6 Plasma Membrane

The ***plasma membrane*** may be defined as *the thin, elastic semipermeable living membrane that serves as a boundary for the cytoplasm.* The term ***"plasma membrane"*** was coined by ***Nageli*** in 1855. Plasma membrane is otherwise called ***cell membrane*** or ***plasmalemma.***

Plasma membrane is the outer limiting membrane in all animal cells. But in plant cells and bacterial cells, it is present inner to the cell wall. It serves as a barrier for the flow of some components into and out of cells. Thus it determines the composition of cytoplasm in the cell.

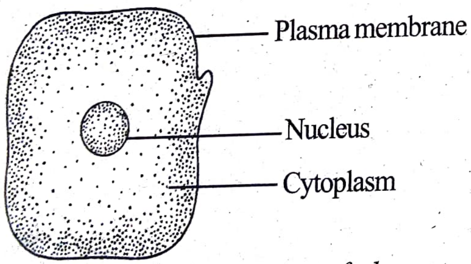

Fig.6.1: A cell showing the position of plasma membrane.

Plasma membrane is about 75A^0 in thick. Its thickness is almost constant in all plant cells, animal cells and bacterial cells (A°; One Angstrom unit = 10^{-8} cm (1/100000000cm). But the blood cells show variations. Even in the same cell its thickness varies at different points.

Plasma membrane is formed of glycoproteins and phospholipids. These molecules are arranged in a definite pattern. The following models are proposed to explain the structure of plasma membrane:

1. *Trilaminar model*
2. *Bimolecular leaflet model*
3. *Lattice model*
4. *Micellar model and*
5. *Fluid mosaic model*

1. Trilaminar Model

This model was proposed by ***Robertson*** in 1950. According to this model, the plasma membrane is formed of three layers. The three layers are an ***outer protein layer***, a ***middle lipid layer*** and an ***inner protein layer.*** The middle layer is 35A° thick and the inner and outer layers are 20A° each. Such a trilaminar membrane is called a ***unit membrane.***

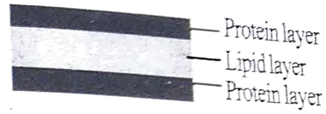

Fig.6.2: Unit membrane.

In the electron micrograph of plasma membrane, the outer and inner dark lines correspond to globular proteins and polar group of lipids and the middle light region corresponds to non-polar lipids.

According to ***Robertson,*** all biological membranes are unit membranes and this concept is called ***unit membrane hypothesis.*** This model explains lipid content, electrical resistance and permeability of membranes.

Unit Membrane Concept

All biological membranes have a ***trilaminar*** structure. Because of the ***unity in structure*** of all membranes of bacteria, plants and animals, it is called an ***unit membrane.*** This concept is called ***unit membrane concept.***

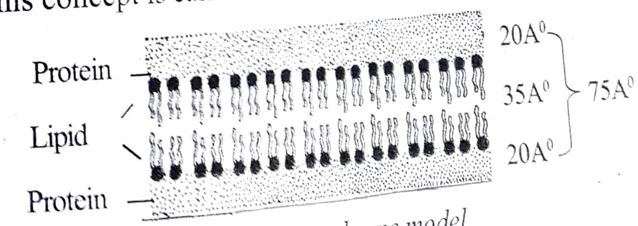

Fig.6.3: Unit membrane model.

The unit membrane concept was proposed by ***Robertson*** in 1959. According to this concept, the plasma membrane is formed of three layers, namely an outer ***protein layer,*** a middle ***lipid layer*** and an inner ***protein layer.*** This trilaminar membrane is called ***unit membrane.***

Robertson believed that all biological membranes are unit membranes. The plasma membranes of prokaryotes and eukaryotes are unit membranes. Again the membranes of endoplasmic reticulum, Golgi bodies, mitochondria, lysosomes, plastids and nucleus are unit membranes.

2. Bimolecular Leaflet Model

This model was proposed by ***Danielli*** and ***Davson*** in 1934. According to this model, the plasma membrane is formed of two layers of lipid molecules coated with protein. Each lipid molecule has a ***hydrophobic tail*** and a ***hydrophilic head***. The hydrophilic heads face outwards and the hydrophobic tails of the two layers face each other. This model explains the biological and chemical properties of plasma membrane, but not the surface tension.

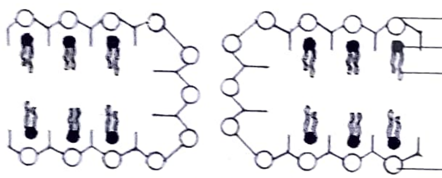

Fig.6.4:Bimolecular model.

3. Lattice Model

This model was proposed by ***Wolpers*** in 1941. According to this model, in the plasma membrane, lipids and proteins are arranged as a ***lattice*** or ***network.*** Proteins form a kind of mechanical frame work. The lipid component is distributed in the meshes of the protein frame.

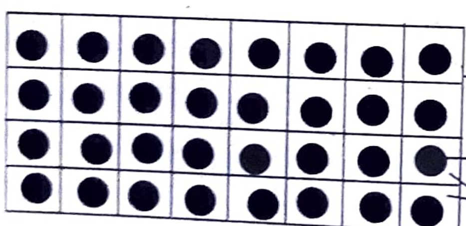

Fig.6.5: Lattice model.

4. Micellar Model

This model was proposed by ***Hilleir*** and ***Hoffman*** in 1953. According to this model, the molecules in the plasma membrane are arranged in the form of globular sub-units called ***micelles.***

The lipid micelles are the building blocks of the membrane and the protein globules are arranged on either side.

In a lipid micelle, the lipid molecules are arranged in the form of a circle. Each ***lipid molecule*** has a ***head*** and a ***tail.*** The head is ***hydrophilic*** and the tail is ***hydrophobic.*** The tail is directed inwards.

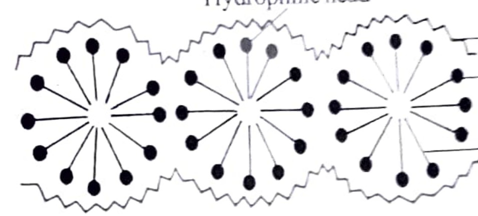

Fig.6.6: Micellar model.

5. Fluid Mosaic Model

Fluid mosaic model explains the structure of plasma membrane. This model was proposed by ***Singer*** and ***Nicolson*** in 1972. According to this model, the plasma membrane consists of ***lipids*** and ***proteins***. The lipid is in the form of ***fluid*** and the proteins are embedded here and there in the lipid in a ***mosaic*** pattern. Hence the name ***fluid mosaic model***.

The lipids are arranged in the form of two layers, an ***outer layer*** and an ***inner layer.***

The proteins do not form a layer.

Each lipid molecule has a ***hydrophobic tail*** and a ***hydrophilic head.*** The hydrophilic heads face outwards and the hydrophobic tails of the two layers face each other.

Lipid molecules are not rigidly positioned in their respective places. They are always in a constant motion and undergo lateral diffusions. While doing so, proteins bound with them also moves drastically.

The protein molecules are ***globular*** and are of two types, namely ***peripheral*** or ***extrinsic proteins*** and ***integral*** or ***intrinsic proteins.*** The peripheral proteins are arranged on the surface and are loosely bound to the lipid. The integral proteins are deeply embedded and are tightly bound to the lipid molecules. The peripheral proteins as well as the outer part of integral proteins are studded with ***sugars.*** Such proteins with attached sugars are called ***glycoproteins.***

If the extrinsic proteins are removed from the membrane, there is no disruption in the membrane structure, but if intrinsic proteins are removed, the membrane structure is disrupted.

Similarly sugars are also attached to the outer surface of some lipids. These lipids with attached sugars are called ***glycolipids.*** The carbohydrates found in intrinsic proteins and glycolipids form a sugary covering called ***glycocalyx***. It recognizes certain foreign proteins as in immune cells and protects the cell from the extracellular digestive fluids.

The fluid mosaic model stresses that the plasma membrane is ***semi fluid*** in nature; the lipid as well as the intrinsic proteins ***move*** freely within the lipid bilayer.

Fluid mosaic model is the ***most accepted model*** because it convincingly explains the transport through the membrane.

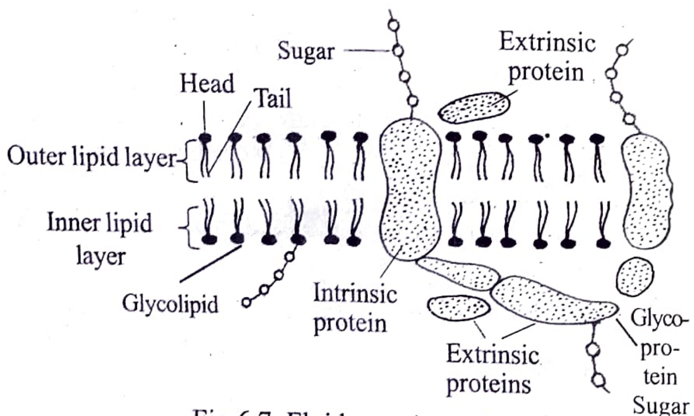

Fig.6.7: Fluid mosaic model.

Chemical Composition

Plasma membrane is formed mainly of ***lipids*** and ***proteins*** and a small proportion of ***carbohydrates, Nucleic acids, salts*** and ***water,*** may also be seen in some membranes.

The lipid-protein ratio varies with the cell types. For example, plasma membrane of nerve cells of CNS has 79% lipids and 20% protein and of muscle cell has 35% lipids and 60% proteins. In the RBC, the ratio of lipid, proteins and carbohydrates is 40:52:8.

1. Lipids: The bulk of plasma membrane is formed of lipids. The main lipid component of the plasma membrane is ***phospholipid.*** Phosphatidyl choline, phosphatidyl ethanolamine, phosphatidyl serine and phosphatidyl inositol are found

in cell membrane of most cell types. Sphingolipids and cholesterol are found in animal cell membranes.

The lipids of the plasma membrane are ***amphipathic*** in nature. It consists of a ***head*** and two ***tails.*** The head is ***hydrophilic*** and ***polar*** and the tails are ***hydrophobic*** and ***non-polar.***

The lipid molecules form a double layer in the plasma membrane. The tails are oriented inwards and the head facing outwards.

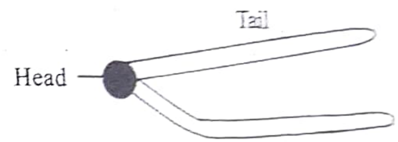

Fig.6.8: A lipid molecule.

2. Proteins: The proteins of plasma membrane have high molecular weight. Three different classes of proteins occur in the plasma membrane. They are ***structural proteins, carrier proteins*** and ***enzymes.***

The structural proteins form the '***back bone***' of the cell membrane. The carrier proteins are involved in active transport. The enzymes include ***ATPase, phosphatase, hexokinase, RNAase*** and ***esterase.***

3. Carbohydrates: They form a cell coat around the plasma membrane. The sugar units may be 2-60 per chain. This chain is found attached to N-terminal end of the protein. Galactose, mannose, N-acetyl glucosamine and sialic acid are the important carbohydrates found in the plasma membrane of RBC. Plasma membrane of ***Amoeba proteus*** contains a large amount of polysaccharides.

4. Nucleic Acids: The plasma membrane of *Arbacia* **egg** contains nucleic acids.

5. Salts: Salts are generally present in the cell membrane. Some of them are present in higher concentrations.

Specializations of Plasma Membrane

The plasma membrane shows here and there some specialized structures. These may be due to outgrowths or ingrowths or contact with adjacent membrane. Such structures include the following:

1. Microvilli
2. Desmosomes
5. Interdigitations
6. Basal infoldings

7. Plasmodesmata

Plasmodesma (singular) is a *cytoplasmic bridge connecting adjacent cells*. Plasmodesmata are found only in ***plant cells.***

The plasmodesmata form fine channels of 20 to 40mm diameter between adjacent cells.

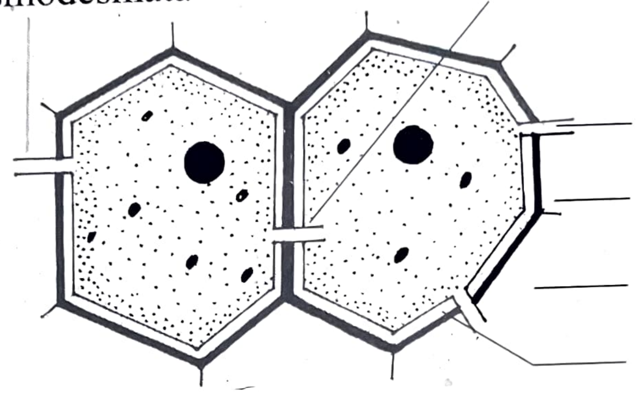

Fig.6.18: Plant cells with plasmodesmata.

The centre of the plasmodesma has a narrow cylindrical structure called ***desmotubule***. The desmotubule is continuous with the endoplasmic reticulum of the adjoining cells.

The space between the wall of the plasmodesma and desmotubule is called ***cytosolic annulus***. Molecules pass through the cytosolic annulus.

The cell wall contains many small openings called ***pits***. The adjacent cells are connected by cytoplasmic bridges through these pits.

The cytoplasm and the endoplasmic reticulum of the adjacent cells make contact through the plasmodesmata.

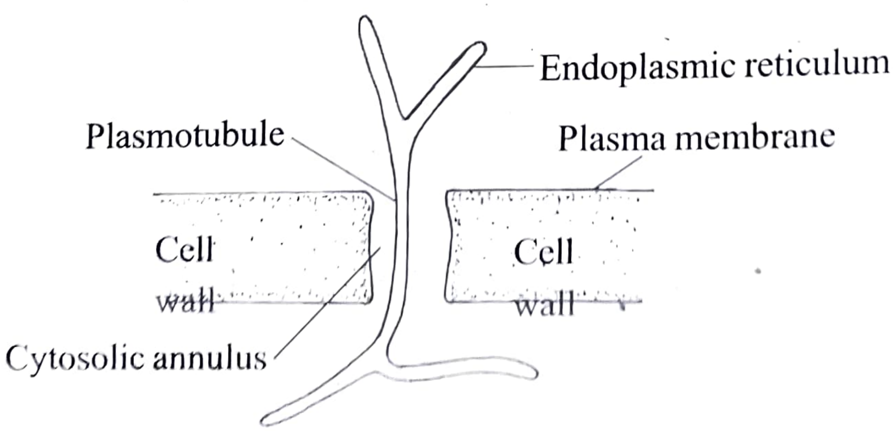

Fig.6.19: Plasmodesma.

Origin of Plasma Membrane

It is believed that plasma membrane is formed by the self assembly of proteins and lipids present in the cytoplasm.

Functions of Plasma Membrane

The plasma membrane has the following functions:

1. Mechanical Support

Plasma membrane gives a definite shape to the cell. It protects the cell contents and keeps the cell components in place.

2. Exchange of Materials

Plasma membrane regulates the exchange of materials into and out of the cell. It allows the needed materials to enter the cell and sends out the unwanted materials from the cell. Hence the cell membrane allows one substance to pass through more easily than another. This property of the cell membrane is said to be ***selective permeability.***

3. Biogenesis of Cell Organelles

Certain cell organelles like endoplasmic reticulum, nuclear membrane, etc. develop from plasma membrane.

4. Absorption

The microvilli of intestinal cells increase the surface area. Hence the rate of absorption increases.

5. Cell Recognition

Mammalian leucocytes recognize foreign cells like bacteria and engulf them by phagocytosis. Similarly, the macrophages of spleen can identify worn out RBCs from healthy RBCs and destroy them. The sites for cell recognition are located on the surface of the plasma membrane. The amino sugar ***sialic acid*** is involved in cell recognition.

6. Antigenic Specificity

The antigen specificities of the cells are located on the surface of the plasma membrane. The antigenic determinants are the glycoproteins of plasma membrane.

The rejection of transplanted tissues is determined by antigens (glycoproteins) located on the cell membrane of implanted cells.

7. Transmission of Impulses

The plasma membrane of nerve fibres transmits nerve impulses.

8. Osmosis

The plasma membrane allows the free movement of water. *The process of movement of water molecules from the region of higher water concentration to the region of lower water concentration* is known as ***osmosis.***

The osmotic process in which the water molecules enter the cell is known as ***endosmosis*** and the reverse process is known as ***ex-osmosis.*** Due to endosmosis, the pressure inside the cell increases. This pressure is termed as ***hydrostatic pressure.*** Since this pressure is caused by osmosis, it is also termed as ***osmotic pressure.*** The plasma membrane maintains a balance between the osmotic pressures of the inter and intracellular fluids.

9. Passive Transport or Diffusion

The movement of molecules across the plasma membrane from the region of higher concentration to a region of lower concentration is called ***passive transport*** or ***diffusion.***

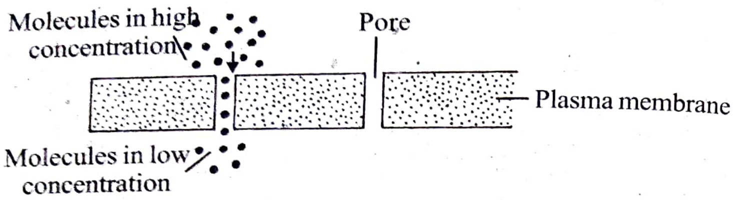

Fig.6.23: Diffusion through plasma membrane.

Diffusion occurs through pores present in the cell membrane. This process does not utilize energy. Hence this process is also called ***down hill movement.***

10. Active Transport

- *The movement of molecules and ions from the region of lower concentration to the region of higher concentration, against the concentration gradient* is called ***active transport.*** So it is compared to ***uphill movement.*** It needs energy. The energy is provided by the mitochondria. In this case, substances do not move by themselves, but they are carried by some carriers present in the membrane. These carriers are mainly membrane ***proteins.***

In kidney and nerve cells, Na^+ ions are expelled outside and K^+ ions are accumulated inside. This phenomenon is called ***ionic pump.*** These cells actively pump these ions against the concentration gradient.

The blood contains 1 mg of glucose per 100 ml. In the formation of urine, the glomerular filtrate present inside the nephron also contains large amount of glucose. From this filtrate, the entire amount of glucose is actively reabsorbed into the blood, so that the urine is completely free from glucose.

11. Endocytosis

Endocytosis is the *engulfing of food or foreign particles through the plasma membrane.* The endocytosis can be differentiated into ***phagocytosis*** and ***pinocytosis.***

1. Phagocytosis or Cell Eating: ***Phagocytosis*** is the *engulfing of **solid particles** through the plasma membrane.* It is also called ***cell eating***. It is observed in a number of protozoans and leucocytes. The cells exhibiting phagocytosis are called ***phagocytes***. The term '***phagocytosis***' was coined by ***Metchnikoff*** in 1885.

The food particles are adsorbed at the surface of the membrane. Later on, they are taken into the cytoplasm by the infolding of the plasma membrane. *The plasma membrane at the infoldings gets pinched off in the form of a small vesicle* called

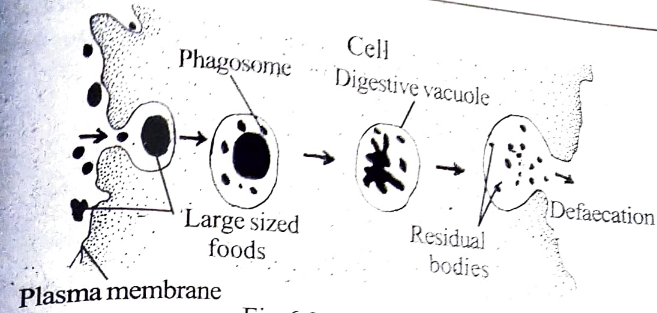

Fig.6.24: Phagocytosis.

phagosomes. Then the phagosomes fuse with lysosomes to form the ***digestive vacuoles***. The food is digested inside the vacuole and the digested food diffuses into the cytoplasm.

Eg.1. Capturing and ingestion of diatoms by Amoeba. 2. Devouring of disease causing germs by WBC, macrophages, etc.

2. Pinocytosis or Cell Drinking: Pinocytosis is the *process of engulfing of fluid particles through the plasma membrane.* It was first observed by ***Lewis.***

During pinocytosis, the plasma membrane is invaginated to form sac- like structures. The fluid food is drawn into the sac. Then the sac is pinched off from the plasma membrane, forming a vesicle called ***pinosome.*** The pinosome later fuses with lysosome. The food is digested by the enzymes of the lysosome. The digested food diffuses into the cytoplasm. Eg. *Absorption of fat droplets by intestinal epithelial cells.*

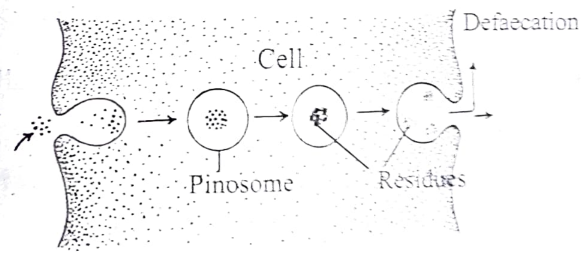

Fig.6.25: Pinocytosis.

12. Exocytosis or Cell Vomiting

The process of exudating** the secretory products from the secretory cells to the **outside of the cell cytoplasm is known as ***exocytosis*** or ***cell vomiting***. This process is also called ***emeiocytosis*** or ***reverse endocytosis.*** Eg. *In pancreatic cells, the enzymatic secretions are passed out through the plasma membrane by exocytosis.*

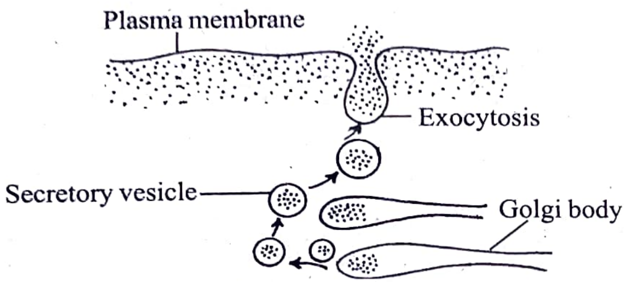

Fig.6.26: Exocytosis.

13.Cytopemphis

Cytopemphis is *the transport of materials through a cell.* The material passes into the cell by endocytosis and then it comes out of the cell by exocytosis without any change.

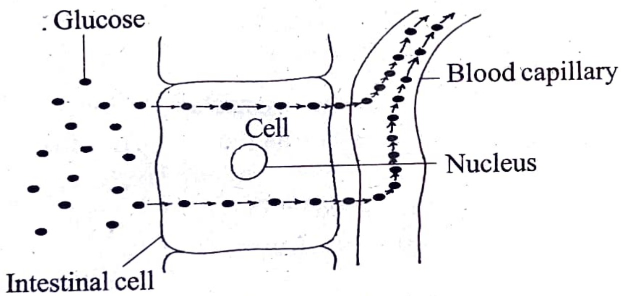

Fig.6.27: Cytopemphis.

Glucose molecules from the intestine move into the blood capillary through the epithelial cells by cytopemphis.

Physical Properties of Plasma Membrane

Plasma membrane exhibits the following physical properties:

1. Surface Charges

The cell membrane has charged particles on the surface. These particles are either positively charged or negatively charged. The protozoans have negative charges. The mammalian RBCs have positive charges. The surface charges in mammalian cells are due to the presence of ***sialic acid.***

The existence of surface charges can be experimentally proved by electrophoresis or by passing current through a solution containing the cells. If the cells have negative charges, they move to the ***anode*** and if they have positive charges, they move to ***cathode.***

2. Wetting Properties

When oil is added to the surface of RBC, the oil drop binds with the cell membrane. ***Dawson*** and ***Belkin*** (1929) found that a drop of oil can readily adhere to the surface of *Amoeba dubia* forming an ***oil cap.*** The wetting property of plasma membrane to oil is due to the presence of lipids in the plasma membrane.

3. Self Repair

Cell membrane can repair minor injuries. When the cell membrane is pricked by a microneedle, the puncture is quickly sealed. In contractile vacuoles, the self repair is a cyclical phenomenon because the contractile vacuole ruptures, when it is fully loaded. When a fragment of cell is isolated, the ends of the plasma membrane fuse together to form a vesicle.

7

Cell Wall

Cell wall is *the outer covering of plant cells.* It is a rigid protective layer around the plasma membrane. It is present only in plant cells and absent from the animal cells. It determines the shape of plant cells.

The cell wall is formed of four layers, namely ***middle lamella, primary cell wall, secondary cell wall*** and ***tertiary cell wall.***

Middle lamella is the intercellular matrix located between the adjacent cells. It is the ***outer layer***. It is formed of pectin, lignin and some proteins.

Primary cell wall is the true cell wall which develops in the still growing cells. It lies inner to middle lamella. It is very thin and permeable to water and solutes. It is mainly formed of cellulose, but in some cases lignin or suberin or cutin wax may also be present in it.

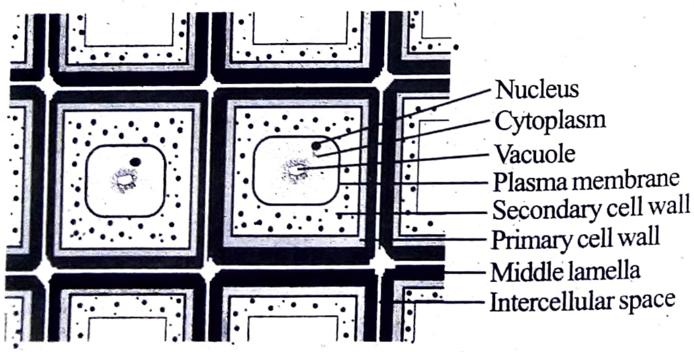

Fig.7.1: Plant cells with cell wall.

Secondary cell wall is found in the mature or non-growing cells. It is ***thick*** and rigid. It is present inner to the primary cell wall and close to plasma membrane. It is composed of cellulose fibrils and an interfibrillar matrix.

Tertiary cell wall is a thin layer located beneath the secondary cell wall. It is present in some old cells.

The cell wall is mainly formed of ***cellulose.*** Other substances present in the cell wall includes hemicellulose, pectin, lignin, fatty acids, minerals, etc.

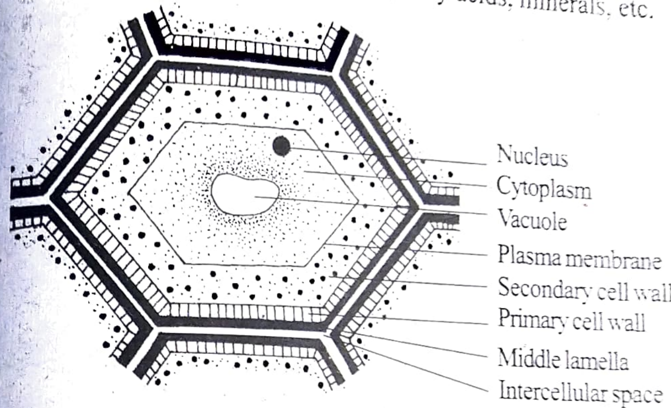

Fig.7.2: A typical plant cell with cell wall.

When the cell wall is examined under electron microscope, it shows two components, namely the ***matrix*** and the ***fibrils.***

The ***matrix*** is the ground substance in which the fibrils are embedded. The matrix is composed of non-cellulosic materials such as ***pectin, lignin, fatty acids*** and ***minerals***. Cellulose fibrils remain embedded in the matrix.

The fibrils are made of ***cellulose.*** Cellulose is a polysaccharide. It is closely related to starch. It is made up of several ***glucose*** units linked together by ***glycosidic*** bonds.

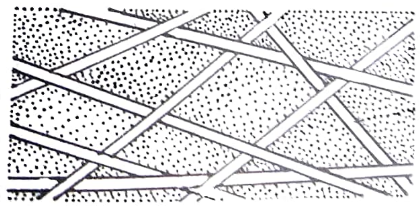

Fig.7.3: *A portion of primary cell wall enlarged. (Electron microscopic view).*

The primary cell wall contains cellulose microfibrils which are loosely arranged and run in all directions. But, in the secondary cell wall there are densely packed macrofibrils which are arranged in parallel orientation.

About 100 cellulose polymers are arranged in a longitudinal bundle to form an ***elementary microfibril.*** The elementary fibrils are ribbon-like. About 20 such fibrils are bound together to form a ***microfibril.*** The microfibril is about 250A^0 in diameter. It has about 2000 cellulose molecules. Many microfibrils join together to form a bundle called ***macrofibril.*** The macrofibril is 0.4 micron wide and has about 500,000 cellulose molecules. The transection of cell wall shows about 5,000 macrofibrils. They are interspread longitudinally. (Fig.9.5)

Fig.9.4: Electron micrograph of secondary cell wall.

Thickenings in Cell Wall

When the cells mature, ***lignin*** deposits on the cell wall. Hence the cell wall becomes thickened. The thickening does not occur uniformly throughout the entire surface. Hence a portion of the wall remains thick and the other regions remain thin. The thickenings occur in the following patterns:

1. **Annular thickenings:** The thickenings occur in the form of rings.
2. **Spiral thickenings:** The thickenings occur in the form of spiral band.
3. **Scalariform thickenings:** The thickening is in the form of a ladder.
4. **Reticulate thickenings:** Here the thickenings occur in the form of a network.

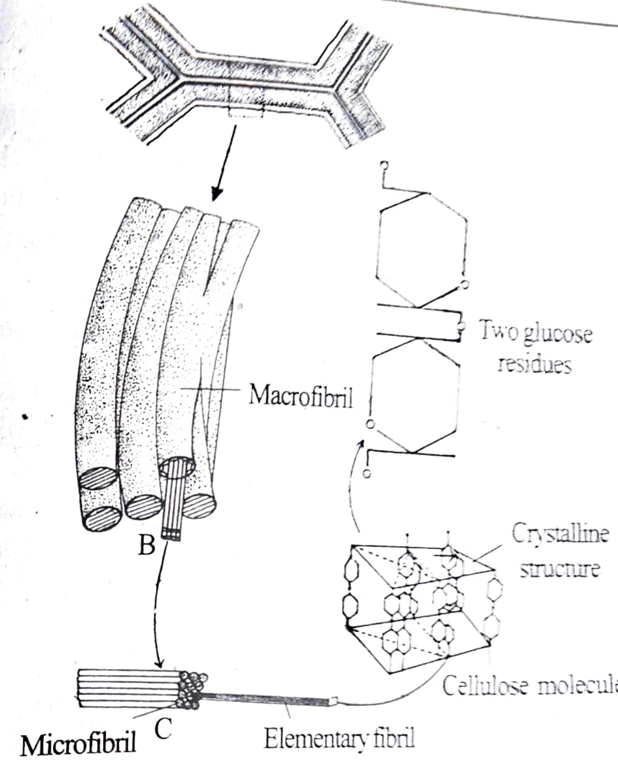

Fig.7.5: Constituents of plant cell wall.

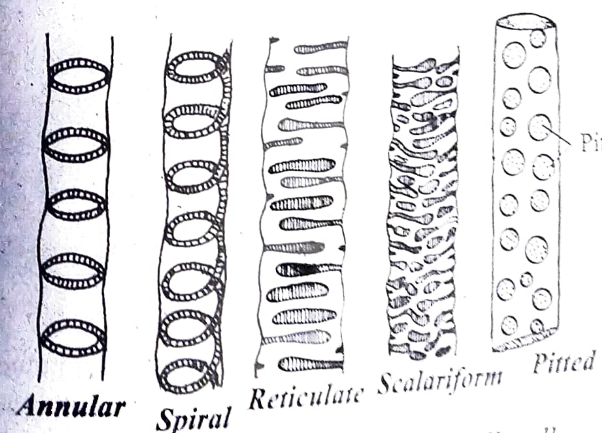

Fig.7.6: Various thickenings in cell wall.

Pits

Pits are ***depressions*** *formed in the cell walls due to cell wall thickenings.* The pits are always **arranged** in pairs lying against each other on the opposite sides of the wall. They are called ***pit pairs.***

A pit occurring singly is called a ***blind pit***. It has no complementary pit on the opposite side.

The space found inside the pit is called ***pit chamber*** or ***pit cavity.*** It opens into the lumen of the cell by an opening called ***pit aperture.*** The pit chambers of a pit pair are separated by a membrane called ***pit membrane***. The pit membrane lies along the junction of two adjacent cells. It is common to both pits of a pit pair and it consists of two primary walls and a middle lamella.

There are two types of pits, namely ***simple pits*** and ***bordered pits.***

A pit pair may be formed of two simple pits or two bordered pits or one simple pit and another bordered pit. When the pair is formed of two simple pits, it is called ***simple pit pair.*** When the pair is formed of two bordered pits, it is called ***bordered pit pair.*** When the pair is formed of one simple pit and a bordered pit, it is called ***half- bordered pit pair.*** When a pit occurs singly opposite to intercellular space, it is called a ***blind pit.***

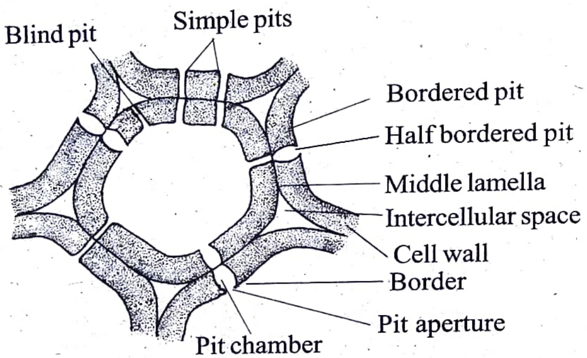

Fig.7.7: A plant cell with different types of pits.

Simple Pits

In simple pits, the ***pit chamber*** remains in the same diameter and the ***pit membrane*** also remains simple and uniform through out. The pit chamber opens into the cell by a ***pit aperture.*** The simple pit may be circular, oval, polygonal or irregular in surface view. Diffusion of protoplasm takes place through these pits.

Bordered Pits

In bordered pits, the pit chamber is funnel-like and it becomes narrow towards the lumen of the cell. The pit chamber opens into the cell by a ***pit aperture.***

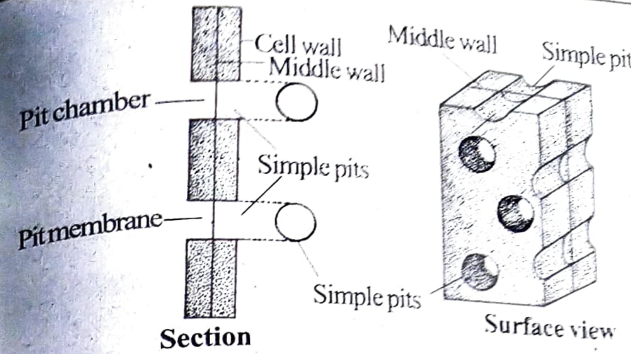

Fig.7.8: Simple pits.

The secondary wall is arched over the pit chamber and it is called ***pit border.*** The overhanging rim forms a border around the pit aperture and hence named ***bordered pits.***

The closing membrane is thickened in its central part. This thickening is called ***torus.*** Bordered pits are found in the cells of angiosperms and conifers.

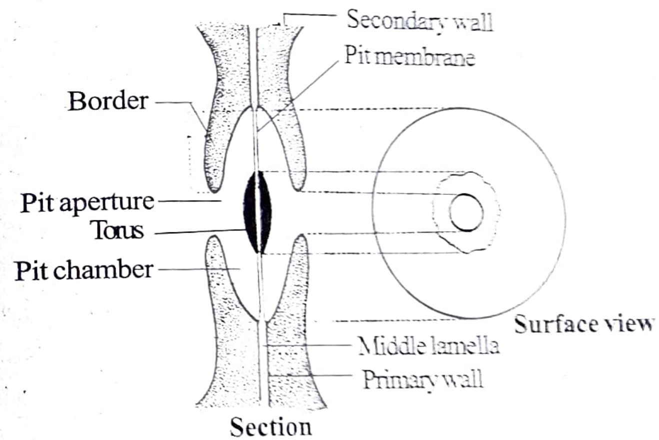

Fig.7.9: Bordered pit.

Plasmodesmata

The ***protoplast*** (protoplasm of plant cell) remains connected with that of the adjacent cells by delicate threads of cytoplasm.

These threads of cytoplasm are called ***plasmodesmata.*** The plasmodesma (singular) passes through the pore or pit in the cell wall. They maintain the continuity

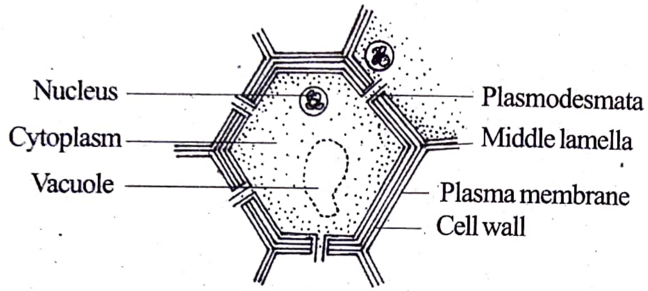

Fig.7.10: Plant cells with plasmodesmata.

of the cytoplasm. They conduct stimuli and transport materials between cells. They also function as channels for transporting protoplasmic substances from one cell to other cells.

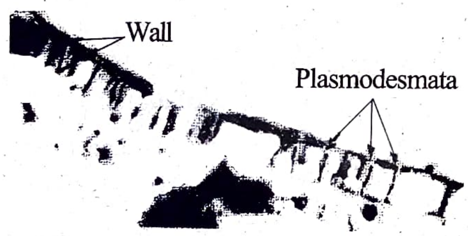

Fig.7.11: Electron micrograph of plant cell wall showing plasmodesmata.

Origin of Cell Wall

New cell wall is formed from Golgi complex during cell ***division.*** At the end of telophase small double walled vesicles accumulate in the centre to form a ***cell plate.*** The adjacent vesicles collapse to form a thin film of cell wall matrix called ***middle lamella.*** On either side of middle lamella cellulose fibrils accumulate to form a

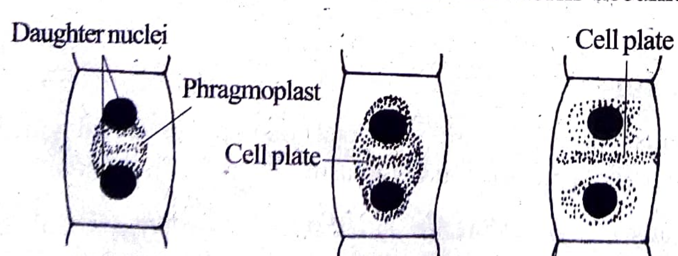

Fig.7.12: Formation of cell wall in a plant cell.

primary cell wall. As the cell matures, the thickness of cell wall increases and the cell wall gets differentiated into ***primary wall, secondary wall*** and ***tertiary wall.*** In mature cells, the primary cell wall remains the outer most layer.

Function of the Cell Wall

The cell wall has the following functions:

1. It gives the cells a definite shape.
2. It gives mechanical support and rigidity to the cell.
3. In root cells, it helps to absorb water from the soil by ***imbibition.***
4. It protects the protoplast from turgor pressure developed in it due to intake of more water by osmosis.