# Transport across membrane

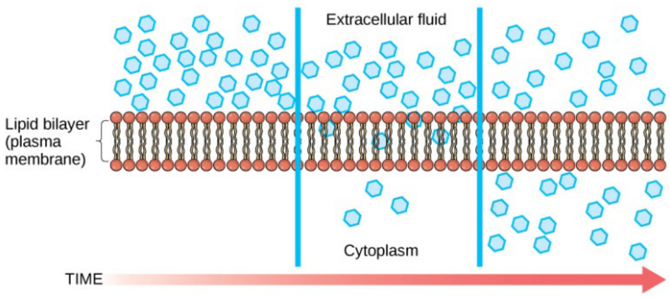
Plasma membranes are selectively permeable, i.e. they allow some substances to pass through, but not others. This may happen passively, as certain materials move back and forth, or the cell may have special mechanisms that facilitate transport.

## Passive Transport

It is a naturally occurring phenomenon and does not require the cell to exert any of its energy to accomplish the movement. It is the most direct forms of membrane transport. Here, substances move from area of higher concentration to area of lower concentration. Physical space in which there is a range of concentrations of a single substance is said to have a concentration gradient.

**Diffusion:**

Diffusion is a passive process of transport. A single substance tends to move from an area of high concentration to an area of low concentration until the concentration is equal across a space. Materials move within cell's cytosol by diffusion, and certain materials move through the plasma membrane by diffusion. It expends no energy. On the contrary, concentration gradients are form of potential energy, dissipated as the gradient is eliminated. Each substance in a medium has its own concentration gradient, independent of concentration gradients of other materials. Each substance will diffuse according to that gradient. Within a system, there will be different rates of diffusion of the different substances in the medium.




**Factors affecting Diffusion:**

- **Extent of the concentration gradient:** The greater the difference in concentration, the more rapid the diffusion.
- **Mass of the molecules diffusing:** Lighter molecules move more fast; therefore, they diffuse more rapidly.
- **Temperature:** Higher temperatures increase the energy and therefore the movement of the molecules, increasing the rate of diffusion.
- **Solvent density:** As the density of a solvent decreases, the rate of diffusion increases.
- **Solubility:** Non-polar or lipid-soluble materials pass through plasma membranes more easily than polar materials, allowing a faster rate of diffusion.
- **Surface area and thickness of the plasma membrane:** Increased surface area increases the rate of diffusion.
- **Distance travelled:** The lesser the distance that a substance must travel, the faster the rate of diffusion.

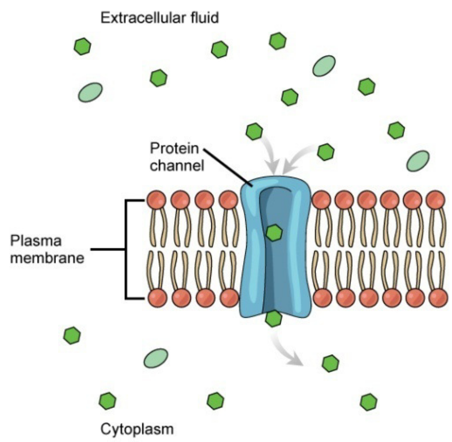
# Facilitated Transport

In facilitated transport or facilitated diffusion, materials diffuse across plasma membrane with the help of membrane proteins. A concentration gradient exists that would allow these materials to diffuse into cell without expending cellular energy. However, these materials are ions or polar molecules that are repelled by the hydrophobic parts of the cell membrane. Facilitated transport proteins shield these materials from the repulsive force of the membrane and thus allow them to diffuse into the cell.

The material being transported is first attached to protein or glycoprotein receptors on exterior surface of the plasma membrane. This allows material that is needed by the cell to be removed from the extracellular fluid. Substances are then passed to specific integral proteins that facilitate their passage. Some of these integral proteins are beta pleated sheets that form pore or channel through phospholipid bilayer. Others are carrier proteins which bind with the substance and aid its diffusion through the membrane.

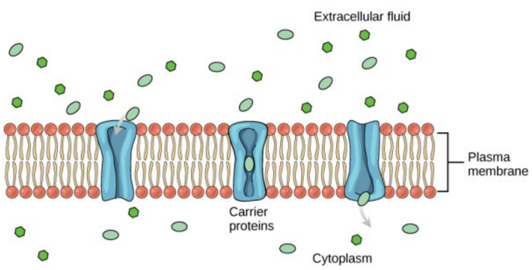
**Channels:**

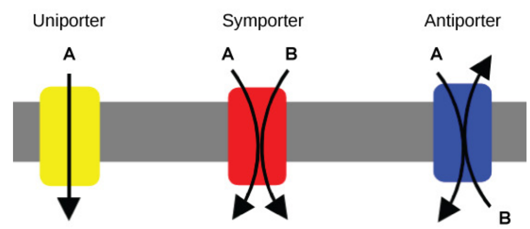
Integral proteins involved in facilitated transport are collectively referred to as transport proteins, and function as either channels for the material or carriers. In both cases, they are transmembrane proteins. Channels are specific for the substance that is being transported. Channel proteins have hydrophilic domains exposed to the intracellular and extracellular fluids; they additionally have a hydrophilic channel through their core that provides hydrated opening through membrane layers. Aquaporins are channel proteins that allow water to pass through the membrane very rapidly. Channel proteins are either open at all times or they are gated, which controls its opening.




Attachment of a particular ion to channel protein may control the opening, or other mechanisms or substances may be involved. In some tissues, sodium and chloride ions pass freely through open channels, whereas in other tissues a gate must be opened to allow passage. In kidney, both forms of channels are found in different parts of renal tubules. Cells involved in transmission of electrical impulses, as in nerve and muscle cells, have gated channels for sodium, potassium, and calcium in their membranes. Opening and closing of channels changes relative concentrations on opposing sides of membrane of ions, resulting in facilitation of electrical transmission along the membranes (in the case of nerve cells) or in muscle contraction (in the case of muscle cells).

**Carrier proteins for Facilitated Transport:**
Another type of protein embedded in plasma membrane is carrier protein. They bind substances and in doing so, trigger changes of its own shape, moving the bound molecule from outside of the cell to its interior; depending on the gradient, material may move in opposite direction. Carrier proteins are typically specific for a single substance. This selectivity adds to the overall selectivity of the plasma membrane. This can cause problems in transporting enough material for the cell to function properly. When all proteins are bound to their ligands, they are saturated and the rate of transport is at its maximum. Increasing the concentration gradient at this point will not result in an increased rate of transport.
Carrier proteins or pumps are of three types. They are also called transporters.
**Uniporter** carries one specific ion or molecule.
**Symporter** carries two different ions or molecules, both in the same direction.
**Antiporter** also carries two different ions or molecules, but in different directions.




An example of this process occurs in the kidney. Glucose, water, salts, ions, and amino acids needed by the body are filtered in one part of the kidney. This filtrate, which includes glucose, is then reabsorbed in another part of the kidney. As there are only finite number of carrier proteins for glucose, if more glucose is present than proteins can handle, excess is not transported and it is excreted from the body in urine. In diabetic individual, this is described as "spilling glucose into the urine." A different group of carrier proteins called glucose transport proteins, or GLUTs, are involved in transporting glucose and hexose sugars through plasma membranes within the body.

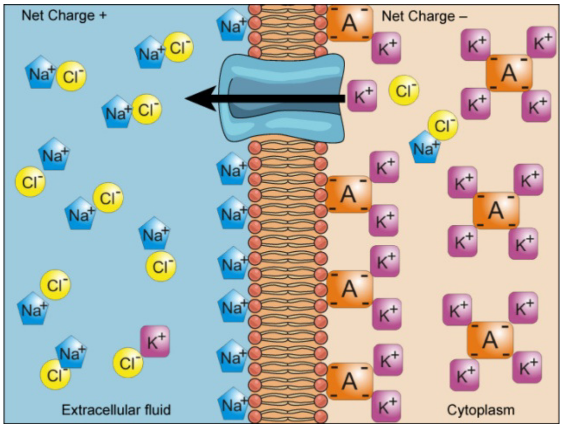
Channel and carrier proteins transport material at different rates. Channel proteins transport much more quickly than do carrier proteins. Channel proteins facilitate diffusion at a rate of tens of millions of molecules per second, whereas carrier proteins work at a rate of a thousand to a million molecules per second.

# Active Transport

This mechanism requires the use of the cell's energy, usually in the form of ATP. If a substance must move into the cell against its concentration gradient—that is, if the concentration of the substance inside the cell is greater than its concentration in extracellular fluid (and vice versa) the cell must use energy to move the substance. Some active transport mechanisms move small-molecular weight materials, such as ions, through the membrane. Other mechanisms transport much larger molecules.

**Electrochemical gradient:**

As ions move into and out of cells and because cells contain proteins that do not move across the membrane and are mostly negatively charged, there is an electrical gradient, i.e. a difference of charge, across the plasma membrane. The interior of living cells is electrically negative with respect to the extracellular fluid in which they are bathed, and at the same time, cells have higher concentrations of $K^+$ and lower concentrations of $Na^+$ than does the extracellular fluid. So in a living cell, the concentration gradient of $Na^+$ tends to drive it into the cell, and electrical gradient of $Na^+$ (a positive ion) also tends to drive it inward to the negatively charged interior. Situation is more complex for other elements such as potassium. Electrical gradient of $K^+$, a positive ion, also tends to drive it into the cell, but the concentration gradient of $K^+$ tends to drive $K^+$ *out* of the cell. The combined gradient of concentration and electrical charge that affects an ion is called its electrochemical gradient.




**Moving against gradient:**

To move substances against a concentration or electrochemical gradient, cell must use energy. This energy is obtained from ATP generated through metabolism. Active transport mechanisms, collectively called pumps, work against electrochemical gradients. Small substances constantly pass through plasma membranes. Much of cell's supply of metabolic energy may be spent in maintaining these processes. Because active transport mechanisms depend on cell's metabolism for energy, they are sensitive to many metabolic poisons that interfere with the supply of ATP.

**Carrier proteins for Active Transport:**

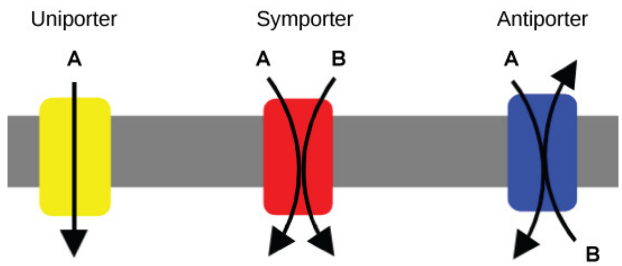
Carrier proteins or pumps are of three types. They are also called transporters.

**Uniporter** carries one specific ion or molecule.

**Symporter** carries two different ions or molecules, both in the same direction.

**Antiporter** also carries two different ions or molecules, but in different directions.

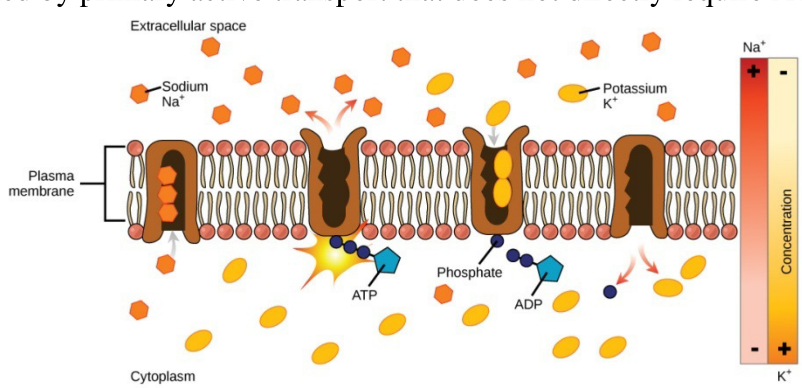
All of these transporters can also transport small, uncharged organic molecules like glucose. These three types of carrier proteins are also found in facilitated diffusion, but they do not require ATP to work in that process. Some examples of pumps for active transport are $Na^+$–$K^+$ ATPase, which 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 are $Ca^{2+}$ ATPase and $H^+$ ATPase, which carry only calcium and only hydrogen ions, respectively. Both are pumps.




**Types of Active Transport:**

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 electrochemical gradient established by primary active transport that does not directly require ATP.




**Primary active transport:**

It functions with the active transport of sodium and potassium allows secondary active transport to occur.

One of the most important pumps in animals cells is sodium-potassium pump ($Na^+$-$K^+$ ATPase), which maintains the electrochemical gradient (and the correct concentrations of $Na^+$ and $K^+$) in living cells. It moves $K^+$ into the cell while moving $Na^+$ out at the same time, at a ratio of three $Na^+$ ions for every two $K^+$ ions moved in. It exists in two forms, depending on its orientation to the interior or exterior of the cell and its affinity for either sodium or potassium ions.

The process consists of the following six steps.

1. With the enzyme oriented towards the interior of the cell, the carrier has a high affinity for sodium ions. Three ions bind to the protein.
2. ATP is hydrolyzed by the protein carrier and a low-energy phosphate group attaches to it.
3. As a result, carrier change shape and re-orients itself towards exterior of the membrane. The protein's affinity for sodium decreases and the three sodium ions leave the carrier.
4. Shape change increases the carrier's affinity for potassium ions, and two such ions attach to the protein. Subsequently, low-energy phosphate group detaches from the carrier.
5. With the phosphate group removed and potassium ions attached, the carrier protein repositions itself towards the interior of the cell.
6. Carrier protein, in its new configuration, has a decreased affinity for potassium, and two ions are released into cytoplasm. The protein now has a higher affinity for sodium ions, and the process starts again.

Several things have happened as a result of this process. At this point, there are more sodium ions outside of cell than inside and more potassium ions inside than out. For every three ions of sodium that move out, two ions of potassium move in. This results in the interior being slightly more negative relative to the exterior. This difference in charge creates conditions necessary for the secondary process. Sodium-potassium pump is, therefore, an electrogenic pump (a pump that creates a charge imbalance), creating electrical imbalance across the membrane and contributing to the membrane potential.

**Secondary active transport**:

It brings sodium ions, and possibly other compounds, into the cell. As sodium ion concentration outside of the plasma membrane is higher, an electrochemical gradient is created. If a channel protein exists and is open, the sodium ions will be pulled through the membrane. This movement is used to transport other substances that can attach themselves to the transport protein through the membrane. Many amino acids, as well as glucose, enter cell this way. This secondary process is also used to store high-energy hydrogen ions in the mitochondria of plant and animal cells for the production of ATP. The potential energy that accumulates in the stored hydrogen ions is translated into kinetic energy as the ions surge through the channel protein ATP synthase, and that energy is used to convert ADP into ATP.