Cell Biology

Chapter (4): Cellular Transport

- Passive transport
- Active transport
- Bulk transport

Cellular Transport

- **Cellular transport is movement of the substances across the cell membrane either into or out of the cell.**

- **The plasma membrane is selectively permeable which permits some particles to pass through it freely, while others need the assistance of specific proteins as channel proteins.**

- **In general, the movement of most substances through the membrane are mediated by membrane transport proteins.**

- **Two properties of the particle determine whether it can pass the plasma membrane without assistance:**

  1. **Its relative solubility in lipid (Hydrophobic property).**
  2. **Its particle size.**

Cellular Transport

- **Hydrophobic (nonpolar, water-hating) molecules, such as carbon dioxide (CO_2) and oxygen (O_2), with small size can easily pass through the lipid bilayer without assistance.**

- **Hydrophilic (polar, water-loving) molecules, such as ions and water (H_2O) cannot pass freely and need the assistance of specific proteins as channel proteins.**

- **In addition, large molecules such as sugars and proteins are too big to pass through the phospholipid bilayer. So, transport proteins within the membrane allow these molecules to pass the membrane.**

- **By this way, polar molecules avoid contact with the nonpolar interior of the membrane, and large molecules are moved through large pores.**

Cellular Transport

Types of cellular transport

- **There are three types of cellular transport:**
    1. **Passive transport**
    2. **Active transport**
    3. **Bulk transport**

1. <u>Passive transport</u>

- **It is the movement of substances cross the membrane from an area of high concentration to an area with lower concentration (*down concentration gradient*).**

- **It does not require energy.**

- **Concentration gradient is the difference in concentration between two adjacent areas.**

Cellular Transport

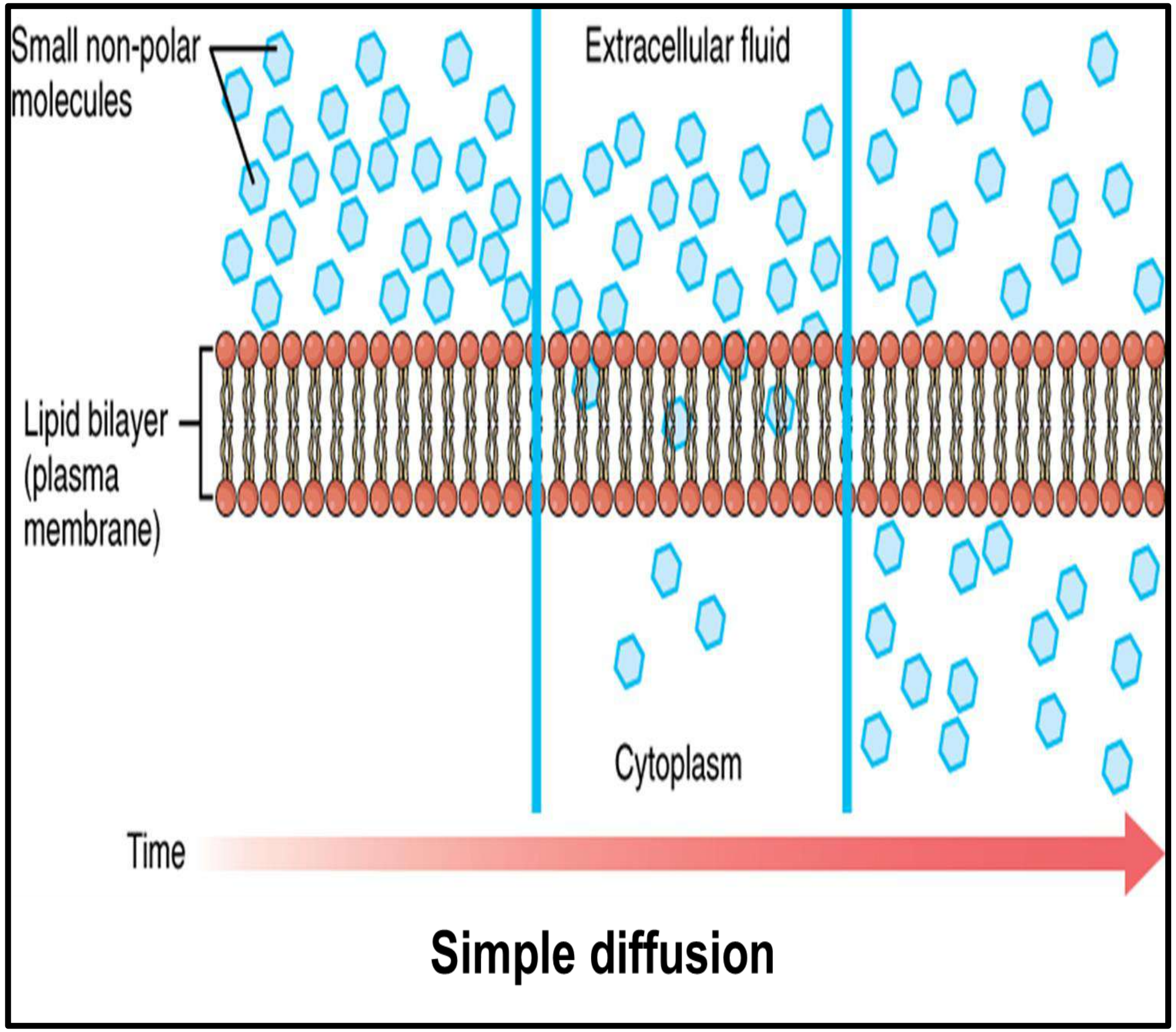
Types of passive transport

- There are three types of passive transport:

    A. Simple diffusion
    B. Facilitated diffusion
    C. Osmosis

A) Simple diffusion

- This type depends on the chemical nature and the size of the substance.
- It is the passive movement of small non-polar substances from a high concentration to a lower concentration.
- Only small non-polar molecules, such as oxygen and carbon dioxide can diffuse easily across the membrane.



Cellular Transport

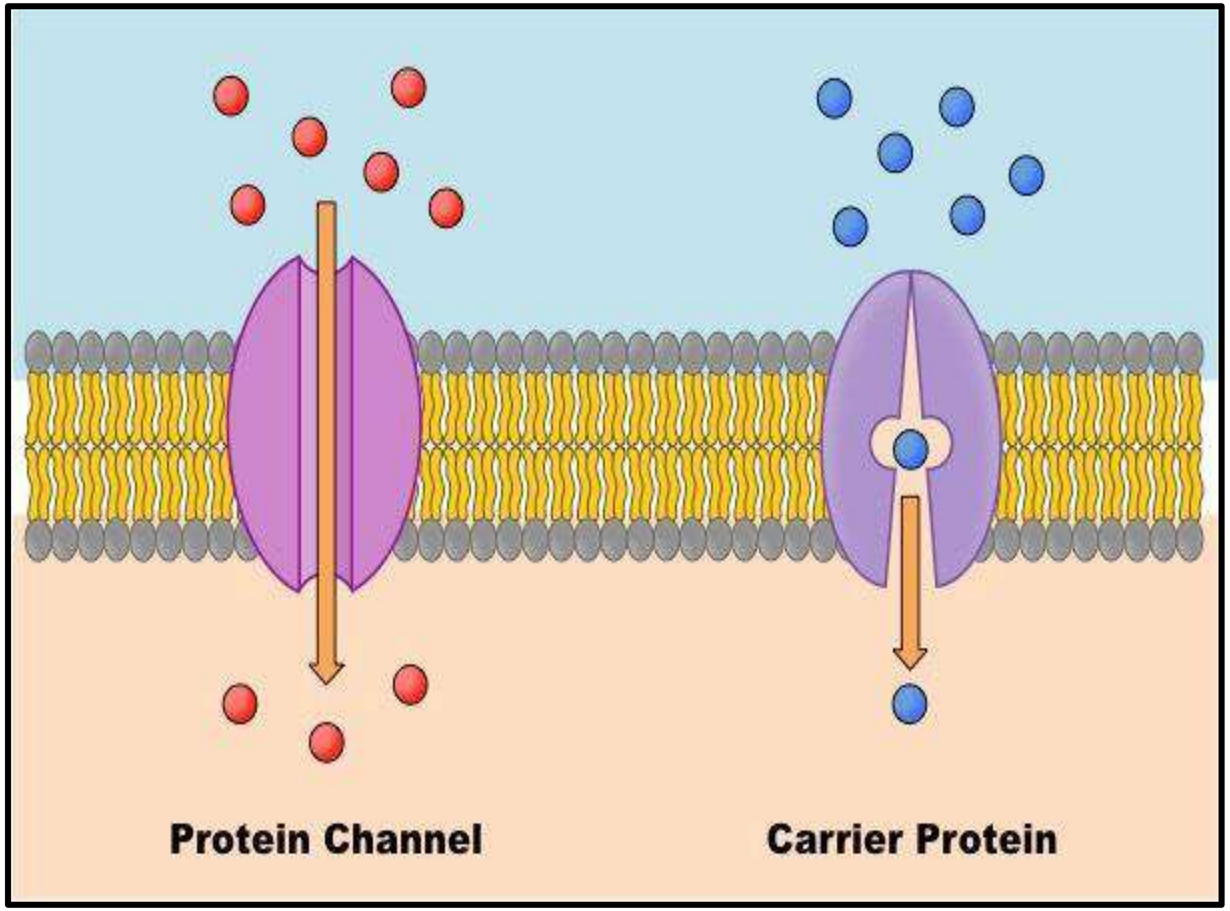
B) Facilitated diffusion

- It is the passive movement of molecules across the cell membrane via special transport proteins (carriers) or channels that are embedded within the cell membrane.

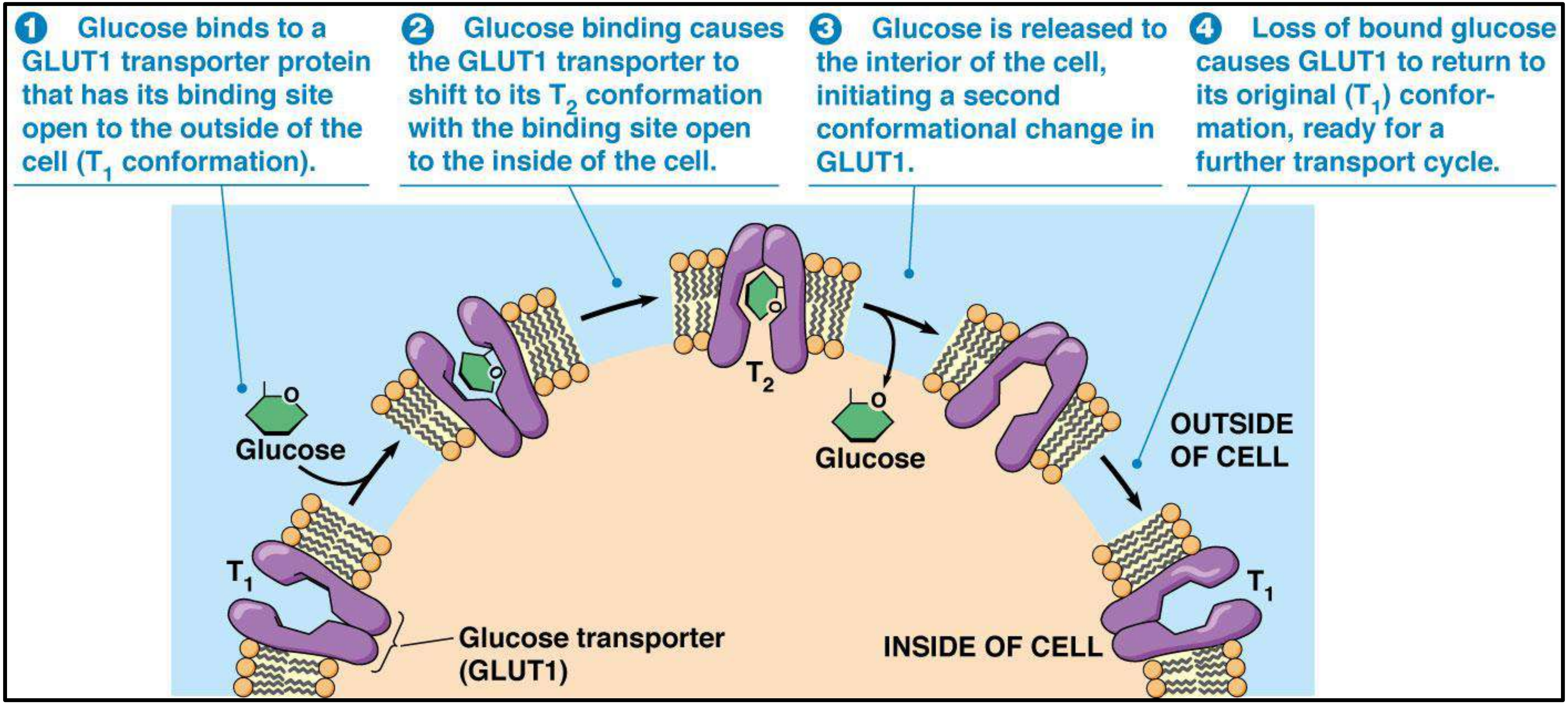
- The movement of molecules occurs down their concentration gradient.

- But polar molecules and charged ions cannot diffuse freely across the plasma membrane due to its hydrophobic nature.

- Examples: glucose, and amino acids can pass through specific carriers, while Na+, K+, Ca+2 and Cl- can pass through channels.



Cellular Transport



Facilitated diffusion of glucose through specific carrier called glucose transporter (GLUT1)

Cellular Transport

C) Osmosis

- **It is the simple diffusion of water molecules across a selectively permeable membrane.**
- **The net movement of water molecules through the membrane is from a solution of high water content to an area of low water content.**
- **There are three types of solutions:**

   1. **Isotonic solution which is a solution with equal concentration of its contents.**
   2. **Hypertonic solution which is a solution with higher concentration of solutes outside the cell than inside the cell.**

- ***When a cell is immersed into a hypertonic solution, water flows out of the cell in order to balance the concentration of the solutes.***

   3. Hypotonic solution which has a lower concentration of solutes outside the cell than inside the cell.

- ***When a cell is immersed into a hypotonic solution, water flows into the cell in order to balance the concentration of the solutes.***

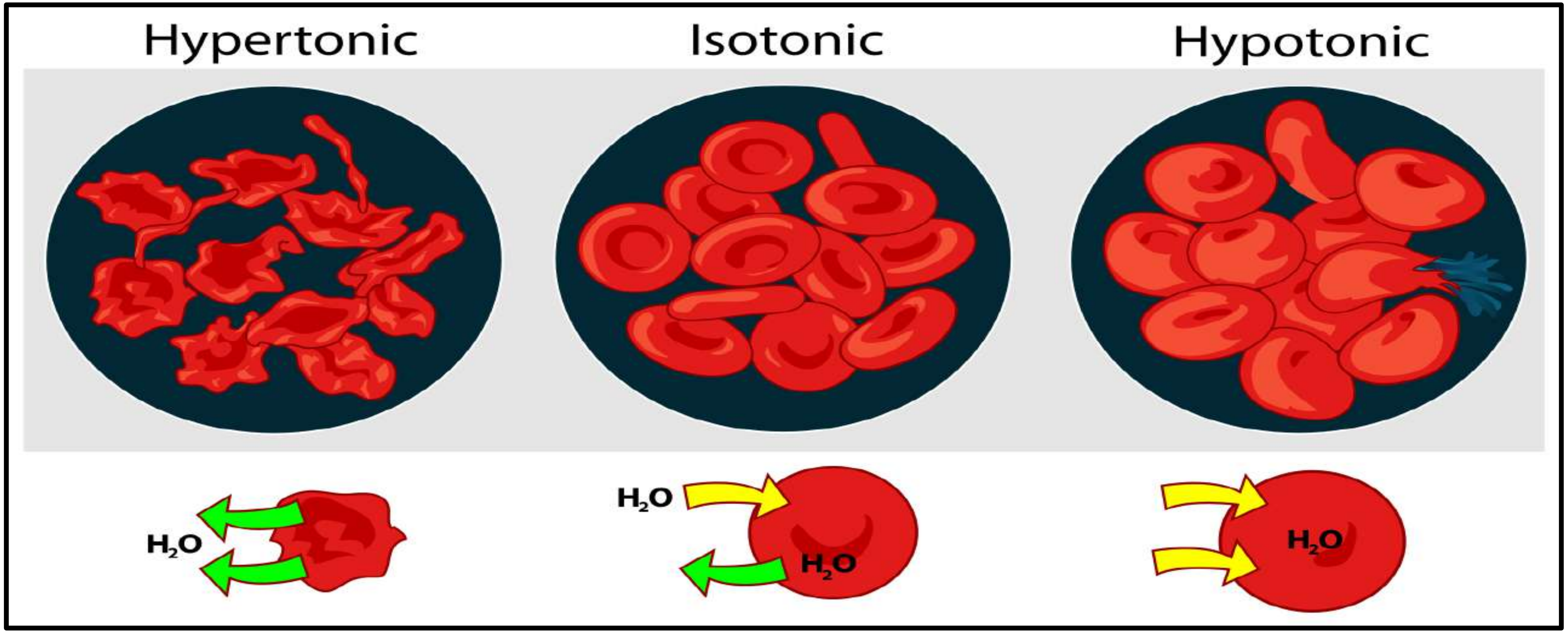
Cellular Transport

<u>Effect of tonicity on the cells without cell wall</u>

1. When the animal cell is immersed into isotonic solution, water will move equally in both directions.

2. When the animal cell is immersed into a hypertonic solution, the cell will lose water, shrink and may die.

3. When the animal cell is immersed into a hypotonic solution, water will enter the cell and it will swell, rupture and die.



Cellular Transport

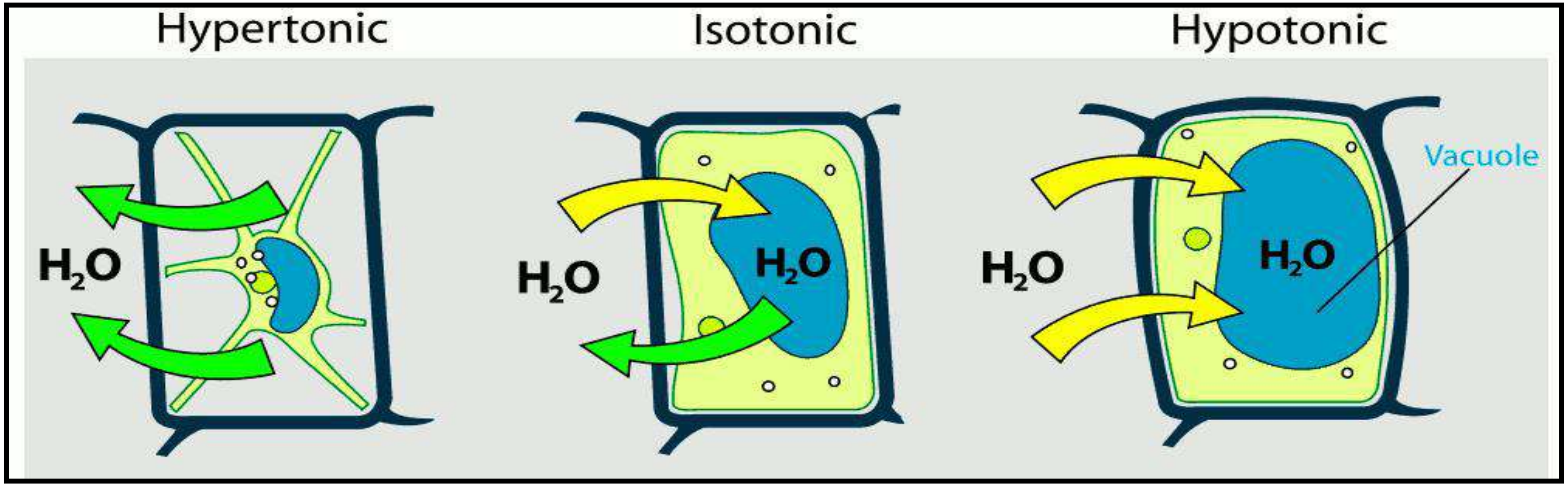
<u>Effect of tonicity on the cells with cell wall</u>

1. When the plant cell is immersed into isotonic solution, water will move equally in both directions.

2. When the plant cell is immersed into a hypertonic solution, cell membrane pulls away from the cell wall (a condition known as plasmolysis).

The reverse process is deplasmolysis which results from putting the cell in hypotonic solution.

3. When the plant cell is immersed into a hypotonic solution, cell membrane pushes against the cell wall (a condition known as turgor).



Cellular Transport

2. Active transport

- It is the movement of all types of molecules across the cell membrane against their concentration gradient (from low to high concentration).

- This type of transport needs two requirements:

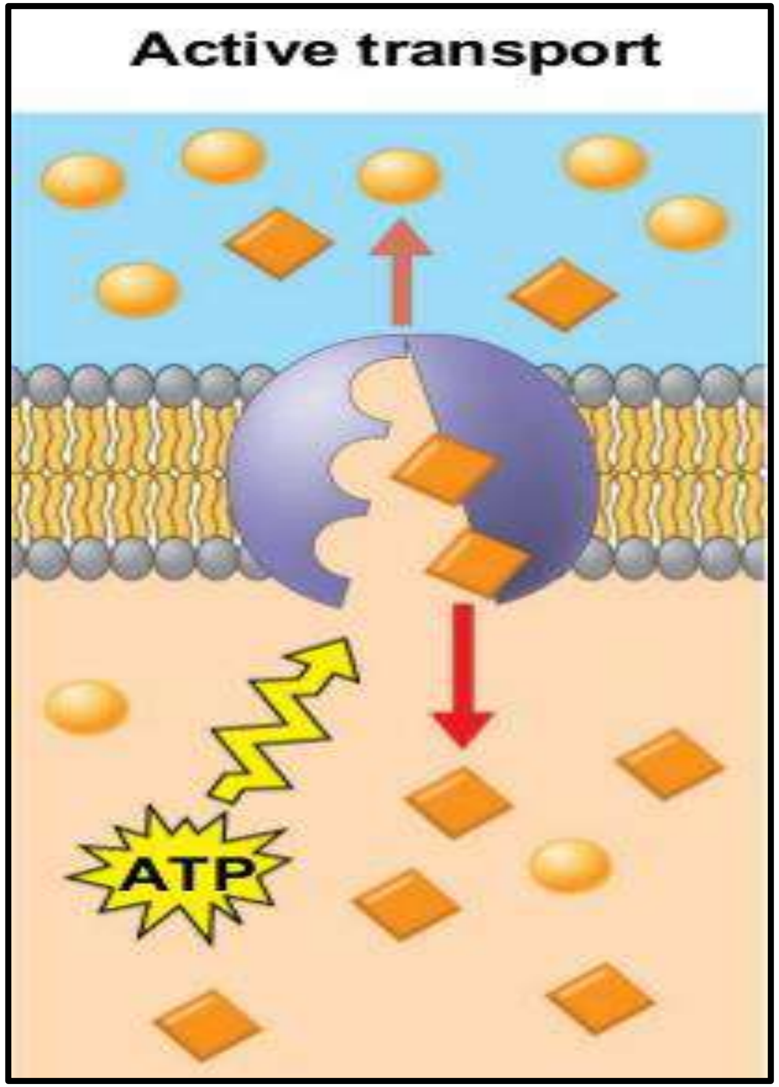
  a. Specific transporters

  b. Energy

- There are two types of active transport:

  a. Primary active transport (direct active transport).

  b. Secondary active transport (coupled transport).



Cellular Transport

2. Active transport

a. Primary active transport (direct active transport).

- It is the transport of molecules across a cell membrane against their concentration gradient by direct use of ATP and special transporters.
- Most of enzymes involved in this type of transport are transmembrane ATPase enzymes.
- Substances that are transported across the cell membrane by primary active transport include ions, such as Na^+, K^+, Mg^{2+}, and Ca^{2+}.
- These charged particles require ion pumps or ion channels to cross membranes.
- One of the best examples of ATPase is sodium-potassium pump (Na^+/K^+-ATPase).
- In general, the cells have low levels of sodium ions and high levels of potassium ions within the cell (intracellular).
- Both sodium and potassium ions play a critical role in cellular action potential.

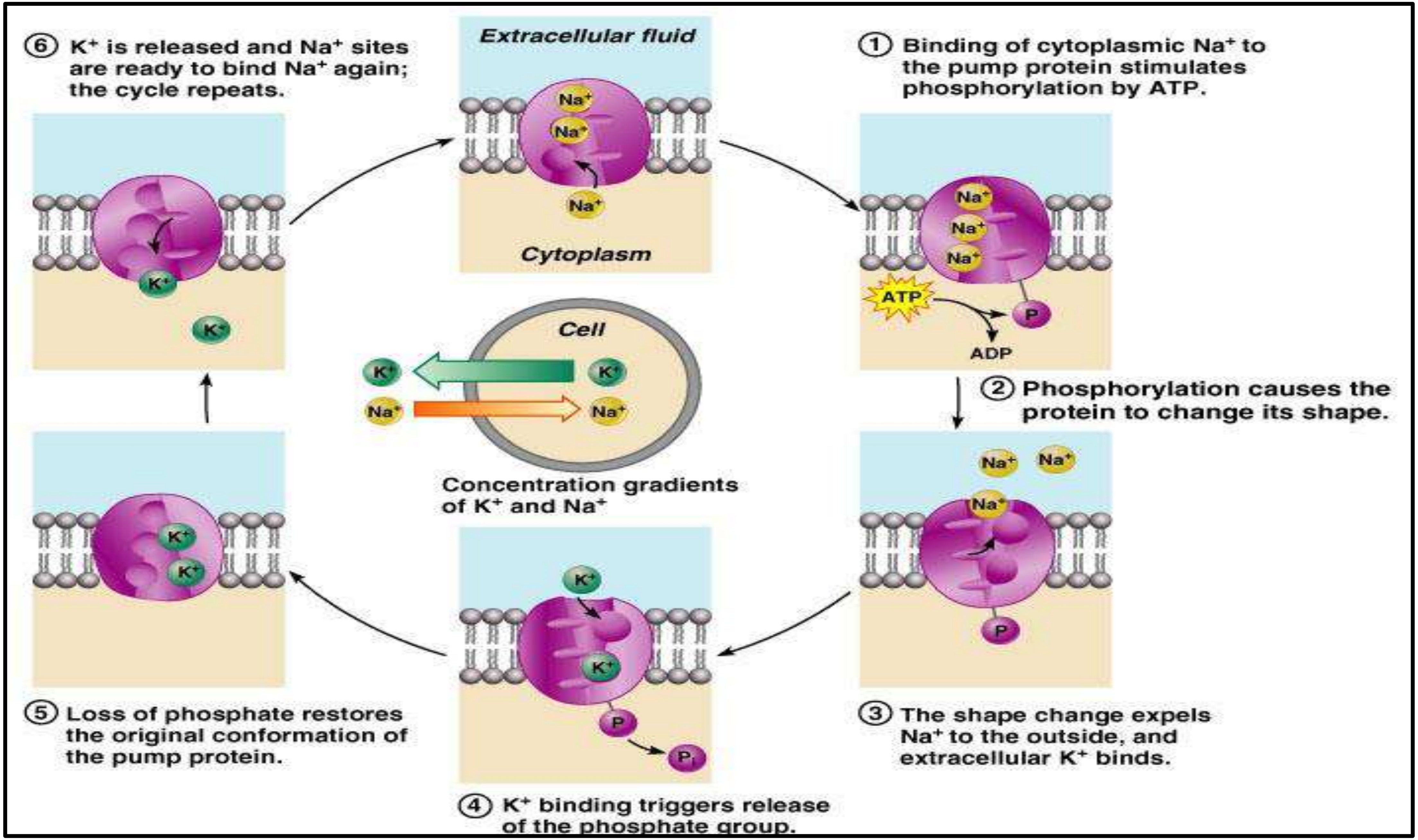
Cellular Transport

2. Active transport

Mechanism of action of Na^+/K^+-ATPase

- **To perform an action potential, Na^+ ions enter the cell while K^+ ions leave the cell.**
- **To prepare the cell for a new action potential, the cell pumps three Na^+ ions out of the cell, and pumps two K^+ ions into the cell using Na^+/K^+-ATPase pump as the following:**
  - **The intracellular site of the pump has a high affinity for Na^+ ions where three intracellular Na^+ ions bind to the pump.**
  - **Binding of Na^+ ions to the pump allow ATP molecule to bind to its binding site associated with the pump which leads to phosphorylation of the pump, and releasing of ADP.**
  - **Phosphorylation of the pump leads to a conformational change in its shape, releasing the Na^+ ions outside the cell.**
  - **This conformational change increases the affinity for K^+ ions, where two K^+ ions bind to the protein.**
  - **Subsequently, the phosphate group detaches from the pump (dephosphorylation), returning the pump to its previous conformational state, allowing the K^+ ions to enter into the cell.**
  - **The process starts again by binding the ATP to the pump.**

Cellular Transport: Mechanism of action of Na^+/K^+-ATPase



Cellular Transport

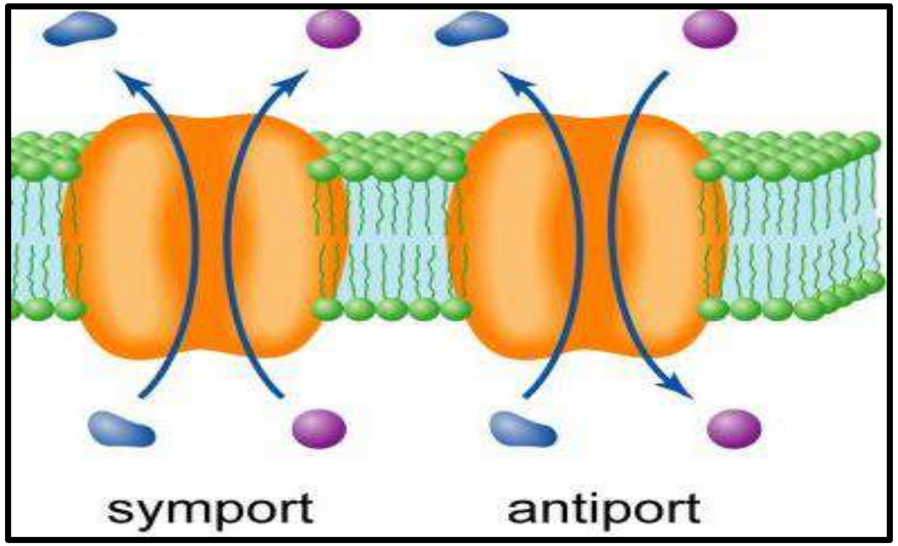
2. Active transport

b. Secondary active transport (coupled transport)

- **It is the transport of molecules across a cell membrane against their concentration gradient by using special transporters and energy, but there is no direct coupling of ATP as the primary active transport.**
- **This type depends on the energy produced by the electrochemical potential difference created by pumping ions in/out of the cell, mainly sodium ions which is called in this type as co-transporter.**
- **There are two type of secondary active transport depending on whether the substances move in the same or opposite directions:**

  1. Co-transport (symport)

  2. Counter transport (antiport)



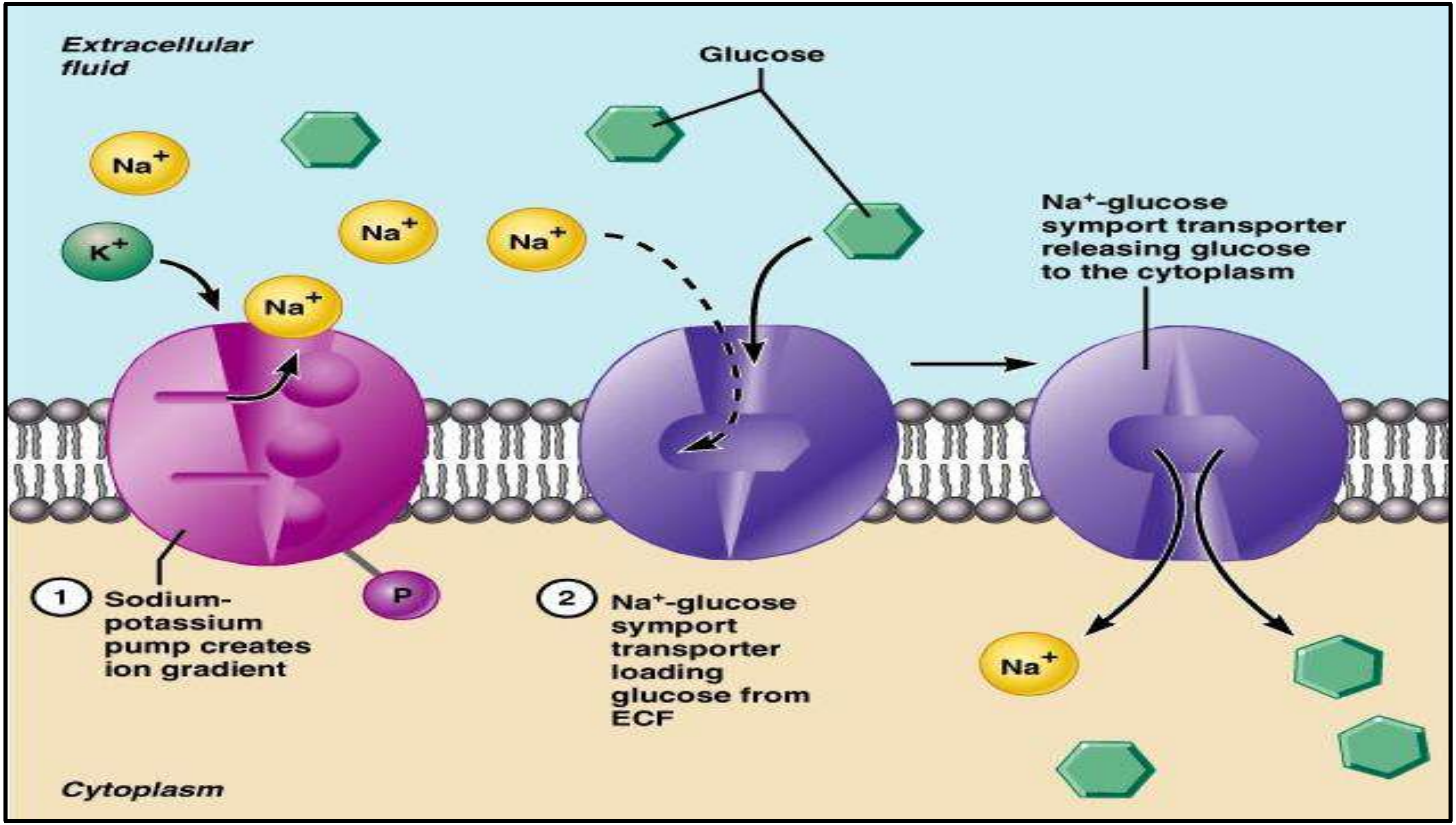
Cellular Transport

2. Active transport

b. Secondary active transport (coupled transport)

1. Co-transport (symport)

- **In symport type, the energy produced from the movement of ions from high to low concentration is used to move other molecules from low to high concentration (against their concentration gradient).**
- **Both molecules are transported in the same direction.**
- **An example is sodium-glucose linked transporter (SGLT), which co-transports one glucose molecule into the cell for every two sodium ions that move into the cell.**



Cotransport (symport): Na^+/glucose symporter

Cellular Transport

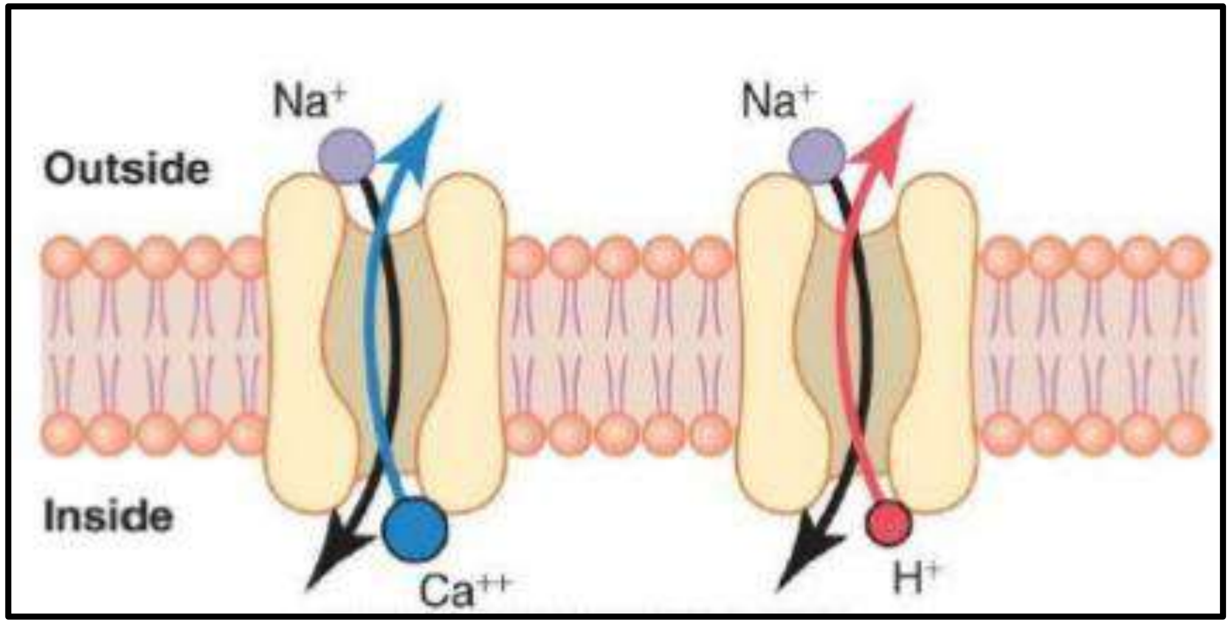
2. Active transport

b. Secondary active transport (coupled transport)

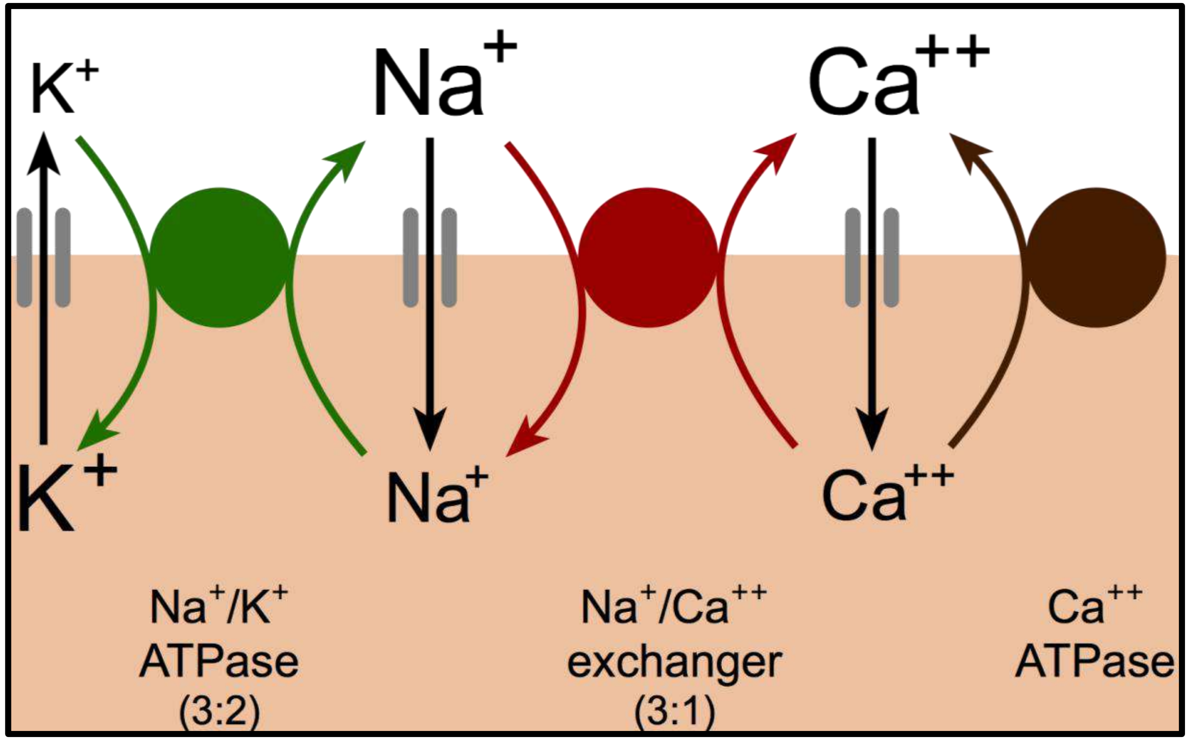
2. Counter transport (antiport)

- In antiport type, the energy produced from the movement of ions from high to low concentration is used to move other molecules from low to high concentration (against their concentration gradient).
- In this type, both molecules are transported in opposite directions across a membrane.
- Examples:
  - Sodium-calcium exchanger or antiporter which allows three sodium ions to enter into the cell, while one calcium ion out of the cell.
  - Sodium-hydrogen exchanger or antiporter which allows one sodium ion to enter into the cell, while one hydrogen ion out of the cell.

Cellular Transport



Counter transport (antiport)



Cellular Transport

3. Bulk transport

- **Bulk transport is an energy-requiring process by which too large molecules or large amount of small molecules and water move into or out of the cells.**

- **It includes both endocytosis and exocytosis processes.**

a. Endocytosis

- **Process by which the cell engulfs macromolecules, large particles (bacteria) and large amount of water.**

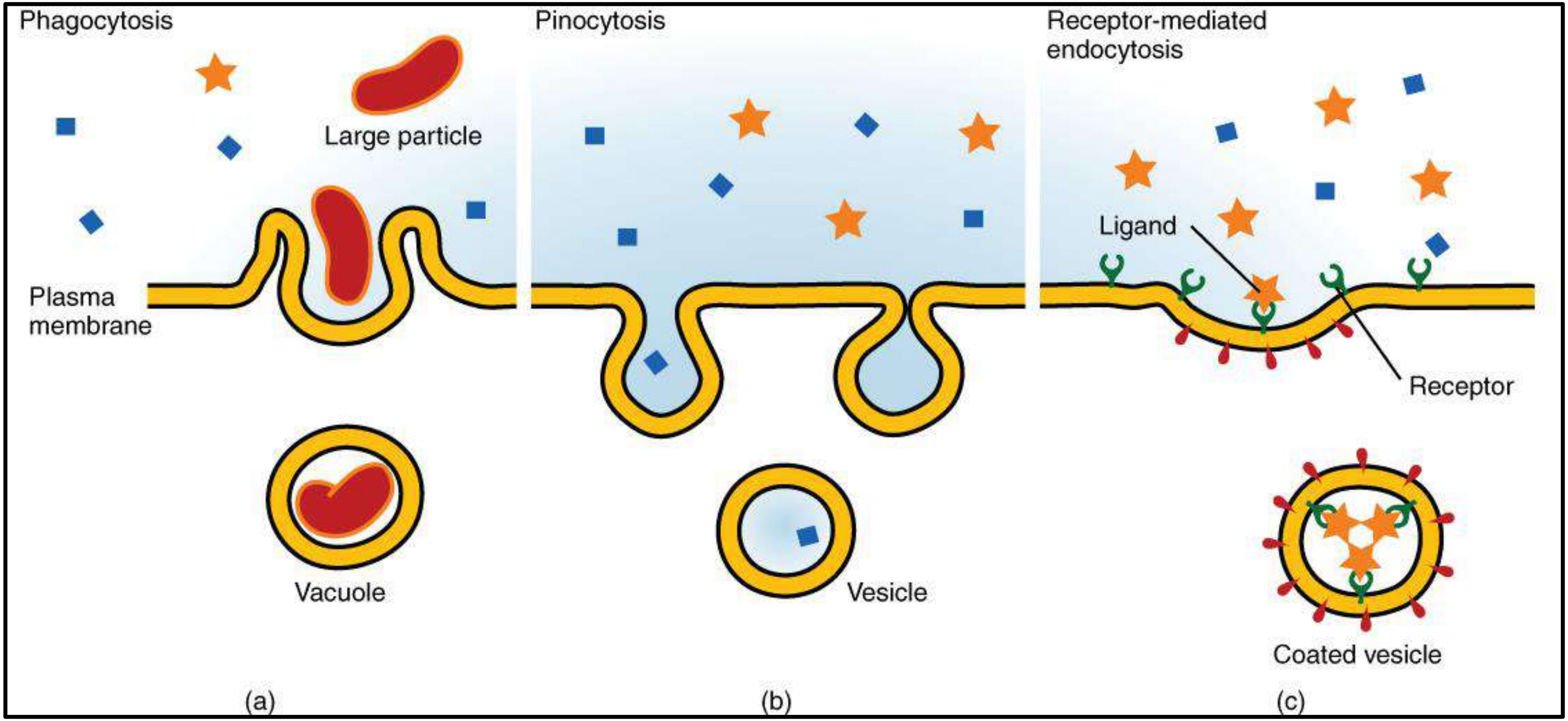
- **It includes the following types:**

  1. Phagocytosis: engulfment of large particles as bacteria.

  2. Pinocytosis: engulfment of large amount of water or large quantity of small particles suspended in extracellular fluid.

  3. Receptor-mediated endocytosis: engulfment of macromolecules as proteins and cholesterol.

Types of endocytosis



Cellular Transport

3. Bulk transport

b. Exocytosis

- **It is a process by which the cells discharge the contents of their secretory vesicles out of the cell into the extracellular space.**