Analyzing Data

Comparing Fatty Acids

The table compares four different fatty acids. Although they all have the same number of carbon atoms, their properties vary.

1. Interpret Data Which of the four fatty acids is saturated? Which are unsaturated?

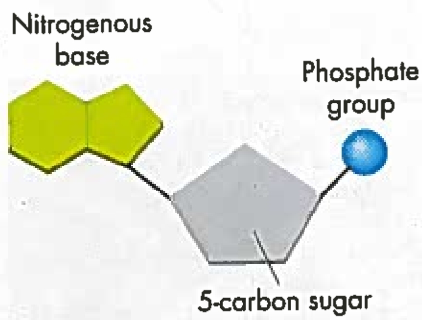
2. Observe How does melting point change as the number of carbon-carbon double bonds increases?

Effect of Carbon Bonds on Melting Point

Fatty Acid	Number of Carbons	Number of Double Bonds	Melting Point (°C)
Stearic acid	18	0	69.6
Oleic acid	18	1	14
Linoleic acid	18	2	−5
Linolenic acid	18	3	−11

3. Infer If room temperature is 25°C, which fatty acid is a solid at room temperature? Which is liquid at room temperature?

FIGURE 2–16 Nucleic Acids The monomers that make up a nucleic acid are nucleotides. Each nucleotide has a 5-carbon sugar, a phosphate group, and a nitrogenous base.

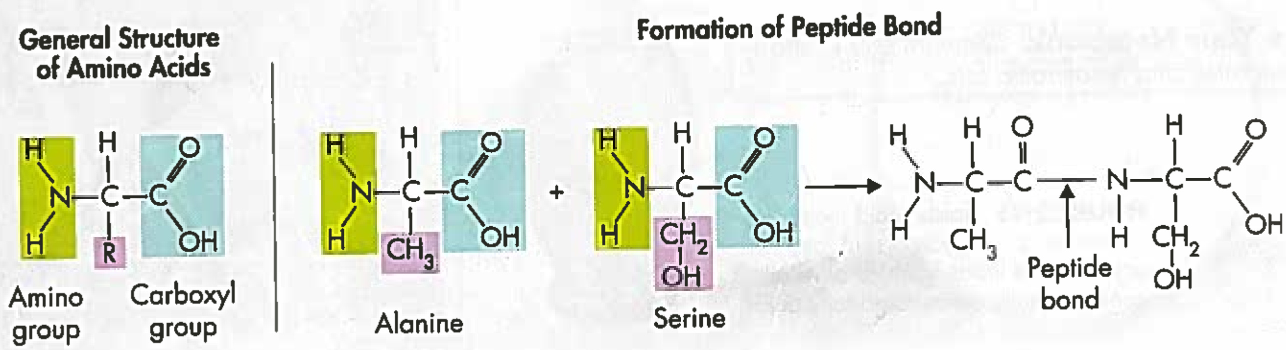


Nucleic Acids **Nucleic acids** are macromolecules containing hydrogen, oxygen, nitrogen, carbon, and phosphorus. Nucleic acids are polymers assembled from individual monomers known as nucleotides. **Nucleotides** consist of three parts: a 5-carbon sugar, a phosphate group ($-PO_4$), and a nitrogenous base, as shown in **Figure 2–16.** Some nucleotides, including the compound known as adenosine triphosphate (ATP), play important roles in capturing and transferring chemical energy. Individual nucleotides can be joined by covalent bonds to form a polynucleotide, or nucleic acid.

Nucleic acids store and transmit hereditary, or genetic, information. There are two kinds of nucleic acids: ribonucleic acid (RNA) and deoxyribonucleic acid (DNA). As their names indicate, RNA contains the sugar ribose and DNA contains the sugar deoxyribose.

Protein **Proteins** are macromolecules that contain nitrogen as well as carbon, hydrogen, and oxygen. Proteins are polymers of molecules called amino acids, shown in **Figure 2–17.** **Amino acids** are compounds with an amino group ($-NH_2$) on one end and a carboxyl group ($-COOH$) on the other end. Covalent bonds called peptide bonds link amino acids together to form a polypeptide. A protein is a functional molecule built from one or more polypeptides. **Some proteins control the rate of reactions and regulate cell processes. Others form important cellular structures, while still others transport substances into or out of cells or help to fight disease.**

FIGURE 2–17 Amino Acids and Peptide Bonding Peptide bonds form between the amino group of one amino acid and the carboxyl group of another amino acid. Note that it is the variable R-group section of the molecule that distinguishes one amino acid from another.



▶ ***Structure and Function*** More than 20 different amino acids are found in nature. All amino acids are identical in the regions where they may be joined together by covalent bonds. This uniformity allows any amino acid to be joined to any other amino acid—by bonding an amino group to a carboxyl group. Proteins are among the most diverse macromolecules. The reason is that amino acids differ from each other in a side chain called the R-group, which have a range of different properties. Some R-groups are acidic and some are basic. Some are polar, some are nonpolar, and some even contain large ring structures.

▶ ***Levels of Organization*** Amino acids are assembled into polypeptide chains according to instructions coded in DNA. To help understand these large molecules, scientists describe proteins as having four levels of structure. A protein's primary structure is the sequence of its amino acids. Secondary structure is the folding or coiling of the polypeptide chain. Tertiary structure is the complete, three-dimensional arrangement of a polypeptide chain. Proteins with more than one chain are said to have a fourth level of structure, describing the way in which the different polypeptides are arranged with respect to each other. **Figure 2–18** shows these four levels of structure in hemoglobin, a protein found in red blood cells that helps to transport oxygen in the bloodstream. The shape of a protein is maintained by a variety of forces, including ionic and covalent bonds, as well as van der Waals forces and hydrogen bonds. In the next lesson, you will learn why a protein's shape is so important.

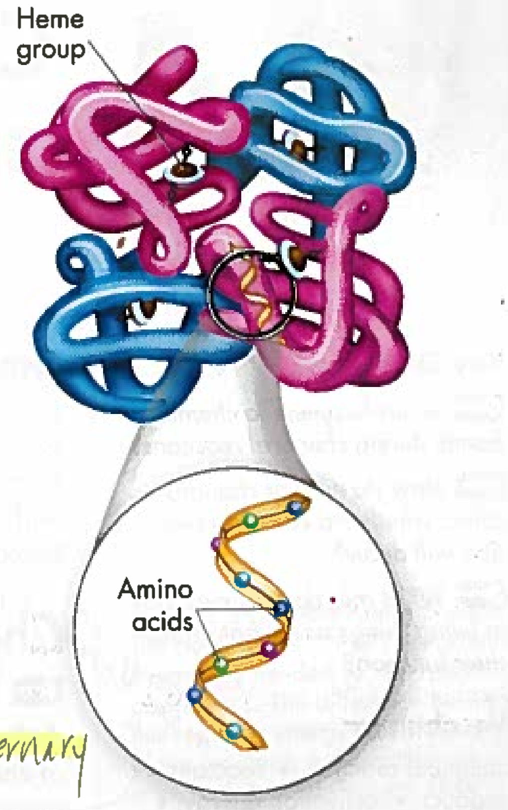


FIGURE 2–18 Protein Structure The protein hemoglobin consists of four subunits. The iron-containing heme group in the center of each subunit gives hemoglobin its red color. An oxygen molecule binds tightly to each heme molecule. **Interpret Visuals** ***How many levels of organization does hemoglobin have?***

2.3 Assessment

Review Key Concepts

1. a. Review What are the major elements of life?

b. Relate Cause and Effect What properties of carbon explain carbon's ability to form different large and complex structures?

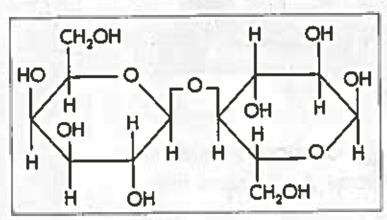
2. a. Review Name four groups of organic compounds found in living things.

b. Explain Describe at least one function of each group of organic compound.

c. Infer Why are proteins considered polymers but lipids not?

VISUAL THINKING

3. A structural formula shows how the atoms in a compound are arranged.



a. Observe What atoms constitute the compound above?

b. Classify What class of macromolecule does the compound belong to?

2.4 Chemical Reactions and Enzymes

Key Questions

What happens to chemical bonds during chemical reactions?

How do energy changes affect whether a chemical reaction will occur?

What role do enzymes play in living things and what affects their function?

Vocabulary

chemical reaction • reactant • product • activation energy • catalyst • enzyme • substrate

Taking Notes

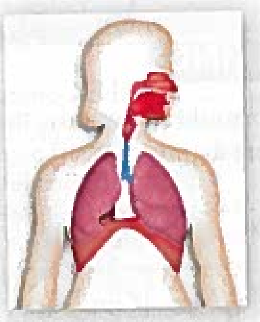
Concept Map As you read, make a concept map that shows the relationship among the vocabulary terms in this lesson.

THINK ABOUT IT Living things, as you have seen, are made up of chemical compounds—some simple and some complex. But chemistry isn't just what life is made of—chemistry is also what life does. Everything that happens in an organism—its growth, its interaction with the environment, its reproduction, and even its movement—is based on chemical reactions.

Chemical Reactions

What happens to chemical bonds during chemical reactions?

A **chemical reaction** is a process that changes, or transforms, one set of chemicals into another. An important scientific principle is that mass and energy are conserved during chemical transformations. This is also true for chemical reactions that occur in living organisms. Some chemical reactions occur slowly, such as the combination of iron and oxygen to form an iron oxide called rust. Other reactions occur quickly. The elements or compounds that enter into a chemical reaction are known as **reactants.** The elements or compounds produced by a chemical reaction are known as **products.** **Chemical reactions involve changes in the chemical bonds that join atoms in compounds.** An important chemical reaction in your bloodstream that enables carbon dioxide to be removed from the body is shown in **Figure 2–19.**



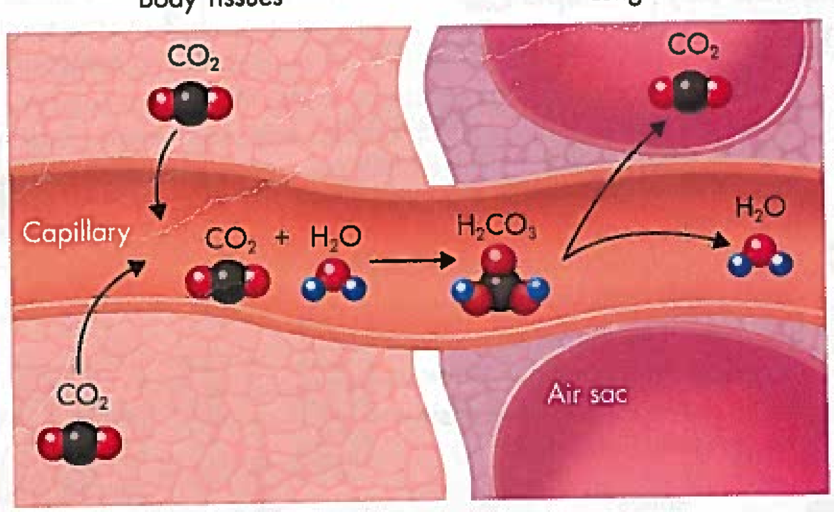


FIGURE 2–19 Carbon Dioxide in the Bloodstream As it enters the blood, carbon dioxide reacts with water to produce carbonic acid (H_2CO_3), which is highly soluble. This reaction enables the blood to carry carbon dioxide to the lungs. In the lungs, the reaction is reversed and produces carbon dioxide gas, which you exhale.

Energy in Reactions

How do energy changes affect whether a chemical reaction will occur?

Energy is released or absorbed whenever chemical bonds are formed or broken. This means that chemical reactions also involve changes in energy.

Energy Changes Some chemical reactions release energy, and other reactions absorb it. Energy changes are one of the most important factors in determining whether a chemical reaction will occur. **Chemical reactions that release energy often occur on their own, or spontaneously. Chemical reactions that absorb energy will not occur without a source of energy.** An example of an energy-releasing reaction is the burning of hydrogen gas, in which hydrogen reacts with oxygen to produce water vapor.

$$2H_2 + O_2 \longrightarrow 2H_2O$$

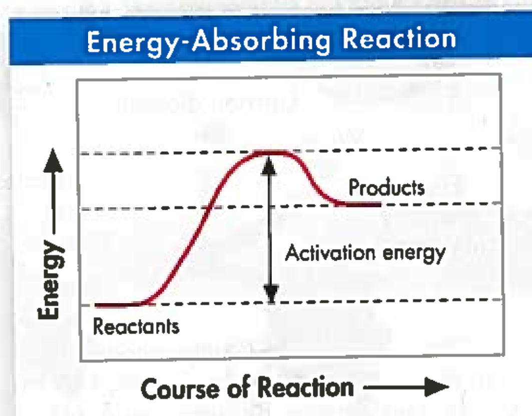
The energy is released in the form of heat, and sometimes—when hydrogen gas explodes—light and sound.

The reverse reaction, in which water is changed into hydrogen and oxygen gas, absorbs so much energy that it generally doesn't occur by itself. In fact, the only practical way to reverse the reaction is to pass an electrical current through water to decompose water into hydrogen gas and oxygen gas. Thus, in one direction the reaction produces energy, and in the other direction the reaction requires energy.

Energy Sources In order to stay alive, organisms need to carry out reactions that require energy. Because matter and energy are conserved in chemical reactions, every organism must have a source of energy to carry out chemical reactions. Plants get that energy by trapping and storing the energy from sunlight in energy-rich compounds. Animals get their energy when they consume plants or other animals. Humans release the energy needed to grow tall, to breathe, to think, and even to dream through the chemical reactions that occur when we metabolize, or break down, digested food.

Activation Energy Chemical reactions that release energy do not always occur spontaneously. That's a good thing because if they did, the pages of this book might burst into flames. The cellulose in paper burns in the presence of oxygen and releases heat and light. However, paper burns only if you light it with a match, which supplies enough energy to get the reaction started. Chemists call the energy that is needed to get a reaction started the **activation energy.** As **Figure 2–20** shows, activation energy is a factor in whether the overall chemical reaction releases energy or absorbs energy.

FIGURE 2–20 Activation Energy The peak of each graph represents the energy needed for the reaction to go forward. The difference between this required energy and the energy of the reactants is the activation energy. **Interpret Graphs** ***How do the energy of the reactants and products differ between an energy-absorbing reaction and an energy-releasing reaction?***



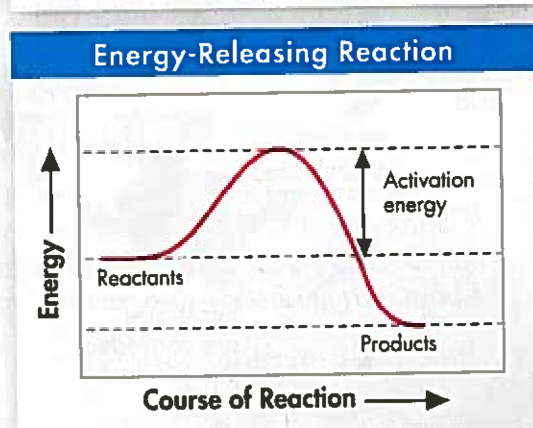


FIGURE 2–21 Effect of Enzymes Notice how the addition of an enzyme lowers the activation energy in this reaction. The enzyme speeds up the reaction.

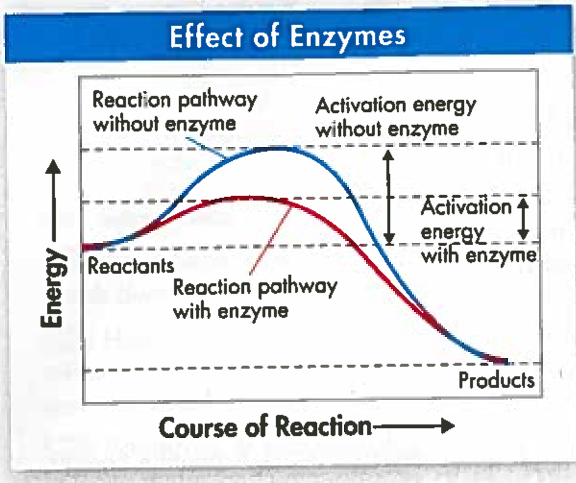
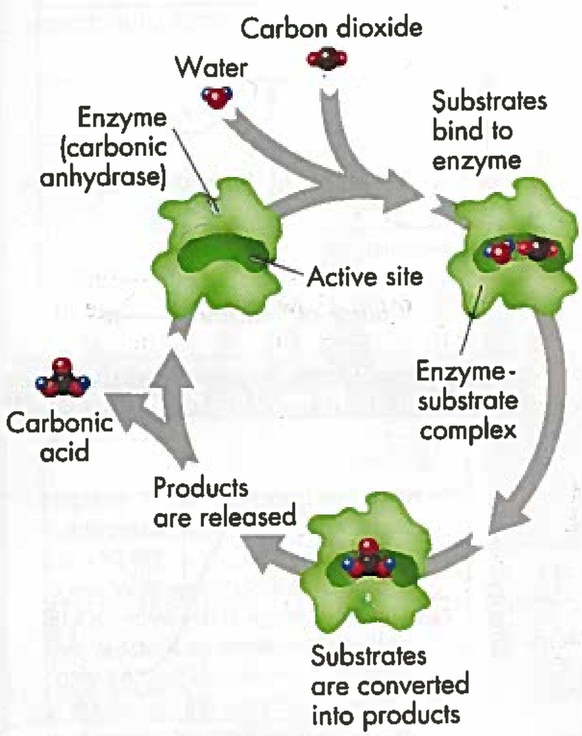


FIGURE 2–22 An Enzyme-Catalyzed Reaction The enzyme carbonic anhydrase converts the substrates carbon dioxide and water into carbonic acid (H_2CO_3). **Predicting** ***What happens to the carbonic anhydrase after the products are released?***



Enzymes

What role do enzymes play in living things and what affects their function?

Some chemical reactions that make life possible are too slow or have activation energies that are too high to make them practical for living tissue. These chemical reactions are made possible by a process that would make any chemist proud—cells make catalysts. A **catalyst** is a substance that speeds up the rate of a chemical reaction. Catalysts work by lowering a reaction's activation energy.

Nature's Catalysts **Enzymes** are proteins that act as biological catalysts. **Enzymes speed up chemical reactions that take place in cells.** Like other catalysts, enzymes act by lowering the activation energies, as illustrated by the graph in **Figure 2–21.** Lowering the activation energy has a dramatic effect on how quickly the reaction is completed. How big an effect does it have? Consider the reaction in which carbon dioxide combines with water to produce carbonic acid.

$$CO_2 + H_2O \longrightarrow H_2CO_3$$

Left to itself, this reaction is so slow that carbon dioxide might build up in the body faster than the bloodstream could remove it. Your bloodstream contains an enzyme called carbonic anhydrase that speeds up the reaction by a factor of 10 million. With carbonic anhydrase on the job, the reaction takes place immediately and carbon dioxide is removed from the blood quickly.

Enzymes are very specific, generally catalyzing only one chemical reaction. For this reason, part of an enzyme's name is usually derived from the reaction it catalyzes. Carbonic anhydrase gets its name because it also catalyzes the reverse reaction that removes water from carbonic acid.

The Enzyme-Substrate Complex How do enzymes do their jobs? For a chemical reaction to take place, the reactants must collide with enough energy so that existing bonds will be broken and new bonds will be formed. If the reactants do not have enough energy, they will be unchanged after the collision.

Enzymes provide a site where reactants can be brought together to react. Such a site reduces the energy needed for reaction. The reactants of enzyme-catalyzed reactions are known as **substrates. Figure 2–22** provides an example of an enzyme-catalyzed reaction.

The substrates bind to a site on the enzyme called the active site. The active site and the substrates have complementary shapes. The fit is so precise that the active site and substrates are often compared to a lock and key, as shown in **Figure 2–23.**

Regulation of Enzyme Activity Enzymes play essential roles in controlling chemical pathways, making materials that cells need, releasing energy, and transferring information. Because they are catalysts for reactions, enzymes can be affected by any variable that influences a chemical reaction. **Temperature, pH, and regulatory molecules can affect the activity of enzymes.**

Many enzymes are affected by changes in temperature. Not surprisingly, those enzymes produced by human cells generally work best at temperatures close to 37°C, the normal temperature of the human body. Enzymes work best at certain pH values. For example, the stomach enzyme pepsin, which begins protein digestion, works best under acidic conditions. In addition, the activities of most enzymes are regulated by molecules that carry chemical signals within cells, switching enzymes "on" or "off" as needed.

MYSTERY CLUE

The chemical reactions of living things, including those that require oxygen, occur more slowly at low temperatures. How would frigid antarctic waters affect the ice fish's need for oxygen?

VISUAL ANALOGY

LOCK AND KEY

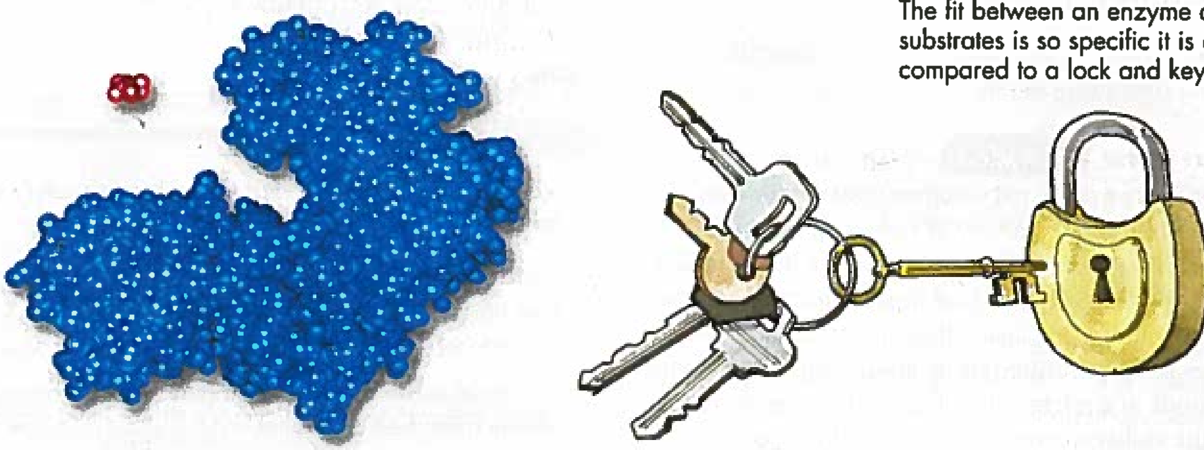


FIGURE 2–23 This space-filling model shows how a substrate binds to an active site on an enzyme. The fit between an enzyme and its substrates is so specific it is often compared to a lock and key.

2.4 Assessment

Review Key Concepts

1. a. Review What happens to chemical bonds during chemical reactions?

b. Apply Concepts Why is the melting of ice not a chemical reaction?

2. a. Review What is activation energy?

b. Compare and Contrast Describe the difference between a reaction that occurs spontaneously and one that does not.

3. a. Review What are enzymes?

b. Explain Explain how enzymes work, including the role of the enzyme-substrate complex.

c. Use Analogies A change in pH can change the shape of a protein. How might a change in pH affect the function of an enzyme such as carbonic anhydrase? (*Hint:* Think about the analogy of the lock and key.)

VISUAL THINKING

4. Make a model that demonstrates the fit between an enzyme and its substrate. Show your model to a friend or family member and explain how enzymes work using your model.

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