

What is a carrier protein?

- A carrier protein spans the thickness of the plasma membrane and changes its conformation so that specific binding sites within the carrier are alternately exposed to the ECF and ICF.
- Carrier-mediated transport systems display 3 characteristics:
 1. **Specificity:** e.g. glucose cannot bind to amino acid carriers and vice versa.
 2. **Saturation:** A limited no. of carrier binding sites are available within a particular plasma membrane for a specific substance. Thus, there is a limit to the amount of substance a carrier can transport across the membrane in a given time. This is called Transport Maximum (T_m).
 3. **Competition:** Several different substances are competing for the same carrier site.

ACTIVE TRANSPORT

Definition:

Active transport is a carrier-mediated transport wherein molecules and ions are moved against their concentration gradient across a membrane and requires expenditure of energy.

The primary active transport carriers are termed as *pumps*.

Active transport is divided into 2 types according to the source of the energy used.

Types of Active Transport

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graph TD; A[Active Transport:] --- B[Primary Active Transport]; A --- C[Secondary Active Transport];
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Active Transport:

Primary Active Transport

Secondary Active Transport

Types of Active Transport:

Active transport is divided into 2 types depending on the source of energy used:

In **primary active transport**, the energy is derived directly from breakdown of adenosine triphosphate (ATP) or from some other high-energy phosphate compound.

In **secondary active transport**, the energy is derived secondarily from energy stored in the form of an ion concentration gradient between the two sides of a cell membrane, created originally by primary active transport. Thus, energy is used but it is “secondhand” energy and NOT directly derived from ATP.

In both instances, transport depends on *carrier proteins*.

However, in active transport, the **carrier protein** functions differently from the carrier in facilitated diffusion because it is capable of imparting energy to the transported substance to move it against the electrochemical gradient by acting as an enzyme and breaking down the ATP itself.

Primary Active Transport

- In primary active transport, energy in the form of ATP is required to change the affinity of the carrier protein binding site when it is exposed on opposite sides of plasma membrane.
- The carrier protein also acts as an enzyme that has **ATPase** activity, which means it splits the terminal phosphate from an ATP molecule to yield ADP and inorganic phosphate plus free energy.

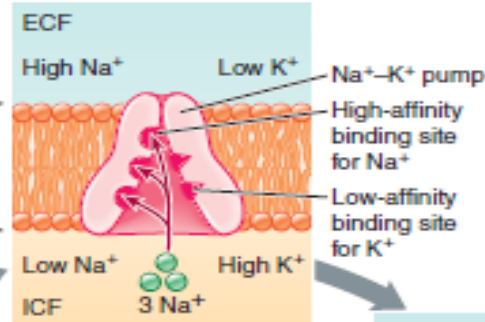
Examples:

1. Sodium-Potassium Pump.
2. Transport of Hydrogen ions: occurs at 2 places in the human body:
 - in the gastric glands of the stomach
 - In the kidneys

1 Pump has 3 high-affinity sites for Na^+ and 2 low-affinity sites for K^+ when exposed to ICF.

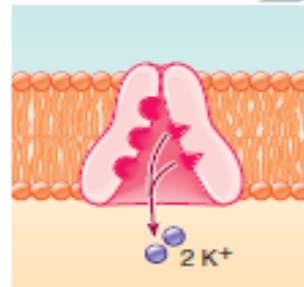
Na^+ concentration gradient

Plasma membrane



K^+ concentration gradient

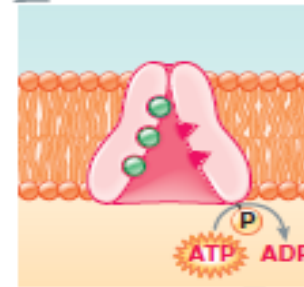
6 Two K^+ are released to ICF (where K^+ concentration is high) as affinity of K^+ binding sites markedly decreases during change in shape. At same time, affinity of Na^+ binding sites greatly increases, returning process to step 1.



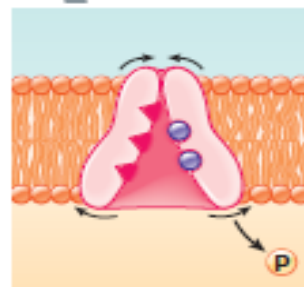
Direction of K^+ transport



2 When 3 Na^+ from ICF (where Na^+ concentration is low) bind to pump, it splits ATP into ADP plus phosphate; phosphate group binds to pump.



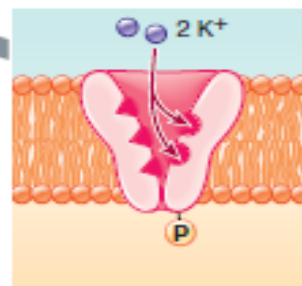
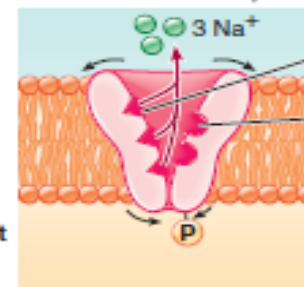
5 When 2 K^+ from ECF (where K^+ concentration is low) bind to pump, it releases phosphate group. Dephosphorylation causes pump to revert to its original conformation.



Direction of Na^+ transport



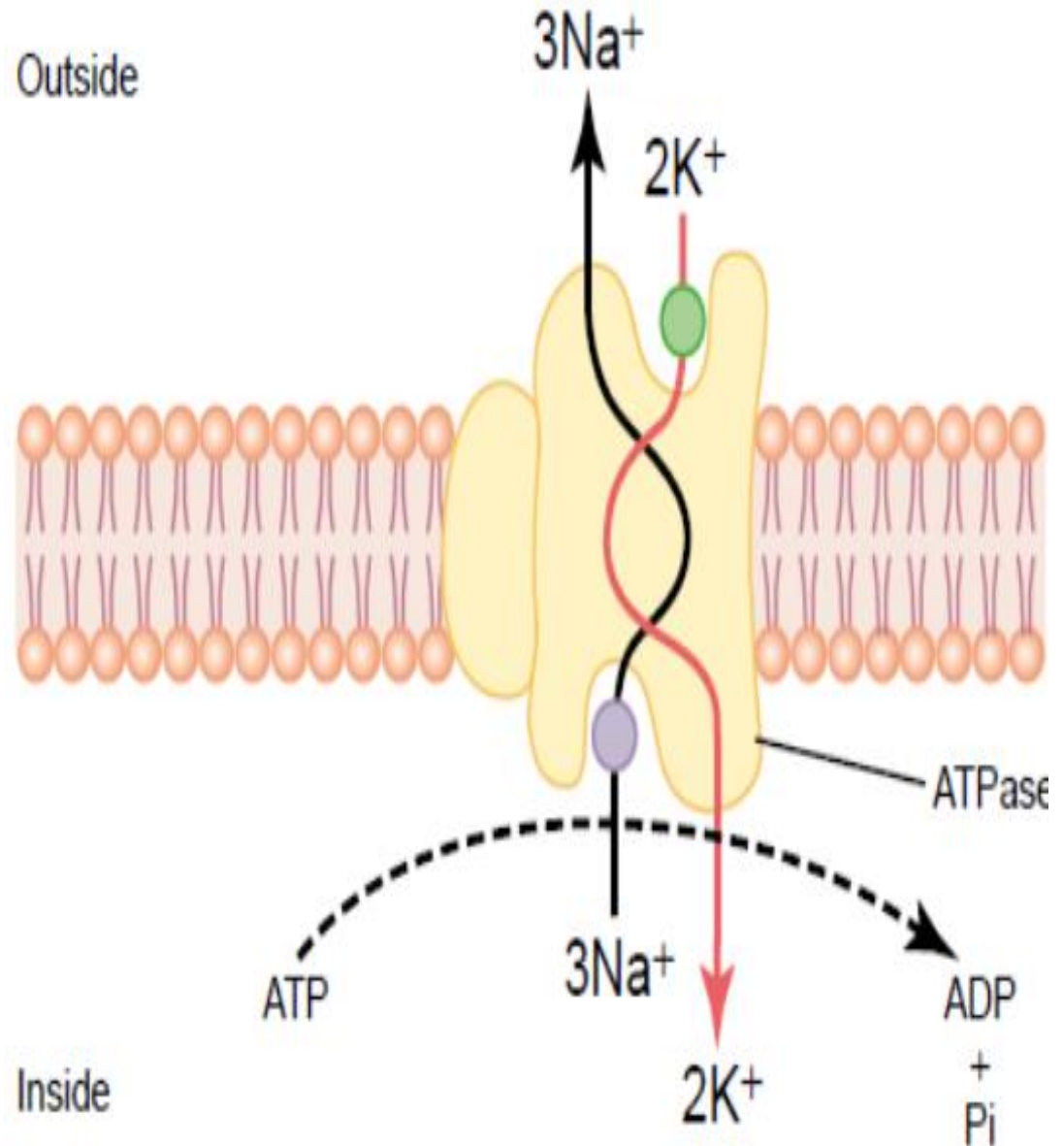
3 Phosphorylation causes pump to change conformation so that Na^+ binding sites are exposed to opposite side of membrane and 3 Na^+ are released to ECF (where Na^+ concentration is high) as affinity of Na^+ binding sites greatly decreases.



4 Change in shape also exposes pump's binding

Na-K PUMP:

- The carrier protein in the pump has 2 subunits; a larger α subunit and a smaller β subunit. They perform the following functions:
 1. **3 receptor sites** for binding **Na** ions on the portion of the protein that protrudes to the inside of the cell.
 2. **2 receptor sites** for **potassium** ions on the outside.
 3. The inside portion of this protein near the sodium binding site has **ATPase** activity.



FUNCTIONS OF SODIUM-POTASSIUM PUMP:

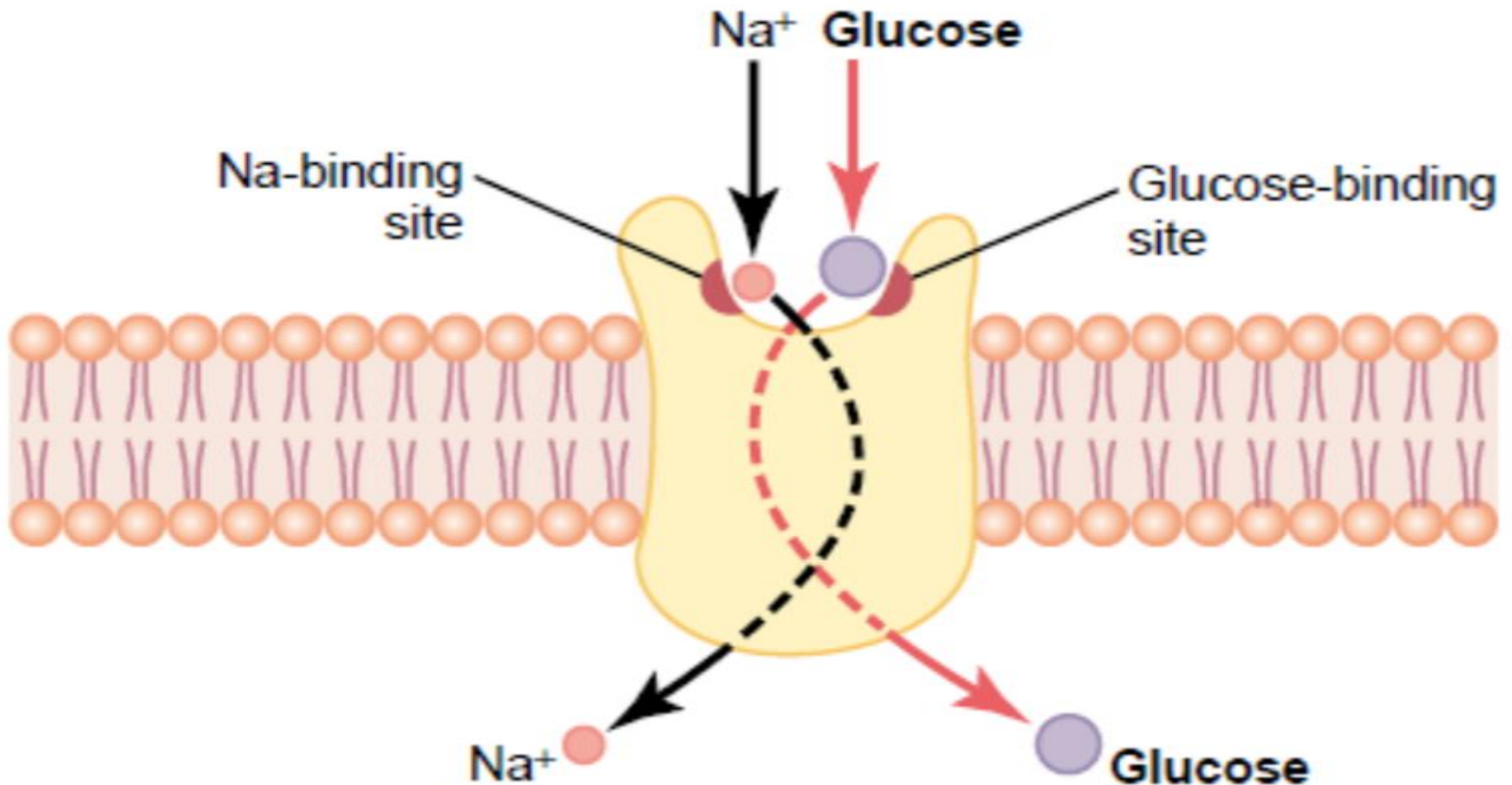
1. Control the *Volume* of each cell: It helps regulate cell volume by controlling the concentrations of solutes inside the cell and thus minimizing osmotic effect that would induce swelling or shrinking of the cell. If the pump stops, the increased Na concentrations within the cell will promote the osmotic inflow of water, damaging the cells.
2. *Electrogenic* nature of the pump: It establishes Na and K concentration gradients across the plasma membrane of all cells; these gradients are critically important in the ability of nerve and muscle cells to generate electrical signals essential to their functioning.
3. *Energy* used for Secondary active transport: The steep Na gradient is used to provide energy for secondary active transport.

SECONDARY ACTIVE TRANSPORT

Secondary active transport: is also called *coupled transport*. In secondary active transport, the downhill flow of an ion is linked to the uphill movement of a second solute either in the same direction as the ion (**co-transport**) or in the opposite direction of the ion (**co-transporter**).

The diffusion of Na^+ down its concentration gradient into the cell can then power the movement of a different ion or molecule against its concentration gradient. If the other molecule or ion is moved in the same direction as Na^+ (that is, into the cell), the coupled transport is called either *cotransport* or *symport*. If the other molecule or ion is moved in the opposite direction (out of the cell), the process is called either *countertransport* or *antiport*.

Co-Transport/ Symport

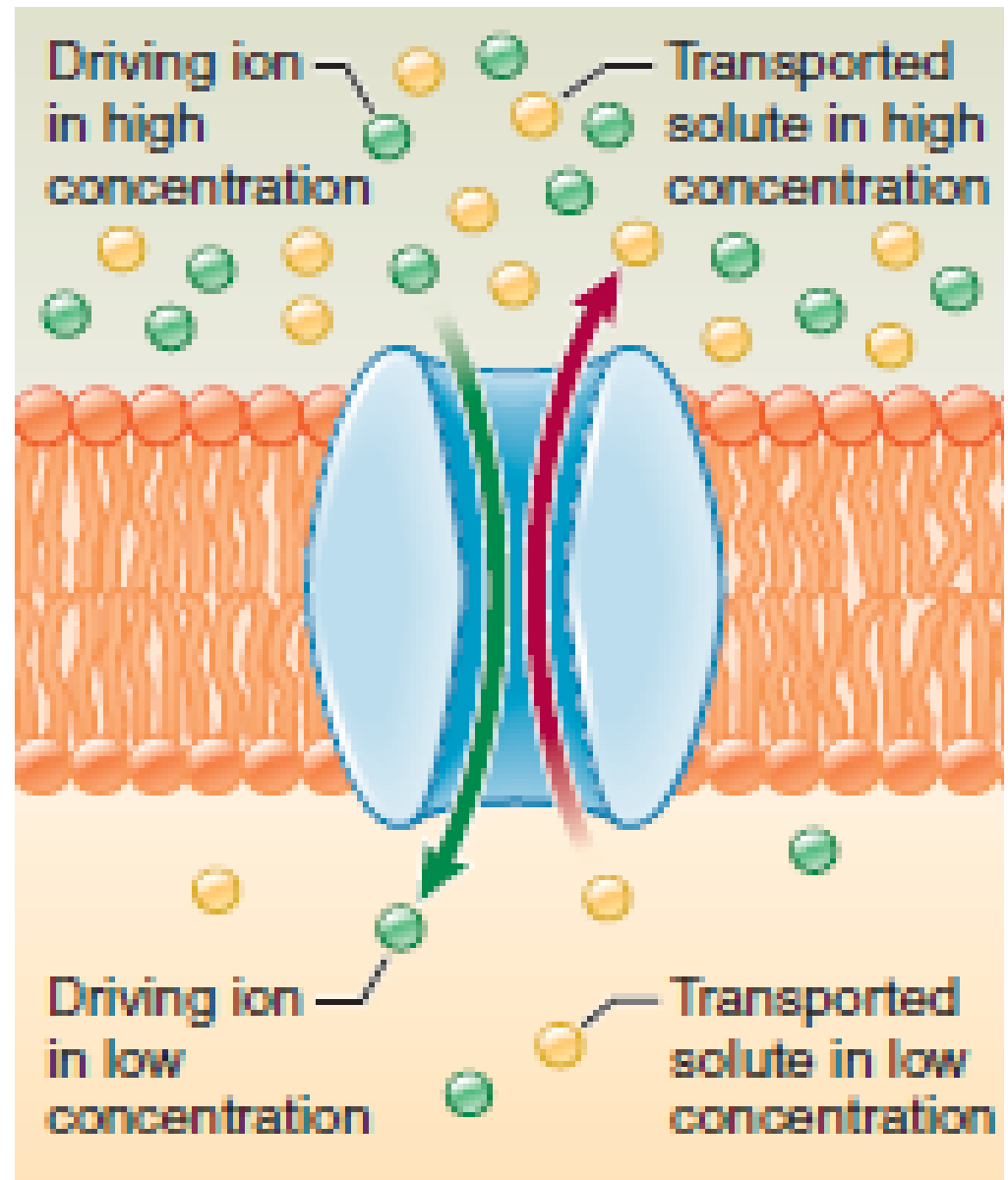


CO-TRANSPORT OR SYMPORT:

- The carrier protein has **two** binding sites: one for the solute being moved against its concentration gradient and one for Na.
- **Sites:** intestinal and kidney cells
- INTESTINAL CELLS: more Na⁺ is present in the ECF (in the intestinal lumen) than inside the cells (because Na-K pump moves the Na out of the cell keeping its intracellular conc. low).
- Because of this conc. difference, more Na binds to the carrier protein in the ECF.
- Binding of Na increases the affinity of the protein for Glucose which is present in low conc. In the ECF.
- When both Na and Glucose are attached to the carrier protein, it undergoes a conformational change and opens to the inside of the cell.
- Both Na & glucose are released to the inside of the cell: Na as there is low conc. & glucose as carrier proteins affinity for it decreases as Na is released.
- The released Na is quickly pumped out by the Na-K pump, keeping the levels of intracellular Na low.
- Thus, Na has been moved down its “downhill” while glucose is moved “uphill”.

COUNTER-TRANSPORT OR ANTI-PORT:

- Sodium ions again attempt to diffuse to the interior of the cell because of their large concentration gradient. This time, the substance to be transported is on the inside of the cell and must be transported to the outside.
- The sodium ion binds to the carrier protein where it projects to the exterior surface of the membrane, while the substance to be counter-transported binds to the interior projection of the carrier protein.
- Once both have bound, a conformational change occurs, and energy released by the sodium ion moving to the interior causes the other substance to move to the exterior.



(b) Antiport

SECONDARY ACTIVE TRANSPORT

CO-TRANSPORT

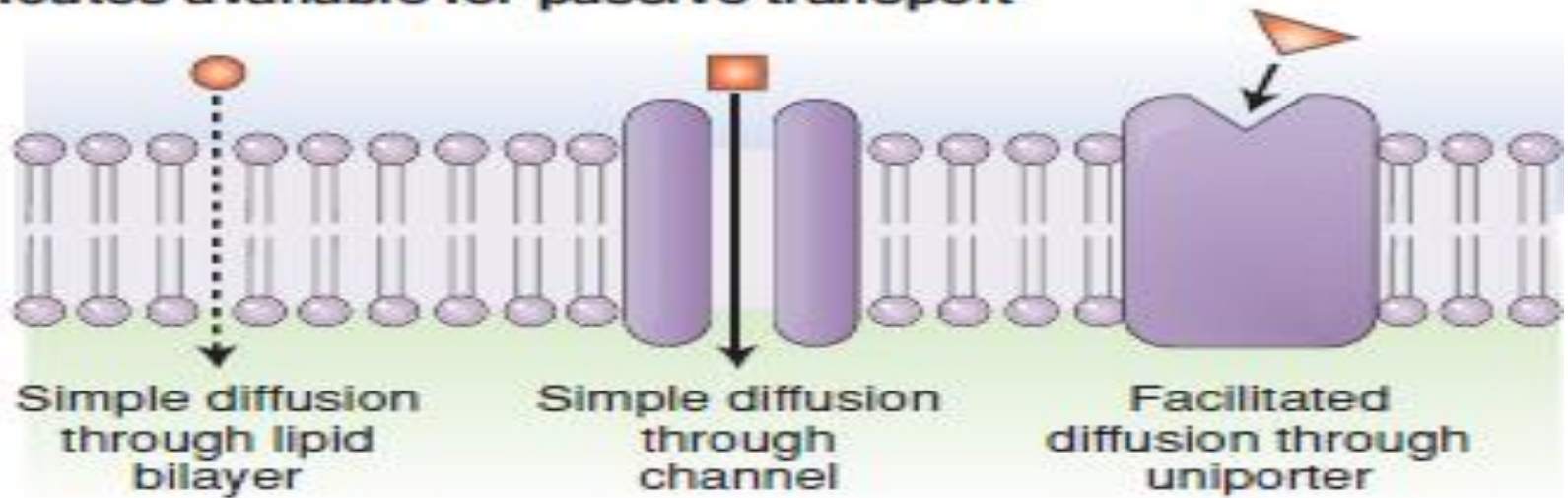
- Symport
- Na moves downhill
- Molecule to be co-transported moved in the same direction as Na, i.e. to the inside of the cell.
- E.g. Na with glucose and amino acids.
- Site: intestinal lumen and renal tubules of kidney.

COUNTER TRANSPORT

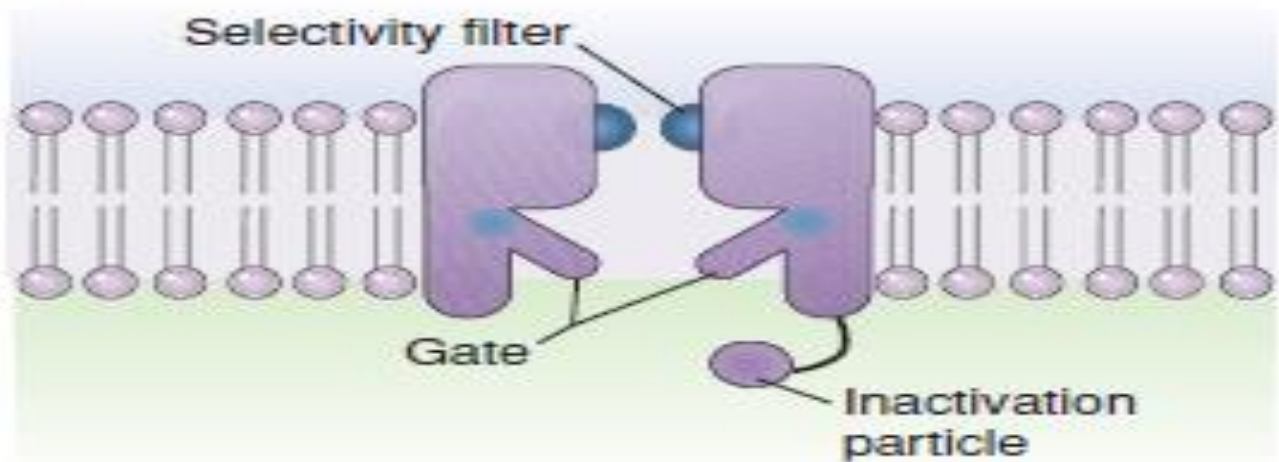
- Anti-port
- Na moves downhill
- Molecule to be counter-transported moves in the opposite direction to Na, i.e. to the outside of the cell.
- E.g. Na with Calcium and Hydrogen ions.
- Site: Na-Ca counter transport in almost all cells of the body and Na-H⁺ in the proximal tubules of the kidney.

REVIEW:

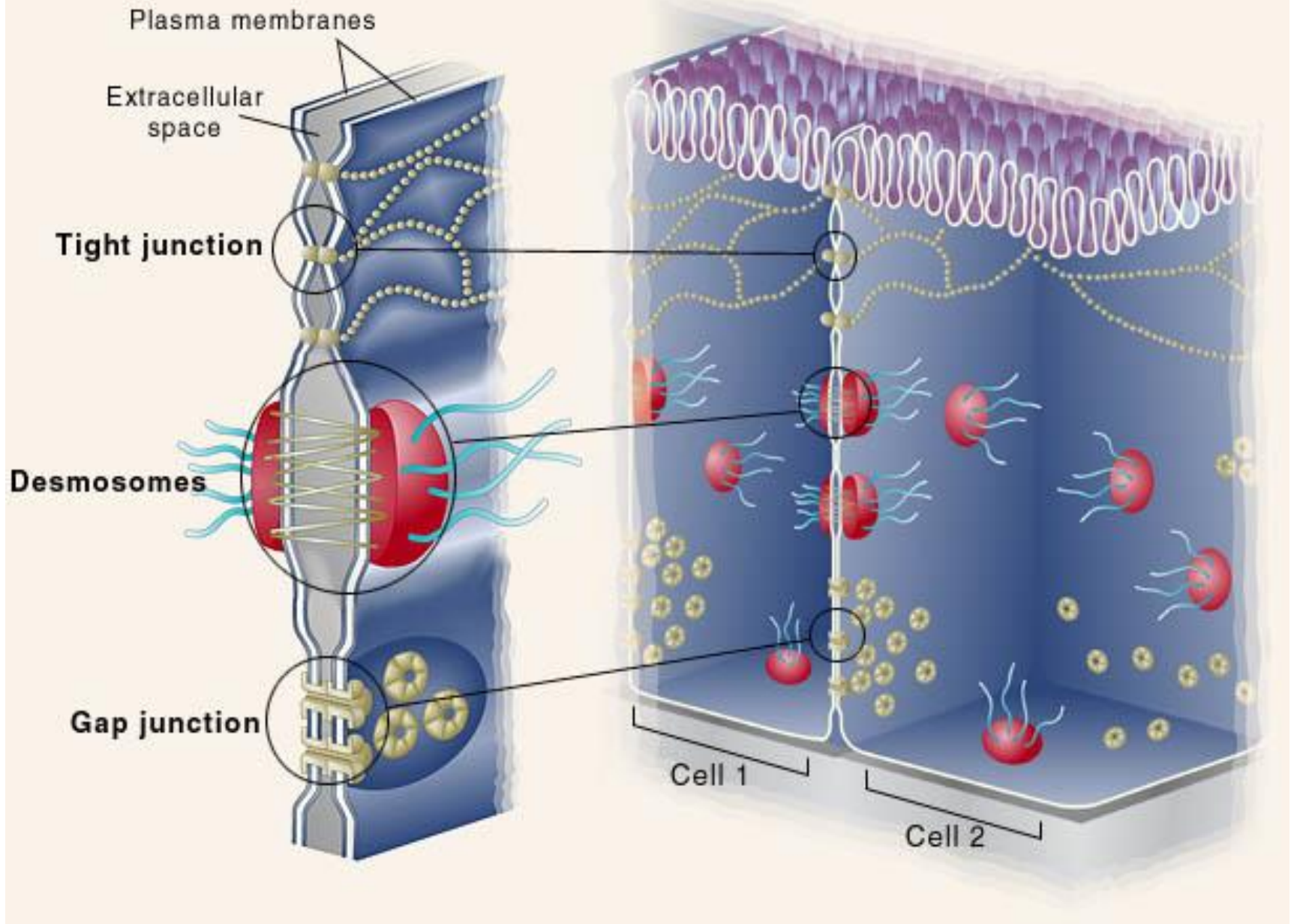
A. Routes available for passive transport



B. Components of ion channels



Specialized cell junctions



MATCH:

- Diffusion
 - Osmosis
 - Carrier-mediated transport
 - Facilitated Diffusion
 - Primary active transport
 - Secondary active transport
1. A passive transport process which can be saturated at high substrate conc.
 2. Depends on a solute conc. to drive the movement of solvent across the plasma membrane.
 3. This uses ATP breakdown to move the substance from low to high conc.
 4. This uses a conc. Gradient for one substance to drive the transport of another.

Questions:

- Give the Fick's law of diffusion. Explain.
- What 2 properties of a particle influence whether it can permeate the plasma membrane.
- State 3 important roles of Na-K Pump.