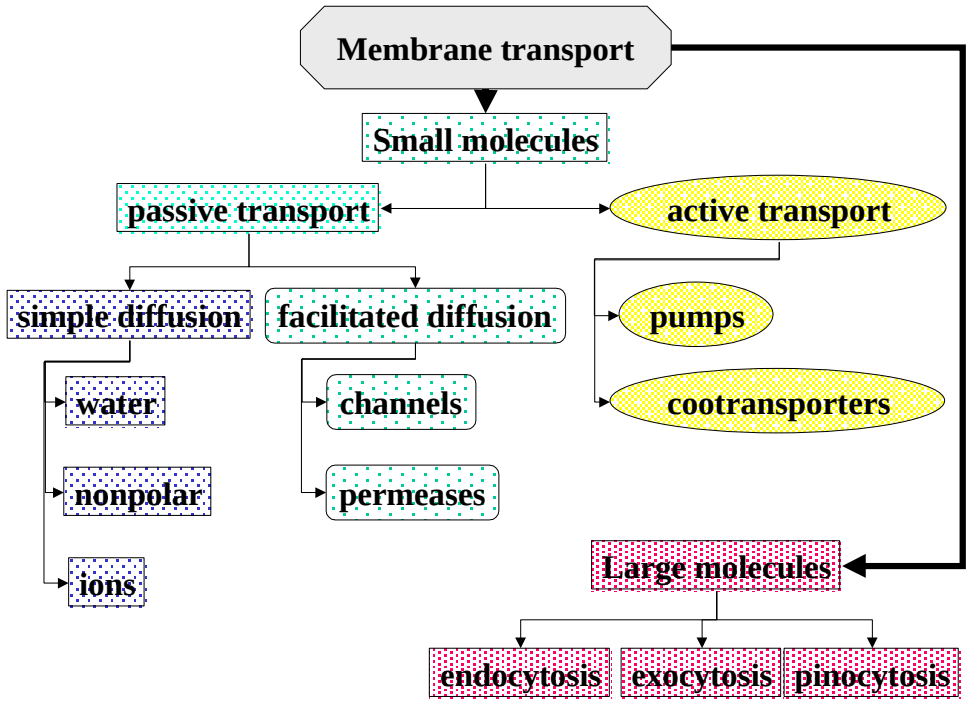
Cell Membrane and Transport Review Sheet

Transport of nutrients, ions, and excretory substances from one side to the other is a major function of the cell membrane. A number of different means have been developed to fulfill this function.

Generally, the permeation of small molecules across the membrane is quite different from engulfing molecules too large to penetrate membrane.



Transport of small molecules

Depending on whether a cell pays for the transport (energetically) or not, we talk about passive (free) and active transport.

Passive transport

- no sweat

Simple diffusion

- no sweat AND no helpers !

The simplest form of transport is passive diffusion. It is a real freebie; it does not even need helpers.

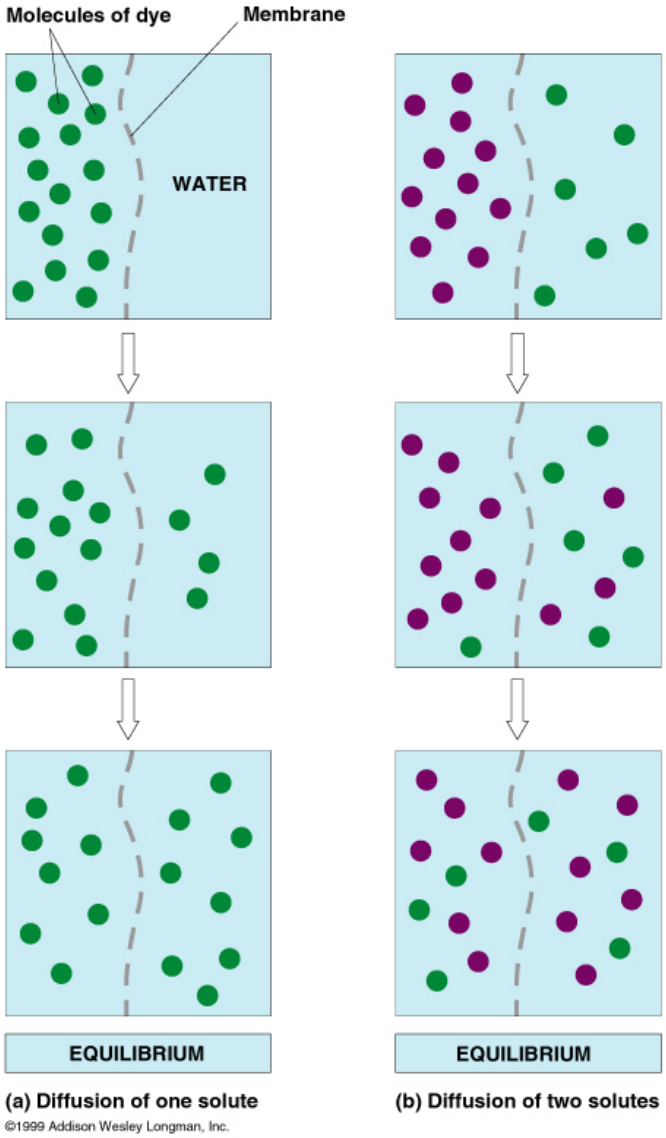
Water diffusion: osmosis

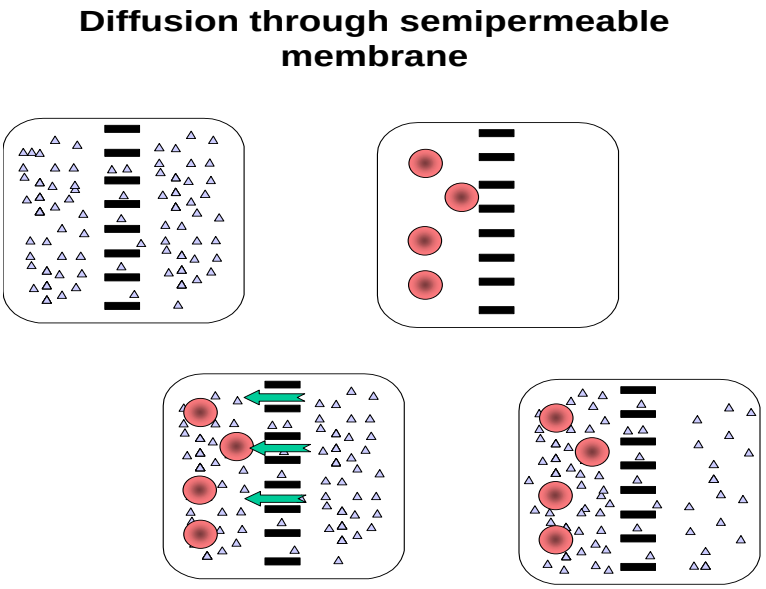
Lipid membranes are semi-permeable; some substances pass through freely (water) some don't (ions).

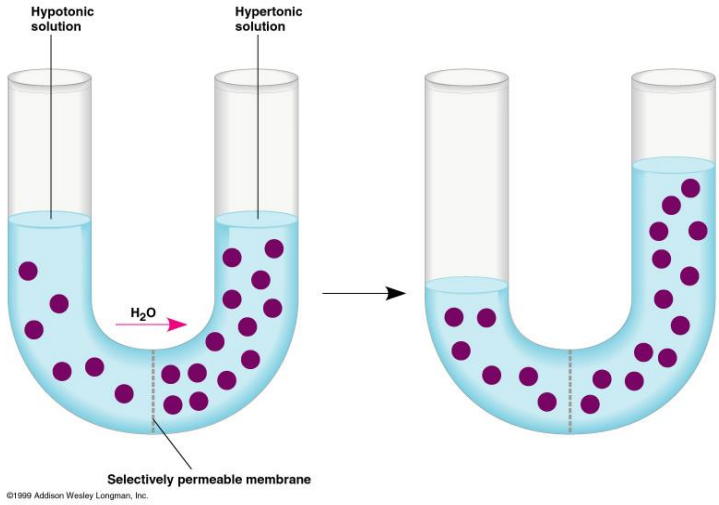
Consider two water solutions, one rich in ions and the other not, which are separated by a semi-permeable membrane. Water can move across the membrane in both directions, but because ions attract water and impede its random diffusion, water is retarded on the ion-rich side, therefore the rate from the ion-rich side is less than the rate of ions permeating the membrane from the other side.

The net movement of water toward the ion-rich solution builds up hydrostatic pressure, called osmotic pressure, which at some point will counteract the attraction of ions. The two sides will then be at equilibrium.

Whenever two solutions are separated by a semi-permeable membrane, net movement of water will be toward the solution more concentrated in substances that do not permeate the membrane.



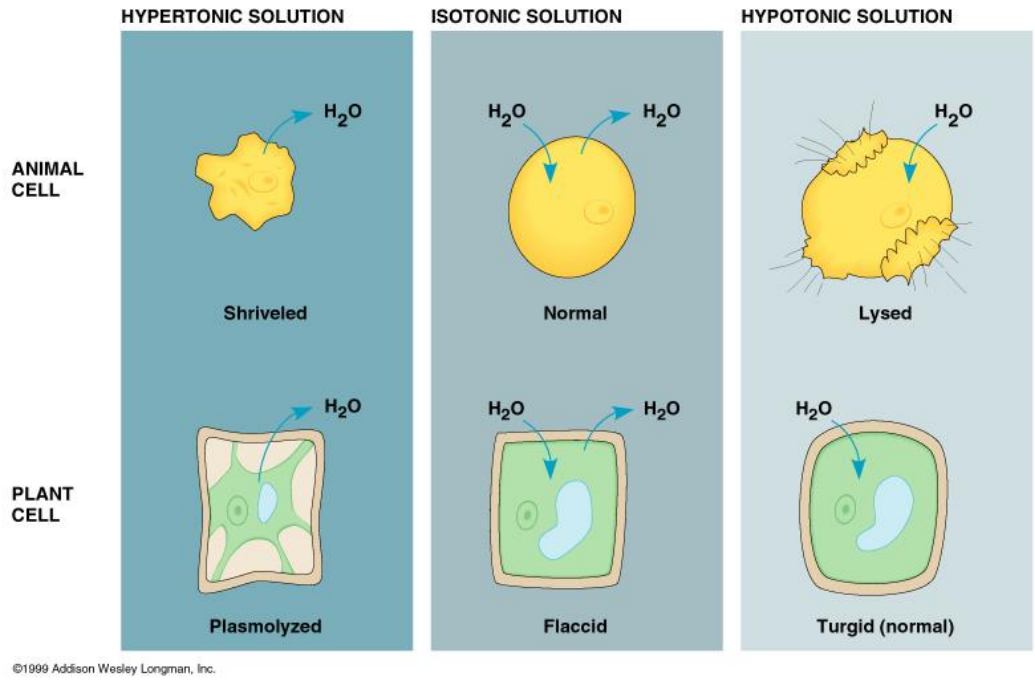


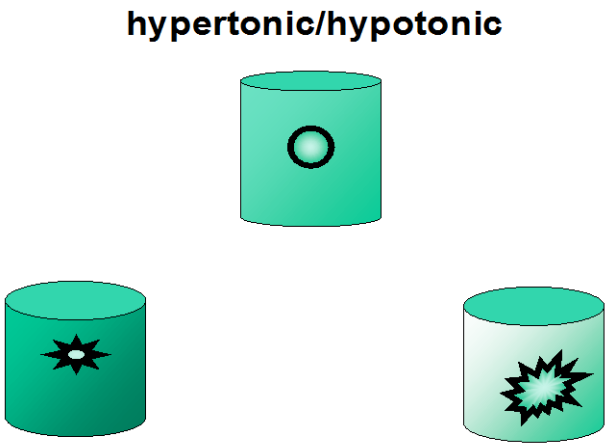


We say, the more concentrated solution is hypertonic with respect to solution less rich in the impermeant substance. The water will always try to rush in to make the more concentrated solution less hypertonic.

The less concentrated solution is referred to as hypotonic, water will attempt to leave this compartment and thereby decrease concentration of impermeant solute.

When two compartments are equally concentrated they are isotonic with respect to each other, and there is no net diffusion of water.





Passive diffusion of water regulated size of lymphocytes (white blood cells): when a lymphocyte is placed in a hypertonic solution ⇒ the cell shrinks ⇒ internal pH decreases ⇒ export of H+ and HCO3- and import of Na+ and Cl- are triggered ⇒ intracellular NaCl increases ⇒ water flows in ⇒ the cell swells up, countering the original shrinkage.

Uncharged molecules

Facilitated diffusion

- helpers, cars and channels

Some molecules diffuse freely but with the help of another molecule.

The kinetics of facilitated (with a helper) transport are different from those of simple diffusion. In the latter, the rate of diffusion is proportional to the concentration of the diffusing molecules; the more of them, the more of them will diffuse across the membrane per unit time.

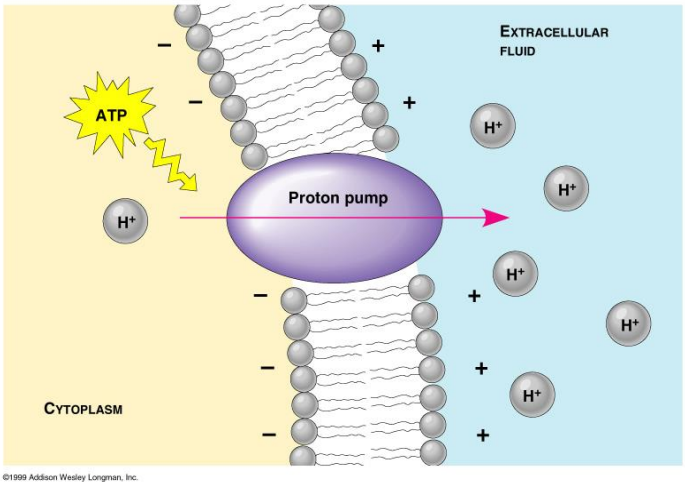
In facilitated diffusion, however, the rate is limited by the availability of the helper molecules. Once all the helpers are saturated, the increasing concentration of diffusing molecules will only increase a waiting line for the helper and will not increase rate of transport.

Such a saturation kinetics is characteristic of any event (transport, chemical reaction) that requires the help of other molecules.

Active transport

- no pain - no gain

Often the transport has to happen in the direction opposite to the concentration gradient. In order to accomplish this, membranes have evolved elaborate schemes to pump the substance from the area of smaller concentration to a compartment with higher concentration. All these schemes cost the cell energy and thus are called active transport.



Examples are ATPase and co-transporters.

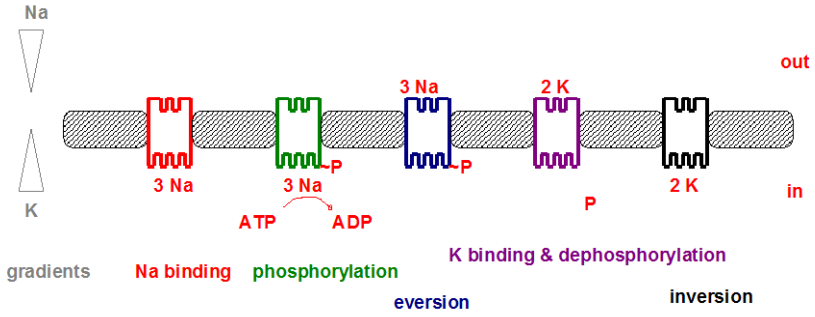
Na/K ATPase (pump)

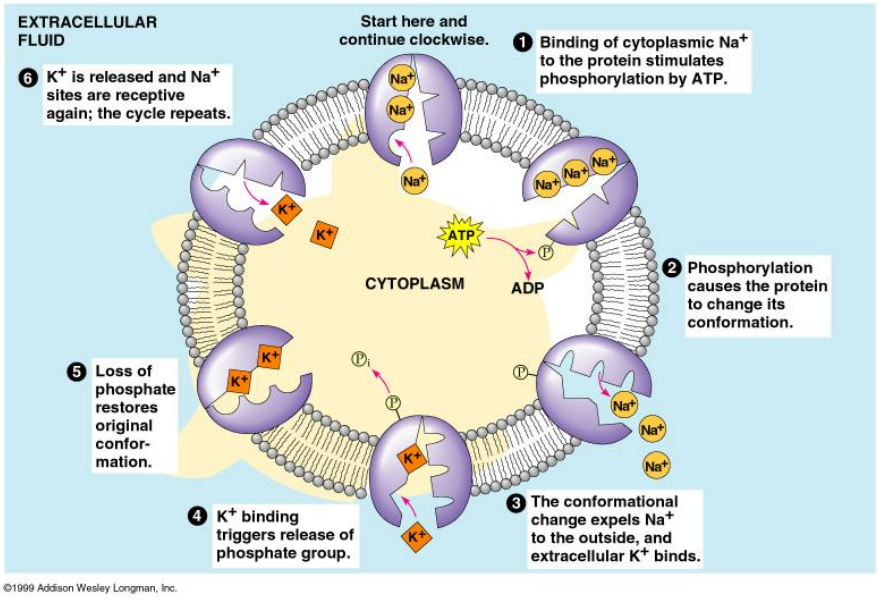
This pump is an ATPase, which means that the enzyme derives its energy from the hydrolysis of ATP.

The function of Na/K ATPase is to set up the electrochemical gradient of the membrane.

It does so by pumping Na out of the cell and pumping K into the cell.

The net effect is to create a chemical potential consisting of two concentration gradients (for Na and for K), as well as electrical potential because three positive charges are pumped out while two positive charges are pumped in. A negative potential inside the cell is thus created.





Mechanism: inside of the cell, Na binding triggers phosphorylation by ATP ⇒ eversion to outside of the cell ⇒ Na release ⇒ K binding triggers dephosphorylation ⇒ inversion to inside of the cell ⇒ K release.

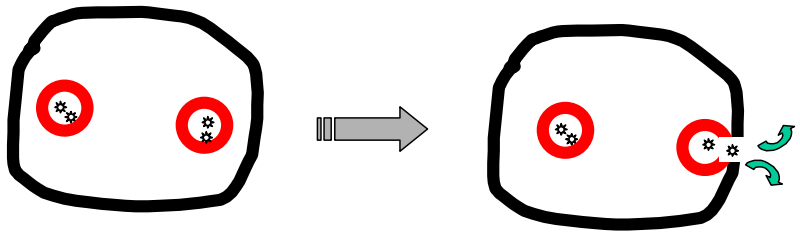
Transport of large molecules

Membranes transport molecules too big to permeate the membrane by engulfing the substance and forming internal vesicles.

Uptake of substances by such a mechanism is called endocytosis; the secretion is called exocytosis.

Exocytosis

In exocytosis, the transport vesicle fuses with the plasma membrane, making the inside of the vesicle continuous with the outside of the cell.



exocytosis

Exocytosis is used in secretion of protein hormones (insulin), serum proteins, extracellular matrix (collagen).

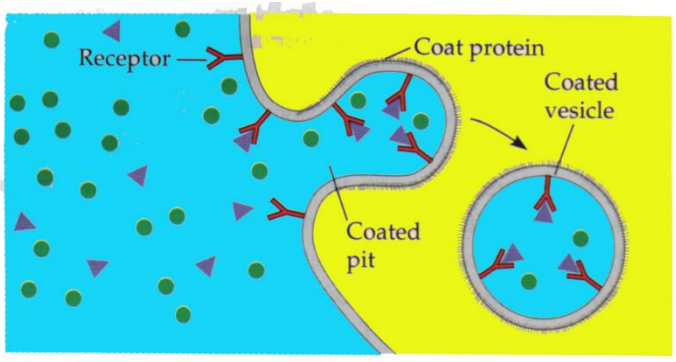
Endocytosis

Endocytosis occurs mainly in animal cells, as plants have rigid cell walls.

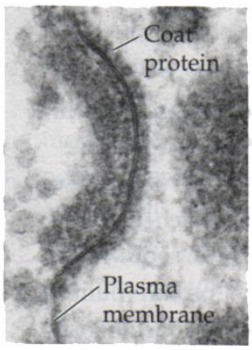
Mechanism: the cell forms pseudopodia that engulf macromolecules ⍰ the pseudopodia fuse, and the membrane pinches off, forming an internal vesicle ⍰ the vesicle fuses with the lysosome ⍰ release.

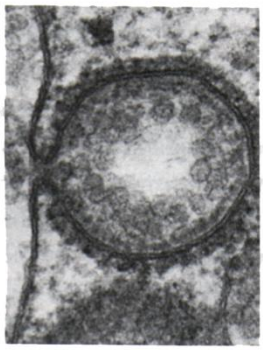
Receptor-mediated endocytosis

Uptake of cholesterol proceeds as follows: LDL (cholesterol-containing particles) are recognized by the receptors on the surface of the cell ⇒ receptors aggregate ⇒ clathrin crosslinks the ends of receptors on the interior side of membrane, forcing the curvature ⇒ membrane pinches off to form a clathrin-coated vesicle ⇒ clathrin falls off to form an uncoated vesicle: an endosome ⇒ fusion with CURL vesicle ⇒ low pH releases the receptor ⇒ which recycles receptor to the membrane.



(c) Receptor-mediated endocytosis

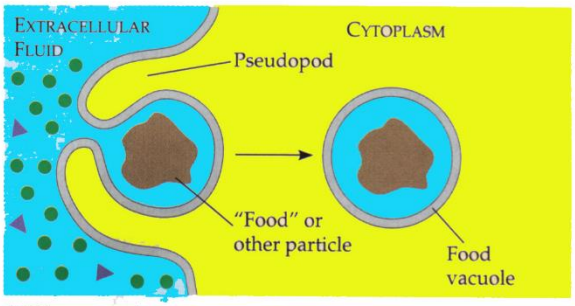




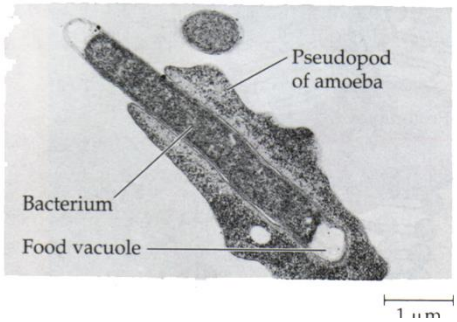
Phagocytosis

Removal of foreign materials or dead cells by immune cells is a form of endocytosis.

For example, phagocytes are macrophages that line blood channels of liver (spleen) and eat up aging rbc's; monocytes penetrate inflamed tissue and remove the invading bacteria.

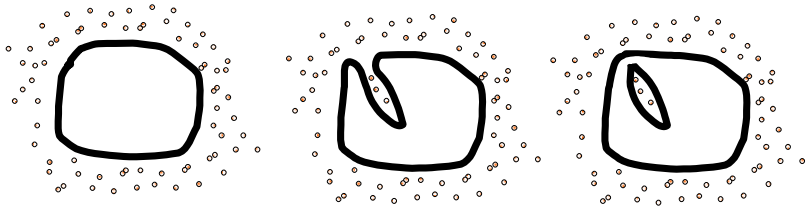


(a) Phagocytosis

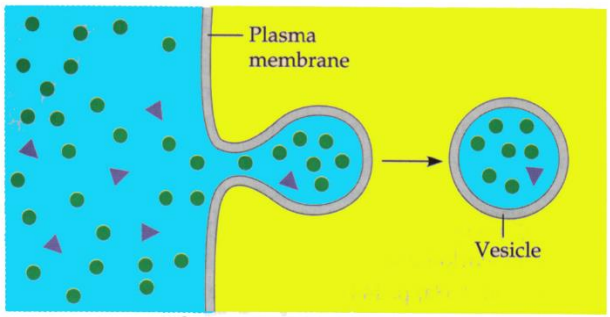


Μεχηανισμ: φορειγν παρτιχλεσ αρε χοατεδ ωιτη αντιβοδιεσ ⇒ a complement reaction labels antibody for recognition by the antibody receptors in the membrane of macrophages ⇒ formation of pseudopodia ⇒ particles are engulfed by binding of antibodies by receptors.

Pinocytosis



pinocytosis



(b) Pinocytosis

Pinocytosis is a nonspecific uptake of extracellular solution. Whatever is in the solution is taken up by the cell.