Cell Physiology

Cell: Is The basic structural, functional and smallest living unit of the body and its aggregate form tissue or organ.

Cell consist of three main parts:

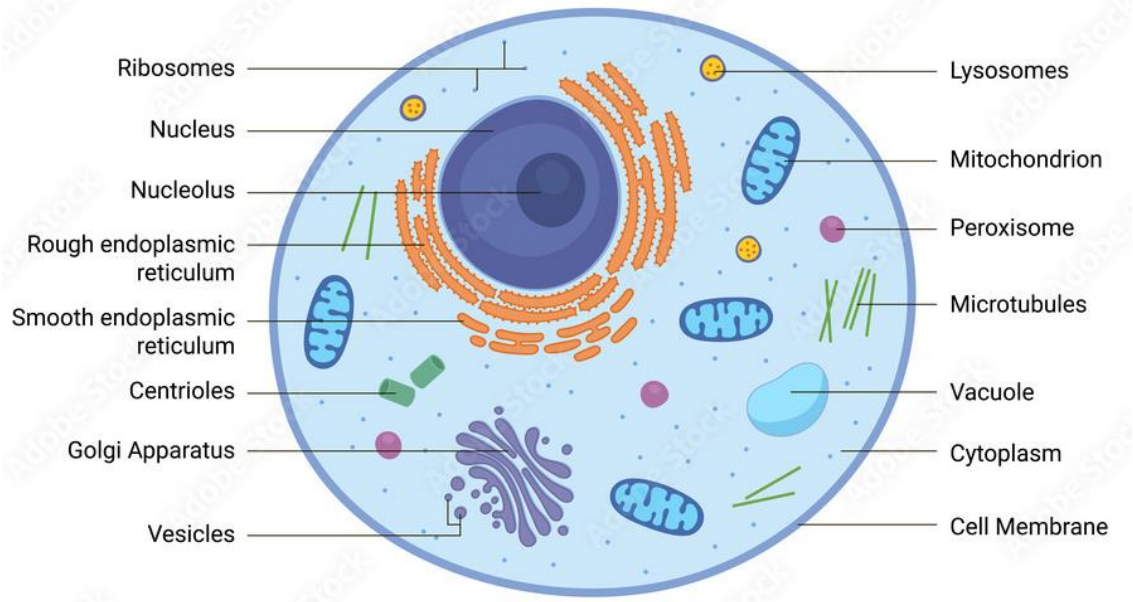
1- Plasma membrane or cell membrane
2- Cytoplasm
3- Nucleus

Plasma Membrane: Each cell is enclosed by a membrane called plasma membrane which separates intracellular fluid from extracellular fluid. It is a selectively permeable membrane which regulates transport of substances into and out of the cell. It allows some substances to pass through it and excludes others. The permeability can be varied due to the presence of ion channels and other transport proteins.

Cytoplasm: Cytoplasm consists of all the contents of cell between plasma membrane and nucleus. It is divided into cytosol and organelles.

- Cytosol is the fluid portion of cytoplasm containing water, solutes, suspended particles etc.
- Organelles, also known as little organs, have characteristic shape and perform specific functions, e.g., ribosome, endoplasmic reticulum, Golgi complex, lysosome, peroxisomes, mitochondria etc.

Nucleus: Nucleus contains most of the DNA in the cell. It contains chromosomes and each chromosome contains genes that control all the functions of the cell.

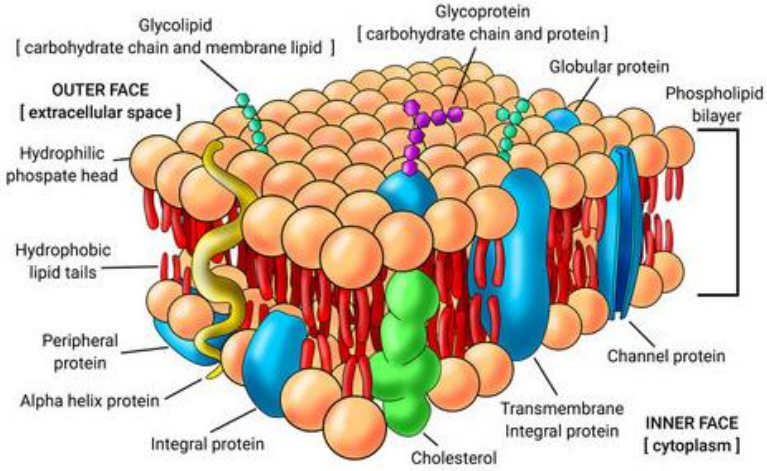


Plasma Membrane

Structure of Cell Membrane:

Cell membrane is a three-layered structure showing an outer electron dense layer, middle electro loosened layer and inner electron dense layer. Membrane is primarily lipoprotein in nature and sometimes it may be glycoprotein.

The lipids are phospholipids, cholesterol and sphingomyelin. Phospholipids are phosphatidyl choline and phosphatidyl ethanol amine. The head end of the molecule contains a phosphate portion and is relatively soluble in water and is called polar or hydrophilic end. The tail is relatively insoluble and is called nonpolar or hydrophobic end.



The uncharged hydro- phobic end resides within the depth of the cell membrane and the charged hydrophilic end is exposed to cytoplasm.
There are different proteins embedded in the cell membrane. Periphenl proteins stud the inside and outside of the membrane. When the protein extends throughout the thickness of the membrane, it is called transmembrane protein channel.

Functions of cell membrane proteins:

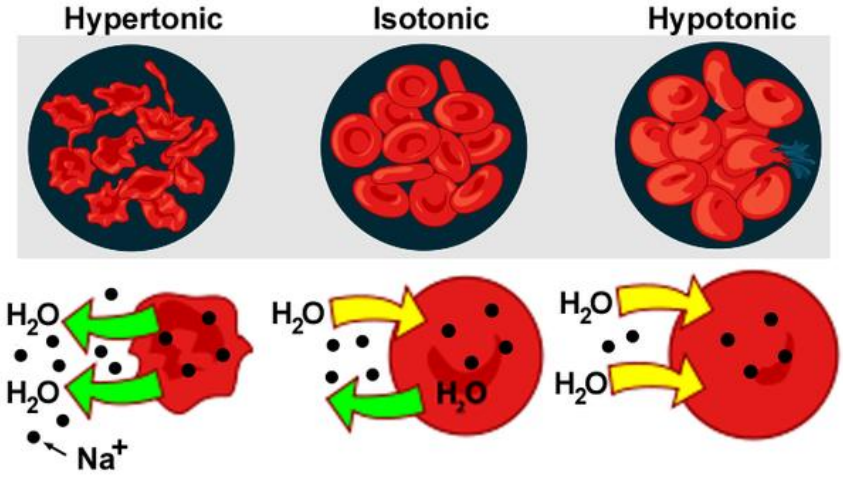
1- Structural proteins contribute to the structure of cell membrane.
2- Some cell membrane proteins are cell adhesion molecules that anchor cells to their neighbours or to the basel lamina, e.g., cadherin, selectin etc.
3- Some proteins function as pumps for active transport of substance
4- Carrier proteins transport substances down their electrochemical gradient.
5- Ion channels permit passage of ions into or out of the cell when activated.
6- Aquaporins are membrane proteins present in most cells, which act as water channels permitting high rate of water flow through the membrane.
7- Proteins act as enzymes catalyzing reactions on the membrane surface.
8- Some membrane proteins act as hormone receptors.

TRANSPORT PROCESSES ACROSS CELL MEMBRANE

1- Osmosis
2- Diffusion
3- Active transport
4- Endocytosis and exocytosis

1- Osmosis: is defined as the movement of water molecules (solvent) across a semi-permeable membrane from a region of lower solute concentration to an area of higher solute concentration.

During osmosis, water molecules pass through the plasma membrane in two ways:(I) by moving through the lipid bilayer because of their small size and high kinetic energy, (2) by moving through aquaporins which are membrane proteins functioning as water channels.



Hypertonic solution: is any external solution that has a high solute concentration and low water concentration compared to body fluids.

Hypotonic solution: is any external solution that has a low solute concentration and high water concentration compared to body fluids.

Isotonic solution: is any external solution that has the same solute concentration and water concentration compared to body fluids.

2- Diffusion: is a passage of ions or molecules from region of higher concentration to region of low concentration and occur either through the lipid matrix or through transmembrane protein channels.

A- Diffusion through lipid matrix: The lipid bilayer is freely permeable to water because the molecules are small and have high kinetic energy and It is also permeable to urea.

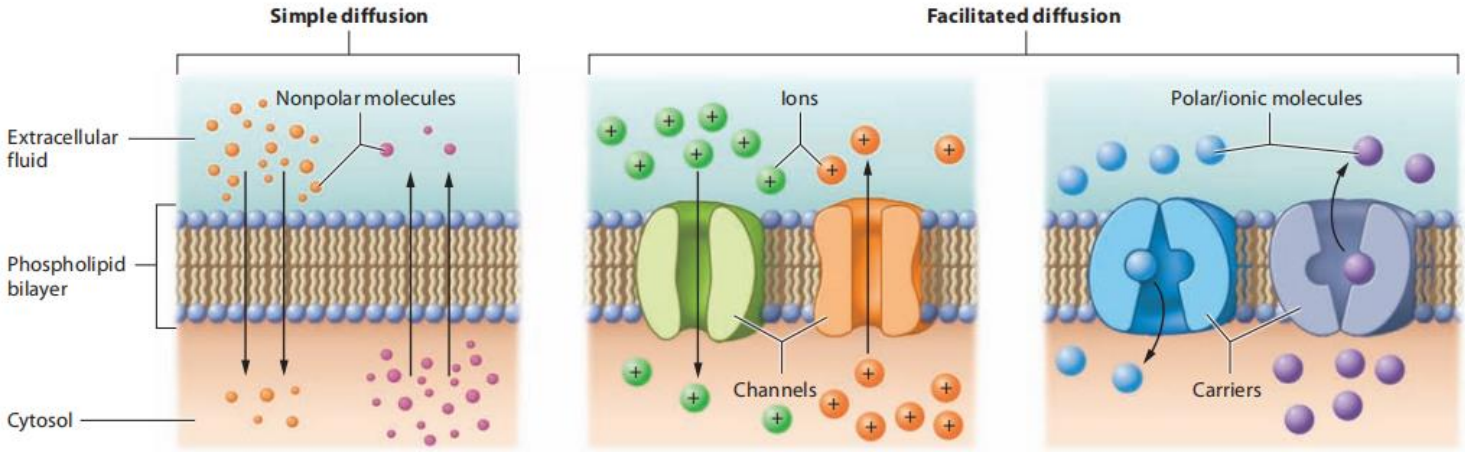
Its permeability to other substances depends on their size, lipid solubility and charge. Plasma membrane is permeable to Non-polar, uncharged, hydrophobic substances like O_2, CO_2, N_2, fatty acids, alcohol, steroid hormones etc.

The lipid bilayer is impermeable to ions and charged or polar molecules like glucose.

B- Diffusion through ion channels or transmembrane protein channels: Ions like Na, K', Ca, Cl etc., can cross the cell membrane only through some channels in the cell membrane. Different types of protein channels are present, open type or those which can be closed. Open channels are also called leak channels. e.g., K' channel.

Two basic types of diffusion occur through a membrane: simple and facilitated

- **Simple diffusion** mostly involves nonpolar solutes (such as hydrocarbons and lipids, and gases such as O2 and CO2) that pass straight through the phospholipid bilayer without assistance from a membrane protein.
- **Facilitated diffusion** involves charged or polar solutes (such as ions and glucose) that cross the phospholipid bilayer with the help of a membrane protein.



(a) Simple diffusion of nonpolar molecules through the phospholipid bilayer

(b) Facilitated diffusion of ions through a channel

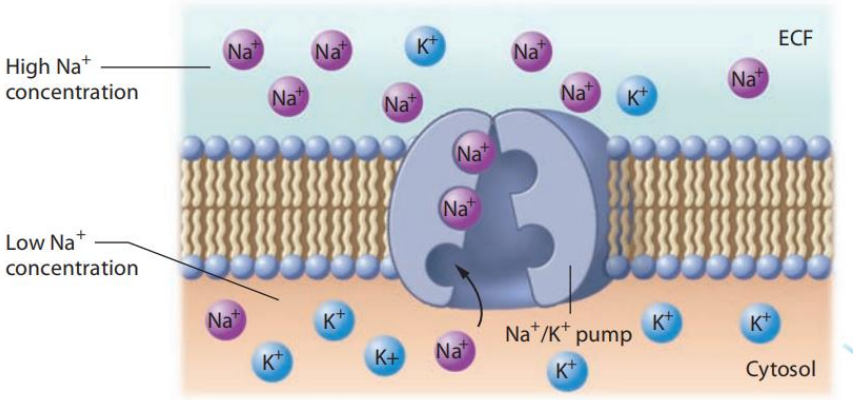
(c) Facilitated diffusion of polar and ionic molecules using a carrier

3- **Active transport:** The passage of substances against their electrical and chemical gradients at the expenditure of energy. The energy is provided by the hydrolysis of ATP in primary active transport. The energy stored in an ionic concentration gradient produced by primary active transport is the source of energy in secondary active transport. Both processes require a carrier protein.

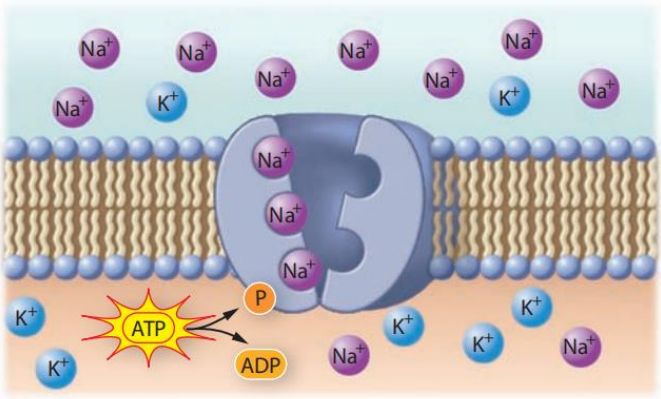
A- **Primary Active Transport**: the carrier protein involved is called pump. 40% of ATP produced in a cell is utilized for primary active transport. The enzymes which catalyze the hydrolysis of ATP is called ATPase. Different types of pumps are:

- Na^+-K^+ pump
- H^+-K^+ pump
- Ca^{2+}pump
- Na^+-H^+ pump

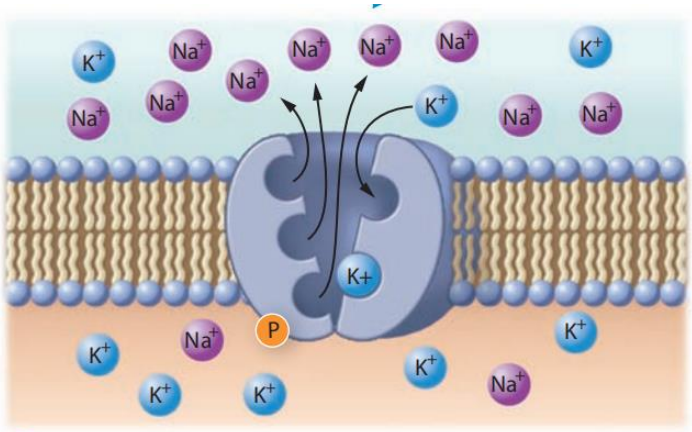
The major primary active transport pump in the body is the antiport pump known as the sodium-potassium pump. Normally the concentration of sodium ions in the ECF is about 10 times greater than that in the cytosol. The reverse is true for potassium ions—its concentration in the cytosol is about 10 times higher than its concentration in the ECF. It is absolutely critical to our homeostasis to maintain the concentration gradients of sodium and potassium ions. These gradients are required for skeletal muscles to contract, hearts to beat, nerves to send impulses, and cells to maintain their osmotic balance, among many other functions.



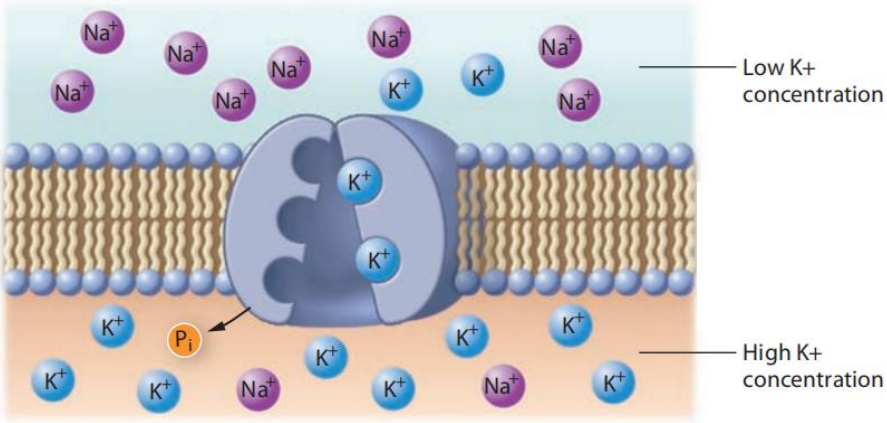
1 The pump binds three Na^+ from the cytosol.



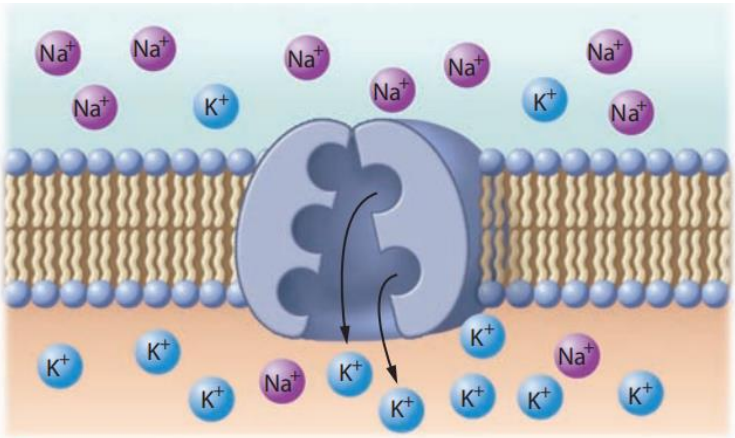
2 ATP is hydrolyzed, the phosphate binds to the pump, and the pump changes shape.



3 The pump releases the three Na^+ into the ECF and binds two K^+.



4 The phosphate detaches, and the pump changes back to its original shape.



5 The pump releases the two K^+ into the cytosol.

B- **Secondary active transport**: In some tissues, the active transport of Na into the ECF by Nat-K' pump is coupled to the transport of other substances across the cell membrane against their concentration gradient. When Na is pumped out, the intracellular Nat concentration falls and a Na gradient is produced across the cell membrane. Here the free energy stored in the Na gradient produced, is used to transport substances like amino acids, sugars, ions

etc., against their concentration gradient. The energy for the transport is not directly obtained from ATP hydrolysis. Its have three types:

- **Uniport** - Here the carrier protein transports one substance in one direction, e.g., glucose transport through glucose transporters in the basal membrane of intestinal epithelial cell into the interstitial space.
- **Symport** -- Here the carrier protein transports two substances in one direction and the transport occurs only if the two substances are attached to the carrier, e.g., Na co-transport of glucose or amino acid across intestinal mucosa.
- **Antiport** -- The carrier protein transports one substance in one direction and another substance in the opposite direction. For example, Na-Ca countertransport in the cardiac muscle.

4- **(A) Endocytosis**: There are three types:

a- Receptor-mediated endocytosis:

b- Phagocytosis

c- Pinocytosis

Receptor-mediated endocytosis: is a highly specific type of endocytosis by which cells take up specific ligands. A specific molecule that binds to a receptor is called the ligand of that receptor. The receptors for these ligands are concentrated in specific areas of the cell membrane called clathrin-coated pits.

The cell membrane fuses around the receptor-ligand complex forming a vesicle which gets pinched off into the cytoplasm called clathrin-coated vesicle.

Phagocytosis: is the process by which aged and worn-out cells, bacteria, viruses, dead tissue etc., are engulfed by phagocytes of the body, such as neutrophils and macrophages. Phagocytosis begins when the particle makes contact with the cell membrane receptor protein. This part of the plasma membrane then invaginates and the invagination is pinched off into the cell forming phagosome. Phagosome fuses with lysosome and the enzymes break down the ingested material.

Pinocytosis: is an active, energy consuming process where extracellular fluid and solutes are taken up into a cell via small vesicles.

(B) Exocytosis: is the fusion of secretory vesicles with the plasma membrane and results in the discharge of vesicle content into the extracellular space and the incorporation of new proteins and lipids into the plasma membrane.