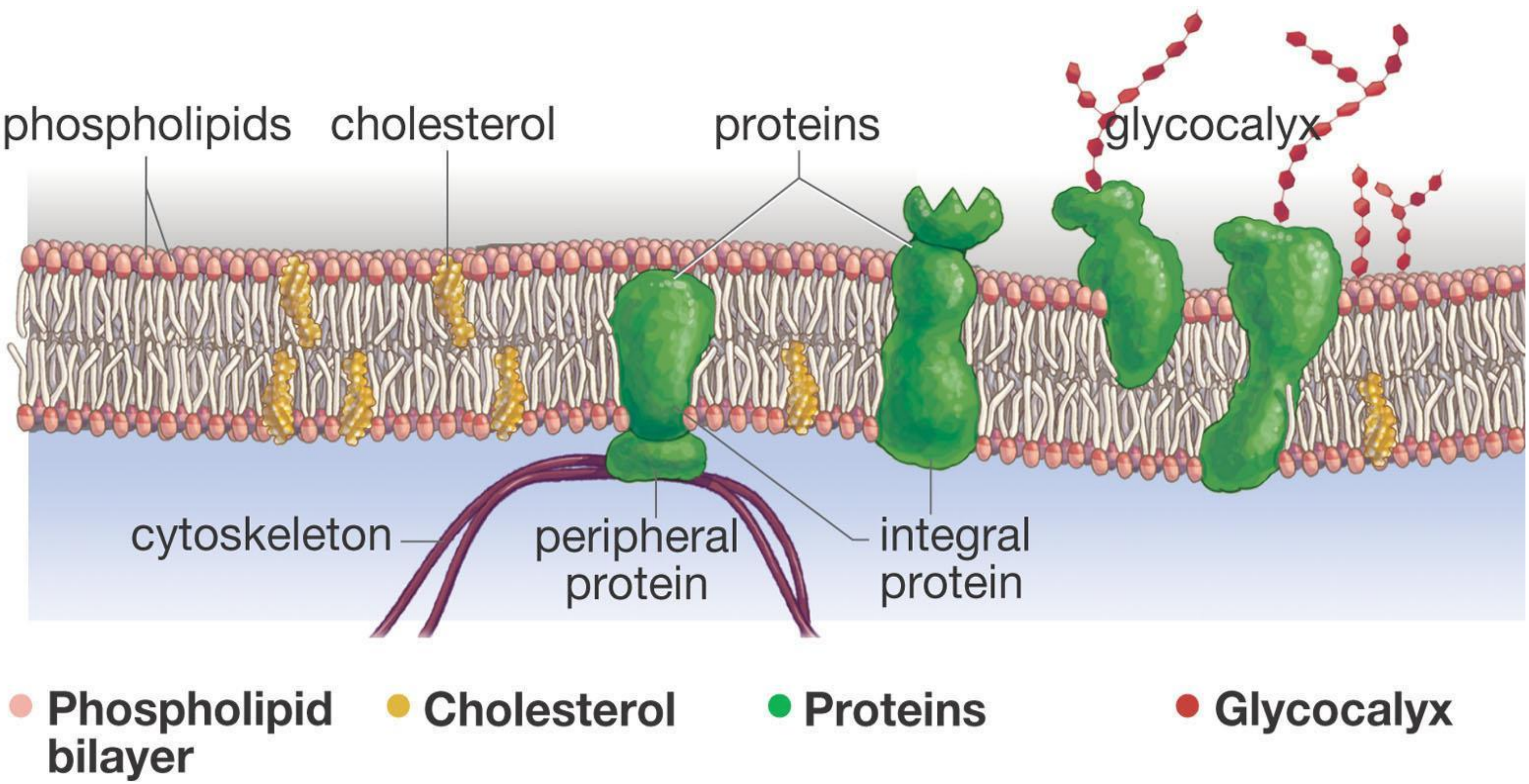
Membrane Transport



Active Transport

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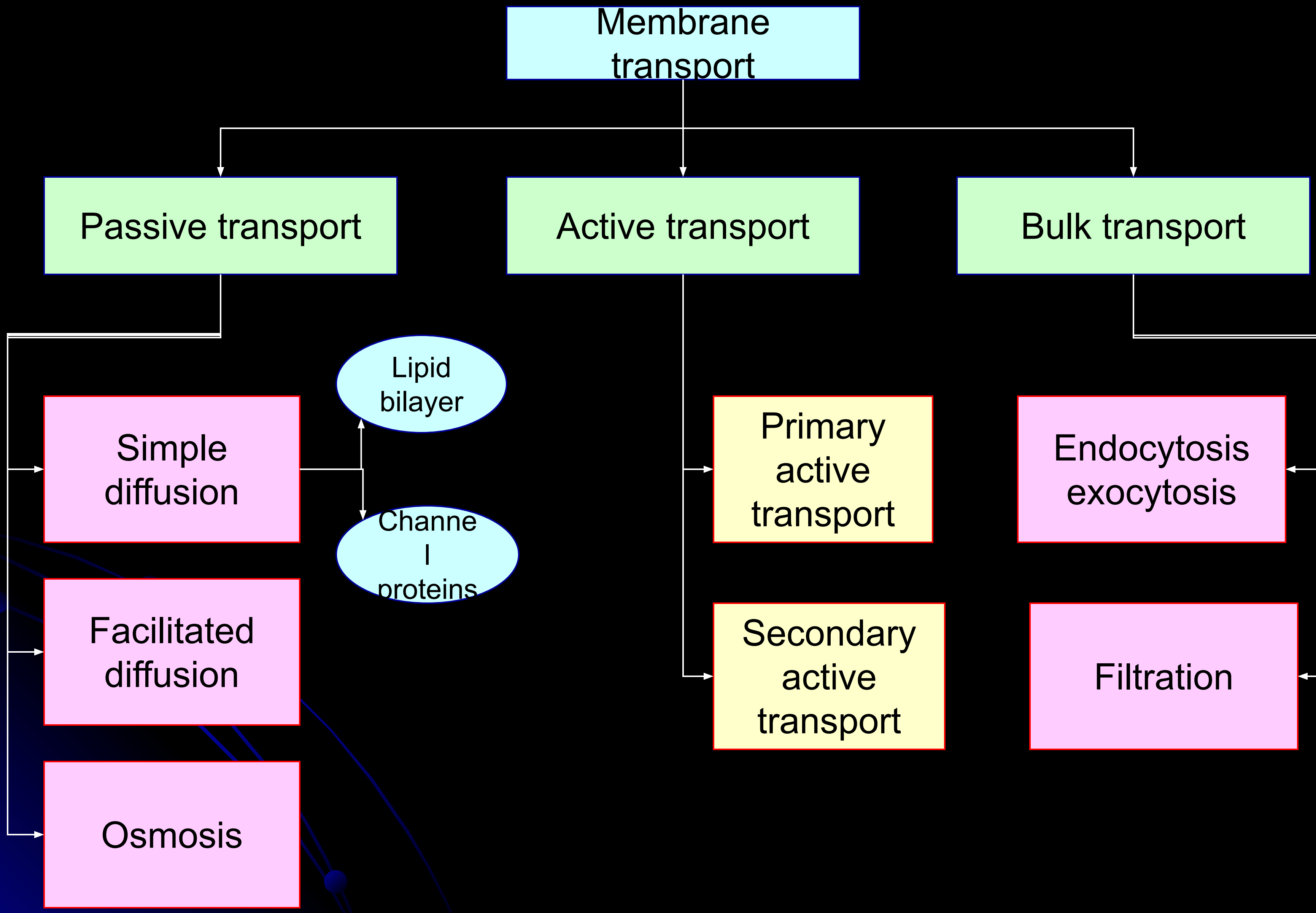
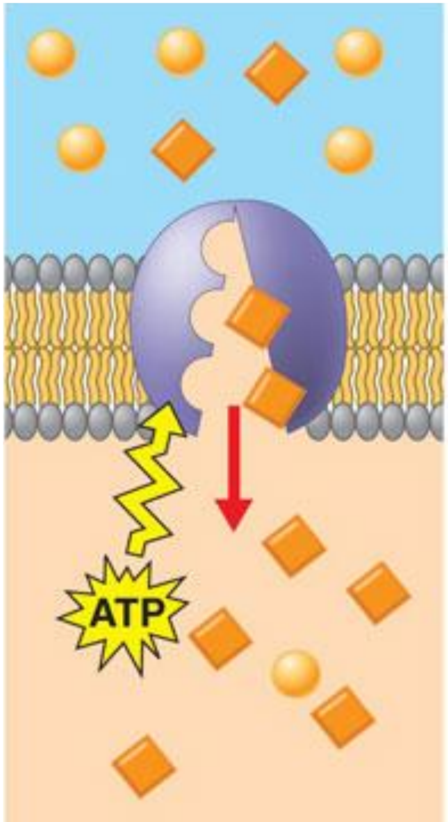
LEARNING OBJECTIVE

- At the end of the lecture ,the students must be able to
- Define active transport
- Describe the types of active transport
- Explain primary active transport with examples
- Discuss sodium –potassium pump
- Explain secondary active transport :co transport and counter transport.


Membrane transport
Passive transport
Active transport
Bulk transport
Simple diffusion
Lipid bilayer
Channel proteins
Facilitated diffusion
Osmosis
Primary active transport
Secondary active transport
Endocytosis exocytosis
Filtration

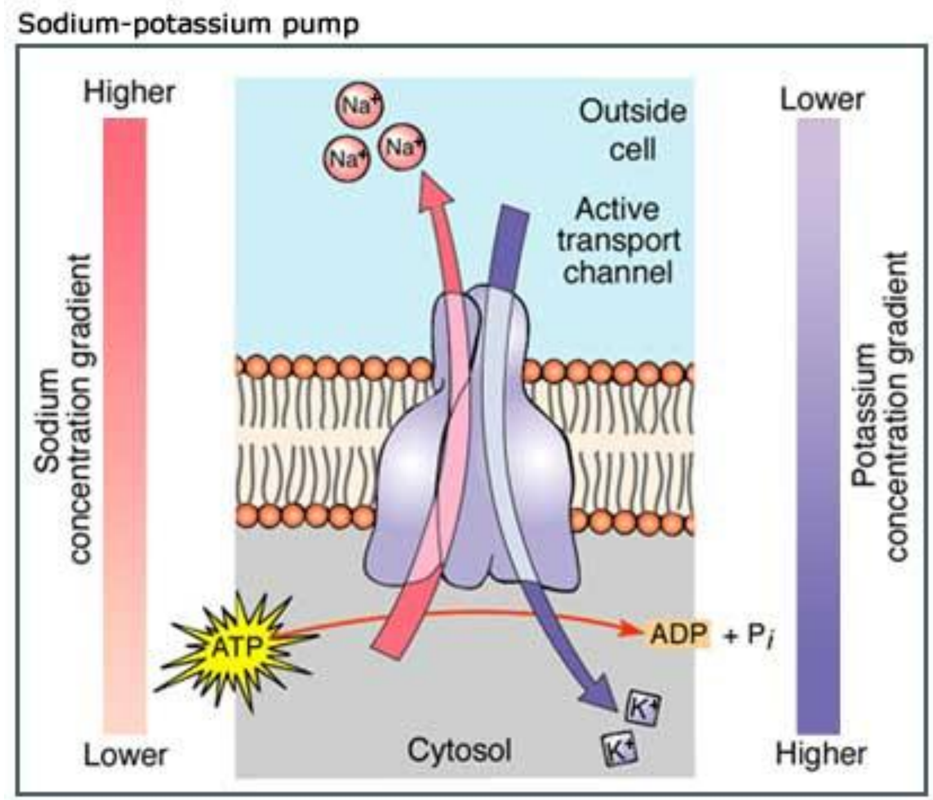
Active Transport

- Transport of substances from low to high concentration gradient
- Energy utilized – ATP
- Carrier protein needed
- These transport proteins are also called ‘pumps’
- Substances, which are transported actively, may be in ionic and non-ionic form. Substances in ionic form are sodium potassium
- calcium, hydrogen, chloride iodide Substances in non-ionic form are glucose, amino acids urea etc.



Active Transport

- The ‘**pumps**’ breakdown ATP with the help of enzyme **ATPase**
- And utilize the energy released for transport of substances
- From low to high concentration

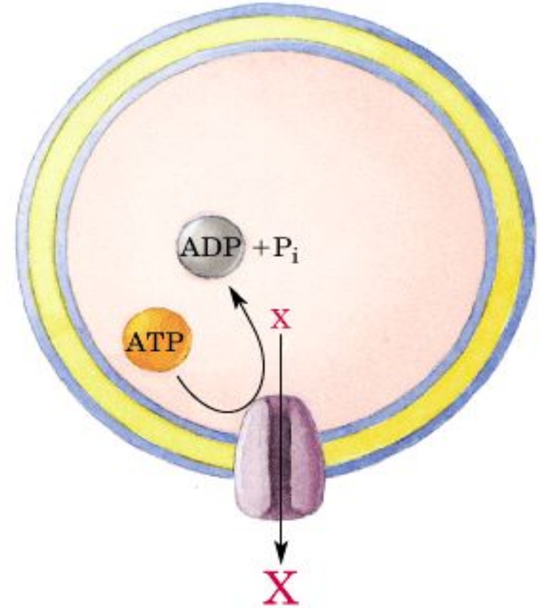


CARRIER PROTEINS OF ACTIVE TRANSPORT

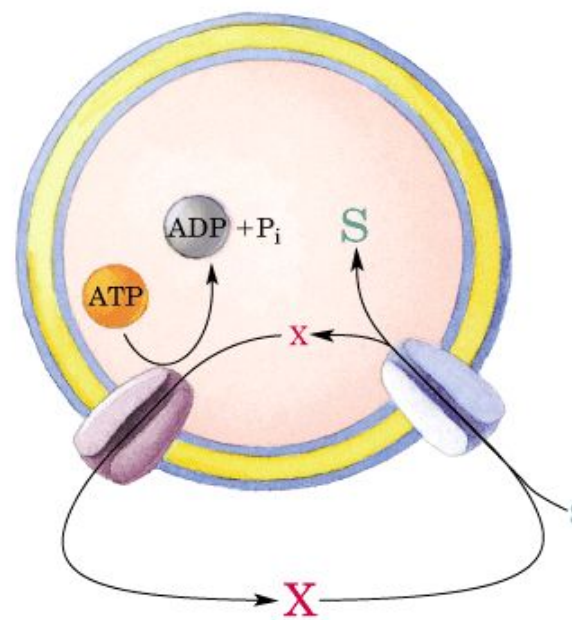
- Carrier proteins involved in active transport are of two types:
- **1. Uniport** Carrier protein that carries only one substance in a single direction is called uniport. It is also known as uniport pump.
- **2. Symport or antiport**. is the carrier protein that transports two substances at a time. Carrier protein that transports two different substances in the same direction is called symport or symport pump. Carrier protein that transports two different substances in opposite directions is called antiport or antiport pump.

Active Transport - Types

- **Primary active transport**
- In primary active transport, the energy is derived directly from breakdown of adenosine triphosphate (ATP) or some other high-energy phosphate compound.Carrier protein has ATPase activity
- **Secondary active transport**
- In secondary active transport, the energy is derived secondarily from energy that has been stored in the form of ionic concentration differences of secondary molecular or ionic substances between the two sides of a cell membrane, created originally by primary active transport. In both instances,transport depends on carrier proteins that penetrate through the cell membrane.Carrier protein does not have ATPase activity,Utilizes energy indirectly.



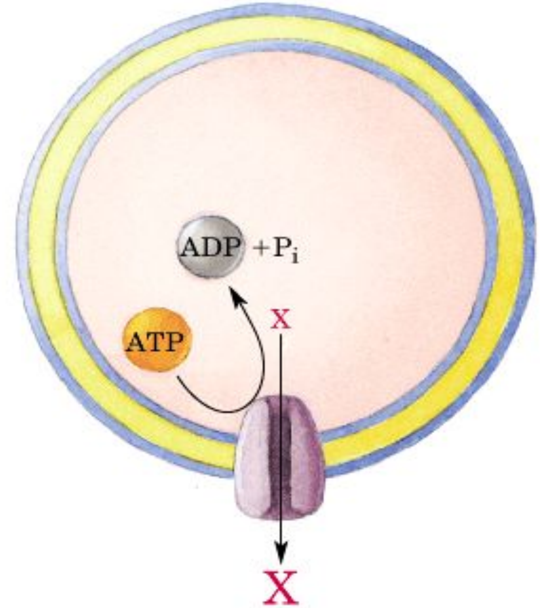
Primary active transport



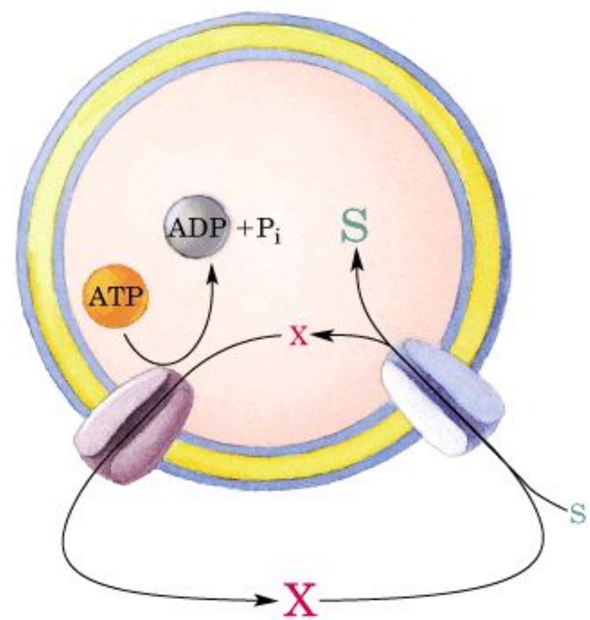
Secondary active transport

Active Transport - Types

- Two types
  - **Co-transport**
  - **Counter-transport**

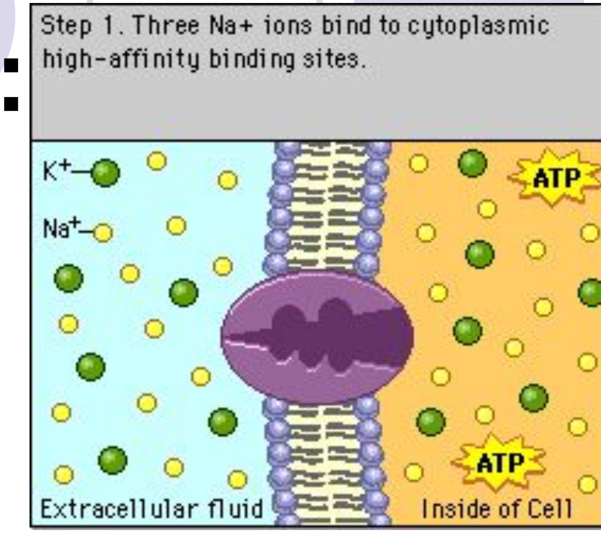


Primary active transport

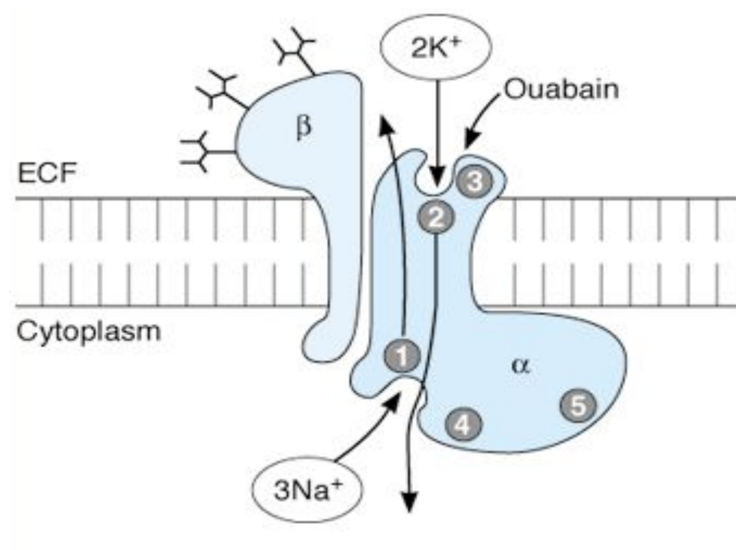


Secondary active transport

Primary Active Transport of Sodium and Potassium:



- Sodium and potassium ions are transported across the cell membrane by means of a common carrier protein called sodium-potassium (Na+-K+) pump. It is also called Na+-K+ ATPase pump or Na+-K+ ATPase.
- This pump transports sodium from inside to outside the cell and potassium from outside to inside the cell. This pump is present in all the cells of the body.
- Na+-K+ pump is responsible for the distribution of sodium and potassium ions across the cell membrane and the development of resting membrane potential.



Structure of Na+-K+ pump

- Carrier protein that constitutes Na+-K+ pump is made up of two protein subunit molecules, an α-subunit with a molecular weight of 100,000 and a β-subunit with a molecular weight of 55,000.
- Transport of Na+ and K+occurs only by α-subunit.
- The β-subunit is a glycoprotein the function of which is not clear.
- α-subunit of the Na+-K+ pump has got six sites:

i. Three receptor sites for sodium ions on the inner (towards cytoplasm) surface of the protein molecule

ii. Two receptor sites for potassium ions on the outer (towards ECF) surface of the protein molecule

iii. One site for enzyme adenosine triphosphatase (ATPase), which is near the sites for sodium.

Mechanism of action of Na+-K+ pump

- Three sodium ions from the cell get attached to the receptor sites of sodium ions on the inner surface of the carrier protein.
- Two potassium ions outside the cell bind to the receptor sites of potassium ions located on the outer surface of the carrier protein.
- Binding of sodium and potassium ions to carrier protein activates the enzyme ATPase. ATPase causes breakdown of ATP into adenosine diphosphate (ADP) with the release of one high energy phosphate.
- Now, the energy liberated causes some sort of conformational

change in the molecule of the carrier protein. Because of this, the outer surface of the molecule (with potassium ions) now faces the inner side of the cell. And, the inner surface of the protein molecule (with sodium ions) faces the outer side of the cell.

- dissociation and release of the ions take place so that the sodium ions are released outside the cell (ECF) and the potassium ions are released inside the cell (ICF).

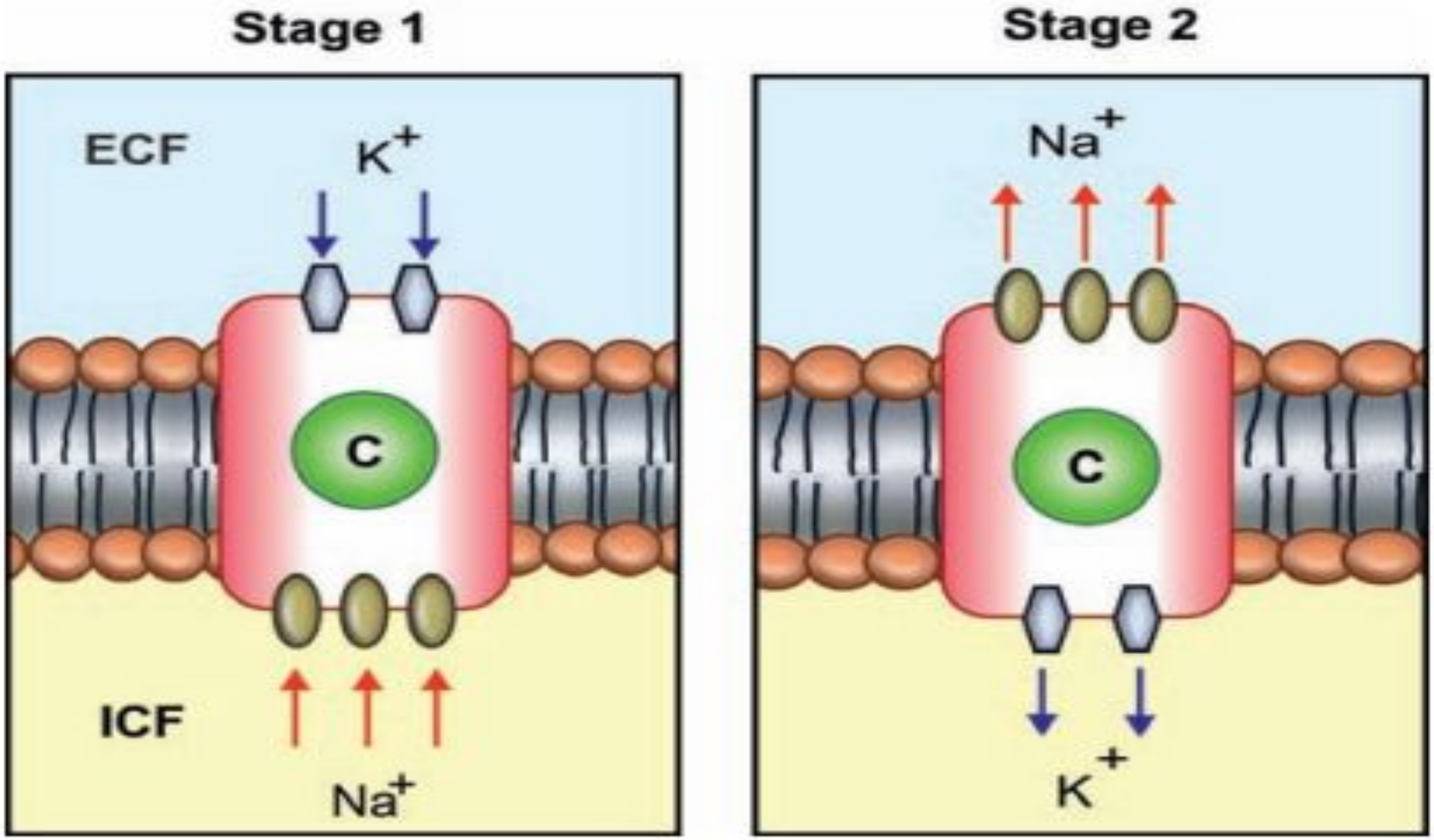
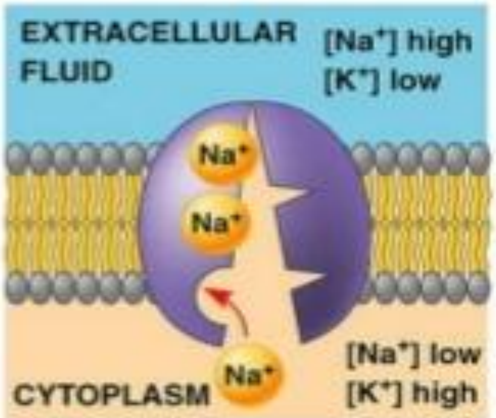
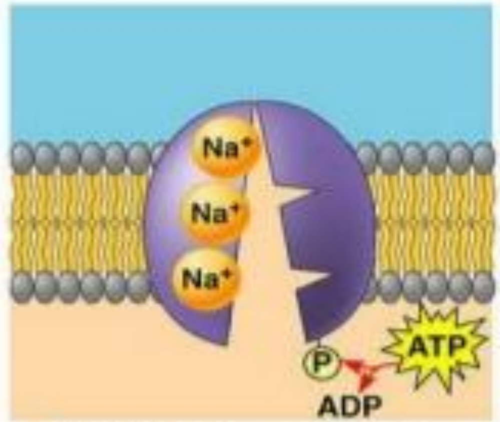


FIGURE 3.4: Hypothetical diagram of sodium-potassium pump. C = carrier protein. Stage 1: Three Na^+ from ICF and two K^+ from ECF bind with 'C'. Stage 2: Conformational change occurs in 'C' followed by release of Na^+ into ECF and K^+ into ICF

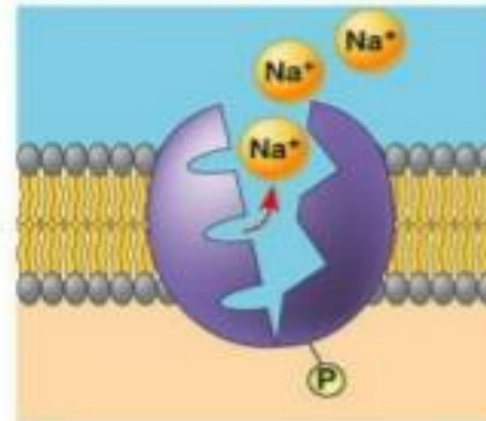
Sodium-Potassium Pump



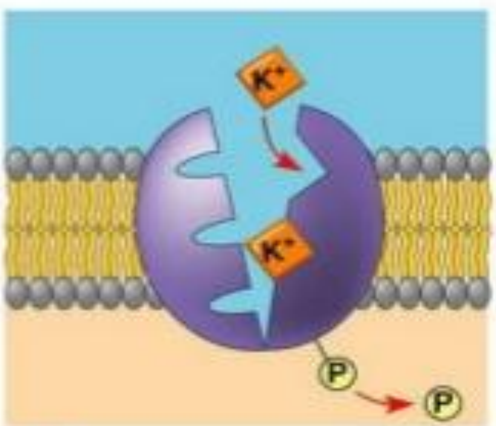
1 Cytoplasmic Na^+ binds to the sodium-potassium pump.



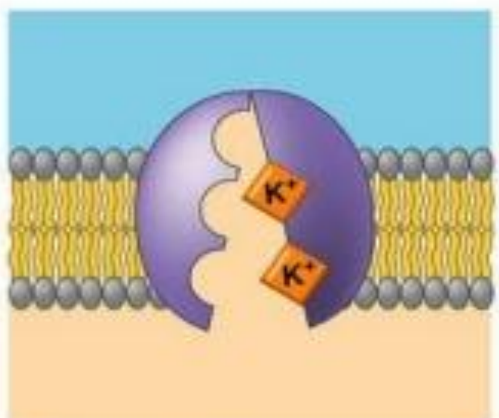
2 Na^+ binding stimulates phosphorylation by ATP.



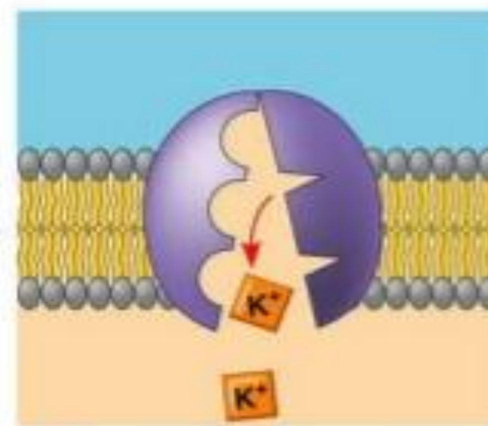
3 Phosphorylation causes the protein to change its conformation, expelling Na^+ to the outside.



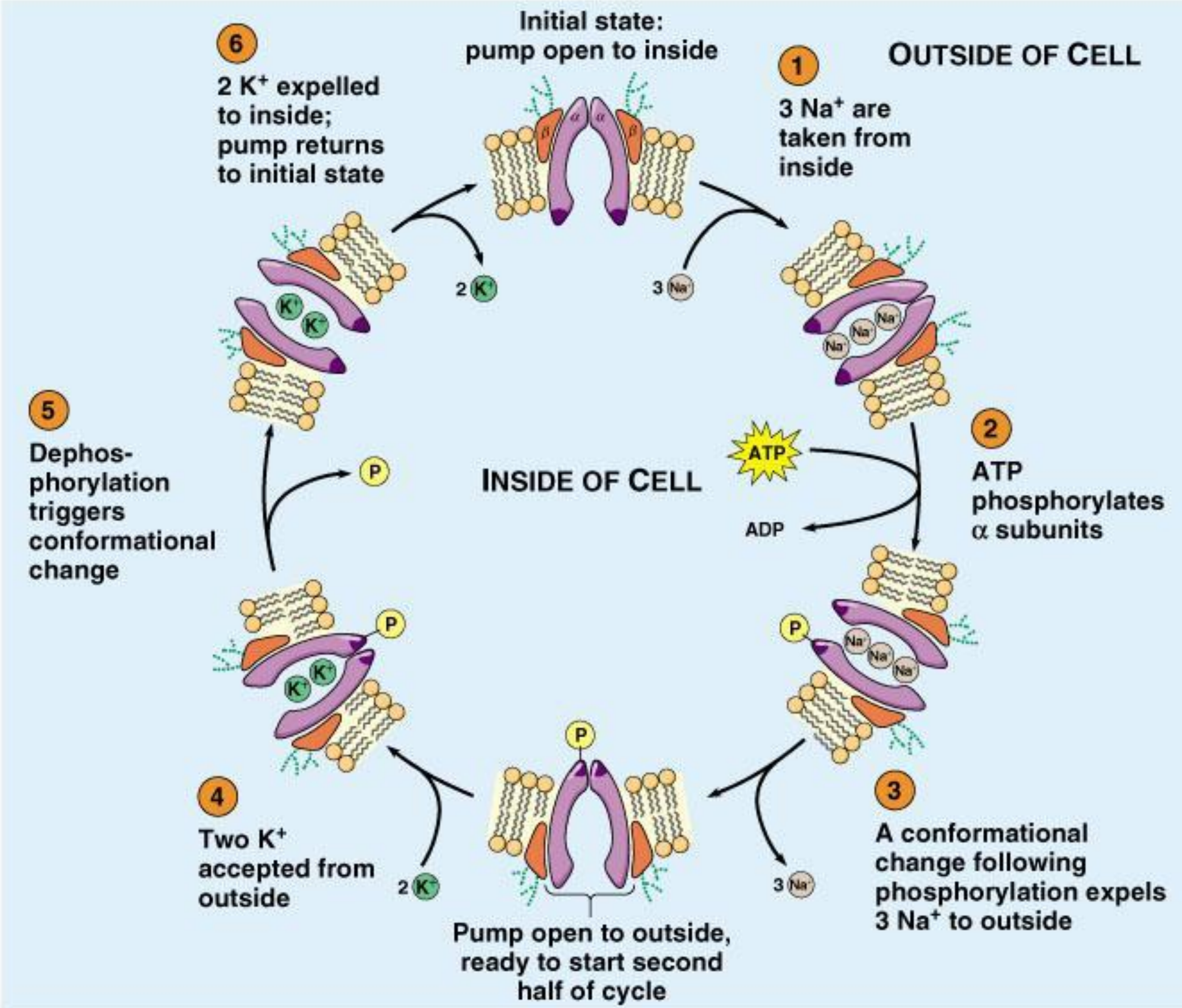
4 Extracellular K^+ binds to the protein, triggering release of the phosphate group.



5 Loss of the phosphate restores the protein's original conformation.



6 K^+ is released and Na^+ sites are receptive again; the cycle repeats.

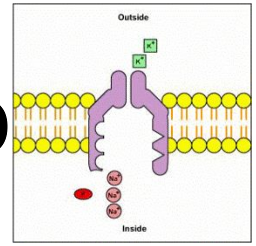


Initial state: pump open to inside
OUTSIDE OF CELL
1
3 Na+ are taken from inside
2
ATP phosphorylates α subunits
ATP
ADP
3
A conformational change following phosphorylation expels 3 Na+ to outside
3 Na+
Pump open to outside, ready to start second half of cycle
P
4
Two K+ accepted from outside
2 K+
5
Dephos-phorylation triggers conformational change
INSIDE OF CELL
6
2 K+ expelled to inside; pump returns to initial state
2 K+
3 Na+

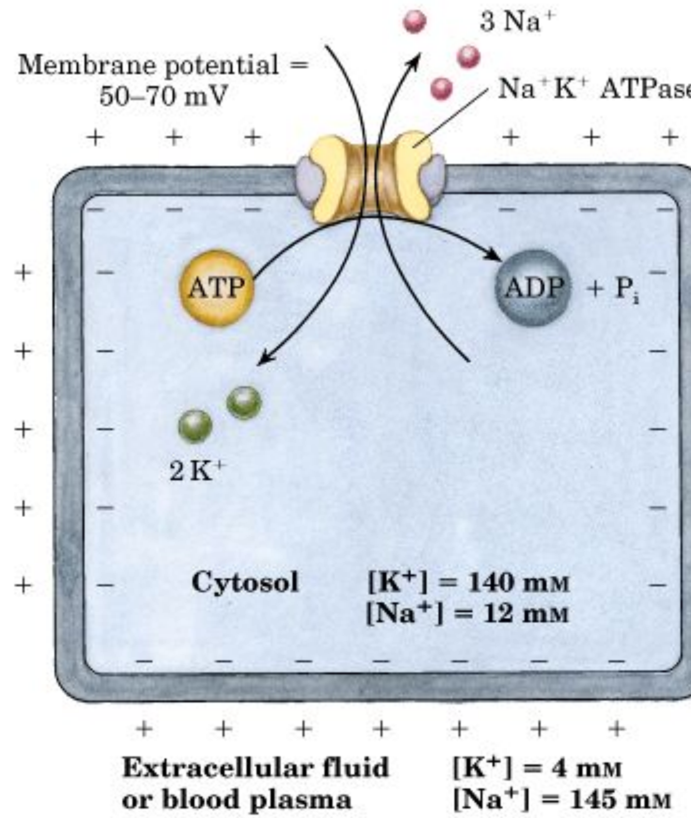
The Na+-K+Pump Is Important for Controlling Cell Volume.

- One of the most important functions of the Na+-K+ pump is to control the volume of each cell.
- Without function of this pump, most cells of the body would swell until they burst.
- If a cell begins to swell for any reason, the Na+-K+pump is automatically activated, moving still more ions to the exterior and carrying water with them.
- Therefore, the Na+-K+pump performs a continual surveillance role in maintaining normal cell volume.

Na^+- K^+ Pump



1. Maintains Na^+ and K^+ difference across the cell membrane
2. Electrogenic pump
   Establishes a negative electrical voltage inside the cell
3. Controls cell volume
   Pumps Na^+ out thus preventing osmosis of water
4. Heat production



Electrogenic activity of Na+-K+ pump

- Na+-K+ pump moves three sodium ions outside the cell and two potassium ions inside cell. Thus, when the pump works once, there is a net loss of one positively charged ion from the cell. Continuous activity of the sodium-potassium pumps causes reduction in the number of positively charged ions inside the cell leading to increase in the negativity inside the cell. This is called the **electrogenic activity of Na+-K+ pump**

Primary Active Transport of Calcium Ions & Hydrogen ions

- Calcium is actively transported from inside to outside the cell by calcium pump. Calcium pump is operated by a separate carrier protein. Energy is obtained from ATP by the catalytic activity of ATPase. Calcium pumps are also present in some organelles of the cell such as sarcoplasmic reticulum in the muscle and the mitochondria of all the cells. These pumps move calcium into the organelles. **Transport of Hydrogen Ions**
- Hydrogen ion is actively transported across the cell membrane by the carrier protein called hydrogen pump. It also obtains energy from ATP by the activity of ATPase.
- The hydrogen pumps that are present in two important organs have some functional significance.

1. Stomach: Hydrogen pumps in parietal cells of the gastric glands are involved in the formation of hydrochloric acid.
2. Kidney: Hydrogen pumps in epithelial cells of distal convoluted tubules and collecting ducts are involved in the secretion of hydrogen ions from blood into urine.

Secondary active transport

- In this transport, ATP is not utilized as energy source.
- Secondary active transport is the transport of a substance with sodium ion, by means of a common carrier protein. When sodium is transported by a carrier protein, another substance is also transported by the same protein simultaneously, either in the same direction (of sodium movement) or in the opposite direction. Thus, the transport of sodium is coupled with transport of another substance.
- Types

co-transport, counter transport

Sodium Co transport

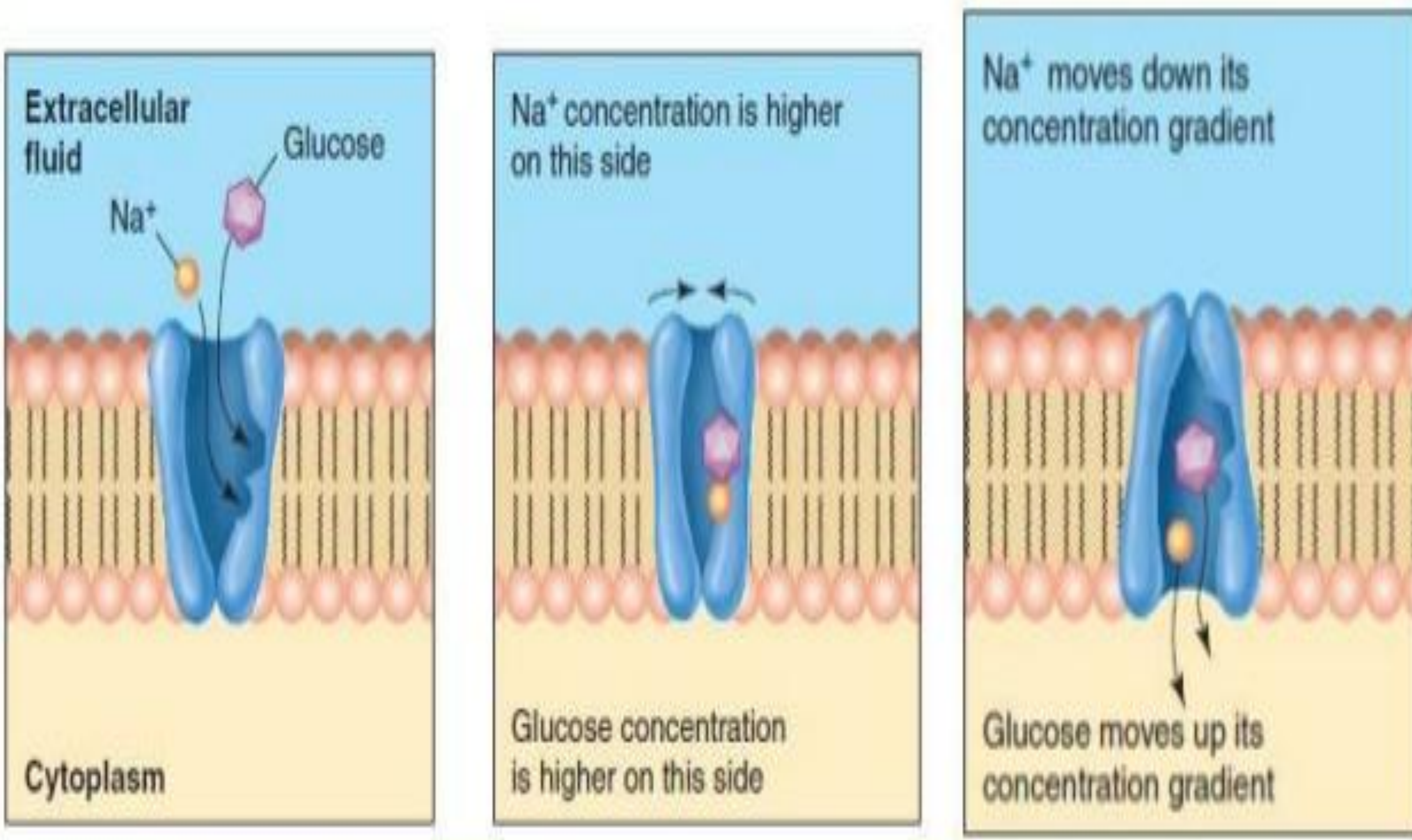
- When Na ions are transported out of the cells by primary active transport a large conc; gradient of Na develops.This represent store house of energy because excess Na always attempt to diffuse inside cell.Under appropriate conditions the diffusion energy of Na can pull other substance along with Na through cell membrane.This phenomenon is called co transport
- .Sodium cotransport is the process in which, along with sodium, another substance is transported by a carrier protein called **symport.** Energy for movement of sodium is obtained by breakdown of ATP. And the energy released by the movement of sodium is utilized for

movement of another substance. Substances carried by sodium cotransport are glucose, amino acids, chloride, iodine, iron and urate.

- Carrier protein for the sodium cotransport has two receptor sites on the outer surface. Among the two sites, one is for binding of sodium

and another site is for binding of other substance.

Sodium glucose co transport



Co transport

- One sodium ion and one glucose molecule from the ECF bind with the respective receptor sites of carrier

protein of the cell membrane. Now, the carrier protein is activated. It causes conformational changes in the carrier protein, so that sodium and glucose are released into the cell.

- Sodium cotransport of glucose occurs during absorption of glucose from the intestine and reabsorption of glucose from the renal tubule.
- The Na^+/glucose transporter is used to actively transport glucose out of the intestine and also out of the kidney tubules and back into the blood.

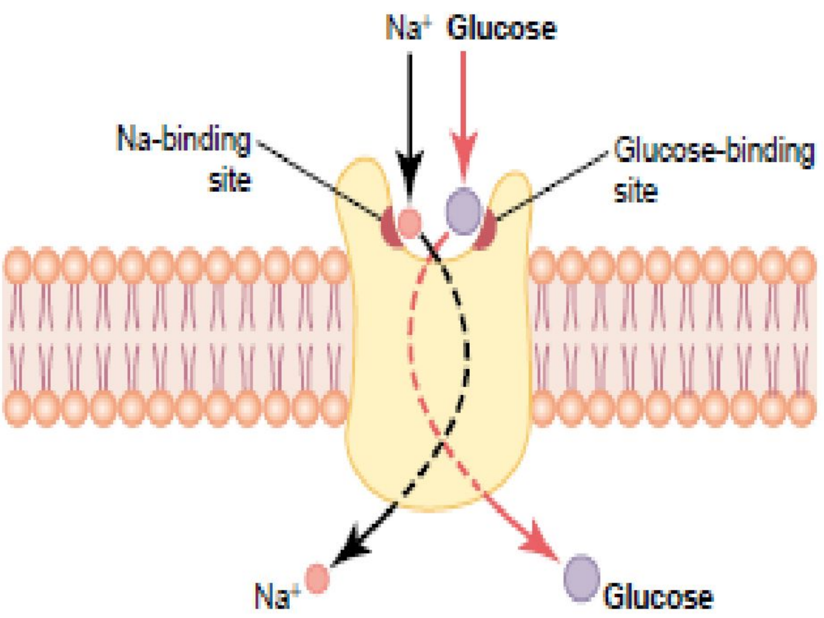


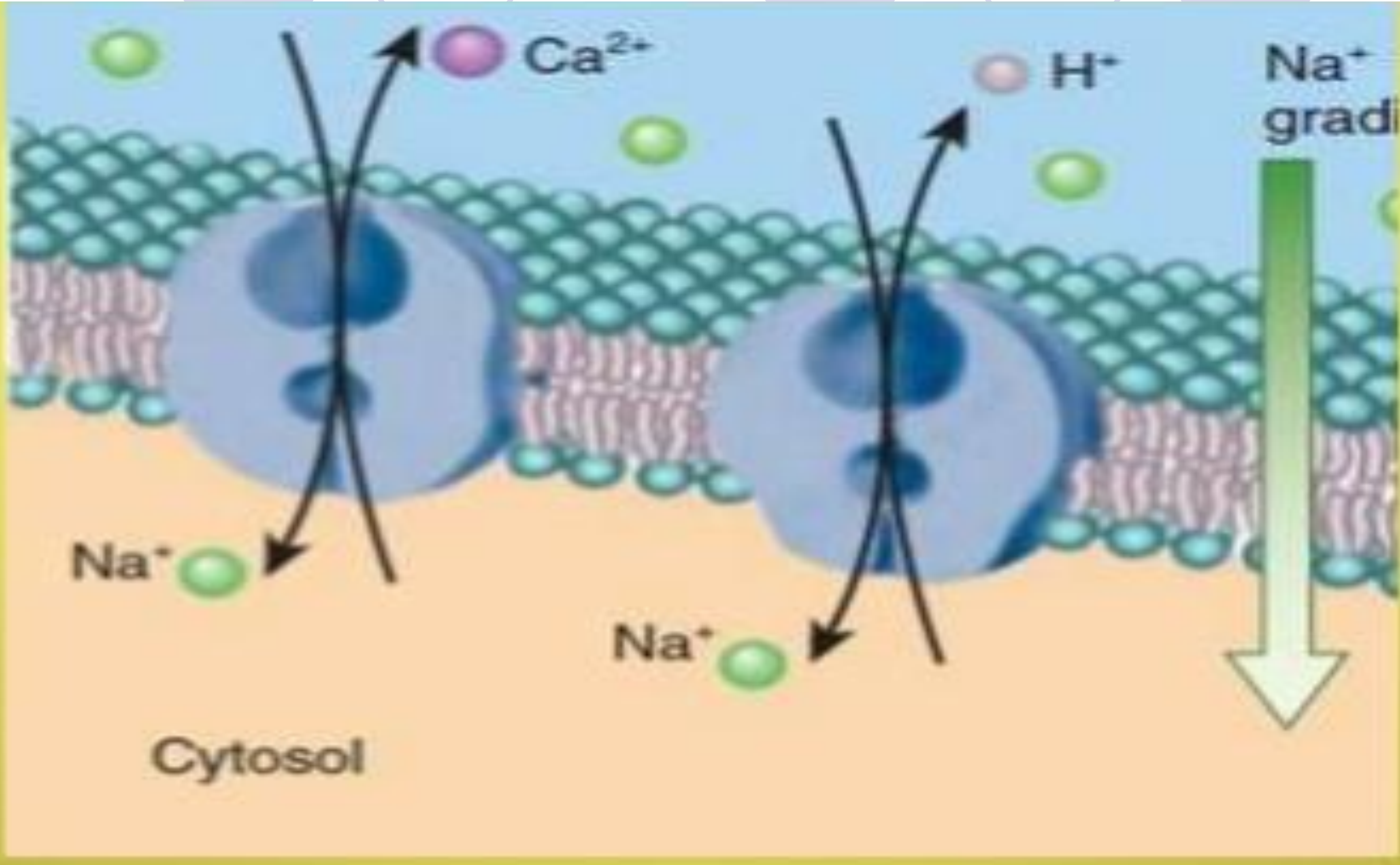
Figure 4–12

Postulated mechanism for sodium co-transport of glucose.

Sodium Counter Transport

- Sodium counter transport is the process by which the substances are transported across the cell membrane in exchange for sodium ions by carrier protein called antiport. Various counter transport systems are:
- **i. Sodium-calcium counter transport**: In this, sodium and calcium ions move in opposite directions with the help of a carrier protein. This type of transport of sodium and calcium ions is present in all the cell.
- **Ii Sodium-hydrogen counter transport**: In this system, the hydrogen ions are exchanged for sodium ions and this occurs in the renal tubular cells. The sodium ions move from tubular lumen into the tubular cells and the hydrogen ions move from tubular cell into the lumen.

Counter transport



Youtube Video Link

Watch "Active Transport | Transport Across the Cell Membrane | Sodium Potassium Pump | Cell Physiology"

https://youtu.be/c8htHfVFt-E