**KEY CONCEPT**

Cells are the basic unit of life.

<table>
<thead>
<tr>
<th>VOCABULARY</th>
</tr>
</thead>
<tbody>
<tr>
<td>cell theory</td>
</tr>
<tr>
<td>cytoplasm</td>
</tr>
</tbody>
</table>

**MAIN IDEA:** Early studies led to the development of the cell theory.

In a phrase, tell what each scientist did to help develop the cell theory.

<table>
<thead>
<tr>
<th>Scientist</th>
<th>Contribution to Cell Theory</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Hooke</td>
<td></td>
</tr>
<tr>
<td>2. Leeuwenhoek</td>
<td></td>
</tr>
<tr>
<td>3. Schleiden</td>
<td></td>
</tr>
<tr>
<td>4. Schwann</td>
<td></td>
</tr>
<tr>
<td>5. Virchow</td>
<td></td>
</tr>
</tbody>
</table>

6. What are the three parts of the cell theory?

7. Give two reasons why the cell theory is important.

   ________________________________
   ________________________________
   ________________________________
   ________________________________
   ________________________________
MAIN IDEA: Prokaryotic cells lack a nucleus and most internal structures of eukaryotic cells.

In the top left side of the Y shape below, write the characteristics of eukaryotic cells. In the top right side of the Y shape below, write the characteristics of prokaryotic cells. At the bottom of the Y shape below, write the characteristics that both kinds of cells have in common. Then lightly cross out those characteristics at the top of the Y.

**Vocabulary Check**

8. What is cytoplasm?

9. Where do you find organelles?

10. What statements summarize scientists’ concepts of cells?

11. Which type of cells have no nucleus?
SECTION 3.1 | CELL THEORY

Power Notes

Scientists who contributed to the cell theory:

The principles of cell theory:
1.
2.
3.

Important technological advances:

The cell theory is:

This is a _________ cell.

This is a _________ cell.

All cells have:
SECTION 3.1  CELL THEORY

Reinforcement

KEY CONCEPT  Cells are the basic unit of life.

The invention of the microscope in the late 1500s revealed to early scientists a whole new world of tiny cells. Most cells are so small that they cannot be seen without a microscope. The discoveries of scientists from the 1600s through the 1800s led to the cell theory, which is a unifying concept of biology. The cell theory has three major principles:

• All organisms are made of cells.
• All existing cells are produced by other living cells.
• The cell is the most basic unit of life.

All cells can be divided into two major groups: prokaryotic cells or eukaryotic cells. The main differences between the two kinds of cells are in their structure:

• Eukaryotic cells have a nucleus defined by a membrane, while prokaryotic cells have no nucleus.
• In eukaryotic cells, the DNA, or genetic information, is found in the nucleus. In prokaryotic cells, the DNA is found in the cytoplasm, the jellylike substance that fills both types of cells.
• Eukaryotic cells have organelles, structures that perform jobs for a cell. Most organelles are surrounded by membranes. Prokaryotic cells do not have organelles surrounded by membranes.

Prokaryotic cells make up organisms called prokaryotes. All prokaryotes are tiny and consist of single cells. Bacteria are prokaryotic cells. Eukaryotic cells make up eukaryotes. You are a eukaryote, as are plants and some types of single-celled organisms. All multicellular organisms, or organisms that have many cells, are eukaryotes.

1. What is the smallest, most basic unit of life?

2. Where is the DNA in a prokaryote? in a eukaryote?

3. Why would you need a microscope to see a prokaryotic organism?

4. A friend tells you he read somewhere that rotting garbage can turn into maggots, which are fly larvae, and the maggots then can grow into adult flies. What part of the cell theory could you use to refute his claim?
KEY CONCEPT
Eukaryotic cells share many similarities.

VOCABULARY

<table>
<thead>
<tr>
<th>cytoskeleton</th>
<th>Golgi apparatus</th>
<th>lysosome</th>
</tr>
</thead>
<tbody>
<tr>
<td>nucleus</td>
<td>vesicle</td>
<td>centriole</td>
</tr>
<tr>
<td>endoplasmic reticulum</td>
<td>mitochondrion</td>
<td>cell wall</td>
</tr>
<tr>
<td>ribosome</td>
<td>vacuole</td>
<td>chloroplast</td>
</tr>
</tbody>
</table>

MAIN IDEA: Cells have an internal structure.
1. Look at Figure 3.5 in your textbook. What are the functions of a cytoskeleton?

2. How is a cytoskeleton like your skeleton?

3. How is a cytoskeleton like your muscles?

MAIN IDEA: Several organelles are involved in making and processing proteins. Write either the function or the name of each organelle. Draw a sketch to help you remember it.

<table>
<thead>
<tr>
<th>Organelle</th>
<th>Function</th>
<th>Sketch</th>
</tr>
</thead>
<tbody>
<tr>
<td>4. nucleus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. ribosomes</td>
<td>helps in the production of proteins and lipids</td>
<td></td>
</tr>
<tr>
<td>6. Golgi apparatus</td>
<td>carries certain molecules from place to place within a cell</td>
<td></td>
</tr>
</tbody>
</table>
**MAIN IDEA:** Other organelles have various functions.
Write the function of each organelle. Draw a sketch to help you remember it.

<table>
<thead>
<tr>
<th>Organelle</th>
<th>Function</th>
<th>Sketch</th>
</tr>
</thead>
<tbody>
<tr>
<td>9. mitochrondion</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. vacuole</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. lysosome</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. centriole</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**MAIN IDEA:** Plant cells have cell walls and chloroplasts.

13. What role do cell walls play in a plant?

14. What is the difference between a cell wall and a cell membrane?

15. Why are chloroplasts important?

**Vocabulary Check**

16. Which cell part is a maze of folded membranes where proteins and lipids are produced?

17. Which cell part converts food into energy that is usable by a cell?
### SECTION 3.2 | CELL ORGANELLES

#### Power Notes

<table>
<thead>
<tr>
<th>Cell Organelle</th>
<th>Organelle Function</th>
<th>Organelle Image</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>![Image 1]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>![Image 2]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>![Image 3]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>![Image 4]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>![Image 5]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>![Image 6]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>![Image 7]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>![Image 8]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>![Image 9]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>![Image 10]</td>
</tr>
</tbody>
</table>
SECTION 3.2 | CELL ORGANELLES

Reinforcement

KEY CONCEPT Eukaryotic cells share many similarities.

Plants, animals, and some single-celled organisms are eukaryotes. Eukaryotic cells have an organized internal structure and organelles that are surrounded by membranes. Organelles look different from each other and have different functions. Several have a specific job in making and processing proteins so that a cell can live, function, and reproduce. Plant and animal cells have a lot of the same parts, but a few of their parts are different. The list below tells you what each cell part does.

<table>
<thead>
<tr>
<th>Part</th>
<th>Job and Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>nucleus</td>
<td>double membrane layer that stores and protects DNA; includes the nucleolus, a dense region where ribosomes are assembled.</td>
</tr>
<tr>
<td>endoplasmic reticulum (ER)</td>
<td>network of thin folded membranes that help produce proteins and lipids; two kinds of ER: smooth and rough</td>
</tr>
<tr>
<td>ribosomes</td>
<td>tiny round organelles that link amino acids together to form proteins; may be in the cytoplasm or on the ER, which makes it look rough</td>
</tr>
<tr>
<td>Golgi apparatus</td>
<td>stacked layers of membranes that sort, package, and deliver proteins</td>
</tr>
<tr>
<td>vesicles</td>
<td>little sacs that carry different molecules where they’re needed; made and broken down as needed by the cell</td>
</tr>
<tr>
<td>mitochondria</td>
<td>bean-shaped organelles that release energy from sugars for the cell</td>
</tr>
<tr>
<td>centrioles</td>
<td>found in animal cells; organize microtubules to form cilia and flagella</td>
</tr>
<tr>
<td>vacuoles</td>
<td>sacs that store materials for the cell; the materials might be water, food molecules, ions, and enzymes</td>
</tr>
<tr>
<td>cell walls</td>
<td>strong layer that protects, supports, and gives shape to plant cells; not found in animal cells</td>
</tr>
<tr>
<td>chloroplasts</td>
<td>change energy from the sun into chemical energy for the plant; not found in animal cells</td>
</tr>
<tr>
<td>cytoplasm</td>
<td>jellylike substance that fills a cell</td>
</tr>
<tr>
<td>cell membrane</td>
<td>double-layer of phospholipids that forms a boundary between a cell and its surrounding environment</td>
</tr>
<tr>
<td>lysosomes</td>
<td>membrane-bound organelles that contain enzymes</td>
</tr>
</tbody>
</table>

1. What are two characteristics of eukaryotic cells.

__________________________________________________________________________

__________________________________________________________________________

2. What is the function of mitochondria?

__________________________________________________________________________

3. What two organelles are found in plant cells but not in animal cells?

__________________________________________________________________________
SECTION 3.3  CELL MEMBRANE  Study Guide

KEY CONCEPT
The cell membrane is a barrier that separates a cell from the external environment.

VOCABULARY
- cell membrane
- selective permeability
- phospholipid
- receptor
- fluid mosaic model

MAIN IDEA: Cell membranes are composed of two phospholipid layers.

1. Draw a phospholipid in the box below. Label the three major parts.

2. Which part of a phospholipid is charged, or polar?

3. Which part of a phospholipid is nonpolar?

4. What type of molecules interact with water, polar or nonpolar?

5. Where does a cell membrane come into contact with water?

6. Why do the phospholipids surrounding the cell form a bilayer?

A cell membrane has other types of molecules embedded in the phospholipid bilayer. List a function of each type of molecule in the table below.

<table>
<thead>
<tr>
<th>Molecule</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>7. Cholesterol</td>
<td></td>
</tr>
<tr>
<td>8. Proteins</td>
<td></td>
</tr>
<tr>
<td>9. Carbohydrates</td>
<td></td>
</tr>
</tbody>
</table>
10. In what way is a membrane fluid?

11. Draw a picture in the box below to represent selective permeability.

MAIN IDEA: Chemical signals are transmitted across the cell membrane.

12. A _______________ detects a signal molecule and carries out an action in response.

13. A _______________ is a molecule that acts as a signal when it binds to a receptor.

14. A ligand that can cross the cell membrane can bind to an _______________ receptor.

15. A ligand that cannot cross the cell membrane can send a message to a cell by binding to a _______________ receptor, which then _______________ shape.

Vocabulary Check

16. What is the fluid mosaic model?

17. The cell membrane allows some, but not all, molecules to cross. What term describes this property?
### SECTION 3.3

#### CELL MEMBRANE

**Power Notes**

<table>
<thead>
<tr>
<th>Functions:</th>
<th>Phospholipids:</th>
</tr>
</thead>
</table>

**Fluid mosaic model:**

Other molecules:
- 
- 
- 

**Sketch a semipermeable membrane.**

**Selective permeability:**
- 
- 
- 
- 

**Receptors:**
- Intracellular
- Membrane
KEY CONCEPT The cell membrane is a barrier that separates a cell from the external environment.

The cell membrane forms a boundary that separates the inside of a cell from the outside environment. It plays an active role by controlling the passage of materials into and out of a cell and by responding to signals. The membrane is made of molecules called phospholipids, which consist of three parts: (1) a charged phosphate group; (2) glycerol; (3) two fatty acid chains.

The structure of phospholipids gives them distinct chemical properties. The phosphate group and glycerol form a polar “head.” The fatty acid chains form a nonpolar “tail.” Cells are both surrounded by water and contain water. In the cell membrane, phospholipids form a double layer, or bilayer. In this way, the polar heads interact with the polar water molecules outside and inside a cell. The nonpolar tails are sandwiched together inside the bilayer, away from the water.

The cell membrane also includes a variety of molecules that give the membrane properties it would not otherwise have.

- Cholesterol molecules make the membrane stronger.
- Proteins help molecules and ions cross the membrane and can act as receptors, proteins that detect a signal and respond by performing an action.
- Carbohydrates help cells distinguish one cell type from another.

The fluid mosaic model describes the characteristics and makeup of the cell membrane. The phospholipids can slip past each other like a fluid. The membrane is made up of many different molecules, like a mosaic.

The cell membrane has a property called selective permeability, which means that it allows some molecules to cross but blocks others. Selective permeability helps a cell maintain homeostasis.

Cells have receptors both in the cell membrane and inside the cell. Receptors help cells communicate with other cells and respond to the environment.

- Membrane receptors bind to signals that cannot cross the cell membrane. They cross the membrane and transmit a message inside the cell by changing shape.
- Intracellular receptors are located inside a cell and bind to molecules that can cross the cell membrane. They may interact with DNA to control certain genes.

1. Why do phospholipids form a bilayer in the cell membrane?

2. How does a sieve (or colander) demonstrate the property of selective permeability?
KEY CONCEPT
Materials move across membranes because of concentration differences.

VOCABULARY
- passive transport
- osmosis
- hypotonic
- diffusion
- isotonic
- facilitated diffusion
- concentration gradient
- hypertonic

MAIN IDEA: Diffusion and osmosis are types of passive transport.

1. What is a concentration gradient?

2. What does it mean for a molecule to diffuse down a concentration gradient?

Complete the concept map below about passive transport.

3. The diffusion of water
4. Requires no energy
5. Is gets energy from
6. Is example
7. Example

8. The higher the concentration of dissolved particles in a solution, the ______________ the concentration of water molecules in that solution.
Suppose you have three solutions with different concentrations of particles. Relative to the concentration of particles in a cell, one solution is isotonic, one is hypertonic, and one is hypotonic. Use this information to answer the next two questions.

9. Which solution has the highest concentration of particles?

10. Which solution has the highest concentration of water molecules?

**MAIN IDEA:** Some molecules diffuse through transport proteins.

11. How does facilitated diffusion differ from simple diffusion?

12. In facilitated diffusion, do molecules move down a concentration gradient or against a concentration gradient?

**Vocabulary Check**

13. The difference in the concentration of a substance from one location to another is a _________.

14. People with excess energy are described as hyper. How does this relate to the meaning of hypertonic?

15. The word *facilitate* means “to make easier.” How does this meaning apply to facilitated diffusion?
**SECTION 3.4**

**DIFFUSION AND OSMOSIS**

**Power Notes**

**How do different solutions affect cells?**

Label the type of solution each red blood cell is in. Draw arrows on each cell to show the direction of osmosis.

1. __________  
2. __________  
3. __________  
4. __________  
5. __________  
6. __________

**Sketch molecules diffusing into a cell.**

**Passive transport:**

**Diffusion:**

**Osmosis:**

**Facilitated diffusion:**

**Sketch molecules entering a cell by facilitated diffusion.**
KEY CONCEPT Materials move across membranes because of concentration differences.

Cells are continuously exchanging materials with their environment across the cell membrane. Passive transport is the movement of molecules across a cell membrane that does not require energy input by the cell. Diffusion, a type of passive transport, is the movement of molecules from an area of higher concentration to an area of lower concentration. This difference in concentration from one area to another is called a concentration gradient. When a molecule diffuses, it can be described as moving down its concentration gradient.

Not all molecules can cross the cell membrane. Facilitated diffusion is the diffusion of molecules across a membrane through transport proteins, proteins that form channels across the membrane.

Diffusion is a result of the natural energy of molecules. When molecules are in solution, they collide and scatter. Over time, these molecules will become evenly spread throughout the solution, which means that the molecules have reached dynamic equilibrium. The molecules continue to move, but their concentration remains equal.

Water also moves from a higher water concentration to a lower water concentration. The diffusion of water is called osmosis. The higher the concentration of dissolved particles that are in a solution, the lower the concentration of water molecules. The reverse is also true. That is, the lower the concentration of dissolved particles that are in a solution, the higher the concentration of water molecules.

Scientists have developed terms to compare the concentration of solutions with some reference point. Here, our reference point is the concentration of particles in a cell.

- An isotonic solution has the same concentration of dissolved particles as a cell. A cell in a isotonic solution will not change.
- A hypertonic solution has a higher concentration of dissolved particles than a cell. A cell in a hypertonic solution will shrivel.
- A hypotonic solution has a lower concentration of dissolved particles than a cell. A cell in a hypotonic solution will swell.

1. Organize the terms isotonic, hypertonic, and hypotonic in order from the solution with the lowest concentration of dissolved particles to the highest concentration.

2. Suppose you have a container divided by a membrane that is permeable to water but not to sugar. Side A has a 10% sugar solution. Side B has a 40% sugar solution. Both start out at 10 cm in height. Over time, the height of one side drops to 7 cm, and the height of the other side increases to 13 cm. Which side of the container is now at 7 cm? Explain.
SECTION 3.5 | ACTIVE TRANSPORT, ENDOCYTOSIS, AND EXOCYTOSIS

Study Guide

KEY CONCEPT
Cells use energy to transport materials that cannot diffuse across a membrane.

VOCABULARY
<table>
<thead>
<tr>
<th>active transport</th>
<th>phagocytosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>endocytosis</td>
<td>exocytosis</td>
</tr>
</tbody>
</table>

MAIN IDEA: Proteins can transport materials against a concentration gradient.

1. How is active transport different than simple diffusion and facilitated diffusion?

2. How is active transport similar to facilitated diffusion?

3. List two characteristics that almost all transport proteins share.

4. List the key distinguishing feature of active transport proteins.

5. Refer to Figure 3.25 to draw a picture in the box below to represent active transport.

6. Most active transport proteins use energy from the breakdown of ____________.
STUDY GUIDE, CONTINUED

MAIN IDEA: Endocytosis and exocytosis transport materials across the membrane in vesicles.

7. A cell may transport a substance in ______________________ if the substance is too large to cross the membrane.

8. During endocytosis, the vesicle membrane fuses with a lysosome, and the membrane and its contents are broken down by ______________________.

Complete the Y diagram below to compare and contrast the processes of endocytosis and exocytosis. Under the heading “endocytosis,” list the characteristics of endocytosis. Under the heading “exocytosis,” list the characteristics of exocytosis. At the bottom of the Y, write the characteristics that both processes have in common. Then lightly cross out those characteristics at the top of the Y.

Vocabulary Check

9. What term means “cell eating” and describes a type of endocytosis?

10. The prefix exo- means “out of,” and the prefix endo- means “taking in.” How do these meanings relate to the meaning of exocytosis and endocytosis?

11. What process drives molecules across a membrane against a concentration gradient?
SECTION 3.5

ACTIVE TRANSPORT, ENDOCYTOSIS, AND EXOCYTOSIS

Power Notes

Sketch molecules entering a cell by active transport.

1. outside

2.

3. inside

4.

Active transport:

Endocytosis:

Exocytosis:

1.

2.

3.
SECTION 3.5

ACTIVE TRANSPORT, ENDOCYTOSIS, AND EXOCYTOSIS

Reinforcement

KEY CONCEPT  Cells use energy to transport materials that cannot diffuse across the membrane.

Cells use active transport to obtain materials they need that they could not get by means of diffusion or facilitated diffusion. Active transport is the movement of a substance against its concentration gradient by the use of transport proteins embedded in the cell membrane and chemical energy. The transport proteins used in active transport are often called pumps. Most often, the chemical energy that is used comes from breakdown of a molecule called ATP. A cell may use this energy directly or indirectly.

• The sodium-potassium pump directly uses energy from the breakdown of ATP to pump two potassium ions into a cell for every three sodium ions it removes from the cell.
• The proton pump indirectly uses energy from the breakdown of ATP to remove hydrogen ions (protons) from a cell. This action creates a charge gradient, which is a form of stored energy. This charge gradient can then be used to drive other pumps to transport molecules such as sucrose.

Some molecules are too large to be transported through proteins. These molecules can be moved in vesicles, so they never actually have to cross the membrane. The movement of these vesicles also requires energy from a cell.

• Endocytosis is the process of taking liquids or large molecules into a cell by engulfing them in a vesicle. During endocytosis, the cell membrane makes a pocket around the material to be brought in. The pocket pinches together around the material and breaks off, forming a vesicle, inside the cell. This vesicle then joins with a lysosome, which breaks down the contents if needed and recycles the vesicle. Phagocytosis is a type of endocytosis and means “cell eating.”
• Exocytosis is the process of releasing materials from a cell by fusion of a vesicle with the cell membrane. In this process, a vesicle forms around select materials. The vesicle is moved to the cell surface, and it fuses with the cell membrane, releasing the contents. Exocytosis plays an important role in releasing hormones and digestive enzymes and in transmitting nerve impulses.

1. In what ways are active transport, endocytosis, and exocytosis similar?

2. In what ways does active transport differ from endocytosis and exocytosis?

3. List one function that exocytosis carries out in the human body.
The operational definition of a variable—a specific description of what is observed and measured in an experiment—is important information when scientists are trying to replicate other scientists’ experiments.

A student wants to measure diffusion rates across a semipermeable membrane. The following experiment is carried out:

- A cellulose membrane is placed in each of three aquariums, separating each one in half. Water can cross the membrane, but salt cannot.
- In each aquarium, one side is filled with a 5% solution of NaCl.
- The other side of Aquarium A is filled with a 10% solution of NaCl.
- The other side of Aquarium B is filled with a 20% solution of NaCl.
- The other side of Aquarium C is filled with a 30% solution of NaCl.
- The amount of time for equilibrium to be reached between the two sides in each aquarium was recorded.

<table>
<thead>
<tr>
<th>Aquarium</th>
<th>Time to Reach Equilibrium (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>67</td>
</tr>
<tr>
<td>B</td>
<td>32</td>
</tr>
<tr>
<td>C</td>
<td>10</td>
</tr>
</tbody>
</table>

1. **Identify** What is the operational definition of the dependent variable in this experiment?

2. **Analyze** What effect does the concentration of solutes have on diffusion rates?

3. **Analyze** In Aquarium C, would the water level on the side with 30% solution of NaCl be higher, lower, or equal to the water level on the side with 5% solution? Explain.
You have learned in Chapter 3 that cells have receptors that allow them to respond to signals from the environment and from other cells. Signals may come in many forms, including light, electrical impulses, and molecules. We will focus on signal molecules, or ligands.

**RESPONSES**

The binding of a receptor to a ligand can trigger many responses. This process is called signal transduction, because the cell is changing (transducing) one type of signal into another. Some of these responses happen right away, such as the cell’s rapid rearrangement of its cytoskeleton. Other responses happen slowly, such as the production of new proteins.

The process of converting one signal into another usually involves a chain of events. That is, the binding of a receptor to its ligand makes the receptor active. The receptor then activates another molecule, which then activates another molecule, and so on. In biology, this chain of events is often called a cascade. You can also think of it as a domino effect. Through this domino effect, a small stimulus can have a big effect. For instance, if the binding of a receptor and ligand causes a cell to read a certain gene, that gene might code for a protein that tells the cell to read more genes, making more proteins.

**RECEPTORS**

The two main types of receptors are membrane receptors and intracellular receptors. Both types of receptors recognize specific ligands, change shape when they bind to a ligand, and trigger a chain of events inside the cell that can have various results. Despite these similarities, membrane receptors and intracellular receptors differ in important ways.

**MEMBRANE RECEPTORS**

Membrane receptors are proteins located within the cell membrane. One end juts outside the cell membrane, and the other end sticks into the cytoplasm on the inside of the cell. The protein may wind back and forth across the membrane. Ligands that cannot cross the plasma membrane bind to the membrane receptors. These molecules tend to be large or polar, and they do not enter the cell. Instead, the binding of the membrane receptor and the ligand causes the receptor to change shape. This change in shape causes the part of the receptor inside the cell to interact with nearby molecules in new ways.

Frizzled is the name of one membrane receptor. It helps control how much B-catenin is present in a cell. B-catenin carries out several functions in a cell. When Frizzled is inactive, any excess B-catenin is broken down very quickly. However, when the Frizzled receptor binds to one of its ligands, it becomes active. The activated Frizzled receptor causes a protein called Dishevelled, in the cytoplasm, to become active. When Dishevelled is active, it stops
proteins from breaking down B-catenin. B-catenin then enters the nucleus and turns on many genes, which make proteins.

**INTRACELLULAR RECEPTORS**

Intracellular receptors are inside the cell. Some intracellular receptors are in the cytoplasm. Others are inside the nucleus. Ligands that can diffuse across the plasma membrane bind to intracellular receptors. These molecules tend to be small and nonpolar. When an intracellular receptor binds to a ligand, the receptor changes shape. This change in shape allows the receptor-ligand complex to interact with nearby molecules in new ways.

The estrogen receptor is an example of an intracellular receptor. Estrogen is a steroid hormone. Steroid hormones can easily cross plasma membranes. The estrogen receptor is in the nucleus. When it is not bound to estrogen, the estrogen receptor is kept inactive by proteins called chaperones. When the estrogen receptor binds to estrogen, the receptor changes shape. This separates the receptor from the chaperone proteins and allows two receptor-ligand complexes to join together. Once joined, the receptors recognize and bind to specific regions of DNA called estrogen response elements. Based on how the receptors interact with other proteins, binding will turn a gene on or off.

**MODELING SIGNAL TRANSDUCTION CASCADES**

| MATERIALS | large poster paper, tape marker, different colors of paper, dominoes, toy cars |

In this activity, you will create a model of a signal transduction cascade. You can use the examples given above or research other examples to create a model of a cell with a membrane receptor and an intracellular receptor. Use the materials listed or other materials that you can think of to demonstrate the domino effect of the signal transduction cascades.

1. Create a cell large enough to contain the transduction cascade. Mark the cell membrane and nuclear membrane. Include at least two “DNA” genes inside the nucleus.
2. Place at least one receptor in the cell membrane and one inside the cell nucleus.
3. Build a cascade to connect the receptors with their target genes.
4. Select a signal molecule, or ligand, for each receptor.
5. On your paper, draw a diagram of your cell and explain what each part represents.
6. Send the signal to each of your receptors and watch the result. Make any adjustments to your cell as necessary.
7. On your paper, explain the results and what those results might mean in a real cell. Explain any limitations of your model.
8. Use your model to demonstrate signal transduction to the rest of your class.
In Chapter 3, you have learned that osmosis is the movement of water molecules across a semipermeable membrane from a region of higher concentration to one of lower concentration. You also learned that the terms isotonic, hypertonic, and hypotonic can be used to describe the concentration of solutions relative to each other.

**SOLUTES AND SOLVENTS**

Osmosis refers to the movement of water, which is the solvent in many solutions. If you compare two solutions of different concentrations, the solution with a higher solute concentration will have a lower solvent concentration, and vice versa. The direction of osmosis—whether a solution is hypotonic or hypertonic—depends on the relative concentrations of solute particles in the solutions, not the types or variety of solute particles.

**WATER BALANCE IN CELLS**

The cytoplasm of a cell contains many different solutes: salts, proteins, sugars, and more. In general, the movement of water in and out of a cell is determined by the concentration of particles dissolved in the cytoplasm compared to the concentration of particles dissolved in the fluid surrounding the cell. Cells that have no cell walls are very sensitive to changes in their surroundings. If the surrounding solution becomes hypertonic or hypotonic, the cell will either shrivel up and die or burst and die, respectively. Cells without cell walls must live in an isotonic environment or have adaptations for osmoregulation, the control of water balance.

Cells that have cell walls, such as plants cells, are much more tolerant of changes in their surroundings. In a hypotonic environment, such as when a piece of celery is put into a glass of water, a plant cell swells until its slightly elastic walls reach their limit and begin to exert pressure against the flow of water. This pressure is called turgor pressure, or turgidity, and is the normal state for most plant cells. Turgor pressure allows plant cells to maximize the volume of water they hold and also allows the plant as a whole to achieve its most rigid state, thereby increasing its exposure to sunlight and maximizing its potential for photosynthesis.

**Experimenting with Osmosis**

In this activity, you will measure the mass of five potato cores and then soak them in solutions of varying concentrations. You will measure their masses the following day and calculate the percent change in mass of each. You will use the data to determine which solutions are hypertonic, hypotonic, and isotonic, and what the concentration of solute is in a potato.
MATERIALS

- aluminum foil
- cups or jars of ~250 mL capacity
- table salt (NaCl)
- 100-mL graduated cylinder
- balance or scale
- knife
- potato corer
- marking pen
- potato
- paper towels
- distilled water

1. Read through steps 2–8 and draw a data table.
2. Label the five cups or jars Distilled water, 0.5% salt, 1% salt, 5% salt, and 10% salt.
3. Place 100 mL of distilled water in the Distilled water cup, 99.5 mL in the 0.5% salt cup, 99 mL in the 1% salt cup, 95 mL in the 5% salt cup, and 90 mL in the 10% salt cup. Add 0.5 grams of table salt to the 0.5% cup, 1 gram of salt to the 1% cup, 5 grams to the 5% cup, and 10 grams to the 10% cup. Stir each solution until the salt dissolves.
4. Cut five cores from a potato. Trim them so they are approximately the same size. Make sure there is no skin on the potato pieces.
5. Find the mass of each piece of potato. After weighing each piece, record the mass in your data table in the same row as one of the solutions, and then place the piece in that solution.
6. When all the potato pieces are in the solutions, make sure they are completely submerged and then cover each cup with aluminum foil. Let them sit overnight.
7. The next day, remove the potato pieces from the cups, blot them dry with the paper towel, and weigh them. Record the masses in the data table. Feel the potatoes and record their turgidity (how limp or crisp each feels).
8. Calculate and record the percent change in mass for each potato piece. Use plus (+) and minus (–) signs to indicate gain or loss of mass.

Answer the following questions on a separate piece of paper.

1. Describe on a molecular level what happened to the potato piece(s) that gained mass.
2. Describe on a molecular level what happened to the potato piece(s) that lost mass.
3. Did any of the potato pieces not change in mass? If so, explain this on a molecular level.
4. Which of the five solutions were hypotonic to potato cells? Which were hypertonic?
5. What is the approximate concentration of solutes in potato cells? Explain how you know.
A. Word Origins  Circle the Greek and Latin word parts in each vocabulary term. Then use the Greek and Latin meanings to construct a very basic definition of the vocabulary word.

| endo- = inside | hyper- = over, above | chloro- = green |
| exo- = outside | hypo- = below | iso- = equal |
| phago- = eating | lys- = loosen | -tonia = state of |
| cyto- = cell | -plast = small body |

<table>
<thead>
<tr>
<th>WORD</th>
<th>DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. endocytosis</td>
<td></td>
</tr>
<tr>
<td>2. exocytosis</td>
<td></td>
</tr>
<tr>
<td>3. phagocytosis</td>
<td></td>
</tr>
<tr>
<td>4. hypertonic</td>
<td></td>
</tr>
<tr>
<td>5. hypotonic</td>
<td></td>
</tr>
<tr>
<td>6. isotonic</td>
<td></td>
</tr>
<tr>
<td>7. lysosome</td>
<td></td>
</tr>
<tr>
<td>8. chloroplast</td>
<td></td>
</tr>
</tbody>
</table>
VOCABULARY PRACTICE, CONTINUED

<table>
<thead>
<tr>
<th>WORD</th>
<th>DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>9. cytoplasm</td>
<td></td>
</tr>
<tr>
<td>10. cytoskeleton</td>
<td></td>
</tr>
</tbody>
</table>

B. Analogies Read each analogy. Decide which term is most like it.

<table>
<thead>
<tr>
<th>active transport</th>
<th>exocytosis</th>
<th>passive transport</th>
</tr>
</thead>
<tbody>
<tr>
<td>cell wall</td>
<td>Golgi apparatus</td>
<td>ribosomes</td>
</tr>
<tr>
<td>concentration gradient</td>
<td>nucleus</td>
<td>selective permeability</td>
</tr>
</tbody>
</table>

1. Chips in a chocolate chip cookie ____________________________
2. Skin of a grape ____________________________
3. Allowing only invited guests in to your party ____________________________
4. Floating on a raft through a tunnel without paddling ____________________________
5. A cab driving you to the party through heavy traffic ____________________________
6. Spitting out watermelon seeds ____________________________
7. Thick fog in one area, clear in another ____________________________
8. An accordion ____________________________
9. The chewy center of a candy ____________________________

Write your own analogies to show the meaning of these terms:
10. cytoskeleton
________________________________________________________
________________________________________________________

11. phagocytosis
________________________________________________________
________________________________________________________
C. Vector Vocabulary  Define the words in the boxes. On the lines across each arrow, write a phrase that describes how the words in the boxes are related to each other.

ACTIVE TRANSPORT
1. ________________
   __________________
   __________________

PASSIVE TRANSPORT
2. ________________
   __________________
   __________________

3. ________________
   __________________

OSMOSIS
4. ________________
   __________________
   __________________

DIFFUSION
5. ________________
   __________________
   __________________

6. ________________
   __________________
   __________________

ISOTONIC
7. ________________
   __________________
   __________________

HYPOTONIC
8. ________________
   __________________
   __________________

HYPERTONIC
9. ________________
   __________________
   __________________

10. ________________
    __________________
    __________________
D. Who Am I? Choose among these terms to answer the riddles below:

<table>
<thead>
<tr>
<th>Term</th>
<th>Term</th>
<th>Term</th>
</tr>
</thead>
<tbody>
<tr>
<td>cell membrane</td>
<td>facilitated diffusion</td>
<td>phospholipid</td>
</tr>
<tr>
<td>cell theory</td>
<td>fluid mosaic model</td>
<td>prokaryotic cell</td>
</tr>
<tr>
<td>centriole</td>
<td>lysosome</td>
<td>receptor</td>
</tr>
<tr>
<td>endoplasmic reticulum</td>
<td>mitochondrion</td>
<td>vacuole</td>
</tr>
<tr>
<td>eukaryotic cell</td>
<td>organelle</td>
<td>vesicle</td>
</tr>
</tbody>
</table>

1. I carry out special jobs in a cell: ________________________________

2. I’m an important concept and I have three main points; the last is that all cells come from existing cells: ________________________________

3. I make up the two layers of the cell membrane: ________________________________

4. I describe the cell membrane structure because it is flexible and could be compared to an arrangement of tiles: ________________________________

5. I am the type of cell that has a nucleus; animal and plant cells are me: ________________________________

6. I am the type of cell without a nucleus; bacteria are me: ________________________________

7. I help molecules diffuse across a membrane through transport proteins: ________________________________

8. I have two types, smooth and rough; I help produce proteins and lipids: ________________________________

9. I contain enzymes and defend cells from viruses and bacteria; animal cells have lots of me: ________________________________

10. I am an organelle shaped like a bean; I provide energy for a cell: ________________________________

11. I am a cylinder-shaped organelle in animal cells, and I help make flagella: ________________________________

12. I am the outer edge that separates a cell from the outside environment; I control what goes in and out of a cell: ________________________________

13. I receive signals from molecules and make sure the right cell gets the right signal at the right time: ________________________________

14. I’m a sac filled with fluid inside a cell; I store materials the cell needs: ________________________________

15. I’m a little organelle that carries materials from one part of the cell to another; I don’t live long, but I can be recycled: ________________________________