16.2: Passive transport

Plasma membranes must allow certain substances to enter and leave a cell, and prevent some harmful materials from entering and some essential materials from leaving. In other words, plasma membranes are selectively permeable; they allow some substances to pass through, but not others. If they were to lose this selectivity, the cell would no longer be able to sustain itself, and it would be destroyed. There are four major types of transport across the cell membrane:

1. Diffusion,
2. Diffusion through a channel,
3. Facilitated diffusion (selective binding), and
4. Active transport (requires ATP).

Recall that plasma membranes are amphiphilic: they have hydrophilic and hydrophobic regions. This characteristic helps move some materials through the membrane and hinders the movement of others.

Nonpolar and lipid-soluble material with a low molecular weight can easily slip through the membrane’s hydrophobic lipid core. Substances such as the fat-soluble vitamins A, D, E, and K readily pass through the plasma membranes in the digestive tract and other tissues. Fat-soluble drugs and hormones also gain easy entry into cells and readily transport themselves into the body’s tissues and organs. Oxygen and carbon dioxide molecules have no charge and pass through membranes by simple diffusion.

Polar substances present problems for the membrane. While some polar molecules connect easily with the cell’s outside, they cannot readily pass through the plasma membrane’s lipid core.

Additionally, while small ions could easily slip through the spaces in the membrane’s mosaic, their charge prevents them from doing so. Ions such as sodium, potassium, calcium, and chloride must have special means of penetrating plasma membranes. Simple sugars and amino acids also need the help of various transmembrane proteins (channels) to...
transport themselves across plasma membranes.

**Diffusion**

Diffusion is a passive process of transport. A single substance moves from a high concentration to a low concentration area until the concentration is equal across a space (figure 16.4). Materials move within the cell’s cytosol by diffusion, and certain materials move through the plasma membrane by diffusion such as lipids and fat-soluble vitamins. Diffusion expends no energy. On the contrary, concentration gradients are a form of potential energy, which dissipates as the gradient is eliminated.

**Osmosis**

Osmosis is the movement of water through a semipermeable membrane according to the water’s concentration gradient across the membrane, which is inversely proportional to the solute’s concentration. While diffusion transports material across membranes and within cells, osmosis transports only water across a membrane, and the membrane limits the solute's diffusion in the water (figure 16.5). Not surprisingly, the aquaporins that facilitate water movement play a large role in osmosis, most prominently in red blood cells and the membranes of kidney tubules. In osmosis, water always moves from an area of higher water concentration to one of lower concentration.

Figure 16.4: Diffusion across the plasma membrane.

Figure 16.5: Illustration of osmosis. In the diagram, the solute cannot pass through the selectively permeable membrane, but the water can.
**Tonicity**

Tonicity describes how an extracellular solution can change a cell’s volume by affecting osmosis. A solution’s tonicity often directly correlates with the solution’s osmolarity. Osmolarity describes the solution’s total solute concentration.

- A solution with low osmolarity has a greater number of water molecules relative to the number of solute particles.
- A solution with high osmolarity has fewer water molecules with respect to solute particles.

In a situation in which a membrane, permeable to water though not to the solute, separates two different osmolarities, water will move from the membrane’s side with lower osmolarity (and more water) to the side with higher osmolarity (and less water).

**Hypotonic solutions**

In a hypotonic situation, the extracellular fluid has lower osmolarity than the fluid inside the cell, and water enters the cell. It also means that the extracellular fluid has a higher water concentration in the solution than does the cell. In this situation, water will follow its concentration gradient and enter the cell.

**Hypertonic solutions**

As for a hypertonic solution, the prefix “hyper” refers to the extracellular fluid having a higher osmolarity than the cell’s cytoplasm; therefore, the fluid contains less water than the cell does. Because the cell has a relatively higher water concentration, water will leave the cell.

**Isotonic solutions**

In an isotonic solution, the extracellular fluid has the same osmolarity as the cell. If the cell’s osmolarity matches that of the extracellular fluid, there will be no net movement of water into or out of the cell, although water will still move in and out. Osmotic pressure changes red blood cells’ shape in hypertonic, isotonic, and hypotonic solutions (figure 16.6).

![Figure 16.6: Comparison of red blood cell morphology in isotonic, hypertonic, and hypotonic solutions.](https://med.libretexts.org/Bookshelves/Basic_Science/Cell_Biology_Genetics_and_Biochemistry_for_Pre-Clinical_Students/1…)

**Factors that affect diffusion**

Molecules move constantly in a random manner, at a rate that depends on their mass, their environment, and the...
amount of thermal energy they possess, which in turn is a function of temperature. While diffusion will go forward in the presence of a substance’s concentration gradient, several factors affect the diffusion rate:

- **Extent of the concentration gradient**: The greater the difference in concentration, the more rapid the diffusion. The closer the distribution of the material gets to equilibrium, the slower the diffusion rate.
- **Mass of the molecules diffusing**: Heavier molecules move more slowly; therefore, they diffuse more slowly. The reverse is true for lighter molecules.
- **Temperature**: Higher temperatures increase the energy and therefore the molecules’ movement, increasing the diffusion rate. Lower temperatures decrease the molecules’ energy, thus decreasing the diffusion rate.
- **Solvent density**: As the density of a solvent increases, the diffusion rate decreases. The molecules slow down because they have a more difficult time passing through the denser medium.
- **Solubility**: Nonpolar or lipid-soluble materials pass through plasma membranes more easily than polar materials, allowing for a faster diffusion rate.
- **Surface area and plasma membrane thickness**: Increased surface area increases the diffusion rate, whereas a thicker membrane reduces it.
- **Distance traveled**: The greater the distance that a substance must travel, the slower the diffusion rate.

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**Facilitated transport (diffusion)**

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

**Ion channels**

Channels are specific for the transported substance. Channel proteins have hydrophilic domains exposed to the intracellular and extracellular fluids. In addition, they have a hydrophilic channel through their core that provides a hydrated opening through the membrane layers (figure 16.7).
Channel proteins are either open at all times or they are “gated,” which controls the channel’s opening. The gating can be controlled by volatage, ligand (such as ATP), or mechanical stimulus. When a particular ion attaches to the channel protein, it 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 open to allow passage. Cells involved in transmitting electrical impulses, such as nerve and muscle cells, have gated channels for sodium, potassium, and calcium in their membranes. Opening and closing these channels changes the relative concentrations on opposing sides of the membrane of these ions, resulting in facilitating electrical transmission along membranes (in the case of nerve cells) or in muscle contraction (in the case of muscle cells).

Carrier proteins

Another type of protein embedded in the plasma membrane is a carrier protein. This aptly named protein binds a substance and, thus triggers a change of its own shape, moving the bound molecule from the cell’s outside to its interior (figure 16.8).

Depending on the gradient, the material may move in the opposite direction. Carrier proteins are typically specific for a single substance. This selectivity adds to the plasma membrane’s overall selectivity. One group of carrier proteins, glucose transport proteins, or GLUTs, are involved in transporting glucose and other hexose sugars through plasma membranes within the body.
Channel and carrier proteins transport material at different rates. Channel proteins transport much more quickly than 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.

References and resources

Text

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Figures

Grey, Kindred, Figure 16.4 Diffusion across the plasma membrane. 2021. https://archive.org/details/16.4_20210926. CC BY 4.0. Added ion channel by Léa Lortal from the Noun Project.

Grey, Kindred, Figure 16.5 Illustration of osmosis. In the diagram, the solute cannot pass through the selectively permeable membrane, but the water can. 2021. https://archive.org/details/16.5_20210926. CC BY 4.0.


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