Membranes

Plasma Membrane

The plasma membrane surrounds the cell and functions as an interface between the living interior of the cell and the nonliving exterior.

All cells have one.

It regulates the movement of molecules into and out of the cell. "WHAT DOES THE CELL MEM. DO?"

Membrane Structure "WHAT IS THE CELL MEMBRANE MADE OF?"

The **fluid-mosaic model** states that membranes are fluids with a mosaic of proteins embedded within the membrane.

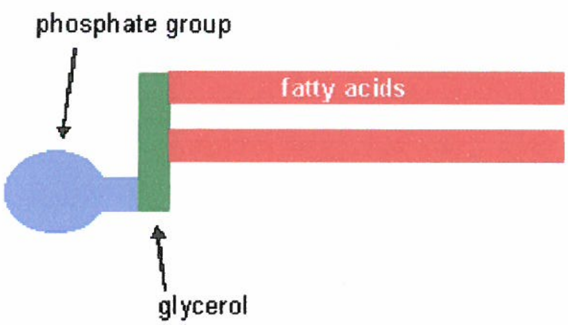
LOTS OF SMALL PIECES THAT MAKE A LARGER PICTURE — MAKE A PART OF

Phospholipids

Most of the lipids in a membrane are phospholipids. → MACROMOL. BRICK

Phospholipids contain glycerol, two fatty acids, and a phosphate group. The phosphate group is polar (*hydrophilic*), enabling it to interact with water. The fatty acid tails are nonpolar (*hydrophobic*) and do not interact with water.

MACRO BRICK — → MACROMOL. BRICK



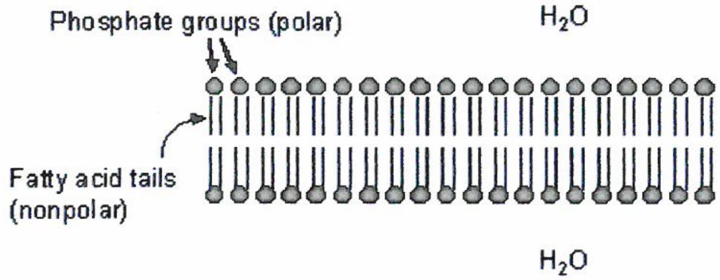
Phospholipid Bilayers

"BI" MEANS 2 OR "DOUBLE"

Phospholipids spontaneously form a bilayer in a watery environment. They arrange themselves so that the polar heads are oriented toward the water and the fatty acid tails are oriented toward the inside of the bilayer (see the diagram below). → FACING

In general, nonpolar molecules do not interact with polar molecules. This can be seen when oil (nonpolar) is mixed with water (polar). Polar molecules interact with other polar molecules and ions. For example table salt (ionic) dissolves in water (polar).

The bilayer arrangement shown below enables the nonpolar fatty acid tails to remain together, avoiding the water. The polar phosphate groups are oriented toward the water.



Flexibility

The phospholipid tails are flexible, causing the lipid bilayer to be fluid. This makes the cells flexible. At body temperature, membranes are a liquid with a consistency that is similar to cooking oil.

Membranes solidify when they get cold. When this happens, they do not function properly. Membranes with unsaturated phospholipid tails solidify at a lower temperature than membranes with less saturation.

Organisms adapted to cold climates have more unsaturated phospholipid tails. Organisms adapted to hot environments have saturated phospholipid tails .

Cholesterol

→ MACRO BRICK

In animals, cholesterol is a major membrane lipid. It may be equal in amount to phospholipids.

It is similar to phospholipids in that it one end is hydrophilic, the other end is hydrophobic.

Cholesterol makes the membrane less permeable to most biological molecules.

★ NEW BRICK ★

Cholesterol lowers the temperature that a membrane solidifies and it decreases fluidity at high temperatures.

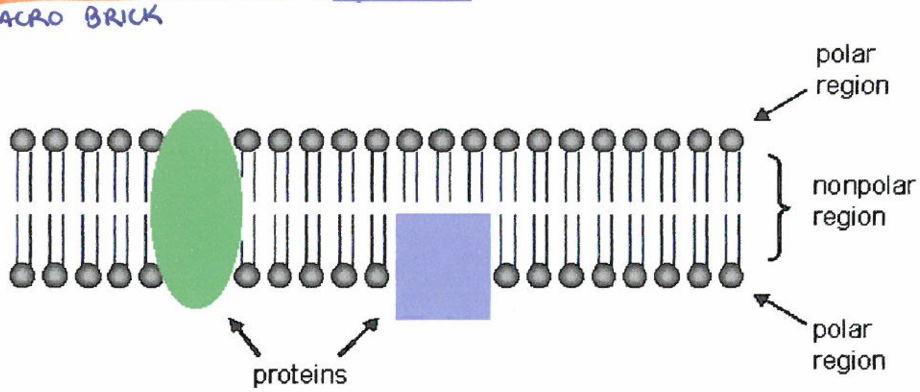
Proteins Embedded in the Membrane

Proteins are scattered throughout the membrane.

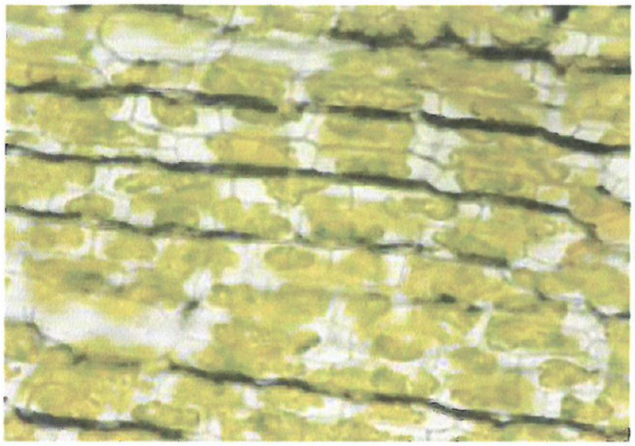
They may be attached to inner surface, embedded in the bilayer, or attached to the outer surface.

Hydrophilic (polar) regions of the protein project from the inner or outer surface. Hydrophobic (nonpolar) regions are embedded within the membrane. The hydrophobic region of the protein is composed of nonpolar amino acids ~~and forms an~~.

MACRO BRICK

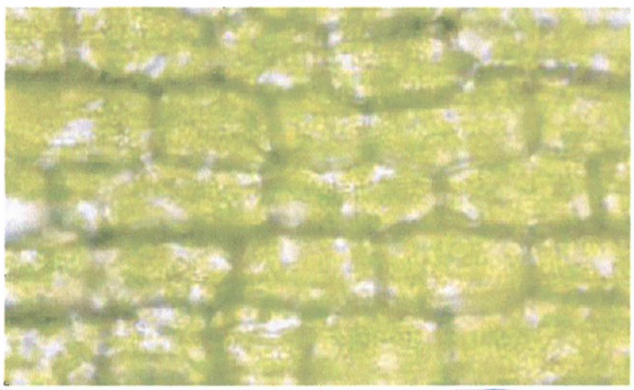


Membrane proteins which are not attached to the cytoskeleton are capable of lateral movement.



Left: These *Elodea* cells were placed in a 10% NaCl solution. The contents of the cells was reduced but the cell walls remained intact. Compare these cells to normal cells in the photograph below.

Click on the image to view an enlargement.



Left: Normal *Elodea* cells X 400

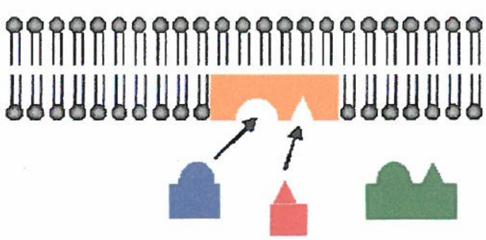
Click on the image to view an enlargement.

Functions of Membrane Proteins

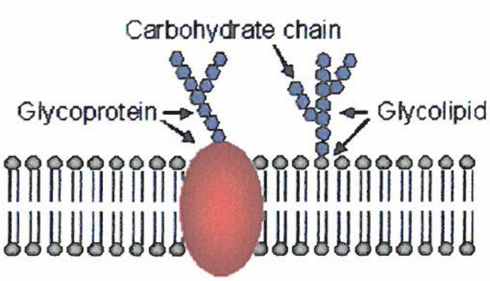
MEMBRANE PROTEIN READING

#1 Enzymes

Some enzymes are embedded within membranes.



#2 Cell-Cell Recognition



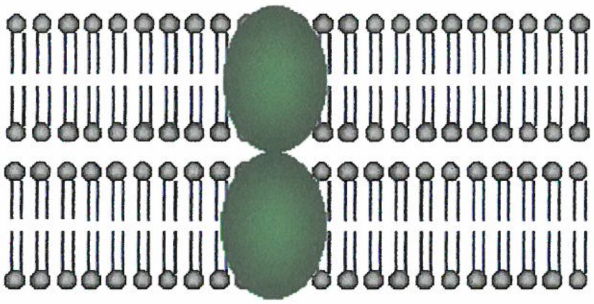
Lipids and proteins within the membrane may have a carbohydrate chain attached.

These glycolipids and glycoproteins often function as cell identification markers, allowing cells to identify other cells. Because the glycoproteins and glycolipids of an individual are unique, our immune system can use them to identify foreign invaders such as bacteria or viruses so that they can be destroyed.

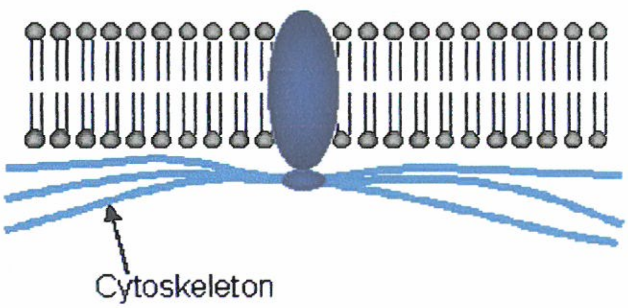
Cells from different tissues may also differ, enabling the identification of different tissue types.

Cell Adhesion - Junctions

Proteins associated with the cell membranes of animal cells may bind to proteins of adjacent cells. These connections, called junctions may serve to bind cells together, to prevent the movement of material between the cells, or to allow cells to communicate with each other.

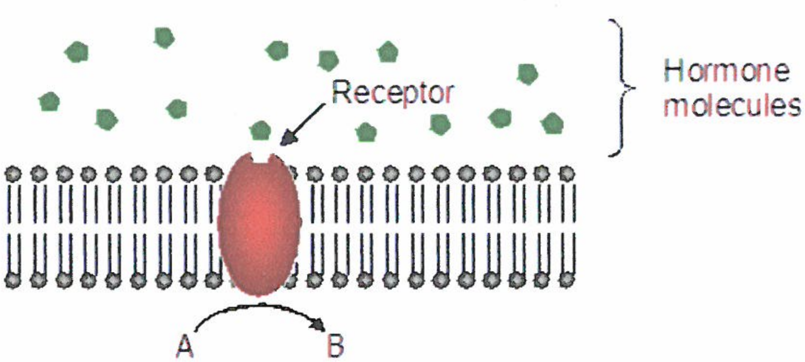


Attachment of the Cytoskeleton and to the Extracellular Matrix



Integrins are proteins that attach to microfilaments on the inside of the cell and to fibronectin on the outside of the cell. Fibronectin molecules attach to Collagen fibers in the extracellular matrix. See Extracellular Matrix in the chapter on cells for more information.

Receptors



Receptors enable cells to detect hormones and a variety of other chemicals in their environment. The binding of a molecule and a receptor initiates a chemical change within the cell. In the diagram above, the binding of hormone and receptor initiates the conversion of chemical A to chemical B.

Hormones are molecules that cells use to communicate with one another. For example, cells in the pancreas produce the hormone insulin when glucose levels in the blood become elevated. The hormone travels within the blood to other parts of the body. It stimulates liver and muscle cells to begin removing the glucose and storing it as glycogen.

#6 Vesicle Trafficking

Vesicles may follow microtubules to their destination.

Proteins within the membrane of the vesicle recognize and attach to proteins in other membranes. This allows vesicles to attach to the membranes of other organelles such as the endoplasmic reticulum, golgi apparatus, or lysosomes.

#7 Transport of Materials Across Cell Membranes

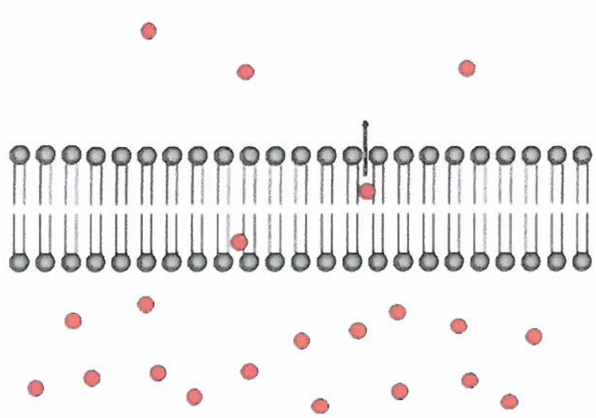
Transport proteins span the membrane and enable the movement of particles across the membrane. Transport proteins are specific. For example, transport proteins that move Na^{+} (SODIUM) across the cell membrane will not move Ca^{++} (CALCIUM).

Passive transport refers to movement of particles across a membrane from the side with a higher concentration of particles to the side with a lower concentration. Because movement follows a concentration gradient, energy is not supplied by the cell. The use of transport proteins may facilitate this process as discussed below. → "ONE SIDE IS HIGH, ONE SIDE IS LOW"

Active transport involves the use of energy supplied by the cell to move materials across the membrane against a concentration gradient. Transport proteins are used and energy is supplied by ATP.

Diffusion

Particles that are more concentrated on one side of a membrane may diffuse across the membrane without any energy being supplied by the cell. The energy for this movement comes from collisions among the particles; there are more collisions on the side with the higher concentration of particles. An area of high concentration therefore has potential energy.

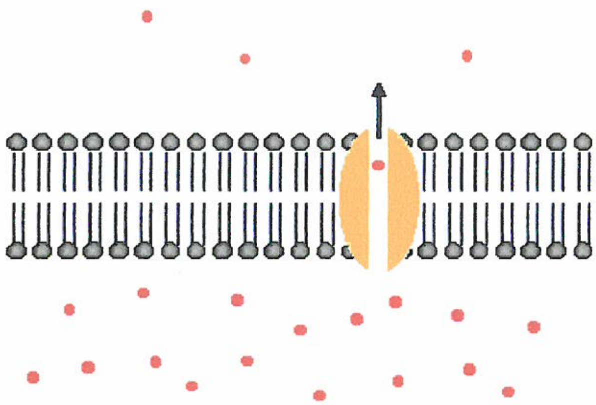


★ NEW BRICK ★

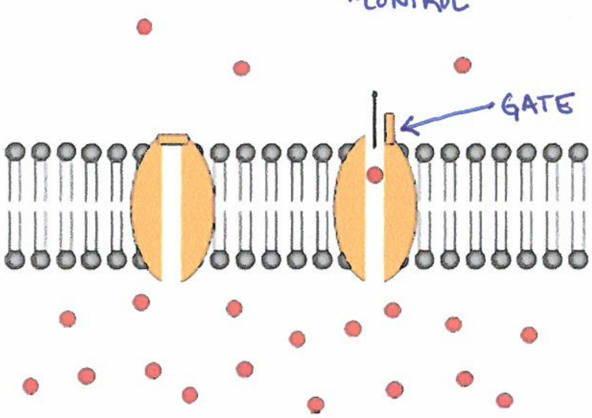
Facilitated Diffusion

Facilitated diffusion involves the use of a protein to facilitate the movement of molecules across the membrane. Additional energy is not required because the particles are traveling down a concentration gradient (high concentration to low concentration). The energy for movement comes from the concentration gradient. There are more collisions among particles on the side of the membrane with a higher concentration causing these particles to move toward areas of lower concentration.

In some cases, molecules pass through ***channel proteins*** that span the membrane.

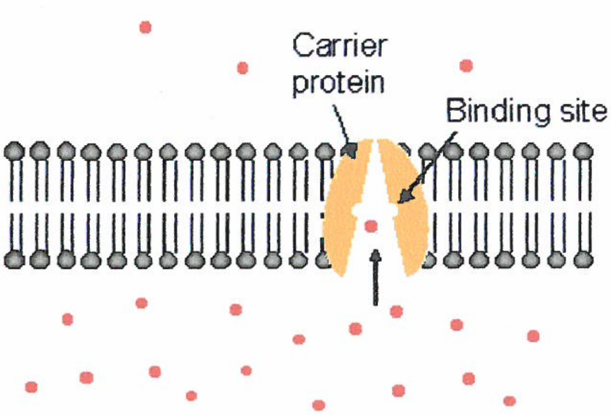


Gated Channels are able to regulate the passage of particles by opening and closing gates that prevent passage.

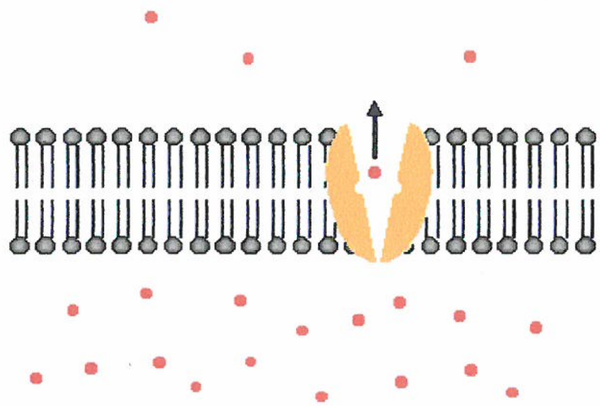


Some gated channels open in response to the difference in ion concentration across the membrane. Other gated channels open when a specific substance binds to the channel protein.

In other cases ***carrier proteins*** allow molecules to pass through when their shape changes.



As can be seen below, the carrier protein changes shape and releases the molecule to the side of the membrane that has the lower concentration.



Additional energy is not required because the molecule is traveling down a concentration gradient (high concentration to low concentration). The energy of movement comes from the concentration gradient.

Active Transport

Active transport is used to move ions or molecules ***against*** a concentration gradient (low concentration to high concentration).

Active transport is like a water pump; it uses energy to pump water uphill where a siphon cannot. Facilitated diffusion (discussed above) is like a siphon in that additional energy is not required but it can only allow movement downhill.

Movement against a concentration gradient requires energy. The energy is supplied by ATP which is released by breaking a phosphate bond to produce ADP:

ATP --> ADP + P_i + energy

Cells that use a lot of active transport have many mitochondria to produce the ATP needed.

The Sodium-Potassium Pump

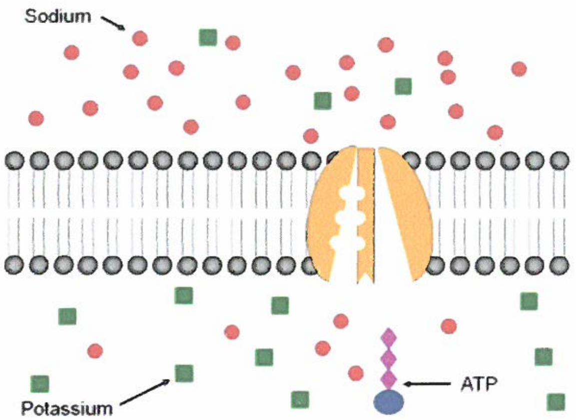
The sodium-potassium pump uses active transport to move 3 sodium ions to the outside of the cell for each 2 potassium ions that it moves in.

It is found in all human cells, especially nerve and muscle cells.

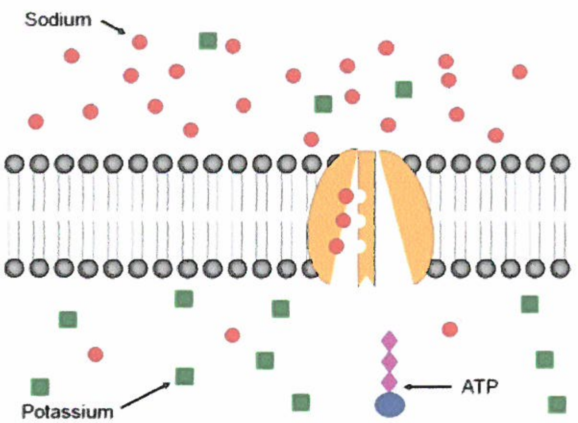
One third of the body's energy expenditure is used to operate the sodium-potassium pump.

Mechanism of operation of the Sodium-Potassium Pump

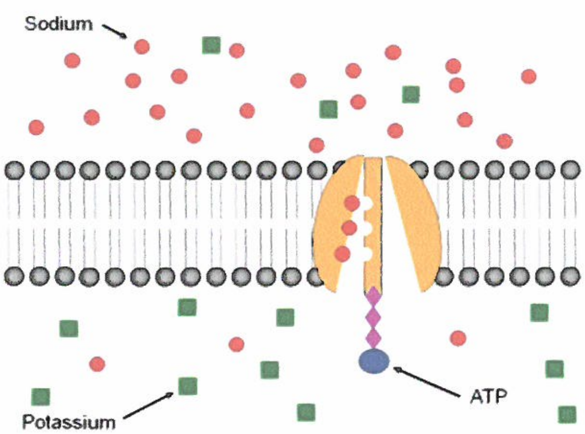
The diagrams below illustrate the mechanism of operation of the sodium-potassium pump. In these diagrams, orange is used to represent the pump protein. Circles are used to represent sodium ions and squares are used to represent potassium ions. The pump has three sodium binding sites and two potassium binding sites.



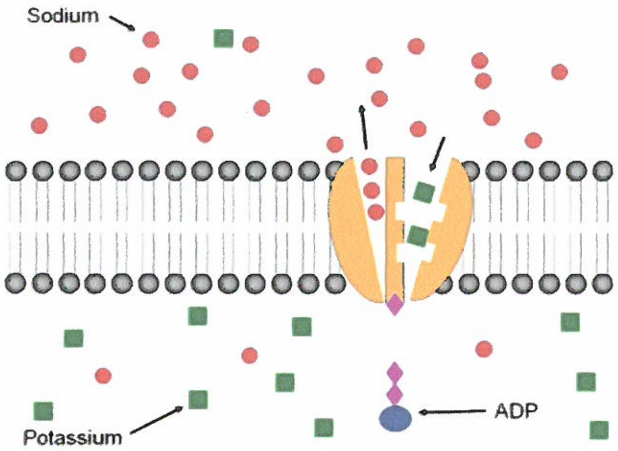
Three sodium ions enter the pump and attach to binding sites.



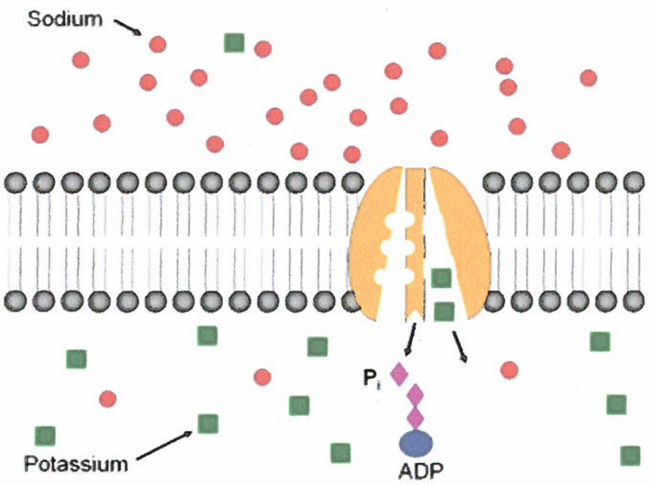
ATP binds to the pump.



One phosphate bond in the ATP molecule breaks, releasing its energy to the pump protein. The pump protein changes shape, releasing the sodium ions to the outside. The new shape reduces its ability to bind to sodium ions and it increases its ability to bind potassium ions. The two potassium binding sites are exposed to the outside, allowing two potassium ions to enter the pump.



When the phosphate group detaches from the pump, the pump returns to its original shape. Its ability to bind potassium ions is decreased and its ability to bind sodium ions is increased. The two potassium ions leave, three sodium ions enter, and the cycle repeats itself.



Examples of Active Transport

Plants move minerals (inorganic ions) into their roots by active transport.

The gills of marine fish have cells that can remove salt from the body by pumping it into the salt water.

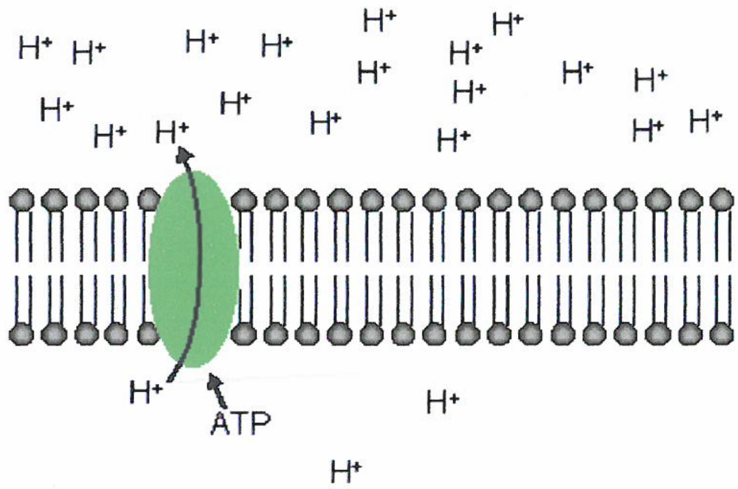
The thyroid gland cells bring in iodine for use in producing hormones.

Cells in the vertebrate kidney reabsorb sodium ions from urine.

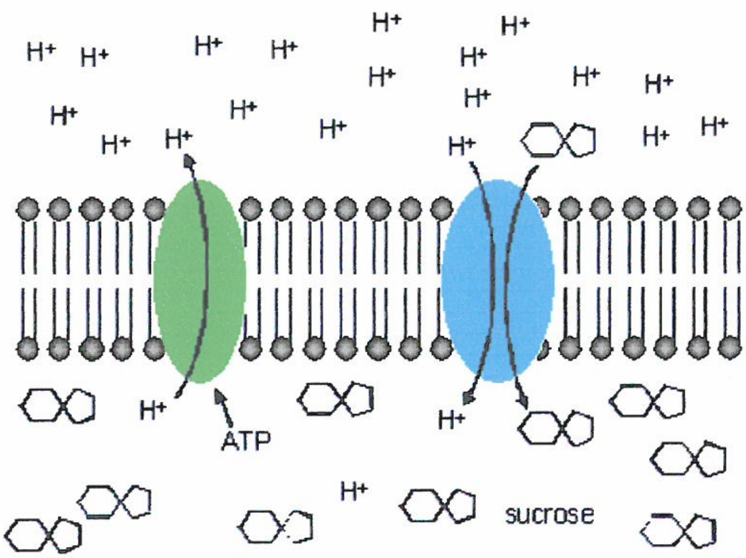
Cotransport

Active transport uses energy to pump materials across a membrane. A concentration gradient of ions or molecules therefore is a high-energy condition. The ions or molecules will attempt to move back across the membrane under pressure (osmotic pressure). This energy can be used to transport other molecules across the membrane.

In the diagram below, energy from ATP is used to produce a concentration gradient of H^+.



Sucrose can be pumped into cells where the concentration of sucrose is already high by using the energy of a high concentration of hydrogen ions on the outside of a cell. Active transport pumps the hydrogen ions out and certain proteins in the cell membrane allow the hydrogen ions to reenter the cell. Hydrogen ions renter the cell through a cotransporter protein because they are more concentrated on the outside. The energy of reentry is used to simultaneously pump sucrose into the cell.



Electrochemical Gradient

A difference in ion concentrations on one side of a membrane compared to the other may result in an electrical charge difference. Electrical charges influence the passive transport of ions. For example, negative ions on one side of a membrane will move toward the other side if there is an abundance of positive ions on that side. Ion movement is therefore influenced by the concentration gradient discussed earlier and the electrical gradient. The two gradients are referred to as the ***electrochemical gradient***.

Endocytosis and Exocytosis

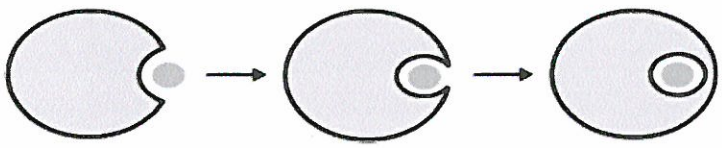
These processes are used for materials that are too big to pass through the plasma membrane via protein transport.

Endocytosis

The process by which a cell engulfs material to bring it into the cell is called endocytosis. Two major forms of endocytosis described below.

Phagocytosis

Phagocytosis refers to the process of taking in large particles. As phagocytosis occurs, the cell surrounds the particle, enclosing it within the plasma membrane. The particle will become completely enclosed within the membrane as it is moved into the cell.



A vacuole is formed that contains the material that has been engulfed.

Pinocytosis

Pinocytosis refers to engulfing macromolecules.

As in phagocytosis, a vesicle is formed which contains the molecules that were brought into the cell.

Vacuoles and vesicles produced by phagocytosis and pinocytosis can fuse with lysosomes (lysosomes are vesicles that contain digestive enzymes).

Phagocytosis and pinocytosis remove membrane from cell surface to form vacuoles that contain the engulfed material.

Receptor-mediated Endocytosis

Macromolecules bind to receptors on the surface of the cell.

Receptors with bound macromolecules aggregate in one area and are brought into the cell by endocytosis.

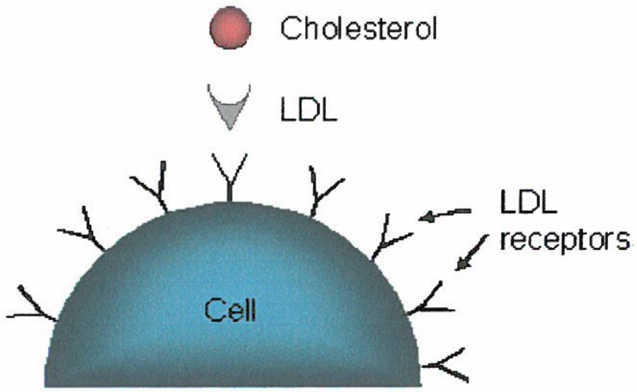
The vesicle containing the macromolecules can release the macromolecules into the cell directly or they can be processed by chemicals contained within lysosomes after fusing with the lysosomes.

The vesicle (and receptors) then returns to the cell surface.

Example: Hypercholesterolemia

Cholesterol is carried by LDL (low-density lipoprotein), which binds to LDL receptors on the cell surface.

Normally cholesterol (and LDL) is brought into the cell by receptor-mediated endocytosis as described above.



A faulty gene for the LDL receptor results in LDL not binding to the cells. The Cholesterol remains in the blood and becomes deposited on arteries. Reduced blood flow in arteries that supply the heart causes heart attacks in patients as early as 6 years.

Exocytosis

Exocytosis moves material to the outside. A vesicle fuses with the plasma membrane and discharges its contents outside. This allows cells to secrete molecules.

The fusion of vesicles to the plasma membrane adds membrane to the cell surface.