2.5 Enzymes

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

MAIN IDEAS

- A catalyst lowers activation energy.
- Enzymes allow chemical reactions to occur under tightly controlled conditions.

VOCABULARY

catalyst, p. 54
enzyme, p. 55
substrate, p. 56

Review
chemical reaction, activation energy, protein, hydrogen bond

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Connect Just how can a Venus flytrap digest a frog? It happens through the action of proteins called enzymes. Enzymes help to start and run chemical reactions in living things. For example, enzymes are needed to break down food into smaller molecules that cells can use. Without enzymes, a Venus flytrap couldn't break down its food, and neither could you.

MAIN IDEA

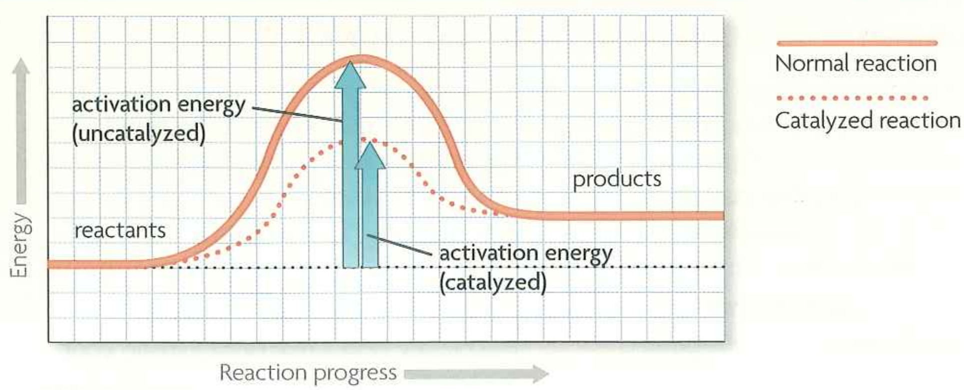
A catalyst lowers activation energy.

Remember what you learned about activation energy in Section 2.4. Activation energy for a chemical reaction is like the energy that is needed to push a rock up a hill. When enough energy is added to get the rock to the top of a hill, the rock can roll down the other side by itself. Activation energy gives a similar push to a chemical reaction. Once a chemical reaction starts, it can continue by itself, and it will go at a certain rate.

Often, the activation energy for a chemical reaction comes from an increase in temperature. But even after a chemical reaction starts, it may happen very slowly. The reactants may not interact enough, or they may not be at a high enough concentration, to quickly form the products of the reaction. However, both the activation energy and rate of a chemical reaction can be changed by a chemical catalyst, as shown in **FIGURE 2.22.** A **catalyst** (KAT-l-ihst) is a substance that decreases the activation energy needed to start a chemical reaction and, as a result, also increases the rate of the chemical reaction.

FIGURE 2.22 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.



Compare the activation energies and the reaction rates in the graph in **FIGURE 2.22**. Under normal conditions, the reaction requires a certain amount of activation energy, and it occurs at a certain rate. When a catalyst is present, less energy is needed and the products form faster. Although catalysts take part in chemical reactions, catalysts are not considered to be either reactants or products because catalysts are not changed or used up during a reaction.

Summarize Describe two functions of catalysts in chemical reactions.

MAIN IDEA

Enzymes allow chemical reactions to occur under tightly controlled conditions.

Chemical reactions in organisms have to take place at an organism's body temperature. Often, reactants are found in low concentrations. Because the reactions must take place very quickly, they usually need a catalyst. **Enzymes** are catalysts for chemical reactions in living things. Enzymes, like other catalysts, lower the activation energy and increase the rate of chemical reactions. In reactions that are reversible, such as the carbon dioxide and carbonic acid reaction described in Section 2.4, enzymes do not affect chemical equilibrium. This means that enzymes do not change the direction of a reaction—they just change the amount of time needed for equilibrium to be reached.

Enzymes are involved in almost every process in organisms. From breaking down food to building proteins, enzymes are needed. For example, amylase is an enzyme in saliva that breaks down starch into simpler sugars. This reaction occurs up to a million times faster with amylase than without it. Enzymes are also an important part of your immune system, as shown in **FIGURE 2.23**.

Almost all enzymes are proteins. These enzymes, like other proteins, are long chains of amino acids. Each enzyme also depends on its structure to function properly. Conditions such as temperature and pH can affect the shape and function, or activity, of an enzyme. Enzymes work best in a small temperature range around the organism's normal body temperature. At only slightly higher temperatures, the hydrogen bonds in an enzyme may begin to break apart. The enzyme's structure changes and it loses its ability to function. This is one reason why a very high fever is so dangerous to a person. A change in pH can also affect the hydrogen bonds in enzymes. Many enzymes in humans work best at the nearly neutral pH that is maintained within cells of the human body.

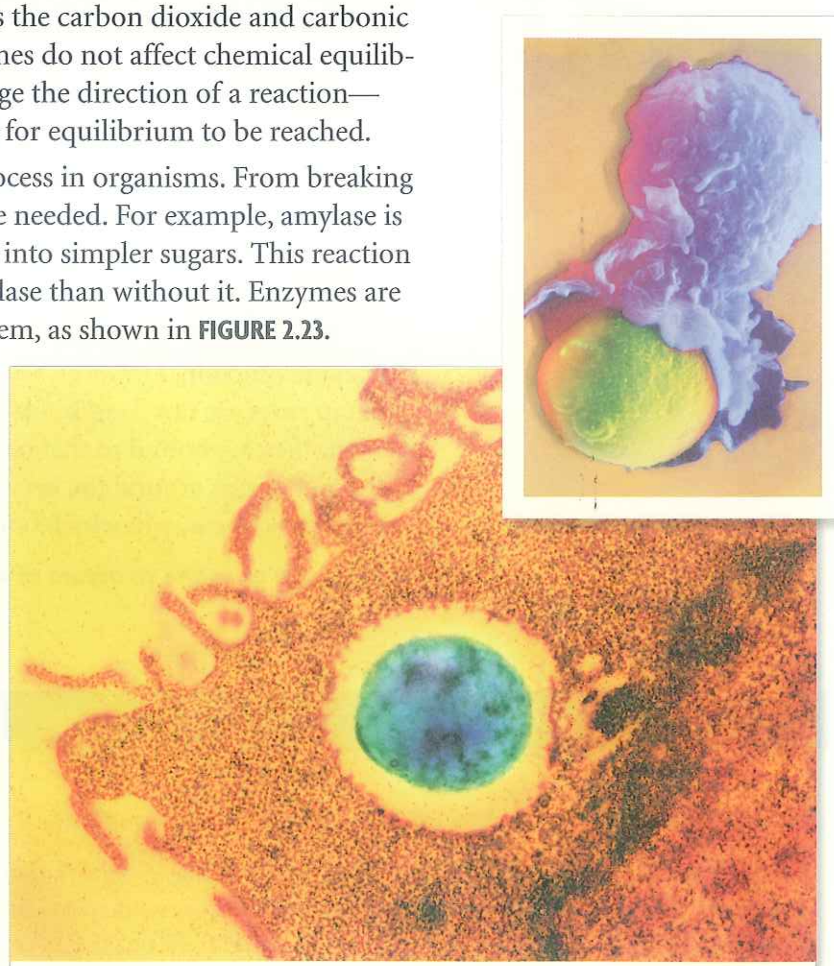
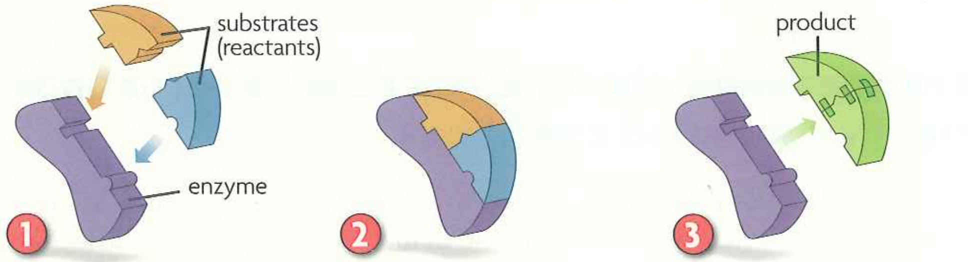


FIGURE 2.23 The inset micrograph (top) shows a white blood cell engulfing an invading pathogen. The larger micrograph shows a pathogen after it has been captured. Once inside a white blood cell, enzymes are used to destroy the pathogen. (inset image: colored SEM; magnification about 3000×; large image: colored TEM; magnification 11,000×)

Connecting **CONCEPTS**

Biochemistry The order of amino acids determines the structure and function of an enzyme. An enzyme's structure often depends on hydrogen bonds between amino acids.

Enzyme structure is important because each enzyme's shape allows only certain reactants to bind to the enzyme. The specific reactants that an enzyme acts on are called **substrates.** For example, amylase only breaks down starch. Therefore, starch is the substrate for amylase. Substrates temporarily bind to enzymes at specific places called active sites. Like a key fits into a lock, substrates exactly fit the active sites of enzymes. This is why if an enzyme's structure changes, it may not work at all. This idea of enzyme function, which is called the lock-and-key model, is shown below.



1 Substrates bind to an enzyme at certain places called active sites.

2 The enzyme brings substrates together and weakens their bonds.

3 The catalyzed reaction forms a product that is released from the enzyme.

The lock-and-key model helps explain how enzymes work. First, enzymes bring substrate molecules close together. Because of the low concentrations of reactants in cells, many reactions would be unlikely to take place without enzymes bringing substrates together. Second, enzymes decrease activation energy. When substrates bind to the enzyme at the enzyme's active site, the bonds inside these molecules become strained. If bonds are strained, or stretched slightly out of their normal positions, they become weaker. Less activation energy is needed for these slightly weakened bonds to be broken.

The lock-and-key model is a good starting point for understanding enzyme function. However, scientists have recently found that the structures of enzymes are not fixed in place. Instead, enzymes actually bend slightly when they are bound to their substrates. In terms of a lock and key, it is as if the lock bends around the key to make the key fit better. The bending of the enzyme is one way in which bonds in the substrates are weakened.

Apply **How does the structure of an enzyme affect its function?**

2.5 ASSESSMENT

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REVIEWING MAIN IDEAS

1. How does a **catalyst** affect the activation energy of a chemical reaction?
2. Describe how the interaction between an **enzyme** and its **substrates** changes a chemical reaction.

CRITICAL THINKING

3. **Infer** Some organisms live in very hot or very acidic environments. Would their enzymes function in a person's cells? Why or why not?
4. **Predict** Suppose that the amino acids that make up an enzyme's active site are changed. How might this change affect the enzyme?

Connecting **CONCEPTS**

5. **Homeostasis** Organisms need to maintain homeostasis, or stable internal conditions. Why is homeostasis important for the function of enzymes?