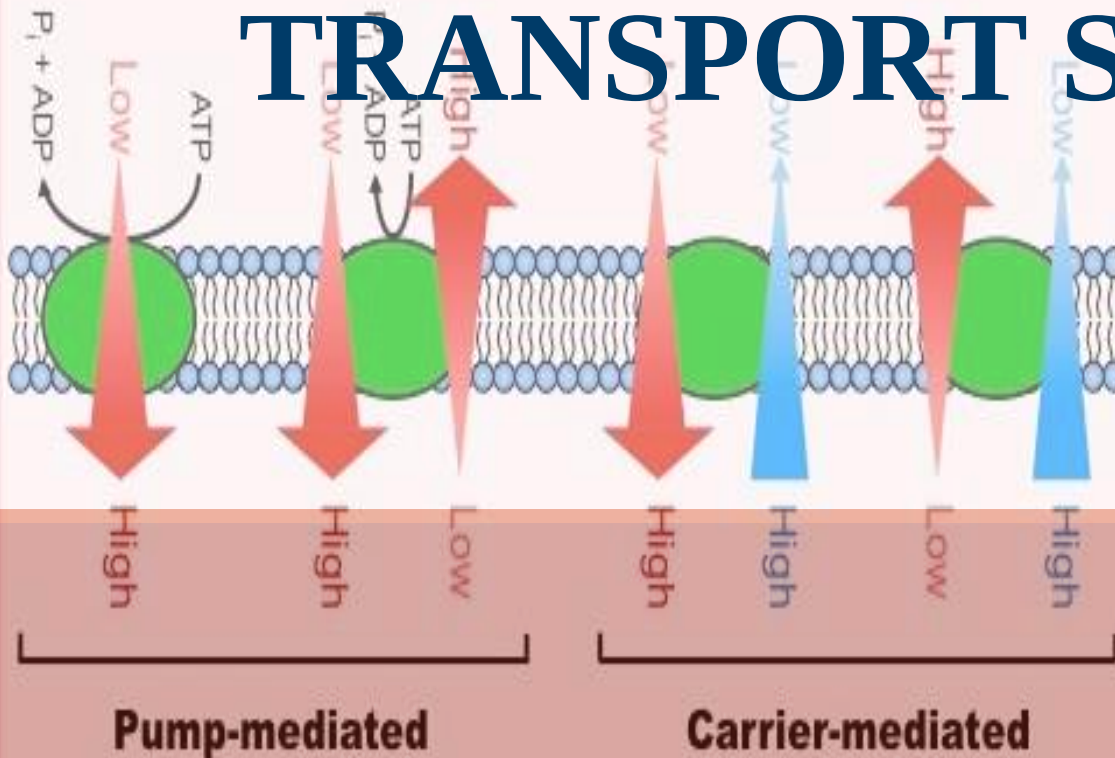


Active Transport

Primary

Secondary

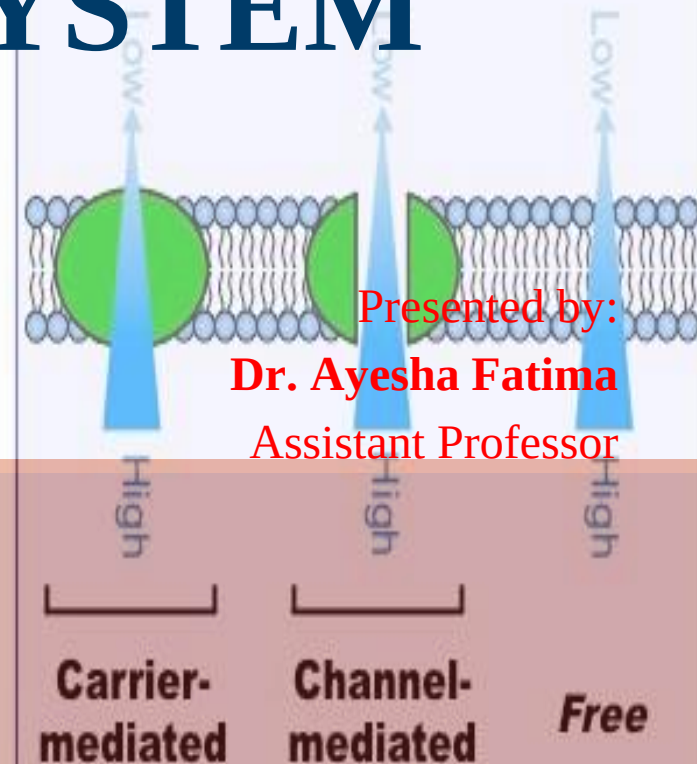
PLASMA MEMBRANE : TRANSPORT SYSTEM



Passive Transport

Facilitated Diffusion

Simple diffusion



Presented by:
Dr. Ayesha Fatima
Assistant Professor

Transport across Cell Membrane

- Plasma membrane acts as a barrier to most, but not all molecules.
- Plasma membrane is a semi-permeable barrier separating the inner cellular environment from the outer cellular environment.
- Since the plasma membrane is made up of a lipid bilayer with proteins attached on the surface allowing substances to pass across it's membrane, possibility of transport across this membrane.
- All lipid soluble substances can easily and freely diffuse in and out, e.g. O_2 and CO_2 . Water soluble substances like ions, glucose and macromolecules should find a special way of transport with the help of integral and trans-membrane proteins which act as binding sites, channels and gates to facilitate movement.
- Transport across cell membrane is classified into four ways:
 1. Passive Transport
 2. Osmosis
 3. Active Transport
 4. Vesicular Transport.

Active Transport

Primary

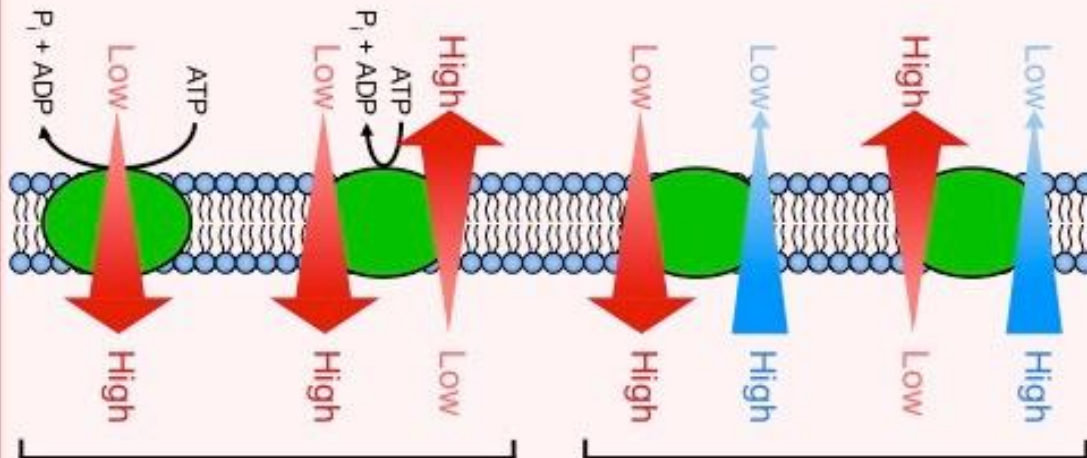
Secondary

Uniport

Cotransport

Antiport

Symport



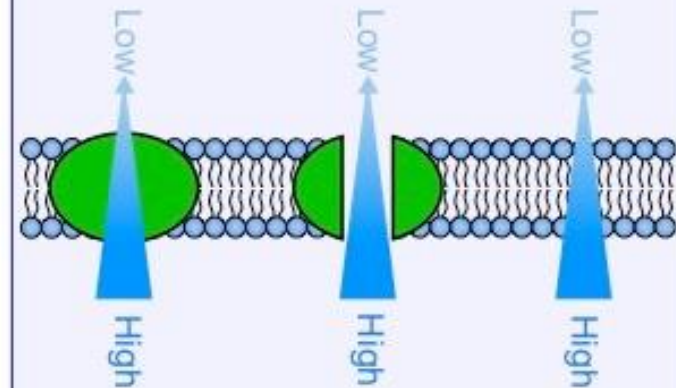
Pump-mediated

Carrier-mediated

Passive Transport

Facilitated Diffusion
(Uniport)

Simple
diffusion



Carrier-mediated

Channel-mediated

Free

Passive Transport : Diffusion

It is the net movement of a substance (liquid or gas) from an area of higher concentration to lower concentration without expenditure of energy is called diffusion.

Diffusion can be further divided as follows:

- A. Simple diffusion
- B. Facilitated diffusion.

A. Simple Diffusion: It is further classified into two categories:

- i. Diffusion of lipid soluble substance through lipid bilayer.
- ii. Diffusion of lipid insoluble substance through protein channels.

i. Diffusion of Lipid Soluble Substance through the Lipid Bilayer:

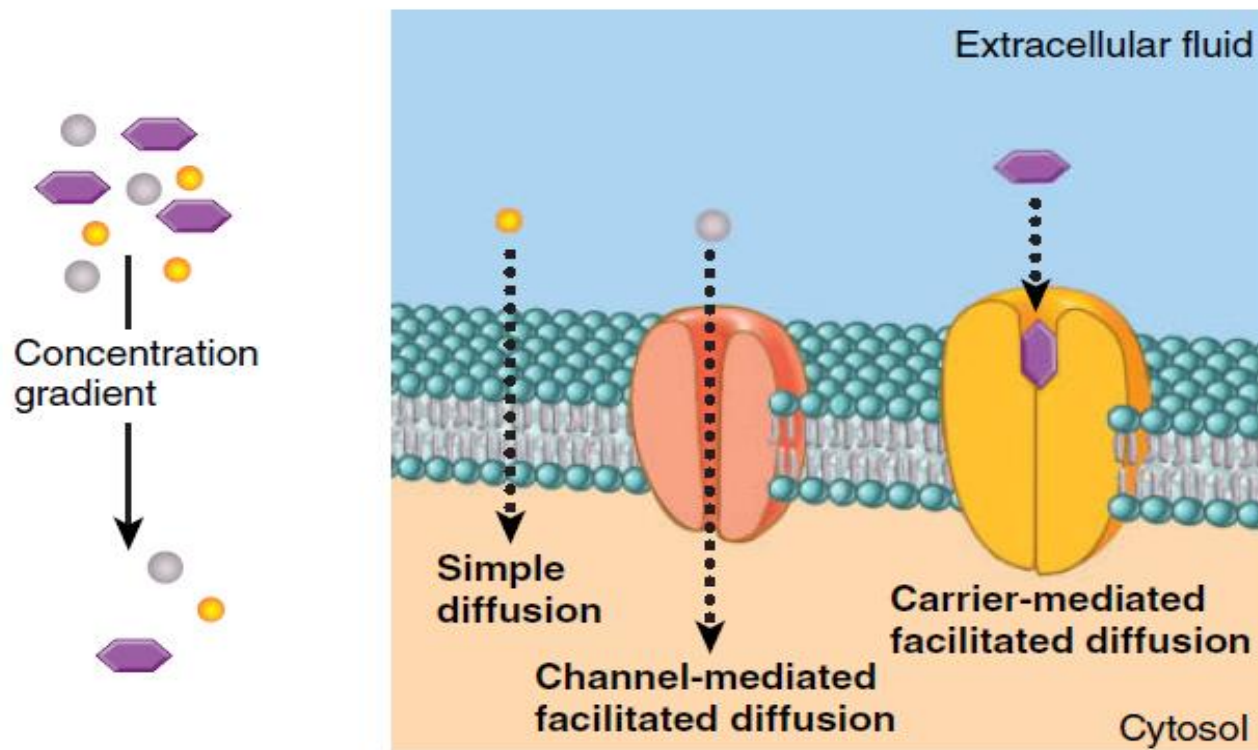
Substance like oxygen and carbon dioxide and alcohols are highly lipid soluble and dissolve in the layer easily and diffuse through the membrane. The rate of diffusion is determined by the solubility of the substance. For example, exchange of gases in the lungs.

ii. Diffusion of Lipid Insoluble Substance through Protein Channels:

This is possible through either selective permeability of protein channel or through gated channels

FIGURE 3.5 Simple diffusion, channel-mediated facilitated diffusion, and carrier-mediated facilitated diffusion.

In simple diffusion, a substance moves across the lipid bilayer of the plasma membrane without the help of membrane transport proteins. In facilitated diffusion, a substance moves across the lipid bilayer aided by a channel protein or a carrier protein.



Facilitated diffusion : Two types, Both differs on the type of protein used.

1. Channel mediated 2. Carrier mediated

FIGURE 3.6 Channel-mediated facilitated diffusion of potassium ions (K^+) through a gated K^+ channel. A gated channel is one in which a portion of the channel protein acts as a gate to open or close the channel's pore to the passage of ions.

Channels are integral membrane proteins that allow specific, small, inorganic ions to pass across the membrane by facilitated diffusion.

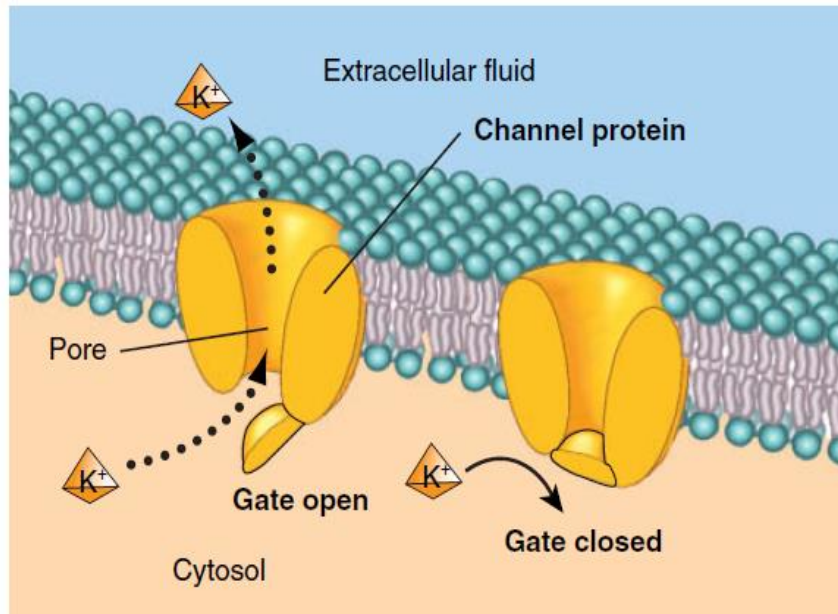
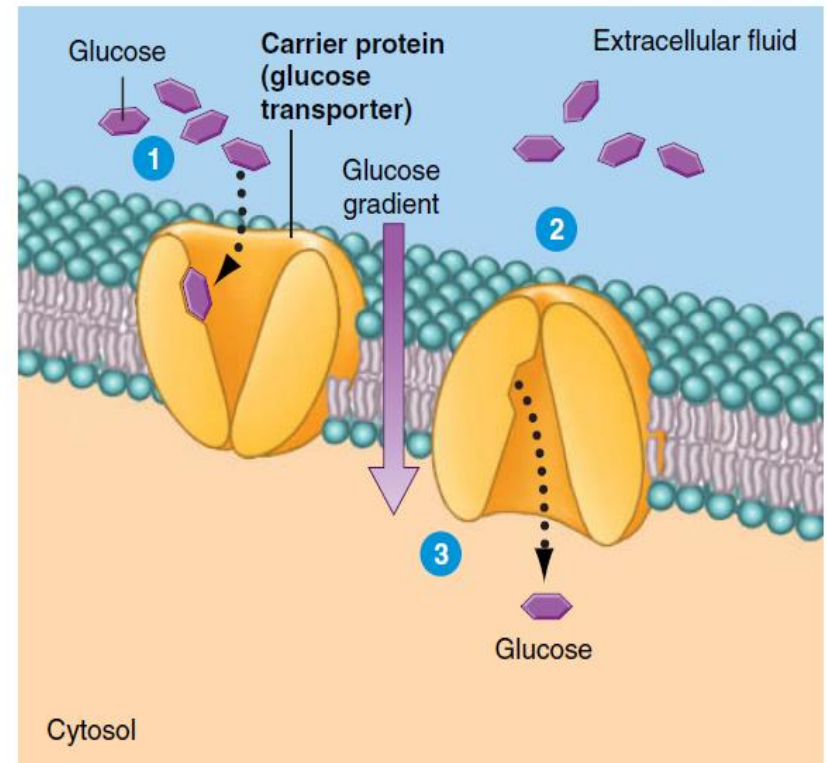


FIGURE 3.7 Carrier-mediated facilitated diffusion of glucose across a plasma membrane. The carrier protein binds to glucose in the extracellular fluid and releases it into the cytosol.

Carriers are integral membrane proteins that undergo changes in shape in order to move substances across the membrane by facilitated diffusion.



CHANNEL-MEDIATED FACILITATED DIFFUSION

- In **channel-mediated facilitated diffusion**, a solute moves down its concentration gradient across the lipid bilayer through a membrane channel.
- Membrane channels are *ion channels*, integral transmembrane proteins that allow passage of small, inorganic ions that are too hydrophilic to penetrate the nonpolar interior of the lipid bilayer.
- Each ion can diffuse across the membrane only at certain sites.
- In typical plasma membranes, the most numerous ion channels are selective for K^+ ions or Cl^- ions; fewer channels are available for Na^+ ions or Ca^{2+} ions.
- Diffusion of ions through channels is generally slower than free diffusion through the lipid bilayer because channels occupy a smaller fraction of the membrane's total surface area than lipids.
- A channel is said to be *gated* when part of the channel protein acts as a “plug” or “gate,” changing shape in one way to open the pore and in another way to close it. Gated channels randomly alternate between the open and closed positions; regulated by chemical or electrical changes inside and outside the cell.
- When the gates of a channel are open, ions diffuse into or out of cells, down their electrochemical gradients.

CARRIER-MEDIATED FACILITATED DIFFUSION

- In **carrier-mediated facilitated diffusion**, a *carrier* (also called a *transporter*) moves a solute down its concentration gradient across the plasma membrane
- The solute binds to a specific carrier on one side of the membrane and is released on the other side after the carrier undergoes a change in shape.
- The solute binds more often to the carrier on the side of the membrane with a higher concentration of solute.
- Once the concentration is the same on both sides of the membrane, solute molecules bind to the carrier on the cytosolic side and move out to the extracellular fluid as rapidly as they bind to the carrier on the extracellular side and move into the cytosol.
- The number of carriers available in a plasma membrane places an upper limit, called the *transport maximum*, on the rate at which facilitated diffusion can occur.
- Once all of the carriers are occupied, the transport maximum is reached, and a further increase in the concentration gradient does not increase the rate of facilitated diffusion, the process of carrier-mediated facilitated diffusion exhibits *saturation*.
- Substances that move across the plasma membrane by carrier mediated facilitated diffusion include glucose, fructose, galactose, and some vitamins

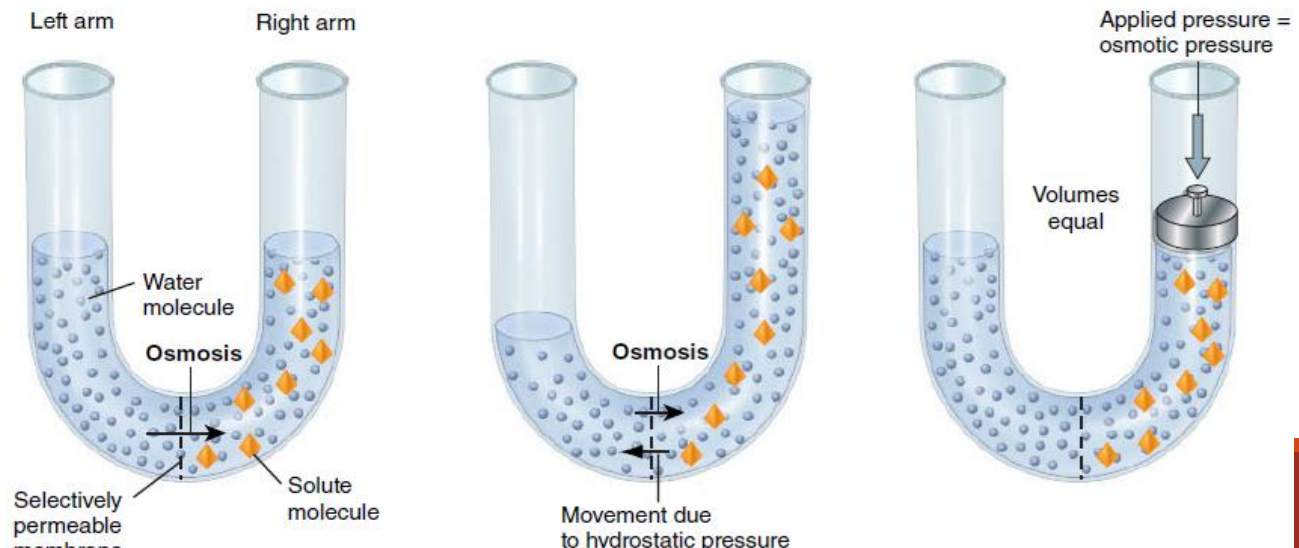
OSMOSIS

- Osmosis is a type of diffusion in which there is net movement of a solvent through a selectively permeable membrane. It is a passive process
- In osmosis, water moves through a selectively permeable membrane from an area of *lower solute concentration* to an area of *higher solute concentration*. Or from an area of higher water concentration to lower water concentration.
- During osmosis, water molecules pass through a plasma membrane in two ways:
 1. by moving between neighboring phospholipid molecules in the lipid bilayer via simple diffusion,
 2. by moving through **aquaporins** or **AQPs**, integral membrane proteins that function as water channels.
- Different types of AQPs have been found in different cells and tissues throughout the body. AQPs are responsible for the production of cerebrospinal fluid, aqueous humor, tears, sweat, saliva, and the concentration of urine.

- Osmosis occurs only when a membrane is permeable to water but is not permeable to certain solutes.
- Diffusion of water across a membrane generates a pressure called **osmotic pressure**. If the pressure in the compartment into which water is flowing is raised to the equivalent of the osmotic pressure, movement of water will stop. This pressure is often called **hydrostatic ('water-stopping') pressure**
- The amount of pressure needed to restore the starting condition equals the osmotic pressure. Hydrostatic pressure is the pressure exerted by a fluid at rest due to gravity

FIGURE 3.8 Principle of osmosis. Water molecules move through the selectively permeable membrane; solute molecules cannot. (a) Water molecules move from the left arm into the right arm, down the water concentration gradient. (b) The volume of water in the left arm has decreased and the volume of solution in the right arm has increased. (c) Pressure applied to the solution in the right arm restores the starting conditions.

Osmosis is the movement of water molecules through a selectively permeable membrane.



- The osmotic pressure of the cytosol is the same as the osmotic pressure of the interstitial fluid outside cells. Because the osmotic pressure on both sides of the plasma membrane is the same, cell volume remains relatively constant.
- When body cells are placed in a solution having a different osmotic pressure than cytosol, however, the shape and volume of the cells change.
- As water moves by osmosis into or out of the cells, their volume increases or decreases
- A solution's **tonicity** is a measure of the solution's ability to change the volume of cells by altering their water content.

- **Isotonic:** The solutions being compared have equal concentration of solutes.
 - When the cell is placed in isotonic solution, the water diffuses in and out of the cell in same rate.
 - Ex. RBC placed in 0.9% NaCl solution, RBC maintain its cell shape and volume.
- **Hypertonic:** The solution with the higher concentration of solutes.
 - When cell is placed in hypertonic solution, water diffuses out of the cell causing the cell to shrink. Such shrinkage is called as Crenation.
 - Ex. RBC placed in 2% NaCl solution, RBC Shrink
- **Hypotonic:** The solution with the lower concentration of solutes.
 - When cell is placed in hypotonic solution, the water diffuses into the cell causing it to swell and possible explode. Explosion/rupture by this process called as lysis.
 - Ex. RBC placed in 0.45% NaCl solution, RBC Swell and rupture called as hemolysis.

Hypertonic solution

Isotonic solution

Hypotonic solution

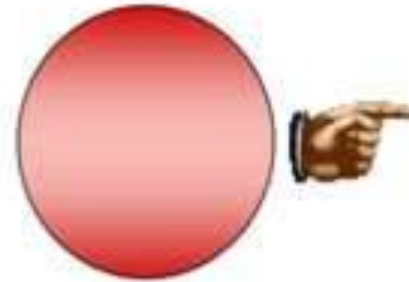
Remains of cell
surface membrane



Crenation: Red blood cell shrinks and turns 'spiky'



Red blood cell



Swells up



Haemolysis: Red blood cell finally burst

CRENATION AND HAEMOLYSIS OF RED BLOOD CELL

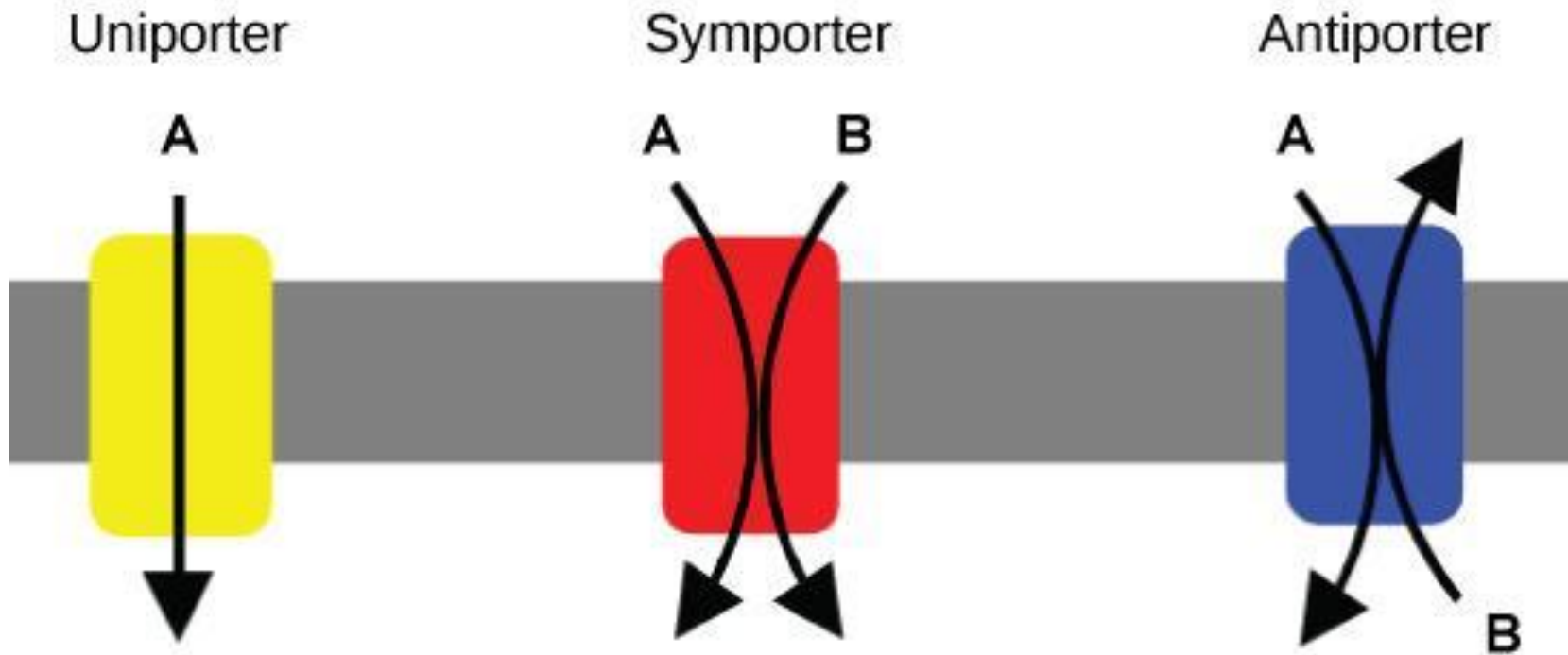
Active Transport

- Some polar or charged solutes that must enter or leave body cells cannot cross the plasma membrane through any form of passive transport because they would need to move “uphill,” *against* their concentration gradients. Such solutes may be able to cross the membrane by a process called **active transport**.
- Active transport is an active process because energy is required for carrier proteins to move solutes across the membrane against a concentration gradient.
- Two sources of cellular energy can be used to drive active transport:
 - (1) Energy obtained from hydrolysis of ATP is the source in *primary active transport*;
 - (2) energy stored in an ionic concentration gradient is the source in *secondary active transport*.
- Active transport processes transport maximum and saturation.
- Solute actively transported across the plasma membrane include several ions, such as Na^+ , K^+ , H^+ , Ca^{2+} , I^- (iodide ions), and Cl^- ; amino acids; and monosaccharides

- Small substances constantly pass through plasma membranes.
- Active transport maintains concentrations of ions and other substances needed by living cells in the face of these passive movements.
- Active transport mechanisms depend on a cell's metabolism for energy.
- Two mechanisms exist for the transport of small-molecular weight material and small molecules.
- **Primary active transport** moves ions across a membrane and creates a difference in charge across that membrane, which is directly dependent on ATP.
- **Secondary active transport** describes the movement of material that is due to the electrochemical gradient established by primary active transport that does not directly require ATP.

Carrier Proteins for Active Transport

- An important membrane adaption for active transport is the presence of specific carrier proteins or pumps to facilitate movement: there are three types of these proteins or **transporters**.
- A **Uniporter** carries one specific ion or molecule.
- A **Symporter** carries two different ions or molecules, both in the same direction.
- An **Antiporter** also carries two different ions or molecules, but in different directions.
- All of these transporters can also transport small, uncharged organic molecules like glucose.
- Some examples of pumps for active transport are **Na⁺-K⁺ ATPase**, which carries sodium and potassium ions, and **H⁺-K⁺ ATPase**, which carries hydrogen and potassium ions.
- Both of these are antiporter carrier proteins.
- Two other carrier proteins (both are pumps) are **Ca²⁺ ATPase** and **H⁺ ATPase**, which carry only calcium and only hydrogen ions, respectively.



A uniporter carries one molecule or ion.

A symporter carries two different molecules or ions, both in the same direction.

An antiporter also carries two different molecules or ions, but in different directions.

PRIMARY ACTIVE TRANSPORT

- In primary active transport, the energy is derived directly from the breakdown of ATP.

Ion-pumps may be of two types:

(i) Electro neutral pumps (ii) Electro genic pumps.

1. **Electro neutral pumps** are those which are associated with transport of ions with no net movement of charge across the membrane.
 - For example **H⁺/K⁺-ATPase** of some animal cells, pumps out **one H⁺ for each K⁺** taken in with no net movement of charge. Therefore, it is an electro neutral pump.
2. **Electro genic pumps** on the other hand, transport ions involving net movement of charge across the membrane.
 - One of the most important pumps is the sodium-potassium pump (Na⁺-K⁺ ATPase), which maintains the electrochemical gradient in living cells.
 - The sodium-potassium pump moves **K⁺ into the cell** while moving **Na⁺ out** at the same time, at a ratio of **three Na⁺ for every two K⁺ ions** moved in.

Electrogenic pumps:- $\text{Na}^+/\text{K}^+ - \text{ATPase}$

- The most prevalent primary active transport mechanism expels sodium ions (Na^+) from cells and brings potassium ions (K^+) in. Because of the specific ions it moves, this carrier is called the **sodium–potassium pump**. Because a part of the sodium–potassium pump acts as an *ATPase*, an enzyme that hydrolyzes ATP, another name for this pump is **$\text{Na}^+ - \text{K}^+ \text{ATPase}$** .
- These sodium–potassium pumps maintain a low concentration of Na^+ in the cytosol, by pumping these ions into the extracellular fluid against the Na^+ concentration gradient.
- At the same time, the pumps move K^+ into cells against the K^+ concentration gradient. Because K^+ and Na^+ slowly leak back across the plasma membrane down their electrochemical gradients—through passive transport or secondary active transport—the sodium–potassium pumps must work nonstop to maintain a low concentration of Na^+ and a high concentration of K^+ in the cytosol.

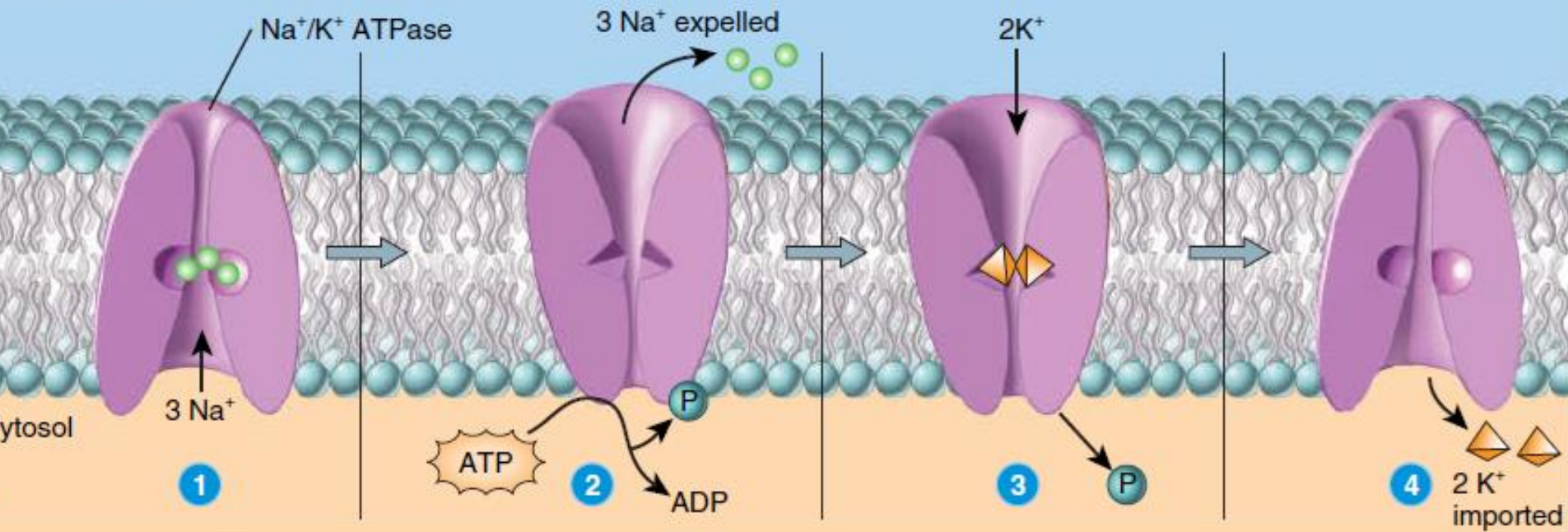
1. Three Na^+ in the cytosol bind to the pump protein.
2. Binding of Na^+ triggers the hydrolysis of ATP into ADP, a reaction that also attaches a phosphate group P to the pump protein. This chemical reaction changes the shape of the pump protein, expelling the three Na^+ into the extracellular fluid. Now the shape of the pump protein favors binding of two K^+ in the extracellular fluid to the pump protein.
3. The binding of K^+ triggers release of the phosphate group from the pump protein. This reaction again causes the shape of the pump protein to change.
4. As the pump protein reverts to its original shape, it releases K^+ into the cytosol. At this point, the pump is again ready to bind three Na^+ , and the cycle repeats.

...o the cell.

...um-potassium pump (Na^+/K^+ ATPase) expels sodium ions (Na^+) and brings

pumps maintain a low intracellular concentration of sodium ions.

extracellular fluid



ions (Na^+) from the
d to the inside surface
um-potassium pump.

Na^+ binding triggers ATP to bind to the pump and be split into ADP and P (phosphate). The energy from ATP splitting causes the protein to change shape, which moves the Na^+ to the outside.

2 potassium ions (K^+) land on the outside surface of the pump and cause the P to be released.

The release of the P causes the pump to return to its original shape, which moves the K^+ into the cell.

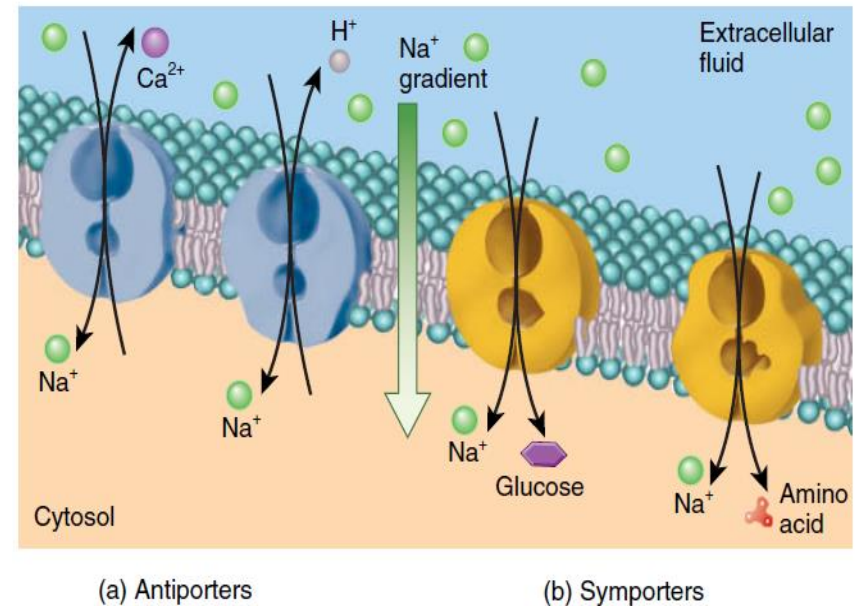
Secondary active transport

- In **secondary active transport**, the energy stored in a Na^+ or H^+ concentration gradient is used to drive other substances across the membrane against their own concentration gradients.
- Because a Na^+ or H^+ gradient is established by primary active transport, secondary active transport *indirectly* uses energy obtained from the hydrolysis of ATP.
- The sodium–potassium pump maintains concentration gradient of Na^+ across the plasma membrane. As a result, the sodium ions have stored energy.
- some of the stored energy converted to kinetic energy and used to transport other substances *against their concentration gradients*.
- In secondary active transport, a carrier protein simultaneously binds to Na^+ and another substance and then changes its shape so that both substances cross the membrane at the same time.
- If these transporters move two substances in the same direction they are called **symporters**; **antiporters**, by contrast, move two substances in opposite directions across the membrane

- Plasma membranes contain several antiporters and symporters that are powered by the Na^+ gradient.
- For instance, the concentration of calcium ions (Ca^{2+}) is low in the cytosol because $\text{Na}^+ - \text{Ca}^{2+}$ antiporters eject calcium ions.
- Likewise, $\text{Na}^+ - \text{H}^+$ antiporters help regulate the cytosol's pH by expelling excess H^+ .
- By contrast, dietary glucose and amino acids are absorbed into cells that line the small intestine by Na^+ –glucose and Na^+ –amino acid symporters .
- In each case, sodium ions are moving down their concentration gradient while the other solutes move “uphill,” against their concentration gradients.

FIGURE 3.11 Secondary active transport mechanisms. (a) Antiporters carry two substances across the membrane in opposite directions. (b) Symporters carry two substances across the membrane in the same direction.

Secondary active transport mechanisms use the energy stored in an ionic concentration gradient (here, for Na^+). Because primary active transport pumps that hydrolyze ATP maintain the gradient, secondary active transport mechanisms consume ATP indirectly.



THANK YOU