Charting New Horizons in Education

Transport through the cell membrane

02

Physiology

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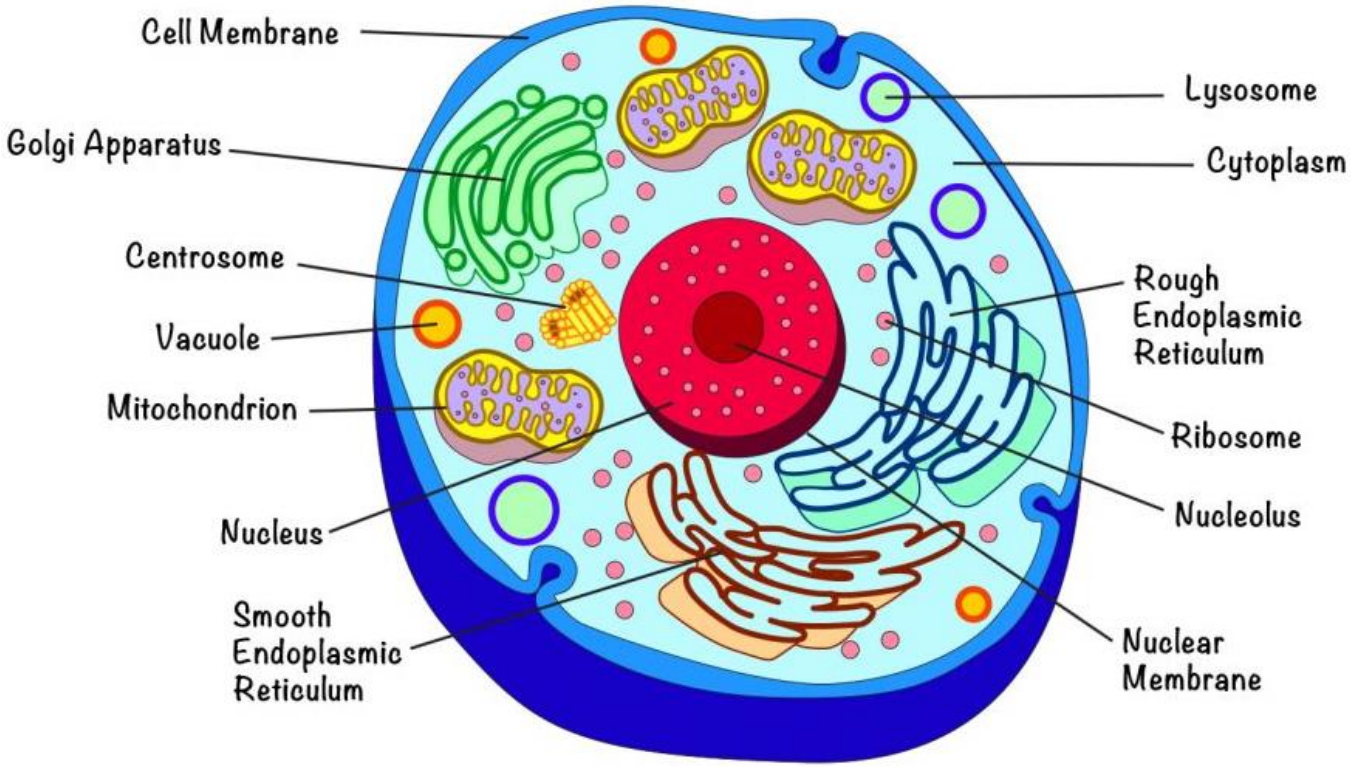
The Cell

- The cell: It is the structural unit of the human body.
- Components of human cell:

1. The cell membrane (also called plasma membrane).
2. The nucleus.
3. The cytoplasm → Organelles.



The cell membrane

- It is a very thin elastic structure which envelopes the cell separating and keeping intracellular fluid (ICF) completely different from extracellular fluid (ECF).

- **Functions:**

1. It forms the outer boundary surrounding the cell to protect it from the external environment.
2. Selective permeability; as it permits the passage of certain substances and prevents others.
3. Detect chemical messengers arriving at the cell surface.
4. Link adjacent cells together by membrane junctions.

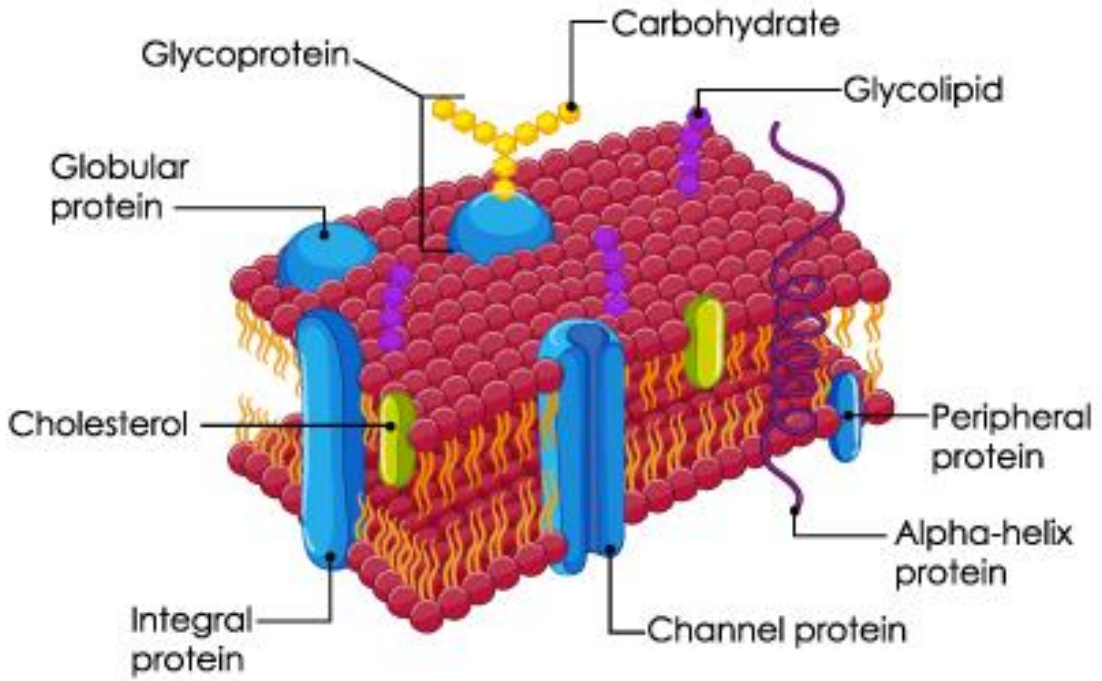
- **Characters:**

1. Very thin; 75-100 A^o (A^o = angstrom= 0.1nm = 10^{-10} m); 7.5 – 10 nm.
2. Elastic.
3. Semipermeable.
4. Dynamic.

The cell membrane

Composition:

1. Proteins: 55%
2. Lipids: 42% → Phospholipids: 25% & Cholesterol 13 % and other lipids (4%)
3. Carbohydrates: 3%



Structure of the cell membrane -1

- Chemical Structure:

1. Lipids:

A. Phospholipids:

1. Each phospholipid molecule in the cell membrane is formed of:

i. Water soluble (hydrophilic) phosphate part.

ii. Fat soluble (hydrophobic) lipid part containing cholesterol.

- The cell membrane is formed of two layers (bilayer) of phospholipid molecules with their hydrophilic phosphate heads directed outwards and inwards and their hydrophobic lipid tails directed to the interior of the membrane.

B. Cholesterol:

- Controls the fluidity of the membrane.

Structure of the cell membrane -2

2. Proteins:

✓ Chemically, they are either;

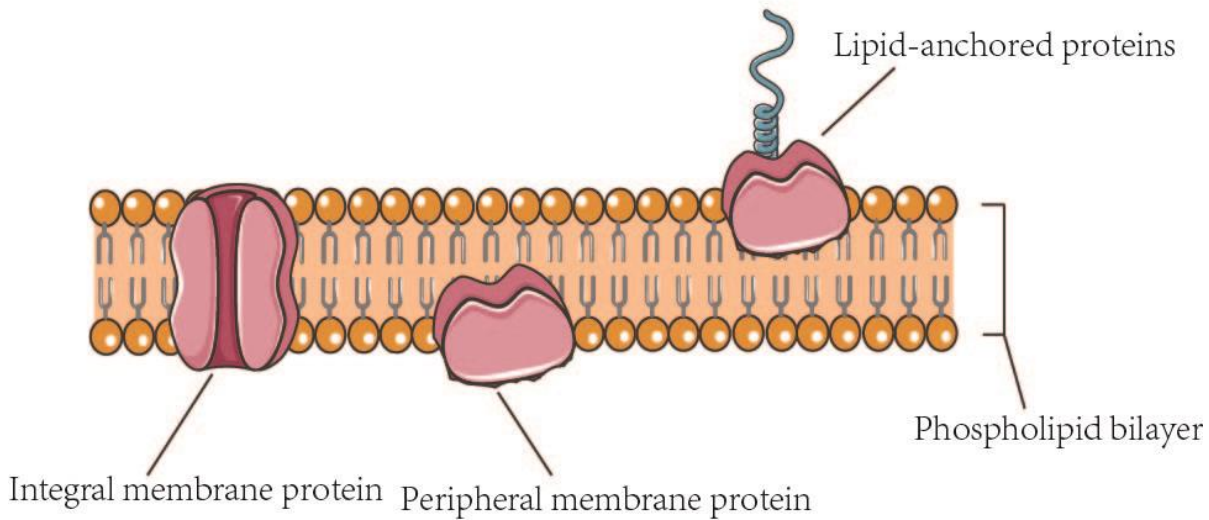
A. Pure proteins.

B. Conjugated proteins with carbohydrates (glycoproteins) or with lipids (lipoproteins).

✓ According to their site; Proteins are either:

A. Peripheral (surface) proteins on the outer or inner surfaces (do not penetrate it).

B. Integral (Transmembrane or through & through proteins) ---- extend all the way through the cell membrane.



Transport mechanisms across cell membrane

- The transport mechanisms of the cell membrane try to keep the composition of the fluids in various body compartments constant at optimal cellular activities. In the same time, it tries to supply the cells with the needed materials and to remove the waste products.
- Substances can pass through the cell membrane in different ways; **Transport either:**

1. Passive:

i.e. No need for energy as substances move with gradient.

2. Active:

i.e. Need energy (ATP) as substances move against gradient.

Passive	Active
Doesn't need energy	Needs energy
Needs gradient (difference)	Doesn't need gradient
- Examples: 1. Diffusion: - Simple diffusion. -Facilitated diffusion 2. Filtration 3. Osmosis	- Examples: 1. Active transport: a. Primary active transport b. Secondary active transport. 2. Vesicular transport: a. Exocytosis b. Endocytosis

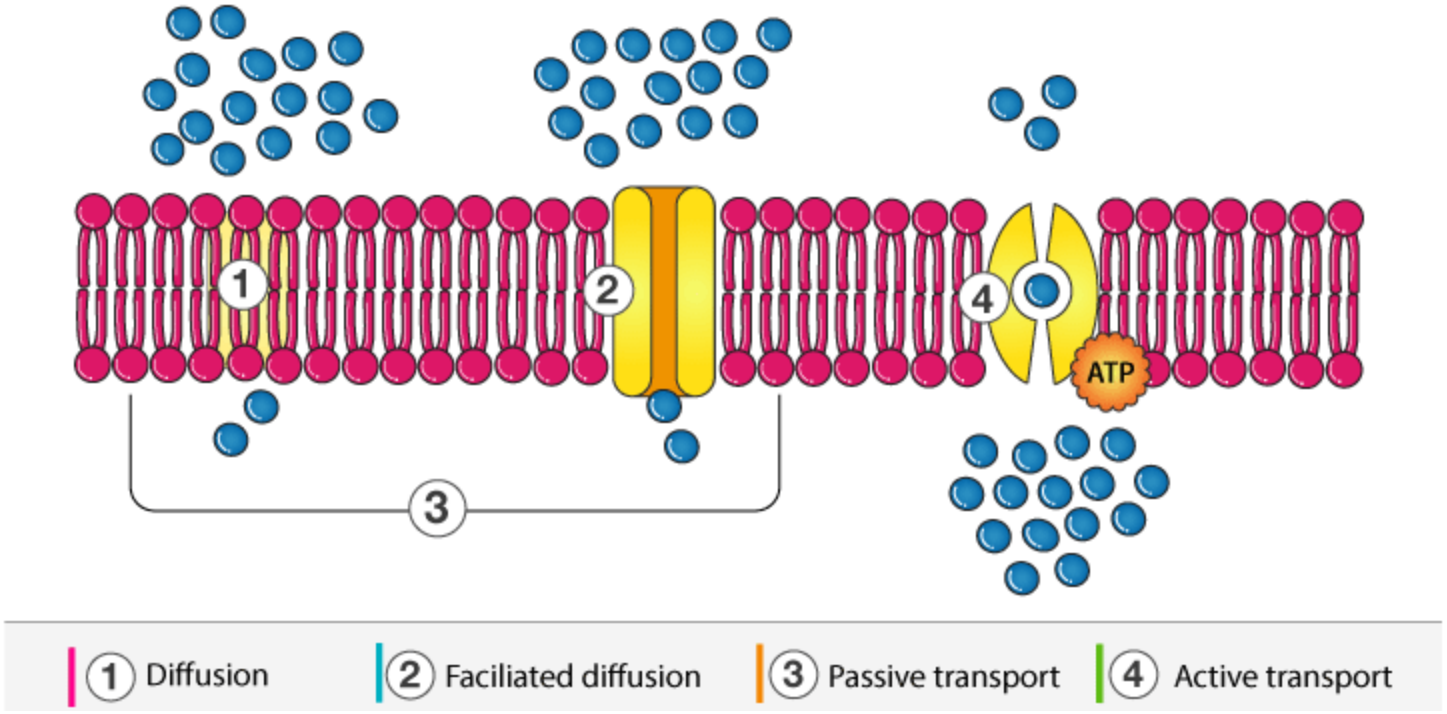
Diffusion

- Diffusion is the process by which a gas or a substance in a solution expands, because of the motion of its particles, to fill all the available volume.
- It is the free movement of substance molecules (particles) through the cell membrane from area of HIGH concentration to area of LOW concentration (concentration gradient) caused by their kinetic energy.
- It is a passive process (requiring no energy).
- With (down) gradient.
- It is produced by the **kinetic motion of the molecules** (which makes them in a continuous random movement), and it occurs in the direction of their concentration (= chemical); i.e. from areas of high concentration to areas of lower concentration or electrical gradients.

Diffusion types

Diffusion across cell membrane can be divided into 2 main groups:

1. **Simple diffusion.**
2. **Facilitated diffusion.**



Simple diffusion

- Simple diffusion means that kinetic movement of molecules or ions occurs through a membrane opening or through intermolecular spaces without any interaction with carrier proteins in the membrane.
- This occurs through the lipid bilayer.

A. Simple diffusion of lipid soluble substances through lipid bilayer:

- Lipid soluble molecules as O_2 and CO_2 diffuse through phospholipid bilayer. So, they cross the cell membranes easily.
- Non- polar, uncharged, lipid soluble and high membrane permeability (O2, steroid hormone, CO2)
- Rate is linear

Facilitated diffusion

- Facilitated diffusion is a process where molecules move across the cell membrane through transport proteins without using energy (ATP), following the concentration gradient from high to low concentration. There are several types of facilitated diffusion:

1. **Ion Leak Channels:** These channels allow specific ions (e.g., Na^+, K^+, Cl^-) to passively move across the membrane, typically being always open. They help maintain the cell's resting membrane potential, such as K^+ leak channels, which contribute to a negative charge inside the cell.

2. **Voltage-Gated Channels:** Activated by changes in membrane potential, these channels open or close in response to the action potential. For example, voltage-gated Na^+ channels open during depolarization, allowing Na^+ to enter the cell, and voltage-gated K^+ channels open during repolarization to allow K^+ to exit.

Facilitated diffusion

3. **Ligand-Gated Channels:** These channels open when a specific molecule (ligand) binds to a receptor on the channel, triggering a conformational change. An example is the nicotinic acetylcholine receptor at the neuromuscular junction, where acetylcholine binding allows Na^+ to flow into the cell, initiating muscle contraction.

4. **Carrier Proteins:** These proteins bind specific molecules (e.g., glucose or amino acids), change shape, and transport the molecule across the membrane. The glucose transporter (GLUT) is an example. Carrier proteins are slower than ion channels but can transport larger or more polar molecules.

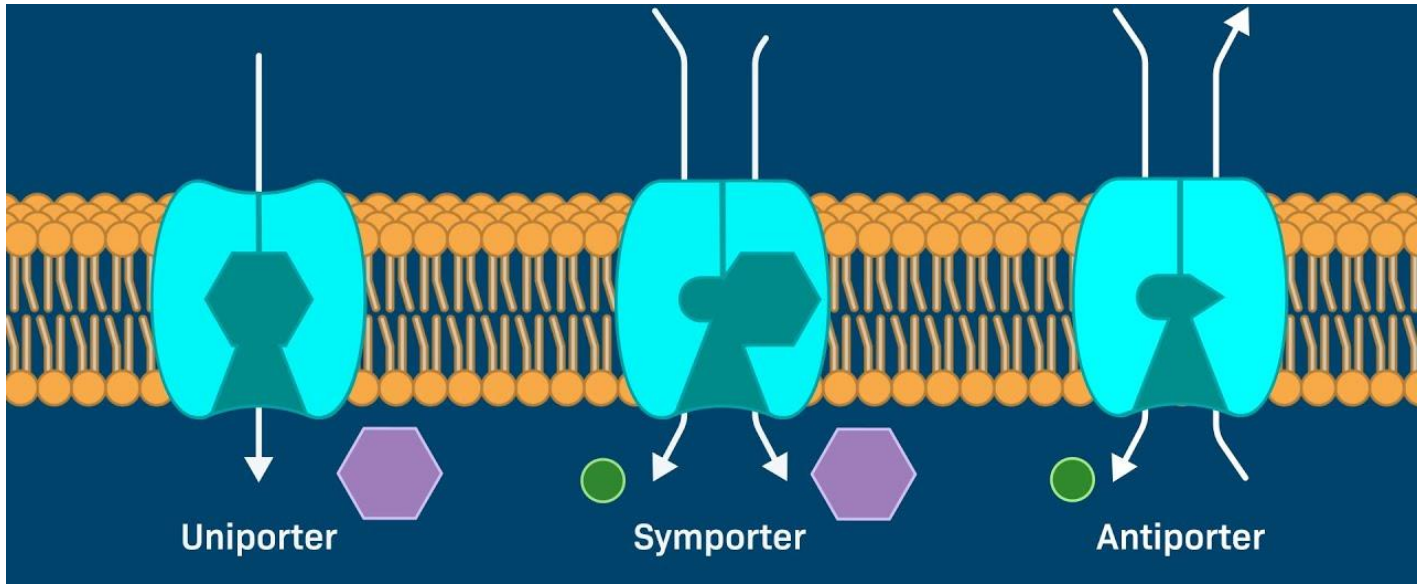
✓ **Transport Rate Limitation:** The transport rate in facilitated diffusion is limited by the number of available transporter proteins. Once these proteins are saturated, the rate of transport cannot increase, even with a higher concentration gradient.

Types of carriers

1. **Uniport:** transport one substance in one direction as Ca^{+2} pump.

2. **Symport :** transport two substances simultaneously in the same direction –> (Co-transport) e.g. Na^{+} and glucose carrier.

3. **Antiport:** transport two substances simultaneously in opposite direction → (Counter-transport). e.g. Na^{+} - K^{+} pump → it transports 3 Na^{+} out of the cell in exchange with 2 K^{+} into the cell.



Cell membrane channels

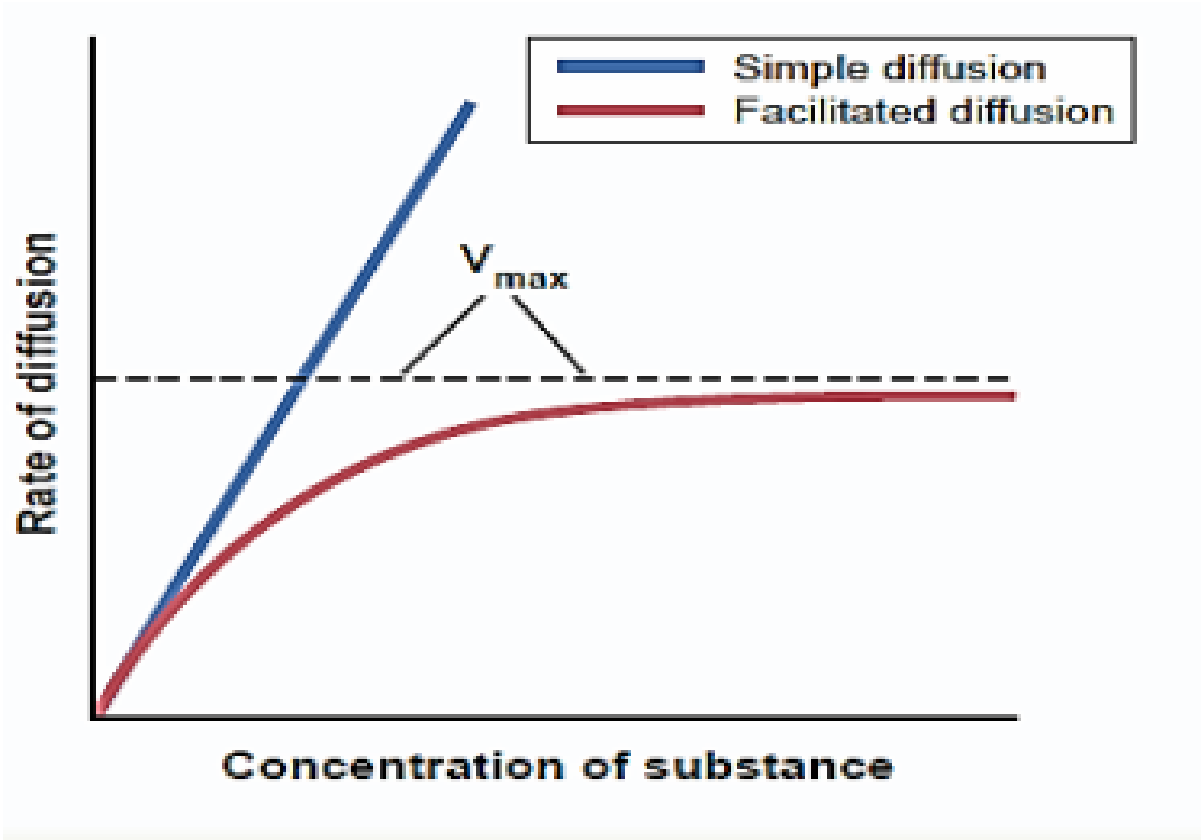
1. **Non gated channels:**

- They are channels that are open all the time allowing passage of ions all the time.
- Sometimes they are called “leak channels” as Na^+ leak channels and K^+ leak channels.

2. **Gated channels:** Have gates that open or close.

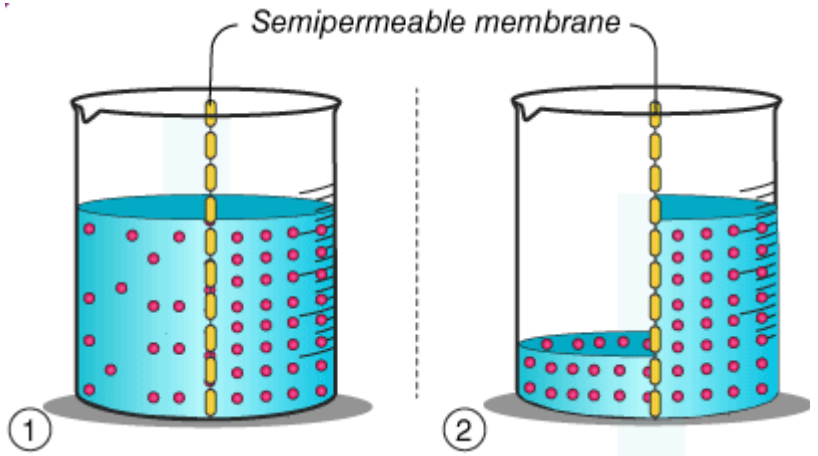
- They are specific allowing passage of only one type of molecule or ion.
- The gated channels are closed during rest by protein acts as a gate that can change their shape to open or close the channels in response to various signals.

Facilitated diffusion



Osmosis

- It's the diffusion of the solvent molecules through a semipermeable membrane from the compartment of lower concentration to the compartment of higher concentration of the solute.
- It is a passive mechanism (no energy needed).
- It occurs according to concentration (chemical) gradient of water molecules.
- Osmosis results in changes in volume on either side of the membrane.



- **For osmosis to occur:**

1. The membrane must be permeable to water and impermeable to the solutes in the solution (i.e. semipermeable)
2. There must be a difference in solute concentration between the two sides of the membrane.

Active transport

- **Characters:**
  - This is the transport of substances through cell membrane against gradient (Uphill); concentration (i.e. from a lesser to a greater concentration) or electric gradients or both (physico-chemical or electrochemical gradient).
  - **It requires energy (ATP);** either direct or indirect.
  - **It requires a carrier protein (with ATPase activity)** → Therefore, the carrier molecules are mostly ATPase enzymes that catalyze the hydrolysis of ATP.
  - Uses 90% of the ATP in our body!

- **Types of active transport; It includes 2 types according to the source of energy used to cause the transport:**

1. Primary active transport.
2. Secondary active transport.

Active transport Vs Facilitated diffusion

Active transport	Facilitated diffusion
Carrier mediated transporter	Carrier mediated transporter
Needs energy	Doesn’t need energy
Against electrochemical gradient	With electrochemical gradient

Primary active transport

- **Characters:**
  - Energy is derived directly from breakdown of ATP (or other high energy phosphate compounds):ATP → ADP + Pi + energy

- **Examples:**

1. **Sodium-Potassium pump (Na^+ - K^+ pump):**

A. It is present in all cell membranes.

B. It transports 3 Na^+ out (efflux) and 2K^+ in (influx).

C. It is an electrogenic pump → Because it creates an electrical potential across the cell membrane. This electrical potential is a basic requirement in nerve and muscle fibers for transmitting nerve and muscle signals

Ca^{+2} ATPase pump

- **Ca^{+2} ATPase pump: It keeps intracellular calcium at very low level.**

- **<u>2 types of Ca^{+2} pump:</u>**
  - One is in the **cell membrane** and **pumps calcium** to the **outside** of the cell.
  - The other **pumps calcium ions into one or more of the intracellular organelles of the cell,** such as the sarcoplasmic reticulum of muscle cells and the mitochondria in all cells.
  - In each of these instances, the carrier protein penetrates the membrane and functions as an enzyme ATPase, having the same capability to cleave ATP as the ATPase of the sodium carrier protein.

The K^+/H^+ ATPase pump

- The K^+/H^+ ATPase pump is a primary active transport system that exchanges potassium (K^+) and hydrogen ions (H^+) across the plasma membrane.

- It uses energy from ATP hydrolysis to transport K^+ into the cell and H^+ out of the cell, against their concentration gradients.

- The pump plays a key role in regulating acid-base balance and electrolyte levels.

- In parietal cells of the stomach, it helps secrete hydrochloric acid (HCl) into the stomach lumen, creating the acidic environment needed for digestion.

«Wherever the art of medicine is loved,
there is also a love of humanity.»

- Hippocrates-

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