Cellular Transport

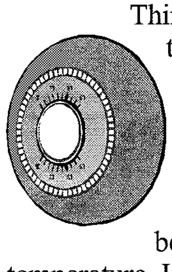
Section 7.1
Introduction to Homeostasis and Cellular Transport

Pre-View 7.1

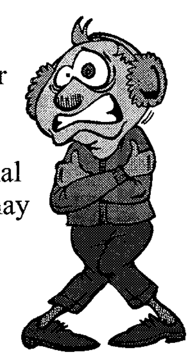
- **Homeostasis** – the process of keeping the internal conditions in an organism stable
- **Cellular transport** – the movement of materials into and out of cells
- **Cell membrane** – the membrane that surrounds the contents of a cell and allows only certain things into and out of the cell
- **Selectively permeable** – a property of cell membranes that allows only certain things to cross but not others
- **Phospholipid bilayer** – the two layers of phospholipid molecules arranged tail to tail that help to make up cell membranes
- **Active transport** – processes such as endocytosis and exocytosis that require some of the cell's energy
- **Passive transport** – processes such as osmosis and diffusion that do not require energy from the cell

Homeostasis — sounds like a word that someone just made up, doesn't it? Well, someone really did make it up. Around 1930 a scientist from Harvard University combined two Greek words meaning "the same" and "steady" and came up with *homeostasis.*

Homeostasis refers to the need for living organisms to maintain a stable internal environment in order to survive. This constant internal environment must be maintained no matter what changes occur in the environment outside of the organism. Maintaining the right amount of oxygen, the correct amount of nutrients, the right temperature, and the correct pH are just a few of the factors that must be strictly controlled for living things to survive and grow. Things on the outside of an organism may change constantly. The temperature may go up and down, oxygen levels may rise or fall, etc., but an organism must constantly adjust to these changes so that their internal conditions stay the same.



Think about the thermostat that controls a furnace in the winter. The thermostat is set to maintain a constant temperature. If the room temperature drops below the set temperature, the thermostat signals the furnace to turn on and produce heat. This heating system keeps the internal room temperature about the same.



The same kind of thing occurs in your body and in other organisms. Your body's internal temperature is around 37°C (98.6°F). This is the temperature that is needed for all of your cells to function properly. You cannot survive for long at too much above or below this temperature. But thankfully, your body constantly adjusts to keep this ideal temperature. If the outside temperature gets too hot, your body will produce sweat to keep your internal temperature about the same. Likewise, if you go out on a cold winter day without a coat, your body may cause you to shiver to keep your internal temperature from dropping too low. Keeping your body at a fairly constant 37°C is an example of how humans maintain homeostasis.

Homeostasis in Cells

Remember that cells make up tissues, tissues make up organs, organs make up organ systems, and organ systems make up the organism. To keep internal conditions constant, each cell must do its part, and so homeostasis must be maintained at a cellular level. The chemical reactions that take place in each cell need a constant internal environment. Since cells are living, they have to be able to take in oxygen and nutrients and get rid of wastes just like all living organisms. The movement of materials into and out of a cell is called **cellular transport**, and the different types of cellular transport are the processes that allow the cells to maintain homeostasis.

Simple Cell Membrane

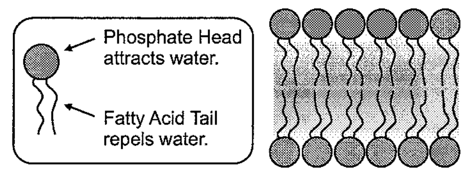


Fig. 7-1
Simple Phospholipid Bilayer Membrane

Cells are able to limit what goes in and out because of the **cell membrane**. The cell membrane allows the materials inside the cell to remain separate from its surroundings. It is also **selectively permeable**, which means it allows certain materials to move into and out of the cell when needed but keeps other materials from crossing the membrane. The cell membrane is able to allow some substance in but to keep others out because of its structure. It is made mostly of a **phospholipid bilayer** — two layers of phospholipids arranged tail to tail (figure 7-1). (You should remember phospholipids from Section 5.3.) The membrane also has various proteins, carbohydrates, and cholesterol mixed in.

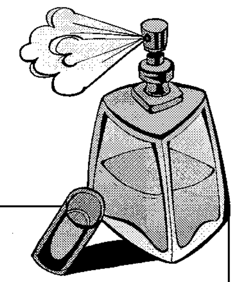
When materials move into and out of the cell, they use either **active transport** or **passive transport**. Active transport means that the cell has to use some of its own energy to move the materials in or out. Some examples of active transport are **endocytosis** and **exocytosis**.

In passive transport, the cell does not have to use any of its own energy. **Osmosis** and **diffusion** are examples of passive transport. Each of these processes allows cells to maintain homeostasis.

The rest of this section will discuss these types of cellular transport in more detail, but for now, review the basics.

Cellular Transport

Section 7.2
Passive Transport: Diffusion



Pre-View 7.2

- **Diffusion** – the movement of molecules from an area of higher concentration to an area of lower concentration
- **Concentration gradient** – a difference in the concentration of ions or other dissolved particles between two regions
- **Equilibrium** – the state of having equal concentrations
- **Facilitated diffusion** – the diffusion of molecules across a membrane through special proteins in the membrane
- **Transport proteins** – proteins present in the cell membrane that allow different types of substances to pass through the membrane

If you opened a bottle of perfume, placed it on a table, and then walked to the other side of the room and waited, eventually you would be able to smell the perfume as the molecules move out of the bottle and into the air. Movement of molecules from an area of higher concentration — like inside the perfume bottle — to an area of lower concentration — outside the perfume bottle — is called **diffusion**.

Diffusion is passive transport because it does not require any energy. When there is a difference in concentration in two areas, the difference is called a **concentration gradient**. In diffusion, the molecules always move from an area of higher concentration to an area of lower concentration.

Some materials can move across the cell membrane into or out of the cell by using diffusion. The molecules will continue moving in or out of the cell as needed until the number of molecules inside the cell and outside the cell are the same. When the concentrations on both sides of the cell membrane are equal, the concentration has reached **equilibrium**. Examples of materials that can diffuse through a cell's membrane are oxygen and carbon dioxide.

In figure 7-2, the oxygen concentration on one side of a cell membrane is greater than the concentration on the other side. By diffusion, the oxygen on the high concentration side of the membrane will move through the membrane to the lower concentration side until the concentrations are equal on both sides. Once the concentrations reach equilibrium, molecules diffuse across the membrane equally so that the concentration remains fairly constant.

Diffusion of Oxygen Through a Cellular Membrane

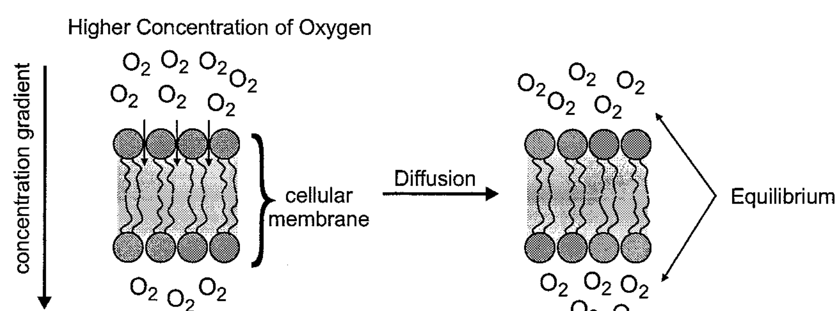


Fig. 7-2

Facilitated Diffusion

Some particles may not be able to penetrate the phospholipid bilayer of a cell membrane, but instead, they can cross the membrane through **transport proteins,** which are also found in the cell membrane. These transport proteins allow some types of ions, sugars, and amino acids to pass through the cell membrane from an area of higher concentration to an area of lower concentration.

Passive Transport: Diffusion

There are different types of transport proteins and each type is selective, meaning each will let through only specific particles. For example, some transport proteins may allow only positively charged ions to pass, and others may allow only negatively charged ions. Since facilitated diffusion moves particles from an area of higher concentration to an area of lower concentration (in the same direction as the concentration gradient), it is a form of passive transport.

Facilitated Diffusion

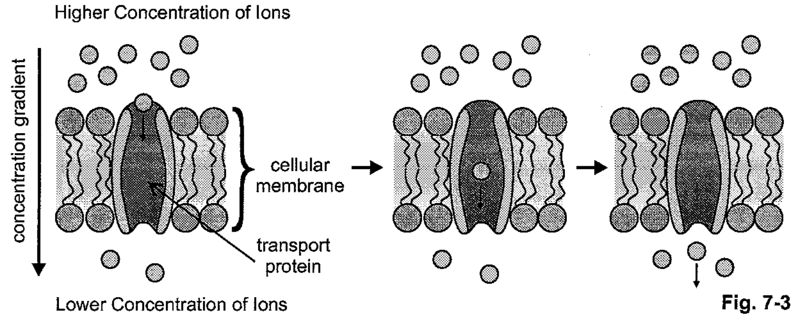
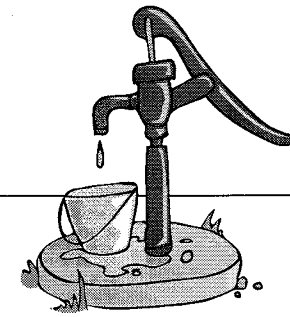


Fig. 7-3

Cellular Transport
Section 7.3
Passive Transport: Osmosis



Pre-View 7.3

- **Osmosis** – the movement of water across a membrane
- **Solute** – dissolved particles
- **Hypertonic** – having a higher solute concentration outside the cell and causing the cell to shrink
- **Hypotonic** – having a higher solute concentration inside the cell and causing the cell to swell
- **Isotonic** – having equal solute concentrations inside and outside the cell

Osmosis is also a type of passive transport since it does not use the cell's energy. Like diffusion, it moves molecules from a higher concentration to a lower concentration. So, you may be wondering what makes osmosis different from diffusion. There are two important things to remember about osmosis.

1. It is always the movement of *water* molecules.
2. It moves water molecules across a selectively permeable membrane through which the **solute** (dissolved particles) cannot cross.

Osmosis occurs when the concentration of a solute (particles other than water) is greater on one side of a membrane than on the other side of the membrane, BUT the solute particles CANNOT diffuse through the membrane. If the solute particles could move through the membrane, they would do so by diffusion. If the solute particles cannot diffuse, water will move through the membrane in order to equalize the concentrations on each side of the membrane. The end result is that water molecules move through the membrane from an area of *higher water concentration* to an area of *lower water concentration* (figure 7-4).

Osmosis: The Movement of Water Through a Selectively Permeable Membrane

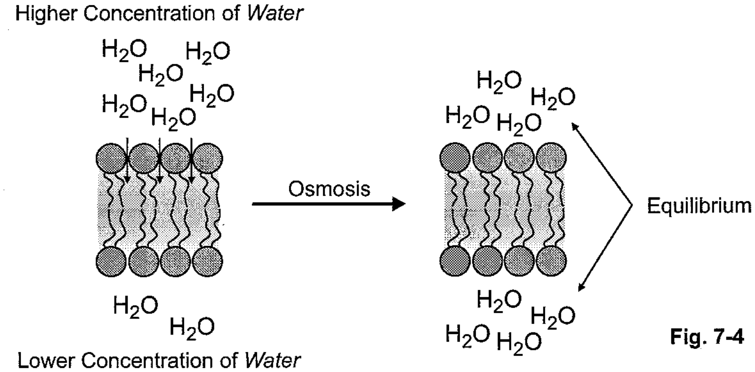


Fig. 7-4

Phospholipid Membrane

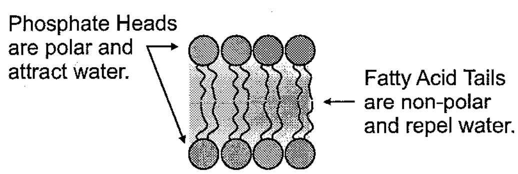


Fig. 7-5

So why does the water move and not the other stuff? It's because of the cell membrane. The phospholipids that make up the cell membrane look something like the diagram in figure 7-5. When the phospholipids line up, there is a non-polar layer between the two layers of phospholipids that is not water-soluble. Just as oil and water don't mix, molecules that are water soluble can't pass through the "oil" layer of the membrane. Sometimes a cell can use facilitated diffusion (as discussed in Section 7.2) to equalize the concentrations, but other times, water will move by osmosis through the membrane.

When we are talking about osmosis, we use three words to describe the solutions: *hypertonic, hypotonic,* and *isotonic.* Here are what those terms mean.

Hypertonic Solution

Have you ever poured salt on a snail or slug in your yard, and then watched as it seemed to melt before your eyes? Adding the salt caused the cells of the slug to be surrounded by a hypertonic solution. **Hypertonic** means that the solution outside the cell membrane contains less water and more solute than the solution inside the cell membrane. Water rushes out of the cell through the cell membrane, and the cell shrivels up. This movement of water out of the cells makes it looks as if the slug is melting.

Hypertonic Solution: Cell Shrinks

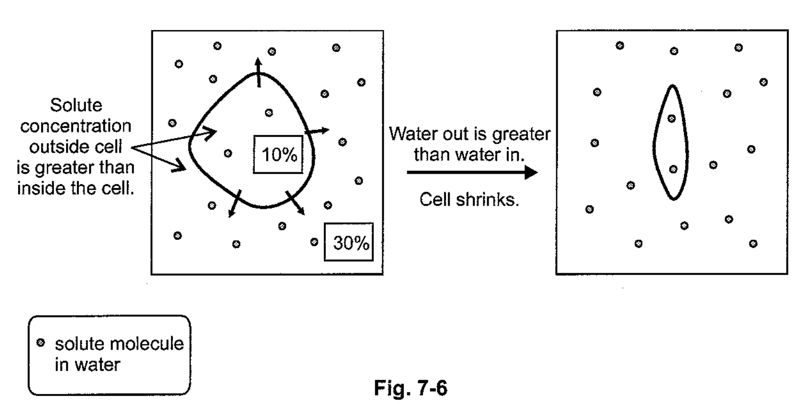


Fig. 7-6

In figure 7-6, a cell with a 10% solute solution is placed in a water solution that is 30% solute. Notice that the water moves from the lower solute concentration to the higher solute concentration. Wait a minute — lower to higher? Can that be right? Yes, remember that osmosis is the movement of water, not the solute molecules as in diffusion. Water moves across the membrane to dilute the area of higher concentration. Water will continue moving out of the cell until the concentrations on either side of the cell membrane are equal. If the solute concentration outside the cell is much higher than inside the cell, the cell may completely shrivel up and die.

Hypotonic Solution

Hypotonic is just the opposite. **Hypotonic** means that the solution inside the cell membrane has a greater concentration of solute molecules than the solution outside the cell.

In figure 7-7, a cell with 30% solute is placed in a solution that contains 10% solute. Again, the water will move across the membrane to dilute the side with the higher concentration. In this case, the water moves into the cell and causes it to swell. Water will continue to move into the cell until the concentrations on either side of the cell membrane are equal.

Hypotonic Solution: Cell Swells

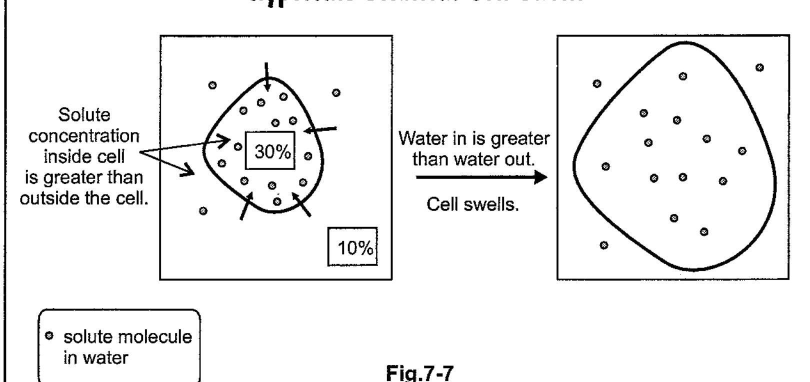


Fig.7-7

Isotonic Solution

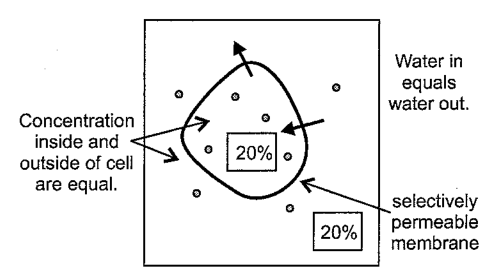


Fig.7-8

Isotonic Solution

Isotonic means that the solution on the outside of the cell membrane has the same concentration as the solution on the inside of the membrane, so there is no net movement of water molecules across the membrane.

In figure 7-8, the solute concentration on both sides of the membrane is equal at 20%. Water molecules will pass in through the membrane at the same rate as they will pass out of the membrane. The cell will remain the same size since it is not gaining or losing water.

> **Hint:** In a hypotonic solution, will a cell shrink or swell? It will swell. A simple word association may help you to remember this answer. Associate "hypo" with an "o" with "hippo." Hippos are large animals. Remember that cells in a hypotonic solution will swell up to the size of a hippo.

Effects of Osmosis on Animal Cells

Since an animal cell has only its cell membrane around it, the cell is very vulnerable to the effects of osmosis.

Hypertonic solutions will cause animal cells to shrink. If the concentrations are very different inside and outside the cell, an animal cell in a hypertonic solution will shrivel and die. For example, salt water is hypertonic to the cells of most vertebrates that live in the ocean. To avoid dehydration that could be fatal to them, these animals constantly drink sea water and then desalt it by pumping the salt out of their gills using *active transport.* (We'll get to that next.) You may have seen pictures of marine turtles that blow salt out of special glands on their noses for the same reason. If a freshwater animal, however, is put in salt water for an extended period of time, its cells will lose too much water in the hypertonic solution, and the animal will die of dehydration.

In a hypotonic solution, animal cells swell. If the cell membrane is not strong enough, the cells will burst. For example, a red blood cell that contains almost 1% solutes will burst if it is put in pure water (0% solute). A saltwater fish that is put in fresh water will eventually die because its cells will gain too much water.

Effects of Osmosis on Plant Cells

Plant cells have a rigid cell wall in addition to the cell membrane, so the effects of osmosis on plant cells are a little different.

In a hypertonic solution, the plant cell loses water. The contents of the cell will shrink some, but the cell wall will still give the cell some shape and structure. Because of the cell wall, a plant cell in a hypertonic solution may not appear smaller. In this condition, however, the plant may wilt. In a highly hypertonic solution, for example if you put a plant in salt water, the contents of the cell will completely shrink away from the rigid cell wall in a process called *plasmolysis*. In extreme conditions, the cell wall may collapse and the cell will die.

In an isotonic solution, a plant cell may not have enough water in it to fully fill the cell wall cavity. Plants in an isotonic solution may appear wilted or *flaccid* (limp).

In a hypotonic solution, plant cells take in water, but their rigid cell walls keep them from bursting. The cell walls allow pressure to build up within the cells. When the pressure equals the osmotic pressure, osmosis ceases. This pressure is called *turgor pressure*. Turgor pressure gives plants *turgor*, rigidity, so that they can "stand up" and not wilt. Have you ever put wilted vegetables in fresh water? If so, you put them into a hypotonic solution. What happens to the vegetables? The water goes into the cells and makes them puff up so they are no longer wilted.

Effects of Osmosis on Plant Cells

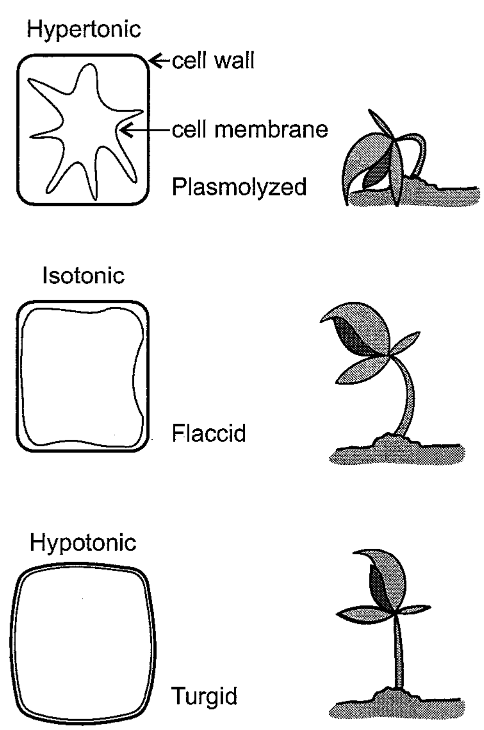


Fig.7-9

Example 1: A red blood cell contains a 0.9% concentration of salt inside the cell. If the red blood cell is placed in a solution that is pure water, what will happen to the cell? Is the solution hypertonic, hypotonic, or isotonic?

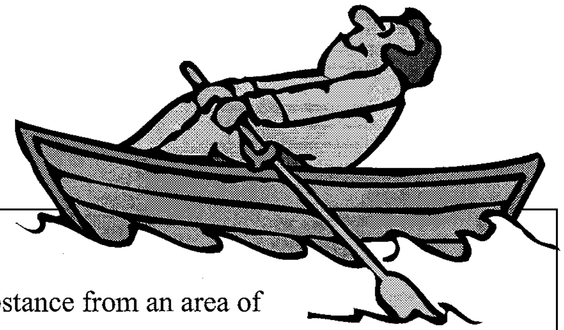
The concentration of salt in the solution is 0%, so the concentration of salt in the red blood cell is greater than the salt concentration of the solution. On the flip side, there is more water on the outside of the cell than on the inside of the cell. Water will enter the cell by osmosis and cause the cell to swell. Since a red blood cell is a type of animal cell, the cell could burst if takes in too much water. The solution is hypotonic because the salt concentration is greater inside the cell than in the solution.

Example 2: A plant cell contains a 1% concentration of solute inside the cell. If the plant cell is placed in a solution that is 5% solute, what will happen to the cell? Is the solution hypertonic, hypotonic, or isotonic?

The concentration of solute inside the plant cell is less than the solute concentration of the solution. Water will leave the cell by osmosis and cause the cell to shrink. Shrinking plant cells cause plants to wilt. The solution is hypertonic because the salt concentration is less inside the cell than in the solution.

Cellular Transport

Section 7.4
Active Transport, Endocytosis, and Exocytosis



Pre-View 7.4

- **Active transport** – a process that requires energy to move a substance from an area of lower concentration to an area of higher concentration
- **Transport protein** – a protein present in the cell membrane that helps to move materials into and out of the cell
- **Endocytosis** – process used by a cell to take in a large particle
- **Exocytosis** – process used by a cell to release materials out of the cell

Active Transport

If molecules that are water soluble can't pass through the cell membrane, how do molecules like glucose, a type of simple sugar, get into the cell? This is where active transport comes in. Cells use active transport to move materials *against* a concentration gradient. Moving materials against the concentration gradient uses energy, similar to rowing a boat upstream. The cell depends on some of the proteins that are in the cell membrane called **transport proteins** to help move materials into and out of the cell. There are different types of transport proteins that work in different ways. Types of transport proteins include *channel proteins*, *carrier proteins*, and *gate proteins*. Many times, the transport protein has a certain shape that allows it to stick to a molecule with a matching shape. When the protein and the molecule are stuck together, the cell uses chemical energy to move the molecule into or out of the cell. Notice in figure 7-10 that the ion is moving *against* the concentration gradient, from lower concentration to higher concentration. Remember, this movement requires energy.

Active Transport

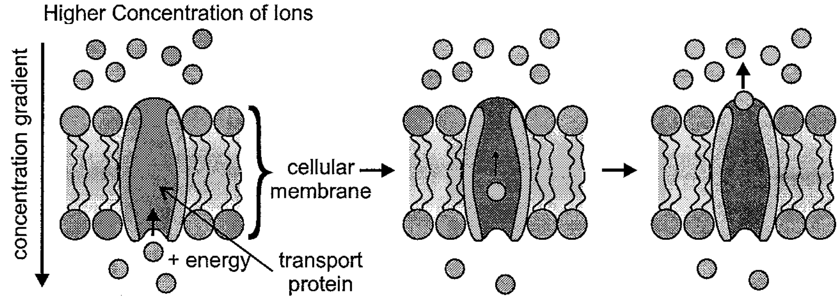


Fig. 7-10

Endocytosis

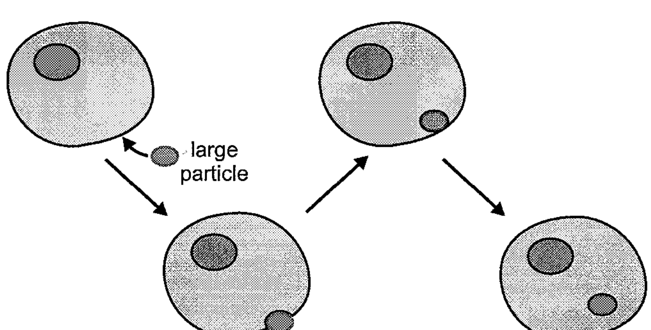


Fig. 7-11

Endocytosis

Sometimes a cell needs to take in a larger particle or to get rid of larger particles that are too big to go through the cell membrane. The cell might use other means of active transport called endocytosis or exocytosis. During **endocytosis,** the cell takes in a larger particle by surrounding it with cell material. It encloses the particle with material from the cell and then pulls it into the cell (figure 7-11).

Hint: Remember "en" for "enter;" particles enter the cell in *en*docytosis.

Exocytosis

If a cell needs to get rid of a larger particle, like a bit of undigested food, it uses **exocytosis**. Exocytosis releases materials from the cell (figure 7-12). It might be used to get rid of waste products or to release a hormone (a chemical messenger) that the cell makes. Inside the cell, the material that is to exit the cell is enclosed in a vesicle. Once the membrane of the vesicle meets the cell membrane, the vesicle membrane breaks open and fuses with the cell membrane. In the process, the particle or hormones are released to the outside.

Hint: Remember "ex" for "exit;" particles exit the cell in *ex*ocytosis.

Exocytosis

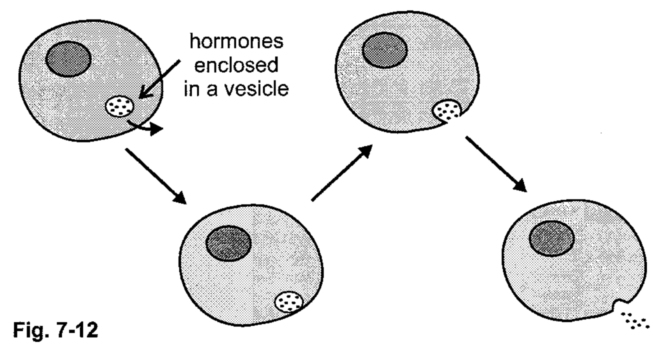


Fig. 7-12