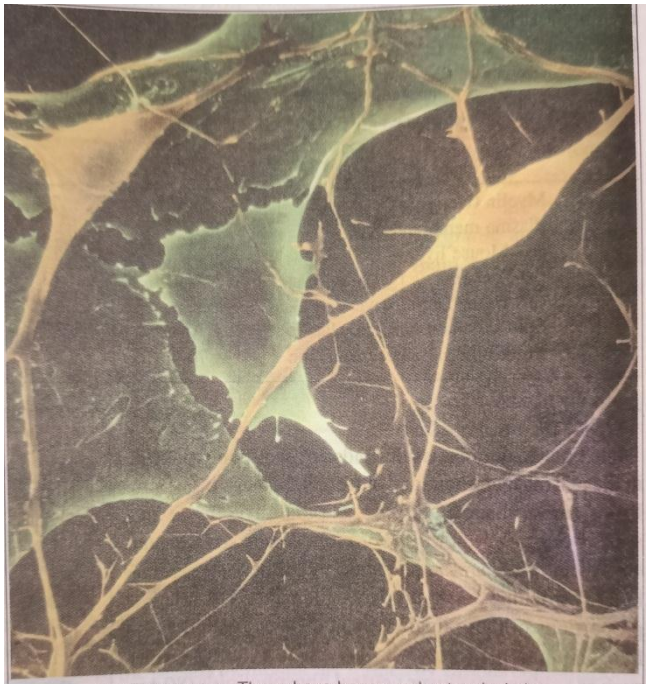
Lecture Series on Biochemistry (Part 5)

Diatoms. A glassy outer shell and a selectively permeable plasma membrane help cells maintain relatively constant internal conditions.



SEM of neurons. These have been used extensively in studying the ultra-structure of the plasma membrane.

Plasma membrane

- Also called cytoplasmic membrane, cell membrane or plasmalemma.
- The term plasma membrane was coined by C.Nageli and C. Cramer in 1855 and the term plasmalemma has been given by J.Q. Plowe in 1931.
- It is a ultrathin, elastic, living, dynamic and selective-transport barrier.
- A fluid-mosaic assembly of molecules of lipids, proteins and carbohydrates.

- Separates the cytoplasm and the surrounding cellular environment.
- Controls the entry of nutrients and exit of waste products, and generates differences in ion concentration between the interior and exterior of the cell.
- Also acts as a sensor of external signals (hormonal, immunological) and allows the cell to react in response to environmental stimuli.

Chemical composition of plasma membrane

- Chemically, plasma membrane and other membranes of different organelles are found to contain proteins, lipids and carbohydrates, but in different ratios.
- For e.g., in the plasma membrane of human red blood cells, proteins represent 52%, lipids 40% and carbohydrates 8%.

Table 5-1. **Chemical composition of some purified membranes (in percentages) (Source : Darnell *et al.*, 1986).**

Membrane	Protein	Lipid	Carbohydrate
1. Myelin (Nerve cell)	18	79	3
2. Plasma membrane :			
(i) Mouse liver	44	52	4
(ii) *Amoeba*	54	42	4
(iii) Human erythrocyte	52	40	8
3. Spinach chloroplast lamellae	70	30	0
4. Mitochondrial inner membrane	76	24	0

Table 5-2. **Some important enzymes present in the plasma membrane (Source : Sheeler and Bianchi, 1987).**

1. Acetyl phosphatase	11. Cholesterol esterase
2. Acetyl cholinesterase (Ectoenzyme of erythrocyte)	12. Guanylase cyclase
3. Acid phosphatase	13. Monoglyceride lipase
4. Adenosine triphosphatase	14. NAD-ase (Ectoenzyme of erythrocyte)
5. Mg^{2+} ATPase (Endoenzyme of erythrocyte)	15. Protein kinase (Endoenzyme of erythrocyte)
6. Na^{+}-K^{+} ATPase (Ectoenzyme of erythrocyte)	16. Phospholipase A
7. Adenylate cyclase (Endoenzyme of erythrocyte)	17. Lactase
8. RNAase	18. Maltase
9. Alkaline phosphatase	19. Sialidase
10. Aminopeptidase	20. UDP glycosidase

Lipids

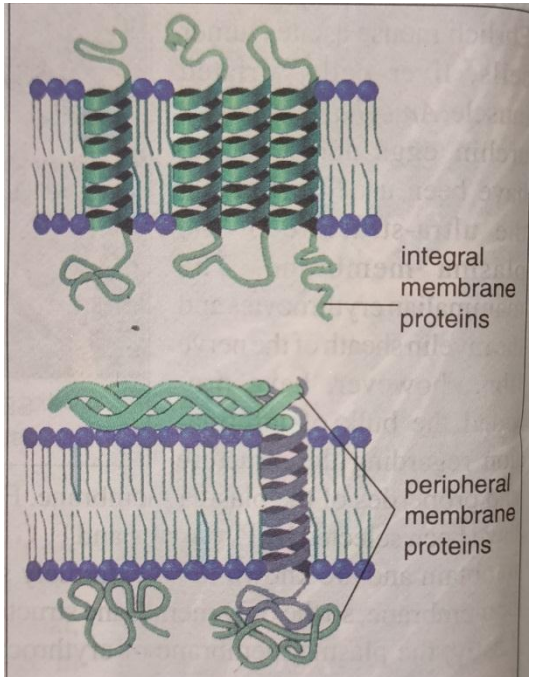
4 major classes of lipids are commonly present

- Phospholipids (most abundant)
- Sphingolipids
- Glycolipids
- Sterols

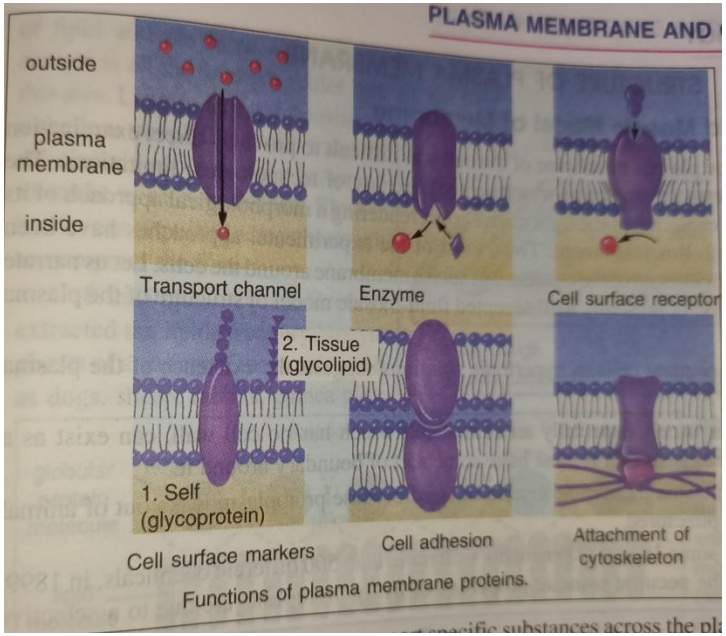
Proteins

- Amount and types of proteins in the membranes are highly variable.
- According to their position in the plasma membrane, proteins fall into 2 main types:
  - Integral or intrinsic proteins and
  - Peripheral or extrinsic proteins
- Both of theses may be ectoproteins or endoproteins

- On the basis of their function, proteins of plasma membrane can also be classified into 3 main types:
  - Structural proteins
  - Enzymes
  - Transport protein



Classes of membrane proteins.



Functions of plasma membrane proteins.

Carbohydrates

- Present as short, unbranched or branched chains of sugars (oligisaccharides) attached either to exterior ectoproteins (forming glycoproteins) or to the polar ends of phospholipids at the external surface of the plasma membrane (forming glycolipids).
- No carbohydrate is located at the cytoplasmic or inner surface of the plasma membrane.

- All types of oligosaccharides of the plasma membrane are formed by various combinations of 6 principal sugars (all of which are glucose-derivatives):
  - D-galactose
  - D-mannose
  - L-fructose
  - N-acetylneuraminic acid (also called sialic acid)
  - N-acetyl-D-glucosamine
  - N-acetyl-D-galactosamine

Structure of plasma membrane

Evolution of Fluid Mosaic Model of Membrane

- Plasmolysis of plant cells in hypertonic solutions suggests the existence of plasma membrane in plant cells.
- The very fact that a cell, especially an animal cell which has no cell wall, can exist as a physically defined entity suggests that it must have some sort of boundary around it.
- Presence of some membrane can be inferred as protoplasm leaks out of animal cell when punctured

- 1899, Overton concluded that the peculiar osmotic properties of living protoplasts are due to a selective solubility mechanism. Hydrophobbic compounds entered cells more rapidly than hydrophilic ones.
- Overton believed this was because of an outer lipoid layer.
- Correctly speculated that this layer might contain cholesterol, lecithin and fatty oils.

- Hober (1910) and Fricke (1925) found that the intact cell had low electrical conductivity indicating the presence of a lipid layer around it.
- In 1917, Langmuir, fabricated a triugh or film balance for measuring the specific minimum surface area occupied by a monomolecular film of lipid and the force necessary to compress all the lipid molecules into this area.
- In 1925, Gorter and Grendel concluded that erythrocytes were covered by a layer of lipids two molecules thick (lipid bilayer or bimolecular lipid layer) oriented with polar groups inside and outside the cell.

Sandwich model

- A lipid bilayer was coated on its either side with hydrated proteins
- Mutual attraction between the hydrocarbon chain sof lipids and electrostaic forces between the protein and “head”of the lipid molecules were thought to maintain the stability of the membrane.
- Lipid bilayer of about 6.0 nm in thickness and the protein layer of about 1.0 nm in thickness, giving a total thickness of about 8.0 nm.

- By studying the surface tension of the cells (Harvey and Cole, 1931; Danielle and Harvey, 1935) suggested the presence of proteins in the plasma membrane, in addition to the lipids.
- In 1935, Danielle and Daveson proposed a model called sandwich model, for membrane structure.

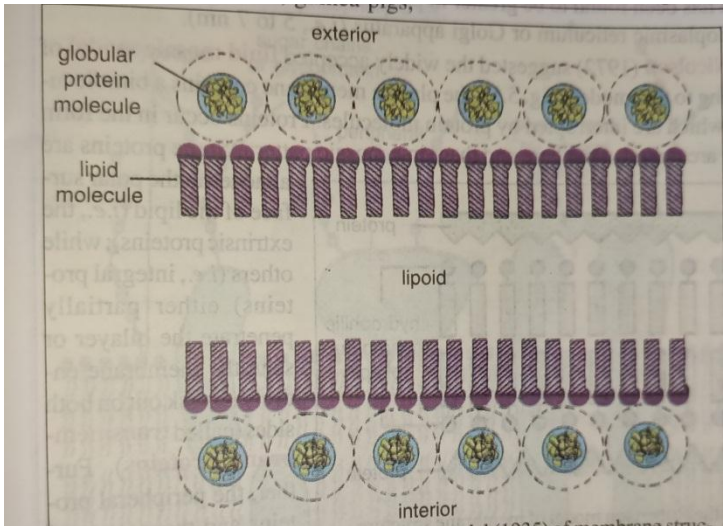


Fig. 5.2. The original Danielli-Davson model (1935) of membrane structure. The bimolecular layer of lipid molecules is of undefined thickness and is covered on each side by a continuous layer of globular proteins (after De Witt, 1977).

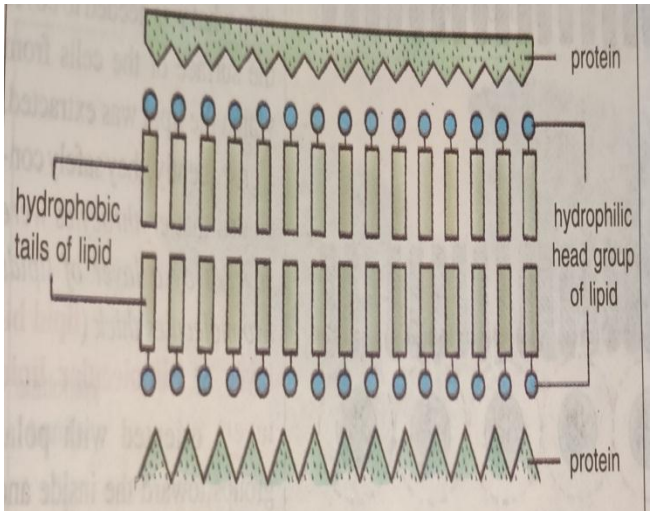


Fig. 5.4. Schematic diagram of the Robertson model of membrane structure. The lipid layer is defined as bimolecular, and the protein is extended but different on the two faces of the membrane (after Thorpe, 1984).

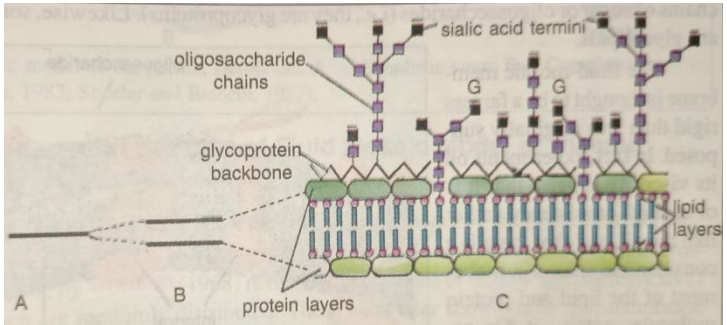
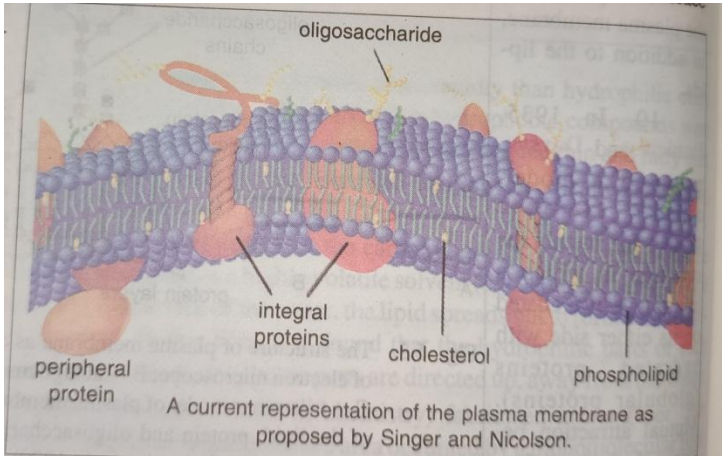


Fig. 5.3. The structure of plasma membrane as observed A—at low magnification of electron microscope; B—at high magnification of electron microscope. C—trilaminar model of plasma membrane showing possible arrangement of the lipid, protein and oligosaccharide molecules in the plasma membrane (after De Robertis *et al.*, 1970).

S.J. Singer and G.L. Nicolson (1972)suggested the widely accepted fluid mosaic model of biological membranes.



A current representation of the plasma membrane as proposed by Singer and Nicolson.

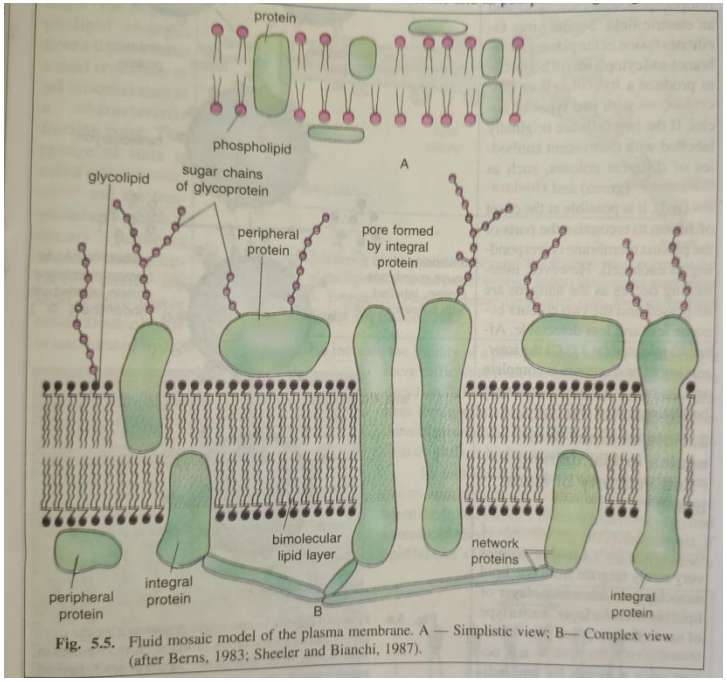


Fig. 5.5. Fluid mosaic model of the plasma membrane. A — Simplistic view; B— Complex view (after Berns, 1983; Sheeler and Bianchi, 1987).

Role of lipid molecules in maintaining Fluid property of membrane

- Types of movements of lipid molecules
- Role of unsaturated fats in increasing membrane fluidity
- Role of cholesterol in maintaining fluidity of membrane