Transport Across Cell Membrane

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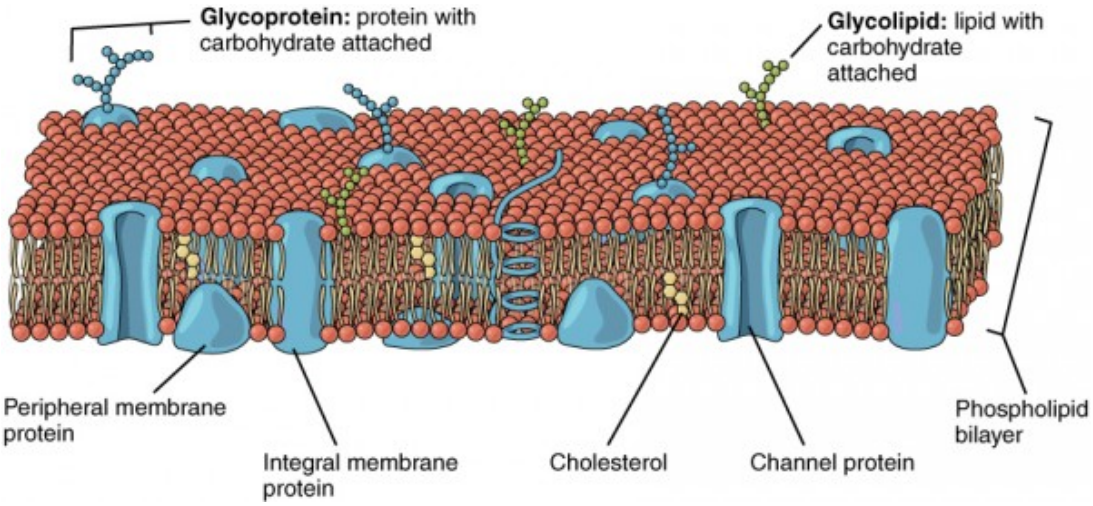
A number of cellular processes involves transport of materials in and outside the cell. The transport of these materials are governed by a number of factors which include presence of a concentration as well as an electrochemical gradient. This article summarizes the different types of transport that can occur across the cell membrane. Specifically, the article differentiates active and passive transport. The different factors that can affect the transport are also discussed in this article.



Transport Across Cell Membrane

The cell membrane is the protective barrier of the cell from the outside environment. It is selectively permeable which means not all materials can pass through it. Its selective permeability decides that essential biomolecules enter the cell cytoplasm, metabolic intermediates remain inside the cell, and waste materials are thrown out. The cell membrane contains a **phospholipid bilaye**r with the **hydrophilic** heads facing the inside and outside of the cell, and a **hydrophobic** tails in the middle. Because of the presence of the phospholipid bilayer, only certain materials can pass readily through the cell membrane.

Two types of transport may occur across a cell membrane. These are passive and active transport. The main difference between the two is the mechanism of transport as well as energy required for the process. These two primarily occur because of the presence of a concentration gradient. A concentration gradient is the gradual difference in the concentration of solutes between two areas.

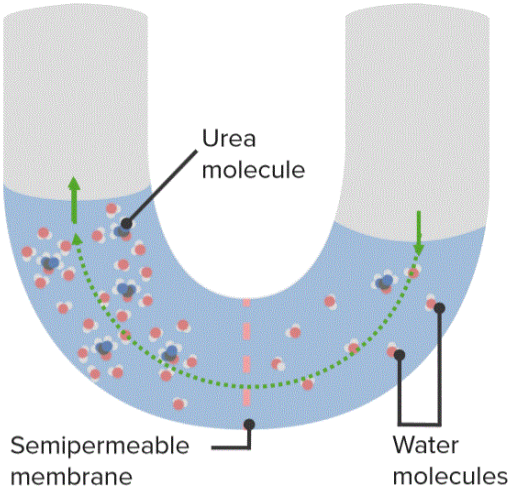
Passive Transport

Passive transport involves moving down a concentration gradient, that is, materials move from an area of higher concentration to an area of lower concentration until no concentration gradient existed. This process does not need energy for it to occur and it does not work against the concentration gradient.

The movement of materials through passive transport is called diffusion. Two types of diffusion may occur across the cell membrane. One is simple diffusion and the other one is facilitated diffusion. Simple diffusion occurs when small, hydrophobic non-polar molecules readily pass through a membrane from a higher concentration to a lower one. Facilitated diffusion is a type of passive transport that involves the use of integral membrane proteins to facilitate passage of larger, charged hydrophilic, and polar molecules across a concentration gradient.

Osmosis

When the substance being transported is solvent (water), the process is called osmosis. The process is driven by osmotic pressure. A classic example of osmosis is the diffusion of water into and out of blood cells depending on the solution the blood is exposed to.

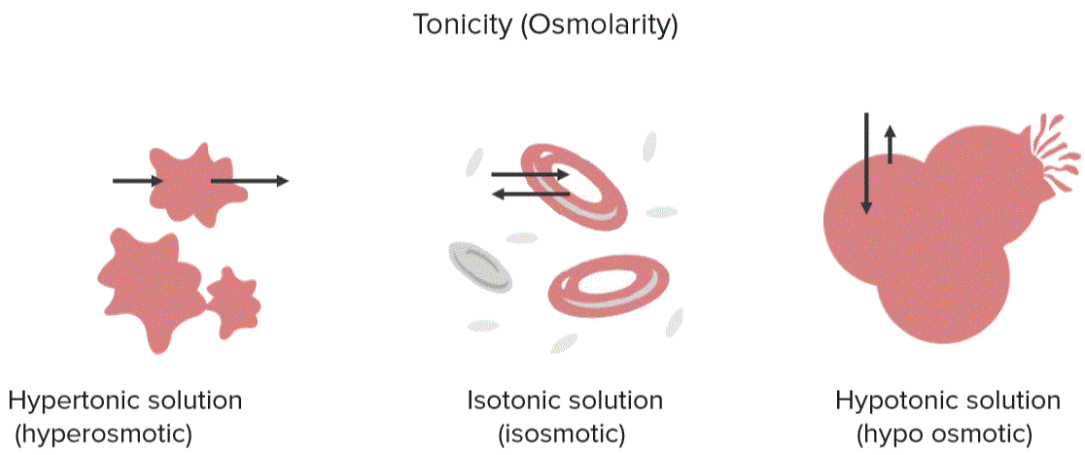


"Osmosis – Passive Transport Mechanisms" Image created by Lecturio

Three types of solutions may be used namely:

- Isotonic
- Hypotonic
- Hypertonic

An isotonic solution is a solution with the same concentration as another solution. A hypotonic solution is a solution that has a lower concentration compared to another solution. While a hypertonic solution is a solution that has a higher concentration compared to another one. For blood cells, the solutions producing the concentration gradient are the cytoplasm and the extracellular solution the blood is exposed to.



“Osmosis Pressure” Image created by Lecturio

When blood is exposed to an isotonic solution, since the concentrations inside and outside the cell are the same, no transport of materials will occur. On the other hand, when blood cells are exposed to a hypotonic solution, the tendency for water is to move from the outside to the inside of the cell. The cell then expands until maximum water capacity is achieved and exceeding it leads to bursting of the blood cells, a process is called plasmoptysis. On the other hand, exposing the cells to a hypertonic solution causes water from the inside of the cell to move out of the cell causing the cell to shrivel, called plasmolysis.

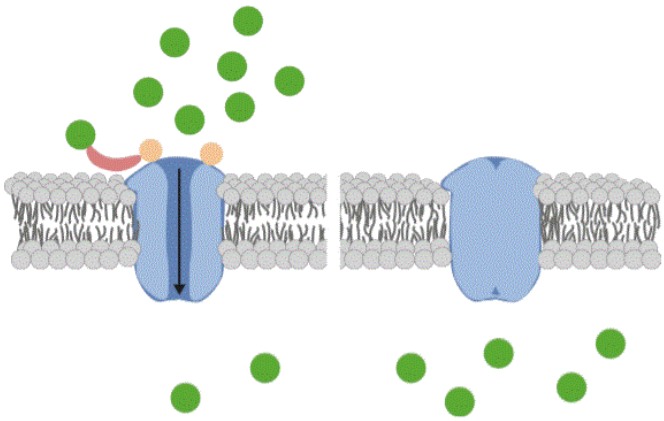
Osmotic pressure is the driving force behind osmosis.

Factors affecting Diffusion

Different factors can affect the diffusion rates. These include concentration, temperature, ionic or molecular size, the shape of ion or molecule, and viscosity. The rate of diffusion is greatly affected by the concentrations of the solutions forming the concentration gradient. The larger the difference in the solute concentrations of the two areas, a faster rate of diffusion will be expected. This is to be able to achieve homeostasis faster.

Temperature also affects the rate of diffusion. Increasing the temperature of the system increases the kinetic energies of the particles in a solution. Since the materials are moving faster, diffusion will occur also faster.

The size and shape of the ion or the molecule to be transported also affect the rate of diffusion. Since materials are to pass through a membrane, the smaller the molecule or ion is, the less interaction it can make with the surface of the membrane. This, in turn, results in faster diffusion. In fact, larger molecules like starches and proteins do not diffuse across cell membranes. On the other hand, the shape of the ion or molecule can either facilitate or prevent its fast diffusion across a membrane. They must have good configuration or shape to better pass through a membrane.



"Facilitated Diffusion requires a Channel Protein or Carrier Protein" Image created by Lecturio

Channel proteins provide an aqueous passage:

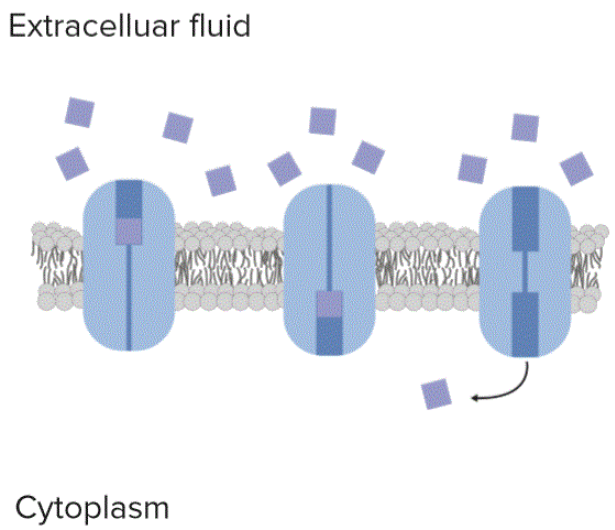
- Diffusion through channel
- Requires no energy
- Hydrophobic interior passage
- Open or closed
- Gated channels

The viscosity of the solution also affects the rate of diffusion. More viscous fluids tend to diffuse slower compared to less viscous ones.

Active Transport

Active transport is another type of movement of material based on a concentration gradient. The main difference of active transport to that of passive transport is that in active transport materials move from a region of lower concentration to a region of higher one. Another difference is energy required in active transport. The added energy is used to push solutes against the concentration gradient.

There three types of active transport, membrane pumps, **endocytosis and exocytosis**. Membrane pumps are carrier proteins that facilitate movement of material from lower concentration to a higher one.



"Facilitated Diffusion requires a carrier protein" Image created by Lecturio

Carrier proteins bind specific molecules:

- High to low concentration
- Conformational change
- Requires no energy
- Selectively permeable membrane

An example of a membrane protein is the Na^+/K^+ pump. Outside the cell, there is a high concentration of Na^+ while inside the cell, there is a high concentration of K^+. The function of the pump is to always push Na^+ outside the cell and more K^+ inside the cell. The process of doing this start by having three Na^+ ions binding to the pump. An ATP molecule then is used up to change the conformation of the pump by attaching one phosphate ion to the pump. This allows the release of Na^+ ions to the outside of the cell. Two K^+ ions then binds to the pump causing the phosphate ion to break allowing easier release of the K^+ to the inside of the cell.

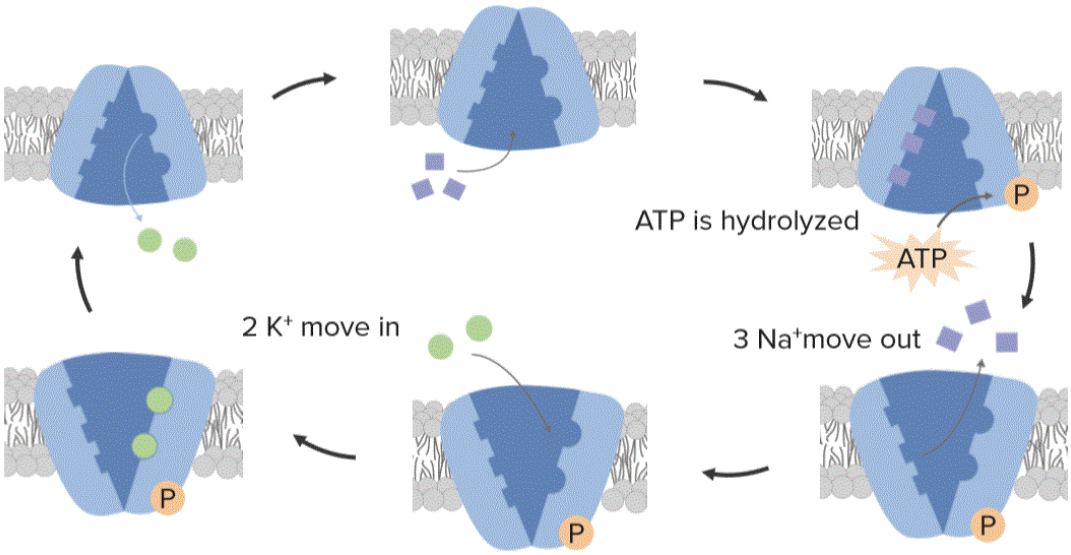
There are two main types of active transport. These are primary active transport and secondary active transport. The main difference between the two types of active transport is the energy source used to drive the transport.

The main energy source in primary active transport is **adenosine triphosphate**, ATP. ATP is used to drive the movement of solutes. On the other hand, secondary active transport uses other forms or sources of energy other than ATP. Considering the example before on the use of Na^+/K^+ pump. In the process, after the transfer of a lot of Na^+ ions outside the cell, the outside becomes more and more positive. Due to the principle of electrostatic repulsion which states that opposite charges repel each other, an **electrochemical** gradient is formed in the process.

This electrochemical gradient is a source fo potential energy that will drive the movement of Na^+ ions outside the cells to enter the cell once more to reduce the positive charges outside. The movement occurs through a **symporter** that uses up the potential energy due to the electrochemical gradient. In terms of the Na^+ ions, the movement is from higher to lower concentration. However, this process is still considered active transport because aside from the Na^+ ions entering the cell, glucose also move from the outside to the inside of the cell.

Since glucose concentration outside is lower compared to the inside of the cell, and since

the process involves the use of energy, this is considered active transport.

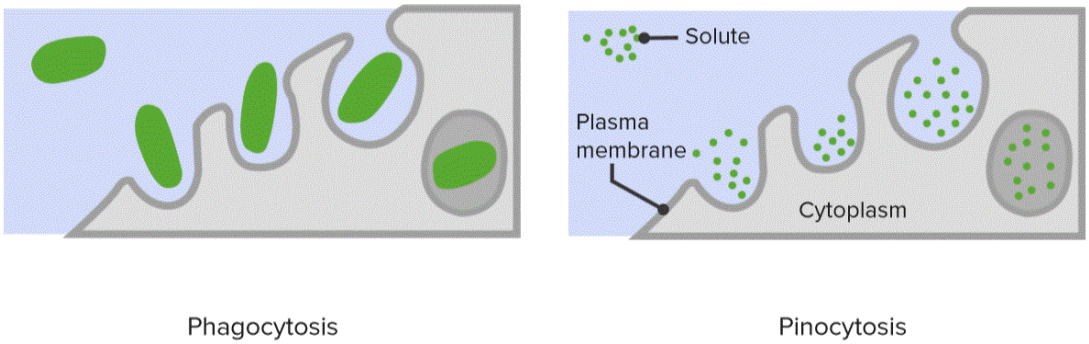


"The Na+/K+ Pump. Active Transport Mechanisms" Image created by Lecturio

Bulk Transport

Bulk transport occurs when a lot of materials are transferred at once.0 Vesicle movements like endocytosis and exocytosis are considered bulk transport. Two types of vesicle movement occurring in cells are endocytosis and exocytosis. Endocytosis brings items inside the cell while exocytosis pushes materials outside the cell.

Endocytosis is an active transport using energy to take in biomolecules or larger particles by formation of vesicles. It involves ingesting external fluid containing macromolecules or other larger particles. This works by having the cell membrane pinch around the material forming a vesicle which will carry the substance in any part of the cell. Two types of endocytosis may occur. These are **phagocytosis and pinocytosis**. Phagocytosis occurs when large materials are ingested at once while pinocytosis involves ingestion of finer and smaller molecules. Commonly, phagocytosis is termed as cell eating while pinocytosis is cell drinking.



"Bulk Transport Mechanisms. Moving a lot of material at once" Image created by Lecturio

Exocytosis, on the other hand, involves a vesicle containing materials fusing with the cell membrane eventually allowing the release of the material to the outside of the cell. This type of transport is used by secretory cells and neurotransmitters. Because these two

processes require energy, they are considered forms of active transport.

Review Questions

The correct answers can be found below the references.

1. Which of the following statements is TRUE?

A. Passive transport uses ATP to drive transport of materials.
B. Active transport involves movement of materials from lower concentration to a higher concentration.
C. Active transport produces energy after transferring the materials.
D. Osmosis occurs when water crosses a membrane through active transport.

2. Which of the following is not considered a type of active transport?

A. Facilitated diffusion
B. Pinocytosis
C. Movement of K^+ through the Na^+/K^+ pump
D. Movement of glucose through symporter

References

1.Cornwall, G. Transport Across Cell Membranes: Moving Things Into and Out of the Cell. Retrieved from Lecturio.com.

2.Voet, D. & Voet, J.G. (2011). Biochemistry. 4th ed. New York: J. Wiley and Sons.

Correct Answers: 1B; 2A

Notes