Dr. pooja kumari
S B college Ara

Transport Across Cell Membranes

Introduction

The plasma membrane is selectively permeable and regulates the movement of ions, molecules, and nutrients between the intracellular and extracellular environments. Transport across membranes is essential for maintaining **cell homeostasis, metabolism, and survival**.

Membrane transport is mainly of two types:

1. **Passive Transport**
2. **Active Transport**

1. Passive Transport

Definition:

Passive transport is the movement of substances across the membrane **along the concentration gradient** (from higher to lower concentration) **without expenditure of metabolic energy (ATP)**.

Characteristics:

- No energy required
- Occurs down the concentration gradient
- Depends on membrane permeability

Types of Passive Transport:

A. Simple Diffusion

Definition:

Movement of molecules from a region of higher concentration to a region of lower concentration directly through the lipid bilayer.

Examples:

- Oxygen (O_2)
- Carbon dioxide (CO_2)
- Small non-polar molecules

Factors Affecting Diffusion:

- Concentration gradient
- Temperature
- Molecular size
- Membrane thickness

Significance:

- Helps in gas exchange
- Maintains equilibrium of small molecules

B. Facilitated Diffusion

Definition:

Movement of substances across the membrane with the help of **specific carrier or channel proteins**, without energy consumption.

Features:

- Highly specific
- Saturable process
- Faster than simple diffusion

Examples:

- Glucose transport by GLUT proteins
- Transport of amino acids
- Ion channels (Na^+, K^+, Ca^{2+})

Difference from Simple Diffusion:

Simple Diffusion	Facilitated Diffusion
No carrier needed	Carrier proteins required

Simple Diffusion	Facilitated Diffusion
Not specific	Highly specific
Not saturable	Saturable

C. Osmosis

Definition:

Movement of water molecules across a selectively permeable membrane from a region of **high water potential (low solute concentration)** to **low water potential (high solute concentration)**.

Types of Solutions:

1. **Hypotonic solution** – Cell swells
2. **Hypertonic solution** – Cell shrinks
3. **Isotonic solution** – No net movement

Importance:

- Maintains cell shape
- Controls turgidity in plant cells
- Regulates fluid balance

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2. Active Transport

Definition:

Active transport is the movement of substances across the membrane **against the concentration gradient** (from lower to higher concentration) using **energy (ATP)**.

Characteristics:

- Requires ATP
- Occurs against gradient
- Highly specific
- Involves carrier proteins (pumps)

Types of Active Transport:

A. Primary Active Transport

Definition:

Transport in which energy is obtained **directly from ATP hydrolysis**.

Example:

Sodium–Potassium Pump (Na^+/K^+ ATPase)

Mechanism:

- Pumps **3 Na^+ ions out** of the cell
- Pumps **2 K^+ ions into** the cell
- Consumes 1 ATP molecule

Significance:

- Maintains membrane potential
- Regulates nerve impulse transmission
- Controls cell volume

B. Secondary Active Transport

Definition:

Transport where energy is derived **indirectly** from an ion gradient created by primary active transport.

Types:

1. **Symport** – Both substances move in same direction
   Example: Glucose–Na^+ cotransport
2. **Antiport** – Substances move in opposite directions
   Example: Na^+–Ca^{2+} exchanger

Difference Between Passive and Active Transport

Passive Transport	Active Transport
No ATP required	ATP required
Along concentration gradient	Against concentration gradient
Simple and facilitated diffusion	Uses pumps and carriers
Cannot concentrate substances	Can concentrate substances

Importance of Membrane Transport

- Nutrient uptake
- Waste removal
- Maintenance of ionic balance
- Cell signaling
- Regulation of cell volume

Conclusion

Transport across membranes is a fundamental cellular process. **Passive transport** maintains equilibrium, while **active transport** allows cells to accumulate essential substances and maintain physiological balance.