CHAPTER

2 Chemistry of Life

GETTING READY TO LEARN

Preview Key Concepts

2.1 Atoms, Ions, and Molecules
All living things are based on atoms and their interactions.

2.2 Properties of Water
Water's unique properties allow life to exist on Earth.

2.3 Carbon-Based Molecules
Carbon-based molecules are the foundation of life.

2.4 Chemical Reactions
Life depends on chemical reactions.

2.5 Enzymes
Enzymes are catalysts for chemical reactions in living things.

Review Academic Vocabulary

Write the correct word for each definition.

cell organism DNA atom molecule

1. ____________________ : any individual living thing
2. ____________________ : genetic material
3. ____________________ : smallest unit of life
4. ____________________ : smallest unit of matter
5. ____________________ : combination of atoms held together by bonds

Preview Biology Vocabulary

Six key terms from this chapter share the same word parts. Read the definitions and guess what the word part means.

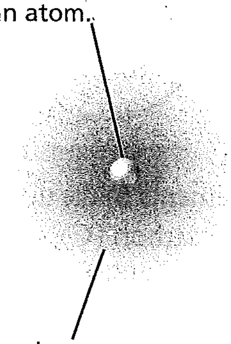
TERM	DEFINITION	WHAT I THINK THE WORD PART MEANS
endothermic	Describes a chemical reaction that absorbs more energy than it releases	
exothermic	Describes a chemical reaction that releases more energy than it absorbs	
cohesion	attraction among molecules of the same substance	
adhesion	attraction among molecules of different substances	
Solution	Mixture of substances that is the same throughout	
solute	A dissolved substance	

SECTION
2.1 Atoms, Ions, and Molecules

KEY CONCEPT All living things are based on atoms and their interactions.

Living things consist of atoms of different elements.

Every physical* thing that you can think of, living or not living, is made of very small particles called atoms. An **atom** is the smallest basic unit of matter, or of any physical substance*. A frog, a car, and your body are all made of atoms.



Atoms

An atom is made up of three types of smaller particles: protons, neutrons, and electrons. Protons and neutrons form the center of an atom, called the nucleus. Electrons are much smaller and form the outer part of the atom. Protons have a positive electrical charge, and electrons have a negative electrical charge. Neutrons have no charge; they are neutral. Atoms have an equal number of protons and electrons, so they are electrically neutral.

Elements

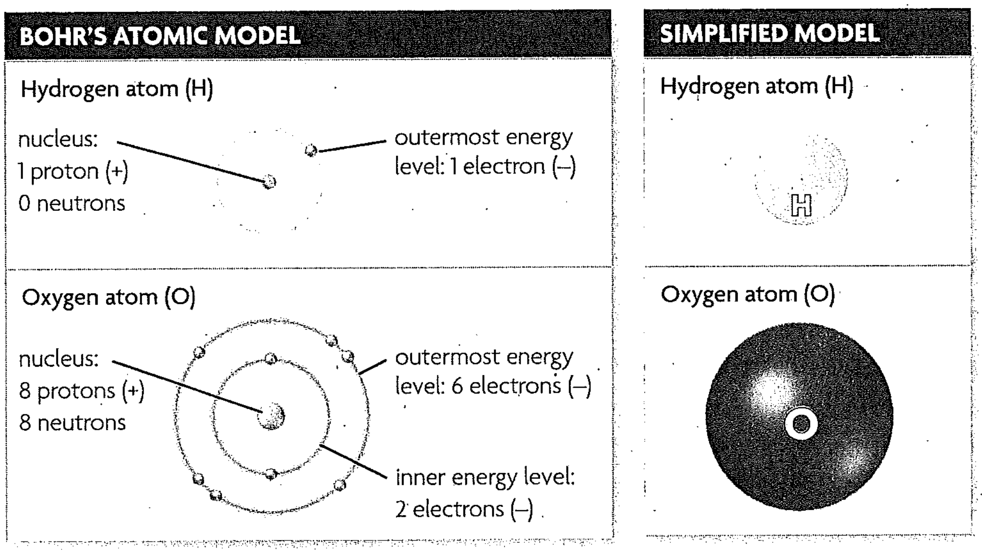
An **element** is one particular type of atom. An element cannot usually be broken down into a simpler substance. Hydrogen, oxygen, aluminum, and gold are all familiar elements. But what makes one element different from other elements? The atoms of each element have a unique number of protons. There are 91 elements that occur naturally on Earth. Only about 25 of those elements are found in living things.

Imagining something as tiny as an atom can be hard. Scientists have come up with different models to try to show what an atom looks like or to show how atoms interact. In the figure on the next page, Bohr's atomic model shows that electrons surround the nucleus in regions called energy levels. Each energy level can hold a different number of electrons. The simplified model shows atoms as balls that differ in size and color.

* ACADEMIC VOCABULARY

physical related to something real, that can be touched or seen, not an idea

substance something physical, or a kind of matter



Just 4 elements make up 96 percent of the human body's mass*. These elements are carbon (C), oxygen (O), nitrogen (N), and hydrogen (H). The other 4 percent of your body consists of mostly calcium (Ca), phosphorous (P), potassium (K), sulfur (S), sodium (Na), and iron (Fe).

Compounds

The atoms of elements found in organisms are often linked, or bonded, to other atoms. A **compound** is a substance made of atoms of different elements bonded together in a certain ratio. Water (H_2O) is a compound of two hydrogen atoms and an oxygen atom. The properties of a compound can be different from the properties of the elements that make up the compound. For example, hydrogen and oxygen are both gases on Earth, but together they can form water. Similarly, a diamond is made of the element carbon, but carbon can also be part of sugars, proteins, and millions of other compounds.

INSTANT REPLAY How are atoms, elements, and compounds related?

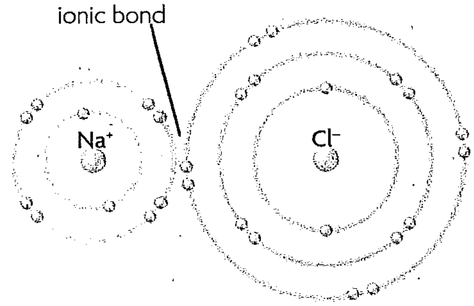
____

____

Ions form when atoms gain or lose electrons.

An **ion** is an atom that has gained or lost one or more electrons. Some ions have a positive charge ($^+$) and some ions have a negative charge ($^-$). The charge gives the ion special properties.

The positive sodium ion (Na^+) and negative chloride ion (Cl^-) attract each other and form an ionic bond.



Sodium ion   Chloride ion

* ACADEMIC VOCABULARY

mass the total amount of matter in an object

Ions are important in living things. For example, calcium ions (Ca^{2+}) are needed for every muscle movement in your body. Chloride ions (Cl^-) are important for a type of chemical signal in your brain.

Positive ions, such as sodium (Na^+), are attracted to negative ions, such as chloride (Cl^-). An **ionic bond** forms between a positively charged ion and a negatively charged ion. Salt, or sodium chloride ($NaCl$) is held together by an ionic bond.

INSTANT REPLAY How does an atom become an ion?

____

Atoms share pairs of electrons in covalent bonds.

Some atoms do not easily gain or lose electrons. Instead, the atoms of many elements will share pairs of electrons. A **covalent bond** forms when atoms share a pair of electrons. A **molecule** is two or more atoms held together by covalent bonds. For example, oxygen (O_2) and water (H_2O) are molecules.

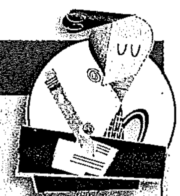
INSTANT REPLAY What kind of bond unites the atoms in a water molecule?

____

2.1 Vocabulary Check

atom	ionic bond
element	covalent bond
compound	molecule
ion	

Mark It Up



Go back and highlight each sentence that has a vocabulary word in **bold.**

1. Name two types of bonds. ______________________________
2. The smallest basic unit of matter is called a(n) ________________.
3. One type of atom, such as hydrogen, is called a(n) ________________.
4. A(n) ________________ is an atom that has gained or lost an electron.
5. ________________ and ________________ are two words that mean a substance made of atoms that are bonded together.

2.1 The Big Picture

6. What is the difference between an ion and an atom?

____

7. Name five elements that make up the molecules in living organisms.

____

SECTION

2.2 Properties of Water

KEY CONCEPT Water's unique properties allow life to exist on Earth.

Life depends on hydrogen bonds in water.

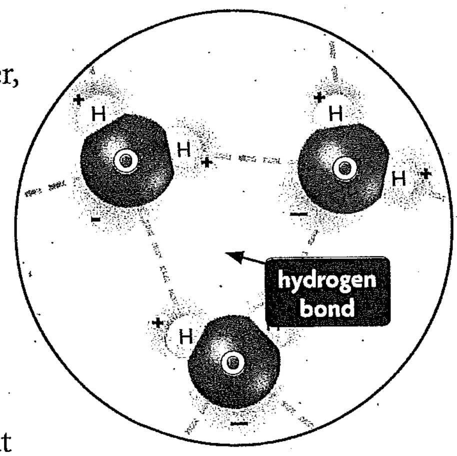
Unlike most things, water expands, or gets bigger, when it freezes. Because of this, ice is less dense than water. Therefore, ice floats in water. When a lake freezes, fish can still survive because the ice floats. The ice layer on the surface of the lake insulates* it and allows the water underneath to stay liquid.

Water and Hydrogen Bonds

Water molecules have special properties. The oxygen has a slightly negative charge, and the hydrogens have slightly positive charges. This makes the molecule polar—like a magnet, a water molecule has positive and negative ends. The positive charge from the hydrogen atom of one water molecule can attract a negative charge from another molecule. This attraction is called a **hydrogen bond.** Hydrogen bonds occur among water molecules and also in proteins, in DNA, and in other molecules.

Properties Related to Hydrogen Bonds

Each individual hydrogen bond is not very strong, but all together, hydrogen bonds give water properties that are important to life.



Hydrogen bonds form between neighboring water molecules. They cause water molecules to stick together.

- **High specific heat** Hydrogen bonds give water a high specific heat. This means that water resists changes in temperature, which is important in helping cells to maintain homeostasis.
- **Cohesion** The attraction among molecules of the same substance is **cohesion.** Cohesion from hydrogen bonds makes water molecules stick to each other. Cohesion is why water forms beads, or droplets, like those you see on a car that has just been washed.
- **Adhesion** The attraction among molecules of different substances is called **adhesion.** In other words, water molecules stick to other things. Adhesion helps plants move water from their roots to their leaves because the water molecules stick to the sides of the tubes that carry water through the plant.

INSTANT REPLAY How does a hydrogen bond form?

____

* ACADEMIC VOCABULARY

insulates keeps warm, or prevents heat from escaping

Many compounds dissolve in water.

To take part in life processes, many molecules and ions must be dissolved in water-based fluids, such as blood or plant sap. When one substance dissolves in another, a solution forms. A **solution** is a mixture of substances that is equally mixed throughout. A solution has two parts:

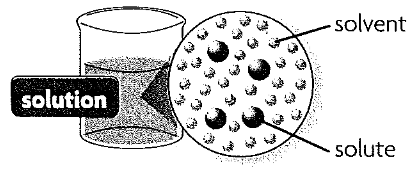
- The **solvent** is the substance that there is more of, and that dissolves the other substance.
- The **solute** is the substance that dissolves in the solvent.

The amount of solute dissolved in a certain amount of solvent is the solution's concentration. A tiny bit of drink mix in one cup of water has very little flavor. Four spoonfuls of drink mix in one cup of water tastes stronger because it has a higher concentration.

Polar molecules—molecules with positive and negative ends—dissolve in water. But some compounds are nonpolar, like fats and oils. Nonpolar molecules do not have charged parts—no positive or negative ends—so they are not attracted to polar molecules like water. Nonpolar molecules will dissolve in nonpolar solvents. For example, vitamin E is nonpolar and dissolves in fats in human bodies.

VISUAL VOCAB

The **solvent** is the substance that is present in the greatest amount, and is the substance that dissolves solutes.



A **solute** is the substance that dissolves.

VOCABULARY

In everyday use, the word *solution* means "an answer." This meaning of solution is different, and means "a mixture."

INSTANT REPLAY What are the two parts of a solution?

____

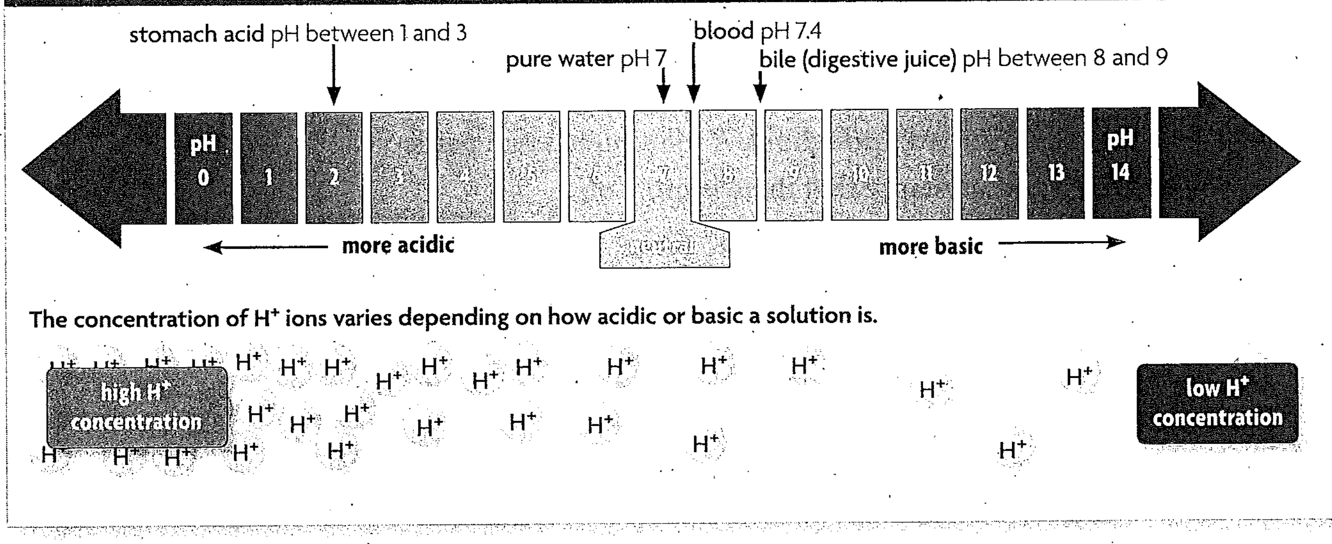
Some compounds form acids or bases.

Some compounds break up into ions when they dissolve in water.

- An **acid** is a compound that releases a proton when it dissolves in water. A proton is a hydrogen ion (H^+). An acid increases the concentration of H^+ ions in a solution.
- A **base** removes H^+ ions from a solution. After a base dissolves in water, the solution has a low H^+ concentration.

The acidity of a solution is the concentration of H^+ ions. Acidity is measured on the **pH** scale. In the figure of the pH scale, you can see that pH is usually between 0 and 14. A solution with a pH of 0 is very acidic, with a high H^+ concentration. A solution with a pH of 14 is very basic, with a low H^+ concentration. Solutions with a pH of 7 are neutral—neither acidic nor basic. Most organisms, including humans, need to keep their pH close to 7. However, some organisms need very different pH ranges to live.

THE pH SCALE



What is the difference between an acid and a base?

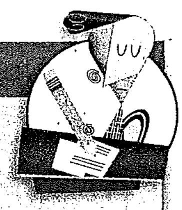
____

2.2 Vocabulary Check

hydrogen bond	solution	acid
cohesion	solvent	base
adhesion	solute	pH

Mark It Up

Go back and highlight each sentence that has a vocabulary word in **bold**.



1. A ____________ is a mixture made of two parts, the ____________, which is the bigger part, and the ____________, which dissolves.
2. Attraction among molecules of the same type is called ____________.
3. Attraction among molecules of different types is called ____________.
4. The ____________ scale measures the concentration of H^+ ions.
5. A high concentration of H^+ ions makes something a(n) ____________ and a low concentration of H^+ ions makes something a(n) ____________.
6. ____________ give water special properties such as cohesion.

2.2 The Big Picture

7. Why are hydrogen bonds important for life? ____________________

____

8. What is the pH level for most human cells?

____

SECTION
2.3 Carbon-Based Molecules

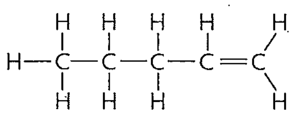
KEY CONCEPT Carbon-based molecules are the foundation of life.

Carbon atoms have unique bonding properties.

Most molecules that make up living things are based on carbon atoms. The structure of a carbon atom allows it to form up to four covalent bonds. It can bond to other carbons or to different atoms. As shown in the figure below, carbon-based molecules have three basic structures: straight chains, branched chains, and rings.

CARBON CHAINS AND RINGS

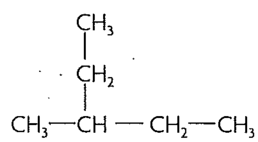
Straight chain



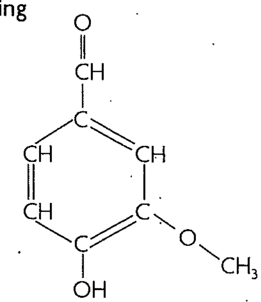
A simplified structure can also be shown as:

$CH_3—CH_2—CH_2—CH=CH_2$

Branched chain



Ring



Each line represents a covalent bond. Each letter represents an atom. Notice that there are four bonds for every carbon atom (C). When a carbon (C) is attached to a hydrogen (H) sometimes there is no line drawn to represent the bond, but the bond is still there.

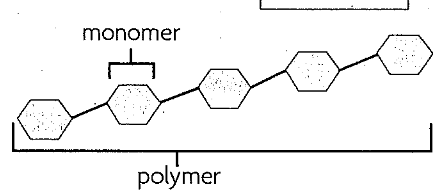
Think of a chain made up of connected loops, or links. Each link is a subunit that makes up the bigger chain. Many carbon-based molecules have subunits that make up a bigger molecule.

Each subunit is called a **monomer.** When monomers are linked together, they form molecules called polymers. A **polymer** is a large molecule made of many monomers bonded together. A polymer can also be called a macro-molecule. *Macro-* means "large," so a macromolecule is a large molecule. The monomers that make up a polymer can all be the same, or they can be different, depending on the type of macromolecule.

VISUAL VOCAB

Each smaller molecule is a subunit called a **monomer.**

mono- = one
poly- = many



A **polymer** is a molecule that contains many monomers bonded together.

INSTANT REPLAY How are polymers and monomers related?

____

Four main types of carbon-based molecules are found in living things.

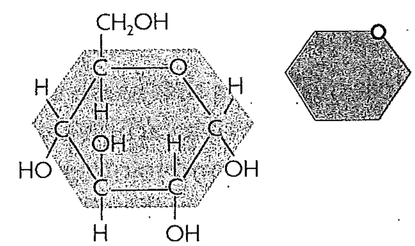
All organisms are made of four types of carbon-based molecules: carbohydrates, lipids, proteins, and nucleic acids.

Carbohydrates

Fruits and grains both contain large amounts of carbohydrates. **Carbohydrates** are molecules made of carbon, hydrogen, and oxygen. Sugars and starches are both types of carbohydrates. These carbohydrates can be broken down to produce energy in cells. Some carbohydrates are part of cell structure in plants.

The most basic carbohydrates are simple sugars. Many simple sugars have five or six carbon atoms. Fructose and glucose are both sugars that have six carbon atoms. The sugar that you might use in the kitchen is made of two sugar molecules bonded together.

Many glucose molecules bonded together form polymers such as starch and cellulose. These polymers are called polysaccharides. Starches are carbohydrates made by plants. Starch can be broken down as a source of energy by plant and animal cells. Cellulose is also made by plants. Cellulose makes up cell walls, the tough outer covering of plant cells. The stringy fibers of vegetables like celery are made of cellulose. The structure of starch molecules is different from the structure of cellulose molecules. The different structures give them their different properties.

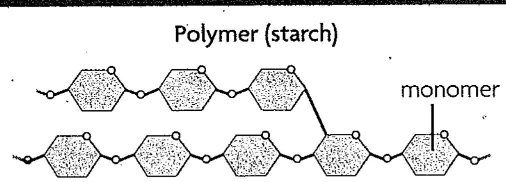


Glucose is a six-carbon sugar. Glucose is often represented by a hexagon, a six-sided figure. Each point on the hexagon represents a carbon, except the point that has an O, for oxygen.

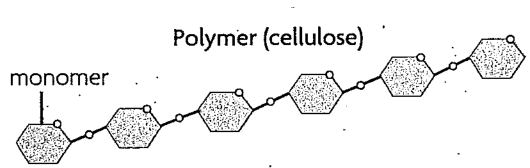
VOCABULARY

Poly- means "many." *Saccharide* means "sugar." A *polysaccharide* is a polymer made of many sugars.

CARBOHYDRATE STRUCTURE



Starch is a polymer of glucose monomers that often has a branched structure.



Cellulose is a polymer of glucose monomers that has a straight, rigid structure.

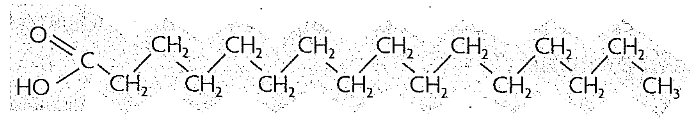
Lipids

Lipids are molecules that include fats, oils, and cholesterol. Lipids are nonpolar, so they do not dissolve in water. Like carbohydrates, most lipids are made of carbon, oxygen, and hydrogen atoms. Some lipids are broken down and used as energy in cells. Other lipids form part of the cell's structure.

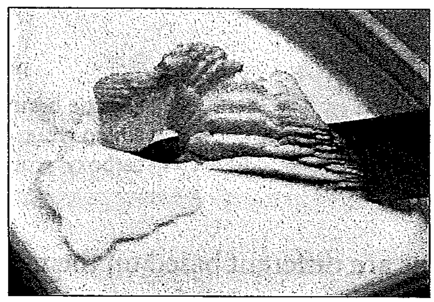
Fats and lipids store large amounts of energy in organisms. Animal fats are found in foods such as meat and butter. Plant fats are found in nuts and oils, like olive oil or peanut oil. Fats and lipids are made of molecules called fatty acids. **Fatty acids** are chains of carbon atoms bonded to hydrogen atoms. In many lipids, the fatty acid chains are attached on one end to another molecule called glycerol. Because of the shape of the fatty acid chains, some fats are liquid at room temperature, like olive oil, and other fats are solid, like butter.

FATTY ACIDS

Fatty acid



Fatty acids are long chains of carbon atoms attached to hydrogen atoms.



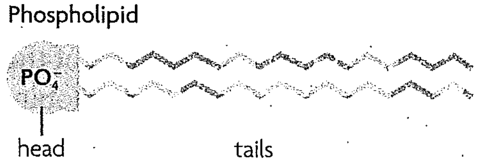
Butter is made up of fatty acids.

All cell membranes are made mostly of another type of lipid, called a phospholipid (FAHS-foh-LIHP-ihd). A phospholipid has glycerol, two fatty acid "tails," and a phosphate group that forms the "head" of the molecule. The phosphate group includes phosphorous and oxygen atoms. This part of the molecule is polar, so it is attracted to water. The fatty acid end of the molecule is nonpolar, and is not attracted to water.

Cholesterol (kuh-LEHS-tuh-RAWL) is a lipid with a ring structure. Although high cholesterol is a health risk, your body needs a certain amount of cholesterol to function. Cholesterol is part of cell membranes. Cholesterol is also an important part of steroid hormones. Cholesterol-based steroids help your body respond to stress and also control sexual development and the reproductive system.

PHOSPHOLIPID STRUCTURE

Phospholipid



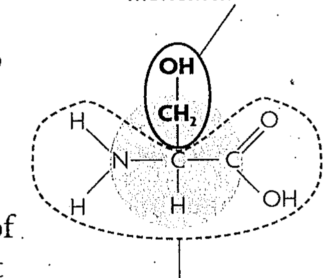
A phospholipid has nonpolar fatty acid "tails" and a polar "head" that contains a phosphate group.

Proteins

Proteins are the most varied of the carbon-based molecules in organisms. There are many different types of proteins. They are involved in many different body functions including movement, eyesight, and digestion.

A **protein** is a polymer made of monomers called amino acids. **Amino acids** are molecules that contain carbon, hydrogen, oxygen, nitrogen, and sometimes sulfur. Organisms use 20 different amino acids to build different types of proteins. Your body can make 12 of the amino acids it needs. The other 8 amino acids come from the foods you eat, such as meat, beans, and nuts.

This part is different for each amino acid monomer.

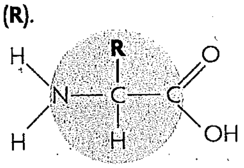


This part is the same for each amino acid monomer.

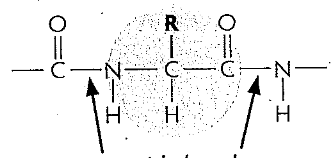
Look at the figure at right to see the amino acid called serine. All amino acids have part of their structure that is the same. Another part of their structure is different for each amino acid. The part that is different is called the side group, or R-group. Amino acids are bonded together to form proteins.

AMINO ACID AND PROTEIN STRUCTURE

All amino acids have a carbon atom bonded to a hydrogen atom, an amino group (NH_2), and a carboxyl group (COOH). Different amino acids have different side groups (**R**).

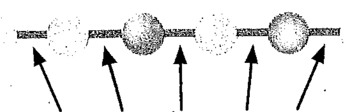


Monomer (amino acid)



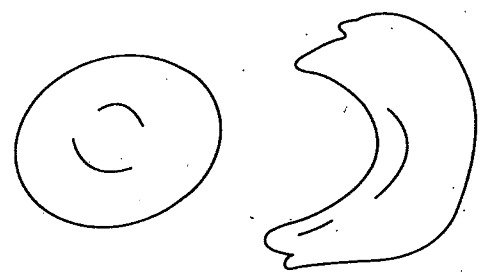
Peptide bonds form between the amino group of one amino acid and the carboxyl group of another amino acid.

Polymer (protein)



A polypeptide is a chain of precisely ordered amino acids linked by peptide bonds. A protein is made of one or more polypeptides.

Proteins are different based on the number and order of amino acids. A protein's function depends on the specific order of the amino acids, which affects the shape of the protein. The side groups of each amino acid can interact with each other and affect the protein's shape. For example, hydrogen bonds can form between different side groups.



Typically, red blood cells are shaped like a saucer (left). A change in just one amino acid in hemoglobin can cause cells to have the curved shape characteristic of sickle cell anemia.

Hemoglobin is the protein in your red blood cells that transports oxygen. Hemoglobin is made of 574 amino acids. Hydrogen bonds help make the structure of this protein. If just one of the amino acids in hemoglobin changes, the structure of the protein can change in a way that prevents the protein from working properly. A change in one amino acid in hemoglobin causes the disorder called sickle cell anemia.

Nucleic Acids

There are two general types of nucleic acids: DNA and RNA. **Nucleic acids** are polymers that are made up of monomers called nucleotides. A nucleotide is made up of a sugar, a phosphate group, and a nitrogen-containing molecule called a base. Nucleic acids contain the instructions to build proteins.

Nucleic acids are different from the other three macromolecules you read about. Carbohydrates, lipids, and proteins have many different structures and functions. Nucleic acids have just one function. They code for proteins. You will learn more about nucleic acids in Unit 3.

INSTANT REPLAY What are four main types of macromolecules found in living things?

____

2.3 Vocabulary Check

monomer	protein
polymer	amino acid
carbohydrate	lipid
fatty acid	nucleic acid

Mark It Up

Go back and highlight each sentence that has a vocabulary word in **bold.**

1. Name four types of macromolecules. ____

2. A protein is made up of monomers called ____________.
3. The carbon chain that makes up part of a lipid is called a ____________.
4. A six-carbon sugar is an example of a ____________ that can join with other molecules to form a ____________ such as starch or cellulose.

2.3 The Big Picture

1. What are three different shapes, or structures, of carbon-based molecules? ____
2. Complete the following chart.

MONOMER	POLYMER	EXAMPLE	FUNCTION
Glucose			
	Protein		
		DNA	

3. What is a phospholipid?

____

4. Living things are sometimes called "carbon-based life forms." Do you think this is a good way to describe life? Explain your answer.

____

SECTION

2.4 Chemical Reactions

KEY CONCEPT Life depends on chemical reactions.

Bonds break and form during chemical reactions.

Plant and animal cells break down sugars to make energy. All cells build protein molecules by bonding amino acids together. These processes are examples of chemical reactions. **Chemical reactions** change substances into different substances by breaking and forming chemical bonds.

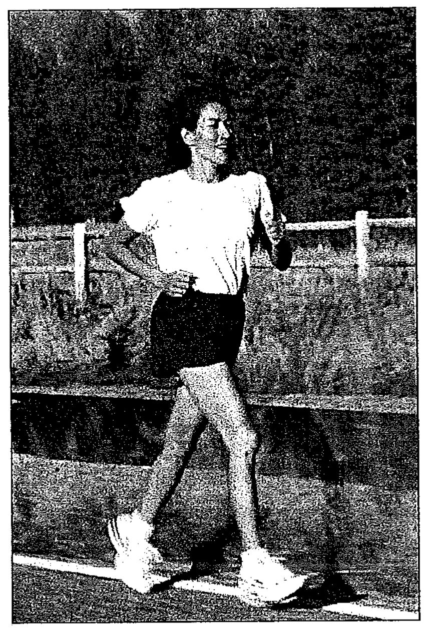
Reactants and Products

The oxygen molecules (O_2) that you breathe in are part of a series of chemical reactions. These chemical reactions use oxygen and glucose ($C_6H_{12}O_6$), and produce carbon dioxide (CO_2), water (H_2O), and energy that your body can use. This process is called cellular respiration.

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

Reactants Direction Products

- **Reactants** are the substances that are changed during a chemical reaction. Oxygen and glucose are the reactants in the reaction shown above.
- **Products** are the substances made by a chemical reaction. Carbon dioxide and water are the products of the above reaction.



The breakdown of glucose provides chemical energy for all activities, including running.

Bond Energy

In order for reactants to change into products, the bonds of the reactants must break, and new bonds must form in the products. Breaking a bond requires energy. **Bond energy** is the amount of energy that it takes to break a bond between two atoms. Bonds between different types of atoms have different bond energies. A certain amount of energy is needed to break the bond between two oxygen atoms. A different amount of energy is needed to break the bond between carbon and hydrogen. Energy is released when bonds form.

Chemical Equilibrium

Some chemical reactions only go one way, from reactants to products, until all the reactants are used up. However, many reactions in living things are reversible. These reactions can move in both directions at the same time. One reaction that goes both directions allows your blood to carry carbon dioxide. Carbon dioxide reacts with water in your blood to form a compound called carbonic acid (H_2CO_3).

$$CO_2 + H_2O \rightleftharpoons H_2CO_3$$

The arrows in this equation show that the reaction goes in both directions. Usually, the direction depends on the amounts of each compound. If there is a high concentration of carbon dioxide—like around your cells—the reaction moves toward the right and carbonic acid forms. If there is a low concentration of carbon dioxide—like in your lungs—the reaction goes toward the left and carbonic acid breaks down.

When a reaction takes place at an equal rate in both directions, the concentration, or amounts, of the reactants and products stays the same. **Equilibrium** (EE-kwuh-LIHB-ree-uhm) is when both the reactants and products are made at the same rate.

INSTANT REPLAY In which part of a chemical reaction do bonds break? In which part do they form?

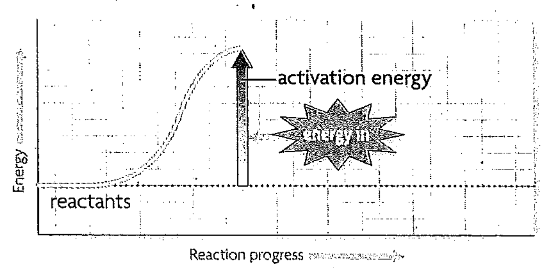
Chemical reactions release or absorb energy.

Energy is both absorbed* and released during a chemical reaction. Some chemical reactions give off more energy than they take in. Other chemical reactions take in more energy than they give off. **Activation energy** is the amount of energy that needs to be absorbed for a chemical reaction to start.

VOCABULARY

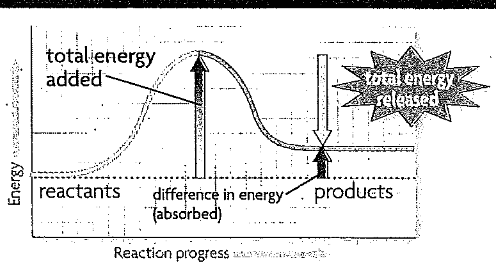
The prefix *exo-* means "out," and the prefix *endo-* means "in." Energy "moves out of" an exothermic reaction, and energy "moves into" an endothermic reaction

ACTIVATION ENERGY



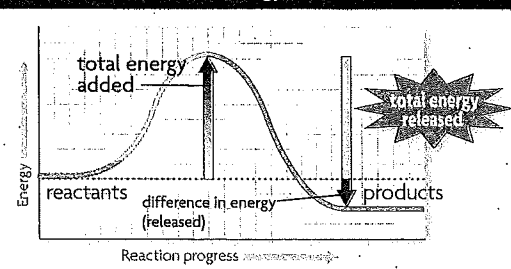
Activation energy is the amount of energy that needs to be absorbed for a chemical reaction to start. When enough activation energy is added to the reactants, bonds in the reactants break and the reaction begins.

ENDOTHERMIC REACTION Energy Absorbed



An **endothermic** chemical reaction absorbs more energy than it releases. The products have a higher bond energy than the reactants, and the difference in bond energy is absorbed from the surroundings. Photosynthesis is an endothermic reaction.

EXOTHERMIC REACTION Energy Released



An **exothermic** chemical reaction releases more energy than it absorbs. The products have a lower bond energy than the reactants, and the difference in bond energy is released to the surroundings. Cellular respiration is an exothermic reaction.

* ACADEMIC VOCABULARY

absorb to take in or use

Both exothermic and endothermic reactions take place in organisms. For example, cellular respiration—the process that uses glucose and oxygen to provide usable energy—is exothermic. It also provides heat that keeps your body warm. Photosynthesis, on the other hand, is endothermic. It absorbs more energy from sunlight than it releases.

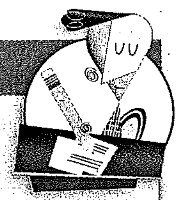
INSTANT REPLAY What is the difference between an exothermic reaction and an endothermic reaction? ______________________________

____

2.4 Vocabulary Check

chemical reaction	equilibrium
reactant	activation energy
product	exothermic
bond energy	endothermic

Mark It Up



Go back and highlight each sentence that has a vocabulary word in **bold.**

Use the words above to fill in the blanks in the section summary below.

Making and breaking chemical bonds are examples of **1.** ______________. Bonds are broken in the **2.** ______________, the chemicals that are changed during the process. Bonds are made in the **3.** ______________, the chemicals that result from the process. If a reaction takes place at an equal rate in both directions, it is in **4.** ______________. The amount of energy needed to break a bond is called the **5.** ______________.

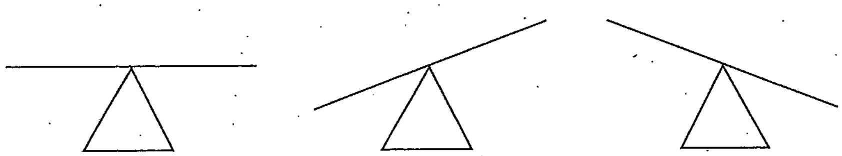
The **6.** ______________ is the amount of energy needed to start a reaction. If a reaction absorbs more energy than it releases it is called an **7.** ______________ reaction. If a reaction releases more energy than it absorbs it is called an **8.** ______________ reaction.

2.4 The Big Picture

9. Look at the chemical reaction below. Draw a circle around the reactant(s). Underline the product(s).

hydrogen peroxide		water		oxygen
H_2O_2	$\longrightarrow$	H_2O	$+$	O_2

10. Imagine a seesaw, like on a children's playground. Which of the following drawings of a seesaw best represents equilibrium? Explain.



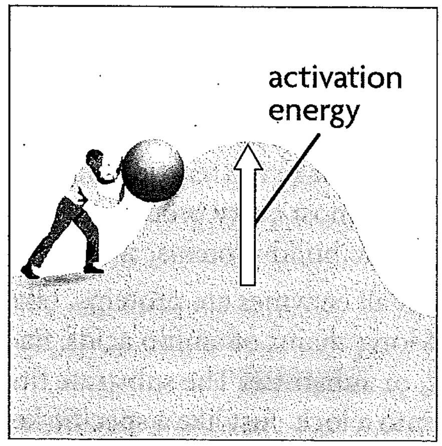
SECTION
2.5 Enzymes

KEY CONCEPT Enzymes are catalysts for chemical reactions in living things.

A catalyst lowers activation energy.

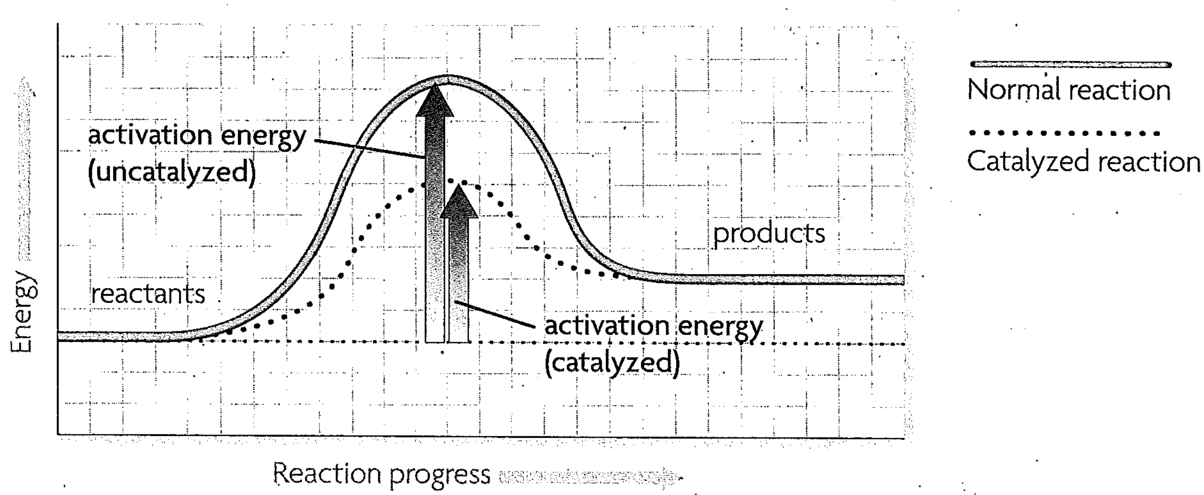
Activation energy for a chemical reaction is like the energy that is needed to push a rock up a hill. Once enough energy is added to get the rock to the top of the hill, the rock can roll down the other side by itself.

Under normal conditions, a reaction requires a certain amount of activation energy, and it occurs at a certain rate. Even after a chemical reaction starts, it may happen very slowly. A **catalyst** (KAT-l-ihst) is a substance that decreases the activation energy needed to start a chemical reaction. As a result, a catalyst also increases the rate of the chemical reaction, or makes the products form faster. A catalyst takes part in a chemical reaction, but it does not get changed or used up. Therefore, a catalyst is not considered a reactant or a product.



Activation energy is like the energy you would need to push a rock up a hill.

CATALYSTS AND ACTIVATION ENERGY



Under normal conditions, a certain amount of activation energy is needed to start a chemical reaction. A catalyst decreases the activation energy needed.

INSTANT REPLAY How does a catalyst affect activation energy?

___

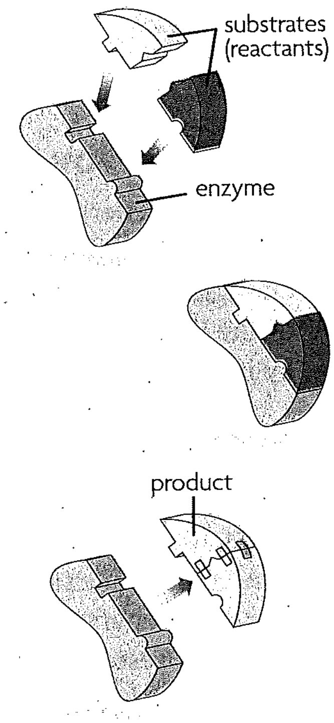
___

Enzymes allow chemical reactions to occur under tightly controlled conditions.

Chemical reactions that happen inside organisms must take place under very specific conditions. They have to occur at the temperature of the organism's body. Often, they have to occur with low concentrations of reactants. Reactions must take place very quickly, so they usually need a catalyst. **Enzymes** are catalysts for chemical reactions in living things.

Like other catalysts, enzymes lower the activation energy of chemical reactions and make the reactions happen more quickly. Enzymes are involved in almost every process in organisms. They are needed to break down food, to build proteins, and for your immune system to work.

Almost all enzymes are proteins. Like other proteins, enzymes are made of long chains of amino acids. Each enzyme binds a particular reactant, or **substrate.** The substrate fits into a part of the enzyme, like a key fits into a lock. Just like a specific key opens a specific lock, each enzyme acts on a specific substrate. The place on the enzyme where the substrate fits—the lock that the key fits into—is called the active site. Like other proteins, enzymes also depend on structure to function properly. Enzyme structure is important because the shape of an enzyme allows only certain molecules to bind to an enzyme's active site.



An enzyme binds to substrates at the active site. It catalyzes a reaction and then releases the new product that has been formed.

INSTANT REPLAY How does the structure of an enzyme affect its function?

____

2.5 Vocabulary Check

catalyst
enzyme
substrate

Mark It Up

Go back and highlight each sentence that has a vocabulary word in **bold**.

1. A catalyst for reactions in living things is a(n) _______________.
2. A(n) _______________ is a reactant that binds to a catalyst.
3. An enzyme is a kind of _______________.

2.5 The Big Picture

4. What are two ways a catalyst affects a chemical reaction?

____

____

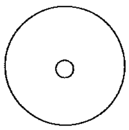
5. A catalyst is not a product or a reactant of a chemical reaction. Why not?

____

Chapter 2 Review

1. The pH of four different solutions (a, b, c, and d) are recorded below. Which solution is most acidic?
   a. pH = 3 **c.** pH = 10
   b. pH = 7 **d.** pH = 14

2. The drawing below represents an atom. Use arrows to show where each of these three parts of an atom are located in the atom's structure.



electron
proton
neutron

3. Why does the order of amino acids affect the structure of a protein?

____

4. How does a catalyst affect the activation energy of a chemical reaction?

____

5. How are the words *catalyst* and *enzyme* related?

____

____

6. What kind of bond gives water its important properties of adhesion, cohesion, and high specific heat?

____

7. What is the difference between an amino acid and a nucleic acid?

____

____

8. Photosynthesis is a chemical reaction that uses more energy than it releases. This type of reaction is
   a. endothermic **c.** at equilibrium
   b. exothermic **d.** ionic

9. Complete the chart below about bonds.

TYPE OF BOND	EXAMPLE OF A MOLECULE WITH THIS TYPE OF BOND	DRAWING OF THIS TYPE OF BOND
Ionic bond		
Covalent bond		
Hydrogen bond		