Cell Physiology

The cell is the structural and functional unit of the living matter and is capable of carrying on the processes of life independently. They provide the structure for the body's tissues and organs, ingesting nutrients and converting them to energy, and performing specialized functions. Cells also contain the body's hereditary code, which controls the substances synthesized by the cells and permits them to make copies of themselves.

Each cell has two major parts:

- nucleus
- the cytoplasm.

The different substances that make up the cell are collectively called protoplasm. Protoplasm (nucleus and the cytoplasm) is composed mainly of five basic substances—water, electrolytes, proteins، lipids, and carbohydrates.

Cell Membrane (Plasma Membrane): is a thin elastic structure that envelops the cell and separate the cytoplasm from the surrounding fluids. It is composed primarily of phospholipids and proteins.

A. Lipid bilayer:

1. Phospholipids have a hydrophilic (water soluble) which is positively charged phosphate group head, and two fatty acid tails (negatively charged lipid group), which are hydrophobic (water insoluble). The hydrophobic tails face each other and form a bilayer.
2. lipid-soluble substances (e.g., O2, CO2, steroid hormones) cross cell membranes because they can dissolve in the hydrophobic lipid bilayer.
3. Water-soluble substances (e.g., Na+, Cl−, glucose, H2O) cannot dissolve in the lipid of the membrane, but may cross through water-filled channels, or pores, or may be transported by carriers.

B. Proteins

1. Integral proteins

■ are anchored to, and imbedded in, the cell membrane through hydrophobic interactions.

■ may span the cell membrane.

■ include ion channels, transport proteins, receptors, and guanosine 5′-triphosphate (GTP)–binding proteins (G proteins).

2. Peripheral proteins

■ are not imbedded in the cell membrane.

■ are not covalently bound to membrane components.

■ are loosely attached to the cell membrane by electrostatic interactions.

C. Intercellular connections

1. Tight junctions (zonula occludens)

■ are the attachments between cells (often epithelial cells).

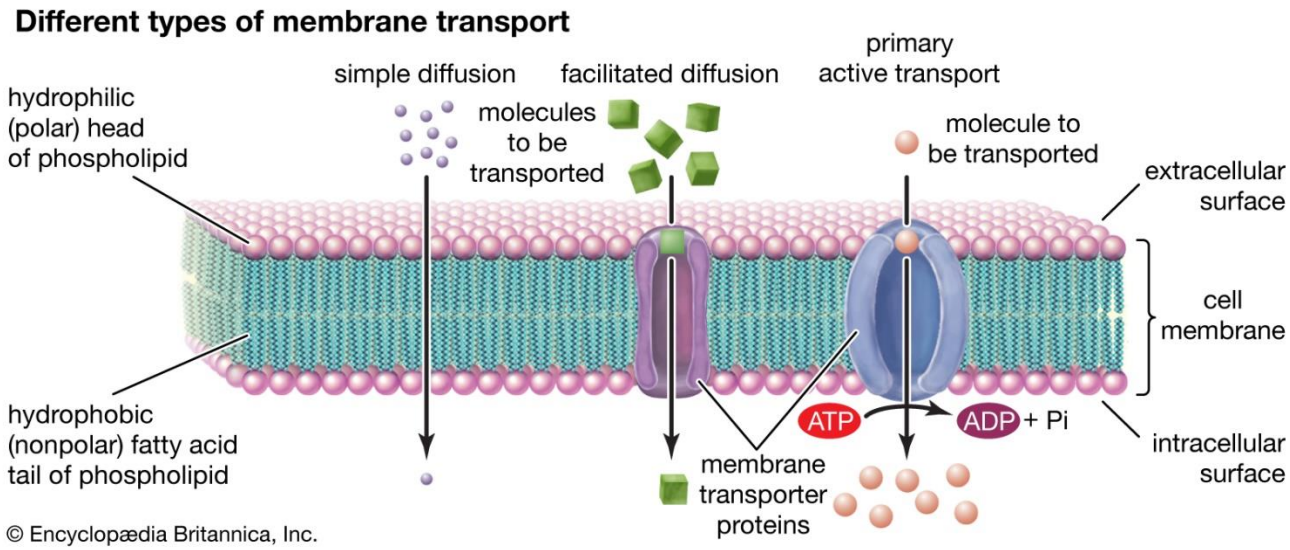
■ may be an intercellular pathway for solutes, depending on the size, charge, and characteristics of the tight junction.

■ may be "tight" (impermeable), as in the renal distal tubule, or "leaky" (permeable), as in the renal proximal tubule and gallbladder.

2. Gap junctions

■ are the attachments between cells that permit intercellular communication.

■ for example, permit current flow and electrical coupling between myocardial cells.



Functions of the Cell Membrane:

1. Transport: It facilitates the transport of materials across it. It is selectively permeable to certain substance and helps transports of substances needed for survival. The various transport mechanisms are:

a. Simple diffusion: It is a passive process in which

- molecules moves from area of higher concentration gradient to that of lower concentration gradient.
- It does not require energy and therefore is passive.
- (oxygen, carbon dioxide, small molecules, etc.) and passive osmosis (water).

b. Facilitated diffusion:

- molecules moves from area of higher concentration gradient to that of lower concentration gradient.
- it does not require energy and therefore is passive.

- It is more rapid than simple diffusion.
- It is carrier mediated and therefore exhibits stereospecificity, saturation, and competition
- Example of facilitated diffusion: glucose transport in muscle and adipose cells is "downhill," is carrier-mediated, and is inhibited by sugars such as galactose; therefore, it is categorized as facilitated diffusion. In diabetes mellitus, glucose uptake by muscle and adipose cells is impaired because the carriers for facilitated diffusion of glucose require insulin.

c. Active transport:

❖ Primary Active Transport
- Move substrates against concentration gradient
- Uses carrier proteins (just like carrier-mediated facilitated diffusion)
- Requires energy, such as ATP

❖ Secondary Active Transport: It is also known as co-transport or coupled transport mechanism.
- One of the solutes (usually Na+) is transported "downhill" and provides energy for the "uphill" transport of the other solute(s). Metabolic energy is not provided directly but indirectly from the Na+ gradient that is maintained across cell membranes.

d. Endocytosis: It is a process by which cell absorbs molecules by engulfing them: Example: Pinocytosis: Small vesicles, by a process of pinocytosis (drinking by cells), encircle and carry fluid within it across the membrane. By the pinocytic process fluid of smaller molecules (0.01-2.0 μm) can be engulfed. The inducer can increase greatly the process of pinocytosis and phagocytosis: The phagocytosis (eating by cells) is similar to engulfing of solid materials by the amoeba.

f. Exocytosis in which cells removed undigested products brought in by endocytosis, or to secrete enzymes and hormones or to excrete substances outside the cell.

2. Helps in the protection of cell. It surrounds cytoplasm of cell and forms a physical barrier between intracellular component and extracellular compartment.

3. It anchors to the cytoskeleton to the extracellular matrix and thereby provide shape to the cell and maintains its structural integrity.

4. Receives stimuli from the outside. The protein component of cell membrane acts as ligand receptors. The cell membrane contain receptor site for some hormones, immune proteins and neurotransmitters thus the cell recognizes and process these signals.

5. Takes in food and excretes waste products.

Cytoplasm and its Organelles: it is the semifluid substance of the cell that is external to the nuclear membrane and internal to the cell membrane. The cytoplasm contains the organelles. The jelly-like fluid portion of the cytoplasm in which the particles are dispersed is called cytosol and contains mainly dissolved proteins, electrolytes، and glucose.

Endoplasmic Reticulum:

a. Rough (Granular) Endoplasmic Reticulum: The roughness of the membrane is due to the presence of the ribosomes.

b. Smooth (Agranular) Endoplasmic Reticulum.

Functions of the Endoplasmic Reticulum

1. As the smooth-surfaced endoplasmic reticulum is very abundant in the interstitial (Leydig) cells of the testis and in cells of the corpus luteum, this reticulum is concerned with the synthesis of steroid hormones.
2. In the parietal cells of the gastric mucosa, it is concerned with secretion of hydrochloric acid.
3. In the skeletal muscle, it (sarcoplasmic reticulum) is concerned in some way with binding of the Ca++ ions and also plays role in conducting impulses in the substances of muscle cells.
4. In the liver cells both types of reticula are concerned with the synthesis of protein and carbohydrate.

Golgi Apparatus:

- This apparatus is prominent in secretory cells, where it is located on the side of the cell from which secretory substances are extruded.
- The Golgi apparatus functions in association with the endoplasmic reticulum.

Lysosomes:

- They are vesicular organelles that form by breaking off from the Golgi apparatus.
- They act as intracellular digestive system of the cell, serving both to degrade materials taken up from outside the cell and to digest obsolete components of the cell itself.
- They contain hydrolytic enzymes.

Peroxisomes:

- Peroxisomes are physically similar to lysosomes.
- They are formed by self-replication or by budding off from the smooth endoplasmic reticulum.
- They contain oxidases.
- A major function of peroxisomes is to catabolize long-chain fatty acids.

- About half the alcohol that a person drinks is detoxified into acetaldehyde by the peroxisomes of the liver cells.

Mitochondria:

- They are called the powerhouses of the cell.
- They generate the chemical energy needed to power the cell's biochemical reactions.
- Chemical energy produced by the mitochondria is stored in a small molecule called adenosine triphosphate (ATP).
- Mitochondria are self-replicative.
- The mitochondria contain DNA similar to that found in the cell nucleus.

Nucleus:

- The nucleus is the control center of the cell and sends messages to the cell to grow and mature, replicate, or die.
- The nucleus contains large quantities of DNA, which comprise the genes.

Nuclear Membrane (nuclear envelope):

- Surrounds the nucleus.
- The nuclear membrane is penetrated by several thousand nuclear pores which permit passage of molecules from the nucleus to the cytoplasm.

Nucleolus:

- The nucleus is responsible for the synthesis of messenger RNA (mRNA) which carries the genetic information in code through the pores in the nucleus.

Energy Production:

- The principal substances from which cells extract energy are foods that react chemically with oxygen—carbohydrates، fats, and proteins.
- In the human body, essentially all carbohydrates are converted into glucose by the digestive tract and liver before they reach the other cells of the body.
- Similarly, proteins are converted into amino acids, and fats are converted into fatty acids.
- Inside the cell، they react chemically with oxygen under the influence of enzymes that control the reactions and channel the energy released in the proper direction.
- Briefly, almost all these oxidative reactions occur inside the mitochondria, and the energy that is released is used to form the high-energy compound ATP. Then، ATP, not the original food, is used throughout the cell to energize almost all the subsequent intracellular metabolic reactions.