3.2.1 Cell structure

3.2.1.1 Structure of eukaryotic cells

SPECIFICATION

- The structure of eukaryotic cells, restricted to the structure and function of:
  - cell-surface membrane
  - nucleus (containing chromosomes, consisting of protein-bound, linear DNA, and one or more nucleoli)
  - Mitochondria
  - chloroplasts (in plants and algae)
  - Golgi apparatus and Golgi vesicles
  - lysosomes (a type of Golgi vesicle that releases lysozymes)
  - Ribosomes
  - rough endoplasmic reticulum and smooth endoplasmic reticulum
  - cell wall (in plants, algae and fungi)
  - cell vacuole (in plants).
- In complex multicellular organisms, eukaryotic cells become specialised for specific functions. Specialised cells are organised into tissues, tissues into organs and organs into systems.
- **Students should be able to** apply their knowledge of these features in explaining adaptations of eukaryotic cells

Source: AQA Spec

Eukaryotic Cells and Organelles

Cells are the **basic building block** of life. Living organisms are classified into one of 5 kingdoms. The biggest division is between the cells of the **prokaryote kingdom** (the bacteria) and those of the other four kingdoms (animals, plants, fungi and protoctista), which are all **eukaryotic cells**.

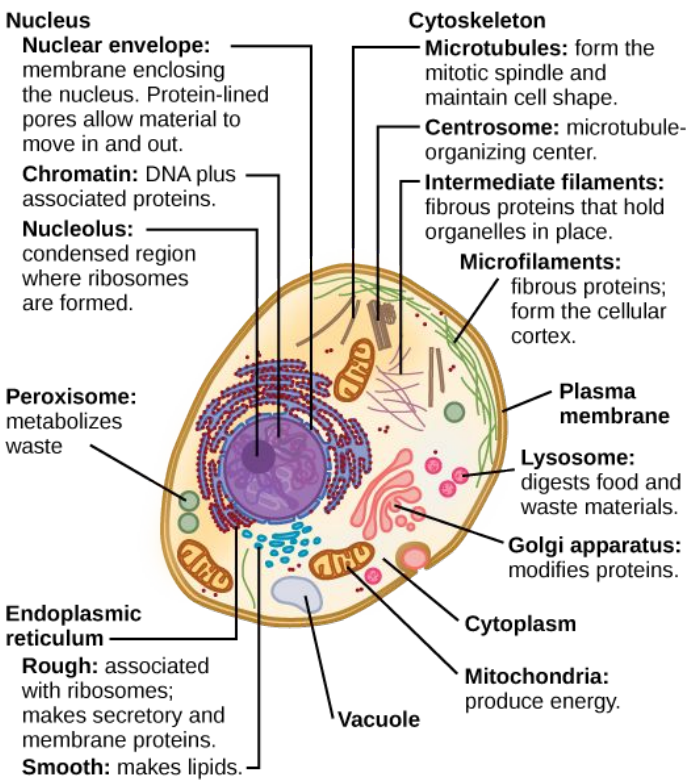
Prokaryotes or Eukaryotes

1. Prokaryotic organisms are **prokaryotic cells** (single-cell organisms) and eukaryotic organisms are made of **eukaryotic cells**.
2. Both cell types contain **organelles**, which are parts of cells, and each organelle **has a specific function**.

The structure of eukaryotic cells

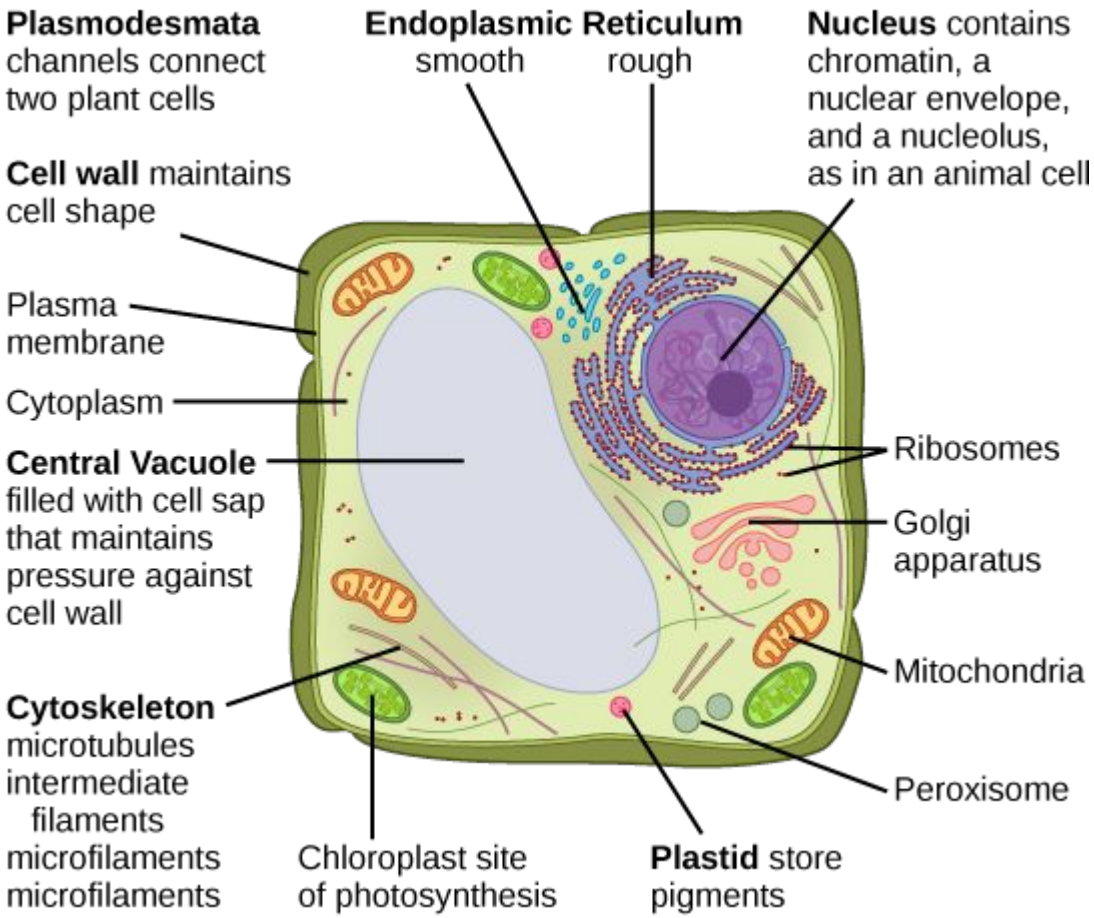
Here are some general diagrammatic representations of plant and animal cells, and some of the structures (organelles) within them.

We need to learn how the structures outlined in the specification are adapted to do their job.



a typical animal cell

The structure of eukaryotic cells



a typical plant cell

Algal and fungal cells

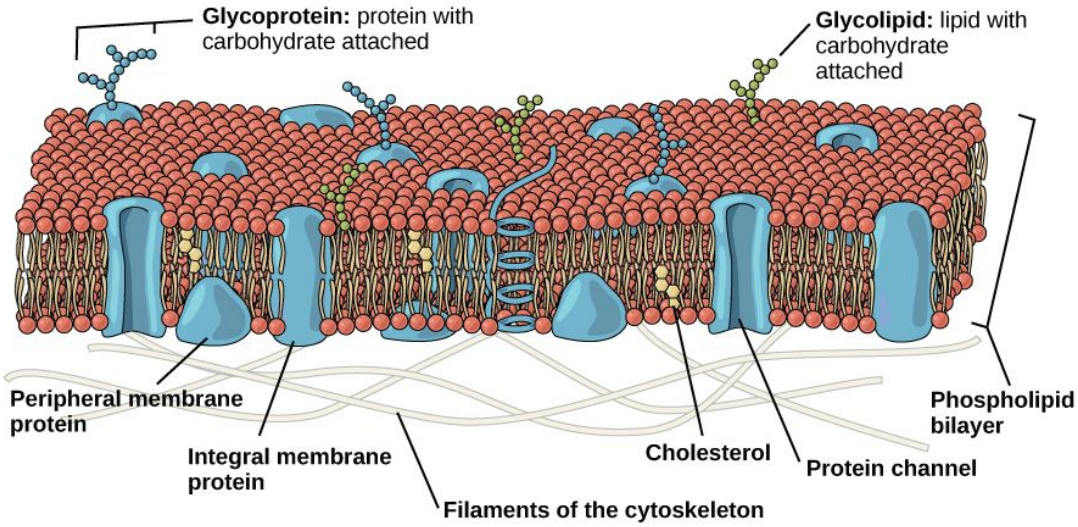
- Algal cells are similar to plant cells with the same organelles, including a cell wall and chloroplasts
- Fungal cells are also very similar but have have two key differences:
  - Their cell walls are made of chitin and not cellulose
  - They don't have chloroplasts because they don't photosynthesise

Algae carry out photosynthesis like plants but they can be single-celled or multicellular. Fungi include yeast and mushrooms.

Organelles and Their Functions

Below is a big list of organelles, including their structure and function. **You will need to know all of these for your exams**. Most organelles are surrounded by **membranes** - don't confuse a diagram of an organelle as a diagram of a whole cell. They are only **parts of cells**.

Cell Membrane (Plasma Membrane)

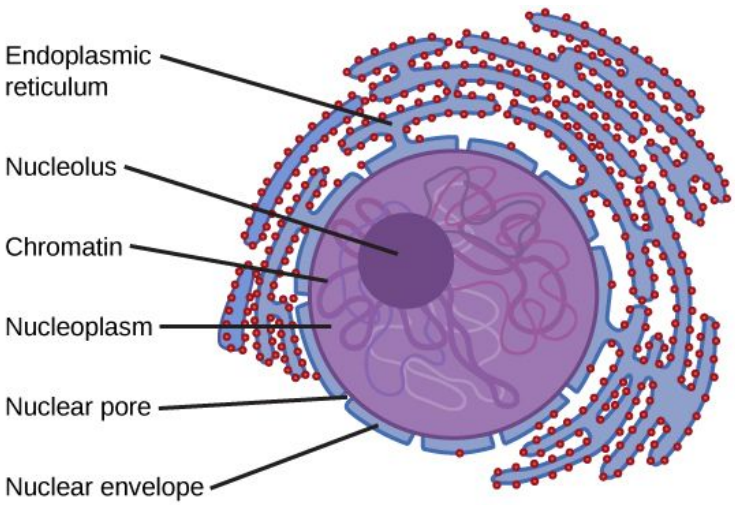


This membrane is found on the **surface** of animal cells and **just inside the cell wall** of other cells. It's made mostly of **lipids** and **protein**.

The cell membrane **regulates the movement** of substances into and out of the cell. **Receptor molecules** on the membrane allow it to respond to chemicals like hormones.

Nucleus

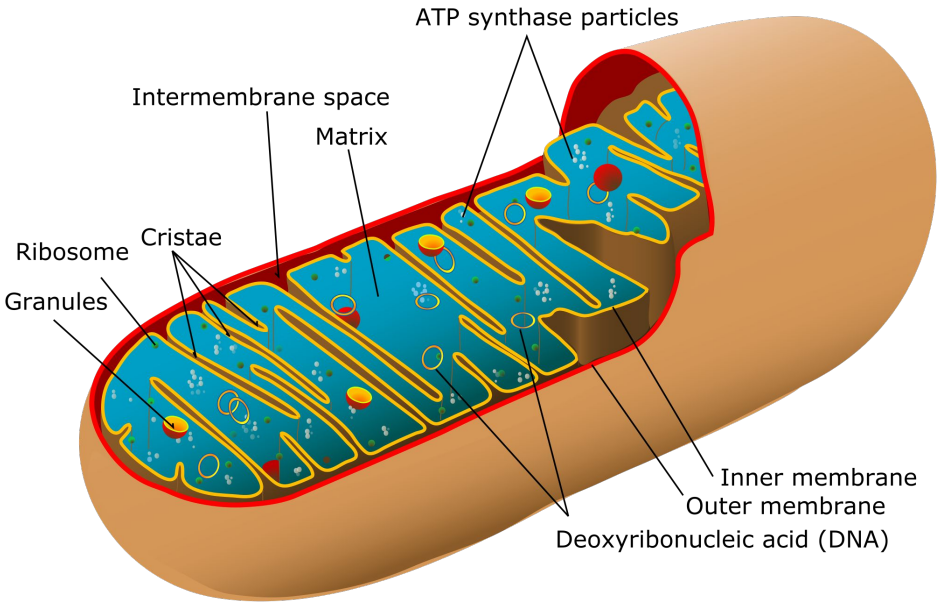
This is the **largest organelle** that is surrounded by a nuclear envelope which contains many **pores**. The nucleus contains chromosomes made from **protein-bound linear DNA** and one or more structures called **nucleolus**.



The nucleus **controls cell activity** through transcription of DNA - which contain instructions to make protein. The **pores** allow substances (i.e RNA) to move between the nucleus and the cytoplasm. The **nucleolus** makes **ribosomes**.

Organelles and Their Functions

Mitochondrion



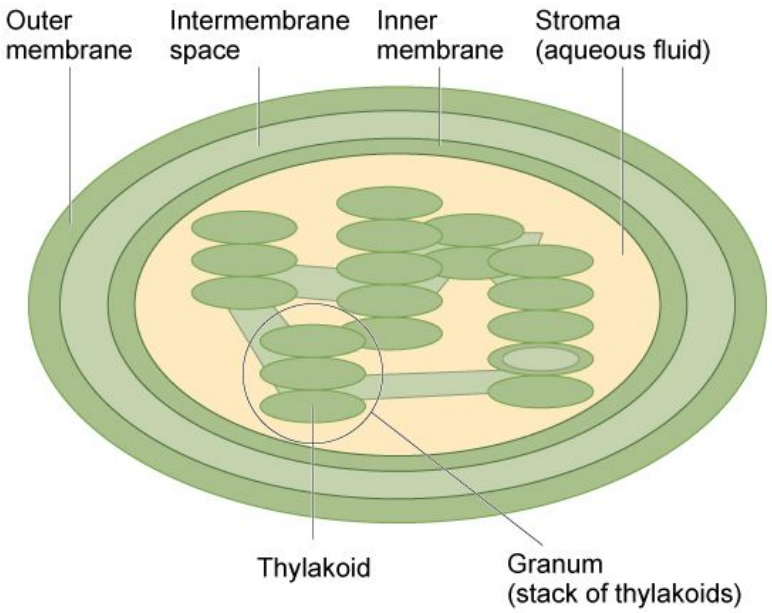
This is an **oval** or **rod-shaped** organelle that has a **double membrane**. The inner membrane is folded to form structures called **cristae**. Inside is the **matrix**, which contains **enzymes** involved in respiration.

Mitochondrion is the site of **aerobic respiration** where **ATP** is produced. They are found in large numbers in very **active** cells and require a **lot of energy**.

Chloroplast

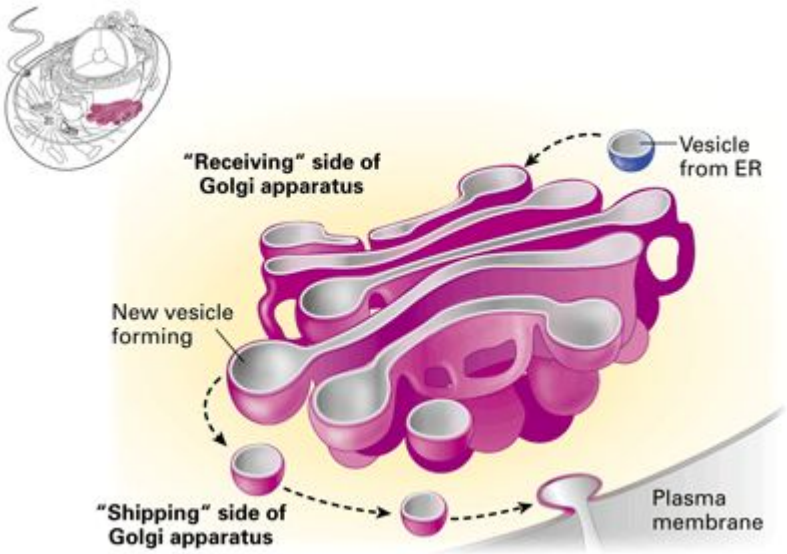
Chloroplast is a **small**, **flattened** structure found in **plant** and **algal** cells. Surrounded by a double membrane with membranes inside called **thylakoid membranes**. These stack up to form **grana**. Grana are linked together by **lamellae** which are thin, flat pieces of t**hylakoid membrane**.

Chloroplast is the site where **photosynthesis** takes place. Some parts of that process happen in the **grana**, and others happen in the **stroma**, which is a **thick liquid** found in chloroplasts.



Organelles and Their Functions

Golgi Apparatus



A series of **fluid filled**, flattened **membrane sacs**. **Vesicles** are often seen at the edges of the sacs.

The golgi apparatus (or golgi body) **processes** and **packages** new lipids and proteins. It also **makes lysosomes**.

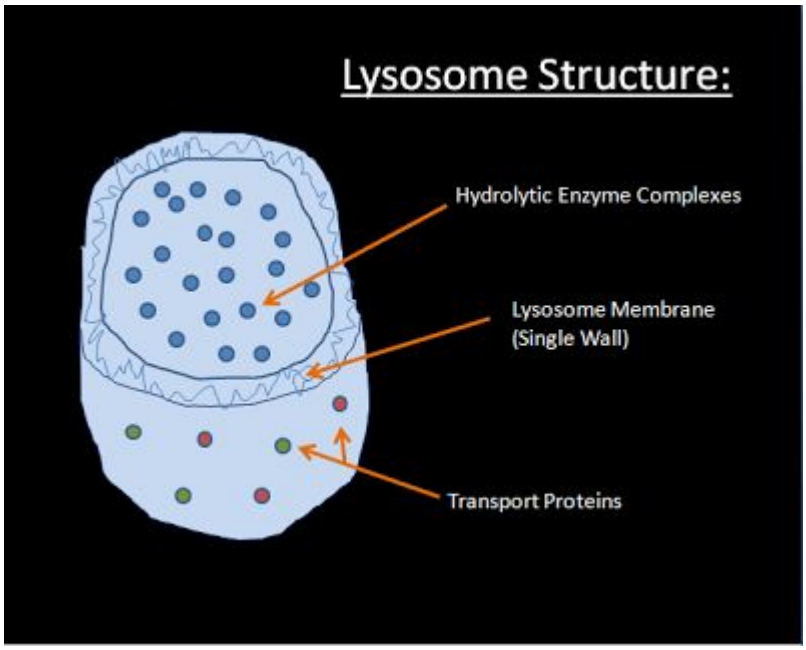
Golgi Vesicle

This is a small fluid-filled sac (see diagram above) found in the **cytoplasm**. It is surrounded by a membrane and **is produced by the Golgi apparatus**.

The vesicle stored **lipids** and **proteins** made by the Golgi apparatus and then **transports** them out of the cell through the **cell-surface membrane**.

Organelles and Their Functions

Lysosome



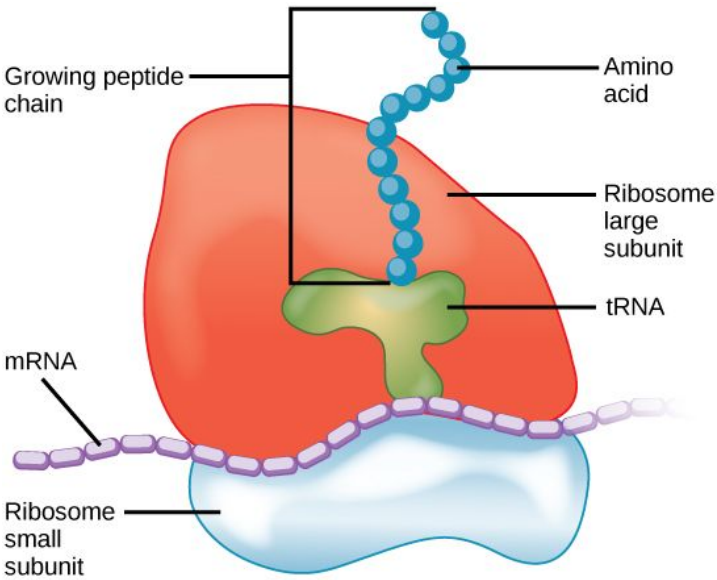
These are **small**, **round** organelles surrounded by a membrane and with **no clear internal structure.** Lysosome is a type of **Golgi vesicle**.

They contain the digestive enzymes **lysozymes**. The enzymes are kept separate from the **cytoplasm** by the membrane and can be used to **digest invading cells** or **break down** worn out components of the cell wall.

Ribosome

The **smallest** and most **numerous** of the cell organelles - ribosomes either **float free** in the cytoplasm or are attached to the **rough endoplasmic reticulum**.

It's made up of **proteins** and **RNA**, is **not** surrounded by a membrane and is the **site** where **proteins** are made.



Organelles and Their Functions

Rough Endoplasmic Reticulum (RER)

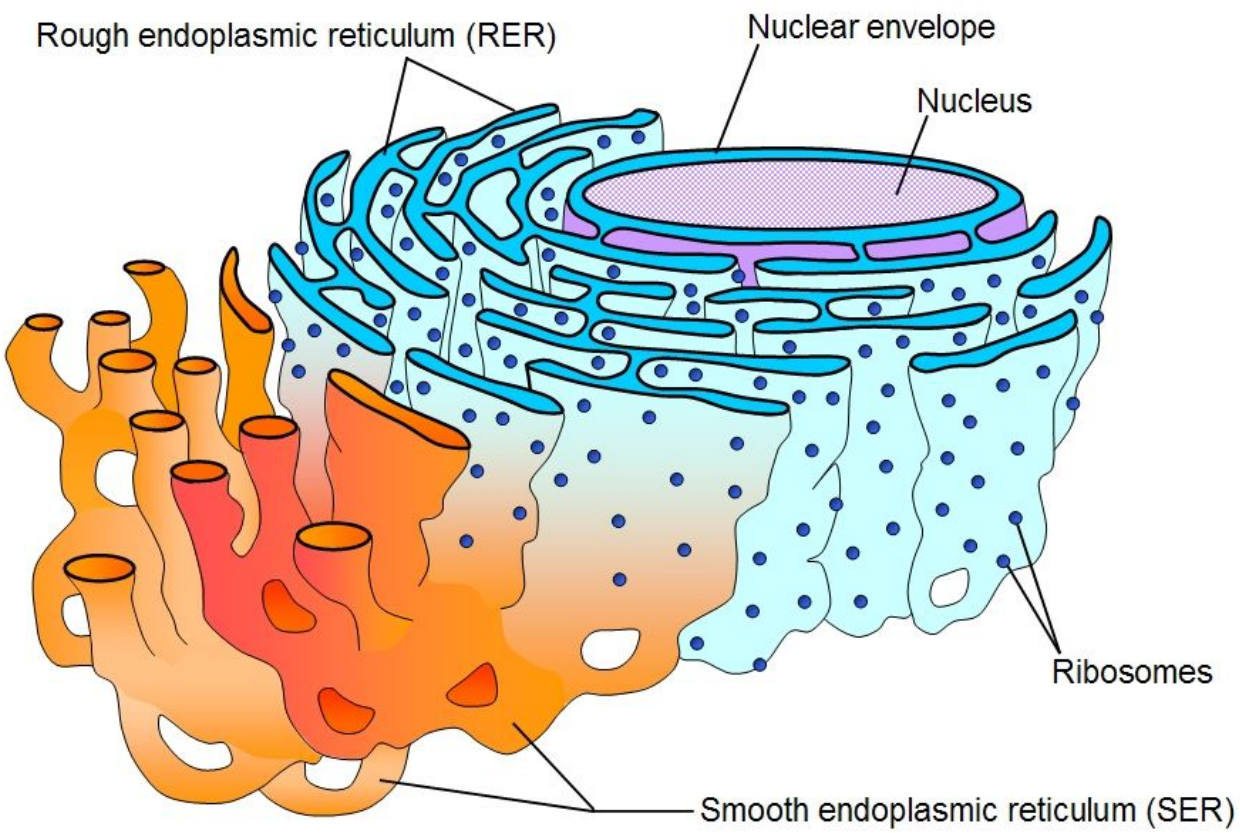
This is a system of membranes that enclose a fluid-filled space. T**he surface is covered with ribosomes.**

RER **folds** and **processes the proteins** that have been produced at the ribosomes.

Smooth Endoplasmic Reticulum (SER)

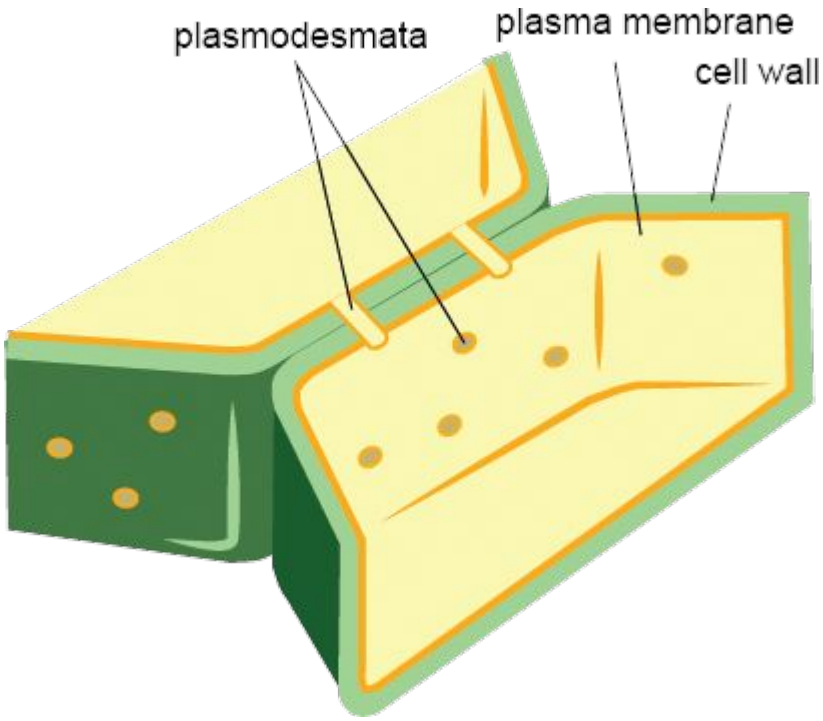
Very similar to rough endoplasmic reticulum, except that **no ribosomes are present.**

SER **synthesises** and processes **lipids**.



Organelles and Their Functions

Cell Wall



The cell wall is a **rigid** structure that surrounds cells in **plants**, **algae** and **fungi**. It's made mainly of the carbohydrate **cellulose** in plant and algae cells. In fungi, the cell wall is made of **chitin**.

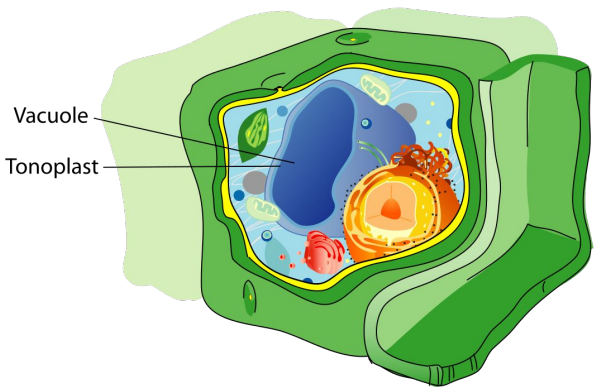
Its primary function is to **support cells** and prevent them from **changing shape**.

Cell Vacuole

A membrane bound organelle found in the **cytoplasm** of plant cells. It contains a weak solution of sugars and salts called **cell sap**. The membrane surrounding plant cell vacuoles is called the **tonoplast**.

They help to **maintain pressure** inside the cell and keep it **rigid**.

The vacuole is also involved in **isolating unwanted chemicals** in the cell.



3.2.1 Cell structure

3.2.1.2 Structure of prokaryotic cells and of viruses

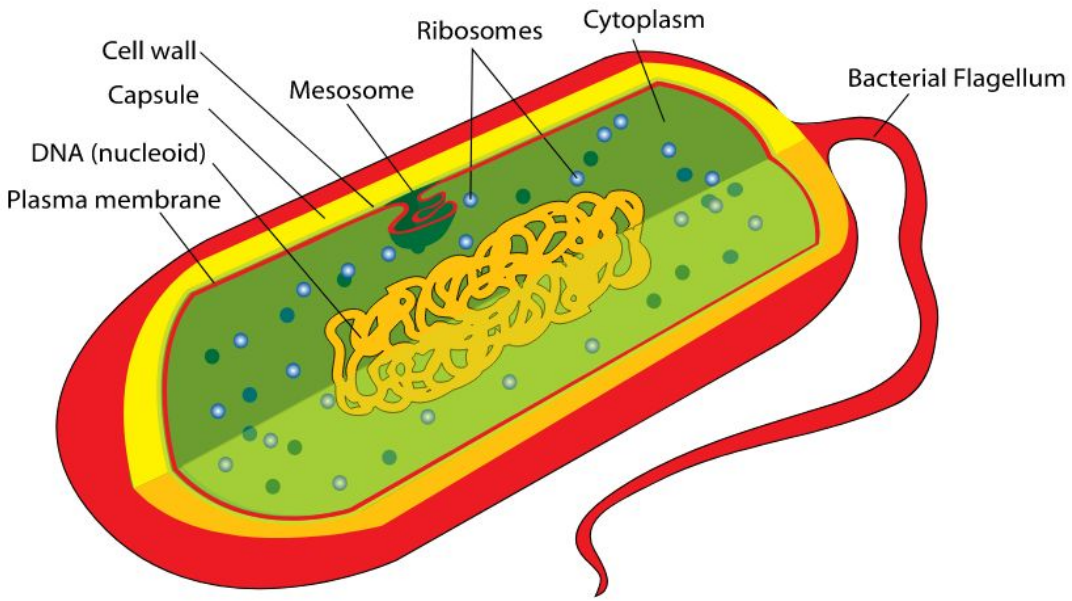
SPECIFICATION

- Prokaryotic cells are much smaller than eukaryotic cells. They also differ from eukaryotic cells in having:
  - cytoplasm that lacks membrane-bound organelles
  - smaller ribosomes
  - 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:
  - one or more plasmids
  - a capsule surrounding the cell
  - one or more flagella.
- Details of these structural differences are not required.
- Viruses are acellular and non-living. The structure of virus particles to include genetic material, capsid and attachment protein.

Source: AQA Spec

Prokaryotic Cells and Viruses

Prokaryotic cells are **smaller** and simpler than **eukaryotic** cells. **Bacteria** are a good example of prokaryotic cells. For your exams you will need to know the **structure** of a prokaryotic cell and what the different **organelles** do.



Cytoplasm

The cytoplasm in prokaryotic cells doesn't have membrane-bound organelles. It does contain **ribosomes** and they are **smaller** than those in a eukaryotic cell.

Plasma membrane

This membrane is made mostly from **lipids** and **proteins** - just like a eukaryotic cell. It controls movement of substances into and out of the cell.

DNA (nucleoid)

Unlike eukaryotic cells, a prokaryotic cell **doesn't have a nucleus**. The DNA is always circular and **floats free** in the cytoplasm as a long, **coiled strand** and is **not attached** to any proteins to form chromatin.

Plasmid

These are small circles of **DNA** that are not part of the main DNA molecule. They contain **genes** (for things like antibiotic resistance) and can be passed between cells. They are not always present in prokaryotic cells and some cells can have several of them.

Prokaryotic Cells and Viruses

Mesosome

A tightly-folded region of the cell membrane containing all the membrane- bound proteins required for **respiration** and **photosynthesis**. Can also be associated with the **nucleoid** (DNA).

Cell wall

This is made from a polymer called **murein** (not cellulose), which is a **glycoprotein** - a protein with a carbohydrate attached.

There are two kinds of cell wall, which can be distinguished by a **Gram stain**: Gram **positive** bacteria have a thick cell wall and stain purple, while Gram **negative** bacteria have a thin cell wall with an outer lipid layer and stain pink.

Capsule (or slime layer)

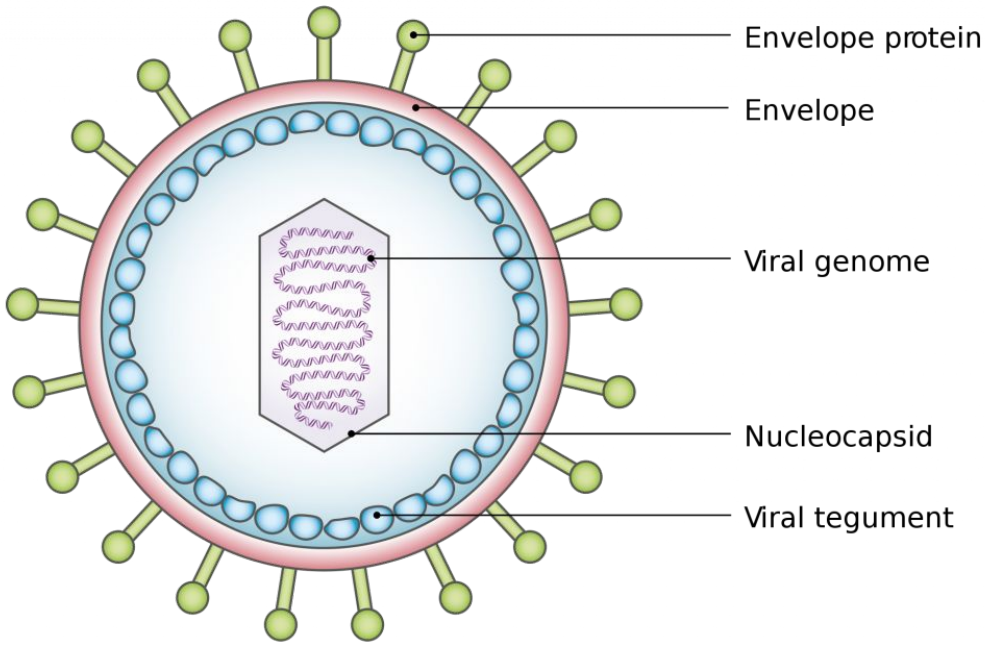
This is a thick **polysaccharide** layer outside of the cell wall, like the glycocalyx of eukaryotes. Used for sticking cells together, as a food reserve, as protection against desiccation and chemicals, and as protection against phagocytosis.

Flagellum

A rigid rotating **helical-shaped tail** used to make the **cell move**. The motor is embedded in the cell membrane and is driven by a H+ gradient across the membrane. Clockwise rotation drives the cell forwards, while anticlockwise rotation causes a chaotic spin. This is the only known example of a rotating motor in nature. Not all prokaryotic cells have a flagellum but some cells have more than one.

Viruses are Acellular - They Are Not Cells

- A virus is just **nucleic acid** surrounded by protein - they are **not alive**.
- They are even **smaller than bacteria**. HIV is only about 0.1 μm across.
- Viruses **do not** have a plasma membrane, cytoplasm or ribosomes
- All viruses will invade and reproduce inside the cells of other organisms - known as **host cells**.



Nucleic acid

Viruses contain a core genetic material made up of either DNA or RNA. Viruses are classified according to the type of nucleic acid they contain.

Capsid (nucleocapsid)

This is a protein coat that surrounds the core of the virus.

Envelope protein (attachment protein)

These are also referred to as **attachment proteins** and they stick out from the edge to let the virus cling to a suitable host cell.

3.2.1 Cell structure

3.2.1.3 Methods of studying cells

SPECIFICATION

- The principles and limitations of optical microscopes, transmission electron microscopes and scanning electron microscopes.
- Measuring the size of an object viewed with an optical microscope. The difference between magnification and resolution.
- Use of the formula:

$$magnification = size\ of\ image / size\ of\ real\ object$$

- Principles of cell fractionation and ultracentrifugation as used to separate cell components.
- **Students should be able to** appreciate that there was a considerable period of time during which the scientific community distinguished between artefacts and cell organelles.

Source: AQA Spec

Magnification and Resolution

To see cells and the organelles found within them, you need to use a microscope. Microscopes produce a **magnified image** of a cell sample, but the **resolution** is equally important.

Magnification

Magnification is how much **bigger** the image appears than the specimen sample is. It's calculated using this formula:

$$magnification = \frac{size\ of\ image}{size\ of\ real\ object}$$

Resolution

The resolution is how **detailed** the image is. The better the resolution, the better the microscope is able to distinguish between two points that are close together.

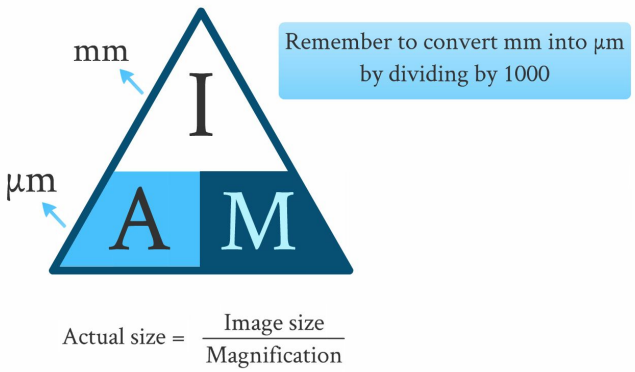
If a microscope cannot separate two objects, more magnification will not help to see them.

Magnification example

Your magnified image is 15mm wide and the actual size of the cell is 0.015mm. What is the magnification?

magnification = 15 ÷ 0.015 = ***x 1000 magnification***

- If no scale bar is given, use the formula *actual size = image ÷ size magnification*
- If you are given the size of the image and the size of the sample in different units in your exam you will need to convert them into the same units before using the formula.
- You also need to be able to rearrange the formula and look for the units required in the answer



Converting between units

cm —*x10*→ mm —*x1000*→ µm —*x1000*→ nm

Optical and Electron Microscopes

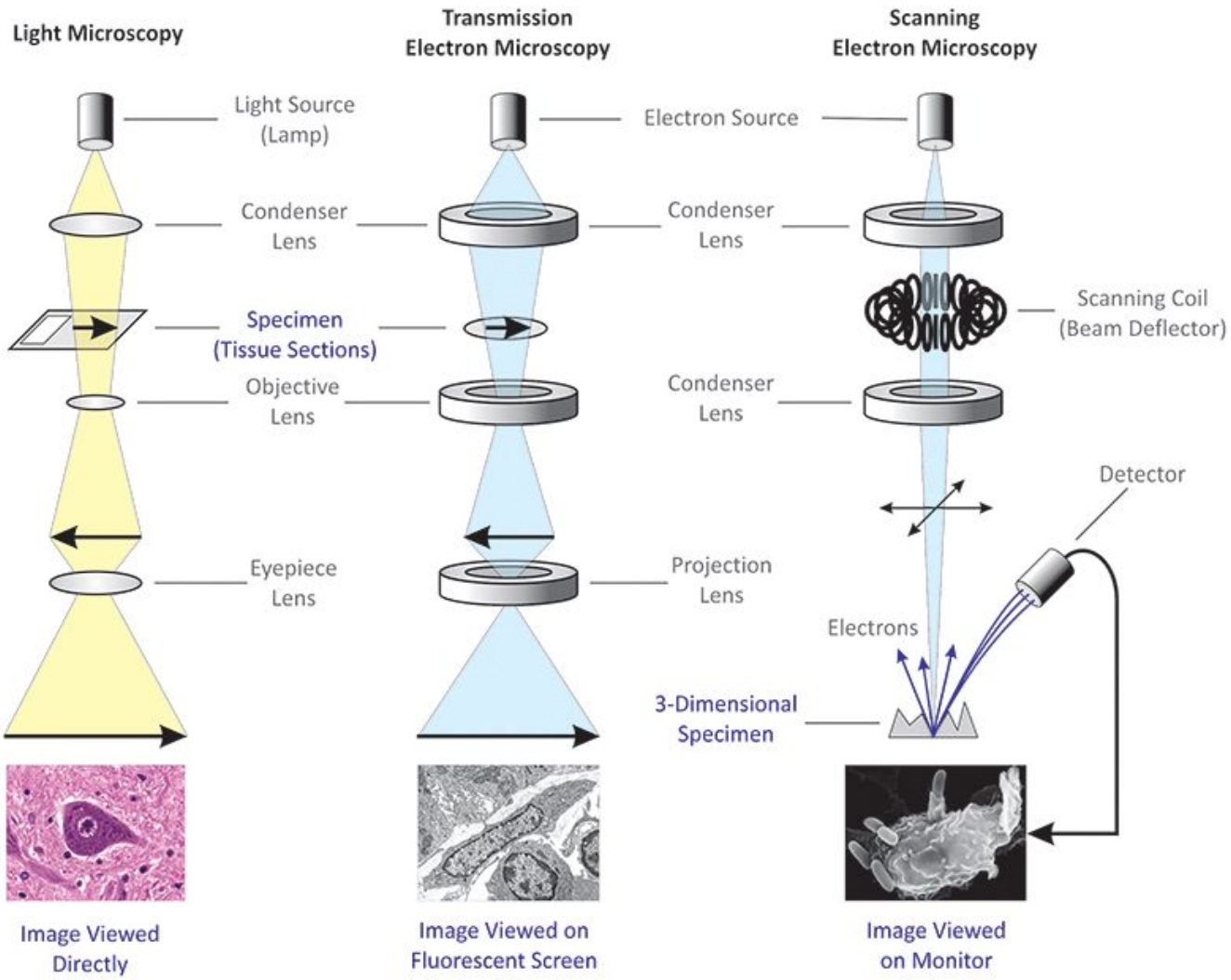
There are two types of microscopes used when studying cells: **optical** (light) microscopes and **electron** microscopes.

Optical (light) microscopes

1. Uses a **light** to form the image
2. Has a maximum resolution of about **0.2 micrometres** (μm). You cannot view organelles that are smaller than 0.2μm - including **ribosomes**, the **endoplasmic reticulum** and **lysosomes**. **Mitochondria** may be visible but not clear. You can see the **nucleus**.
3. Maximum useful **magnification** of optical microscopes is about **x 1500.**

Electron microscopes

1. Uses **electrons** to form an image.
2. Has a **higher resolution** than optical microscopes to give a **more detailed image** (and can be used to view all organelles)
3. Maximum resolution of about **0.0002 micrometres** (μm) - about 1000 times higher than optical.
4. Maximum useful **magnification** of an electron microscope is about **x 1,500,000**.



Scanning or Transmission Electron Microscopes

There are two basic types of electron microscopes: t**ransmission electron microscope** (TEM) and the **scanning electron microscope** (SEM).

Transmission electron microscopes (TEMs)

1. Uses electromagnets to focus a beam of electrons which is transmitted through a specimen
2. The densest parts of the specimen absorb more electrons which makes them look darker
3. TEMs produce a high resolution image to see internal structure of organelles
4. They can only be used on thin specimens

Scanning electron microscopes (SEMs)

1. Scans a beam of electrons over the specimen that knocks off electrons that are gathered in a cathode ray tube to form an image
2. The images show the surface of the specimen and can be 3D
3. Good for use on thick specimens
4. SEMs give a lower resolution image than TEMs

Viewing specimens under an optical microscope

Step by step instructions for preparing a temporary mount of a specimen on a slide:

1. Pipette a drop of water onto the slide and use tweezers to place a thin section of the specimen on the drop
2. Add a drop of stain to highlight objects in the cell (e.g. eosin for cytoplasm, iodine in potassium iodine solution for starch grains in plant cells)
3. Add a cover slip (square of clear plastic) to protect the specimen. Stand the slip upright on the slide and tilt and lower it until the specimen is cover - making sure not to get any air bubbles under.

Cell Fractionation

To view some organelles under an electron microscope you need to separate them from the rest of the cell. This can be done using **cell fractionation** and there are three steps to this technique.

Step 1: Homogenisation - Breaking up the cells

Homogenisation can be done by **vibrating** the cells or by **grinding** them up. Both methods **break up** the plasma membrane and release the organelles into a solution that is **ice cold** to reduce enzyme activity that breaks down organelles. The solution also needs to be **isotonic**, which means to have the **same concentration of chemicals** as the cells being broken down to avoid damage to the organelles through **osmosis**. A **buffer** solution to **prevent pH changes** should also be used.

Step 2: Filtration - Getting rid of cell debris

The homogenised cell solution needs to be **filtered** through **gauze** so that any l**arge cell debris** like connective tissue is removed. Organelles are **much smaller** than the debris so they pass the gauze and don't get filtered.

Step 3: Ultracentrifugation - Separating the organelles

To separate a particular organelle from your homogenised solution, you use a process called ultracentrifugation:

1. Cell fragments are poured into a tube and the tube is put into a centrifuge (a machine which separates material by spinning). The solution is spun at low speed and the heaviest organelles, like nuclei, will get moved to the bottom by the centrifugal force. They form a thick sediment called the pellet and the rest of the organelles stay suspended in fluid above the sediment - this is called the supernatant.
2. Supernatant is drained off and poured into another tube which is then spun at a higher speed in the centrifuge. The next heaviest organelles (the mitochondria) form a pellet and the supernatant is drained off and spun again at even higher speed.
3. The whole process is repeated at higher and higher speeds until all of the organelles have been separated. Each time, the pellet at the bottom contains lighter and lighter organelles.

Diagram of Ultracentrifugation Process