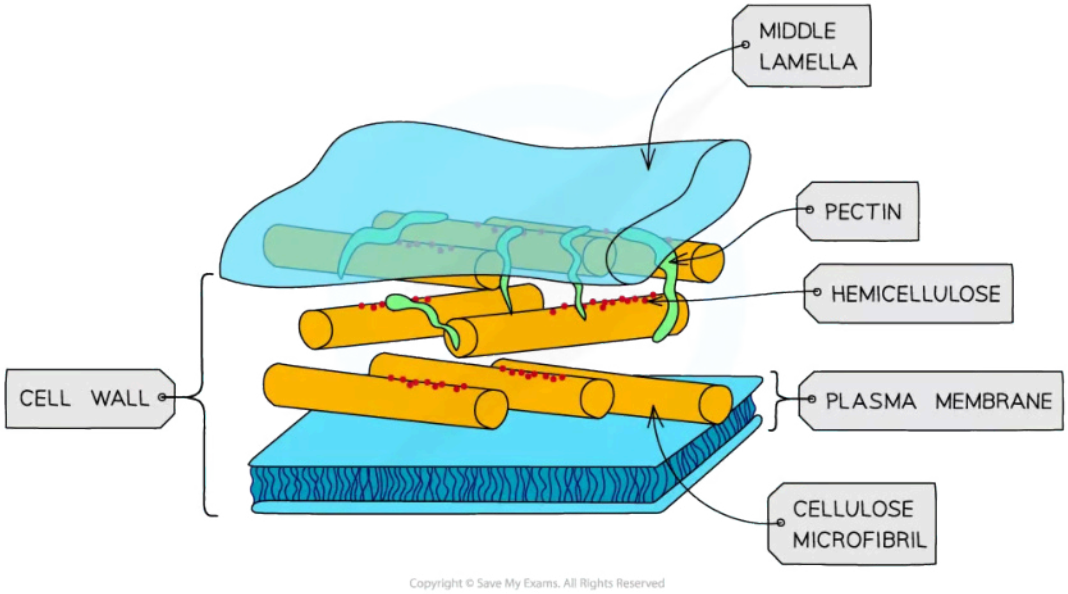
Plant cells contain large, permanent vacuoles

Cell wall

- Found in plant cells but **not in animal cells**
- Formed outside of the cell membrane and offer **structural support** to the cell

- Cell walls are extra-cellular, so are not technically cellular organelles
- 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



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

Functions of Life


Your notes

Functions of Life

- Unicellular (single-celled) and multicellular (many cells) organisms must carry out the following functions to stay alive:
  - **M**etabolism - all the enzyme-catalysed reactions occurring in a cell, including cell respiration
  - **R**eproduction - the production of offspring. It may be sexual or asexual
  - **H**omeostasis - the ability to maintain and regulate internal conditions within tolerable limits, including temperature
  - **G**rowth - the permanent increase in size
  - **R**esponse - (or sensitivity), the ability to respond to external or internal changes (stimuli) in their environment. Thus improving their chance of survival
  - **E**xcretion - the disposal of metabolic waste products, including carbon dioxide from respiration
  - **N**utrition - the acquisition of energy and nutrients for growth and development, either by, absorbing organic matter or by synthesising organic molecules (e.g. photosynthesis)

- Unicellular organisms have **adapted** unique ways to carry out these functions compared to multicellular organisms
  - **Mitochondria** are present to provide energy through **respiration**
  - The **cell membrane** controls movement of materials in and out of the cell to **maintain homeostasis**
  - **Ribosomes** are present to **produce proteins** for growth and repair, in addition **enzymes** for vital cell functions
  - **Vacuoles** are used for digestion purposes and also to store waste substance
  - **Cilia** or **flagella** are used for movement of the organism in response to changes in the environment

Eukaryotic Cell Structure: Comparisons & Atypical Examples


Your notes

Cell Structure: Animals, Fungi & Plants

- Eukaryotic cells exist in four kingdoms
  - The **animal** kingdom
  - The **plant** kingdom
  - The **fungal** kingdom
  - The **protist** (protoctista) kingdom
- The cells of each of these possess unique characteristics and structures that contribute to their **differences**

Differences in eukaryotic cell structure

Cell walls

- Animal cell **do not** have a cell wall
- Plant cell walls are composed of the polysaccharide **cellulose**
- Fungal cell walls are made up mainly of **glucans**, **chitin** and **glycoproteins**

Vacuoles

- Vacuoles **can be present in animal cells** but they tend to be **small**, **temporary** and **numerous** when present with unique functions
- Plant cells have **large permanent vacuoles** used for the storage of various substances
- Like animal cells, fungal cells **can contain vacuoles** but they are **small** and **non-permanent**

Chloroplasts

- Animal cells **do not** have chloroplasts
- Plant cells possess **many chloroplasts** used for the production of carbohydrates through **photosynthesis**
- Fungal cells **do not** have chloroplasts

Presence of centrioles

- Animal cells **do contain centrioles** used in the role of **microtubule organisation** during cell division
- Plant cells **do not** possess centrioles
- Fungal cells **do not** possess centrioles

Presence of cilia and flagella

- Animal cells can have **cilia and flagella**, associated with a **basal body** (a protein structure from which the cilia are assembled), and are used in various functions such as the **movement** of an egg cell through the oviduct or the movement of fluids in the respiratory tract
- Plant cells **do not** contain cilia or flagella
- True fungi **do not** contain cilia or flagella

Other differences

- Animal and fungal cells store their carbohydrates as **glycogen**, whereas plants so carbohydrates as **starch**
- Animal cells are **flexible** as they lack a rigid cell wall, whereas plant cells have a **fixed shape**. Fungal cells, although they have a cell wall, can be **flexible** and their shape may vary


Your notes

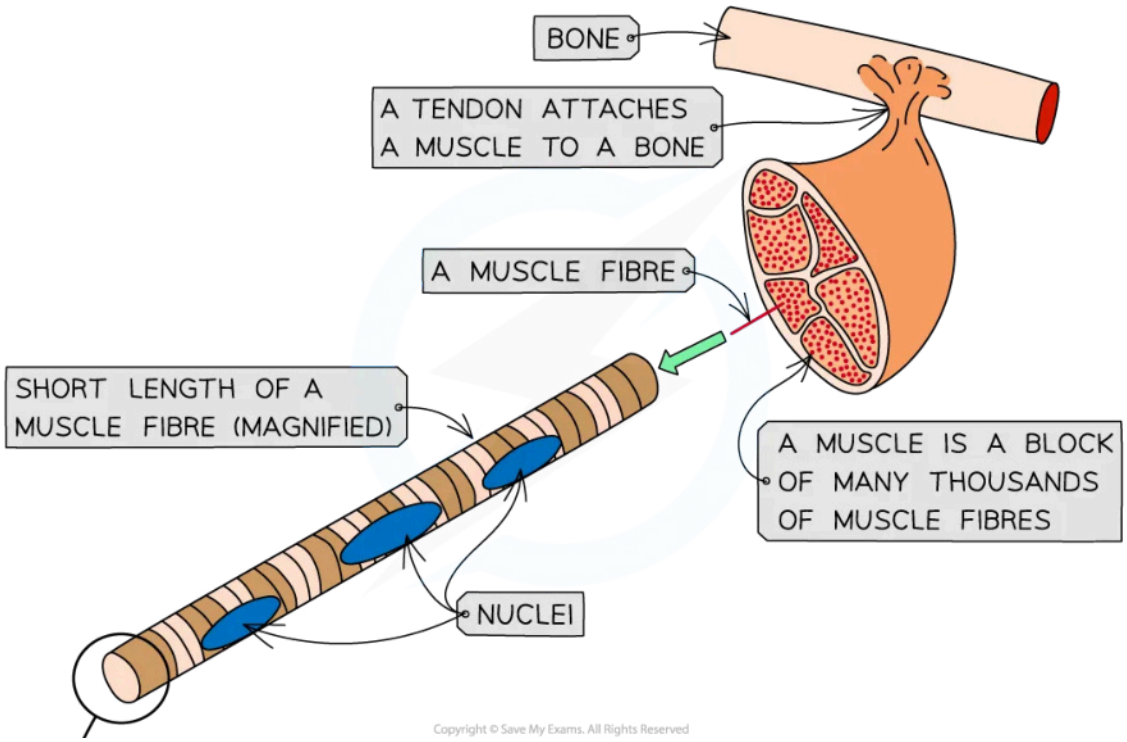
Atypical Cell Structure

Your notes

- Some eukaryotic cells have a very unique or **atypical structure** which enables them to carry out specialised functions
- The **number of nuclei** can be used to illustrate atypical examples
- Skeletal muscle, aseptate fungal hyphae, red blood cells and phloem sieve tubes are examples of cells/tissue with structures that question the integrity of the cell theory

Atypical examples

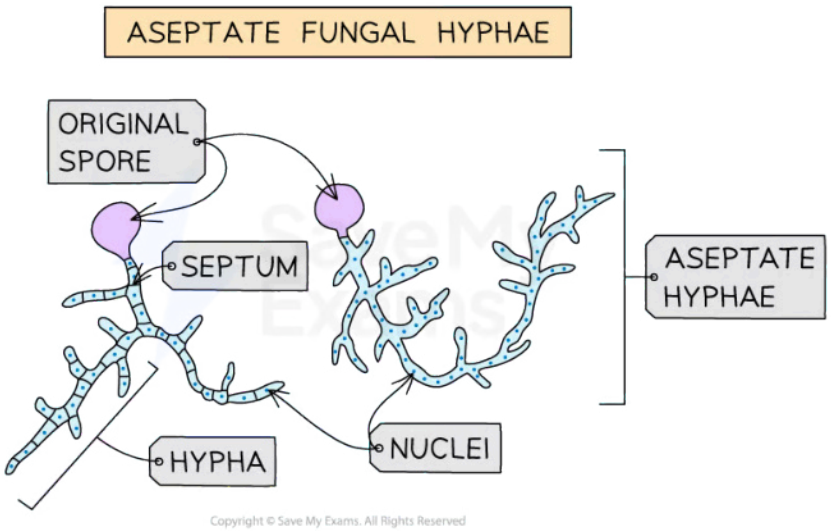
Striated muscle fibres



- Striated muscle fibres (fused muscle cells) are:
  - **Longer** than typical cells (up to 300 mm in length in comparison to a cardiac muscle cell which has a length of 100 - 150 µm)
  - Have **multiple nuclei** surrounded by a single membrane (sarcolemma)
  - Striated muscle cells are formed from **multiple cells which have fused together** (which is how they have many nuclei rather than one) that work together as a single unit
  - These features challenge the concept that cells work independently of each other even in a multicellular organism

Aseptate fungal hyphae

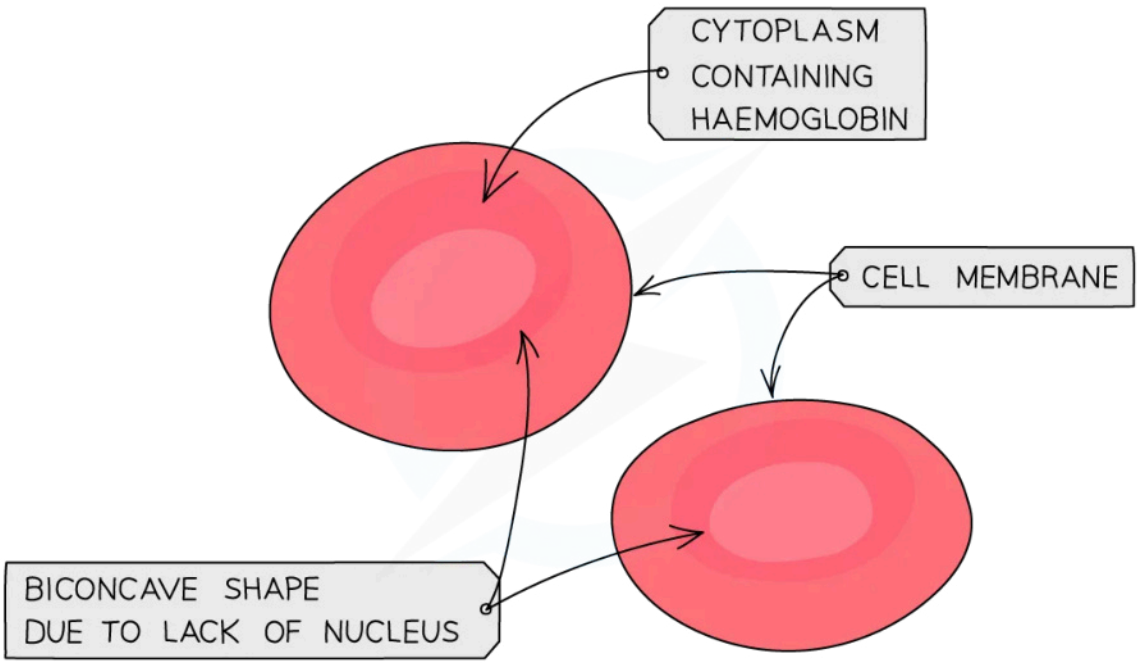
Your notes



- Fungi have many long, narrow branches called **hyphae**
- Hyphae have cell membranes, cell walls and some have septa
- Aseptate fungal hyphae do not have septa, thus these cells are **multinucleated** with continuous cytoplasm
- The cells have no end walls making them appear as one cell

Red blood cells

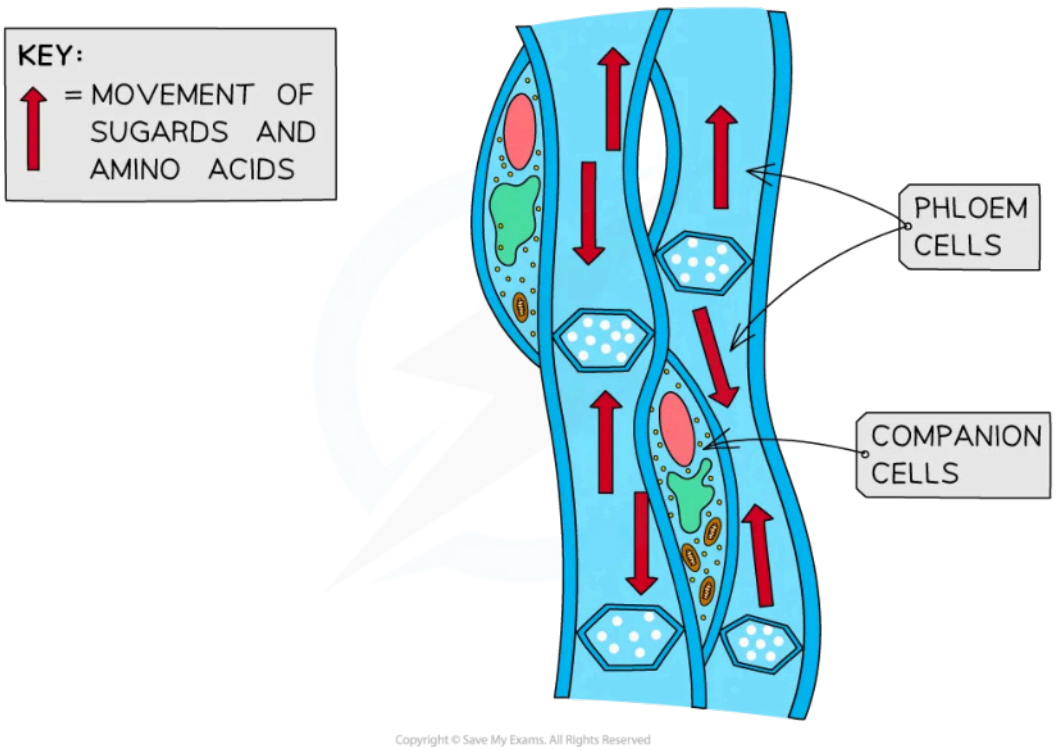
Your notes



- Red blood cells, a type of animal cell, are unique in that they **do not contain a nucleus**
- The reason for this is to enable the cell to carry a large volume of the oxygen binding pigment **haemoglobin**
- The biconcave shape of red blood cells means they have maximum surface area to improve their oxygen carrying capacity

Phloem sieve tubes

Your notes



- These serve a plant by **transporting dissolved substances**, such as sucrose, around the plant
- These unique tissues have **no end cell wall** and **lack many cell organelles** such as nuclei, mitochondria and ribosomes
- Because of the lack of their own organelles, sieve tube elements can only survive due to the presence of **companion cells** which sit alongside next to the sieve tube elements and help to maintain the cytoplasm of the sieve tubes

Cell Types & Structures: Skills


Your notes

Cell Types & Structures: Skills

- It is important to be able to recognise various organelles from light and electron microscope images
- When interpreting micrographs to identify and deduce the function of the cell it is important to:
  1. Identify whether it is a **prokaryotic or eukaryotic** cell - look to see if a **nucleus** is present or not
  2. Identify which type of eukaryotic cell it is (**plant or animal**) by looking for a **cell wall** or **vacuole**
  3. Identify the **organelles present** in the cells and consider their function

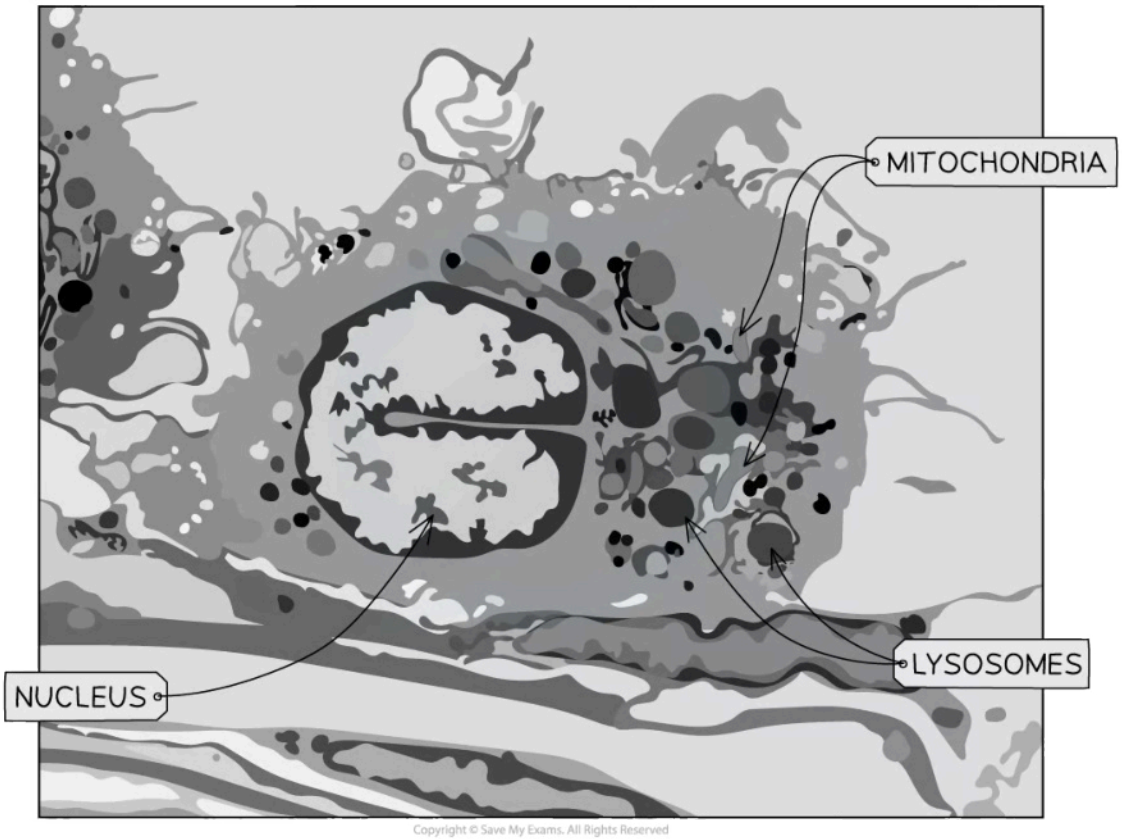
- You should be confident in identifying the following structures and organelles:
  - Nucleoid region in a prokaryotic cell
  - Prokaryotic cell wall
  - Nucleus
  - Mitochondria
  - Chloroplast
  - Sap vacuole
  - Golgi apparatus
  - Rough and smooth endoplasmic reticulum
  - Chromosomes
  - Ribosomes
  - Plant cell wall
  - Plasma membrane
  - Microvilli

- Some identifiable features of key organelles are:
  - Chloroplast
    - Has **distinctive stacks** of thylakoids
    - Double membrane
    - Has a roughly oval shape
    - Larger than mitochondria
    - Indicates the cell is a plant cell
  - Nucleus
    - Has a nuclear membrane and a **dark nucleolus** within
    - It has a roughly spherical shape
  - Vacuole
    - Occupies a large space within a cell
    - Often shows up as a very light shade (white) within an electron micrograph
    - Indicates the cell is a **plant cell**
  - Cell wall
    - Located around the perimeter of the cell
  - Mitochondria
    - Roughly oval-shaped
    - **Double membrane**

- Sometimes observed with visible **cristae** (foldings of the inner membrane)

Your notes

An interpretation of an electron micrograph of a cell

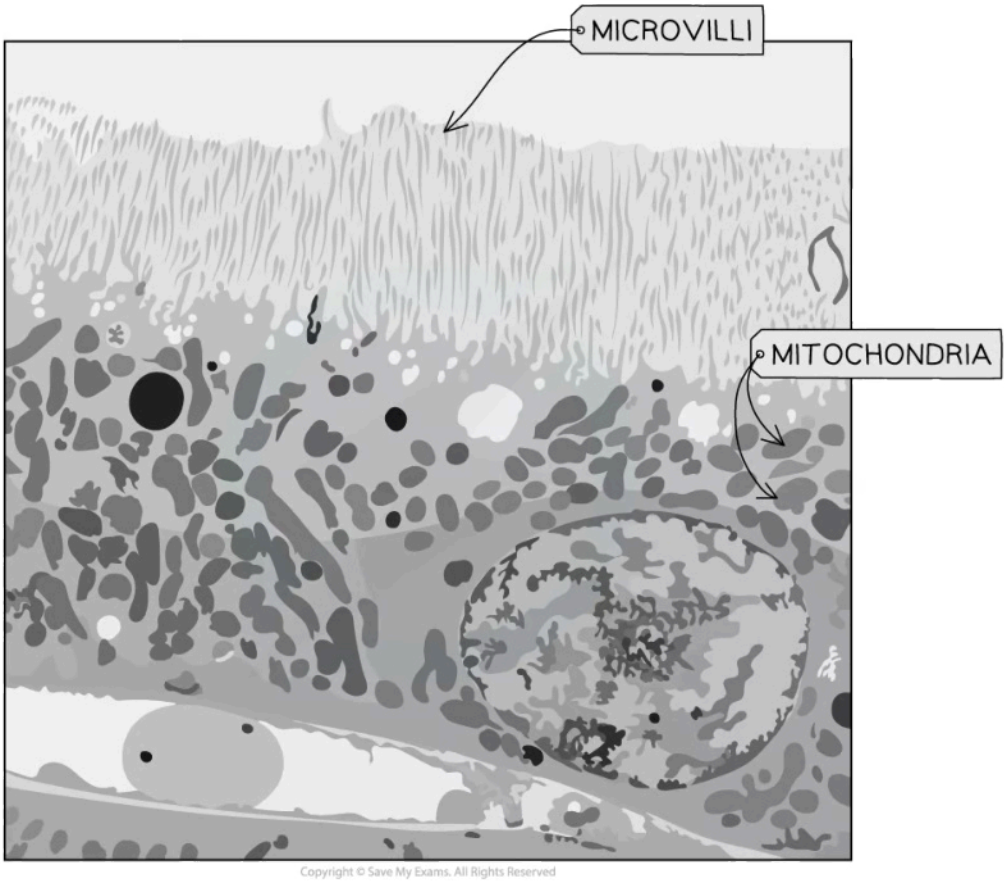


Electron micrograph of cell 1

- To identify this cell consider the following
  - The cell has a **nucleus** - therefore it is a **eukaryotic cell**
  - This cell does **not have** a **cell wall** or **central vacuole** - therefore it is an **animal cell**
  - The cell has a **large u-shape nucleus** - so it can manipulate itself through small pores
  - There are a large number of **lysosomes** in the cell - so it can **digest substances** found within the cell
  - There are a large number of **mitochondria** - this means it has sufficient **energy** for its many metabolic reactions
  - The deduction, therefore, is that this cell needs a lot of energy to break down substances that enter the cell and that it can move where it wants. This cell is a **macrophage**

An interpretation of an electron micrograph of a cell

Your notes



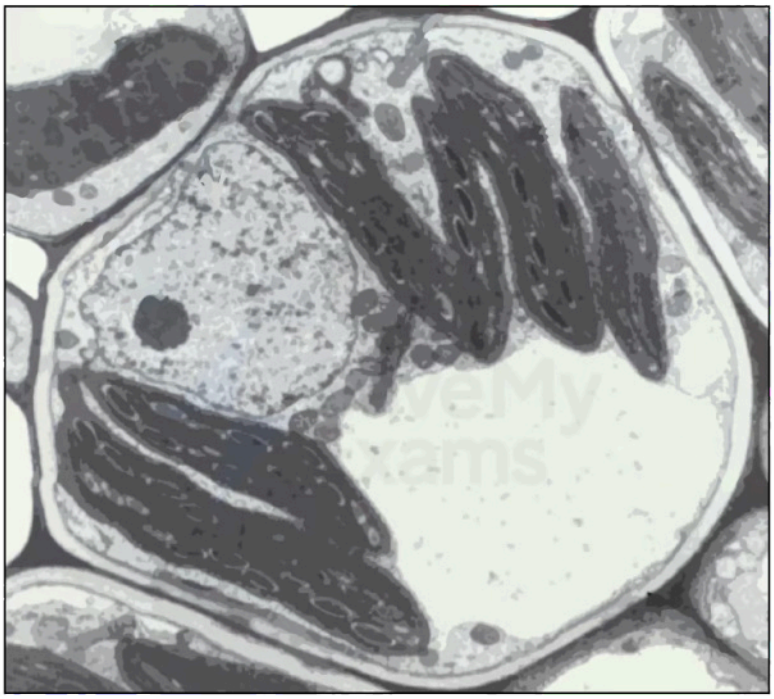
Electron micrograph of cell 2

- To identify this cell consider the following
  - The cell has a **nucleus** - therefore it is a **eukaryotic cell**
  - This cell does **not have** a **cell wall** or **central vacuole** - therefore it is an **animal cell**
  - There are a **large number of mitochondria** - so it requires significant energy for **many metabolic reactions**
  - The cell has **microvilli** packed closely together (brush border) - so it needs to **increase the surface area** and prevent any substance from crossing into the cell
  - The deduction, therefore, is that this cell needs a lot of energy to control what enters or exits this cell and that the cell requires many of the substance to be absorbed. This cell is a **ciliated epithelium of the small intestine**

Worked example

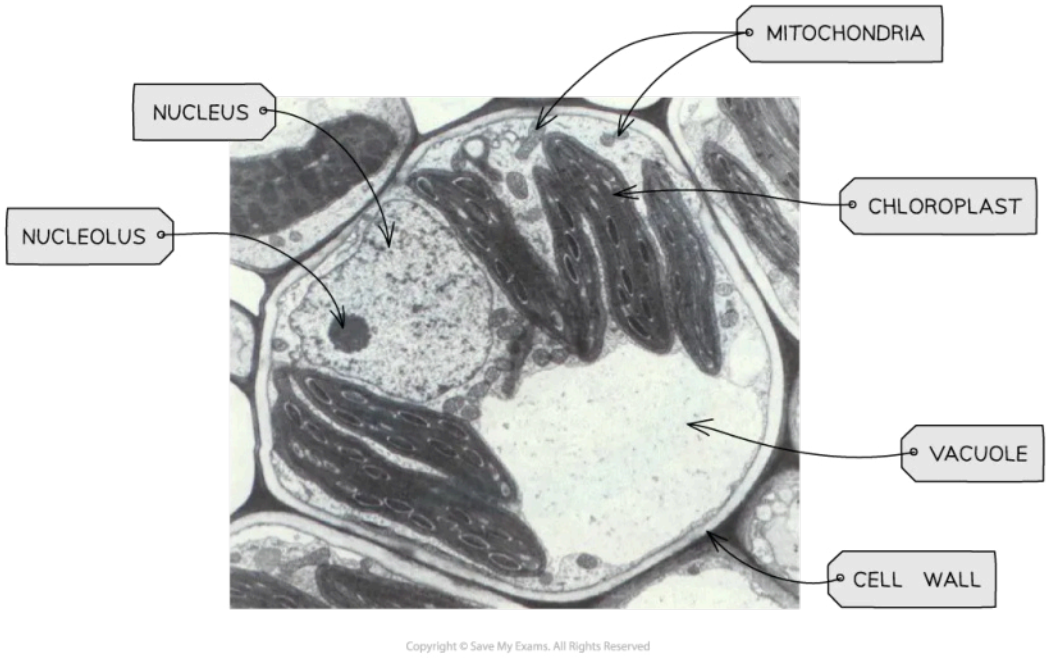
The image below shows a cell as viewed through an electron microscope.

Identify three organelles and the type of cell.



Answer:

Your notes



- Identifiable organelles are:
  - Nucleus and nucleolus
  - Mitochondria
  - Chloroplast
  - Vacuole
  - Cell wall
- This is a **plant cell**

Your notes

Your notes

Drawing Cells: Skills

Drawing the ultrastructure of 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 that 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

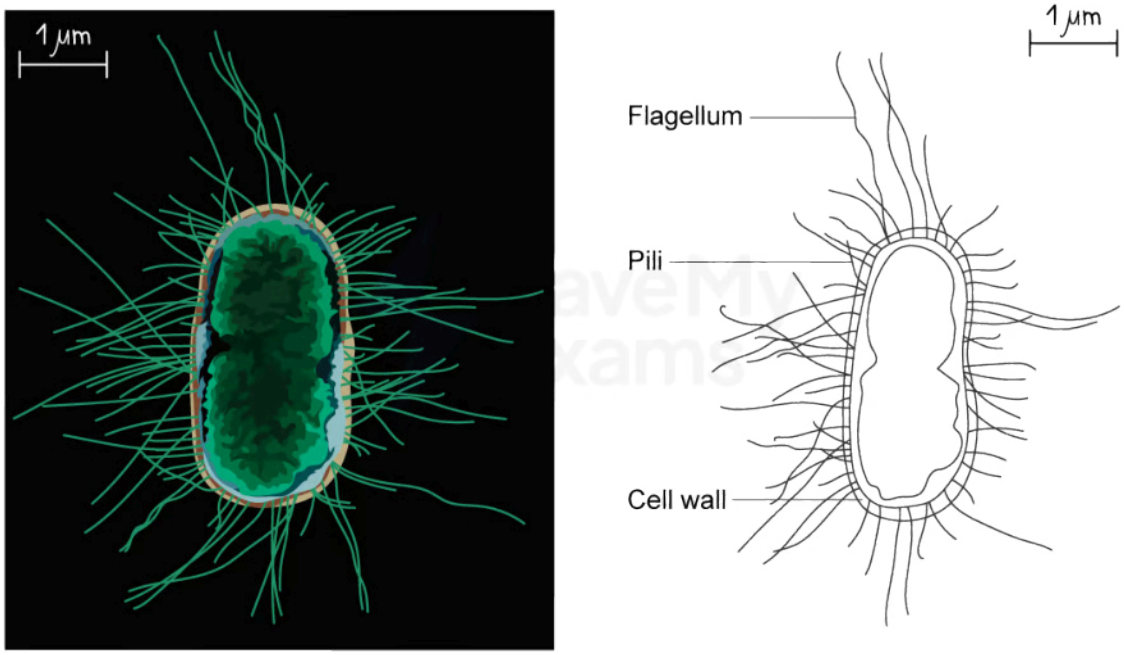
Drawing conventions

- The drawing must have a title
- The **magnification** under which the observations shown by the drawing are made must be recorded where possible
  - A scale bar may be used
- 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 sketching)
- **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 visualising 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)
- You are also expected to include the **functions** of organelles and cells as part of the annotations made

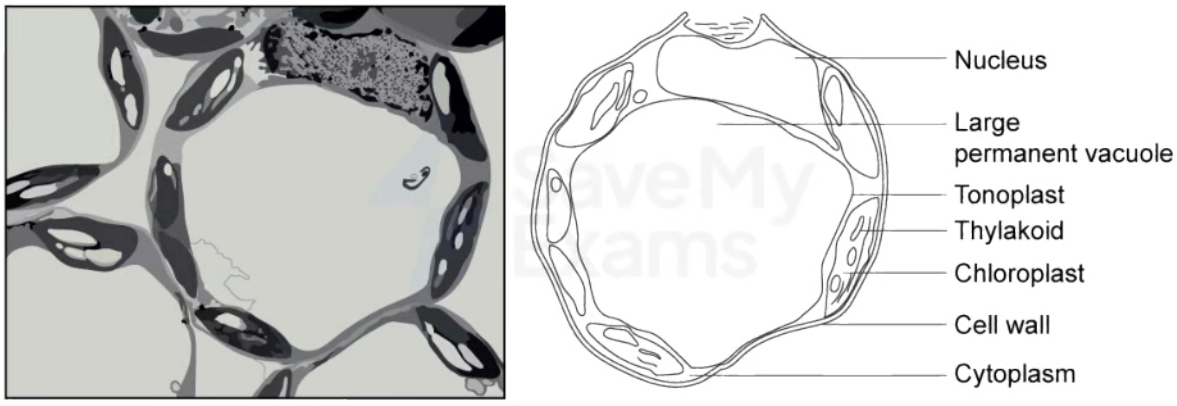
Examples of biological drawings

Scanning electron micrograph and drawing of a prokaryotic cell

Your notes



Transmission electron micrograph and drawing of a plant cell



Examiner Tip

When producing a biological drawing, it is vital that you only ever draw what you see and not what you think you see or assume should be visible.