

# ENZYMES

## 35.1 INTRODUCTION

Our body requires many compounds for its functioning. These compounds are obtained mainly through diet in the form of carbohydrates, proteins, vitamins and fats. These are then converted into various compounds necessary for the functioning of the cells in the body. Carbohydrates, proteins and fats are too large to be taken up by the cell as it is. Therefore, they are first broken down into small simpler molecules that are utilized for the synthesis of other important compounds. Well, how these macromolecules are broken and converted into other compounds? All these reactions are carried out by very important molecules of the cell called "*Enzymes*". Without enzymes living processes will be very slow. For example, without the presence of enzymes in our digestive tract, it would take about 50 years to digest a single meal. Enzymes make the reactions go at a very high rate in order to meet the requirement of the body. Thus enzymes are biological catalyst, which catalyses metabolic reactions. Each specific reaction requires a specific enzyme. The activity of each enzyme is controlled. If any of the enzymes are not there or become defective, it becomes very difficult for the cell to manage its survival. Thus many diseases occur due to defective enzymes. Let us learn more about enzymes in this lesson.

## 35.2 OBJECTIVES

After reading this lesson, you will be able to:

- define enzymes.
- name the enzymes
- explain the action of enzymes
- classify the enzymes.
- state the characteristic features of enzymes
- describe the use of enzymes in various aspects of life and industry.

### 35.3 WHAT ARE ENZYMES ?

Let us begin with a simple activity where you can actually experience the action of an enzyme.

**Activity:** You can experience the breaking down of starch (present in chapatis that you eat) into glucose by an enzyme called amylase present in saliva. You simply have to chew your bite at least 40 times and the sweet taste that you experience is the glucose obtained from the breakdown of starch.

Now that you have experienced an enzyme working in your body, let us define

**Enzymes are protein catalysts for the biochemical reactions in all living cells.**

The term enzyme is derived from Greek en=in; zyme=leaven or ferment. Yeast cells were the first to reveal enzyme activity in living organisms.

### 35.4 NOMENCLATURE

Let us now learn to identify different enzymes carrying out different reactions or how the enzymes can be named?

**Enzymes are mostly known by common names obtained by adding the suffix -ase to the name of the substrate or to the reaction they catalyze.**

For example, Glucose oxidase is an enzyme catalyzing the oxidation of glucose. Glucose-6-phosphatase carries out hydrolysis of phosphate from glucose-6-phosphate. Proteinase, Deoxyribonuclease and ribonuclease hydrolyze proteins, Deoxyribonucleic acid and Ribonucleic acid, respectively.

Based on their activity, the enzymes are divided into six major classes:

- a. **Oxidoreductases:** Enzymes involved in oxidation and reduction.
- b. **Transferases :** Transfer functional group (e.g. amino or phosphate groups between donor and acceptor.)
- c. **Hydrolases:** Transfer water, that is, they catalyze the hydrolysis of a substrate.
- d. **Lyases:** Add or remove the elements of water, ammonia or carbon dioxide.
- e. **Isomerases:** Catalyze structural change within one molecule.
- f. **Ligases:** Join two molecules together at the expense of a high energy phosphate bond (adenosine triphosphate (ATP)).

## INTEXT QUESTIONS 35.1

1. What are enzymes?  
.....
2. How are the enzymes named?  
.....
3. Classify the enzymes according to their activity.  
.....

### 35.5 ENZYMES ARE SPECIFIC IN THEIR ACTION

Enzymes exhibit specificity or activity towards only one particular type of compound. This is due to a particular shape of the enzymes, specific arrangement of amino acid in its active site and the structure of the substrate. The active site has two regions:

- (i) **Binding site:** This includes the region of the active site which comes in contact with the substrate or where the substrate binds to the enzyme.
- (ii) **Catalytic site:** This is the region within the active site and is responsible for catalysis.

The active site of an enzyme may be clefts or crevices with three dimensional entity. The substrates are bound to the binding site of the enzyme by relatively weak forces

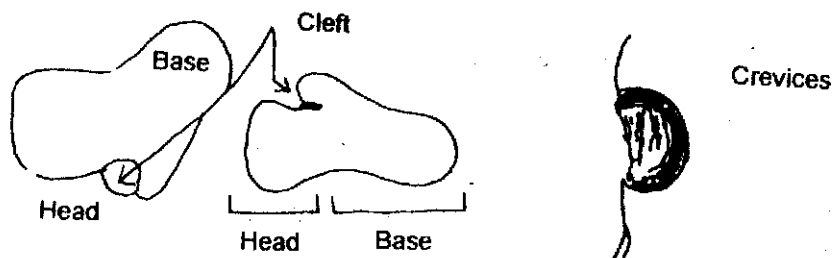


Fig. 5.1: A diagrammatic representation of cleft and crevices in a model three dimensional structure of an enzyme.

Two theories have been proposed to explain the specificity of enzyme action.

- a. **Lock and Key theory:** In 1890, Emil Fisher proposed a model to explain the great specificity of enzymes. He explained the interaction between substrate and enzymes in terms of a "Lock and Key". According to this concept the catalytic site of the enzymes by itself is complementary in shape to that of the substrate. That means it fits each other as shown in figure. The enzymic reaction is possible if the substrate matches the active centre as the key fits the lock. If the substrate ("key") becomes slightly modified, it no longer fits the active centre ("lock") and no reaction takes place.

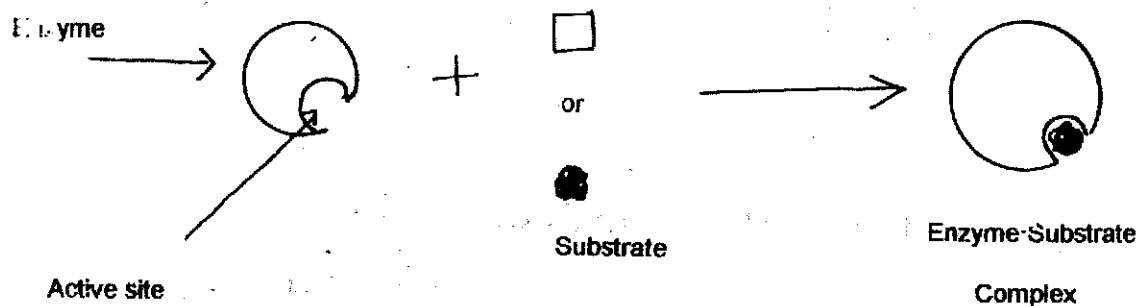


Fig. 35.2: Representation of lock and key theory of enzyme substrate interaction.

Note in fig. 35.2 that only the substrate that fits the active site binds to the enzyme and allows the reaction to take place. Note the substrate that does not have the complementary shape to the active site is not acted upon.

b. **Induce-fit theory:** This was proposed by D.E. Koshland. According to this theory, the enzyme changes shape upon binding the substrate. The final shape of the enzyme and the shape of the substrate are only complementary i.e. fit each other only after binding as shown in figure 35.3.

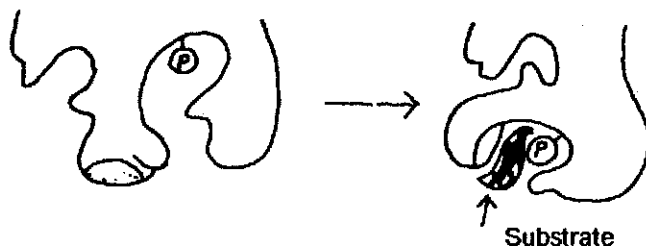
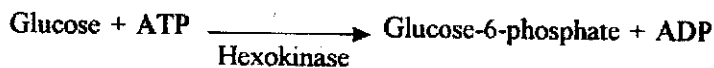


Fig. 35.3: Representation of an induced fit by a conformational change in the protein structure.

Once the substrate interacts with the enzyme, it just does not convert into a product and release it. The reaction is a multistep process and can be written as follows:



Where E is enzyme, S is substrate and P is product. For Example:



In this reaction, glucose is the substrate (S) and glucose-6-phosphate is the final product (P). Hexokinase is the enzyme (E) catalyzing the phosphorylation of glucose.

## INTEXT QUESTIONS 35.2

1 How many regions does the active site of an enzyme have? Name them

.....

2. What are the two theories that have been proposed to explain the specificity of an enzyme action?

### 35.6 ENERGETICS OF ENZYME ACTION

For any reaction to occur, the two or more compounds involved in the reaction must come in contact or collide. Each participant of the reaction has some amount of the energy which is required to surmount a barrier separating the reactants from becoming the product. Let us consider going uphill and to the other side of the hill. Imagine there is a barrier right at the bottom before we start climbing. As we climb we require a definite amount of energy to cross the barrier and to reach the top of the hill from where going down to the other side will be easy. Enzyme also act in such a way. The energy required for the proton on a substrate to reach to an intermediate position (at this stage the energy of the system goes through a maximum), like the top of the hill, is called **activation energy** and the system is said to be in the **transition state**. Now, how do enzymes help the reaction go faster? They reduce the activation energy thus making the substrate go to the product state faster (Now the peak of the hill has become less steep and shorter, so we can reach the other side of the hill faster). The activation energy determines whether the reaction is fast or slow. Higher the activation energy, slower is the reaction.

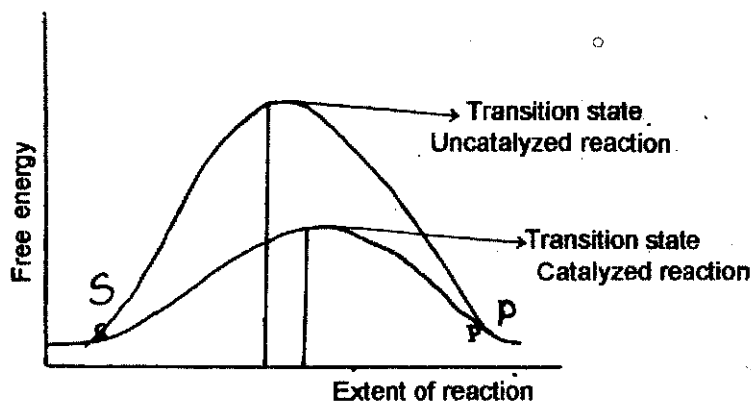


Fig. 35.4: Diagrammatic representation of the free energy of activation of chemical reaction.

In fig. 35.4 note that the energy required to reach the transition state is much lower in catalyzed reaction than that required in an uncatalyzed reaction. In this figure S the substrate and P the product.

### 35.7 CHARACTERISTICS OF ENZYMES

Enzymes share some properties with chemical catalysts, but they also differ in several ways.

### 35.7.1 Properties that are common in chemical catalysts and enzymes

- Like chemical catalysts, enzymes are neither consumed nor produced during the course of a reaction
- They also do not cause reaction to take place, but simply speed up the reaction that would otherwise take place at a much slower rate.
- Enzymes do not affect the equilibrium of a reversible reaction, rather accelerate both the forward and the backward reactions to the same extent.
- Enzymes catalyze energetically feasible reaction only.

### 35.7.2 Differences between enzymes and chemical catalysts

- Enzymes exhibit high specificity so that they carry out metabolic processes following strict pathways. The substrate specificity of the enzyme means that they utilize only one kind of substrate. Group specificity indicates that a presence of a chemical group on a substrate is must for the enzyme activity. Chemical catalysts on the other hand are more general and can act on various similar substrate molecules.
- Enzymes catalyze the reactions under mild conditions i.e. at normal pressure, low temperature and pH close to neutral. Since enzymes are of proteinaceous nature (besides the exception of some ribonucleic acids now known to catalyze some reactions) they are susceptible to temperature variation and to change of pH. Chemical catalysis occur often at high temperature or pressure
- Enzymes' activities are controlled. It means that the activity of an enzyme changes according to various environmental factors and the need of the cell
- The rate of an enzymatic reaction is proportional to the amount of enzyme.

## 35.8 APPLICATIONS OF ENZYMES

You have already learnt about different types of enzymes. Enzymes carrying out different functions are employed in various fields of agriculture and industry. Some of the applications of different enzymes are listed below

1. Amylase preparations prepared from extracts of mold fungi are widely used for starch hydrolysis. These are used for making high quality bread and alcoholic formulations. starters in the making of beer.
2. Enzyme pectinase, which breaks down pectin, a component of plant cell envelope is used in fruit juice, natural perfume, oil and cosmetics.
3. Proteolytic enzymes eg trypsin, chymotrypsin, etc. are used in leather industries for tanning and bating processes. Laccase is used in pulp and paper etc. gent industries
4. Enzyme glucose oxidase is used in the production of lactic acid, and in bleaching and clarifying mineral water, eliminating oxygen from canned products and bottled soft drinks to prevent oxidation and rancidity.

Proteolytic enzymes are used as protein stain remover for clothes

6. Bacterial enzymes are used in the production of artificial proteins and petrol products for feeding farm animals.
7. Digestive enzymes (pepsin and trypsin) are commonly used by people having difficulty in digestion or disease like dyspepsia.
8. Proteolytic enzymes (trypsin and chymotrypsin) are used in surgery for cleansing wounds and tissues streptokynase and eurokynase are enzymes which degrade blood clots and used on patient suffering from thrombosis.
9. Immobilized enzymes are used in the technological synthesis of hormonal preparations and drugs of biological origin.

---

### INTEXT QUESTIONS 35.3

---

1. How do enzymes increase the rate of a reaction?  
.....
2. What is the transition state of a chemical reaction?  
.....
3. Which group of enzyme catalyses the transfer of functional groups from one molecule to another?  
.....
4. List two differences between a chemical catalyst and an enzyme.  
.....
5. What enzymes are used in surgery for cleansing wounds and tissues?  
.....
6. Which enzyme is prepared from mold fungi and used in baking industry?  
.....

---

### 35.10 WHAT YOU HAVE LEARNT

- Enzymes are biological catalyst.
  - Enzymes speed up reactions in our body.
  - Enzymes are named after the substrate they act upon and the reaction they catalyze.
  - Enzymes catalyze only specific reaction and act upon specific substrates.
-

- The specificity of the enzyme reaction is based on the structure of the substrate and the enzyme itself
- Enzymes speed up the reaction by reducing the activation energy
- Enzymes are classified on the basis of the reaction they catalyze
- Enzymes share certain properties with chemical catalysts but also differ from them in certain ways
- Enzymes are used in many industries useful to us

### 35.11 TERMINAL EXERCISE

1. What is "Lock and Key theory"?
2. Match the classes of the enzyme from Group A with the reaction they catalyze in Group B

A	B
i) transferases	a) oxidation-reduction reaction
ii) hydrolases	b) form or remove a double bond
iii) lyases	c) breakdown of bonds by the addition of water
iv) isomerases	d) transfer of a functional group
v) oxidoreductases	e) change the form of a compound

3. List five applications of enzymes.

### CHECK YOUR ANSWERS

#### Intext Questions 35.1

1. Enzymes are protein catalysts for the biochemical reactions in all living organisms. Section 35.3
2. The enzymes have a specific active site which binds to the substrate molecule. In the active site, the enzyme catalyzes the reaction. Section 35.4
3. The enzymes have been divided into six groups according to the International Union of Biochemistry (IUB). Section 35.5

#### Questions 35.2

The active site has two regions-boundary and catalytic.

- The two theories that have been proposed to explain the specificity of enzyme action are (i) Lock and Key Theory and (ii) Induce fit theory (Section 35.5)

### Intext Questions 35.3

- Enzymes increase the rate of reaction by decreasing the free activation energy (refer to Section 35.6 and Figure 35.4).
- The transition state of a reaction is that when the proton on a substrate reaches an intermediate position i.e. the energy of the reaction is maximum (refer to Section 35.6)
- Transferases catalyze the transfer of functional group from one molecule to another (refer to Section 35.7).
- Refer to section 35.8.
- Proteolytic enzymes trypsin and chymotrypsin.

### TERMINAL EXERCISE

- Refer to Section 35.5 and Figure 35.2.
- A B  
i) d)  
ii) c)  
iii) b)  
iv) e)  
v) a)
- Refer to Section 35.8.