7.3 Cell Transport

Key Questions

🔑 *What is passive transport?*

🔑 *What is active transport?*

Vocabulary

diffusion • facilitated diffusion • aquaporin • osmosis • isotonic • hypertonic • hypotonic • osmotic pressure

Taking Notes

Compare/Contrast Table As you read, create a compare/contrast table for passive and active transport.

THINK ABOUT IT In the previous lesson, cell walls and cell membranes were compared to the roof and walls of a factory. When you think about how cells move materials in and out, it can be helpful to think of a cell as a nation. Before you can learn anything about a nation, it's important to understand where it begins and where it ends. The boundaries of a nation are its borders, and nearly every country tries to regulate and control the goods that move across those borders, like the shipping containers seen here entering and leaving the port of Seattle. Each cell has its own border, which separates the cell from its surroundings and also determines what comes in and what goes out. How can a cell separate itself from its environment and still allow material to enter and leave? That's where transport across its border, the cell membrane, comes in.

MYSTERY CLUE

As Michelle ran, she perspired, losing salts from her bloodstream. And as she drank more and more water during the race, the concentration of dissolved salts and minerals in her bloodstream decreased. How do you think these phenomena contributed to Michelle's condition?

Passive Transport

🔑 *What is passive transport?*

Every living cell exists in a liquid environment. One of the most important functions of the cell membrane is to keep the cell's internal conditions relatively constant. It does this by regulating the movement of molecules from one side of the membrane to the other.

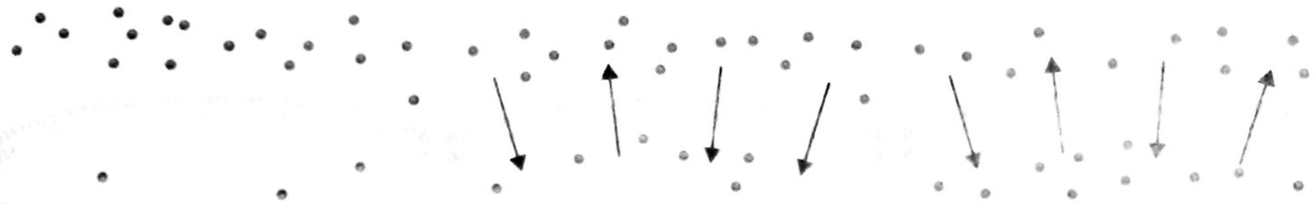
Diffusion Cellular cytoplasm consists of many different substances dissolved in water. In any solution, solute particles move constantly. They collide with one another and tend to spread out randomly. As a result, the particles tend to move from an area where they are more concentrated to an area where they are less concentrated. When you add sugar to coffee or tea, for example, the sugar molecules move away from their original positions in the sugar crystals and disperse throughout the hot liquid. The process by which particles move from an area of high concentration to an area of lower concentration is known as **diffusion** (dih FYOO zhun). Diffusion is the driving force behind the movement of many substances across the cell membrane.

What does diffusion have to do with the cell membrane? Suppose a substance is present in unequal concentrations on either side of a cell membrane, as shown in **Figure 7–15.** If the substance can cross the cell membrane, its particles will tend to move toward the area where it is less concentrated until it is evenly distributed. Once the concentration of the substance on both sides of the cell membrane is the same, equilibrium is reached.

Even when equilibrium is reached, particles of a solution continue to move across the membrane in both directions. However, because almost equal numbers of particles move in each direction, there is no further net change in the concentration on either side.

Diffusion depends on random particle movements. Therefore, substances diffuse across membranes without requiring the cell to use additional energy. **The movement of materials across the cell membrane without using cellular energy is called passive transport.**

FIGURE 7–15 Diffusion Diffusion is the process by which molecules of a substance move from an area of higher concentration to an area of lower concentration. It does not require the cell to use energy. Predict *How would the movement of solute particles seen here be different if the initial area of high concentration had been on the inside of the cell instead of the outside?*



There is a higher concentration of solute on one side of the membrane than on the other.

Diffusion causes a net movement of solute particles from the side of the membrane with the higher solute concentration to the side with the lower solute concentration.

Once equilibrium is reached, solute particles continue to diffuse across the membrane in both directions but at approximately equal rates, so there is no net change in solute concentration.

Facilitated Diffusion Since cell membranes are built around lipid bilayers, the molecules that pass through them most easily are small and uncharged. These properties allow them to dissolve in the membrane's lipid environment. But many ions, like Cl^-, and large molecules, like the sugar glucose, seem to pass through cell membranes much more quickly than they should. It's almost as if they have a shortcut across the membrane.

How does this happen? Proteins in the cell membrane act as carriers, or channels, making it easy for certain molecules to cross. Red blood cells, for example, have protein carriers that allow glucose to pass through them in either direction. Only glucose can pass through these protein carriers. These cell membrane channels facilitate, or help, the diffusion of glucose across the membrane. This process, in which molecules that cannot directly diffuse across the membrane pass through special protein channels, is known as **facilitated diffusion.** Hundreds of different proteins have been found that allow particular substances to cross cell membranes. Although facilitated diffusion is fast and specific, it is still diffusion, so it does not require any additional use of the cell's energy.

In Your Notebook *Explain how you can demonstrate diffusion by spraying air freshener in a large room.*

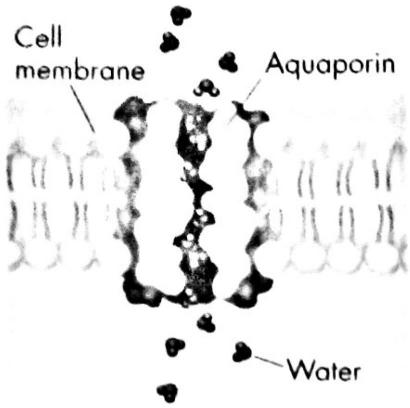


FIGURE 7–16 An Aquaporin

Osmosis: An Example of Facilitated Diffusion Surprising new research has added water to the list of molecules that enter cells by facilitated diffusion. Recall that the inside of a cell's lipid bilayer is hydrophobic, or "water-hating." Because of this, water molecules have a tough time passing through the cell membrane. However, many cells contain water channel proteins, known as **aquaporins** (ak wuh PAWR inz), that allow water to pass right through them, as shown in **Figure 7–16.** The movement of water through cell membranes by facilitated diffusion is an extremely important biological process—the process of osmosis.

Osmosis is the diffusion of water through a selectively permeable membrane. In osmosis, as in other forms of diffusion, molecules move from an area of higher concentration to an area of lower concentration. The only difference is that the molecules that move in the case of osmosis are water molecules, not solute molecules. The process of osmosis is shown in **Figure 7–17.**

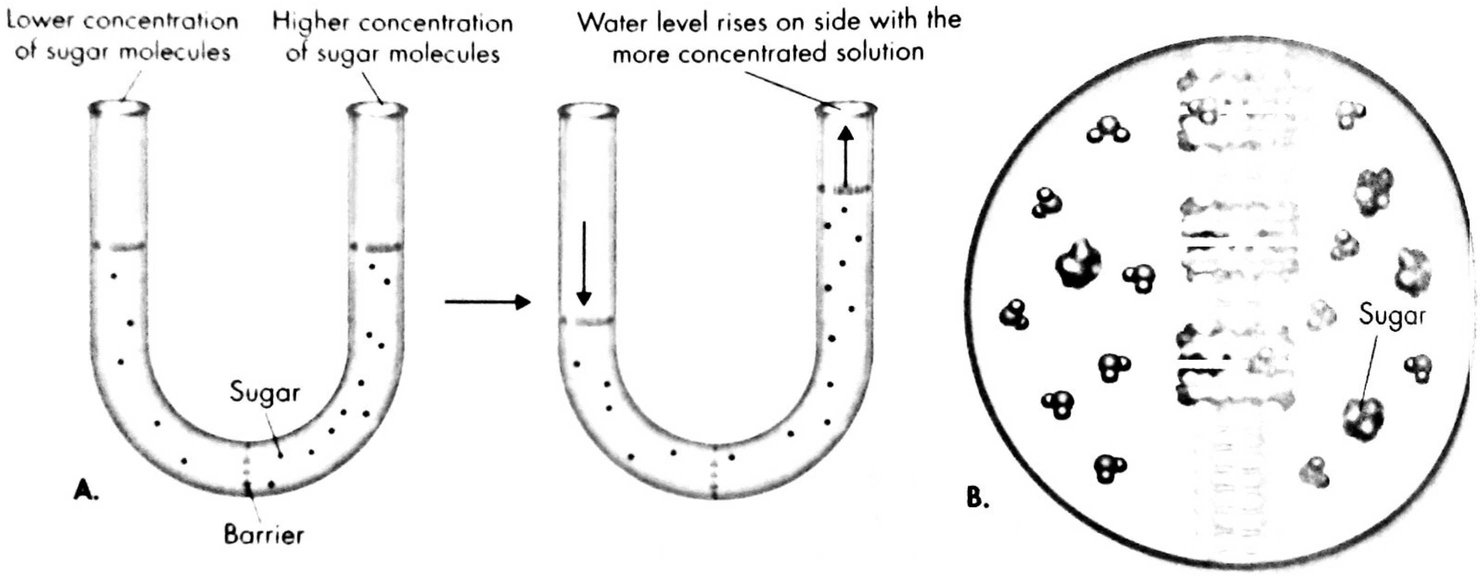


FIGURE 7–17 Osmosis Osmosis is a form of facilitated diffusion. **A.** In a laboratory experiment, water moves through a selectively permeable barrier from an area of lower to higher solute concentration. **B.** In the cell, water passes in through aquaporins embedded in the cell membrane. Although water moves in both directions through aquaporins, there is a net movement of water from an area of lower to higher sugar concentration. **Apply Concepts** ***Does osmosis require the cell to use energy?***

▶ ***How Osmosis Works*** Look at the experimental setup in **Figure 7–17A.** The barrier is permeable to water but not to sugar. This means that water can cross the barrier in both directions, but sugar cannot. To start, there are more sugar molecules on the right side of the barrier than on the left side. Therefore, the concentration of water is lower on the right, where more of the solution is made of sugar. Although water molecules move in both directions across the membrane, there is a net movement of water toward the concentrated sugar solution.

Water will tend to move across the membrane until equilibrium is reached. At that point, the concentrations of water and sugar will be the same on both sides of the membrane. When this happens, the two solutions will be **isotonic,** which means "same strength." Note that "strength" refers to the amount of solute, not water. When the experiment began, the more concentrated sugar solution (right side of the tube) was **hypertonic,** or "above strength," compared to the left side. So the dilute sugar solution (left side of the tube) was **hypotonic,** or "below strength," compared to the right side. **Figure 7–17B** shows how osmosis works across a cell membrane.

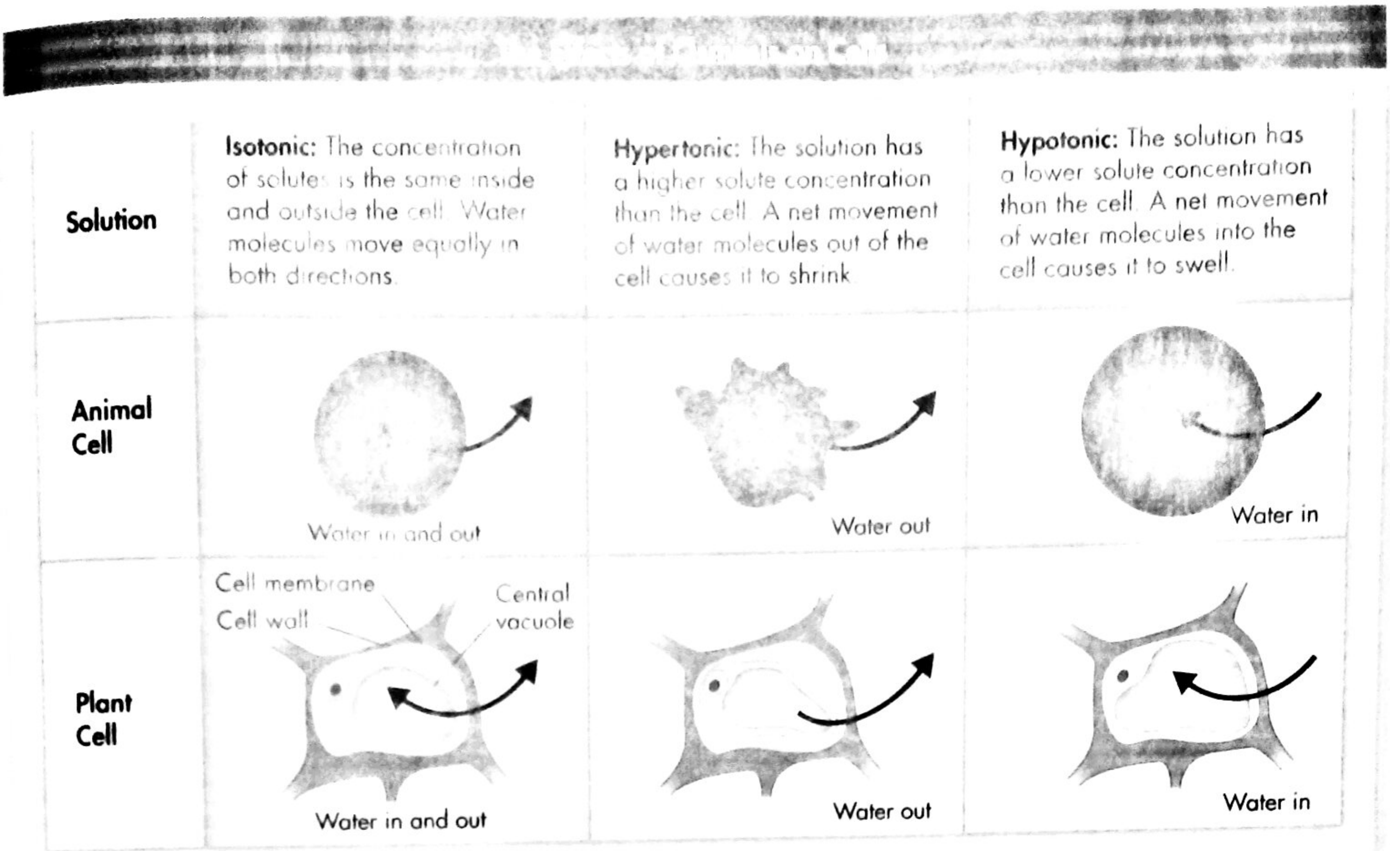


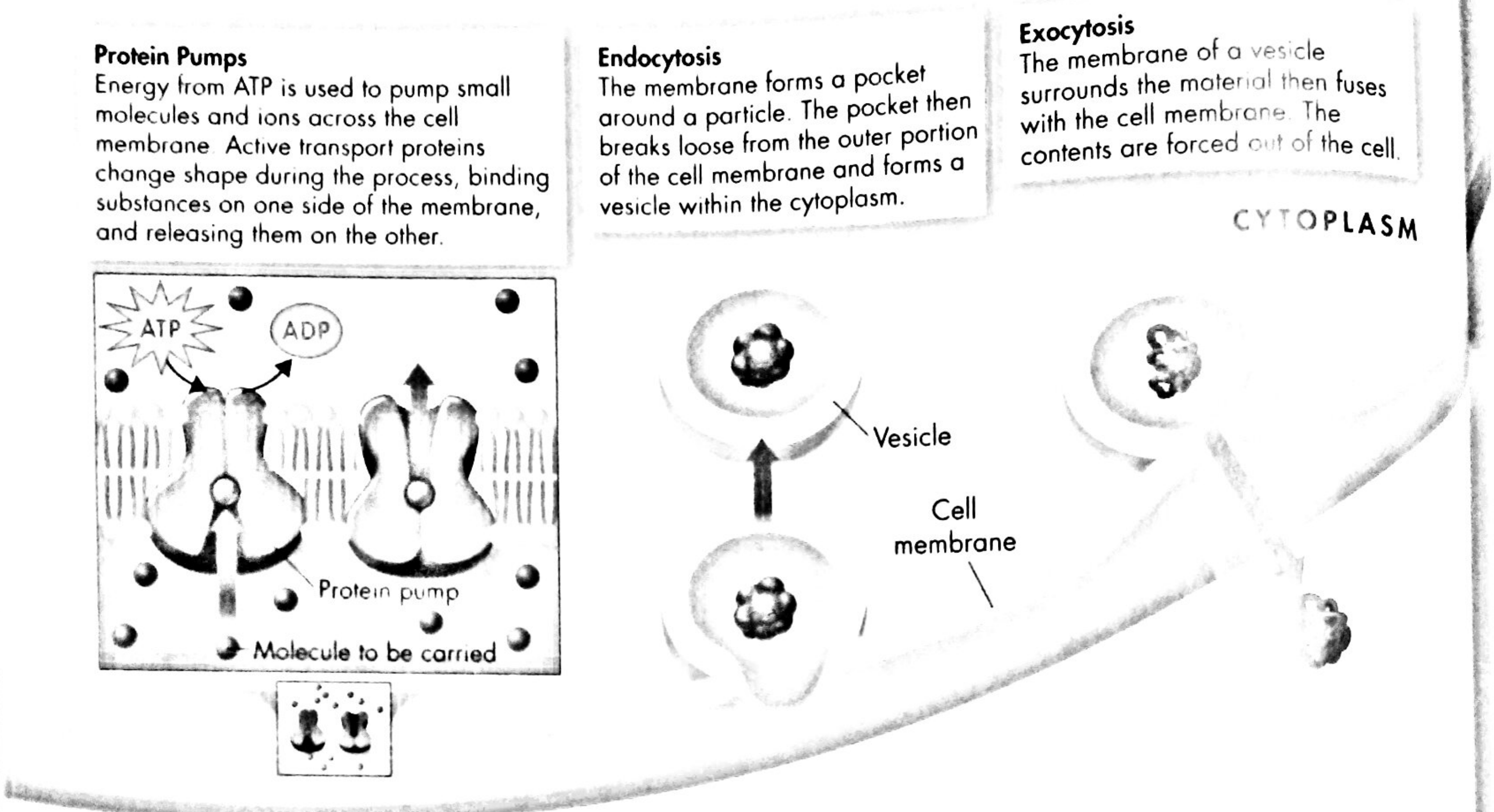
FIGURE 7–18 Osmotic Pressure Water molecules move equally into and out of cells placed in an isotonic solution. In a hypertonic solution, animal cells, like the red blood cell shown, shrink, and plant cell central vacuoles collapse. In a hypotonic solution, animal cells swell and burst. The central vacuoles of plant cells also swell, pushing the cell contents out against the cell wall. **Predict** ***What would happen to the cells of a saltwater plant if the plant were placed in fresh water?***

▶ ***Osmotic Pressure*** Driven by differences in solute concentration, the net movement of water out of or into a cell produces a force known as **osmotic pressure.** As shown in **Figure 7–18,** osmotic pressure can cause an animal cell in a hypertonic solution to shrink, and one in a hypotonic solution to swell. Because cells contain salts, sugars, proteins, and other dissolved molecules, they are almost always hypertonic to fresh water. As a result, water tends to move quickly into a cell surrounded by fresh water, causing it to swell. Eventually, the cell may burst like an overinflated balloon. In plant cells, osmotic pressure can cause changes in the size of the central vacuole, which shrinks or swells as water moves into or out of the cell.

Fortunately cells in large organisms are not in danger of bursting because most of them do not come in contact with fresh water. Instead, the cells are bathed in blood or other isotonic fluids. The concentrations of dissolved materials in these isotonic fluids are roughly equal to those in the cells themselves.

What happens when cells do come in contact with fresh water? Some, like the eggs laid in fresh water by fish and frogs, lack water channels. As a result, water moves into them so slowly that osmotic pressure is not a problem. Others, including bacteria and plant cells, are surrounded by tough walls. The cell walls prevent the cells from expanding, even under tremendous osmotic pressure. Notice how the plant cell in **Figure 7–18** holds its shape in both hypertonic and hypotonic solutions while the animal red blood cell does not. However, increased osmotic pressure makes plant cells extremely vulnerable to cell wall injuries.

In Your Notebook *In your own words, explain why osmosis is really just a special case of facilitated diffusion.*



VISUAL SUMMARY

ACTIVE TRANSPORT

FIGURE 7–19 Energy from the cell is required to move particles against a concentration gradient.
Compare and Contrast ***What are the similarities and differences between facilitated diffusion and active transport by protein pump?***

Active Transport

What is active transport?

As powerful as diffusion is, cells sometimes must move materials against a concentration difference. **The movement of materials against a concentration difference is known as active transport. Active transport requires energy.** The active transport of small molecules or ions across a cell membrane is generally carried out by transport proteins—protein pumps—that are found in the membrane itself. Larger molecules and clumps of material can also be actively transported across the cell membrane by processes known as endocytosis and exocytosis. The transport of these larger materials sometimes involves changes in the shape of the cell membrane. The major types of active transport are shown in **Figure 7–19.**

Molecular Transport Small molecules and ions are carried across membranes by proteins in the membrane that act like pumps. Many cells use protein pumps to move calcium, potassium, and sodium ions across cell membranes. Changes in protein shape seem to play an important role in the pumping process. A considerable portion of the energy used by cells in their daily activities is spent providing the energy to keep this form of active transport working. The use of energy in these systems enables cells to concentrate substances in a particular location, even when the forces of diffusion might tend to move these substances in the opposite direction.

Bulk Transport Larger molecules and even solid clumps of material can be transported by movements of the cell membrane known as bulk transport. Bulk transport can take several forms, depending on the size and shape of the material moved into or out of the cell.

▶ ***Endocytosis*** Endocytosis (en doh sy TOH sis) is the process of taking material into the cell by means of infoldings, or pockets, of the cell membrane. The pocket that results breaks loose from the outer portion of the cell membrane and forms a vesicle or vacuole within the cytoplasm. Large molecules, clumps of food, even whole cells can be taken up in this way.

Phagocytosis (fag oh sy TOH sis) is a type of endocytosis, in which extensions of cytoplasm surround a particle and package it within a food vacuole. The cell then engulfs it. Amoebas use this method for taking in food, and white blood cells use phagocytosis to "eat" damaged cells, as shown in **Figure 7–20.** Engulfing material in this way requires a considerable amount of energy and is considered a form of active transport.

In a process similar to phagocytosis, many cells take up liquid from the surrounding environment. Tiny pockets form along the cell membrane, fill with liquid, and pinch off to form vacuoles within the cell. This type of endocytosis is known as pinocytosis (py nuh sy TOH sis).

▶ ***Exocytosis*** Many cells also release large amounts of material, a process known as exocytosis (ek soh sy TOH sis). During exocytosis, the membrane of the vacuole surrounding the material fuses with the cell membrane, forcing the contents out of the cell. The removal of water by means of a contractile vacuole is one example of this kind of active transport.

BUILD Vocabulary

PREFIXES The prefix *endo-* in *endocytosis* comes from a Greek word meaning "inside" or "within." The prefix *exo-* in *exocytosis* means "outside."

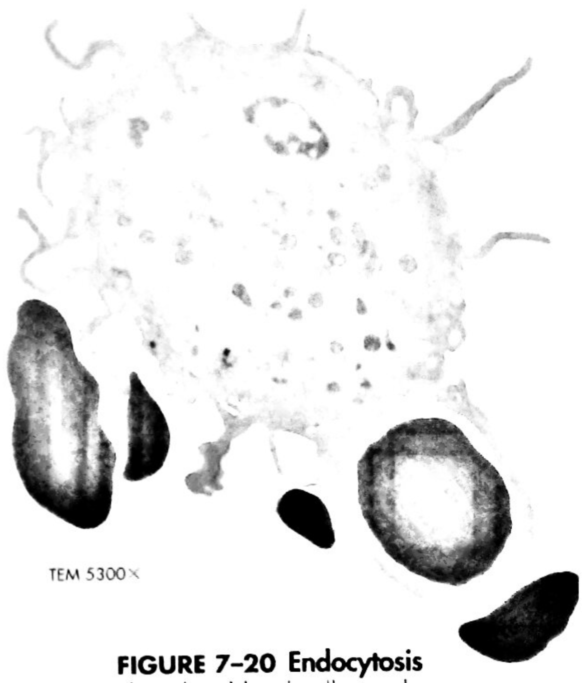


FIGURE 7–20 Endocytosis The white blood cell seen here is engulfing a damaged red blood cell by phagocytosis—a form of endocytosis. Extensions, or "arms," of the white blood cell's cell membrane have completely surrounded the red blood cell.

7.3 Assessment

Review Key Concepts

1. **a. Review** What happens during diffusion?
   b. Explain Describe the process of osmosis.
   c. Compare and Contrast What is the difference between diffusion and facilitated diffusion?
2. **a. Review** How is active transport different from passive transport?
   b. Explain Describe the two major types of active transport.
   c. Compare and Contrast How is endocytosis different from exocytosis?

BUILD VOCABULARY

3. Based on the meanings of *isotonic, hypertonic,* and *hypotonic*, write definitions for the prefixes *iso-*, *hyper-*, and *hypo-*. Then come up with another set of words that uses these prefixes (the words do not need to have the same suffixes).
4. The prefix *phago-* means "to eat." The prefix *pino-* means "to drink." Look up the definition of *-cytosis*, and write definitions for *phagocytosis* and *pinocytosis*.

7.4 Homeostasis and Cells

Key Questions

How do individual cells maintain homeostasis?

How do the cells of multicellular organisms work together to maintain homeostasis?

Vocabulary

homeostasis • tissue • organ • organ system • receptor

Taking Notes

Preview Visuals Before you read, look at **Figures 7–22** and **7–23.** Then write two questions you have about the micrographs. As you read, write answers to your questions.

THINK ABOUT IT From its simple beginnings, life has spread to every corner of our planet, penetrating deep into the earth and far beneath the surface of the seas. The diversity of life is so great that you might have to remind yourself that all living things are composed of cells, have the same basic chemical makeup, and even contain the same kinds of organelles. This does not mean that all living things are the same: Differences arise from the ways in which cells are specialized and the ways in which cells associate with one another to form multicellular organisms.

The Cell as an Organism

How do individual cells maintain homeostasis?

Cells are the basic living units of all organisms, but sometimes a single cell is the organism. In fact, in terms of their numbers, unicellular organisms dominate life on Earth. A single-celled organism does everything you would expect a living thing to do. Just like other living things, unicellular organisms must maintain **homeostasis,** relatively constant internal physical and chemical conditions. **To maintain homeostasis, unicellular organisms grow, respond to the environment, transform energy, and reproduce.**

Unicellular organisms include both prokaryotes and eukaryotes. Prokaryotes, especially bacteria, are remarkably adaptable. Bacteria live almost everywhere—in the soil, on leaves, in the ocean, in the air, even within the human body.

Many eukaryotes, like the protozoan in **Figure 7–21,** also spend their lives as single cells. Some types of algae, which contain chloroplasts and are found in oceans, lakes, and streams around the world, are single celled. Yeasts, or unicellular fungi, are also widespread. Yeasts play an important role in breaking down complex nutrients, making them available for other organisms. People use yeasts to make bread and other foods.

Don't make the mistake of thinking that single-celled organisms are always simple. Prokaryote or eukaryote, homeostasis is still an issue for each unicellular organism. That tiny cell in a pond or on the surface of your pencil still needs to find sources of energy or food, to keep concentrations of water and minerals within certain levels, and to respond quickly to changes in its environment. The microscopic world around us is filled with unicellular organisms that are successfully maintaining that homeostatic balance.

FIGURE 7–21 Unicellular Life Single-celled organisms, like this freshwater protozoan, must be able to carry out all of the functions necessary for life (SEM 600×).

Multicellular Life

How do the cells of multicellular organisms work together to maintain homeostasis?

Unlike most unicellular organisms, the cells of human beings and other multicellular organisms do not live on their own. They are interdependent; and like the members of a winning baseball team, they work together. In baseball, each player plays a particular position: pitcher, catcher, infielder, outfielder. And to play the game effectively, players and coaches communicate with one another, sending and receiving signals. Cells in a multicellular organism work the same way. **The cells of multicellular organisms become specialized for particular tasks and communicate with one another to maintain homeostasis.**

Cell Specialization The cells of a multicellular organism are specialized, with different cell types playing different roles. Some cells are specialized to move; others, to react to the environment; still others, to produce substances that the organism needs. No matter what its role, each specialized cell, like the ones in **Figures 7–22** and **7–23**, contributes to homeostasis in the organism.

In Your Notebook *Where in the human body do you think you would find cells that are specialized to produce digestive enzymes? Why?*

BUILD Vocabulary

PREFIXES The prefix *homeo-* in **homeostasis** means "the same." Organisms are constantly trying to maintain homeostasis, to keep their internal physical and chemical conditions relatively constant despite changes in their internal and external environments.

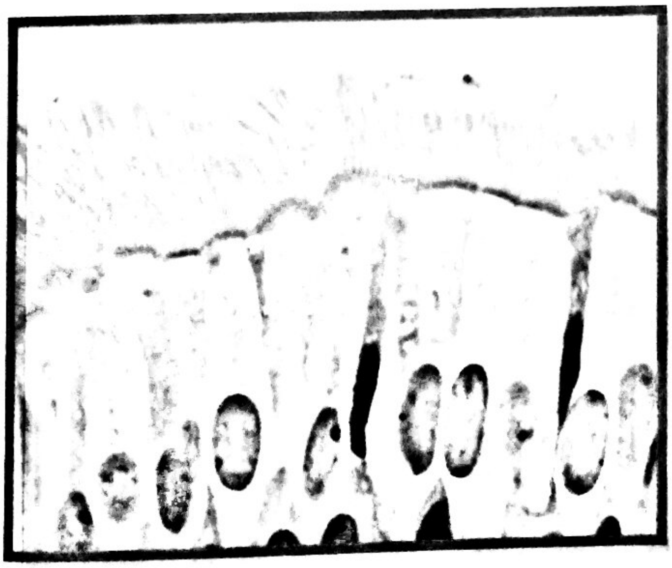


FIGURE 7–22 Specialized Animal Cells: Human Trachea Epithelium (LM 1000×)

▶ ***Specialized Animal Cells*** Even the cleanest, freshest air is dirty, containing particles of dust, smoke, and bacteria. What keeps this bad stuff from getting into your lungs? That's the job of millions of cells that work like street sweepers. These cells line the upper air passages. As you breathe, they work night and day sweeping mucus, debris, and bacteria out of your lungs. These cells are filled with mitochondria, which produce a steady supply of the ATP that powers the cilia on their upper surfaces to keep your lungs clean.

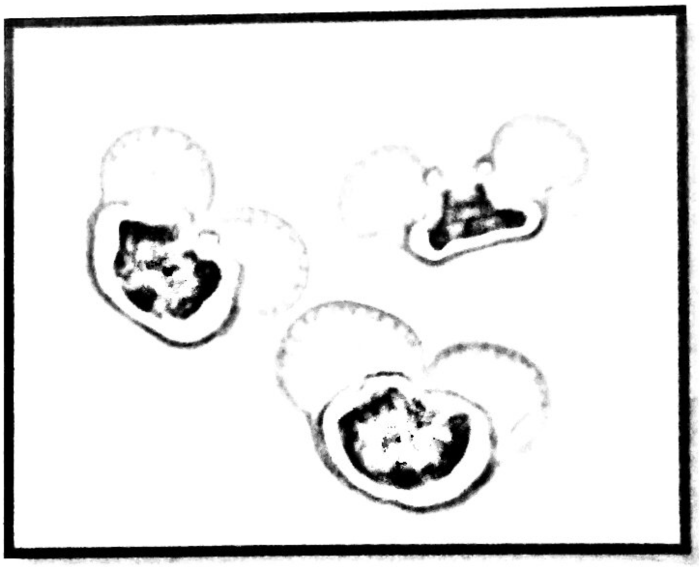


FIGURE 7–23 Specialized Plant Cells: Pine Pollen (LM 430×)

▶ ***Specialized Plant Cells*** How can a pine tree, literally rooted in place, produce offspring with another tree hundreds of meters away? It releases pollen grains, some of the world's most specialized cells. Pollen grains are tiny and light, despite tough walls to protect the cells inside. In addition, pine pollen grains have two tiny wings that enable them to float in the slightest breeze. Pine trees release millions of pollen grains like these to scatter in the wind, land on seed cones, and begin the essential work of starting a new generation.

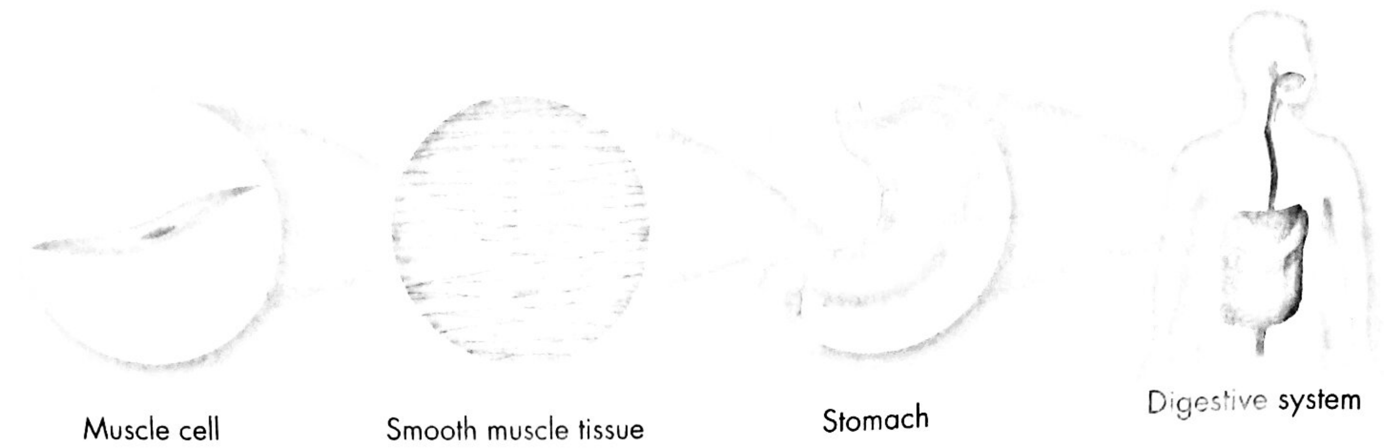


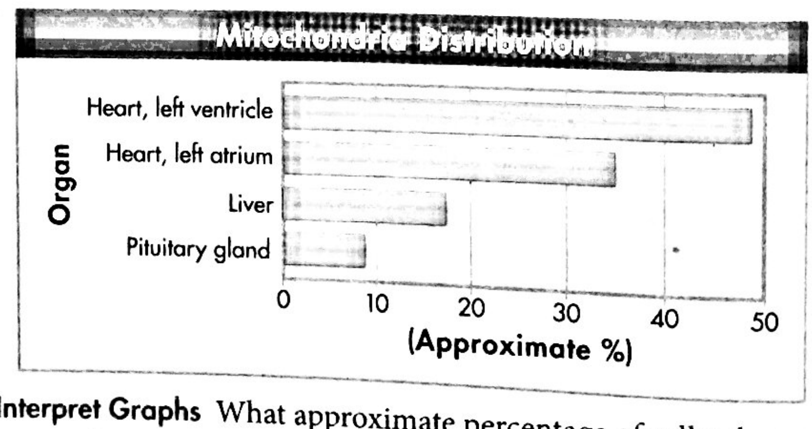
FIGURE 7–24 Levels of Organization From least complex to most complex, the levels of organization in a multicellular organism include cells, tissues, organs, and organ systems.

Levels of Organization The specialized cells of multicellular organisms are organized into tissues, then into organs, and finally into organ systems, as shown in **Figure 7–24.** A **tissue** is a group of similar cells that performs a particular function. Many tasks in the body are too complicated to be carried out by just one type of tissue. In these cases, many groups of tissues work together as an **organ.** For example, each muscle in your body is an individual organ. Within a muscle, however, there is much more than muscle tissue. There are nervous tissues and connective tissues too. Each type of tissue performs an essential task to help the organ function. In most cases, an organ completes a series of specialized tasks. A group of organs that work together to perform a specific function is called an **organ system.** For example, the stomach, pancreas, and intestines work together as the digestive system.

Analyzing Data

Mitochondria Distribution in the Mouse

Scientists studied the composition of several organs in the mouse. They found that some organs and tissues contain more mitochondria than others. They described the amount of mitochondria present as a percentage of total cell volume. The higher the percentage volume made up of mitochondria, the more mitochondria present in the cells of the organ. The data are shown in the graph.



1. **Interpret Graphs** What approximate percentage of cell volume in the mouse liver is composed of mitochondria?

2. **Calculate** Approximately how much more cellular volume is composed of mitochondria in the left ventricle than in the pituitary gland? MATH

3. **Infer** There are four chambers in the mouse heart, the right and left ventricles, and the right and left atria. Based on the data given, which chamber, the left ventricle or left atrium, do you think pumps blood from the heart to the rest of the body? Explain your answer.

The organization of the body's cells into tissues, organs, and organ systems creates a division of labor among those cells that allows the organism to maintain homeostasis. Specialization and interdependence are two of the remarkable attributes of living things. Appreciating these characteristics is an important step in understanding the nature of living things.

Cellular Communication Cells in a large organism communicate by means of chemical signals that are passed from one cell to another. These cellular signals can speed up or slow down the activities of the cells that receive them and can even cause a cell to change what it is doing in a most dramatic way.

Certain cells, including those in the heart and liver, form connections, or cellular junctions, to neighboring cells. Some of these junctions, like those in **Figure 7–25,** hold cells together firmly. Others allow small molecules carrying chemical messages or signals to pass directly from one cell to the next. To respond to one of these chemical signals, a cell must have a **receptor** to which the signaling molecule can bind. Some receptors are on the cell membrane; receptors for other types of signals are inside the cytoplasm. The chemical signals sent by various types of cells can cause important changes in cellular activity. For example, the electrical signal that causes heart muscle cells to contract begins in a region of the muscle known as the pacemaker. Ions carry that electrical signal from cell to cell through a special connection known as a gap junction, enabling millions of heart muscle cells to contract as one in a single heartbeat. Other junctions hold the cells together, so the force of contraction does not tear the muscle tissue. Both types of junctions are essential for the heart to pump blood effectively.

FIGURE 7–25 Cellular Junctions Some junctions, like the one seen in brown in this micrograph of capillary cells in the gas bladder of a toadfish, hold cells together in tight formations (TEM 21,600×).

7–4 Assessment

Review Key Concepts

1. a. Review What is homeostasis?

b. Explain What do unicellular organisms do to maintain homeostasis?

c. Apply Concepts The contractile vacuole is an organelle found in paramecia, a group of unicellular organisms. Contractile vacuoles pump out fresh water that accumulates in the organisms by osmosis. Explain how this is an example of the way paramecia maintain homeostasis.

2. a. Review What is cellular specialization?

b. Explain How do cellular junctions and receptors help an organism maintain homeostasis?

c. Predict Using what you know about the ways muscles move, predict which organelles would be most common in muscle cells.

WRITE ABOUT SCIENCE

Description

3. Use an area in your life—such as school, sports, or extracurricular activities—to construct an analogy that explains why specialization and communication are necessary for you to function well.