Cell

Kamrun Nahar, PhD
Associate Professor
Department of Agricultural Botany
Faculty of Agriculture
Sher-e-Bangla Agricultural University, Dhaka

The Cell

1665- English Scientist, **Robert Hooke**, **"discovered cells"** while looking at a thin slice of cork. The word cell, meaning "little room," was introduced by Robert Hooke to describe the small cavities separated by cell walls in cork tissue. Cell is the structural and functional unit of any organism.

Prokaryotic and Eukaryotic Cell

Based on the presence of a nucleus or membrane-bound organelles, cells are broadly classified as Prokaryotic cells or Eukaryotic cells.

The prokaryotes (pro, before; karyon, nucleus) are represented by Bacteria, including the cyanobacteria, and the eukaryotes (eu, true; karyon, nucleus) by all other living organisms.

Prokaryotic cells lack both, a well-defined nucleus and membrane-bound cell organelles. Examples of prokaryotes are blue-green algae, bacteria and mycoplasma.

Eukaryotic cells are defined as cells containing organized nucleus and organelles which are enveloped by membrane-bound organelles. Examples of eukaryotic cells are plants, animals, protists, fungi.

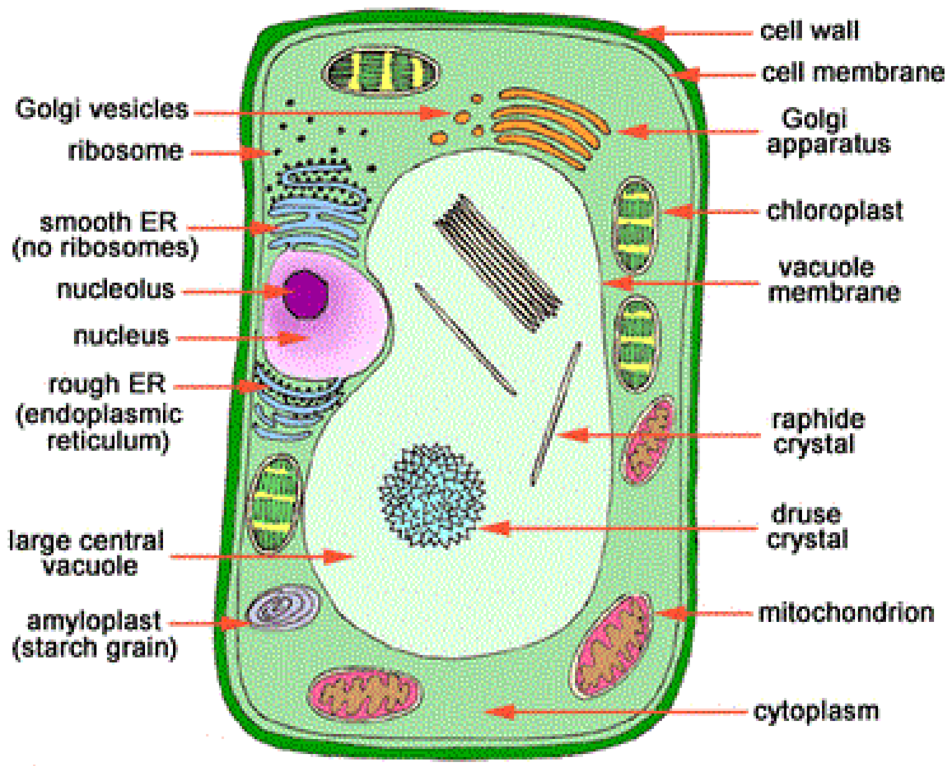


Fig.: Structural components of plant cell

An Inventory of Plant Cell Components

The cell wall is not living while the protoplast is living.

Cell components	
A. Cell Wall Middle lamella Primary wall Secondary wall Plasmodesmata	
B. Protoplasm **a. Cell membrane** **b. Nucleus** Nuclear envelope Nucleoplasm Chromatin Nucleolus **c. Cytoplasm** 1. Cytosol (cytoplasmic ground substance, hyaloplasm) 2. Utrastructural organelles **Organelles bounded by two membranes:** i) Plastids ii) Mitochondria **Organelles bounded by one membrane:** i) Peroxisomes ii) Vacuoles, bounded by tonoplast iii) Ribosomes **Endomembrane system (major components):** i) Endoplasmic reticulum ii) Golgi apparatus iii) Vesicles **Cytoskeleton:** Microtubules Actin filaments	

Cell Wall

The structure of cell-wall

The walls of mature plant cells are differentiated into **middle lamella, primary cell wall, secondary cell wall**.

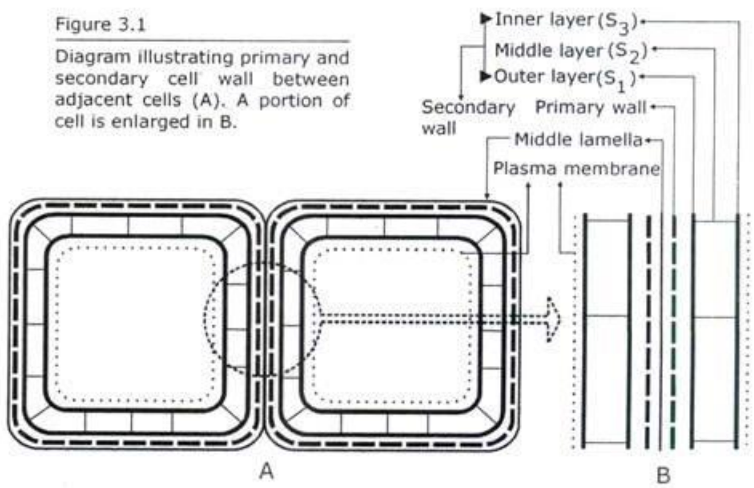


Fig: Cell Wall

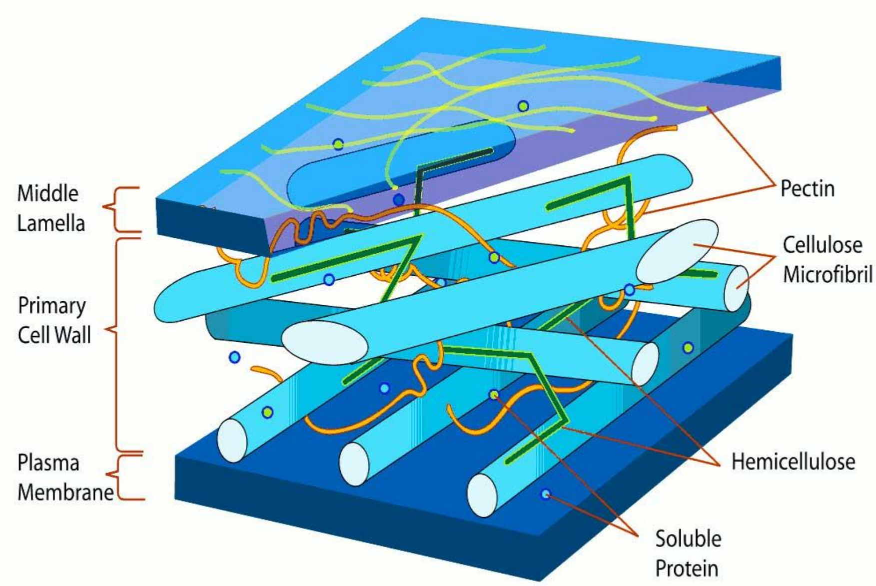


Fig: Cell Wall

Plant Cell Wall Structure

The plant cell wall is multi-layered and consists of up to three sections. From the outermost layer of the cell wall, these layers are identified as the middle lamella, primary cell wall, and secondary cell wall. While all plant cells have a middle lamella and primary cell wall, not all have a secondary cell wall.

- **Middle lamella:** This contains polysaccharides called pectins. Pectins aid in cell adhesion by helping the cell walls of adjacent cells to bind to one another.

- **Primary cell wall:** This layer is formed between the middle lamella and plasma membrane in growing plant cells. It is primarily composed of cellulose microfibrils contained within a gel-like matrix of hemicellulose fibers and pectin polysaccharides. The primary cell wall provides the strength and flexibility needed to allow for cell growth.
- During development of middle lamella and primary wall, certain openings are left at places between the adjacent cells. These are called plasmodesmata. Through these pores cytoplasmic continuity is maintained between the neighboring cells.
- **Secondary cell wall:** This layer is formed between the primary cell wall and plasma membrane in some plant cells. Once the primary cell wall has stopped dividing and growing, it may thicken to form a secondary cell wall. This rigid layer strengthens and supports the cell. In addition to cellulose and hemicellulose, some secondary cell walls contain lignin. Lignin strengthens the cell wall and aids in water conductivity in plant vascular tissue cells.

Plant Cell Wall Function

A major role of the cell wall is to form a framework for the cell to prevent over expansion. Cellulose fibers, structural proteins, and other polysaccharides help to maintain the shape and form of the cell. Additional **functions of the cell wall** include:

- **Support:** The cell wall provides mechanical strength and support. It also controls the direction of cell growth.
- **Withstand turgor pressure:** Turgor pressure is the force exerted against the cell wall as the contents of the cell push the plasma membrane against the cell wall. This pressure helps a plant to remain rigid and erect, but can also cause a cell to rupture.
- **Regulate growth:** The cell wall sends signals for the cell to enter the cell cycle in order to divide and grow.
- **Regulate diffusion:** The cell wall is porous allowing some substances, including proteins, to pass into the cell while keeping other substances out.
- **Communication:** Cells communicate with one another via plasmodesmata (pores or channels between plant cell walls that allow molecules and communication signals to pass between individual plant cells).
- **Protection:** The cell wall provides a barrier to protect against plant viruses and other pathogens. It also helps to prevent water loss.
- **Storage:** The cell wall stores carbohydrates for use in plant growth, especially in seeds.

Thickening of Cell Wall

In contrast to primary wall, secondary wall is thicker and more rigid due to lignin deposition.
The deposition of secondary wall materials occurs in such a way that various patterns are formed on the cell wall.

The following patterns are commonly noted:

1. Annular thickening: These are ring like thickening present on the inner side of primary wall. The rest of the wall is thin. Ex. Protoxylem.

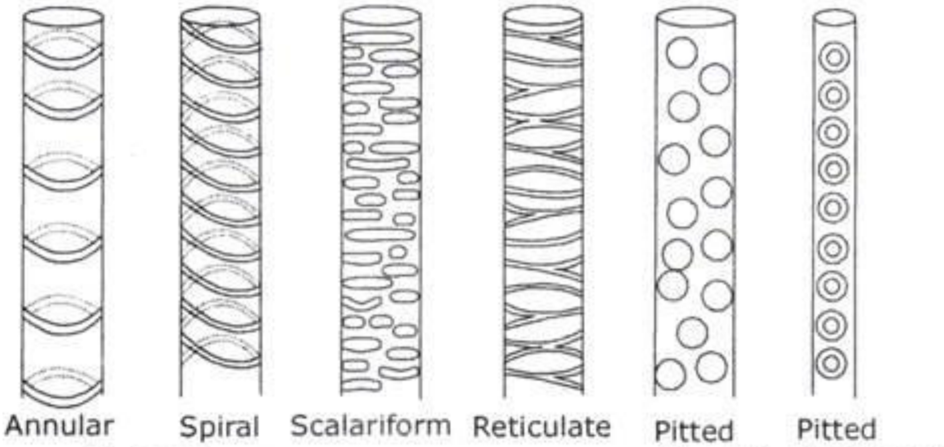


Fig 3.17

Diagrammatic representation of the different types of thickening of cell wall in longitudinal view.

2. Spiral or helical thickening:

These are spiral or helical thickening of secondary wall materials. There may be more than one helix. Ex. Protoxylem.

3. Scalariform thickening:

The thickenings appear as parallel transverse bands like the rungs of a ladder. Ex. Protoxylem.

4. Reticulate thickening:

The secondary wall appears as a network as the meshes remain thin. Ex. Metaxylem.

5. Pitted thickening:

These are more or less circular areas, called pit, where secondary wall materials are not deposited. Ex. Metaxylem.

Pit and primary pit-field

Secondary cell walls are commonly characterized by the presence of cavities called **pits**. A pit in a cell wall usually occurs opposite a pit in the wall of an adjoining cell, and the two opposing pits constitute a **pit-pair**. The middle lamella and the two primary walls between the two pit cavities are called the **pit membrane**. Pits arise from differential deposition of secondary wall material; none is deposited over the pit membrane.

Whereas secondary walls have pits, primary walls have thin areas called **primary pit-field**. During the deposition of the secondary wall, the pitsare formed over the primary pit-fields. Plasmodesmata are commonly aggregated in the primary pit-fields. When a secondary wall develops, the plasmodesmata remain in the pit membrane as connections between the protoplasts of the adjoining cells.

Pits vary in size and detailed structure, but two principal types are recognized in cells with secondary walls: **simple pits** and **bordered pits.** The basic difference between the two kinds of pit is that, in the bordered pit, the secondary wall arches over the pit cavity and narrows down its opening to the lumen of the cell. The overarching secondary wall constitutes the **border**. In simple pits, no such overarching occurs. In bordered pits, the part of the cavity enclosed by the border is called the **pitchamber**, and the opening in the border is the **aperture**. A combination of simple pits is termed a ***simple pit pair***, and of two opposing bordered pits a ***bordered pit-pair***

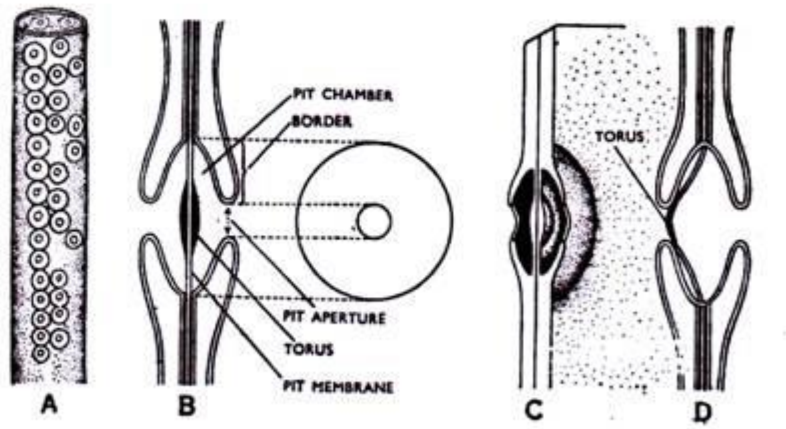


Fig. 514. Bordered pits (diagrammatic). A. A vessel with bordered pits in front view. B. Same in sectional view. C. Perspective diagram of the same. D. Sectional view of a bordered with changed position of torus.

Cell membrane (plasma membrane)

The cell membrane (plasma membrane/biomembrene) is a thin semi-permeable membrane that surrounds the cytoplasm of a cell. Its function is to **protect the integrity** of the interior of the cell by **allowing certain substances into the cell** while keeping **other substances out**. It also serves as a base of **attachment for the cytoskeleton** in some organisms and the cell wall in others. Thus the cell membrane also serves to help support the cell and help maintain its shape.

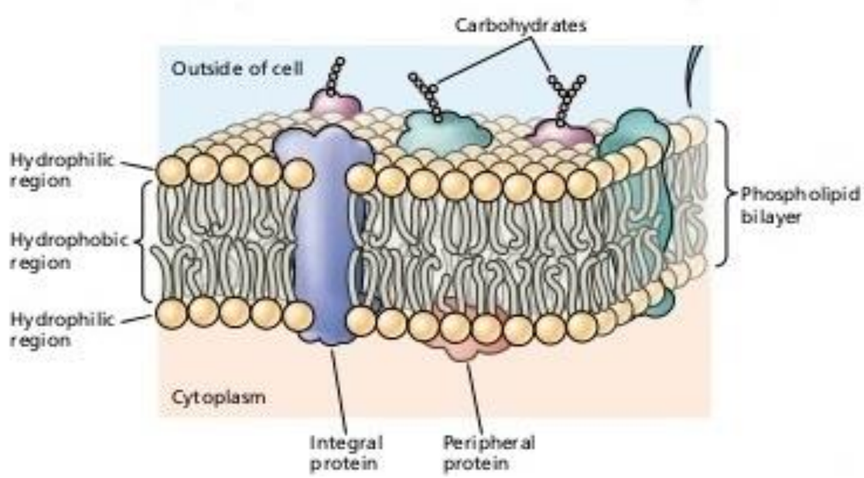


Fig: Cell membrane

Phospholipids form a lipid bilayer in which their hydrophilic (attracted to water) head areas spontaneously arrange to face the aqueous cytosol and the extracellular fluid, while their hydrophobic (repelled by water) tail areas face away from the cytosol and extracellular fluid. The **lipid bilayer is semi-permeable**, allowing only certain molecules to diffuse across the membrane.

Glycolipids are located on cell membrane surfaces and have **a carbohydrate sugar chain attached to them**. They help the cell to **recognize other cells of the body**.

Cell Membrane Proteins

The cell membrane contains two types of associated proteins.

i) **Peripheral membrane proteins** are exterior to and connected to the membrane by interactions with other proteins.

   Peripheral membrane proteins are bound to the **membrane surface.**
   Peripheral proteins serve a variety of functions in the cell. For example, some are involved in interactions between the plasma membrane and components of the cytoskeleton, such as microtubules and actin microfilaments

ii) **Integral membrane proteins** are inserted into the membrane and most pass through the membrane. Portions of these transmembrane proteins are exposed on both sides of the membrane. Cell membrane proteins have a number of different functions.

   Integral proteins are embedded in the **lipid bilayer**. Most integral proteins span the entire width of the phospholipid bilayer, so one part of the protein interacts with the outside of the cell, another part interacts with the hydrophobic core of the membrane, and a third part interacts with the interior of the cell, the cytosol. Proteins that serve as **ion channels** are always integral membrane proteins, as are certain receptors that participate in **signal transduction pathways**

iii) **Anchored proteins** are bound to the **membrane surface** via **lipid molecules** like fatty acids, prenyl groups derived from the isoprenoid pathway, glycosylphosphatidylinositol (GPI)-anchored proteins, etc.

Cytoplasm

Cytosol and all the cell organelles consist the cytoplasm.

Cytosol

The cytosol, also known as **intracellular fluid (ICF) or cytoplasmic matrix**, is the liquid found inside cells. Most of the cytosol is **water, which makes up about 70%** of the total volume of a typical cell.
Cytosol is the intra-cellular fluid that is present inside the cells. On the other hand, cytoplasm is that part of the cell which is contained within the entire cell membrane.
Cytosol comprises of a lot of **water, dissolved ions, large water soluble molecules, smaller minute molecules and proteins**.
Cytoplasm on the other hand is made of water up to 80% nucleicacids, enzymes, lipids, non-organic ions, amino acids, carbohydrates, and lightweight molecular compounds.
It is in the cytosol that all the metabolic chemical reactions of prokaryotes take place.

Function

Signal transduction from the cell membrane to sites within the cell, such as the cell nucleus,[55] or organelles.

Takes part in cell division/cytokinosis (cytoplasm of a single eukaryotic cell divides into two daughter cells).
Transport metabolites from their site of production to where they are used.
Cytosol is the site of most metabolic chemical reactions in prokaryotes.

Plastid

All plastids are derived from proplastids, which are present in the meristematic regions of the plant. Proplastids and young chloroplasts commonly divide by binary fission, but more mature chloroplasts also have this capacity.

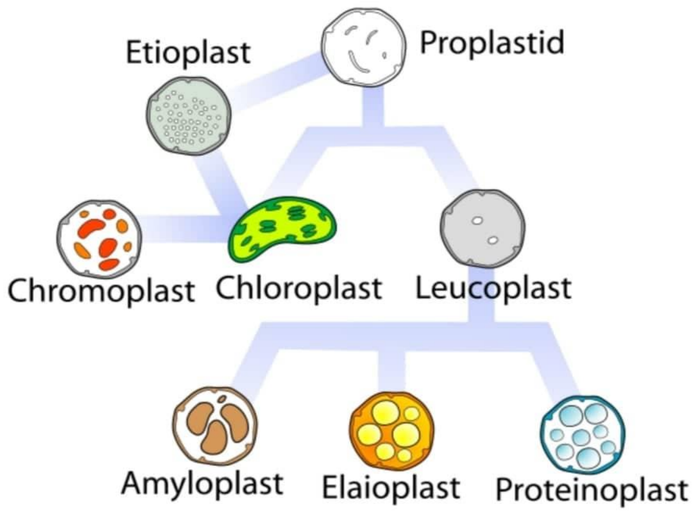


Fig: Plastid

In plants, plastids may differentiate into several forms, depending upon which function they play in the cell. Undifferentiated plastids (*proplastids*) may develop into any of the following variants:

- Chloroplasts: green plastids for photosynthesis; *see also etioplasts, the predecessors of chloroplasts*
- Etioplasts are chloroplasts that have not been exposed to light. They are usually found in flowering plants (Angiosperms) grown in the dark. If a plant is kept out of light for several days, its normal chloroplasts will actually convert into etioplasts. Etioplasts lack active pigment and can technically be considered leucoplasts. High concentrations of etioplasts will cause leaves to appear yellow rather than green.
- Chromoplasts: colored plastids for pigment synthesis and storage.
- Gerontoplasts: control the dismantling (break down) of the photosynthetic apparatus during plant senescence
- Leucoplasts: colorless plastids for monoterpene synthesis; leucoplasts sometimes differentiate into more specialized plastids:
  - Amyloplasts: for starch storage and detecting gravity (for geotropism)
  - Elaioplasts: for storing fat
  - Proteinoplasts: for storing and modifying protein
  - Tannosomes: for synthesizing and producing tannins and polyphenols

Depending on their morphology and function, plastids have the ability to differentiate, or redifferentiate, between these and other forms.

Chloroplast

Parts of Chloroplasts

- **Outer membrane –** It is a semi-porous membrane and is permeable to small molecules and ions, which diffuses easily. The outer membrane is not permeable to larger proteins.
- **Intermembrane Space –** It is usually a thin intermembrane space about 10-20 nanometers and it is present between the outer and the inner membrane of the chloroplast.
- **Inner membrane –** The inner membrane of the chloroplast forms a border to the stroma. It regulates passage of materials in and out of the chloroplast. In addition of regulation activity, the fatty acids, lipids and carotenoids are synthesized in the inner chloroplast membrane.
- **Stroma-** Stroma is a alkaline, aqueous fluid which is protein rich and is present within the inner membrane of the chloroplast. The space outside the thylakoid space is called the stroma. The chloroplast DNA chlroplast ribosomes and the thylakoid sytem, starch granules and many proteins are found floating around the stroma.
- **Thylakoid System-** The thylakoid system is suspended in the stroma. The thylakoid system is a collection of membranous sacks called thylakoids. The **chlorophyll** is found in the **thylakoids** and is the sight for the process of **light reactions of photosynthesis** to happen. The **thylakoids are arranged in stacks known as grana. Each granum contains around 10-20 thylakoids**. The **thylakoids contain chlorophylls and carotenoids**, and these pigments absorb light during the process of photosynthesis. Light-absorbing pigments are grouped with other molecules such as **proteins to form complexes known as photosystems**. The two different kinds of photosystems are photosystems I and II, and they have roles in different parts of the light-dependent reactions.
- In the **stroma, enzymes make complex organic molecules that are used to store energy**, such as carbohydrates. The **stroma also contains its own DNA and ribosomes** that are similar to those found in photosynthetic bacteria. For this reason, chloroplasts are thought to have evolved in eukaryotic cells from free-living bacteria, just as mitochondria did.

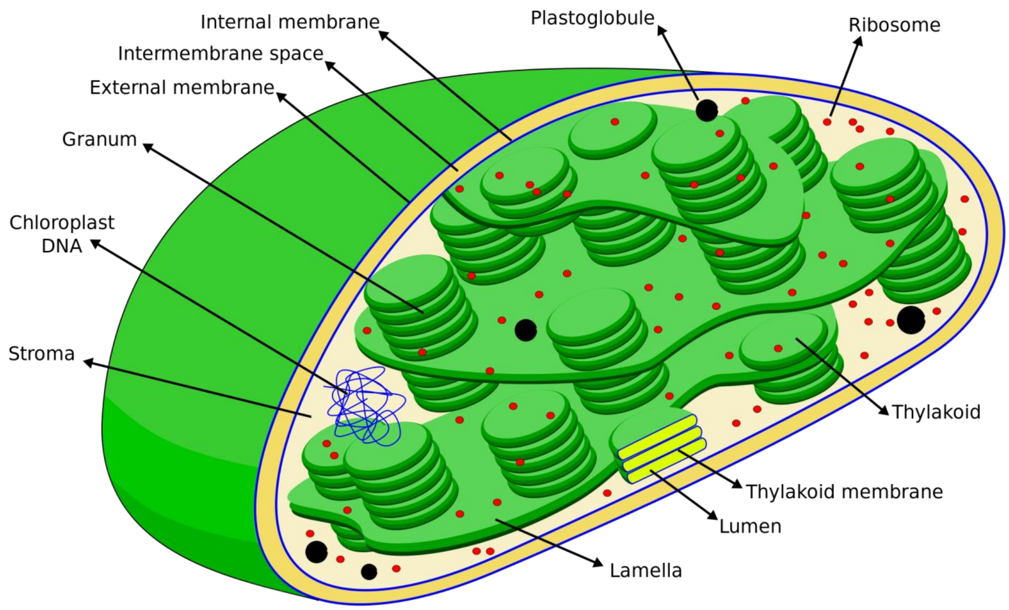


Fig.: Chloroplast

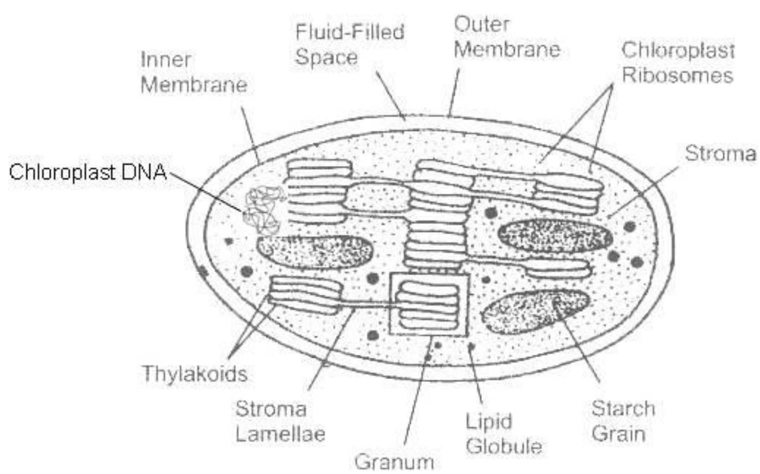


Fig.: Chloroplast

Functions of Chloroplast

The purpose of the chloroplast is to make sugars that feed the cell's machinery. Photosynthesis is the process of a plant taking energy from the Sun and creating sugars. When the energy from the Sun hits a chloroplast and the chlorophyll molecules, **light energy is converted into the chemical energy found in compounds such as ATP and NADPH**. Those energy-rich compounds move into the **stroma** where **enzymes fix the carbon atoms from carbon dioxide (CO_2)**. The molecular reactions eventually create **sugar and oxygen (O_2)**.

Mitochondria

Some of the major regions include:

Outer membrane: Small molecules can pass freely through the outer membrane. This outer portion includes proteins called porins, which form channels that allow proteins to cross. The outer membrane also hosts a number of enzymes with a wide variety of functions.

Intermembrane space: This is the area between the inner and outer membranes.

Inner membrane: This membrane holds proteins that have several roles. Because there are no porins in the inner membrane, it is impermeable to most molecules. Molecules can only cross the inner membrane in special membrane transporters. The **inner membrane is where most ATP is created**.

Cristae: These are the folds of the inner membrane. They increase the surface area of the membrane, therefore increasing the space available for chemical reactions.

Matrix: This is the space within the inner membrane. **Containing hundreds of enzymes, it is important in the production of ATP. Mitochondrial DNA is housed here**.

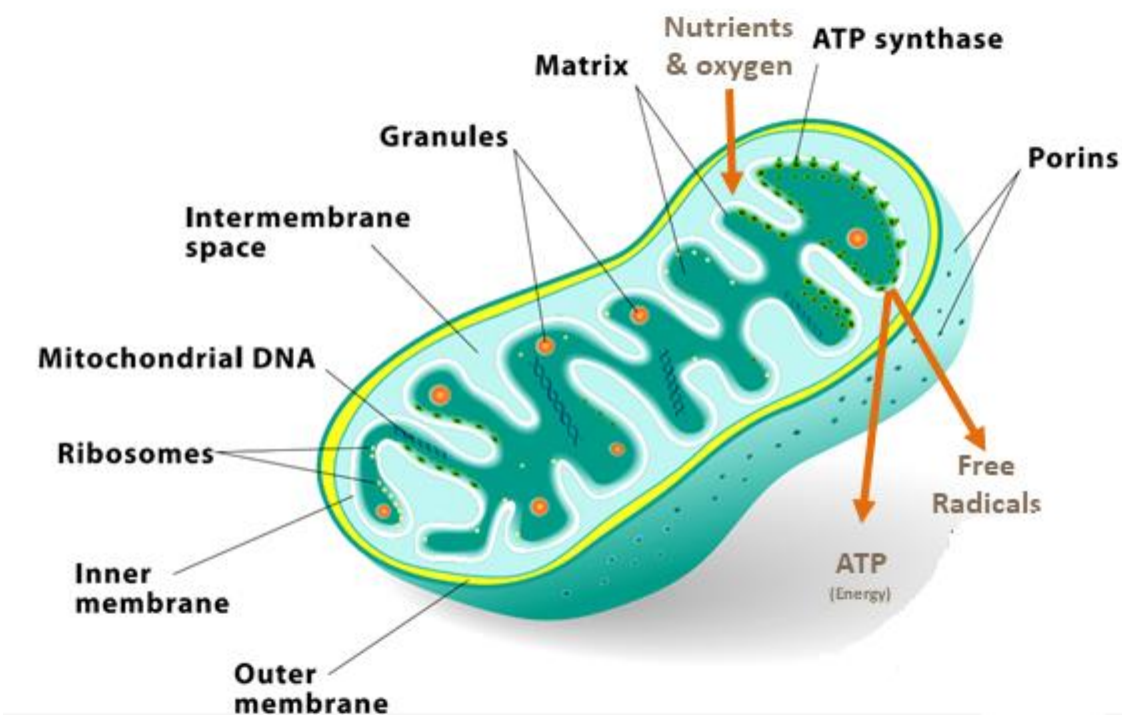


Fig: Mitochondrion

Function

ATP, a complex organic chemical found in all forms of life, is often referred to as the molecular unit of currency because it powers metabolic processes. Most ATP is produced in mitochondria through a series of reactions, known as the **citric acid cycle or the Krebs cycle**.

Energy production mostly takes place on the **folds or cristae of the inner membrane**.

Mitochondria convert chemical energy from the food we eat into an energy form that the cell can use. This process is called oxidative phosphorylation.

The Krebs cycle produces a chemical called NADH. NADH is used by enzymes embedded in the cristae to produce ATP. In molecules of ATP, energy is stored in the form of chemical bonds. When these chemical bonds are broken, the energy can be used.

Vacuole

A vacuole is an organelle in cells which functions to hold various solutions or materials. This includes solutions that have been created and are being stored or excreted, and those that have been phagocytized, or engulfed, by the cell. A vacuole is simply a chamber surrounded by a membrane (called **tonoplast**), which keeps the cytosol from being exposed to the contents inside. Because vacuoles are surrounded by semi-permeable membranes, they only let certain molecules through.

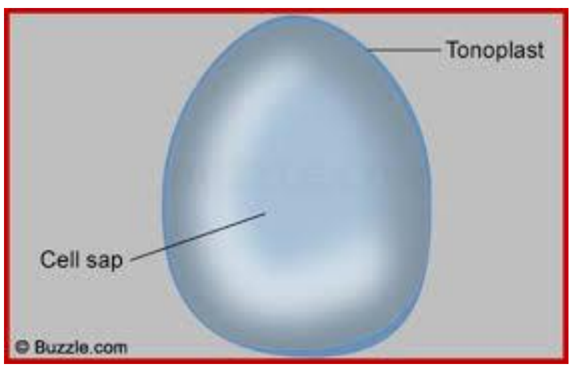


Fig. Vacuole

Functions of vacuole

- **Acts as water storage**
- **Maintains turgor pressure**
- **Endocytosis and Exocytosis**
  Exocytosis – The process of excreting material from the cell.
  Endocytosis – The process of taking materials into the cell.
- Vacuole stores toxic substances of cell.

Nucleus

The nucleus (pl. **nuclei**) is composed of the following structures-

1. Nuclear envelope
2. Nucleoplasm / karyolymph
3. Nucleolus
4. Chromatin fibres

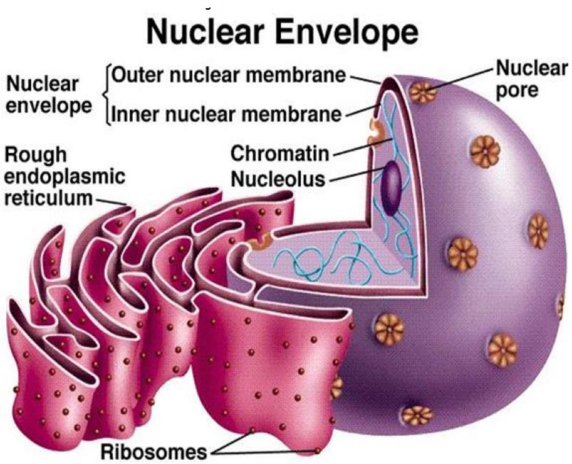


Figure: Nucleus with rough ER

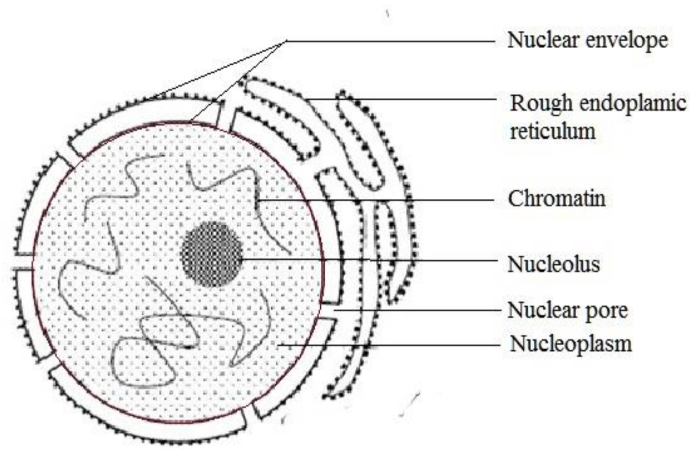


Figure: Basic structure of a nucleus with rough ER

1. Nuclear envelope: Nucleus is bounded by two lipoprotein membranes, the inner and outer membrane. The outer membrane of nuclear envelope remains continuous with the membranes of endoplasmic reticulum. It contains many pores or annuli through which movement of substances takes place between cytoplasm and nucleus.

Functions:

- Nuclear envelope allows free exchange of ions between the nucleus and the cytoplasm.
- Nuclear pores are the pathways for the exchange of the macromolecules from nucleus to cytoplasm and provide direct contact between the cytosol and nucleoplasm

2. Nucleoplasm / karyolymph: The space bounded by nuclear envelope is filled by transparent, semi-solid and slightly acidophilic matrix called nucleoplasm. The nucleoplasm contains dissolved sugars, nucleotides, nucleic acids, energy rich compounds and a variety of enzymes.

Function: It contains materials for the synthesis of nucleic acids (DNA and RNA).

3. Nucleolus: In the nucleoplasm there occurs a conspicuous/large spherical body attached to a particular chromosome on a definite location. This is called nucleolus. It is composed of a large amount of ribosomal proteins and ribosomal RNA.

Functions:

- It acts as a store house for ribosomal proteins and ribosomal RNA.

- It disappears during nuclear division and forms matrix sheath around the chromosome.

4. Chromatin fibres: The nucleoplasm contains thread-like, coiled and much elongated structures called chromatin fibres. During cell division these chromatin fibres form thread-like structures of definite shapes and sizes which are called chromosomes.

Function: It is the hereditary materials of the cells.

Endoplasmic reticulum

The endoplasmic reticulum are complex network of tube like membranes. They are found in all eukarytoic cells and structurally continuous with the nucleus of the cell. The lumen is filled with fluid. There are two types of endoplasmic reticulum - smooth and rough.

- **Smooth Endoplasmic reticulum** - They complex network of tube like membranes with smooth surface as they are lack of ribosomes on surfaces.

- **Rough Endoplasmic reticulum** - They complex network of tube like membranes with rough surface as the ribosomes are attached to its surface.

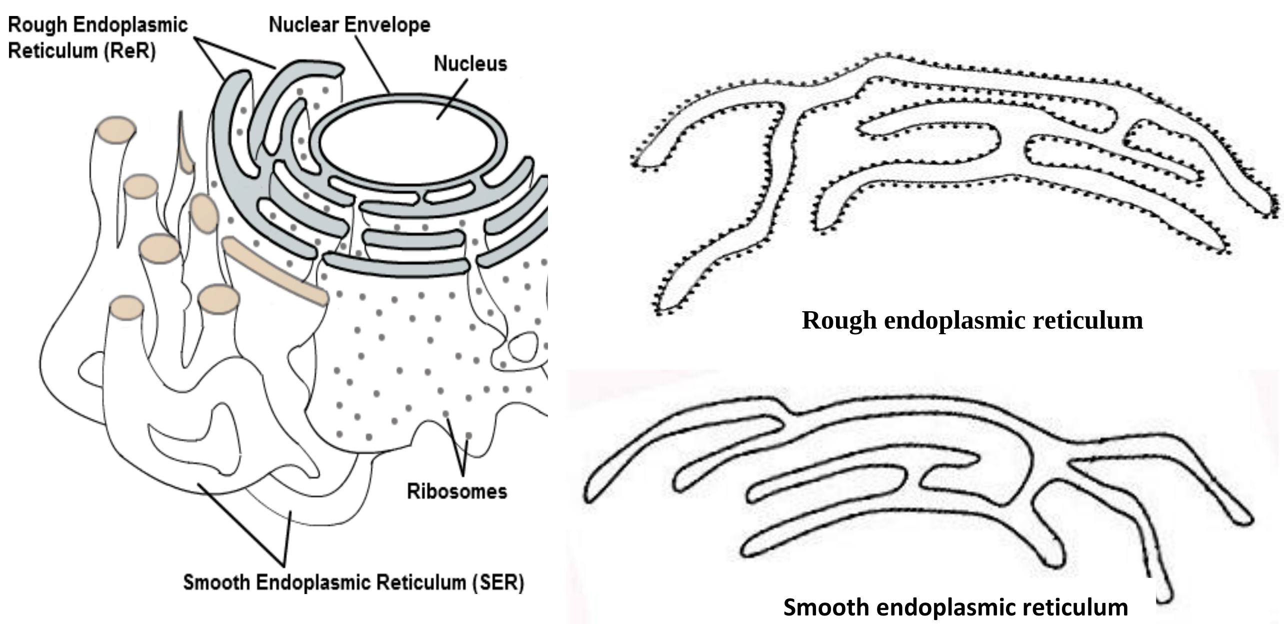


Fig: Endoplasmic reticulums of plant cell (RER and SER associated with nuclear envelope)

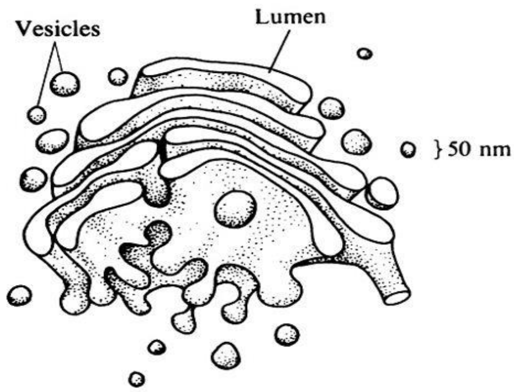
Functions: The main function of the endoplasmic reticulum is the translation and folding of new proteins which takes place in the rough ER. The expression and synthesis of lipids happens in the smooth ER.

Golgi apparatus or Golgi complex

Each Golgi apparatus is made up of one or more Golgi bodies (or dictyosomes). Dictyosomes are arranged in stacks of 3-10 flattened sacs (cisternae) and vesicles. The cisternae close to center of cell are called *cis* face (forming face) and the cisternae close to plasma membrane are called *trans* face (maturing). The medial cisternae are between *trans* and *cis* cisternae. Golgi body is a dynamic structure; new cisternae are continuously produced from endoplasmic reticulum at *cis* face while old cisternae are lost in the form of vesicle at *trans* face.

Function:

- It is involved in the transport and processing of many substances (lipids, proteins etc.) that are produced in ER (SER and RER) and eventually discharged outside the cell via Golgi vasicles.
- It plays a key role in synthesis and secretion of complex polysaccharides like cell wall polysaccharides.



(*a*) Golgi apparatus and secretory vesicles