Plasma Membrane

The plasma membrane is also called the cell membrane, this membrane is found in all cells that separates the interior of the cell from the outside environment. In bacterial and plant cells, a cell wall is attached to the plasma membrane on its outside surface.

The actual mechanism of its origin is till today is not clear. Someone Scientist said that membrane is an independent organelle which enlarges with growth naturally. Others Scientist regarded that due to deposition of surface active substances at the phase boundary. it originates by self-accumulation of its chemical component of molecules. **Bell suggested that the phragmosomes**, those appear during middle lamella formation and are composed of polysaccharides, help in the formation of new plasma membrane on reaction with lipoprotein.

The **term 'Plasma membrane'** was given by **Wilhelm Pfeffer** in 1877. It is situated just inside the cell wall and is also termed as **cell membrane, plasma lemma or cytomembrane**. The term **'Plasma-lemma'** was given by **J. Q. Plowe**" in the year 1931. **C. Nageli and C. Cramer** in the year 1855 used the term **'Cell membrane'**. **Overton** in 1902 was the first man who studied the structure of plasma membrane and stated that it is composed of a thin layer of lipid.

Gorter and Grandell in 1935 suggested that plasma membrane is made up of **double layer of lipid molecules**. **Robertson in 1961 said that Plasma membrane is made of triple layer of Protein-lipid-Protein molecules and** gave a **"Unit Membrane Concept"**. According to whim all the membranes of the cell were constructed of protein-lipid-protein.

Singer and Nicholson in 1972 proposed a **"Fluid Mosaic Model"** of plasma membrane. According to whim lipid and integral proteins are present in a mosaic arrangement and the biological membranes are semifluid so that the lipids as well as integral proteins are able to make movement within the bilayer.

Structure of Plasma Membrane:

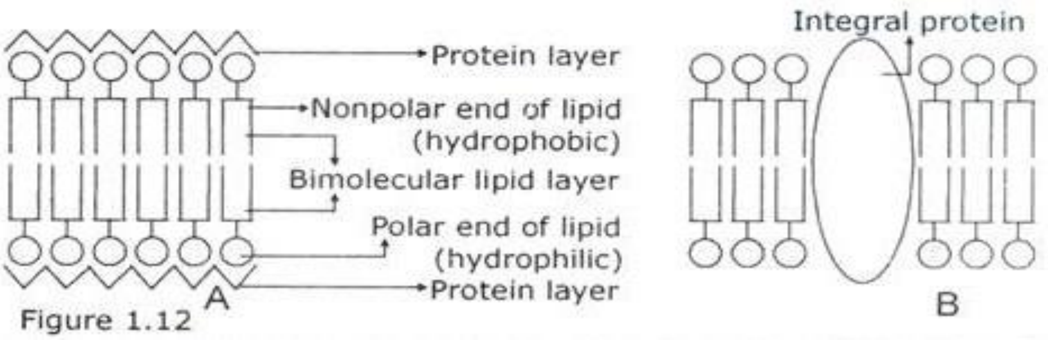
The plasma membrane is not readily visible under light microscope. The membrane enclosing a cell is called cell membrane or plasma membrane as in (animal cells) and plasma lemma in (plant cells). It contains proteins and lipids in the ratio of 80 : 20 % in bacteria on one extreme and on the other extreme 20:80 % in some nerve cells. The over all composition of most of the cell membranes is 40-50 % protein and 50-60% lipids; both the components vary in their composition.

The cytoplasm of the cell is bounded on the outer side by a delicate, flexible, thin layer called the plasma lemma or ectoplast. It is 75-100 A^0 thick. Likewise to the inner side it is bounded by another membrane said as tonoplast which is 75-100 A^0 thick. The main function of cell membrane is to regulate the transfer of materials inside and outside of the cell.

It acts as a selectively or differentially permeable membrane. It prevents the entrance of toxic elements into the cytoplasm and provides only a one-way passage for materials like minerals into the cell and checks their outward movement. In the above process, the substances enter the cell by first being absorbed on the plasma membrane and then being transmitted inside the cell.

Electron microscopic studies have revealed that the 7-8 nm or 6 nm to 10 nm thick, plasma membrane is consists of three layers—two outer dense layer, each about 2 nm thick and a middle less dense area of 3.5 nm across, for a total thickness of 7.5 nm. The two electron dense regions separated by an electron light central region (Fig.2.7). These three layers together are called **"trilaminar". Robertson in 1959** termed them as **"Unit membrane";** he proposed the **"unit membrane hypothesis".**

According to whim all the biological membranes have "trilaminar" organisation. This concept express that the outer dense layers represent the protein and the enclosed less dense are the lipids. Very small pores, none of which are of greater diameter than 5 nm, interrupt the continuity of the membrane.(1.12)



Schematic Representation of Molecular Organization of the Plasma Membrane

Chemical Composition of Plasma Membrane:

The plasma membrane is composed of mainly proteins (60-80%) and lipids (20-40%) and a small percentage (%) of carbohydrate, (1-5%). Proteins are the main components of plasma membrane since they provide mechanical support and act as channels for different vital or physiological activities. Water makes about 29% of total weight. **Robertson in 1959** proposed that plasma membrane is three-layered structure where proteins form the outer and inner layers of membrane that encloses lipids to form a unit membrane.

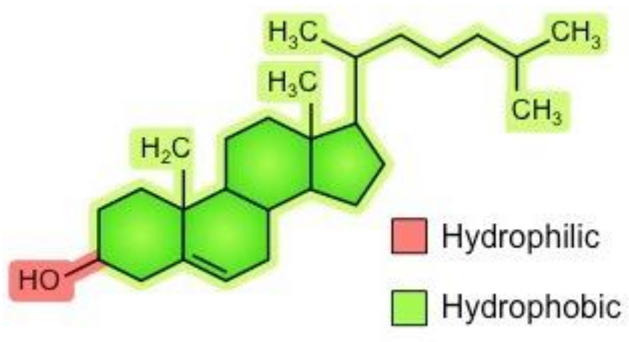
Very recently **Bell in 1962** has suggested that the presence of polysaccharides in the outer layer of plasma membrane and this saccharide gives the stability to the lipoprotein complex. Besides, that some thirty (30) enzymes have been isolated from different plasma membrane. Among them, most important are 5-nucleotides, phosphomonesterase, adenyl cyclase, Na^+ - K^+ activated ATPase, alkaline phosphatase.

The basic concept of Plasma membrane is made by following components. Lipid, Protein and Carbohydrate.

1.Lipid:

The lipids identified in the plasma membrane consist of cholesterol. **Cholesterol** is found in **animal** cell membranes and functions to improve stability and reduce fluidity, phospholipids and galactolipids. Cholesterol acts as a bi-directional regulator of membrane fluidity. Cholesterol is a component of animal cell membranes, where it functions to maintain integrity and mechanical stability. Cholesterol is an *amphipathic* molecule (like phospholipids), meaning it has both hydrophilic and hydrophobic regions. Cholesterol's hydroxyl (-OH) group is *hydrophilic* and aligns towards the phosphate heads of phospholipids. The remainder of the molecule (steroid ring and hydrocarbon tail) is *hydrophobic* and associates with the phospholipid tails. **It is absent in plant cells,** as these plasma membranes are surrounded and supported by a rigid cell wall made of cellulose.

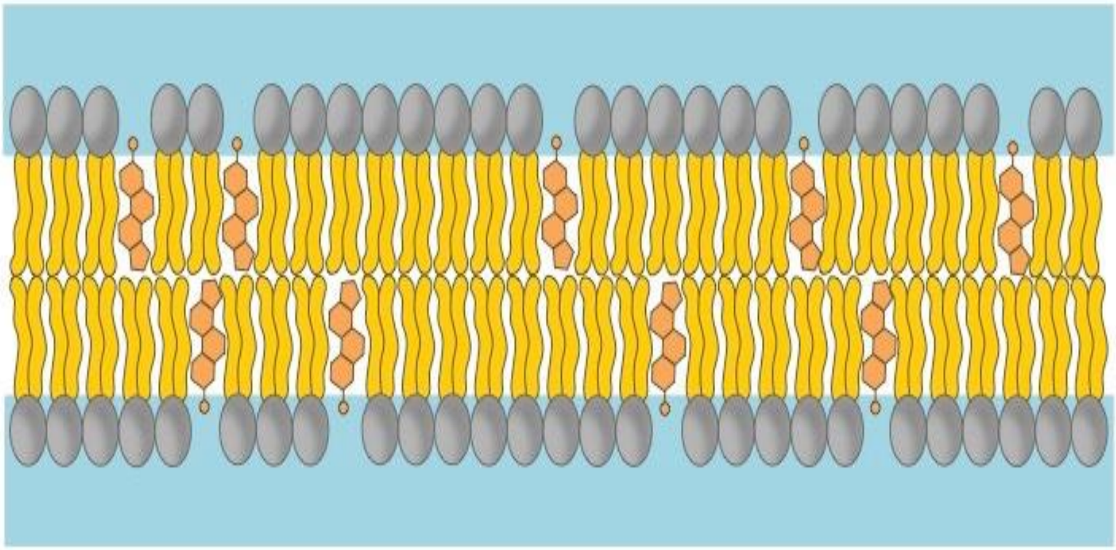
H_2C = Ethene, H_3C = Pantane, CH_3= Methenide



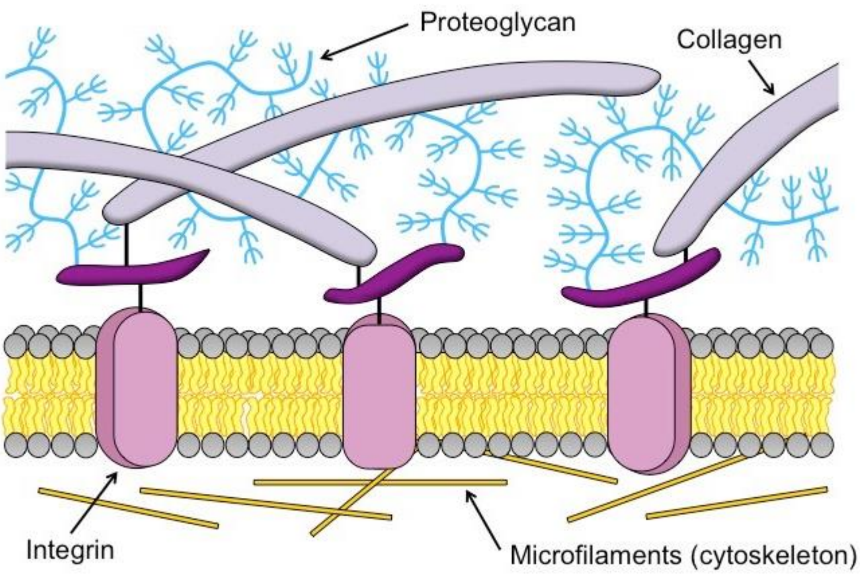
Cholesterol in mammalian membranes reduces membrane fluidity and permeability to some solutes

Cholesterol interacts with the fatty acid tails of phospholipids to moderate the properties of the membrane. Cholesterol functions to immobilise the outer surface of the membrane, reducing fluidity.

- ❖ It makes the membrane less permeable to very small water-soluble molecules that would otherwise freely cross.
- ❖ It functions as to separate phospholipid tails and so prevent crystallisation of the membrane.
- ❖ It helps secure peripheral proteins by forming high density lipid rafts capable of anchoring the protein.
- ❖ At high temperatures it stabilises the membrane and raises the melting point
- ❖ At low temperatures it intercalates between the phospholipids and prevents clustering.



- ❖ The extracellular matrix is a mesh of protein fibres and glycoproteins that exist externally of the cell in multicellular organisms
- ❖ The extracellular matrix typically provides structural and biochemical support to surrounding cells, including:
- ❖ Providing sites for anchorage by cells within a tissue and segregating separate tissues from one another
- ❖ Sequestering and storing growth factors until receipt of a chemical signal (thereby regulating intercellular communication)



The phospholipids include phosphatidylcholine, phosphatidylethanolamine and sphingomyelin. The phospholipids are found to be associated with the outer protein shell in the plasma membrane. Glycerol and fatty acid constitute lipid molecules. **Phospholipids** form a bilayer with phosphate heads facing outwards and fatty acid tails facing inwards. In the membrane the lipid molecules consist of two parts -a head and two tails. The head is composed of glycerol and is hydrophilic where as the tails are composed of fatty acids that are hydrophobic. The head and tail are usually designated as polar and nonpolar end respectively.

Structure of Phospholipids:

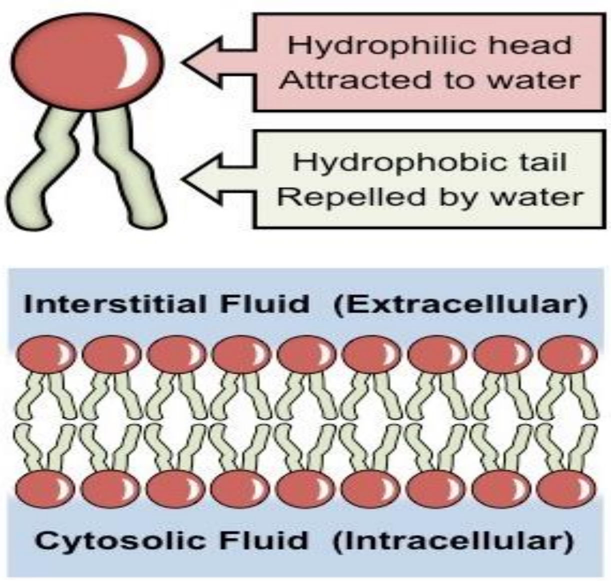
Phospholipid is Consist of a polar head (*hydrophilic*) composed of a glycerol and a phosphate molecule. Consist of two non-polar tails (*hydrophobic*) composed of fatty acid (hydrocarbon) chains. Because phospholipids contain both hydrophilic (*water-loving*) and lipophilic (*fat-loving*) regions, they are classed as amphipathic.

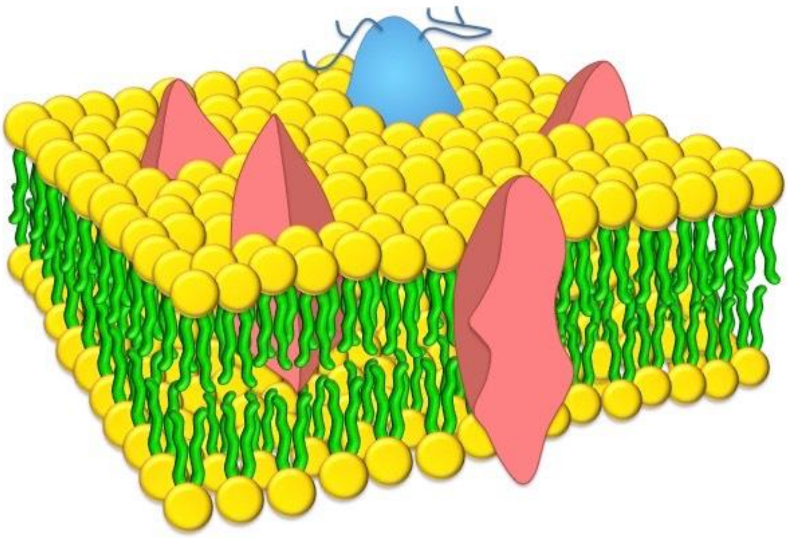
Arrangement in Plasma Membranes:

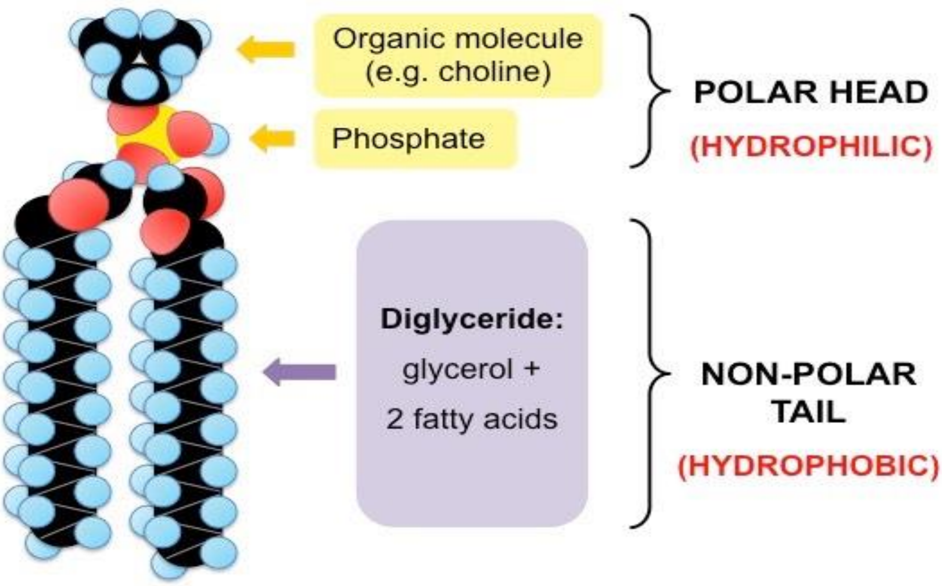
Phospholipids spontaneously arrange into a bilayer. The hydrophobic tail regions face inwards and are shielded from the surrounding polar fluids, while the two hydrophilic head regions associate with the cytosolic and extracellular fluids respectively.

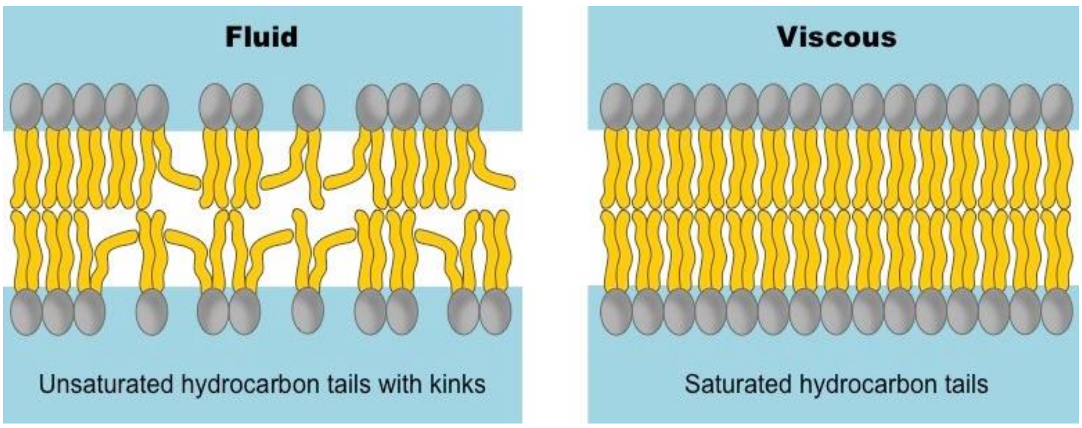
Properties of the Phospholipid Bilayer:

- **The bilayer** is held together by weak *hydrophobic interactions* between the tails.
- **Hydrophilic/hydrophobic** layers restrict the passage of many substances.
- **Individual phospholipids** can move within the bilayer, allowing for membrane fluidity and flexibility.
- **The fluidity allows** for the spontaneous breaking and reforming of membranes (endocytosis / exocytosis).
- **Phospholipid bilayers** are embedded with proteins, which may be either permanently or temporarily attached to the membrane
- **Integral proteins** are permanently attached to the membrane and are typically transmembrane.
- **Peripheral proteins** are temporarily attached by non-covalent interactions and associate with one surface of the membrane






Organic molecule (e.g. choline)
Phosphate
POLAR HEAD
(HYDROPHILIC)
Diglyceride:
glycerol +
2 fatty acids
NON-POLAR TAIL
(HYDROPHOBIC)


Fluid
Unsaturated hydrocarbon tails with kinks
Viscous
Saturated hydrocarbon tails

The lipid molecules are oriented in two (bimolecular) layers with their hydrophilic polar ends directed towards protein and the hydrophobic nonpolar ends face each other. Hydrogen bonds, ionic linkages or electrostatic forces bind the protein and lipid components.

2.Protein:

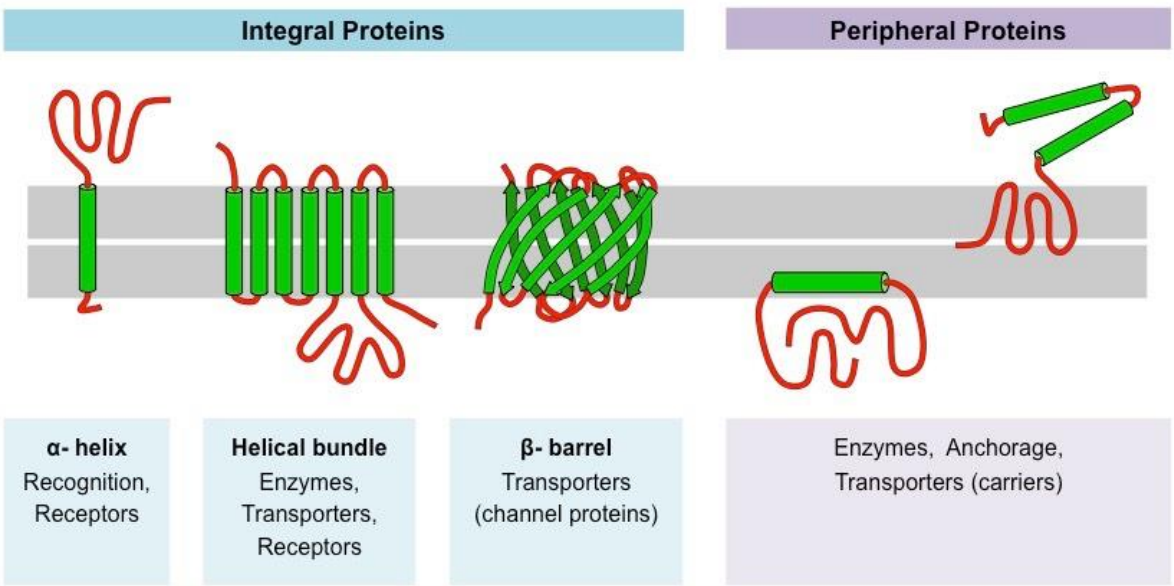
In the membrane it is present as enzyme protein, carrier protein and structural protein. The enzyme proteins have catalytic activity. The carrier proteins help to transport materials in and out of the cell across membrane. The structural proteins play an important role to form the structure of membrane.

Structure of Membrane Proteins:

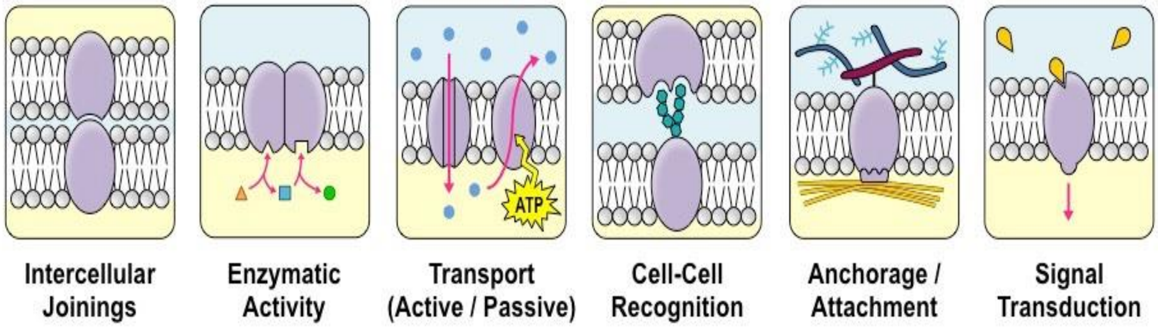
The amino acids of a membrane protein are localised according to polarity:

- ❖ Non-polar (hydrophobic) amino acids associate directly with the lipid bilayer.
- ❖ Polar (hydrophilic) amino acids are located internally and face aqueous solutions.
- ❖ Transmembrane proteins typically adopt one of two tertiary structures :

  1-Single helices / helical bundles

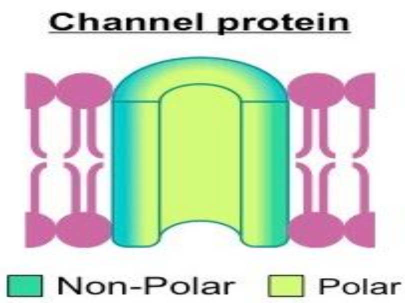


2- Beta barrels (common in channel proteins)



Functions of Membrane Proteins: Membrane proteins can serve a variety of key functions:

- **Junctions** : Serve to connect and join two cells together
- **Enzymes** : Fixing to membranes localises metabolic pathways
- **Transport** : Responsible for facilitated diffusion and active transport
- **Recognition** : May function as markers for cellular identification
- **Anchorage** : Attachment points for cytoskeleton and extracellular matrix
- **Transduction** : Function as receptors for peptide hormones



3.Carbohydrates:

They occur in the form of glycolipids and glycoproteins. Both of these forms are confined exclusively to the external membrane surface. **Bell in 1962** gives his opinion that polysaccharides confer some stability to the lipoprotein complex in the membrane. Carbohydrates are the major component of plasma membranes.

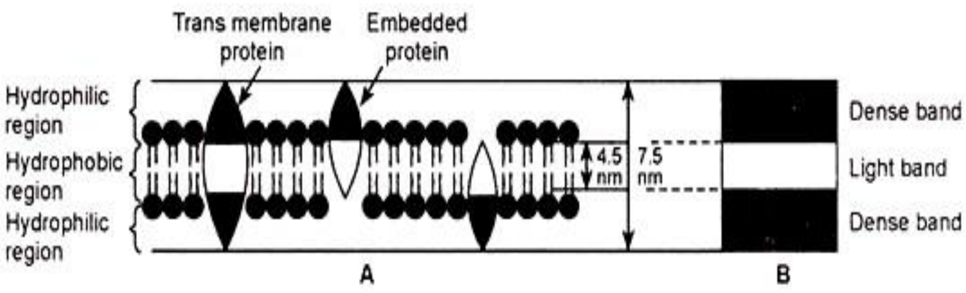
They are always found on the exterior surface of cells and are bound either to proteins (forming glycoproteins) or to lipids (forming glycolipids).

These carbohydrate chains may consist of 2–60 monosaccharide units and can be either straight or branched. Along with peripheral proteins, carbohydrates form specialized sites on the cell surface that allow cells to recognize each other. This recognition function is very important to cells, as it allows the immune system to differentiate between body cells (called "self") and foreign cells or tissues (called "non-self").

Similar types of glycoproteins and glycolipids are found on the surfaces of viruses and may change frequently, preventing immune cells from recognizing and attacking them. These carbohydrates on the exterior surface of the cell—the carbohydrate components of both glycoproteins and glycolipids—are collectively referred to as the glycocalyx (meaning "sugar coating"). The glycocalyx is highly hydrophilic and attracts large amounts of water to the surface of the cell. This aids in the interaction of the cell with its watery environment and in the cell's ability to obtain substances dissolved in the water.

The most widely accepted model of plasma membrane is the **"fluid mosaic model"** which was proposed by **Singer and Nicholson in 1972.**

According to this model, the membrane is composed of lipids and proteins organized as follows (Fig. 2.7):



'ig. 2.7. The fluid-mosaic model of membrane organisation. **A.** Membrane consists of a lipid bilayer. The hydrophilic head groups of lipid molecules orient outward while the hydrophobic tail groups orient inward. Transmembrane proteins are embedded within the lipid molecules. The region of the protein molecule present within the membrane is hydrophobic while that extending outside the membrane is hydrophilic. **B.** Electron microscopic image shows the trilaminar appearance of the membrane, two electron dense bands separated by a light band.

(a) Two monolayers of lipid molecules form a lipid bilayer.

(b) The protein molecules are embedded within the lipid bilayer. The lipid bilayer is a fluid and the lipid molecules are in a state of “liquid crystal” i.e., they are not fixed on a position and at the same time, they are not free to move. The membrane protein and lipids, both can have lateral movement within the lipid bilayer.

1. Lipid Bilayer:

The lipid bilayer is made up of two lipid layers, each layer being one molecule thick. This organisation is common to all biological membranes, but there are notable differences in the particular kinds of lipids present. Each lipid molecule has a ‘hydrophilic’ head and one or two ‘hydrophobic’ tails, making them **“amphipathic”** molecules.

The hydrophilic ends of the lipid molecules are oriented toward the outside of the membrane of the cell, while their hydrophobic tails are oriented inward, the latter constitute the interior hydrophobic region of the membrane (Fig. 2.7). The tails of the lipid molecules are made up of fatty acids (Fig. 2.8), both saturated and unsaturated fatty acids may be present.

In myelin membrane, unsaturated fatty acids constitute less than 10%, while in the mitochondrial and chloroplast membranes, unsaturated fatty acids make up more than 50% of the fatly acids. Tails of saturated fatty acids extend freely but those of the unsaturated chain bend at the double bond.

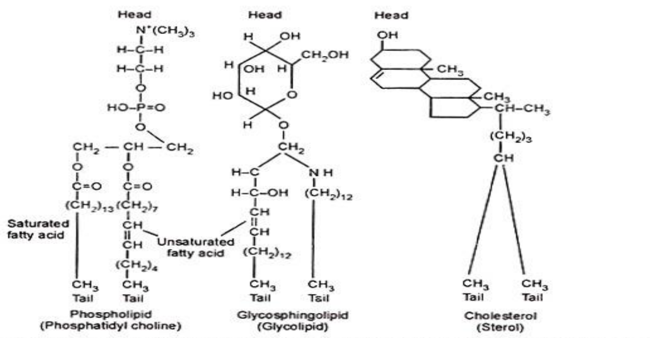


Fig. 2.8. Lipid molecules found in biological membranes. A lipid molecule has a hydrophilic head and hydrophobic tail(s). The unsaturated fatty acid tail bends at the position of unsaturation (CH=CH).

2. Membrane Proteins:

In general, the ratio of lipids and proteins is equal (about 50% each) in the biological membranes but the organellar membranes contains a high proportion (75-80%) of proteins. Integral proteins are embedded within the lipid bilayer, and they can move laterally within the bilayer.

The region (domain) of the protein molecule lying within the lipid bilayer is "hydrophobic" while that lying out side the bilayer is "hydrophilic".

The protein molecules that pass through the lipid bilayer and are exposed on both the sides of the lipid bilayer are called trans-membrane (Fig. 2.9). Trans-membrane proteins have one or more regions containing 21-26 hydrophobic amino acids which are coiled into an α-helix.

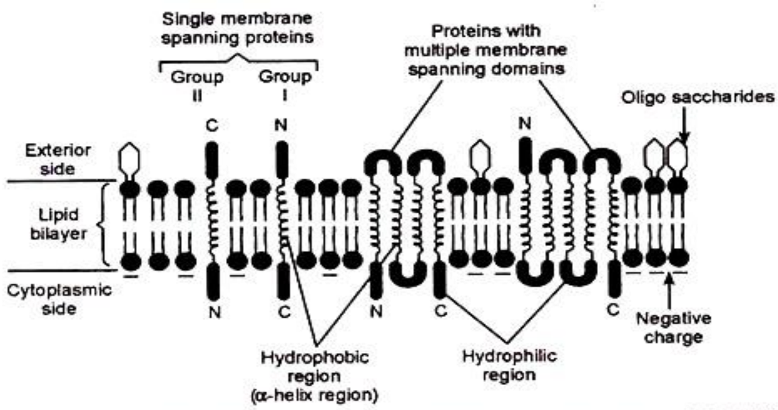


Fig. 2.9. Diagrammatic representation of membrane proteins and asymmetry of lipid bilayer. Single membrane spanning proteins may have their N-terminal located on the interior (cytoplasmic side) of the membrane or on the exterior side. Multiple membrane spanning proteins may have their both (N and C terminal) ends or only one of the two ends located on the cytoplasmic side. The exterior surface contains oligosaccharides. But the cytoplasmic surface contains the lipid molecules with predominantly unsaturated fatty acids resulting in a negative charge.

The membrane proteins are of different kinds regarding their organisation within the membrane:

(i) Proteins with single membrane-spanning region (hydrophobic region), and

(ii) Proteins with multiple membrane-spanning regions.

Proteins with single membrane-spanning region:

These are of two types:

(a) Group I Proteins:

Group I proteins are those whose N-terminal end is exposed to the exterior of the cell, while the C-terminal end is exposed in the cytoplasm (Fig. 2.9).

(b) Group II Proteins:

Such proteins have their C-terminal end exposed to the exterior of the cell, while their N-terminal end is exposed into the cytoplasm (Fig. 2.9). Such proteins are less common.

Proteins with multiple membrane-spanning regions (hydrophobic regions): These are of two types:

1.Proteins with 'odd' number of hydrophobic regions:

In such proteins, the N-terminal and C-terminal regions lie on different sides of the membrane (Fig. 2.9).

2. Proteins with 'even' number of hydrophobic regions:

These proteins have both, their N-terminal and C-terminal ends on the same side of the lipid bilayer (Fig. 2.9)

Lipids are synthesized in the Endoplasmic Reticulum (ER), and are transported to the cytoplasmic surface of the membrane, from where they are transported to the outer monolayer of the lipid bilayer. The protein involved in this movement is called flippase. The outer surface of the membrane is rich in carbohydrate groups such as, glycoproteins or glycolipids (Fig. 2.9). The inner surface (cytoplasmic surface), on the other hand, is charged negatively (-) due to the predominance of unsaturated fatty acid chains in the lipid molecules forming the inner monolayer.

Thus there is an asymmetry in the organisation of the lipid bilayer of the plasma membrane. One important property of the plasma membrane is that it can produce “vesicles” by a process of budding. The vesicles can fuse with the membrane by the reverse process.

These three terms are widely used in structure of Plasma membrane.

- ✓ **Amphiphilic**: Having one surface consisting of hydrophilic amino acids and the opposite surface consisting of hydrophobic (or lipophilic) ones.
- ✓ **Hydrophilic**: Having an affinity for water; able to absorb, or be wetted by water, “water-loving.”
- ✓ **hydrophobic**: Lacking an affinity for water; unable to absorb, or be wetted by water, “water-fearing

The Fluid Mosaic Model of Plasma Membrane:

In Fluid Mosaic Model of the plasma membrane is explain that an i**ntegral membrane proteins are inserted into the lipid bilayer, whereas peripheral proteins are bound to the membrane indirectly by protein-protein interactions**. Most integral membrane proteins are trans-membrane.

This model was proposed by **S.J. Singer and Garth L. Nicolson in 1972**. This model explains the structure of the plasma membrane of animal cells as a mosaic of components such as phospholipids, proteins, cholesterol, and carbohydrates. These components give a fluid character to the membranes.

The fluid mosaic model describes the structure of the plasma membrane as a mosaic of components -including phospholipids, cholesterol, proteins, and carbohydrates-that gives the membrane a fluid character. Plasma membranes range from 5 to 10 nm in thickness. For comparison, human red blood cells, visible via light microscopy, are approximately 8 µm wide, or approximately 1,000 times wider than a plasma membrane. The proportions of proteins, lipids, and carbohydrates in the plasma membrane vary with cell type.

For example, myelin contains 18% protein and 76% lipid. The mitochondrial inner membrane contains 76% protein and 24% lipid.

Singer and Nicolson have to explain its major features (Fig. 4.12).

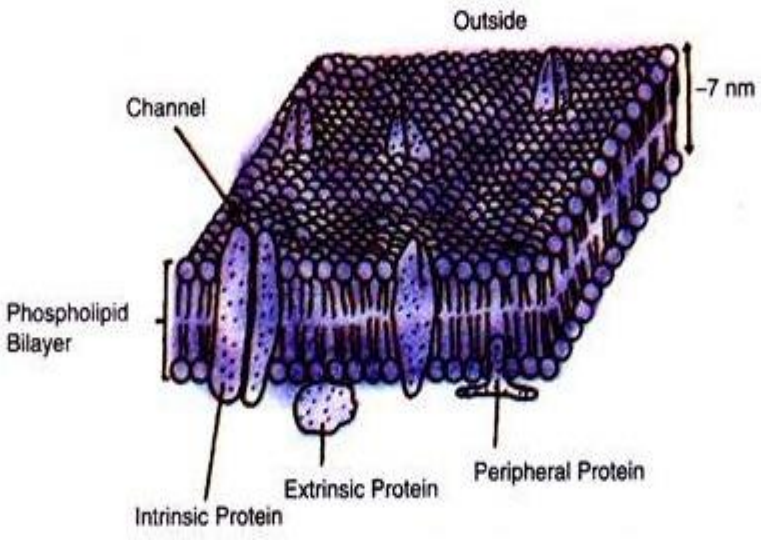
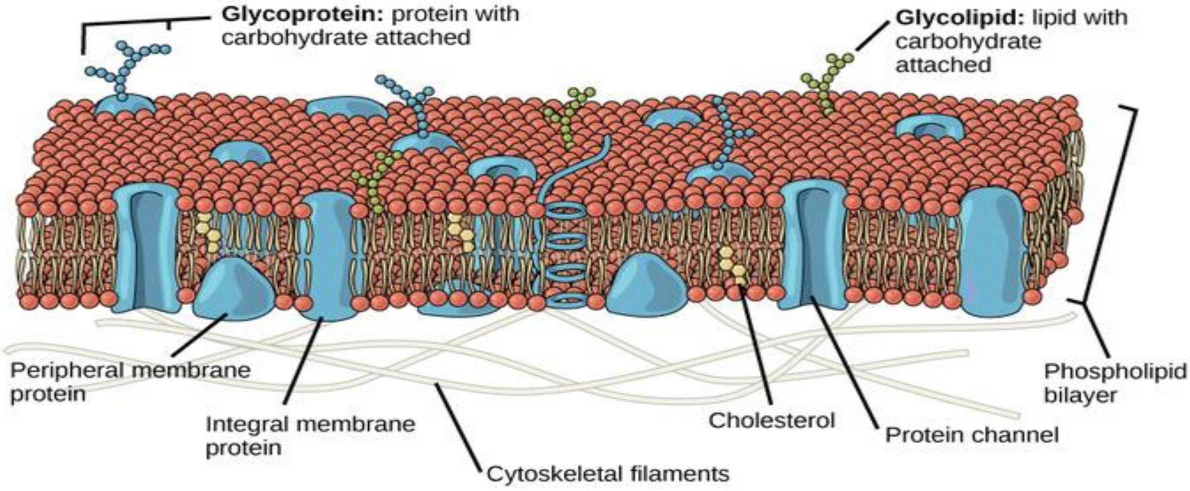
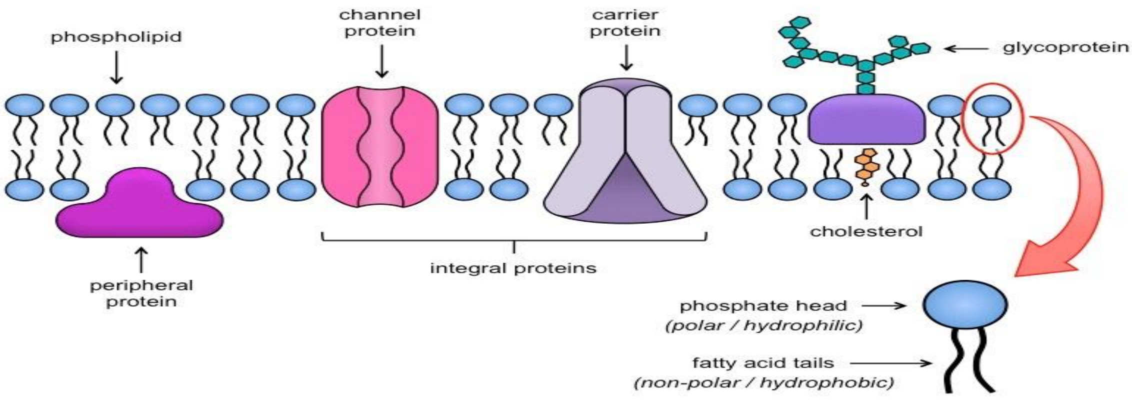


Fig. 4.12 : Fluid mosaic model of bacterial membrane.





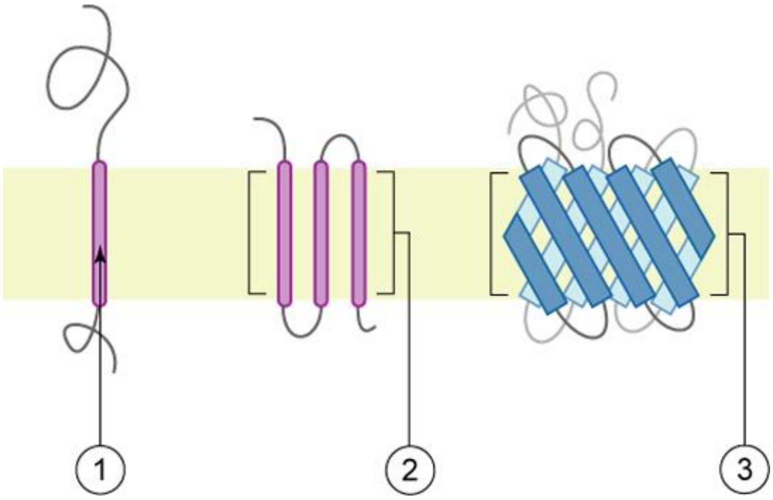
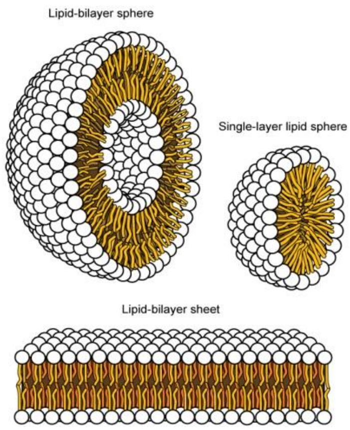
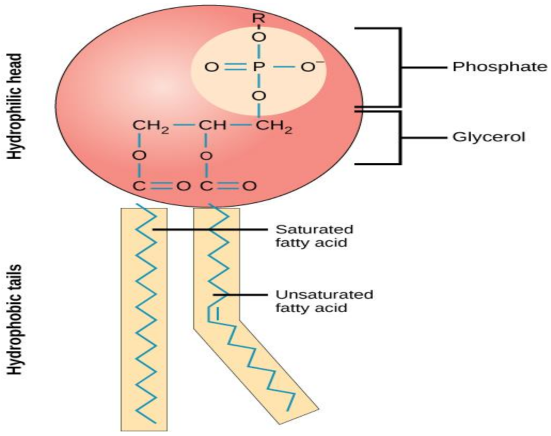


Figure Structure of integral membrane proteins:

This model is well accepted. According to this model, the plasma membrane is quasifluid structure in which lipids and proteins are arranged in a mosaic manner. Like following figure.





The globular proteins are of two types: extrinsic (peripheral) proteins and intrinsic (integral) proteins. The extrinsic protein is soluble and, therefore, dissociates from the membrane, while the intrinsic protein is insoluble and could not (or rarely) dissociate. The intrinsic proteins are partially embedded either on outer surface or on inner surface of the bilayer and take part in lateral diffusion in lipid bilayer.

The lipid matrix of membrane has fluidity that permits the membrane components to move laterally. The membrane fluidity is due to the hydrophobic interactions of lipids and proteins. The fluidity is important for a number of membrane functions. Phospholipids and many intrinsic proteins are amphipatic i.e. they possess both hydrophilic and hydrophobic groups.

Phospholipids are the complex lipids which are made up of glycerol, two fatty acids and, in place of a third fatty acid, a phosphate group bounded to one of several organic groups (Fig. 4.13).

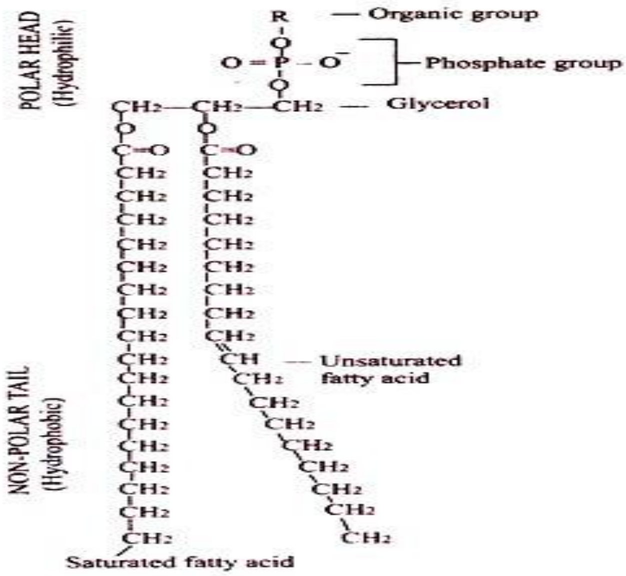


Fig. 4.13 : Chemical composition of a phospholipid molecule.

They have polar (hydrophilic) as well as non-polar (hydrophobic) regions. Polar portion consists of a phosphate group and glycerol, while non-polar portion consists of fatty acids.

All non-polar parts of phospholipid make contact only with the non-polar portion of the neighbouring molecules. The polar portion occurs towards outside. This characteristic feature gives the appearance of bilayer. However, between the fatty acid chains proper spacing is maintained by interspersing unsaturated chains throughout the membrane. This type of arrangement maintains the semi-fluidity of plasma membrane.

The presence of complex lipids becomes a key character of certain microorganisms on the basis of which they can be identified.

For example, the cell wall of **Mycobacterium** contains high amount of lipids such as waxes and glycolipids which gives the bacterium a distinctive staining characteristic.

In some microorganisms such as mycoplasmas and fungi, sterols are found to be associated within the plasma membrane (Fig.4.14).

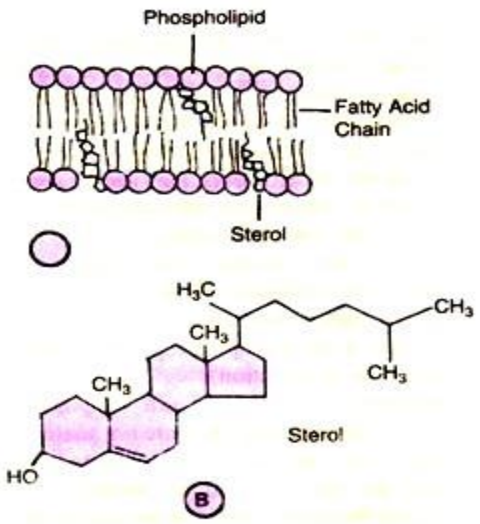


Fig. 4.14 : Presence of steroids in plasma membrane (A), and chemical structure of a steroid (B).

Sterols are structurally different from the lipids. The -OH group in cholesterol makes it a sterol. Sterols are alcohols composed of hydrocarbon rings attached to hydrocarbon chain. The sterols separate the fatty acid chains and check packing which harden the plasma membrane at low temperature.

In case of certain bacteria hopanoids are present which have similar role to that of sterols found in certain fungi. These hopanoids do not require oxidation step for their biosynthesis, therefore due to lack of oxygen, anaerobic bacteria also contain hopanoids.

Functions of Plasma Membrane:

Besides enclosing the cell and protecting it from the external environment, the plasma membrane has several important functions, such as, regulating the movement of materials inside and outside the cell, metabolic functions, communication between different cells and adhesion between cells.

1.Movement of Materials: Movement (import and export) of materials occur by different mechanisms, for e.g. :

(a) Simple diffusion,

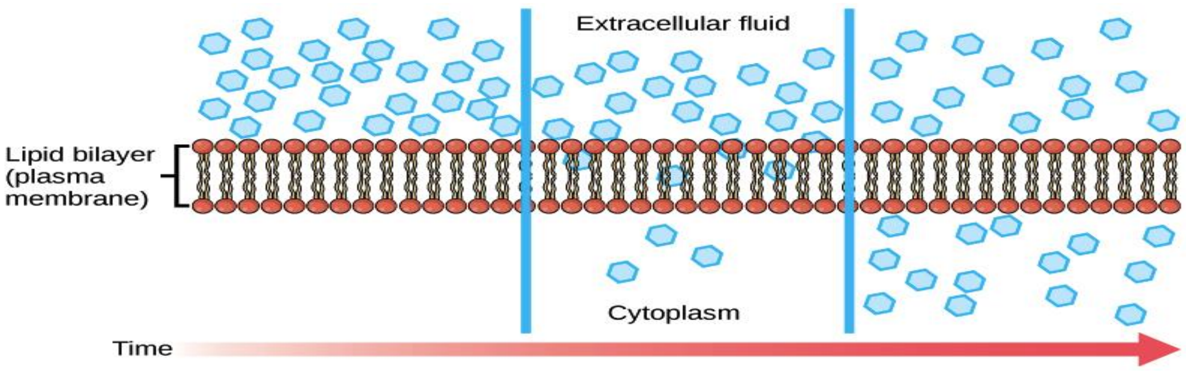
(b) Facilitated diffusion,

(c) Active transport, and

(d) Endocytosis and exocytosis.

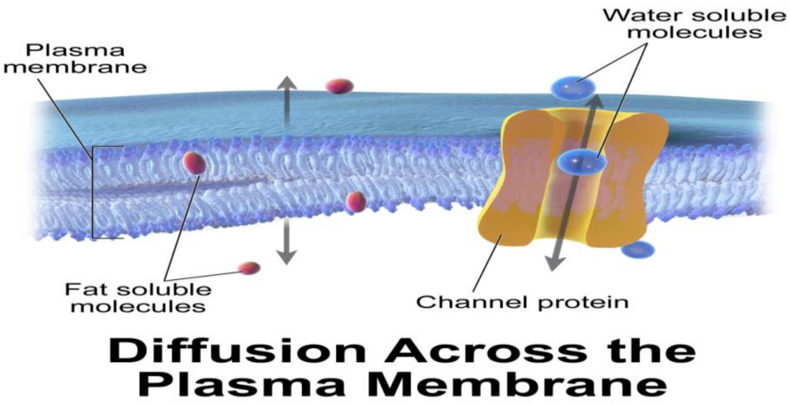
(a) Simple Diffusion:

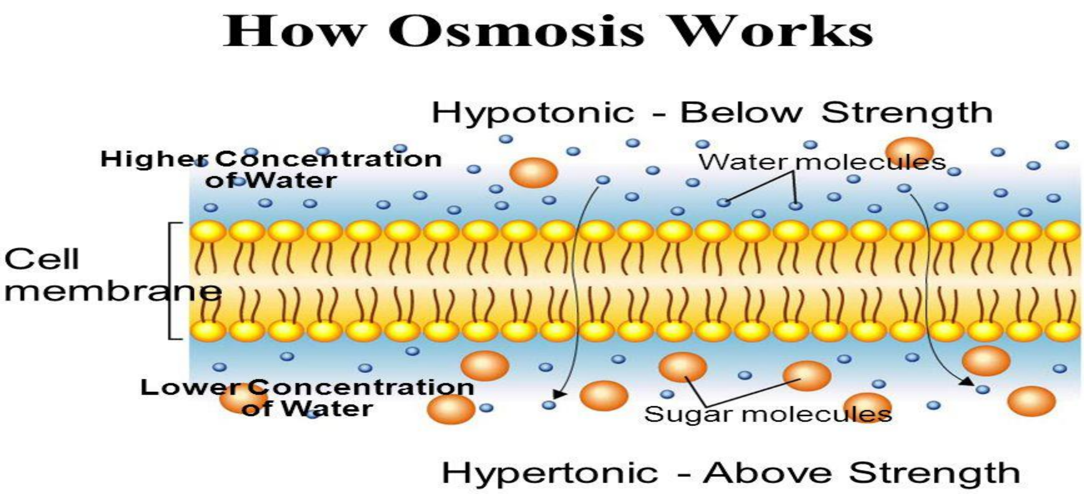
Simple diffusion refers to the unaided movement of a substance from the region of its higher concentration to a region of its lower concentration till an equilibrium is achieved. Some solutes diffuse through the plasma membrane more readily than the others.

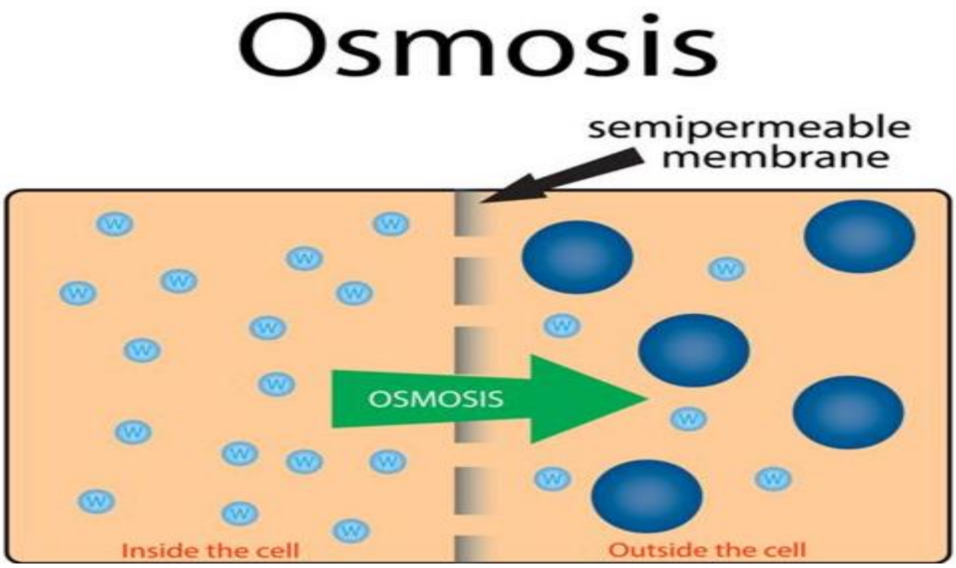


Simple diffusion

Therefore, the plasma membrane is called as a selectively permeable or differentially permeable membrane. When water molecules move through a differentially permeable membrane from lower to higher concentration of solutes, the process is called osmosis.


Water soluble molecules
Plasma membrane
Fat soluble molecules
Channel protein
Diffusion Across the Plasma Membrane

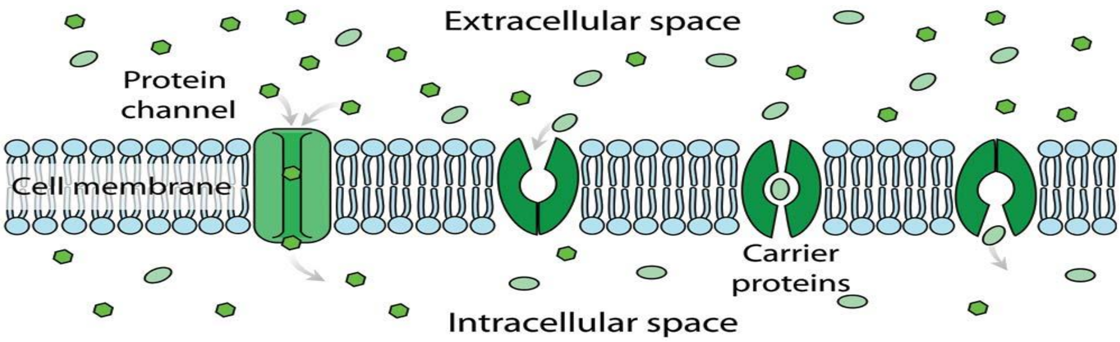

How Osmosis Works
Hypotonic - Below Strength
Higher Concentration of Water
Water molecules
Cell membrane
Lower Concentration of Water
Sugar molecules
Hypertonic - Above Strength


Osmosis
semipermeable membrane
OSMOSIS
Inside the cell
Outside the cell

(b) Facilitated Diffusion:

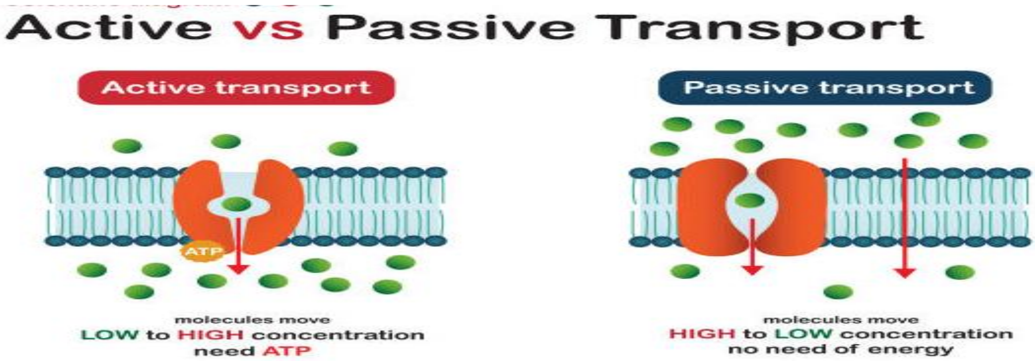
It is similar to simple diffusion but the rate of the solute movement increases by interaction with specific membrane transporters. The transporters are "trans membrane proteins."

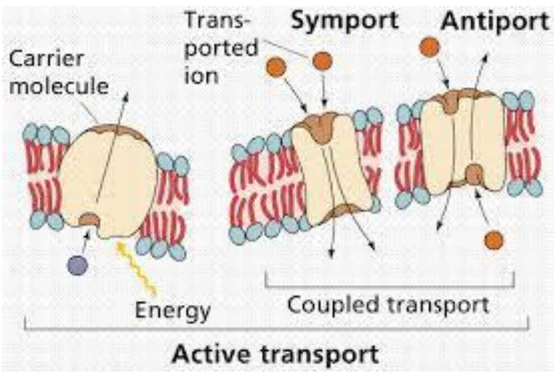
Facilitated diffusion in cell membrane, showing ion channels and carrier proteins

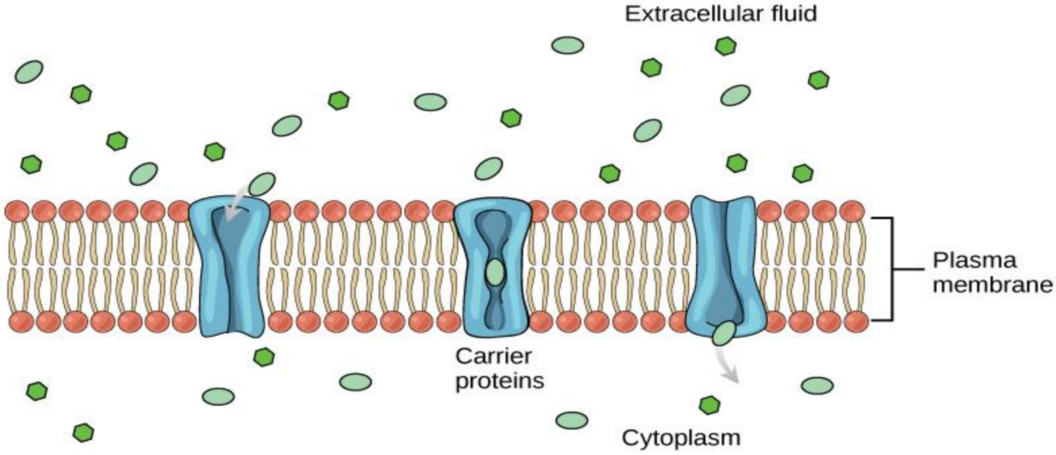


(c) Active Transport:

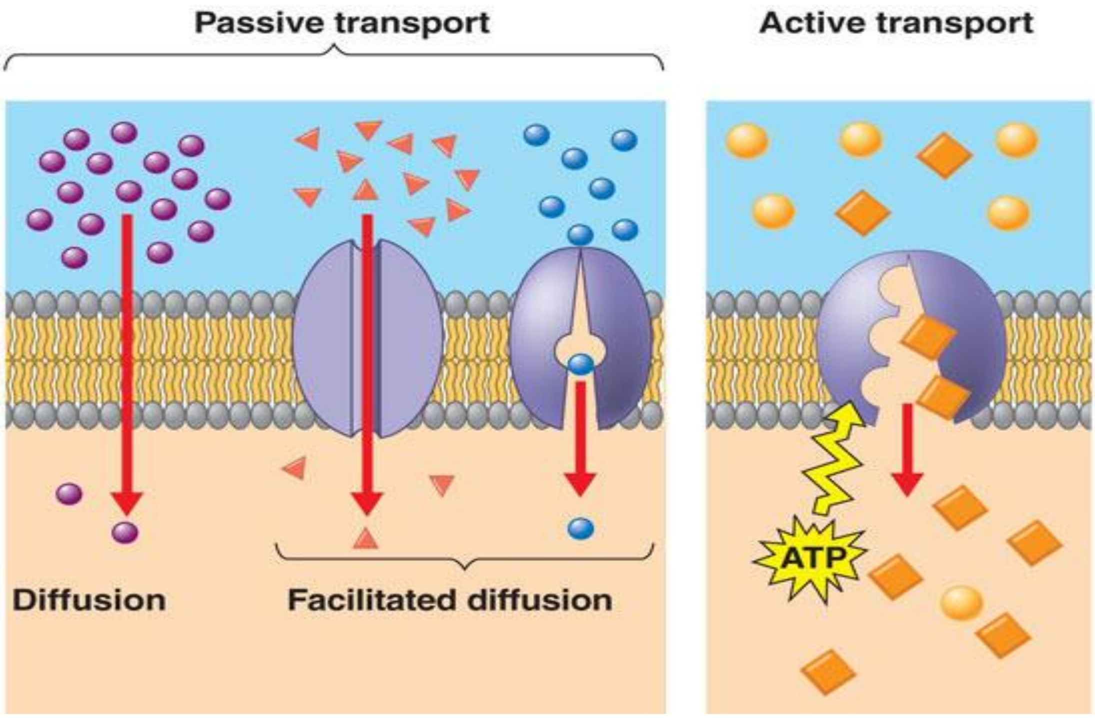
It is the mechanism by which movement of solutes occurs in one direction (unidirectional), i.e., from lower to higher concentration. This is an energy requiring process. The energy is obtained from hydrolysis of ATP and from other sources.

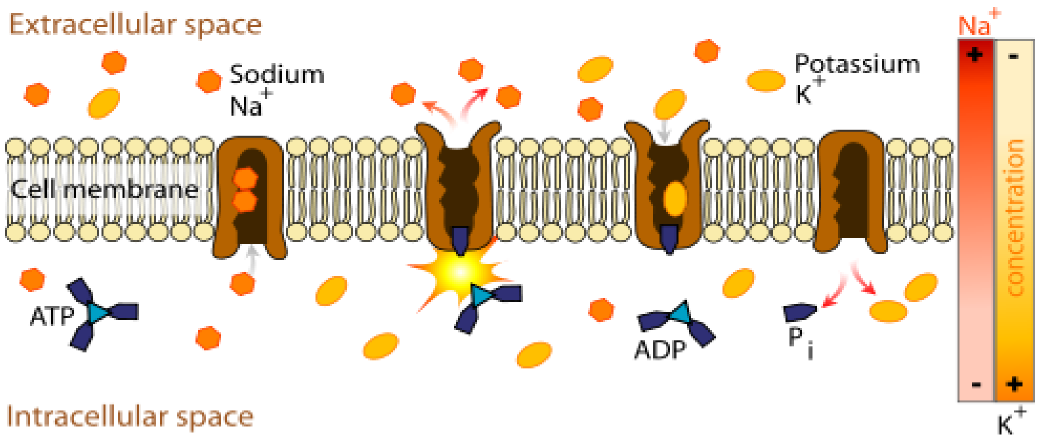






Passive transport





(d) Endocytosis and Exocytosis:

Certain substances are imported within the cell or expelled out of the cell via membrane “vesicles”. The uptake of the external substances via vesicles is called endocytosis, while the excretion of substances via vesicles is called exocytosis.

Endocytosis is divided into two types. The uptake of large particles through vesicles is called phagocytosis, while the uptake of small particles and water soluble molecules, such as, enzymes, hormones, antibiotics etc., is called pinocytosis (Fig. 2.10).

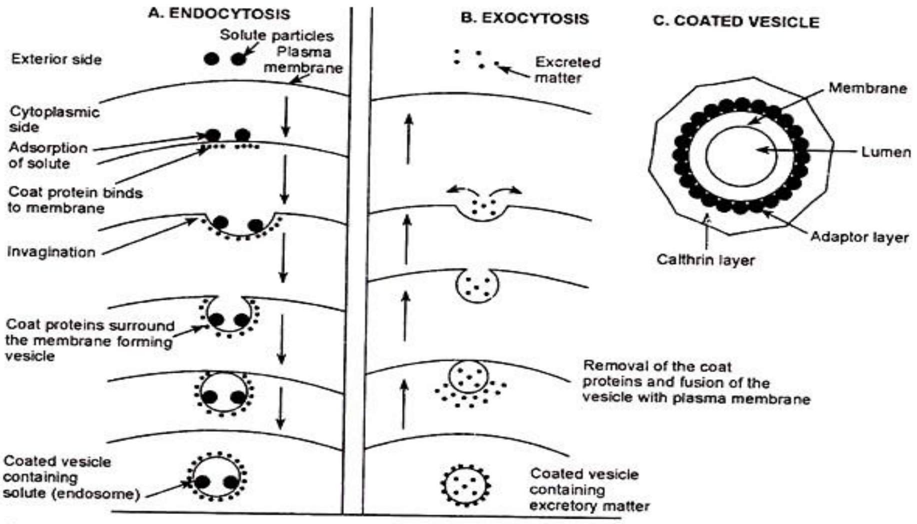
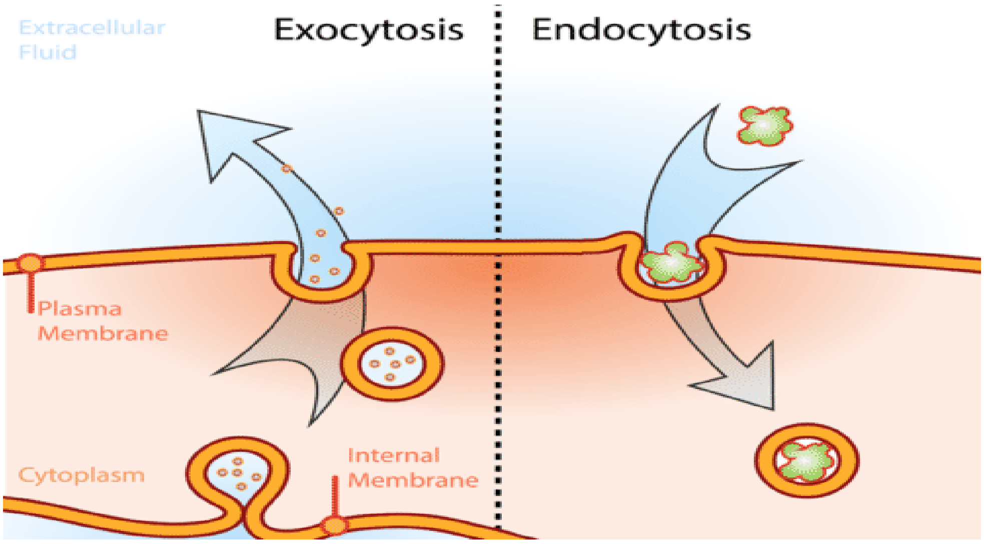
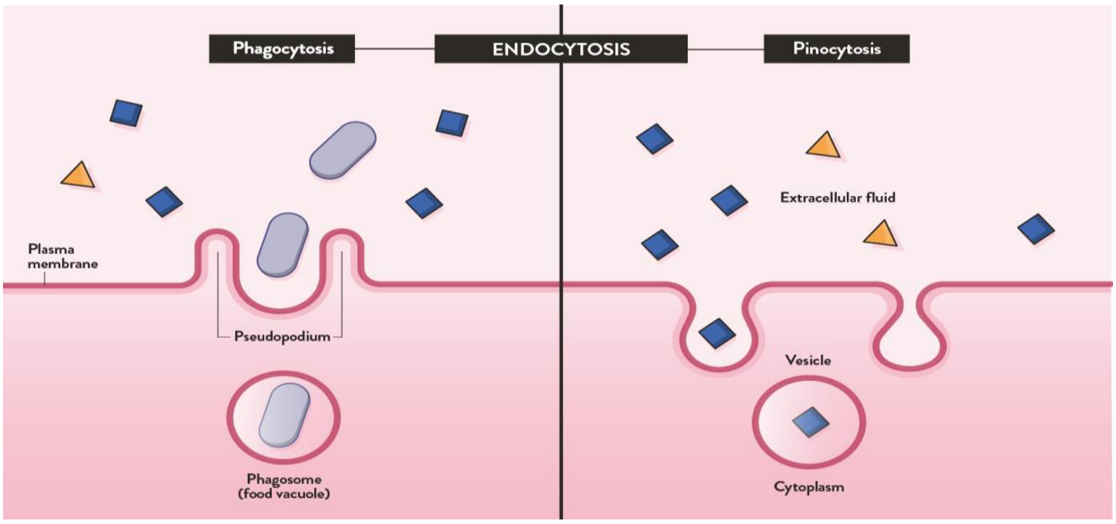


Fig. 2.10. Diagrammatic representation of endocytosis and exocytosis and a coated vesicle. Exocytosis is the reverse process of endocytosis. **A.** Endocytosis : specific proteins form a coat around the invaginating membrane. **B.** Exocytosis: protein coat is removed ; then the vesicle fuses with the palsma membrane. **C.** Two layers of protein coat are present on the vesicle. The inner layer is formed by adaptors while the outer layer is composed of calthrin.





The extracellular substance taken into the cell via endocytosis is called ligand. The ligand binds to specific receptors, i.e., trans membrane proteins, present in the membrane. This triggers the formation of endocyticvesicles, the process is called "internalization" of receptor.

Some specific proteins, called coat proteins, bind to the plasma membrane on the cytoplasmic side; subsequently, the membrane starts deformation and invagination (Fig. 2.10).

The coat proteins surround the invaginating membrane. Ultimately, a vesicle is formed that includes the extracellular substance.

The vesicle is coated by two types of proteins: (i) adaptor, and (ii) calthrin. Such vesicles are called **"calthrin-coated vesicles".** Adaptors bind to the integral membrane proteins of the vesicle and to the calthrin (Fig. 2.10).

Different types of adaptors exist in the vesicles of different origin. For example, endocytic vesicles formed from plasma membrane have HA2 adaptor, while the vesicles produced by Golgi complex have HA1 adaptor. These adaptors differ in their composition. HA1 adaptor consists of γ-adaptin, β'-adaptin P47 and P20. HA2 adaptor is composed of α-adaptin, β-adaptin, P50 and P17.

Calthrin forms the outher coat of the vesicles in the form of a polyhedral coat. Calthrin is a protein complex called "triskelion" which consists of 3 light and 3 heavy chains. Each light chain has a molecular weight ranging from 30,000 to 40,000 Daltons. The molecular weight of each heavy chain is 180,000 daltons.

When the coated vesicle reaches the target membrane, its protein coat is removed. Subsequently, the vesicle fuses with the target membrane and releases its contents. The vesicle without the coat is called an endosome.

Exocytosis is the reverse process of endocytosis (Fig. 2.10). The substance to be excreted is enclosed within a vesicle at the Trans region of the Golgi complex. This vesicle is called **"exocytic"** or **"secretory"** vesicle; it is also coated with specific coal proteins (Fig. 2.10).

When the vesicle reaches the plasma membrane, it becomes uncoated and finally fuses with the membrane. The substance enclosed in the vesicle is, as a result, discharged outside the cell.

Thus there are three methods of physical transfer of materials (ranging from ions to small molecules and macromolecules) from outside into the cell:

(i) Through Channels:

The channels are made by trans membrane proteins. Ions are transferred by this process. Separate channels exist for K^+, Na^+, and Ca^{2+} etc.

(ii) By Receptor Itself:

The ligand, such as sugars, binds to the receptor and is transported from extracellular side to the cytoplasm side of the membrane.

(iii) Receptor Internalization:

The ligand binds to receptor which triggers the process of internalization. Vesicle is formed by endocytosis and the ligand is brought into the cell.

2. Metabolic Functions:

Plasma membrane plays an important role in metabolism. Several enzymes are located on the cell surface, such as, those involved in extracellular nutrient breakdown and those involved in cell wall biosynthesis. In prokaryotes, respiratory enzymes are located in the plasma membrane.

3. Communication Recognition and Adhesion:

Some important functions of the plasma membrane are the communication between cells, recognition and cell to cell adhesion. Such functions are carried out by "receptors" which are trans membrane proteins or integral proteins.

The extracellular substance, called **"ligand"** binds to the specific receptors. This binding triggers a change in the function of the membrane. It can transduce signal in the cytoplasm, the phenomenon is called "signal transduction".

There are two types of signal transduction:

(i) When a ligand binds to the receptor (a trans membrane protein), it activates the kinase activity of the cytoplasmic domain of the receptor leading to its phosphorylation. The phosphorylated receptor associates with the target protein in the cytoplasm.

(ii) The ligand receptor binding may activate the G protein associated with the plasma membrane. G proteins are guanine nucleotide-binding trimeric proteins consisting of the subunits a (monomer) and βγ (dimer). G protein is inactive when the trimer (αβγ) is bound to GDP.

On activation, GDP (bound to the a subunit) is replaced by GTP and the G protein dissociates into the subunits α and βγ dimer. Then one of the active subunits (either α or βγ) acts upon the target proteins in the cytoplasm. It either activates or represses the target proteins.

Different cells may have different receptors, and therefore, they may respond to different signals. One type of receptor may respond to protein hormones, some other type of receptor respond to neuro transmitters (e.g., acetylcholine), while another type of receptors respond to antigens etc.

Formation of tissues and organs in multicellular organisms occurs when cells adhere to each other in specific ways. Glycoproteins arc known to be involved in cell-to-cell recognition and adhesion. Membrane junctions are formed in animal cells for different functions. "Tight junctions" prevent the movement of molecules through the spaces between adjacent cells.

Desmosomes (specialized areas of cell surface that serve to bind the surface to another structure) provide mechanical strength to hold the cells together in conditions when tissues are exposed to forces that lead to stretching.

"Gap junctions" occur in both, vertebrates and invertebrates, especially in tissues which require quick communication between cells, e.g., nerve cells, muscles etc. They enable small molecules to move from one cell to the other.