Section 1 Passive Transport

Objectives

- **Relate** concentration gradients, diffusion, and equilibrium.
- **Predict** the direction of water movement into and out of cells.
- **Describe** the importance of ion channels in passive transport. 4A 4B
- **Identify** the role of carrier proteins in facilitated diffusion. 4A 4B

Key Terms

passive transport
concentration gradient
equilibrium
diffusion
osmosis
hypertonic solution
hypotonic solution
isotonic solution
ion channel
carrier protein
facilitated diffusion

Study TIP

Reading Effectively

As you read this chapter, write the objectives for each section on a sheet of paper. Rewrite each objective as a question, and answer these questions as you read the section.

Diffusion

You constantly interact with your environment, whether you are eating or putting on a raincoat to help keep you dry. Your body also responds to external conditions to maintain a stable internal condition. Just as you must respond to your environment to maintain stability, all other organisms and their cells must respond to external conditions to maintain a constant internal condition. Recall that when organisms adjust internally to changing external conditions, they are maintaining homeostasis. One way cells maintain homeostasis is by controlling the movement of substances across their cell membrane. Cells must use energy to transport some substances across the cell membrane. Other substances move across the cell membrane without any use of energy by the cell.

Random Motion and Concentration

Movement across the cell membrane that does not require energy from the cell is called **passive transport**. To understand passive transport, imagine two rooms of equal size separated by a wall with a closed door, as shown in **Figure 1.** Suppose you release several rubber balls into the first room. The balls move randomly, bouncing off the walls, the floor, the ceiling, and each other. Also suppose the balls can bounce forever without slowing down. The balls become evenly distributed throughout the room. What happens when you open the door between the rooms? Some of the balls in the first room bounce through the doorway and into the second room, as shown in Figure 1. You do not have to use energy to make the balls move into the second room. They enter the second room because of their own random motion. Occasionally, a ball will bounce back into the first room. However, most of the balls that pass through the doorway move from the first room, where their concentration is high, to the second room, where their concentration is low. A difference in the concentration of a substance, such as the balls, across a space is called a **concentration gradient**.

As more balls enter the second room, the concentration of balls in the second room increases, while the concentration of balls in the first room decreases. Eventually the concentration of balls in the two rooms will be equal. The balls will still bounce around the rooms, but they will move from the second room to the first room just as often as they move from the first room to the second room. At this point, the system is said to be in equilibrium, as shown in Figure 1. **Equilibrium** *(ee kwih LIHB ree uhm)* is a condition in which the concentration of a substance is equal throughout a space.

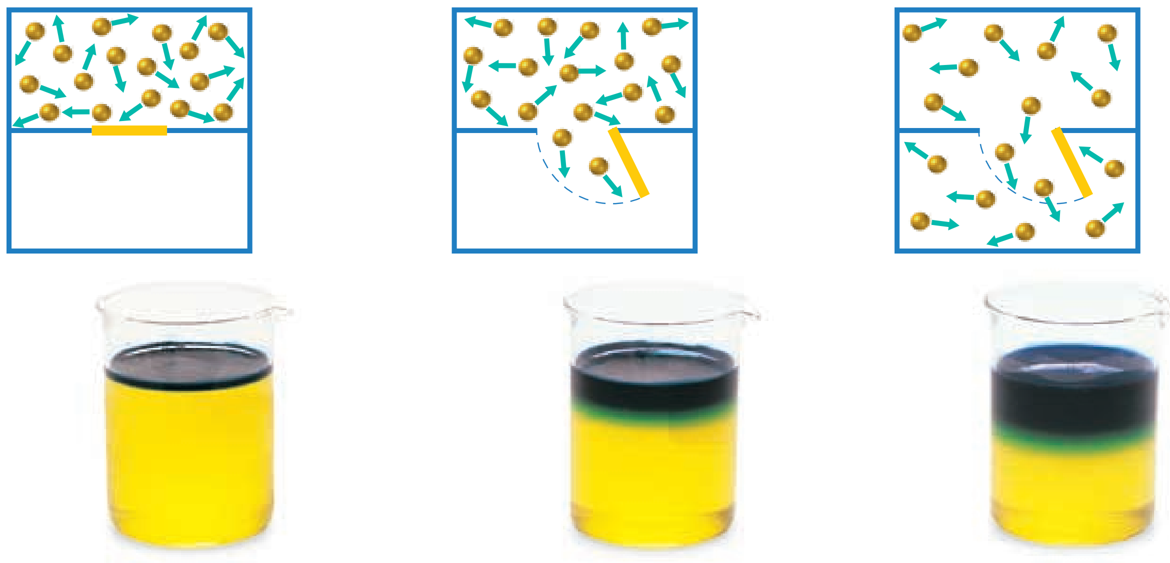
Figure 1 **Models of diffusion**

Because of diffusion, food coloring (blue) will gradually move through uncolored gelatin (yellow), as shown in the beakers below.

1. Randomly bouncing balls are distributed evenly throughout a closed room.

2. If the door to an adjoining room is opened, the balls begin to enter, or diffuse into, that room.

3. At equilibrium, the concentration of balls inside the two rooms will be equal.



Movement of Substances

Like these imaginary rubber balls, particles of a substance in a solution also move around randomly. If there is a concentration gradient in the solution, the substance will move from an area of high concentration to an area of lower concentration. The movement of a substance from an area of high concentration to an area of lower concentration caused by the random motion of particles of the substance is called **diffusion** *(dih FYOO zhuhn)*. If diffusion is allowed to continue, equilibrium eventually results.

Many substances, such as molecules and ions dissolved in the cytoplasm and in the fluid outside cells, enter or leave cells by diffusing across the cell membrane. Inside the cell, the concentrations of most of these substances are different from their concentrations outside the cell. Thus, for each of these substances a concentration gradient exists across the cell membrane. To diffuse "down" its concentration gradient—from an area of high concentration to an area of lower concentration—a substance must be able to pass through the cell membrane.

The cell membrane is selectively permeable to substances. The nonpolar interior of the lipid bilayer repels ions and most polar molecules. Thus, these substances are prevented from diffusing across the cell membrane. In contrast, molecules that are either very small or nonpolar can diffuse across the cell membrane down their concentration gradient. The diffusion of such molecules across the cell membrane is the simplest type of passive transport.

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Topic: Water Movement in Cells

Keyword: HX4189

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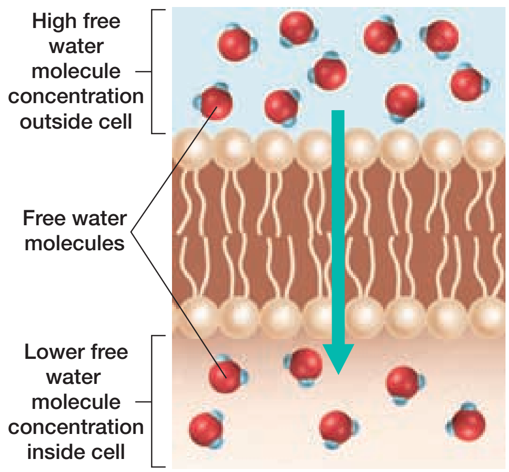
Osmosis

Water molecules are small and can diffuse through the cell membrane, as shown in **Figure 2.** The diffusion of water through a selectively permeable membrane is called **osmosis** *(ahz MOH sihs)*. Like other forms of diffusion, osmosis involves the movement of a substance—water—down its concentration gradient. Osmosis is a type of passive transport.

What causes osmosis? Recall that a solution is a substance dissolved in another substance. In the solutions on either side of the cell membrane, many ions and polar molecules are dissolved in water. When these substances dissolve in water, some water molecules are attracted to them and so are no longer free to move around. If the solutions on either side of the cell membrane have different concentrations of dissolved particles, they will also have different concentrations of "free" water molecules. Then osmosis will occur as free water molecules move into the solution with the lower concentration of free water molecules.

Figure 2 Osmosis

Water diffuses across the cell membrane by osmosis.



Observing Osmosis 2A 2B 2C 4B

QUICK LAB

You can observe the movement of water into or out of a grape under different conditions.

Materials

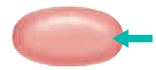
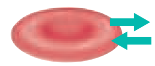
3 grapes, 3 small jars with lids, saturated sugar solution, grape juice, tap water, marking pen, paper towel, balance

Procedure

1. Make a data table with four columns (Solution, Original mass, Predicted mass, and Actual mass) and a row for each solution (Sugar solution, Grape juice, and Water).
2. Fill one jar with the sugar solution. Fill a second jar with grape juice. (The grape will be more visible inside the jar if you fill the jar with white grape juice, as shown in the middle jar in the photo above right.) Fill the third jar with tap water. Label each jar according to the solution it contains.
3. Using the balance, find the mass of each grape. Place one grape in each jar, and record the mass of each jar in your data table. Put a lid on each jar.
4. Predict whether the mass of each grape will increase or decrease over time. Explain your predictions.
5. After 24 hours, remove each grape from its jar, and dry it gently with a paper towel. Using the balance, find its mass again. Record your results.
6. Clean up your materials before leaving the lab.

Analysis

1. **Identify** the solutions in which osmosis occurred.
2. **Critical Thinking** **Evaluating Conclusions** How did you determine whether osmosis occurred in each of the three solutions?
3. **Critical Thinking** **Evaluating Hypotheses** Did the mass of each grape change as you predicted? Why or why not?

Table 1 Hypertonic, Hypotonic, and Isotonic Solutions			
If the fluid outside the cell has...	**Then outside fluid is...**	**Water diffuses...**	**Effect on cell**
...lower free water molecule concentration than cytoplasm	...hypertonic.	...out of cell. 	Cell shrinks.
...higher free water molecule concentration than cytoplasm	...hypotonic.	...into cell. 	Cell swells.
...same free water molecule concentration as cytoplasm	...isotonic.	...into and out of cell at equal rates. 	Cell stays same size.

The direction of water movement across the cell membrane depends on the relative concentrations of free water molecules in the cytoplasm and in the fluid outside the cell. There are three possibilities for the direction of water movement:

1. **Water moves out.** When water diffuses out of the cell, the cell shrinks. A solution that causes a cell to shrink because of osmosis is called a **hypertonic** *(hie puhr TAHN ihk)* **solution.** If the fluid outside the cell has a higher concentration of dissolved particles than the cytoplasm has, then the outside fluid also has a lower concentration of free water molecules than the cytoplasm.
2. **Water moves in.** When water diffuses into the cell, the cell swells. A solution that causes a cell to swell because of osmosis is called a **hypotonic** *(hie poh TAHN ihk)* **solution.** If the fluid outside the cell has a lower concentration of dissolved particles than the cytoplasm has, then the outside fluid also has a higher concentration of free water molecules than the cytoplasm.
3. **No net water movement.** If the cytoplasm and the fluid outside the cell have the same concentration of free water molecules, water diffuses into and out of the cell at equal rates. This results in no net movement of water across the cell membrane, and the cell stays the same size—a state of equilibrium. A solution that produces no change in cell volume because of osmosis is called an **isotonic** *(ie soh TAHN ihk)* **solution.** **Table 1** summarizes the effects of hypertonic, hypotonic, and isotonic solutions on cells.

If left unchecked, the swelling caused by a hypotonic solution could cause a cell to burst. Different kinds of cells have different adaptations that deal with this problem. The cells of plants and fungi have rigid cell walls that keep the cells from expanding too much. Some unicellular eukaryotes have contractile vacuoles *(kuhn TRAK tihl VAK yoo ohlz),* which are organelles that collect excess water inside the cell and force the water out of the cell. Animal cells have neither cell walls nor contractile vacuoles. However, many animal cells can avoid swelling caused by osmosis by removing dissolved particles from the cytoplasm. The removal of dissolved particles from a cell increases the concentration of free water molecules inside the cell.

WORD *Origins*

The words *hypertonic, hypotonic,* and *isotonic* have the same ending, *–tonic,* which is from the Greek *tonos,* meaning "tension." The prefix *hyper–* is from the Greek *hyper,* meaning "over." The prefix *hypo–* is from the Greek *hypo,* meaning "lower." The prefix *iso–* is from the Greek *isos,* meaning "same

Crossing the Cell Membrane

Real Life

Does temperature affect how odors travel?

Odor-causing molecules travel across a room by diffusing through the air. If you cook a pizza, its aroma will fill the kitchen.

Predicting Outcomes

Describe the motion of odor-causing molecules as they heat up.

Recall that ions and most polar molecules cannot diffuse across the cell membrane because they cannot pass through the nonpolar interior of the lipid bilayer. However, such substances can cross the cell membrane when they are aided by transport proteins. Transport proteins called *channels* provide polar passageways through which ions and polar molecules can move across the cell membrane. Each channel allows only a specific substance to pass through the cell membrane. For example, some channels allow only one type of ion to cross the cell membrane, while others transport a particular kind of sugar or amino acid. This selectivity is one of the most important properties of the cell membrane because it enables a cell to control what enters and leaves.

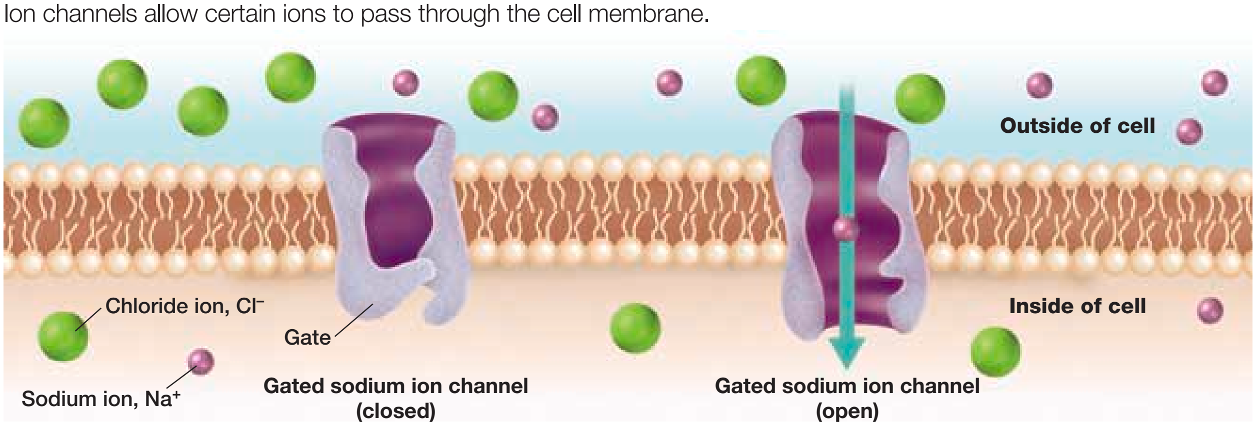
Diffusion Through Ion Channels

Ions such as sodium, Na^+, potassium, K^+, calcium, Ca^{2+}, and chloride, Cl^-, are involved in many important cell functions. For example, ions are essential to the ability of nerve cells to send electrical signals throughout your body. Muscle cells in your heart could not make your heart beat without the movement of ions between the cells. Although ions cannot diffuse through the nonpolar interior of the lipid bilayer, they can cross the cell membrane by diffusing through ion channels. An **ion channel** is a transport protein with a polar pore through which ions can pass. As **Figure 3** shows, the pore of an ion channel spans the thickness of the cell membrane. Thus, an ion that enters the pore can cross the cell membrane without contacting the nonpolar interior of the lipid bilayer.

The pores of some ion channels are always open. In other ion channels, the pores can be closed by ion channel gates. A model of an ion channel with a gate is shown in Figure 3. Ion channel gates may open or close in response to different kinds of stimuli. These include the stretching of the cell membrane, a change in electrical charge, or the binding of specific molecules to the ion channel. In this way, the stimuli are able to affect the ability of particular ions to cross

Figure 3 **Ion channels**

Ion channels allow certain ions to pass through the cell membrane.



the cell membrane. Like the diffusion of small molecules and nonpolar molecules through the lipid bilayer, the diffusion of ions through ion channels is a form of passive transport. No use of energy by the cell is required because the ions move down their concentration gradients.

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Topic: Ion Channels
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Electrical Charge and Ion Transport

The rate of movement of a substance across the cell membrane is generally determined by the concentration gradient of the substance. The movement of a charged particle, such as an ion, across the cell membrane is also influenced by the particle's positive or negative electrical charge. The inside of a typical cell is negatively charged with respect to the outside of the cell. Opposite charges attract, and like charges repel. Thus, a more positively charged ion located outside the cell is more likely to diffuse into the cell, where the charge is negative. Conversely, a more negatively charged ion located inside the cell is more likely to diffuse out of the cell. The direction of movement caused by an ion's concentration gradient may oppose the direction of movement caused by the ion's electrical charge. Thus, an ion's electrical charge often affects the diffusion of the ion across the cell membrane. This is very important to the functioning of nerve cells in animals.

DATA LAB

Analyzing the Effect of Electrical Charge on Ion Transport

Background

The electrical charge of an ion affects the diffusion of the ion across the cell membrane. Some ions are more concentrated inside cells, and some ions are more concentrated outside cells. Use the table below to answer the following questions:

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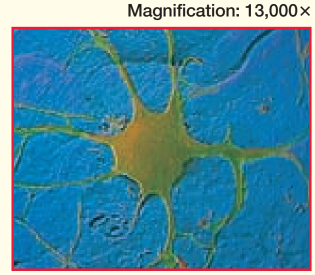


Nerve cell

Ion Charges and Concentration Inside and Outside Cell

Ion	Charge of ion	Concentration of ion outside cell : inside cell
Sodium (Na^+)	Positive	10:1
Potassium (K^+)	Positive	1:20
Calcium (Ca^{2+})	Positive	10,000:1
Chloride (Cl^-)	Negative	12:1

Analysis

1. **Identify** the ion that is more concentrated inside the cell than outside the cell.
2. **Identify** those ions that are more concentrated outside the cell than inside the cell.
3. **Critical Thinking** **Recognizing Relationships** Do the positive charges of calcium ions and sodium ions make these ions more likely to move into or out of the cell?
4. **Critical Thinking** **Inferring Relationships** Which ions' electrical charges oppose the direction of movement that is caused by their concentration gradient?

Facilitated Diffusion

Most cells also have a different kind of transport protein that can bind to a specific substance on one side of the cell membrane, carry the substance across the cell membrane, and release it on the other side. Such proteins are called **carrier proteins.** When carrier proteins are used to transport specific substances—such as amino acids and sugars—down their concentration gradient, that transport is called facilitated diffusion. **Facilitated** *(fah SIHL uh tayt ehd)* **diffusion,** shown in **Figure 4,** is a type of passive transport. It moves substances down their concentration gradient without using the cell's energy.

Step 1 The carrier protein binds a specific molecule on one side of the cell membrane.

Step 2 A change in the shape of the carrier protein exposes the molecule to the other side of the cell membrane.

Step 3 The carrier protein shields the molecule from the interior of the lipid bilayer. The molecule is then released from the carrier protein, which returns to its original shape.

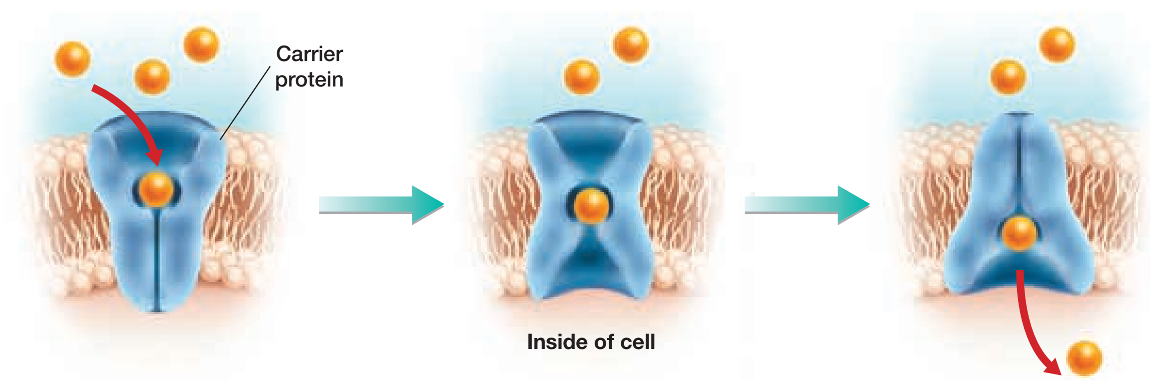
BIO graphic

Figure 4

Facilitated Diffusion

Carrier proteins transport substances down their concentration gradient.

1. A molecule outside the cell binds to a carrier protein on the cell membrane.
2. The carrier protein transports the molecule across the cell membrane.
3. The molecule is released from the carrier protein inside the cell.



Section 1 Review

1. **Distinguish** between diffusion and equilibrium. 4B
2. **Describe** how the diffusion of ions across a cell membrane differs from the diffusion of nonpolar molecules across the cell membrane. 2C 2D 4B
3. **Explain** how some substances cross the cell membrane by facilitated diffusion. 4A 4B
4. **Critical Thinking** **Predicting Outcomes** Predict what would happen to a cell that is placed in a hypertonic solution, and explain why this would occur. 2C
5. **TAKS Test Prep** Which substance crosses the cell membrane by facilitated diffusion? 4B
   A a sugar
   B water
   C sodium ion
   D chloride ion

Active Transport

Section 2

Movement Against a Concentration Gradient

Although facilitated diffusion can help move amino acids and sugars across the cell membrane, it can only transport these substances down their concentration gradient. Cells must transport certain amino acids, sugars, and other substances into their cytoplasm from the surrounding fluid. But many of these substances have a low concentration outside cells and a higher concentration inside cells. Their concentration gradients would cause these important substances to move out of the cell rather than into the cell. So, cells also have a way to move some substances against their concentration gradient—from an area of low concentration to an area of higher concentration.

The transport of a substance across the cell membrane against its concentration gradient is called **active transport**. Unlike passive transport, active transport requires the cell to use energy because the substance is being moved against its concentration gradient. Most often, the energy needed for active transport is supplied directly or indirectly by ATP.

Some active-transport processes involve carrier proteins. Like the carrier proteins used in facilitated diffusion, the carrier proteins used in active transport bind to specific substances on one side of the cell membrane and release them on the other side of the cell membrane. But in active transport, the substances bind to carrier proteins where they are low in concentration and are released where they are higher in concentration. Thus, carrier proteins in active transport function as "pumps" that move substances against their concentration gradient. For this reason, these carrier proteins are often called membrane pumps.

Sodium-Potassium Pump

One of the most important membrane pumps in animal cells is a carrier protein called the sodium-potassium pump. In a complete cycle, the **sodium-potassium pump** transports three sodium ions, Na^+, out of a cell and two potassium ions, K^+, into the cell. Sodium ions are usually more concentrated outside the cell than inside the cell, and potassium ions are typically more concentrated inside the cell than outside the cell. Thus, the sodium-potassium pump actively transports both sodium ions and potassium ions against their concentration gradients. The energy needed to power sodium-potassium pumps is supplied by ATP. In some cells, sodium-potassium pumps are so active that they use much of the ATP produced by the cells.

Objectives

- **Compare** active transport with passive transport. 4B 9A
- **Describe** the importance of the sodium-potassium pump. 4A 4B 9A
- **Distinguish** between endocytosis and exocytosis. 4B
- **Identify** three ways that receptor proteins can change the activity of a cell. 4A 4B 9A

Key Terms

active transport
sodium-potassium pump
endocytosis
exocytosis
receptor protein
second messenger

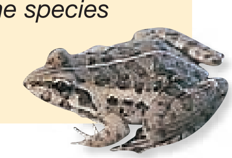
Real Life

Why saltwater frogs aren't in a pickle.

Some frogs have urea—a salty product of metabolism that is usually secreted as urine—in their blood. This makes their bodies nearly as salty as seawater, allowing them to live in saltwater environments.

Finding Information

Find out the species name of a saltwater frog.



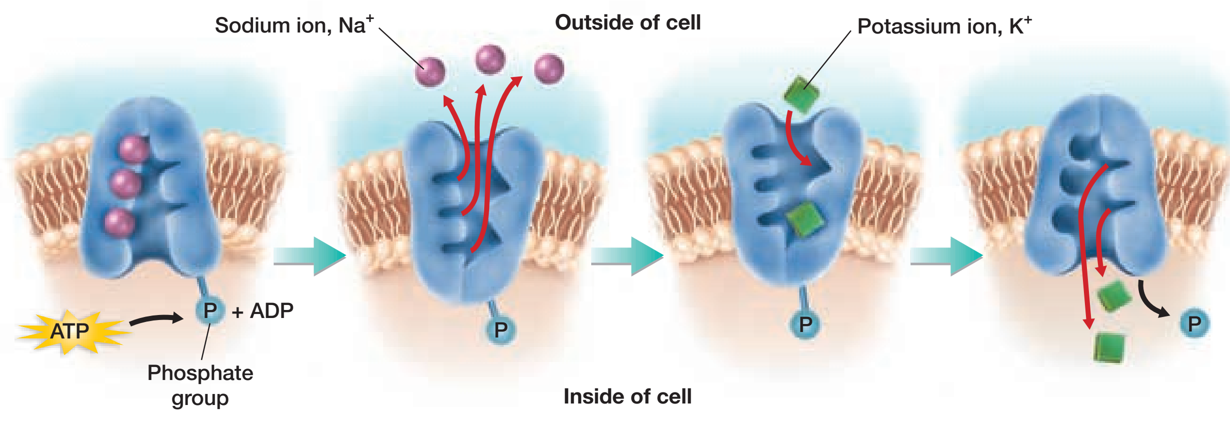
BIO graphic

Figure 5

Sodium-Potassium Pump

The sodium-potassium pump actively transports sodium ions, Na^+, and potassium ions, K^+, against their concentration gradient.

1. Three sodium ions, Na^+ and a phosphate group (P) from ATP bind to the pump.
2. The pump changes shape, transporting the three sodium ions across the cell membrane.
3. Two potassium ions, K^+, bind to the pump and are transported across the cell membrane.
4. The phosphate group and the two potassium ions are released inside the cell.



A model of the sodium-potassium pump is shown in **Figure 5.**

Step 1 Three sodium ions inside the cell bind to the sodium-potassium pump. Because energy is needed to move the sodium ions against their concentration gradient, a phosphate group is removed from ATP and also binds to the pump.

Step 2 The pump changes shape, transporting the three sodium ions across the cell membrane and releasing them outside the cell.

Step 3 The pump is now exposed on the surface of the cell. Two potassium ions outside the cell bind to the pump. The phosphate group is released, changing the shape of the pump.

Step 4 The pump is again exposed to the inside of the cell. The two potassium ions are transported across the cell membrane and are released inside the cell.

The sodium-potassium pump is important for two main reasons. First, the pump prevents sodium ions from accumulating in the cell. Sodium ions continuously diffuse into the cell through ion channels embedded in the lipid bilayer of the cell membrane. The increased concentration of sodium ions would then cause water to enter the cell by osmosis, causing the cell to swell or even burst. Second, the sodium-potassium pump helps maintain the concentration gradients of sodium ions and potassium ions across the cell membrane. Many cells use the sodium-ion concentration gradient to help transport other substances, such as glucose, across the cell membrane.

Movement in Vesicles

Many substances, such as proteins and polysaccharides, are too large to be transported by carrier proteins. These substances are moved across the cell membrane by vesicles. The movement of a substance into a cell by a vesicle is called **endocytosis** *(ehn doh sie TOH sihs)*. During endocytosis, the cell membrane forms a pouch around a substance, as shown in **Figure 6.** The pouch then closes up and pinches off from the membrane to form a vesicle. Vesicles formed by endocytosis may fuse with lysosomes or other organelles.

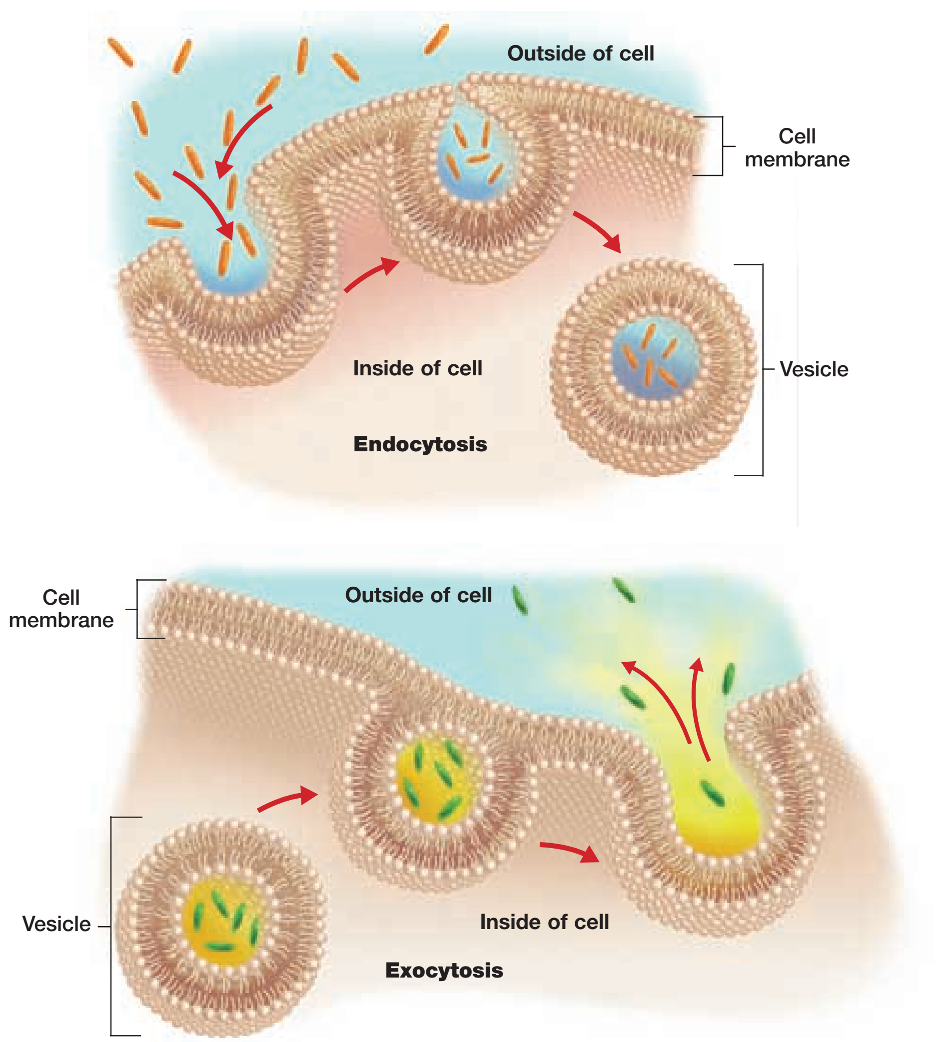
The movement of a substance by a vesicle to the outside of a cell is called **exocytosis** *(ek soh sie TOH sihs),* also shown in Figure 6. During exocytosis, vesicles in the cell fuse with the cell membrane, releasing their contents. Cells use exocytosis to export proteins that are modified by the Golgi apparatus. Nerve cells and cells of various glands, for example, release proteins by exocytosis.

Study TIP

Interpreting Graphics
As you look at Figure 6, notice that during endocytosis, the cell membrane pinches off to become the vesicle membrane. Conversely, during exocytosis, the vesicle membrane becomes part of the cell membrane.

Figure 6 Endocytosis and exocytosis

Vesicles transport substances into and out of cells.



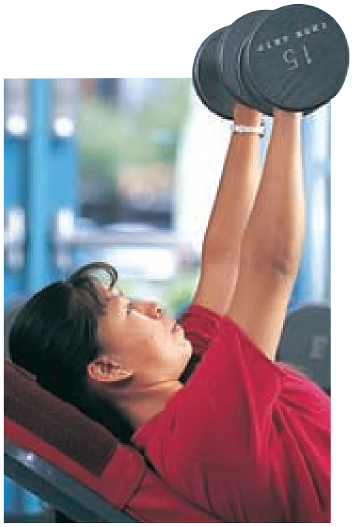


Figure 7 Action of signal molecules. When you exercise, signal molecules are bound by receptor proteins on your muscle cells, signaling your muscles to contract.

Membrane Receptor Proteins

We are constantly bombarded with information from other people and through television, the Internet, and many other media. To interpret information, we must be able to communicate and to distinguish between important and unimportant information. Similarly, your body's cells must communicate with each other to coordinate your growth, metabolism, and other activities. Cells that do not lie next to each other cannot communicate directly. Instead, some cells release *signal molecules* that carry information to nearby cells and throughout the body. Hormones are one familiar example of signal molecules. Hormones are made in one part of the body and carried in the bloodstream to other parts, where they have their effects.

Cells must also respond to important information and filter out unimportant information. Cells can receive the messages carried by certain signal molecules because the cell membrane contains specialized proteins that bind these signal molecules. Such proteins are called receptor proteins. A **receptor protein** is a protein that binds to a specific signal molecule, enabling the cell to respond to the signal molecule. For example, the muscles of the person exercising in **Figure 7** could not contract without receptor proteins and signal molecules that tell the muscles when to contract and when to relax.

Functions of Receptor Proteins

A signal molecule is bound by a receptor protein that fits that molecule, as shown in **Figure 8.** Most receptor proteins are embedded in the lipid bilayer of the cell membrane. The part of the protein that fits the signal molecule faces the outside of the cell.

The binding of a signal molecule by its complementary receptor protein causes a change in the receiving cell. This change can occur in the following three ways: by causing changes in the permeability of the receiving cell; by triggering the formation of second messengers inside the cell; and by activating enzymes inside the cell.

Figure 8 Changes in permeability

Some receptor proteins are coupled with ion channels.

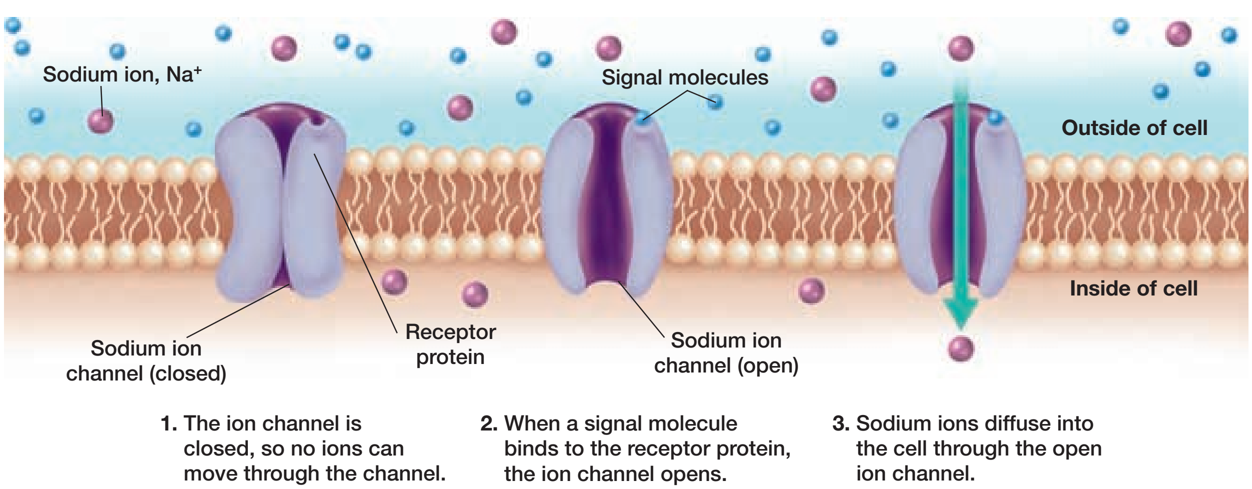
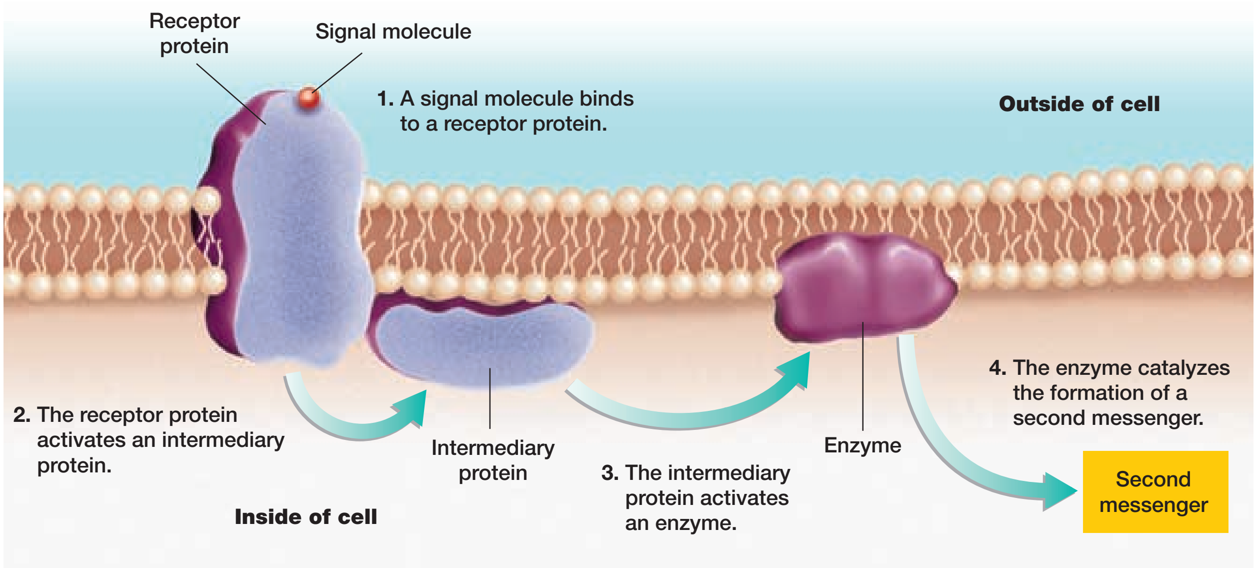


Figure 9 **Second messengers**

Some receptor proteins trigger the production of second messengers.



Changes in Permeability The receptor protein may be coupled with an ion channel, as shown in Figure 8. The binding of a signal molecule to the receptor protein causes the ion channel to open, allowing specific ions to cross the cell membrane. This type of receptor protein is especially important in the nervous system.

Second Messengers The receptor protein may cause the formation of a second messenger inside the cell, as shown in **Figure 9.** When it is activated, a **second messenger** acts as a signal molecule in the cytoplasm. The second messenger amplifies the signal of the first messenger—that is, the original signal molecule. Second messengers can change the functioning of a cell in several ways. For example, some second messengers activate enzymes, triggering a series of biochemical reactions in the cell. Other second messengers change the permeability of the cell by opening ion channels in the cell membrane.

Enzyme Action The receptor protein may act as an enzyme. When a signal molecule binds to the receptor protein, the receptor protein may speed up chemical reactions inside the cell. Receptor proteins may also activate other enzymes located inside the cell or in the cell membrane, triggering chemical reactions in the cell. In this way, the signal molecule can cause many changes in the functioning of the receiving cell.

Many drugs affect the binding of signal molecules to receptor proteins. Some drugs, such as the illegal drug heroin, imitate signal molecules by binding to receptor proteins on a receiving cell, altering the function of the cell. Other drugs block or interfere with receptor proteins, preventing signal molecules from binding to the receptor proteins. For example, signal molecules that bind to receptor proteins on heart-muscle cells stimulate the cells, causing the heart rate to

Real Life

Many medicines are drugs that bind to receptor proteins.

Some of these drugs interfere with the receptor's ability to bind to signal molecules.

Finding Information

Research some medicines that bind to receptor proteins.

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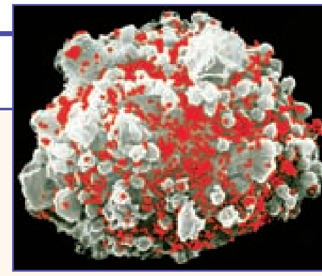
Topic: **Receptor Proteins**

Keyword: **HX4157**

SCiLINKS. Maintained by the National Science Teachers Association increase. Beta blockers, which are drugs prescribed to patients with a rapid heartbeat, bind to some of these receptor proteins. Beta blockers therefore interfere with the binding of signal molecules to the receptor proteins, preventing the heart rate from increasing too rapidly.

The Shifting Allegiance of HIV



One of the more puzzling aspects of the AIDS epidemic is the slow onset of the disease after infection. In a person infected by HIV, the virus that causes AIDS, it may take 8 to 10 years for full blown AIDS—destruction of the immune system—to develop.

Docking

When HIV is introduced into the human bloodstream, the virus particles circulate throughout the whole body, but they only infect certain cells—large cells called *macrophages.* Why only macrophages? Spikes composed of protein cover the surface of each HIV particle. These spikes come into contact with all cells the virus encounters as it moves through the blood, yet the virus ignores most of the cells. Only when an HIV spike comes into contact with a cell whose surface receptor proteins exactly correspond the spike's shape does the HIV particle attach to the cell and infect it.

The cell surface receptor protein that matches HIV's spikes is called *CD4,* and it is found on both macrophages and the infection-fighting cells of the immune system called *lymphocytes.* Why then are lymphocytes not infected right away, as macrophages are?

After docking onto the CD4 receptor of a macrophage, the HIV particle requires a second receptor protein to enter the cell. This second receptor, called a co-receptor, pulls the HIV particle across the cell membrane. Macrophages have a co-receptor that HIV recognizes, but lymphocytes lack this specific co-receptor.

Onset of AIDs

During the long period before AIDS develops, HIV is continuously reproduced inside macrophages. While HIV grows in these infected cells, it does not harm them. As the virus reproduces, it accumulates random changes in its genetic material. Eventually and by chance, HIV changes in such a way that its spike proteins now recognize a *new* co-receptor, one present on the surface of lymphocytes. When the body's lymphocytes become infected with HIV, the consequences are deadly—HIV eventually destroys most of the body's supply of lymphocytes. This shift in the allegiance of HIV from one type of co-receptor to another leads directly to the onset of AIDS.

Section 2 Review

1. **Distinguish** between passive transport and active transport. 4B

2. **Describe** how the sodium-potassium pump helps prevent animal cells from bursting. 4B 9A

3. **Compare** two ways that the binding of a signal molecule to a receptor protein causes a change in the activity of the receiving cell. 4B 9A

4. **Identify** the terms *endocytosis* and *exocytosis* and distinguish between them. 4B

5. **Critical Thinking** **Applying Information** During exercise, potassium ions accumulate in the fluid that surrounds muscle cells. Which cell membrane protein helps muscle cells counteract this tendency? Explain your answer. 4B

6. **TAKS Test Prep** The concentration of molecule X is greater inside a cell than outside. If the cell acquires X from its surroundings, X must cross the cell membrane by means of 4B
   - **A** exocytosis.
   - **B** active transport.
   - **C** receptor proteins.
   - **D** second messengers.