TOPIC: THE CELL-ULTRA STRUCTURE OF CELL

LECTURE NO:02

B.SC PART-II(SUB.)-GROUP A

DATE: 25TH MARCH 2020

AUTHOR: DR.NIRMAL KUMARI

2.1 Objectives:-

After reading this unit the readers should be able to:

Define plasma membrane

Describe the ultra structure of plasma membrane

Explain the chemical composition of plasma membrane

Outline the various theories of plasma membrane

Discuss the functions of plasma membrane

2.2 Introduction:-

Every cell, prokaryotic or eukaryotic, is surrounded by a thin layer of outermost boundary called the **plasma membrane or cell membrane or plasma - lemma**. The plasma membrane is a discrete structure and is remarkably complex in its molecular organization. It maintains the difference of the internal environment of the cell from its external environment by controlling the entrance and exit of the molecules and ions. It checks the loss of metabolically useful substances and encourages the release of toxic metabolic byproducts of the cell. Thus, it functions as **semi-permeable or selectively permeable membrane**. It is about 70-100Å in thickness. In plant cells plasma lemma is further covered by cellulosic cell wall. It is an important cell organelle composed of lipids and proteins. It possesses devices for attachment to other cells for cell-to-cell communications, ion pumps for controlling internal milieu of the cell, receptors for hormones and mechanisms for the production of secondary messengers that activates the cell's physiological response.

2.3 History:-

It had been shown by **Karl W. Nageli** (1817-1891) that the cell membrane is semi-permeable and is responsible for the osmotic and other related phenomena exhibited by living cells. Before 1855, he used the term zellen membrane in his early papers. The term plasma membrane was used in 1855 by him to describe the membrane as a firm protective film that is formed by out flowing cytoplasm of an injured cell when protein rich cell sap came in contact with water.

2.4 Plasma Membrane:-

2.4.1 Ultra Structure of Plasma Membrane

2.4.1.1 Symmetrical Mole cular Structure of Plasma Membrane:-

Plasma membrane is a tripartite structure and is made up of three layers, having total thickness of 75Å. Two di-electronic layers are there, each of 25Å thickness, enclosing a middle dielectronic layer whi ch is also 25Å thick. The middle layer is a tri-molecular layer of lipids having its non-polar hydrophobic groups facing inwards, wherea s polar hydrophilic groups facing outwards. The hydrophilic polar groups are covered by a pr otein layer which is 20 to 25Å thick. The protein c hains lie at right angles to the lipids.

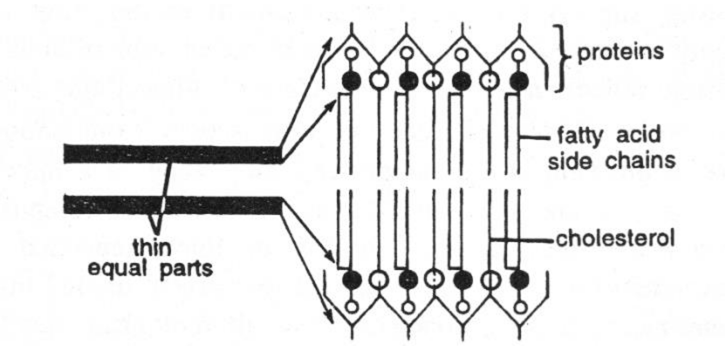

Fig. 2.1: Symmetrical pattern of molecules in plasma membrane (Source: Singh and Tomar, 2008)

2.4.1.2 Asymmetrical Molecular Structure of Plasma Membrane :-

It is also a tripartite structure having a thick inner dielectronic component of 35-40 Å, a narrow outer dielectronic component of 25Å thickness, and a central dielectronic layer (bimolecular layer of lipids) w hich is 30Å wide; thus total thickness comes to 90-95Å.

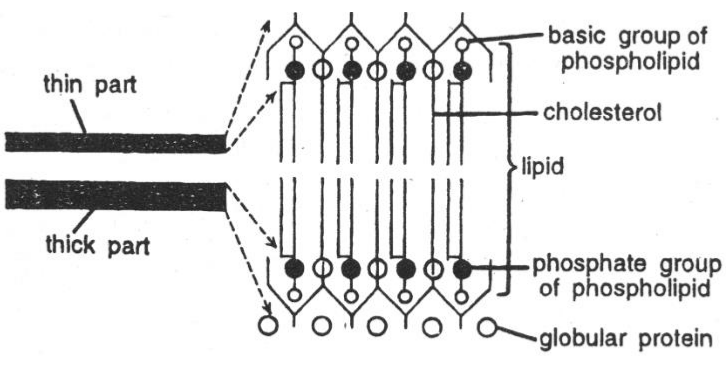

Fig. 2.2 : Asymmetrical pattern of plasma membrane

In different types of cells the thickness of plasma membrane varies. For example, in red blood corpuscles of rabbit, the plasma membrane is about 215 Å thick whereas, in intestinal epithelial cells it is 105 Å in thickness. Very small pores measuring about 10Å in diameter (smaller than pores of nuclear membrane) have been discovered in the me mbranes.

2.4.2 Chemical Comp osition of the Plasma Membran e:-

Plasma membrane is primarily composed of protein and lipid, alth ough carbohydrate is often present in association with protein (as glycoprotein) or lipid (as glycolipid). However, the relative proportions of protein and lipid vary considerably in membranes from different sources.

2.4.2.1:- Lipids

The plasma membrane contains about 20 to 79% lipids mainly of three types like phospholipids, cholesterol and glycolipids. The phospholipids which mak e up between 55% and 75% of the total lipid content, consists chiefly of lecithin and cephalin. The remainder consists of sphingolipids (with an amino group) and glycolipid conjugates with carbohydrates. Phospholipids derived from glycerol are called phosphoglycerides.

A phosphoglycerides is made up of two fatty acid chains, a glycerol backbone and a phosphorylated alcohol. The outer layer of phospholipids consists mai nly of lecithin and sphingomyeline, while the in ner layer is composed mainly of phosphatidyl ethanolamine and phosphatidyl serine (both are phosphoglycerides). The glycolipids (sugar containing lipids) are mainly in the outer half of the bilayer.

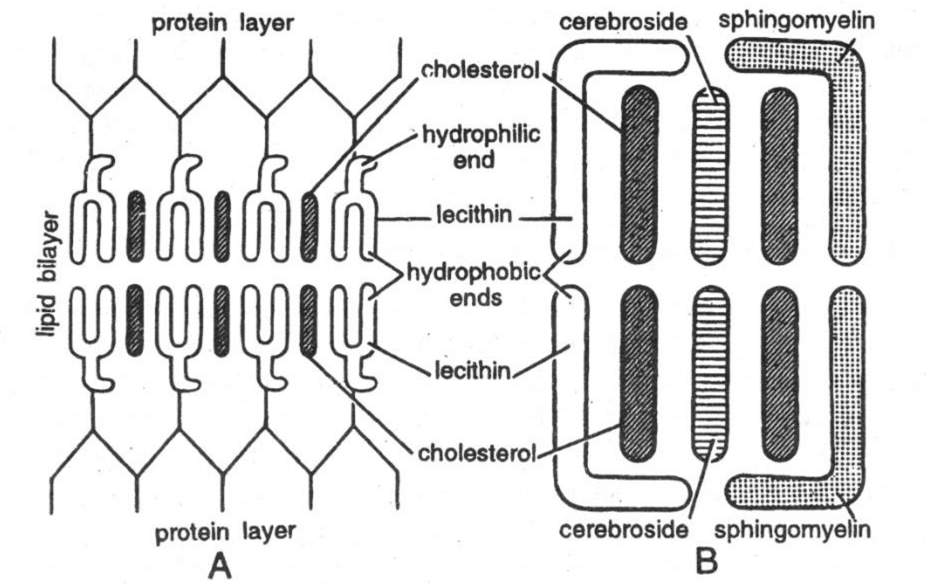

Fig. 2.3: A p hospholipids cholesterol complex of cell membra ne

Cholesterol is present in eukaryotes but not in prokaryotes. Plasma membrane of cells such as erythrocyte, liver cells and m yelinated nerve cells are rich in cholesterol.

Membrane lipids are amphipathic molecules. They contain both a hydrophobic and hydrophilic moiety. Hydrophilic unit is also called the polar head groups, is represented by a circle and their hydrocarbon tails are depicted by straight or wavy lines. Polar head groups have affinity for water, whereas their hydrocarbons tails avoid water. This can be accomplished by forming a micelle, in which polar head groups are on the surface and hydrocarbon tails are directed inside.

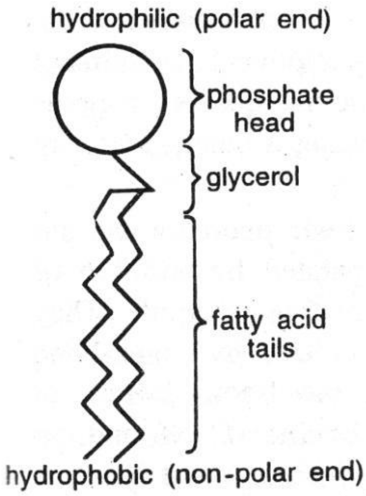

Fig.2. 4: A phospholipids molecule

Another arrangement of lipid molecule in a membrane is a bimolecular sheet, which is also called a lipid bilayer. Ph ospholipids and glycolipids are key membrane constituents of bimolecular sheets. Hydropho bic interactions are the major driving force for the formation of lipid bilayer. The lipid bilay er of the membrane is interrupted only by the proteins that traverse it. This bilayer consists primarily of:

Neutral Phospholipid s and Cholesterol: These include phosphatidylenoline, lecithin cerebroside, and sphingomyeline and phosphatidyl ethanolamine. They are without any electric charge at neutral pH and are closely packed in the bilayer along with cholesterol.

Acidic Phospholipids: These constitute about 5% to 20% fra ctions of the total phospholipids of plas ma membrane. They are **negatively charged** and are associated with proteins by w ay of lipid-protein interactions. Common examples are phosphatidyl inositol, phosphatidylserine, sulpholipids, phosphatidyl glycerol and Cardiolipin.

In plasma membrane, lipid fra ctions form permeability barrier and structural framework.

2.4.2.2 Proteins:-

Proteins are the main component of plasma membrane. Myelin sheath (membrane surrounding some nerve axo ns) is composed of about 80% lipids and 20% protein and presence of lipid makes myelin an excellent insulator. Eukaryotes membrane which serves primarily as permeability barriers possesses about 50% proteins and 50% lipid. Plasma membrane that are actively involved in energy transfer, such as inner membrane of mitochondria, chloroplasts and membranes of aerobic prokaryotes have large amounts of proteins i.e. about 75%. They not only provide mechanical support but also act as carriers or channels, serving for transport. In addition numerous enzymes, antigens and various kinds of receptor molecules are present in plasma membranes. Membrane proteins are classified as **integral (intrinsic) or peripheral (extrinsic**) according to the degree of their association with the membrane (Singer, 1971).

Peripheral Proteins: They are also called extrinsic proteins associated with membrane surface. These can be separated by addition of salts, soluble in aqueous solutions and usually free of lipids. They are bound to the surface by electrostatic and hydrogen bond interactions. They form outer and inner layers of the lipid bilayer of plasma membrane. Common examples are cytochrome-C found in mitochondria, acetyl cholinesterase in electroplax membrane and spectrin found in erythrocytes.

Integral or Intrinsic Proteins: These proteins penetrate the lipid layer wholly or partially and represent more than 70% of the two protein types. Their polar ends protrude from the membrane surface while non-polar regions are embedded in the interior of the membrane. Usually they are insoluble in water solutions and can be separate them from the membrane by detergents or organic solvents. The major integral proteins span the thickness of the membrane and have a small amount of carbohydrates on the pole at the outer surface. This protein appears to be involved in the diffusion of anions across the membrane. Integral proteins may be attached to the oligosaccharides to form glycoprotein or to phospholipid to form lipoproteins or proteolipids. Common intrinsic proteins are rhodopsin found in retinal rod cells and cytochrome oxidase found in mitochondrial membranes.

Every protein in the cell membrane is distributed asymmetrically with respect to the lipid bilayer.

2.4.2.3 Enzymes:-

About 30 enzymes have been found in various membranes. Those most constantly found are 5'-nucleotidase, Na^+-K^+ activated ATPase, alkaline phosphatase, adenylcyclase, RNAse and acid phosphomonoestrase. Na^+-K^+ activated Mg^+ ATPase plays an important role in the ionic exchange and may also act as carrier protein or permease across the plasma membrane. Some enzymes have a preferential localization. For example, alkaline phosphatase and ATPase are more abundant in bile capillaries, while disaccharides are present in microvilli of the intestine. Enzymes are asymmetrically distributed, for example in the outer surface of erythrocytes there are acetylcholinestrase, nicotinamide adenine dinucleotidase and Na^+-K^+ ATPase. In the inner surface there is NADH-diaphorase, G3PD, adenylate cyclase, protein kinase and ATPase.

2.4.2.4 Carbohydrates

The membranes of eukaryotic cells usually contain 2% to 10% carbohydrates in the form of glycolipids and glycoproteins. Hexose, hexosamine, fucose and sialic acid are the commonest carbohydrates found in the membrane. Plasma membranes of neuronal surface contain gangliosides (Lapertina, 1967) and are probably involved in the ion transfers. The distribution of oligosaccharid es is also highly asymmetrical.

2.4.2.5 Salts and wat er:-

They are also present in cell membranes. Water in cell membranes forms parts of membrane structure as it does in all cell constituents.

2.4.3 Lamella-model of plasma membrane (Danielli-Davson model)

Danielli-Davson model (1934) suggested that the plasma membrane consists of two layers of lipid molecules arra nged radially with their hydrophobic hydrocarbon chains toward each other and with their respective polar groups arranged outwar dly and inwardly throughout the entire double layer of lipid molecules. The polar ends of the lipid molecules are associated with a monom olecular layer of polar globular protein molecule. The entire structure thus consisted of double layer of lipid molecule sandwic hed between two continuous layers of protein. The lipid molecules are set at right angles to the surface and are so arranged in two layers that their non-polar hydrophobic fatty acid tails face each other and their polar hydrophilic phosphate heads face the protein layer. The proteins involved were thought to be globular. More over, lamellar theory assumed the cell mem brane to be a stable structure with little functional specificity and variability.

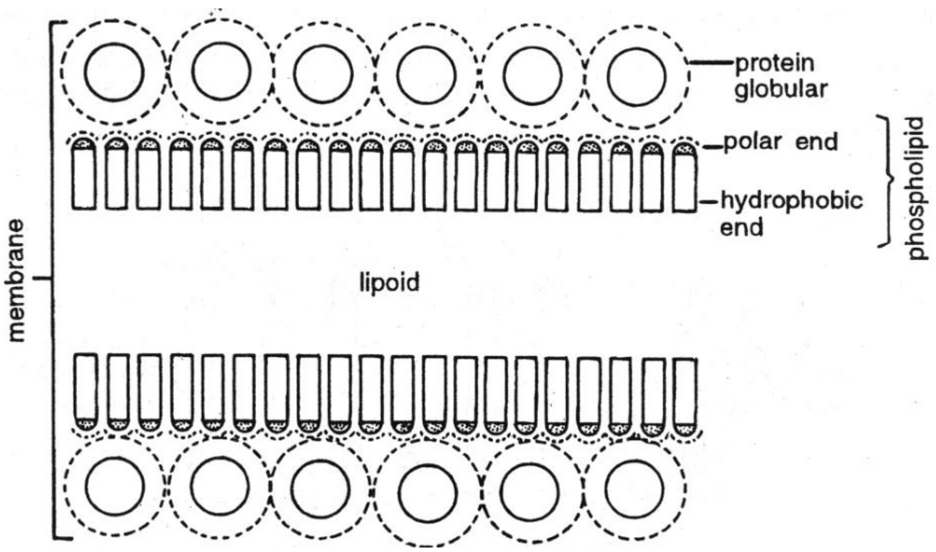

Fig. 2.5: A schematic diagram of Davson-Danielli model of membrane structure

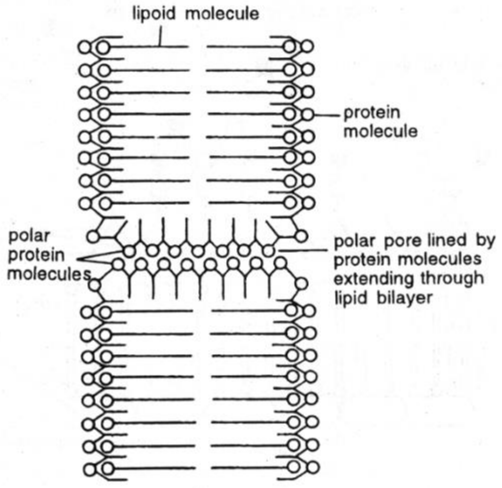

Fig. 2.6: A modification of original Danielli-Davson model, showing pores lin ed by polar protein molecules extending through the lipid bilayer

2.4.4 Miceller model of plasma Membrane:-

According to the view **of Hiller and Hoffman (1953**), plasma mem brane consists of a mosaic of globular subunits or micelles. If fatty acid molecules are comple tely surrounded by water, they may form aggreg ate called micelles in which the hydropho bic regions of fatty acid molecules are oriented toward the interior of the micelle away from the aqueous phase and their hydrophilic groups are at the surface in contact with the surrounding water. Micelles may be in the form of small spheres of bimolecular layers. These micelles are closely packed together having a central core of lipid molecules and hydrophilic shell of polar groups. Each lipid micelle measures 40Å t o 70Å in diameter. Protein component of the plasma membrane forms a monolayer on either side of the lipid micelles and is represente d by globular type. The spaces between the globular micelles are thought to represent water filled pores which measures about 4Å in diameter. These pores are bounded partly by t he polar groups of micelles and partly by the polar groups of associated protein molecules.

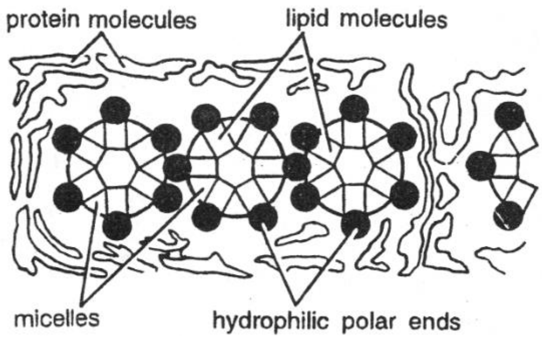

Fig.2.7: Plasma membrane based on Miceller theory (diagrammatic)

2.4.5 Fluid Mosaic Model of plasma membrane:-

It was proposed by **Singer and Nicholson (1972**). The lipids are thought to be arranged primarily in a bilayer in which proteins are embedded to varying degrees. Singer classifies membrane protein s as peripheral or integral. The proteins varied in size and dissolved to varying degrees in the lipid matrix are able to diffuse later ally in the plane of membrane, and the entire structure is hence dynamic. In this model, lipid molecules may exhibit intra molecular move ment or may rotate about their axis or ma y display flip-flop movement including transfer from one side of bilayer to the other.

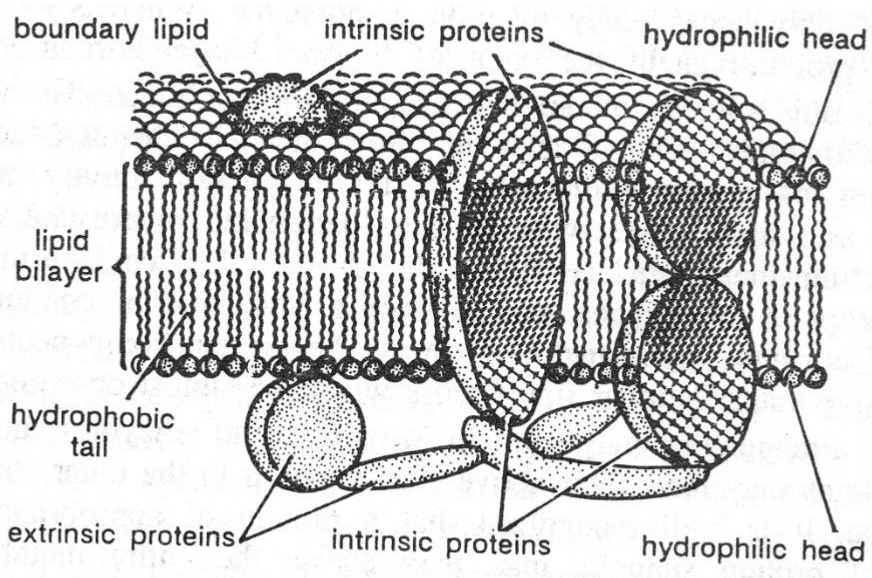

Fig. 2.8: Plasma membrane based upon Fluid-mosaic model

The lipids, glycoprot ein and many of the intrinsic proteins of the membranes are amphipathic molecules. Thes e amphipathic molecules constitute liquid cr ystalline aggregates in which the polar groups are directed toward the water phase and the n on-polar groups are situated inside the bilayer. T he lipid bilayer forms the structural matrix which serves as the permeability barrier of the membrane. In membranes with high lipid content, lipid bilayer is extensive and interrupted only occasionally by protein molecules, whereas in membranes with high protein content, the extent of lipid bilayer is reduced. Thus, fluid mosaic model may describe the chemical c omposition of the molecular organization and ultra structure of plasma membranes. This arrangement allows various enzymes and antigenic glycoprotein to have their active sites exposed to the outer surface of the membrane. The fluidity of membrane also implies that both the lipid and the protein have consid erable freedom of movement within the bilayer. The fluidity of the lipid depends on the degree of saturation of the hydrocarbon chains and on the ambient temperature. A considerabl e proportion of the lipids in the membrane are unsaturated, so that melting point of the bil ayer is below body temperature.

2.5 Functions of Plasma Membrane:-

The plasma membrane serves many functions such as:

It maintains the individuality and form of the cell.

It keeps the cell contents in place and distinct from the environmental materials. It protects the cell from injury.

It regulates the flow of materials into and out of the cell to maintain the concentration and kinds of molecules and ions in the cell. A cell remains alive as long as the cell membrane is able to determine which materials should enter or leave the cell.

It forms organelles within the cytoplasm.

Its junctions keep the cells together.

It's infolds help in the intake of materials by endocytosis (pinocytosis and phagocytosis).

It's out folds (microvilli) increase the surface area for absorption of nutrients. The out folds also form protective sheaths around cilia and flagella.

Its receptor molecules permit flow of information into the cell.

Its oligosaccharide molecule helps in recognizing self from non-self.

By controlling flow of material and information into the cell, the plasma membrane makes metabolism possible.

It permits exit of secretions and wastes by exocytosis.

It controls cellular interactions necessary for tissue formation and defense against microbes.

It helps certain cells in movement by forming pseudopodia as in Amoeba and leucocytes.

The bio-membranes around the organelles help the latter to:

Maintain their identity and functional individuality.

Receive and turn out required material.

2.6 SUMMARY

The plasma membrane constitutes the outermost boundary of the cell and it is remarkably complex in its molecular organization. It is composed of almost equal parts of proteins and lipids. It allows only selected ions and macromolecules to enter or leave the cell, thus it functions as a semi permeable membrane.

Ultra structure of plasma membrane may be of symmetrical or asymmetrical molecular structure in nature. Plasma membrane is a tripartite structure in both of the above types, the difference lies in the thickness of the three layers. In symmetrical molecular structure all the three layers, the outer and inner adielectronic along with the middle di-electronic layer are of 25Å thickness each having total thickness of 75Å. While in asymmetrical structure the inner adielectronic component is of 35Å to 40Å thickness, the outer dielectronic component is of 25Å thick and the central dielectronic layer is 30Å wide, thus total thickness becomes 90-95Å.

Plasma membrane is primarily composed of proteins and lipids, although carbohydrate is often present in association with proteins (as glycoproteins) or lipids (as glycolipids). However, the relative proportions of proteins and lipids vary considerably in membranes. Enzymes are also found in plasma membranes which play an important role in ionic exchange. Besides, salt and water are also present. The arrangement of lipids and proteins molecules is explained through various theories.

Lamella model of plasma membrane is consisted of a double layer of lipid molecules arranged radially with their hydrophobic hydrocarbon chains towards each other and with their respective polar groups arranged outwardly and inwardly. The double layer of lipids is sandwiched between two continuous layers of proteins. According to miceller theory, plasma membrane consists of a mosaic of globular subunits or micelles. These micelles are closely packed together having the lipid molecules in the central core. Protein components form a monolayer on the entire surface of the lipid micelles forming a globule. The widely accepted theory is fluid mosaic models of membrane as it can be used to describe the structure of different membranes. In this model the lipids are arranged in a bilayer in which proteins are embedded as peripheral or integral. The proteins varied in size and dissolved to varying degrees in the lipid matrix, diffuse laterally in the plane of membranes and the entire structure is hence dynamic.

Plasma membrane performs variety of functions as they impart shape to the cell and protects the cell contents. It regulates the cellular semi permeability, resorption, excretion and secretion. It contributes to the formation of various cell organelles within the cell. Its junctions keep the cells together.

2.7 GLOSSARY:-

Plasma membrane - A microscopic membrane made up of lipids and proteins which forms the external boundary of the cytoplasm of a cell or encloses a vacuole, and regulates the passage of molecules in and out of the cytoplasm.

Permeability- The ability of a barrier to let any substance pass through it.

Ions- An atom or molecule with a net electric charge due to the loss or gain of one or more electrons.

Semi permeable- Allowing certain substances especially small molecules or ions to pass through it but not others, especially allowing the passage of a solvent but not of certain solutes.

Receptor- A receptor is a protein molecule in a cell or on the surface of a cell to which a substance such as a hormone, a drug, or an antigen can bind, causing a change in the activity of the cell.

Dielectric- Having the property of transmitting electric force without conduction.

Hydrophobic- The substances that have an affinity for water due to the formation of hydrogen bonds.

Hydrophilic- Hydrophilic molecules typically have polar groups enabling them to readily absorb or dissolve in water as well as in other polar solvents.

Micelles- It is an aggregate of molecules in a colloidal solution, such as those formed by detergents.

Peripheral proteins/extrinsic proteins- Peripheral membrane proteins are proteins that adhere only temporarily to the biological membrane with which they are associated. These molecules attach to integral membrane proteins, or penetrate the peripheral regions of the lipid bilayer.

Integral proteins/intrinsic proteins- An integral membrane protein (IMP) is a type of membrane protein that is permanently attached to the biological membrane. All trans membrane proteins are IMPs, but not all IMPs are trans membrane proteins.

Amphipathy- It is the property of a molecule having both polar (water-soluble) and non polar (not water-soluble) affinities in its structure.

Enzyme- The proteins which acts as catalysts within living cells and increases the rate of biochemical reactions.

****