# Cell-The Unit of Life

## CELL

- CELL is the fundamental structural and functional unit of all living organisms.
- A cell is capable of independent existence and can carry out all the functions which are necessary for a living being.
- A cell carries out nutrition, respiration, excretion, transportation and reproduction; the way an individual organism does. Unicellular organisms are capable of independent existence which shows a cell's capability to exist independently. Due to this, a cell is called the fundamental and structural unit of life. All living beings are composed of the basic unit of life, i.e. cell.

**CELL THEORY** (Schleiden, Schwann and Virchow):

- In 1838, Matthias Schleiden, a German botanist, examined a large number of plants and observed that all plants are composed of different kinds of cells which form the tissues of the plant. At about the same time, Theodore
- Schwann (1839), a British Zoologist, studied different types of animal cells and reported that cells had a thin outer layer which is today known as the 'plasma membrane'. He also concluded, based on his studies on plant tissues, that the presence of cell wall is a unique character of the plant cells. On the basis of this, Schwann proposed the hypothesis that the bodies of animals and plants are composed of cells and products of cells. Schleiden and Schwann together formulated the cell theory. This theory however, did not explain as to how new cells were formed. Rudolf Virchow (1855) first explained that cells divided and new cells are formed from pre-existing cells (Omnis cellula-e cellula). He modified the hypothesis of Schleiden and Schwann to give the cell theory a final shape.

**Cell theory as understood today is:**

(i) all living organisms are composed of cells and products of cells.

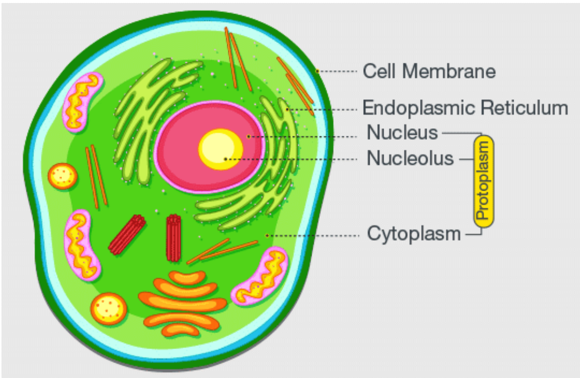
(ii) all cells arise from pre-existing cells

## History

- Robert Hooke first saw dead cell in 1665.
- Anton Von Leeuwenhoek first saw and described a live cell.
- Robert Brown later discovered the nucleus.

**Terms-**

1. Protoplasm: The living substance of cell. Contain cytoplasm and nucleus.
2. Cytoplasm: The jelly-like fluid within a cell, excluding the nucleus.
3. Cytosol- The jelly-like fluid within a cell, excluding the nucleus and cell organelle.
4. Somatoplasm: The Protoplasm of somatic cells.
5. Germplasm: The Protoplasm of germ cells.



6. Ectoplasm: The outer, more fluid portion of the cytoplasm, closer to the cell membrane.
7. Endoplasm: The inner, denser portion of the cytoplasm, closer to the nucleus.

## Cells size and shape

- Cells differ greatly in size, shape and activities.
- For example, Mycoplasmas, the smallest cells, 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 7.0 µm in diameter.
- Nerve cells are some of the longest 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.

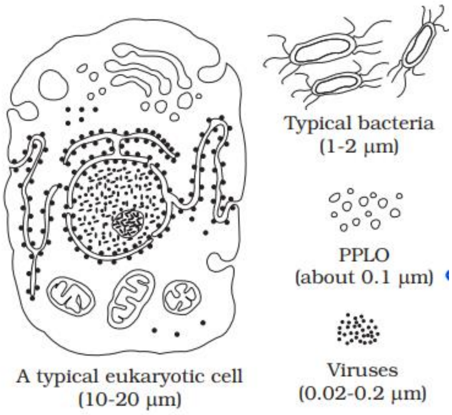
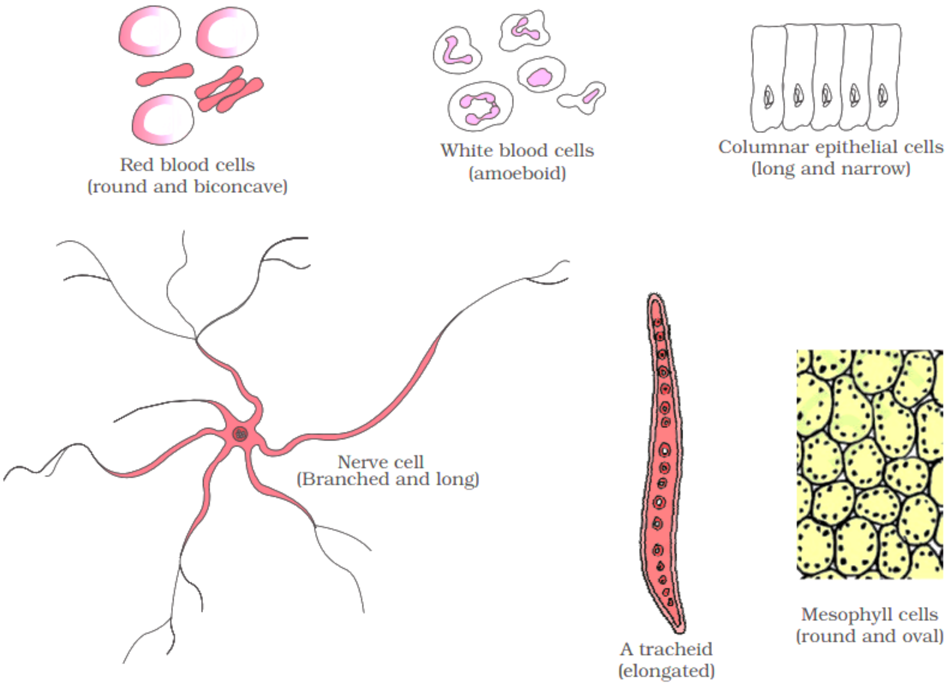



**Figure 8.2** Diagram showing comparison of eukaryotic cell with other organisms



Cells can be eukaryotic and prokaryotic.

**Prokaryotic cells**

- **No Nucleus**: Prokaryotic cells lack a true nucleus. Instead, their genetic material is found in a single circular chromosome that floats freely in the cytoplasm.
- **Simple Structure**: Prokaryotic cells are structurally simpler compared to eukaryotic cells. They lack membrane-bound organelles such as mitochondria, endoplasmic reticulum, and Golgi apparatus.
- **Ribosomes**: Prokaryotic cells contain ribosomes(70s), which are responsible for protein synthesis. These ribosomes are smaller than those found in eukaryotic cells.
- **Cell Wall**: Most prokaryotic cells have a cell wall composed of peptidoglycan. This provides structural support and protection.
- **Flagella and Pili**: Prokaryotic cells may have flagella for movement and pili for attachment to surfaces or other cells. These structures are simpler than those found in eukaryotic cells.
- **Circular DNA**: Prokaryotic cells typically have a single circular DNA molecule that contains most of their genetic information. This DNA is not enclosed within a nucleus.
- **Binary Fission**: Prokaryotic cells reproduce through a process called binary fission, where the cell divides into two daughter cells, each containing a copy of the genetic material.
- **Small Size**: Prokaryotic cells are generally smaller in size compared to eukaryotic cells, typically ranging from 0.2 to 2.0 micrometers in diameter.

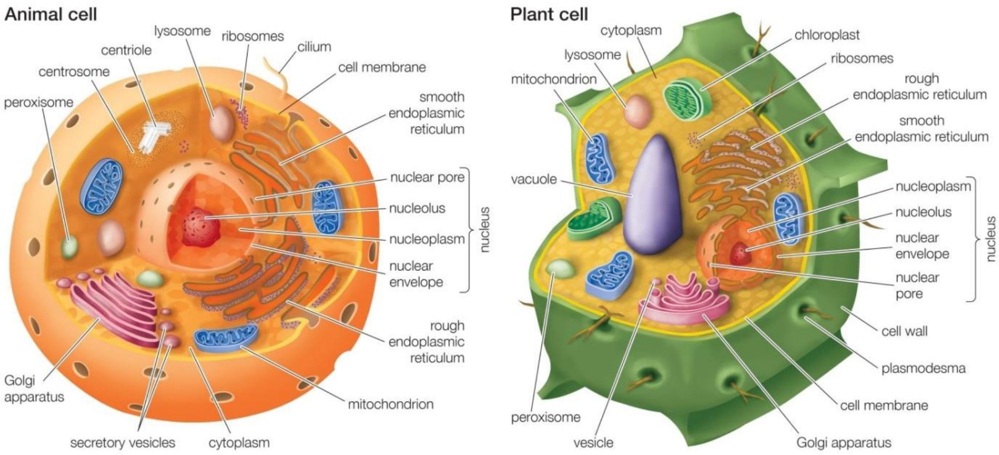
**Eukaryotic cells**

- **Nucleus**: Eukaryotic cells have a distinct nucleus enclosed within a double membrane. The nucleus houses the cell's genetic material, organized into linear chromosomes.
- **Membrane-Bound Organelles**: Eukaryotic cells contain various membrane-bound organelles, each with specific functions. These organelles include the endoplasmic reticulum, Golgi apparatus, mitochondria, lysosomes, and chloroplasts (in plant cells).
- **Complex Structure**: Eukaryotic cells exhibit a more complex internal structure compared to prokaryotic cells due to the presence of organelles.
- **Large Size**: Eukaryotic cells are generally larger in size compared to prokaryotic cells, typically ranging from 10 to 100 micrometres in diameter.
- **Linear DNA**: The genetic material in eukaryotic cells is organized into multiple linear chromosomes within the nucleus. These chromosomes are associated with histone proteins, forming chromatin.
- **Cytoplasm**: Eukaryotic cells have a cytoplasmic matrix known as cytosol, where organelles are suspended. Cellular organelles are responsible for specific functions such as protein synthesis, energy production, and waste management.

- **Endomembrane System**: Eukaryotic cells possess an endomembrane system, consisting of the endoplasmic reticulum, Golgi apparatus, vesicles, and lysosomes.
- **Mitochondria**: Eukaryotic cells typically contain mitochondria, organelles responsible for generating energy in the form of ATP through cellular respiration.
- **Reproduction**: Eukaryotic cells reproduce through mitosis (for somatic cells) or meiosis (for gametes), processes that ensure the faithful transmission of genetic material during cell division.

| Properties | Prokaryotic cell | Eukaryotic cell |
|---|---|---|
| Example- | Bacteria and Archaea | Protists, fungi, animals, and plants |
| Meaning | prokaryotic means "before nucleus" | eukaryotic means "true nucleus" |
| Location of DNA | DNA is concentrated in a region that is not membrane-enclosed, called the nucleoid | DNA is in an organelle called the nucleus, which is bounded by a double membrane |
| Membrane-bounded structures | Absent | Present (+); Lysosome, Golgi complex, ER, Mitochondria and Chloroplast |
| Size | Small | Large |
| Nucleus | Absent | Present |
| Cell wall | Present | Present in plant and fungi |
| Nuclear membrane | Absent | Present |
| Ribosome | Present (70s) | Present (70s and 80s) |
| Cell membrane | Peptidoglycan, LPS | Lipid bilayer and cellulose |
| Histone | Absent | Present |
| Cellular organization | Singled celled | Multicellular mostly |

## Animal cell and Plant cell-




| **ORGANELLES** | **Location(plant/animal)** | **FUNCTIONS** |
|---|---|---|
| 1.Nucleus | Both | DNA storage and control of cells activity, genetic information |
| 2.Mitochondria | Both | Energy currency of cell; ATP production |
| 3.Chloroplast | Plant | Capture energy from sun, food production; Photosynthesis |
| 4.Ribosome | Both | Protein synthesis |
| 5.Peroxisome | Both | Oxidation of Fatty acid and other component |
| 6.cytoskeleton | Both | Structure and shape; |
| 7.Vacoule | Both | Storage area |
| 8.Cytoplasm | Both | Home of cell organelles |
| 9.Cell wall | Plant | Protection and support |
| 10.Golgi bodies | Both | Packaging, protein processing |
| 11.Lysosome | Animals mainly, plant rare | Breakdown/digest food and waste material. |
| 12.Cell membrane | Both | Control inward and outward movement of substance;<br>selective permeability |
| 13.Endoplasmic reticulum | Both | protein synthesis(RER); lipid synthesis(SER) |

## 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 then the plasma membrane. Although each layer of the envelope performs distinct function, they act together as a single protective unit.
- Bacteria can be classified into two groups on the basis of the differences in the cell envelopes and the manner in which they respond to the staining procedure developed by Gram viz., those that take up the gram stain are Gram positive and the others that do not are called Gram negative bacteria.
- Glycocalyx differs in composition and thickness among different bacteria. It could be a loose sheath called the slime layer in some, while in others it may be thick and tough, called the capsule.
- The cell wall determines the shape of the cell and provides a strong structural support to prevent the bacterium from bursting or collapsing.
- 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 extensions of plasma membrane into the cell. These extensions are in the form of vesicles, tubules and lamellae. They help in cell wall formation, DNA replication and distribution to daughter cells. They also help in respiration, secretion processes, to increase the surface area of the plasma membrane and enzymatic content.
- In some prokaryotes like cyanobacteria, 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. Bacterial flagellum is composed of three parts – filament, hook and basal body.
- The filament is the longest portion and extends from the cell surface to the outside. 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 of a special protein.
- The fimbriae are small bristle like fibres sprouting out of the cell. In some bacteria, they are known to help attach the bacteria to rocks in streams and also to the host tissues.

## Plasma membrane

- Other name of Plasma membrane- Bio membrane, Cell membrane, living membrane.
- It forms the barrier that separates the cytoplasm from the exterior environment, thus defining a cell's physical and chemical boundaries.
- All cellular membranes, both plasma membranes and organelle membranes, consist of a bilayer of phospholipids in which other lipids and specific types of proteins are embedded.
- It is semipermeable and selective permeable in nature.
- Dynamic, fluid structures, and most of their molecules move in the plane of membrane

### Functions of Plasma membrane

- Protective layer
- Separate internal environment of cell from surrounding.
- Semipermeable
- Selectively permeable
- Help in transport
- Contains receptors
- Cell signaling

### Composition of Plasma membrane

- Phospholipid Bilayer: The fundamental structural component of the plasma membrane is a double layer of phospholipid molecules. Each phospholipid molecule consists of a hydrophilic (water-attracting) head and two hydrophobic (water-repelling) tails. These molecules arrange themselves in a bilayer with their hydrophilic heads facing outward towards the aqueous environments inside and outside the cell, while their hydrophobic tails face inward, shielding themselves from water.
- Proteins: Proteins are embedded within or associated with the phospholipid bilayer. There are two main types of proteins found in the plasma membrane:
- Integral Proteins: These proteins are firmly embedded within the lipid bilayer. They may span the entire width of the membrane (transmembrane proteins) or partially penetrate it. Transmembrane proteins often serve as channels or carriers for specific molecules or ions, facilitating their transport across the membrane. Other integral proteins may function as receptors, participating in cell signalling, or as enzymes, catalysing specific biochemical reactions.

- Peripheral Proteins: These proteins are not embedded within the lipid bilayer but are instead attached to the membrane's surface. They interact with integral proteins or with the polar heads of phospholipids. Peripheral proteins play various roles, including providing structural support, participating in cell signaling, and facilitating cell-cell communication.

- Carbohydrates: Carbohydrates are often found attached to proteins (glycoproteins) or lipids (glycolipids) on the extracellular surface of the plasma membrane. These carbohydrate chains form the glycocalyx, which helps in cell recognition, cell-cell communication, and immune response.
- Cholesterol: Cholesterol molecules are interspersed within the phospholipid bilayer. Cholesterol helps to regulate the fluidity and stability of the membrane by preventing the phospholipid molecules from packing too closely together or becoming too loosely packed.

**Some models of plasma membrane-**

**Lipid Models-**

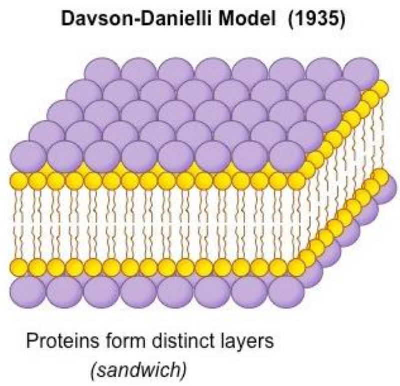
**The Overton model**, proposed by scientist Overton in 1902, suggests that the cell membrane is primarily composed of lipids, arranged in a single layer.

**The Gorter and Grendel model**, developed in 1926, expanded on the Overton model by proposing that the lipid of the cell membrane consists of two layers of lipids. This led to the concept of the lipid bilayer membrane. where hydrophilic heads of phospholipids face outward towards the aqueous environment while hydrophobic tails are present in middle position of plasma membrane.

**Sandwich Model**

**The Danielli and Davson model**-

It proposed in 1935, introduced the idea of Sandwich Model. According to their model single layered globular proteins are present in both side of lipid bilayer.



**The Robertson model-**

- The Robertson model, also known as the unit membrane model, was proposed by J. D. Robertson in 1959. This model represents a significant advancement in the understanding of cell membrane structure.
- According to the unit membrane model, the cell membrane is composed of a trilaminar structure consisting of three layers: two dense outer layers and a less dense central layer. The outer layers are believed to be composed of proteins, while the central layer is primarily made up of phospholipids.
- This model proposed that the membrane structure is consistent across different types of cells and organelles.

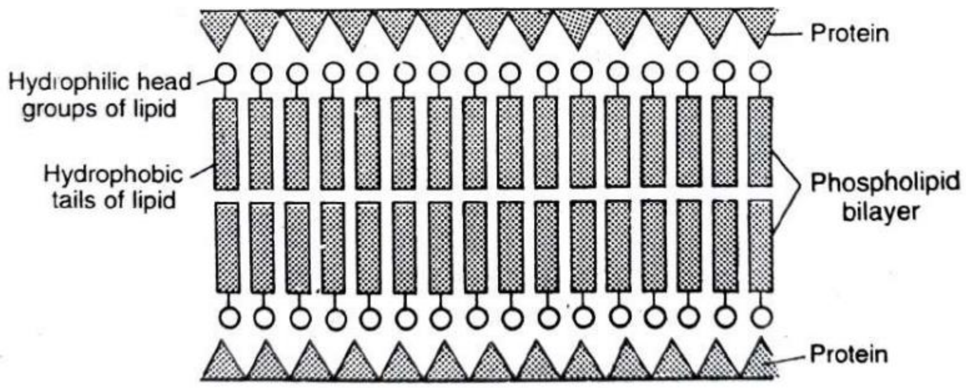



**Fig. 3.4 Robertsonian unit membrane model**

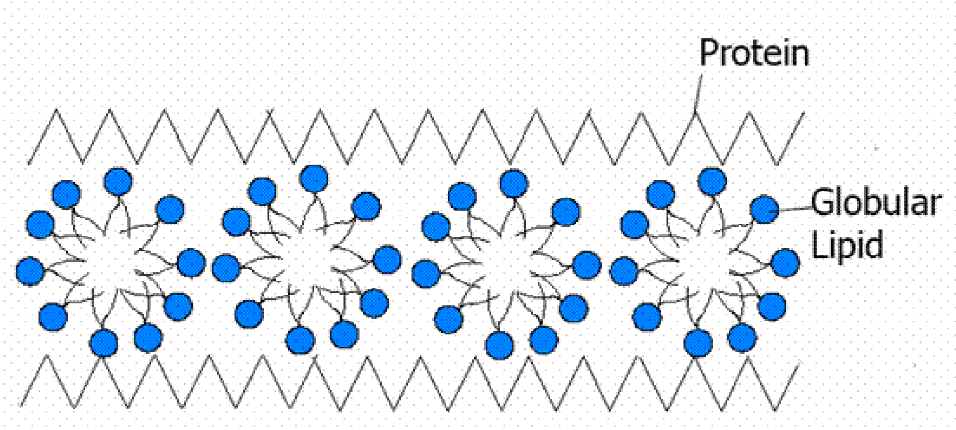
**Micellar Theory. "Hilleir and Hoffman (1953)**

1) The Plasma membrane is formed by the arrangement of globular Sub-units or Micelles in Mosaic fashion.

2) When fatty acid molecule are completely enclosed by water and organized then they are called Micelles.

(3) In each micelle the hydrophilic end of lipid is towards outside while hydrophobic ends towards inside.

(4) A single layer of Protein is present on either side of lipid micelle.




**The Singer and Nicolson model**-

It also known as the **fluid mosaic model**, was proposed by **Singer and Nicolson** in **1972**.

According to the fluid mosaic model:

- The membrane is primarily composed of a lipid bilayer, consisting of phospholipids arranged with their hydrophilic heads facing outward towards the aqueous environment and their hydrophobic tails facing inward.
- The membrane is considered a mosaic of various components, primarily lipids and proteins, arranged in a non-uniform manner. Proteins of different types and functions are embedded within the lipid bilayer, creating a mosaic-like pattern.

**Types of proteins present in membrane-**

- Integral membrane proteins- Integral membrane proteins are embedded within the lipid bilayer.
- Peripheral membrane proteins-Peripheral membrane proteins are attached to the membrane surface.

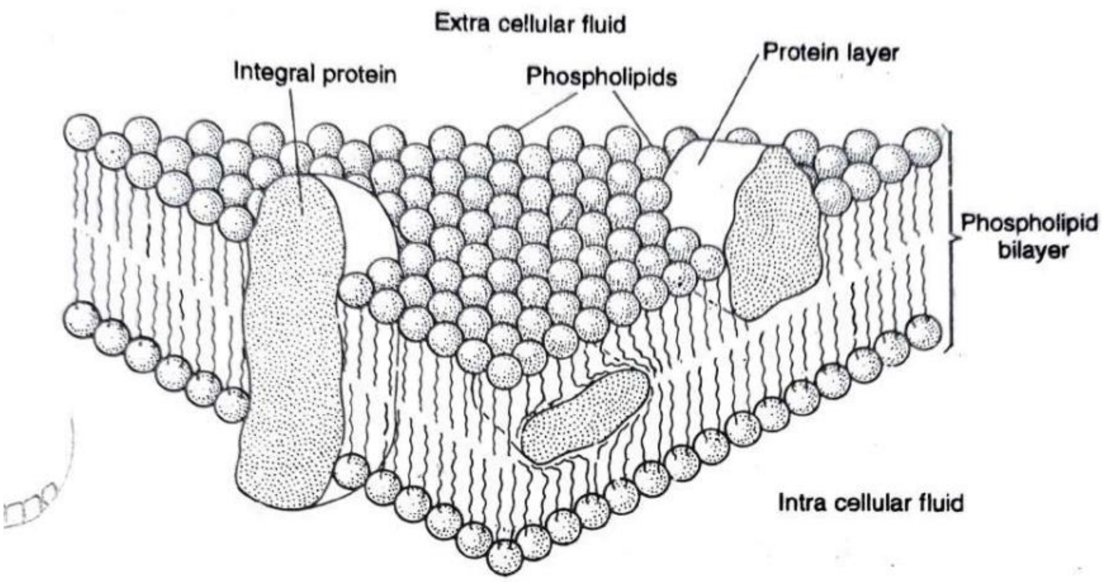



Fig. 3.5 Fluid mosaic model

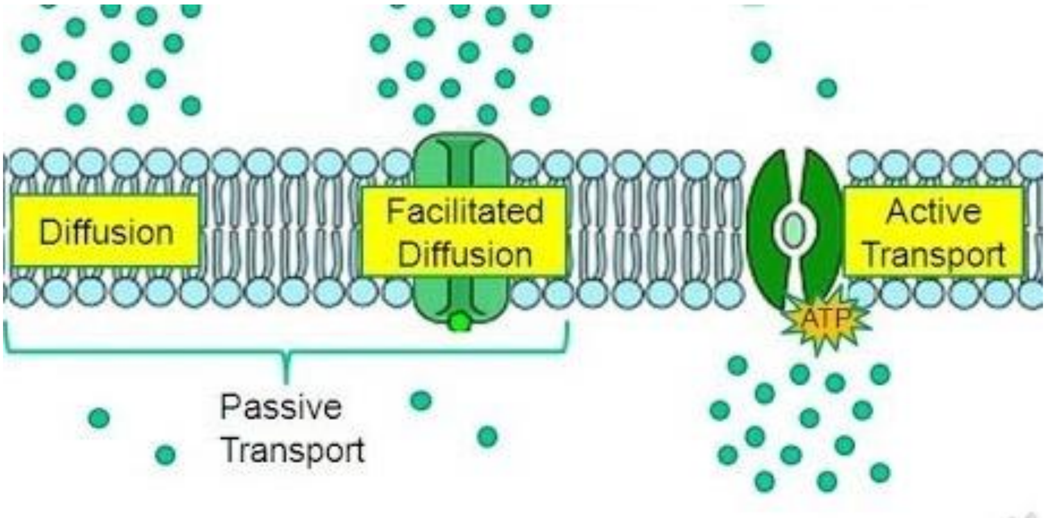
**MEMBRANE TRANSPORT**

**ACTIVE TRANSPORT**

- Against the concentration gradient(low concentration→ high concentration)
- ATP(energy) required.
- With the help of Transport with is ATP Dependent

**PASSIVE TRANSPORT**

- Along the concentration gradient(high concentration→ low concentration)
- No ATP(energy) required.
- With protein (facilitated diffusion) and Without protein (simple diffusion)




**1. Passive diffusion**: This is a simple process which depends on the concentration gradient of a particular substance across the membrane. Passage of water and gases through membrane occurs by passive diffusion. This process does not require energy.

**2. Facilitated diffusion**: This is somewhat comparable with diffusion since the solute moves along the concentration gradient (from higher to lower concentration) and no energy is needed. But the most important distinguishing feature is that facilitated diffusion occurs through the mediation of carrier or transport proteins. Specific carrier proteins for the transport of glucose, galactose, leucine, phenylalanine etc. have been isolated and characterized.

**3. Active transport** : Active transport occurs against a concentration gradient and this is dependent on the supply of metabolic energy (ATP). Active transport is also a carrier mediated process like facilitated diffusion. The most important primary active transport systems are ion-pumps (through the involvement of pump ATPases or ion transporting ATPases).

Example-

**Na+-K+ pump**: The cells have a high intra- cellular K+ concentration and a low Na+ concentration. This is essentially needed for the survival of the cells. High cellular K+ is required for the optimal glycolysis (pyruvate kinase is dependent on K+) and for protein biosynthesis. Further, Na+ and K+ gradients across plasma membranes are needed for the transmission of nerve impulse.

**Factor affect simple diffusion are-**

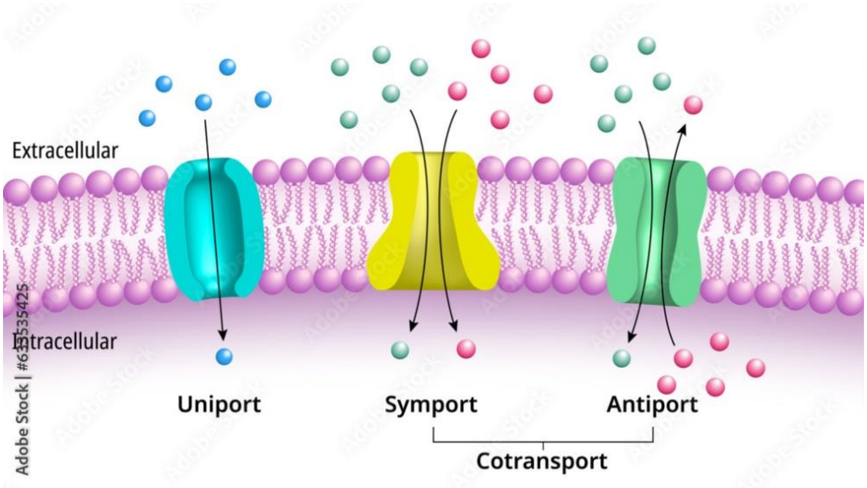
1. Temperature ∝ Diffusion
2. Solute concentration ∝ Diffusion
3. Distance ∝ 1/Diffusion
4. Molecule size ∝ 1/Diffusion
5. Hydrophobic molecule ∝ Diffusion

**Transport systems**

1. Uniport system: This involves the movement of a single molecule through the membrane e.g. transport of glucose to the erythrocytes.
2. Symport system : The simultaneous transport of two different molecules in the same direction e.g. transport of Na+ and glucose to the intestinal mucosal cells from the gut.
3. Antiport system: The simultaneous trans- port of two different molecules in the opposite direction e.g exchange of Cl- and HCO3 in the erythrocytes.

Uniport, symport and antiport systems are considered as secondary active transport systems.

Cotransport system : In cotransport, the transport of a substance through the membrane is coupled to the spontaneous movement of another substance. The symport and antiport systems referred to above are good examples of cotransport system.




**Transport of macromolecules**

The transport of macromolecules such as proteins, polysaccharides and polynucleotides across the membranes is equally important. This is brought about by two independent mechanisms namely **endocytosis** intake of macromolecules by the cells (e.g. uptake of LDL by cells) and **exocytosis** release of macromolecules from the cells to the outside (e.g. secretion of hormones-insulin, PTH)

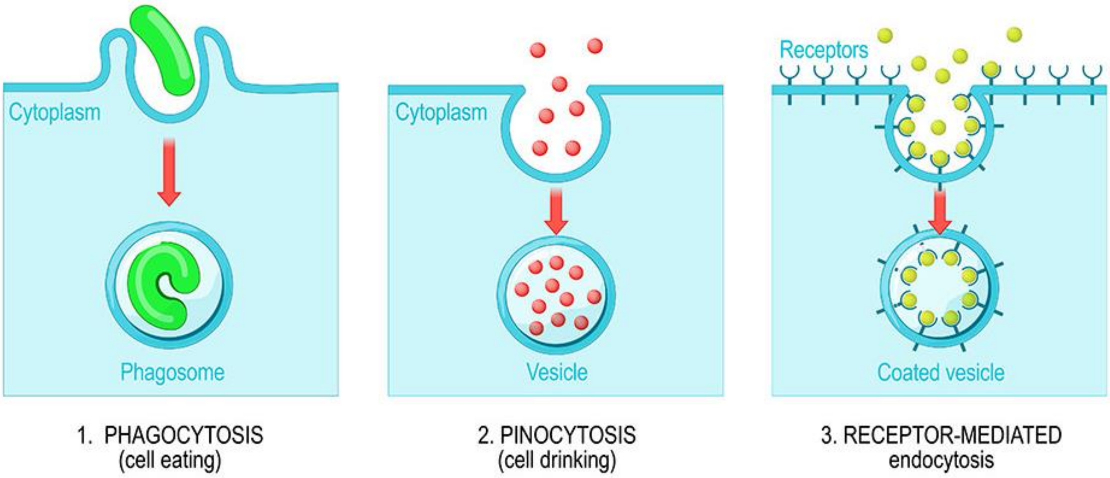
**What is the need of Endocytosis?**

■ Carrier and channel proteins discussed in the preceding section transport small molecules through the phospholipid bilayer. Eukaryotic cells are also able to take up macromolecules and particles from the surrounding medium
■ Small molecules such as sugar, ions, amino acids can be transported through plasma membrane with the help of integral membrane protein form (channel, carriers and pump)
Endocytosis is needed to transport macromolecules.

The former of these activities is known as phagocytosis (cell eating) and occurs largely in specialized types of cells. Other forms of endocytosis take place in all eukaryotic cells.

**Endocytosis**

1. Phagocytosis
2. Pinocytosis (Fluid phase endocytosis)
3. Receptor mediated endocytosis (Clathrin-mediated endocytosis)



## Phagocytosis

Reported by Metchikoff

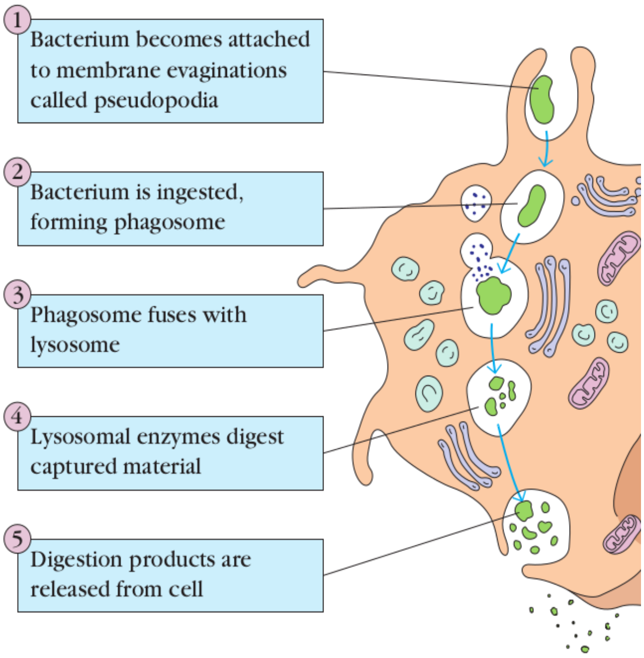
. During phagocytosis cells engulf large particles such as bacteria, cell debris, or even intact cells.

Binding of the particle to receptors on the surface of the phagocytic cell triggers the extension of pseudopodia-an actin- based movement of the cell surface.

• The pseudopodia surround the particle and their membranes fuse to form a large intracellular vesicle called a phagosome(intracellular vesicle).

• The phagosomes then fuse with lysosomes, producing phagolysosomes, in which the ingested material is digested by the action of lysosomal acid hydrolases.

Many amoebas use phagocytosis to capture food particles, such as bacteria or other protozoans




## Role of Phagocytosis in multicellular Organism

In multicellular animals, the major roles of phagocytosis are to provide a defense against invading microorganisms and to eliminate aged or damaged cells from the body.

In mammals, phagocytosis of microorganisms is the function of three types of white blood cells macrophages, neutrophils, and dendritic cells- which are frequently referred to as "professional phagocytes.“

These cells play critical roles in the body's defense systems by eliminating microorganisms from infected tissues.

In addition, macrophages as well as other cell types, including fibroblasts and epithelial cells, eliminate aged or dead cells from tissues throughout the body.

## Pinocytosis

Fluid phase endocytosis.

Invagination of solute or fluid.

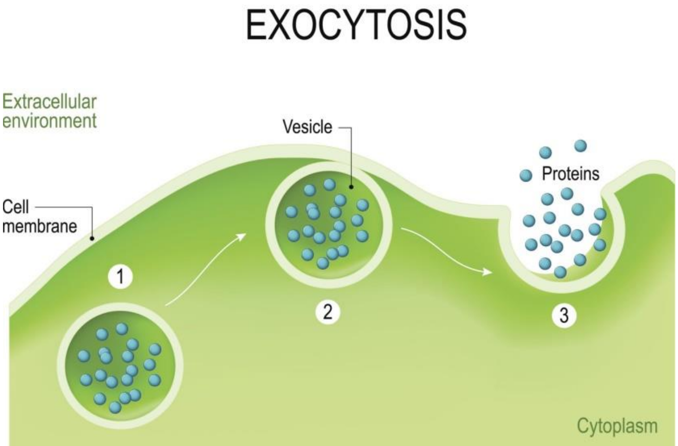
Can occur selectively as well as non-selectively.

**Exocytosis**

Transport vesicle destined for plasma membrane undergo fusion with the plasma membrane and release the contents outside the cell in the process called exocytosis.

**The process of exocytosis involves several steps:**

- **Vesicle Formation:** Specialized vesicles containing molecules to be released are formed within the cell's cytoplasm. These vesicles are typically produced by the Golgi apparatus or endoplasmic reticulum.
- **Vesicle Transport:** The vesicles move towards the cell membrane along cytoskeletal elements such as microtubules or actin filaments.
- **Membrane Fusion:** When the vesicle reaches the cell membrane, it fuses with it. This fusion is mediated by specific proteins present on both the vesicle membrane and the target membrane. The interaction between these proteins helps to bring the membranes into close proximity and initiate fusion.




- **Release of Contents:** Once fusion occurs, the contents of the vesicle are released into the extracellular space. These contents may include neurotransmitters, hormones, enzymes, or other signaling molecules, depending on the cell type and function.
- **Membrane Recycling:** After exocytosis, the cell membrane must be recycled to maintain its integrity.

## MEMBRANE PROTEINS

Membrane proteins are amphiphilic, hydrophobic and hydrophilic regions demy

PERIPHERAL PROTEINS /EXTRENSIC

Peripheral membrane proteins(cytosolic)

Interact with the surface of the lipid bilayer of cell membranes.

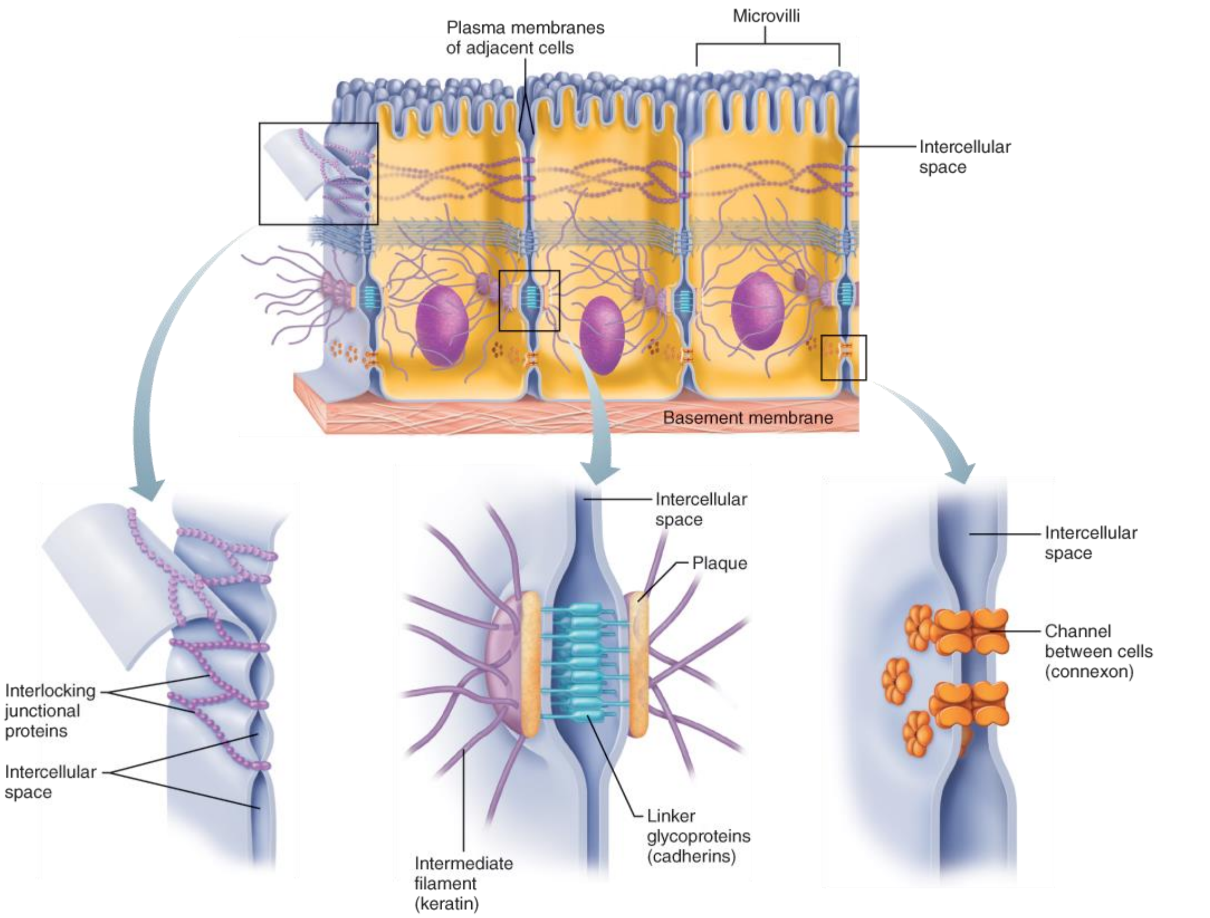
Do not enter into the hydrophobic space within the cell membrane

EXAMPLE: cytochrome c, high potential iron protein, adrenodoxin reductase, some flavoproteins, Spectrin, Ankyrin

INTEGRAL PROTEINS INTRENSIC

Membrane proteins (All transmembrane proteins) Include transporters, linkers, channels, receptors, enzymes, structural membrane-anchoring domains

EXAMPLE: Glycophorin, rhodopsin, Band3, GPCR, etc.




**(a) Tight junctions:** Impermeable junctions prevent molecules from passing through the intercellular space.

**(b) Desmosomes:** Anchoring junctions bind adjacent cells together and help form an internal tension-reducing network of fibers.

**(c) Gap junctions:** Communicating junctions allow ions and small molecules to pass from one cell to the next for intercellular communication.

**Gap junctions**

- These are specialized intercellular channels that allow direct communication and exchange of small molecules, ions, and electrical signals between adjacent cells.
- They are formed by **connexin proteins**, which assemble into hexameric structures called **connexons**. These connexons on one cell membrane align with connexons on the membrane of an adjacent cell, forming a continuous channel called a gap junction.

- Gap junctions are crucial for coordinating cellular activities in tissues such as **cardiac muscle**, where they facilitate rapid electrical signaling, and in **nervous tissue**, where they allow for the passage of neurotransmitters and signaling molecules between neurons.

**Tight junctions**

- These are specialized membrane structures that form a barrier between adjacent cells, sealing the intercellular space.
- They are composed of transmembrane proteins, such as **claudins** and **occludins**.

- Tight junctions play a critical role in maintaining the integrity of epithelial and endothelial cell layers in tissues like the **intestinal epithelium** and **blood-brain barrier**, controlling the selective permeability of these barriers and preventing leakage of harmful substances.

**Desmosomes-**

- These are specialized junctions between cells that provide strong adhesion and mechanical strength, particularly in tissues subjected to mechanical stress, like skin and heart muscle.
- They consist of proteins that anchor cells together and form a strong bond, contributing to tissue integrity and stability.

**Hemidesmosomes-**

- these are similar to desmosomes in that they provide adhesion between cells, but they differ in their structure and function.
- Hemidesmosomes anchor epithelial cells to the basement membrane, providing stability and resistance to mechanical stress.
- They consist of **integrins** and other proteins that link the cell's cytoskeleton to proteins in the extracellular matrix.

**Types of Membrane**

- **Impermeable Membrane**:
  This type of membrane that does not allow the passage of any substances through it except some gases.
  Example –The unfertilized ovum (egg) of certain fish species often has an impermeable plasma membrane, which serves to protect the egg from external influences such as water penetration or the entry of harmful substances.
- **Semipermeable Membrane**:
  A semipermeable membrane allows certain substances(solvent) to pass through while blocking others(solute).
  This selective permeability is often based on factors like size, charge, or solubility.
  Biological membranes, such as the cell membrane, are typically semipermeable.
- **Selectively Permeable Membrane**:
  This term is essentially synonymous with semipermeable membrane. A selectively permeable membrane is one that permits the passage of certain substances while blocking others, based on specific properties of the molecules or ions involved.
  Example – cell membrane of animal cell