AN OVERVIEW OF CELL

You have earlier observed cells in an onion peel or human cheek cells under the microscope. Let us recollect their structure. The onion cell which is a typical plant cell, has a distinct cell wall as its outer boundary and just within it is the **cell membrane**. The cells of the human cheek have an outer membrane as the delimiting structure of the cell. Inside each cell is a dense membrane bound structure called **nucleus**. This nucleus contains the **chromosomes** which in turn, contain the genetic material, DNA.

Cells that have membrane bound nuclei are called **eukaryotic** whereas cells that lack a membrane-bound nucleus are **prokaryotic**. In both prokaryotic and eukaryotic cells, semi-fluid matrix called **cytoplasm** occupies the volume of the cell. The **cytoplasm is the main arena of cellular activities** in both the plant and animal cells.

Besides nucleus, the eukaryotic cells have other membrane-bound distinct structures called **organelles** like the endoplasmic reticulum (ER), the Golgi complex, lysosomes, mitochondria, microbodies and vacuoles. The prokaryotic cells lack such membrane-bound organelles.

Ribosomes are non-membrane bound organelles found in all cells – both eukaryotic as well as prokaryotic. Within the cell, ribosomes are found not only in the cytoplasm but also within the two organelles – chloroplasts (in plants) and mitochondria and on rough ER. Animal cells contain another non-membrane bound organelle called **centriole** which helps in cell division.

Cell differs greatly in size, shape and activities. For example, *Mycoplasma*, the smallest cell, are only 0.3 μm in length while bacteria could be 3 to 5 μm. The largest isolated single cell is the egg of an **ostrich**. Among multicellular organisms, human red blood cells are about 7 μm in diameter. Nerve cells are some of the largest cells. Cells also vary greatly in their shape. They may be disc-like, polygonal, columnar, cuboid, thread-like, or even irregular. The shape of the cell may vary with the function they perform.

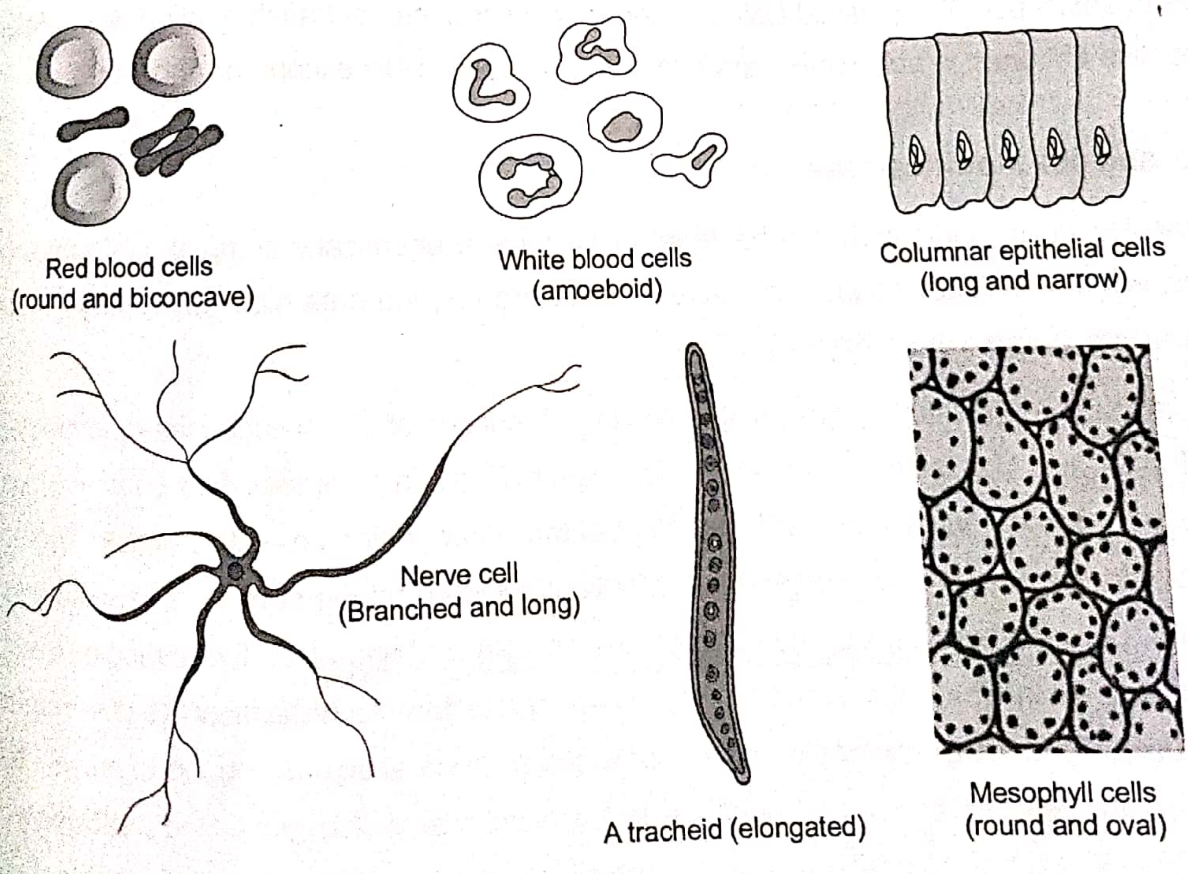

Fig. : Diagram showing different shapes of the cells.

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PROKARYOTIC CELLS

The prokaryotic cells are represented by bacteria, blue-green algae, *Mycoplasma* and PPLO (Pleuro pneumonia-like organisms). They are generally smaller in size and multiply much faster than the eukaryotic cells. They may vary greatly in shape and size but exhibit a similar basic cellular organisation.

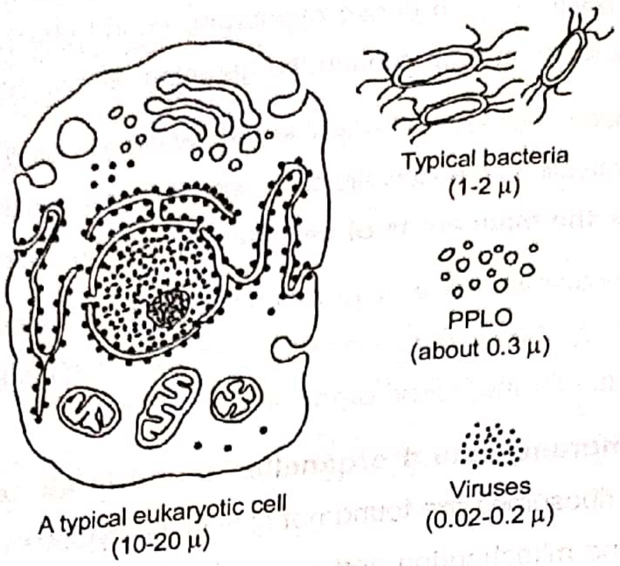

Fig. : Diagram showing comparison of eukaryotic cell with other organisms

The organisation of the prokaryotic cell is fundamentally similar even though prokaryotes exhibit a wide variety of shapes and functions. Most prokaryotes have a cell wall surrounding the cell membrane. The fluid matrix filling the cell is the cytoplasm. There is no well-defined nucleus. The genetic material is basically naked, not enveloped by a nuclear membrane. In addition to the genomic DNA (the single chromosome/circular DNA), many bacteria have small circular DNA outside the genomic DNA. These smaller DNA are called **plasmids**. The plasmid DNA confers certain unique phenotypic characters to such bacteria. One such character is resistance to antibiotics. The plasmid DNA is used to monitor bacterial transformation with foreign DNA. No organelles, like the ones in eukaryotes, are found in prokaryotic cells except for ribosomes.

Cell Envelope and its Modifications

Most prokaryotic cells, particularly the bacterial cells, have a chemically complex cell envelope. The cell envelope consists of a tightly bound three-layered structure *i.e.*, the outermost **glycocalyx** followed by **the cell wall** and the **plasma membrane.**

Glycocalyx is the outermost layer comprising a coating of mucous or polysaccharides macromolecules, which protects the cells and also helps in adhesion. This layer differs in thickness and chemical composition in different bacteria. Some have a loose sheath called **slime layer**, which protects the cell from loss of water and nutrients. Others may have a thick and tough covering known as **capsule**. The capsule and slime layer are made up of polysaccharides, but may sometimes contain proteins also. The capsule is responsible for giving gummy and sticky character to the cell. **It allows bacterium to hide from host's immune system.** The **cell wall** determines the shape of the cell and provides a strong structural support to prevent the bacterium from bursting or collapsing. This layer is rigid due to a special macromolecule called **peptidoglycan** (murein or mucopeptide). A number of antibiotics (*e.g.*, penicillin) inhibits cross linking of peptidoglycan strands. Therefore, cells undergo lysis in the presence of these antibiotics.

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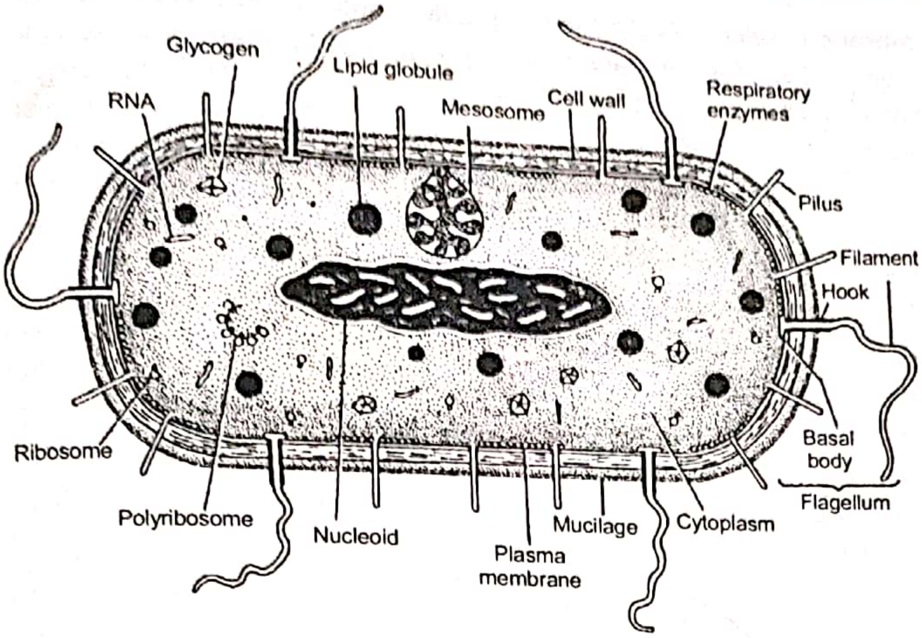

Fig. : Cell structure of bacteria under electron microscope

Gram staining (developed by **Christian Gram**) is a special technique, which is used to classify bacteria into two groups, viz. Gram-positive and Gram-negative bacteria. Those bacteria that take up the Gram stain are **Gram positive** and the others that do not are called **Gram negative** bacteria.

Knowledge Cloud

Flow chart representing Gram staining technique

Bacterial smear
↓
Air drying
↓
Stained with crystal violet / gentian violet (30 seconds)
↓
Bacteria get stained (Bluish purple)
↓
Washed with water
↓
Iodine staining (0.5% solution) (Iodine works as mordant)
↓
Formation of Crystal Violet Iodine (CVI) complex
↓
Treatment with alcohol

- Some bacteria retain the stain → Gram positive
- Destained bacteria → Counter staining with safranin → Pink colour appears → Gram negative

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The plasma membrane is selectively permeable in nature and interacts with the outside world. This membrane is similar structurally to that of the eukaryotes. A special membranous structure is the **mesosome** which is formed by the invagination of plasma membrane into the cell. These extensions are in the form of **vesicles**, **tubules** and **lamellae**. They help in the **cell wall formation, DNA replication and distribution to daughter cells.** They also help in respiration, secretion process, to increase the surface area of the plasma membrane and enzymatic content. **Mesosome is found in gram positive bacteria.** In some photosynthetic prokaryotes like cyanobacteria, and purple bacteria, there are other membranous extensions into the cytoplasm called **chromatophores** which contain pigments.

Bacterial **cells** may be motile or non-motile. If motile, they have thin filamentous extensions from their cell wall called **flagella**. Bacteria show a range in the number and arrangement of flagella. The flagellum is composed of three parts – **filaments**, **hook** and **basal body**. The filament is the longest portion and extends from the cell surface to the outside. It is a hollow rigid cylindrical structure made up of the protein called **flagellin**. Basal body is a rod-like structure which consists of rings.

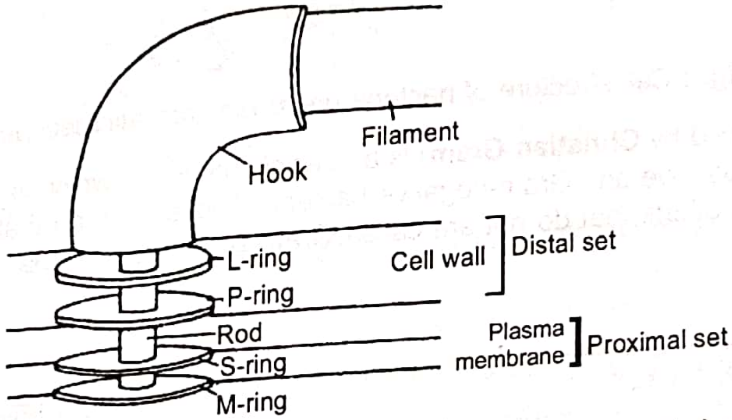

Fig. : A sectional view of a bacterial cell showing the detailed structure of the flagellum and attachment of flagellum to the bacterial cell

Besides flagella, **pili** and **fimbriae** are also surface structures of the bacteria but do not play a role in motility. The **pili** are elongated tubular structures made up of a special protein *i.e.*, **pilin**. True pili have been reported only in Gram-negative bacteria so far and in these forms they are involved in mating process. During this process, usually partial transfer of DNA from one cell (donor cell) to another cell (recipient cell) takes place. Formation of pili is generally controlled and is specific for a cell type as conjugation takes place between compatible bacterial cells. The **fimbriae** are small bristle-like fibres sprouting out of the cell. These seem to be slender tubes composed of helically arranged protein subunits, which are 3-10 nm in diameter. In some bacteria, they are known to help in attaching the bacteria to rocks in streams and also to the host tissues.

Ribosomes and Inclusions Bodies

In prokaryotes, ribosomes are associated with the plasma membrane of the cell. They are about 15 nm by 20 nm in size and are made up of two subunits – 50 S and 30 S units which when present together form 70 S prokaryotic ribosomes. Ribosomes are the site of protein synthesis. Cytoplasmic ribosomes synthesise proteins, which remain within cells but the ribosomes on the plasma membrane make proteins that are transported out. Several ribosomes may attach to a single mRNA and form a chain called **polyribosomes** or **polysome**. The ribosomes of a polysome translate the mRNA into proteins.

Inclusion bodies : Reserve material in prokaryotic cells are stored in the cytoplasm in the form of inclusion bodies. These are not bounded by any membrane system and lie free in the cytoplasm, *e.g.*, phosphate granules, cyanophycean granules and glycogen granules. Some other inclusion bodies may be surrounded by a single layer non unit membrane, which is 2-4 nm thick, *e.g.*, poly-β-hydroxybutyrate granules, sulphur granules and gas vacuole. Gas vacuoles are found in blue-green algae, purple and green photosynthetic bacteria.

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Knowledge Cloud

Gram positive	Gram negative
The bacteria remain coloured blue or purple with Gram staining even after washing with alcohol.	The bacteria do not retain the stain when washed with alcohol.
Outer membrane is absent.	Outer membrane is present.
Cell wall is 20-80 nm thick.	Cell wall is 8-12 nm thick.
The wall is smooth.	Wall is wavy and comes in contact with plasmalemma only at a few loci.
Murein content is 70 – 80%	Murein content is 10 – 20%.
Basal body of the flagellum contains 2 rings. (S and M)	Basal body of the flagellum has 4 rings. (L, P, S and M)
Teichoic acid present in cell wall.	Teichoic acid absent in cell wall.
A few pathogenic bacteria belong to Gram-positive group. *e.g.* *Bacillus, Clostridium, Lactobacillus, Streptococcus, Leuconostoc, Staphylococcus, Corynebacterium*	Most of the pathogenic bacteria belong to Gram-negative group. *e.g.* *E. coli, Salmonella, Acetobacter, Azotobacter, Vibrio, Agrobacterium, Shigella, Xanthomonas*

Example 3 : *Which is the main arena of cellular activities?*

Solution : Cytoplasm.

Example 4 : *Which type of cell lacks membrane-bound organelles?*

Solution : Prokaryotic cell.

Example 5 : *What is the function of cell wall in a prokaryotic cell?*

Solution : It provides additional strength and structural support to the prokaryotic cell.

Example 6 : *Name the extrachromosomal segments of DNA found in a prokaryotic cell.*

Solution : Plasmids.

Example 7 : *Which three structures collectively form cell envelope of a bacterial cell?*

Solution : Glycocalyx, cell wall and plasma membrane.

Example 8 : *Give a function of glycocalyx.*

Solution : It helps to protect the cell from mechanical and chemical damage.

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EUKARYOTIC CELLS

Eukaryotic cells are those cells which possess an organised nucleus with a nuclear envelope. Some of the important characteristics of eukaryotic cells are cytoskeletal structure, membrane-bound organelles and organisation of genetic material into chromosomes. These cells occur in protista, fungi, plants and animals. A eukaryotic cell like a prokaryotic cell is covered by a cell envelope. The cell envelope is formed of only plasma membrane in animal cells. It consists of plasma membrane and cell wall in plant cell, fungal cells and some protists. All eukaryotic cells are not identical due to many differences.

Table : Difference between Prokaryotic and Eukaryotic cell

	Prokaryotic Cell		Eukaryotic Cell
1.	The cell size is usually small.	1.	The cell size is comparatively larger .
2.	Nuclear region is poorly defined due to absence of nuclear envelope. Nucleoid (genetic material) is not surrounded by a nuclear membrane and is in direct contact with the cytoplasm.	2.	Distinct nucleus is present. Nuclear material is surrounded by a nuclear membrane and is not in direct contact with cytoplasm.
3.	Nucleoid is equivalent to a single chromosome or prochromosome. Hence the amount of DNA is comparatively low.	3.	Nucleus contains more than one chromosome. Hence, the amount of DNA is comparatively very high.
4.	Nucleolus is absent.	4.	Nucleolus is present.
5.	Protein synthesis occurs only in cytoplasm.	5.	Protein synthesis takes place in cytoplasm, mitochondria and plastids.
6.	Membrane-bound organelles are absent.	6.	Membrane-bound organelles are present (e.g., mitochondria, plastids, endoplasmic reticulum, golgi apparatus, lysosome etc.)
7.	Ribosomes are of 70S type.	7.	Ribosomes are of 80S type: 70S type ribosome occurs in mitochondria and plastids.
8.	Centrioles (centrosome, central apparatus) are absent.	8.	Centrioles are usually present.
9.	True sap vacuoles are usually absent. Instead gas vacuoles may be found.	9.	True or sap vacuoles are commonly found, e.g., plant cells.
10.	Thylakoids, if present, lie freely in cytoplasm.	10.	Thylakoids, if present are grouped inside chloroplast as granum.
11.	Additional small circular DNA segment or plasmids may occur.	11.	Plasmids are absent.
12.	Having single envelope system.	12.	Having double/two envelope system.

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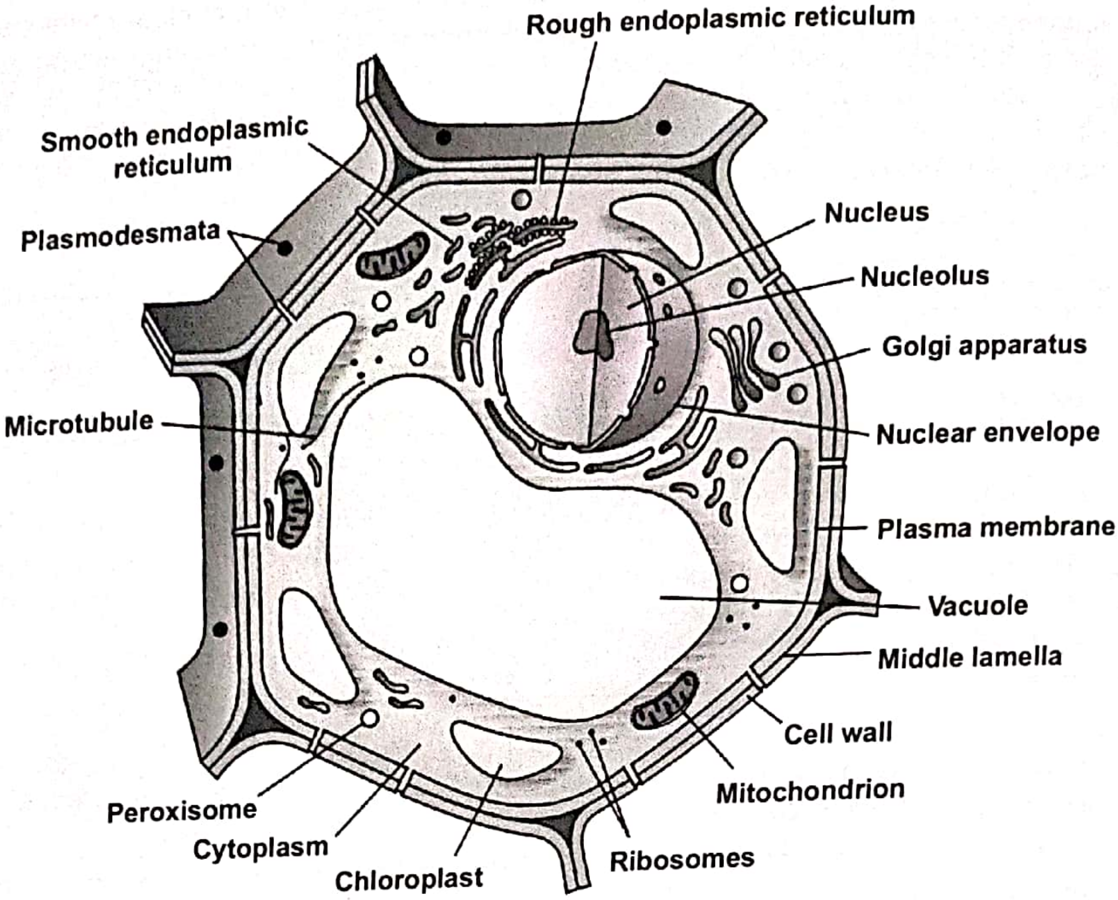
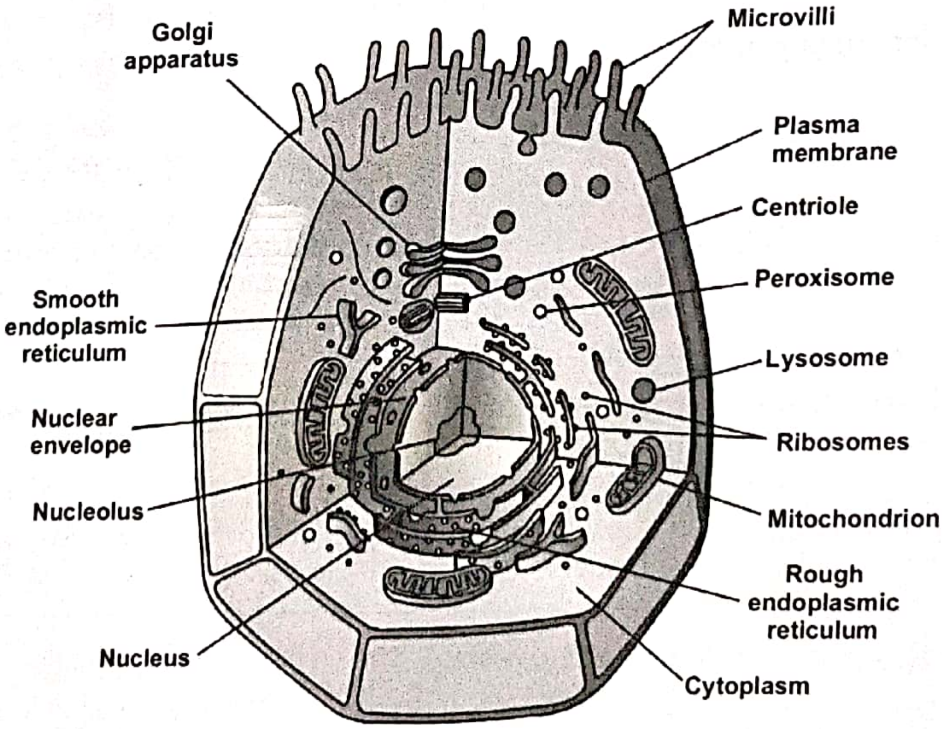


(a)



(b)

Fig. : Diagram showing :
(a) Plant cell **(b)** Animal cell

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Table : Differences between Plant cell and Animal cell

Plant cell	Animal cell
1. Plant cells are generally larger than animal cells.	1. Animal cells are generally small in size.
2. Plasma membrane of plant cells is surrounded by a rigid cell wall made up of cellulose.	2. Cell wall is absent. The outermost covering of the animal cell is plasma membrane.
3. Plastids are present.	3. Plastids are absent.
4. Most mature plant cells have a permanent and large central sap vacuole.	4. Vacuoles in animal cells are many, small and temporary.
5. Plant cells have many simpler units of Golgi apparatus, called dictyosomes.	5. Animal cells have a single highly complex and prominent Golgi apparatus.
6. Almost all plant cells lack centrosome and centrioles.	6. Animal cells have centrosome and centrioles.

Let us now look at individual cell organelles to understand their structure and functions.

Plasma Membrane or Cell Membrane

Plasma membrane is an absolute requirement for all living organisms as it is responsible for the relationship of a cell with the outside world. The detailed structure of the membrane was studied only after the invention of electron microscope in the 1950s. Meanwhile, chemical studies on the cell membrane enabled the scientists to deduce the possible structure of the plasma membrane. The chemical studies done especially on the human red blood cells (RBCs), enabled the scientists to deduce the possible structure of plasma membrane.

On the basis of these studies, scientists found that the cell membrane is composed of lipids that are arranged in a bilayer. These lipids are arranged within the membrane with the polar head towards the outer sides and the **hydrophobic** (non-polar) tails towards the inner sides. The polar ends (head) interact with water and are called **hydrophilic**. This ensures that the non-polar tail of saturated hydrocarbons or hydrophobic tail is protected from the aqueous environment.

Later, biochemical investigation clearly revealed that the cell membranes also possess protein and carbohydrate. The ratio of protein and lipid varies considerably in different cell types. **In human beings, the membrane of the erythrocyte (RBC) has approximately 52 percent protein and 40 percent lipids.**

Depending on the ease of extraction, membrane proteins can be classified as integral or peripheral. The **peripheral proteins** lie on the surface of the membrane while the **integral proteins** are partially or totaly buried in the membrane. The integral proteins which run throughout lipid bilayer are known as **tunnel proteins** (Trans membrane proteins). These proteins cannot be removed easily and their removal requires crude methods of treatment like detergents. Thus, the membrane has been described as **Protein icebergs floating in sea of phospholipids**. An improved model of the structure of cell membrane was proposed by **Singer and Nicolson** (1972) widely accepted as **Fluid Mosaic Model**.

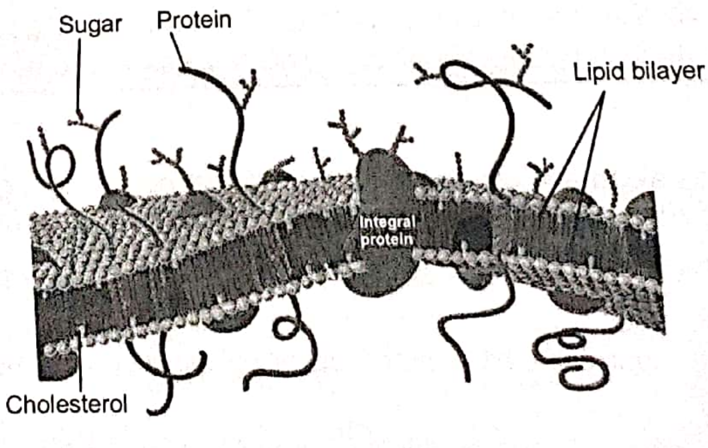

Fig. : Fluid mosaic model of plasma membrane

According to this, the quasi-fluid nature of lipids enables lateral movement of proteins within the overall bilaye
This ability to move within the membrane is measured as its fluidity.

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Functions :

1. The fluid nature of the membrane is important from the point of view of functions like cell growth, formation of intercellular junctions, secretion, endocytosis, cell division, etc.
2. Plasma membrane allows the transport of the molecules across it. The membrane is selectively permeable to some molecules present on either side of it. The passage of substances across cell membranes occurs by various methods such as **passive transport, active transport.**
   (i) **Passive transport :** Many molecules can move across the membrane without any requirement of energy and this is called the passive transport. Neutral solutes may move across the membrane by the process of simple diffusion along the concentration gradient *i.e.*, from higher concentration to the lower.
   Water may also move across the plasma membrane from higher to lower concentration. The movement of water by diffusion through membrane is called **osmosis**. As the polar molecules cannot pass through the non-polar lipid bilayer, they require a carrier protein of the membrane to facilitate their transport across the membrane.
   (ii) **Active transport:** It is an uphill movement of materials across the membrane where the solute particles move against their concentration gradient *i.e.*, from their lower to higher concentration. Such a transport requires energy, which is obtained from ATP. Thus, it is an energy dependent process.
   For example, Na^+/K^+ pump in animal cells.

Knowledge Cloud

Bulk transport :

A. **Endocytosis** : It involves intake of materials in the form of carrier vesicles formed by invagination of small regions of plasma membrane. Endocytosis is of two types i.e., **pinocytosis** and **phagocytosis** as explained below :
   (a) **Pinocytosis :** It is also called **cell drinking process,** as fluid materials having high molecular weight such as proteins, amino acids, fats, insulin, lipoproteins, etc., in the form of globules of fluid enter the cytoplasm by invagination of plasma membrane. Globules of fluid materials are called **pinosomes** which are pinched off from the plasma membrane inside the cytoplasm in the form of small **pinocytic vesicles.**
   (b) **Phagocytosis :** It is bulk intake of large sized solid particles by the cell using the plasma membrane. It is also called **cell eating process**. It occurs in all protozoans and in special cells of metazoans such as leucocytes of blood, the reticular cells of spleen etc. It is pinched off from the plasma membrane inside the cytoplasm in the form of food vacuole or phagocytic vesicle. This will further be digested by lysosomes.

B. **Exocytosis :** It is a process of exudating the secretory products or undigested waste products to outside of the cell cytoplasm through plasma membrane. This process is also called **cell vomiting or ephagy.**

Cell Wall

The cells of bacteria, fungi, algae and plants have an additional non-living, rigid structure called the cell wall that surrounds the plasma membrane. The composition of cell wall varies in different groups.

1. **Fungal cell wall :** The fungal cell wall is generally composed of chitin, a polymer of N-acetylglucosamine (NAG) units.
2. **Algal cell wall :** The algal cell wall is made up of cellulose, galactans, mannans and minerals like calcium carbonate.
3. **Plant cell wall :** The plant cell wall is chiefly composed of the insoluble polysaccharides (cellulose). Certain other compounds, such as hemicellulose, pectin and proteins are also present in the cell wall. The cell wall of plants consists of two regions : primary wall and secondary wall.

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Primary wall : A young plant cell forms a single layer of wall material. This layer is known as the primary cell wall. The primary wall is thin, elastic and capable of expansion in a growing cell. It grows by addition of more wall material within the existing one. Meristematic and parenchymatous cells have primary cell wall only.

Secondary wall : In mature cell, more layers of wall material are added internal to the primary wall. These layers are called the secondary cell wall. Addition of secondary wall brings about thickening of the cell wall. Thickening of cell wall occurs particularly in cells that form the harder woody parts of plants such as lignified and suberised cell wall.

Middle lamella : Adjacent cells in a plant tissue are held together by a thin, sticky, amorphous layer of cementing material. This layer is called the middle lamella. Middle lamella is chiefly made up of **calcium and magnesium pectate.** In ripening fruits, the pectate compounds solubilize to a jelly-like material, making the fruits soft. The cell wall and middle lamella may be traversed by plasmodesmata which connect the cytoplasm of neighbouring plant cells.

Functions of Cell Wall :

The cell wall serves many functions :

1. It maintains shape of the cells.
2. It protects the cells from mechanical injury.
3. It wards off the attacks of pathogens like viruses, bacteria, fungi, etc.
4. It allows the materials to pass in and out of the cell.
5. It helps in cell-to-cell interaction and provides barrier to undesirable macromolecules.

Pits : The cell wall is not uniform in thickness throughout; because at certain places secondary wall is not laid down. Such unthickened areas are called pits. Pits of the adjacent cells generally lie opposite to each other and form pit pairs.

Pits are of two types :

(i) **Simple pit :** Pit cavity is uniform in diameter.

(ii) **Bordered pit :** Pit cavity is flask-shaped, as in tracheids.

Plasmodesmata : It forms the living component in the dead wall. A number of plasmodesmata or cytoplasmic strands are present in pit through which the cytoplasm of one cell is in contact with other. These are lined by plasma membrane and cotains a fine tubule called **desmotubule**. Endoplasmic reticulum plays a role in origin of plasmodesmata. These form the symplastic system between two cells.

Example 9 : *What are the two types of proteins found in a plasma membrane?*

Solution : Integral and peripheral.

Example 10 : *Who gave fluid mosaic model w.r.t. cell membrane?*

Solution : Singer and Nicolson.

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