McGraw-Hill Education

Biology

United Arab Emirates Edition

GRADE 9 ADVANCED

VOLUME 1

Project: McGraw-Hill Education United Arab Emirates Edition Advanced Science Grade 9 Year 3 Vol 1 Student Edition – Biology
All Chapters from Glencoe Biology, Student Edition ©2017

COVER: Teguh Mujiono/Shutterstock

mheducation.com/prek-12

Printed in the United Arab Emirates.

ISBN: 978-1-52-686739-1 *(Student Edition)*
MHID: 1-52-686739-7 *(Student Edition)*
ISBN: 978-1-52-686740-7 *(Teacher Edition)*
MHID: 1-52-686740-0 *(Teacher Edition)*

1 2 3 4 5 6 7 8 9 XXX 22 21 20 19 18 17

ePub Edition

ISBN: 978-1-52-686744-5 *(Student Edition)*
MHID: 1-52-686744-3 *(Student Edition)*
ISBN: 978-1-52-686745-2 *(Teacher Edition)*
MHID: 1-52-686745-1 *(Teacher Edition)*

"Extensive knowledge and modern science must be acquired. The educational process we see today is in an ongoing and escalating challenge which requires hard work.
We succeeded in entering the third millennium, while we are more confident in ourselves."

H.H. Sheikh Khalifa Bin Zayed Al Nahyan
President of the United Arab Emirates

Contents in Brief

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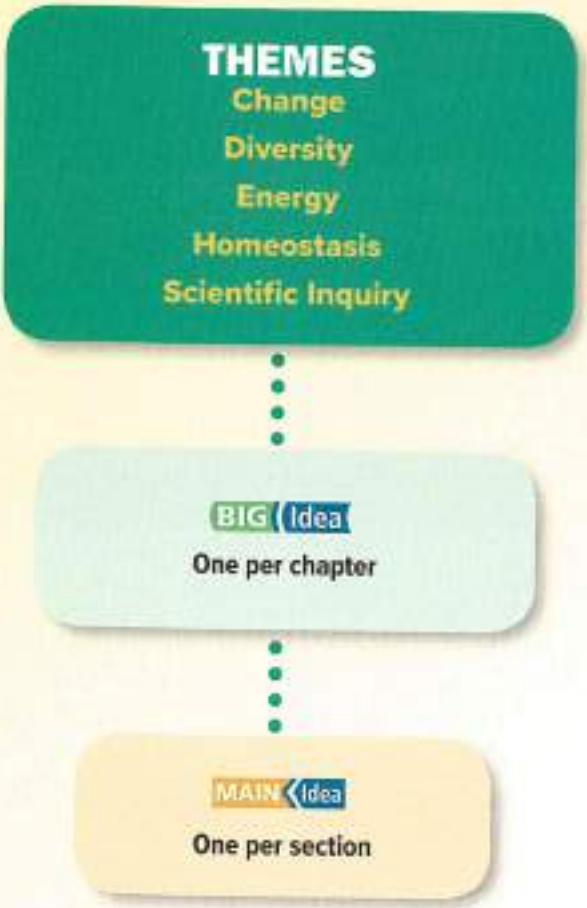
Contents

Your book is divided into units and chapters that are organized around Themes, Big Ideas, and Main Ideas of biology.

THEMES are overarching concepts used throughout the entire book that help you tie what you learn together. They help you see the connections among major ideas and concepts.

BIG Idea appear in each chapter and help you focus on topics within the themes. The Big Ideas are broken down even further into Main Ideas.

MAIN Idea draw you into more specific details about biology. All the Main Ideas of a chapter add up to the chapter's Big Idea.



Student Guide

Contents

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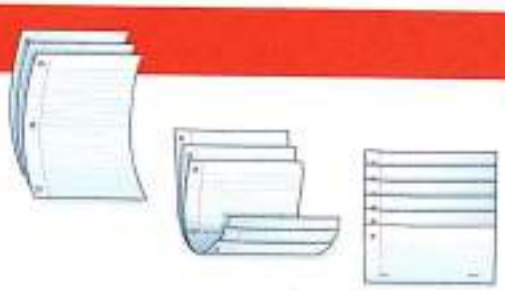
FOLDABLES®

by Dinah Zike

Folding Instructions

The following pages offer step-by-step instructions to make the Foldables study guides.

Layered-Look Book

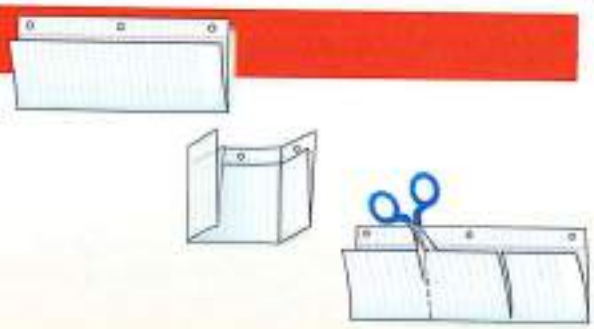


1. Collect three sheets of paper and layer them about ½ inch apart vertically. Keep the edges level.
2. Fold up the bottom edges of the paper to form six equal tabs.
3. Fold the papers and crease well to hold the tabs in place. Staple along the fold. Label each tab.

Trifold Book

1. Fold a vertical sheet of paper into thirds.
2. Unfold and label each row.

Three-Tab Book



1. Fold a vertical sheet of paper from side to side. Make the front edge about 2 cm shorter than the back edge.
2. Turn lengthwise and fold into thirds.
3. Unfold and cut only the top layer along both folds to make three tabs. Label each tab.

Two- and Four-Tab Books

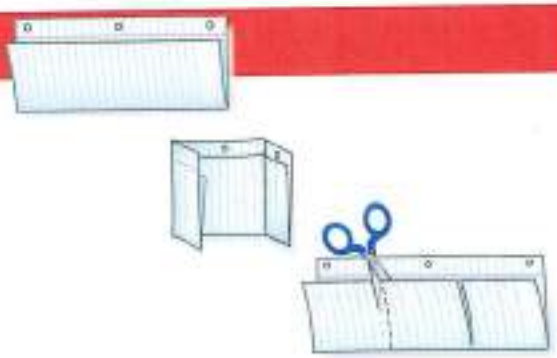
1. Fold a sheet of paper in half.
2. Fold in half again. If making a four-tab book, then fold in half again to make three folds.
3. Unfold and cut only the top layer along the folds to make two or four tabs. Label each tab.

Foldables

Four-Door Book

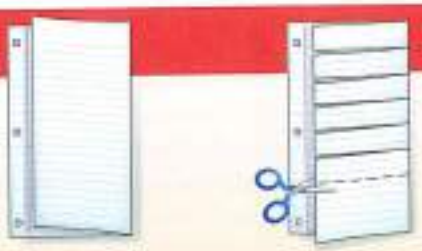
1. Find the middle of a horizontal sheet of paper. Fold both edges to the middle and crease the folds.
2. Fold the folded paper in half, from top to bottom.
3. Unfold and cut along the fold lines of the top layers to make four tabs. Label each tab.

Concept-Map Book



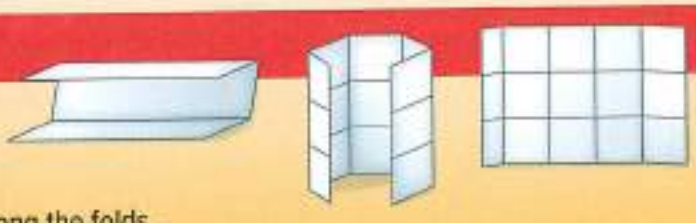
1. Fold a vertical sheet of paper from top to bottom. Make the top edge about 2 cm shorter than the bottom edge.
2. Turn lengthwise and fold into thirds.
3. Unfold and cut only the top layer along both folds to make three tabs. Label the top and each tab

Vocabulary Book



1. Fold a vertical sheet of notebook paper in half.
2. Cut along every third line of only the top layer to form tabs. Label each tab.

Folded Chart



1. Fold a sheet of paper lengthwise into thirds.
2. Fold the paper widthwise into fifths.
3. Unfold, lay the paper lengthwise, and draw lines along the folds. Label the table.

CHAPTER 1

Cellular Structure and Function

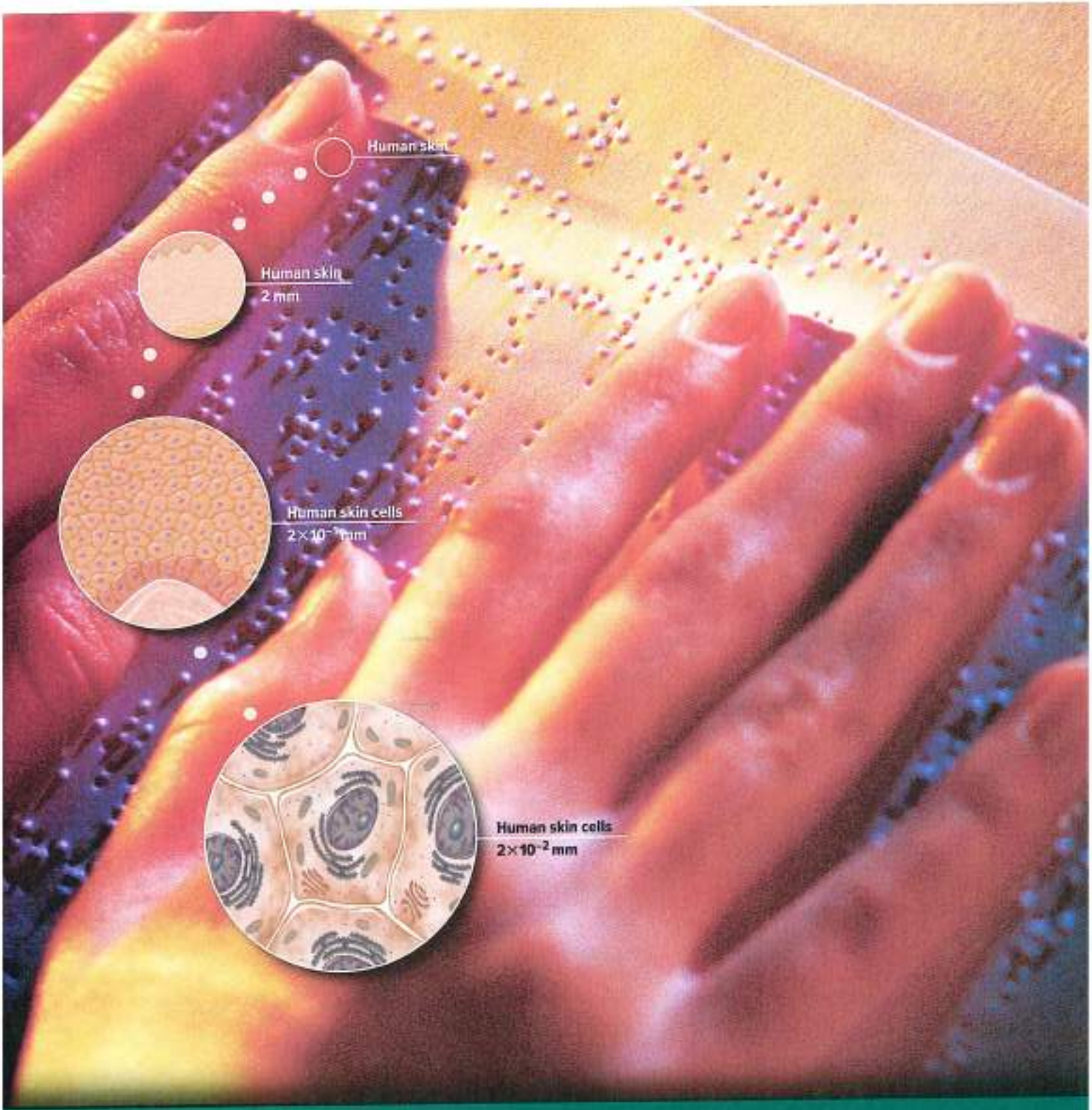
Launch Lab

What is a cell?

All things are made of atoms and molecules, but only in living things are the atoms and molecules organized into cells. In this lab, you will use a compound microscope to view slides of living things and nonliving things.

FOLDABLES

Make a layered-look book using the titles shown. Use it to organize your notes on cellular transport.



THEME FOCUS Scientific Inquiry

Scientific inquiry led to the invention of the microscope, which made many discoveries possible.

BIG Idea Cells are the structural and functional units of all living organisms.

Section 1

Reading Preview

Essential Questions

- How are the advances in microscope technology related to discoveries about cells?
- What are the similarities and differences between compound light microscopes and electron microscopes?
- What are the principles of the cell theory?
- What are the differences between a prokaryotic cell and a eukaryotic cell?

Review Vocabulary

organization: the orderly structure shown by living things

New Vocabulary

cell
cell theory
plasma membrane
organelle
eukaryotic cell
nucleus
prokaryotic cell

Cell Discovery and Theory

MAIN Idea **The invention of the microscope led to the discovery of cells.**

Real-World Reading Link The different parts of your body might seem to have nothing in common. Your heart, for example, pumps blood throughout your body, while your skin protects and helps cool you. However, your body parts have one thing in common—they are composed of cells.

History of the Cell Theory

For centuries, scientists had no idea that the human body consists of trillions of cells. Cells are so small that their existence was unknown before the invention of the microscope. In 1665, as indicated in **Figure 1,** an English scientist named Robert Hooke made a simple microscope and looked at a piece of cork, the dead cells of oak bark. Hooke observed small, box-shaped structures, such as those shown in **Figure 2.** He called them cellulae (the Latin word meaning *small rooms*) because the boxlike cells of cork reminded him of cells, or small, narrow confining rooms. It is from Hooke's work that we have the term *cell.* A **cell** is the basic structural and functional unit of all living organisms.

During the late 1600s, Dutch scientist Anton van Leeuwenhoek (LAY vun hook) designed his own microscope after he was inspired by a book written by Hooke. To his surprise, he saw living organisms in pond water, milk, and various other substances. The work of these scientists and others led to new branches of science and many new and exciting discoveries.

Figure 1

Microscopes in Focus

The invention of microscopes, improvements to the instruments, and new microscope techniques have led to the development of the cell theory and a better understanding of cells.

1665 Robert Hooke observes cork and names the tiny chambers that he sees cells. He publishes drawings of cells, fleas, and other minute bodies in his book *Micrographia.*

1830–1855 Scientists discover the cell nucleus (1833) and propose that both plants and animals are composed of cells (1839).

1500 | 1600 | 1700 | 1800

1590 Dutch lens grinders Hans and Zacharias Janssen invent the first compound microscope by placing two lenses in a tube.

1683 Dutch biologist Anton van Leeuwenhoek discovers single-celled, animal-like organisms, now called protozoans.

The cell theory Scientists continued observing the living microscopic world using glass lenses. In 1838, German scientist Matthias Schleiden carefully studied plant tissues and concluded that all plants are composed of cells. A year later, another German scientist, Theodor Schwann, reported that animal tissues also consisted of individual cells. Prussian physician Rudolph Virchow proposed in 1855 that all cells are produced from the division of existing cells. The observations and conclusions of these scientists and others are summarized as the cell theory. The **cell theory** is one of the fundamental ideas of modern biology and includes the following three principles:

1. All living organisms are composed of one or more cells.
2. Cells are the basic unit of structure and organization of all living organisms.
3. Cells arise only from previously existing cells, with cells passing copies of their genetic material on to their daughter cells.

Reading Check **Explain** Can cells appear spontaneously without genetic material from previous cells?

LM Magnification: 100×

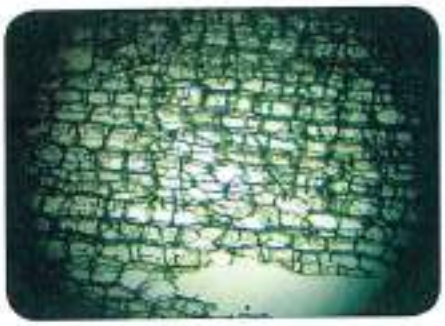


Figure 2 Robert Hooke used a basic light microscope to see what looked like empty chambers in a cork sample.
Infer *what you think Hooke would have seen if these were living cells.*

Microscope Technology

The discovery of cells and the development of the cell theory would not have been possible without microscopes. Improvements made to microscopes have enabled scientists to study cells in detail, as described in **Figure 1.**

Turn back to the opening pages of this chapter and compare the illustrations of the skin shown there. Note that the detail increases as the magnification and resolution–the ability of the microscope to make individual components visible–increase. Hooke and van Leewenhoek would not have been able to see the individual structures within human skin cells with their microscopes. Developments in microscope technology have given scientists the ability to study cells in greater detail than early scientists ever thought possible.

Based on what you've read about cells, how would you now answer the analysis questions?

1939 Ernest Everett Just writes the textbook *Biology of the Cell Surface* after years of studying the structure and function of cells.

1981 The scanning tunneling microscope (STM) allows scientists to see individual atoms.

1900

2000

1880–1890 Louis Pasteur and Robert Koch, using compound microscopes, pioneered the study of bacteria.

1970 Lynn Margulis, a microbiologist, proposes the idea that some organelles found in eukaryotes were once free-living prokaryotes.

2008 3–dimensional structured illumination microscopy (3D-SIM) combines a 3-D view, high resolution, and multiple colors.

Compound light microscopes The modern compound light microscope consists of a series of glass lenses and uses visible light to produce a magnified image. Each lens in the series magnifies the image of the previous lens. For example, when two lenses each individually magnify 10 times, the total magnification is 100 times (10 × 10). Scientists often stain cells with dyes to see them better when using a light microscope because cells are so tiny, thin, and translucent. Over the years, scientists have developed various techniques and modifications for light microscopes, but the properties of visible light will always limit resolution with these microscopes. Objects cause light to scatter, which blurs images. The maximum magnification without blurring is around 1000×.

Electron microscopes As they began to study cells, scientists needed greater magnification to see the details of tiny parts of cells. During the second World War, in the 1940s, they developed the electron microscope. Instead of lenses, the electron microscope uses magnets to aim a beam of electrons at thin slices of cells. This type of electron microscope is called a transmission electron microscope (TEM) because electrons are passed, or transmitted, through a specimen to a fluorescent screen. Thick parts of the specimen absorb more electrons than thin parts, forming a black-and-white shaded image of the specimen. Transmission electron microscopes can magnify up to 500,000×, but the specimen must be dead, sliced very thin, and stained with heavy metals.

Over the past 65 years, many modifications have been made to the original electron microscopes. For example, the scanning electron microscope (SEM) is one modification that directs electrons over the surface of the specimen, producing a three-dimensional image. One disadvantage of using a TEM and an SEM is that only nonliving cells and tissues can be observed. Photomicrographs made with electron microscopes can be found online.

CAREERS IN BIOLOGY

Technology Representative
Companies that manufacture scientific equipment employ representatives to demonstrate and explain their products to the scientific community. A technology representative is an expert in these new technology products and brings this expertise to scientists who might use the products in the laboratory.

MiniLab 1

Discover Cells

How can you describe a new discovery? Imagine that you are a scientist looking through the eyepiece of some newfangled instrument called a microscope and you see a field of similarly shaped objects. You might recognize that the shapes that you see are not merely coincidence and random objects. Your whole idea of the nature of matter is changing as you view these objects.

Procedure

1. Identify the safety concerns of this lab before work begins.
2. Prepare a data table in which you will record observations and drawings for three slides.
3. View the **slide images** that your teacher projects for the class.
4. Describe and draw what you see. Be sure to include enough detail in your drawings to convey the information to other scientists who have not observed cells.

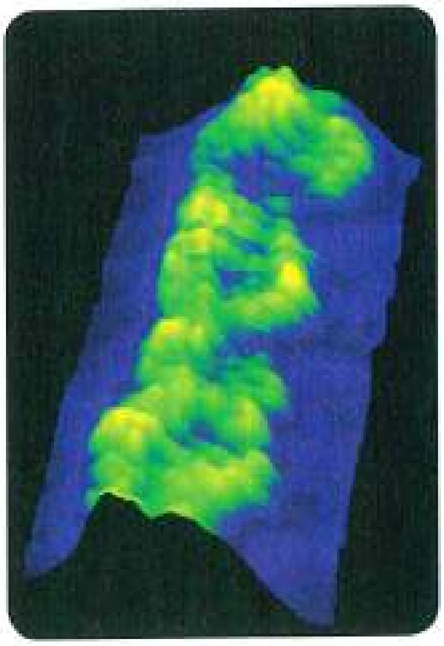
Analysis

1. **Describe** what analogies or terms could explain the images in your drawings.
2. **Explain** how you could show Hooke, with twenty-first-century technology, that his findings were valid.

Another type of microscope, the scanning tunneling electron microscope (STM), involves bringing the charged tip of a probe extremely close to the specimen so that the electrons "tunnel" through the small gap between the specimen and the tip. This instrument has enabled scientists to create three-dimensional computer images of objects as small as atoms. Unlike TEM and SEM, STM can be used with live specimens. **Figure 3** shows DNA, the cell's genetic material, magnified with a scanning tunneling electron microscope.

The atomic force microscope (AFM) measures various forces between the tip of a probe and the cell surface. To learn more about AFM, read the *Cutting Edge Biology* feature at the end of this chapter.

False-Color STM Magnification: 2,000,000×



DNA

Figure 3 The scanning tunneling microscope (STM) provides images, such as this DNA molecule, in which cracks and depressions appear darker and raised areas appear lighter. **Name** *an application for which an STM might be used.*

Basic Cell Types

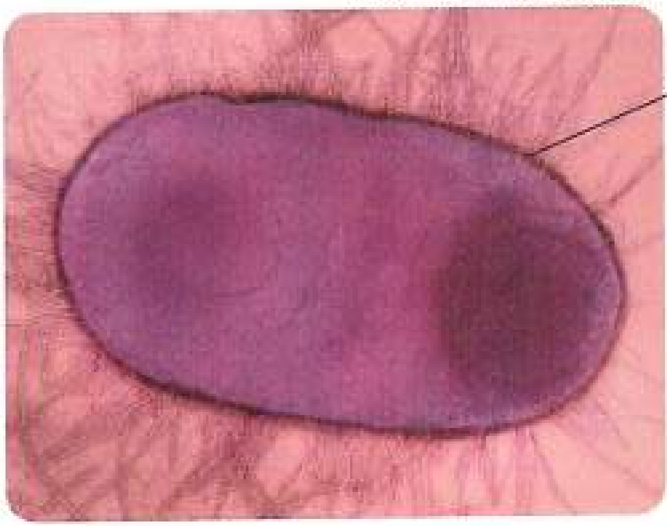
You have learned, according to the cell theory, that cells are the basic units of all living organisms. By observing your own body and the living things around you, you might infer that cells must exist in various shapes and sizes. You also might infer that cells differ based on the functions they perform for an organism. However, all cells have at least one physical trait in common: they all have a structure called a plasma membrane. A **plasma membrane**, labeled in **Figure 4,** is a special boundary that helps control what enters and leaves the cell. Each of your skin cells has a plasma membrane, as do the cells of a rattlesnake. This critical structure is described in detail in the next section.

Cells generally have a number of functions in common. For example, most cells have genetic material in some form that provides instructions for making substances that the cell needs. Cells also break down molecules to generate energy. Scientists have grouped cells into two broad categories. These categories are prokaryotic (pro kar ee AW tik) cells and eukaryotic (yew kar ee AW tik) cells. **Figure 4** shows TEM photomicrographs of these two cell types. The images of the prokayotic cell and eukaryotic cell have been enlarged so that you can compare the cell structures. Eukaryotic cells generally are one to one hundred times larger than prokaryotic cells.

Reading Check **Compare** the sizes of prokaryotic cells and eukaryotic cells.

Figure 4 The prokaryotic cell on the left is smaller and appears less complex than the eukaryotic cell on the right. The prokaryotic cell has been enlarged for the purpose of comparing each cell's internal sturctures.

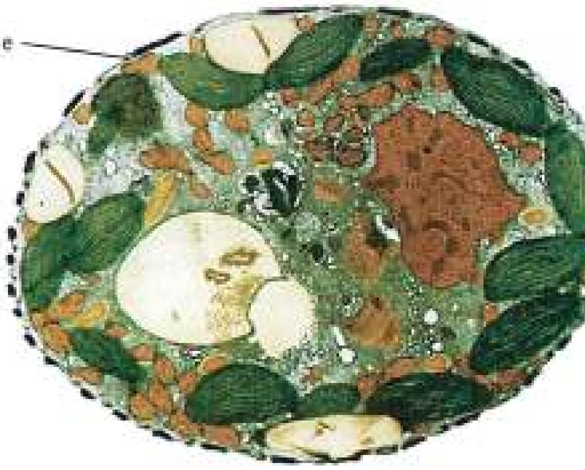
Color-Enhanced TEM Magnification: 15,000×



Plasma membrane

Prokaryotic cell

Color-Enhanced Magnification: unavailable



Eukaryotic cell

Refer again to **Figure 4** and compare the types of cells to see why scientists place them into two broad categories that are based on internal structures. Both have a plasma membrane, but one cell contains many distinct internal structures called **organelles**–specialized structures that carry out specific cell functions.

Eukaryotic cells contain a nucleus and other organelles that are bound by membranes, also referred to as membrane-bound organelles. The **nucleus** is a distinct central organelle that contains the cell's genetic material in the form of DNA. Organelles enable cell functions to take place in different parts of the cell at the same time. Most organisms are made up of eukaryotic cells and are called eukaryotes. However, some unicellular organisms, such as some algae and yeast, also are eukaryotes.

Prokaryotic cells are defined as cells without a nucleus or other membrane-bound organelles. As you can see in **Figure 4,** prokaryotic cells are simpler than eukaryotic cells. Most unicellular organisms, such as bacteria, are prokaryotic cells. Thus, they are called prokaryotes. Many scientists think that prokaryotes are similar to the first organisms that lived on Earth.

Origin of cell diversity Scientists continue to investigate why there are two basic types of cells. The answer might be that eukaryotic cells evolved from prokaryotic cells millions of years ago. According to the endosymbiont theory, a symbiotic relationship involves one prokaryotic cell living inside of another and both cells benefiting from the relationship.

Imagine how organisms would be different if the eukaryotic form had not evolved. Because eukaryotic cells are larger and have distinct organelles, these cells have developed specific functions. Having specific functions has led to cell diversity, and thus more diverse organisms that can adapt better to their environments. Life-forms more complex than bacteria might not have evolved without eukaryotic cells.

VOCABULARY

WORD ORIGIN

Eukaryote
Prokaryote
eu- prefix; from Greek, meaning *true*
pro- prefix; from Greek, meaning *before*
-kary from Greek, meaning *nucleus*

Section 1 Assessment

Section Summary

- Microscopes have been used as tools for scientific study since the late 1500s.
- Scientists use different types of microscopes to study cells.
- The cell theory summarizes three principles.
- There are two broad groups of cell types: prokaryotic cells and eukaryotic cells.

Understand Main Ideas

1. MAIN Idea **Explain** how the development and improvement of microscopes changed the study of living organisms.
2. **Compare and contrast** a compound light microscope and an electron microscope.
3. **Summarize** the cell theory.
4. **Differentiate** the plasma membrane and the organelles.

Think Critically

5. **Describe** how you would determine whether the cells of a newly discovered organism were prokaryotic or eukaryotic.

MATH in Biology

6. If the overall magnification of a series of two lenses is 30×, and one lens magnifies 5×, what is the magnification of the other lens? Calculate the total magnification if the 5× lens is replaced by a 7× lens.

Section 2

Reading Preview

Essential Questions

- How does a cell's plasma membrane function?
- What are the roles of proteins, carbohydrates, and cholesterol in the plasma membrane?

Review Vocabulary

ion: an atom or group of atoms with a positive or negative electric charge

New Vocabulary

selective permeability
phospholipid bilayer
transport protein
fluid mosaic model

The Plasma Membrane

MAIN Idea **The plasma membrane helps to maintain a cell's homeostasis.**

Real-World Reading Link When you approach your school, you might pass through a gate in a fence that surrounds the school grounds. The fence prevents people who should not be there from entering, and the gate allows students, staff, and parents to enter. Similarly, prokaryotic cells and eukaryotic cells have structures that maintain control of their internal environments.

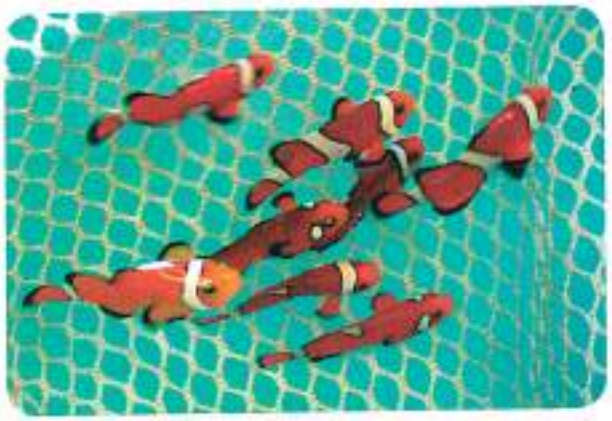
Function of the Plasma Membrane

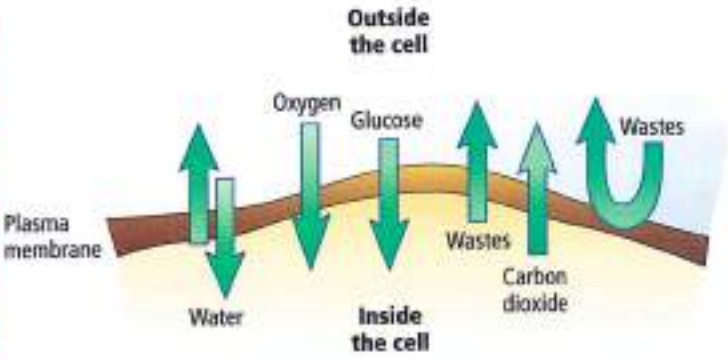
Recall that the process of maintaining balance in an organism's internal environment is called homeostasis. Homeostasis is essential to the survival of a cell. One of the structures that is primarily responsible for homeostasis is the plasma membrane. The plasma membrane is a thin, flexible boundary between a cell and its environment that allows nutrients into the cell and allows waste and other products to leave the cell. All prokaryotic cells and eukaryotic cells have a plasma membrane to separate them from the watery environments in which they exist.

A key property of the plasma membrane is **selective permeability** (pur mee uh BIH luh tee), by which a membrane allows some substances to pass through while keeping others out. Consider a fish net as an analogy of selective permeability. The net shown in **Figure 5** has holes that allow water and other substances in the water to pass through, but not the fish. Depending on the size of the holes in the net, some kinds of fish might pass through, while others are caught. The diagram in **Figure 5** illustrates selective permeability of the plasma membrane. The arrows show that substances enter and leave the cell through the plasma membrane. Control of how, when, and how much of these substances enter and leave a cell relies on the structure of the plasma membrane.

Reading Check **Define** the term *selective permeability.*

Figure 5
Left: The fish net selectively captures fish while allowing water and other debris to pass through.
Right: Similarly, the plasma membrane selects substances entering and leaving the cell.





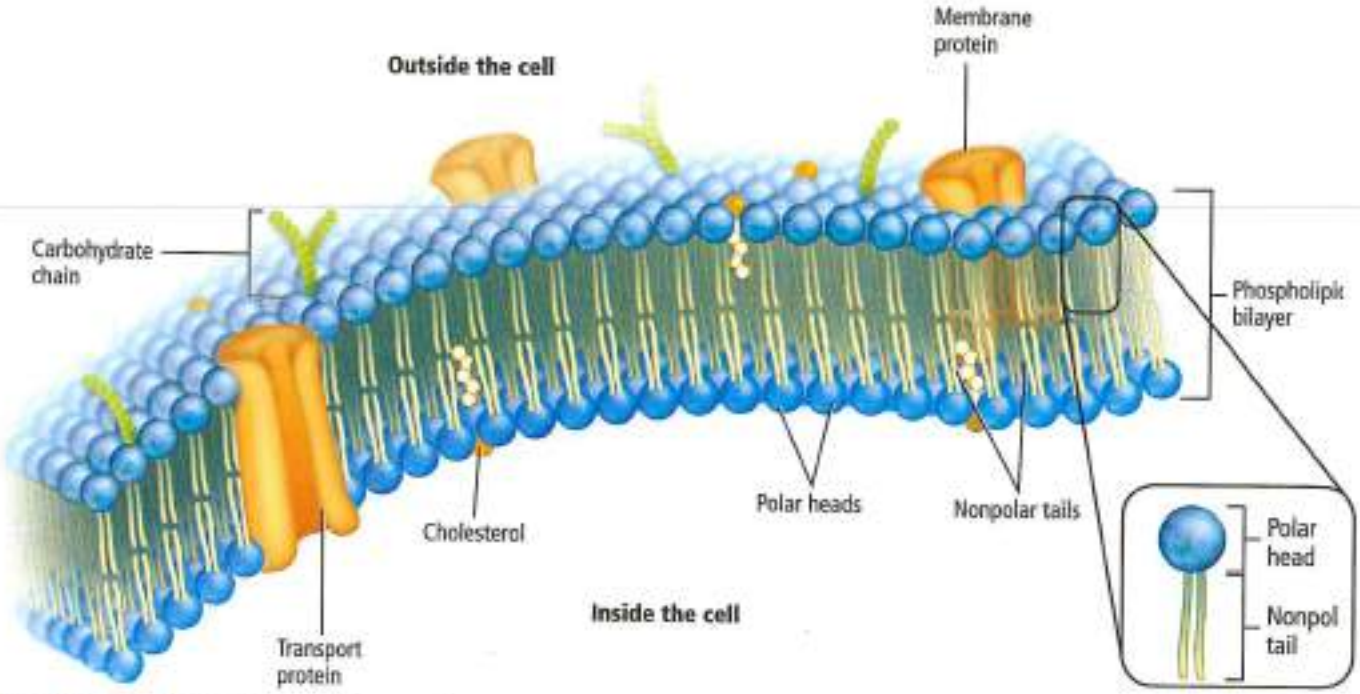


Figure 6 The phospholipid bilayer looks like a sandwich, with the polar heads facing the outside and the nonpolar tails facing the inside.
Infer how hydrophobic substances cross a plasma membrane.

Structure of the Plasma Membrane

Connection Chemistry Most of the molecules in the plasma membrane are lipids. Lipids are large molecules that are composed of glycerol and three fatty acids. If a phosphate group replaces a fatty acid, a phospholipid forms. A phospholipid (fahs foh LIH pid) is a molecule that has a glycerol backbone, two fatty acid chains, and a phosphate-containing group. The plasma membrane is composed of a **phospholipid bilayer,** in which two layers of phospholipids are arranged tail-to-tail, as shown in **Figure 6.** In the plasma membrane, phospholipids arrange themselves in a way that allows the plasma membrane to exist in the watery environment.

The phospholipid bilayer Notice in **Figure 6** that each phospholipid is diagrammed as a head with two tails. The phosphate group in each phospholipid makes the head polar. The polar head is attracted to water because water also is polar. The two fatty acid tails are nonpolar and are repelled by water.

The two layers of phospholipid molecules resemble a sandwich, with the fatty acid tails forming the interior of the plasma membrane and the phospholipid heads facing the watery environments found inside and outside the cell, as shown in **Figure 6.** This bilayer structure is critical for the formation and function of the plasma membrane. The phospholipids are arranged in such a way that the polar heads can be closest to the water molecules and the nonpolar tails can be farthest away from the water molecules.

When many phospholipid molecules come together in this manner, a barrier is created that is polar at its surfaces and nonpolar in the middle. Water-soluble substances will not move easily through the plasma membrane because they are stopped by the nonpolar middle. Therefore, the plasma membrane can separate the environment inside the cell from the environment outside the cell.

VOCABULARY

SCIENCE USAGE V. COMMON USAGE

Polar

Science usage: having an unequal distribution of charge
The positive end of a polar molecule attracts the negative end of a polar molecule.

Common usage: relating to a geographic pole or region
The polar ice cap in Greenland is, on average, 1.6 km thick.

Other components of the plasma membrane Moving with and among the phospholipids in the plasma membrane are cholesterol, proteins, and carbohydrates. When found on the outer surface of the plasma membrane, proteins called receptors transmit signals to the inside of the cell. Proteins at the inner surface anchor the plasma membrane to the cell's internal support structure, giving the cell its shape. Other proteins span the entire membrane and create tunnels through which certain substances enter and leave the cell. These **transport proteins** move needed substances or waste materials through the plasma membrane and therefore contribute to the selective permeability of the plasma membrane.

Reading Check **Describe** the benefit of the bilayer structure of the plasma membrane.

Locate the cholesterol molecules in **Figure 6.** Nonpolar cholesterol is repelled by water and is positioned among the phospholipids. Cholesterol helps to prevent the fatty-acid tails of the phospholipid bilayer from sticking together, which contributes to the fluidity of the plasma membrane. Although avoiding a high-cholesterol diet is recommended, cholesterol plays a critical role in plasma membrane structure and it is an important substance for maintaining homeostasis in a cell.

Other substances in the membrane, such as carbohydrates attached to proteins, stick out from the plasma membrane to define the cell's characteristics and help cells identify chemical signals. For example, carbohydrates in the membrane might help disease-fighting cells recognize and attack a potentially harmful cell.

Study Tip

Question Session Work with a partner and ask each other questions about the plasma membrane. Discuss each other's answers. Ask as many questions as you think of while taking turns.

DATA ANALYSIS LAB 1

Based on Real Data*

Interpret the Diagram

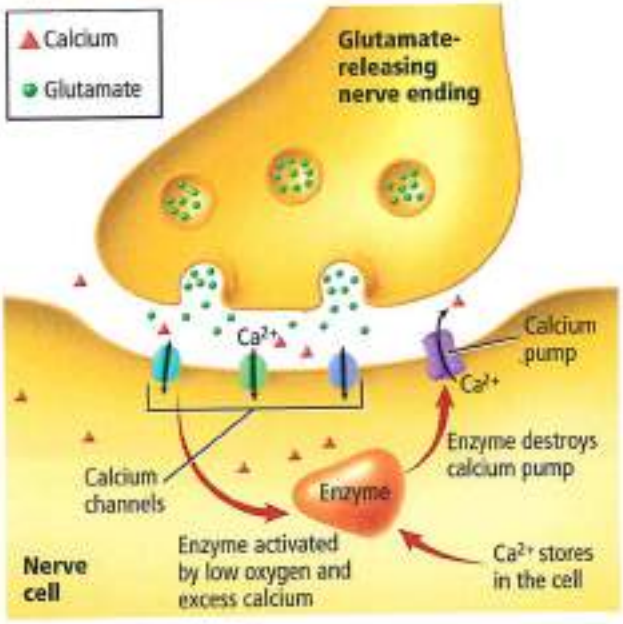
How are protein channels involved in the death of nerve cells after a stroke? A stroke occurs when a blood clot blocks the flow of oxygen-containing blood in a portion of the brain. Nerve cells in the brain that release glutamate are sensitive to the lack of oxygen and release a flood of glutamate when oxygen is low. During the glutamate flood, the calcium pump is destroyed. This affects the movement of calcium ions into and out of nerve cells. When cells contain excess calcium, homeostasis is disrupted.

Think Critically

1. **Interpret** how the glutamate flood destroys the calcium pump.
2. **Predict** what would happen if Ca^{2+} levels were lowered in the nerve cell during a stroke.

*Data obtained from: Choi, D.W. 2005. Neurodegeneration: cellular defences destroyed. *Nature* 433: 696–698.

Data and Observations



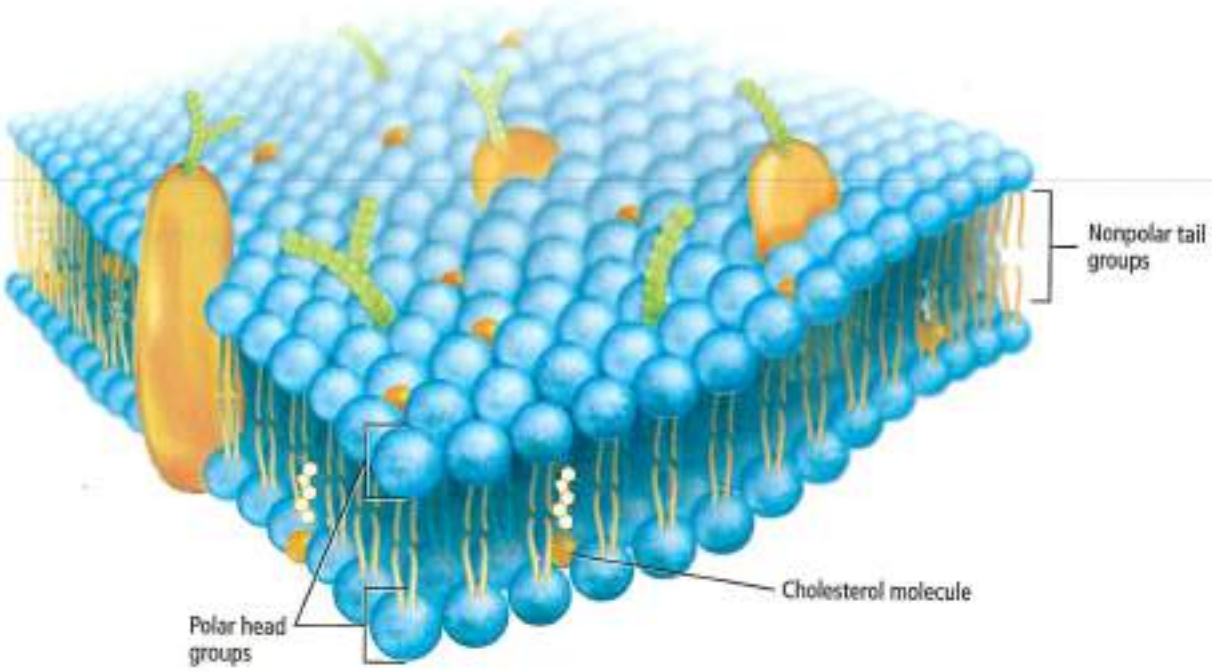


Figure 7 The fluid mosaic model refers to a plasma membrane with substances that can move around within the membrane.

Together, the phospholipids in the bilayer create a "sea" in which other molecules can float, like apples floating in a barrel of water. This "sea" concept is the basis for the **fluid mosaic model** of the plasma membrane. The phospholipids can move sideways within the membrane, just as apples move around in water. At the same time, other components in the membrane, such as proteins, also move among the phospholipids. Because there are different substances in the plasma membrane, a pattern, or mosaic, is created on the surface. You can see this pattern in **Figure 7.** The components of the plasma membrane are in constant motion, sliding past one another.

Section 2 Assessment

Section Summary

- Selective permeability is a property of the plasma membrane that allows it to control what enters and leaves the cell.
- The plasma membrane is made up of two layers of phospholipid molecules.
- Cholesterol and transport proteins aid in the function of the plasma membrane.
- The fluid mosaic model describes the plasma membrane.

Understand Main Ideas

1. MAIN Idea **Describe** how the plasma membrane helps maintain homeostasis in a cell.
2. **Explain** how the inside of a cell remains separate from its environment.
3. **Diagram** the plasma membrane and label each component.
4. **Identify** the molecules in the plasma membrane that provide basic membrane structure, cell identity, and membrane fluidity.

Think Critically

5. **Explain** what effect more cholesterol in the plasma membrane will have on the membrane.

WRITING in Biology

6. Using what you know about the term *mosaic*, write a paragraph describing another biological mosaic.

Section 3

Reading Preview

Essential Questions

- What are the structures of a typical eukaryotic cell, and what are their functions?
- What are the similarities and differences between plant and animal cells?

Review Vocabulary

enzyme: a protein that speeds up the rate of a chemical reaction

New Vocabulary

cytoplasm
cytoskeleton
ribosome
nucleolus
endoplasmic reticulum
Golgi apparatus
vacuole
lysosome
centriole
mitochondrion
chloroplast
cell wall
cilium
flagellum

Structures and Organelles

MAIN Idea **Eukaryotic cells contain organelles that allow the specialization and the separation of functions within the cell.**

Real-World Reading Link Suppose you start a company to manufacture hiking boots. Each pair of boots could be made individually by one person, but it would be more efficient to use an assembly line. Similarly, eukaryotic cells have specialized structures that perform specific tasks, much like a factory.

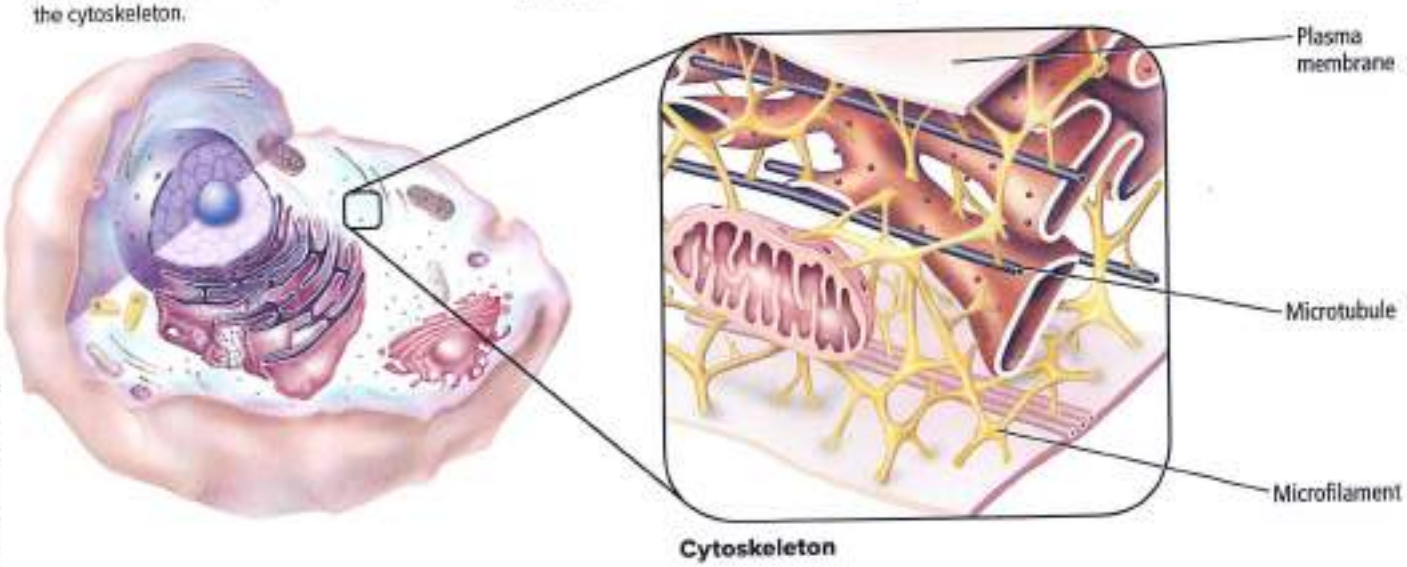
Cytoplasm and Cytoskeleton

You just have investigated the part of a cell that functions as the boundary between the inside and outside environments. The environment inside the plasma membrane is a semifluid material called **cytoplasm.** In a prokaryotic cell, all of the chemical processes of the cell, such as breaking down sugar to generate the energy used for other functions, take place directly in the cytoplasm. Eukaryotic cells perform these processes within organelles in their cytoplasm. At one time, scientists thought that cell organelles floated in a sea of cytoplasm.

More recently, cell biologists have discovered that organelles do not float freely in a cell, but are supported by a structure within the cytoplasm similar to the structure shown in **Figure 8.** The **cytoskeleton** is a supporting network of long, thin protein fibers that form a framework for the cell and provide an anchor for the organelles inside the cells. The cytoskeleton also has a function in cell movement and other cellular activities.

The cytoskeleton is made of substructures called microtubules and microfilaments. Microtubules are long, hollow protein cylinders that form a rigid skeleton for the cell and assist in moving substances within the cell. Microfilaments are thin protein threads that help give the cell shape and enable the entire cell or parts of the cell to move. Microtubules and microfilaments rapidly assemble and disassemble and slide past one another. This allows cells and organelles to move.

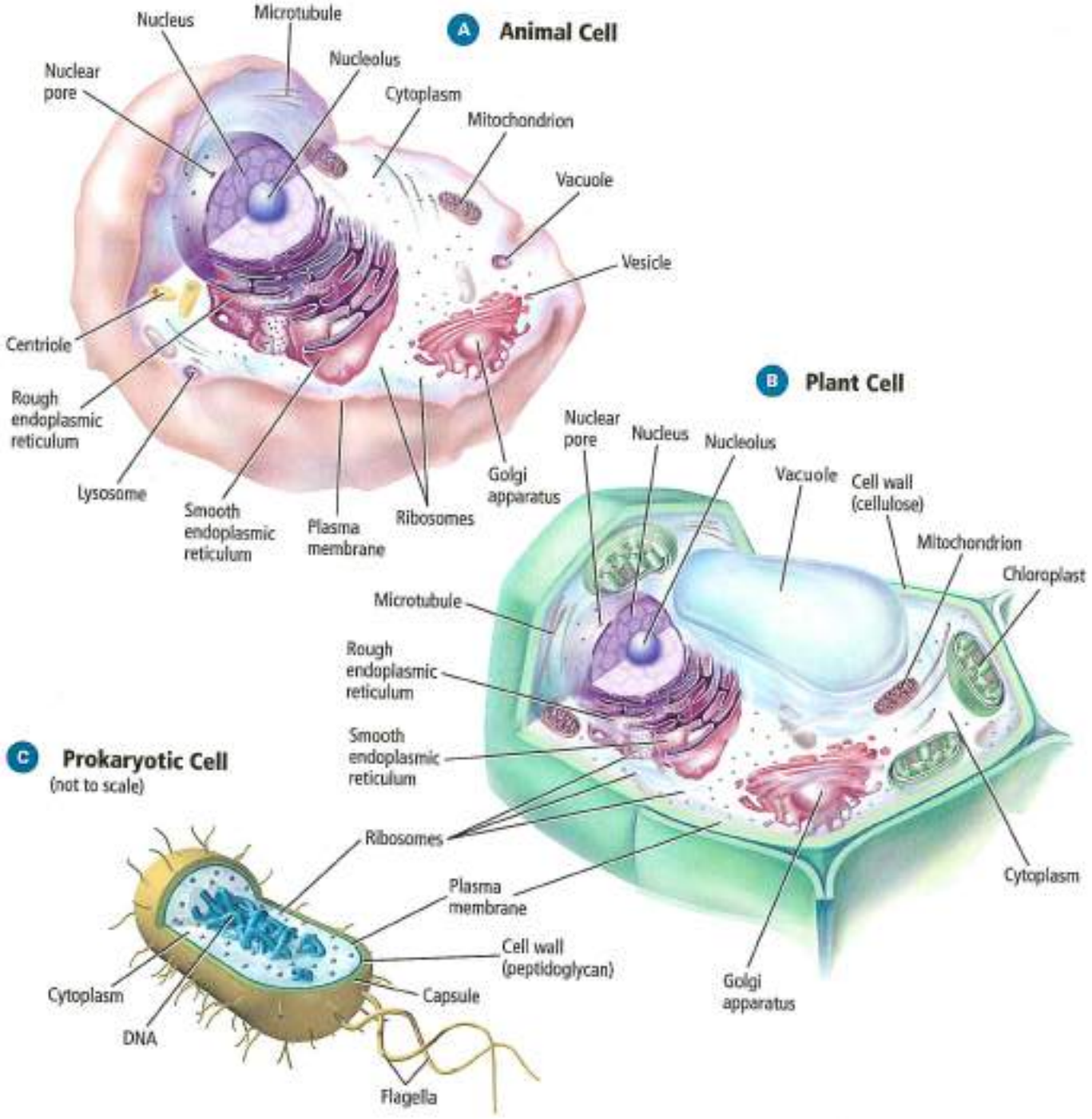
Figure 8 Microtubules and microfilaments make up the cytoskeleton.



Visualizing Cells

Figure 9

Compare the illustrations of a plant cell, animal cell, and prokaryotic cell. Some organelles are found only in plant cells; others are found only in animal cells. Prokaryotic cells do not have membrane-bound organelles.



Cell Structures

In a factory, there are separate areas set up for performing different tasks. Eukaryotic cells also have separate areas for tasks. Membrane-bound organelles make it possible for different chemical processes to take place at the same time in different parts of the cytoplasm. Organelles carry out essential cell processes, such as protein synthesis, energy transformation, digestion of food, excretion of wastes, and cell division. Each organelle has a unique structure and function. You can compare organelles to a factory's offices, assembly lines, and other important areas that keep the factory running. As you read about the different organelles, refer to the diagrams of plant and animal cells in **Figure 9** to see the organelles of each type.

The nucleus Just as a factory needs a manager, a cell needs an organelle to direct the cell processes. The nucleus, shown in **Figure 10,** is the cell's managing structure. It contains most of the cell's DNA, which stores information used to make proteins for cell growth, function, and reproduction.

The nucleus is surrounded by a double membrane called the nuclear envelope. The nuclear envelope is similar to the plasma membrane, except the nuclear membrane has nuclear pores that allow larger-sized substances to move in and out of the nucleus. Chromatin, which is a complex DNA attached to protein, is spread throughout the nucleus.

Reading Check **Describe** the role of the nucleus.

Ribosomes One of the functions of a cell is to produce proteins. The organelles that help manufacture proteins are called **ribosomes.** Ribosomes are made of two components–RNA and protein–and are not bound by a membrane like other organelles are. Within the nucleus is the site of ribosome production called the **nucleolus,** shown in **Figure 10.**

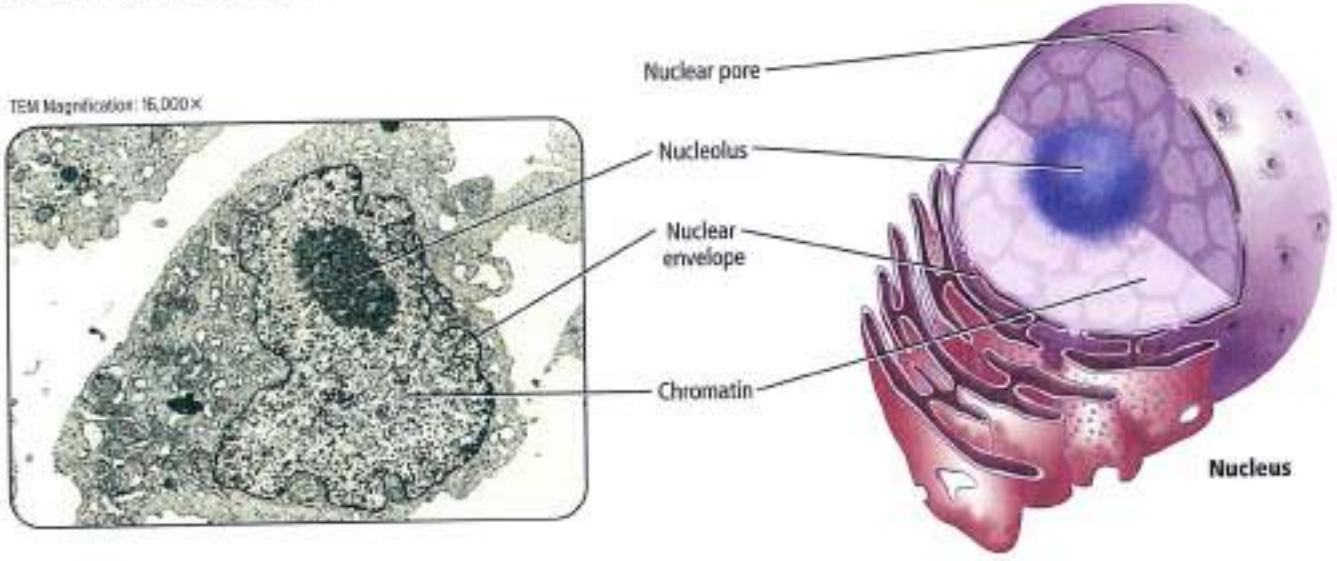
Cells have many ribosomes that produce a variety of proteins that are used by the cell or are moved out and used by other cells. Some ribosomes float freely in the cytoplasm, while others are bound to another organelle called the endoplasmic reticulum. Free-floating ribosomes produce proteins for use within the cytoplasm of the cell. Bound ribosomes produce proteins that will be bound within membranes or used by other cells.

VOCABULARY

WORD ORIGIN

Cytoplasm
Cytoskeleton
cyte- prefix; from Greek, meaning *cell*

Figure 10 The nucleus of a cell is a three-dimensional shape. The photomicrograph shows a cross section of a nucleus.
Infer ***why all of the cross sections of a nucleus are not identical.***



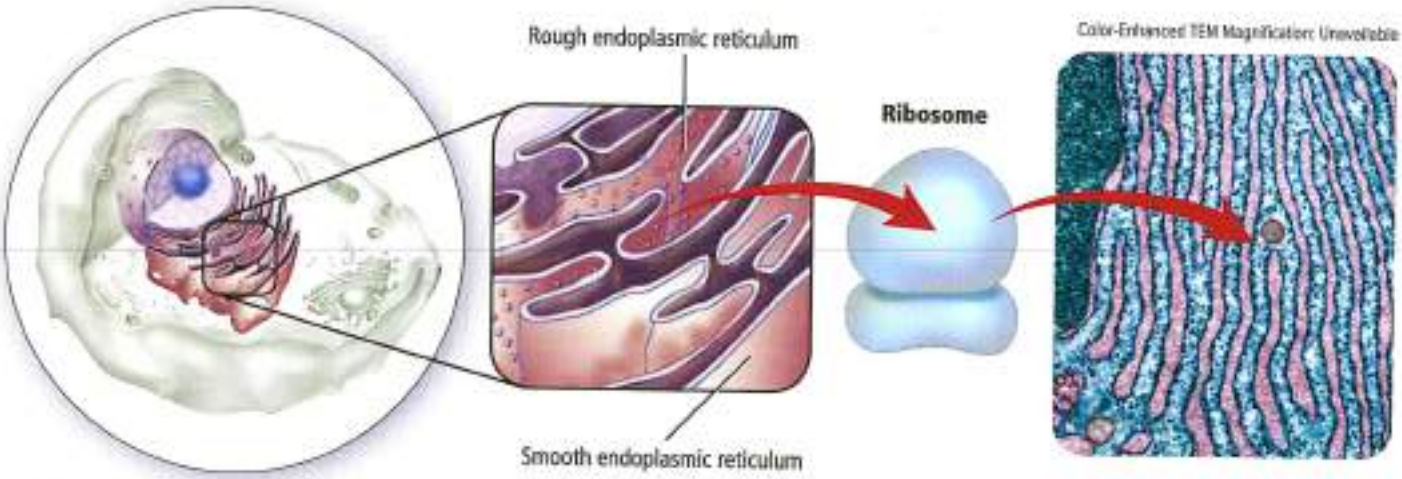


Figure 11 Ribosomes are simple structures made of RNA and protein that may be attached to the surface of the rough endoplasmic reticulum. They look like bumps on the endoplasmic reticulum.

Endoplasmic reticulum The **endoplasmic reticulum** (en duh PLAZ mihk • rih TIHK yuh lum), also called ER, is a membrane system of folded sacs and interconnected channels that serves as the site for protein and lipid synthesis. The pleats and folds of the ER provide a large amount of surface area where cellular functions can take place. The area of ER where ribosomes are attached is called rough endoplasmic reticulum. Notice in **Figure 11** that the rough ER appears to have bumps on it. These bumps are the attached ribosomes that will produce proteins for export to other cells.

Figure 11 also shows that there are areas of the ER that do not have ribosomes attached. The area of ER where no ribosomes are attached is called smooth endoplasmic reticulum. Although the smooth ER has no ribosomes, it does perform important functions for the cell. For example, the smooth ER provides a membrane surface where a variety of complex carbohydrates and lipids, including phospholipids, are synthesized. Smooth ER in the liver detoxifies harmful substances.

DATA ANALYSIS LAB 2

Based on Real Lab Data*

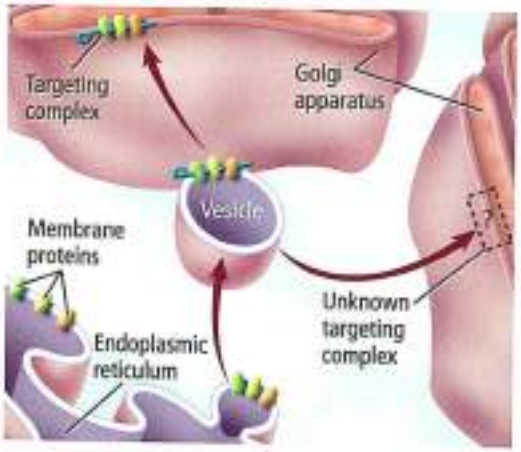
Interpret the Data

How is vesicle traffic from the ER to the Golgi apparatus regulated? Some proteins are synthesized by ribosomes on the endoplasmic reticulum (ER). The proteins are processed in the ER, and vesicles containing these proteins pinch off and migrate to the Golgi apparatus. Scientists currently are studying the molecules that are involved in fusing these vesicles to the Golgi apparatus.

Think Critically

1. **Interpret the diagram** by naming two complexes on the Golgi apparatus that might be involved in vesicle fusion.
2. Hypothesize an explanation for vesicle transport based on what you have read about cytoplasm and the cytoskeleton.

Data and Observations



*Data obtained from: Brittle, E. E., and Waters, M. G. 2000. ER-to-golgi traffic—this bud's for you. *Science* 289: 403–404.

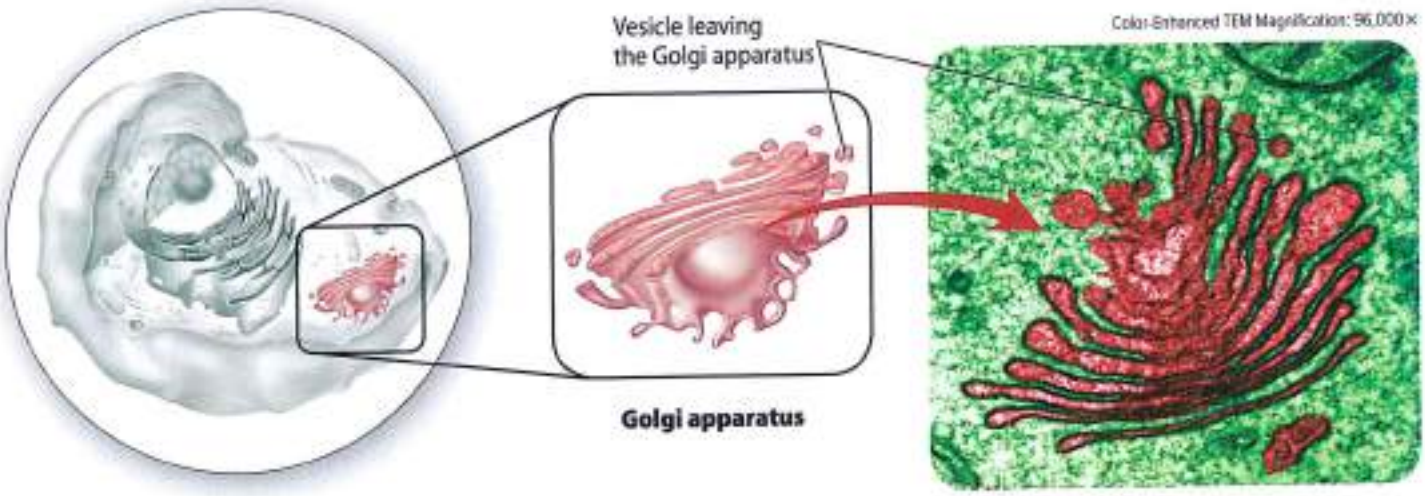
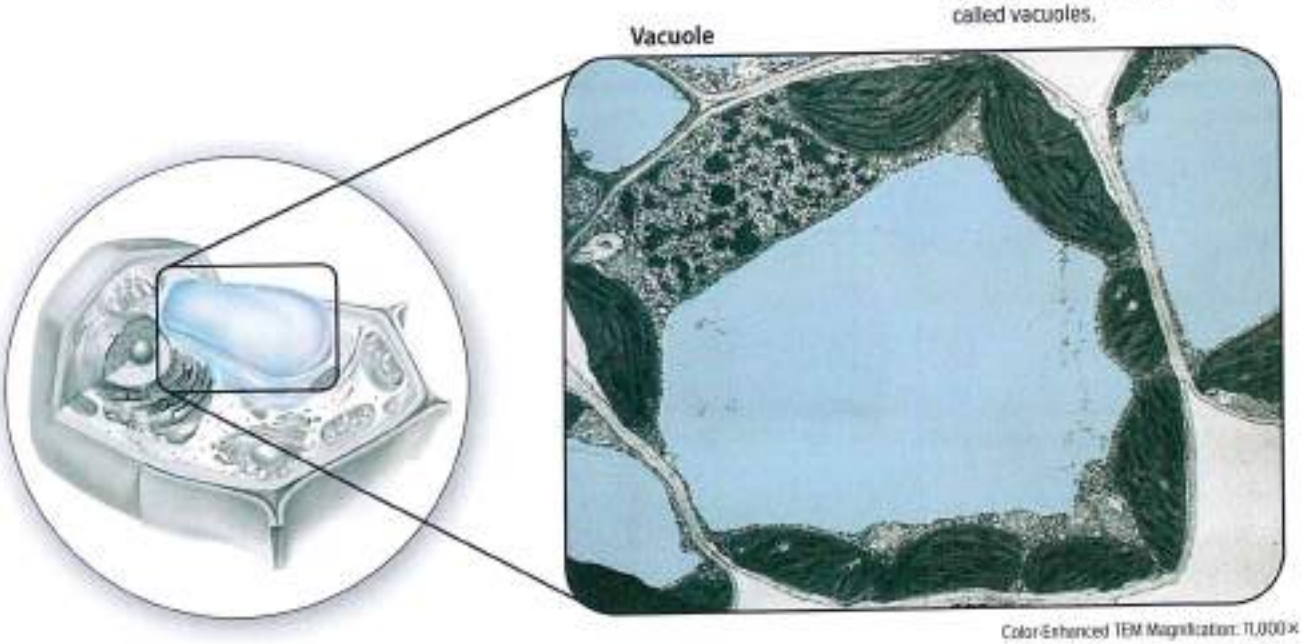


Figure 12 Flattened stacks of membranes make up the Golgi apparatus.

Golgi apparatus After hiking boots are made in a factory, they must be organized into pairs, boxed, and shipped. Similarly, after proteins are made in the endoplasmic reticulum, some might be transferred to the Golgi (GAWL jee) apparatus, illustrated in **Figure 12.** The **Golgi apparatus** is a flattened stack of membranes that modifies, sorts, and packages proteins into sacs called vesicles. Vesicles then can fuse with the cell's plasma membrane to release proteins to the environment outside the cell. Observe the vesicle in **Figure 12.**

Vacuoles A factory needs a place to store materials and waste products. Similarly, cells have membrane-bound vesicles called vacuoles for temporary storage of materials within the cytoplasm. A **vacuole,** such as the plant vacuole shown in **Figure 13,** is a sac used to store food, enzymes, and other materials needed by a cell. Some vacuoles store waste products. Interestingly, animal cells usually do not contain vacuoles. If animal cells do have vacuoles, they are much smaller than those in plant cells.

Figure 13 Plant cells have large membrane-bound storage compartments called vacuoles.



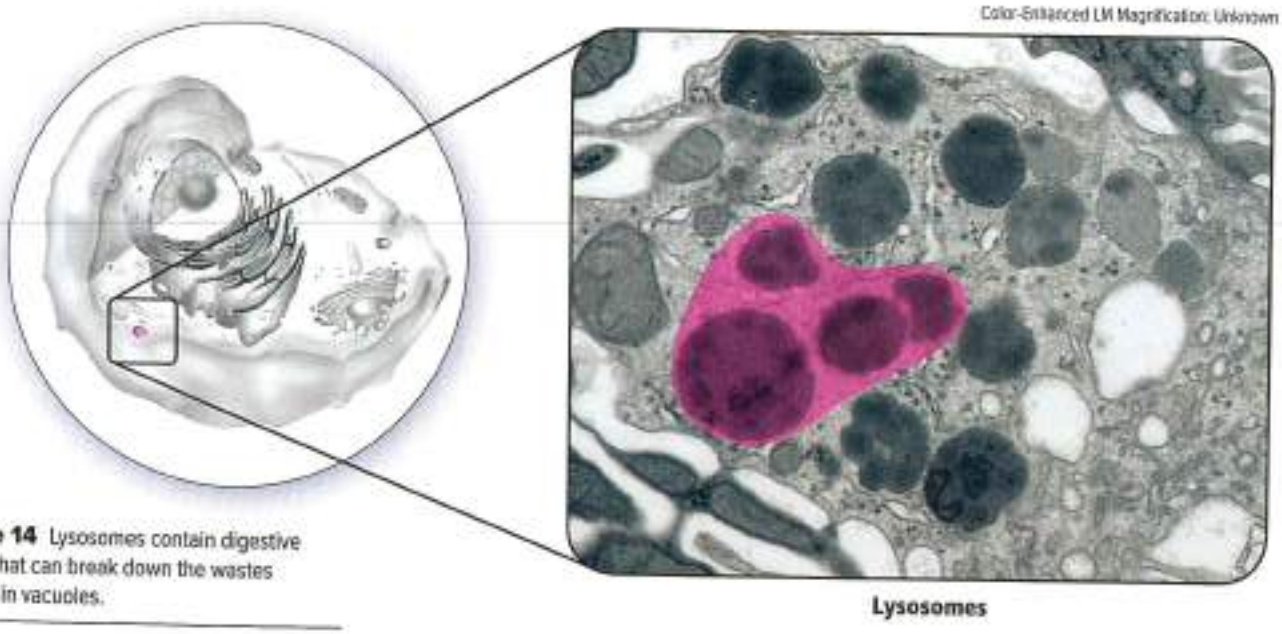
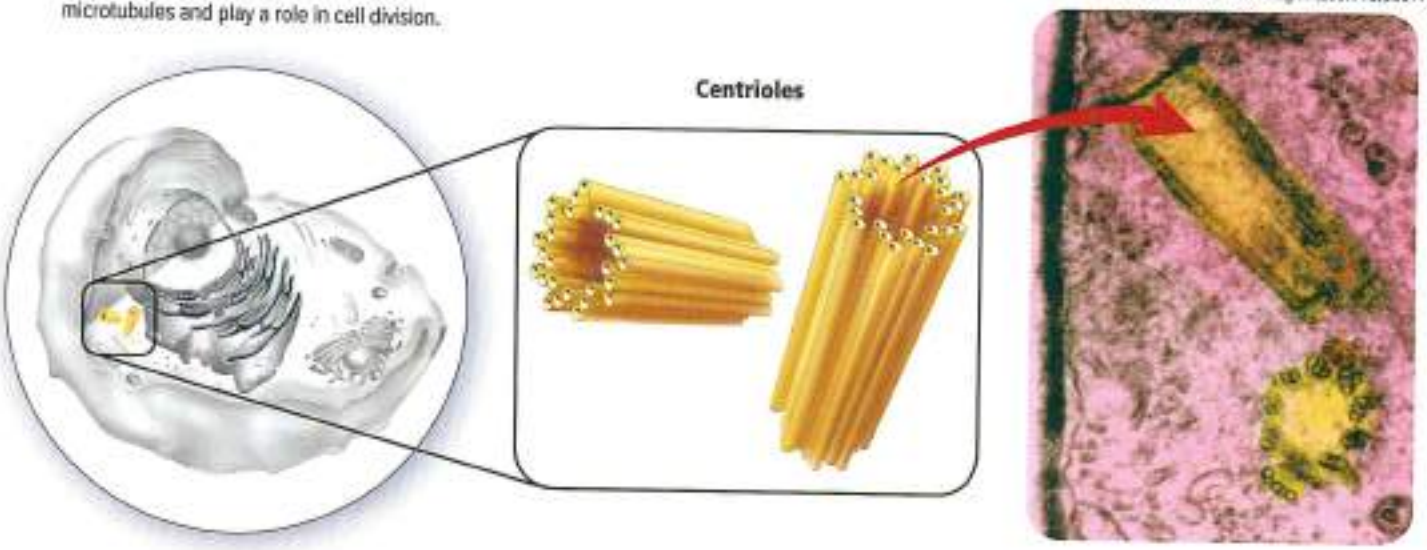


Figure 14 Lysosomes contain digestive enzymes that can break down the wastes contained in vacuoles.

Lysosomes Factories and cells also need cleanup crews. In a cell, there are **lysosomes,** shown in **Figure 14,** which are vesicles that contain substances that digest excess or worn-out organelles and food particles. Lysosomes also digest bacteria and viruses that have entered the cell. The membrane surrounding a lysosome prevents the digestive enzymes inside from destroying the cell. Lysosomes can fuse with vacuoles and dispense their enzymes into the vacuoles. These enzymes digest the wastes inside.

Centrioles Previously in this section, you read about microtubules and the cytoskeleton. Groups of microtubules form another structure called a centriole (SEN tree ol). **Centrioles,** shown in **Figure 15,** are organelles made of microtubules that function during cell division. Centrioles are located in the cytoplasm of animal cells and most protists and usually are near the nucleus.

Figure 15 Centrioles are made of microtubules and play a role in cell division.



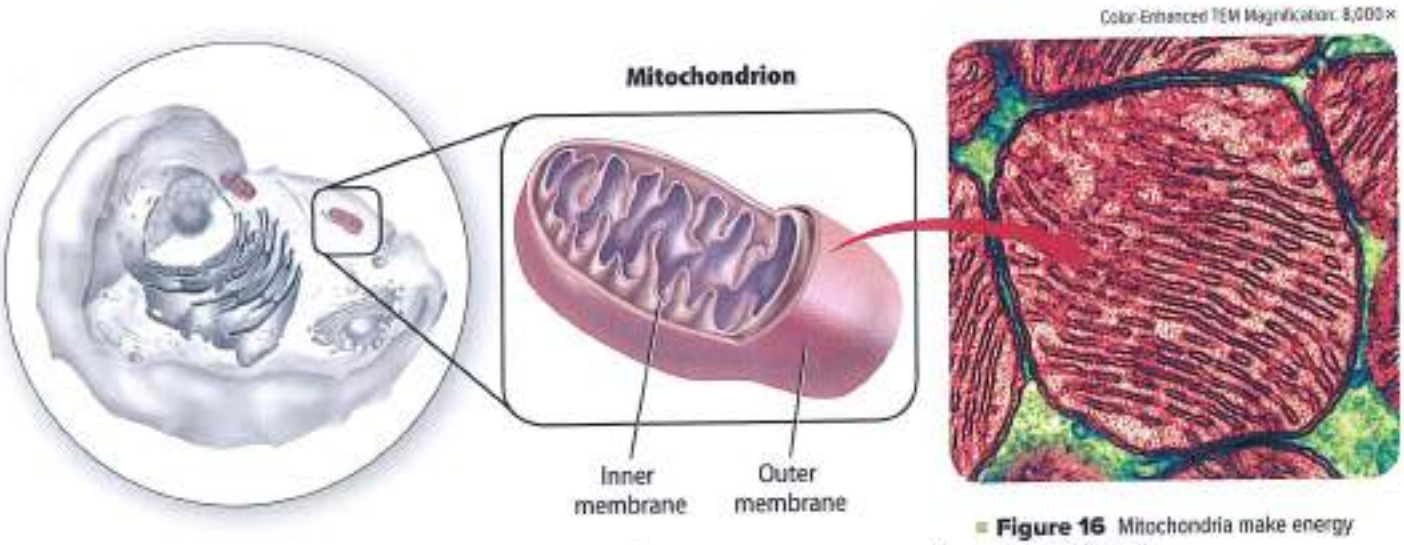


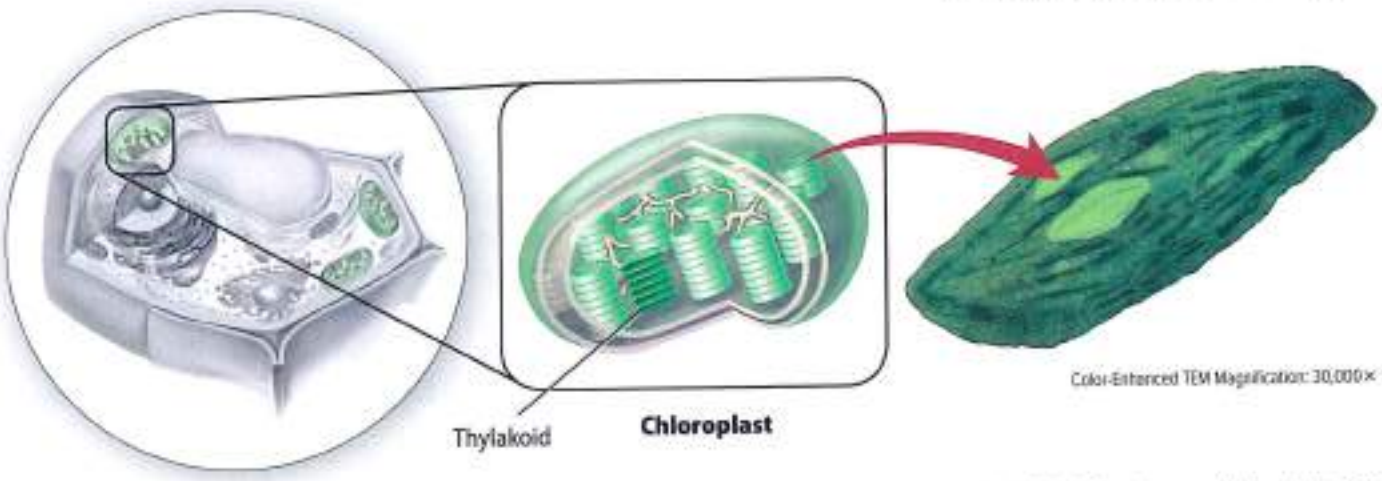
Figure 16 Mitochondria make energy available to the cell.
Describe *the membrane structure of a mitochondrion.*

Mitochondria Imagine now that a boot factory has its own generator that produces the electricity it needs. Cells also have energy generators called **mitochondria** (mi tuh KAHN dree uh; singular, mitochondrion), which convert fuel particles (mainly sugars) into usable energy. **Figure 16** shows that a mitochondrion has an outer membrane and a highly folded inner membrane that provides a large surface area for breaking the bonds in sugar molecules. The energy produced from that breakage is stored in the bonds of other molecules and later used by the cell. For this reason, mitochondria often are referred to as the "powerhouses" of cells.

Chloroplasts Factory machines need electricity that is generated by burning fossil fuels or by collecting energy from alternative sources, such as the Sun. Plant cells have their own way of using solar energy. In addition to mitochondria, plants and some other eukaryotic cells contain **chloroplasts,** which are organelles that capture light energy and convert it to chemical energy through a process called photosynthesis. Examine **Figure 17** and notice that inside the inner membrane are many small, disk-shaped compartments called thylakoids. It is there that the energy from sunlight is trapped by a pigment called chlorophyll. Chlorophyll gives leaves and stems their green color.

Chloroplasts belong to a group of plant organelles called plastids, some of which are used for storage. Some plastids store starches or lipids. Others, such as chromoplasts, contain red, orange, or yellow pigments that trap light energy and give color to plant structures such as flowers and leaves.

Figure 17 In plants, chloroplasts capture and convert light energy to chemical energy.



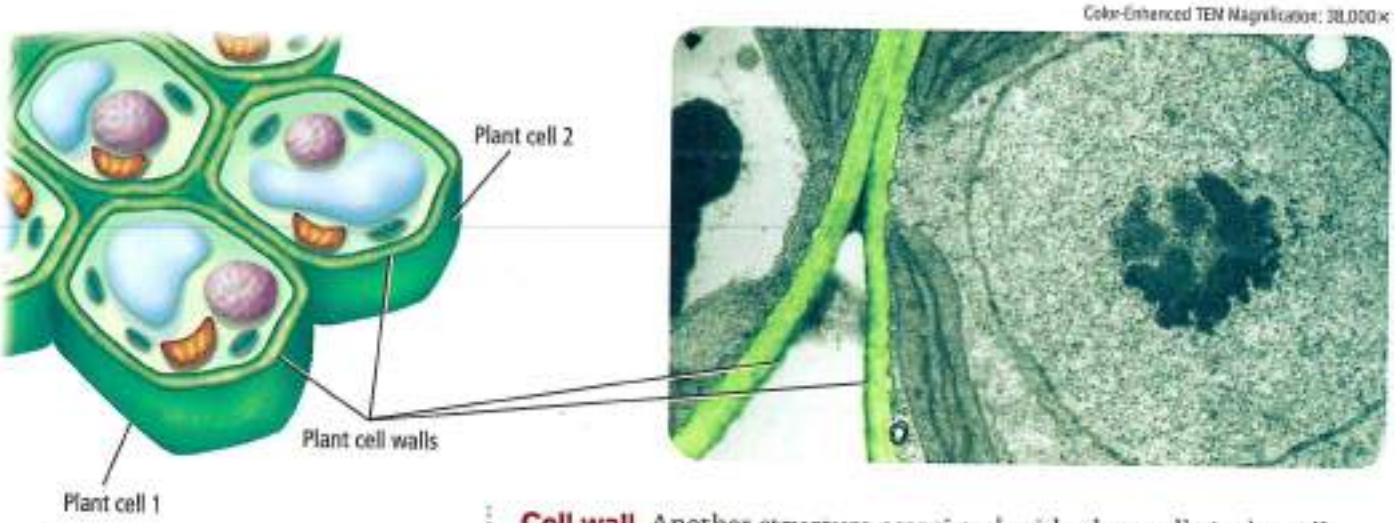


Figure 18 The illustration shows plant cells and their cell walls. Compare this to the transmission electron micrograph showing the cell walls of adjacent plant cells.

Cell wall Another structure associated with plant cells is the cell wall, shown in **Figure 18.** The **cell wall** is a thick, rigid, mesh of fibers that surrounds the outside of the plasma membrane, protects the cell, and gives it support. Rigid cell walls allow plants to stand at various heights–from blades of grass to California redwood trees. Plant cell walls are made of a carbohydrate called cellulose, which gives the cell walls their inflexible characteristics. **Table 1** summarizes cell walls and various other cell structures.

Cilia and flagella Some eukaryotic cell surfaces have structures called cilia and flagella that project outside the plasma membrane. As shown in **Figure 19, cilia** (singular, cilium) are short, numerous projections that look like hairs. The motion of cilia is similar to the motion of oars in a rowboat. **Flagella** (singular, flagellum) are longer and less numerous than cilia. These projections move with a whiplike motion. Cilia and flagella are composed of microtubules arranged in a 9 + 2 configuration, in which nine pairs of microtubules surround two single microtubules. Typically, a cell has one or two flagella.

Prokaryotic cilia and flagella contain cytoplasm and are enclosed by the plasma membrane. These structures are made of complex proteins. While both structures are used for cell movement, cilia are also found on stationary cells.

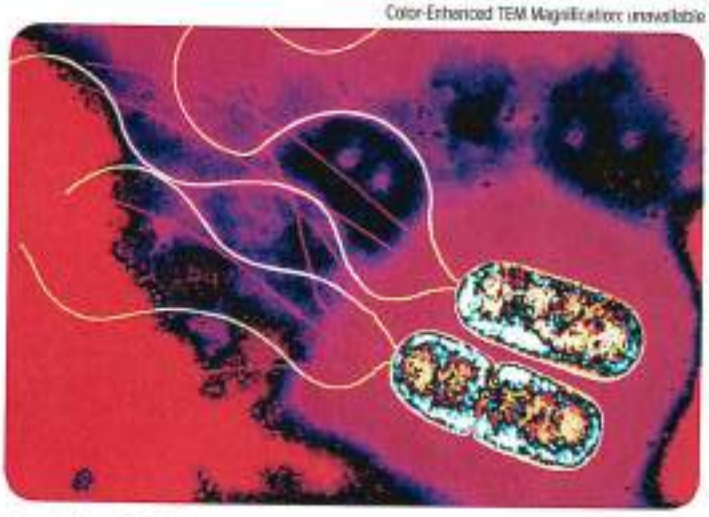
Figure 19 The hairlike structures in the photomicrograph are cilia, and the tail-like structures are flagella. Both structures function in cell movement.

***Infer** where in the body of an animal you would predict cilia might be found.*

Color-Enhanced SEM Magnification: 12,000×

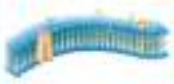
Cilia on the surface of a *Paramecium*

Color-Enhanced TEM Magnification unavailable



Bacteria with flagella

Table 1 Summary of Cell Structures

Cell Structure	Example	Function	Cell Type
Cell wall		An inflexible barrier that provides support and protects the plant cell	Plant cells, fungi cells, and some prokaryotes
Centrioles		Organelles that occur in pairs and are important for cell division	Animal cells and most protist cells
Chloroplast		A double-membrane organelle with thylakoids containing chlorophyll; where photosynthesis takes place	Plant cells and some protist cells
Cilia		Projections from cell surfaces that aid in locomotion and feeding; also used to sweep substances along surfaces	Some animal cells, protist cells, and prokaryotes
Cytoskeleton		A framework for the cell within the cytoplasm	All eukaryotic cells
Endoplasmic reticulum		A highly folded membrane that is the site of protein synthesis	All eukaryotic cells
Flagella		Projections that aid in locomotion and feeding	Some animal cells, prokaryotes, and some plant cells
Golgi apparatus		A flattened stack of tubular membranes that modifies proteins and packages them for distribution outside the cell	All eukaryotic cells
Lysosome		A vesicle that contains digestive enzymes for the breakdown of excess or worn-out cellular substances	Animal cells and rare in plant cells
Mitochondrion		A membrane-bound organelle that makes energy available to the rest of the cell	All eukaryotic cells
Nucleus		The control center of the cell that contains coded directions for the production of proteins and cell division	All eukaryotic cells
Plasma membrane		A flexible boundary that controls the movement of substances into and out of the cell	All cells
Ribosome		Organelle that is the site of protein synthesis	All cells
Vacuole		A membrane-bound vesicle for the temporary storage of materials	Plant cells—one large; rarely animal cells—a few small

CAREERS IN BIOLOGY

Science Communications Specialist Many publishers of scientific material hire communications specialists to write about research and its importance to the general public. This often is accomplished through press releases, ads, pamphlets, and targeted mailings.

Comparing Cells

Table 1 summarizes the structures of eukaryotic plant cells and animal cells. Notice that plant cells contain chlorophyll; they can capture and transform energy from the Sun into a usable form of chemical energy. This is one of the main characteristics that distinguishes plants from animals. In addition, recall that animal cells usually do not contain vacuoles. If they do, vacuoles in animal cells are much smaller than vacuoles in plant cells. Also, animal cells do not have cell walls. Cell walls give plant cells protection and support.

Organelles at Work

With a basic understanding of the structures found within a cell, it becomes easier to envision how those structures work together to perform cell functions. Take, for example, the synthesis of proteins.

Protein synthesis begins in the nucleus with the information contained in the DNA. Genetic information is copied and transferred to another genetic molecule called RNA. Then RNA and ribosomes, which have been manufactured in the nucleolus, leave the nucleus through the pores of the nuclear membrane. Together, RNA and ribosomes manufacture proteins. Each protein made on the rough ER has a particular function; it might become a protein that forms a part of the plasma membrane, a protein that is released from the cell, or a protein transported to other organelles. Other ribosomes will float freely in the cytoplasm and also make proteins.

Most of the proteins made on the surface of the ER are sent to the Golgi apparatus. The Golgi apparatus packages the proteins in vesicles and transports them to other organelles or out of the cell. Other organelles use the proteins to carry out cell processes. For example, lysosomes use proteins, enzymes in particular, to digest food and waste. Mitochondria use enzymes to produce a usable form of energy for the cell.

After reading about the organelles in a cell, it becomes clear why people equate the cell to a factory. Each organelle has its job to do, and the health of the cell depends on all of the components working together.

Section 3 Review

Section Summary

- Eukaryotic cells contain membrane-bound organelles in the cytoplasm that perform cell functions.
- Ribosomes are the sites of protein synthesis.
- Mitochondria are the powerhouses of cells.
- Plant and animal cells contain many of the same organelles, while other organelles are unique to either plant cells or animal cells.

Understand Main Ideas

1. MAIN Idea **Identify** the role of the nucleus in a eukaryotic cell.
2. **Summarize** the role of the endoplasmic reticulum.
3. **Create** a flowchart comparing the parts of a cell to an automobile production line.
4. **Compare and contrast** structures of plant and animal cells.

Think Critically

5. **Hypothesize** how lysosomes would be involved in changing a caterpillar into a butterfly.

WRITING in Biology

6. Categorize the structures and organelles in **Table 1** into lists based on cell type and then draw a concept map illustrating your organization.

Section 4

Reading Preview

Essential Questions

- What are the processes of diffusion, facilitated diffusion, and active transport?
- What is the effect of a hypotonic, hypertonic, or isotonic solution on a cell?
- How do large particles enter and exit cells?

Review Vocabulary

homeostasis: the regulation of the internal environment of a cell or organism to maintain conditions suitable for life

New Vocabulary

diffusion
dynamic equilibrium
facilitated diffusion
osmosis
isotonic solution
hypotonic solution
hypertonic solution
active transport
endocytosis
exocytosis

Cellular Transport

MAIN Idea **Cellular transport moves substances within the cell and moves substances into and out of the cell.**

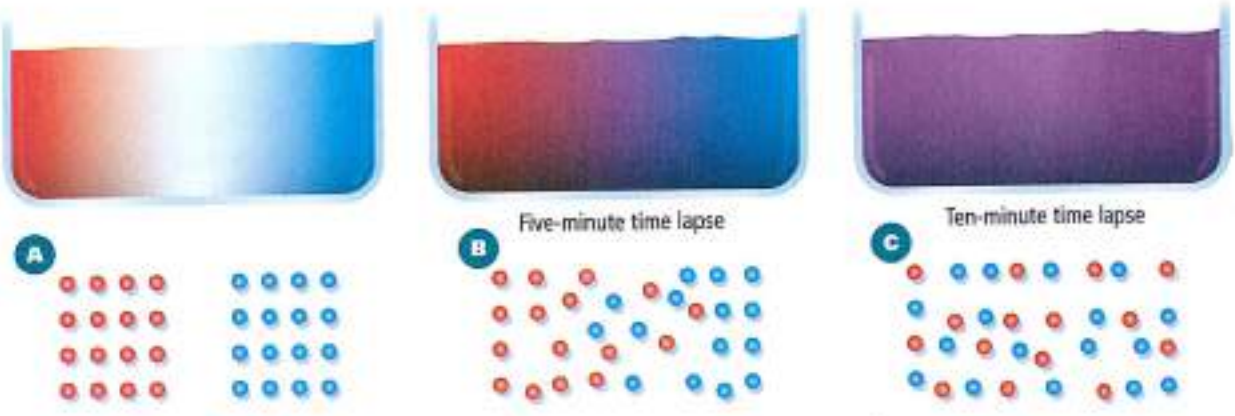
Real-World Reading Link Imagine studying in your room while cookies are baking in the kitchen. You probably did not notice when the cookies were put into the oven because you could not smell them. But, as the cookies baked, the movement of the aroma from the kitchen to your room happened through a process called diffusion.

Diffusion

Connection to Chemistry As the aroma of baking cookies makes its way to you, the particles are moving and colliding with each other in the air. This happens because the particles in gases, liquids, and solids are in random motion. Similarly, substances dissolved in water move constantly in random motion called Brownian motion. This random motion causes **diffusion,** which is the net movement of particles from an area where there are many particles of the substance to an area where there are fewer particles of the substance. The amount of a substance in a particular area is called concentration. Therefore, substances diffuse from areas of high concentration to low concentration. **Figure 20** illustrates the process of diffusion. Additional energy input is not required for diffusion because the particles already are in motion.

For example, if you drop red and blue ink into a container of water at opposite ends of the container, which is similar to the watery environment of a cell, the process of diffusion begins, as shown in **Figure 20(A).** In a short period of time, the ink particles have mixed as a result of diffusion to the point where a purple-colored blended area is visible. **Figure 20(B)** shows the initial result of this diffusion.

Figure 20 Diffusion causes the inks to move from high-ink concentration to low-ink concentration until the colors become evenly blended in the water.



Given more time, the ink particles continue to mix and, in this case, continue to form the uniform purple mixture shown in **Figure 20(C).** Mixing continues until the concentrations of red ink and blue ink are the same in all areas. The final result is the purple solution. After this point, the particles continue to move randomly, but no further change in concentration will occur. This condition, in which there is continuous movement but no overall change, is called **dynamic equilibrium.**

One of the key characteristics of diffusion is the rate at which diffusion takes place. Three main factors affect the rate of diffusion: concentration, temperature, and pressure. When concentration is high, diffusion occurs more quickly because there are more particles that collide. Similarly, when temperature or pressure increases, the number of collisions increases, thus increasing the rate of diffusion. Recall that at higher temperatures particles move faster, and at higher pressure the particles are closer together. In both cases, more collisions occur and diffusion is faster. The size and charge of a substance also affects the rate of diffusion.

VOCABULARY

ACADEMIC VOCABULARY

Concentration
the amount of a component in a given area or volume
The concentration of salt in the aquarium was too high, causing the fishes to die.

FOLDABLES
Incorporate information from this section into your Foldable.

Diffusion across the plasma membrane In addition to water, cells need certain ions and small molecules, such as chloride ions and sugars, to perform cellular functions. Water can diffuse across the plasma membrane, as shown in **Figure 21(A),** but most other substances cannot. Another form of transport, called **facilitated diffusion,** uses transport proteins to move other ions and small molecules across the plasma membrane. By this method, substances move into the cell through a water-filled transport protein, called a channel protein, that opens and closes to allow the substance to diffuse through the plasma membrane, as shown in **Figure 21(B).** Another type of transport protein, called a carrier protein, also can help substances diffuse across the plasma membrane. Carrier proteins change shape as the diffusion process continues to help move the particle through the membrane, as illustrated in **Figure 21(C).**

Diffusion of water and facilitated diffusion of other substances require no additional input of energy because the particles are moving from an area of high concentration to an area of lower concentration. This is also known as passive transport. You will learn later in this section about a form of cellular transport that does require energy input.

Reading Check **Describe** how sodium (Na^+) ions get into cells.

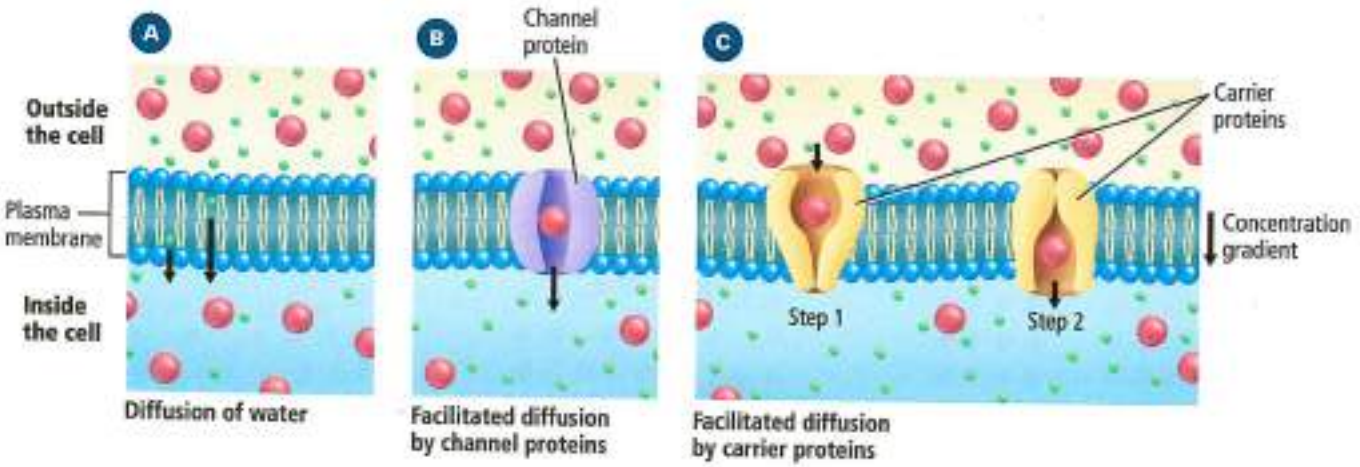


Figure 21 Although water moves freely through the plasma membrane, other substances cannot pass through the phospholipid bilayer on their own. Such substances enter the cell by facilitated transport.

Osmosis: Diffusion of Water

Water is a substance that passes freely into and out of a cell through the plasma membrane. The diffusion of water across a selectively permeable membrane is called **osmosis** (ahs MOH sus). Regulating the movement of water across the plasma membrane is an important factor in maintaining homeostasis within the cell.

How osmosis works Recall that in a solution, a substance called the solute is dissolved in a solvent. Water is the solvent in a cell and its environment. Concentration is a measure of the amount of solute dissolved in a solvent. The concentration of a solution decreases when the amount of solvent increases.

Examine **Figure 22,** showing a U-shaped tube containing solutions with different sugar concentrations separated by a selectively permeable membrane. What will happen if the solvent (water) can pass through the membrane but the solute (sugar) cannot?

Water molecules diffuse toward the side with the greater sugar concentration–the right side. As water moves to the right, the concentration of the sugar solution decreases. The water continues to diffuse until dynamic equilibrium occurs–the concentration of the solutions is the same on both sides. Notice in **Figure 22** that the result is an increase in solution level on the right side. During dynamic equilibrium, water molecules continue to diffuse back and forth across the membrane. But, the concentrations on each side no longer change.

Reading Check **Compare and contrast** diffusion and osmosis.

Mini Lab 2

Investigate Osmosis

What will happen to cells placed in a strong salt solution? Regulating the flow and amount of water into and out of a cell is critical to the survival of that cell. Osmosis is one method used to regulate a cell's water content.

Procedure

1. Identify the safety concerns of this lab before work begins.
2. Prepare a control **slide** using **onion epidermis, water,** and **iodine stain** as directed by your teacher.
3. Prepare a test slide using onion epidermis, **salt water,** and iodine stain as directed by your teacher.
4. Predict the effect, if any, that the salt solution will have on the onion cells in the test slide.
5. View the control slide using a **compound microscope** under low power and sketch several onion cells.
6. View the test slide under the same magnification and sketch your observations.

Analysis

1. **Analyze and conclude** whether your prediction was correct or incorrect. Explain.
2. **Explain** Use the process of osmosis to explain what you observe.

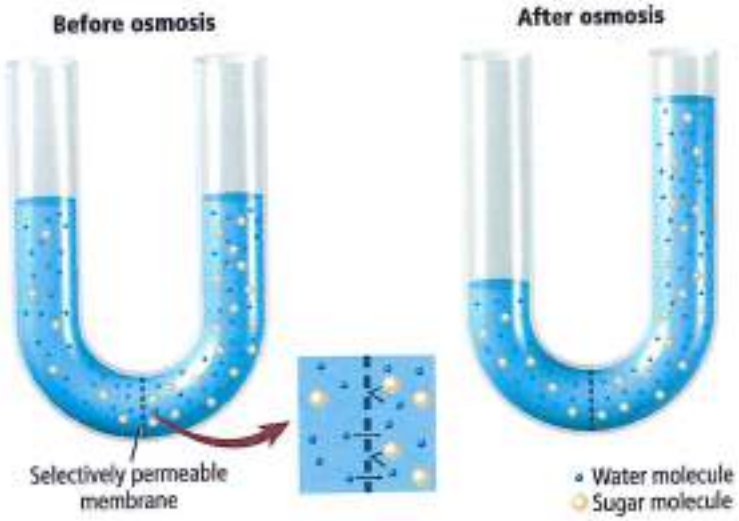


Figure 22 Before osmosis, the sugar concentration is greater on the right side. After osmosis, the concentrations are the same on both sides.
Name the term for this phenomenon.

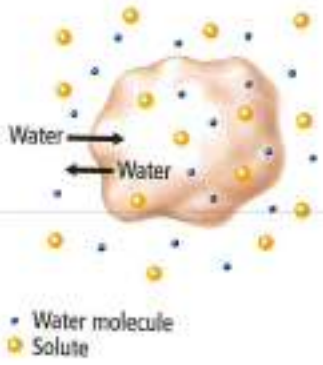
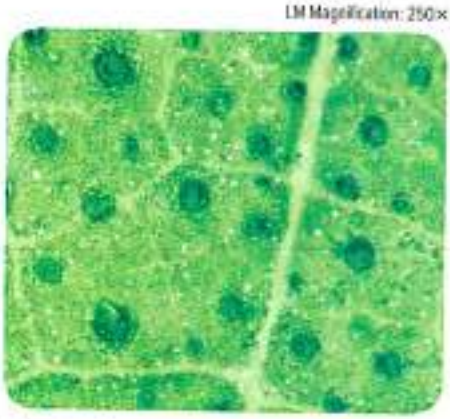


Figure 23 In an isotonic solution, water molecules move into and out of the cell at the same rate, and cells retain their normal shape. The animal cell and the plant cells have their normal shapes in an isotonic solution.

Color-Enhanced TEM Magnification: 15000×

Animal cell

LM Magnification: 250×



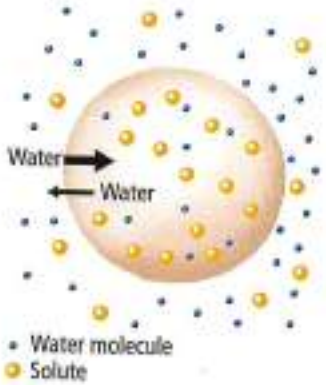
Plant cells

Cells in an isotonic solution When a cell is in a solution that has the same concentration of water and solutes–ions, sugars, proteins, and other substances–as its cytoplasm, the cell is said to be in an **isotonic solution.** *Iso-* comes from the Greek word meaning *equal.* Water still moves through the plasma membrane, but water enters and leaves the cell at the same rate. The cell is at equilibrium with the solution, and there is no net movement of water. The cells retain their normal shape, as shown in **Figure 23.** Most cells in organisms are in isotonic solutions, such as blood.

Cells in a hypotonic solution If a cell is in a solution that has a lower concentration of solute, the cell is said to be in a **hypotonic solution.** *Hypo-* comes from the Greek word meaning *under.* There is more water outside of the cell than inside. As a result of osmosis, the net movement of water through the plasma membrane is into the cell, as illustrated in **Figure 24.** Pressure generated as water flows through the plasma membrane is called osmotic pressure. In an animal cell, as water moves into the cell, the pressure increases and the plasma membrane swells. If the solution is extremely hypotonic, the plasma membrane might be unable to withstand this pressure and the cell might burst.

Because they have a rigid cell wall that supports them, plant cells do not burst when in a hypotonic solution. As the pressure inside a cell increases, the plant's central vacuole fills with water, pushing the plasma membrane against the cell wall, shown in the plant cells in **Figure 24.** Instead of bursting, the plant cell becomes firmer. Grocers use this process to keep produce looking fresh by misting fruits and vegetables with water.

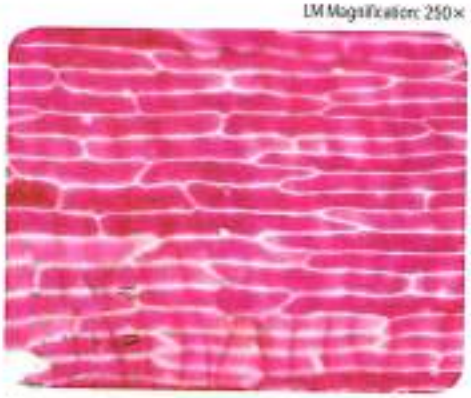
Figure 24 In a hypotonic solution, water enters a cell by osmosis, causing the cell to swell. Animal cells may continue to swell until they burst. Plant cells swell beyond their normal size as internal pressure increases.



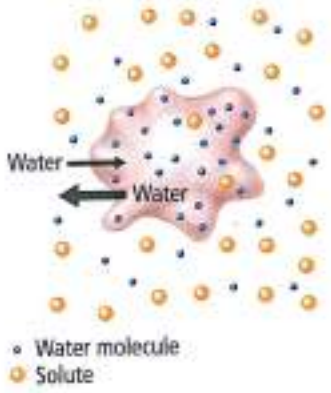
Color-Enhanced SEM Magnification: 15000×

Animal cell

LM Magnification: 250×



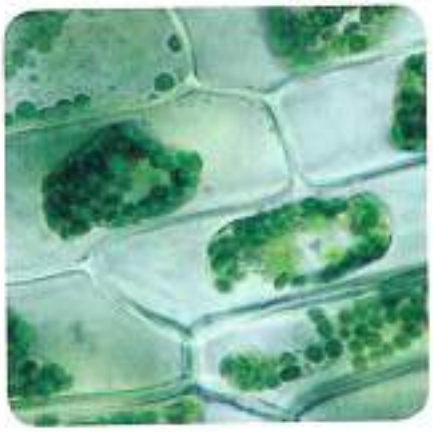
Plant cells



Color-Enhanced SEM Magnification: 15000×

Animal cells

LM Magnification: 250×



Plant cells

Figure 25 In a hypertonic solution, water leaves a cell by osmosis, causing the cell to shrink. Animal cells shrivel up as they lose water. As plant cells lose internal pressure, the plasma membrane shrinks away from the cell wall.

Cells in a hypertonic solution When a cell is placed in a **hypertonic solution,** the concentration of the solute outside of the cell is higher than it is inside. *Hyper-* comes from the Greek word meaning *above.* During osmosis, the net movement of water is out of the cell, as illustrated in **Figure 25.** Animal cells in a hypertonic solution shrivel because of decreased pressure in the cells. Plant cells in a hypertonic solution lose water, mainly from the central vacuole. The plasma membrane shrinks away from the cell wall. Loss of water in a plant cell causes wilting.

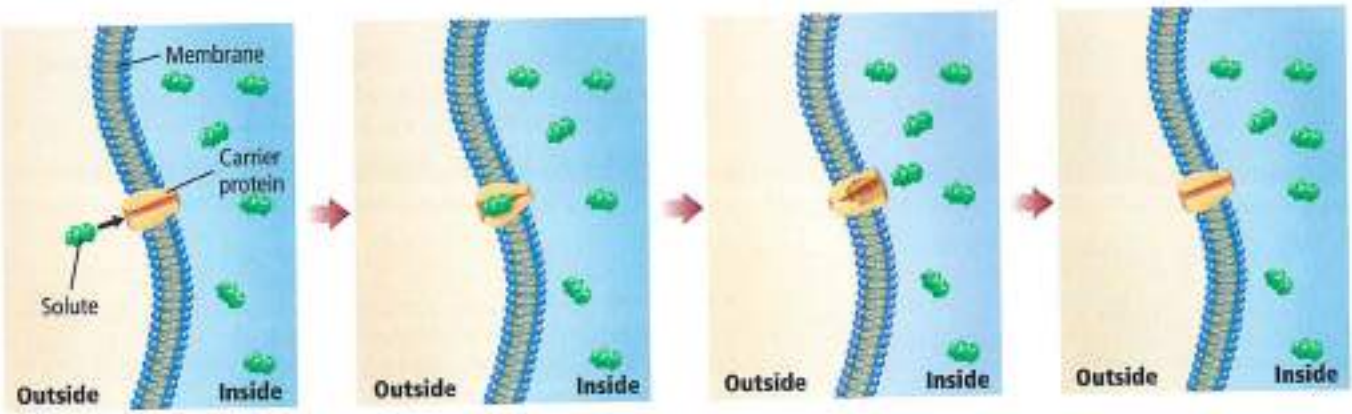
Reading Check **Compare and contrast** the three types of solutions.

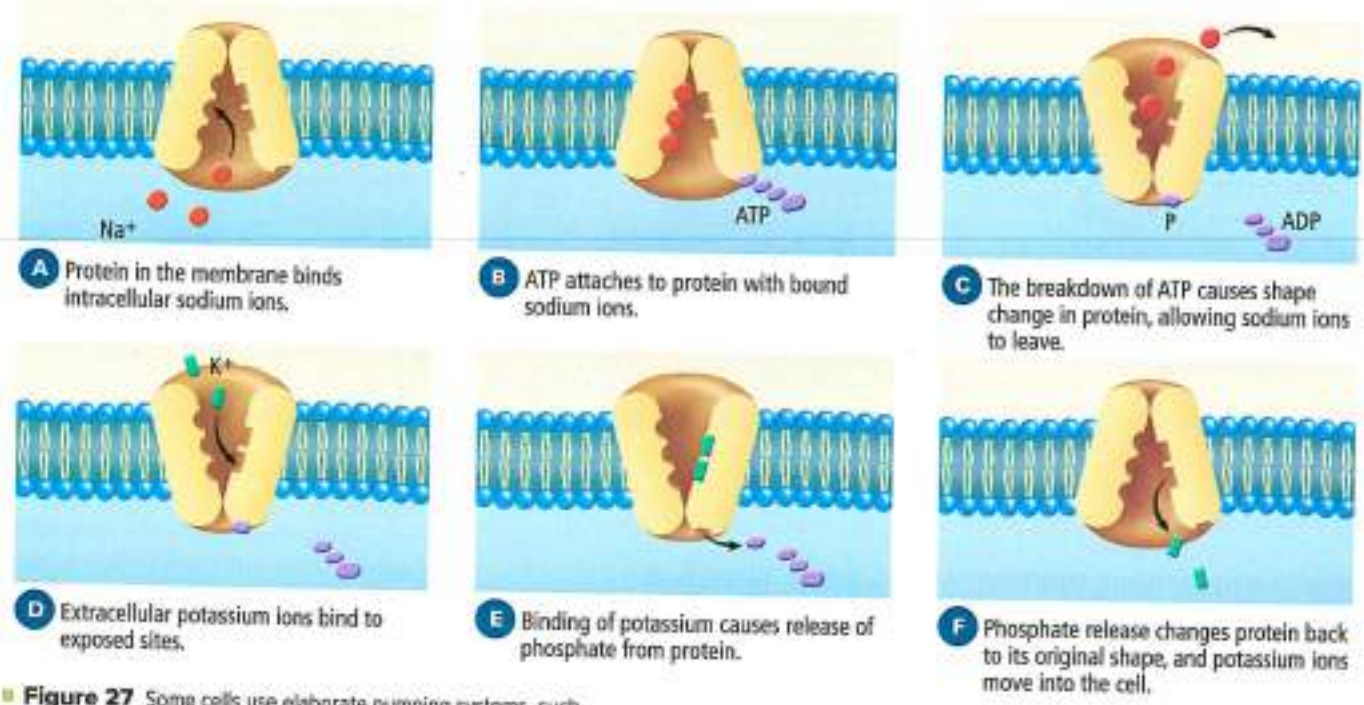
Active Transport

Sometimes substances must move from a region of lower concentration to a region of higher concentration against the passive movement from higher to lower concentration. This movement of substances across the plasma membrane against a concentration gradient requires energy; therefore, it is called **active transport. Figure 26** illustrates how active transport occurs with the aid of carrier proteins, commonly called pumps. Some pumps move one type of substance in only one direction, while others move two substances either across the membrane in the same direction or in opposite directions. Because of active transport, the cell maintains the proper balance of substances it needs. Active transport helps maintain homeostasis.

Figure 26 Carrier proteins pick up and move substances across the plasma membrane against the concentration gradient and into the cell.

Explain ***why active transport requires energy.***





A Protein in the membrane binds intracellular sodium ions.

B ATP attaches to protein with bound sodium ions.

C The breakdown of ATP causes shape change in protein, allowing sodium ions to leave.

D Extracellular potassium ions bind to exposed sites.

E Binding of potassium causes release of phosphate from protein.

F Phosphate release changes protein back to its original shape, and potassium ions move into the cell.

Figure 27 Some cells use elaborate pumping systems, such as the Na^+/K^+ ATPase pump shown here, to help move substances through the plasma membrane.

Na^+/K^+ ATPase pump One common active transport pump is called the sodium-potassium ATPase pump. This pump is found in the plasma membrane of animal cells. The pump maintains the level of sodium ions (Na^+) and potassium ions (K^+) inside and outside the cell. This protein pump is an enzyme that catalyzes the breakdown of an energy-storing molecule. The pump uses the energy to transport three sodium ions out of the cell while moving two potassium ions into the cell. The high level of sodium on the outside of the cell creates a concentration gradient. Follow the steps in **Figure 27** to see the action of the Na^+/K^+ ATPase pump.

The activity of the Na^+/K^+ ATPase pump can result in yet another form of cellular transport. Substances, such as sugar molecules, must come into the cell from the outside, where the concentration of the substance is lower than it is inside. This requires energy. Recall, however, that the Na^+/K^+ ATPase pump moves Na^+ out of the cell, which creates a low concentration of Na^+ inside the cell. In a process called coupled transport, the Na^+ ions that have been pumped out of the cell can couple with sugar molecules and be transported into the cell through a membrane protein called a coupled channel. The sugar molecule, coupled to a Na^+ ion, enters the cell by facilitated diffusion of the sodium, as shown in **Figure 28.** As a result, sugar enters the cell without spending any additional cellular energy.

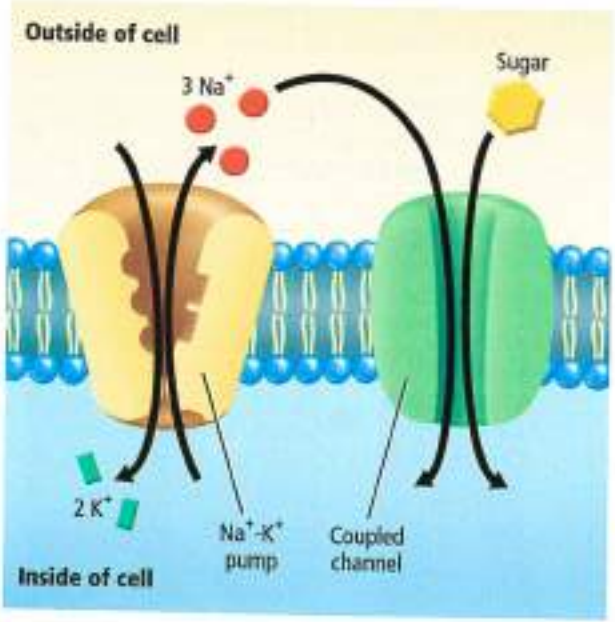


Figure 28 Substances hitch their way into or out of a cell by coupling with another substance that uses an active transport pump.

Compare and contrast *active and passive transport across the plasma membrane.*

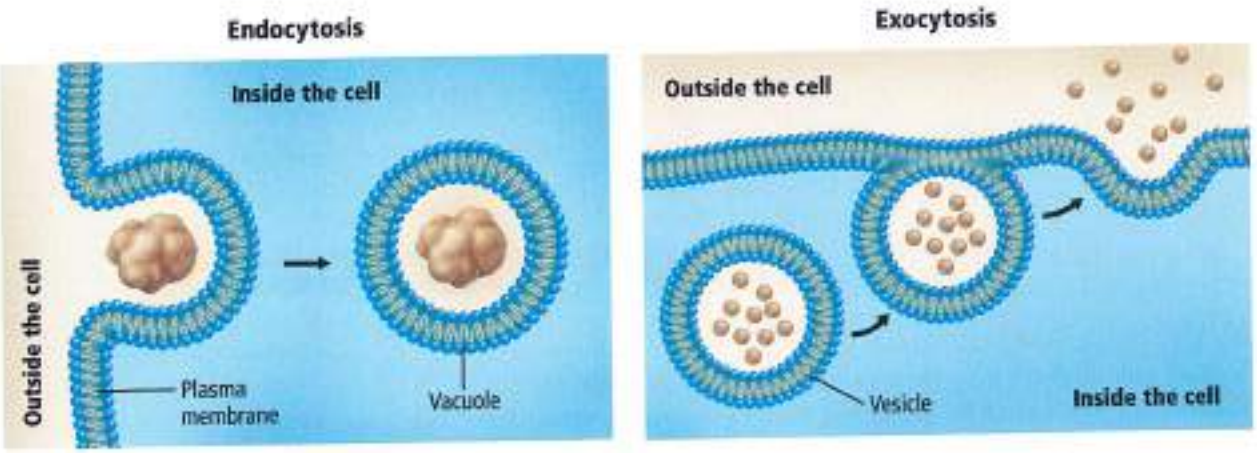


Figure 29
Left: Large substances can enter a cell by endocytosis.
Right: Substances can be deposited outside the cell by exocytosis.

Transport of Large Particles

Some substances are too large to move through the plasma membrane by diffusion or transport proteins and must get inside the cell by a different process. **Endocytosis** is the process by which a cell surrounds a substance in the outside environment, enclosing the substance in a portion of the plasma membrane. The membrane then pinches off and leaves the substance inside the cell. The substance shown on the left in **Figure 29** is engulfed and enclosed by a portion of the cell's plasma membrane. The membrane then pinches off inside of the cell, and the resulting vacuole, with its contents, moves to the inside of the cell.

Exocytosis is the secretion of materials at the plasma membrane. The illustration on the right in **Figure 29** shows that exocytosis is the reverse of endocytosis. Cells use exocytosis to expel wastes and to secrete substances, such as hormones, produced by the cell. Both endocytosis and exocytosis require the input of energy. Cells maintain homeostasis by moving substances into and out of the cell. Some transport processes require additional energy input, while others do not. Together, the different types of transport allow a cell to interact with its environment while maintaining homeostasis.

Section 4 Assessment

Section Summary

- Cells maintain homeostasis using passive and active transport.
- Concentration, temperature, and pressure affect the rate of diffusion.
- Cells must maintain homeostasis in all types of solutions, including isotonic, hypotonic, and hypertonic.
- Some large molecules are moved into and out of the cell using endocytosis and exocytosis.

Understand Main Ideas

1. MAIN Idea **List and describe** the types of cellular transport.
2. **Describe** how the plasma membrane controls what goes into and comes out of a cell.
3. **Sketch** a before and an after diagram of an animal cell placed in a hypotonic solution.
4. **Contrast** how facilitated diffusion is different from active transport.

Think Critically

5. **Describe** Some organisms that normally live in pond water contain water pumps. These pumps continually pump water out of the cell. Describe a scenario that might reverse the action of the pump.
6. **Summarize** the role of the phospholipid bilayer in cellular transport in living cells.

CUTTING-EDGE BIOLOGY

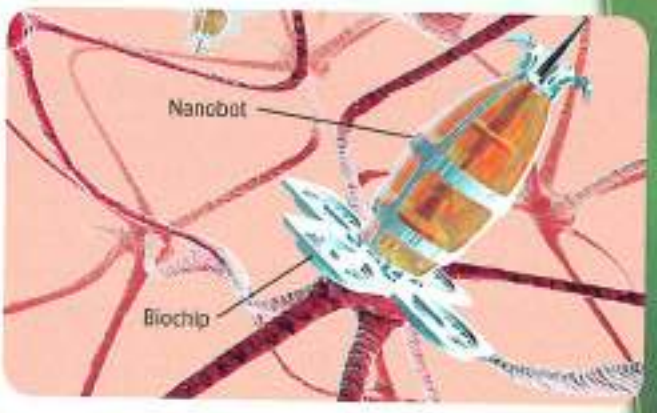
EXPLORING NANOTECHNOLOGY

Imagine that cancer cells could be detected and destroyed one by one, or that a new drug could be tested on a single cell to evaluate its clinical performance. Advances in technologies that allow scientists to focus on individual cells might make these scenarios a reality in the near future.

Nanotechnology (na no tek NAW luh jee) is the branch of science that deals with the development and use of devices on the nanometer scale. A nanometer (nm) is one billionth of a meter (10^{-9} m). To put this scale into perspective, consider that most human cells are between 10,000 and 20,000 nm in diameter. Nanotechnology is a fast-growing branch of science that likely will leave its mark on everything from electronics to medicine.

Atomic force microscopes At the National Institute of Advanced Industrial Science and Technology in Hyogo, Japan, researchers are using nanotechnology in the form of an atomic force microscope (AFM) to operate on single cells. The microscope is actually used as a "nanoneedle." The AFM creates a visual image of a cell using a microscopic sensor that scans the cell. Then the probe of the AFM, sharpened into a needle tip that is approximately 200 nm in diameter, can be inserted into the cell without damaging the cell membrane.

Some scientists envision many applications for this technique. The nanoneedle might help scientists study how a cell responds to a new drug or how the chemistry of a diseased cell differs from that of a healthy cell. Another application for the nanoneedle might be to insert DNA strands directly into the nucleus of a cell to test new gene therapy techniques that might correct genetic disorders.



This computer-generated image shows a nanobot armed with a biochip. Someday, a biochip, which is an electronic device that contains organic materials, might repair a damaged nerve cell.

Lasers Nanotechnology applications, perhaps in the form of nanosurgery, could be used to investigate how cells work or to destroy individual cancer cells without harming nearby healthy cells. Researchers at Harvard University have developed a laser technique that allows them to manipulate a specific component of the cell's internal parts without causing damage to the cell membrane or other cell structures. Imagine having the capability to perform extremely delicate surgery on a cellular level!

In the future, nanotechnology might be our first line of defense to treat cancer. It also might become the standard technique to test new drugs or even become a favored treatment used in gene therapy.

WRITING in Biology

Review Write an overview of one technology related to medicine and healthcare that you find interesting. Describe its advantages and challenges. You may include a presentation with your overview.

BIOLAB

WHICH SUBSTANCES WILL PASS THROUGH A SELECTIVELY PERMEABLE MEMBRANE?

Background: **All membranes in cells are selectively permeable. In this lab, you will examine the movement of some biologically important molecules through a dialysis membrane that is analogous to the plasma membrane. Because a dialysis membrane has tiny pores, it is permeable only for tiny molecules.**

Question: *Which substances pass through a dialysis membrane?*

Materials

cellulose dialysis tubing (2)
400-mL beakers (2)
string
scissors
distilled water
small plastic dishpan
starch solution
albumin solution
glucose solution
NaCl solution
iodine solution (tests starch)
anhydrous Benedict's reagent (tests glucose)
silver nitrate solution (tests NaCl)
biuret reagent (tests albumin)
10-mL graduated cylinder
test tubes (2)
test-tube rack
funnel
wax pencil
eye droppers

Safety Precautions

Procedure

1. Identify the safety concerns of this lab before work begins.
2. Construct a data table as instructed by your teacher. Predict which substances will pass through the dialysis membrane.
3. Collect two lengths of dialysis tubing, two 400-mL beakers, and the two solutions that you have been assigned to test.
4. Label the beakers with the type of solution that you place in the dialysis tubing.
5. With a partner, prepare and fill one length of dialysis tubing with one solution. Rinse the outside of the bag thoroughly. Place the filled tubing bag into a beaker that contains distilled water.
6. Repeat Step 5 using the second solution.
7. After 45 minutes, transfer some of the water from each beaker into separate test tubes.
8. Add a few drops of the appropriate test reagent to the water.
9. Record your results and determine whether your prediction was correct. Compare your results with those of other groups in your class and record the results for the two solutions that you did not test.
10. **Cleanup and Disposal** Wash and return all reusable materials. Dispose of test solutions and used dialysis tubing as directed by your teacher. Wash your hands thoroughly after using any chemical reagent.

Analyze and Conclude

1. **Evaluate** Did your test molecules pass through the dialysis tubing? Explain.
2. **Think Critically** What characteristics of a plasma membrane give it more control over the movement of molecules than the dialysis membrane has?
3. **Error Analysis** How could failing to rinse the dialysis tube bags with distilled water prior to placing them in the beaker cause a false positive test for the presence of a dissolved molecule? What other sources of error might lead to inaccurate results?

POSTER SESSION

Communicate A disease called cystic fibrosis occurs when plasma membranes lack a molecule that helps transport chloride ions. Research this disease and present your finding to your class using a poster.

Chapter 1 Study Guide

THEME FOCUS Scientific Inquiry It was through scientific inquiry that the microscope, cells, and protozoans were discovered. These discoveries led to new branches of science.

BIG Idea Cells are the structural and functional units of all living things.

Section 1 Cell Discovery and Theory

cell
cell theory
plasma membrane
eukaryotic cell
nucleus
organelle
prokaryotic cell

MAIN Idea **The invention of the microscope led to the discovery of cells.**

- Microscopes have been used as tools for scientific study since the late 1500s.
- Scientists use different types of microscopes to study cells.
- The cell theory summarizes three principles.
- There are two broad groups of cell types: prokaryotic cells and eukaryotic cells.
- Eukaryotic cells each contain a nucleus and organelles.

Section 2 Plasma Membrane

selective permeability
phospholipid bilayer
transport protein
fluid mosaic model

MAIN Idea **The plasma membrane helps to maintain a cell's homeostasis.**

- Selective permeability is the property of the plasma membrane that allows it to control what enters and leaves the cell.
- The plasma membrane is made up of two layers of phospholipid molecules.
- Cholesterol and transport proteins aid in the function of the plasma membrane.
- The fluid mosaic model describes the plasma membrane.

Section 3 Structures and Organelles

cytoplasm
cytoskeleton
nucleolus
ribosome
endoplasmic reticulum
Golgi apparatus
vacuole
centriole
lysosome
chloroplast
mitochondrion
cell wall
cilium
flagellum

MAIN Idea **Eukaryotic cells contain organelles that allow the specialization and the separation of functions within the cell.**

- Eukaryotic cells contain membrane-bound organelles in the cytoplasm that perform cell functions.
- Ribosomes are the sites of protein synthesis.
- Mitochondria are the powerhouses of cells.
- Plant and animal cells contain many of the same organelles, while other organelles are unique to either plant cells or animal cells.

Section 4 Cellular Transport

diffusion
dynamic equilibrium
facilitated diffusion
osmosis
hypotonic solution
isotonic solution
active transport
hypertonic solution
endocytosis
exocytosis

MAIN Idea **Cellular transport moves substances within the cell and moves substances into and out of the cell.**

- Cells maintain homeostasis using passive and active transport.
- Concentration, temperature, and pressure affect the rate of diffusion.
- Cells must maintain homeostasis in all types of solutions, including isotonic, hypotonic, and hypertonic.
- Some large molecules are moved into and out of the cell using endocytosis and exocytosis.

Chapter 1 Assessment

Section 1

Vocabulary Review

Each of the following sentences is false. Make each sentence true by replacing the italicized word with a vocabulary term from the Study Guide page.

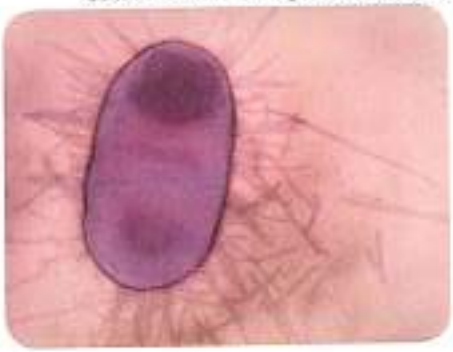
1. The *nucleus* is a structure that surrounds a cell and helps control what enters and exits the cell.
2. A(n) *prokaryote* has membrane-bound organelles.
3. *Organelles* are basic units of all organisms.

Understand Main Ideas

4. If a microscope has a series of three lenses that magnify individually 5×, 5×, and 7×, what is the total magnification of the microscope?
   A. 25× **C.** 17×
   B. 35× **D.** 175×
5. Which is not part of the cell theory?
   A. The basic unit of life is the cell.
   B. Cells came from preexisting cells.
   C. All living organisms are composed of cells.
   D. Cells contain membrane-bound organelles.

Use the photo to answer question 6.

Color-Enhanced TEM Magnification: 15,000×



6. The photomicrograph shows which kind of cell?
   A. prokaryotic cell **C.** animal cell
   B. eukaryotic cell **D.** plant cell

Constructed Response

7. MAIN Idea Explain how the development of the microscope changed how scientists studied living organisms.
8. **Short Answer** Compare and contrast prokaryotic cells and eukaryotic cells.

Think Critically

9. THEME FOCUS Scientific Inquiry Why might a microscopist, who specializes in the use of microscopes to examine specimens, use a light microscope instead of an electron microscope?
10. **Analyze** A material is found in an asteroid that might be a cell. What criteria must the material meet to be considered a cell?

Section 2

Vocabulary Review

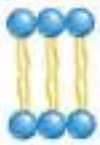
Complete the sentences below using vocabulary terms from the Study Guide page.

11. A _____ is the basic structure that makes up the plasma membrane.
12. _____ proteins move needed substances or waste materials through the plasma membrane.
13. _____ is the property that allows only some substances in and out of a cell.

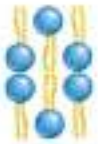
Understand Main Ideas

14. Which of the following orientations of phospholipids best represents the phospholipid bilayer of the plasma membrane?

A.

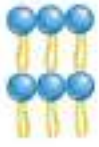


C.



B.

D.



15. Which situation would increase the fluidity of a phospholipid bilayer?
   A. decreasing the temperature
   B. increasing the number of proteins
   C. increasing the number of cholesterol molecules
   D. increasing the number of unsaturated fatty acids

Chapter 1 Assessment

Constructed Response

16. MAIN Idea Explain how the plasma membrane maintains homeostasis within a cell.

17. **Open Ended** Explain what a mosaic is and then explain why the term *fluid mosaic model* is used to describe the plasma membrane.

18. **Short Answer** How does the orientation of the phospholipids in the bilayer allow a cell to interact with its internal and external environments?

Think Critically

19. **Hypothesize** how a cell would be affected if it lost the ability to be selectively permeable.

20. **Predict** What might happen to a cell if it no longer could produce cholesterol?

Section 3

Vocabulary Review

Fill in each blank with the vocabulary term from the Study Guide page that matches the function definition.

21. _____ stores wastes

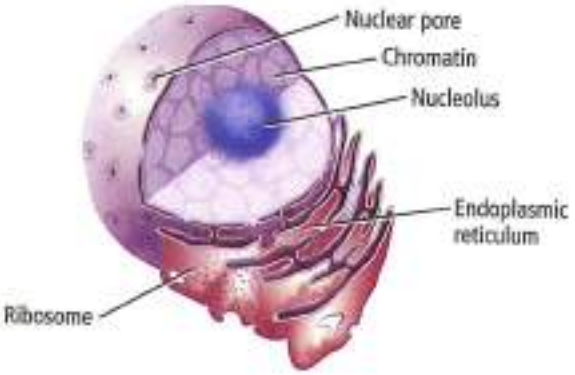
22. _____ produces ribosomes

23. _____ generates energy for a cell

24. _____ sorts proteins into vesicles

Understand Main Ideas

Use the diagram below to answer questions 25 and 26.



25. Which structure synthesizes proteins that will be used by the cell?
   - **A.** chromatin
   - **B.** nucleolus
   - **C.** ribosome
   - **D.** endoplasmic reticulum

26. Which is the site of protein synthesis?
   - **A.** nuclear pore
   - **B.** endoplasmic reticulum
   - **C.** chromatin
   - **D.** nucleolus

27. In which structure would you expect to find a cell wall?
   - **A.** human skin cell
   - **B.** cell from an oak tree
   - **C.** blood cell from a cat
   - **D.** liver cell from a mouse

Constructed Response

28. **Short Answer** Describe why the cytoskeleton within the cytoplasm was a recent discovery.

29. **Short Answer** Compare the structures and functions of the mitochondrion and chloroplast below.

30. MAIN Idea Suggest a reason why packets of proteins collected in a vacuole might merge with lysosomes.

Think Critically

31. **Identify** a specific example in which the cell wall structure has aided the survival of a plant in its natural habitat.

32. **Infer** why plant cells that transport water against the force of gravity contain many more mitochondria than other plant cells do.

Section 4

Vocabulary Review

Explain the difference in the terms in each pair below. Then explain how the terms are related.

33. active transport, facilitated diffusion

34. endocytosis, exocytosis

35. hypertonic solution, hypotonic solution

Understand Main Ideas

36. Which is not a factor that affects the rate of diffusion?

A. conductivity
B. concentration
C. pressure
D. temperature

37. Which type of transport requires energy input from the cell?

A. active transport
B. facilitated diffusion
C. osmosis
D. simple diffusion

Constructed Response

38. Short Answer Why is active transport an energy-utilizing process?

39. Short Answer Some protists that live in a hypotonic pond environment have cell membrane adaptations that slow water uptake. What adap-tations might this protist living in the hypertonic Great Salt Lake have?

LM Magnification: 75×

40. MAIN Idea Summarize how cellular transport helps maintain homeostasis within a cell.

Think Critically

41. Hypothesize how oxygen crosses the plasma membrane if the concentration of oxygen is lower inside the cell than it is outside the cell.

42. Analyze Farming and watering that are done in very dry regions of the world leave salts that accumulate in the soil as water evaporates. Based on what you know about concentration gradients, why does increasing soil salinity have adverse effects on plant cells?

Summative Assessment

43. BIG Idea Cells are the structural and functional units of living things. Create an analogy where "smaller parts" provide structure and funtion for a "whole." Relate it to cells and living things by giving specific examples.

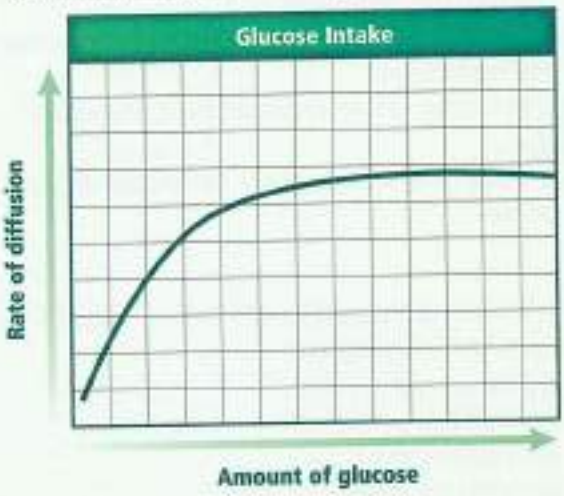
44. Use what you have learned about osmosis and cellular transport to design an apparatus that would enable a freshwater fish to survive in a saltwater habitat.

45. WRITING in Biology Create a poem that describes the functions of at least five cell organelles.

DBQ Document-Based Questions

The graph below describes the relationship between the amount of glucose entering a cell and the rate at which the glucose enters the cell with the help of carrier proteins. Use this graph to answer questions 46 and 47.

Data obtained from: Raven, P.H., et al. 2002. *Biology*. 6th ed.: 99.



46. Summarize the relationship between the amount of glucose and the rate of diffusion.

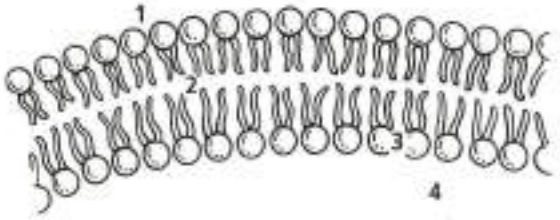
47. Infer why the rate of diffusion tapers off with higher amounts of glucose. Make an illustration to explain your answer.

Standardized Test Practice

Cumulative

Multiple Choice aligned with PISA study skills

Use the illustration below to answer questions 1 and 2.



1. Which number in the illustration represents the location where you would expect to find water-insoluble substances?
   - **A.** 1
   - **B.** 2
   - **C.** 3
   - **D.** 4

2. Which is the effect of having the polar and nonpolar ends of phospholipid molecules oriented as they are in the illustration?
   - **A.** It allows transport proteins to move easily through the membrane.
   - **B.** It controls the movement of substances across the membrane.
   - **C.** It helps the cell to maintain its characteristic shape.
   - **D.** It makes more room inside the phospholipid bilayer.

3. Which of these habitats would be best suited for a population of *r*-strategists?
   - **A.** desert
   - **B.** grassland
   - **C.** deciduous forest
   - **D.** tropical rain forest

4. Which adaptation helps plants survive in a tundra biome?
   - **A.** deciduous leaves that fall off as winter approaches
   - **B.** leaves that store water
   - **C.** roots that grow only a few centimeters deep
   - **D.** underground stems that are protected from grazing animals

5. Which is a nonrenewable resource?
   - **A.** clean water from freshwater sources
   - **B.** energy provided by the Sun
   - **C.** an animal species that has become extinct
   - **D.** a type of fish that is caught in the ocean

6. In which type of cell would you find a chloroplast?
   - **A.** prokaryote
   - **B.** animal
   - **C.** plant
   - **D.** fungus

Use this incomplete equation to answer questions 7 and 8.

$$CH_4 + 4Cl_2 \rightarrow \_\_HCl + \_\_CCl_4$$

7. The chemical equation above shows what can happen in a reaction between methane and chlorine gas. The coefficients have been left out in the product side of the equation. Which is the correct coefficient for HCl?
   - **A.** 1
   - **B.** 2
   - **C.** 4
   - **D.** 8

8. Which is the minimum number of chlorine (Cl) atoms needed for the reaction shown in the equation?
   - **A.** 1
   - **B.** 2
   - **C.** 4
   - **D.** 8

9. Why is *Caulerpa taxifolia* considered an invasive species in some coastal areas of North America?
   - **A.** It is dangerous to humans.
   - **B.** It is nonnative to the area.
   - **C.** It grows slowly and invades over time.
   - **D.** It outcompetes native species for resources.

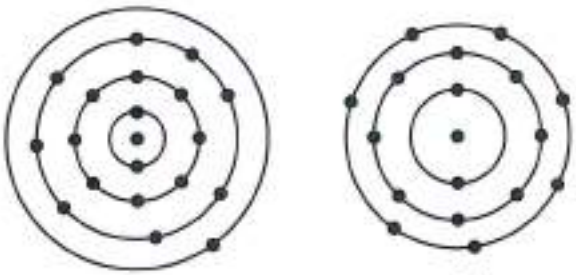
Short Answer aligned with SAT exam skills

10. Use a flowchart to organize information about cell organelles and protein synthesis. For each step, analyze the role of the organelle in protein synthesis.

11. Compare and contrast the functions of carbohydrates, lipids, proteins, and nucleic acids.

12. State why the polarity of water molecules makes water a good solvent.

Use the figure below to answer question 13.



13. Use the figure to describe how the ionic compound potassium chloride (KCl) is formed.

14. What might happen if cell membranes were not selectively permeable?

15. Choose a specific natural resource and develop a plan for the sustainable use of that resource.

16. What can you infer about the evolution of bacterial cells from studying their structure?

Extended Response aligned with SAT exam skills

The illustration below shows a single animal cell in an isotonic solution. Use the illustration to answer question 17.

17. Describe what would happen to this cell in a hypertonic solution and in a hypotonic solution.

18. Explain why direct economic value is not the only important consideration of biodiversity.

19. Analyze why an electron microscope can produce higher magnification than a light microscope can.

20. Assess why transport proteins are needed to move certain substances across a cell membrane.

Essay Questions aligned with SAT exam skills

Recently, some international trade agreements have allowed scientists and companies to patent the discoveries they make about organisms and their genetic material. For instance, it is possible to patent seeds that have genes for disease resistance and plants that can be used in medicine or industry. Owners of patents now have greater control over the use of these organisms.

Using the information in the paragraph above, answer the following question in essay format.

21. Based on what you know about biodiversity, identify some pros and cons of a patent system. Write an essay exploring the pros and cons of patenting discoveries about organisms.

CHAPTER 2

Chemistry in Biology

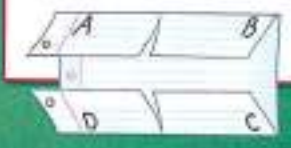
Launch Lab

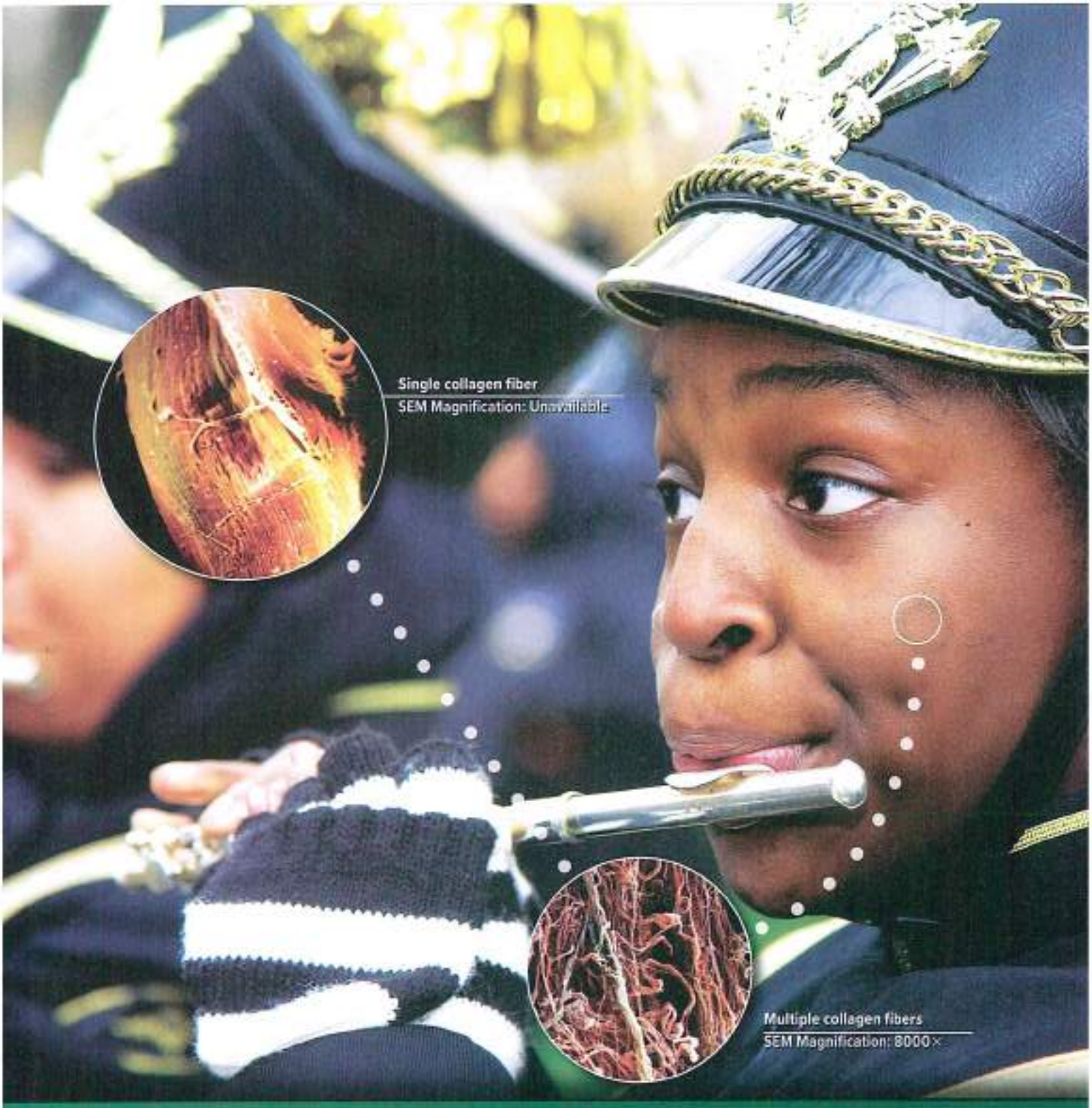
How does the nutrient content of foods compare?

Your body's structures and functions depend on chemical elements including those found in proteins, carbohydrates, fats, vitamins, minerals, and water. In this lab, you will investigate nutrients that provide those elements.

FOLDABLES

Make a four-door book using the labels shown. Use it to organize your notes on enzyme activity.





THEME FOCUS Energy

In every chemical reaction, there is a change in energy.

BIG Idea Atoms are the foundation of biological chemistry and the building blocks of all living organisms.

Section 1

Reading Preview

Essential Questions

- What are atoms?
- How are the particles that make up atoms diagrammed?
- What are the similarities between covalent and ionic bonds?
- How are van der Waals forces described?

Review Vocabulary

substance: a form of matter that has a uniform and unchanging composition

New Vocabulary

atom
nucleus
proton
neutron
electron
element
isotope
compound
covalent bond
molecule
ion
ionic bond
van der Waals force

Atoms, Elements, and Compounds

MAIN Idea **Matter is composed of tiny particles called atoms.**

Real-World Reading Link Many scientists think that the universe began with a sudden, rapid expansion billions of years ago. They think that the building blocks that make up the amazing diversity of life we see today are a result of that expansion. The study of those building blocks is the science of chemistry.

Atoms

Chemistry is the study of matter, its composition, and properties. Matter is anything that has mass and takes up space. All of the organisms that you study in biology are made up of matter. **Atoms** are the building blocks of matter.

Connection to History In the fifth century B.C.E., Greek philosophers Leucippus and Democritus first proposed the idea that all matter is made up of tiny, indivisible particles. It wasn't until the 1800s that scientists began to collect experimental evidence to support the existence of atoms. As technology improved over the next two centuries, scientists proved not only that atoms exist but also that they are made up of even smaller particles.

The structure of an atom An atom is so small that billions of them could fit on the head of a pin. Yet, atoms are made up of even smaller particles called neutrons, protons, and electrons, as illustrated in **Figure 1.** Neutrons and protons are located at the center of the atom, which is called the **nucleus. Protons** are positively charged particles (p^+), and **neutrons** are particles that have no charge (n^0). **Electrons** are negatively charged particles (e^-) that are located outside the nucleus. Electrons constantly move around an atom's nucleus in energy levels. The basic structure of an atom is the result of the attraction between protons and electrons. Atoms contain an equal number of protons and electrons, so the overall charge of an atom is zero.

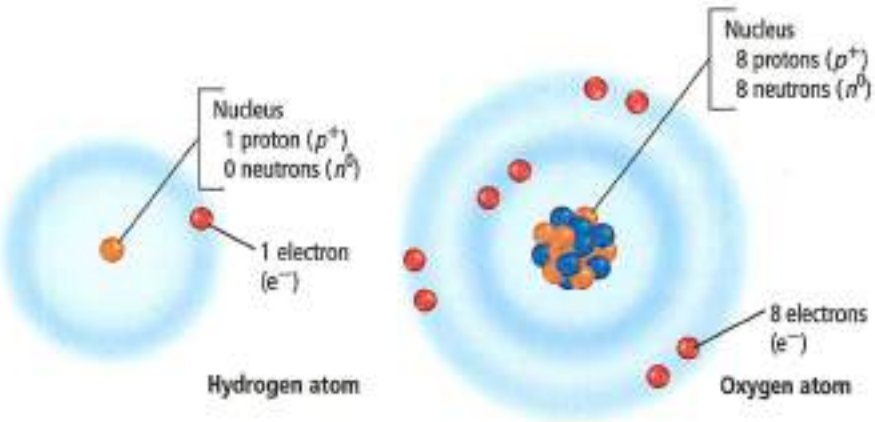


Figure 1 Hydrogen has only one proton and one electron. Oxygen has eight protons, eight neutrons, and eight electrons. The electrons move around the nucleus in two energy levels (shown as the darker shaded rings).
***Infer** the charge of an atom if it contained more electrons than protons.*

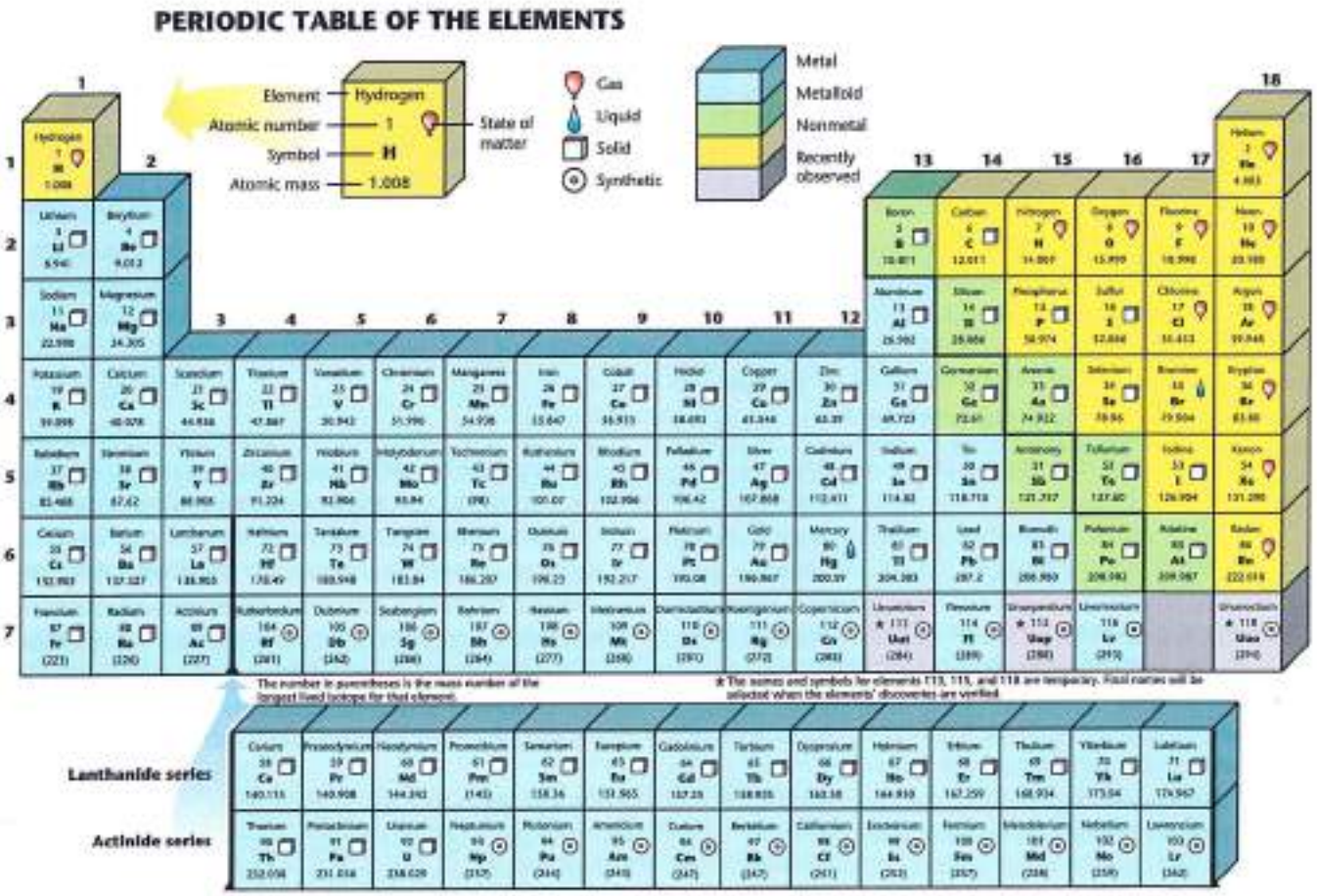


Figure 2 The periodic table of the elements organizes all of the known elements. Examine the biologists' guide to the periodic table on the back cover of this book.

Elements

An **element** is a pure substance that cannot be broken down into other substances by physical or chemical means. Elements are made of only one type of atom. There are over 100 known elements, 92 of which occur naturally. Scientists have collected a large amount of information about the elements, such as the number of protons and electrons each element has and the atomic mass of each element. Also, each element has a unique name and symbol. All of these data, and more, are collected in an organized table called the periodic table of the elements.

The periodic table of the elements As shown in **Figure 2,** the periodic table is organized into horizontal rows, called periods, and vertical columns, called groups. Each individual block in the grid represents an element. The table is called periodic because elements in the same group have similar chemical and physical properties. This organization even allows scientists to predict elements that have not yet been discovered or isolated. As shown in **Figure 3,** elements found in living organisms also are found in Earth's crust.

Figure 3 The elements in Earth's crust and living organisms vary in their abundance. Living things are composed primarily of three elements: carbon, hydrogen, and oxygen.

Interpret *what the most abundant element is that exists in living things.*

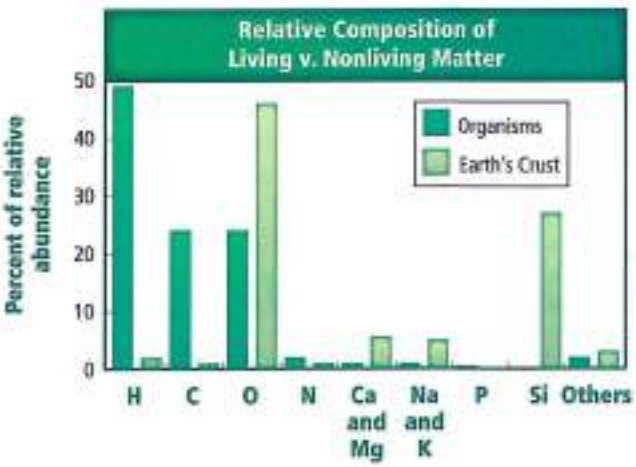
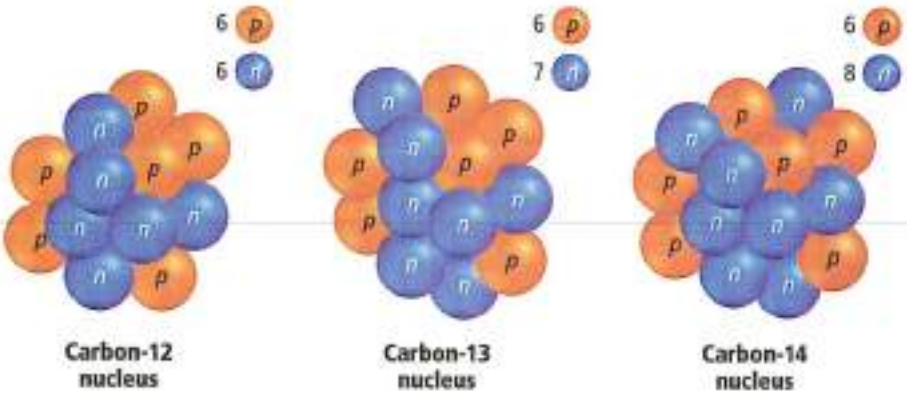


Figure 4 Carbon-12 and carbon-13 occur naturally in living and nonliving things. All living things also contain a small amount of carbon-14. **Compare** *the similarities and differences of isotopes.*



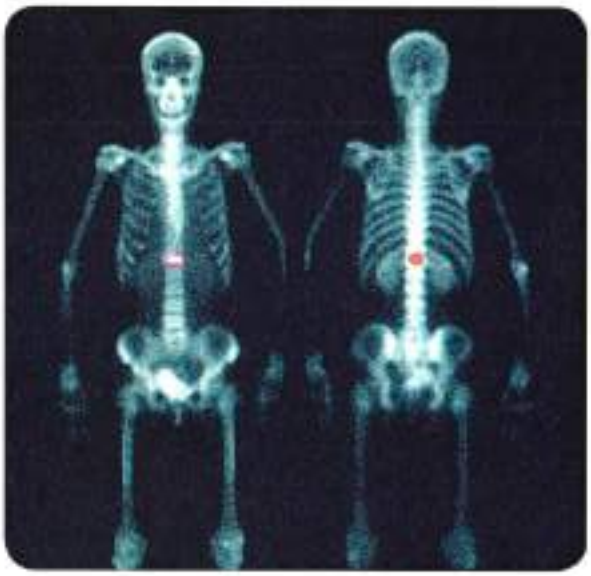
Isotopes Although atoms of the same element have the same number of protons and electrons, atoms of an element can have different numbers of neutrons, as shown in **Figure 4.** Atoms of the same element that have different numbers of neutrons are called **isotopes.** Isotopes of an element are identified by adding the number of protons and neutrons in the nucleus. For example, the most abundant form of carbon, carbon-12, has six protons and six neutrons in its nucleus. One carbon isotope–carbon-14–has six protons and eight neutrons. Isotopes of elements have the same chemical characteristics.

Radioactive isotopes Changing the number of neutrons in an atom does not change the overall charge of the atom. However, changing the number of neutrons can affect the stability of the nucleus, in some cases causing the nucleus to decay, or break apart. When a nucleus breaks apart, it gives off radiation that can be detected. Isotopes that give off radiation are called radioactive isotopes.

Carbon-14 is a radioactive isotope that is found in all living things. Scientists know the half-life, or the amount of time it takes for half of carbon-14 to decay, so they can calculate the age of an object by finding how much carbon-14 remains in the sample. Other radioactive isotopes have medical uses, as shown in **Figure 5.**

Reading Check **State** the difference between an isotope and a radioactive isotope.

Figure 5 Radioactive isotopes are used to help doctors diagnose disease, and locate and treat certain types of cancer.



Brilliant fireworks displays depend on compounds such as the metal strontium.

Table salt is the compound NaCl.

Wetlands are sources of living things made of complex compounds and the simple compound methane (CH_4).

Figure 6 You and your world are made of compounds.

Compounds

Elements can combine to form more complex substances. A **compound** is a pure substance formed when two or more different elements combine. There are millions of known compounds and thousands more discovered each year. **Figure 6** shows a few of them. Each compound has a chemical formula made up of the chemical symbols from the periodic table. You might know that water is the compound H_2O. Sodium chloride (NaCl) is the compound commonly called table salt. The fuel people use in cars is a mixture of hydrocarbon compounds. Hydrocarbons have only hydrogen and carbon atoms. Methane (CH_4) is the simplest hydrocarbon. Bacteria in areas such as the wetlands shown in **Figure 6** release 76 percent of global methane from natural sources by decomposing plants and other organisms. They are made of compounds, too.

Compounds have several unique characteristics. First, compounds are always formed from a specific combination of elements in a fixed ratio. Water always is formed in a ratio of two hydrogen atoms and one oxygen atom, and each water molecule has the same structure. Second, compounds are chemically and physically different from the elements that comprise them. For example, water has different properties than hydrogen and oxygen.

Another characteristic of compounds is that they cannot be broken down into simpler compounds or elements by physical means, such as tearing or crushing. Compounds, however, can be broken down by chemical means into simpler compounds or into their original elements. Consider again the example of water. You cannot pass water through a filter and separate the hydrogen from the oxygen, but a process called electrolysis, illustrated in **Figure 7,** can break water down into hydrogen gas and oxygen gas.

Figure 7 Electrolysis of water produces hydrogen gas that can be used for hydrogen fuel cells.

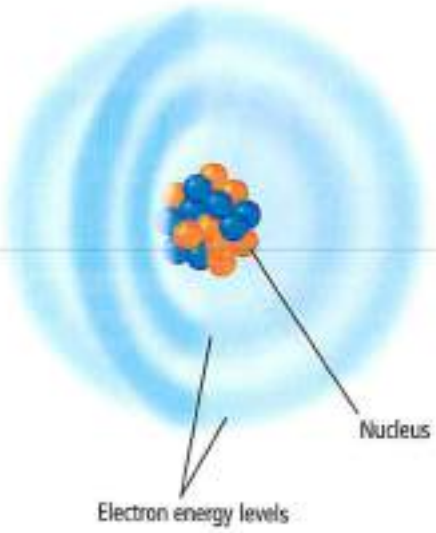


Figure 8 Electrons are moving constantly within the energy levels surrounding the nucleus.

Chemical Bonds

Compounds such as water, salt, and methane are formed when two or more substances combine. The force that holds the substances together is called a chemical bond. Think back to the protons, neutrons, and electrons that make up an atom. The nucleus determines the chemical identity of an atom, and the electrons are involved directly in forming chemical bonds. Electrons travel around the nucleus of an atom in areas called energy levels, as illustrated in **Figure 8.** Each energy level has a specific number of electrons that it can hold at any time. The first energy level, which is the level closest to the nucleus, can hold up to two electrons. The second can hold up to eight electrons.

A partially filled energy level is not as stable as an energy level that is empty or completely filled. Atoms become more stable by losing electrons or attracting electrons from other atoms. This results in the formation of chemical bonds between atoms. It is the forming of chemical bonds that stores energy and the breaking of chemical bonds that provides energy for processes of growth, development, adaptation, and reproduction in living things. There are two main types of chemical bonds–covalent bonds and ionic bonds.

Covalent bonds When you were younger, you probably learned to share. If you had a book that your friend wanted to read as well, you could enjoy the story together. In this way, you both benefited from the book. Similarly, one type of chemical bond forms when atoms share electrons in their outer energy levels.

The chemical bond that forms when electrons are shared is called a **covalent bond.** **Figure 9** illustrates the covalent bonds between oxygen and hydrogen that form water. Each hydrogen (H) atom has one electron in its outermost energy level, and oxygen (O) has six. Because the outermost energy level of oxygen is the second level, which can hold up to eight electrons, oxygen has a strong tendency to fill the energy level by sharing the electrons from the two nearby hydrogen atoms. Hydrogen does not completely give up the electrons; it also has a strong tendency to share electrons with oxygen to fill its outermost energy level. Two covalent bonds form, which creates water.

Most compounds in living organisms have covalent bonds holding them together. Water and other substances with covalent bonds are called molecules. A **molecule** is a compound in which the atoms are held together by covalent bonds. Depending on the number of pairs of electrons that are shared, covalent bonds can be single, double, or triple, as shown in **Figure 10.**

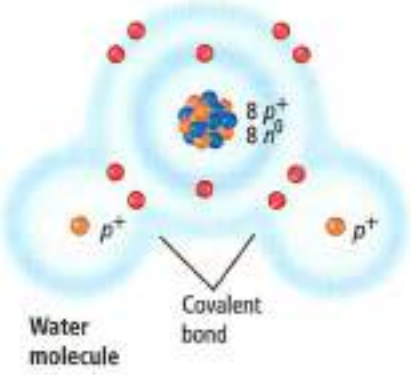


Figure 9 In water (H_2O), two hydrogen atoms each share one electron with one oxygen atom. Because the oxygen atom needs two electrons to fill its outer energy level, it forms two covalent bonds, one with each hydrogen atom.

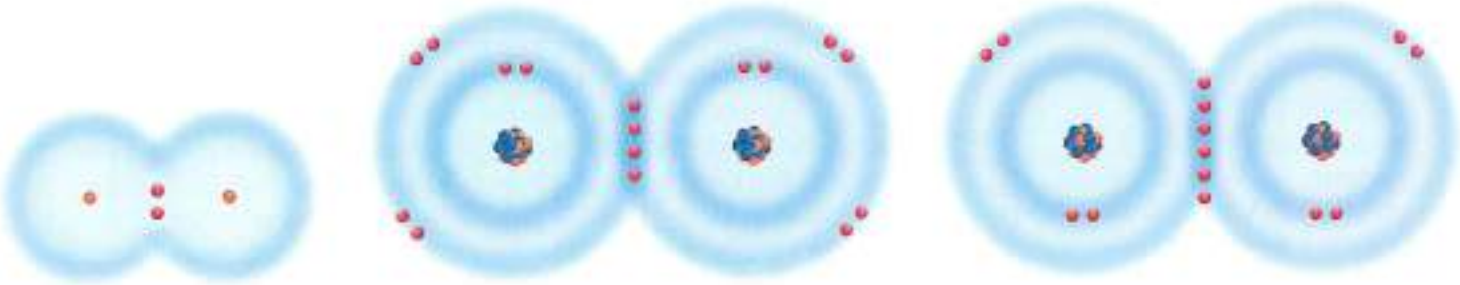


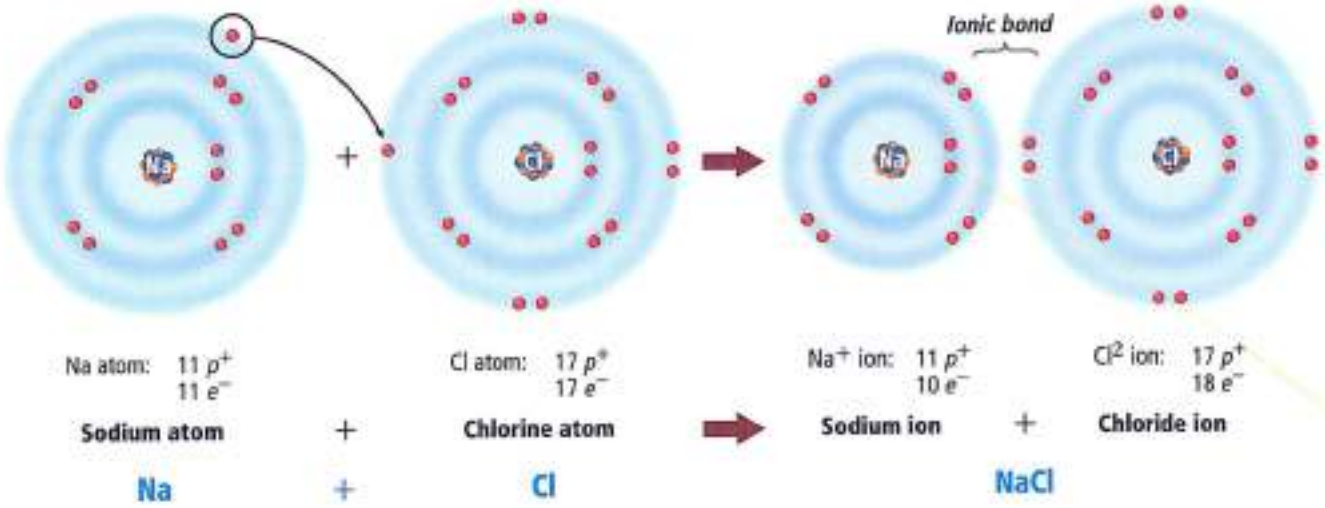
Figure 10 A single bond has one pair of shared electrons, a double bond has two pairs, and a triple bond has three pairs.

Ionic bonds Recall that atoms are neutral; they do not have an electric charge. Also recall that for an atom to be most stable, the outermost energy level should be either empty or completely filled. Some atoms tend to give up (donate) or obtain (accept) electrons to empty or fill the outer energy level to be stable. An atom that has lost or gained one or more electrons becomes an **ion** and carries an electric charge. For example, sodium has one electron in its outermost energy level. Sodium can become more stable if it gives up this one electron, leaving its outer energy level empty. When it gives away this one negative charge, the neutral sodium atom becomes a positively charged sodium ion (Na^+). Similarly, chlorine has seven electrons in its outer energy level and needs just one electron to fill it. When chlorine accepts an electron from a donor atom, such as sodium, chlorine becomes a negatively charged ion (Cl^-).

An **ionic bond** is an electrical attraction between two oppositely charged atoms or groups of atoms called ions. **Figure 11** shows how an ionic bond forms as a result of the electrical attraction between Na^+ and Cl^- to produce NaCl (sodium chloride). Substances formed by ionic bonds are called ionic compounds.

Ions in living things include sodium, potassium, calcium, chloride, and carbonate ions. They help maintain homeostasis as they travel in and out of cells. In addition, ions help transmit signals among cells that allow you to see, taste, hear, feel, and smell.

Figure 11 To form ions, sodium donates an electron and chlorine gains an electron. An ionic bond forms when the oppositely charged ions come close together.



VOCABULARY

WORD ORIGIN

Atom
comes from the Greek word *atomos*, meaning *not divisible*

Some atoms tend to donate or accept electrons more easily than other atoms do. Look at the periodic table of elements inside the back cover of this textbook. The elements identified as metals tend to donate electrons, and the elements identified as nonmetals tend to accept electrons. The resulting ionic compounds have some unique characteristics. For example, most dissolve in water. When dissolved in solution, ionic compounds break down into ions and these ions can carry an electric current. Most ionic compounds, such as sodium chloride (table salt), are crystalline at room temperature. Ionic compounds generally have higher melting points than do molecular compounds formed by covalent bonds.

Connection to Earth Science Although most ionic compounds are solid at room temperature, other ionic compounds are liquid at room temperature. Like their solid counterparts, ionic liquids are made up of positively and negatively charged ions. Ionic liquids have important potential in real-world applications as safe and environmentally friendly solvents that can possibly replace other harmful solvents. The key characteristic of ionic liquid solvents is that they typically do not evaporate and release chemicals into the atmosphere. Most ionic liquids are safe to handle and store, and they can be recycled after use. For these reasons, ionic liquids are attractive to industries that are dedicated to environmental responsibility.

Reading Check **Compare** ionic solids and liquids.

Mini Lab 1

Test for Simple Sugars

What common foods contain glucose? Glucose is a simple sugar that provides energy for cells. In this lab, you will use a reagent called Benedict's solution, which indicates the presence of –CHO (carbon, hydrogen, oxygen) groups. A color change determines the presence of glucose and other simple sugars in common foods.

Procedure

1. Identify the safety concerns of this lab before work begins.
2. Create a data table with columns labeled *Food Substance*, *Sugar Prediction*, *Observations*, and *Results*.
3. Choose four **food substances** from those provided by your teacher. Read the food labels and predict the presence of simple sugar in each food. Record your prediction.
4. Prepare a **hot water bath** with a temperature between 40°–50°C using a **hot plate** and **1000-mL beaker.**
5. Label four **test tubes.** Obtain a **graduated cylinder.** Add 10 mL of a different food substance to each test tube. Then add 10 mL of **distilled water.** Swirl gently to mix.
6. Add 5 mL of **Benedict's solution** to each tube. Use a clean **stirring rod** to mix the contents.
7. Using **test-tube holders,** warm the test tubes in the hot water bath for 2–3 min. Record your observations and results.

Analysis

1. **Interpret Data** Did any of the foods contain simple sugars? Explain.
2. **Think Critically** Could a food labeled "sugar-free" test positive using Benedict's solution as an indicator? Explain.

van der Waals Forces

You have learned that positive ions and negative ions form based on the ability of an atom to attract electrons. If the nucleus of the atom has a weak attraction for the electron, it will donate the electron to an atom with a stronger attraction. Similarly, elements in a covalent bond do not always attract electrons equally. Recall also that the electrons in a molecule are in random motion around the nuclei. This movement of electrons can cause an unequal distribution of the electron cloud around the molecule, creating temporary areas of slightly positive and negative charges.

When molecules come close together, the attractive forces between these positive and negative regions pull on the molecules and hold them together. These attractions between the molecules are called **van der Waals forces,** named for Dutch physicist Johannes van der Waals, who first described the phenomenon. The strength of the attraction depends on the size of the molecule, its shape, and its ability to attract electrons. Although van der Waals forces are not as strong as covalent and ionic bonds, they play a key role in biological processes.

Scientists have determined that geckos can climb smooth surfaces because of van der Waals forces between the atoms in the hairlike structures on their toes, shown in **Figure 12,** and the atoms on the surface they are climbing.

van der Waals forces in water Consider how van der Waals forces work in a common substance–water. The areas of slight positive and negative charges around the water molecule are attracted to the opposite charge of other nearby water molecules. These forces hold the water molecules together. Without van der Waals forces, water molecules would not form droplets, and droplets would not form a surface of water. It is important to understand that van der Waals forces are the attractive forces between the water molecules, not the forces between the atoms that make up water.

SEM Magnification: 240 ×

Figure 12 Geckos have millions of microscopic hairs on the bottoms of their feet that are about as long as two widths of a human hair. Each spreads into 1000 smaller pads.

Section 1 Assessment

Section Summary

- Elements are pure substances made up of only one kind of atom.
- Isotopes are forms of the same element that have a different number of neutrons.
- Compounds are substances with unique properties that are formed when elements combine.
- Elements can form covalent and ionic bonds.

Understand Main Ideas

1. MAIN Idea **Diagram** Sodium has 11 protons and 11 neutrons in its nucleus. Draw a sodium atom. Be sure to label the particles.
2. **Explain** why carbon monoxide (CO) is or is not an atom.
3. **Explain** Are all compounds molecules? Why or why not?
4. **Compare** van der Waals forces, ionic bonds, and covalent bonds.

Think Critically

5. **Explain** how the number of electrons in an energy level affects bond formation.

MATH in Biology

6. Beryllium has four protons in its nucleus. How many neutrons are in beryllium-9? Explain how you calculated your answer.

Section 2

Reading Preview

Essential Questions

- What are the parts of a chemical reaction?
- How can energy changes be related to chemical reactions?
- What is the importance of enzymes in living organisms?

Review Vocabulary

process: a series of steps or actions that produce an end product

New Vocabulary

chemical reaction
reactant
product
activation energy
catalyst
enzyme
substrate
active site

Chemical Reactions

MAIN Idea **Chemical reactions allow living things to grow, develop, reproduce, and adapt.**

Real-World Reading Link When you lie down for the night, you might think that your body is completely at rest. In fact, you are still digesting the food that you ate that day, the scrape on your elbow is healing, and your muscles and bones are growing and developing. All the things that happen inside your body are the result of chemical reactions.

Reactants and Products

A new car with shining chrome and a clean appearance is appealing to many drivers. Over time, however, the car might get rusty and lose some of its appeal. Rust is a result of a chemical change called a chemical reaction. A **chemical reaction** is the process by which atoms or groups of atoms in substances are reorganized into different substances. Chemical bonds are broken and formed during chemical reactions. The rust on the chain in **Figure 13** is a compound called iron oxide (Fe_2O_3), and it was formed when oxygen (O_2) in the air reacted with iron (Fe).

It is important to know that substances can undergo changes that do not involve chemical reactions. For example, consider the water in **Figure 13.** The water is undergoing a physical change. A physical change alters a substance's appearance but not its composition. The water is water before and after the change.

How do you know when a chemical reaction has taken place? Although you might not be aware of all the reactions taking place inside your body, you know that the surface of the chain in **Figure 13** has changed. What was once silver and shiny is now dull and orange-brown. Other clues that a chemical reaction has taken place include the production of heat or light, and the formation of a new gas, liquid, or solid.

Figure 13 After a chemical change, such as rusting, a new substance is formed. During a physical change, such as ice melting or water boiling, the chemical makeup of the water is not altered.

Chemical change

Physical change

Chemical equations When scientists write chemical reactions, they express each component of the reaction in a chemical equation. In written chemical equations, chemical formulas describe the substances in the reaction with arrows indicating the process of change.

Reactants and products A chemical equation shows the **reactants,** the starting substances, on the left side of the arrow. The **products,** the substances formed during the reaction, are on the right side of the arrow. The arrow can be read as "yields" or "react to form."

Reactants ⟶ Products

The following chemical equation can be written to describe the reaction that provides energy to the volleyball players in **Figure 14.**

$$C_6H_{12}O_6 + O_2 \longrightarrow CO_2 + H_2O$$

Glucose and oxygen react to form carbon dioxide and water.

Balanced equations In chemical reactions, matter cannot be created or destroyed. This principle is called the law of conservation of mass. Accordingly, all chemical equations must show this balance of mass. This means that the number of atoms of each element on the reactant side must equal the number of atoms of the same element on the product side. Coefficients are used to make the number of atoms on each side of the arrow equal.

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O$$

Multiply the coefficient by the subscript for each element. You can see in this example that there are six carbon atoms, twelve hydrogen atoms, and eighteen oxygen atoms on each side of the arrow. The equation confirms that the number of atoms on each side is equal, and therefore the equation is balanced.

Reading Check Explain why chemical equations must be balanced.

Energy of Reactions

Connection to Physics A sugar cookie is made with flour, sugar, and other ingredients mixed together, but it is not a cookie until it is baked. Something must start the change from dough to cookie. The key to starting a chemical reaction is energy. For the chemical reactions that transform the dough to a cookie, energy in the form of heat is needed. Similarly, most compounds in living things cannot undergo chemical reactions without energy.

Figure 14 The process that provides your body with energy involves the reaction of glucose with oxygen to form carbon dioxide and water.

VOCABULARY

ACADEMIC VOCABULARY

Coefficient
in a chemical equation, the number written in front of a reactant or a product
The number 6 in $6Fe_2O_3$ is a coefficient.

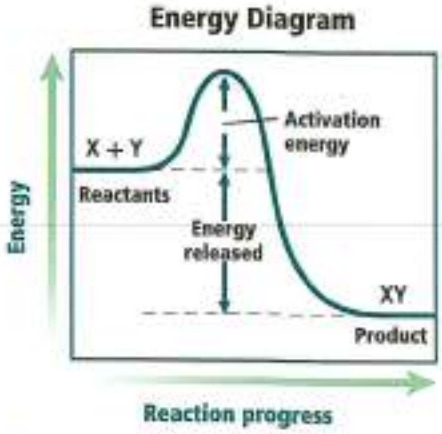
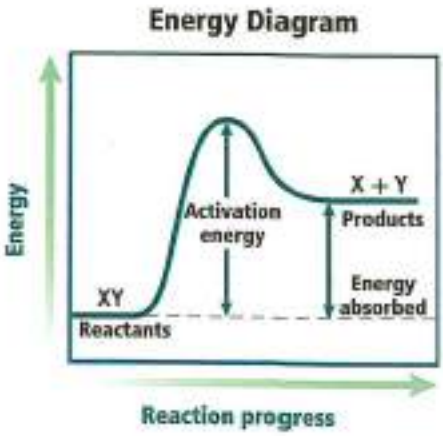


Figure 15 The flame of the match provides activation energy—the amount of energy needed to begin a reaction. The reaction gives off energy in the form of heat and light.

Activation energy The minimum amount of energy needed for reactants to form products in a chemical reaction is called the **activation energy.** For example, you know that a candle will not burn until you light its wick. The flame provides the activation energy for the reaction of the substances in the candle wick with oxygen. In this case, once the reaction begins, no further input of energy is needed and the candle continues to burn on its own. **Figure 15** shows that for the reactants X and Y to form product XY, energy is required to start the reaction. The peak in the graph represents the amount of energy that must be added to the system to make the reaction occur. Some reactions rarely happen because they have a very high activation energy.

Energy change in chemical reactions Compare how energy changes during the reaction in **Figure 15** to how energy changes during the reaction in **Figure 16.** Both reactions require activation energy to get started. However, the reaction in **Figure 15** has lower energy in the product than in the reactants. This reaction is exothermic–it released energy in the form of heat. The reaction in **Figure 16** is endothermic–it absorbed heat energy. The energy of the products is higher than the energy of the reactants. In every chemical reaction, there is a change in energy caused by the making and breaking of chemical bonds as reactants form products. Exothermic reactions keep your internal body temperature at about 37°C.

Figure 16 In an endothermic reaction, the energy of the products is higher than the energy of the reactant.



Enzymes

All living things are chemical factories driven by chemical reactions. However, these chemical reactions proceed very slowly when carried out in the laboratory because the activation energy is high. To be useful to living organisms, additional substances must be present where the chemical reactions occur to reduce the activation energy and allow the reaction to proceed quickly.

A **catalyst** is a substance that lowers the activation energy needed to start a chemical reaction. Although a catalyst is important in speeding up a chemical reaction, it does not increase how much product is made and it does not get used up in the reaction. Scientists use many types of catalysts to make reactions occur thousands of times faster than the reaction would be able to occur without the catalyst.

Special proteins called **enzymes** are the biological catalysts that speed up the rate of chemical reactions in biological processes. Enzymes are essential to life. Compare the progress of the reaction described in **Figure 17** to see the effect of an enzyme on a chemical reaction. Like all catalysts, the enzyme is not used up by the chemical reaction. Once it has participated in a chemical reaction, it can be used again.

An enzyme's name describes what it does. For example, amylase is an important enzyme found in saliva. Digestion of food begins in the mouth when amylase speeds the breakdown of amylose, one of the components of starch. Like amylase, most enzymes are specific to one reaction.

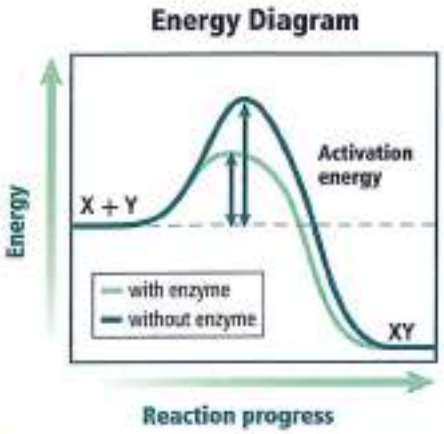


Figure 17 When an enzyme acts as a biological catalyst, the reaction occurs at a rate that is useful to cells.

Compare *the activation energy of the reaction without an enzyme to the activation energy of the reaction with an enzyme.*

MiniLab 2

Investigate Enzymatic Browning

What factors affect enzymatic browning? When sliced, an apple's soft tissue is exposed to oxygen, causing a chemical reaction called oxidation. Enzymes in the apple speed this reaction, producing darkened, discolored fruit. In this lab, you will investigate methods used to slow enzymatic browning.

Procedure

1. Identify the safety concerns of this lab before work begins.
2. Predict the relative amount of discoloration that each of the following apple wedges will show when exposed to air. Justify your predictions.
   Sample 1: Untreated apple wedge
   Sample 2: Apple wedge submerged in boiling water
   Sample 3: Apple wedge submerged in lemon juice
   Sample 4: Apple wedge submerged in sugar solution
3. Prepare 75 mL of each of the following: **boiling water, lemon juice,** and **sugar solution** in three **250-mL beakers.**
4. Slice an **apple** into four wedges. Immediately use **tongs** to submerge each wedge in a different liquid. Put one wedge aside.
5. Submerge the wedges for three minutes, then place them on a **paper towel,** skin-side down. Observe for 10 min, and then record the relative amount of discoloration of each apple wedge.

Analysis

1. **Analyze** how each treatment affected the chemical reaction that occurred on the fruit's soft tissue. Why were some of the treatments successful?
2. **Think critically** about what factors a restaurant owner who wants to serve fresh-cut fruit might consider when choosing a recipe and preparation method.

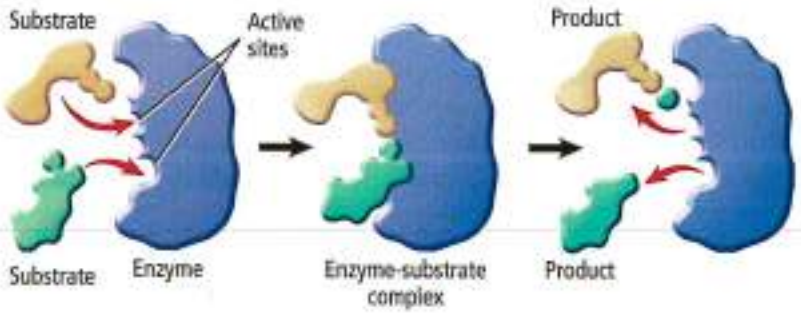


Figure 18 Substrates interact with enzymes at specific places called active sites. Only substrates with a specific shape can bind to the active site of an enzyme.

FOLDABLES
Incorporate information from this section into your Foldable.

Follow **Figure 18** to learn how an enzyme works. The reactants that bind to the enzyme are called **substrates.** The specific location where a substrate binds on an enzyme is called the **active site.** The active site and the substrate have complementary shapes. This enables them to interact in a precise manner, similar to the way in which puzzle pieces fit together. As shown in **Figure 18,** only substrates with the same size and shape as the active site will bind to the enzyme.

Once the substrates bind to the active site, the active site changes shape and forms the enzyme-substrate complex. The enzyme-substrate complex helps chemical bonds in the reactants to be broken and new bonds to form—the substrates react to form products. The enzyme then releases the products.

Factors such as pH, temperature, and other substances affect enzyme activity. For example, most enzymes in human cells are most active at an optimal temperature close to 37°C. However, enzymes in other organisms, such as bacteria, can be active at other temperatures.

Enzymes affect many biological processes. When a person is bitten by a venomous snake, enzymes in the venom break down the membranes of that person's red blood cells. Hard green apples ripen because of the action of enzymes. Photosynthesis and cellular respiration provide energy for the cell with the help of enzymes. Just as worker bees are important for the survival of a beehive, enzymes are the chemical workers in cells.

Section 2 Assessment

Section Summary

- Balanced chemical equations must show an equal number of atoms for each element on both sides.
- Activation energy is the energy required to begin a reaction.
- Catalysts are substances that alter chemical reactions.
- Enzymes are biological catalysts.

Understand Main Ideas

1. MAIN Idea **Identify** the parts of this chemical reaction: A+B → AB.
2. **Diagram** the energy changes that can take place in a chemical reaction.
3. **Explain** why the number of atoms of reactants must equal the number of atoms of products formed.
4. **Describe** the importance of enzymes to living organisms.

Think Critically

MATH in Biology

5. For the following chemical reaction, label the reactants and products, and then balance the chemical equation. ___H_2O_2 → ___H_2O + ___O_2

WRITING in Biology

6. Draw a diagram of a roller coaster and write a paragraph relating the ride to activation energy and a chemical reaction.

Section 3

Reading Preview

Essential Questions

- How does the structure of water make it a good solvent?
- What are the similarities and differences between solutions and suspensions?
- What are the differences between acids and bases?

Review Vocabulary

physical property: characteristic of matter, such as color or melting point, that can be observed or measured without changing the composition of the substance

New Vocabulary

polar molecule
hydrogen bond
mixture
solution
solvent
solute
acid
base
pH
buffer

Water and Solutions

MAIN Idea **The properties of water make it well suited to help maintain homeostasis in an organism.**

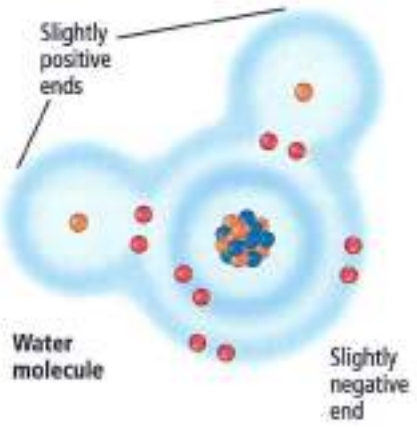
Real-World Reading Link You probably know that the main color on a globe is blue. That's because water covers about 70 percent of Earth's surface, giving it the blue color you see from a distance. Now imagine zooming in to a single cell of an organism on Earth. Water accounts for approximately 70 percent of that cell's mass. It is one of the most important molecules for life.

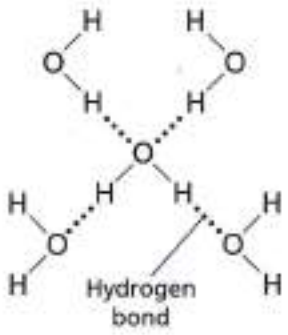
Water's Polarity

Earlier in this chapter, you discovered that water molecules are formed by covalent bonds that link two hydrogen (H) atoms to one oxygen (O) atom. Because electrons are more strongly attracted to the oxygen atom's nucleus, the electrons in the covalent bond with hydrogen are not shared equally. In water, the electrons spend more time near the oxygen atom's nucleus than they do near the hydrogen atoms' nuclei. **Figure 19** shows that there is an unequal distribution of electrons in a water molecule. This, along with the bent shape of water molecules, results in the oxygen end of the molecule having a slightly negative charge and the hydrogen ends of the molecule having a slightly positive charge. Molecules that have an unequal distribution of charges are called **polar molecules,** meaning that they have oppositely charged regions.

Polarity is the property of having two opposite poles, or ends. A magnet has polarity—there is a north pole and a south pole. When the two ends are brought close to each other, they attract each other. Similarly, when a charged region of a polar molecule comes close to the oppositely charged region of another polar molecule, a weak electrostatic attraction results. In water, the electrostatic attraction is called a hydrogen bond. A **hydrogen bond** is a weak interaction involving a hydrogen atom and a fluorine, oxygen, or nitrogen atom. Hydrogen bonding is a strong type of van der Waals force. **Figure 20** describes polarity and the other unique properties of water that make it important to living things.

Figure 19 Because water molecules have a bent shape and electrons are not shared equally between hydrogen and oxygen, hydrogen bonds form among the molecules. Due to the attraction among the atoms that make up water, the surface of water supports a water strider.



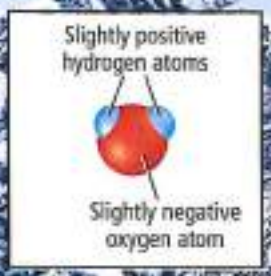


Water strider

Visualizing Properties of Water

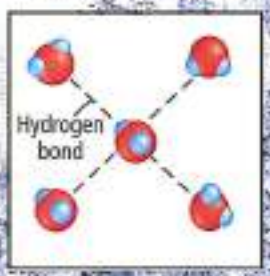
Figure 20
Water is vital to life on Earth. Its properties allow it to provide environments suitable for life and to help organisms maintain homeostasis. Humans can survive many days without food but only a few days without water.

Water Molecule

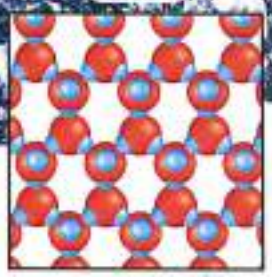


- A water molecule is made up of one oxygen atom and two hydrogen atoms.
- A water molecule is polar. Its bent shape results in a slightly positive charge on the hydrogen atoms and a slightly negative charge on the oxygen atom. As a result, it forms hydrogen bonds.
- Water is called the universal solvent because many substances dissolve in it.

Hydrogen Bonding

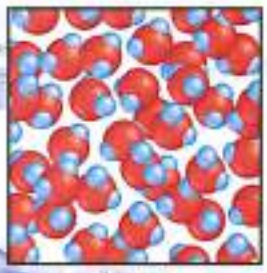


Solid



Liquid water becomes more dense as it cools to 4°C. Yet, ice is less dense than liquid water. As a result, nutrients in bodies of water mix because of changes in water density during spring and fall. Also, fish can survive in winter because ice floats—they continue to live and function in the water beneath the ice.

Liquid



Water is adhesive—it forms hydrogen bonds with molecules on other surfaces. Capillary action is the result of adhesion. Water travels up the stem of a plant, and seeds swell and germinate by capillary action.

Water is cohesive—the molecules are attracted to each other because of hydrogen bonds. This attraction creates surface tension, which causes water to form droplets and allows insects and leaves to rest on the surface of a body of water.

Mixtures with Water

You are probably familiar with powdered drink products that dissolve in water to form a flavored beverage. When you add a powdered substance to water, it does not react with water to form a new product. You create a mixture. A **mixture** is a combination of two or more substances in which each substance retains its individual characteristics and properties.

Homogeneous mixtures When a mixture has a uniform composition throughout, it is called a homogeneous (hoh muh JEE nee us) mixture. A **solution** is another name for a homogeneous mixture. For example, in the powdered drink mix solution shown in **Figure 21,** the drink mix is on top, in the middle, and at the bottom of the container. The water retains its properties and the drink mix retains its properties.

In a solution, there are two components: a solvent and a solute. A **solvent** is a substance in which another substance is dissolved. A **solute** is the substance that is dissolved in the solvent. In the case of the drink mix, water is the solvent and the powdered substance is the solute. A mixture of salt and water is another example of a solution because the solute (salt) dissolves completely in the solvent (water). Saliva moistens your mouth and begins the digestion of some of your food. Saliva is a solution that contains water, proteins, and salts. In addition, the air you breathe is a solution of gases.

Heterogeneous mixtures Think about the last time you ate a salad. Perhaps it contained lettuce and other vegetables, croutons, and salad dressing. Your salad was a heterogeneous mixture. In a heterogeneous mixture, the components remain distinct, that is, you can tell what they are individually. Compare the mixture of sand and water to the solution of salt and water next to it in **Figure 22.** Sand and water form a type of heterogeneous mixture called a suspension. Over time, the particles in a suspension settle to the bottom.

A colloid is a heterogeneous mixture in which the particles do not settle out like the sand settled from the water. You are probably familiar with many colloids, including fog, smoke, butter, mayonnaise, milk, paint, and ink. Blood is a colloid made up of plasma, cells, and other substances.

Reading Check **Distinguish** between solutions and suspensions.

Figure 21 The drink mix forms a homogeneous mixture in water. The particles of the solute (drink mix) are dissolved and spread throughout the solvent (water).

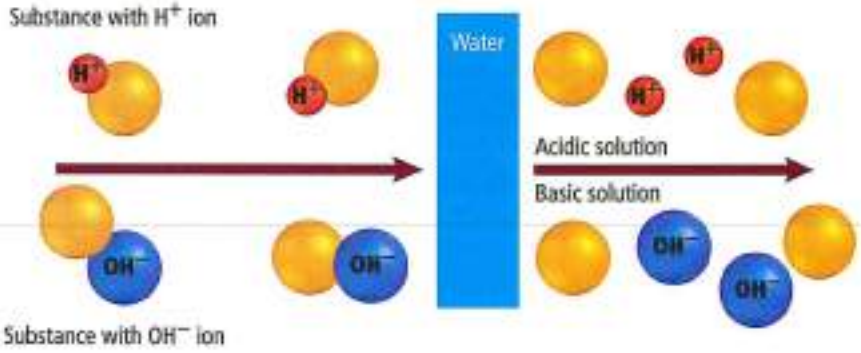
VOCABULARY

ACADEMIC VOCABULARY

Suspend
to keep from falling or sinking
A slender thread suspended the spider from the web.

Figure 22
Left: Sand and water form a heterogeneous mixture; you can see both the liquid and the solid. The homogeneous mixture of salt and water is a liquid; you cannot see the salt.
Right: Blood is a heterogeneous mixture called a colloid.

Figure 23 Substances that release H^+ in water are acids. Substances that release OH^- in water are bases.



Acids and bases Many solutes readily dissolve in water because of water's polarity. This means that an organism, which might be as much as 70 percent water, can be a container for a variety of solutions. When a substance that contains hydrogen is dissolved in water, the substance might release a hydrogen ion (H^+) because it is attracted to the negatively charged oxygen atoms in water, as shown in **Figure 23.** Substances that release hydrogen ions when they are dissolved in water are called **acids.** The more hydrogen ions a substance releases, the more acidic the solution becomes.

Similarly, substances that release hydroxide ions (OH^-) when they are dissolved in water are called **bases.** Sodium hydroxide (NaOH) is a common base that breaks apart in water to release sodium ions (Na^+) and hydroxide ions (OH^-). The more hydroxide ions a substance releases, the more basic the solution becomes.

Acids and bases are key substances in biology. Many of the foods and beverages that we eat and drink are acidic, and the substances in the stomach that break down the food, called gastric juices, are highly acidic.

DATA ANALYSIS LAB 1

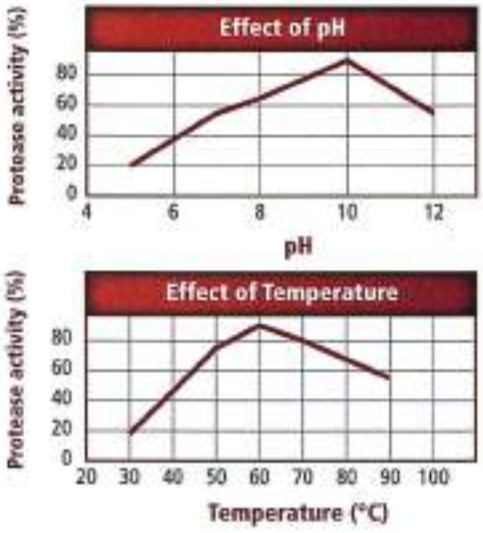
Based on Real Data*

Recognize Cause and Effect

How do pH and temperature affect protease activity? Proteases are enzymes that break down protein. Bacterial proteases often are used in detergents to help remove stains such as egg, grass, blood, and sweat from clothes.

Data and Observations

A protease from a newly isolated strain of bacteria was studied over a range of pH values and temperatures.



Think Critically

1. **Identify** the range of pH values and temperatures used in the experiment.
2. **Summarize** the results of the two graphs.
3. **Infer** If a laundry detergent is basic and requires hot water to be most effective, would this protease be useful? Explain.

*Data obtained from: Adinarayana, et al. 2003. Purification and partial characterization of thermostable serine alkaline protease from a newly isolated *Bacillus subtilis* PE-11. *AAPS PharmSciTech 4: article 56.*

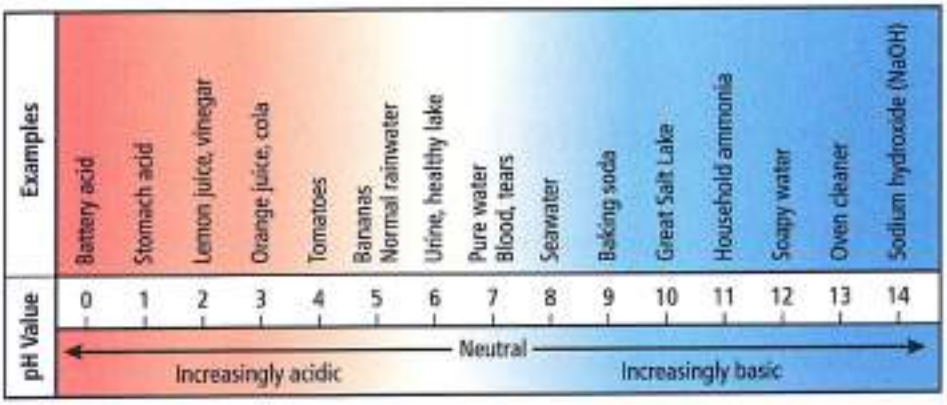


Figure 24 The pH scale is used to indicate the relative strength of acids and bases—in other words, the amount of hydrogen ions (H^+) in a solution.

pH and buffers The amount of hydrogen ions or hydroxide ions in a solution determines the strength of an acid or base. Scientists have devised a convenient way to measure how acidic or basic a solution is. The measure of concentration of H^+ in a solution is called **pH**. As shown in **Figure 24,** pure water is neutral and has a pH value of 7.0. Acidic solutions have an abundance of H^+ and have pH values lower than 7. Basic solutions have more OH^- than H^+ and have pH values higher than 7.

Connection Health The majority of biological processes carried out by cells occur between pH 6.5 and 7.5. In order to maintain homeostasis, it is important to control H^+ levels. If you've ever had an upset stomach, you might have taken an antacid to feel better. The antacid tablet is a buffer to help neutralize the stomach acid. **Buffers** are mixtures that can react with acids or bases to keep the pH within a particular range. In cells, buffers keep the pH in a cell within the 6.5 to 7.5 pH range. Your blood, for example, contains buffers that keep the pH about 7.4.

CAREERS IN BIOLOGY

Pool Technician Every recreational body of water, such as a recreational swimming pool, training spa, or medical therapy pool, must meet strict requirements for water quality. Pool technicians make sure these requirements are met by monitoring water pH, bacteria and algae levels, and water clarity.

Section 3 Assessment

Section Summary

- Water is a polar molecule.
- Solutions are homogeneous mixtures formed when a solute is dissolved in a solvent.
- Acids are substances that release hydrogen ions into solutions. Bases are substances that release hydroxide ions into solutions.
- pH is a measure of the concentration of hydrogen ions in a solution.

Understand Main Ideas

1. MAIN Idea **Describe** one way in which water helps maintain homeostasis in an organism.
2. **Relate** the structure of water to its ability to act as a solvent.
3. **Draw** a pH scale and label water (H_2O), hydrochloric acid (HCl), and sodium hydroxide (NaOH) in their general areas on the scale.
4. **Compare and contrast** solutions and suspensions. Give examples of each.

Think Critically

5. **Explain** how baking soda ($NaHCO_3$) is basic. Describe the effect of baking soda on the H^+ ion concentration of stomach contents with pH 4.
6. **Predict** If you add hydrochloric acid (HCl) to water, what effect would this have on the H^+ ion concentration? On the pH?

Section 4

Reading Preview

Essential Questions

- What is the role of carbon in living organisms?
- What are the four major families of biological macromolecules?
- What are the functions of each group of biological macromolecules?

Review Vocabulary

organic compound: a carbon-based substance that is the basis of living matter

New Vocabulary

macromolecule
polymer
carbohydrate
lipid
protein
amino acid
nucleic acid
nucleotide

The Building Blocks of Life

MAIN Idea **Organisms are made up of carbon-based molecules.**

Real-World Reading Link Children enjoy toy trains because they can link long lines of cars together and make patterns by joining cars of similar color or function. Similarly, in biology, there are large molecules made of many smaller units joined together.

Organic Chemistry

The element carbon is a component of almost all biological molecules. For this reason, life on Earth often is considered carbon-based. Because carbon is an essential element, scientists have devoted an entire branch of chemistry, called organic chemistry, to the study of organic compounds, which are those compounds containing carbon.

As shown in **Figure 25,** carbon has four electrons in its outermost energy level. Recall that the second energy level can hold eight electrons, so one carbon atom can form four covalent bonds with other atoms. These covalent bonds enable the carbon atoms to bond to each other, which results in a variety of important organic compounds. These compounds can be in the shape of straight chains, branched chains, and rings, such as those illustrated in **Figure 25.** Together, carbon compounds lead to the diversity of life on Earth.

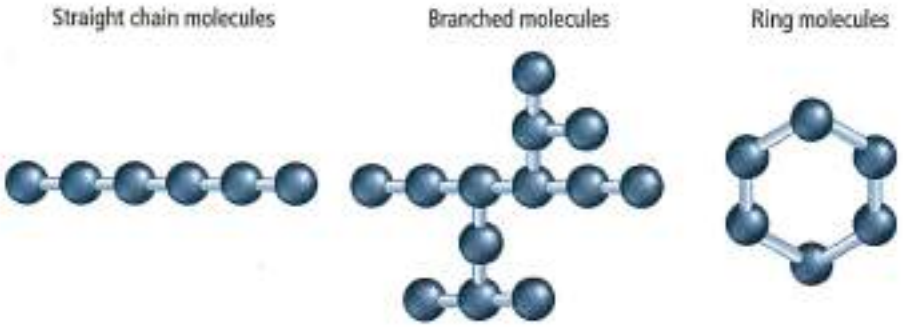
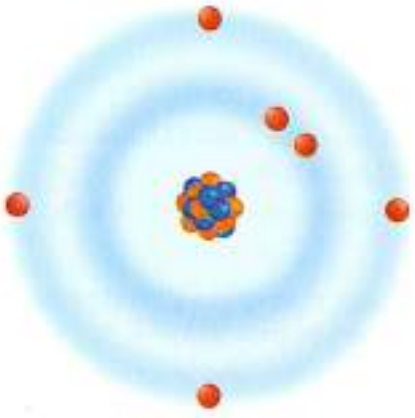


Figure 25 The amazing diversity of life is based on the variety of carbon compounds. The half-filled outer energy level of carbon allows for the formation of straight chain, branched, and ring molecules.



Carbon

Macromolecules

Carbon atoms can be joined to form carbon molecules. Similarly, most cells store small carbon compounds that serve as building blocks for large molecules. **Macromolecules** are large molecules that are formed by joining smaller organic molecules together. These large molecules are also called polymers. **Polymers** are molecules made from repeating units of identical or nearly identical compounds called monomers that are linked together by a series of covalent bonds. As shown in **Table 1,** biological macromolecules are organized into four major categories: carbohydrates, lipids, proteins, and nucleic acids.

Reading Check **Use an analogy** to describe macromolecules.

VOCABULARY

WORD ORIGIN

Polymer

poly- prefix; from Greek, meaning *many*

-meros from Greek, meaning *part*

Table 1 **Biological Macromolecules**

Group	Example	Function
Carbohydrates	 **Bread and grains**	• Store energy • Provide structural support
Lipids	 **Bees' wax**	• Store energy • Provide barriers
Proteins	 **Hemoglobin**	• Transport substances • Speed reactions • Provide structural support • Make hormones
Nucleic acids	 **DNA**	• Store and communicate genetic information

Study Tip

Double-Entry Notes Fold a piece of paper in half lengthwise and write the boldfaced subheadings that appear under the *Biological Macromolecules* heading on the left side. As you read the text, make a bulleted list of notes about the important ideas and terms.

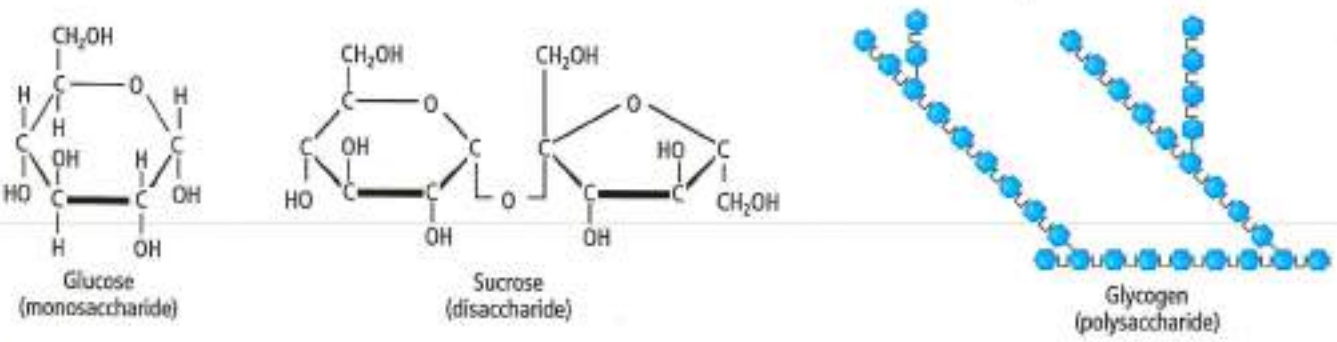


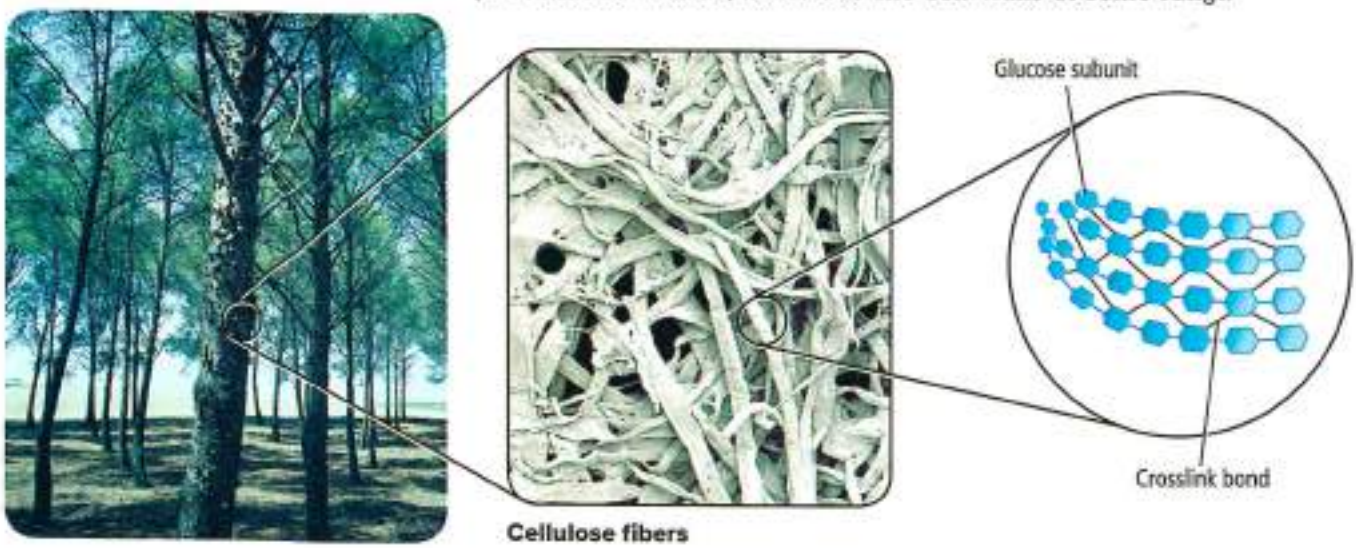
Figure 26 Glucose is a monosaccharide. Sucrose is a disaccharide composed of glucose and fructose monosaccharides. Glycogen is a branched polysaccharide made from glucose monomers.

Carbohydrates Compounds composed of carbon, hydrogen, and oxygen in a ratio of one oxygen and two hydrogen atoms for each carbon atom are called **carbohydrates**. A general formula for carbohydrates is written as $(CH_2O)_n$. Here the subscript n indicates the number of CH_2O units in a chain. Biologically important carbohydrates that have values of n ranging from three to seven are called simple sugars, or monosaccharides (mah nuh SA kuh ridz). The monosaccharide glucose, shown in **Figure 26,** plays a central role as an energy source for organisms.

Monosaccharides can be linked to form larger molecules. Two monosaccharides joined together form a disaccharide (di SA kuh rid). Like glucose, disaccharides serve as energy sources. Sucrose, also shown in **Figure 26,** which is table sugar, and lactose, which is a component of milk, are both disaccharides. Longer carbohydrate molecules are called polysaccharides. One important polysaccharide is glycogen, which is shown in **Figure 26.** Glycogen is an energy storage form of glucose that is found in the liver and skeletal muscle. When the body needs energy between meals or during physical activity, glycogen is broken down into glucose.

In addition to their roles as energy sources, carbohydrates have other important functions in biology. In plants, a carbohydrate called cellulose provides structural support in cell walls. As shown in **Figure 27,** cellulose is made of chains of glucose linked together into tough fibers that are well suited for their structural role. Chitin (KI tun) is a nitrogen-containing polysaccharide that is the main component in the hard outer shells of shrimp, lobsters, and some insects, as well as the cell walls of some fungi.

Figure 27 The cellulose in plant cells provides the structural support for trees to stand in a forest.



Lipids Another important group of biological macromolecules is the lipid group. **Lipids** are molecules made mostly of carbon and hydrogen that make up the fats, oils, and waxes. Lipids are composed of fatty acids, glycerol, and other components. The primary function of lipids is to store energy. A lipid called a triglyceride (tri GLIH suh rid) is a fat if it is solid at room temperature and an oil if it is liquid at room temperature. In addition, triglycerides are stored in the fat cells of the body. Plant leaves are coated with lipids called waxes to prevent water loss, and the honeycomb in a beehive is made of beeswax.

Saturated and unsaturated fats Organisms need lipids to function properly. The basic structure of a lipid includes fatty acid tails, as shown in **Figure 28.** Each tail is a chain of carbon atoms bonded to hydrogen and other carbon atoms by single or double bonds. Lipids that have tail chains with only single bonds between the carbon atoms are called saturated fats because no more hydrogens can bond to the tail. Lipids that have at least one double bond between carbon atoms in the tail chain can accommodate at least one more hydrogen and are called unsaturated fats. Fats with more than one double bond in the tail are called polyunsaturated fats.

Phospholipids A special lipid shown in **Figure 28,** called a phospholipid, is responsible for the structure and function of the cell membrane. Lipids are hydrophobic, which means they do not dissolve in water. This characteristic is important because it allows lipids to serve as barriers in biological membranes.

Steroids Another important category of lipids is the steroid group. Steroids include substances such as cholesterol and hormones. Despite its reputation as a "bad" lipid, cholesterol provides the starting point for other necessary lipids such as vitamin D and the hormones estrogen and testosterone.

DATA ANALYSIS LAB 2

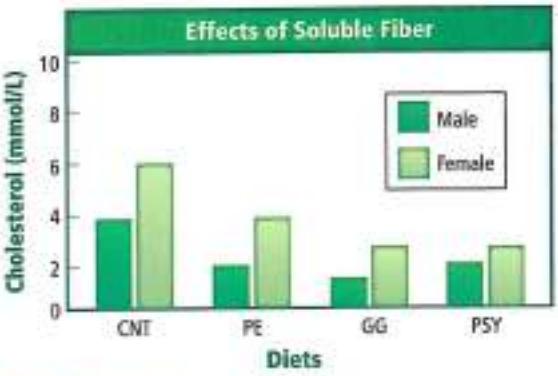
Based on Real Data*

Interpret the Data

Does soluble fiber affect cholesterol levels? High amounts of a steroid called cholesterol in the blood are associated with the development of heart disease. Researchers study the effects of soluble fiber in the diet on cholesterol.

Data and Observations

This experiment evaluated the effects of three soluble fibers on cholesterol levels in the blood: pectin (PE), guar gum (GG), and psyllium (PSY). Cellulose was the control (CNT).



Think Critically

1. **Calculate** the percentage of change in cholesterol levels as compared to the control.
2. **Describe** the effects that soluble fiber appears to have on cholesterol levels in the blood.

*Data obtained from: Shen, et al. 1998. Dietary soluble fiber lowers plasma LDL cholesterol concentrations by altering lipoprotein metabolism in small, female mammals. *Journal of Nutrition* 128: 1434-1441.

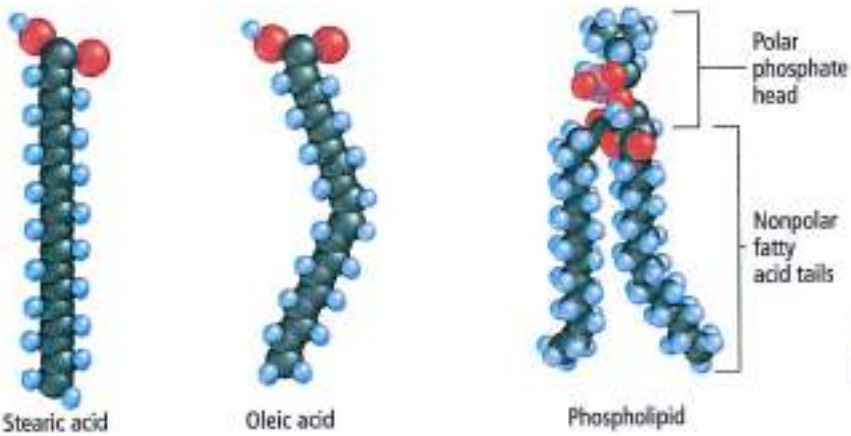


Figure 28 Stearic acid has no double bonds between carbon atoms; oleic acid has one double bond. Phospholipids have a polar head and two nonpolar tails.

Figure 29
Left: The general structure of an amino acid has four groups around a central carbon.
Right: The peptide bond in a protein happens as a result of a chemical reaction.
Interpret *which other molecule is a product when a peptide bond forms.*

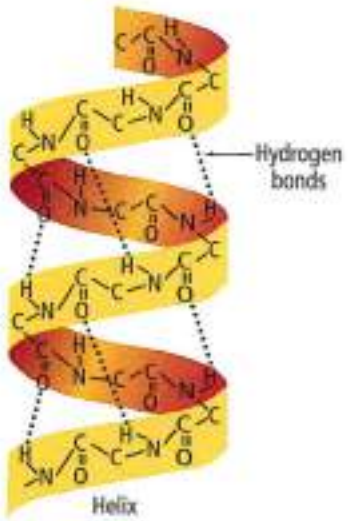
Proteins Another primary building block of living things is protein. A **protein** is a compound made of small carbon compounds called amino acids. **Amino acids** are small compounds that are made of carbon, nitrogen, oxygen, hydrogen, and sometimes sulfur. All amino acids share the same general structure.

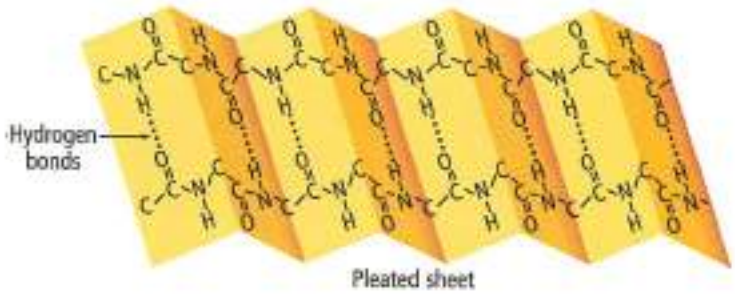
Amino acid structure Amino acids have a central carbon atom like the one shown in **Figure 29.** Recall that carbon can form four covalent bonds. One of those bonds is with hydrogen. The other three bonds are with an amino group ($-NH_2$), a carboxyl group (-COOH), and a variable group (-R). The variable group makes each amino acid different. There are 20 different variable groups, and proteins are made of different combinations of all 20 different amino acids. Several covalent bonds called peptide bonds join amino acids together to form proteins, which is also shown in **Figure 29.** A peptide bond forms between the amino group of one amino acid and the carboxyl group of another.

Three-dimensional protein structure Based on the variable groups contained in the different amino acids, proteins can have up to four levels of structure. The number of amino acids in a chain and the order in which the amino acids are joined define the protein's primary structure. After an amino acid chain is formed, it folds into a unique three-dimensional shape, which is the protein's secondary structure. **Figure 30** shows two basic secondary structures: the helix and the pleat. A protein might contain many helices, pleats, and folds. The tertiary structure of many proteins is globular, such as the hemoglobin protein shown in **Table 1,** but some proteins form long fibers. Some proteins form a fourth level of structure by combining with other proteins.

Protein function Proteins make up about 15 percent of your total body mass and are involved in nearly every function of your body. For example, your muscles, skin, and hair are made of proteins. Your cells contain about 10,000 different proteins that provide structural support, transport substances inside the cell and between cells, communicate signals within a cell and between cells, speed up chemical reactions, and control cell growth.

Figure 30 The shape of a protein depends on the interactions among the amino acids. Hydrogen bonds help the protein hold its shape.





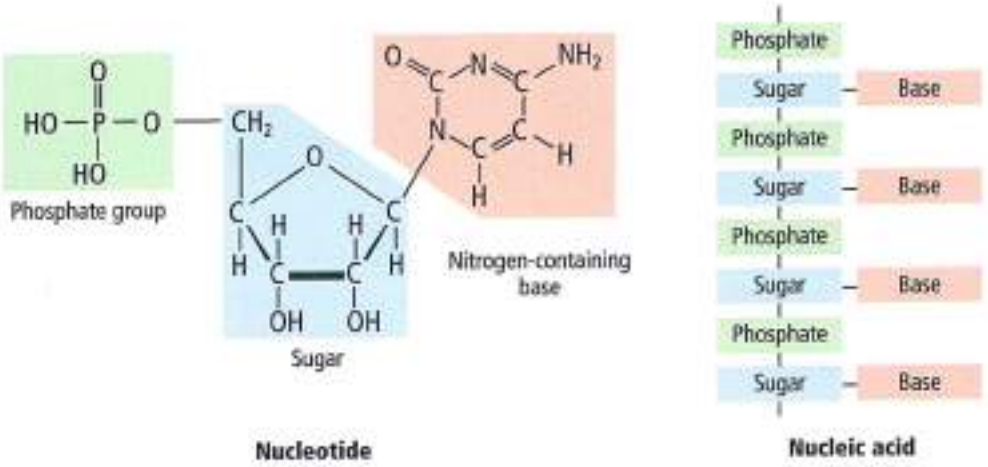


Figure 31
Left: DNA nucleotides contain the sugar deoxyribose. RNA nucleotides contain the sugar ribose.
Right: Nucleotides are joined together by bonds between their sugar group and phosphate group.

Nucleic acids The fourth group of biological macromolecules are nucleic acids. **Nucleic acids** are complex macromolecules that store and transmit genetic information. Nucleic acids are made of smaller repeating subunits composed of carbon, nitrogen, oxygen, phosphorus, and hydrogen atoms, called **nucleotides.** **Figure 31** shows the basic structure of a nucleotide and nucleic acid. There are five major nucleotides, all of which have three units–a phosphate, a nitrogenous base, and a ribose sugar.

There are two types of nucleic acids found in living organisms: deoxyribonucleic (dee AHK sih rib oh noo klay ihk) acid (DNA) and ribonucleic (rib oh noo KLAY ihk) acid (RNA). In nucleic acids such as DNA and RNA, the sugar of one nucleotide bonds to the phosphate of another nucleotide. The nitrogenous base that sticks out from the chain is available for hydrogen bonding with other bases in other nucleic acids.

A nucleotide with three phosphate groups is adenosine triphosphate (ATP). ATP is a storehouse of chemical energy that can be used by cells in a variety of reactions. It releases energy when the bond between the second and third phosphate group is broken. Less energy is released when the bond between the first and second phosphate group is broken.

Section 4 Assessment

Section Summary

- Carbon compounds are the basic building blocks of living organisms.
- Biological macromolecules are formed by joining small carbon compounds into polymers.
- There are four types of biological macromolecules.
- Peptide bonds join amino acids in proteins.
- Chains of nucleotides form nucleic acids.

Understand Main Ideas

1. MAIN Idea **Explain** If an unknown substance found on a meteorite is determined to contain no trace of carbon, can scientists conclude that there is life at the meteorite's origin?
2. **Compare** the types of biological macromolecules and their functions.
3. **Determine** the components of carbohydrates and proteins.
4. **Discuss** the importance of amino acid order to a protein's function.

Think Critically

5. **Summarize** Given the large number of proteins in the body, explain why the shape of an enzyme is important to its function.
6. **Draw** two structures (one straight chain and one ring) of a carbohydrate with the chemical formula $(CH_2O)_6$.

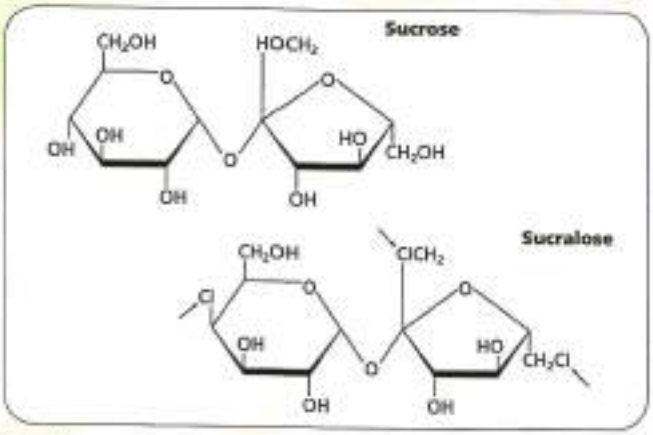
CUTTING-EDGE BIOLOGY

SWEETER THAN SUGAR

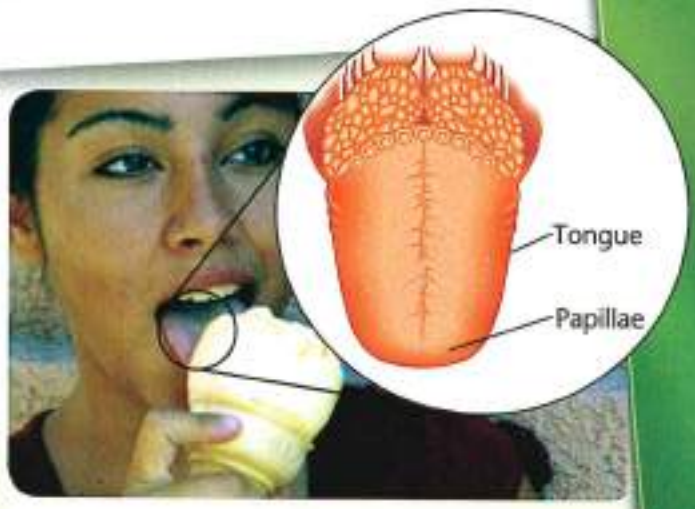
The reason why people love desserts is right on the tips of their tongues—literally. The taste buds in that location are the receptors that register sweetness most strongly. Many of the small bumps, called papillae, that you see on your tongue contain taste buds.

Registering Sweetness When you eat, the molecules from food temporarily bind themselves to protein molecules in the receptor cells of your tongue. As a result, the receptors send electrical impulses through your nerves to your brain. Your brain interprets the impulses as taste. Sometimes the taste is what you think of as sweet.

Natural vs. Artificial Sweeteners are substances added to foods to make them taste sweet. There are many natural sweeteners, such as table sugar and honey. An artificial sweetener is a man-made substance that has the same effect on taste buds as sugar does. Artificial sweeteners, such as saccharin, cyclamate, and aspartame, are hundreds of times sweeter than any naturally occurring sugar.



The difference between sucrose and sucralose is the substitution of three chlorine (Cl) atoms for three hydroxyl (OH) groups.



Taste buds on your tongue send impulses to your brain so that your brain can interpret how the food or drink tastes.

The molecules of these artificial sweeteners mimic the geometry and composition of natural sweeteners and are able to bind to the receptor cells in human taste buds.

One recently developed artificial sweetener, sucralose, has a chemical structure that is nearly identical to sucrose, or table sugar. The only difference is three hydroxyl (OH) groups in sucrose are replaced by chlorine atoms (Cl) in sucralose. This keeps the human body from metabolizing sucralose and makes it calorie-free.

Artificial sweeteners are used in many products, from diet sodas to children's medications. They provide the sweetness that people crave without the calories that natural sweeteners contain. Scientists continue to search for new sweeteners that are economical and healthful to customers.

WRITING in Biology

Marketing Campaign Research an artificial sweetener that has been approved by the FDA. Devise a marketing campaign to inform consumers about your chosen artificial sweetener. Your marketing campaign might include a press release, television or radio commercials, Web ads, social networking sites, or other methods of spreading information.

BIOLAB

Design Your Own

WHAT FACTORS AFFECT AN ENZYME REACTION?

Background: **The compound hydrogen peroxide, H_2O_2, is produced when organisms metabolize food, but hydrogen peroxide damages cell parts. Organisms combat the buildup of H_2O_2 by producing the enzyme peroxidase. Peroxidase speeds up the breakdown of hydrogen peroxide into water and oxygen.**

Question: *What factors affect peroxidase activity?*

Possible Materials

400-mL beaker	50-mL graduated cylinder
kitchen knife	10-mL graduated cylinder
hot plate	tongs or large forceps
test-tube rack	square or rectangular pan
ice	stopwatch or timer
beef liver	nonmercury thermometer
dropper	3% hydrogen peroxide
distilled water	potato slices

18-mm × 150-mm test tubes
buffer solutions (pH 5, pH 6, pH 7, pH 8)

Safety Precautions

CAUTION: ***Use only GFCI-protected circuits for electrical devices.***

Plan and Perform the Experiment

1. Identify the safety concerns of this lab before work begins.
2. Choose a factor to test. Possible factors include temperature, pH, and substrate (H_2O_2) concentration.
3. Form a hypothesis about how the factor will affect the reaction rate of peroxidase.
4. Design an experiment to test your hypothesis. Create a procedure and identify the controls and variables.
5. Create a data table for recording your observations and measurements.
6. Make sure your teacher approves your plan before you proceed.
7. Conduct your approved experiment.
8. **Cleanup and Disposal** Clean up all equipment as instructed by your teacher and return everything to its proper place. Wash your hands thoroughly with soap and water.

Analyze and Conclude

1. **Describe** how the factor you tested affected the enzyme activity of peroxidase.
2. **Graph** your data, and then analyze and interpret your graph.
3. **Discuss** whether or not your data supported your hypothesis.
4. **Infer** why hydrogen peroxide is not the best choice for cleaning an open wound.
5. **Error Analysis** Identify any experimental errors or other errors in your data that might have affected the accuracy of your results.

SHARE YOUR DATA

Compare your data with the data collected by other groups in the class that tested the same factor. Infer reasons why your group's data might differ from the data collected by other groups.

Chapter 2 Study Guide

THEME FOCUS **Energy** In every chemical reaction, there is a change in energy caused by the making and breaking of chemical bonds as reactants form products.

BIG Idea **Atoms are the foundation of biological chemistry and the building blocks of all living things.**

Section 1 Atoms, Elements, and Compounds

atom
nucleus
proton
neutron
electron
element
isotope
compound
covalent bond
molecule
ion
ionic bond
van der Waals force

MAIN Idea **Matter is composed of tiny particles called atoms.**

- Atoms consist of protons, neutrons, and electrons.
- Elements are pure substances made up of only one kind of atom.
- Isotopes are forms of the same element that have a different number of neutrons.
- Compounds are substances with unique properties that are formed when elements combine.
- Elements can form covalent and ionic bonds.

Section 2 Chemical Reactions

chemical reaction
reactant
product
activation energy
catalyst
enzyme
substrate
active site

MAIN Idea **Chemical reactions allow living things to grow, develop, reproduce, and adapt.**

- Balanced chemical equations must show an equal number of atoms for each element on both sides.
- Activation energy is the energy required to begin a reaction.
- Catalysts are substances that alter chemical reactions.
- Enzymes are biological catalysts.

Section 3 Water and Solutions

polar molecule
hydrogen bond
mixture
solution
solvent
solute
acid
base
pH
buffer

MAIN Idea **The properties of water make it well suited to help maintain homeostasis in an organism.**

- Water is a polar molecule.
- Solutions are homogeneous mixtures formed when a solute is dissolved in a solvent.
- Acids are substances that release hydrogen ions into solutions. Bases are substances that release hydroxide ions into solutions.
- pH is a measure of the concentration of hydrogen ions in a solution.

Section 4 The Building Blocks of Life

macromolecule
polymer
carbohydrate
lipid
protein
amino acid
nucleic acid
nucleotide

MAIN Idea **Organisms are made up of carbon-based molecules.**

- Carbon compounds are the basic building blocks of living organisms.
- Biological macromolecules are formed by joining small carbon compounds into polymers.
- There are four types of biological macromolecules.
- Peptide bonds join amino acids in proteins.
- Chains of nucleotides form nucleic acids.

Chapter 2 Assessment

Section 1

Vocabulary Review

Describe the difference between the terms in each pair.

1. electron, proton
2. ionic bond, covalent bond
3. isotope, element
4. atom, ion

Understand Main Ideas

Use the photo below to answer question 5.

5. What does the image above show?
   - **A.** a covalent bond
   - **B.** a physical property
   - **C.** a chemical reaction
   - **D.** van der Waals forces

6. Which process changes a chlorine atom into a chloride ion?
   - **A.** electron gain
   - **B.** electron loss
   - **C.** proton gain
   - **D.** proton loss

7. MAIN Idea Which of these is a pure substance that cannot be broken down by a chemical reaction?
   - **A.** a compound
   - **B.** a mixture
   - **C.** an element
   - **D.** a neutron

8. How do the isotopes of hydrogen differ?
   - **A.** in the number of protons
   - **B.** in the number of electrons
   - **C.** in the number of energy levels
   - **D.** in the number of neutrons

Constructed Response

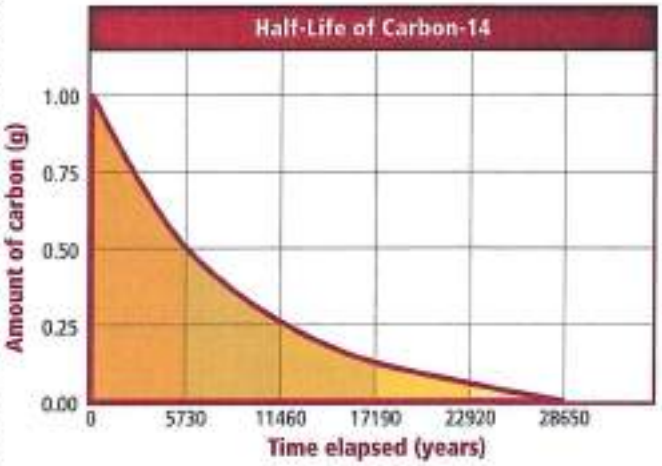
9. **Short Answer** What is a radioactive isotope? List uses of radioactive isotopes.

10. **Short Answer** What factor determines that an oxygen atom can form two covalent bonds while a carbon atom can form four?

11. **Open Ended** Why is it important for living organisms to have both strong bonds (covalent and ionic) and weak bonds (hydrogen and van der Waals forces)?

Think Critically

Use the graph below to answer question 12.



12. **Analyze** According to the data, what is the half-life of carbon-14? How can this information be used by scientists?

13. **Explain** The gecko is a reptile that climbs on smooth surfaces such as glass using van der Waals forces to adhere to the surfaces. How is this method of adhesion more advantageous than covalent interactions?

Section 2

Vocabulary Review

Match the term on the left with the correct definition on the right.

14. activation energy
15. substrate
16. enzyme
17. product

- **A.** a protein that speeds up a reaction
- **B.** a substance formed by a chemical reaction
- **C.** the energy required to start a reaction
- **D.** a substance that binds to an enzyme

Chapter 2 Assessment

Understand Main Ideas

18. THEME FOCUS Energy Which of the following is a substance that lowers the activation energy?

A. an ion **C.** a catalyst
B. a reactant **D.** a substrate

19. In which of the following are bonds broken and new bonds formed?

A. chemical reactions **C.** isotopes
B. elements **D.** polar molecules

20. Which statement is true of chemical equations?

A. Reactants are on the right.
B. Products are on the right.
C. Products have fewer atoms than reactants.
D. Reactants have fewer atoms than products.

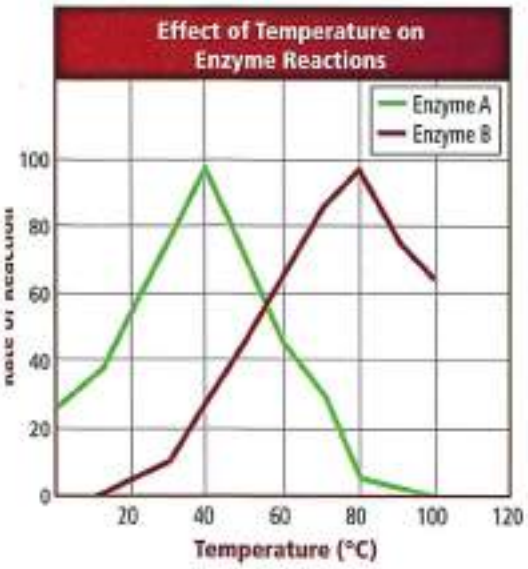
Constructed Response

21. Short Answer What features do all reactions involving enzymes have in common?

22. Open Ended Identify and describe factors that can influence enzyme activity.

Think Critically

Use the graph to answer questions 23 and 24.



23. Describe the effect that temperature has on the rate of the reactions using the graph above.

24. MAIN Idea Which enzyme is more active in a human cell? Why?

Section 3

Vocabulary Review

State the relationship between the terms in each pair.

25. solution, mixture

26. pH, buffer

27. acid, base

28. solvent, solute

29. polar molecule, hydrogen bond

Understand Main Ideas

Use the figure below to answer question 30.

30. What does the image above show?

A. a heterogeneous mixture **C.** a solution
B. a homogeneous mixture **D.** a suspension

31. Which statement is not true about pure water?

A. It has a pH of 7.0.
B. It is composed of polar molecules.
C. It is composed of ionic bonds.
D. It is a good solvent.

32. Which is a substance that produces OH^- ions when it is dissolved in water?

A. a base **C.** a buffer
B. an acid **D.** salt

Constructed Response

33. MAIN Idea Why are hydrogen bonds so important for living organisms?

34. Short Answer Hydrochloric acid (HCl) is a strong acid. What ions are formed when HCl dissolves in water? What is the effect of HCl on the pH of water?

35. Open Ended Explain the importance of buffers to living organisms.

Think Critically

36. **Predict** two places in the body where buffers are used to limit sharp changes in pH.

37. **Draw** a diagram of table salt (NaCl) dissolved in water.

Section 4

Vocabulary Review

Complete the following sentences with vocabulary terms from the Study Guide page.

38. Carbohydrates, lipids, proteins, and nucleic acids are _____.

39. Proteins are made from _____ that are joined by _____.

40. _____ make up fats, oils, and waxes.

41. DNA and RNA are examples of _____.

Understand Main Ideas

42. Which two elements are always found in amino acids?

A. nitrogen and sulfur
B. carbon and oxygen
C. hydrogen and phosphorus
D. sulfur and oxygen

43. Which joins amino acids together?

A. peptide bonds
B. hydrogen bonds
C. van der Waals forces
D. ionic bonds

44. Which substance is not part of a nucleotide?

A. a phosphate
B. a base
C. a sugar
D. water

Constructed Response

45. **Open Ended** Why do cells contain both macromolecules and small carbon compounds?

46. **Open Ended** Why can't humans digest all carbohydrates?

Think Critically

47. MAIN Idea **Create** a table for the four main biological macromolecules that lists their component and functions.

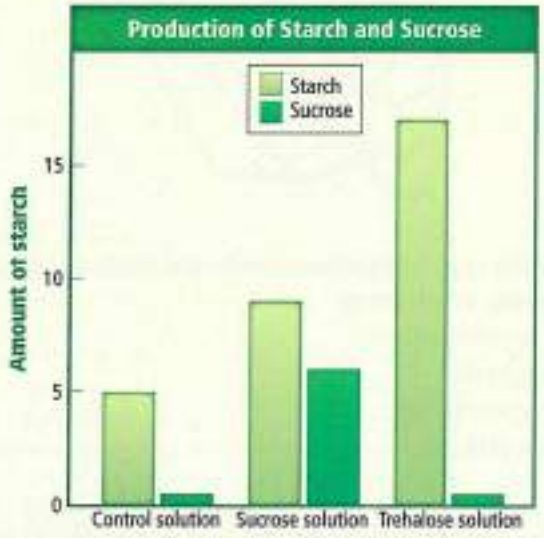
Summative Assessment

48. BIG Idea Diagram the basic unit of matter, describe the parts, and relate them to each other.

49. WRITING in Biology Research and write a job description for a biochemist. Include the types of tasks that biochemists perform and materials that are used in their research.

DBQ Document-Based Questions

Starch is the major carbon storehouse in plants. Experiments were performed to determine if trehalose might regulate starch production in plants. Leaf disks were incubated for three hours in sorbitol (the control), sucrose, and trelahose solutions. Then, levels of starch and sucrose in the leaves were measured. Use the data to answer the questions below.



Data obtained from: Kolbe, et al. Trehalose 6-phosphate regulates starch synthesis via post translational redox activation of ADP-glucose pyrophosphorylase. *Proceedings of the National Academy of Sciences of the USA* 102(31): 11118–11123.

50. Summarize the production of starch and sucrose in the three solutions.

51. What conclusion might the researchers have reached based on these data?

Standardized Test Practice

Cumulative

Multiple Choice aligned with PISA study skills

1. If a population of parrots has greater genetic diversity than a hummingbird population in the same region, which outcome could result?
   - **A.** The parrot population could have a greater resistance to disease than the hummingbird population.
   - **B.** Other parrot populations in different regions could become genetically similar to this one.
   - **C.** The parrot population could have a greater variety of abiotic factors with which to interact.
   - **D.** The parrot population could interact with a greater variety of other populations.

Use the diagram below to answer questions 2 and 3.

2. Which type of macromolecule can have a structure like the one shown?
   - **A.** a carbohydrate
   - **B.** a lipid
   - **C.** a nucleotide
   - **D.** a protein

3. Which molecular activity requires a folded structure?
   - **A.** behavior as a nonpolar compound
   - **B.** function of an active site
   - **C.** movement through cell membranes
   - **D.** role as energy storage for the cell

4. Which describes the effects of population increase and resource depletion?
   - **A.** increased competition
   - **B.** increased emigration
   - **C.** exponential population growth
   - **D.** straight-line population growth

5. Which property of populations might be described as random, clumped, or uniform?
   - **A.** density
   - **B.** dispersion
   - **C.** growth
   - **D.** size

6. Which is an example of biodiversity with direct economic value?
   - **A.** sparrow populations that have great genetic diversity
   - **B.** species of a water plant that makes a useful antibiotic
   - **C.** trees that create a barrier against hurricane winds
   - **D.** villagers who all use the same rice species for crops

Use the illustration below to answer question 7.

7. Which term describes the part of the cycle labeled *A*?
   - **A.** condensation
   - **B.** evaporation
   - **C.** runoff
   - **D.** precipitation

8. Which is a characteristic of exponential growth?
   - **A.** the graphical representation goes up and down
   - **B.** the graphical representation has a flat line
   - **C.** a growth rate that increases with time
   - **D.** a growth rate that stays constant in time

Short Answer aligned with SAT exam skills

9. Assess what might happen if there were no buffers in human cells.

10. Choose an example of an element and a compound and then contrast them.

Use the chart below to answer question 11.

Factors Affecting Coral Survival	
Factor	**Optimal Range**
Water temperature	23°C to 25°C
Salinity	30 to 40 parts per million
Sedimentation	little or no sedimentation
Depth	up to 48 m

11. Using the data in the chart, describe which region of the world would be optimal for coral growth.

12. Provide a hypothesis to explain the increase in species diversity as you move from the polar regions to the tropics.

13. In a country with a very slow growth rate, predict which age groups are the largest in the population.

14. Why is it important that enzymes can bind only to specific substrates?

Extended Response aligned with SAT exam skills

15. Suddenly, after very heavy rains, many fish in a local lake begin to die, yet algae in the water seem to be doing very well. You know that the lake receives runoff from local fields and roads. Form a hypothesis about why the fish are dying, and suggest how to stop the deaths.

16. When scientists first discovered atoms, they thought they were the smallest parts into which matter could be divided. Relate how later discoveries led scientists to revise this definition.

17. Identify and describe three types of symbiotic relationships and provide an example of each.

Essay Questions aligned with SAT exam skills

Many kinds of molecules found in living organisms are made of smaller monomers that are put together in different sequences, or in different patterns. For example, organisms use a small number of nucleotides to make nucleic acids. Thousands of different sequences of nucleotides in nucleic acids provide the basic coding for all the genetic information in living things.

Using the information in the paragraph above, answer the following question in essay format.

18. Describe how it is beneficial for organisms to use monomers to create complex macromolecules.

CHAPTER 3

Digestive and Endocrine Systems

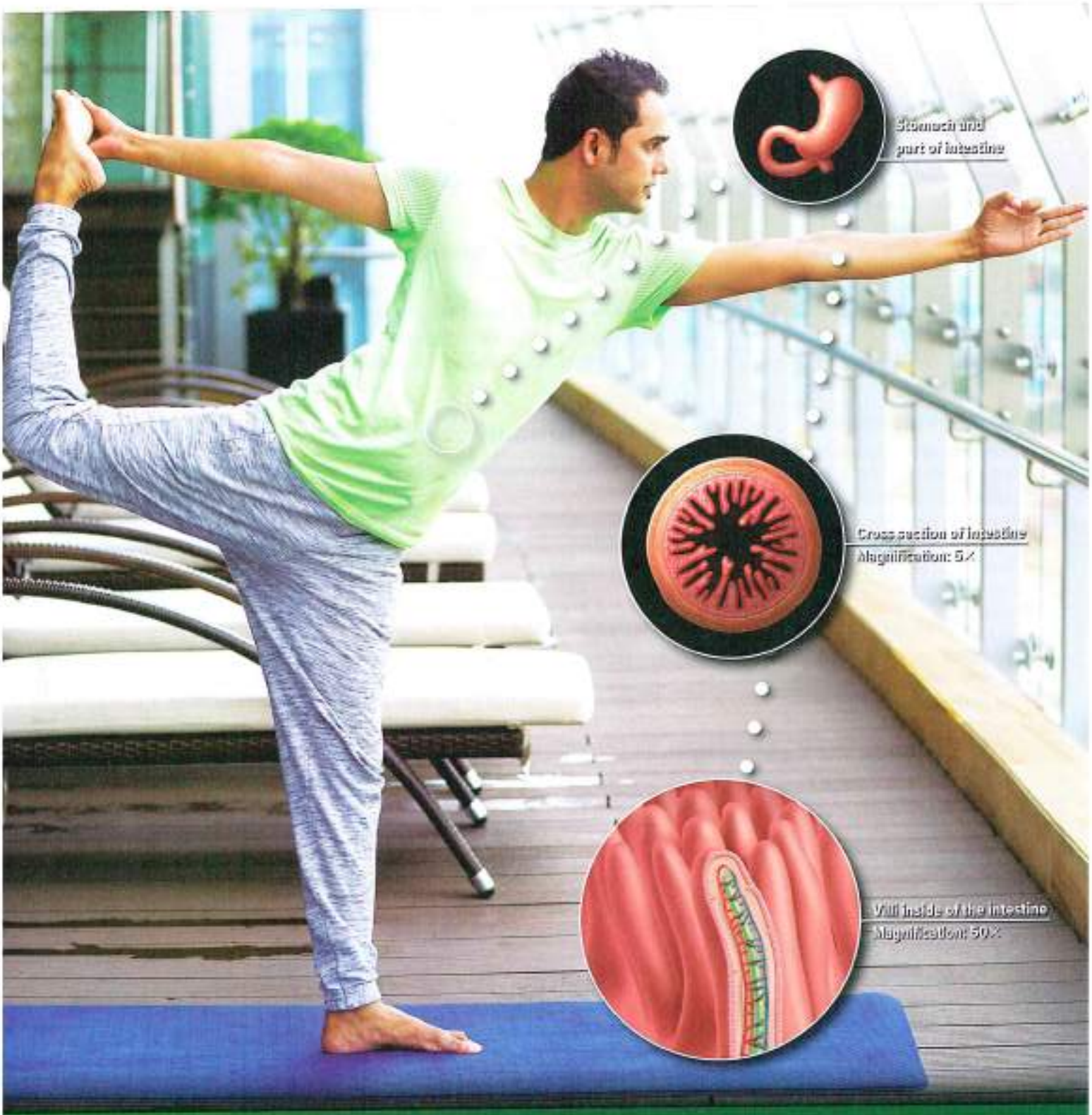
Launch Lab

How does the enzyme pepsin aid digestion?

The acidic digestive juices in the stomach contain the enzyme pepsin. In this lab, you will investigate the role of pepsin in digestion.

FOLDABLES

Make a folded chart using the titles shown. Use it to organize your notes on hormones.



THEME FOCUS Homeostasis

Homeostasis is maintained by negative feedback in the endocrine system.

BIG Idea The digestive system breaks down food to provide energy and nutrients for the body. The endocrine system produces hormones that regulate body functions.

Section 1

Reading Preview

Essential Questions

- What are the three main functions of the digestive system?
- What are the structures of the digestive system and what are their functions?
- What is the process of chemical digestion?

Review Vocabulary

nutrient: vital component of foods that provides energy and materials for growth and body functions

New Vocabulary

mechanical digestion
chemical digestion
amylase
esophagus
peristalsis
pepsin
small intestine
liver
villus
large intestine

The Digestive System

MAIN Idea **The digestive system breaks down food so nutrients can be absorbed by the body.**

Real-World Reading Link During an average lifespan, as much as 45 tons of food can pass through a person's digestive system. The food will travel almost 9 m through the digestive tract. What happens as food passes through this long tube?

Functions of the Digestive System

There are three main functions of the digestive system. The digestive system ingests food, breaks it down so nutrients can be absorbed, and eliminates what cannot be digested. Refer to **Figure 1** and **Figure 2** as you learn about the structure and function of the digestive system.

Digestion Supose on Friday night, you and your friends meet to have pizza. You bite into a slice and begin to chew. How does your body digest that pizza?

Mechanical digestion involves chewing food to break it down into smaller pieces. It also includes the action of smooth muscles in the stomach and small intestine that churn the food. **Chemical digestion** involves the breakdown of large molecules in food into smaller substances by enzymes. The smaller substances can be absorbed into the body's cells. Enzymes are proteins that speed up biological reactions. When you chew the bites of pizza, **amylase,** an enzyme found in saliva, begins the process of chemical digestion by breaking down starches into sugars.

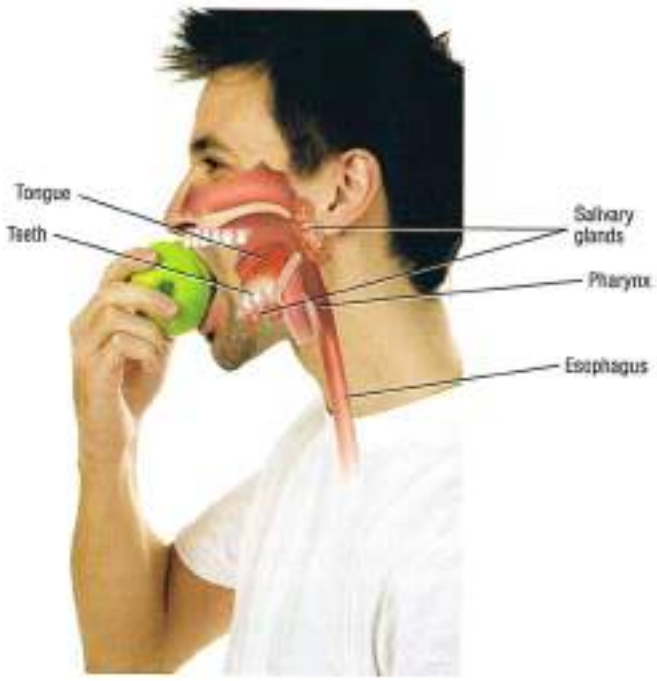


Figure 1 Mechanical digestion starts in the mouth. Secretions from the salivary glands keep food moist and begin the process of chemical digestion. Food moves through the pharynx into the esophagus.

Esophagus When the tongue pushes chewed food to the back of the mouth, the swallowing reflex is stimulated. The food is forced by the action of the tongue into the upper portion of the esophagus. The **esophagus** is a muscular tube that connects the pharynx, or throat, to the stomach, as illustrated in **Figure 2.** The wall of the esophagus is lined with smooth muscles that contract rhythmically to move the food through the digestive system in a process called **peristalsis**. Peristalsis continues throughout the digestive tract. Even if a person were upside down, food would still move toward the stomach.

When a person swallows, the small plate of cartilage called the epiglottis covers the trachea. If this opening is not closed, food can enter the trachea and cause a person to choke. The body responds to this by initiating the coughing reflex in an attempt to expel the food to keep the food from entering the lungs.

Stomach When food leaves the esophagus, it passes through a circular muscle called a sphincter, and into the stomach. The sphincter between the esophagus and stomach is the cardiac sphincter. The walls of the stomach are composed of three overlapping layers of smooth muscle that are involved with mechanical digestion. As the muscles contract, they further break down the food and mix it with the secretions of glands that line the inner wall of the stomach.

Connection Chemistry Recall that pH is a measure of a solution's acidity. The environment inside the stomach is very acidic. Stomach glands, called gastric glands, secrete an acidic solution, which lowers the pH in the stomach to about 2. This is about the same level of acidity as lemon juice. If the sphincter in the upper portion of the stomach allows any leakage, some of this acid might move back into the esophagus, causing what is commonly known as heartburn.

The acidic environment in the stomach is favorable to the action of **pepsin,** an enzyme involved in the process of the chemical digestion of proteins. Cells in the lining of the stomach secrete mucus to help prevent damage from pepsin and the acidic environment. Although most absorption occurs in the small intestine, some substances, such as alcohol and aspirin, are absorbed by cells that line the stomach. While empty, the capacity of the stomach is about 50 mL. When full, it can expand to 2-4 L.

The muscular walls of the stomach contract and push food farther along the digestive tract. The consistency of the food resembles tomato soup as it passes through the pyloric sphincter at the lower end of the stomach into the small intestine. **Figure 3** illustrates peristalsis in the small intestine.

Reading Check **Compare** digestion in the mouth with digestion in the stomach.

Figure 2 The esophagus extends from the pharynx to the stomach and is approximately 25 cm long.
Describe *why humans are classified as coelomates.*

Figure 3 The smooth muscles in the walls of the digestive tract contract in the process of peristalsis.

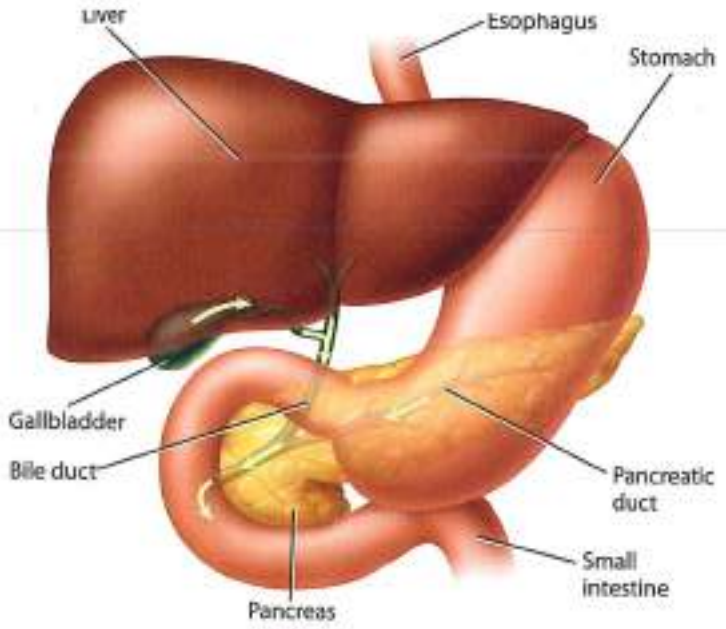


Figure 4 Chemical digestion in the small intestine depends on the activities of the liver, pancreas, and gallbladder.
Discuss *the importance of each of these organs in the process of chemical digestion.*

Small intestine The **small intestine** is approximately 7 m in length and is the longest part of the digestive tract. It is called *small* because its diameter is 2.5 cm compared to the 6.5 cm diameter of the large intestine. The smooth muscles in the wall of the small intestine continue the process of mechanical digestion and push the food farther through the digestive tract by peristalsis.

The completion of chemical digestion in the small intestine depends on three accessory organs–the pancreas, liver, and gallbladder, as illustrated in **Figure 4.** The pancreas serves two main functions. One is to produce enzymes that digest carbohydrates, proteins, and fats. The other is to produce hormones, which will be discussed later in this chapter. The pancreas secretes an alkaline fluid to raise the pH in the small intestine to slightly above 7, which creates a favorable environment for the action of intestinal enzymes.

The **liver** is the largest internal organ of the body and produces bile, which helps to break down fats. About 1 L of bile is produced every day, and excess bile is stored in the gallbladder to be released into the small intestine when needed. **Figure 5** shows gallstones, which are cholesterol crystals that can form in the gallbladder.

Study Tip

Sequence and Order Using your notes, work with a partner to review the sequence of the organs in the digestive system. Then, practice retelling the sequence without your notes. Ask questions of one another for deeper learning.

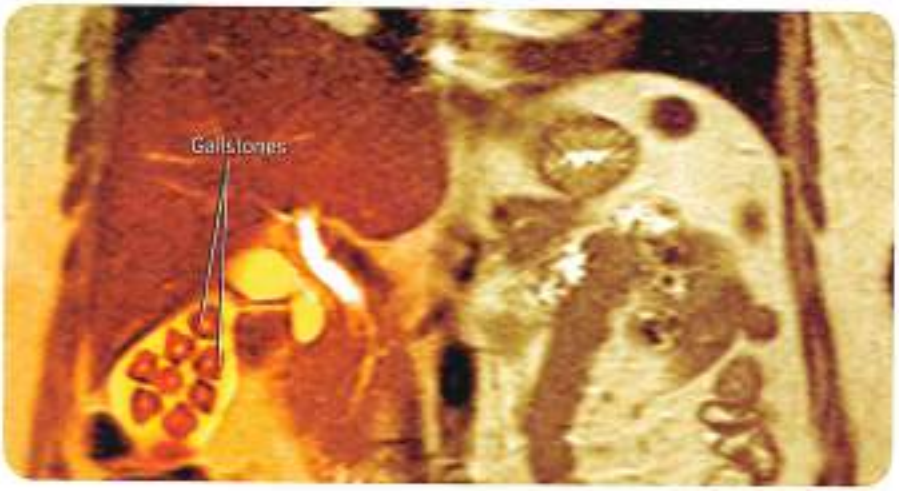


Figure 5 Gallstones can obstruct the flow of bile from the gallbladder. Note the gallstones on this MRI film of a gallbladder.

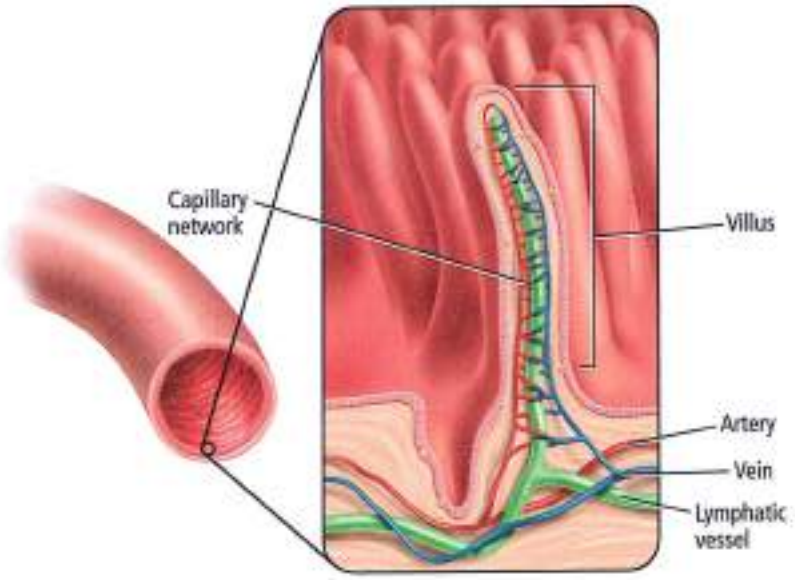


Figure 6 A villus is a fingerlike extension of the lining of the small intestine. Nutrients diffuse into capillaries in the villi and reach body cells by means of circulating blood.

Chemical digestion is completed and most of the nutrients from food are absorbed from the small intestine into the bloodstream through fingerlike structures called **villi** (singular, villus). Villi, illustrated in **Figure 6,** increase the surface area of the small intestine, giving the small intestine approximately the same surface area as a tennis court.

Refer again to **Figure 1** and **Figure 2** to follow the movement of digested food through the digestive system. Once digestion is complete, the remaining food, now in a semiliquid form called chyme, moves into the large intestine. Chyme is made up of materials that cannot be digested or absorbed by villi in the small intestine.

Mini Lab 1

Investigate Digestion of Lipids

How do bile salts and pancreatic solution affect digestion? Lipids, or fats, are not water soluble. The body compensates by producing bile, a chemical that breaks apart fat and helps the molecules mix with the watery solution in the small intestine. In this lab, you will investigate the breakdown of lipids.

Procedure

1. Identify the safety concerns of this lab before work begins.
2. Study the lab procedure and construct a data chart.
3. Label **three test tubes.** Add 5 mL **vegetable oil** and 8-10 drops **phenolphthalein** to each. Shake well. If the color is not pink, add **NaOH solution** one drop at a time until the solution turns pink.
4. Add 125 mL **water** to a **250-mL beaker.** Warm to about 40°C.
5. Prepare the test tubes as follows, then seal each with a **stopper.**
   Test Tube A: 5 mL **distilled water,** pinch of **bile salt**
   Test Tube B: 5 mL **pancreatic solution,** pinch of bile salt
   Test Tube C: 5 mL pancreatic solution
6. Shake each tube to mix the contents and gently place in the beaker. Record your observations.
7. Dispose of test tube contents in the designated container.

Analysis

1. **Analyze** What did a color change inside a test tube indicate? What caused the change?
2. **Draw conclusions** based on your results. Describe the roles of bile and pancreatic solution in digestion.

Table 1 Time for Digestion

Digestive Structure	Primary Function	Time Food in Structure
Mouth	Mechanical and chemical digestion	5–30 s
Esophagus	Transport (swallowing)	10 s
Stomach	Mechanical and chemical digestion	2–24 h
Small intestine	Mechanical and chemical digestion	3–4 h
Large intestine	Water absorption	18 h–2 days

Large intestine The **large intestine** is the end portion of the digestive tract. It is about 1.5 m long and includes the colon, the rectum, and a small saclike appendage called the appendix. Although the appendix has no known function, it can become inflamed and swollen, resulting in appendicitis. If inflamed, the appendix will likely have to be removed surgically.

Some kinds of beneficial bacteria are normal in the colon. These bacteria produce vitamin K and some B vitamins available to the body.

A primary function of the colon is to absorb water from the chyme. The indigestible material then becomes more solid and is called feces. Peristalsis continues to move feces toward the rectum, causing the walls of the rectum to stretch. This initiates a reflex that causes the final sphincter muscle to relax, and the feces are eliminated from the body through the anus. Refer to **Table 1** to review the primary function of each structure of the digestive system and how long food usually remains in each structure as it is being digested.

Section 1 Assessment

Section Summary

- The digestive system has three main functions.
- Digestion can be categorized as mechanical or chemical.
- Most nutrients are absorbed in the small intestine.
- Accessory organs provide enzymes and bile to aid digestion.
- Water is absorbed from chyme in the colon.

Understand Main Ideas

1. MAIN Idea **Describe** the process that breaks down food so that nutrients can be absorbed by the body.
2. **Analyze** the difference between mechanical digestion and chemical digestion. Explain why chemical digestion is necessary for the body.
3. **Summarize** the three main functions of the digestive system.
4. **Analyze** what the consequence might be if the lining of the small intestine were completely smooth instead of having villi.

Think Critically

5. **Design** an experiment to gather data about the effect of pH on the digestion of different types of food.

MATH in Biology

6. A can of carbonated beverage typically holds about 354 mL of fluid. Compare this amount with the volume of an empty stomach. Give a ratio.
7. **Explain** why the pH in the digestive system changes. Give examples and explain the importance of these changes.

Section 2

Reading Preview

Essential Questions

- Depending on activity level, what caloric intake is needed to maintain proper body weight?
- How are proteins, carbohydrates, and fats used by the body?
- What are the roles of vitamins and minerals in maintaining homeostasis?
- How can you apply the information in MyPyramid and on food labels to establishing healthy eating habits?

Review Vocabulary

amino acid: the basic building block of proteins

New Vocabulary

nutrition
Calorie
vitamin
mineral

Nutrition

MAIN Idea **Certain nutrients are essential for the proper function of the body.**

Real-World Reading Link There is a saying, "You are what you eat." What do you think that means? Much of the time, you have freedom to choose what you eat. However, your choices have consequences. What you eat can affect your health now and in the future.

Calories

Nutrition is the process by which a person takes in and uses food. Foods supply the building blocks and energy to maintain body mass. The daily input of energy from food should equal the amount of energy a person uses daily. A **Calorie** (with an uppercase C) is the unit used to measure the energy content of foods. A Calorie is equal to 1 kilocalorie, or 1000 calories (with a lowercase c). A calorie is the amount of heat needed to raise the temperature of 1 mL of water by 1°C.

The energy content of a food can be measured by burning the food and converting the stored energy to heat. Not all foods have the same energy content. The same mass of different foods does not always equal the same number of Calories. For example, one gram of carbohydrate or protein contains four Calories. One gram of fat contains nine Calories. To lose weight, more Calories must be used than consumed. The opposite is true to gain weight. In 2005, **Table 2** compares average Calorie usage with different activities. The exact number of calories burned will vary depending on weight and gender.

Table 2 **Activities and Average Calorie Usage**

Activity	Calories Used Per Hour	Activity	Calories Used Per Hour
Baseball	282	Hiking and backpacking	564
Basketball	564	Hockey (field and ice)	546
Bicycling	240–410	Jogging	740–920
Cross-country skiing	700	Skating	300
Football	540	Soccer	540

Figure 7 Your body needs carbohydrate-rich foods like these every day.

VOCABULARY

SCIENCE USAGE V. COMMON USAGE

Consume

Science usage: to eat or drink
We consume Calories when we eat food.

Common usage: to deplete/consume
The child deplete/consume his energy in playing

Carbohydrates

Cereal, pasta, potatoes, strawberries, and rice all contain a high proportion of carbohydrates. Recall that sugars, such as glucose, fructose, and sucrose, are simple carbohydrates that are found in fruits, soda pop, and candy. Complex carbohydrates are macromolecules such as starches, which are long chains of sugars. Foods such as those shown in **Figure 7** have a high starch content, as do some vegetables.

Complex carbohydrates are broken down into simple sugars in the digestive tract. Simple sugars are absorbed through villi in the small intestine into blood capillaries and circulated throughout the body to provide energy for cells. Excess glucose is stored in the liver in the form of glycogen. Cellulose, sometimes called dietary fiber, is another complex carbohydrate found in plant foods. Although humans cannot digest fiber, it is important because fiber helps keep food moving through the digestive tract and helps with the elimination of wastes. Bran, whole-grain breads, and beans are good sources of fiber.

Reading Check **Compare** simple and complex carbohydrates.

Fats

In proper amounts, fats are an essential part of a healthful diet. Fats are the most concentrated energy source available to the body, and they are building blocks for the body. Fats also protect some internal organs and help maintain homeostasis by providing energy and by storing and transporting certain vitamins. However, not all fats are beneficial.

Connection to Health Recall that fats are classified according to their chemical structure as saturated or unsaturated. Meats, cheeses, and other dairy products are sources of saturated fats. A diet high in saturated fats might result in high blood levels of cholesterol, which can lead to heart problems. Plants are the main source of unsaturated fats. They are not associated with heart disease, although excessive consumption of any type of fat can lead to weight gain.

A general rule is that saturated fats are solid and unsaturated fats are liquid at room temperature. The olive oil in **Figure 8** contains less saturated fat than the butter, which is why the olive oil is liquid at room temperature. Fats are digested in the small intestine and broken down into fatty acids and glycerol. Fatty acids can be absorbed through the villi and circulated in the blood throughout the body.

Figure 8 The way in which naturally low-fat foods are cooked and served can increase saturated fat content. Olive oil may be a better cooking option than butter for this reason.

Proteins

You have learned that proteins are basic structural components of all cells, and that amino acids are the building blocks of proteins. Enzymes, hormones, neurotransmitters, and membrane receptors are just a few important proteins in the body.

During the process of digestion, proteins in foods are broken down to their subunit amino acids. The amino acids are absorbed into the bloodstream and carried to various body cells. These body cells, through the process of protein synthesis, assemble the amino acids into proteins needed for body structures and functions.

Humans require 20 different amino acids for protein synthesis. The human body can produce 12 of the 20 amino acids needed for cellular function. Essential amino acids are the eight amino acids that must be included in a person's diet. Animal products, such as meats, fish, poultry, eggs, and dairy products, are sources of all eight essential amino acids. Vegetables, fruits, and grains contain amino acids, but no single plant food source contains all eight essential amino acids. However, certain combinations, such as the beans and rice shown in **Figure 9,** provide all of the essential amino acids.

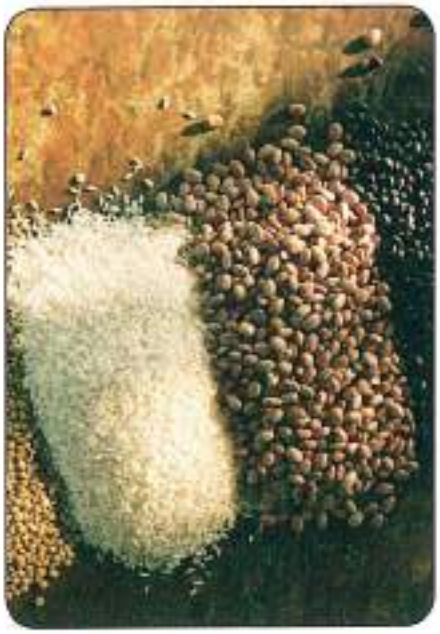


Figure 9 Beans and rice can be combined to provide all the essential amino acids.
Explain ***why it is important to eat foods that contain the essential amino acids.***

MyPlate

Figure 10 MyPlate replaces the food pyramid, which had been a symbol of good nutrition in some countries. MyPlate emphasizes the ratios of food groups rather than exact serving sizes. It recommends that a person eat about 30 percent grains, 30 percent vegetables, 20 percent fruits, 20 percent protein, with a small side of dairy such as a yogurt cup or glass of skim milk.

Figure 10 MyPlate can help you choose the foods and the amounts of those foods that are right for you.

Vitamins and Minerals

In addition to carbohydrates, fats, and proteins, your body needs vitamins and minerals to function properly. **Vitamins** are organic compounds that are needed in small amounts for metabolic activities. Many vitamins help enzymes function properly. Some vitamins are produced within the body. Vitamin D is made by cells in your skin. Some B vitamins and vitamin K are produced by bacteria living in the large intestine. However, sufficient quantities of most vitamins cannot be made by the body, but a well-balanced diet can provide the vitamins that are needed. Some vitamins that are fat-soluble can be stored in small quantities in the liver and fatty tissues of the body. Other vitamins are water-soluble and cannot be stored in the body. Foods providing an adequate level of these vitamins should be included in a person's diet on a regular basis.

Minerals are inorganic compounds used by the body as building materials, and they are involved with metabolic functions. For example, the mineral iron is needed to make hemoglobin. Recall that oxygen binds to hemoglobin in red blood cells and is delivered to body cells as blood circulates in the body. Calcium, another mineral, is an important component of bones.

Vitamins and minerals are essential parts of a healthy diet. **Table 3** on the next page lists some important vitamins and minerals, their benefits, and some food sources that can provide these necessary nutrients. Over-the-counter vitamins are also available. Taking more than the recommended daily allowance, however, can be dangerous and should not be done without consulting a doctor.

CAREERS IN BIOLOGY

Registered Dietician A registered dietician addresses a variety of health issues by showing patients how to make healthful decisions about their diets.

Nutrition Labels

Nutrition labels are provided on commercially packaged foods like those shown in **Figure 11.** These labels are based on a 2000-Calorie-per-day diet. Labels can be especially useful for monitoring fat and sodium intake, which are two nutrients that need to be consumed in moderation. Some federal departments require that food labels list the following information.

- name of the food
- net weight or volume
- name and address of manufacturer, distributor, or packager
- ingredients
- nutrient content

Table 3 Major Roles of Some Vitamins and Minerals

Vitamin	Major Role in the Body	Possible Sources	Mineral	Major Role in the Body
A	• Vision • Health of skin and bones		**Ca**	• Strengthening of teeth and bone • Nerve conduction • Contraction of muscle
D	• Health of bones and teeth		**P**	• Strengthening of teeth and bone
E	• Strengthening of red blood cell membrane		**Mg**	• Synthesis of proteins
Riboflavin (B_2)	• Metabolism		**Fe**	• Synthesis of hemoglobin
Folic Acid	• Formation of red blood cells • Formation of DNA and RNA		**Cu**	• Synthesis of hemoglobin
Thiamine	• Metabolism of carbohydrates		**Zn**	• Healing of wounds
Niacin (B_3)	• Metabolism		**Cl**	• Balance of water
Pyridoxine (B_6)	• Metabolism of amino acids		**I**	• Synthesis of thyroid hormone
B_{12}	• Formation of red blood cells		**Na**	• Nerve conduction • Balance of pH
C	• Formation of collagen		**K**	• Nerve conduction • Contraction of muscle

Figure 11 Notice how many servings are in each food container. The percent daily values are based on an individual serving, not the entire package.

Section 2 Assessment

Section Summary

- The energy content of food is measured in Calories.
- Carbohydrates, fats, and proteins are three major groups of nutrients.
- Carbohydrates are a major source of energy for the body.
- Fats and proteins provide energy and are important building blocks for the body.
- Vitamins and minerals are essential for proper metabolic functioning.
- The *MyPyramid Plan* and food labels are tools that you can use to eat healthfully.

Understand Main Ideas

1. MAIN Idea **Explain** the roles of vitamins and minerals in the process of maintaining homeostasis.
2. **Describe** what proteins, carbohydrates, and fats are used for in the process of digestion.
3. **Recommend** what nutrients a vegetarian should add to his or her diet.
4. **Explain** why keeping a count of Calories consumed and Calories used is important in maintaining proper functioning of the body.

Think Critically

5. **Summarize** how many Calories you consume during one day by recording everything you eat or drink. Compare this to how many Calories you burn in an average day.

WRITING in Biology

6. Write a short article for your school newspaper describing what is needed for a well-balanced diet.

Section 3

Reading Preview

Essential Questions

- What are the functions of the glands that make up the endocrine system?
- What is the role of the endocrine system in maintaining homeostasis?
- What are the feedback mechanisms that regulate hormone levels in the body?

Review Vocabulary

homeostasis: the regulation of an organism's internal environment to maintain life

New Vocabulary

endocrine gland
hormone
pituitary gland
thyroxine
calcitonin
parathyroid hormone
insulin
glucagon
aldosterone
cortisol
antidiuretic hormone

The Endocrine System

MAIN Idea **Systems of the human body are regulated by hormonal feedback mechanisms.**

Real-World Reading Link When driving a car, everyone usually maintains a similar speed. When cars go faster or slower than the accepted speed, the chance of an accident increases. Similarly, hormones must stay in the proper balance to maintain homeostasis in the body.

Action of Hormones

The endocrine system is composed of glands and functions as a communication system. **Endocrine glands** produce hormones, which are released into the bloodstream and distributed to body cells. A **hormone** is a substance that acts on certain target cells and tissues to produce a specific response. Hormones are classified as steroid hormones and nonsteroid or amino acid hormones, based on their structure and mechanism of action.

Steroid hormones Estrogen and testosterone are two examples of steroid hormones. Both of these hormones affect the human reproductive system. All steroid hormones work by causing the target cells to initiate protein synthesis, as illustrated in **Figure 12.**

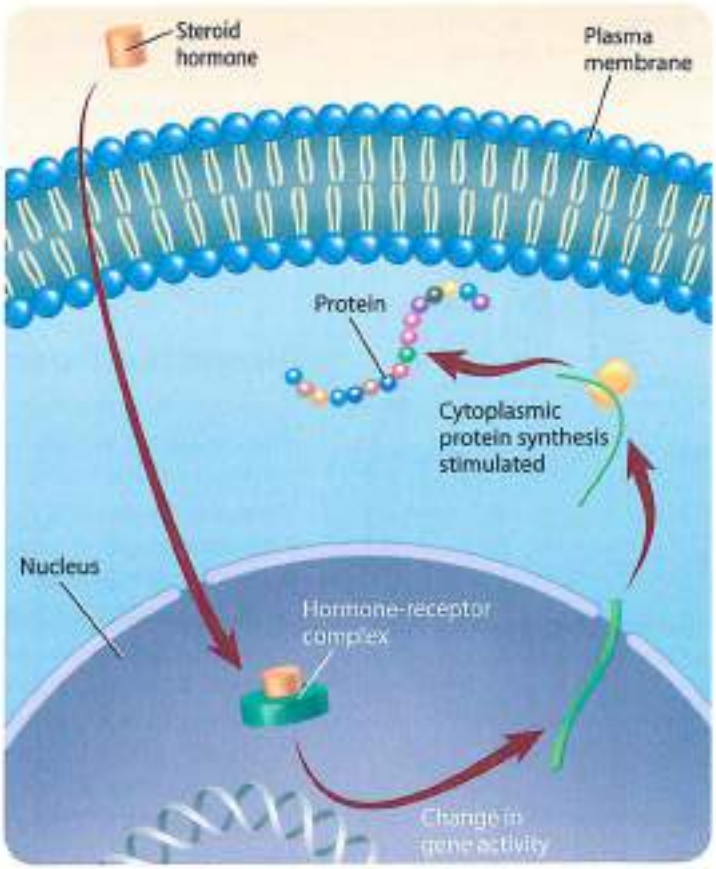


Figure 12 A steroid hormone passes through a cell membrane, binds to a receptor within the cell, and stimulates protein synthesis.

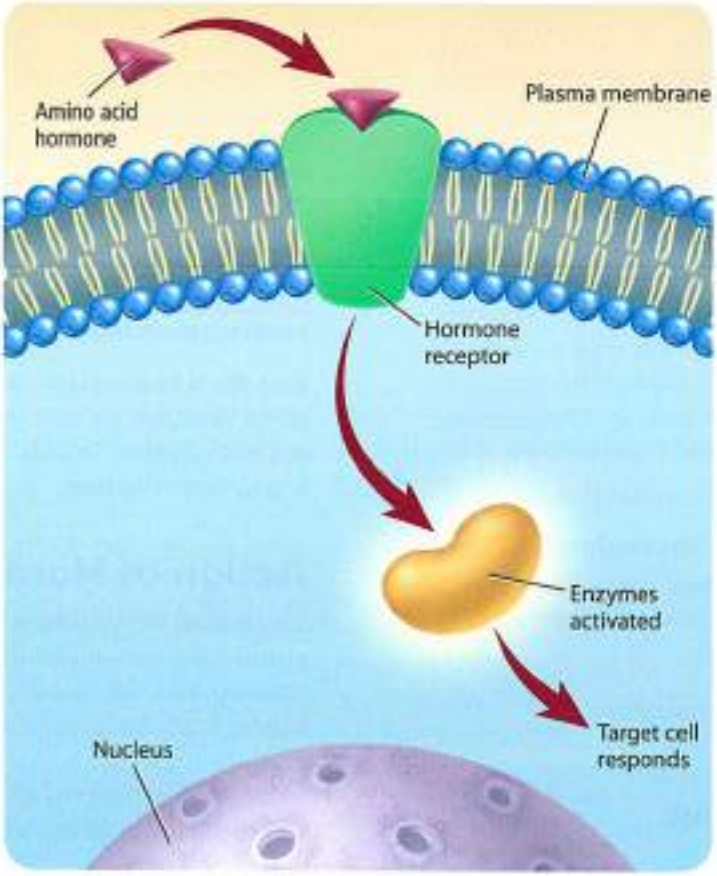


Figure 13 An amino acid hormone binds to a receptor on the plasma membrane before entering the cell.
Explain *the difference between amino acid hormones and steroid hormones.*

Steroid hormones are soluble in lipids and therefore can diffuse through the plasma membrane of a target cell. Once inside a target cell, they bind to a receptor in the cell. The hormone and the receptor that are bound together bind to DNA in the nucleus, which activates specific genes.

Amino acid hormones Insulin and growth hormones are two examples of nonsteroid, or amino acid, hormones. As the name implies, these hormones are composed of amino acids. Amino acid hormones must bind to receptors found on the plasma membrane of a target cell because they cannot diffuse through the plasma membrane. Once the hormone binds to the receptor, the receptor activates an enzyme found on the inside of the membrane. This usually initiates a biochemical pathway, eventually causing the cell to produce the desired response, as illustrated in **Figure 13.**

Negative Feedback

Homeostasis in the body is maintained by internal feedback mechanisms called negative feedback. Negative feedback returns a system to a set point once it deviates sufficiently from that set point. As a consequence, the system varies within a particular range. You already might be familiar with an example of a negative feedback system in your own home, as illustrated in **Figure 14.**

For example, the temperature in a house might be maintained at 21°C. The thermostat in the house detects the temperature, and when the temperature drops below 21°C, the thermostat sends a signal to the heat source, which turns it on and produces more heat. Soon the temperature rises above 21°C, and the thermostat sends a signal to the heat source to shut off. The heat source will not turn on again until the room temperature drops below 21°C and is detected by the thermostat. Because this process can go on indefinitely, negative feedback often is described as a loop.

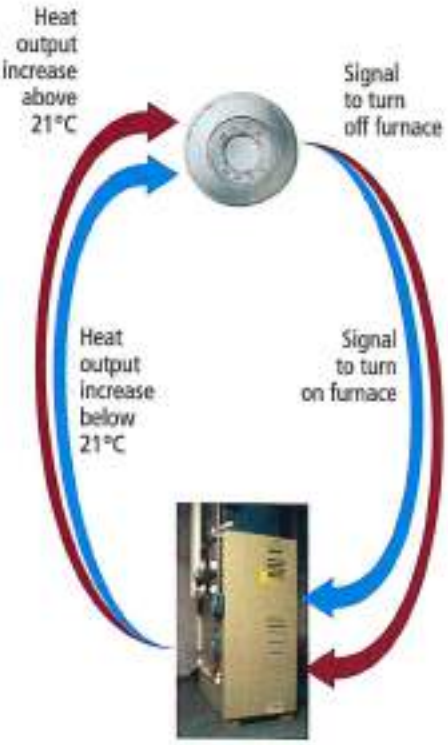
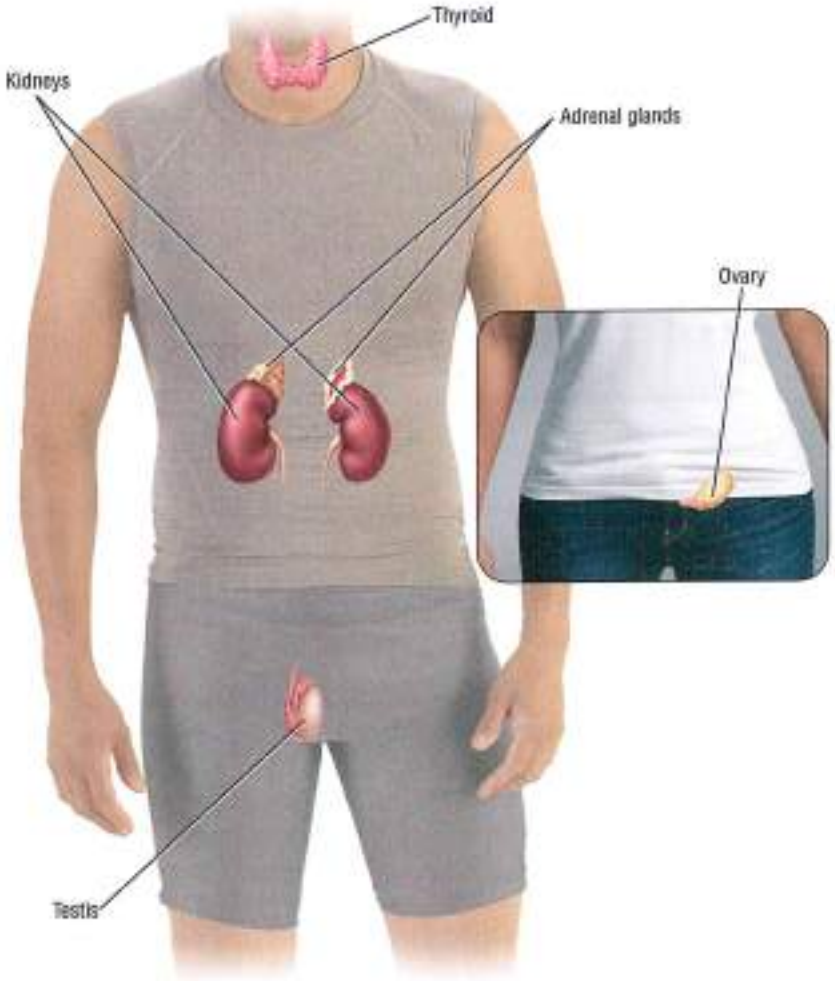


Figure 14 A furnace turns on or off based on the relationship of the detected room temperature and the set point.

■ **Figure 15** The principal glands of the endocrine system are located throughout the body.



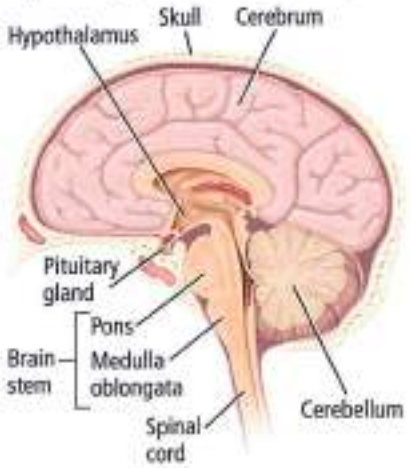
Endocrine Glands and Their Hormones

The endocrine system, shown in **Figure 15,** includes all the glands that secrete hormones–pituitary, thyroid, parathyroid, and adrenal glands, the pancreas, ovaries, testes, pineal gland, and the thymus gland.

Pituitary gland The pituitary gland is situated at the base of the brain, as illustrated in **Figure 16.** This gland is sometimes called the "master gland" because it regulates so many body functions. Despite its small size, it is the most important endocrine gland. The **pituitary gland** secretes hormones that not only regulate many body functions but also regulates other endocrine glands, such as the thyroid gland, the adrenal glands, the testes, and the ovaries.

A few pituitary hormones act on tissues rather than on specific organs. Human growth hormone (hGH) regulates the body's physical growth by stimulating cell division in muscle and bone tissue. This hormone is especially active during childhood and adolescence.

■ **Figure 16** The pituitary gland is located at the base of the brain. This gland has a diameter of approximately 1 cm and weighs 0.5–1 g.



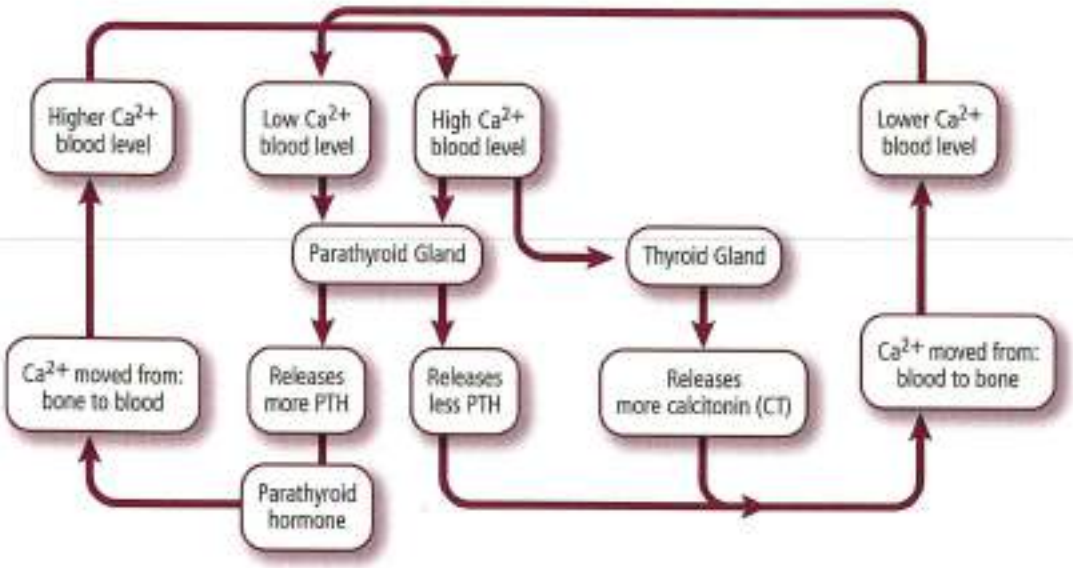


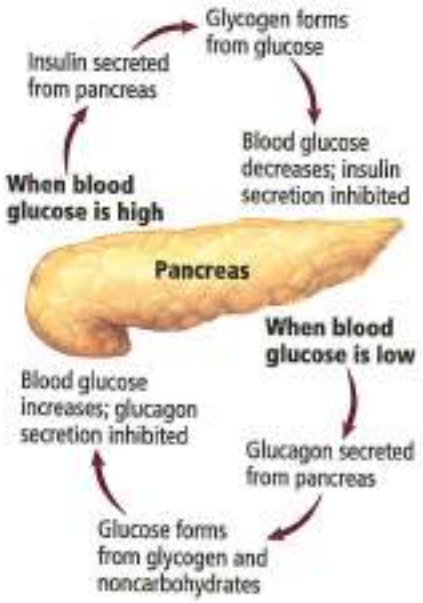
Figure 17 Parathyroid hormone (PTH) and calcitonin (CT) regulate the level of calcium in the blood.
Explain *how PTH and CT illustrate negative feedback.*

Thyroid and parathyroid glands Identify the thyroid and parathyroid glands in **Figure 17.** One hormone produced by the thyroid gland is thyroxine. Like hGH, **thyroxine** does not act on specific organs; rather, it causes cells of the body to have a higher rate of metabolism. The thyroid gland also produces calcitonin. **Calcitonin** is a hormone that is partly responsible for the regulation of calcium, an important mineral for bone formation, blood clotting, nerve function, and muscle contraction. Calcitonin lowers blood calcium levels by signaling bones to increase calcium absorption and also signaling the kidneys to excrete more calcium.

When blood calcium levels are too low, the parathyroid glands increase production of parathyroid hormone. **Parathyroid hormone** increases blood calcium levels by stimulating the bones to release calcium. The action of this hormone also causes the kidneys to reabsorb more calcium and the intestines to absorb more calcium from food. The thyroid and parathyroid glands have opposite effects on blood calcium levels. However, as they work together, they maintain homeostasis.

Reading Check **Explain** how negative feedback is important in maintaining homeostasis.

Figure 18 Glucagon and insulin work together to maintain the level of sugar in the blood.



Pancreas As discussed in Section 1, the pancreas has a crucial role in the production of enzymes that digest carbohydrates, proteins, and fats. The pancreas also secretes the hormones insulin and glucagon, which work together to maintain homeostasis, as illustrated in **Figure 18.** When blood glucose levels are high, the pancreas releases insulin. **Insulin** signals body cells, especially liver and muscle cells, to accelerate the conversion of glucose to glycogen, which is stored in the liver. When blood glucose levels are low, glucagon is released from the pancreas. **Glucagon** binds to liver cells, signaling them to convert glycogen to glucose and release the glucose into the blood.

Diabetes is a disease that results from the body not producing enough insulin or not properly using insulin. Type 1 diabetes, which usually appears in people by the age of 20, occurs when the body cannot produce insulin. Type 2 diabetes occurs in 70–80 percent of people diagnosed with diabetes, and usually occurs after the age of 40. It results from the cells of the body becoming insensitive to insulin. Complications from diabetes include coronary heart disease, retinal and nerve damage, and acidosis, or low blood pH. In both types of diabetes, the blood glucose levels must be monitored and maintained to prevent complications from the disease.

Adrenal glands Refer again to **Figure 15.** The adrenal glands are located just above the kidneys. The outer part of the adrenals is called the cortex, which manufactures the steroid hormone aldosterone and a group of hormones called glucocorticoids. **Aldosterone** primarily affects the kidneys and is important for reabsorbing sodium. **Cortisol,** another glucocorticoid, raises blood glucose levels and also reduces inflammation.

The body has different mechanisms for responding to stress, such as those concerning the role of the nervous system and the "fight or flight response." The endocrine system also is involved with these types of responses. An "adrenaline rush" occurs when there seems to be a sudden burst of energy during a stressful situation. The inner portions of the adrenal glands secrete epinephrine, also called adrenaline, and norepinephrine. Together, these hormones increase heart rate, blood pressure, breathing rate, and blood sugar levels, all of which are important in increasing the activity of body cells.

CAREERS IN BIOLOGY

Endocrinologist An endocrinologist studies glands that secrete hormones and the diseases involving those glands.

FOLDABLES®
Incorporate information from this section into your Foldable.

Mini Lab 2

Model the Endocrine System

How do hormones help the body maintain homeostasis? Activities such as taking a test or running a race place demands on your body. Your body's responses to these demands cause changes in your body. Your endocrine and nervous systems work together to ensure a stable internal environment.

Procedure

1. Identify the safety concerns of this lab before work begins.
2. Identify a sport or activity. Brainstorm what body actions occur as you prepare for, take part in, and recover from the activity.
3. Imagine that you are writing a computer program that your body will follow to complete the activity. Sequence the steps that you brainstormed in Step 2.
4. Review your program. Insert steps where the endocrine system might secrete hormones to maintain homeostasis. Use your knowledge and available resources to identify the specific hormones involved. Include body responses to these hormones as separate steps.
5. Compare your program with those developed by other students.

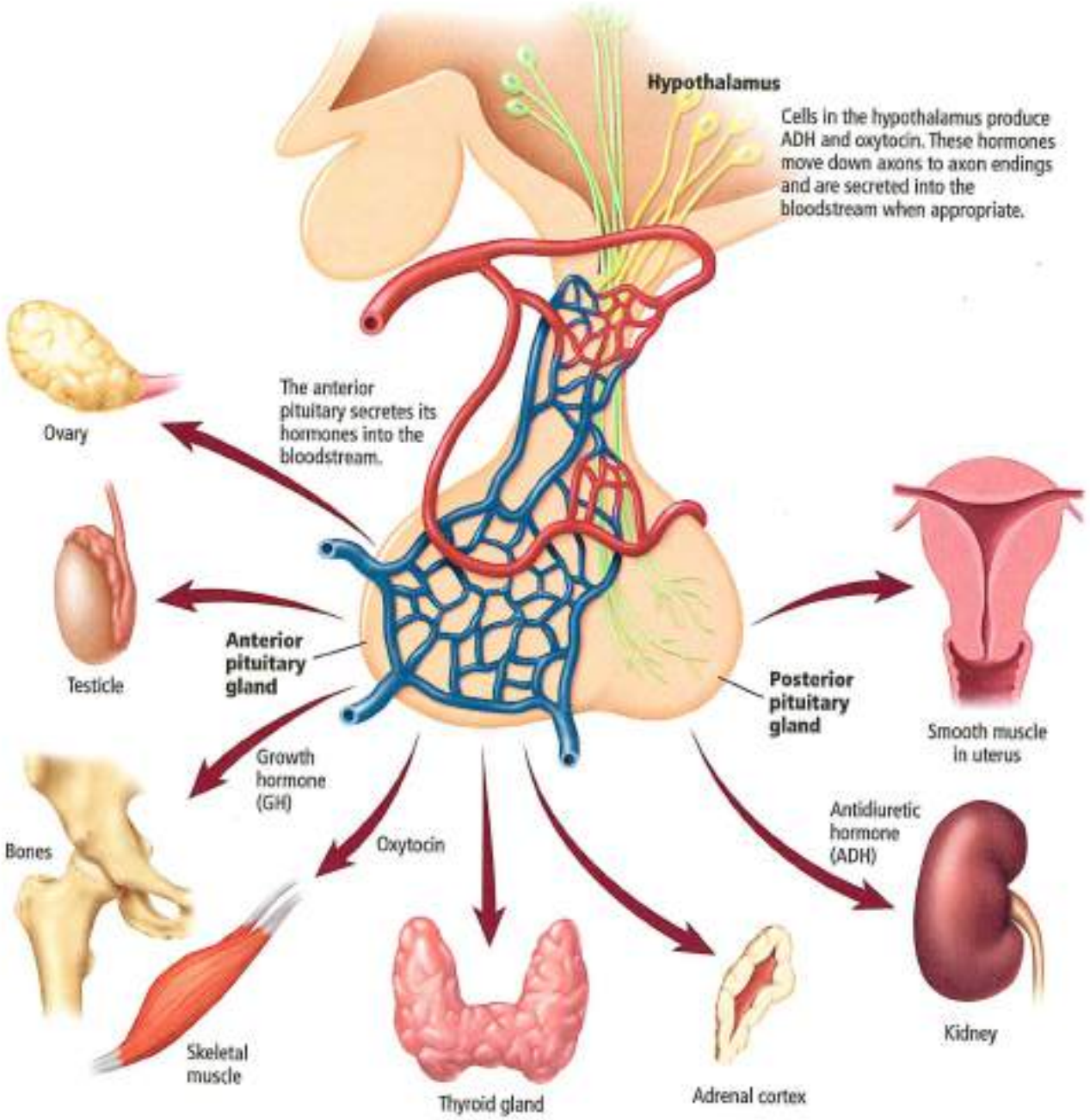
Analysis

1. **Think Critically** Did some of the same hormones appear in most of the other programs that you studied in Step 5? Why or why not?
2. **Draw conclusions** by describing the major body systems represented in your program. What does this show about the range of body functions controlled by the endocrine system?

Visualizing the Endocrine System

Figure 19

The hypothalamus maintains homeostasis by serving as a link between the nervous system and the endocrine system. The pituitary releases growth hormone, ADH, and oxytocin as needed by the body. The pituitary gland also manufactures and secretes hormones that regulate the testes, the ovaries, and the thyroid and adrenal glands.



Link to the Nervous System

The nervous and endocrine systems are similar in that they both are involved in regulating the activities of the body and maintaining homeostasis. Refer to **Figure 19** to study the role of the hypothalamus in homeostasis. Recall that this part of the brain is involved with many aspects of homeostasis. The hypothalamus produces two hormones, oxytocin and antidiuretic hormone (ADH). These hormones are transported through axons and stored in axon endings located in the pituitary gland.

The **antidiuretic hormone** functions in homeostasis by regulating water balance. ADH affects portions of the kidneys called the collecting tubules. Think back to the last time you were working outside on a hot summer day. You produced a lot of sweat to help keep you cool, and you might have become dehydrated. When this happens, cells in your hypothalamus detect that you are dehydrated–that the level of water in the blood is low–and respond by releasing ADH from axons in the pituitary gland that have been storing the hormone.

As illustrated in **Figure 20,** ADH travels in the blood to the kidneys, where it binds to receptors on certain kidney cells. This causes the kidneys to reabsorb more water and decrease the amount of water in the urine, increasing the water level in the blood. If there is too much water in a person's blood, the hypothalamus decreases the release of ADH, and the urine tends to be more dilute. ADH production is stimulated by nausea and vomiting, both of which cause dehydration. Blood loss of 15 or 20 percent by hemorrhage results in the release of ADH.

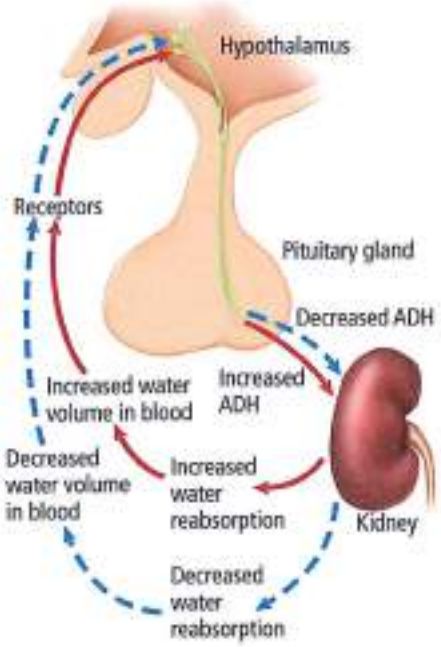


Figure 20 Antidiuretic hormone (ADH) helps to control the concentration of water in the blood.

Section 3 Assessment

Section Summary

- Endocrine glands produce substances called hormones.
- Hormones travel throughout the body in the bloodstream.
- Hormones are classified as steroid hormones or amino acid hormones.
- Hormone levels are influenced by feedback systems.
- The endocrine system helps to maintain homeostasis with signals from internal mechanisms called negative feedback.

Understand Main Ideas

1. MAIN Idea **Assess** the reasons why hormone feedback systems are referred to as "negative feedback."
2. **Predict** when you would expect to find high levels of insulin in a person's blood and when you would expect to find high levels of glucagon in a person's blood.
3. **Explain** how the endocrine and nervous systems work together to maintain homeostasis.
4. **Identify** and describe the functions of pituitary, thyroid, parathyroid, pancreas, and adrenal glands.

Think Critically

5. **Research** Iodine is essential for thyroid gland function. Fetal and childhood iodine deficiency is a major cause of mental retardation in the world, yet the deficiency is preventable. Predict how iodine deficiency might lead to mental retardation or other health issues. Research what has been and what is being done to alleviate this concern. Include information about sources of iodine in your response.
6. **Analyze** how a malfunction in a negative feedback mechanism can lead to the death of an organism.

In the Field

Careers: Forensic Pathologist and Forensic Toxicologist

Tools and Techniques of Forensic Pathology

The condition of a dead body can speak volumes about the circumstances surrounding the death. Forensic pathologists gather data from a body, then analyze it to determine when and how a person died. The tools, techniques, and scientific methods that forensic pathologists use help investigators plot the last hours of a person's life, as well as the events that led to death.

Digestion and time of death During an autopsy, the pathologist examines the victim's stomach contents. Why is this important? At the moment of death, digestion stops. The pathologist can use the condition of the stomach to estimate a time line. If the stomach is entirely empty, the victim probably died at least three hours after he or she last ate. If the small intestine also is empty, death likely occurred at least ten hours after the last meal.

Is it possible to identify the type of food in the stomach? In some cases, yes. A scanning electron microscope can be used to identify food particles. A stomach sample that matches the last known meal also can help investigators establish a time period.

A brain slice might be used to determine a cause of death.

Stomach contents can reveal poisoning Toxic substances such as household products, poisons, and drugs can be involved in a death. A forensic toxicologist, a specialist who can identify foreign chemicals that can lead to death, might be called.

While one piece of evidence rarely serves as conclusive proof, forensic pathologists are trained to note specific details. These details can add up and sometimes help tell the story of the final hours of a person's life.

WRITING in Biology

Classifieds Your city has an opening for a forensic pathologist. Write an advertisement for the job. Be sure to include specific techniques and procedures with which applicants should be familiar, as well as general skills and characteristics applicants should have.

BIOLAB

Design Your Own

HOW DOES THE RATE OF STARCH DIGESTION COMPARE AMONG CRACKERS?

Background: **Starch digestion begins in the mouth. The enzyme amylase, present in saliva, catalyzes the breakdown of starch into sugar molecules, the smallest of which is glucose, an important energy source. Foods, including crackers, vary in starch content. In this lab, you will compare how quickly starch is digested in several types of crackers to determine the relative amount in each.**

Question: *How does the amount of time required for starch digestion by amylase compare among various types of crackers?*

Possible Materials

variety of crackers
mortar and pestle
test tubes and test tube rack
filter paper
funnels
balance
beaker
Bunsen burner or hot plate
graduated cylinder
iodine solution
droppers
watch glasses
amylase solution
glass markers or wax pencil

Safety Precautions

WARNING: ***Iodine can irritate and will stain skin.***

Plan and Perform the Experiment

1. Discuss the safety concerns of this lab before work begins.
2. Examine three types of crackers. Design an experiment to compare the amount of time required to digest the starch in each. You will use the enzyme amylase to stimulate the digestion of starch. Iodine, a chemical indicator that turns blue-black when starch is present, will indicate when starch digestion is complete.
3. Construct a data chart to record your observations.
4. Consider these points with your group and modify the plan as necessary.
   - What factors will be held constant?
   - Have you established a control sample?
   - How will you know when starch digestion is complete in each sample?
   - How will you keep constant the amount of each type of cracker tested?
   - Will the chart accommodate your data?
5. Make sure your teacher approves your plan before you proceed.
6. Carry out your experiment.
7. **Cleanup and Disposal** Dispose of test tube contents as directed. Clean and return glassware and equipment. Wash your hands thoroughly after handling chemicals and glassware.

Analyze and Conclude

1. **Analyze** how the amylase affected the starch in the crackers.
2. **Observe and Infer** In which cracker was starch digested most quickly? What does this indicate about the amount of starch in this cracker compared to the others?
3. **Think Critically** What variations among human mouths might affect the action of amylase on starch? Explain.
4. **Error Analysis** Did any steps in your procedure introduce uncontrolled variables into the experiment? Explain how the procedure could be redesigned to make these factors constant.

APPLY YOUR SKILL

Design an experiment to determine how varying a condition such as temperature or pH would affect the digestion of starch by amylase in one of the crackers.

Chapter 3 Study Guide

THEME FOCUS Homeostasis Homeostasis is maintained by negative feedback in glands such as the thyroid, parathyroid, pancreas, and adrenal glands.

BIG Idea **The digestive system breaks down food to provide energy and nutrients for the body. The endocrine system produces hormones that regulate body functions.**

Section 1 The Digestive System

mechanical digestion
chemical digestion
amylase
esophagus
peristalsis
pepsin
small intestine
liver
villus
large intestine

MAIN Idea **The digestive system breaks down food so nutrients can be absorbed by the body.**

- The digestive system has three main functions.
- Digestion can be categorized as mechanical or chemical.
- Most nutrients are absorbed in the small intestine.
- Accessory organs provide enzymes and bile to aid digestion.
- Water is absorbed from chyme in the colon.

Section 2 Nutrition

nutrition
Calorie
vitamin
mineral

MAIN Idea **Certain nutrients are essential for the proper function of the body.**

- The energy content of food is measured in Calories.
- Carbohydrates, fats, and proteins are three major groups of nutrients.
- Carbohydrates are a major source of energy for the body.
- Fats and proteins provide energy and are important building blocks for the body.
- Vitamins and minerals are essential for proper metabolic functioning.
- Food labels are tools you can use to eat healthfully.

Section 3 The Endocrine System

endocrine gland
hormone
pituitary gland
thyroxine
calcitonin
parathyroid hormone
insulin
glucagon
aldosterone
cortisol
antidiuretic hormone

MAIN Idea **Systems of the human body are regulated by hormonal feedback mechanisms.**

- Endocrine glands produce substances called hormones.
- Hormones travel throughout the body in the bloodstream.
- Hormones are classified as steroid hormones or amino acid hormones.
- Hormone levels are influenced by feedback systems.
- The endocrine system helps to maintain homeostasis with signals from internal mechanisms called negative feedback.

Chapter 3 Assessment

Section 1

Vocabulary Review

For each set of terms, choose the one term that does not belong and explain why it does not belong.

1. esophagus, pancreas, large intestine

2. pepsin, glycogen, glucose

3. bile, amylase, peristalsis

Understand Main Ideas

4. Which action takes place in the stomach?
   - **A.** Large fat molecules are digested into smaller molecules.
   - **B.** Proteins are broken down.
   - **C.** Amylase breaks down starches into smaller sugar molecules.
   - **D.** Insulin is secreted for use in the small intestine.

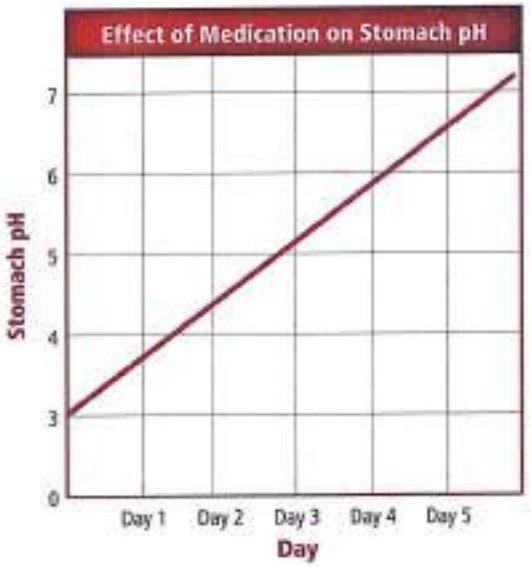
5. Which row in the chart contains the words that best complete this statement? The (1) produces (2), which is secreted into the (3).

Row	1	2	3
A	liver	bile	small intestine
B	gallbladder	pepsin	stomach
C	pancreas	acid	large intestine
D	villi	amylase	mouth

   - **A.** Row A
   - **B.** Row B
   - **C.** Row C
   - **D.** Row D

6. A person complaining of digestion problems is not digesting fats well. Which is a reasonable explanation for this condition?
   - **A.** The pyloric sphincter is blocked.
   - **B.** The bile duct is blocked.
   - **C.** The person is secreting excess bile.
   - **D.** The stomach is secreting too much acid.

Use the graph to answer question 7.



7. A person has been taking a medication for 5 days. Which of the following is likely to be a consequence of this medication?
   - **A.** Pepsin would not be able to break down proteins.
   - **B.** Amylase would not be able to break down starch.
   - **C.** Bile would not be able to be produced.
   - **D.** Enzymes secreted by the pancreas would not function well.

Constructed Response

8. **Short Answer** Explain why the term *heartburn* is an inaccurate description of this condition.

9. MAIN Idea Refer to **Table 1** to summarize the digestive processes that occur in the following structures: mouth, large intestine, stomach, small intestine, and esophagus.

10. **Open Ended** Why can a person live without a gall bladder? Assess the effects, if any, that this would have on the person's ability to digest food.

Think Critically

11. **Explain** why a drug manufacturer might add vitamin K to some antibiotics in tablet or pill form.

12. **Hypothesize** why the human body has an appendix if the appendage has no known useful function.

Chapter 3 Assessment

Section 2

Vocabulary Review

Describe each of the following vocabulary terms.

13. nutrition

14. vitamin

15. Calorie

Understand Main Ideas

16. Which are characteristics of saturated fats?
- **A.** liquid at room temperature and found in vegetable oils
- **B.** mostly absorbed in the large intestine
- **C.** derived from animal sources and are solid at room temperature
- **D.** tend to lower blood cholesterol

17. Which carbohydrate is not digestible and provides fiber in your diet?
- **A.** sucrose
- **B.** starch
- **C.** glycogen
- **D.** cellulose

18. Which combinations in the stomach break down high-protein foods?
- **A.** a low pH and pepsin
- **B.** a high pH and bile
- **C.** a high pH and pepsin
- **D.** a low pH and bile

Use the image below to answer question 19.

19. If you ate the entire bag of chips, what percent of the recommended daily value of saturated fat would you consume?
- **A.** 14 percent
- **B.** 28 percent
- **C.** 5 percent
- **D.** 35 percent

Constructed Response

20. **CAREERS IN BIOLOGY** According to dieticians, low-carbohydrate diets are usually high in fat and protein. Evaluate what health risks might be associated with a long-term intake of foods high in fats and proteins.

21. MAIN Idea Describe what factors, besides not having enough food, might cause a person to be malnourished.

Think Critically

22. **Explain** why a diet high in fiber might reduce the chance of colon cancer.

23. **Infer** the reasons why obesity rates in some countries have continued to rise steadily for at least the past 30 years.

Section 3

Vocabulary Review

Explain the difference between the terms in each pair. Then explain how the terms are related.

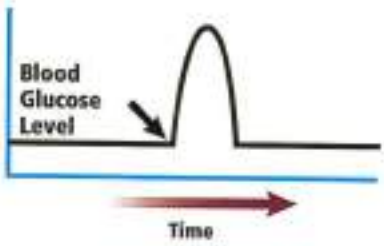
24. insulin, glucagon

25. estrogen, growth hormone

26. cortisol, epinephrine

Understand Main Ideas

Use the graph below to answer question 27.



27. The graph shows blood glucose levels over a period of time. Which hormone might have caused a sudden surge as indicated by the arrow?
- **A.** antidiuretic hormone
- **B.** growth hormone
- **C.** glucagon
- **D.** insulin

28. Which hormones are released from nerve cells rather than from endocrine glands?
- **A.** antidiuretic hormone and oxytocin
- **B.** growth hormone and thyroxine
- **C.** insulin and glucagon
- **D.** norepinephrine and epinephrine

29. Which pairs of hormones have opposite effects?
- **A.** calcitonin and parathyroid hormone
- **B.** epinephrine and norepinephrine
- **C.** growth hormone and thyroxine
- **D.** aldosterone and cortisol

Use the photos below to answer question 30.

A.

B.

30. Which person is likely to have high levels of epinephrine?
- **A.** person A
- **B.** person B
- **C.** both persons
- **D.** neither person

Constructed Response

31. **THEME FOCUS Homeostasis** What would be the direct effect of overproduction of calcitonin? Analyze how this might disrupt homeostasis in systems other than the endocrine system.

32. **Short Answer** Assess how the long-term use of cortisol would impact a person's ability to fight infection.

Think Critically

33. **MAIN Idea** Create an analogy using a balance describing the relationship between calcitonin and parathyroid hormone.

34. **Hypothesize** Why is insulin usually injected instead of taken orally?

Summative Assessment

35. **BIG Idea** Breakfast is considered the most important meal of the day. Based on the food pyramid, plan a balanced breakfast and explain why the nutrients are important. Then describe the processes that will take place in your digestive and endocrine systems after you have eaten. Why is breakfast so important?

36. **WRITING in Biology** This chapter began with a situation where you were eating a pizza. Write a short story describing the events that occur as the food moves through your digestive tract. *Hint: Be sure to include all major groups of nutrients.*

DBQ Document-Based Questions

Source: *Dietary Guidelines for America 2005*

Estimated Calorie Requirements in Gender and Age Groups

Gender	Age	Moderately Active	Active
Female	9–13	1600–2000	1800–2200
	14–18	2000	2400
	19–30	2000–2200	2400
	31–50	2000	2200
	51+	1800	2000–2200
Male	9–13	1800–2200	2000–2600
	14–18	2400–2800	2800–3200
	19–30	2600–2800	3000
	31–50	2400–2600	2800–3000
	51+	2400	2400–2800

37. According to the chart, which gender needs more Calories?

38. Describe the general trend regarding the number of Calories needed to maintain energy balance in relation to age.

39. Why do individuals in the 19-30-year-old group need the most Calories?

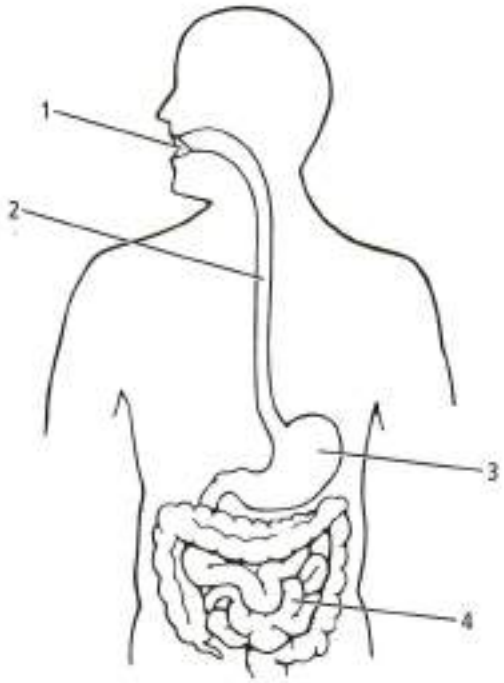
Standardized Test Practice

Cumulative

Multiple Choice aligned with PISA study skills

1. What is the function of melanin in the epidermis?
   - **A.** to protect tissue from ultraviolet radiation
   - **B.** to provide support for blood vessels
   - **C.** to stimulate the growth of hair in the follicles
   - **D.** to waterproof and protect the skin surface

Use the diagram below to answer questions 2 and 3.

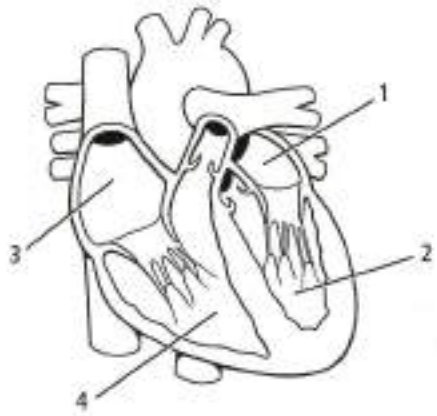


2. In which part of the digestive system do chemical and mechanical digestion first occur?
   - **A.** 1
   - **B.** 2
   - **C.** 3
   - **D.** 4

3. Which process happens first in a nerve cell when a stimulus reaches its threshold?
   - **A.** Potassium channels in the cell membrane open.
   - **B.** Neurotransmitters are released into the synapse.
   - **C.** Sodium ions move into the nerve cell.
   - **D.** The cell becomes negatively charged.

4. Where would fat stored in bones be found?
   - **A.** compact bone
   - **B.** osteocytes
   - **C.** red marrow
   - **D.** yellow marrow

Use the diagram below to answer question 5.



5. Which is the path that blood follows as it flows through the heart immediately after returning from the head and body?
   - **A.** $1 \rightarrow 2$
   - **B.** $2 \rightarrow 1$
   - **C.** $3 \rightarrow 4$
   - **D.** $4 \rightarrow 3$

6. Which describes how filtering occurs in the excretory system?
   - **A.** Blood enters nephrons of the kidneys, and excess water and wastes are filtered from the blood.
   - **B.** Urine leaves the kidneys through ureters.
   - **C.** Water and nutrients are absorbed back into the blood.
   - **D.** Water is added to excess nitrogenous wastes from the digestive system to form urine.

Short Answer aligned with SAT exam skills

Use the graph below to answer questions 7 and 8.

7. Compare and contrast the feeding behavior of the fishes shown in the graph.

8. Predict how the graph might appear if the territorial fish showed territorial behavior only during one season of the year.

9. Assess why a diet with no protein would be unhealthy.

10. What are two benefits to the young of mammals in receiving milk from their mothers?

11. Explain how the different body structures in roundworms and annelids enable them to move.

12. A person who exercises in extreme heat can lose salts that contain potassium and sodium through his or her sweat. What can you infer about the effect of overexertion on the nervous system?

13. Differentiate the three main vessels through which blood flows as it goes from the heart through the body and returns to the heart.

Extended Response aligned with SAT exam skills

14. Evaluate how a swim bladder helps a fish maintain its depth.

15. Evaluate how high blood pressure and kidney damage could be related.

16. Name three components of sympathetic stimulation, and assess how they could be helpful to a human's survival.

Essay Questions aligned with SAT exam skills

Humans need vitamin C in their diets because it strengthens the function of the immune system and prevents a disease called scurvy. Vitamin C is water-soluble, so it is not stored in the body. Vitamin C is often suggested for someone who is just getting sick or is already sick. Some people recommend taking very high doses of vitamin C, sometimes even thousands of times higher than the recommended dose. Medical researchers disagree about the effectiveness of taking large doses of vitamin C. Some think that it does nothing, while others think that it is helpful. However, almost all medical researchers agree that taking large doses of vitamin C for short periods of time is probably not harmful.

Using the information in the paragraph above, answer the following question in essay format.

17. Formulate a hypothesis about whether taking large doses of vitamin C for a cold is helpful. Explain one way this hypothesis could be tested.

Student Resources

For students and parents/guardians

Investigation and experimentation are key components of your biology class. Use this reference to learn lab techniques that will enhance your lab experience. Laboratory safety is vital to a successful investigation and experiment; we've outlined basic laboratory safety principles here.

The skillbuilder handbook helps you sharpen your problem-solving skills so you can get the most out of reading and understanding scientific writing and data. Improving skills such as making comparisons, analyzing information, reading time lines, and using graphic organizers also can help you boost your test scores.

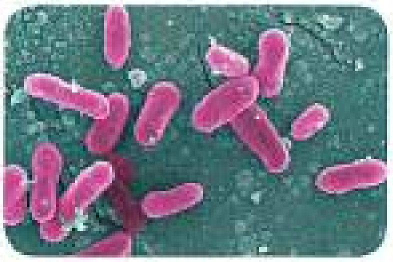
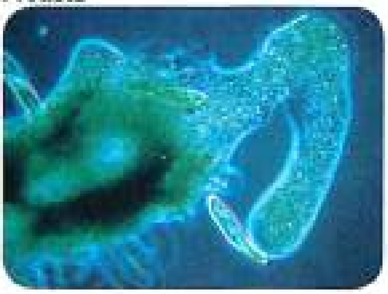
The reference handbook is another tool that will assist you. The classification tables, word origins, and the periodic table of the elements are resources that will help increase your comprehension.

Table of Contents

Six-Kingdom Classification

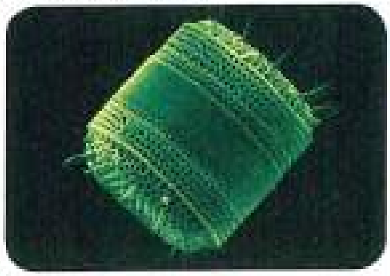
The classification used in this text combines information gathered from the systems of many different fields of biology. For example, phycologists–biologists who study algae–have developed their own system of classification, as have mycologists–biologists who study fungi. The naming of animals and plants is controlled by two completely different sets of rules. The six-kingdom system, although not ideal for reflecting the phylogeny of all life, is useful for showing relationships. Taxonomy is an area of biology that evolves just like the species it studies. In **Table 1**, only the major phyla are listed, and one genus is named as an example. For more information about each taxon, refer to the chapter in the text in which the group is described.

Table 1 **Six-Kingdom Classification**

Kingdom	Phylum/Division* (Common Name)	Typical Example (Common Name)	Characteristics
Bacteria  *Salmonella*	Actinobacteria	*Mycobacterium*	• unicellular • most absorb food from surroundings • some are photosynthetic • some are chemosynthetic • many are parasites • many are round, spiral, or rod-shaped • some form colonies
	Omnibacteria	*Salmonella* (salmonella)	
	Spirochaetae (spirochetes)	*Treponema*	
	Chloroxybacteria	*Prochloron*	
	Cyanobacteria (blue green algae)	*Nostoc* (nostoc)	
Archaea  *Methanococcus jannaschii*	Aphragmabacteria	*Mycoplasma*	• unicellular • some absorb food from surroundings • some are photosynthetic • some are chemosynthetic • many are found in extremely harsh environments including salt ponds, hot springs, swamps, and deep-sea hydrothermal vents
	Halobacteria	*Halobacterium*	
	Methanocreatrices	*Methanobacillus*	
Protista  *Amoeba*	Sarcodina (amoeba)	*Amoeba* (amoeba)	• unicellular • take in food • free-living or parasitic • move by means of pseudopods
	Ciliophora (ciliates)	*Paramecium* (paramecium)	• unicellular • take in food • have large numbers of cilia
	Apicomplexa (apicomplexan)	*Plasmodium* (plasmodium)	• unicellular • take in food • no means of movement • are parasites in animals

*In the Kingdom Plantae the major phyla are referred to as "divisions."

Kingdom	Phylum/Division* (Common Name)	Typical Example (Common Name)	Characteristics
Protista *(continued)*	Zoomastigina (zooflagellates)	*Trypanosoma*	• unicellular • take in food • free-living or parasitic • have one or more flagella
	Euglenophyta (euglenoids)	*Euglena* (euglena)	• unicellular • photosynthetic or take in food • most have one flagellum
	Bacillariophyta (diatoms)	*Navicula*	• unicellular • photosynthetic • have unique double shells made of silica
	Pyrrophyta (dinoflagellates)	*Gonyaulax*	• unicellular • photosynthetic • contain red pigments • have two flagella
	Rhodophyta (red algae)	*Chondrus*	• most are multicellular • photosynthetic • contain red pigments • most live in deep, salt water
	Phaeophyta (brown algae)	*Laminaria*	• most are multicellular • photosynthetic • contain brown pigments • most live in salt water
	Chlorophyta (green algae)	*Ulva*	• unicellular, multicellular, or colonies • photosynthetic • contain chlorophyll • live on land, in freshwater, or salt water
	Acrasiomycota (cellular slime mold)	*Dictyostelium*	• unicellular or multicellular • absorb food • change form during life cycle • cellular and plasmodial slime molds
	Myxomycota (acellular slime mold)	*Physarum*	
	Oomycota (water mold/ downy mildew	*Phytophthora*	• multicellular • are either parasites or decomposers • live in freshwater or salt water


Diatom


Red algae


Slime mold

*In the Kingdom Plantae the major phyla are referred to as "divisions."

Reference Handbook

Kingdom	Phylum/Division* (Common Name)	Typical Example (Common Name)	Characteristics
Fungi  Bread mold	Zygomycota (common mold)	*Rhizopus* (bread mold)	• multicellular • absorb food • spores are produced in sporangia
	Ascomycota (sac fungi)	*Saccharomyces* (yeast)	• unicellular and multicellular • absorb food • spores produced in asci
	Basidiomycota (club fungi)	*Crucibulum* (bird's nest fungus)	• multicellular • absorb food • spores produced in basidia
	Deuteromycota (imperfect fungi)	*Penicillium* (penicillum)	• members with unknown reproductive structures • imperfect fungi
	Chytridiomycota	*Chytridium* (chrytid)	• some are saprobes • some parasitize protists, plants, and animals
Plantae  Liverwort	Hepaticophyta (liverworts)	*Monosolenium* (Pellia)	• multicellular nonvascular plants • reproduce by spores produced in capsules • green • grow in moist, land environments
	Anthocerophyta (hornworts)	*Anthoceros*	
	Bryophyta (moss)	*Polytrichum* (haircap moss)	
	Lycophyta (club moss)	*Lycopodium* (wolf's claw)	• multicellular vascular plants • spores are produced in cone-like structures • live on land • photosynthetic
	Arthrophyta	*Equisetum* (horsetails)	• vascular plants • ribbed and jointed stems • scale-like leaves • spores produced in cone-like structures
 Wood fern	Pterophyta (ferns)	*Polypodium* (ferns)	• vascular plants • leaves called fronds • spores produce in clusters or sporangia called sori • live on land or in water
	Ginkgophyta (ginko)	*Ginkgo* (ginko)	• deciduous trees • only one living species • have fan-shaped leaves with branching veins and fleshy cones with seeds

*In the Kingdom Plantae the major phyla are referred to as "divisions."

Kingdom	Phylum/Division* (Common Name)	Typical Example (Common Name)	Characteristics
Plantae *(continued)*  Welwitschia	Cycadophyta (cycad)	*Cyas* (palm tree)	• palm-like plants • have large, feather-like leaves • produce seeds in cones
	Coniferophyta (conifer)	*Pinus* (pine tree)	• deciduous or evergreen • trees or shrubs • needle-like or scale-like leaves • seeds produced in cones
	Gnetophyta (gnetophyte)	*Welwitschia* (welwitschia)	• shrubs or woody vines • seeds produced in cones • division contains only three genera
	Anthophyta (flowering plant)	*Rhododendron* (rhododendron)	• dominant group of plants • flowering plants • have fruit with seeds
Animalia  Sponge	Porifera (sponges)	*Spongilla* (sponge)	• aquatic organisms that lack true tissues and organs • asymmetrical and sessile
	Cnidaria (cnidarians)	*Hydra* (hydra)	• radially symmetrical • digestive cavity with one opening • most have tentacles armed with stinging cells • live in aquatic environments singly or in colonies
	Platyhelminthes (flatworms)	*Dugesia* (planaria)	• unsegmented, bilaterally symmetrical • no body cavity • digestive cavity, if present, has only one opening • parasitic and free-living species
 Abalone	Nematoda (roundworms)	*Trichinella* (trichinella)	• pseudocoelomate, unsegmented, bilaterally symmetrical • tubular digestive tract • without cilia • live in great numbers in soil and aquatic sediments
	Mollusca (mollusks)	*Nautilus* (nautilus)	• soft-bodied coelomates • bodies are divided into three parts: head-foot, visceral mass, and mantle • many have shells • almost all have a radula • aquatic and terrestrial species

*In the Kingdom Plantae the major phyla are referred to as "divisions."

Reference Handbook

Kingdom	Phylum/Division* (Common Name)	Typical Example (Common Name)	Characteristics
Animalia *(continued)*  Sand dollar	Annelida (segmented worms)	*Hirudo* (leech)	• coelomate, serially segmented, bilaterally symmetrical • complete digestive tract • most have setae on each segment that anchor them during crawling • terrestrial and aquatic species
	Arthropoda (arthropods)	*Colias* (butterflies)	• chitinous exoskeleton covering segmented bodies • paired, jointed appendages • many have wings • land and aquatic species
	Echinodermata (echinoderm)	*Cucumaria* (sea cucumber)	• marine organisms • have spiny or leathery skin and a water-vascular system with tube feet • radially symmetrical
	Chordata (chordates)		• segmented coelomates with a notochord • possess a dorsal nerve cord, pharyngeal slits, and a tail at some stage of life • most have paired appendages
 Sea otter	**Chordata Subphylum:** Urochordata	*Polycarpa* (sea squirt)	• young have all of the main chordate features; adults have only pharyngeal gill slits
	Chordata Subphylum: Cephalochordata	*Branchiostoma* (amphioxus)	• adults have all of the main features of chordates
	Chordata Subphylum: Vertebrata	*Panthera* (panther)	• the hallmark feature of all vertebrates is a spinal column

*In the Kingdom Plantae the major phyla are referred to as "divisions."

Three-Domain Classification

Increasingly, biologists are classifying organisms into categories larger than kingdoms called domains. The three domains are: Domain Bacteria, Domain Archaea, and Domain Eukarya. With future discoveries, this classification system might change to incorporate new information.

DOMAIN	Bacteria	Archaea	Eukarya			
KINGDOM	Bacteria	Archaea	Protista	Fungi	Plantae	Animalia

Scientific Word Origins

This list of prefixes, suffixes, and roots is provided to help you understand science terms used throughout this biology textbook. The list identifies whether the prefix, suffix, or root is of Greek *(G)* or Latin *(L)* origin. Also listed is the meaning of the prefix, suffix, or root and a science word in which it is used.

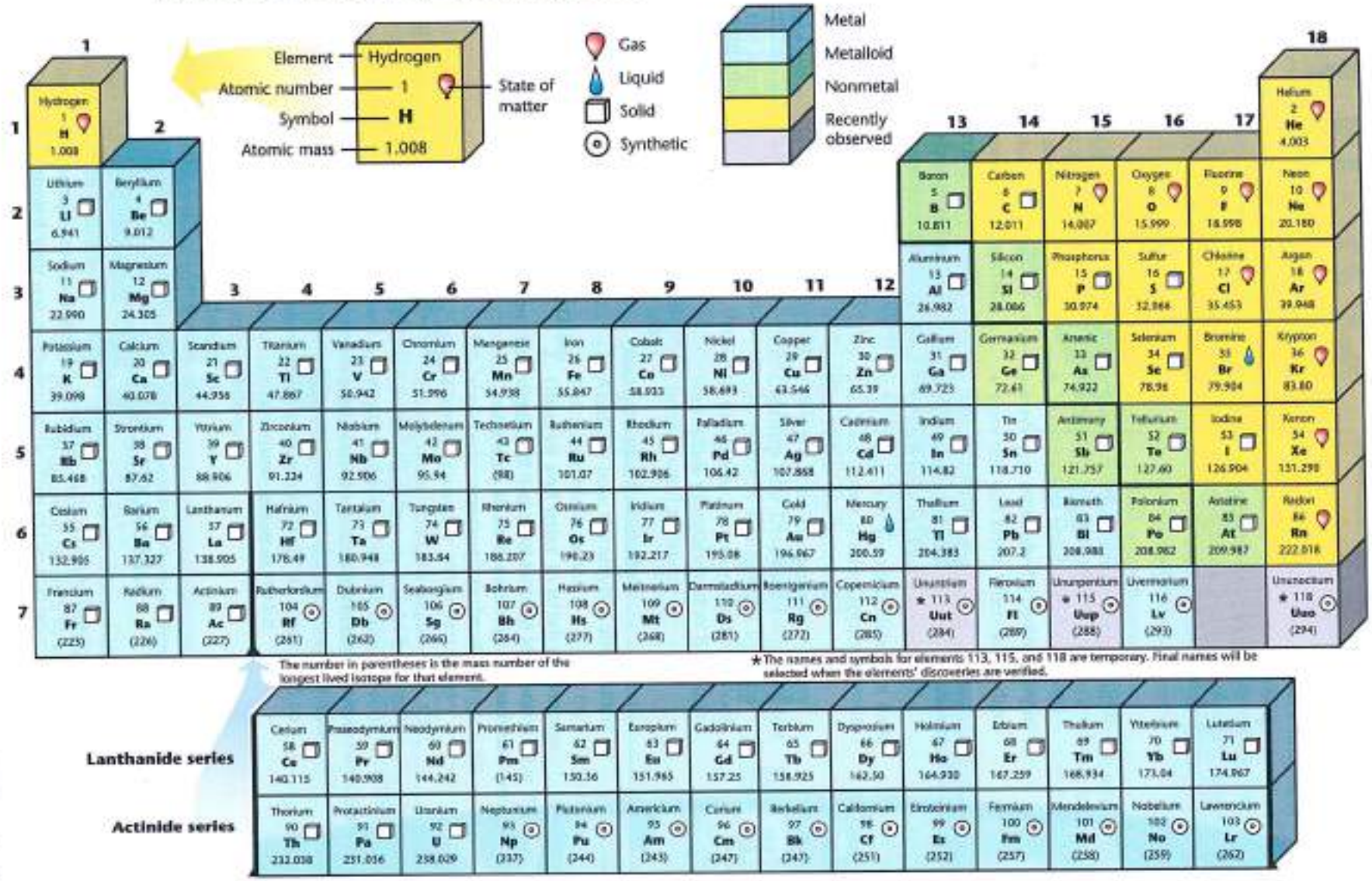
Origin	Meaning	Example
A		
ad *(L)*	to, toward	adaxial
aero *(G)*	air	aerobic
an *(G)*	without	anaerobic
ana *(G)*	up	anaphase
andro *(G)*	male	androceium
angio *(G)*	of seed	angiosperm
anth/o *(G)*	flower	anthophyte
anti *(G)*	against	antibody
aqu/a *(L)*	of water	aquatic
archae *(G)*	ancient	archaeologist
arthro, artio *(G)*	jointed	arthropod
askos *(G)*	bag	ascospore
aster *(G)*	star	Asteroidea
autos *(G)*	self	autoimmune
B		
bi *(L)*	two	bipedal
bio *(G)*	life	biosphere
C		
carn *(L)*	flesh	carnivore
ceph *(G)*	head	cephalopod
chloros *(G)*	light green	chlorophyll
chroma *(G)*	pigmented	chromosome
cide *(L)*	to kill	insecticide
circ *(L)*	circular	circadian
cocc/coccus *(G)*	small and round	streptococcus
con *(L)*	together	convergent
cyte *(G)*	cell	cytoplasm
D		
de *(L)*	remove	decompose
dendron *(G)*	tree	dendrite
dent *(L)*	tooth	edentate
derm *(G)*	skin	epidermis
di *(G)*	two	disaccharide
dia *(G)*	apart	diaphragm
dorm *(L)*	sleep	dormancy

Origin	Meaning	Example
E		
echino *(G)*	spiny	echinoderm
ec *(G)*	outer	ecosystem
ella(e) *(L)*	small	organelle
endo *(G)*	within	endosperm
epi *(G)*	upon	epidermis
eu *(G)*	true	eukaryote
exo *(G)*	outside	exoskeleton
F		
fer *(L)*	to carry	conifer
G		
gastro *(G)*	stomach	gastropod
genesis *(G)*	to originate	oogenesis
gen/(e)(o) *(G)*	kind	genotype
gon *(G)*	reproductive	archegonium
gravi *(L)*	heavy	gravitropism
gymn/o *(G)*	naked	gymnosperm
gyn/e *(G)*	female	gynecium
H		
hal(o) *(G)*	salt	halophyte
hapl(o) *(G)*	single	haploid
hemi *(G)*	half	hemisphere
hem(o) *(G)*	blood	hemoglobin
herb/a(i) *(L)*	vegetation	herbivore
heter/o *(G)*	different	heterotrophic
hom(e)/o *(G)*	same	homeostasis
hom *(L)*	human	hominid
hydr/o *(G)*	water	hydrolysis
I		
inter *(L)*	between	internode
intra *(L)*	within	intracellular
is/o *(G)*	equal	isotonic
J		
jug *(L)*	to join	jugular

Origin	Meaning	Example
K		
kary *(G)*	nucleus	eukaryote
kera *(G)*	hornlike	keratin
L		
leuc/o *(G)*	white	leukocyte
logy *(G)*	study of	biology
lymph/o *(L)*	water	lymphocyte
lysis *(G)*	break up	dialysis
M		
macr/o *(G)*	large	macromolecule
meg/a *(G)*	great	megaspore
meso *(L)*	in the middle	mesophyll
meta *(G)*	after	metaphase
micr/o *(G)*	small	microscope
mon/o *(G)*	only one	monocotyledon
morph/o *(G)*	form	morphology
N		
nema *(G)*	a thread	nematode
neuro *(G)*	nerve	neuron
nod *(L)*	knot	nodule
nomy(e) *(G)*	system of laws	taxonomy
O		
olig/o *(G)*	small, few	oligochaete
omn *(L)*	all	omnivore
orni(s) *(G)*	bird	ornithology
oste/o *(G)*	bone formation	osteocyte
ov *(L)*	an egg	oviduct
P		
pal(a)e/o *(G)*	ancient	paleontology
para *(G)*	beside	parathyroid
path/o *(G)*	suffering	pathogen
ped *(L)*	foot	centipede
per *(L)*	through	permeable
peri *(G)*	around, about	peristalsis
phag/o *(G)*	eating	phagocyte
phot/o *(G)*	light	photosynthesis
phyl *(G)*	race, class	phylogeny
phyll *(G)*	leaf	chlorophyll
phyte *(G)*	plant	epiphyte
pinna *(L)*	feather	pinnate

Origin	Meaning	Example
P (continued)		
plasm/o *(G)*	to form	plasmodium
pod *(G)*	foot	gastropod
poly *(G)*	many	polymer
post *(L)*	after	posterior
pro *(G) (L)*	before	prokaryote
prot/o *(G)*	first	protocells
pseud/o *(G)*	false	pseudopodium
R		
re *(L)*	back to original	reproduce
rhiz/o *(L)*	root	rhizoid
S		
scope *(G)*	to look	microscope
some *(G)*	body	lysome
sperm *(G)*	seed	gymnosperm
stasis *(G)*	remain constant	homeostasis
stom *(G)*	mouthlike opening	stomata
syn *(G)*	together	synapse
T		
tel/o *(G)*	end	telophase
terr *(L)*	of Earth	terrestrial
therm *(G)*	heat	endotherm
thylak *(G)*	sack	thylakoid
trans *(L)*	across	transpiration
trich *(G)*	hair	trichome
trop/o *(G)*	a change	gravitropism
trophic *(G)*	nourishment	heterotrophic
U		
uni *(L)*	one	unicellular
V		
vacc/a *(L)*	cow	vaccine
vore *(L)*	eat greedily	omnivore
X		
xer/o *(G)*	dry	xerophye
Z		
zo/o *(G)*	living being	zoology
zygous *(G)*	two joined	homozygous

PERIODIC TABLE OF THE ELEMENTS



The number in parentheses is the mass number of the longest lived isotope for that element.

★The names and symbols for elements 113, 115, and 118 are temporary. Final names will be selected when the elements' discoveries are verified.

Reference Handbook

Safety Symbols

These safety symbols are used in laboratory and field investigations in this book to indicate possible hazards. Learn the meaning of each symbol and refer to this page often. *Remember to wash your hands thoroughly after completing lab procedures.*

SAFETY SYMBOLS	HAZARD	EXAMPLES	PRECAUTION	REMEDY
DISPOSAL 	Special disposal procedures need to be followed.	certain chemicals, living organisms	Do not dispose of these materials in the sink or trash can.	Dispose of wastes as directed by your teacher.
BIOLOGICAL 	Organisms or other biological materials that might be harmful to humans	bacteria, fungi, blood, unpreserved tissues, plant materials	Avoid skin contact with these materials. Wear mask or gloves.	Notify your teacher if you suspect contact with material. Wash hands thoroughly.
EXTREME TEMPERATURE 	Objects that can burn skin by being too cold or too hot	boiling liquids, hot plates, dry ice, liquid nitrogen	Use proper protection when handling.	Go to your teacher for first aid.
SHARP OBJECT 	Use of tools or glassware that can easily puncture or slice skin	razor blades, pins, scalpels, pointed tools, dissecting probes, broken glass	Practice common-sense behavior and follow guidelines for use of the tool.	Go to your teacher for first aid.
FUME 	Possible danger to respiratory tract from fumes	ammonia, acetone, nail polish remover, heated sulfur, moth balls	Make sure there is good ventilation. Never smell fumes directly. Wear a mask.	Leave foul area and notify your teacher immediately.
ELECTRICAL 	Possible danger from electrical shock or burn	improper grounding, liquid spills, short circuits, exposed wires	Double-check setup with teacher. Check condition of wires and apparatus. Use GFI-protected outlets.	Do not attempt to fix electrical problems. Notify your teacher immediately.
IRRITANT 	Substances that can irritate the skin or mucous membranes of the respiratory tract	pollen, moth balls, steel wool, fiberglass, potassium permanganate	Wear dust mask and gloves. Practice extra care when handling these materials.	Go to your teacher for first aid.
CHEMICAL 	Chemicals that can react with and destroy tissue and other materials	bleaches such as hydrogen peroxide; acids such as sulfuric acid, hydrochloric acid; bases such as ammonia, sodium hydroxide	Wear goggles, gloves, and an apron.	Immediately flush the affected area with water and notify your teacher.
TOXIC 	Substance may be poisonous if touched, inhaled, or swallowed.	mercury, many metal compounds, iodine, poinsettia plant parts	Follow your teacher's instructions.	Always wash hands thoroughly after use. Go to your teacher for first aid.
FLAMMABLE 	Open flame may ignite flammable chemicals, loose clothing, or hair.	alcohol, kerosene, potassium permanganate, hair, clothing	Avoid open flames and heat when using flammable chemicals.	Notify your teacher immediately. Use fire safety equipment if applicable.
OPEN FLAME 	Open flame in use, may cause fire.	hair, clothing, paper, synthetic materials	Tie back hair and loose clothing. Follow teacher's instructions on lighting and extinguishing flames.	Always wash hands thoroughly after use. Go to your teacher for first aid.

Eye Safety
Proper eye protection must be worn at all times by anyone performing or observing science activities.

Clothing Protection
This symbol appears when substances could stain or burn clothing.

Animal Safety
This symbol appears when safety of animals and students must be ensured.

Radioactivity
This symbol appears when radioactive materials are used.

Handwashing
After the lab, wash hands with soap and water before removing goggles.

A Biologist's Guide To The Periodic Table