Chapter

1

Cell and Plasma Membrane (BC 1.1)

1. Name all cellular organelles with one function for each.

Ans. The different cellular organelles and their functions are illustrated in **Table 1.1**.

Table 1.1: Different cellular organelles and their functions

Organelles	Functions
Plasma membrane	Protection, a selective barrier, maintains the shape of the cell
Endoplasmic reticulum	Translation and folding of new proteins (rough endoplasmic reticulum), synthesis of lipids (smooth endoplasmic reticulum)
Golgi apparatus	Sorting and modification of proteins
Mitochondria	Energy production from the oxidation of food substances and the release of ATP
Nucleus	Maintenance of genetic material (DNA) controls all cell activities, including RNA transcription
Nucleolus	Ribosome production
Lysosome	Breakdown of large molecules
Vacuole	Storage helps to maintain homeostasis
Peroxisome	Breakdown of hydrogen peroxide, fatty acids, and amino acids
Ribosome	Translation of RNA into proteins

2. Draw a neat and labelled diagram of the cell.

Ans. Refer to **Figure 1.1** for a neatly drawn and well-labelled diagram of the cell.

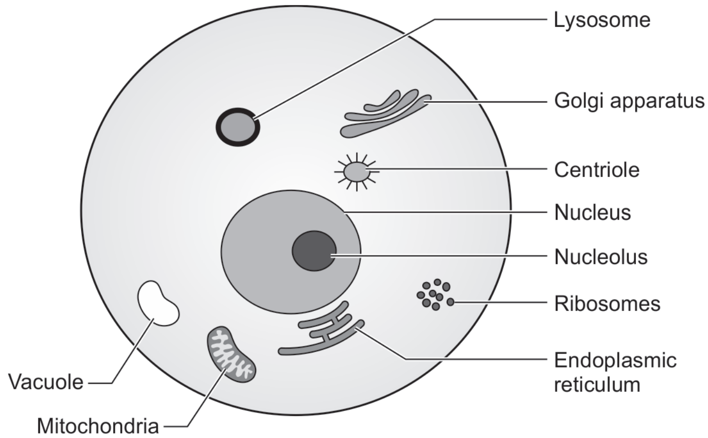

Fig. 1.1: Eukaryotic cell

3. **Compare and contrast prokaryotic cells with eukaryotic cell.**

Ans. Comparison between prokaryotic and eukaryotic cells in **Table 1.2**.

Table 1.2: Comparison of prokaryotic and eukaryotic cell

Property	Prokaryotic cell	Eukaryotic cell
Size	Small	Large
Cell membrane	Rigid	Flexible
Nucleus	Not well-defined	Well-defined with nucleolus
Sub-cellular organelles	Absent	Present
Cytoplasm	Organelles and cytoskeleton absent	Organelles and cytoskeleton present
Cell division	Binary fission	Mitosis and meiosis
Transport system	Absent	Present

4. **Write short notes on the fluid mosaic model of the membrane.***

Ans. Proposed by SJ Singer and Nicolson in 1972. The membrane comprises a lipid bilayer with embedded proteins (enzymes, transporters, and receptors). Membrane lipids are amphipathic, so they spontaneously form a bilayer in an aqueous medium by arranging their hydrophilic ends exposed to water and hydrophobic tails away from water **(Fig. 1.2)**. Membrane lipids are mainly phospholipids, glycolipids, and cholesterol.

Phospholipids—glycerophospholipids and sphingomyelin.

Glycolipids—cerebroside and gangliosides are on the outer surface of the membrane.

Cholesterol—provides fluidity to the membrane by arranging the hydroxyl group towards the aqueous surface and the remaining rings towards the hydrophobic region of the membrane. Membrane lipids show lateral, flip-flop, and rapid rotational movements.

Hydrophobic interaction between the hydrocarbon tails in the phospholipids keeps the bilayer intact, and the amount of phospholipids keeps the bilayer in a fluid state.

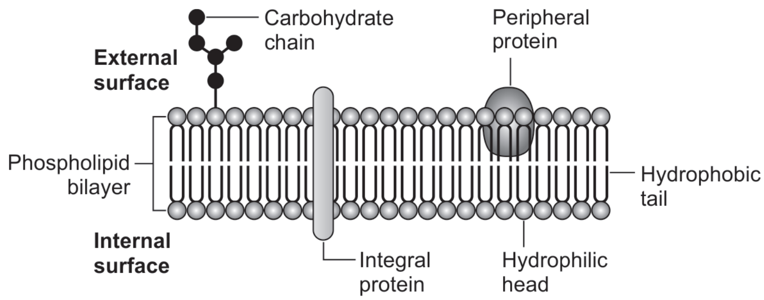

Fig. 1.2: Fluid mosaic model of membrane structure

Factors affecting membrane fluidity:

i. *Amount of unsaturated fatty acids*—the more unsaturated fatty acids, the more fluidity will be.
ii. *Saturated fatty acids*—decrease the membrane fluidity.
iii. *Cholesterol*—increases the membrane fluidity at low temperatures.

Membrane proteins are of two types:

1. **Peripheral membrane proteins** are attached loosely to the inner or outer aspect of the membrane.
2. **Integral membrane proteins** are deeply embedded in bilayer structure. Proteins that extend all along the membrane bilayer are called trans-membrane proteins.

Functions of membrane proteins:

i. Transport across the membrane
ii. Receptors
iii. Membrane-bound enzymes
iv. Components of the respiratory chain

Asymmetry in membranes: Protein to lipid ratio varies in different membranes to suit their functions. The inner mitochondrial membrane, which has an electron transport chain is rich in proteins with a protein. Lipid ratio of 3.2, whereas in the myelin sheath, designed to insulate the nerve fibres, this ratio is 0.23. Also, there is asymmetry concerning the distribution of phospholipids, e.g., phosphatidylcholine and sphingomyelin are predominantly on the outer leaflet, and phosphatidylserine, phosphatidylinositol, and phosphatidylethanolamine are predominantly on the inner leaflet.

5. Write the functions of the plasma membrane.

Ans. A plasma membrane is a selective, asymmetric sheet-like enclosed structure made up of lipids and proteins separating the cell from the external environment and dividing the interior of a cell into different compartments. Fluid outside the membrane is called extracellular fluid; inside the cell is intracellular fluid.

Functions of plasma membrane:

i. Protects cytoplasm and organelles
ii. Maintains the shape and size of the cell
iii. Selective barrier – permits only required substances in either direction
iv. Cell-cell interaction.

6. Describe the characteristics of facilitated diffusion. Mention two examples of transport by facilitated diffusion.*

Ans. **Definition:** Movement of particles along the concentration gradient with the help of transport proteins. Facilitated diffusion does not require energy, e.g. glucose, galactose, leucine, and other amino acids.

Mechanism: Ping-Pong Model

Carrier protein has two conformations: **Ping** and **pong** conformation. Pong conformation of the carrier protein exposed to higher concentration of molecules. The binding of molecules induces a conformational change to ping conformation, which is exposed to lower concentration, thus releasing the molecules. Once the molecule is released, the conformation of carrier protein reverts to pong form, which reveals the molecules to higher concentrations. The whole process repeats for the transport of one more molecule **(Fig. 1.3)**.

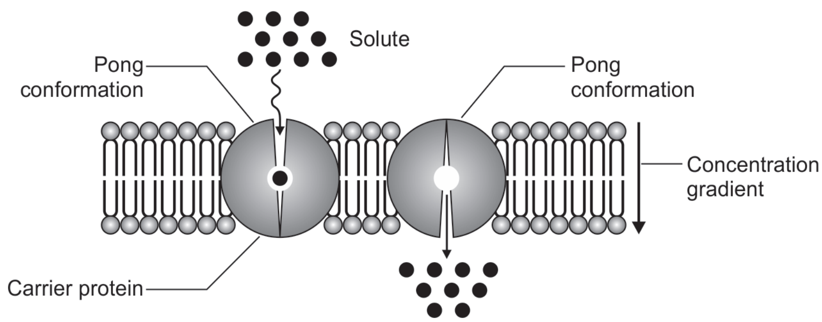

Fig. 1.3: Facilitated diffusion

7. Explain the active transport with suitable examples.*

Ans. **Definition**: Carrier-mediated transfer of molecules against the concentration gradient (from lower concentration to higher concentration) with the help of energy (ATP). Substances actively transported through cell membranes include Na^+, K^+, Ca^{2+}, Fe^{++}, H^+, Cl^- and I^-. Active transport is susceptible to inhibition, and this property is used to design drugs for some diseases.

Classification

i. **Primary active transport**—energy is derived from direct hydrolysis of ATP, e.g. Na^+, K^+ pump, Ca^{2+} pump, H^+ pump

ii. **Secondary active transport**—ATP is used indirectly for their function, e.g. *Symport:* Glucose – sodium, amino acid – sodium transport
Antiport: Sodium – calcium, sodium-hydrogen pump.

i. Primary active transport

For example, the Na^+–K^+ pump and Na^+–K^+ ATPase pump $3Na^+$ from the inside of the cell to the outside and bring in $2K^+$ from outside to inside with the hydrolysis of one ATP molecule **(Fig. 1.4)**.

Biological functions:

a. Maintains the cell volume
b. Transmission of nerve impulse.

Inhibitors of Na^+–K^+ pump and their significance

a. **Digoxin** is used to treat congestive cardiac failure (CCF).

b. **Ouabain** arrow poison, also used in the treatment of CCF.

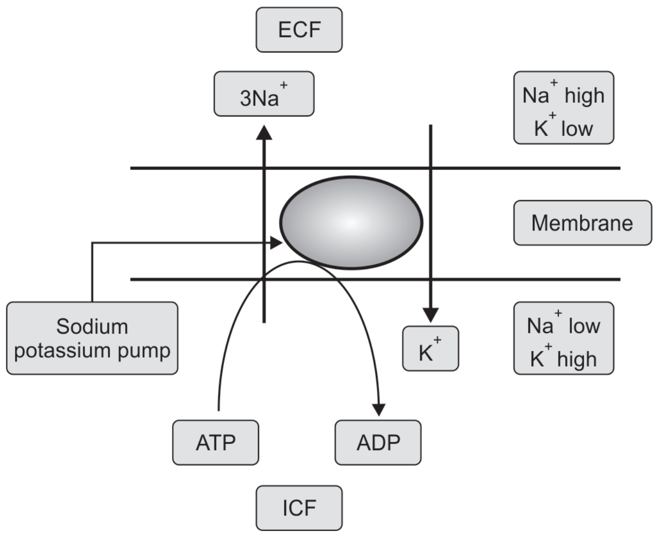

Fig. 1.4: Na^+–K^+ antiport
(ECF : Extracellular fluid; ICF : Intracellular fluid)

ii. Secondary active transport

In secondary active transport, sodium moves along the gradient, pulling glucose against the concentration gradient. Here, energy is required to pump the sodium back to ECF.

For example: Na^+ glucose CO transport **(Fig. 1.5)**

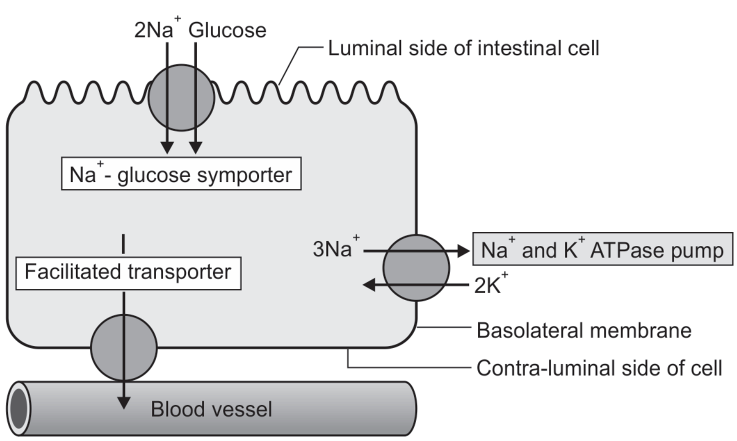

Fig. 1.5: Sodium-glucose co-transport

8. Describe transport processes across the membrane.*

Ans. The membrane is the selectively permeable barrier. Non-polar substances gain easy access because of solubility in the lipid bilayer, but polar substances cross the membrane selectively.

The selectivity of membrane transport depends upon:

a. **Size:** Small solutes pass through more quickly than larger ones.
b. **Charge of the molecule:** Molecules with less charge pass more quickly than ones with a significant charge.
c. **Transport proteins**
d. **Molecules:** Water readily transverses through the membrane

Classification of transport mechanisms across the membrane:

1. Passive transport
2. Active transport
3. Endocytosis/exocytosis
4. Ionophores.

1. ***Passive transport***

Three types:

a. Simple diffusion
b. Facilitated diffusion
c. Ion channels

a. **Simple diffusion:** The movement of particles across the membrane along the concentration gradient without involving carrier proteins. Energy is not required for simple diffusion, e.g. small and lipophilic molecules like O_2, CO_2, N_2, ions, and water.

b. **Facilitated diffusion** (refer to question number 6): Movement of the particles with the help of transport proteins along the concentration gradient. Facilitated diffusion does not require energy and is carried out by a ping-pong mechanism **(Fig. 1.3)**, e.g. glucose, galactose, leucine, and other amino acids.

c. **Ion channels:** Ions pass through the ion channels and open or close upon receiving a signal. Ion channels are of two types.
   i. *Voltage-gated:* Open due to changes in membrane potential, e.g. Ca^{2+}, Na^+ and K^+ channels.
   ii. *Ligand-gated:* Binding of ligand to receptor site results in opening and closing of the channel, e.g. acetylcholine receptor.

2. ***Active transport (refer to question number 7)***

3. ***Endocytosis and exocytosis***

Endocytosis: Intake of macromolecules into the cells, e.g. uptake of low-density lipoproteins (LDL), polysaccharides, proteins, and polynucleotides.

Two types:

a. **Pinocytosis:** Uptake of fluid and fluid contents by cell (cellular drinking).
b. **Phagocytosis:** Ingestion of larger particles like bacterial cells and tissue debris by macrophages, further hydrolysed by lysosomes.

Exocytosis: Release of macromolecules from the cell to the outside, e.g. calcium-dependent secretion from vesicles (secretion of hormones).

4. ***Ionophores:*** Channels that carry small compounds such as ions across the membrane.

   Two types:

   a. **Carrier ionophores:** Valinomycin, which inhibits oxidative phosphorylation.
   b. **Channel forming ionophores:** Gramicidin A (inhibits oxidative phosphorylation).

KEY POINTS

- **Hartnup's disease:** Defects in the absorption of neutral amino acids in the intestine and defective reabsorption in the kidney.
- **Cystinuria:** Defect in reabsorption of cysteine in the kidney.
- **Vitamin D-resistant rickets:** Defective renal reabsorption of phosphate from the kidney.
- **Myasthenia gravis:** Defect in acetylcholine receptors (ligand-gated channels).
- **Cystic fibrosis:** Due to mutations in chloride channels.
- **Digoxin:** Inhibitor of the sodium-potassium pump. Inhibition by digoxin will increase intracellular calcium concentration and myocardial contractility. So, digoxin is used in the treatment of congestive cardiac failure.
- **Omeprazole:** Inhibitor of hydrogen-potassium ATPase. Omeprazole inhibits acid secretion, so it is used to treat peptic ulcers.
- **P-glycoprotein (MDR1 transporter):** An ATP-dependent efflux pump involved in drug resistance by pumping out chemotherapeutic agents from cancer cells, reducing drug efficacy.

  Facilitated transporters can be classified concerning the direction of solute movement:

  a. *Uniport*: Movement of one molecule at a time (bidirectional) by transporter-transport of fructose in the intestine.
  b. *Symport*: Movement of two molecules simultaneously in the same direction, e.g. sodium-glucose transport in the intestine.
  c. *Antiport*: Movement of two molecules simultaneously in the opposite direction, e.g. chloride–bicarbonate in the RBC.
- **Liddle's syndrome:** A genetic disorder due to increased sodium channel activity in the kidney, leading to hypertension and hypokalemia.
- **Glucose transporters (GLUT family):** GLUT-4 is insulin-dependent and plays a crucial role in glucose uptake in muscle and adipose tissue. Defects in GLUT-4 translocation are implicated in insulin resistance and type 2 diabetes mellitus.