CHAPTER 2

How Cells Function

the BIG idea

All cells need energy and materials for life processes.

Key Concepts

SECTION 1
Chemical reactions take place inside cells.
Learn why water and four types of large molecules are important for cell functions.

SECTION 2
Cells capture and release energy.
Learn about the process of photosynthesis and the two ways cells release energy.

SECTION 3
Materials move across the cell's membranes.
Learn about the different ways materials move through cells.

California ClassZone

CLASSZONE.COM
Chapter 2 online resources: Content Review, two Visualizations, two Resource Centers, Math Tutorial, and Test Practice

EXPLORE the BIG idea

Just a Spoonful of Sugar

7.1.a Students know cells function similarly in all living organisms.

Pour a little warm water into each of two cups. Stir eight spoonfuls of sugar into one of the cups. Drop several raisins into each cup and wait for six hours. After six hours, compare the raisins in each cup.

Observe and Think How are the raisins different? How would you explain your observation?

Internet Activity: Photosynthesis

7.1.b Students know the characteristics that distinguish plant cells from animal cells, including chloroplasts and cell walls.

Go to **ClassZone.com** to examine how plants use energy from sunlight to make sugar molecules. This process takes place in chloroplasts inside plant cells.

Observe and Think What are the starting materials of photosynthesis? What are the products?

NSTA scilinks.org SCILINKS
Photosynthesis **Code: MDL032**

CHAPTER 2

Getting Ready to Learn

CONCEPT REVIEW

- Cells are the basic units of living things.
- Some cells have organelles that perform special functions for the cell.
- Animal cells and plant cells have similar structures, but plant cells have cell walls and chloroplasts.

VOCABULARY REVIEW

cell membrane, p. 20
organelle, p. 20
chloroplast, p. 23
mitochondria, p. 23
molecule *See Glossary.*

CONTENT REVIEW
CLASSZONE.COM
Review concepts and vocabulary.

TAKING NOTES

OUTLINE

As you read, copy the headings on your paper in the form of an outline. Then add notes in your own words that summarize what you read.

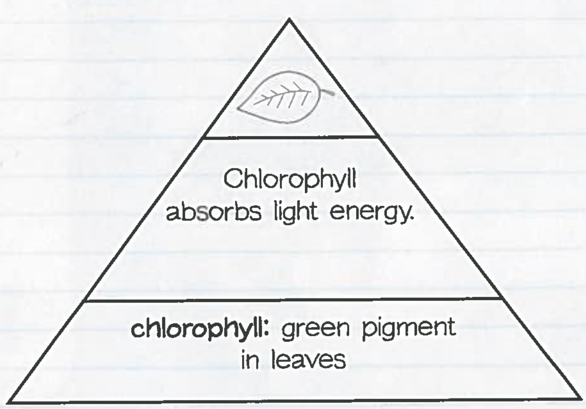
VOCABULARY STRATEGY

Draw a **word triangle** diagram for each new vocabulary term. On the bottom line, write and define the term. Above that, write a sentence that uses the term correctly. At the top, draw a small picture to show what the term looks like.

See the Note-Taking Handbook on pages R45–R51.

SCIENCE NOTEBOOK

I. Chemical reactions take place inside cells.
   A. All cells are made of the same elements.
   B. Large molecules support cell function.
      1. Carbohydrates
         a.
         b.
      2. Lipids
         a.
         b.



KEY CONCEPT

2.1 Chemical reactions take place inside cells.

CALIFORNIA Content Standard

7.1.a Students know cells function similarly in all living organisms.

BEFORE, you learned

- All living things are made of cells
- Cells need energy to sustain life
- Plant and animal cells have similarities and differences

NOW, you will learn

- About the types of elements found in all cells
- About the functions of large molecules in the cell
- Why water is important to the activities of the cell

VOCABULARY

chemical reaction p. 42
carbohydrate p. 42
lipid p. 43
protein p. 43
nucleic acid p. 43

THINK ABOUT

What are cells made of?

Food provides you with important substances for your body. Have you ever heard the words *protein, carbohydrate,* and *lipid*? Each of the foods shown in the photograph provides some of these substances. Your cells break down these substances for energy and to make other substances. Cells of other organisms also use, break down, and make substances. Can you guess what types of organisms are the sources of the substances in the photograph?

OUTLINE
Take notes on this main idea. You can use the beginning of an outline shown on page 40 to get you started.

I. Main idea
  A. Supporting idea
    1. Detail
    2. Detail
  B. Supporting idea

All cells are made of the same elements.

People use microscopes to observe the tiny cells that make up all living things. A light microscope can even show the parts of a cell. But it cannot show the basic building blocks of matter. All matter in the universe—living and nonliving—is made of particles called atoms. Different substances are made of different types of atoms. Each element has its own type of atom. More than a hundred different elements exist. Each element has its own properties. For example, part of the air around you is oxygen—a colorless, odorless gas. Atoms of oxygen, joined with other atoms, make up most of your body.

Elements in the Human Body	
Oxygen	65.0%
Carbon	18.5%
Hydrogen	9.5%
Nitrogen	3.3%
Calcium	1.5%
Phosphorus	1.0%
other 19 elements	1.2%

Source: CRC Handbook of Chemistry and Physics

Of all the elements found on Earth, about 25 are essential for life. As you can see from the table at left, just 6 elements account for about 99 percent of the mass of the human body. Atoms of oxygen and atoms of carbon together make up more than 80 percent of your body. But very little of this matter exists as single atoms. Instead, most of the matter in and around you is in the form of molecules.

A molecule consists of two or more atoms joined together. The atoms can be of the same element. For example, a molecule of oxygen gas (O_2) is made of two atoms of oxygen. Molecules can also be made of atoms of different elements. For example, a molecule of water (H_2O) is made of two atoms of hydrogen (H) joined with one atom of oxygen (O).

Most activities that take place within cells involve the interaction of atoms and molecules. A **chemical reaction** is a process in which bonds between atoms are broken and new bonds are formed. Chemical reactions rearrange the atoms into different molecules. Energy is needed to break bonds between atoms. Energy is released when new bonds form.

RESOURCE CENTER
CLASSZONE.COM
Explore molecules in living things.

Large molecules support cell function.

There are four main types of large molecules that make up living things: carbohydrates, lipids, proteins, and nucleic acids. These molecules work together in a cell. The four types of molecules in all living things contain carbon atoms. These large molecules are made up of smaller parts called subunits.

Carbohydrates

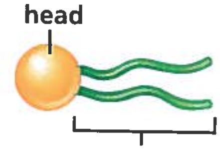
Carbohydrates provide structure and store energy in cells. Complex carbohydrates, such as cellulose, are made of **sugars**.

A **carbohydrate** (KAHR-boh-HY-DRAYT) is a type of molecule made up of subunits of sugars. Carbohydrates are used for energy. They are also used for structure. Carbohydrates can be broken down to provide the cell with energy. Simple carbohydrates are sugars made from atoms of carbon, oxygen, and hydrogen. Inside cells, sugar molecules are broken down. This process provides usable energy for the cell.

Simple sugar molecules can be linked into long chains to form more complex carbohydrates, such as starch, cellulose, and glycogen. Starch and cellulose are complex carbohydrates made by plant cells. When a plant cell makes more sugar than it can use, extra sugar molecules are stored in long chains called starch. Plants also make cellulose, which is the material that makes up the cell wall.

Lipids

Lipids are the fats, oils, and waxes found in living things. Like carbohydrates, simple lipids are made of atoms of carbon, oxygen, and hydrogen. Lipids can be used by cells for energy and for making structures. However, atoms in lipids are arranged differently from atoms in carbohydrates. Many common lipids consist of a molecule called glycerol bonded to long chains called fatty acids. This structure gives lipids unique properties. One extremely important property of most lipids is that they do not dissolve in water.



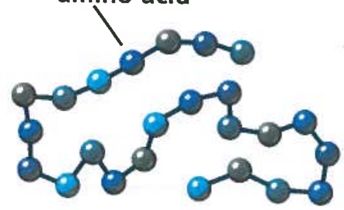
Lipids make up the membranes surrounding the cell and organelles. Fatty acids form long tails.

CHECK YOUR READING How do cells use carbohydrates and lipids?

Proteins

Proteins are a type of molecule made of smaller molecules called amino acids. Amino acids contain the elements carbon, oxygen, hydrogen, nitrogen, and sometimes sulfur. In proteins, amino acids are linked into long chains that fold into three-dimensional shapes. The structure and function of a protein are determined by the type, number, and order of the amino acids in it.

Your body gets amino acids from breaking down protein in foods such as meat, eggs, cheese, and some beans. After taking in amino acids, your cells use them to build proteins needed for the cells to function. Some amino acids can be made by the body. Others must be taken in from an outside food source.



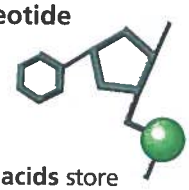
Proteins are made up of **amino acids.** Proteins carry out most of the chemical activity in cells.

There are many types of proteins. Enzymes are proteins that control chemical reactions in the cells. Other proteins support the growth and repair of cells. The action of proteins in your muscles allows you to move. Some of the proteins in your blood fight infections. Another protein in your blood delivers oxygen to all the cells in your body. Proteins are also important parts of cell membranes. Some proteins in the cell membrane transport materials into and out of the cell.

Nucleic Acids

Nucleic acids (noo-KLEE-ihk) are the molecules that hold the instructions for cells to develop, grow, and reproduce themselves. There are two types of nucleic acids: DNA and RNA. Both DNA and RNA are made from carbon, oxygen, hydrogen, nitrogen, and phosphorus. The subunits of nucleic acids are called nucleotides.

DNA provides the information used by a cell for making proteins the cell needs. This information is in the form of a code based on the specific order of different nucleotides in the DNA.

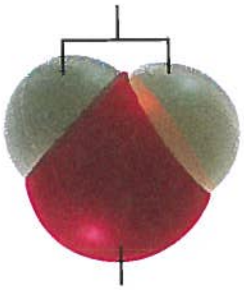


Nucleic acids store and translate the genetic information a cell needs to function. Nucleic acids, such as DNA, are made up of **nucleotides.**

The pattern of nucleotides in DNA is then coded into RNA. RNA delivers the information into the cytoplasm. Other types of RNA molecules in the cytoplasm produce the proteins.

CHECK YOUR READING What is the function of DNA and RNA?

About two-thirds of every cell is water.



Each **water** molecule is made of two **hydrogen** atoms bonded to one **oxygen** atom.

All of the chemical reactions inside the cell take place in water. In fact, water makes up about 70 percent of most cells. Chemical reactions also take place in water outside the cell membrane.

Water has an important property—its molecules are polar. Polar molecules have a region of positive charge and a region of negative charge. The hydrogen atoms have a slight positive charge. They attract negative regions of other polar molecules and repel positive regions. The oxygen atom in a water molecule has a slight negative charge and so it attracts positive regions. Many other materials are either made of polar molecules or break easily into pieces with positive and negative charges. These materials tend to dissolve in water because the interactions between charges tend to move the molecules around. Other molecules, such as those in fats and oils, tend to stay together and not dissolve in water.

INVESTIGATE Oil and Water

What happens when you combine oil and water?

SKILL FOCUS
Observing (7.1.a)

MATERIALS
- vegetable oil
- milk
- water
- 3 beakers
- food coloring
- stirring stick

TIME
10 minutes

PROCEDURE

1. Pour a small amount of oil into one beaker and an equal amount of milk into another.
2. Pour water into a third beaker and add enough food coloring to make the water darkly colored.
3. Add equal amounts of the colored water to the beaker of oil and the beaker of milk. Stir the liquids to mix them. Record your observations.

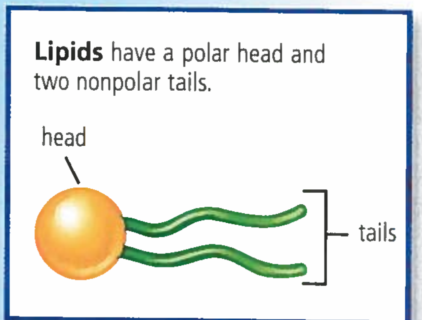
WHAT DO YOU THINK?

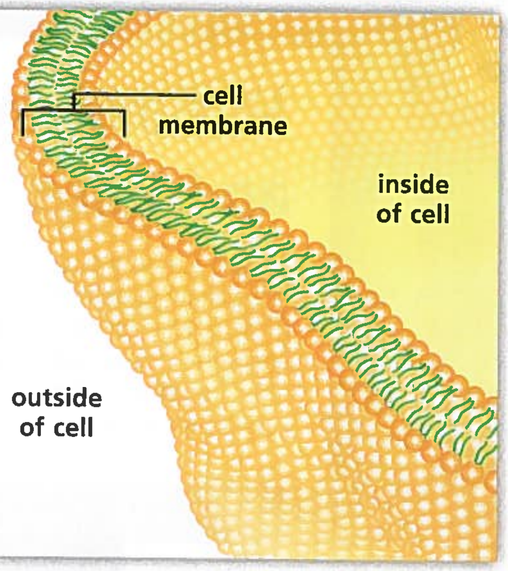
- Compare and contrast the behavior of the mixture of oil and water with that of the mixture of milk and water.
- Why does a mixture of oil and water behave differently from a mixture of milk and water?

CHALLENGE The outside of a cell is surrounded by water. Explain how lipids can keep a cell's inside separated from its outside.

Cell Membrane

The cell membrane is made of a double layer of lipids.





Most lipids do not dissolve in water. A special type of lipid makes up cell membranes. These special lipid molecules have two parts: a head and two tails. The head is polar and so tends to be pulled by water molecules. The tails are not polar. The tails tend to interact with other tails, rather than the water molecules.

As you can see in the diagram above, the heads of some lipids in cell membranes face outward, toward the water that surrounds the cell. The heads of other lipids face toward the watery inside of the cell. The tails of the two sets of lipids form the inside of the membrane and makes the barrier between the inside and outside of the cell.

READING TIP

As you read about the properties of cells, notice the arrangements of lipids in the diagram of the cell.

CHECK YOUR READING How do the heads and tails of lipids help form a barrier in water?

2.1 Review

KEY CONCEPTS

1. Explain how just a few elements can make up all living things. **(7.1.a)**
2. What functions do proteins, carbohydrates, lipids, and nucleic acids perform? **(7.1.a)**
3. What does it mean to describe water molecules as being polar? **(7.1.a)**

CRITICAL THINKING

4. **Compare and Contrast** How are carbohydrates and lipids similar? How are they different?
5. **Draw Conclusions** What do the major types of molecules that make up living things have in common?

CHALLENGE

6. **Model** Some people have compared the nucleic acids DNA and RNA to a blueprint for life. How are DNA and RNA like a blueprint? How are they different from a blueprint?

SCIENCE on the JOB

TEXTILE DESIGNER

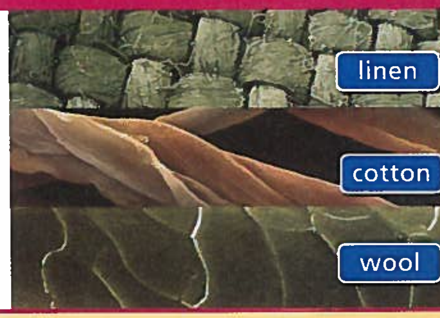
Natural Dyes and Cells

7.1.b Students know the characteristics that distinguish plant cells from animal cells, including chloroplasts and cell walls.

Where does the blue in your blue jeans come from? How about the red, yellow, green, or pink in your favorite wool or cotton sweater? Most fabrics are colored with dyes made in labs, but some designers prefer to use natural dyes and natural cloth. All textile designers must understand the science of dyes and fibers to produce the colors they want.

Fibers

Natural fibers come either from plants or animals. Wool is an animal fiber. Silk is also made up of animal cells. Cotton, linen, and rayon are fibers made from plants. Plant fibers have thick cell walls, made mostly of cellulose. Animal fibers, on the other hand, contain mainly proteins.



Dyes

Most natural dyes come from plants, but sometimes insects are used. The indigo plant is used for most blue dyes, including dye for blue jeans. Insects are most often used to make reds. All dyes are made of molecules—carbon, oxygen, hydrogen, and other atoms. The molecules of the dye bind to the molecules of the fibers, adding the dye's color to the fiber.

Color Fixers

A mordant is a chemical compound that combines with dye as a color fixer, or color keeper. The mordant strengthens the bonds between natural dye molecules and fibers. A stronger bond means the color is less likely to fade or wash out of the fibers. Most mordants are liquid solutions containing metals, such as chromium.

EXPLORE

1. **EXPERIMENT** Design an experiment using onion skins, beets, or blackberries to color white wool or white cotton. The procedure should include chopping the plant and heating it with water to make the dye. Be sure that your procedure includes only one variable. Your experiment should start with a question, such as "How do the fabrics differ?" or "Which dye works best?"
2. **CHALLENGE** Using different mordants with the same dye can produce different colors. For example, dandelion leaf dye produces yellow-green, gray-green, tan, or gold with different mordants. Explain why this happens.

KEY CONCEPT

2.2 Cells capture and release energy.

CALIFORNIA Content Standards

7.1.b Students know the characteristics that distinguish plant cells from animal cells, including chloroplasts and cell walls.

7.1.d Students know that mitochondria liberate energy for the work that cells do and that chloroplasts capture sunlight energy for photosynthesis.

BEFORE, you learned

- The cell is the basic unit of all living things
- Plant cells and animal cells have similarities and differences
- Plants and animals need energy and materials

NOW, you will learn

- Why cells need energy
- How energy is captured and stored
- How plants and animals get energy

VOCABULARY

chemical energy p. 47
glucose p. 47
photosynthesis p. 48
chlorophyll p. 48
cellular respiration p. 50
fermentation p. 52

THINK ABOUT

What do these cells have in common?

Both muscle cells and plant cells need energy to live. Your muscle cells need energy to help you move and perform other functions. Even though plant cells don't move in the same way that muscles move, they still need energy. How do muscle cells and plant cells get energy?

OUTLINE
Remember to include this heading in your outline of this section.

I. Main idea
  A. Supporting idea
    1. Detail
    2. Detail
  B. Supporting idea

All cells need energy.

To stay alive, cells need a constant supply of energy. All cells use chemical energy. **Chemical energy** is the energy stored in the bonds between atoms of every molecule. To stay alive, cells must be able to release the chemical energy in the bonds.

A major energy source for most cells is stored in a sugar molecule called **glucose.** When you need energy, cells release chemical energy from glucose. You need energy to run and walk—and even during sleep. Your cells use energy from food to carry out all of their activities.

Think about muscle cells. When you run, muscle cells release chemical energy from glucose to move your legs. The more you run, the more glucose your muscle cells need. You eat food to restore the glucose supply in your muscles. But how do plant cells get more glucose? Plants transform the energy in sunlight into the chemical energy in glucose and other sugars.

CHECK YOUR READING What are two ways that cells get glucose?

Some cells capture light energy.

The original source of energy for almost all organisms is sunlight. Plants change the energy in sunlight into a form of energy their cells can use—the chemical energy in glucose. All animals benefit from the ability of plants to convert sunlight to food energy. Animals either eat plants, or they eat other animals that have eaten plants.

Photosynthesis (FOH-toh-SIHN-thih-sihs) is the process that plant cells use to change the energy from sunlight into chemical energy. Photosynthesis takes place in plant cells that have chloroplasts. Chloroplasts contain **chlorophyll** (KLAWR-uh-fihl), a light-absorbing pigment, or colored substance, that traps the energy in sunlight.

The process of photosynthesis involves a series of chemical steps, or reactions. The illustration on the next page shows an overview of how photosynthesis changes starting materials into new products.

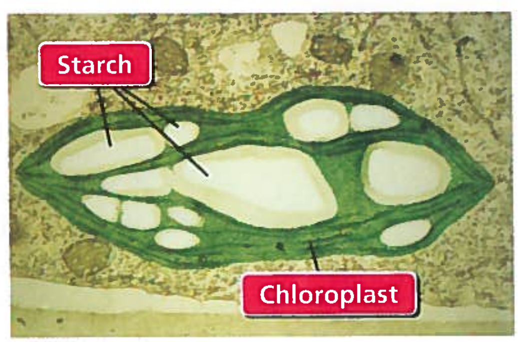
READING TIP

As you read each numbered item here, find the number on the diagram on page 49.

1. **The starting materials** of photosynthesis are carbon dioxide and water. The plant takes in carbon dioxide from the air and water from the soil.
2. **The process** takes place when carbon dioxide and water enter the plant's chloroplasts. Chlorophyll captures energy from sunlight, which is used to change carbon dioxide and water into new products.
3. **The products** of photosynthesis are oxygen and sugars such as glucose. The plant releases most of the oxygen to the air as a waste product and keeps the glucose for its energy needs.

CHECK YOUR READING Summarize photosynthesis. Remember that a summary includes only the most important information.

Plants do not immediately use all of the glucose they make. Some of the glucose molecules are linked together to build large carbohydrates called starch. Plants can store starch and later break it down into glucose or other sugars when they need energy. Sugars and starches supply food for animals that eat plants.

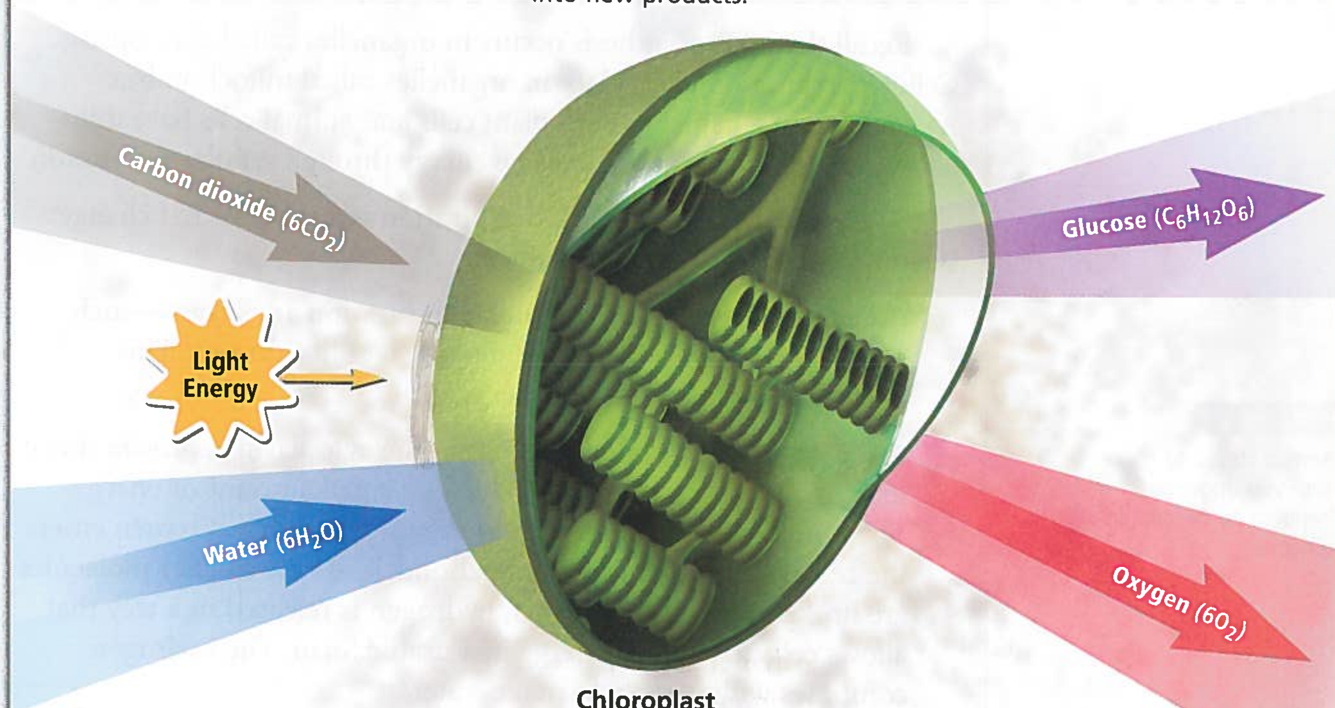


The starch in this plant cell stores energy.

CHECK YOUR READING How do plants store glucose?

Photosynthesis

1. **The starting materials** Carbon dioxide from the air and water from the soil enter the chloroplasts.
2. **The process** Inside the chloroplasts, chlorophyll captures energy from sunlight. This energy is used to change starting materials into new products.
3. **The products** Glucose supplies energy and is a source of materials for the plant; most oxygen is released into the air.



Water $6H_2O$ + Carbon dioxide $6CO_2$ + Light Energy ⟶ Glucose $C_6H_{12}O_6$ + Oxygen $6O_2$

READING VISUALS In what part of the diagram are starting materials changed?

All cells release energy.

All cells must have energy to function. Glucose and other sugars are cell food. When they are broken down, they are the power source for cell activities in almost all living things. When glucose is stored as glycogen or taken in as starch, it must be broken down into individual sugar molecules before cells are able to use it. Chemical energy is stored in the bonds of sugars. When a sugar molecule is broken down, a usable form of energy is released for the cell's life functions.

Cells can release energy in two basic processes: cellular respiration and fermentation. Cellular respiration requires oxygen, but fermentation does not. In addition, cellular respiration releases much more usable energy than does fermentation.

CHECK YOUR READING What is released when a sugar molecule is broken down?

Cellular Respiration

Cellular respiration is a process in which cells use oxygen to release energy stored in sugars such as glucose. In fact, most of the energy used by the cells in your body is provided by cellular respiration.

Recall that photosynthesis occurs in organelles called chloroplasts. Cellular respiration takes place in organelles called mitochondria. As you read in Chapter 1, both plant cells and animal cells have mitochondria. Both types of cells release energy through cellular respiration.

Like photosynthesis, cellular respiration is a process that changes starting materials into new products.

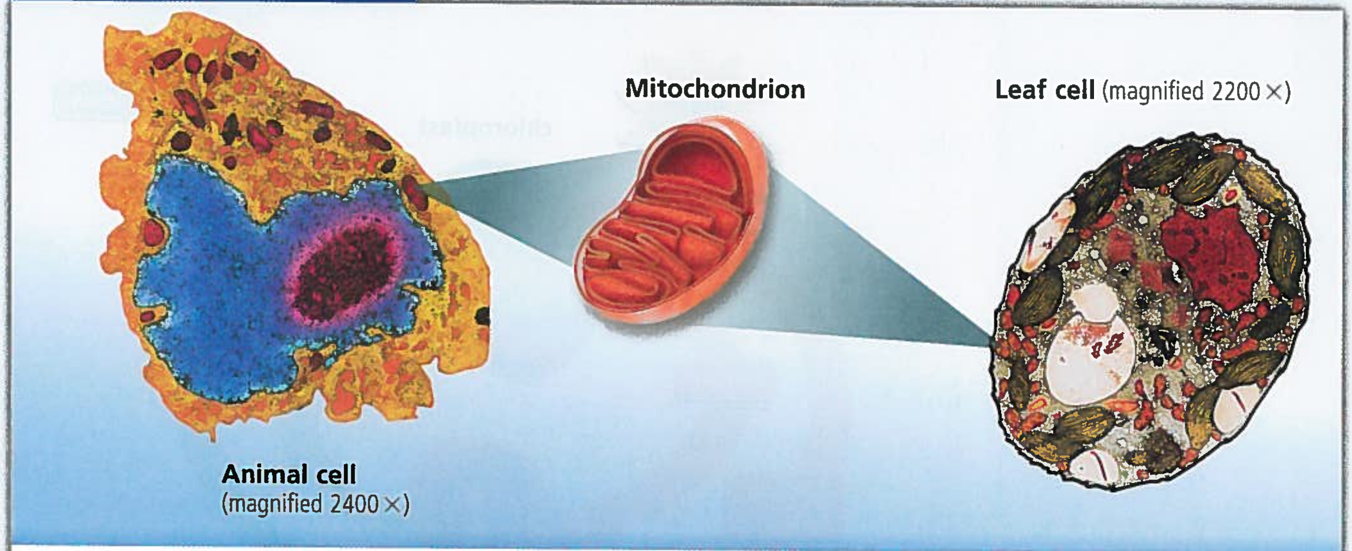
1. **The starting materials** of cellular respiration are sugars—such as glucose—and oxygen. First glucose is split into two. This releases a small amount of energy.
2. **The process** begins when glucose in the cytoplasm is broken down into smaller molecules. This releases a small amount of energy. These molecules then move into the mitochondria. Oxygen enters the cell and travels into the mitochondria. As the smaller molecules are broken down even further, hydrogen is released in a way that allows cells to capture energy in a usable form. The hydrogen combines with oxygen to make water.
3. **The products** are energy, carbon dioxide, and water.

READING TIP Reread step 2 to make sure you understand what happens to oxygen and glucose.

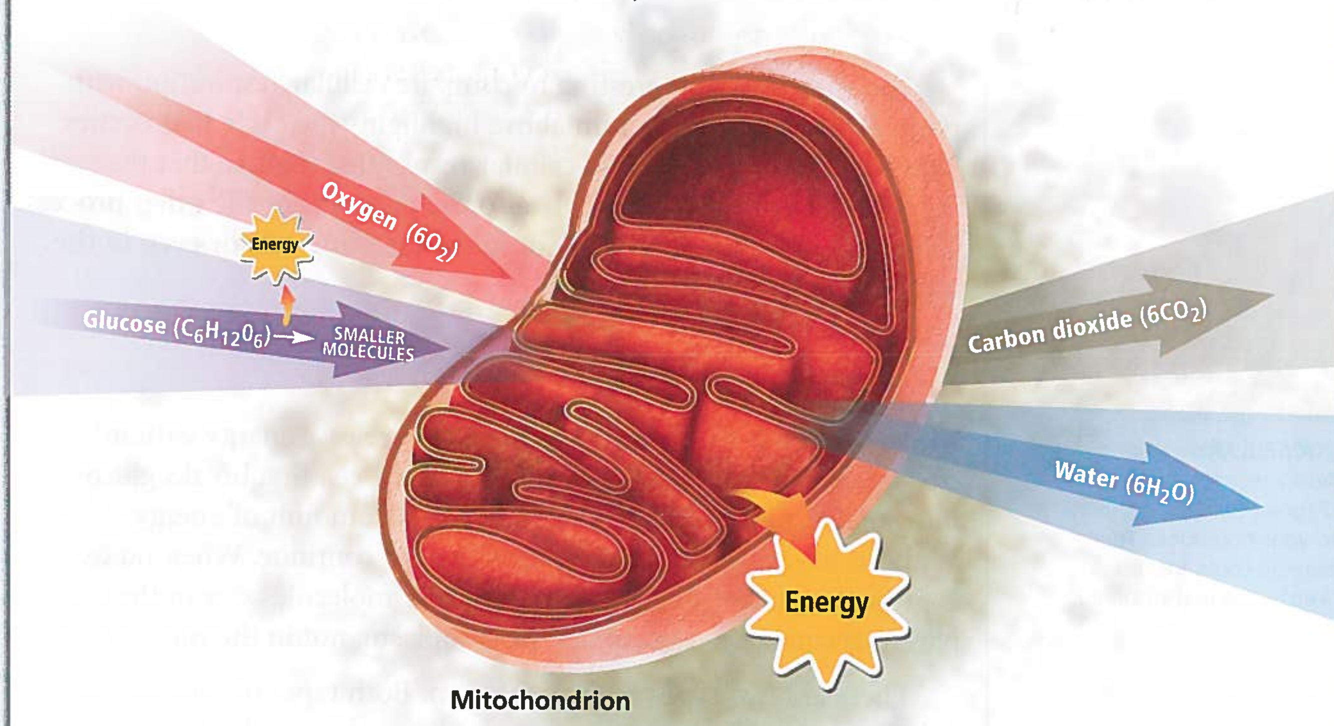
Some of the energy released during cellular respiration is transferred to other molecules. They then carry the energy where it is needed for the activities of the cell. The rest of the energy is released as heat. Carbon dioxide formed during cellular respiration is released by the cell.

CHECK YOUR READING What are the three products of cellular respiration?

Cellular Respiration



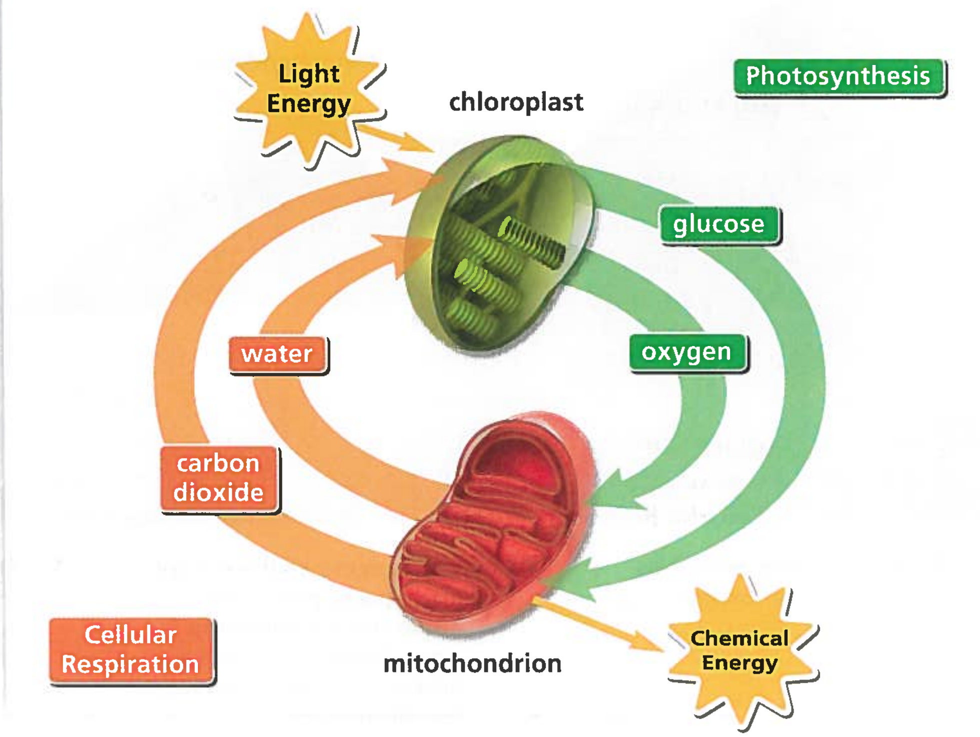
1. **The starting materials** Glucose and oxygen enter the cell.
2. **The process** Glucose is split into smaller molecules. Inside the mitochondria more chemical bonds are broken. Oxygen is needed for this process.
3. **The products** Energy is released, and water and carbon dioxide are produced.



Glucose $C_6H_{12}O_6$	+	Oxygen $6O_2$	→	Chemical Energy	+	Water $6H_2O$	+	Carbon dioxide $6CO_2$

READING VISUALS Where in the process is energy released?

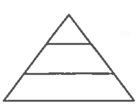
Photosynthesis and Respiration Cycle



You may find it interesting to compare cellular respiration with photosynthesis. The diagram above highlights the cycle that occurs between photosynthesis and cellular respiration. Notice that the starting materials of one process are also the products of the other process. This cycle does not necessarily occur in the same cell, or even in the same organism.

Fermentation

VOCABULARY
Add a word triangle diagram for *fermentation* to your notebook. Your triangle could include a sketch of a loaf of bread.



Fermentation is the process by which cells release energy without oxygen. Recall that in cellular respiration the cell first breaks glucose into smaller molecules. This releases a small amount of energy. Without oxygen, cellular respiration cannot continue. When no oxygen is present in eukaryotic cells, these smaller molecules stay in the cytoplasm. Fermentation occurs in the cytoplasm, not in the mitochondria.

There are two types of fermentation. Both types of fermentation help the cell break down sugars and release energy. Alcoholic fermentation produces alcohol and carbon dioxide. Lactic acid fermentation produces lactic acid.

CHECK YOUR READING Use a Venn diagram to compare and contrast fermentation and cellular respiration.

The production of many foods that people eat every day involve either alcoholic fermentation or lactic acid fermentation. Three of these foods are bread, yogurt, and cheese.

Bread is often made by mixing flour, milk, and sugar with a microorganism you know as yeast. Yeast runs out of oxygen and uses fermentation to convert the sugar into alcohol and carbon dioxide. Bubbles of carbon dioxide gas forming inside the dough cause it to rise. When the dough is baked, the small amount of alcohol evaporates. The yeast is killed, and the carbon dioxide bubbles give the bread a light, spongy structure.

Some bacteria release energy through lactic acid fermentation. These bacteria convert the sugar found in milk into lactic acid. The bacteria are used to make yogurt, cheese, and sourdough bread. Lactic acid changes the acidity of a bread mixture to give it a slightly sour flavor. In yogurt, the buildup of lactic acid causes the milk to thicken, producing the creamy texture of yogurt. If fermentation continues for a long time, the milk eventually turns into cheese.

CALIFORNIA Focus

Since the days of the gold rush, San Francisco has been famous for its sourdough bread. Fermentation products from local strains of yeast *(Candida milleri)* and bacteria *(Lactobacillus sanfrancisco)* give the bread its special, sour flavor.

INVESTIGATE Fermentation

How can you tell if fermentation releases material?

PROCEDURE

1. Add 1/2 teaspoon of yeast to the empty water bottle.
2. Fill the bottle about three-quarters full with the sugar solution.
3. Place the balloon tightly around the mouth of the bottle.
4. Gently swirl the bottle to mix the yeast and sugar solution.
5. After 20 minutes, observe the balloon and record your observations.

WHAT DO YOU THINK?

- What changes did you observe? What do you think is the source of energy that caused these changes?
- What accounts for the change in the amount of gas inside the balloon?

CHALLENGE Design an experiment to answer the following question. How might the temperature of the sugar solution affect the process?

SKILL FOCUS
Observing (7.1.a)

MATERIALS
- dry yeast
- measuring spoons
- small water bottle
- warm sugar solution
- balloon

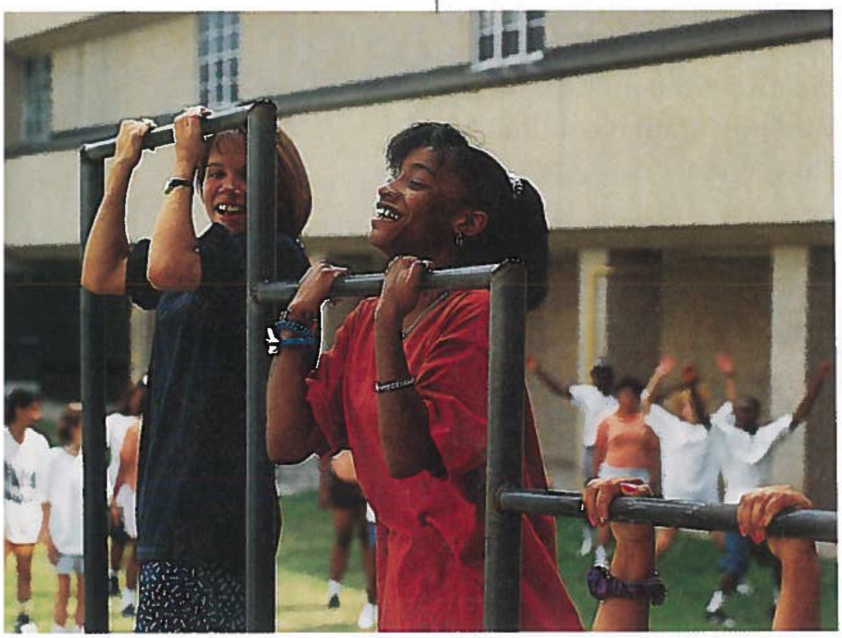
TIME
30 minutes

Energy and Exercise

Your muscle cells, like some organisms, are able to release energy through both cellular respiration and fermentation. While you are at rest, your muscle cells use specialized molecules to store both energy and oxygen.

During hard exercise, your muscle cells may use up all their stores of energy and oxygen. Then your muscle cells rely on fermentation to break down sugars. There is much less energy available to cells that use fermentation. That is why you cannot continue to run rapidly for long distances. When your cells use fermentation to release energy, one of the waste products is lactic acid. The lactic acid can cause a burning sensation in your muscles.

APPLY Why might these students feel a burning sensation in their arm muscles while doing pull-ups?



When you stop after this type of exercise, your muscles continue to hurt and you continue to breathe hard for many minutes. During this time, your muscles are playing catch-up. They use the oxygen brought into your blood by your heavy breathing to finish breaking down the byproducts of fermentation. As the lactic acid is converted into carbon dioxide and water, the burning sensation in your muscles goes away. Your muscles build back up their stores of energy and oxygen until the next time they are needed.

CHECK YOUR READING How do your muscles release energy during hard exercise?

2.2 Review

KEY CONCEPTS

1. Which form of energy is especially important for living things? Why? (7.1.d)
2. How is photosynthesis important to life on Earth? (7.1.d)
3. What starting materials do cells need for cellular respiration? (7.1.d)

CRITICAL THINKING

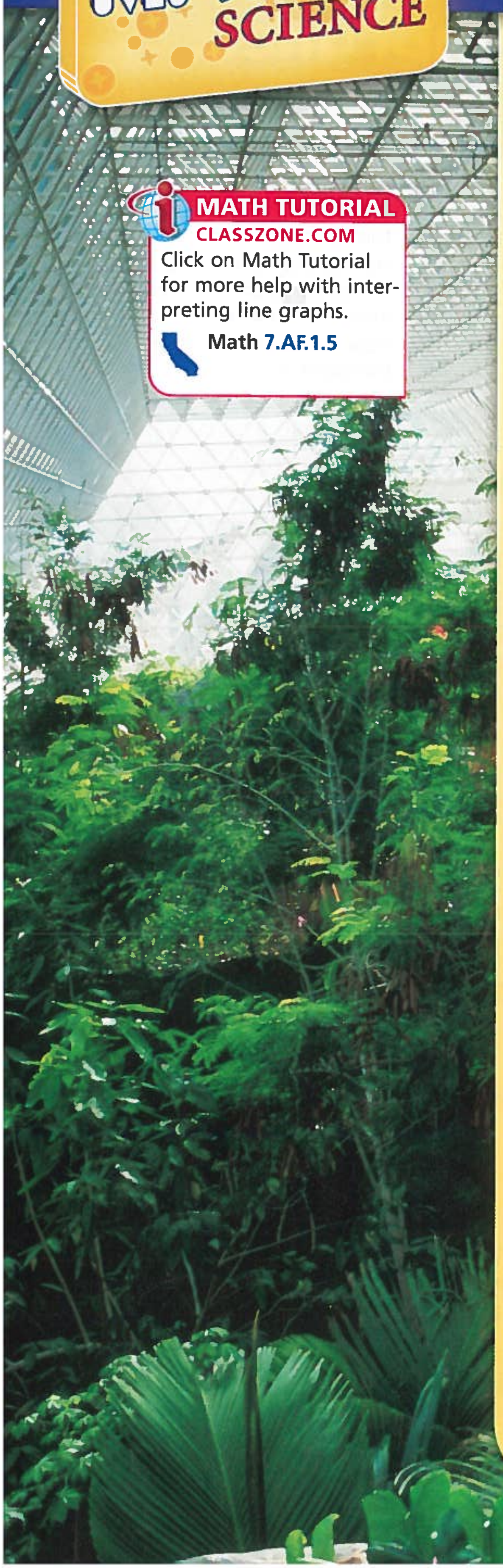
4. **Compare and Contrast** How are photosynthesis and cellular respiration similar? How are they different?
5. **Predict** Suppose that in a lab you could remove all the oxygen from a terrarium. What would happen to the plants? Why?

CHALLENGE

6. **Synthesize** In everyday language, the word *respiration* refers to breathing. How is breathing related to cellular respiration? **Hint:** The air we breathe out contains more carbon dioxide than the air we breathe in.

MATH in SCIENCE

SKILL: INTERPRETING GRAPHS



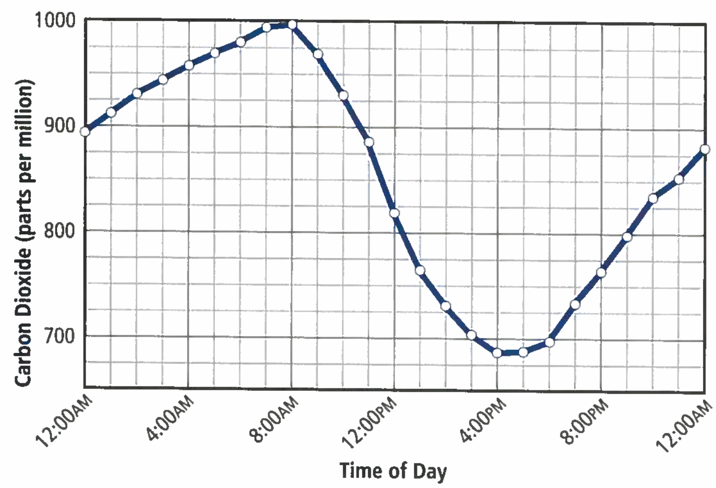
MATH TUTORIAL
CLASSZONE.COM
Click on Math Tutorial for more help with interpreting line graphs.
Math 7.AF.1.5

Carbon Dioxide Levels in Biosphere 2

Biosphere 2 is a research and education center in Arizona that can house people, plants, and animals. It was built to find out whether people could get the food and breathable air needed to survive in a small sealed environment over a two-year period.

Example

Data on carbon dioxide levels in the air of Biosphere 2 were collected at 15-minute intervals for several weeks. The graph below shows the amounts of carbon dioxide (CO_2) in the air on January 20, 1996.



Answer the following questions.

1. What intervals are shown on the *x*-axis? What is shown on the *y*-axis?
2. At what time of day does the carbon dioxide concentration reach its highest point? About how many parts per million of CO_2 are in the air at that time?
3. Between what hours is the CO_2 level decreasing?

CHALLENGE The data in the graph were collected on a sunny day. How might the graph look different if the day had been overcast?

KEY CONCEPT

2.3 Materials move across the cell's membranes.

CALIFORNIA Content Standard

7.1.a Students know cells function similarly in all living organisms.

BEFORE, you learned

- All cells have an outer covering called the cell membrane
- Cells need starting materials for life-sustaining processes
- Cells need to get rid of waste products

NOW, you will learn

- How materials move into and out of the cell through the cell membrane
- How energy is involved in transporting some materials into and out of cells
- How surface area affects transport in cells

VOCABULARY

diffusion p. 56
passive transport p. 58
osmosis p. 59
active transport p. 60

EXPLORE Diffusion (7.1.a)

How do particles move?

PROCEDURE

1. Fill the beaker with tap water.
2. Add 3 drops of food coloring to the water.
3. For 10 minutes, observe what happens. Write down your observations.

MATERIALS

- beaker
- water
- food coloring

WHAT DO YOU THINK?

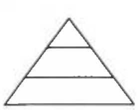
- What changes did you observe?
- What might have caused the changes?

Some materials move by diffusion.

When you walk toward the shampoo section in a store, you can probably smell a fragrance even before you get close. The process by which the scent spreads through the air is an example of diffusion. **Diffusion** (dih-FYOO-zhuhn) is the process by which molecules spread out, or move from areas where there are many of them to areas where there are fewer of them.

Diffusion occurs because the molecules in gases, liquids, and even solids are in constant motion in all directions. This random movement of molecules tends to spread molecules out until they are evenly distributed. But diffusion does more than just spread a scent around a room. Diffusion helps cells maintain conditions necessary for life. For example, the oxygen needed for cellular respiration enters cells by diffusion. Similarly, the carbon dioxide produced by cellular respiration leaves cells by diffusion.

VOCABULARY
Add a word triangle diagram for *diffusion* to your notebook.



Concentration

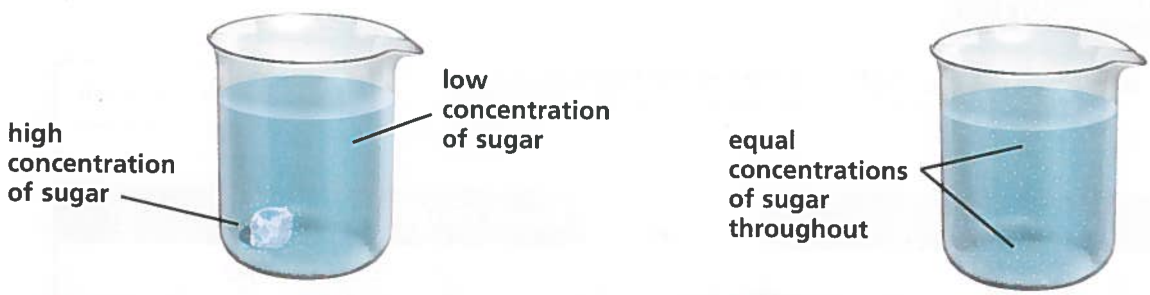
Diffusion occurs naturally as particles move from an area of higher concentration to an area of lower concentration. The concentration of a substance is the number of particles of that substance in a specific volume. For example, if you dissolved 9 grams of sugar in 1 liter of water, the concentration of the sugar solution would be 9 grams per liter, or 9 g/L. When there is a difference in the concentration of a substance between two areas, diffusion occurs.

Generally, the greater the difference in concentration between two areas, the more rapidly diffusion occurs. As the difference in concentration decreases, diffusion slows down. The number of particles moving to one area is balanced by the number moving in the other direction. Particles are still moving in all directions, but these movements do not change the concentrations.

CHECK YOUR READING Summarize what happens during diffusion. (Remember, a summary includes only the most important information.)

Concentration and Diffusion

A sugar cube dissolving in water provides an example of diffusion.



1. Shortly after a sugar cube is placed in a beaker of water, the concentration of sugar is high near the sugar cube and very low elsewhere in the beaker.
2. Over time, diffusion causes the concentration of sugar to become the same throughout the beaker. Particles are still moving.

Diffusion in Cells

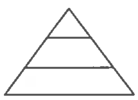
Diffusion is one way by which materials move in and out of cells. Small molecules such as oxygen can pass through tiny gaps in the cell membrane by diffusion. For example, consider the conditions that result from photosynthesis in a leaf cell.

- Photosynthesis produces oxygen inside the cell.
- The concentration of oxygen molecules becomes higher inside the cell than outside.
- Oxygen molecules move out of the cell by diffusion.

RESOURCE CENTER
CLASSZONE.COM
Learn more about diffusion.

In a plant cell, some of the oxygen produced by photosynthesis is used in cellular respiration. The remaining oxygen diffuses out of the cell. Much of it escapes to the air. Some of it diffuses to other cells where there is a lower concentration of oxygen. This process of diffusion continues from one cell to the next.

VOCABULARY
Add a word triangle diagram for *passive transport* to your notebook. You may want to use words instead of a sketch in the top part of your triangle.



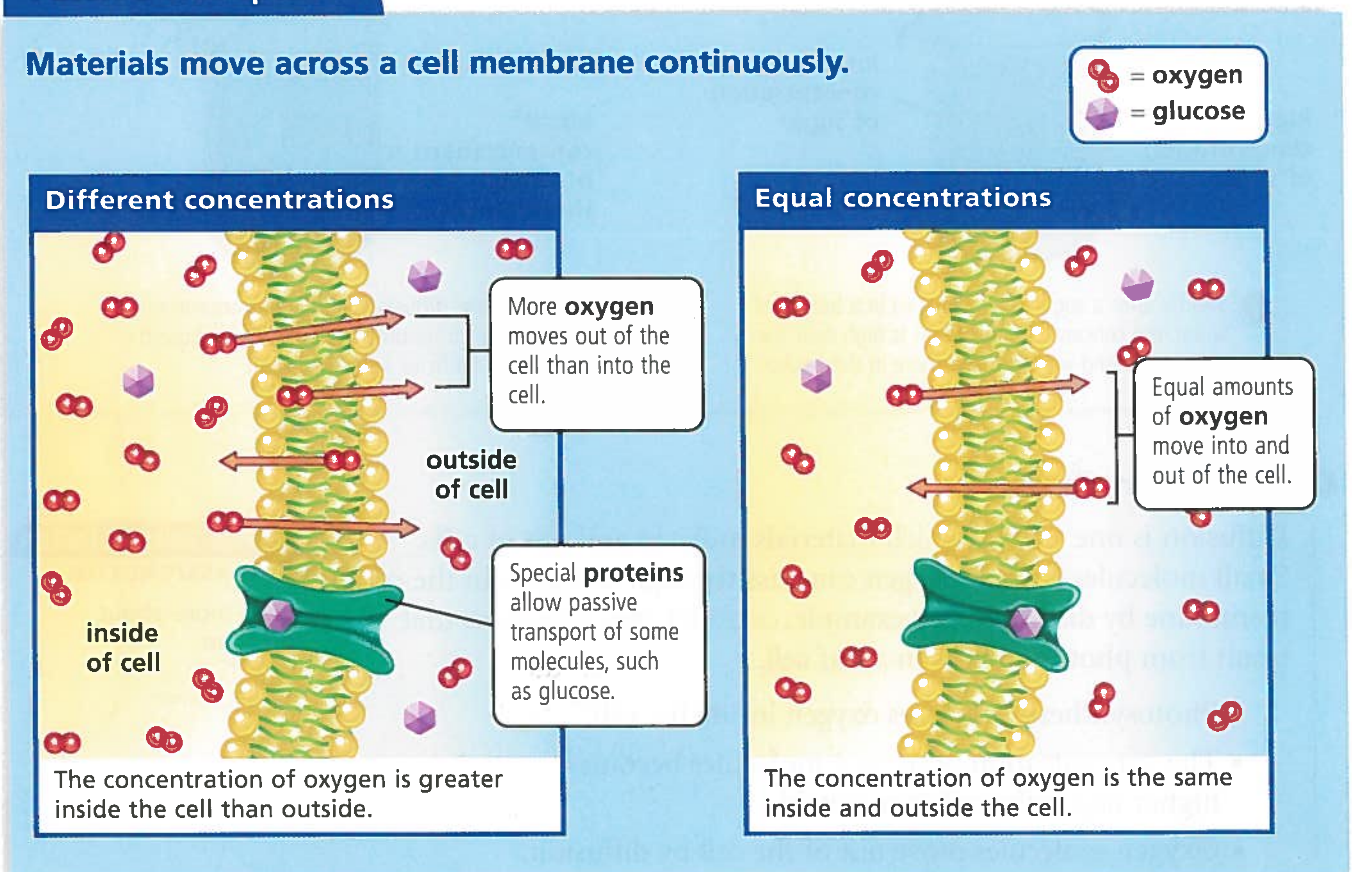
Remember that cell membranes are made of lipids. The lipids prevent large molecules, such as glucose, from passing through the membrane. Some molecules, such as oxygen, pass right through the membranes. Oxygen molecules pass back and forth until the concentration of oxygen is the same on both sides of the membrane. Diffusion occurs right through the cell membrane.

Some molecules can move through special passages in the cell membrane. Each passage is formed by proteins that allow just one type of molecule, such as glucose, to pass.

When molecules move through the cell membrane in either of these ways, they tend to balance the concentration on the two sides of the membrane. The cell does not use energy to move these materials. Scientists use the term **passive transport** for the movement of materials that does not use the cell's energy.

CHECK YOUR READING What is passive transport? Your answer should mention energy.

Passive Transport

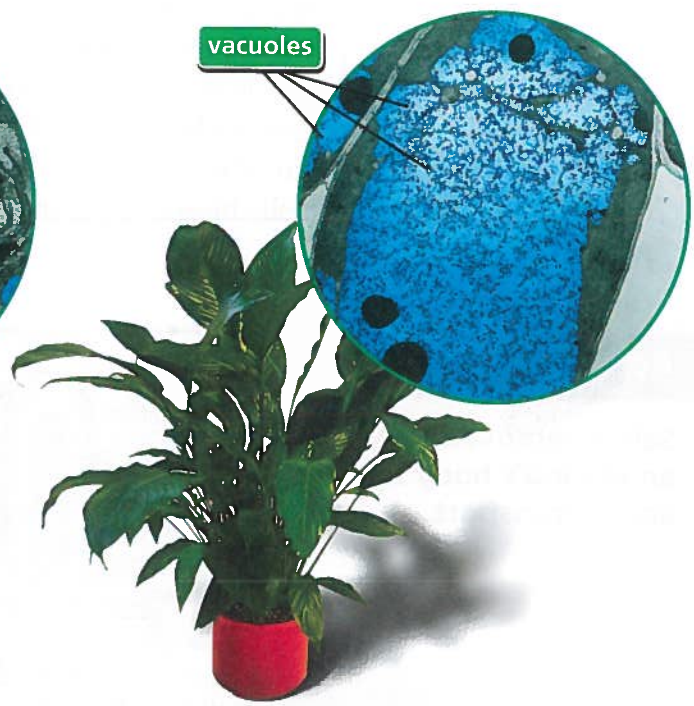


Osmosis

You have read about the importance of water to cells. Water molecules move through cell membranes by diffusion. The diffusion of water through a membrane is given a special name, **osmosis** (ahz-MOH-sihs). If the concentration of water is higher outside a cell than inside, water moves into the cell. If the concentration of water is lower outside a cell, water moves out of the cell.

You can easily observe the effect of osmosis on plants. If you forget to water a plant, it wilts. Why? The soil dries out, and the plant's roots have no water to absorb. As a result, water leaves the plant cells by osmosis and they shrink. If you water the plant, water becomes available to enter the shrunken cells by osmosis. The leaves will return to normal as water moves into the cells.

Without water, a plant droops. The cells have little water in their vacuoles, shown in blue. (magnified 1200×)



Water moves into leaf cells by osmosis and fills the vacuoles, shown in blue. (magnified 1200×)

Some transport requires energy.

Not all materials that move into and out of a cell can do so by diffusion. For cells to carry out life functions, materials must often move from areas of low concentration into areas of high concentration. This process of moving materials requires energy.

OUTLINE
Remember to include the blue heading and notes on the red headings in your outline.

Active Transport

Active transport is the process of using energy to move materials through a membrane. This process is different from diffusion and other types of passive transport, which do not require energy.

CHECK YOUR READING How is active transport different from passive transport?

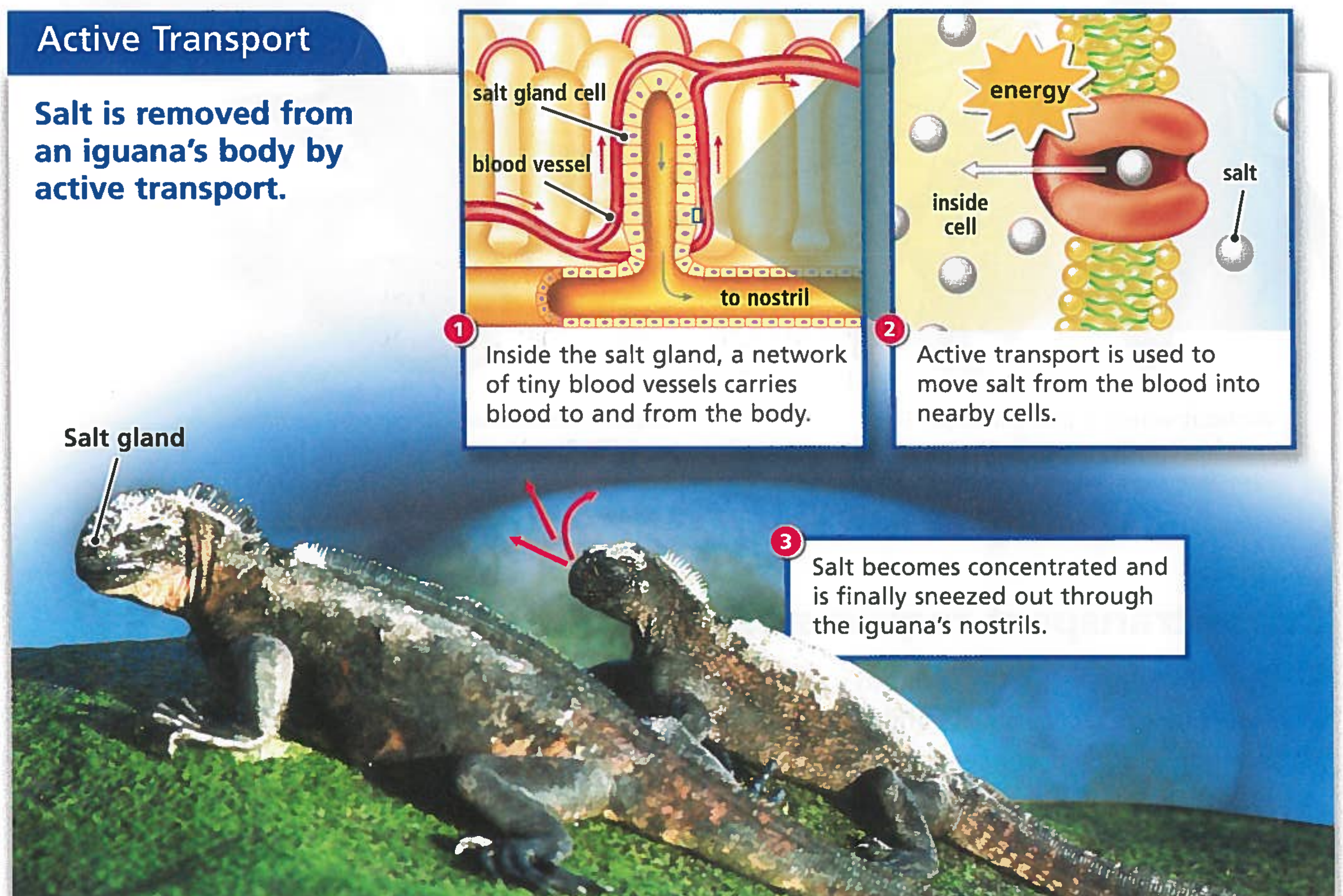
VISUALIZATION CLASSZONE.COM
Observe active transport at work.

Cells use active transport to perform important life functions, including the removal of excess salt from the body. Consider the example of active transport in marine iguanas, shown below. These lizards swim and feed in the salty ocean. As a result, they soak up a lot of salt. Too much salt can seriously damage the iguanas' cells, so the cells must get rid of the excess.

The solution to the marine iguana's salt problem is found in two small glands between its eyes and nostrils. Cells in these glands remove excess salt from the blood by active transport. Even when cells in these glands have a higher concentration of salt than is in the iguana's blood, the cells use chemical energy to continue taking salt out of the blood. The gland forms a droplet of salt, which the iguana easily blows out through its nostrils.

Active Transport

Salt is removed from an iguana's body by active transport.



1 Inside the salt gland, a network of tiny blood vessels carries blood to and from the body.

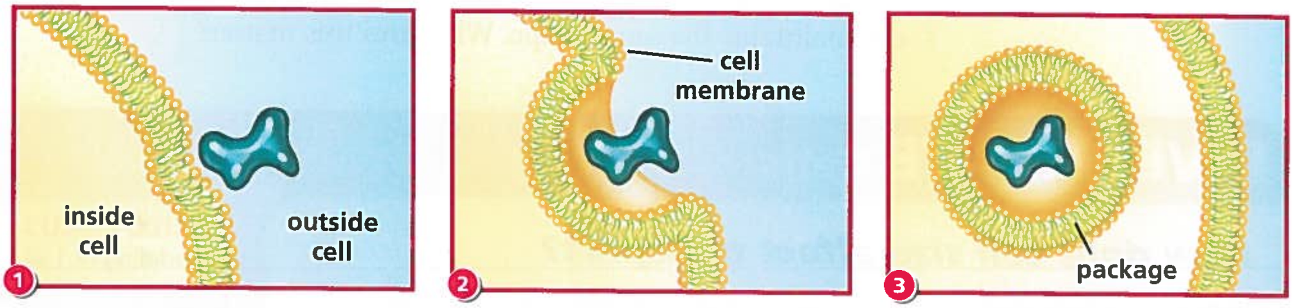
2 Active transport is used to move salt from the blood into nearby cells.

3 Salt becomes concentrated and is finally sneezed out through the iguana's nostrils.

You may not be able to blow salt out of your nostrils, but your kidneys help maintain healthful salt levels in your body. Your kidneys filter wastes from your blood by active transport. Cells in the kidneys remove excess salt from the blood.

Endocytosis

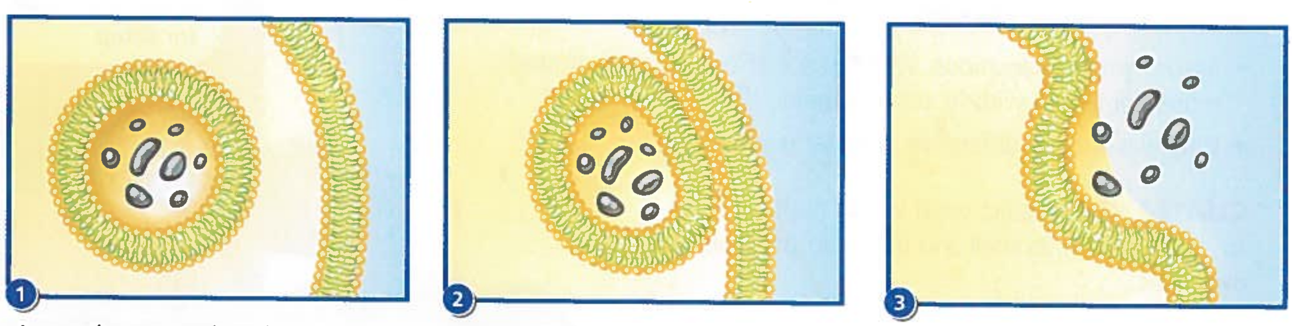
Cells also need to move materials that are too large to go through the cell membrane or a protein channel. As the diagram below illustrates, endocytosis (EHN-doh-sy-TOH-sihs) occurs when a large bit of material is captured within a pocket of the membrane. This pocket breaks off and forms a package that moves into the cell. Cells in your body can use endocytosis to absorb essential nutrients, like iron.



1. As a particle approaches, the cell membrane folds inward, creating a pocket.
2. The particle moves into the pocket, and the membrane closes around it, forming a package.
3. The package breaks away from the cell membrane, bringing the particle into the cell.

Exocytosis

When a cell needs to get rid of large materials, the process of endocytosis is reversed. In exocytosis (EHK-soh-sy-TOH-sihs), a membrane within the cell encloses the material that needs to be removed. This package moves to the cell membrane, joins with it, and the material is expelled. Cells often use exocytosis to flush out waste materials or to expel proteins or hormones made by the cell.



1. A membrane-enclosed package carries materials from inside the cell to the cell membrane.
2. The membrane of the package attaches to the cell membrane, and the two membranes merge.
3. The materials are pushed out of the cell as the membrane of the package becomes part of the cell membrane.

Cell size affects transport.

Most cells are very small. In fact, most cells are too small to be seen without a microscope. The average cell in your body is about 20 micrometers (0.02 millimeters) in diameter. Most of the cells on this planet are bacteria, which are only 3 to 5 micrometers in diameter. How can something as important as a cell be so tiny? Actually, if cells were not so small, they could never do their jobs.

Everything the cell must take in or get rid of has to go through the cell membrane. The amount of cell membrane limits the ability of cells to get substances from the outside or transport waste and other materials to the outside. This ability is related to surface area. The relationship between surface area and volume controls cell size. As a cell gets larger, its volume increases faster than its surface area if the cell maintains the same shape. Why does this matter?

INVESTIGATE Cells

How does cell size affect transport?

Demonstrate how small size helps make it possible for cells to get resources.

PROCEDURE

1. Use the knife to cut a large piece of egg white from the egg.
2. Trim the egg white into a small cube, about 1 cm square, and a large cube, about 2 cm square.
3. Pour 100 mL of water into the beaker. Add 10 drops of blue food coloring and stir. Place both cubes into the solution. Leave them in the colored water overnight.
4. Remove each cube gently from the water with a spoon. Place both on a paper towel. With the knife, cut each cube in half. Use the ruler to measure how far the blue water penetrated into the surface of each one.

WHAT DO YOU THINK?

- Record your observations. Which piece of egg was penetrated more, compared with its total diameter, by the blue water?
- Why was there a difference in water penetration?

CHALLENGE Predict what would happen to an egg left in its shell and placed in the blue water overnight.

SKILL FOCUS
Modeling (7.1.a)

MATERIALS
- 2 hard-boiled, peeled eggs
- knife
- ruler
- 100 mL water
- glass beaker
- dark blue food coloring
- spoon
- paper towel

TIME
30 minutes for setup

Surface Area and Volumes of Cubes

	Number of Cubes	Side Length	Surface Area	Volume
4 cm 	1	4 cm	$96\ cm^2$	$64\ cm^3$
2 cm 	8	2 cm	$192\ cm^2$	$64\ cm^3$
1 cm 	64	1 cm	$384\ cm^2$	$64\ cm^3$

As the cell gets bigger, there comes a time when its surface area is not large enough to allow resources to travel to all parts of the cell. Bird eggs and frog eggs are much larger than typical cells, but they have a storehouse of food and also rapidly divide to produce multicellular embryos. In fact, a multicellular embryo is a good illustration of another way cells get around the surface-area-to-volume problem: they divide. The ratio of surface area to volume in newly divided cells is much higher, providing more surface area for exchanging materials.

A cell's shape also affects its surface area. For example, some single-celled organisms are thin and flat, providing increased surface area. Other cells, such as nerve cells and muscle cells, are long and thin, which also gives them a higher ratio of surface area to volume.

READING TIP

Look at the chart above. Notice that the volumes are all the same, but the surface area changes.

CHECK YOUR READING How is diffusion different in a small, flat cell and a large, round cell?

2.3 Review

KEY CONCEPTS

1. How are the processes of diffusion and osmosis alike? **(7.1.a)**
2. What is the difference between active and passive transport? Use the term *energy* in your answer. **(7.1.a)**
3. How does the surface area of a cell limit the growth of the cell? **(7.1.a)**

CRITICAL THINKING

4. **Apply** If you put a carnation in water, through what process does the water enter the stem?
5. **Predict** If a marine iguana were to spend a few days in a freshwater tank, would it continue to blow salt droplets from its nostrils? Why or why not?

CHALLENGE

6. **Predict** Freshwater protozoa, which are unicellular organisms, have a greater concentration of salt inside them than does the surrounding water. Does water move into or out of the protozoa?

CHAPTER INVESTIGATION

Diffusion

OVERVIEW AND PURPOSE The cell membrane controls what diffuses into and out of a cell. What factors affect the diffusion of substances across the cell membrane? In this investigation, you will

- observe the diffusion of a solution through plastic wrap
- determine how the concentration of iodine affects the amount of diffusion in a given time

Problem

Write It Up

How does the concentration of a substance affect its diffusion through a membrane?

Hypothesize

Write It Up

After step 4, write a hypothesis to explain how the concentration of iodine will affect the amount of diffusion in 20 minutes. Your hypothesis should be in the form of an "if . . . , then . . . , because . . . " statement.

MATERIALS

- eyedroppers
- cornstarch solution
- baby food jar with lid
- plastic wrap
- Lugol's iodine solution
- iodine solution A, B, or C
- graduated cylinder (if available)

7.1.a, 7.7.c

Procedure

1. Make a data table like the one shown on the sample notebook page.

2. Use one eyedropper to put several drops of cornstarch solution on the lid of the jar. With another eyedropper, add a few drops of Lugol's iodine to the solution on the lid. Observe and record what happens when iodine mixes into water and starch.

3. Fill the jar about three-fourths full with the cornstarch solution. Place the plastic wrap loosely over the jar. Adjust it so that the center of the plastic dips a little into the cornstarch solution.

4. Pour 10 mL of the iodine solution that you are given (A, B, or C) on the plastic wrap membrane. Solution A is the most concentrated and C is the least. Record your observations. Now write your hypothesis.

Content Standard
7.1.a Students know cells function similarly in all living organisms.

Investigation Standard
7.7.c Communicate the logical connection among hypotheses, science concepts, tests conducted, data collected, and conclusions drawn from the scientific evidence.

5 Examine the solutions above and below the membrane after 20 minutes. Record any color changes, as well as the intensity of any changes, that you observe. Also look at your classmates' solutions, noting which solution (A, B, or C) each used.

Observe and Analyze

Write It Up

1. **IDENTIFY VARIABLES** Identify the constants. What is the same in the experiment for all groups?

   Identify the independent variable. What is being changed between groups?

   Identify the dependent variable. What is being observed?

2. **RECORD OBSERVATIONS** Draw before-and-after pictures of your setup and label each drawing. Be sure to show the colors of the solutions on both sides of the membrane in each drawing.
3. **INFER** Make a drawing to show the direction in which molecules diffused through the membrane in your experiment.
4. **COMPARE AND CONTRAST** Compare the observations you made about your iodine solution with the observations made by your classmates. Be sure to record which iodine solution (A, B, or C) produced which changes.

Conclude

Write It Up

1. **ANALYZE** Which iodine solution (A, B, or C) produced the greatest color change?
2. **INTERPRET** Do the class's results support your hypothesis? Explain.
3. **IDENTIFY LIMITS** Describe anything that might have varied from group to group. How might these variations affect your results?
4. **INTERPRET** Did starch diffuse through the membrane into the iodine solution? How do you know? Did iodine diffuse through the membrane into the cornstarch solution? How do you know?
5. **INFER** Which solution do you think contains larger molecules, cornstarch or iodine? Why weren't the larger molecules able to diffuse through the membrane?
6. **APPLY** Identify two real-life situations in which diffusion occurs.

INVESTIGATE Further

CHALLENGE Investigate the role of temperature in diffusion. Predict how changes in the temperature of the iodine solution will affect the diffusion process. Explain.

Diffusion

Table 1. Color Changes

Solution	Color at 0 min		Color at 20 min	
	cornstarch solution	iodine solution	cornstarch solution	iodine solution
A				
B				
C				

2 Chapter Review

the BIG idea

All cells need energy and materials for life processes.

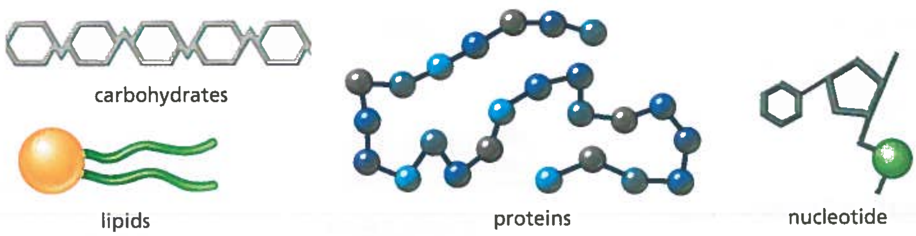
CONTENT REVIEW
CLASSZONE.COM

KEY CONCEPTS SUMMARY

1 Chemical reactions take place inside cells.

All cells are made of the same elements. Cells contain four types of large molecules—**carbohydrates, lipids, proteins,** and **nucleic acids**—that support cell function.

About two-thirds of every cell is water. The properties of water are important to cell function.

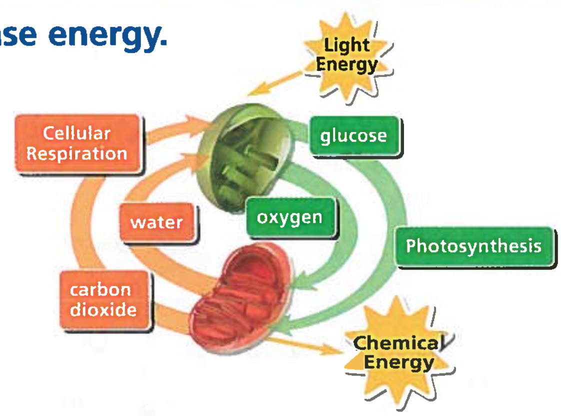


VOCABULARY
chemical reaction p. 42
carbohydrate p. 42
lipid p. 43
protein p. 43
nucleic acid p. 43

2 Cells capture and release energy.

All cells need energy. Some cells capture light energy through **photosynthesis.** All cells release chemical energy.

Cellular respiration and **fermentation** are two ways that cells release energy from glucose.



VOCABULARY
chemical energy p. 47
glucose p. 47
photosynthesis p. 48
chlorophyll p. 48
cellular respiration p. 50
fermentation p. 52

3 Materials move across the cell's membranes.

Passive transport does not use a cell's energy. It is the movement of materials to an area of lower concentration. **Diffusion** and **osmosis** are examples of passive transport.

Active transport uses a cell's energy. It is both the movement of materials to an area of higher concentration and the movement of large materials.

passive transport

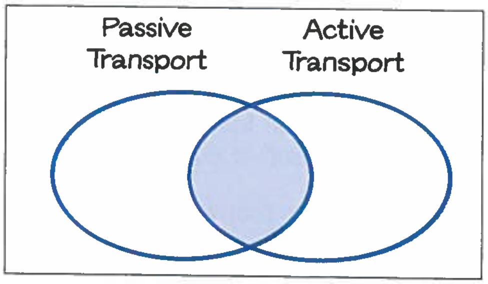
active transport

VOCABULARY
diffusion p. 56
passive transport p. 58
osmosis p. 59
active transport p. 60

Reviewing Vocabulary

Use terms from the vocabulary lists on page 66 to answer these questions.

1. Which molecule stores information?
2. Which term describes the process when two or more atoms bond together?
3. What kind of energy do cells use?
4. Which term describes the process in which cells release energy without using oxygen?
5. Which process occurs in chloroplasts?
6. From what sugar molecule do many living things release energy?
7. Which chemical that aids in photosynthesis do you find in a chloroplast?
8. Which term means "diffusion of water across cell membranes"?
9. What two processes have opposite effects?
10. Use a Venn diagram to compare and contrast passive transport and active transport.



Reviewing Key Concepts

Multiple Choice *Choose the letter of the best answer.*

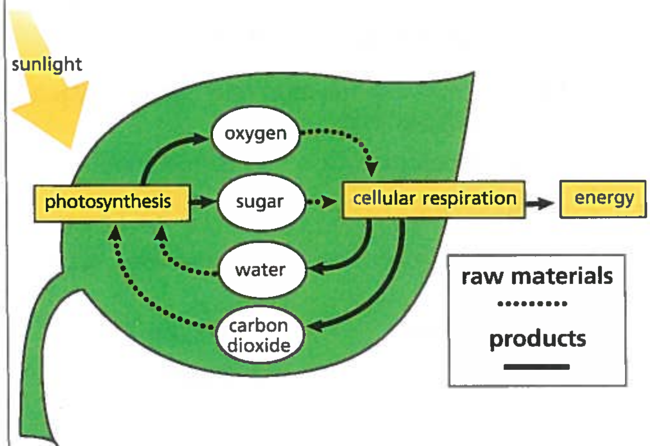
11. The fats, oils, and waxes found in living things are known as (7.1.a)
    - **a.** lipids
    - **b.** proteins
    - **c.** carbohydrates
    - **d.** glucose
12. What do cells use as a source of energy and for energy storage? (7.1.a)
    - **a.** proteins
    - **b.** water
    - **c.** cytoplasm
    - **d.** carbohydrates
13. Leaf cells use chlorophyll to absorb (7.1.b)
    - **a.** oxygen
    - **b.** light energy
    - **c.** carbon dioxide
    - **d.** glucose
14. The cells of a redwood tree require oxygen for the process of (7.1.d)
    - **a.** photosynthesis
    - **b.** cellular respiration
    - **c.** fermentation
    - **d.** endocytosis
15. In fermentation, cells release energy without (7.1.a)
    - **a.** alcohol
    - **b.** water
    - **c.** glucose
    - **d.** oxygen
16. Both a whale and a seaweed use which of the following to change glucose into energy? (7.1.a)
    - **a.** water
    - **b.** photosynthesis
    - **c.** cellular respiration
    - **d.** bonding
17. The movement of materials across a cell membrane, requiring energy, is called (7.1.a)
    - **a.** diffusion
    - **b.** osmosis
    - **c.** passive transport
    - **d.** active transport

Short Answer *Write a short answer to each question.*

18. Why is water needed by cells? (7.1.a)
19. Describe the main function of nucleic acids. (7.1.a)
20. What is the role of chlorophyll in a plant's leaves? (7.1.d)
21. Explain why a carrot feels spongy after being soaked in salt water. (7.1.a)
22. Explain how the ways in which plants and animals get their energy differ. (7.1.b)

Thinking Critically

The illustration below summarizes the relationship between photosynthesis and cellular respiration. Use it to answer the next three questions.



23. **OBSERVE** What are the starting materials of photosynthesis? What are the starting materials of cellular respiration? (7.1.d)

24. **OBSERVE** What are the products of photosynthesis? What are the products of cellular respiration? (7.1.d)

25. **DRAW CONCLUSIONS** What does the diagram above reveal about the connections between photosynthesis and cellular respiration? (7.1.d)

26. **RECOGNIZE CAUSE AND EFFECT** Explain why chemical reactions are essential to living creatures. (7.1.a)

27. **MODEL** How does a glass filled with oil and water illustrate the properties of a cell membrane? What properties does it not illustrate? (7.1.a)

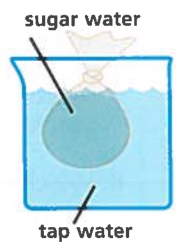
28. **INFER** The French scientist Louis Pasteur mixed yeast and grape juice in a sealed container. When he opened the container, the grape juice contained alcohol. Explain what happened. (7.1.a)

29. **DRAW CONCLUSIONS** Why would it be harmful to your health to drink seawater? (7.1.a)

Process	Requires Energy?	Moves from Higher to Lower Concentration?
Diffusion	no	yes
Osmosis		
Active transport		
Passive transport		

30. **CHART INFORMATION** Copy and complete the chart shown above. The first line is done for you. (7.1.a)

31. **PREDICT** Look at the diagram at the right. The bag has pores that are bigger than the sugar molecules. What will be true of the concentration of the sugar water after a few hours? (7.1.a)



the BIG idea

32. **COMPARE AND CONTRAST** Look again at the picture on pages 38–39. Now that you have read the chapter, how would you add to or change your answer to the question? (7.1.d)

33. **INFER** Does your body get all its energy from the Sun? Explain. (7.1.d)

34. **WRITE** Imagine that your community has a high level of carbon dioxide emission from cars and factories. A developer wants to build a shopping center on the remaining forest land. Would this action increase or decrease carbon dioxide levels? Why? Write a paragraph explaining your answer. (7.1.d)

UNIT PROJECTS

Check your schedule for your unit project. How are you doing? Be sure that you have placed data or notes from your research in your project folder.

Standards-Based Assessment

For more practice, go to . . .
TEST PRACTICE
CLASSZONE.COM

Analyzing Data

7.1.b, 7.1.d

Elodea plants in beakers of water were placed at different distances from a light source. The number of bubbles that formed on the plants was counted and recorded. The data table shows the results.

Beaker	Distance from light	Bubbles per minute
1	200 cm	2
2	100 cm	10
3	50 cm	45
4	20 cm	83

Study the data and answer the questions below.

1. What gas do the bubbles consist of?

a. carbon dioxide
b. hydrogen
c. water vapor
d. oxygen

2. What is the relationship between the distance from the light source and the rate of bubble formation?

a. The rate increases as the distance increases.
b. The rate decreases as the distance increases.
c. The rate stays the same as the distance increases.
d. The rate changes in a way unrelated to distance.

3. If another beaker with *elodea* were placed 150 cm from the light, about how many bubbles would form each minute?

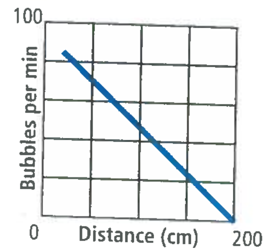
a. 1
b. 7
c. 11
d. 24

4. What is the independent variable in this experiment?

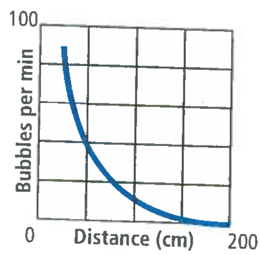
a. type of plant
b. number of bubbles
c. distance from light
d. amount of time

5. Which graph best represents the data shown in the table?

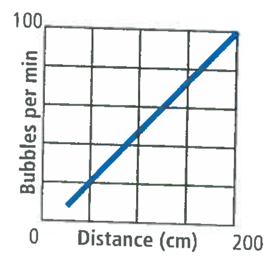
a.



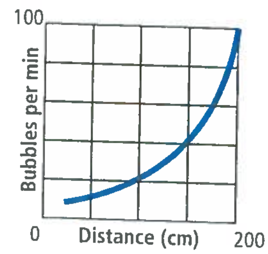
b.



c.



d.



Extended Response

Answer each question. Include some of the terms shown in the word box. In your answers underline each term you use.

chemical energy	cellular respiration
osmosis	chloroplasts
fermentation	glucose
photosynthesis	diffusion

6. A person rides his bicycle several miles. What process is used by the cells in his legs to release energy at the beginning of the ride? at the end of the ride? Explain.

7. A student places a plant in a sealed container and puts the container on a windowsill. She leaves the plant there for a week. Will the plant have the starting materials it needs to carry out photosynthesis during the entire week? Explain.