CHAPTER

2

PLASMA MEMBRANE

→ Also known as, ***Cell membrane*** or, ***Cytoplasmic membrane*** or, ***Plasmalemma***.

→ It is a dynamic, fluid and **selectively permeable membrane** structure.

→ Forms the external boundary of the cell.

→ Thickness: ~ 75Å.

Discovery:

→ ***Ernst Overton,*** in 1890s, first gained the insight into the chemical nature of cell membrane.

→ ***E. Gorter and F. Grendel,*** in 1925, gave the first proposal about the presence of a lipid bilayer in cellular membrane. They also suggested that, the polar group of each leaflet were directed outward towards the aqueous environment.

→ **Davson and Danielli,** in 1935, proposed that the plasma membrane was composed of lipid bilayer, lined by a layer of globular proteins on both inner and outer surface. Later, in 1950s, they revised their proposal saying that apart from the inner and outer protein layer, the protein layer is also penetrated by protein-lined pores that provide channel for polar solutes and ions to enter and exit the cell.

→ ***Jonathan Singer*** and ***Garth Nicolson,*** in 1972, proposed the **fluid-mosaic model**.

Important functions of plasma membrane:

- Separates the cell from the external environment.
- Protects the cell from injury.
- Allows selective permeability of materials and informations between two cells.
- Contain receptors for certain hormones.

Fluid-mosaic model *(Figure 2.1)***:**

According to this model,

→ Membranes do not have a uniform deposition of lipids and proteins, but a mosaic of the two.

→ Membrane is not solid, but **quasi fluid** in nature.

→ The lipid molecules are present as a bilayer.

→ Protein molecules are present on both, inside and outer side of the lipid bilayer.

→ Individual lipid molecules can move laterally, within the plane of the membrane.

→ The components, being mobile, are capable of coming together and forming various types of temporary interactions.

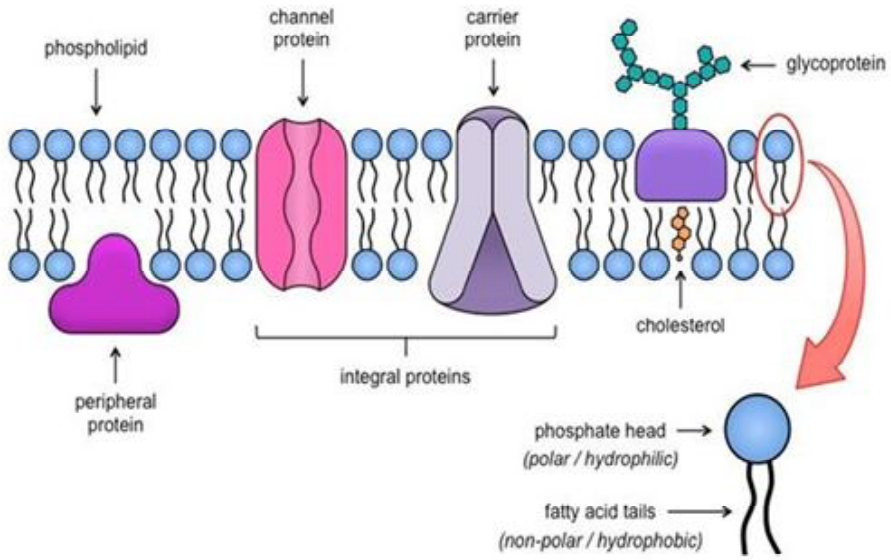


Figure 2.1: Fluid mosaic model of plasma membrane

Composition of plasma membrane:

→ All plasma membranes consists of lipids and protein whose composition varies depending upon the type of the cell *(Table 2.1)*.

→ Carbohydrates are present in the bound form, either to proteins (termed as, glycoproteins) or to lipids (termed as glycolipids).

❖ Carbohydrates are abundantly found in eukaryotic cell.

→ The basic unit of the plasma membrane is the lipid bilayer, which is composed of amphipathic lipid molecules.

→ The polar head of the lipid molecules remain in contact with the aqueous phase (intra- or extracellular), whereas the non-polar tail face each other and constitutes the hydrophobic interior of the membrane.

→ Hydrophobic interaction plays the primary role in the organization of the lipid bilayer.

Functions of lipid bilayer:

- Serves as the structural backbone of the membrane.
- Provides the barrier preventing random movement of water-soluble materials into and out of the cell.

Plasma membrane	Lipids (%)	Proteins (%)	Carbohydrates (%)
Human erythrocyte	43	49	8
Mouse liver	52	44	4
Amoeba	42	54	4
Mitochondrial inner membrane	24	76	0
Spinach lamellae	30	70	0

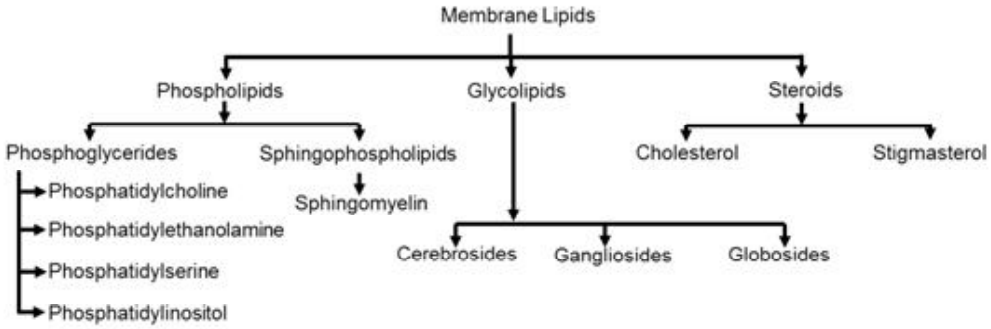
Table 2.1: Chemical constituents of some membranes

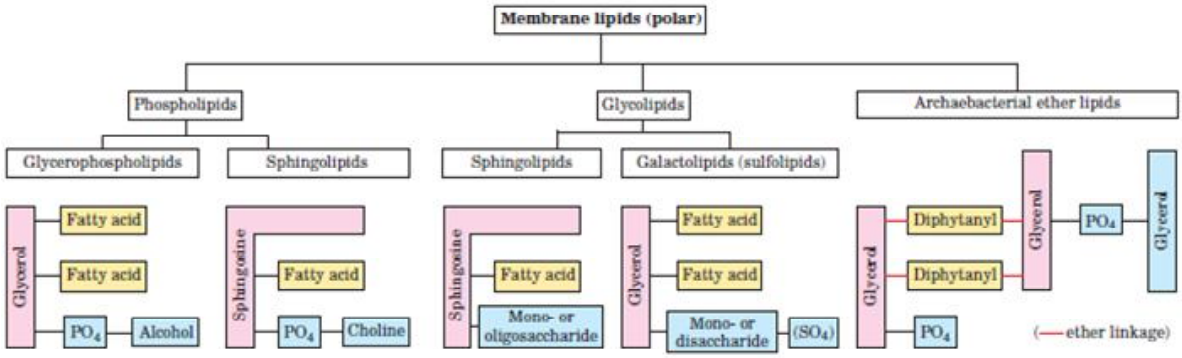
I. Membrane lipids

→ Membrane contains wide diversity of **amphipathic** lipids (lipids containing both hydrophilic as well as hydrophobic regions.

→ Membrane lipids may be fully **saturated** (lack double bond), **monounsaturated** (possess one double bond), or **polyunsaturated** (possess more than one double bond).

→ There are three main types of membrane lipids: phospholipids, glycolipids and sterols.





1. Phospholipids:

→ Phospholipids are made up of 4 components:
- ∗ an alcohol (glycerol or, sphingosine)
- ∗ fatty acids
- ∗ phosphate, and
- ∗ alcohol, attached to the phosphate

→ The fatty acid is hydrophobic, and the rest of the molecules are hydrophilic in nature.

→ Two types of phospholipids are present, glycerophospholipids and sphingophospholipids.

- **Glycerophospholipids:**
  - ♦ Phospholipids derived from glycerol.
  - ♦ Also called as, ***Phosphoglycerides***.
  - ❖ Phosphoglycerides are the most abundant phospholipids found in the plasma membrane.
- **Sphingophospholipids:**
  - ♦ Contains an amino alcohol (called sphingosine) instead of glycerol.
  - ♦ The amino group of the sphingosine backbone is linked to the fatty acid by amide bond.
  - ❖ Sphingomyelin is the most abundant sphingophospholipid.

→ The plasma membrane of animal cells contains four major phospholipids,
- ∗ Phophatidylcholine (the most abundant glycerophospholipids in plasma membrane).
- ∗ Phophatidylserine
- ∗ Phophatidylethanolamine
- ∗ Sphingomyelin

Phospholipid	Net charge (at neutral pH)
Phophatidylcholine	No charge
Phophatidylethanolamine	No charge
Phosphatidylinositol	Negative
Phophatidylserine	Negative

Table 2.2: Major phospholipids and their net charge.

❖ Phospholipids containing net positive charge are very rare.

2. Glycolipids:

→ Can be derived from either glycerol or sphingosine.

→ Contains carbohydrate (either monosaccharide or oligosaccharide) covalently attached to the lipid.

→ Found exclusively in the outer leaflet of the plasma membrane, with their carbohydrate part exposed on the cell surface.

→ Examples *(Figure 2.2)*,

Simplest glycolipid: Cerebroside (contains a single sugar residue, either glucose or galactose).

Complex glycolipid: Ganglioside (contains a branched chain of seven sugar residues).

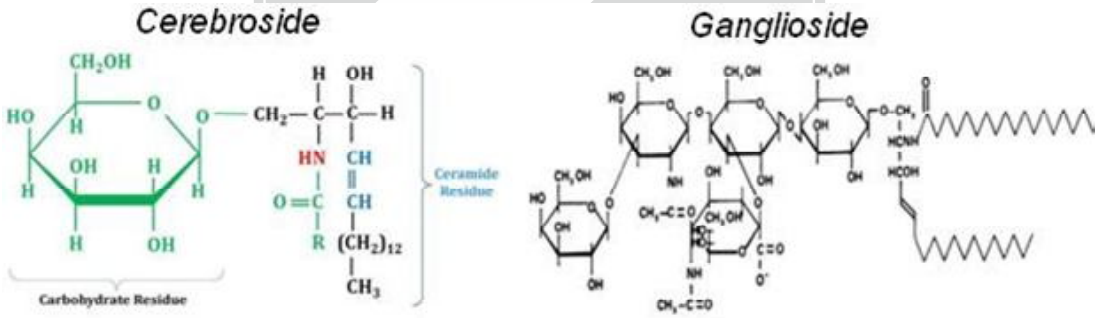


Figure 2.2: Chemical structure of glycolipids.

3. Sterols:

→ It is planar and a relatively rigid structure.

→ The basic structure of sterol is a steroid nucleus, consisting of four fused rings (three with six carbons and one with five).

❖ **Cholesterol** *(Figure 2.3)*,

∗ is the major sterol present in plasma membrane of animal cell.

∗ is absent in plant cell (Instead, ***stigmasterol*** or ***sitosterol*** is present).

∗ is also absent in bacterial plasma membrane (**Except:** ***Mycoplasma***).

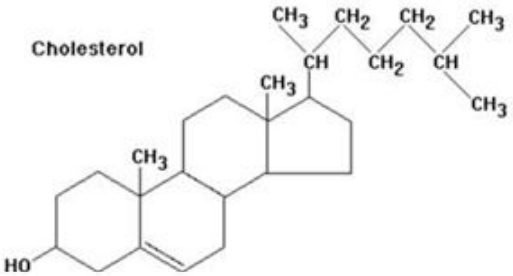


Figure 2.3: Chemical structure of cholesterol

Lipid aggregates

Amphipathic lipids can form three types of aggregates in presence of water *(Figure 2.4)*.

- **Micelles:** It is formed when there is the presence of only one fatty acid chain. The molecules form small and spherical micellar structure of diameter ~20 nm. The hydrophobic fatty acid chains hide inside the micelle.
- **Bilayer:** Two lipid monolayers combine to form a two-dimensional sheet.
- **Liposome:** Lipid bilayer forms a hollow sphere. These are closed structures bound by single bilayer, and filled with solvent.

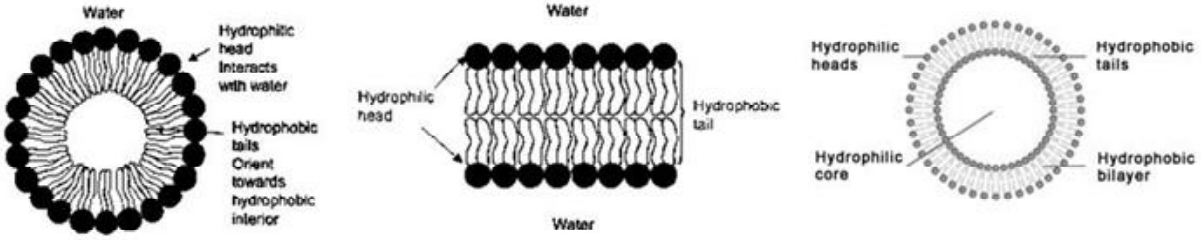


Figure 2.4: Various forms of lipid aggregates.

II. Membrane proteins *(Figure 2.1)***:**

→ Responsible for most of the dynamic processes carried out by membranes.

→ Classified as, peripheral proteins, integral membrane proteins or lipid-anchored proteins.

1. Peripheral proteins:

- Also known as ***extrinsic proteins***.
- Located entirely outside the lipid bilayer, either on the cytoplasmic side or the extracellular side.
- Do not interact with the hydrophobic core of the phospholipid bilayer.
- Bound to membranes by non-covalent bonds (mainly, **electrostatic** and **hydrogen bonds**).
- Bound to the membrane either,
  - indirectly by interactions with integral membrane proteins, or,
  - directly by interactions with lipid polar groups.
- Most of them are soluble in aqueous solution.
- *Example:* Phospholipase C, cholesterol oxidases, spectrin, defenins, etc.

2. Integral proteins:

- Also known as ***intrinsic proteins***.
- They penetrate the lipid bilayer and are held very tightly there.
- Integral proteins are mostly transmembrane proteins (i.e., they pass entirely through the lipid bilayer and have domains that protrude from both, extracellular as well as cytoplasmic sides of the membrane).
- The non-polar residues (containing hydrophobic side chains) in the transmembrane proteins interact with the fatty acyl groups of the membrane phospholipids and anchors themselves to the membrane.
- Transmembrane proteins may be single pass (***monotopic***) or multipass (***polytopic***).
- *Example:* Insulin receptors, integrins, cadherins, glycophorin, rhodopsin, ion channels and gates, gap junction proteins, etc.

❖ All transmembrane proteins are amphipathic.