CHAPTER

5 Enzymes

BIO WATCH

Scan this page to watch a clip on how the enzymes in washing powders work.

Before watching, discuss what you expect to see or hear.

QUESTIONS

- What do you think the enzymes in the washing powders do to the stains on the T-shirt?
- Do you think these enzymes can do the same job in boiling water? Can you explain your reasoning?
- Do you think enzymes are living things?

Isn't it amazing how the toughest stains can be removed from your favourite T-shirts after washing? It is not done with the aid of special powers. It is through "special powders". A lot of washing powders available in the market contain biological catalysts called enzymes. What are enzymes?

5.1 Enzymes Are Biological Catalysts

In this section, you will learn the following:

- Define *catalyst*.
- Define *enzyme*.
- Describe why enzymes and reaction rate are important in sustaining life in living organisms.

What are catalysts?

Did you know that catalysts are involved in many reactions in our daily lives? For example, hydrogen peroxide can be broken down into water and oxygen.

$$\underset{\text{hydrogen peroxide}}{2H_2O_2} \longrightarrow \underset{\text{water}}{2H_2O} + \underset{\text{oxygen}}{O_2}$$

This reaction occurs very slowly. It can be sped up by adding manganese dioxide. The manganese dioxide remains unchanged. Manganese dioxide is a catalyst.

Figure 5.1 *Manganese dioxide can be used to speed up the breakdown of hydrogen peroxide.*

A **catalyst** is a substance that can increase the rate of a chemical reaction, without being chemically changed by the reaction.

What are enzymes?

Enzymes are different from manganese dioxide because of these reasons:

- Enzymes are made of proteins.
- Unlike manganese dioxide, they can be destroyed by high temperature and pH.

Therefore, enzymes are known as *biological catalysts*.

Enzymes are biological catalysts that can increase the rate of a chemical reaction, without being chemically changed by the reaction. They are made of proteins and are involved in all metabolic reactions.

In living organisms, numerous reactions are catalysed by enzymes. Without enzymes, normal activities may not be able to be maintained.

LINK

What are proteins? Recall what you have learnt in Chapter 4.

QUICK CHECK

Enzymes are biological catalysts, mainly made of fats.

True or false?

What reactions do enzymes catalyse?

(a) Reactions in digestion

Some food molecules are large and insoluble in water. These molecules cannot diffuse through the cell surface membrane. Imagine a meal consisting of fish and rice:

- Rice contains starch, a very large carbohydrate molecule.
- Fish contains two types of large molecules: proteins and fats.

When you eat this meal, the fish and rice go into your stomach and then into your intestines. Both these organs are lined with cells. Large molecules such as proteins, fats and starch cannot diffuse across the cell surface membranes of these cells. The large molecules must first be converted into simpler smaller substances which are

- soluble in water;
- small enough to diffuse through cell surface membranes (Figure 5.2).

This process of breaking down food molecules into smaller substances is known as **digestion** of food.

Food is digested by **digestive enzymes**. Some examples of digestive enzymes can be found in Table 5.1.

LINK
What is digestion?
Find out in Chapter 7.

Table 5.1 *Examples of digestive enzymes and their functions*

Enzyme	Function
Amylase	Digests starch to maltose
Maltase	Digests maltose to glucose
Protease	Digests proteins to amino acids
Lipase	Digests fats to fatty acids and glycerol

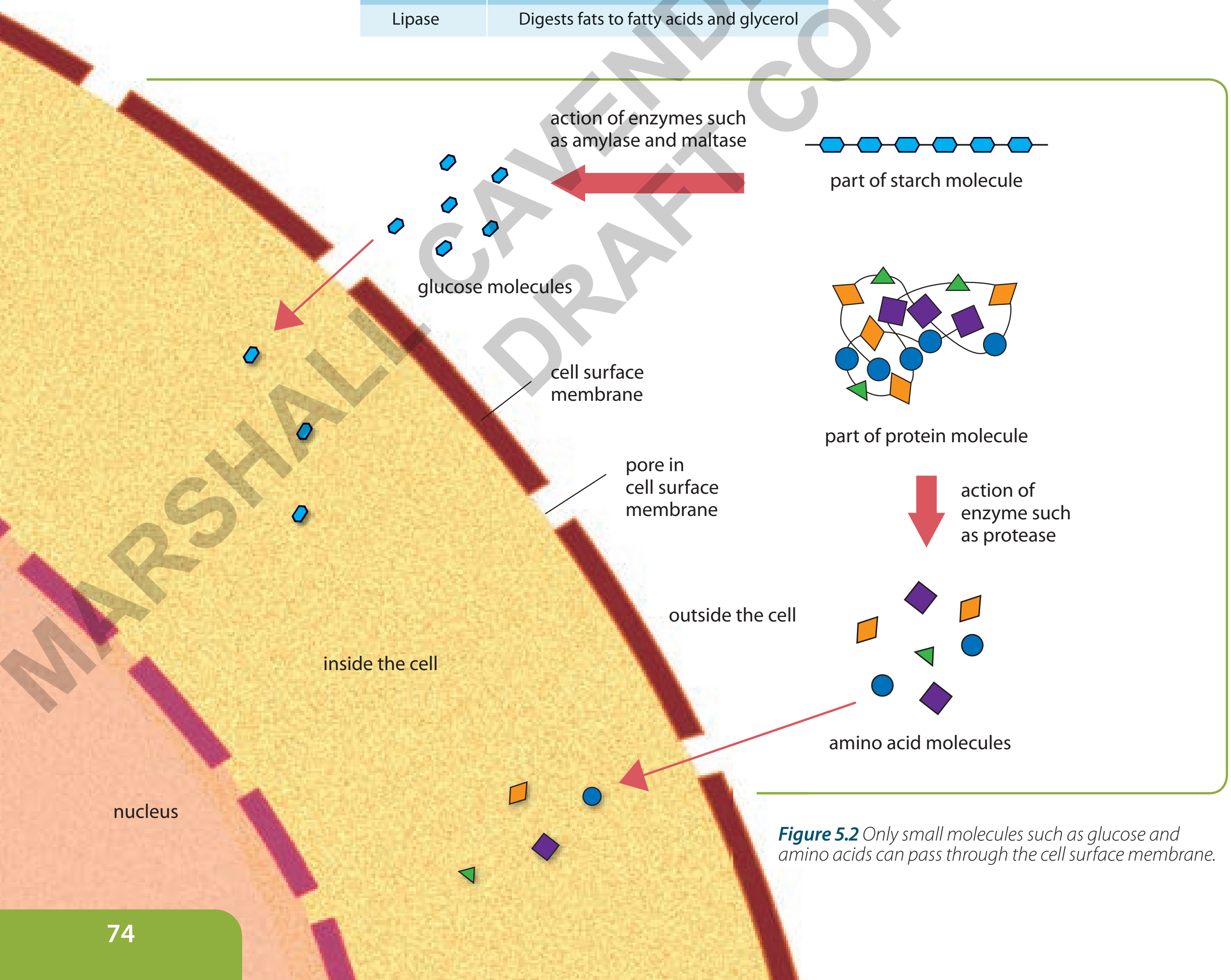
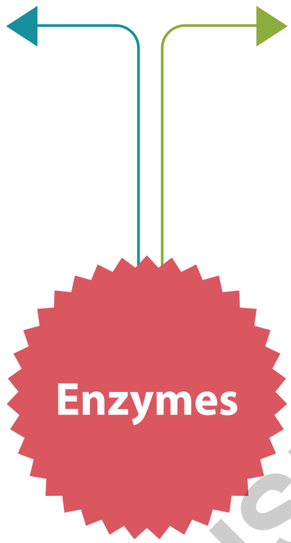


Figure 5.2 *Only small molecules such as glucose and amino acids can pass through the cell surface membrane.*

(b) Reactions that build up or break down complex substances

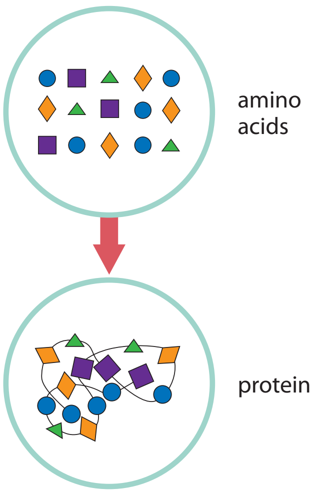
Besides digestion, other biological reactions also require one or more enzymes as catalysts. Figure 5.3 shows that enzyme-catalysed reactions can be classified into

- reactions that build up complex substances (anabolic reactions);
- reactions that break down complex substances (catabolic reactions).



Build up complex substances

Cells build up or synthesise complex substances from simpler ones. For example, amino acids taken into the cells may be used to build up proteins. The cytoplasm contains special enzymes to catalyse such reactions.



▲ Protein being built up from amino acids

Break down complex substances

Cells break down complex substances to simple substances. For example:

- Large molecules in food are converted to smaller molecules by digestive enzymes.
- In cell respiration, glucose is broken down to release energy and form carbon dioxide and water. This process involves a series of chemical reactions, each catalysed by a different enzyme. The enzymes act together to completely break down glucose.
- Hydrogen peroxide is sometimes produced during chemical reactions in the cells. This substance is toxic to the cells. Both plant and animal cells produce the enzyme catalase to break down hydrogen peroxide to water and oxygen, hence removing the toxic effect. Catalase is especially abundant in the blood and liver of mammals.

$$2H_2O_2 \xrightarrow{\text{catalase}} 2H_2O + O_2$$

hydrogen peroxide → water + oxygen

Figure 5.3 *Classifying enzyme-catalysed reactions*

It is important to note that *although enzymes catalyse practically all the chemical reactions that occur in an organism, they are produced only when needed*. For example, digestive enzymes are produced only when there is food to digest in the gut.

How are enzymes named?

Enzymes are named according to a scientific system. The name of each enzyme

- shows the substance on which the enzyme acts;
- ends in *ase*.

For example, lipase refers to an enzyme that acts on lipids (Figure 5.4).

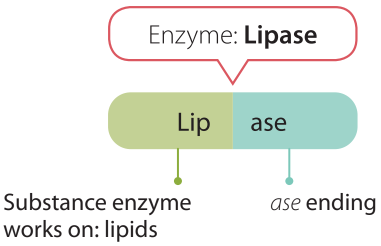


Figure 5.4 *Example showing how the enzyme lipase was named*

ENRICHMENT *INFO*

Previously, enzymes were simply named by the persons who discovered them. For example, pepsin was discovered and named by a scientist who was studying digestive processes. *Pepsin* means *to digest* in Greek. However, naming enzymes this way led to much confusion. Thus, a scientific way of naming enzymes had to be devised.

ENRICHMENT THINK

At low temperatures, enzymes are inactive but not destroyed.

1 Why do we place meat in the freezer?

2 Why does meat need to be cooked as soon as it is thawed?

ENRICHMENT THINK

Do you think denaturation is a reversible process?

Denaturation is the change in the three-dimensional structure of an enzyme or any other soluble protein, caused by heat or chemicals such as acids or alkalis.

Denaturation results in the loss or alteration of the enzyme's active site (Figure 5.8). The substrate can no longer fit into the enzyme's active site, and no reaction will occur. Hence, when an enzyme is denatured, it can no longer act as a catalyst.

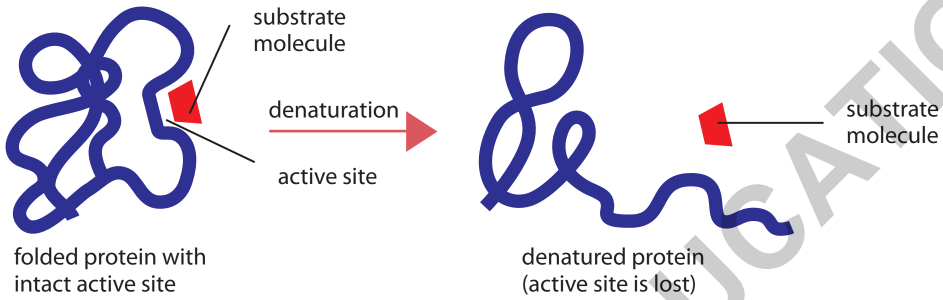


Figure 5.8 *At temperatures above 45°C, some enzymes are denatured. Enzymes lose their active sites when they are denatured.*

Let's Investigate 5A

Objective

To investigate how temperature affects enzyme action

Procedure

1 Label and fill test tubes A_1, B_1, C_1 and D_1 with 5 cm^3 of starch solution respectively.

2 Label and fill test tube D_2 with 3 cm^3 of distilled water, and test tubes A_2, B_2 and C_2 with 3 cm^3 of diastase solution respectively.

3 Set up the experiment as shown in Figure 5.9 by placing the test tubes into water baths of varying temperatures:
- A_1, A_2: 0°C
- B_1, B_2: 37.0°C
- C_1, C_2: 100.0°C
- D_1, D_2: 37.0°C

4 Pour the contents of test tubes A_2, B_2, C_2 and D_2 into test tubes A_1, B_1, C_1 and D_1, respectively.

5 Test the solution in each test tube (A_1, B_1, C_1 and D_1) for the presence of starch using iodine solution.

6 Observe and record your results.

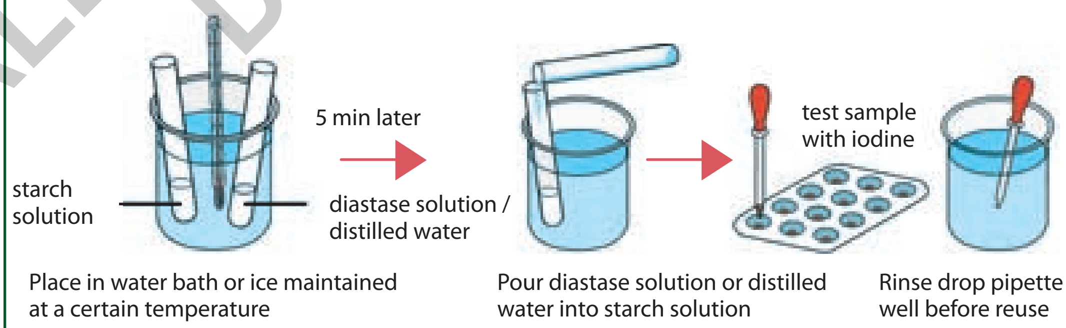


Figure 5.9 *Experimental set-up to show how temperature affects enzyme activity*

Discussion

The less time taken to digest starch, the more active the enzyme is. In this investigation, enzyme activity is measured by calculating $\frac{1}{T}$ (the reciprocal of the time taken to digest starch). What can you conclude about the effect of temperature on the activity of diastase from the graph of $\frac{1}{T}$ against temperature?

LINK PWB

Practical 5A, pp. 39–41

HELPFUL NOTES

The reciprocal of time (T) means $\frac{1}{T}$.

For example:

Time (sec)	10	20	30
$\frac{1}{T}$	0.1	0.2	0.3

Let's Review

Section A: Multiple-choice Questions

1 At 10°C, protease was used to digest 1 g of protein to polypeptides. How much protein would be digested within the same amount of time if the experiment was repeated at 20°C?

A 0.15 g B 0.25 g
C 0.5 g D 2 g

2 A Petri dish was filled with agar jelly containing starch. Four holes were cut in the jelly. Each hole was filled with the substances shown in Figure 5.10.

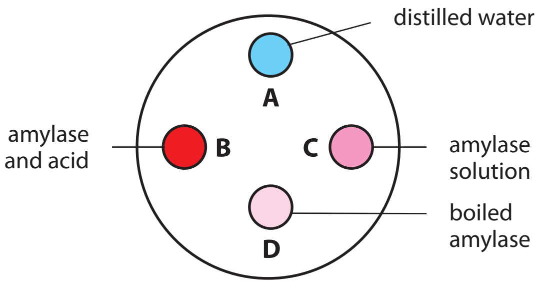
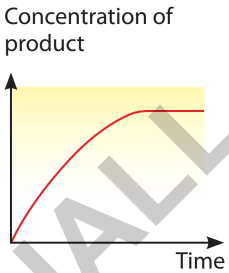


Figure 5.10

After 30 minutes, iodine solution was poured over the jelly. Which hole has the largest yellow-brown region surrounding it?

3 Which graph shows the changes in the concentration of the product in an enzyme-controlled reaction?

A


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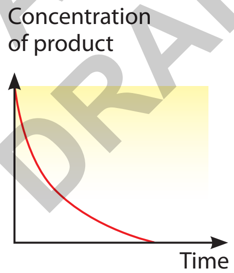
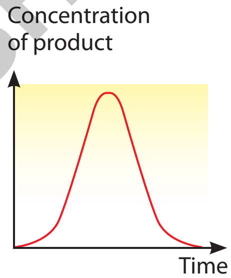
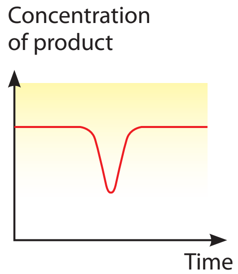


C


D


Section B: Short-answer and Structured Questions

1 **(a)** Why are enzymes so specific in their actions?
(b) State **three** characteristics of enzymes.
(c) Describe how an enzyme works.

2 **(a)** S Explain the effect of temperature on enzyme activity with reference to kinetic energy, shape and fit, frequency of effective collisions and denaturation.
(b) Explain the effect of pH on enzyme activity with reference to shape and fit and denaturation.

3 Digestive enzymes are used in some washing powders. The stains on your clothes caused by organic matter, such as sweat, blood, curry and plant material, consist of large molecules, often proteins and fats. These large molecules do not dissolve easily in water.
(a) How would digestive enzymes help to clean clothes with proteins and fats on them?
(b) It is recommended on the packet of biological washing powders that clothes be washed at low temperatures (less than 45°C). Why?
(c) Not all the dirt on clothes is made of protein or fat, for example, the oil from a bicycle chain. To get rid of this sort of dirt, clothes need to be washed at much higher temperatures (70–80°C). What problem would this cause if you were washing with a biological powder?
(d) To solve the problem in (c), industrial biologists studied the enzymes of sulfur bacteria that flourish in hot springs. Here, the water temperature is often close to the boiling point. Why would using enzymes from these organisms make a better biological washing powder?