Physiology | Lecture 3

Active transport

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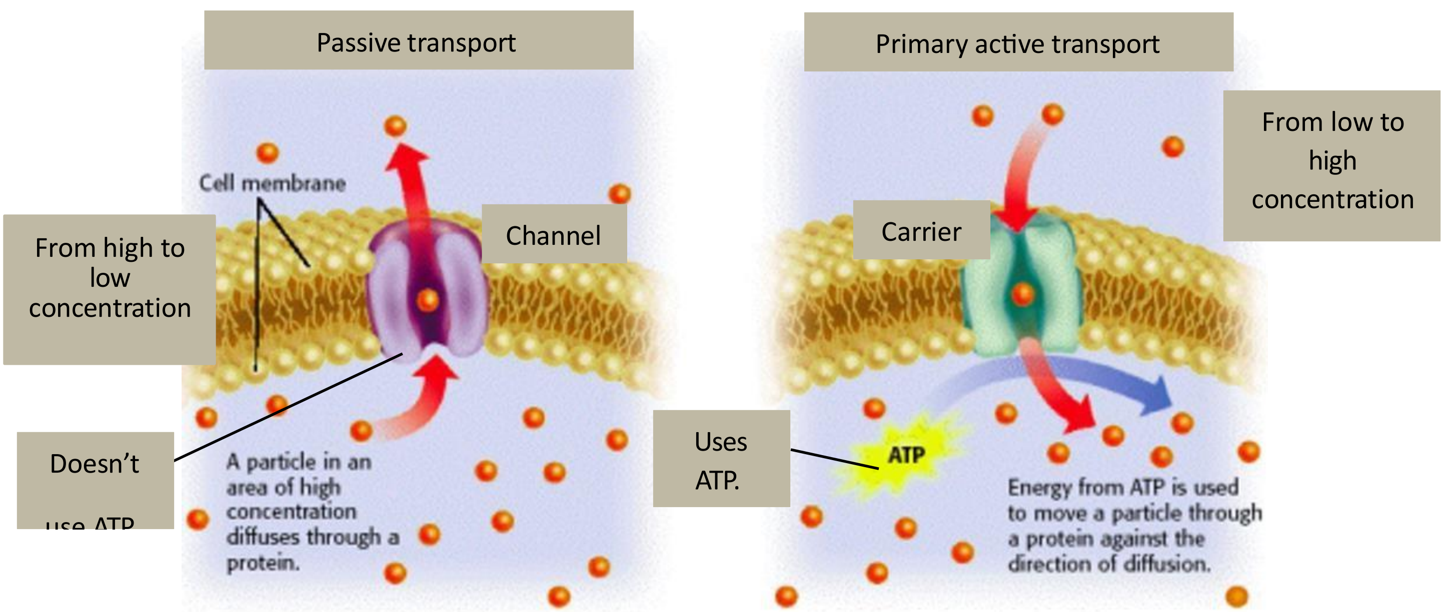
Active Transport

Active transport **consumes** macro energetic molecules, we divide it into three main subcategories: **Primary**, **secondary** active transport and **vesicular** transport.

1-Primary active transport:

In this type, we have carriers (not channels) that must be phosphorylated (getting phosphate group from ATP) to transport particles from the low concentration to high concentration.

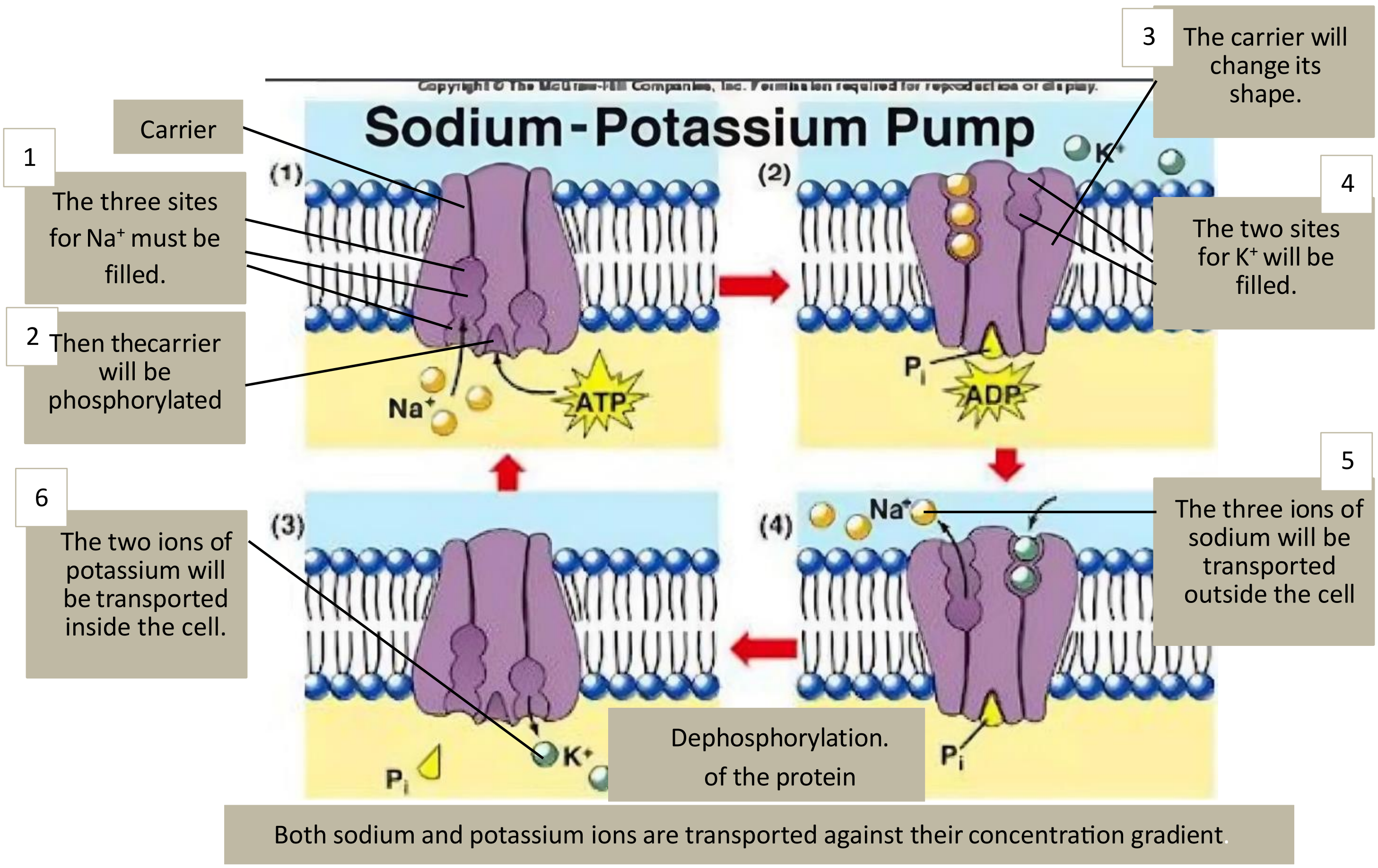


Pumps are carriers, whenever you hear "**Pump**" you should know it's **primary active transport**.

We will talk about 4 pumps in this sheet, with some information about each one of them:

A- Na^+/K^+ pump:

Transporting sodium and potassium, there is a high concentration of sodium outside the cell, and high concentration of potassium inside, as we know, Active transport is a transporting from low concentration to high concentration, so it transports sodium outside the cell and potassium inside the cell.



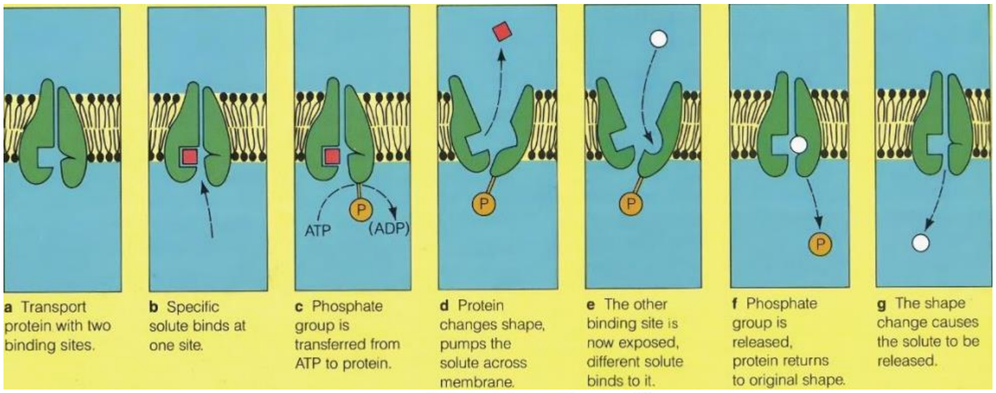
When the carrier phosphorylated by ATP there are conformational changes happen to the shape of the protein ,then when the carries de-phosphorylated the protein return to its previous shape

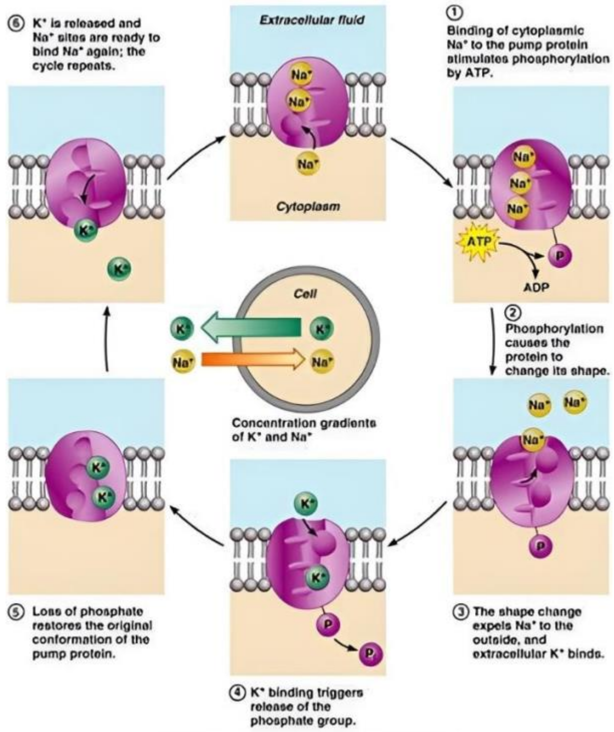
You noticed that this pump keeps high concentration of sodium outside the cell (by transporting 3 sodium ions outside the cell), you will know that this high concentration of sodium outside the cell leads the secondary active transport when we talk about it.

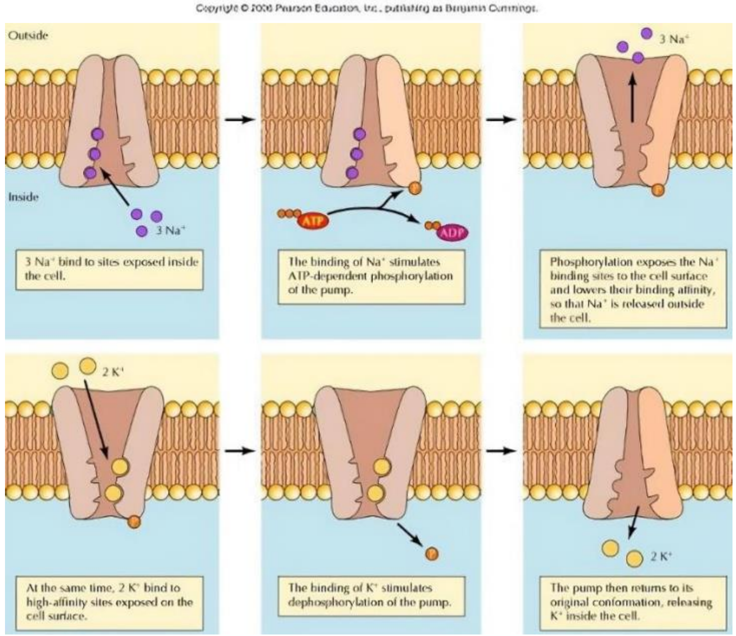
Now imagine if this pump isn't working, what will happen? The sodium ions will have a high condense to diffuse inside the cell (from high to low concentration), and the osmolarity inside the cell will increase, leading the cell to be swelled (burst).

In conclusion, **this pump is important for the cell and its activity**.

These are extra pictures of this pump, our doctor didn't say more information about these pictures than the above picture.







B- **H^+ pump**:

In stomach, we are releasing hydrochloric acid, to synthesize this acid, the H^+ ions must be transported from the low concentration of it (outside the stomach) to the high concentration of it (inside the stomach) using H^+ pumps, and along with the chloride ions, hydrochloric acid is synthesized.
This mechanism could be done using H^+/K^+ pumps too.

C- **H^+/K^+ pump**.

D- **Ca^{+2} pump**:

Inside the endoplasmic reticulum, we have a high concentration of calcium, we are getting this concentration by Ca^{+2} pumps, we have a plenty of these pumps in the membrane of endoplasmic reticulum transporting calcium from the cytosol into endoplasmic reticulum.

Also, it keeps a low concentration of Ca^{+2} ions inside the cells, for example: In the cardiac muscle, Ca^{+2} pump is used to transport Ca^{+2} ions out of it, if the Ca^{+2} ions kept inside the muscle it will remain contracted, that will stop the heart from working.

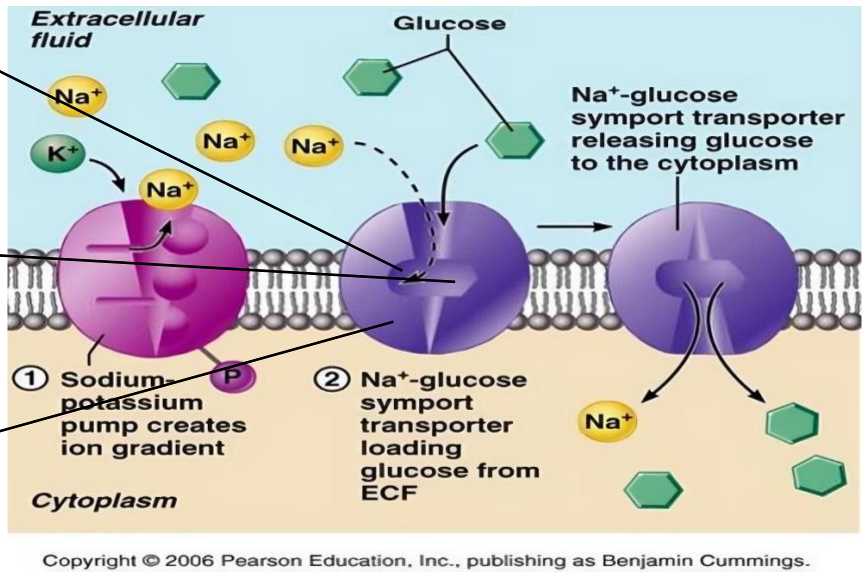
2-Secondary active transport:

Carriers that can transport Na^+ along with another particle, **Na^+** in this type is transported from the **high** concentration to the **low** concentration, the **other particle** is transported from the **low** concentration to the **high** concentration.

A binding site for Na^+.

A binding site for another particle.

This carrier is called **sodium dependent carrier**.

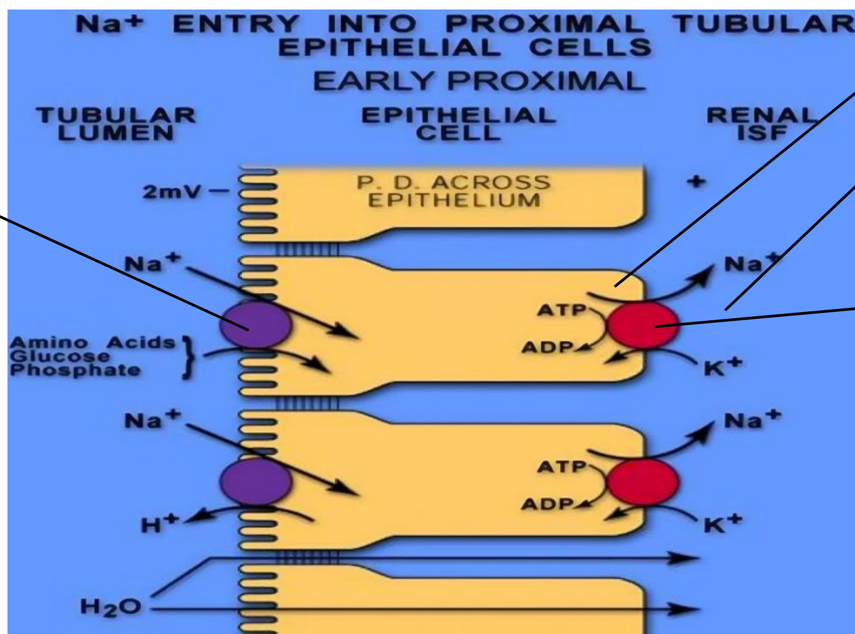


In this type of active transport, there is not directly use of ATP.

But, it happens because of the primary active transport which transport uses ATP.

Secondary uses the driving force that is created by primary active transport to transport other molecules.

Secondary active transport carrier (**called sodium dependent carrier**) that uses Na^+ transporting (from high to low concentration of Na^+) to transport other particles from low to high concentration of it.



Inside the cell.

outside the cell.

Primary active transport carrier (Na^+/K^+ pump) keeping high concentration of Na^+ ions outside the cell.

This example occurs especially through the epithelial cells of the intestinal tract to promote (increase) absorption of these (Glucose and Amino Acids) substances into the blood.

When you hear "Na^+ dependent carrier" then this transport is **Secondary active transport**.

Based on the movement direction of particles, we can divide Secondary active transport into Co-transport and Counter transport.

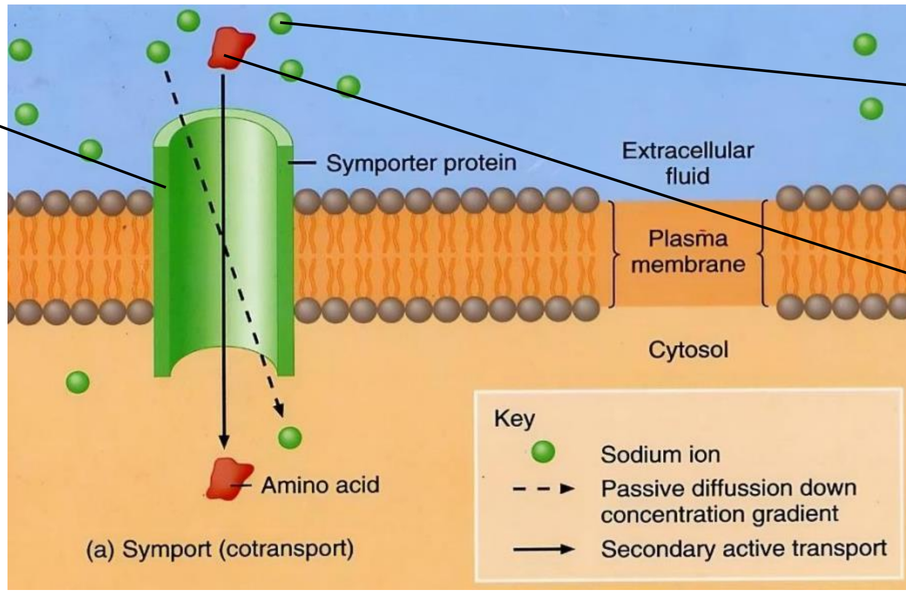
A- Co-transport:

In this type, both particles are transported in the same direction.

It could be called Symport too.

This is a carrier not a channel, don't let its shape fool you.

It transports particles in the same direction, so it's Co-transport (symport).



It's transporting Na+ ions from high to low concentration.

It's transporting Amino Acids from low to high concentration.

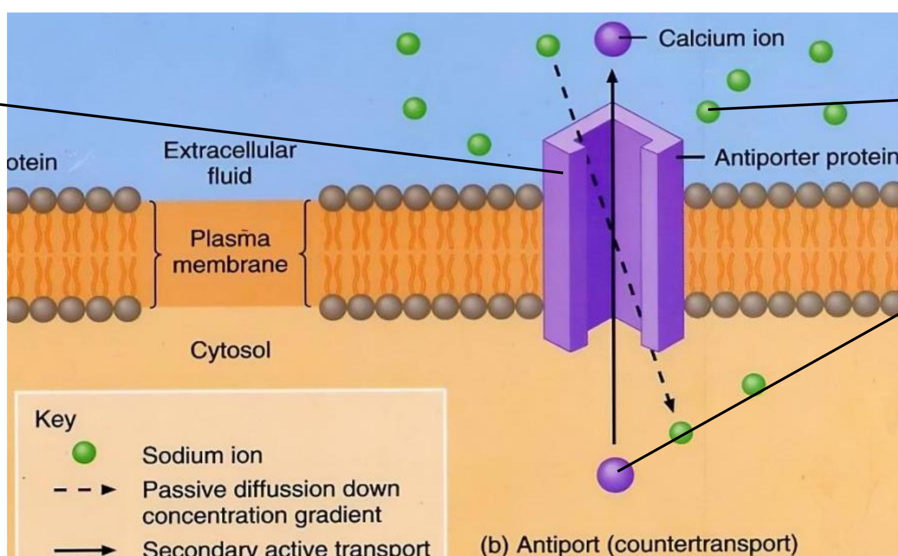
B- Counter transport:

In this type, particles are transported in opposite directions.

It could be called Antiport too.

Again, this is a carrier not a channel, don't let its shape fool you.

It transports particles in opposite directions, so it's Counter transport (antiport).



It's transporting Na+ ions from high to low concentration.

It's transporting Ca^{+2} ions from low to high concentration.

In conclusion, the work of secondary active transport depends on Na+ ions concentration, so as we mentioned before, Na^+/K^+ pump (primary active transport) is important for the cell.

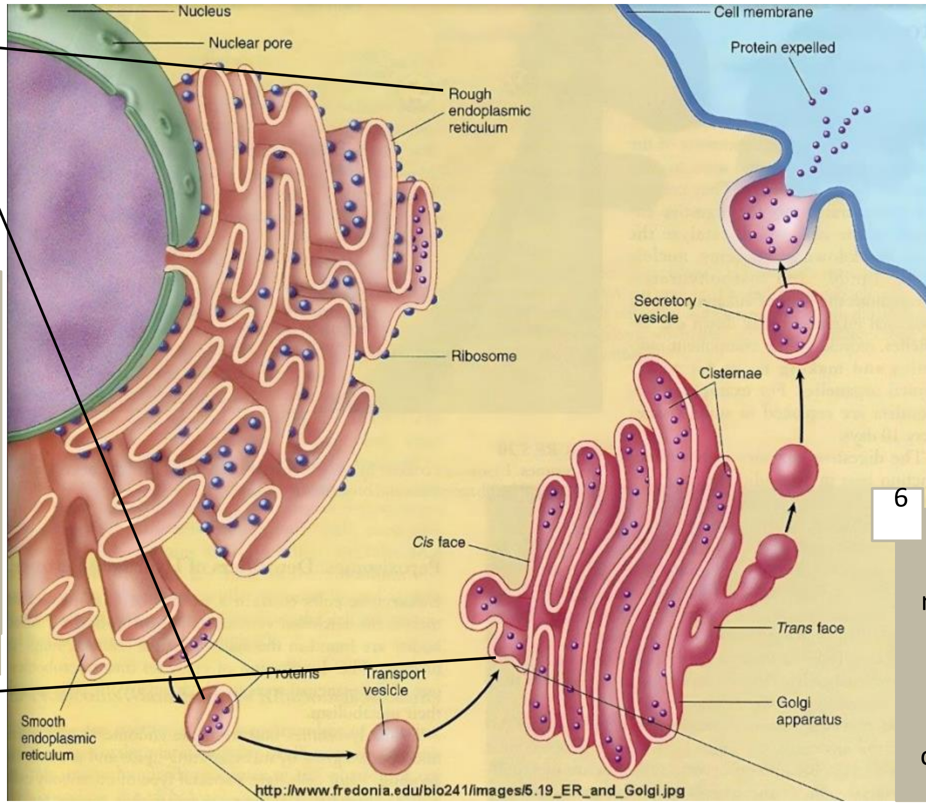
3-Vesicular transport:

1 Synthesizes proteins.

2 Proteins are transported in vesicles.

3 These vesicles are attached to motor proteins which are transported on the cytoskeleton (Microtubules) by phosphorylation and dephosphorylation (Uses ATP)

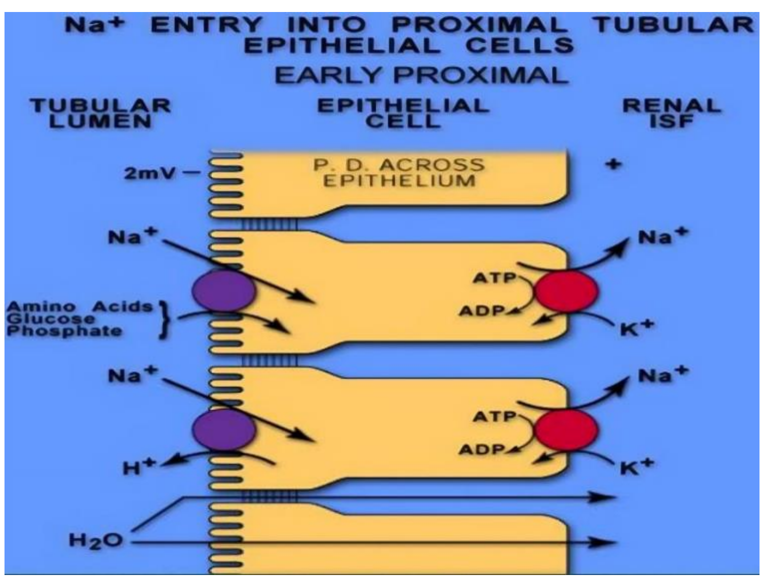
4 Then they reach Golgi Apparatus.



5 Golgi Apparatus packages these proteins and send them to their exact destinations, how Golgi knows their destinations? Each protein has an **address sequence**, which specify its destination.

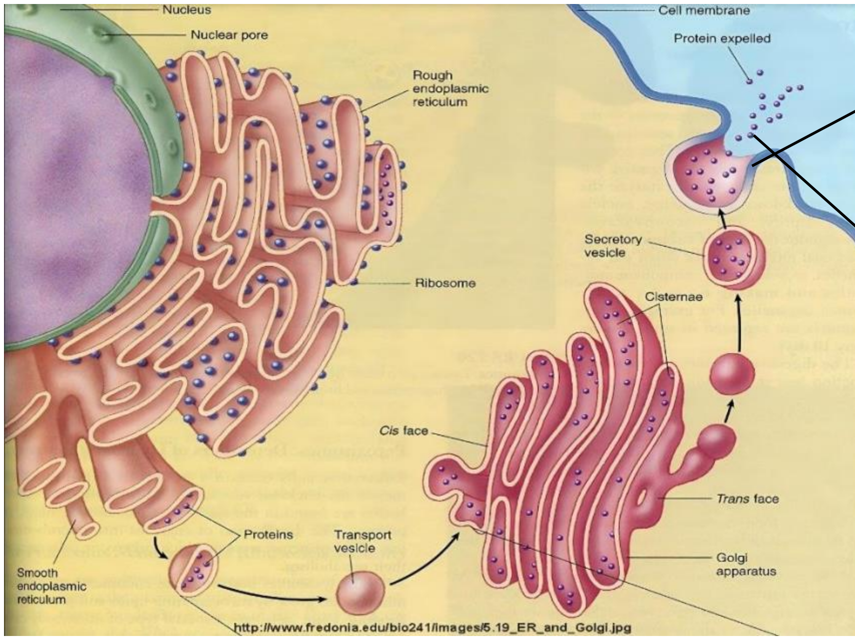
6 After the vesicle is fused with the membrane, proteins could be secreted, or used in the membrane, as carriers for example.

The cell is highly regulated, one of these regulations is the specificity of Golgi Apparatus in sending vesicles to their exact destination, for example, Golgi sends Na^+/K^+ pump exactly to Renal ISF part not to Tubular lumen part.



Terms Related to Vesicular Transport

A- Exocytosis:

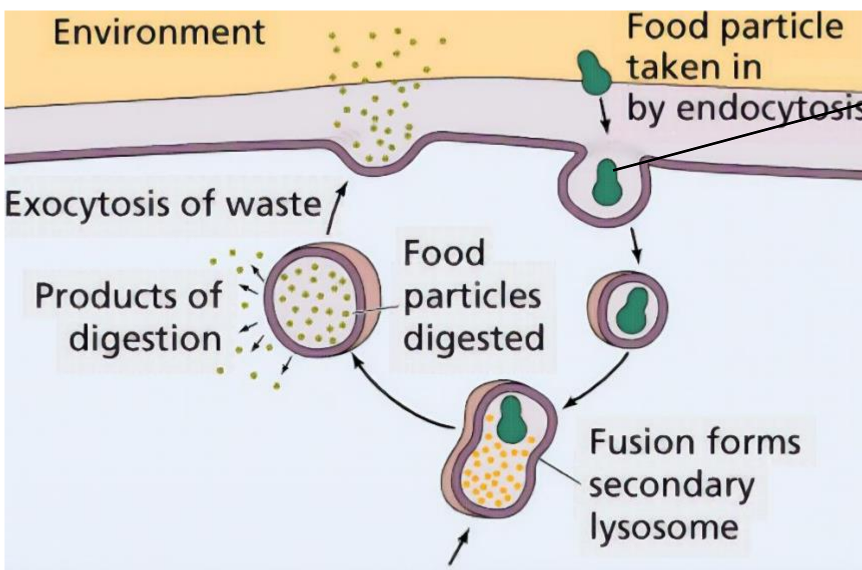


The fusing of vesicle with the membrane.

Secretion the content of the vesicle outside the cell.

This is called Exocytosis.

B- Endocytosis:



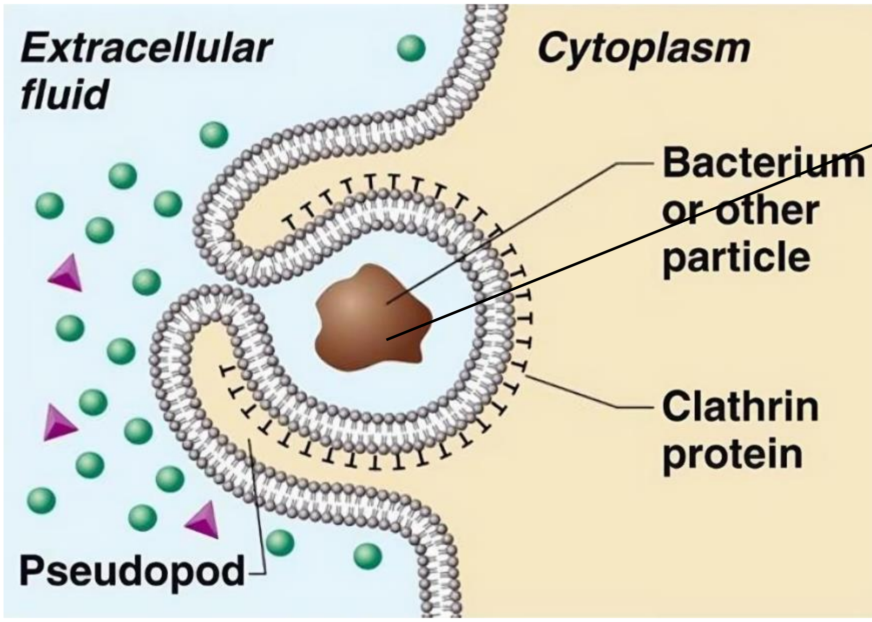
A reversal of Exocytosis, engulfing particles into the cell.

This is called Endocytosis.

C- Phagocytosis:

There are many cells having phagocytic function in our body.

These cells must recognize pathogens, for example antibodies on pathogens are recognized by phagocytic cells.



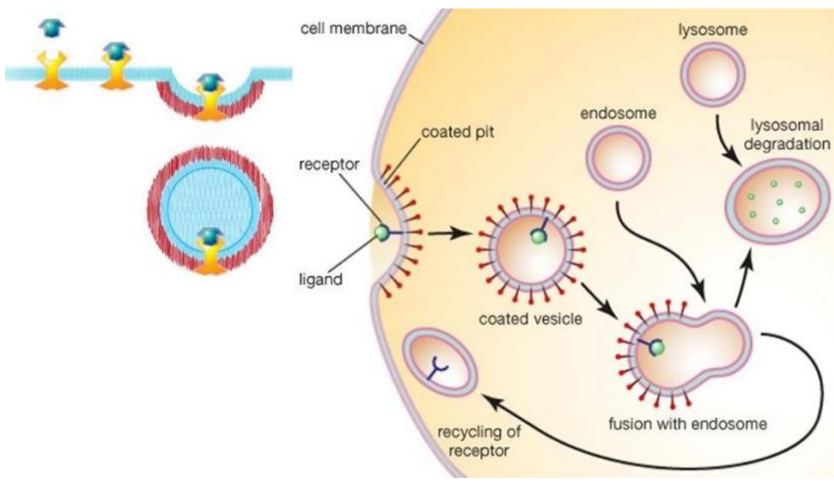
It's also Endocytosis, but engulfing Pathogens, Bacteria and Viruses.

Called Phagocytosis.

D- Receptor Mediated Endocytosis:

There are some particles that can be recognized by their specific receptor.

Once these Ligands bind to their receptor, the endocytosis will be activated.

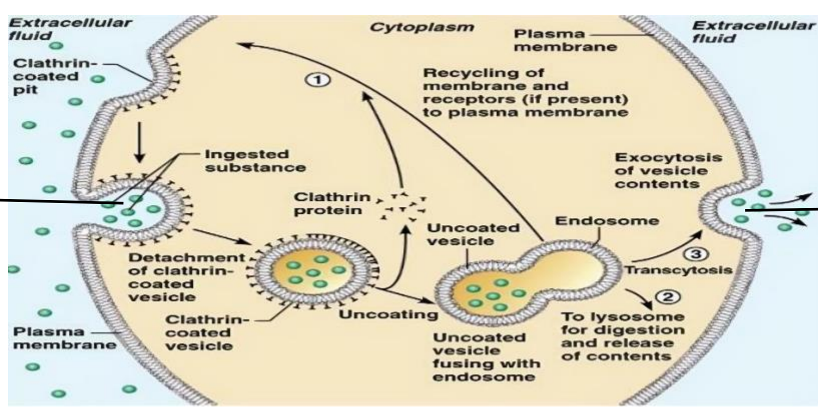


Lysosome will degrade the vesicle and destroy the Ligand.

The receptor will be recycled.

E- Transcytosis:

Simply, particles will be engulfed by Endocytosis from one side of the cell.



And secreted by Exocytosis from other side of the cell.

F- Pinocytosis:

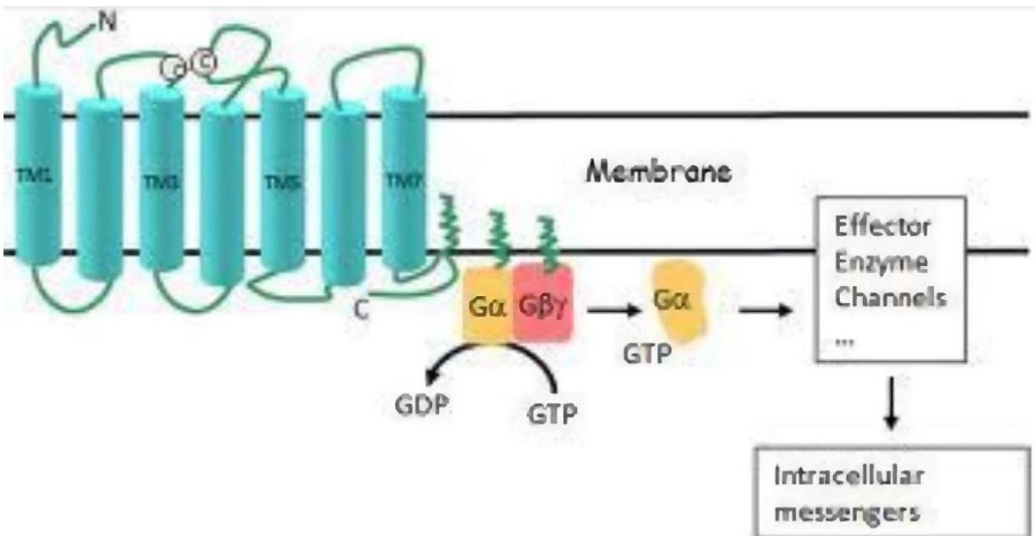
Engulfing water inside the cell (drinking), that happens in some types of Bacteria, not in our bodies.

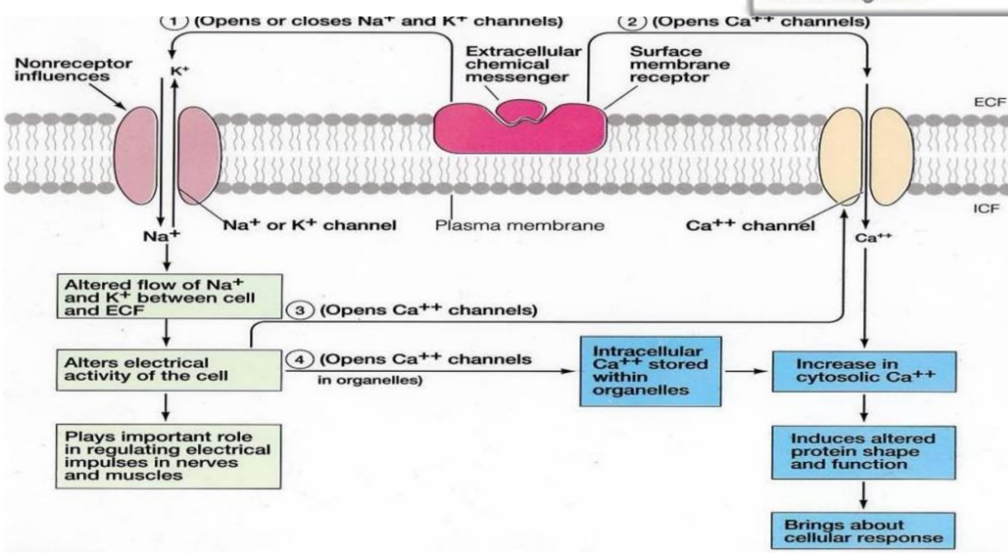
الدكتور تكلم عنه وغير موجود بالسلايدات

Control of Transport and Activity of Enzymes

Over plasma membrane we have receptors, those receptors are specific, some of them are linked to channels through G-proteins (A group of protein structures, G because they use GTP). This is some sort of signal transduction mechanism that control the activity of the cell.

Once we have a ligand bound to the specific receptor, one of the G-protein subunits will dissociate (alpha subunit in this example), this subunit will cause the opening of sodium channel.





This picture isn't true, because the receptor is linked to two types of channels, Na^+ and Ca^{++}.

Each receptor could be linked to one type of channels.

Anyway, by these receptors we can control the activity of channels, by activating or deactivating them.

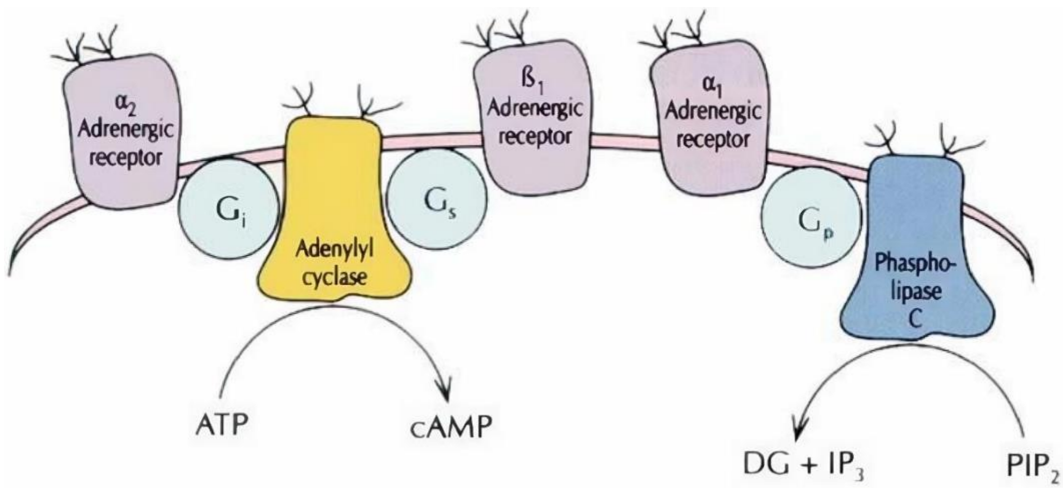
Also, the activity of channels can be controlled by specific enzymes, as you can see in the picture, we can have some type of receptors linked to:

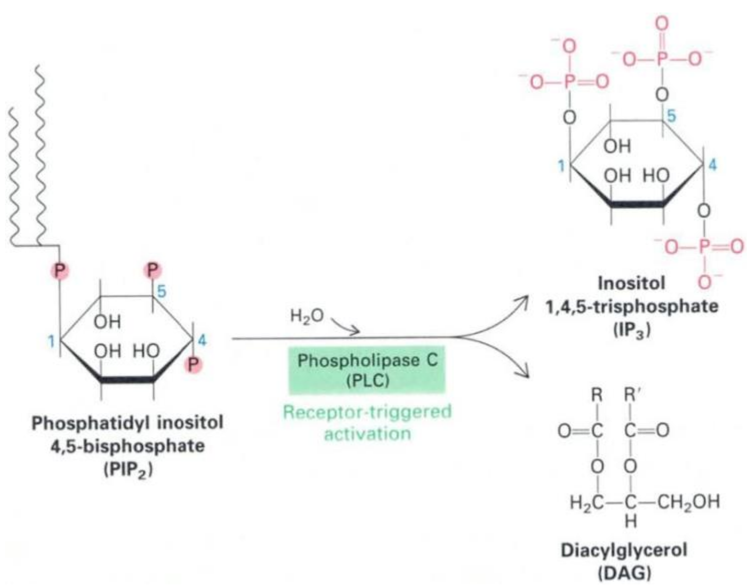
A- An enzyme called **Adenylyl cyclase**:

increases the concentration of cAMP, some channels according to the concentration of cAMP become more active.

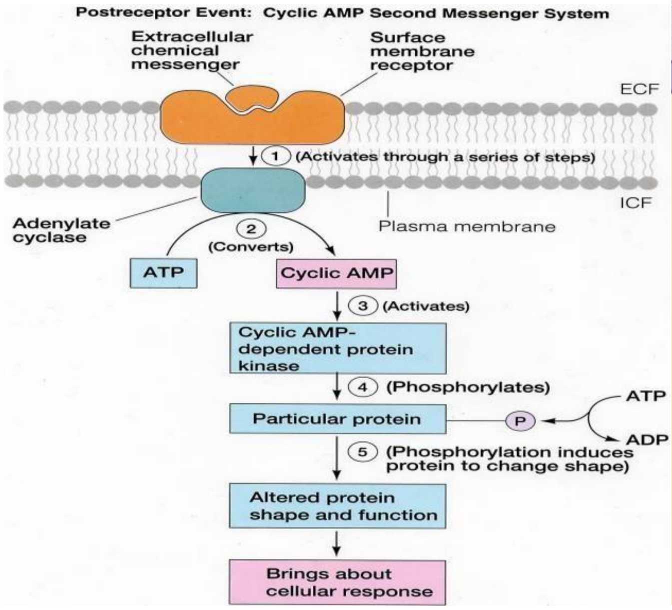
B- An enzyme called **Phospholipase C**:

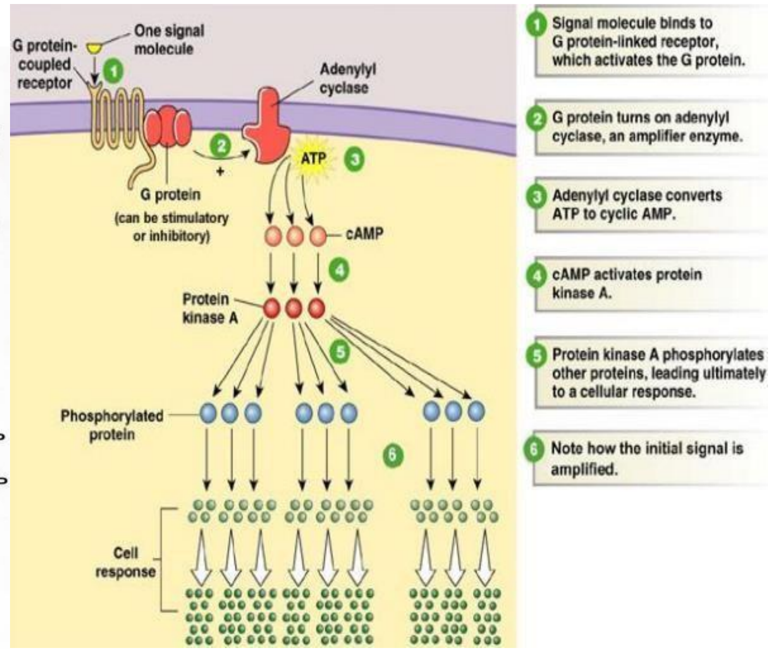
Splits PIP_2 (Phosphatidylinositol 4,5-bisphosphate) into IP3 (inositol 1,4,5-trisphosphate) and DG (Diacylglycerol), IP3 can change the activity of Ca^{+2} channels on the membrane of endoplasmic reticulum causing the release of Ca^{+2} ions from the endoplasmic reticulum into cytosol to change the activity of that cell.

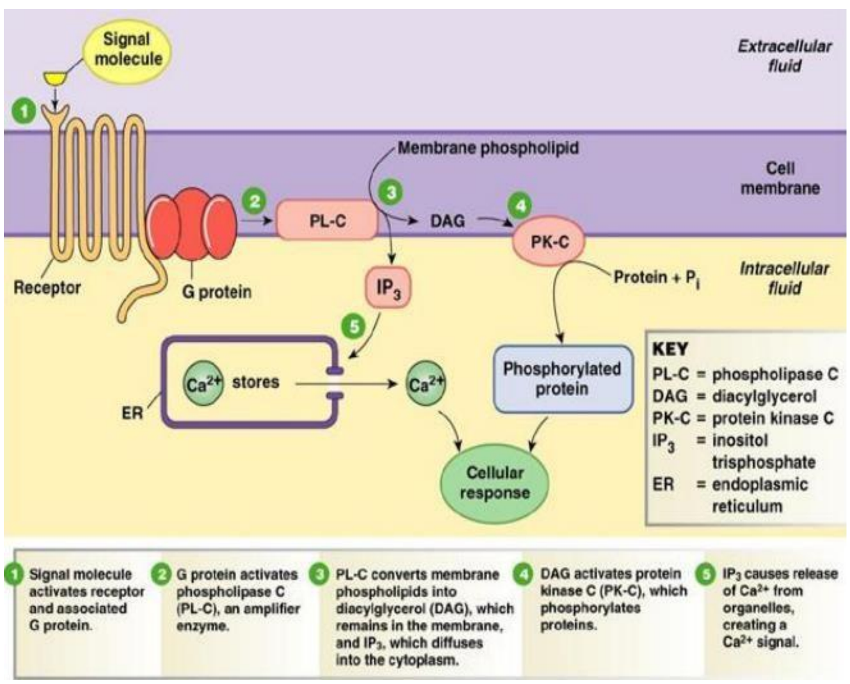




Extra pictures, our doctor didn't say more information about them than the above picture.

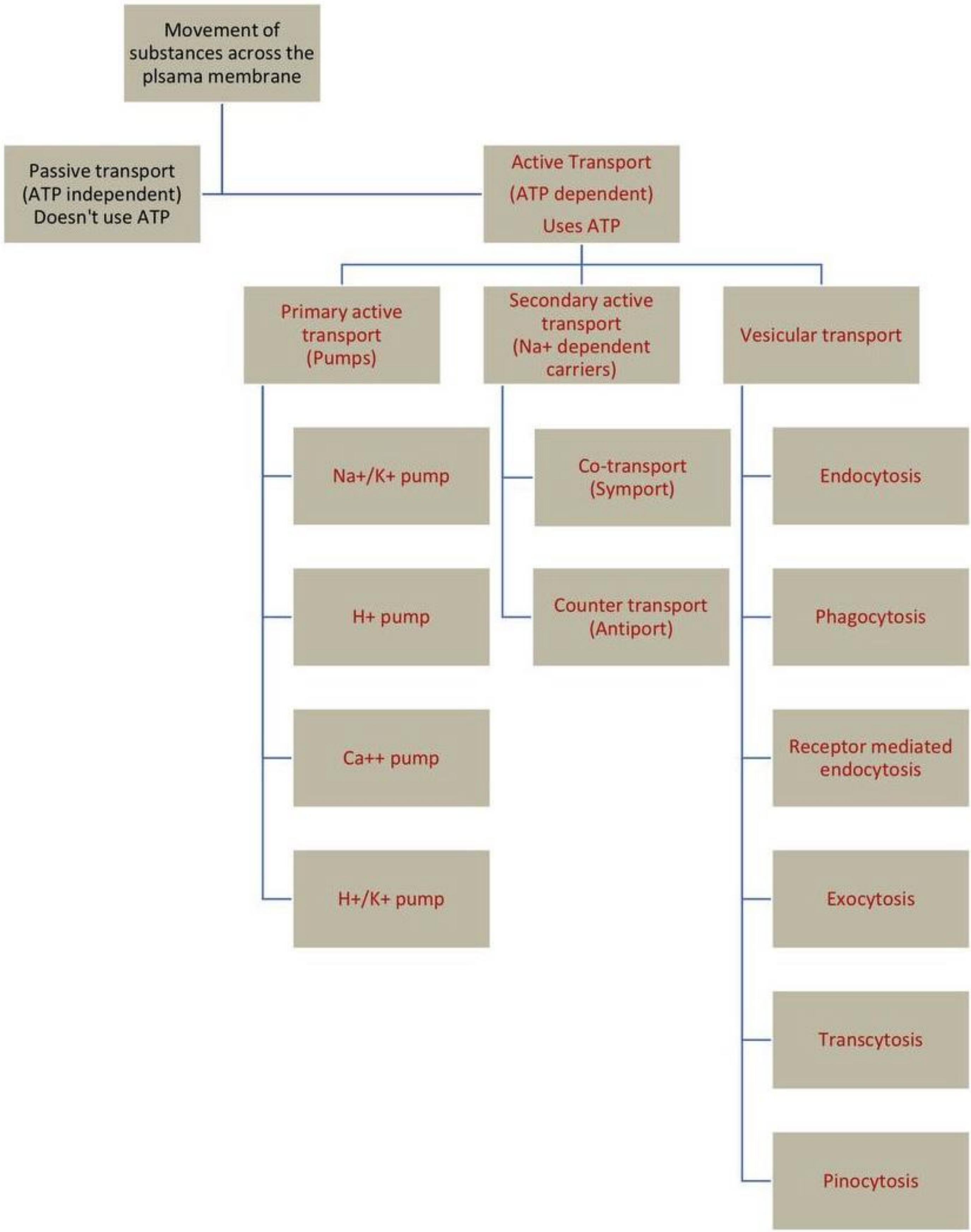






Transport Across Plasma Membranes

Summary



PROCESS	ENERGY SOURCE	DESCRIPTION	EXAMPLES
DIFFUSION			
Simple diffusion	Kinetic energy	Net movement of particles (ions, molecules, etc.) from an area of their higher concentration to an area of their lower concentration, that is, along their concentration gradient	Movement of fats, oxygen, carbon dioxide through the lipid portion of the membrane
Facilitated diffusion	Kinetic energy	Same as simple diffusion, but the diffusing substance is attached to a lipid-soluble membrane carrier protein or moves through a membrane channel	Movement of glucose and some ions into cells
Osmosis	Kinetic energy	Simple diffusion of water through a selectively permeable membrane	Movement of water into and out of cells directly through the lipid phase of the membrane or via membrane pores (aquaporins)
FILTRATION			
	Hydrostatic pressure	Movement of water and solutes through a semipermeable membrane (either through the plasma membrane or between cells) from a region of higher hydrostatic pressure to a region of lower hydrostatic pressure, that is, along a pressure gradient	Movement of water, nutrients, and gases through a capillary wall; formation of kidney filtrate

Transport Process	Description	Substances Transported
Osmosis	Movement of water molecules across a selectively permeable membrane from an area of higher water concentration to an area of lower water concentration.	Solvent: water in living systems.
Diffusion	Random mixing of molecules or ions due to their kinetic energy. A substance diffuses down a concentration gradient until it reaches equilibrium.	
Diffusion through the lipid bilayer	Passive diffusion of a substance through the lipid bilayer of the plasma membrane.	Nonpolar, hydrophobic solutes: oxygen, carbon dioxide, and nitrogen; fatty acids, steroids, and fat-soluble vitamins; glycerol, small alcohols; ammonia. Polar molecules: water and urea.
Diffusion through membrane channels	Passive diffusion of a substance down its electrochemical gradient through channels that span a lipid bilayer; some channels are gated.	Small inorganic solutes, mainly ions: K^+, Cl^-, Na^+, and Ca^{2+}. Water.
Facilitated Diffusion	Passive movement of a substance down its concentration gradient via transmembrane proteins that act as transporters; maximum diffusion rate is limited by number of available transporters.	Polar or charged solutes: glucose, fructose, galactose, and some vitamins.
Active Transport	Transport in which cell expends energy to move a substance across the membrane against its concentration gradient through transmembrane proteins that act as transporters; maximum transport rate is limited by number of available transporters.	Polar or charged solutes.
Primary active transport	Transport of a substance across the membrane against its concentration gradient by pumps; transmembrane proteins that use energy supplied by hydrolysis of ATP.	Na^+, K^+, Ca^{2+}, H^+, I^-, Cl^-, and other ions.
Secondary active transport	Coupled transport of two substances across the membrane using energy supplied by a Na^+ or H^+ concentration gradient maintained by primary active transport pumps. Antiporters move Na^+ (or H^+) and another substance in opposite directions across the membrane; symporters move Na^+ (or H^+) and another substance in the same direction across the membrane.	Antiport: Ca^{2+}, H^+ out of cells. Symport: glucose, amino acids into cells.
Transport in Vesicles	Movement of substances into or out of a cell in vesicles that bud from the plasma membrane; requires energy supplied by ATP.	
Endocytosis	Movement of substances into a cell in vesicles.	
Receptor-mediated endocytosis	Ligand-receptor complexes trigger infolding of a clathrin-coated pit that forms a vesicle containing ligands.	Ligands: transferrin, low-density lipoproteins (LDLs), some vitamins, certain hormones, and antibodies.
Phagocytosis	"Cell eating"; movement of a solid particle into a cell after pseudopods engulf it to form a phagosome.	Bacteria, viruses, and aged or dead cells.
Pinocytosis	"Cell drinking"; movement of extracellular fluid into a cell by infolding of plasma membrane to form a pinocytic vesicle.	Solutes in extracellular fluid.
Exocytosis	Movement of substances out of a cell in secretory vesicles that fuse with the plasma membrane and release their contents into the extracellular fluid.	Neurotransmitters, hormones, and digestive enzymes.

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