Cell Membrane Transport Processes

Active Transport (Part-I)

Learning Objectives:

- ❖ Define “Active Transport” and list its different types.
- ❖ Describe the sources of energy of active transport.
- ❖ Explain the mechanism of Na^+ - K^+ pump.
- ❖ List the important functions of Na^+ - K^+ pump.

Active Membrane Transport:

- Whenever a cell uses energy to move solutes across the membrane, the process is referred to as ***active***. Substances moved actively across the plasma membrane are usually unable to pass in the necessary direction by passive transport processes.

- The substance may be *too large to pass through the channels*, *incapable of dissolving in the lipid bilayer*, or *unable to move down its concentration gradient.*

- There are two major means of active membrane transport:

  - **Active transport.**

  - **Vesicular transport.**

Active Membrane Transport – *Active Transport:*

- Materials may be moved against its concentration gradient by this means. Movement of the material must be coupled with an energy-yielding reaction.

- It is unidirectional, and is actually independent of concentration gradient, although it is set up in the first place because of an unfavorable gradient.

- Active transport can be ***simple*** *(one substance is pumped by one system*), or ***coupled*** *(two substances are transported simultaneously by the same system).*

- Coupled transport may be:

  - ***Contransport or symport*** = both substances move in the same direction.

  - ***Countertransport or antiport*** = substances moving opposite ways.

Active Membrane Transport – *Active Transport:*

- The energy to power active transport can come from:

  - Splitting of ATP may be coupled to the transport ***(Primary active transport).***

  - Exergonic (passive, facilitated) movement of one molecule may be used to power endergonic (active) movement of another ***(secondary active transport).*** Transport may be also driven indirectly by energy stored in ionic gradients created by primary active transport pumps. ***(this will be discussed with the cellular functions facilitated by Na^+ - K^+ pump in part-II lecture).***

- ***Secondary active transport systems are all coupled systems .***

Sodium-Potassium Pump *(Na^+ - K^+ Pump):*

- In *primary active transport*, hydrolysis of ATP results in the phosphorylation of the transport protein. This step causes the protein to change its shape in such a manner that it "pumps" the bound solute across the membrane.

- The most investigated example of a *primary active transport system* is ***the sodium-potassium pump,*** for which the carrier, or "pump," is an enzyme called ***Na^+ - K^+ ATPase.***

- In the body, *the concentration of K^+ inside the cell is some 10 times higher than that outside, and the reverse is true of Na^+. These ionic concentration differences are essential for excitable cells like muscle and nerve cells to function normally and for all body cells to maintain their normal fluid volume.*

- Because Na^+ and K^+ leak slowly but continuously through leakage channels in the plasma membrane along their concentration gradient (and cross more rapidly in stimulated muscle and nerve cells), ***the Na^+- K^+ pump operates almost continuously as an antiporter.***

- ***It simultaneously drives Na^+ out of the cell against a steep concentration gradient and pumps K^+ back in.***

Mnemonics to remember!

Na-K pump: Pumps K in and Na out

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PUMPKIN

Mechanism of *Na^+ - K^+ Pump:* ***(the next slide image shows the mechanism in details)***

- The pump is an ***allosteric protein***, meaning that ***it has two configurations***:

  - The two configurations are referred to as **E_1** and **E_2** **.**
  - **E_1** opens to the cytoplasmic side, and has a ***high affinity for Na^+.***
  - **E_2** opens to the outside of the cell, and has a ***high affinity for K^+.***

- **Step-1:** 3 Na^+ are bound to inside of membrane, with pump in E_1 configuration.

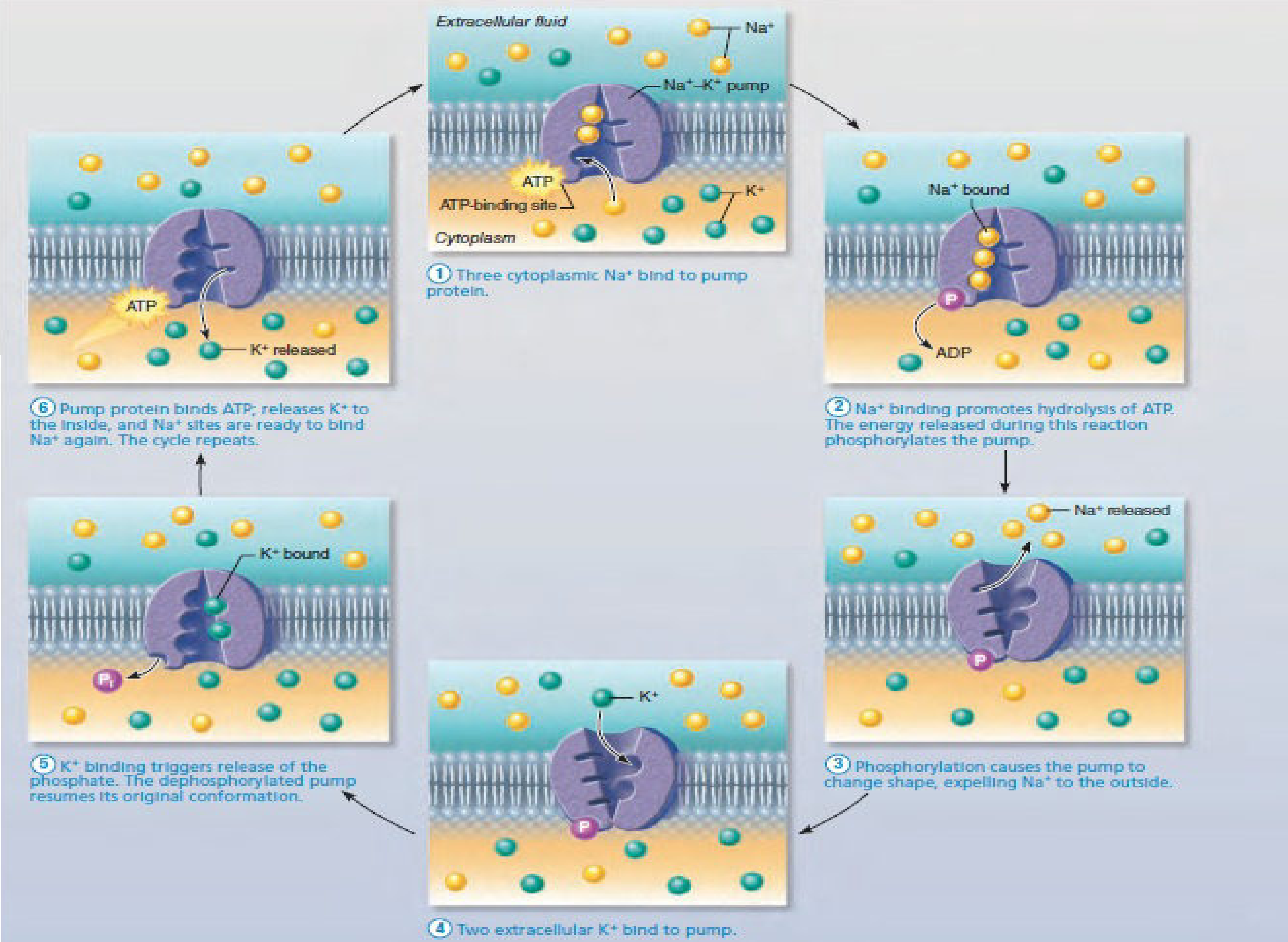
- **Step-2:** Step-1 triggers the enzyme to split ATP, which provides the energy to change the configuration to E_2. the enzyme itself may be phosphorylated.

- **Step-3:** Bound Na^+ are released to extracellular environment.

- **Step-4:** 2 K^+ are bound to outside of membrane, with pump in E_2 configuration.

- **Step-5:** Step-4 triggers dephosphorylation of the enzyme, which provides the energy to move the K^+ to inside the membrane.

- **Step-6:** K^+ are released into cytoplasm, allowing enzyme to change back to E_1 configuration.



Primary active transport* is the process in which solutes are moved across cell membranes against electrochemical gradients using energy supplied directly by ATP. The action of the *Na+–K+ pump is an important example of primary active transport.

Na^+ - K^+ Pump - Functions:

- **Electrochemical:** The cell is like a battery, and its charge is maintained by the Na^+ - K^+ Pump . It maintains a voltage within cells of -20 to -200 milvolts:
  - Every cell maintain some –ve voltage within the cell, necessary for life.
  - Nerve & muscle cells use this electrochemical energy for conduction impulses.
  - The charge is maintained by anions predominating within the cell.
- **Biochemical:** K^+ ions have many functions inside the cell, e.g. ribosomes function & enzyme activation of many enzymes. Sodium inhibits these processes.

Na^+ - K^+ Pump - Functions:

- **Osmotic:** Distribution of Na^+ & K^+ ions is a major factor in determining osmotic pressure across the cell membrane:

  - This is essential in maintaining cell size and shape.
  - Determine blood pressure.
  - The kidneys retain water in the body, by pumping Na^+ back into the blood, out of the provisional urine in the kidney tubules.

- **Energy source for other transport:**

  - Na^+ - K^+ Pump sets up concentration gradients of these ions, across the membrane.
  - If passive ion channels are opened, Na^+ can diffuse passively back into the cell and K^+ can likewise move out the cell.
  - These movements are exergonic, i.e. energy is released by these movements and can be used to power the movement of other ions, or nutrients.