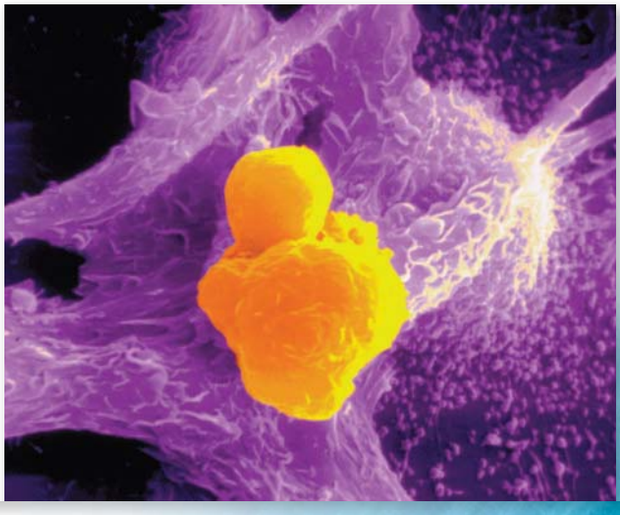
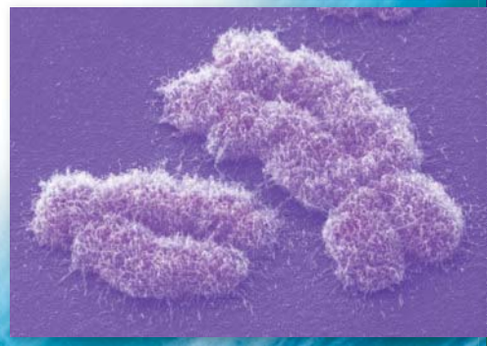
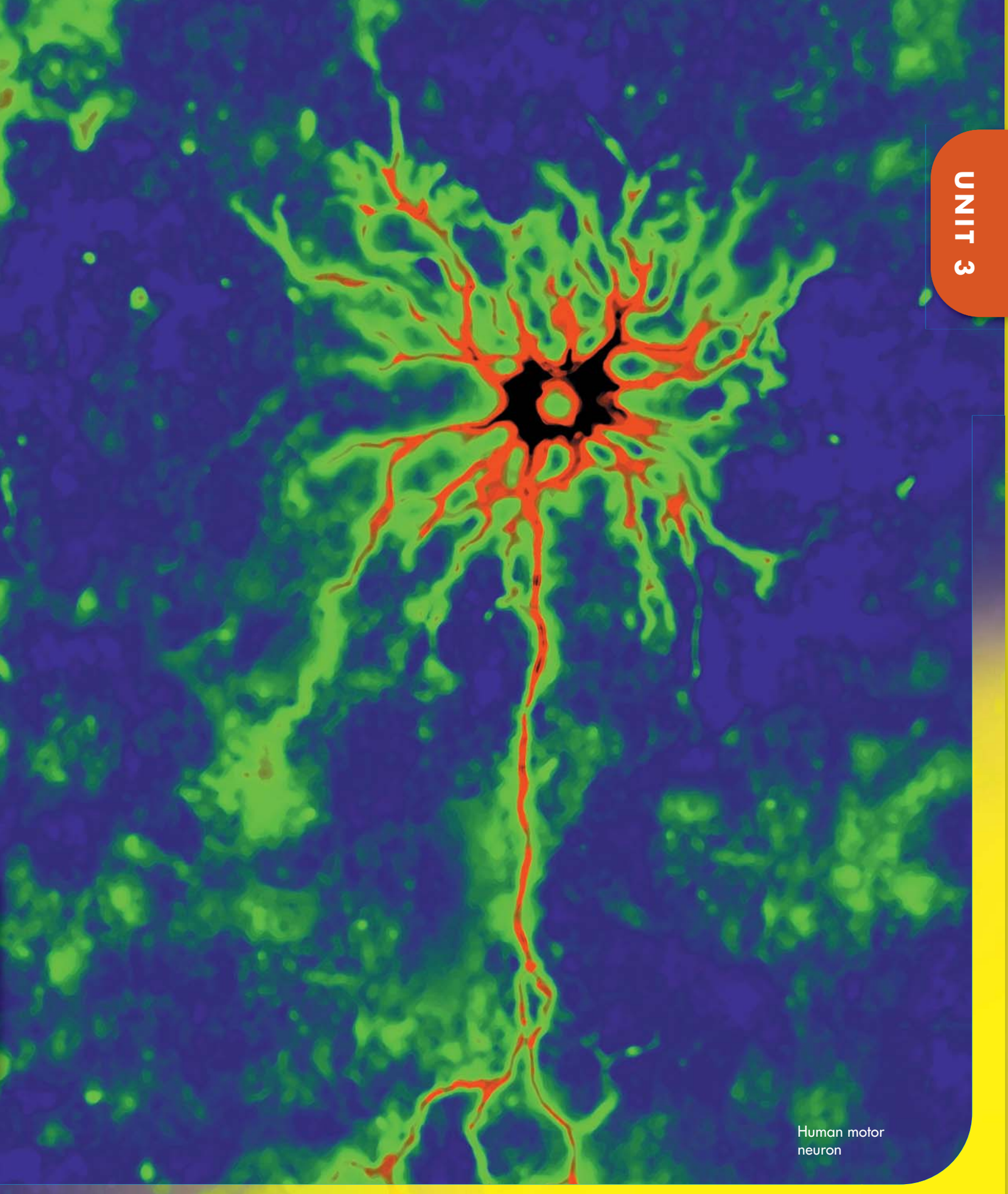
UNIT 3 Cells



Macrophage (purple) attack on a cancer cell (yellow)



Sex chromosomes of a human male: Y (left) and X (right)



Human motor neuron

DISCOVERIES IN SCIENCE

Cell Biology

1665

Robert Hooke builds a microscope to look at tiny objects. He discovers cells after observing a thin piece of cork under a microscope. He also finds cells in plants and fungi.

Hooke's microscope

1772

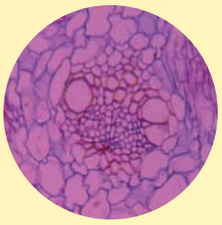
British clergyman and chemist, Joseph Priestly, presents his paper, *On Different Kinds of Air,* in which he describes his discovery of oxygen and other previously-unknown gases found in air. He also demonstrates that oxygen is produced by plants.

1839

Theodor Schwann shows that all animal tissue is made of cells. With plant biologist, Matthias Schleiden, Schwann identifies cell components, such as membranes and a nucleus common, to many eukaryotic cells.

1855

Rudolf Virchow publishes a theory stating that all cells come from another cells. He explains, "Where a cell exists, there must have been a preexisting cell."



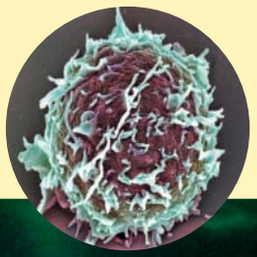
Animal cells

1945

Keith R. Porter, Albert Claude, and Ernest F. Fullam publish the first electromicrograph of a cell. Small organelles, such as the endoplasmic reticulum and the Golgi apparatus, are visible for the first time.

LATE 1950s

Canadian scientists Ernest McCulloch and James Till begin research on stem cells in rodents. Bone marrow stem cells can produce several types of blood cells.



Bone marrow stem cell

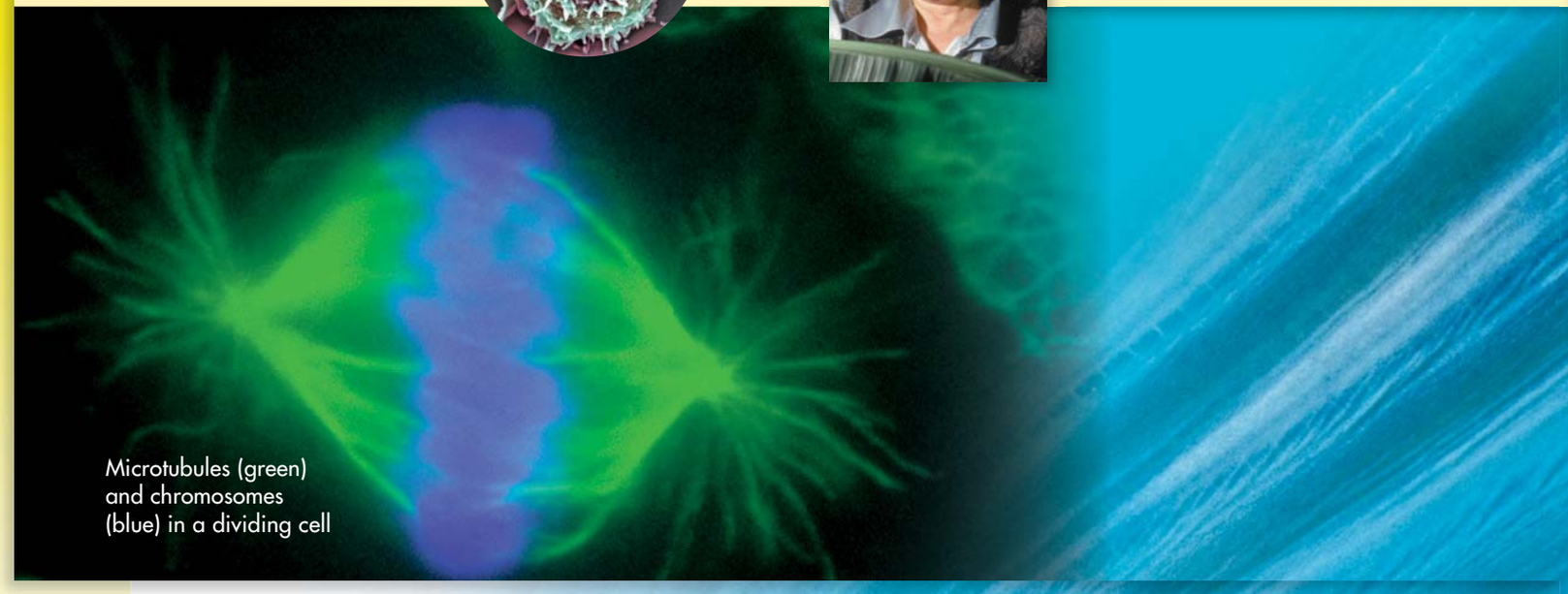
1971

Lynn Margulis proposes the endosymbiotic theory of the origins of cell organelles. This theory states that chloroplasts and mitochondria in eukaryotes evolved from prokaryotes.

Lynn Margulis

2004

Richard Axel, and Linda Buck earn the Noble Prize in Medicine or Physiology for their discovery of how olfactory cells detect odors and how the brain processes information to provide a sense of smell.



Microtubules (green) and chromosomes (blue) in a dividing cell

BIOLOGY CAREER

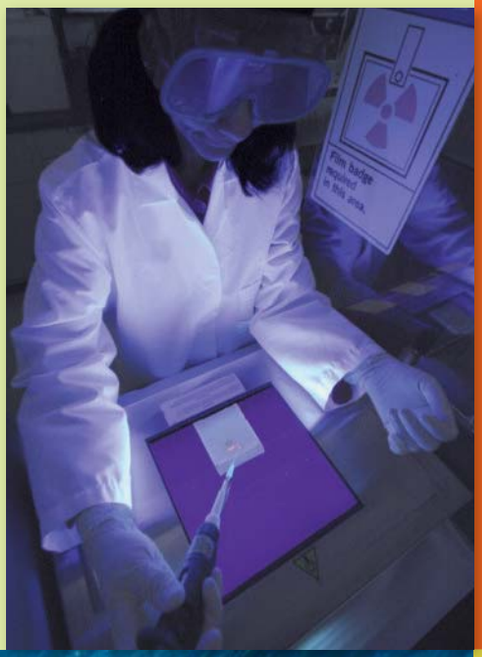
Cell Biologist

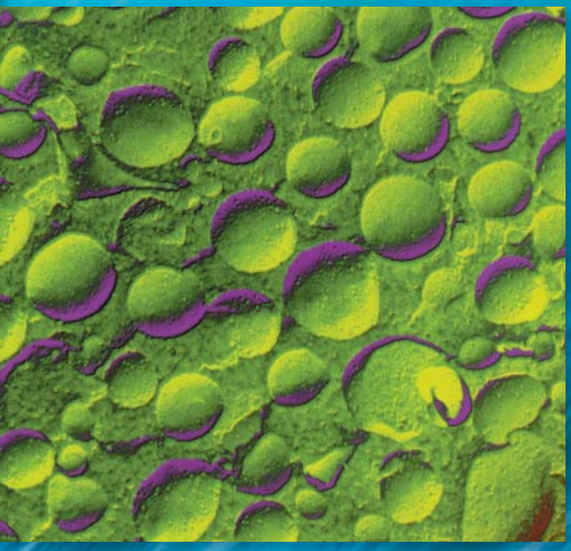
Shubha Govind

Shubha Govind is a professor of biology at City College, City University of New York. Govind considers her most important scientific contribution to be developing a model system for using genetic tools to study the molecular basis of host-parasite interaction in fruit flies. She is studying how blood cells of fruit flies are formed and how they guard against infections when flies are attacked by parasites. She is also studying how parasites have evolved to overcome the immune reactions of the fly.

Govind grew up in India, and her family traveled a lot. As she traveled, she was impressed with the diversity of flora and fauna in different parts of the country. By the time she reached middle school, she knew that she wanted to be a biologist.

Apart from science, Govind enjoys reading, listening to music and spending time with family and friends.





Freeze fracture of cell

Chapter Planner 8

Cells and Their Environment

		Standards	Teach Key Ideas
CHAPTER OPENER, pp. 172–173	15 min.	*National Science Education Standards*	
SECTION 1 Cell Membrane, pp. 175–177 › Homeostasis › Lipid Bilayer › Membrane Proteins	45 min.	LSCell 1, LSCell 2, LSCell 4, UCP4, UCP5, PS2	**Bellringer Transparency** **Transparencies** B10 Membrane Proteins **Visual Concepts** Phospholipid • Lipid Bilayer • Parts of the Cell Membrane
SECTION 2 Cell Transport, pp. 178–183 › Passive Transport › Osmosis › Active Transport	90 min.	LSCell 1, LSCell 2, LSCell 3, LSCell 4, LSMat 1, UCP4, UCP5, SI1, SI2, PS2, PS3, PS4, PS5, ST2, HNS2	**Bellringer Transparency** **Transparencies** B19 Ion Channels • B18 Facilitated Diffusion • B16 Osmosis • B17 Hypertonic, Hypotonic and Isotonic Solutions • B21 Sodium-Potassium Pump • B22 Endocytosis and Exocytosis **Visual Concepts** Concentration Gradient • Equilibrium • Diffusion in a Liquid • Osmosis • Comparing Hypertonic, Isotonic, and Hypotonic Conditions • Diffusion Through Ion Channels • Passive Transport: Facilitated Diffusion • Comparing Active and Passive Transport • Active Transport • Sodium-Potassium Pump • Endocytosis • Exocytosis
SECTION 3 Cell Communication, pp. 184–189 › Sending Signals › Receiving Signals › Responding to Signals	45 min.	LSCell 4, LSCell 6, LSBeh 1, LSBeh 2, UCP5	**Bellringer Transparency** **Transparencies** B20 Changes in Permeability

See also PowerPoint® Resources

Chapter Review and Assessment Resources

- SE Super Summary, p. 190
- SE Chapter Review, p. 191
- SE Standardized Test Prep, p. 193
- Review Resources
- Chapter Tests A and B
- Holt Online Assessment

CHAPTER FastTrack

Thorough instruction will require the times shown.

Basic Learners

- TE Organizing Concepts, p. 176
- TE Demonstrating Osmosis, p. 180
- Directed Reading Worksheets*
- Active Reading Worksheets*
- Lab Manuals, Level A*
- Study Guide* ■
- Note-taking Workbook*
- Special Needs Activities and Modified Tests*

Advanced Learners

- TE Developing Metaphors, p. 185
- Critical Thinking Worksheets*
- Concept Mapping Worksheets*
- Science Skills Worksheets*
- Lab Datasheets, Level C*

Key

SE Student Edition
TE Teacher's Edition
Chapter Resource File
Workbook
Transparency
CD or CD-ROM
* Datasheet or blackline master available
■ Also available in Spanish

All resources listed below are also available on the Teacher's One-Stop Planner.

Why It Matters	Hands-On	Skills Development	Assessment
Build student motivation with resources about high-interest applications.	SE **Inquiry Lab** Salty Cells, p. 173*■	TE **Reading Toolbox** Assessing Prior Knowledge, p. 172 SE **Reading Toolbox,** p. 174	
TE **Demonstration** Selectively Permeable Membrane, p. 176		SE **Reading Toolbox** Four-Corner Fold, p. 177	SE **Section Review** TE **Formative Assessment** **Spanish Assessment***■ **Section Quiz**■
TE **Salt Pollution,** p. 181 TE **Demonstration** Cell Membrane Analogy, p. 182	SE **Quick Lab** Osmosis, p. 181*■ SE **Inquiry Lab** Cell Size and Diffusion, p. 188*■ **Quick Lab** Demonstrating Diffusion* **Skills Practice Lab** Observing Osmosis in Eggs*	SE **Reading Toolbox** Word Parts, p. 180 TE **Reading Toolbox** Word Parts, p. 180	SE **Section Review** TE **Formative Assessment** **Spanish Assessment***■ **Section Quiz**■
SE **Heady Effects** p. 187 TE **Demonstration** Sending Signals, p. 184	SE **Quick Lab** Sensitive Plants, p. 185*■	SE **Reading Toolbox** Finding Examples, p. 186 TE **Reading Toolbox** Finding Examples, p. 186 TE **Reading Toolbox** Visual Literacy, p. 187	SE **Section Review** TE **Formative Assessment** **Spanish Assessment***■ **Section Quiz**■
	See also Lab Generator		**See also Holt Online Assessment Resources**

Resources for Differentiated Instruction

English Learners

TE Analogies, p. 175
TE What's the Difference?, p. 180
TE Relating Text and Visuals, p. 182
TE Understanding Terms, p. 184
Directed Reading Worksheets*
Active Reading Worksheets*
Lab Manuals, Level A*
Study Guide*■
Note-taking Workbook*
Multilingual Glossary

Struggling Readers

TE Organizing Concepts, p. 176
TE What's the Difference?, p. 180
TE Relating Text and Visuals, p. 182
Directed Reading Worksheets*
Active Reading Worksheets*
Lab Manuals, Level A*
Study Guide*
Note-taking Workbook*
Special Needs Activities and Modified Tests*

Special Education Students

TE A Model for Diffusion, p. 179
Directed Reading Worksheets*
Active Reading Worksheets*
Lab Manuals, Level A*
Study Guide*■
Note-taking Workbook*
Special Needs Activities and Modified Tests*

Alternative Assessment

TE Making Drawings, p. 179
Science Skills Worksheets*
Section Quizzes*■
Chapter Tests A, B, and C*■

Chapter 8

Overview

The purpose of this chapter is to describe the structure of the cell membrane and its role in homeostasis. Substances are moved in and out of cells through cell transport mechanisms, such as diffusion, osmosis, pumps, and vesicles. Cells communicate and coordinate activity by sending chemical signals that carry information to other cells.

READING TOOLBOX

Assessing Prior Knowledge Students should understand the following concepts:
- cellular nature of life
- basic biochemistry

Visual Literacy Ask students to point out the basic cell parts in the image, such as the cell membrane, nucleus, and cytoplasm. Have them describe their functions to foreshadow the diagrams they will see in the lessons. LS Visual

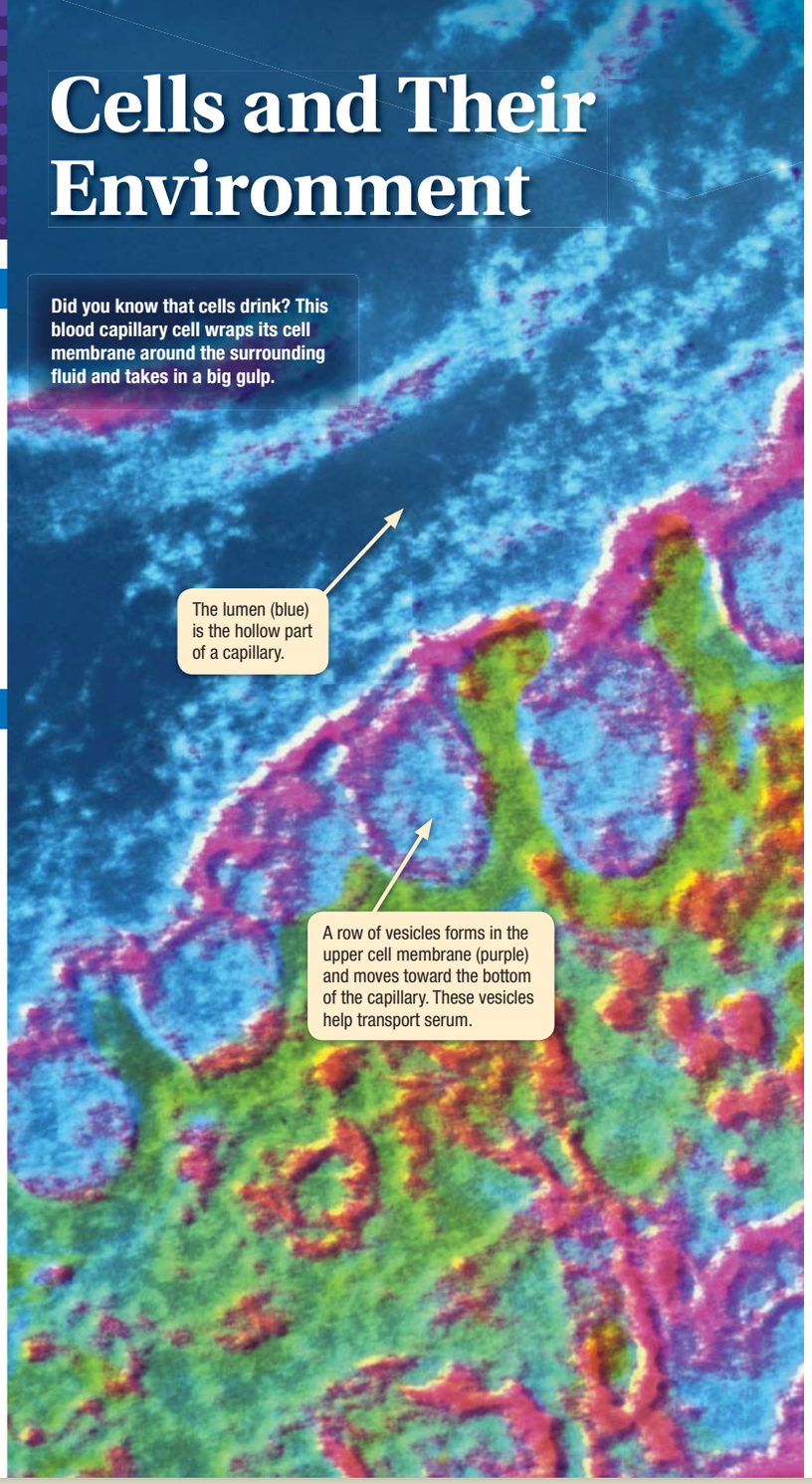
Chapter 8

Cells and Their Environment

Preview

Why It Matters

Cells interact with their environment to exchange nutrients and wastes and to coordinate activities over long distances.



Chapter Correlations

National Science Education Standards

LSCell 1 Cells have particular structures that underlie their functions.

LSCell 2 Most cell functions involve chemical reaction.

LSCell 3 Cells store and use information to guide their functions.

LSCell 4 Cell functions are regulated.

LSCell 6 Cells can differentiate and form complete multicellular organisms.

LSMat 1 All matter tends toward more disorganized states.

LSBeh 1 Multicellular animals have nervous systems that generate behavior.

LSBeh 2 Organisms have behavioral responses to internal changes and to external stimuli.

UCP4 Evolution and equilibrium

UCP5 Form and function

SI1 Abilities necessary to do scientific inquiry

SI2 Understandings about scientific inquiry

PS2 Structure and properties of matter

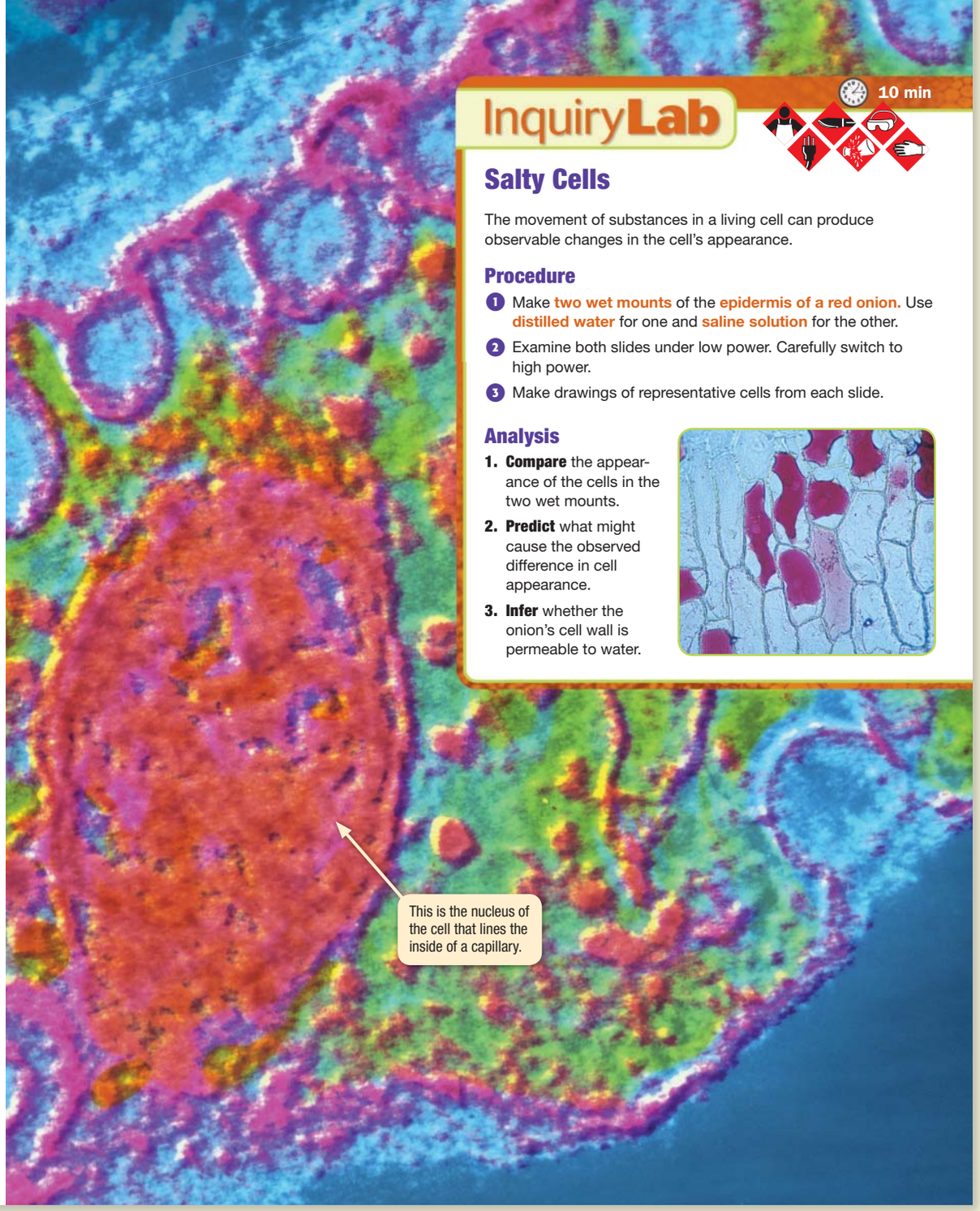
PS3 Chemical reactions

PS4 Motions and forces

PS5 Conservation of energy and increase in disorder

ST2 Understandings about science and technology

HNS2 Nature of scientific knowledge



InquiryLab

10 min

Salty Cells

The movement of substances in a living cell can produce observable changes in the cell's appearance.

Procedure

1. Make **two wet mounts** of the **epidermis of a red onion.** Use **distilled water** for one and **saline solution** for the other.
2. Examine both slides under low power. Carefully switch to high power.
3. Make drawings of representative cells from each slide.

Analysis

1. **Compare** the appearance of the cells in the two wet mounts.
2. **Predict** what might cause the observed difference in cell appearance.
3. **Infer** whether the onion's cell wall is permeable to water.

InquiryLab

Teacher's Notes Use at least a 5% saline solution.

Materials
- cover slip (2)
- distilled water
- compound microscope
- microscope slide (2)
- red onion
- saline solution
- dropper
- knife

Answers to Analysis

1. The cells that were placed in the saline solution appeared to have shriveled contents that pulled away from the cell wall. The other cells seemed to be full of cytoplasm.
2. Water leaving the saline immersed cell would cause the cell contents to shrivel. Water that enters the cells immersed in water would cause the cytoplasm to swell.
3. Yes. If water can move from the inside of the cell to the cell's outer surroundings, the cell wall must be water permeable.

Key Resources

Interactive Tutor

READING TOOLBOX

Using Words

Accept reasonable answers.

1. A *phospholipid* is a fat containing phosphorus.
2. *Exocytosis* refers to a process by which substances are moved outside the cell.

Using Language

1. bacteria and fungal spores
2. for example, such as, like, including

Using Fold Notes

You may want to review students' Fold Notes to see if they have followed the directions accurately. Conduct a short class discussion on the similarities and differences so students can check their own work.

READING TOOLBOX

These reading tools can help you learn the material in this chapter. For more information on how to use these and other tools, see **Appendix: Reading and Study Skills.**

Using Words

Word Parts You can tell a lot about a word by taking it apart and examining its prefix and root.

Your Turn Use the information in the table to predict the meaning of the following words:

1. *phospholipid*
2. *exocytosis*

Word Parts

Word part	Type	Meaning
phospho-	prefix	containing phosphorus
lipid	root	a fat
exo-	prefix	outside
cyto	root	cell

Using Language

Finding Examples Concrete examples often help clarify new information. Certain words and phrases can help you recognize examples. These words include *for example, such as, like,* and *including.*

Your Turn Use what you have learned about examples to answer the following questions.

1. Find the examples in the following sentence: Some cells also use exocytosis to remove infecting microbes, such as bacteria or fungal spores.
2. Find the examples in the introductory paragraph above.

Using FoldNotes

Four-Corner Fold A four-corner fold is useful when you want to compare the characteristics of four topics. The four-corner fold can organize the characteristics of the four topics side by side under the flaps. Similarities and differences between the four topics can then be easily identified.

Your Turn Make a four-corner fold to help you learn about four topics in this chapter.

1. Fold a sheet of paper in half from top to bottom. Then, unfold the paper.
2. Fold the top and bottom of the paper to the crease in the center.
3. Fold the paper in half from side to side. Then, unfold the paper.
4. Using scissors, cut the top flap creases made in step 3 to form four flaps.

Section 1

Cell Membrane

Key Ideas	Key Terms	Why It Matters
How does the cell membrane help a cell maintain homeostasis? How does the cell membrane restrict the exchange of substances? What are some functions of membrane proteins?	phospholipid lipid bilayer	A simple defect in a cell membrane protein can make a life-or-death difference. In people who have cystic fibrosis, the cell membrane is does not work properly.

Every cell is surrounded by a cell membrane. The cell membrane protects the cell and helps move substances and messages in and out of the cell. By regulating transport, the membrane helps the cell maintain constancy and order.

Homeostasis

All living things respond to their environments. For example, we sweat when we are hot and shiver when we are cold. These reactions help our bodies maintain homeostasis. Recall that homeostasis is the maintenance of stable internal conditions in a changing environment. Individual cells, as well as organisms, must maintain homeostasis in order to live. **One way that a cell maintains homeostasis is by controlling the movement of substances across the cell membrane.**

Like the swimmer and the jellyfish in **Figure 1,** cells are suspended in a fluid environment. Even the cell membrane is fluid. It is made up of a "sea" of lipids in which proteins float. By allowing some materials but not others to enter the cell, the cell membrane acts as a gatekeeper. In addition, it provides structural support to the cytoplasm, recognizes foreign material, and communicates with other cells. These functions also contribute to maintaining homeostasis.

Reading Check *What are some roles of the cell membrane? (See the Appendix for answers to Reading Checks.)*

SCILINKS
www.scilinks.org
Topic: Homeostasis
Code: HX80753

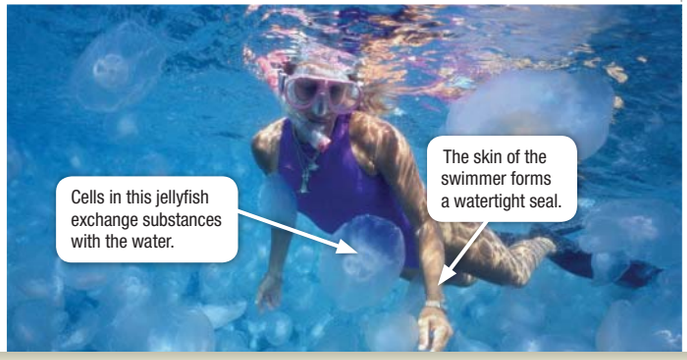


Figure 1 The cells of the jellyfish exchange materials more freely with the sea water than do the cells of the swimmer.

Differentiated Instruction

English Learners

Analogies Have students think of analogies for the role of the cell membrane. For example, the membrane could be compared to checkpoints at a nation's border. At checkpoints, shipments are stopped and inspected, and admitted to enhance the nation's economy. Ask how customs inspections are like the cell membrane. (Incoming molecules are also inspected at the cell membrane, and admitted to enhance the functioning of the cell. The cell would shut down if the cell membrane were not permeable.) LS Logical

Key Resources

Transparencies
B10 Membrane Proteins

Visual Concepts
Phospholipid
Lipid Bilayer
Parts of the Cell Membrane

Section 1

Focus

This section describes how the structure of the cell membrane helps maintain homeostasis, and restricts the exchange of substances. The functions of membrane proteins also are discussed.

Bellringer

Use the Bellringer transparency to prepare students for this section.

Teach

Teaching Key Ideas

Maintaining Homeostasis Remind students that snakes and lizards are ectothermic. Have students suggest ways a lizard maintains homeostasis, such as moving to sun or shade and hibernation. Ask students to imagine their "normal body covering" as a T-shirt and shorts. Have them hypothesize how their own activities might change if they were ectothermic and what special precautions they would need to take to maintain a constant body temperature. LS Interpersonal

Teach, *continued*

Demonstration

Selectively Permeable Membrane Choose 3 to 5 different brands of plastic bags. Mix some cornstarch and water in each bag and close tightly. Place each bag into a larger, clear container of water with iodine mixed in. Remind students that iodine is an indicator for starch. With students, determine which bags represent a permeable membrane (starch water and iodine water is purple), a selectively permeable membrane (starch water is purple and iodine water is orange, or starch water is white and iodine water is purple), or a nonpermeable membrane (starch water is white and iodine water is orange). LS **Visual/Logical**

phospholipid (FAHS foh LIP id) a lipid that contains phosphorus and that is a structural component in cell membranes

lipid bilayer (LIP id BIE LAY uhr) the basic structure of a biological membrane, composed of two layers of phospholipids

Lipid Bilayer

The cell membrane is made of a "sea" of phospholipids. As **Figure 2** shows, a **phospholipid** is a specialized lipid made of a phosphate "head" and two fatty acid "tails." The phosphate head is polar and is attracted to water. In contrast, the fatty acid tails are nonpolar and are repelled by water.

Structure Because there is water inside and outside the cell, the phospholipids form a double layer called the **lipid bilayer.** The nonpolar tails, repelled by water, make up the interior of the lipid bilayer. The polar heads are attracted to the water, so they point toward the surfaces of the lipid bilayer. One layer of polar heads faces the cytoplasm, while the other layer is in contact with the cell's immediate surroundings.

Barrier Only certain substances can pass through the lipid bilayer. **The phospholipids form a barrier through which only small, nonpolar substances can pass.** Ions and most polar molecules are repelled by the nonpolar interior of the lipid bilayer.

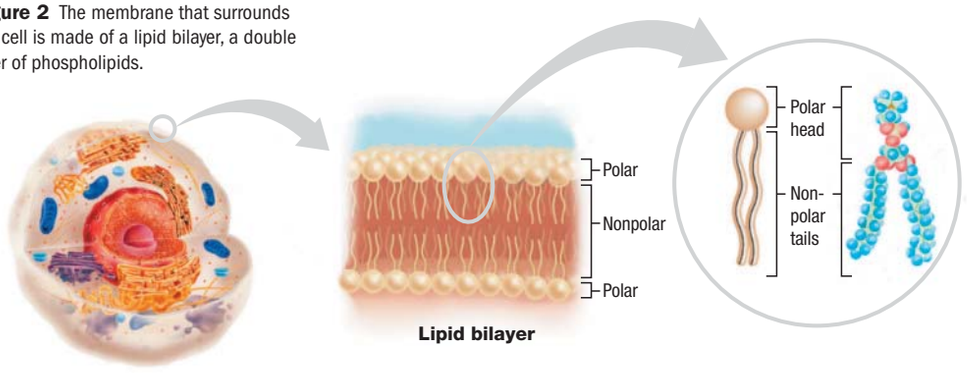
Membrane Proteins

Various proteins can be found in the cell membrane. Some proteins face inside the cell, and some face outside. Other proteins may stretch across the lipid bilayer and face both inside and outside.

Proteins in Lipids What holds these proteins in the membrane? Recall that proteins are made of amino acids. Some amino acids are polar, and others are nonpolar. Nonpolar portions of a protein are attracted to the interior of the lipid bilayer but are repelled by water on either side of the membrane. In contrast, polar parts of the protein are attracted to the water on both sides of the lipid bilayer. These opposing attractions help hold the protein in the membrane.

Reading Check ***Why can't ions pass through the lipid bilayer?***

Figure 2 The membrane that surrounds the cell is made of a lipid bilayer, a double layer of phospholipids.



The lipid bilayer is the foundation of the cell membrane.

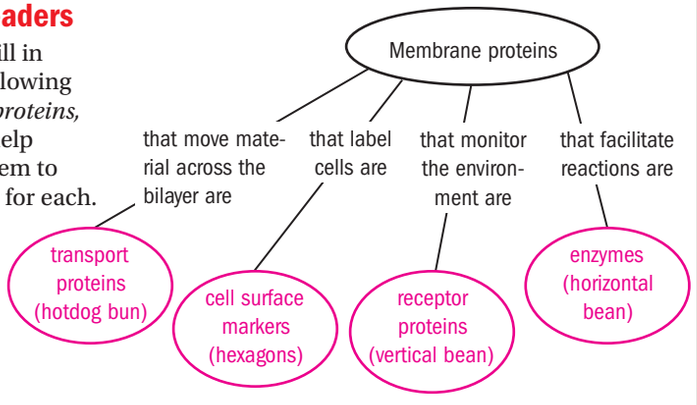
The arrangement of phospholipids in the lipid bilayer makes the cell membrane selectively permeable.

A phospholipid's "head" is polar, and its two fatty acid "tails" are nonpolar.

Differentiated Instruction

Basic Learners/Struggling Readers

Organizing Concepts Have students fill in the concept map shown using the following terms: *cell surface markers, receptor proteins, enzymes,* and *transport proteins.* To help students remember the terms, ask them to come up with an icon and descriptor for each. Examples are shown. LS **Visual**



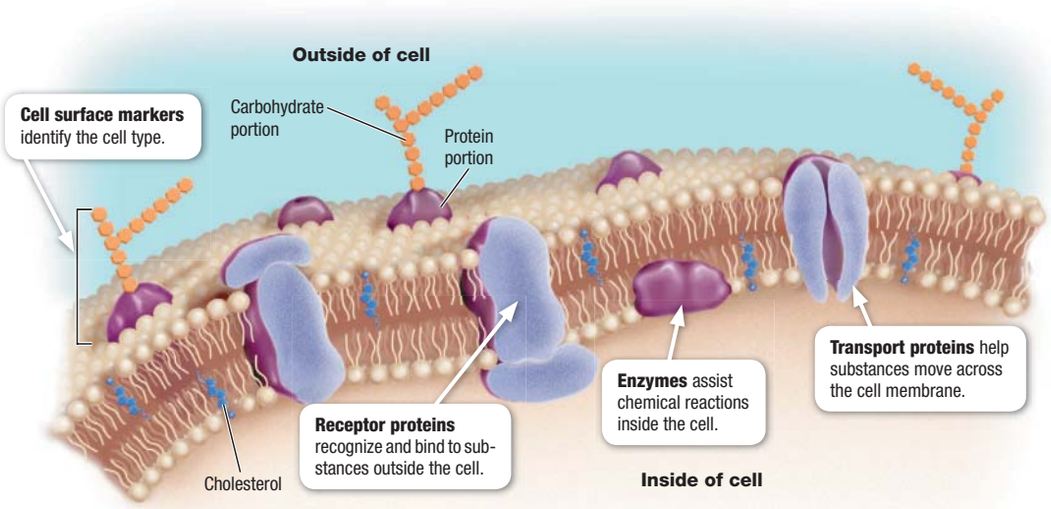


Figure 3 The cell membrane contains various proteins that have specialized functions.

Types of Proteins As **Figure 3** shows, membranes contain different types of proteins. **› Proteins in the cell membrane include cell-surface markers, receptor proteins, enzymes, and transport proteins.**

- **Cell-Surface Markers** Like a name tag, a chain of sugars acts as a marker to identify each type of cell. Liver cells have a different chain of sugars from heart cells. These sugars (carbohydrates) are attached to the cell surface by proteins called *glycoproteins*. Glycoproteins help cells work together.
- **Receptor Proteins** Receptor proteins enable a cell to sense its surroundings by binding to certain substances outside the cell. When this happens, it causes changes inside the cell.
- **Enzymes** Many proteins in the cell membrane help with important biochemical reactions inside the cell.
- **Transport Proteins** Many substances that the cell needs cannot pass through the lipid bilayer. Transport proteins aid the movement of these substances into and out of the cell.

READING TOOLBOX

Four-Corner Fold Make a four-corner fold to compare four types of proteins found in the cell membrane.

Section 1 Review

› KEY IDEAS

1. **Relate** the functions of the cell membrane to homeostasis.
2. **Describe** the types of substances that can pass through the lipid bilayer of the cell membrane.
3. **Outline** four functions of proteins within the cell membrane.

CRITICAL THINKING

4. **Applying Logic** What would happen if the cell membrane were fully permeable to all substances in the cell's environment?
5. **Predicting Outcomes** What would happen if the cell were exposed to a drug that disabled the transport proteins in the cell membrane?

ALTERNATIVE ASSESSMENT

6. **Making Models** Create a model of the lipid bilayer, including its associated proteins. Your model may be made of clay or household items. Present your model to the class. Indicate the role of each type of protein in maintaining homeostasis.

Answers to Section Review

1. The cell membrane provides structural support to the cytoplasm, recognizes foreign material, communicates with other cells, and helps transport substances to maintain homeostasis.
2. only small, nonpolar substances
3. Cell-surface markers identify the type of cell. Receptor proteins enable a cell to detect and respond to its surroundings. Enzymes are involved in biochemical reactions in the cell. Transport proteins aid the movement of specific substances into and out of the cell.
4. All substances in the cell's environment could pass through into the cell, homeostasis would be disrupted, and the cell would probably die.
5. If important substances could not pass through the cell membrane, homeostasis within the cell would be disrupted, and the cell would probably die.
6. Students' models should match Figure 3. Check that the functions of the proteins are labeled correctly.

Teaching Key Ideas

Protein Analogies Team students to develop analogies for each of the types of proteins, such as a cell-surface marker protein is like a road-sign, a receptor protein is like sonar, and so on. Discuss the analogies and their rationales in class.

READING TOOLBOX

Four-Corner Fold Advise students to include what each protein does. Check students' work for accuracy.

› Close

Formative Assessment

The functions of the proteins in the lipid bilayer can best be summarized as ____.

A. releasing energy for respiration (Incorrect. The mitochondria within the cell release energy, not the cell membrane.)

B. enabling substances to move into and out of the cell (Incorrect. Many proteins are involved in other functions, such as identifying the cell, speeding up biochemical reactions, and responding to changes.)

C. reproducing the membrane as the cell grows (Incorrect. Growth and reproduction are controlled by the cell's nucleus.)

D. maintaining homeostasis by a variety of functions (Correct! The proteins are involved in identifying the cell, speeding up biochemical reactions, moving materials into and out of the cell, and responding to changes.)

Section 2

Section 2 Cell Transport

Key Ideas	Key Terms	Why It Matters
❯ What determines the direction in which passive transport occurs? ❯ Why is osmosis important? ❯ How do substances move against their concentration gradients?	equilibrium concentration gradient diffusion carrier protein osmosis sodium-potassium pump	The cell's membrane is a little like a country's border. Both barriers regulate who or what enters and who or what leaves.

❯ Focus

This section describes how substances move across cell membranes either directly or through channels. Passive transport, osmosis, and active transport are discussed.

Bellringer

Use the Bellringer transparency to prepare students for this section.

Teaching Key Ideas

Create Operational Definitions Ask students to define the terms *passive, active,* and *transport* in their own words. Then ask them to imagine sitting in a boat that is moving downstream with the current. Then, imagine using a small motor to move the same boat upstream against the current. Ask students to determine which action shows passive transport and which shows active transport. Help them realize that active transport requires an input of energy and goes against the natural flow like the motor moving the boat upstream. LS Verbal

Answers to Caption Questions

Figure 4: crowded areas
Figure 6: outside of cell membrane

The cell must move substances of varying size, electrical charge, and composition into and out of the cell. Substances may enter and leave the cell in a variety of ways. Sometimes the cell must use energy to move a substance across the cell membrane. In *active transport,* the cell is required to use energy to move a substance. In *passive transport,* the cell does not use energy.

Passive Transport

In a solution, randomly moving molecules tend to fill up a space. When the space is filled evenly, a state called **equilibrium** is reached. The amount of a particular substance in a given volume is called the *concentration* of the substance. When one area has a higher concentration than another area does, as **Figure 4** shows, a **concentration gradient** exists. Substances move from an area of higher concentration to an area of lower concentration. This movement down the concentration gradient is called **diffusion.**

The cell membrane separates the cytoplasm from the fluid outside the cell. Some substances enter and leave the cell by diffusing across the cell membrane. The direction of movement depends on the concentration gradient and does not require energy. ❯ **In passive transport, substances cross the cell membrane down their concentration gradient.** Some substances diffuse through the lipid bilayer. Others diffuse through transport proteins.

Figure 4 If people acted like molecules, they would fill up the space in this room evenly over time. ❯ **What area of this room has a high concentration of people?**

Key Resources

Transparencies
B19 Ion Channels
B18 Facilitated Diffusion
B16 Osmosis
B17 Hypertonic, Hypotonic, and Isotonic Solutions
B21 Sodium-Potassium Pump
B22 Endocytosis and Exocytosis

Visual Concepts
Concentration Gradient
Equilibrium
Diffusion in a Liquid
Osmosis
Comparing Hypertonic, Isotonic, and Hypotonic Conditions
Diffusion Through Ion Channels
Passive Transport: Facilitated Diffusion
Comparing Active and Passive Transport
Active Transport
Sodium-Potassium Pump
Endocytosis
Exocytosis

Simple Diffusion Small, nonpolar molecules can pass directly through the lipid bilayer. This type of movement is called *simple diffusion.* As **Figure 5** shows, oxygen diffuses into the cell through the lipid bilayer. The concentration of oxygen is higher outside the cell than it is inside. Thus, oxygen moves down its concentration gradient into the cell. In contrast, the concentration of carbon dioxide is often higher inside the cell than it is outside. So, carbon dioxide diffuses out of the cell. Natural steroid hormones, which are nonpolar and fat soluble, can also diffuse across the lipid bilayer.

Facilitated Diffusion Many ions and polar molecules that are important for cell function do not diffuse easily through the nonpolar lipid bilayer. During *facilitated diffusion,* transport proteins help these substances diffuse through the cell membrane. Two types of transport proteins are channel proteins and carrier proteins.

Channel Proteins Ions, sugars, and amino acids can diffuse through the cell membrane through channel proteins. These proteins, sometimes called *pores,* serve as tunnels through the lipid bilayer. Each channel allows the diffusion of specific substances that have the right size and charge. For example, only sodium ions can pass through the sodium ion channel shown in **Figure 5.**

Carrier Proteins Carrier proteins transport substances that fit within their binding site, as **Figure 6** shows. A carrier protein binds to a specific substance on one side of the cell membrane. This binding causes the protein to change shape. As the protein's shape changes, the substance is moved across the membrane and is released on the other side.

Reading Check *Why does oxygen diffuse into the cell?*

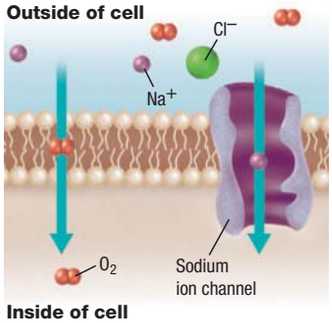


Figure 5 Nonpolar molecules, such as O_2, diffuse through the lipid bilayer. Channel proteins allow certain ions, such as Na^+, to diffuse through the cell membrane. Cl^- ions cannot pass through the sodium ion channel.

equilibrium a state that exists when the concentration of a substance is the same throughout a space

concentration gradient a difference in the concentration of a substance across a distance

diffusion the movement of particles from regions of higher density to regions of lower density

carrier protein a protein that transports substances across a cell membrane

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interact online
Keyword: HX8CENF6

Facilitated Diffusion

1 A molecule outside the cell binds to a carrier protein on the cell membrane.

2 The carrier protein changes shape, which releases the molecule inside the cell.

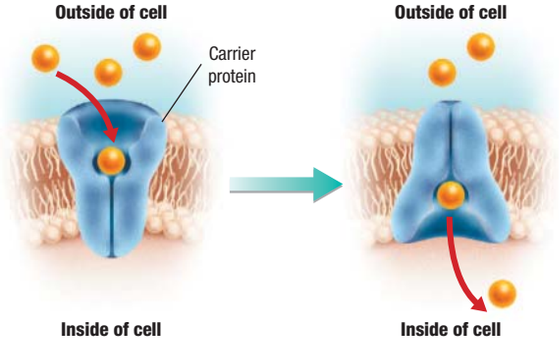

Figure 6 Carrier proteins allow the diffusion of specific molecules by binding the molecules on one side of the cell membrane and releasing them on the other side.
Which side of this membrane has a higher concentration of molecules?

Teaching Key Ideas

Transport Proteins Contrast transport proteins for students. As you describe how a channel protein functions, use a puzzle or toddler's "matching shape" toy—objects can pass only through holes of the same shape. Contrast this with a carrier protein by using a piece of flexible tubing or the top of a small sock and moving the same objects through it. Have students notice how the protein (tubing) changes shape to move the object through.

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interact online

Students can interact with "Facilitated Diffusion" by going to go.hrw.com and typing in the keyword HX8CENF6.

Differentiated Instruction

Alternative Assessment

Making Drawings Have students make their own drawings of the processes of simple diffusion, facilitated diffusion, osmosis, and active transport. Ask students to include brief captions in their own words that describe what is happening in each process. LS Visual

Special Education Students

A Model for Diffusion This simple demonstration helps developmentally delayed students see the concrete results of diffusion. Have students fill a beaker about three-fourths full of water. Let the beaker stand until the water is still. Add one drop of food coloring to the surface of the water. Students will observe that the drop spreads out until the water is uniformly colored. This may take several minutes. Ask students what happened to the drop of food coloring. (It moved throughout the water, from where it was more concentrated to where it is less concentrated.) LS Visual

Teach, *continued*

Teaching Key Ideas

Sore Throat Remedy Explain the role of osmosis when gargling with a saltwater solution to soothe a sore throat. Swollen throat tissue, which contains water, causes some of the pain. Throat tissue has a higher concentration of water than the surrounding saltwater environment. As a result, water moves by osmosis from the throat tissue into the saltwater solution. The loss of water reduces the swelling and relieves some of the pain.

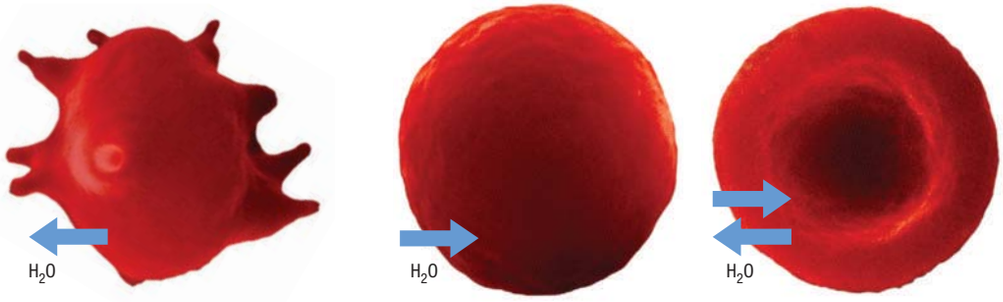
Teaching Key Ideas

Applications of Osmosis Put the following questions on the board or overhead transparency.

1. Why are green leafy vegetables sprinkled with water at the supermarket? (prevents wilting due to water loss)
2. Why is salt sometimes used to preserve foods? (Microorganisms present on the foods shrink and die in the hypertonic solution.)

READING TOOLBOX

Word Parts *Hypotonic* means "lower concentration." Give students other examples of words using these prefixes and elicit operational definitions. Examples are: hyperactive, hypersensitive, hyperventilate, hypodermis, hypoglycemic, hypothermia.



Hypertonic Solution The fluid outside is more concentrated. As water moves out of the cell, the cell shrinks.

Hypotonic Solution The fluid outside is less concentrated. As water moves into the cell, the cell swells.

Isotonic Solution Water moves into and out of the cell at the same rate. The cell stays the same size.

Figure 7 Red blood cells change shape due to the movement of water. The direction of water movement depends on the difference between the concentration of the solution outside the cell and the concentration of the cytosol.

READING TOOLBOX

Word Parts The prefix *hyper-* means "higher than," and *hypertonic* means "higher concentration." If *hypo-* means "lower than," what does *hypotonic* mean?

osmosis the diffusion of water or another solvent from a more dilute solution (of a solute) to a more concentrated solution (of the solute) through a membrane that is permeable to the solvent

Osmosis

Water can diffuse across a selectively permeable membrane in a process called **osmosis.** Osmosis is a type of passive transport that is very important to keeping cells functional. ❯ **Osmosis allows cells to maintain water balance as their environment changes.**

When ions and polar substances dissolve in water, they attract and bind some water molecules. The remaining water molecules are free to move around. If a concentration gradient exists across a membrane for solutes, a concentration gradient also exists across the membrane for free water molecules. Osmosis occurs as free water molecules move down their concentration gradient into the solution that has the lower concentration of free water molecules.

Water Channels Polar water molecules do not diffuse directly through the bilayer. But the cell membrane contains channel proteins that only water molecules can pass through. Thus, osmosis in cells is a form of facilitated diffusion. In humans, water channels help in the regulation of body temperature, in digestion, in reproduction, and in water conservation in the kidneys.

Predicting Water Movement The direction of water movement in a cell depends on the concentration of the cell's environment. **Figure 7** shows a red blood cell in solutions of three concentrations.

1. Water moves out. If the solution is *hypertonic,* or has a higher solute concentration than the cytoplasm does, water moves out of the cell. The cell loses water and shrinks.

2. Water moves in. If the solution is *hypotonic,* or has a lower solute concentration than the cytoplasm does, water moves into the cell. The cell gains water and expands in size.

3. No net change in water movement occurs, or equilibrium is reached. If the solution is *isotonic,* or has the same solute concentration that the cytoplasm does, water diffuses into and out of the cell at equal rates. The cell stays the same size.

Differentiated Instruction

Struggling Readers/English Learners

What's the Difference? *Hypotonic, isotonic,* and *hypertonic* are terms that indicate the relative concentrations of solute in two systems. Ask students to think of memory aids for these terms. For example, a cell in a hypertonic environment shrinks (*hyper*—shrinking). A cell in a hypotonic environment swells (*hypo*—swells like a hippo). LS Verbal

Basic Learners

Demonstrating Osmosis Cut three potato slices about 1 cm thick. Place one slice in distilled water, one in tap water, and one in a saltwater solution (15 g salt in 250 mL tap water). Leave them overnight. Explain that distilled water is a hypotonic environment; tap water is an isotonic environment; and salt water is a hypertonic environment. Have students predict what will happen to the potato slices. Compare the resulting size of the potato slices with the blood cells in **Figure 7.** LS Visual

Hands-On

QuickLab

MULTI-DAY 15 min

Osmosis

You will observe the movement of water into or out of a grape under various conditions.

Procedure

1. Make a data table with four columns and three rows.
2. Fill **one jar** with a **sugar solution.** Fill a **second jar** with **grape juice.** Fill a **third jar** with **tap water.** Label each jar with the name of the solution that it contains.
3. Use a **balance** to find the mass of each of **three grapes.** Place one grape in each jar, and put the lids on the jars.
4. Predict whether the mass of each grape will increase or decrease over time. Explain your predictions.
5. After 24 h, remove each grape from its jar, and dry the grape gently with a **paper towel.** Using the balance, find each grape's mass again. Record your results.

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 had predicted? Why or why not?

Effects of Osmosis If left unchecked, the swelling caused by a hypotonic solution could cause a cell to burst. The rigid cell walls of plants and fungi prevent the cells of these organisms from expanding too much. In fact, many plants are healthiest in a hypotonic environment, as **Figure 8** shows. Some unicellular eukaryotes have *contractile vacuoles,* which 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 actively removing solutes from the cytoplasm. The removal of dissolved solutes from a cell increases the concentration of free water molecules inside the cell.

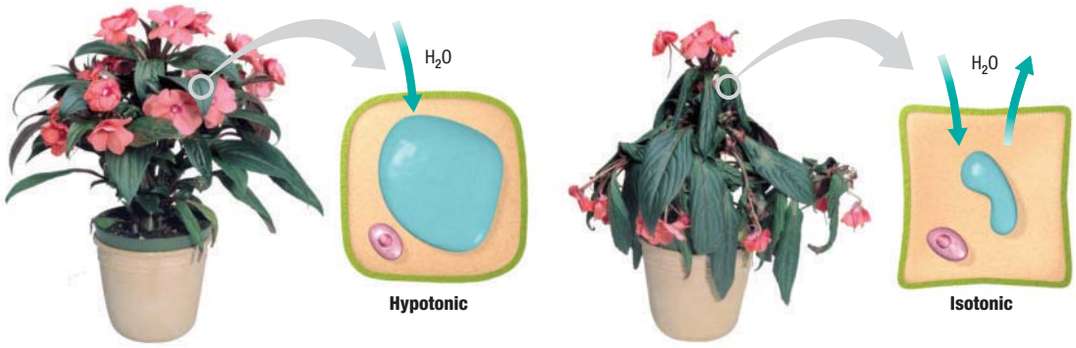


Figure 8 Plant cells are healthiest in a hypotonic environment. When its cells swell, the plant stands rigid. In an isotonic environment, a plant wilts. **What would happen if you added water to the plant on the right?**

Why It Matters

Salt Pollution Tell students that in some areas, salt is sprinkled over icy roads to melt the ice. Plants growing along the roadside are often seriously damaged or killed. The damaged plants look similar to those that have been through a very hot, dry summer. A higher-than-normal salt concentration in the environment causes plant cells to lose water through osmosis. Without sufficient water, the plants die.

QuickLab

Teacher's Notes Review the use of a balance to find the mass of objects. Make a saturated sugar solution by stirring sugar into sugar to water one teaspoon at a time until no more sugar dissolves.

Materials
- balance
- grape juice
- grapes (3)
- unbreakable plastic jars or similar containers (3)
- sugar
- water
- paper towel

Answers to Analysis

1. The tap water is a hypotonic solution because the grape swelled. The sugar solution is a hypertonic solution because it caused the grape to shrink. Depending on the sugar content of the grape juice, the juice may be isotonic (the grape neither swelled nor shrunk) or hypertonic (the grape swelled).
2. The evidence for osmosis is an increase or a decrease in the mass of the grapes.
3. Students who had a clear understanding of osmosis before the experiment probably will not change their thinking.

Teach, *continued*

Demonstration

Cell Membrane Analogy Bring an air pump and an inflatable ball to class. Ask a student to inflate the ball with the pump. Relate this activity to a cell membrane pump. (The air pump uses the energy supplied by the student to move air against a pressure gradient.) Tell students that membrane pumps use energy supplied by the cell to move substances against their concentration gradient. LS **Logical/Visual**

go.hrw.com
interact online

Students can interact with "Sodium-Potassium Pump" by going to go.hrw.com and typing in the keyword HX8CENF9.

Answers to Caption Questions

Figure 9: outside the cell

SCILINKS
www.scilinks.org
Topic: Active Transport
Code: HX80018

sodium-potassium pump a carrier protein that uses ATP to actively transport sodium ions out of a cell and potassium ions into the cell

Active Transport

Sometimes, cells must transport substances against their concentration gradients. This movement is called *active transport* because the cell must use energy to move these substances. **Active transport requires energy to move substances against their concentration gradients.** Most often, the energy needed for active transport is supplied directly or indirectly by ATP.

Pumps Many active transport processes use carrier proteins to move substances. In facilitated diffusion, the carrier proteins do not require energy. In active transport, the carrier proteins do require energy to "pump" substances against their concentration gradient.

One of the most important carrier proteins in animal cells is the **sodium-potassium pump,** shown in **Figure 9.** Sodium ions inside the cell bind to the carrier protein. A phosphate group from ATP transfers energy to the protein. The protein changes shape and releases the sodium ions outside the cell membrane. Outside the cell, potassium ions bind to the pump. As a result, the phosphate group is released from the pump. The pump returns to its original shape and releases the potassium ions inside the cell membrane. For every three sodium ions taken out, two potassium ions are brought inside.

This pump prevents sodium ions from building up in the cell. Osmosis results when sodium ion levels are high. The cell could swell or even burst if too much water enters. The concentration gradients of sodium ions and potassium ions also help transport other substances, such as glucose, across the cell membrane.

Figure 9 The sodium-potassium pump actively transports both Na^+ and K^+ ions across the cell membrane. **In this figure, is the concentration of sodium ions higher inside the cell or outside the cell?**

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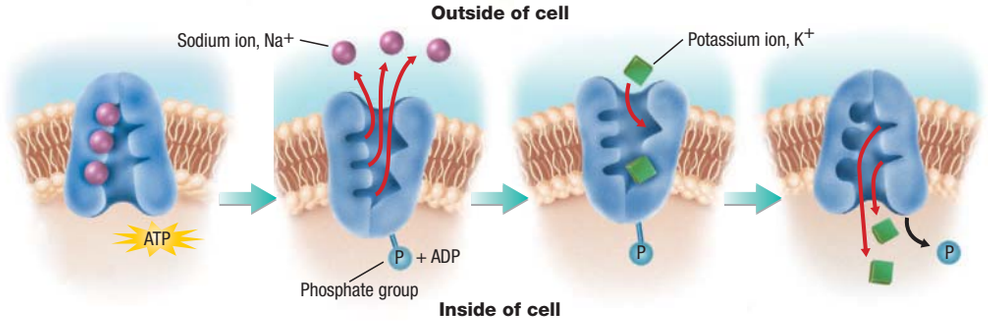
Keyword: HX8CENF9

Sodium-Potassium Pump

1. Three sodium ions bind to the pump. A phosphate from ATP also binds, which transfers energy.
2. The pump changes shape, releasing the three sodium ions on the other side of the membrane.
3. Two potassium ions bind to the pump and are tranported across the cell membrane.
4. The phosphate group is released. The pump returns to its original shape, releasing the two potassium ions.



Differentiated Instruction

English Learners/Struggling Readers

Relating Text and Visuals Interpreting **Figure 9** can be difficult for students with reading and language difficulties. Review each step slowly. Put a visual key on the board for all of the names, codes, and symbols shown in the figure. Ask students to describe what happens to each component in the drawing (ATP, ADP, Na^+, K^+, and P) from steps 1 to 4. Be sure that they realize that *P* and *potassium* are not the same. LS **Visual**

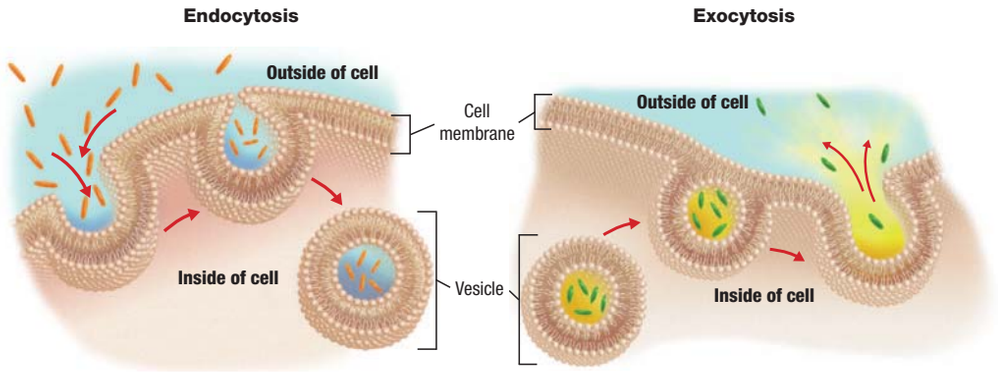


Figure 10 A cell moves large substances or large amounts of materials in vesicles. Vesicles can fuse with the cell membrane to take in and release substances.

Vesicles Many substances, such as proteins and polysaccharides, are too large to be transported by carrier proteins. Instead, they cross the cell membrane in vesicles. Recall that vesicles are membrane-bound sacs. The vesicle membrane is a lipid bilayer, like the cell membrane. Therefore, vesicles can bud off from the membrane, fuse with it, or fuse with other vesicles.

The movement of a large substance into a cell by means of a vesicle is called *endocytosis*. During endocytosis, shown in **Figure 10,** the cell membrane forms a pouch around the substance. The pouch then closes up and pinches off from the membrane to form a vesicle inside the cell. Vesicles that form by endocytosis may fuse with lysosomes or other organelles.

The movement of material out of a cell by means of a vesicle is called *exocytosis*. During exocytosis, shown in **Figure 10,** vesicles inside the cell fuse with the cell membrane. From the cell membrane, the contents of the vesicle are released to the outside of the cell. Cells use exocytosis to export proteins modified by the Golgi apparatus. Some protists release their waste products through this process. Some cells also use exocytosis to remove bacteria or other microbes.

ACADEMIC VOCABULARY
release to set free

Reading Check *What is the structure of the vesicle membrane?*

Section 2 Review

KEY IDEAS

1. **Compare** the functions of channel proteins and carrier proteins in facilitated diffusion.
2. **Explain** why the presence of dissolved particles on one side of a membrane results in diffusion of water across the membrane.
3. **List** two ways that a cell can move a substance against its concentration gradient.

CRITICAL THINKING

4. **Applying Logic** Based on have learned about homeostasis and osmosis, why should humans avoid drinking sea water?
5. **Predicting Outcomes** If a cell were unable to make ATP, how would the cell membrane's transport processes be affected?

METHODS OF SCIENCE

6. **Designing an Experiment** What data would a biologist need to collect to determine whether a specific molecule is transported into cells by diffusion, by facilitated diffusion, or by active transport?

Answers to Section Review

1. Channel proteins act as tunnels through the lipid bilayer for ions, sugars, and amino acids—substances that have the right size and charge. Carrier proteins bind to substances with the right shape, moving these substances to the other side of the cell membrane.
2. Dissolved particles reduce the number of water molecules that can move freely on that side. Water then moves by osmosis from the side where the free water molecule concentration is higher to the side where the concentration is lower.
3. pumps and vesicles
4. Sea water has a higher concentration of salt than that in the fluids surrounding human cells. Drinking sea water increases the concentration of salt in the body's fluids, which causes water to leave the cells by osmosis.
5. Active transport processes would stop, because they use the energy in ATP. Passive transport processes would continue until the concentration gradients disappeared.
6. size of molecule, polarity of molecule, whether the molecule can accumulate inside a cell despite higher concentration inside than outside, and whether the cell uses up more energy in the presence of the molecule than in its absence

Teaching Key Ideas

Contrasting Processes Direct students to look at **Figure 10.** Two opposite processes are shown. Ask students to cite evidence from the diagram that the processes are opposite. To many students, the diagrams will look the same unless you help them see the differences. LS Visual

Teaching Key Ideas

Phagocytosis Remind students how amoebas take in food and release wastes through phagocytosis. Compare this process of taking in fragments of organic matter or entire cells and releasing wastes with endocytosis and exocytosis.

Close

Formative Assessment

The direction of water movement in cells depends on _____.

A. which carrier proteins are in the cell membrane (Incorrect. Carrier proteins transport materials other than water.)
B. whether the surrounding solution is hypertonic, hypotonic, or isotonic (Correct! The concentration of water in the environment determines whether it moves in or out of the cell.)
C. the actions of the sodium-potassium pump (Incorrect. This pump moves sodium and potassium against the concentration gradient.)
D. whether vesicles are present (Incorrect. Vesicles help cells take in fragments of organic matter or entire cells.)

Section 3

Section 3 Cell Communication

Key Ideas	Key Terms	Why It Matters
How do cells use signal molecules? How do cells receive signals? How do cells respond to signaling?	signal receptor protein second messenger	Cells developed sophisticated methods of communication long before humans developed the Internet, cell phones, or even regular conversation.

Focus

This section describes how cells communicate and coordinate activities.

Bellringer

Use the Bellringer transparency to prepare students for this section.

Teach

Demonstration

Sending Signals Play a short game of "telephone" with the class. Write a statement on a piece of paper. Have one student whisper that message into the ear of the next student and so on through the class. Have the last student say aloud what he or she heard. Have students compare this final statement with the original. Then, review the text headings and diagrams to provide students with an overview of how messages sent between cells are very specific and the importance of a message being received accurately. LS Verbal

Answers to Caption Questions

Figure 11: specific; only the phone with the correct phone number can receive and respond to the signal

Figure 12: squares

We communicate in many ways to share information. In **Figure 11,** one person is surfing the Internet, another is talking on her cell phone, and two are having a face-to-face conversation. All of these are forms of communication. To coordinate activities, information must be shared. Cells in multicellular organisms depend on the activities of other cells to survive. Even unicellular organisms need to communicate—for example, to find a mate.

Sending Signals

You use different methods to communicate in different ways. You may whisper a secret to a trusted friend, or you may shout a warning to several people nearby. You may phone a friend who is far away, or you may put an ad in the newspaper for everyone to see.

Cells also use various methods of communication. These methods vary depending on whether the target is specific or general. They also depend on whether the target is nearby or far away. **Cells communicate and coordinate activity by sending chemical signals that carry information to other cells.** A *signaling cell* produces a **signal,** often a molecule, that is detected by the *target cell.* Typically, target cells have specific proteins that recognize and respond to the signal.

Figure 11 This young man dials a phone number, which sends a signal to a target. **Is this target general or specific?**

Targets Neighboring cells can communicate through direct contact between their membranes. Short-distance signals may act locally, a few cells away from the originating cell. Long-distance signals are carried by hormones and nerve cells. Hormones are signal molecules that are made in one part of the body. Hormones are distributed widely in the bloodstream throughout the body, but they affect only specific cells. Nerve cells also signal information to distant locations in the body, but their signals are not widely distributed.

Environmental Signals While most signal molecules originate within the body, some signals come from outside. For example, light has a great effect on the action of hormones in plants. The length of the day determines when some plants flower.

Reading Check *Compare the targets of signaling hormones and nerve cells.*

Key Resources

Transparencies
B20 Changes in Permeability

Differentiated Instruction

English Learners

Understanding Terms To help English learners differentiate between "signal" and "target" cells, focus on the adjectives. Relate "signaling" to other types of signals, such as a hand wave, an ambulance siren, or a dog barking. Have them describe what the "target" is in each instance. LS Verbal

Hands-On

QuickLab

10 min

Sensitive Plants

The sensitive plant *(Mimosa pudica)* reacts to touch. This reaction results from rapid cell-to-cell communication.

Procedure

1. Observe and sketch the extended leaves on the *Mimosa* plant branch.
2. Touch the tip of the end leaf on this branch. Observe the plant's reaction.
3. Make a sketch showing the branch's new appearance.

Analysis

1. **Identify** what stimulus produced the plant's response.
2. **Describe** the plant's response.

3. **Explain** whether the reaction behavior was communicated beyond the leaf that was touched.
4. CRITICAL THINKING **Making Inferences** Plants can respond to touch, although they lack a nervous system. Propose a mechanism for the response you observed.

Receiving Signals

A target cell is bombarded by hundreds of signals. But it recognizes and responds only to the few signals that are important for its function. This response to some signals, but not to others, is made possible by **receptor proteins,** such as the ones in the cell's membrane.

signal anything that serves to direct, guide, or warn

receptor protein a protein that binds specific signal molecules, which causes the cell to respond

Binding Specificity A receptor protein binds specific substances, such as signal molecules. The outer part of the protein is folded into a unique shape, called the *binding site*. **A receptor protein binds only to signals that match the specific shape of its binding site.** As **Figure 12** shows, only signal molecules that have the "right" shape can fit into the receptor protein. Signal molecules that have the "wrong" shape have no effect on that particular receptor protein. A cell may also have receptor proteins that bind to molecules in its environment. Some cells may have receptor proteins that can detect and respond to light. Receptor proteins enable a cell to detect its environment.

SCILINKS
www.scilinks.org
Topic: Receptor Proteins
Code: HX81274

Effect Once it binds the signal molecule, the receptor protein changes its shape in the membrane. This change in shape relays information into the cytoplasm of the target cell.

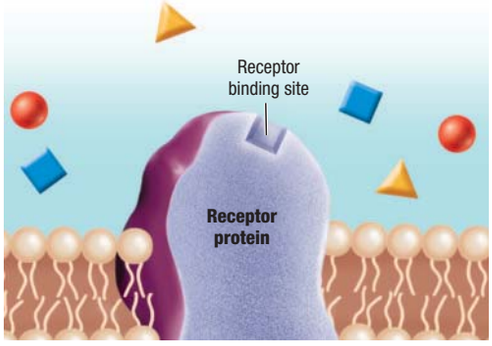


Figure 12 The binding site of this receptor protein has a specific shape to which only one type of signal molecule can bind. **Which of these molecules would bind with the receptor?**

Differentiated Instruction

Advanced Learners/GATE

Developing Metaphors Have students create a variety of examples to share with the class that demonstrate the importance of selectivity in responding to various signals. For example, students at the beach would respond to a lifeguard's flag differently than a referee's flag at a football game. An accurate interpretation of the message represented by the lifeguard's flag would be very important to the safety of the individual. Have students display their work as posters. These posters will be helpful for struggling readers and English learners. LS Verbal

QuickLab

Teacher's Notes Mimosa leaves will curl in response to being shaken, heated, or rapidly cooled. A gentle touch will result in a slower response, so that the response can be more easily observed.

Materials
- mimosa plant

Answers to Analysis

1. touching the tip of a leaf
2. Individual leaflets curled up.
3. Yes. The neighboring leaflets curled, starting at the leaflet that was first stimulated.
4. Plants release messenger chemicals or electrical impulses as a source of cell-to-cell communication.

Teaching Key Ideas

Selectivity Use **Figure 12** to emphasize the selective nature of the receptor proteins and the importance of not responding to every signal. Use the toddler "shape matching" toy again to demonstrate the specificity of binding sites. LS Visual

Teach, *continued*

READING TOOLBOX

Finding Examples Ion channels are the examples of transport proteins on this page.

Close

Formative Assessment

Which of the following changes shape immediately after a receptor protein binds with a signal molecule?

A. receptor protein (Correct! The binding of a signal molecule results in a change in the receptor protein's shape.)

B. signal molecule (Incorrect. The signal molecule does not change shape after binding.)

C. transport proteins (Incorrect. Transport proteins may change as a result of the change in the receptor protein's shape, but the change in the receptor protein's shape occurs immediately after the receptor protein binds with the signal molecule.)

D. second messenger (Incorrect. After binding, the change in the receptor protein's shape results in the activation of an intermediary protein, which activates an enzyme, which then forms a second messenger.)

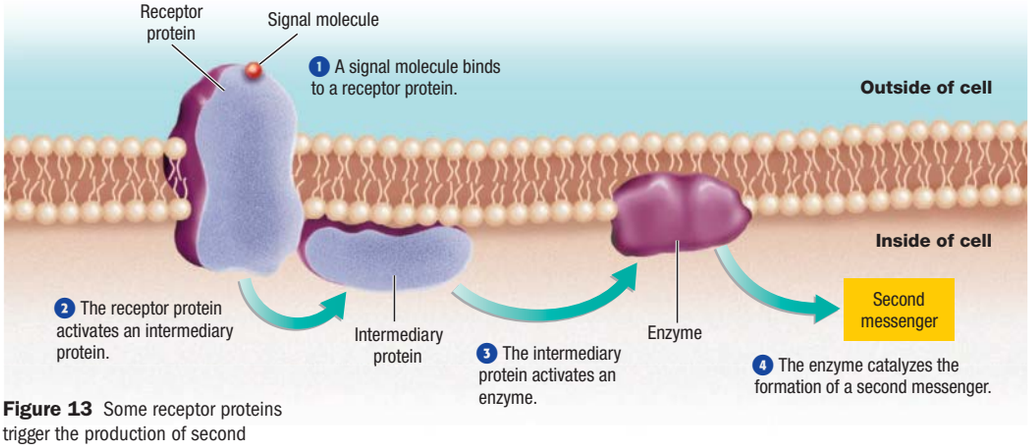


Figure 13 Some receptor proteins trigger the production of second messengers.

READING TOOLBOX

Finding Examples Search the text on this page to find an example of the function of a transport protein.

second messenger a molecule that is generated when a specific substance attaches to a receptor on the outside of a cell membrane, which produces a change in cellular function

Responding to Signals

When a signal molecule binds to a receptor protein, the protein changes shape, which triggers changes in the cell membrane. **The cell may respond to a signal by changing its membrane permeability, by activating enzymes, or by forming a second messenger.**

- **Permeability Change** Transport proteins may open or close in response to a signal. For example, a nerve impulse may result when ion channels in nerve cells open after receiving a signal.
- **Enzyme Activation** Some receptor proteins activate enzymes in the cell membrane. Some receptors are enzymes themselves and are activated by the binding of a signal molecule. Enzymes trigger chemical reactions in the cell.
- **Second Messenger** Binding of a signal molecule outside the cell may cause a second messenger to form, as **Figure 13** shows. The **second messenger** acts as a signal molecule within the cell and causes changes in the cytoplasm and nucleus.

Reading Check *How does membrane permeability change?*

Section 3 Review

KEY IDEAS

1. **Identify** one function of signal molecules in a multicellular organism.
2. **Describe** the relationship between receptor proteins and signal molecules.
3. **List** three ways that a receptor protein may respond when a signal molecule binds to it.

CRITICAL THINKING

4. **Applying Logic** Why do you think that there are many forms of communication between body cells?
5. **Applying Logic** Why is specificity between a receptor protein and a signal molecule important?

WRITING FOR SCIENCE

6. **Finding Information** Use library or Internet resources to research a human disease that results from problems in the transport of molecules across the cell membrane. Describe the disease's symptoms and treatments. Summarize your findings in a written report.

Answers to Section Review

1. to carry information to other cells of the body
2. Receptor proteins bind to the signal molecules with a very specific complementary shape.
3. Receptor proteins can activate enzymes, cause a change in membrane permeability, or cause the formation of a second messenger that will have an effect in another part of the cell.
4. Many different forms of communication might be due to the many different types of body cells and the need for specific messages over long distances.
5. Specificity helps ensure that only that particular signal molecule is received by a particular cell and responded to.
6. Answers will vary. Cystic fibrosis is caused by a mutation that results in a faulty transport protein that no longer allows chloride ions in and out of the cell, or is missing altogether. Students might also research pigmentation defects that result from abnormal transport of melanin granules, cancer due to defective transport of growth factor receptors, or other diseases.

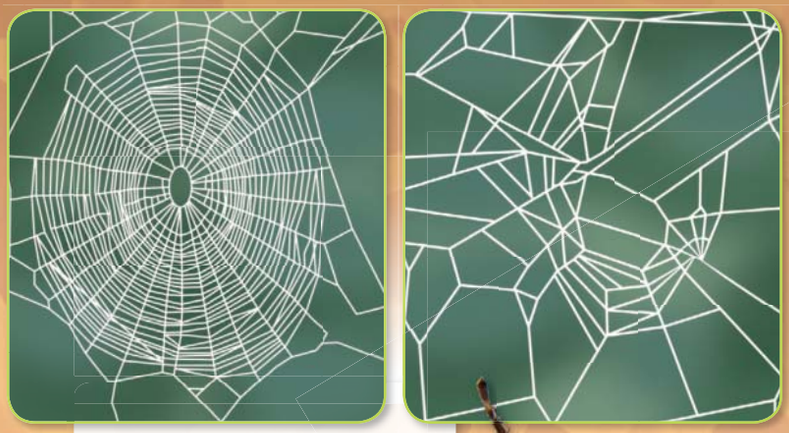
Why It Matters

Heady Effects

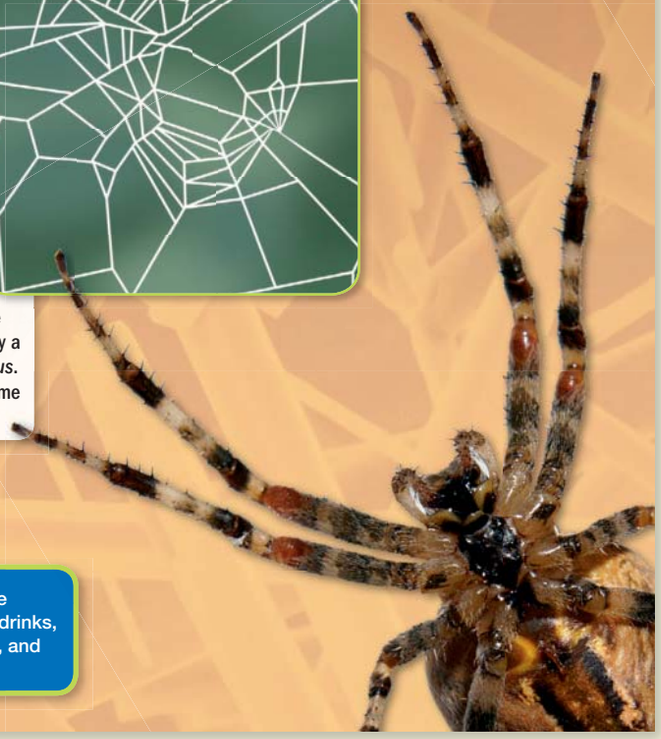
Many people start their day with a hot cup of coffee. Coffee contains a chemical stimulant, caffeine, that produces a feeling of heightened alertness.

Caffeine

The shape of the caffeine molecule is similar to the shape of a signal molecule that your body produces naturally. Receptor proteins respond to this signal in a chain of events that increases heart rate, blood flow, and the amount of sugar in the bloodstream.



Wacky Webs Most spider webs look like the one on the left. This web was created by a common garden spider, *Araneus diadematus*. The web on the right was created by the same spider after it was fed caffeine-dosed flies.



Quick Project Find out the average caffeine content in milligrams (mg) of coffee, tea, cola drinks, energy drinks, chocolate milk, dark chocolate, and milk chocolate.

Why It Matters

Teacher's Notes Caffeine—one of a group of chemicals called xanthines—is found not only in coffee, but also in tea, many soft drinks (not just colas), chocolate, and over-the-counter as a stimulant. While heightened alertness may come with a normal dose—the amount found in one to three cups of coffee—more than that can produce nervousness, insomnia, and tremors. Student athletes who use large amounts of caffeine may exhibit irritability, hypertension, seizures, or other symptoms. While the effects of caffeine on athletic performance are not significant, the NCAA limits the amount of caffeine in a urine specimen to 15 micrograms per mL, or the amount in about five to six cups of coffee.

READING TOOLBOX

Visual Literacy Have students review the photographs of the web before and after the spider was fed the caffeine-dosed flies. Help them hypothesize how the responses that caffeine evokes results in a skewed web. LS Verbal

Answers to Research

(average values)
Coffee (8 oz, brewed) 135 mg
Tea (8 oz, brewed) 50 mg
Sport drink (i.e. Gatorade®) 0 mg
Cola drink (12 oz) 45 mg
Chocolate milk (8 oz) 5 mg
Dark chocolate (1.5 oz) 31 mg
Milk chocolate (1.5 oz) 10 mg

Lab

Inquiry

Chapter 8 Lab

Time Required

One 45-minute lab period

Safety Cautions

Phenolphthalein solutions are flammable, and the vapors can explode when mixed with air. Make sure that there are no flames or sources of ignition, such as sparks, when you are using the phenolphthalein solution.

Tips and Tricks

Agar Preparation Remember to wear chemical splash safety goggles when working with sodium hydroxide. Prepare phenolphthalein agar by adding drops of 0.1 M sodium hydroxide solution (prepared by using 4 g NaOH diluted to 1 L) to turn the agar red. Pour the mixture into a flat pan to a depth of slightly more than 3 cm. After the agar hardens, cut it into 3 × 3 × 6 cm rectangles.

Make sure that students rinse their knives between each cutting to prevent vinegar on the previous cube from contaminating the next cube.

Disposal Wrap the phenolphthalein agar in newspaper, and then place the newspaper in the garbage. Dilute the vinegar with water, and then pour the vinegar down the sink.

Objectives

- Relate a cell's size to its surface area–to-volume ratio.
- Predict how the surface area–to-volume ratio of a cell will affect the diffusion of substances into the cell.

Materials

- safety goggles
- lab apron
- disposable gloves
- block of phenolphthalein agar (3 cm × 3 cm × 6 cm)
- knife, plastic
- ruler, metric
- beaker, 250 mL
- vinegar, 150 mL
- spoon, plastic
- paper towel

Safety

Cell Size and Diffusion

Substances enter and leave a cell in several ways, including by diffusion. Substances that a cell needs must come from outside the cell to the cell's center. How easily a cell can exchange substances depends on the ratio of its surface area to its volume (surface area ÷ volume). Surface area is a measure of the exposed outer surface of an object. Volume is the amount of space that an object takes up.

In this lab, you will design an experiment to investigate how a cell's size affects the diffusion of substances into the cell. To do so, you will make cell models using agar that contains phenolphthalein. Phenolphthalein is an indicator that changes color in the presence of an acidic solution.

Preparation

1. SCIENTIFIC METHODS **State the Problem** How does a cell's size affect the delivery of substances via diffusion to the center of the cell?
2. SCIENTIFIC METHODS **Form a Hypothesis** Form a testable hypothesis that explains how a cell's size affects the rate of diffusion of substances from outside the cell.

Procedure

Design an Experiment

1. Design an experiment that tests your hypothesis and that uses the materials listed for this lab. Predict what will happen during your experiment if your hypothesis is correct.

Answer to Preparation

2. Sample answer: The larger the cell, the longer it takes for substances to diffuse into the cell's center.

Answers to Procedure

Sample Procedure

1. Trim the agar block with a knife to make three cubes with side lengths of 1 cm, 2 cm, and 3 cm. Calculate the surface area, volume, and surface area–to-volume ratio for each cube.
2. Place the three cubes in the beaker, and cover them with vinegar. Using the plastic spoon, turn the cubes frequently.
3. After 10 minutes, use the spoon to remove the agar cubes. Blot the cubes dry using a paper towel.
4. Cut each cube in half. Measure the distance (in mm) the vinegar diffused.
5. Calculate the rate of diffusion (mm/min).

2. Write a procedure for your experiment. Identify the variables that you will control, the experimental variables, and the responding variables. Construct any tables that you will need to record your data. Make a list of all safety precautions that you will take. Have your teacher approve your procedure before you begin.

Conduct Your Experiment

3. Put on safety goggles, gloves, and a lab apron.
4. Carry out your experiment. Record your observations in your data table.
5. Follow your teacher's instructions for cleaning up your lab materials. Wash your hands before leaving the lab.

Diffusion in Cubes

Size (cm)	Ratio	Distance (mm)

Analyze and Conclude

1. **Interpreting Observations** Describe any changes in the appearance of the agar cubes. Explain why these changes occurred.
2. **Summarizing Results** Make a graph labeled "Diffusion distance (mm)" on the vertical axis and "Surface area–to-volume ratio" on the horizontal axis. Plot your group's data on the graph.
3. SCIENTIFIC METHODS **Analyzing Results** Using the graph you made in item 2, make a statement relating the surface area–to-volume ratio and the distance that the substance diffuses.
4. **Summarizing Results** Make a second graph using your group's data. Label the vertical axis "Rate of diffusion (mm/min)" (distance that vinegar moved ÷ time). Label the horizontal axis "Surface area–to-volume ratio." Plot your group's data on the graph.
5. **Analyzing Results** Referring to the graph that you made in item 4, write a statement that relates the surface area–to-volume ratio and the rate at which the substance diffuses.
6. SCIENTIFIC METHODS **Evaluating Methods** In what ways do your agar models simplify or fail to simulate the features of cells?
7. **Calculating** Calculate the surface area and the volume of a cube that has a side length of 5 cm. Calculate the surface area and volume of a cube that has a side length of 10 cm. Determine the surface area–to-volume ratio of each cube. Which cube has the greater surface area–to-volume ratio?
8. SCIENTIFIC METHODS **Evaluating Conclusions** How does the size of a cell affect the rate at which substances diffuse into the cell?
9. **Further Inquiry** Write a new question about cell size and diffusion that could be explored in another investigation.

SCILINKS
www.scilinks.org
Topic: Diffusion
Code: HX80406

Extensions

10. How does cell transport in prokaryotic cells differ from cell transport in eukaryotic cells?
11. Which of the following can diffuse across the cell membrane without the help of a transport protein: water, carbohydrates, lipids, or proteins?

Answers to Analyze and Conclude

1. Cubes appear light pink near their surfaces because the phenolphthalein changed color in response to the acid in the vinegar.
2. The line plotted on the graph should be horizontal.
3. The diffusion distance is the same regardless of the surface area–to-volume ratio.
4. The line plotted on the graph should be horizontal.
5. The rate of diffusion is constant regardless of the surface area–to-volume ratio.
6. Agar models ignore the selective permeability of cell membranes, the role of membrane proteins in facilitated diffusion and active transport, and other mechanisms of cell transport.
7. For a cube with a side length of 5 cm: surface area = 150 cm^2, volume = 125 cm^3; surface-to-volume ratio = 6:5. For a cube with side length of 10 cm: surface area = 600 cm^2; volume = 1,000 cm^3; surface-area-to-volume ratio = 3:5. The small cube has the greater surface-area-to-volume ratio.
8. The size of the cell does not affect the rate of diffusion.
9. Sample answer: How does cell size affect the amount of a substance that diffuses into it?

Answers to Extensions

10. The transport of materials across the cell membrane is essentially the same in prokaryotes and eukaryotes, except that prokaryotes do not exhibit endocytosis or exocytosis.
11. water and lipids

Key Resources

- Holt Lab Generator
- Lab Datasheet (Levels A, B, C)
- Holt Science Biology Video Labs
- Virtual Investigations

Chapter 8

SUPER SUMMARY

Have students connect the major concepts in this chapter through an interactive Super Summary. Visit **go.hrw.com** and type in the key word **HX8CENS** to access the Super Summary for this chapter.

Reteaching Key Ideas

Identifying Structure and Function Ask students to make a drawing of a cell membrane, including the lipid bilayer and the types of proteins in the membrane. Have them use captions to describe the functions of the cell membrane. LS Visual

Demonstrating Transport Divide students into four groups, and assign each group the task of demonstrating simple diffusion, facilitated diffusion, osmosis, or active transport. For example, part of a skit might have one student grasping another's arm to show binding. LS Kinesthetic

Constructing a Graphic Organizer Ask students to construct a graphic organizer that shows the cause and effect relationships that are involved in cell communication. LS Visual

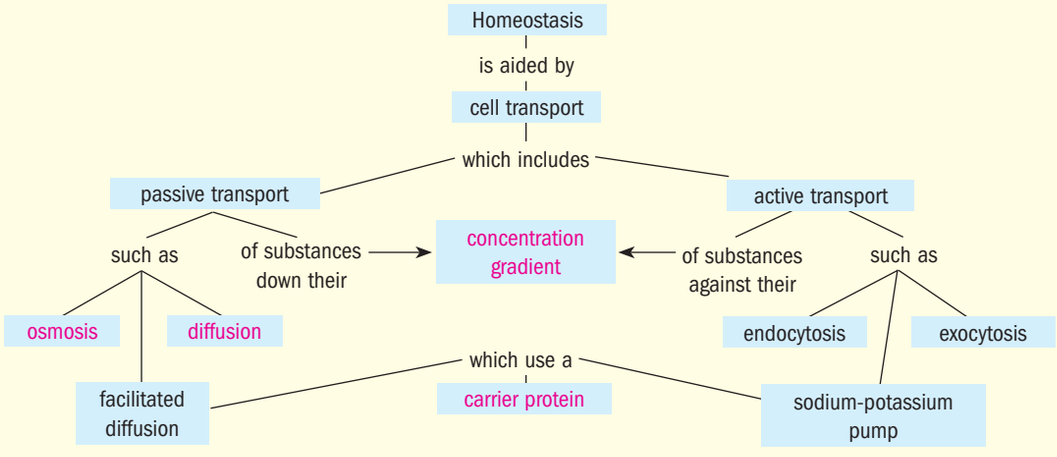
Chapter 8 Summary

go.hrw.com
SUPER SUMMARY
Keyword: HX8CENS

Key Ideas	Key Terms
1 Cell Membrane › One way that a cell maintains homeostasis is by controlling the movement of substances across the cell membrane. › The lipid bilayer is selectively permeable to small, nonpolar substances. › Proteins in the cell membrane include cell-surface markers, receptor proteins, enzymes, and transport proteins.	**phospholipid** (176) **lipid bilayer** (176)
2 Cell Transport › In passive transport, substances cross the cell membrane down their concentration gradient. › Osmosis allows cells to maintain water balance as their environment changes. › Active transport requires energy to move substances against their concentration gradients.	**equilibrium** (178) **concentration gradient** (178) **diffusion** (178) **carrier protein** (178) **osmosis** (180) **sodium-potassium pump** (182)
3 Cell Communication › Cells communicate and coordinate activity by sending chemical signals that carry information to other cells. › A receptor protein binds only to the signals that match the specific shape of its binding site. › The cell may respond to a signal by changing its membrane permeability, by activating enzymes, or by forming a second messenger.	**signal** (184) **receptor protein** (185) **second messenger** (186)

Answer to Concept Map

The following is one possible answer to Chapter Review question 2.



Chapter 8 Review

READING TOOLBOX

1. **Four-Corner Fold** Make a four-corner fold to compare methods cells use to transport substances across their membranes.
2. **Concept Map** Make a concept map that shows how cells maintain homeostasis. Try to include the following terms in your map: *concentration gradient, diffusion, osmosis,* and *carrier protein.*

Using Key Terms

3. Differentiate between *diffusion* and *osmosis*.

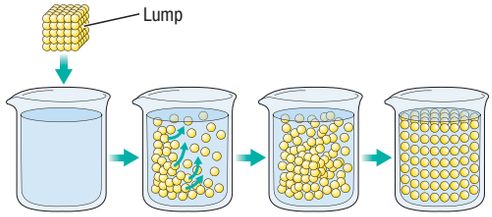
Use each of the following terms in a separate sentence.

4. *equilibrium*
5. *concentration gradient*

Understanding Key Ideas

6. In the cell membrane, the fatty acid tails of phospholipid molecules point
   - **a.** toward each other.
   - **b.** away from each other.
   - **c.** toward the cytoplasm.
   - **d.** toward the outside of the cell.
7. What keeps membrane proteins within the cell membrane?
   - **a.** the pressure of the cytoskeleton against the proteins in the membrane
   - **b.** the pressure of the phospholipids in the lipid bilayer against the proteins in the membrane
   - **c.** the pressure of the cytoplasm against the proteins in the membrane
   - **d.** the attractions between the polar and nonpolar portions of the proteins and the lipid bilayer
8. What does the sodium-potassium pump do?
   - **a.** It moves sodium and potassium into the cell.
   - **b.** It moves sodium and potassium out of the cell.
   - **c.** It moves sodium into the cell and potassium out of the cell.
   - **d.** It moves sodium out of the cell and potassium into the cell.
9. A cell that produces a signal molecule is called a
   - **a.** target cell.
   - **b.** marker cell.
   - **c.** recipient cell.
   - **d.** signaling cell.
10. Signal molecules bind to
    - **a.** carbohydrates.
    - **b.** phospholipids.
    - **c.** marker proteins.
    - **d.** receptor proteins.

Use the diagram to answer the questions that follow.



11. What process does the diagram show?
    - **a.** osmosis
    - **b.** diffusion
    - **c.** active diffusion
    - **d.** facilitated diffusion
12. In this process, the substance moves
    - **a.** down its concentration gradient.
    - **b.** independently of its concentration.
    - **c.** against its concentration gradient.
    - **d.** from an area of lower concentration to an area of higher concentration.

Explaining Key Ideas

13. **Explain** why the cell needs a selectively permeable barrier.
14. **Describe** the structure of the lipid bilayer of the cell membrane.
15. **Relate** osmosis and diffusion.
16. **Contrast** the action of carrier proteins in facilitated diffusion and active transport.
17. **Explain** how the sodium-potassium pump contributes to homeostasis in an animal.
18. **Compare** two ways that the binding of a signal molecule to a receptor protein causes a change in the activity of the receiving cell.

Assignment Guide

Section	Questions
1	6, 7, 13, 14, 19, 20, 21
2	1, 2, 3, 4, 5, 8, 11, 12, 15, 16, 17, 22, 23, 24, 28, 29, 30, 31
3	9, 10, 18, 25, 26, 27

Review

Reading Toolbox

1. Check students' work for accuracy.
2. See previous page for answer to concept map.

Using Key Terms

3. *Diffusion* is the movement of a substance down its concentration gradient whereas osmosis is the diffusion of water.
4. When a space is filled evenly, a state called *equilibrium* is reached.
5. In active transport, substances move against the *concentration gradient.*

Understanding Key Ideas

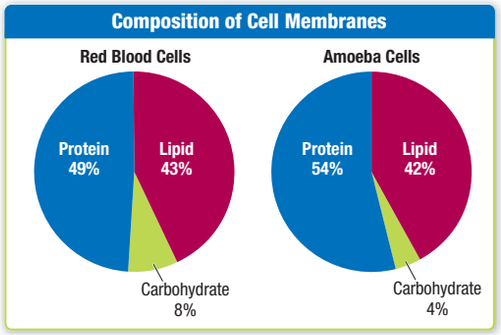
6. a 7. d 8. d 9. d
10. d 11. b 12. a

Explaining Key Ideas

13. A selectively permeable barrier enables needed materials to pass into and out of the cell while keeping other materials out.
14. The phospholipids are oriented in a double layer. The nonpolar tails make up the interior of the lipid bilayer. The polar heads are oriented toward the outside and interior of the cell.
15. Osmosis is a type of diffusion that involves free water molecules.
16. In facilitated diffusion, carrier proteins move substances down their concentration gradients. In active transport, carrier proteins use energy to move substances against their concentration gradient.
17. The pump prevents sodium ions from accumulating in the cell, thus helping the cell maintain its sodium ion balance. Osmosis resulting from an increased sodium ion concentration could cause the cell to swell and burst. Thus, the sodium-potassium pump also helps the cell maintain its water balance.
18. When a signal molecule binds to a receptor protein, the receptor protein may cause an ion channel to open. Alternatively, the activated receptor protein may activate a second messenger, which may activate enzymes or open ion channels.

Using Science Graphics

The amounts of protein, lipid, and carbohydrate found in the cell membrane differ depending on the type of cell. The two diagrams show the composition of the cell membrane of a human red blood cell and the cell membrane of an amoeba, a single-celled protist. Use the diagrams to answer the questions that follow.



19. **Identify** the type of cell in which the percentage of the cell membrane made up of proteins is larger.
20. **Identify** the type of cell in which the ratio of carbohydrate to lipid is smaller.

Critical Thinking

21. **Recognizing Relationships** How does the arrangement of phospholipids influence the permeability of the lipid bilayer?
22. **Applying information** Using what you know about osmosis, explain what would happen to a jellyfish if it were placed in a freshwater lake.
23. **Applying Information** During exercise, potassium ions tend to accumulate in the fluid that surrounds muscle cells. Which protein in the cell membrane helps muscle cells counteract this tendency? Explain your answer.
24. **Inferring Relationships** When a cell takes in substances through endocytosis, the outside of the cell membrane becomes the inside of the vesicle. What might this transformation suggest about the structure of the cell membrane?
25. **Making Inferences** What would happen if all receptor proteins were removed from the membranes of all liver cells?

Alternative Assessment

26. **Cellular Conversation** When a physician taps your knee, your leg automatically jerks. Use Internet or library resources to learn about the rapid cell signaling that is involved in this knee-jerk reflex. Write a "conversation" that could occur between these cells. Create a comic strip, a short story, or a skit based on the conversation, and present it to your class.

Why It Matters

27. **Research** The molecular structure of caffeine is similar to the structure of a signal molecule that your body produces naturally. Find out what this signal molecule is, and compare its structure to caffeine's. Propose some properties of the binding site of the receptor protein to which caffeine binds.

Methods of Science

28. **Evaluating Models** A student wants to model osmosis by placing a mesh bag in a solution of salt water. The bag fills up with a saltwater concentration that is the same as the concentration of the solution outside of the bag. Is this model a good model for osmosis?
29. **Connecting Concepts** Transport proteins in the membrane of a lysosome move hydrogen ions into the lysosome. Use this information to predict whether digestive enzymes in a lysosome work best in a neutral, basic, or acidic environment.

Math Skills

30. **Concentration** The concentration of a solution in Beaker A is 0.4 g/mL. Beaker B contains 8 mL of water. Two milliliters of the solution in Beaker A is poured into Beaker B. When the solution in Beaker B reaches equilibrium, what is its concentration?
31. **Ratios** Suppose a sodium-potassium pump transports 12 sodium ions out of the cell. How many potassium ions did this pump transport into the cell?

Using Science Graphics

19. the amoeba cell
20. the amoeba cell

Critical Thinking

21. Nonpolar molecules can pass through the membrane unassisted because the nonpolar lipid tails in the interior of the bilayer repel water and other polar/water-soluble molecules and ions.
22. The jellyfish's tissues would absorb freshwater by osmosis and most likely die.
23. The sodium-potassium pump transports potassium ions into muscle cells.
24. This suggests that the cell membrane's inner and outer layers have common elements and may be very similar in structure.
25. The liver cells would be unable to communicate with each other and cells in the rest of the body; the organism would die.

Alternative Assessment

26. Students' stories and cartoons should not be overly complicated, including just a few main cell types.

Why It Matters

27. Caffeine replaces adenosine in the binding sites, changing normal cell responses. So, the binding site must be complementary to the parts that are similar in caffeine and adenosine.

Methods of Science

28. No, because the bag is not selectively permeable.
29. One can infer that the inside of the lysosome is acidic because of the hydrogen ions in lysosomes.

Math Skills

30. $0.4\ g/mL \times 2\ mL = 0.8\ g$ of sugar; $2\ mL + 8\ mL = 10\ mL$; The concentration of the solution in beaker B will be 0.8 g/10 mL, or 0.08 g/mL.
31. A sodium potassium pump transports 2 potassium ions into the cell for every 3 sodium ions it transports out of the cell. $12 \times 2/3 = 8$. The pump transports 8 potassium ions into the cell.

Chapter 8

Standardized Test Prep

TEST TIP If time permits, take short mental breaks to improve your concentration during a test.

Science Concepts

1. Why are phospholipids ideal for making up the selectively permeable cell membrane?

A They repel small ions.
B They react readily with water molecules.
C They form triple layers that insulate the cell.
D They have a nonpolar and a polar region.

2. The membrane-bound proteins that identify a cell type are

F enzymes.
G glycoproteins.
H receptor proteins.
J transport proteins.

3. Which substance crosses the cell membrane by facilitated diffusion?

A oxygen
B sugar
C sodium ion
D chloride ion

4. The concentration of molecule X is greater inside a cell than it is outside the cell. If the cell acquires X from its surroundings, X must cross the cell membrane by means of

F exocytosis.
G active transport.
H receptor proteins.
J second messengers.

5. A cell begins to swell when it is placed in an unknown solution. What can you conclude about the solution?

A The solution is isotonic.
B The solution is hypotonic.
C The solution is saturated.
D The solution is hypertonic.

6. Which proteins transmit information into a cell by binding to signal molecules?

F end proteins
G marker proteins
H channel proteins
J receptor proteins

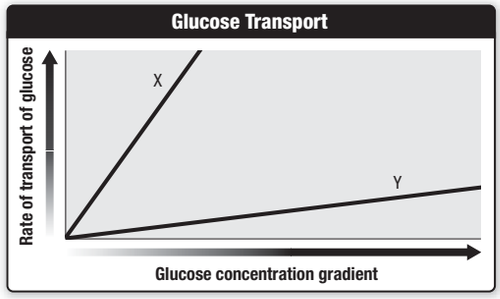
Math Skills

7. What will happen to a cell (1% salt) that is placed in a 5% salt solution?

A Salt moves in.
B Salt moves out
C Water moves in.
D Water moves out.

Using Science Graphics

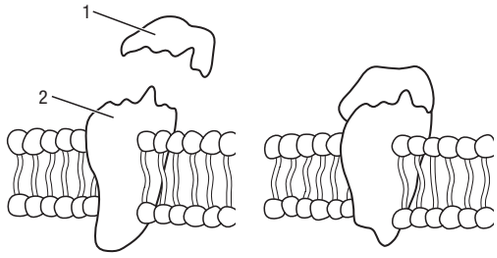
This graph shows the rate of glucose transport across a cell membrane versus the concentration gradient. Use the graph to answer the question that follows.



8. If Line X represents the facilitated diffusion of glucose, what could Line Y represent?

A diffusion of glucose through osmosis
B diffusion of glucose through the lipid bilayer
C diffusion of glucose through carrier proteins
D active transport of glucose through carrier proteins

This diagram shows a cellular process that occurs at the cell membrane. Use the diagram to answer the question that follows.



9. What happens immediately after structure 1 binds to structure 2?

F Structure 1 is destroyed.
G Structure 2 becomes larger.
H Structure 2 changes in shape.
J Structure 1 is released from the membrane.

State Resources

For specific resources for your state, visit go.hrw.com and type in the keyword **HSHSTR**.

Test Practice with Guided Reading Development

Answers

1. D	**2.** G	**3.** B
4. G	**5.** B	**6.** J
7. D	**8.** B	**9.** H

TEST DOCTOR

Question 4 **F** is incorrect because materials move from inside the cell to the outside through exocytosis. **G** is correct because substances move against the concentration gradient during active transport. **H** is incorrect because receptor proteins receive signals from other cells. **J** is incorrect because second messengers stem from actions by receptor proteins.

Question 5 **A** is incorrect because an isotonic solution has the same concentration as the cell. **B** is correct because in a hypotonic solution, the concentration of water outside is greater than the water concentration inside. **C** is incorrect because a saturated solution is not necessarily hypotonic. **D** is incorrect because in a hypertonic solution, the concentration of water inside is greater than that outside.

Question 6 **F** is incorrect because this is not a category of protein. **G** is incorrect because marker proteins identify the type of cell. **H** is incorrect because channel proteins transport substances through the cell membrane. **J** is correct because receptor proteins bind to signal molecules, which causes changes in the cell membrane.