2-Structure of Biological Membranes & Transport across Membranes

Structure of Biological Membranes

- The plasma membrane is an envelope surrounding the cell. It separates and protects the cell from the external hostile environment.
- Besides being a protective barrier, plasma membrane provides a connecting system between the cell and its environment.
- The subcellular organelles such as nucleus, mitochondria, lysosomes are also surrounded by membranes.

Chemical composition

- The membranes are composed of lipids, proteins and carbohydrates. Among the lipids, amphipathic lipids (containing hydrophobic and hydrophilic groups) namely phospholipids, glycolipids and cholesterol, are found in the animal membranes.
- Many animal cell membranes have thick coating of complex polysaccharides referred to as **glycocalyx**.
- The oligosaccharides of glycocalyx interact with collagen of intercellular matrix in the tissues.

- A lipid bilayer model originally proposed for membrane structure in 1935 by **Davson and Danielle** has been modified.
- Fluid mosaic model, proposed by Singer and Nicolson, is a more recent and acceptable model for membrane structure.
- The biological membrane usually have a thickness of 5-8 nm.
- A membrane is essentially composed of a lipid bilayer. The **hydrophobic** (nonpolar) regions of the lipids face each other at the core of the bilayer while the **hydrophilic** (polar) regions face outward.

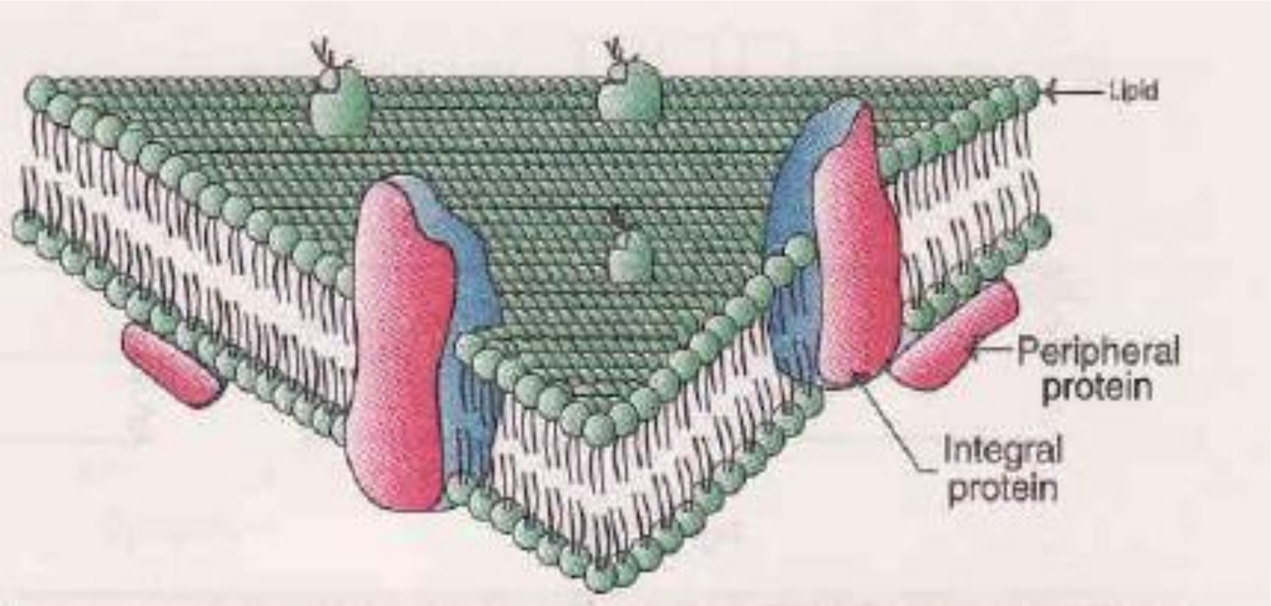
- Globular proteins are irregularly embedded in the lipid bilayer. Membrane proteins are categorized into two groups-

1.Extrinsic (peripheral) membrane proteins are loosely held to the surface of the membrane and they can be easily separated e.g. cytochrome c of mitochondria.

2.Intrinsic (integral) membrane proteins are tightly bound to the lipid bilayer and they can be separated only by the use of detergents or organic solvents e.g. hormone receptors, cytochrome P450.

- The membrane is **asymmetric** due to the irregular distribution of proteins. The lipid and protein subunits of the membrane give an appearance of **mosaic** or a ceramic tile.

The fluid mosaic model of membrane structure



Transport across Membranes

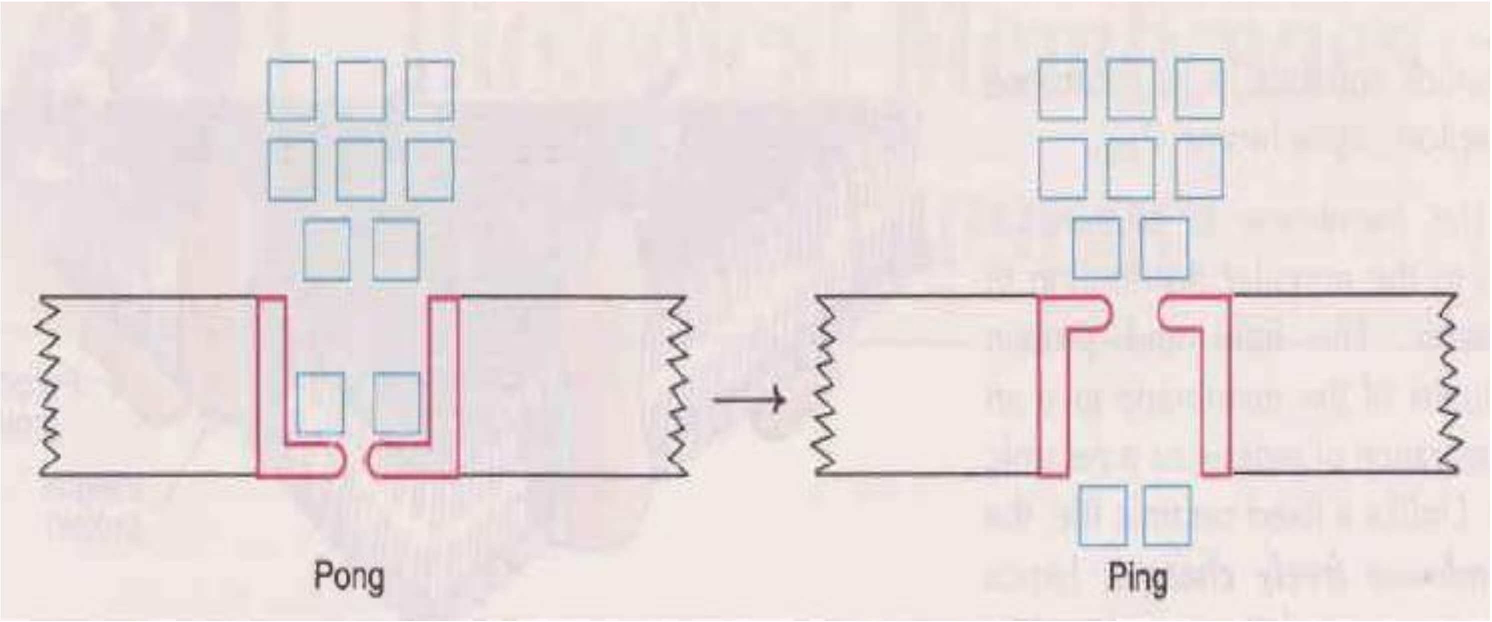
- The biological membranes are relatively impermeable. The membrane, therefore, forms a barrier for the free passage of compounds across it.
- Three distinct mechanisms have been identified or the transport of solutes (metabolites) through the membrane-

1. Passive diffusion
2. Facilitated diffusion
3. Active transport

1.Passive diffusion : This is a simple process which depends on the concentration gradient of a particular substance across the membrane passage of water and gases through membrane occurs by passive diffusion.

This process does not require energy.

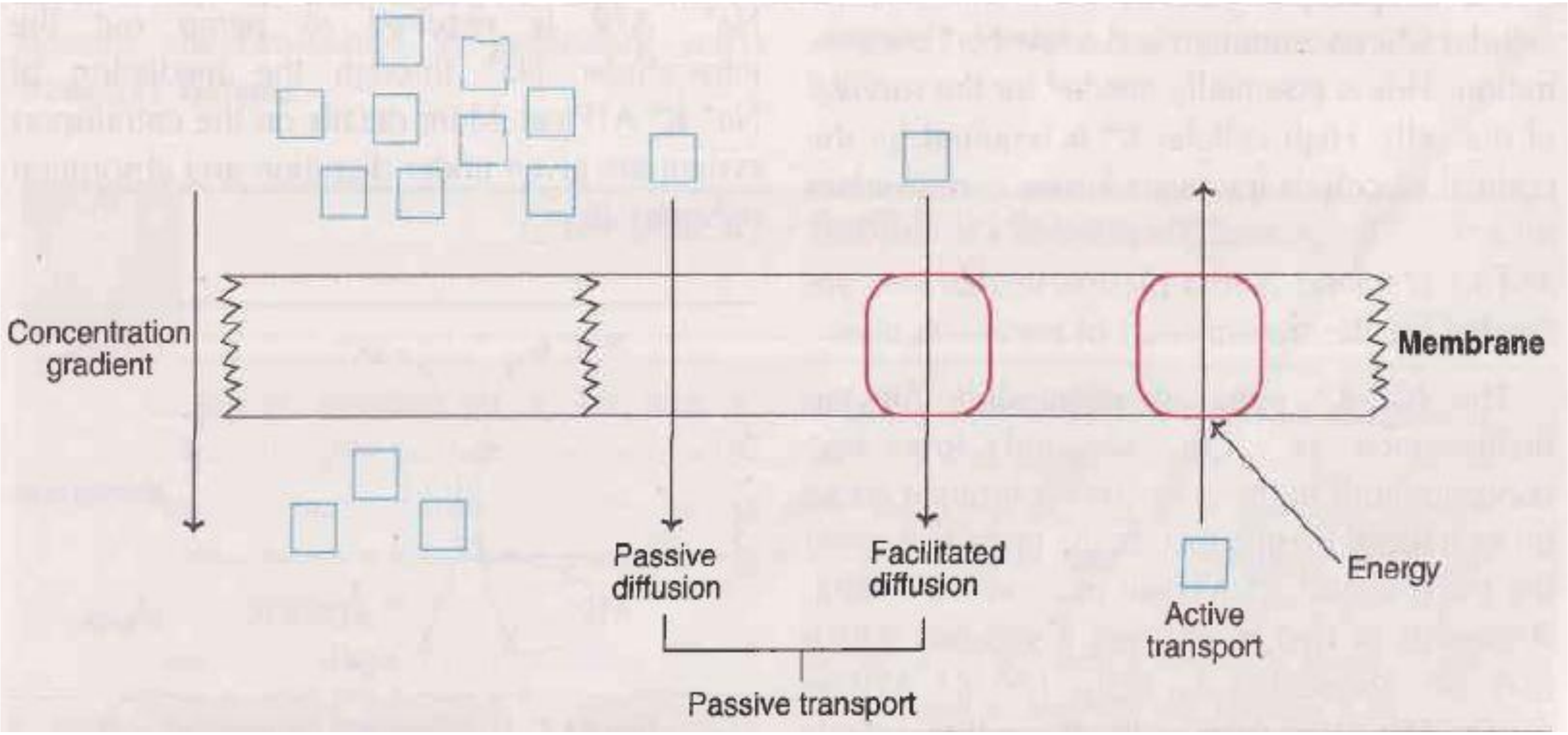
2. Facilitated diffusion : This is somewhat comparable with diffusion since the solute moves along the concentration gradient (from higher to lower concentration)and **no energy is needed**. But the most important distinguishing feature is that facilitated diffusion occurs through the mediation of carrier or transport proteins. Specific carrier proteins for the transport of glucose, galactose, leucine, phenylalanine etc. have been isolated and characterized.



A diagrammatic representation of 'ping-pong' model for facilitated diffusion

3. Active transport : Active transport occurs against a concentration gradient and this is **dependent on the supply of metabolic energy (ATP).**

Active transport is also a carrier mediated process like facilitated diffusion. The most important primary active transport systems are ion-pumps (through the involvement of pump ATPases or ion transporting ATPases).



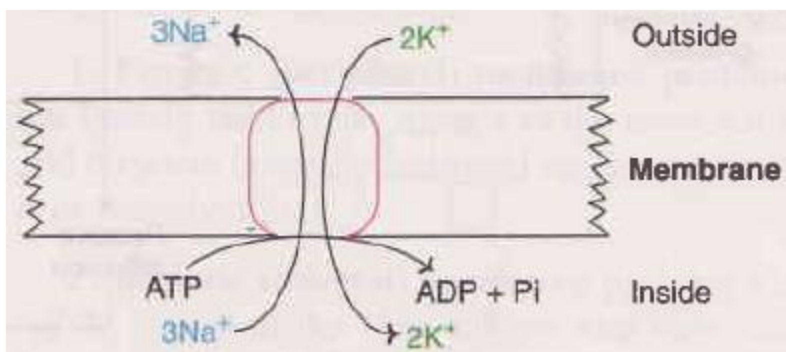
Mechanism of transport across biological membrane

- Na+-K+ pump : The cells have a high intracellular K+ concentration and a low Na+ concentration.
- This is essentially needed for the survival of the cells. High cellular K+ is required for the optimal glycolysis (pyruvate kinase is dependent on K+) and for protein biosynthesis. Further, Na+ and K+ gradients across plasma membranes are needed for the transmission of nerve impulse. The Na+-K+ pump is responsible for the maintenance of high K+ and low Na+ Concentrations in the cells.

$$3\,Na^{+}\,(in) + 2K^{+}\,(out) + ATP \longrightarrow 3Na^{+}\,(out) + 2K^{+}\,(in) + ADP + Pi$$

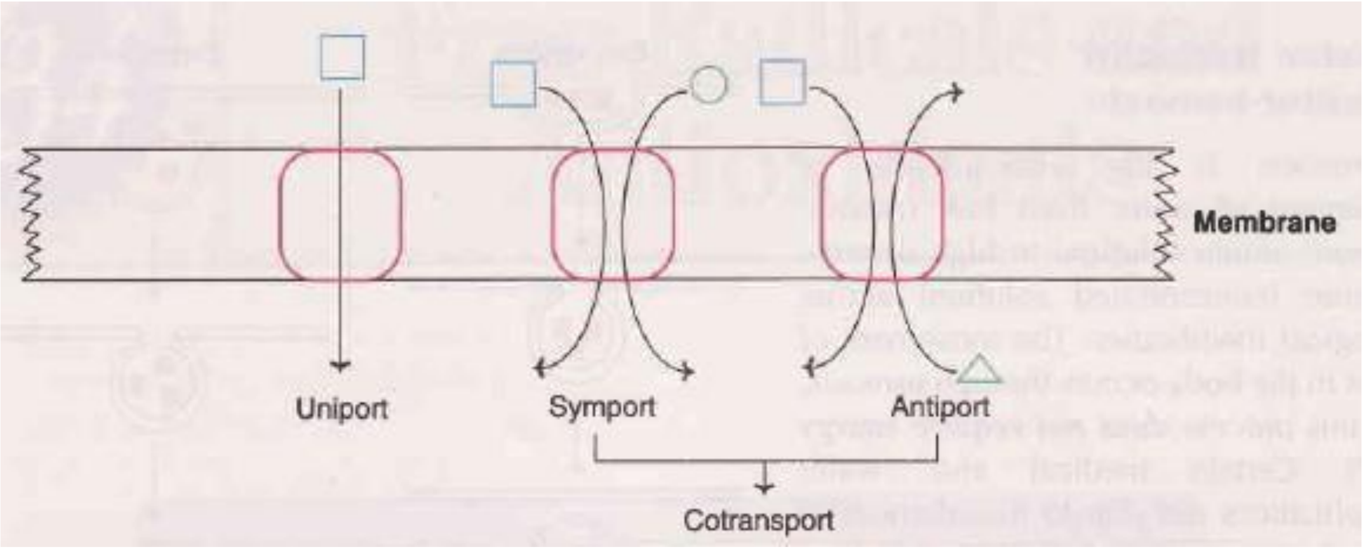
A major portion of the cellular ATP (up to 70 %, in nerve cells) is in fact utilized by Na+-K+ pump to maintain the requisite cytosolic Na+ and K+ levels. Ouabain inhibits Na+-K+ ATPase.

Ouabain is a steroid derivative extracted from the seeds of an African shrub. It is a poison used to tip the hunting arrows by the tribals in Africa.



Diagrammatic representation of Na+-K+ pump (Red colour block represents the enzyme Na+-K+ ATPase

Transport Systems



The transport systems may be divided into 3 categories-

1.Uniport system : This involves the movement of a **single molecule** through the membrane e.g. transport of glucose to the erythrocytes.

2.Symport system : The simultaneous transport of **two different molecules in the same direction** e.g. transport of Na+ and glucose to the intestinal mucosal cells from the gut.

3.Antiport system: The simultaneous transport of **two different molecules in the opposite direction** e.g exchange of Cl- and HCO3 in the erythrocytes. Uniport, symport and antiport systems are considered as secondary active transport systems.

The symport and antiport systems referred to are good examples of **cotransport system**.

Proton pump in the stomach : This is an **antiport transport system** of gastric parietal cells.

It is brought out by the enzyme **H^+-K^+ ATPase** to maintain highly acidic (pH=1) conditions in the lumen of the stomach.

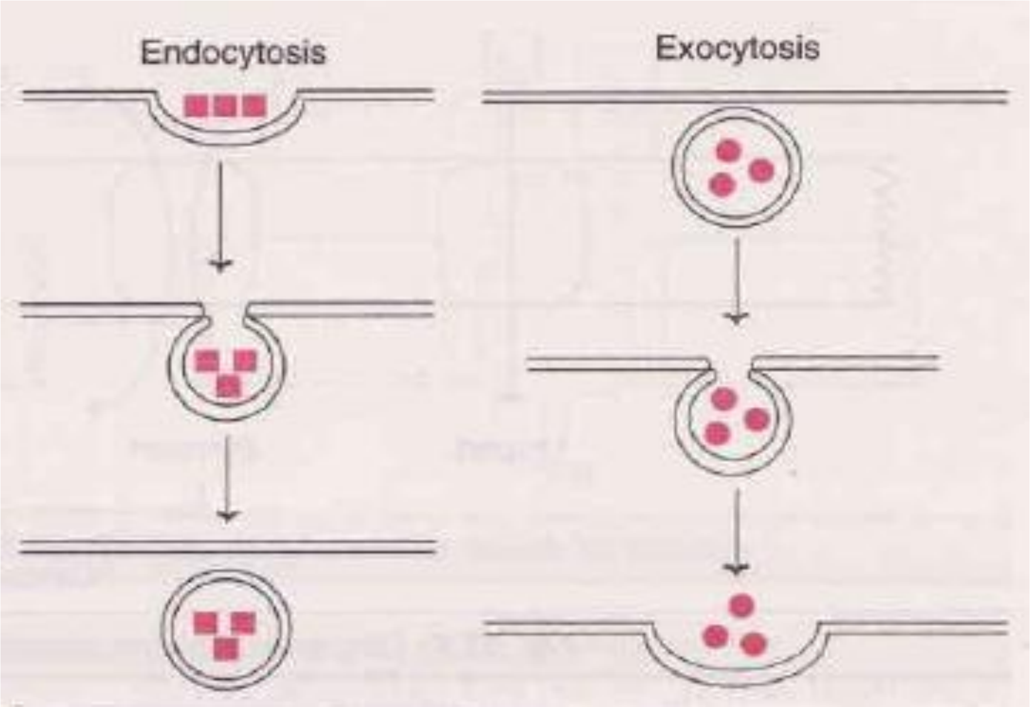
Proton pump antiports two cytoplasmic protons ($2H^+$) and two extracellular potassium ($2K^+$) ions for a molecule of ATP hydrolysed. The chloride ions secreted by Cl^- channels combine with protons to form gastric HCl.

- Osmosis is the phenomenon of movement of water from low osmotic pressure (dilute solution) to high osmotic pressure (concentrated solution) across biological membranes. The movement of water in the body occurs through osmosis, and this process **does not require energy (ATP).** Certain medical and health complications are due to disturbances in osmosis. e.g. edema, diarrhea, cholera, inflammation of tissues.

- The transport of macromolecules such as proteins, polysaccharides and polynucleotides across the membranes is brought about by two independent mechanisms namely **endocytosis** intake of macromolecules by the cells and **exocytosis** release of macromolecules from the cells to the outside.

Endocytosis : It is estimated that approximately 2% of the exterior surface of plasma membrane possesses characteristic coated pits. These pits can be internalized to form coated vesicles which contain an unusual protein called **clathrin**. The uptake of low density lipoprotein (LDL) molecules by the cells is a good example of endocytosis. (**Pinocytosis**- The **ingestion of liquid** into a cell by the budding of small vesicles from the cell membrane.)

Exocytosis: The release of macromolecules to the outside of the cells mostly occurs via the participation of Golgi apparatus. The macromolecules are transported to the plasma membrane in vesicles and let out. The secretion of hormones (e.g. insulin, parathyroid hormone) usually occurs by exocytosis.



Diagrammatic representation of endocytosis and exocytosis

THANKS