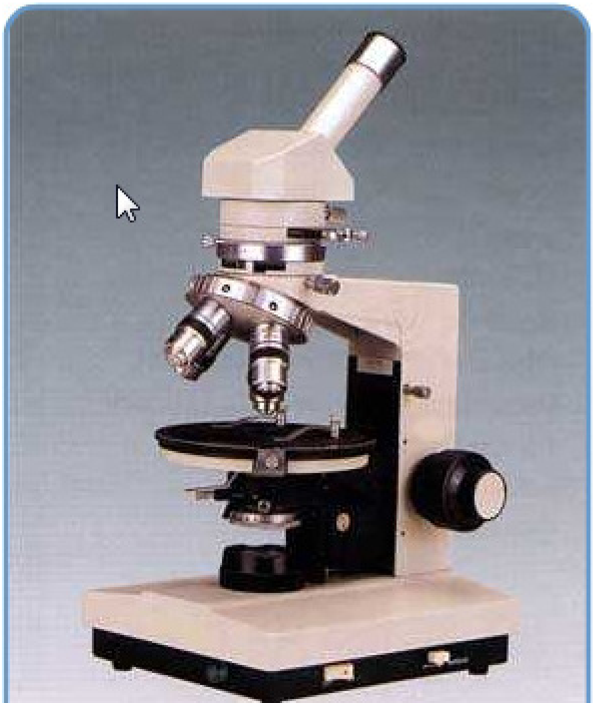
**Microscopes - magnification and resolution**

The cell is the basic unit of an organism and consists of a jelly-like material surrounded by a cell membrane.

It can be seen with a light microscope (LM) but many of the structures within a cell - **organelles** - can only be seen clearly with an electron microscope (EM). That is partly because an EM has a greater **magnifying power** (ability to enlarge something).


Microscope

However, increasing only magnification has its limits because at some point magnification reveals nothing more - the details only look bigger and vaguer. This is because if 2 objects are a distance of less than half the wavelength of light apart, they cannot be distinguished as separate by a LM. Any object less than half the wavelength of light in size will not be seen at all by a LM.

Using electrons instead of light means that the illumination has a much shorter wavelength than light. This is good because minute detail can be detected. We say that an EM has a bigger **resolving power** (bigger **resolution**) than an LM.

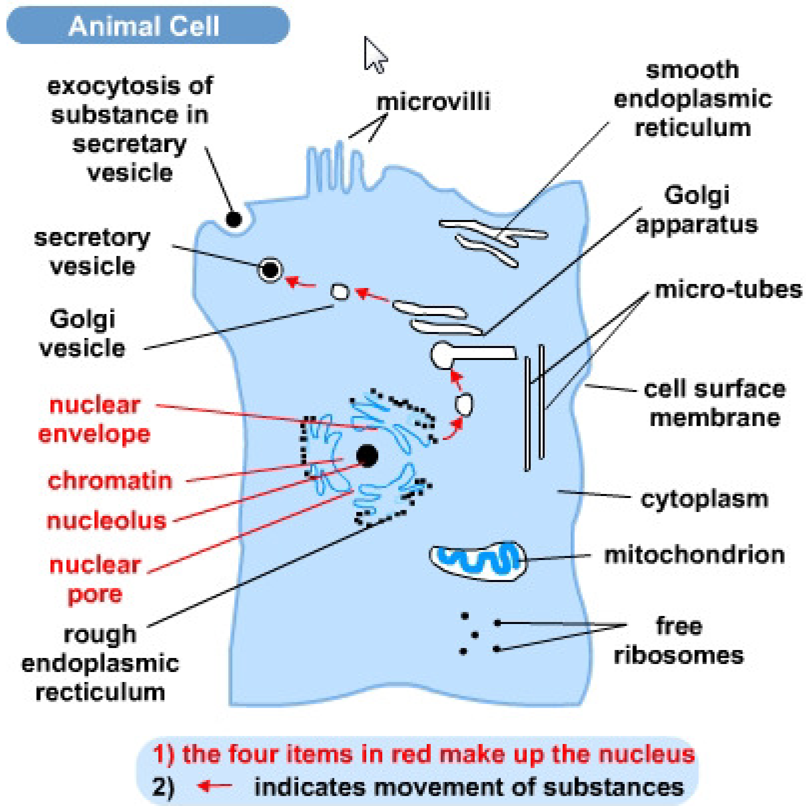
**Prokaryotic and eukaryotic cells**

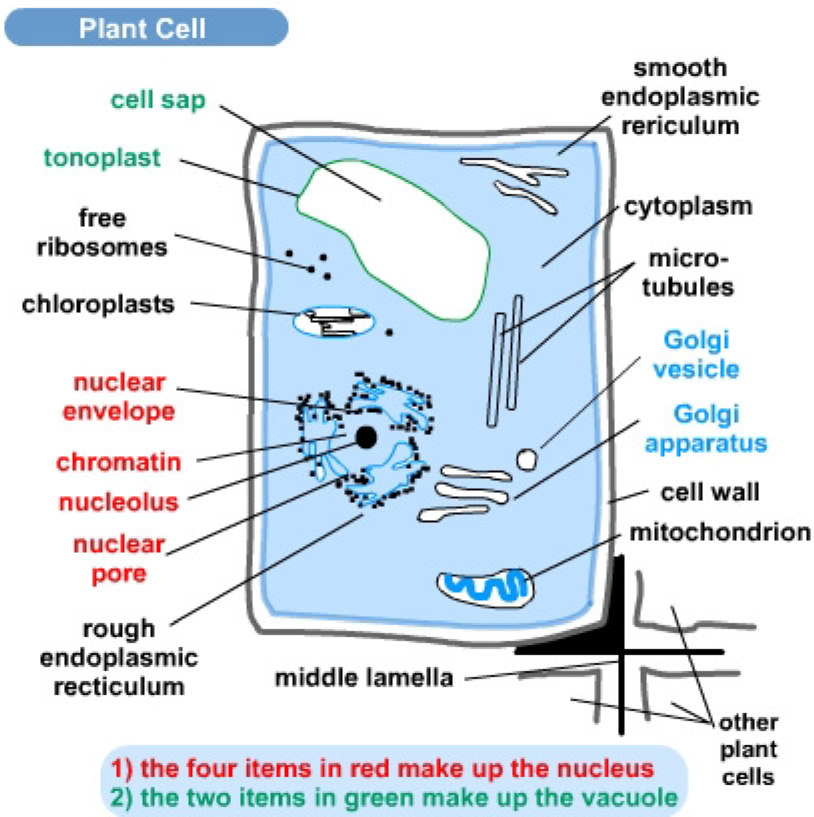
**There are 2 basic cell types:**

- **Prokaryotic**: bacteria and cyanobacteria (which used to be called blue-green algae).

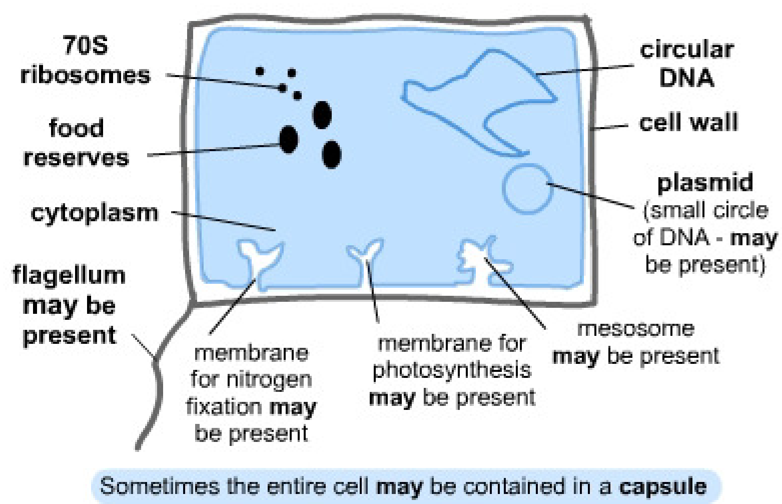
- **Eukaryotic**: all other cells, such as protoctista, fungi, plant and animal cells.

***Eukaryotic cells, i.e. animal and plant cells***.






*Prokaryotic cells - i.e. bacteria and cyanobacteria*.



| | Prokaryotic | Eukaryotic | |
|---|---|---|---|
| **Features** | | Plant | Animal |
| Size(diameter) | 0.5 - 5 µm | 40 µm | 15 µm |
| Cell wall | Yes (contains peptidoglycan) | Yes (contains cellulose) | No |
| Genetic Material | DNA is naked. A single circular molecule | DNA linear, associated with histones (proteins), in a nucleus, surrounded by a nuclear envelope. | |
| Ribosomes | 70S ribosomes (smaller) | 80S ribosomes (larger) | |
| ER, Golgi apparatus | No | Yes | |
| Mitochondria | No(respiration occurs on an infolding of the cell membrane called the mesosome.) | Yes | |
| Chloroplasts | No | Yes | No |

**Cytosol and Endoplasmic Reticulum (ER)**

**Cytoplasm** refers to the jelly-like material with organelles in it.

If the organelles were removed, the soluble part that would be left is called the **cytosol**. It consists mainly of water with dissolved substances such as amino acids in it.

Also present in the cytosol are larger proteins and enzymes used in reactions within the cell. Running through the cytosol is **endoplasmic reticulum (ER)**, a system of flattened cavities lined by a thin membrane. It is the site of the synthesis of many substances in the cell and so provides a compartmentalised area in which this takes place. The cavities also function as a transporting system whereby substances can move through them from one part of the cell to another.

There are 2 types of ER - **rough (RER)** and **smooth (SER)**. SER obviously looks as though it has a smooth surface. It is where lipids and steroids are made so you would expect there to be a lot of SER in liver cells where lipid is metabolised.

RER looks rough on the surface because it is studded with very small organelles called **ribosomes**. Ribosomes are made of **RNA** and protein and are the site of protein synthesis (see DNA and Genetic Code).

There may be free ribosomes in the cytoplasm as well, which also are the site of protein synthesis. The proteins (which include enzymes) that are synthesised then move into the cavities of the RER to be transported.

**Golgi apparatus**

The **Golgi apparatus** is a series of flattened layers of plate-like membranes.

The proteins that are made by the RER for export from the cell are pinched off at the end of the cavity of the RER, so that a layer of membrane surrounds them. The whole structure is called a vesicle. This vesicle will move through the cytosol and fuse with the membrane of the Golgi apparatus.

In the cavity of the Golgi apparatus, the vessel proteins are modified for export - for example, by having a carbohydrate added to the protein. At the end of a Golgi cavity, the secretory product is pinched off so that the vesicle containing the substance can move through the cytosol to the cell surface membrane.

The vesicle will fuse with this membrane and so release the secretory product. If the vesicle contains digestive enzymes, it is called a **lysosome**. Lysosomes may be used inside the cell during endocytosis, or to break-down old, redundant organelles.

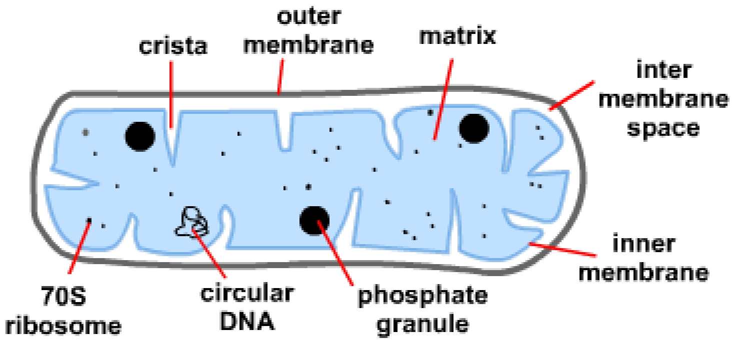
**Mitochondria**

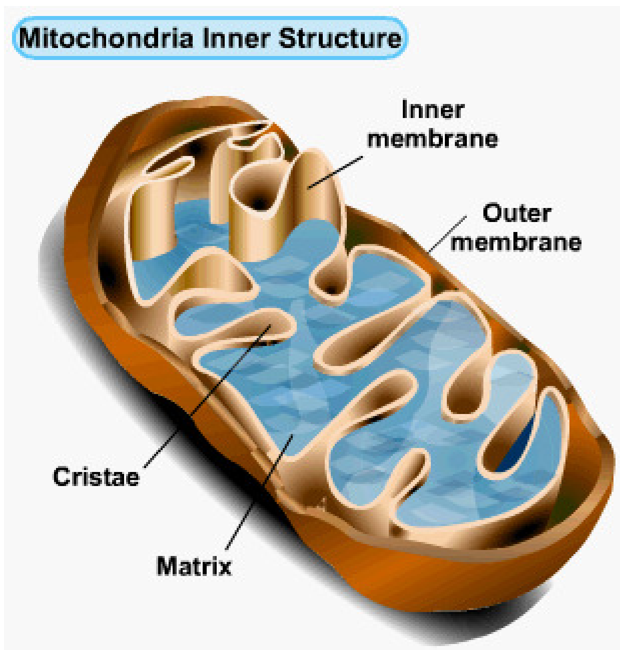
A typical cell may contain 1,000 mitochondria, though some will contain many more. Generally, they are sausage-shaped organelles whose walls consist of **2 membranes**.

The inner membrane is folded inwards to form projections called **cristae**. Inside this is the **matrix**.

Most of the reactions for aerobic respiration take place in the mitochondria so it is an incredibly important organelle.

During respiration, ATP is produced, which is used to provide energy for the cells' reactions. Most of the ATP is produced on the inner mitochondrial membrane.It is highly folded so there is maximum surface area available.



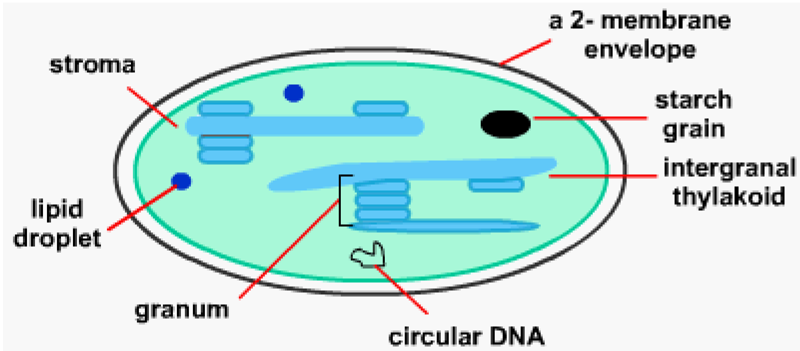

**Cell wall and chloroplasts**

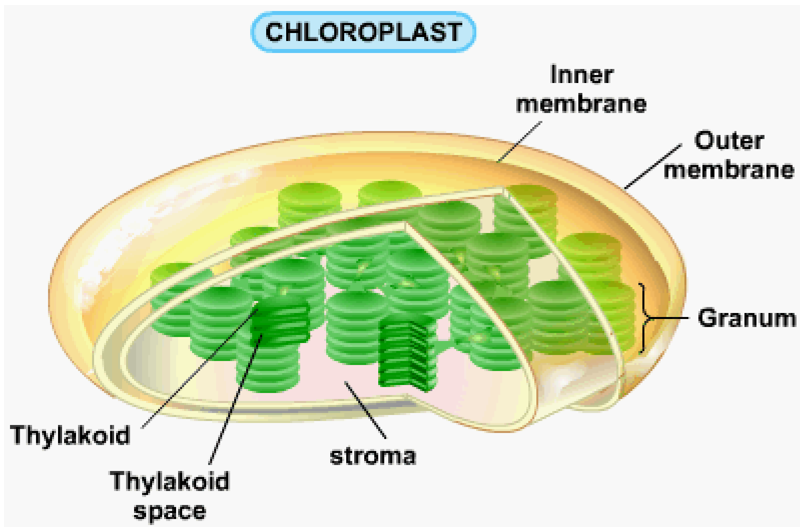
These are only found in plant cells.

Chloroplasts will be discussed in photosynthesis - but, like the mitochondria - they have an **envelope** of two membranes making up the outer "wall".

They have pairs of membranes called **thylakoids** arranged in stacks, each stack being called a **granum**. Connecting different grana together are **inter-granal thylakoids**. Surrounding the internal membranes, inside the envelope is the **stroma**.

The reactions of photosynthesis take place in the membranes and stroma of the chloroplast.




The cell wall is rigid and made of **cellulose fibres** running through a mixture of other polysaccharides (more complex sugars) such as pectins and hemicelluloses.

The sticky **middle lamella** that holds next-door cells together is made of calcium pectate and magnesium pectate.

In young cells, the cellulose fibrils of the primary cell wall run parallel to each other. In older cells, a secondary cell wall may be laid down where the fibres are all parallel to each other, but at a different angle to those of the primary cell wall.

The cell wall is fully permeable unless a substance called **lignin** is deposited in the cellulose layers. Lignin makes the cell wall very strong and resistant to strain but it also makes it impermeable. If all the gaps between the fibres are filled in, the wall becomes completely impermeable and the cell will die.

**Nucleus**

The nucleus is separated from the surrounding cytoplasm by the double membrane around it, the **nuclear envelope**. This regulates the flow of substances into and out of the nucleus.

At some points around the nucleus, the 2 membranes fuse to create **nuclear pores** - these are channels through which substances can move. The outer of the 2 membranes is continuous with the ER.

Within the nuclear envelope is the nucleoplasm. In this are suspended thread-like chromosomes (for chromosome structure see DNA and Genetic Code).

Another structure within the nucleus is the nucleolus. The RNA, which will be made into ribosomes, is synthesised in the nucleolus.

**Other organelles**

**Vacuole**: a fluid-filled space in the cytoplasm surrounded by a membrane called the **tonoplast**. It contains a solution of sugars and salts called the cell **sap**.

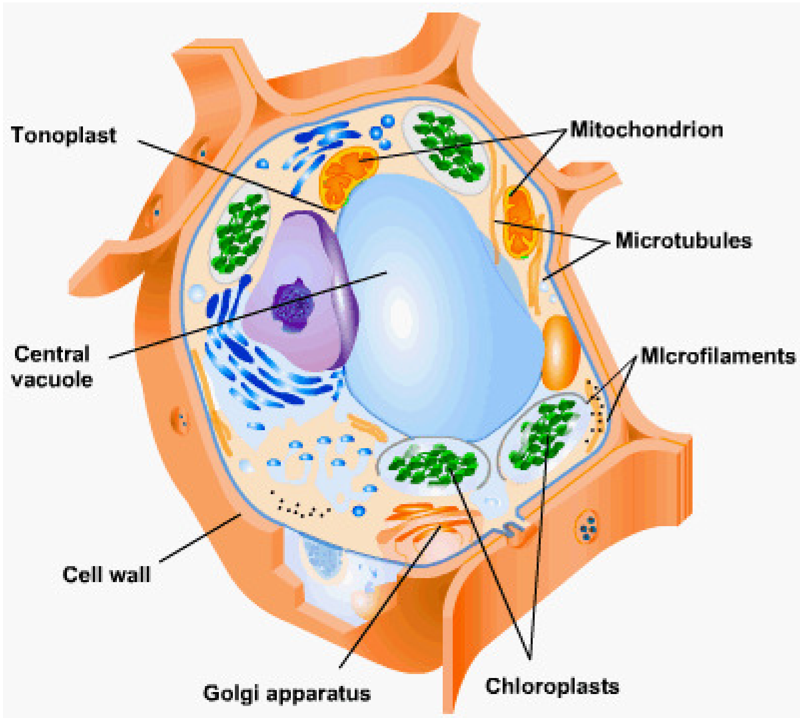
**Microtubules**: hollow rod-like structures with walls of tubulin protein. They provide the structural support of cells and can aid transport through the cell.

**Microfilaments**: rod-like structures made of contractile protein. Again, like microtubules, provide support and aid movement.

**Centrioles**: a pair of short hollow cylinders, usually found near the nucleus of an animal cell. They are involved in the formation of spindle fibres used in mitosis (see **Reproduction and Cell Cycle Learn-it**).

**Cilia**: hollow tubes extending outside some cells. They move fluid, which is outside the cell - for example, ciliated cells lining the respiratory tract move mucus, away from the lungs.

**Flagella**: similar to cilia, though longer. Used in the movement of the whole cell. The only structure like this in humans is the tails of the sperm.




**Investigating the function of cell organelles**

To obtain reliable information about the activity of an organelle, it is necessary to isolate it and test it individually.

First the cells are broken open or cell fractionation occurs to produce a homogenate or suspension. This is done using a blender with the cells in an isotonic, cold solution. Because the solution is isotonic, the organelles neither gain, or loose water by osmosis and as it is cold, the action of enzymes, which might damage the organelles, is prevented.

Differential centrifugation of the suspension is then carried out. A tube containing the suspension is spun in a centrifuge at a speed, which causes the heaviest organelles to be thrown to the bottom, forming a sediment. The other lighter organelles remain floating in the clear supernatant fluid above the sediment.

The sediment may be removed and the activity of the heaviest organelles such as the nucleus, determined. The supernatant may then be spun at a faster speed so that lighter organelles like the mitochondria sediment out.

# Endosymbiotic Theory

- **The mitochondrion consumes oxygen** to efficiently extract energy from carbon sources like glucose, producing carbon dioxide and water in the process.
- **The chloroplast consumes water and carbon dioxide** as it captures energy from light and funnels it into the chemical energy of glucose, releasing oxygen in the process.

**Endosymbiotic theory** proposes that these organelles were once prokaryotic cells, living inside larger host cells. The prokaryotes may initially have been parasites or even an intended meal for the larger cell, somehow escaping digestion.

Whatever the cause of their initial internment, these prokaryotes might soon have become willing prisoners to a grateful warden. The prisoner prokaryotes might have provided crucial nutrients (in the case of the primitive chloroplast) or helped to exploit oxygen for extracting energy (in the case of the primitive mitochondrion). The prokaryotes, in turn, would have received protection and a steady environment in which to live.

Multiple lines of evidence support the endosymbiotic theory. Endosymbiosis is observed elsewhere in biology. Mitochondria and chloroplasts have intriguing similarities in structure, reproduction, biochemistry, and genetic makeup to certain prokaryotes. The plain fact that mitochondria and chloroplasts have any genetic information of their own argues in favor of the theory.

Because virtually all eukaryotes have some sort of mitochondria, while only photosynthetic eukaryotes have chloroplasts, it has been proposed that endosymbiosis occurred twice, in series. First, an aerobic (oxygen-using) heterotrophic prokaryote was taken in by a larger host cell. In time, the prokaryote co-evolved with the host, eventually becoming something like a mitochondrion. Next, a photosynthetic prokaryote was taken in by a mitochondrion-containing cell. This model of eukaryote origins is called *serial endosymbiosis.*