Department of Biochemistry /Second Stage

Lecture-4: Symport (Cotransport)

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Definition

In symport, both the driving ion and the transported molecule move **in the same direction across the membrane**.

Characteristics

- Both substrates bind to the transporter simultaneously
- Transport is obligatorily coupled
- Frequently used for nutrient uptake

Example: Na^+/Glucose Symporter (SGLT)

The Na^+/glucose symporter is located in the **intestinal epithelium and renal tubules**.

Mechanism

- Na^+ moves into the cell down its electrochemical gradient.
- Glucose is transported into the cell **against its concentration gradient**.
- Energy from Na^+ influx drives glucose accumulation inside the cell.

This mechanism enables glucose absorption even when intracellular glucose concentration is already high.

Physiological Importance

- Efficient nutrient absorption in the intestine
- Glucose reabsorption in kidneys
- Basis of oral rehydration therapy

Antiport (Countertransport)

Definition

In antiport systems, one molecule enters the cell while another exits, moving in **opposite directions**.

Characteristics

- Strictly coupled exchange
- Critical for ion homeostasis
- Often involved in calcium and pH regulation

Example: Na^+/Ca^{2+} Exchanger (NCX)

The Na^+/Ca^{2+} exchanger is especially important in **cardiac muscle cells**.

Mechanism

- Typically transports **3 Na^+ ions into the cell**
- Simultaneously exports **1 Ca^{2+} ion**
- Net movement is electrogenic

This exchanger rapidly reduces cytosolic Ca^{2+} levels after muscle contraction, enabling relaxation.

Physiological Importance

- Regulation of intracellular Ca^{2+} concentration
- Cardiac muscle relaxation
- Prevention of Ca^{2+} toxicity

Comparison with Primary Active Transport

Feature	Primary Active Transport	Secondary Active Transport
ATP usage	Direct	Indirect
Energy source	ATP hydrolysis	Ion gradient
Transport protein	Pump	Carrier
Example	Na^+/K^+-ATPase	Na^+/glucose symporter

Transport Kinetics and Specificity

Carrier-mediated transport displays:

- Saturation at high substrate concentration
- Competitive inhibition by similar molecules
- Regulation by phosphorylation or allosteric modulators

These properties allow cells to fine-tune transport according to metabolic demand.

Regulation of Membrane Transport

Transport systems are dynamically regulated by:

- Hormones (e.g., insulin regulating GLUT4)
- Membrane potential changes
- Protein phosphorylation
- Cellular signaling pathways

This regulation ensures rapid adaptation to environmental and metabolic changes.

Physiological and Clinical Significance

Defects in membrane transport proteins cause numerous diseases:

- **Cystic fibrosis:** defective Cl^- channel
- **Diabetes mellitus:** impaired glucose transport
- **Channelopathies:** epilepsy, cardiac arrhythmias
- **Renal transport disorders:** electrolyte imbalance

Thus, membrane transport is a cornerstone of both physiology and medicine.

Table: Membrane Transport Mechanisms

Type	Transport Protein	Energy Source	Direction	Examples	Main Function
Simple Diffusion	None	None	Down gradient	O_2, CO_2	Gas exchange
Facilitated Diffusion	Carrier	None	Down gradient	GLUT	Nutrient uptake
Channel-mediated	Channel	None	Down electrochemical	Na^+, K^+	Electrical signaling
Primary Active Transport	Pump (ATPase)	ATP	Against gradient	Na^+/K^+-ATPase	Ion gradients
Secondary Active (Symport)	Carrier	Ion gradient	Same direction	Na^+/Glucose	Absorption
Secondary Active (Antiport)	Carrier	Ion gradient	Opposite directions	Na^+/Ca^{2+}	Ca^{2+} balance
Osmosis	Aquaporin	None	Down water potential	Water	Osmoregulation
Vesicular Transport	Vesicles	ATP	Bulk transport	Endocytosis	Macromolecules

Short Essay Questions

1. Discuss the thermodynamic forces governing membrane transport and their biological significance.
2. Compare channel proteins and carrier proteins in terms of mechanism and kinetics.
3. Explain how secondary active transport couples ion gradients to nutrient uptake.
4. Describe the physiological importance of the Na^+/K^+-ATPase.

Notes : 1- Channels vs Carriers

- Channels: fast, no saturation (usually), gated
- Carriers: slower, saturable, undergo conformational change

2- Primary vs Secondary Active Transport

- Primary: ATP used directly
- Secondary: ATP used indirectly via ion gradients

3-Ion Gradients as Energy Storage

- Na^+ gradients in animals
- H^+ gradients in plants, bacteria, mitochondria