

Al-Mustaqbal University

College of Engineering and Technologies

Biomedical Engineering Department



Biology

Lecture: 4

Transportation Across The Cell Membrane

(Passive and Active Transport)

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Introduction

Imagine living in a house that has walls without any windows or doors. Nothing could enter or leave the house. Now imagine living in a house with holes in the walls instead of windows and doors. Things could enter or leave the house, but you wouldn't be able to control what came in or went out. Only if a house has walls with windows and doors that can be opened or closed can you control what enters or leaves. For example, windows and doors allow you to let the dog in and keep the bugs out.

Transport Across Membranes

If a cell were a house, the plasma membrane would be walls with windows and doors. Moving things in and out of the cell is an important role of the plasma membrane. It controls everything that enters and leaves the cell. There are two basic ways that substances can cross the plasma membrane: passive transport and active transport.

1. Passive Transport

Passive transport occurs when substances cross the plasma membrane without any input of energy from the cell. No energy is needed because the substances are moving from an area where they have a higher concentration to an area where they have a lower concentration. Concentration refers to the number of particles of a substance per unit of volume. The more particles of a substance in a given volume, the higher the concentration. A substance always moves from an area where it is more concentrated to an area where it is less concentrated. It's a little like a ball rolling down a hill. It goes by itself without any input of extra energy.

There are several different types of passive transport, including simple diffusion, osmosis, and facilitated diffusion. Each type is described below.

a. Simple Diffusion

Simple diffusion is the movement of a substance across a membrane, due to a difference in concentration, without any help from other molecules. The substance simply moves from the side of the membrane where it is more concentrated to the side where it is less concentrated.

Figure below shows how diffusion works. Substances that can squeeze between the lipid molecules in the plasma membrane by simple diffusion are generally very small, hydrophobic molecules, such as molecules of oxygen and carbon dioxide.

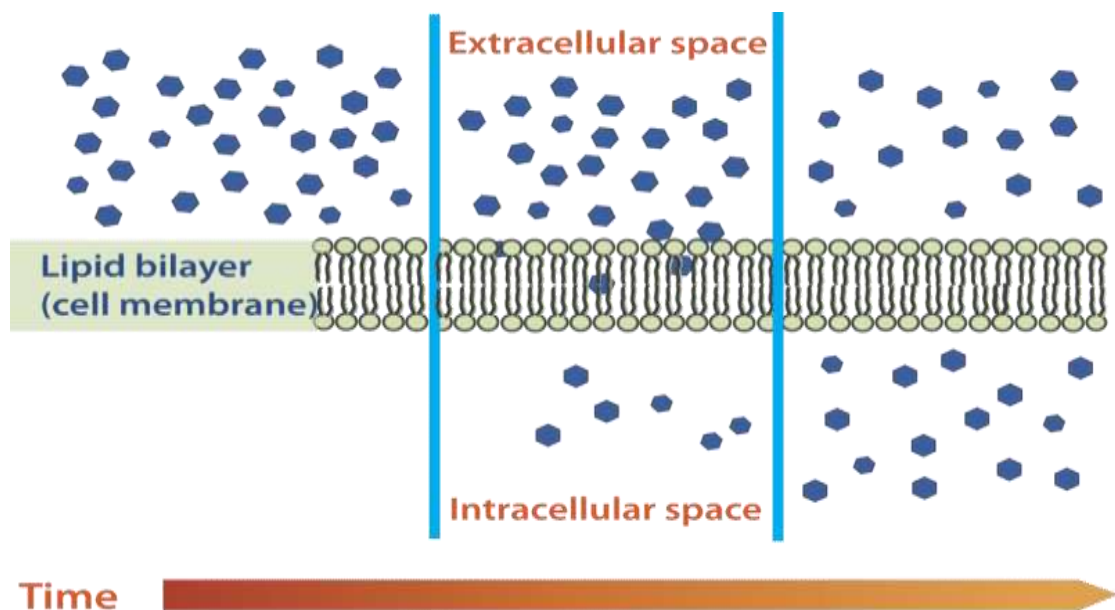


Figure 1. Simple Diffusion across Plasma Membrane.

Diffusion Across a Cell Membrane. Molecules diffuse across a membrane from an area of higher concentration to an area of lower concentration until the concentration is the same on both sides of the membrane.

b. Osmosis

Osmosis is a special type of diffusion — the diffusion of water molecules across a membrane. Like other molecules, water moves from an area of higher concentration to an area of lower concentration. Water moves in or out of a cell until its concentration is the same on both sides of the plasma membrane.

Hypotonic Solutions

Three terms—hypotonic, isotonic, and hypertonic—are used to relate the osmolarity of a cell to the osmolarity of the extracellular fluid that contains the cells. In a hypotonic situation, the extracellular fluid has lower osmolarity than the fluid inside the cell, and water enters the cell. (In living systems, the point of reference is always the cytoplasm, so the prefix hypo- means that the extracellular fluid has a lower concentration of solutes, or a lower osmolarity, than the cell cytoplasm.) It also means that the extracellular fluid has a higher concentration of water in the solution than does the cell. In this situation, water will follow its concentration gradient and enter the cell, causing the cell to expand.

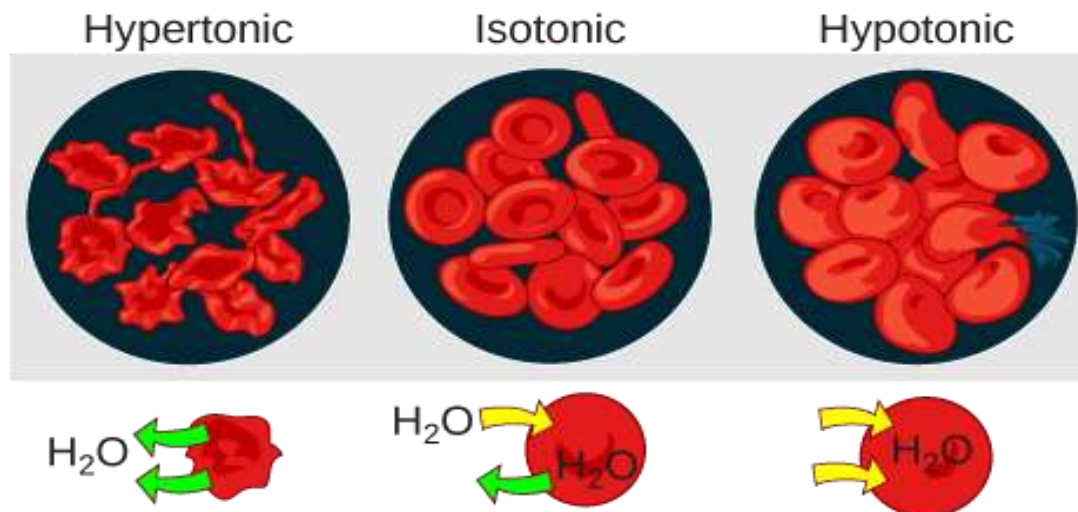


Figure 2. Changes in Cell Shape Due to Dissolved Solutes: Osmotic pressure changes the shape of red blood cells in hypertonic, isotonic, and hypotonic solutions.

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 concentration of water, water will leave the cell, and the cell will shrink.

Isotonic Solutions

In an isotonic solution, the extracellular fluid has the same osmolarity as the cell. If the osmolarity of the cell 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.

Blood cells and plant cells in hypertonic, isotonic, and hypotonic solutions take on characteristic appearances. Cells in an isotonic solution retain their shape. Cells in a hypotonic solution swell as water enters the cell, and may burst if the concentration gradient is large enough between

the inside and outside of the cell. Cells in a hypertonic solution shrink as water exits the cell, becoming shriveled.

c. Facilitated Diffusion

Water and many other substances cannot simply diffuse across a membrane. Hydrophilic molecules, charged ions, and relatively large molecules such as glucose all need help with diffusion. The help comes from special proteins in the membrane known as **transport proteins**. Diffusion with the help of transport proteins is called **facilitated diffusion**. There are several types of transport proteins, including channel proteins and carrier proteins. Both are shown in **Figure** below.

- Channel proteins form pores, or tiny holes, in the membrane. This allows water molecules and small ions to pass through the membrane without coming into contact with the hydrophobic tails of the lipid molecules in the interior of the membrane.
- Carrier proteins bind with specific ions or molecules, and in doing so, they change shape. As carrier proteins change shape, they carry the ions or molecules across the membrane.

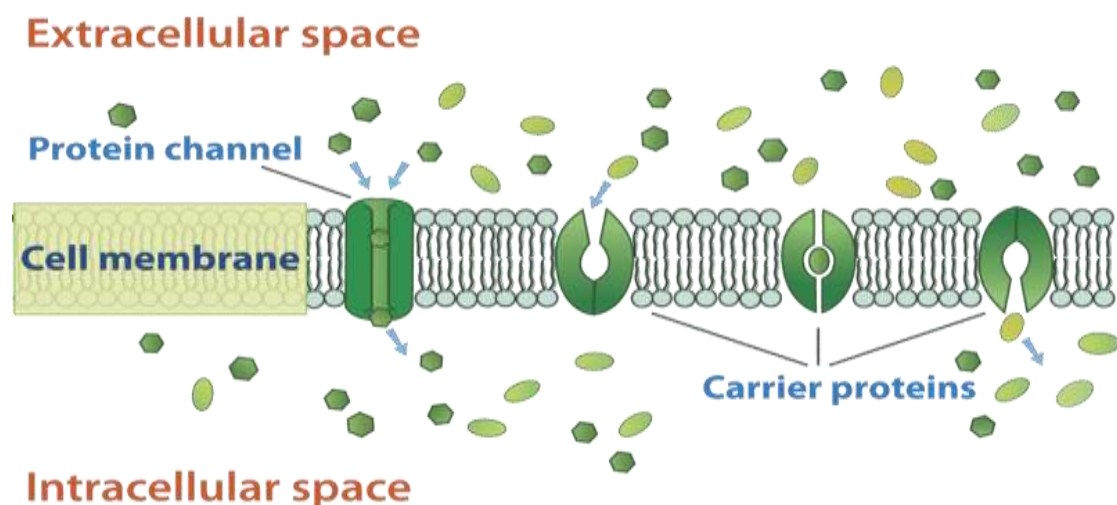


Figure 3. Facilitated Diffusion across Cell Membrane.

Facilitated Diffusion Across a Cell Membrane. Channel proteins and carrier proteins help substances diffuse across a cell membrane. In this diagram, the channel and carrier proteins are helping substances move into the cell (from the extracellular space to the intracellular space).

2.Active Transport

Active transport occurs when energy is needed for a substance to move across a plasma membrane. Energy is needed because the substance is moving from an area of lower concentration to an area of higher concentration. This is a little like moving a ball uphill; it can't be done without adding energy. The energy for active transport comes from the energy-carrying molecule called ATP. Like passive transport, active transport may also involve transport proteins.

Sodium-Potassium Pump

An example of active transport is the **sodium-potassium pump**. When this pump is in operation, sodium ions are pumped out of the cell, and potassium ions are pumped into the cell. Both ions move from areas of lower to higher concentration, so ATP is needed to provide energy for this “uphill” process. **Figure** below explains in more detail how this type of active transport occurs.

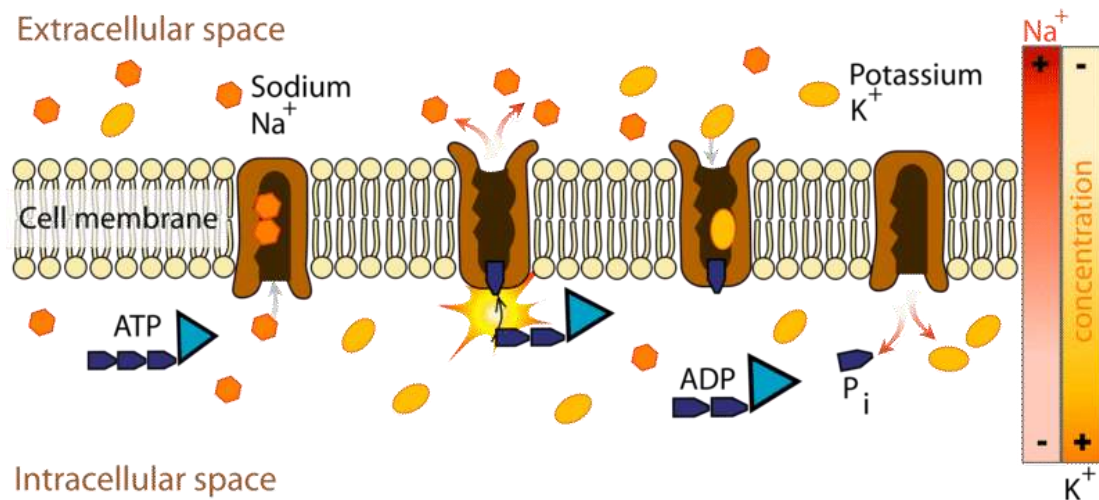


Figure 4. Active Transport.

The sodium-potassium pump. The sodium-potassium pump moves sodium ions (Na⁺) out of the cell and potassium ions (K⁺) into the cell. First, three sodium ions bind with a carrier protein in the cell membrane. Then, the carrier protein receives a phosphate group from ATP. When ATP loses a phosphate group, energy is released. The carrier protein changes shape, and as it does, it pumps the three sodium ions out of the cell. At that point, two potassium ions bind to the carrier protein. The process is reversed, and the potassium ions are pumped into the cell.

Vesicle Transport

Some molecules, such as proteins, are too large to pass through the plasma membrane, regardless of their concentration inside and outside the cell. Very large molecules cross the plasma membrane with a different sort of help, called **vesicle transport**. Vesicle transport requires energy, so it is also a form of active transport. There are two types of vesicle transport: endocytosis and exocytosis. Both types are shown in **Figure** below and described below.

- **Endocytosis** is the type of vesicle transport that moves a substance into the cell. The plasma membrane completely engulfs the substance, a vesicle pinches off from the membrane, and the vesicle carries the substance into the cell. When an entire cell is engulfed, the process is called phagocytosis. When fluid is engulfed, the process is called pinocytosis.
- **Exocytosis** is the type of vesicle transport that moves a substance out of the cell. A vesicle containing the substance moves through the cytoplasm to the cell membrane. Then, the vesicle membrane fuses with the cell membrane, and the substance is released outside the cell. You can watch an animation of exocytosis at the link below.

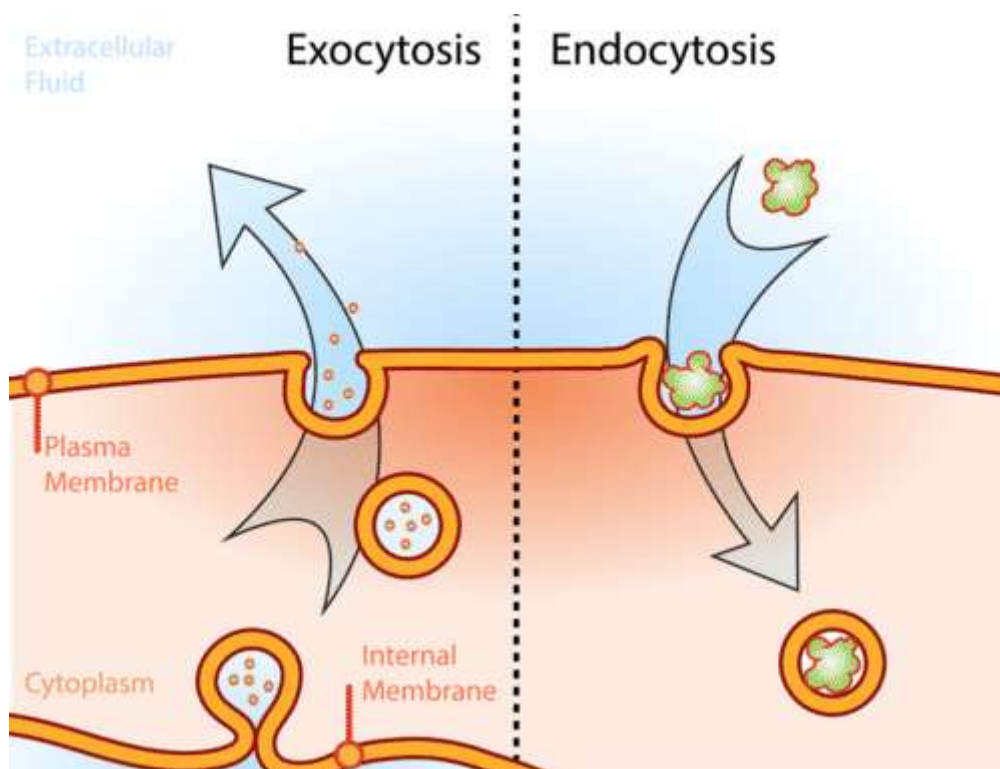


Figure 5. Illustration of the two types of vesicle transport, Exocytosis and Endocytosis.

Homeostasis and Cell Function

For a cell to function normally, a stable state must be maintained inside the cell. For example, the concentration of salts, nutrients, and other substances must be kept within a certain range. The process of maintaining stable conditions inside a cell (or an entire organism) is homeostasis. Homeostasis requires constant adjustments, because conditions are always changing both inside and outside the cell. The processes described in this lesson play important roles in homeostasis. By moving substances into and out of cells, they keep conditions within normal ranges inside the cells and the organism as a whole.

References

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