CELL BIOLOGY

Dr. Treefa F. Ismail **4th stage**

Lecture 4: Transport through Cell Membrane **25/10/2021**

In cellular biology, membrane transport refers to the collection of mechanisms that regulate the passage of solutes such as ions and small molecules through biological membranes, which are lipid bilayers that contain proteins embedded in them.

The cell membrane is selectively permeable. It lets some substances pass through rapidly and some substances pass through more slowly, but prevents other substances passing through it at all.

Molecules can move into or out of cells by 2 basic mechanisms:

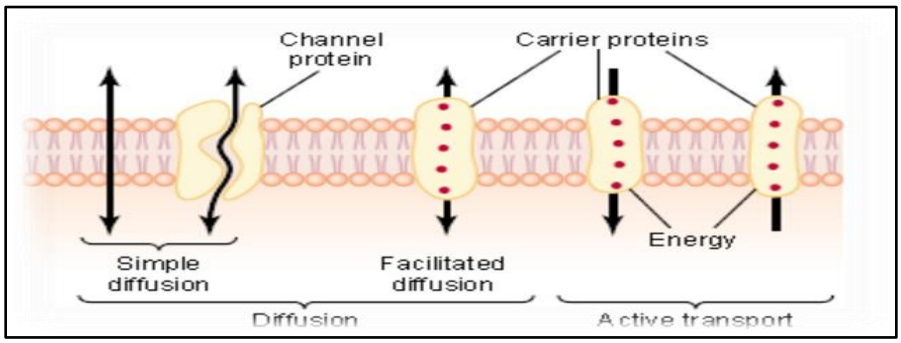
1- Passive transport or diffusion
2- Active transport

*PASSIVE TRANSPORT or DIFFUSION:

It is the movement of the molecules from a region of higher concentration to a region of their lower concentration. The molecules move down a concentration gradient. Molecules have kinetic energy, which makes them move about randomly. As a result of diffusion molecules reach an equilibrium where they are evenly spread out.
Diffusion is a PASSIVE process which means no energy is used to make the molecules move, they have a natural kinetic energy.
Diffusion is important to cells because it allows them to gain the useful substances they require to obtain energy and grow, and lets them get rid of waste products.

It is further devided into:

1- Simple diffusion through lipid layer
2- Simple diffusion through protein layer
3- Facilitated or carrier-mediated diffusion

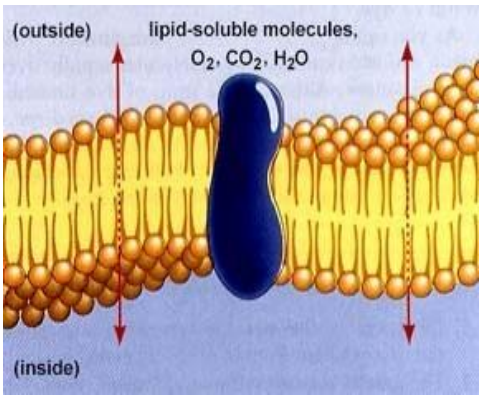


Simple Diffusion through Lipid Bilayer

- Lipid layer of the cell membrane is permiable to lipid soluble substances like oxygen, carbon dioxide and alcohol.

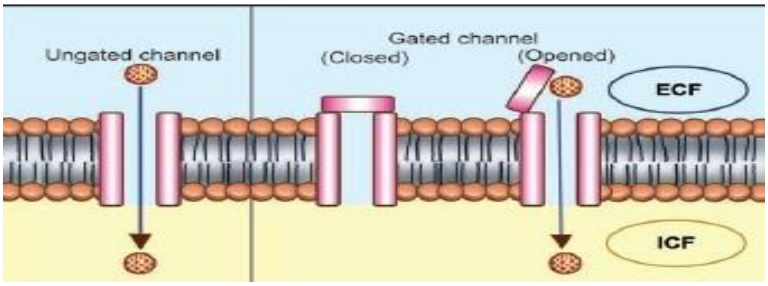
- The diffusion through lipid layer is directly proportional to the solubility.

1. Oxygen – Non-polar so diffuses very quickly.
2. Carbon dioxide – non Polar but very small so diffuses quickly.
3. Water – Polar but also very small so diffuses quickly.



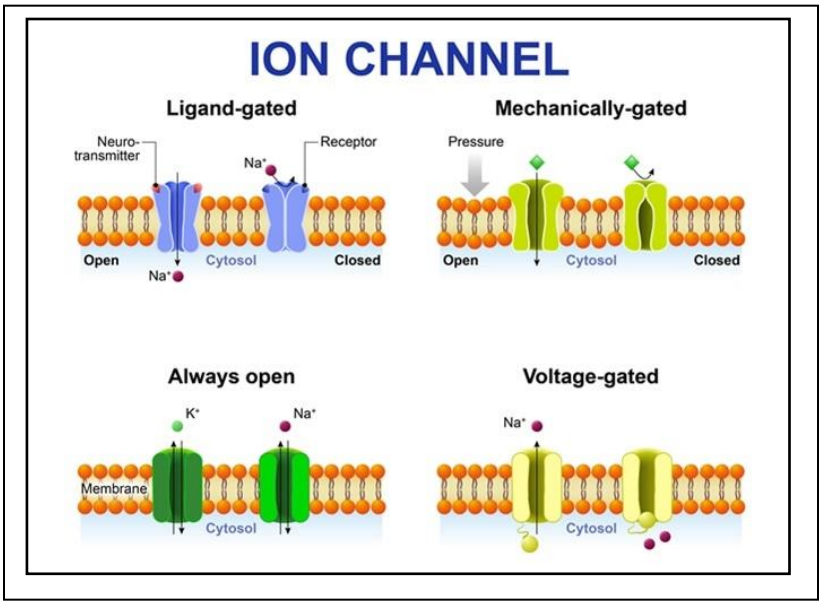
Simple Diffusion through Protein Layer

Proteins form the channels for diffusion of substances which are water soluble:
-Some channels are continuously open are called Ungated channels.
-Some channels are always closed and are called Gated channels.



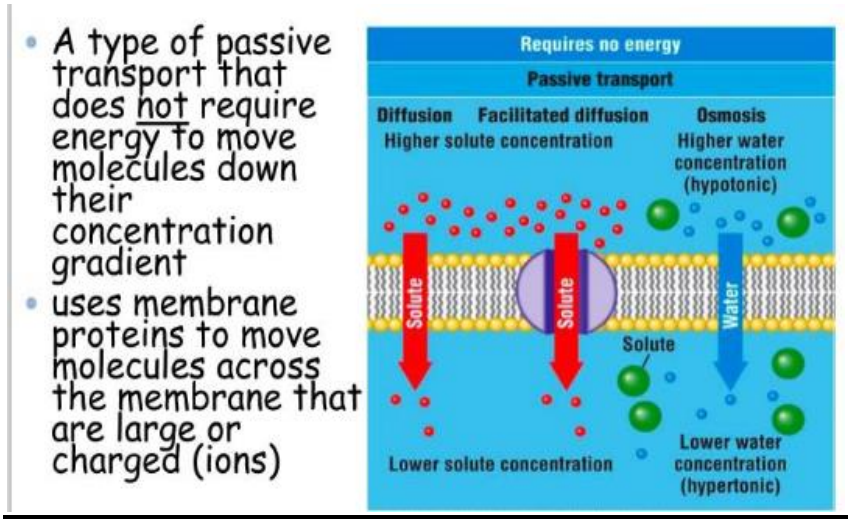
Gated channels:

These are further devided into:
1- Voltage-gated channels.
2- ligand-gated channels.
3- mechanically gated channels.



Facilitated Diffusion:

Large polar molecules such as glucose and amino acids, cannot diffuse across the phospholipid bilayer. Also ions such as Na^+ or Cl^- cannot pass. The diffusion by which water soluble substances having larger molecules are transported through cell membrane with the help of carrier protein is called **FACILITATED DIFFUSION**. Movement of molecules is still PASSIVE just like ordinary diffusion, the only difference is, the molecules go through a protein channel instead of passing between the phospholipids.



FACTORS THAT DETERMINE THE RATE OF DIFFUSION:

These are eight factors as given:

1. The steepness of the concentration gradient.
2. Temperature.
3. Solubility of the substance.
4. permeability of the cell membrane.
5. Thickness of the cell membrane
6. Size of the molecule.
7. Size of the ions.
8. Charge of the ions.

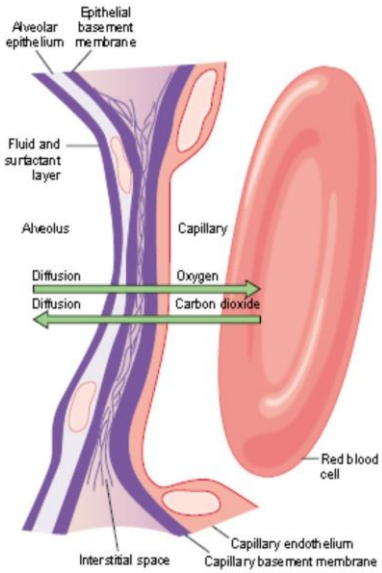
SPECIAL TYPES OF PASSIVE TRANSPORT

In adddition to diffusion,there are some special types of passive transport,i.e:

Bulk flow, Filtration, Osmosis.

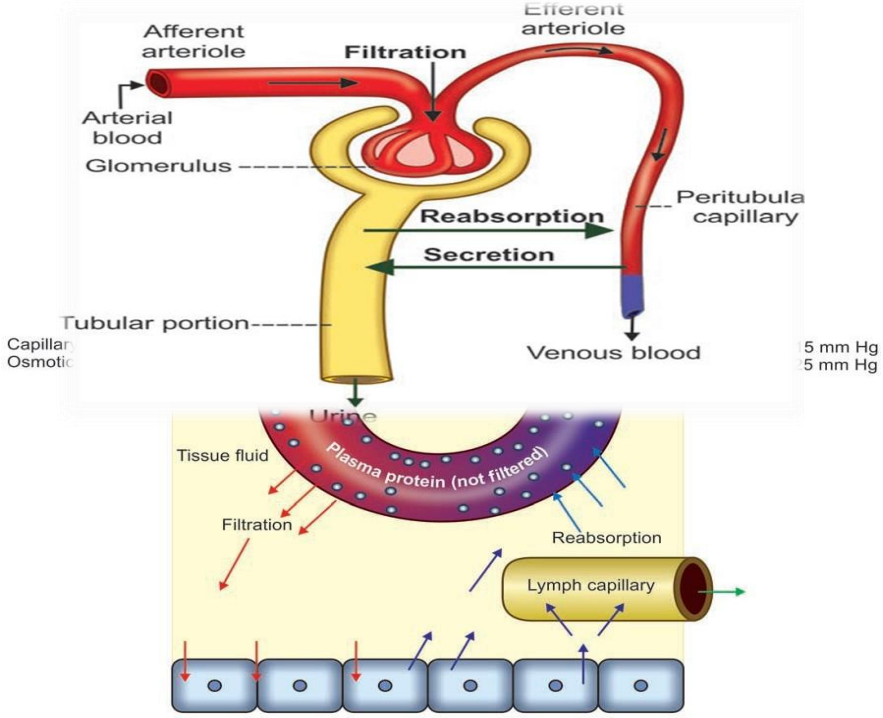
BULK FLOW:

Bulk flow is the movement of large quantity of substances from a region of high pressure to the region of low pressure.
It is due to the pressure gradient of the substances across the cell membrane



FILTRATION:

Movement of water and solutes from an area of high hydrostatic pressure to an area of low hydrostatic pressure is called Filtration.



OSMOSIS:

Cells can gain or lose water by the process of osmosis. This depends on the water concentration of the solution inside the cell compared to water concentration of the solution outside the cell.

Solutions with a high concentration of solute molecules, such as sugars or salts, have a low concentration of water molecules and vice versa.

Osmosis is the net movement of water from a region of high water concentration to a region of low water concentration through a selectively permeable membrane.

Or the spontaneous net movement of solvant molecules through a semi-permeable membrane into a region of higher solute concentration, in the direction that tends to equalize the solute concentration on the two sides.

OSMOTIC PRESSURE

Osmotic pressure is the pressure created by solutes in a fluid during osmosis.
The external pressure required to be applied so that there is no net movement of solvent across the membrane.

Importance of osmotic pressure:

In plants:

It allow for water uptake photosynthesis and general stability. Osmosis ensure that all cells and stuctures within a plants have correct water pressure and volume.

In Animals:

Our cells have a semipermeable membranes that do not allow salt particles to flow in and out. The only way then (water down) anover salted cell is to allow water to move back and forth.

Preserving fruits and meat:

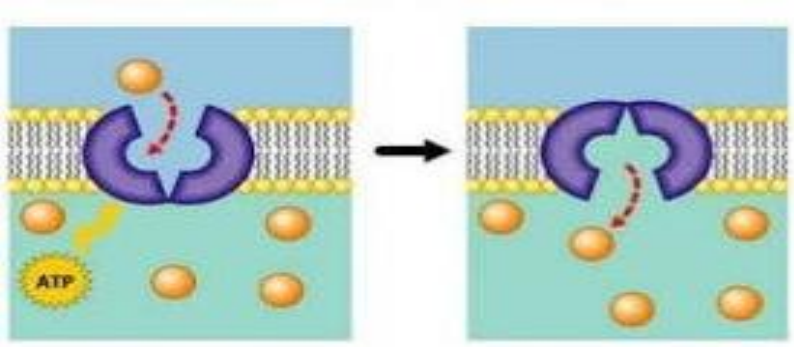
Osmosis is also used for preserving fruits and meats, through the process is quiet different for the two. In the case of fruits, osmosis is used to dehydrate it. In case of meat, osmosis draws salt into it, thus preventing the intrution of bacteria.

Biological importance of osmosis:

1- Fluid Balance
2- Blood volume (osmosis significantly contributes to the regulation of blood volume and urine excretion).
3- Transfusion (isotonic solution of NACL or glucose are commonly used in i/v transfusion in hospital for treatment of dehydration, burns etc).

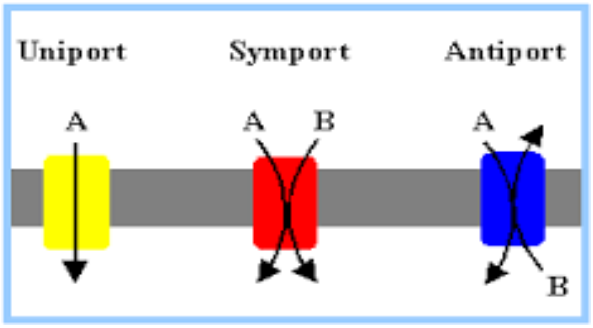
*ACTIVE TRANSPORT:

Is when substances cross the cell membrane against the concentration gradient, using energy and carriers in the membrane.



Carrier Proteins of Active Transport

There are several types of membrane transport proteins:-
uniports and **cotransport** **(Symport & Antiport)**.
Uniports can move solutes from one side to another, change the position of the proteins. Cotransport systems can simultaneously sending two solutes across the lipid bilayer. Solutes are sent in the same direction or opposite directions Transport proteins does not need to be acts natural direction.



Mechanism of active transport

When a substance to be transported across the cell membrane comes near the cell, it combines with the carrier protein of the cell membrane and forms substance-protein complex. This complex moves towards the inner surface of the cell membrane. Now, the substance is released from the carrier proteins. The same carrier protein moves back to the outer surface of the cell membrane to transport another molecule of the substance.

Substances transported by active transport:

Substances, which are transported actively, are in ionic form and non- ionic form.
Substances in ionic form are sodium, potassium, calcium, hydrogen, chloride and iodide while Substances in non-ionic form are glucose, amino acids and urea.

TYPES ACTIVE TRANSPORT:

A- Primary active transport

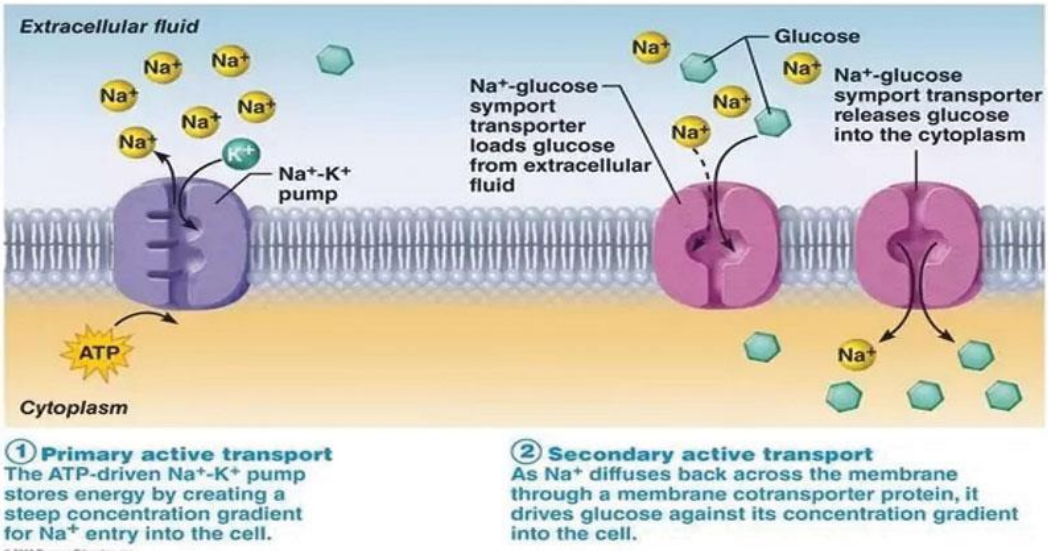
In **primary active transport**, the energy is derived directly from the breakdown of ATP to **transport** molecules across a membrane against their concentration gradient.
Therefore, all groups of ATP-powered pumps contain one or more binding sites for ATP, which are always present on the cytosolic face of the membrane.

Primary active transport is also called direct active transport or uniport. Substances that are transported across the cell membrane by primary active transport include metal ions, such as Na+, K+, Mg2+, and Ca2+.

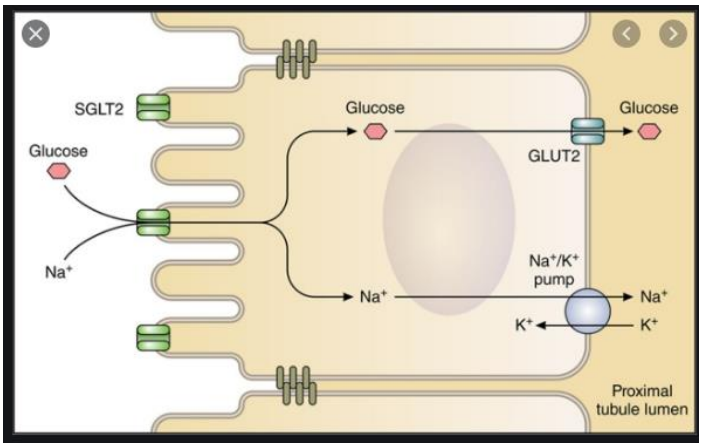
Most of the enzymes that perform this type of transport are transmembrane ATPases.
The most studied example of primary active transport is the plasma membrane Na+,K+-ATPase. Other familiar examples of primary active transport are the redox H+-gradient generating system of mitochondria and the ATP-driven acid (H+) pump found in the epithelial lining of the stomach.

B- Secondary active transport

In the **secondary active transport**, the energy is derived secondarily from energy that has been stored in the form of ionic concentration **differences** between the two sides of a membrane.
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.
One molecule helps set up the needed gradient to allow for the movement of many chemicals into and out of the cell. The energy derived from the pumping of protons across a cell membrane is frequently used as the energy source in secondary active transport.



In humans, sodium (Na+) is a commonly co-transported ion across the plasma membrane, whose electrochemical gradient is then used to power the active transport of a second ion or molecule against its gradient.



Importance of Active Transport:-

This process is vital for living organisms and is important for the following reasons:
(1) Absorption of most nutrients from the intestine
(2) Rapid and selective absorption of nutrients by cells
(3) Maintaining a membrane potential
(4) Maintaining water and ionic balance between cells and extracellular fluids.

SPECIAL TYPES OF ACTIVE TRANSPORT

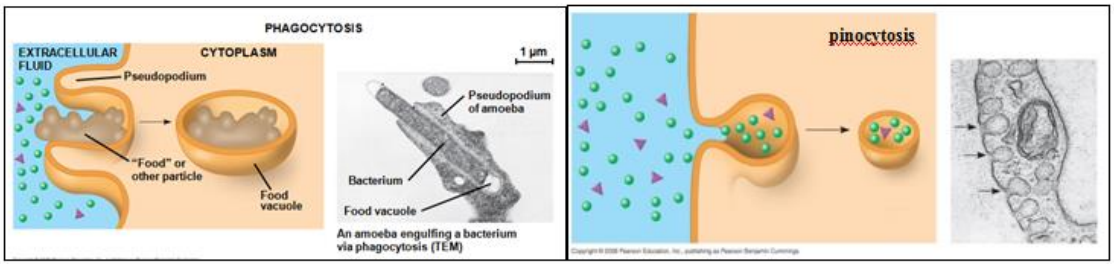
Membrane transport of Macromolecules can divide into

1. Endocytosis
2. Exocytosis
3. Transcytosis.

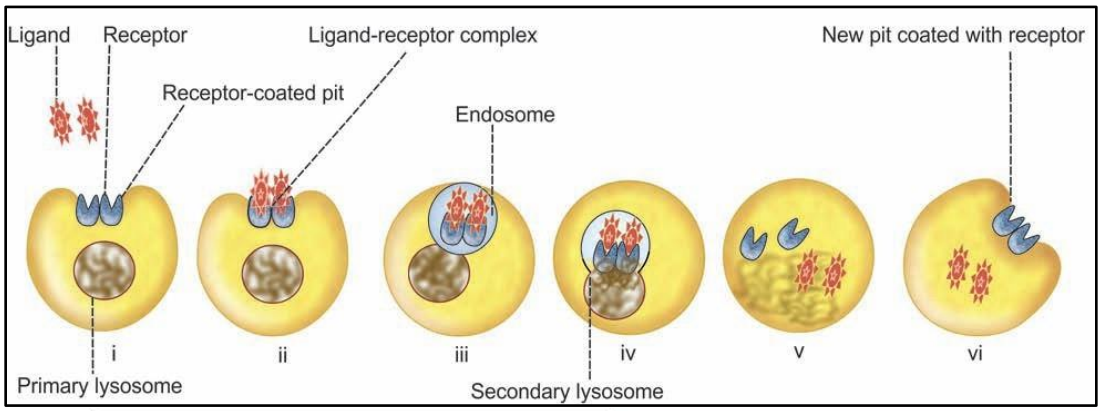
Endocytosis is the process of capturing a substance or particle from outside the cell by engulfing it with the cell membrane, and bringing it into the cell.

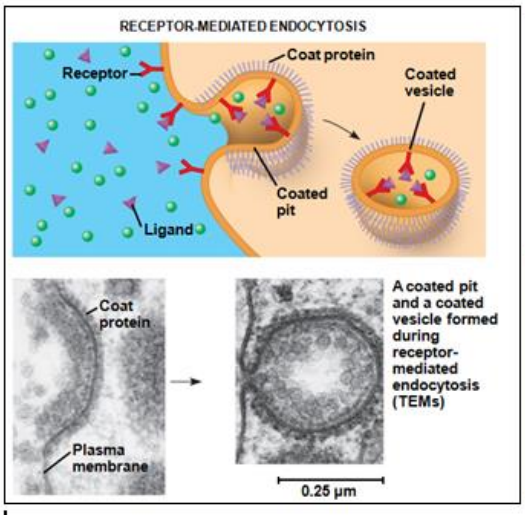
There are three types of endocytosis:
- Phagocytosis ("cellular eating"): A cell engulfs a particle in a vacuole, the vacuole fuses with a lysosome to digest the particle
Larger bacteria, larger antigens and other larger foreign bodies are taken inside the cell by means of phagocytosis. Only few cells in the body like neutrophils, monocytes and the tissue macrophages show phagocytosis. Among these cells, the macrophages are the largest phagocytic cells.

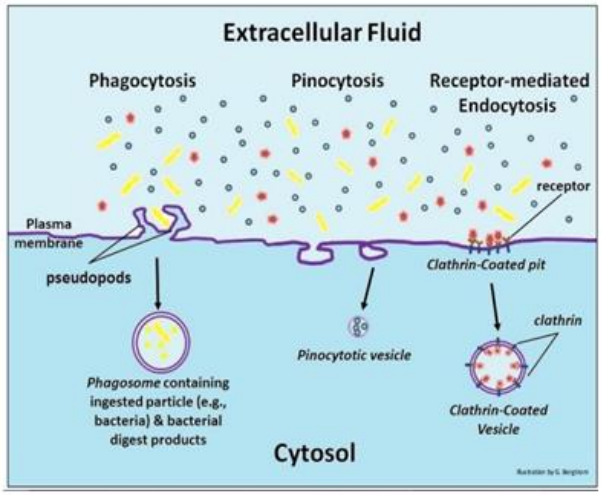
- Pinocytosis ("cellular drinking"): Molecules are taken up when extracellular fluid is "gulped" into tiny vesicles



- **Receptor-mediated endocytosis**: is the transport of macromolecules with the help of a receptor protein. Surface of cell membrane has some pits which contain a receptor protein called **clathrin.** Binding of ligands to receptors triggers vesicle formation, A **ligand** is any molecule that binds specifically to a receptor site of another molecule

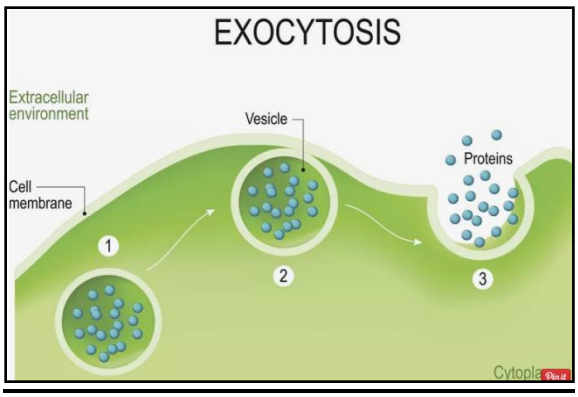






Exocytosis

Removes the cell's waste products– parts of molecules that are not used by the cell.

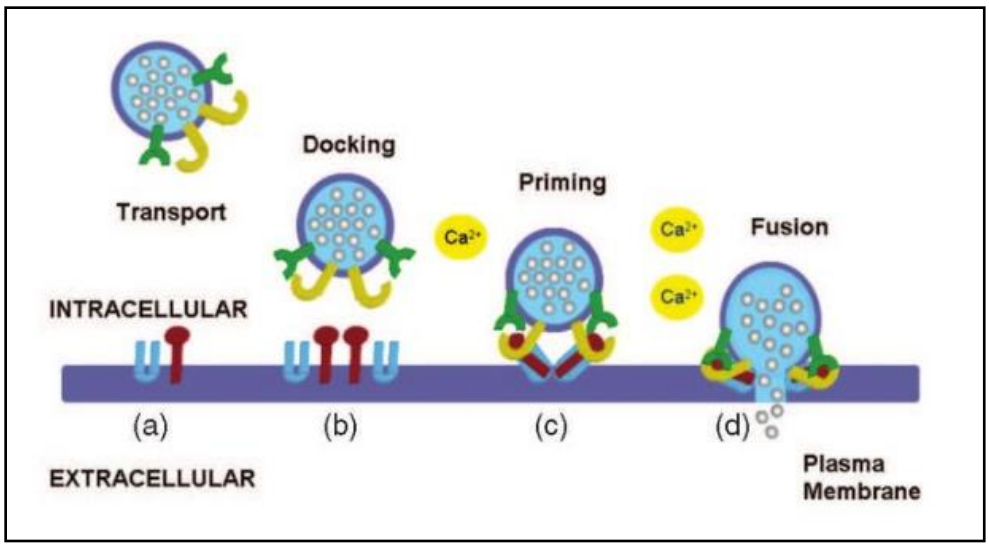


In exocytosis, transport vesicles migrate to the membrane, fuse with it, and release their contents. Many secretory cells use exocytosis to export their products.
There are five steps involved:-

1- **Vesicle Trafficking:** Vesicles are transported to the cell membrane along microtubules of the cytoskeleton. Movement of the vesicles is powered by the motor proteins kinesins, dyneins, and myosins.
2- **Vesicle Tethering:** Upon reaching the cell membrane, the vesicle becomes linked to and pulled into contact with the cell membrane.
3- **Vesicle Docking:** Docking involves the attachment of the vesicle membrane with the cell membrane. The phospholipid bilayers of the vesicle membrane and cell membrane begin to merge.
4- **Vesicle Priming:** Priming occurs in regulated exocytosis and not in constitutive exocytosis. This step involves specific modifications that must happen in certain cell membrane molecules for exocytosis to occur. These modifications are required for signaling processes that trigger exocytosis to take place.
5- **Vesicle Fusion:** There are two types of fusion that can take place in exocytosis.

In **complete fusion:-**
-The vesicle membrane fully fuses with the cell membrane. The energy required to separate and fuse the lipid membranes comes from ATP. -The fusion of the membranes creates a fusion pore, which allows the contents of the vesicle to be expelled as the vesicle becomes part of the cell membrane.

In **kiss-and-run fusion**:-
-The vesicle temporarily fuses with the cell membrane long enough to create a fusion pore and release its contents to the exterior of the cell.
-The vesicle then pulls away from the cell membrane and reforms before returning to the interior of the cell.



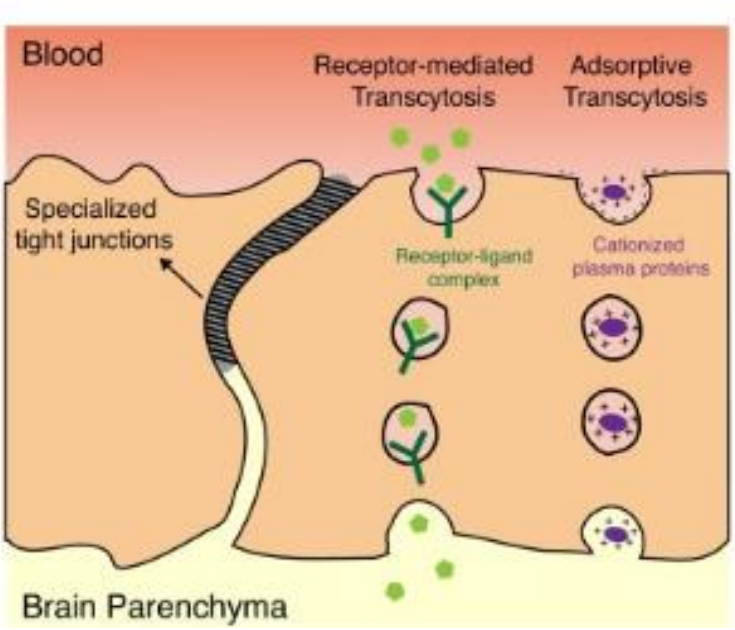
TRANSCYTOSIS:

Trans-cytosis is a transport mechanism in which an extracellular macromolecule enters through one side of a cell, migrates across cytoplasm of the cell and exits through the other side.

MECHANISM OF TRANSCYTOSIS

Cell encloses the extracellular substance by invagination of the cell membrane to form a vesicle. Vesicle then moves across the cell and thrown out through opposite cell membrane by means of exocytosis. Transcytosis involves the receptor-coated pits as in receptor-mediated endocytosis. Receptor protein coating the pits in this process is caveolin and not clathrin. Transcytosis is also called, vesicle trafficking.

Example of this type of transport is the movement of proteins from capillary blood into interstitial fluid across the endothelial cells of the capillary. Many pathogens like human immuno deficiency virus (HIV) are also transported by this mechanism.



ACTIVE TRANSPORT VS FACILITATED DIFFUSION

Active transport mechanism is different from facilitated diffusion by two ways:

1. Carrier protein of active transport needs energy, whereas the carrier protein of facilitated diffusion does not need energy
2. In active transport, the substances are transported against the concentration or electrical or electrochemical gradient. In facilitated diffusion, the substances are transported along the concentration or electrical or electrochemical gradient.