2.0 THE CELL MEMBRANE STUCTURE

2.1 Basic Characteristics

Cell membrane which also referred to as biological membrane has the following characteristics

a) Thickness: vary from 7 to10 nm.
b) Composition: is mainly made up of Lipids, Protein and Carbohydrate (small amounts).
c) Protein to lipid ratio in most cells membranes is approximately 50:50.In bacteria it can be as high as 80:20 and as low as 20:80 in nerve cells.
d) Lipid component is usually phospholipids, and in some membranes it may be glycolipids and / or steroids.
e) **Protein component—**range from few simple polypeptides to hundreds of different proteins
f) All are bilayer
g) Are amphipathic molecules i.e. they have hydrophilic "heads" and hydrophobic "tails".

2.2 Models of cell membrane Structure

2.2.1 **C. Nageli, W. Pfeffer and C.E. Overton model**

a) In late 19th century they discovered that the rate at which a given substance move in the cell is directly related to its solubility in lipid.
b) The more soluble it is in lipid, the more readily a substance passes in the cell. Overton proposed that cells are covered by a membrane containing a thin film of lipid.

2.2.2 **Langmuir** Model

a) LangmuirL;. discovered that phospholids spread on a water surface spontaneously to form a film whose
dimensions suggeFsts it to be one molecule thick.
b) Phospholipids are amphipathic i.e. they have hydrophilic and hydrophobic regions.
c) Langmuir theorized that monomolecular films involve an organized arrangement in which the hydrophilic or "head" groups of the lipid molecule are aligned next to the water surface while hydrophobic "tail" extend out toward the air.

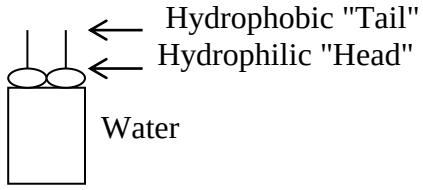


Fig. 22.1 Langmir membrane model

2.2.3. Lipid bilayer model proposed by Gorter and Grendel

a) Based on study of Red Blood Cell (ghosts) in 1920's.
b) Corter and Grendel—found that when the extracted lipids were spread as a monolayer on water, the film was found to cover the area twice as that of the calculated surface area of the red blood cells from which the lipid had been extracted.
c) They concluded that lipid that form the lipid bilayer would be most stable if the hydrophilic head groups were exposed to the aqueous environments at the two membrane surfaces, and the hydrophobic "tails" were sequestered away from water in the two membrane interior.

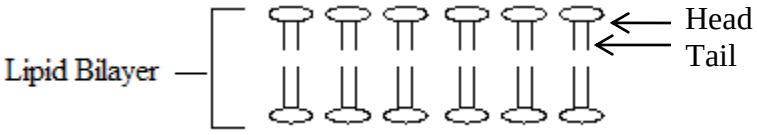


Fig. 2.2 Lipid bilayer model proposed by Gorter and Grendel

2.2.4 Danielli—Davson Model - 1925

a) Proposed that plasma membrane has an inner bilayer of lipid molecules, oriented with their hydrophilic head groups towards the membrane surface are covered on both sides by layers of protein.

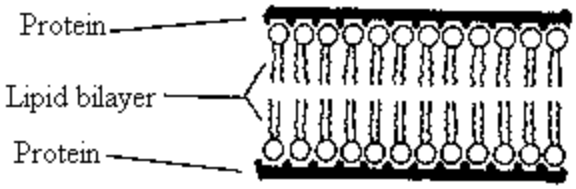


Fig. 2.3 Danielli—Davson Model

b) This was the basic model for membrane structure accepted by biologists for many years. It was, however, inadequate in explaining many of the findings of later research.

2.2.5 The Unit Membrane hypothesis Proposed by J.D Robertson

a) When membranes are observed under electron microscope they were found to be 7-8nm in thickness.
b) The staining appearance of such membrane was; two electron dense lines separated by a more lightly central zone. Such membrane with three zones has "trilaminar" in appearance.

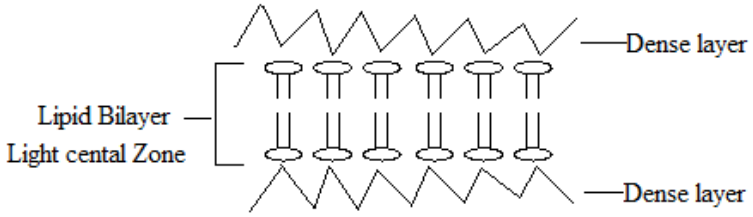


Fig. 2.4 Robertson Unit membrane model hypothesiss

2.2.6 The Fluid Mosaic Plasma membrane Model Proposed by S.J Singer and G.Nicolson.

Singer-Nichoson or S-N fluid mosaic membrane model was published in science Journal in 1972 is the one used to explain the structure of cell membrane. According to this model three principles guide the organization of all biological membrane.

a) Membrane lipids are arranged predominantly in form of a bilayer, but this bilayer may be frequently interrupted by the presence of embedded protein.
b) Membrane proteins exist in two classes; integrated proteins embedded in the lipid bilayer, and peripheral proteins bound to the bilayer surface.
c) Proteins and lipid molecules are randomly distributed in the membrane.

d) The lipid bilayer is fluid, thereby permitting lateral and rotational movements of both membrane proteins and lipids.

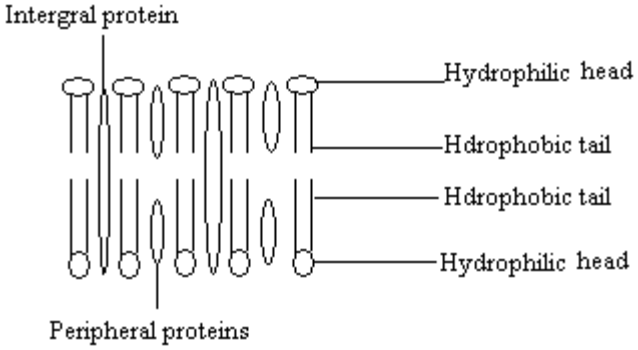


Fig. 2.5 Fluid Mosaic Plasma membrane Model Proposed by S.J Singer and G.Nicolson

2.6 Modifications of S-N model

Several scholars have been suggested modification of S-N model among them are Jacobson et al., 1995, Helms and Zurzolo 2004 and Innokentiy et al 2010" . These include;

a) Lateral diffusion of bilayer membrane appear to be restricted and heterogenous occasioned by a supramolecular protein complex and protein domain called lipid rafts (domains in micron).
b) Membrane microdomains may be found in the lipid bilayer- this is evidenced by existence of variety of phospholipid molecules, differences in their molecular shape and physical properties, and their asymmetric distribution in the bilayer.
c) These membrane Dynamics help to explain the ever changing membrane mobility and proximity relationship of lipid and protein molecules in the plasma membrane. Also they help explain how plasma membrane impact on cellular process such as ligand receptor recognition, antigen presentation, intercellular interaction between target and Killer cells.

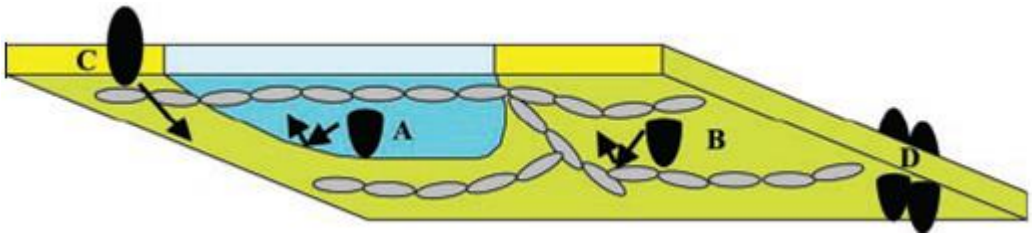
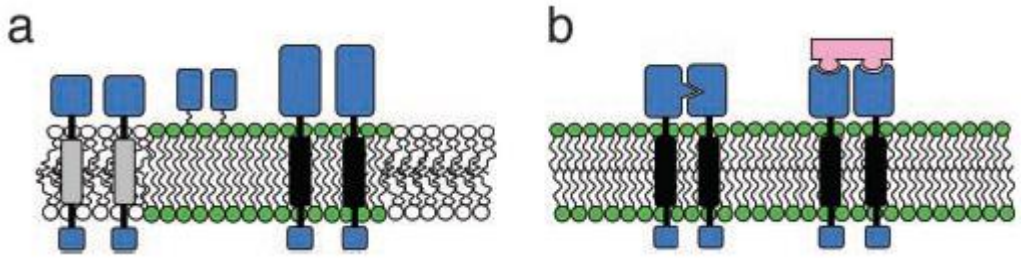


Fig. 2.5

Proteins experience different types of restrictions to translational diffusion in the plasma membrane. The view of the membrane is shown from beneath. A, Proteins showing preferential accumulation in a lipid microdomain may be confined to the area of the microdomain if the activation energy of passing the domain barrier is larger than the kinetic energy of the protein. The extent to which passing a domain barrier is prohibited is determined by the preference of the protein for the lipid environment: if the protein interacts preferentially and avidly with lipids of the microdomain, it may be reluctant to leave. B and C, The cytoskeleton is also important in restricting free, lateral diffusion of membrane proteins. Proteins whose intracellular domain is long are unable to pass through a fence composed of afilament of the cytoskeleton (B), whereas proteins with a short intracellular domain are free to move across such a fence (C). D, Associations of proteins experience more viscous force; therefore, their translational diffusion rate is usually smaller than that of monomeric proteins. *Adopted from Vereb et al 2003, PNAS vol.100(14) 8083-8058*



Association of proteins can be induced by selective accumulation of proteins in distinct lipid microdomains (*a*) or by specific protein–protein interactions (*b*). (*a*) The membrane contains lipid microdomains with distinct lipid compositions. These membrane areas harbor different sets of proteins. Green lipid molecules preferentially accumulate proteins whose transmembrane domain is displayed in black and also proteins that are attached to the extracellular leaflet of the membrane (glycosylphosphatidylinositol-anchored proteins). The mechanism for the selective accumulation of proteins in a given lipid environment can be explained by a preference of proteins for the chemical (hydrophobicity) or physical (membrane thickness, microviscosity) properties of the lipid microdomain. Nanometer-sized protein associations can be considered a lipid-mediated interaction in this case. (*b*) Specific protein– protein interactions mediated by transmembrane proteins or ligands binding to them also may be responsible for the generation of protein associations. *Adopted from Vereb et al 2003, PNAS vol.100(14) 8083-8058*

Explain structure of natural using studies from artificial lipid bilayer membrane

Natural membrane have been studied in relationship to artificial bilayer membrane.
Attempts to create artificial bilayer membrane has resulted into the following types;

1) Planar bilayer

2) Vesicular bilayer -liposome

Fig.2.5 Simulating lipid bilayer model

a) The physical and chemical properties-thickness, electrical properties, permeability to water and solutes, temperature dependent changes in state, electron-spin-resonance spectrum and X-ray diffraction patterns of artificial bilayer membrane resemble that of natural membrane.
b) This is evidence that natural membrane are bilayer.
c) However continuity of bilayer may be interrupted by the presence of the embedded protein.
d) Lipid bilayer differ in the type of the lipid constituents.

2.3 Type of lipids found in a bilayer membrane

a) Phospholipids -dominate in most cells. These include;
i) **Phosphogycerids** -abundant e.g. phosphatidylcholine, phosphatidylethanolamine etc.
ii) **Sphingophospholids** eg sphinggomyelin - important in animal plasma membrane,but scarce or absent in mitochondrial, chloroplast and bacterial plasma membranes.
b) **Glycolipids** -are abundant in myein and chloroplast membranes.
c) **Steroids**-e.g.- cholesterols- significant in animal plasma membranes and myeins.
-sitosterols and stigmasterols are restricted to plasma membrane of plant cell

Two types of lipids fatty acids chain are employed in its construction of lipid layer. These are;

a) **Saturated lipids** -over 90% of fatty acids in myelin are saturated
b) **Unsaturated lipids**- in mitochondrion and in chloroplasts about 50% of the fatty acids are unsaturated.

2.4 Arrangements of membrane proteins

Types of proteins in fluid mosaic membrane
1) Integral proteins
2) Peripheral proteins

1. Integral proteins

- Are embedded into lipid bilayer.
- Account for the bulk of membrane proteins including membrane associated enzymes, receptor and antigens.
- Can be removed by exposure to detergents or organic solvents.
- May span the bilayer completely (trans-membrane proteins) or embedded in one side of bilayer.
- Are amphipathic molecules- hydrophobic tail are buried in the membrane interior and its hydrophobic end interacts with the tails of lipid bilayer.
- Hydrophilic head are exposed at the membrane surface.

2. Peripheral Proteins

- Bound to membrane relatively weak by ionic interaction with the hydrophilic head groups of the lipid bilayer.
- Are easily removed by raising ionic strengthen.
- Do not cover the entire surface of the lipid bilayer, leaving many vacant areas where the lipid head groups are exposed at the membrane surface.

2.5 Membrane fluidity

- Plasma membranes may be fluid rather than rigid
- Lipid bilayer molecules in membranes are in a state called fluid crystal state i.e. they are never fixed in position as crystals nor do they have complete freedom of movememt as in fluids.
- In fluid crystal state individual lipid molecules are capable of lateral diffusion with the bilayer but always retain the same orientation, with their hydrophilic head groups pointed towards the membrane surface and their hydrophobic tails projecting towards the membrane interior.

Types of movements in plasmic membrane proteins.

1) Lateral diffusion (sideways movement) ← →

2) Rotation 

3) Flip flop-movement forward with sudden reversal of movements

Factors affecting the fluidity of plasma membrane

The difference in lipid constituents may affect: a) permeability b) Fluidity c) enzymatic activity.

1) Type of lipid present in the bilayer-an increase in unsaturated fatty acids or an decrease in choresterol increases fluidity.
2) Size of fatty acid chains-decrease in chain size increases fluidity.

2.6 Basic functions of Cell membrane

1) Serves as the boundary to the cell that permits the passage of selected materials in and out of the cell at a carefully regulated rate.
   Allows inward flow (passage) of food and extraction of waste material out of the cell.
2) Contain cell cytoplasm.
3) Mushroom structures pointing toward the interior of the cell are thought to be the major sites of oxygen utilization.