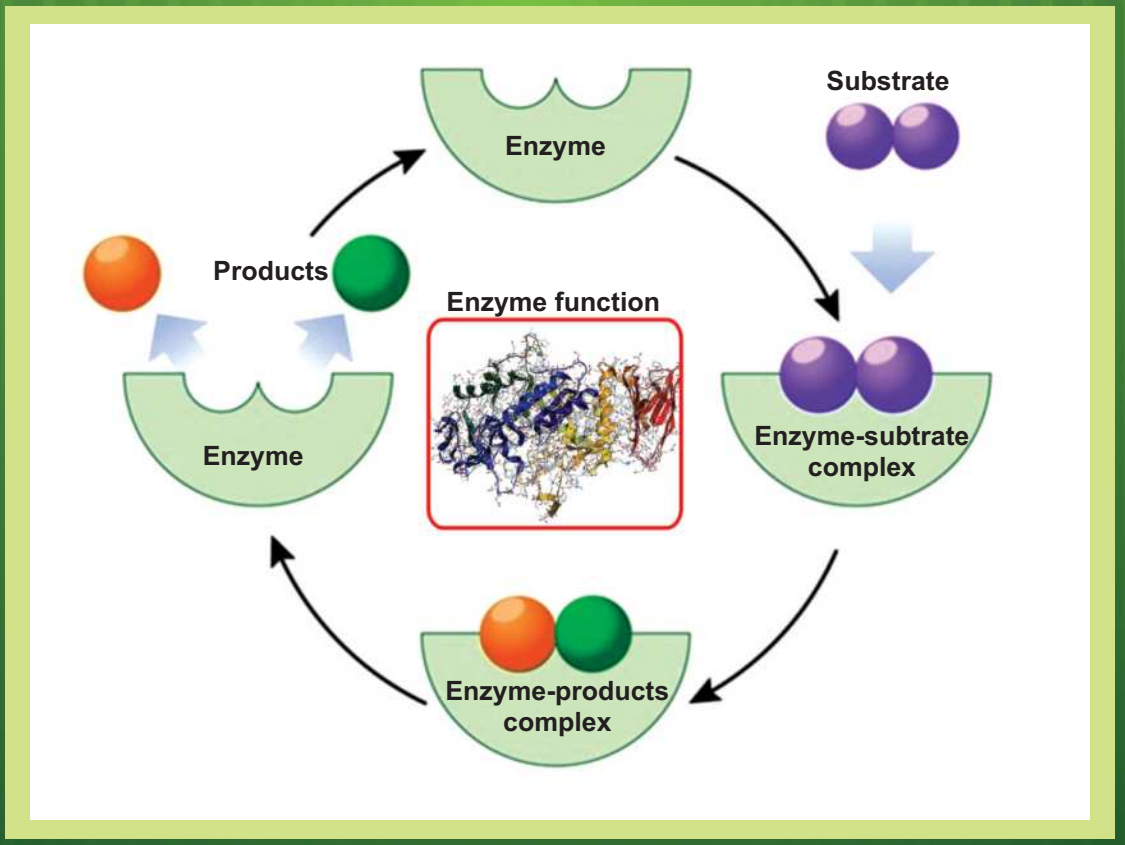
ENZYMES

Chapter 6

Major Concept

In this Unit you will learn:

- Definition and Characteristics of Enzymes
- Mechanism of Enzyme Action (Lock-n-key Model)
- Specificity of Enzyme



Life is another name of activity, therefore thousands of chemical reactions take place in the body of an organism. These reactions of an organism are collectively called metabolic reactions and this phenomenon of chemical activity called metabolism. The metabolic activities are always of two types, either constructive or destructive.

In constructive reactions large molecules are formed to form a structure of cell or body. These reactions are called anabolic reactions and this type of metabolism is called **anabolism**. On the contrary, the destructive reaction in which large molecules breakdown in small molecules to produce energy or to re-utilize further or to discard called catabolic reactions. The type of this metabolic activity is called **catabolism**.

The chemical reaction requires particular conditions to carry down at proper rate, especially temperature and pressure. The conditions of temperature and pressure inside cell or organism are generally found not suitable for chemical reactions e.g. inside human body normal temperature remain $37^{o}C$ and pressure is 120/80 m.m of Hg. These conditions of temperature and pressure are not enough to perform any chemical reactions. Now question arises here how biochemical or metabolic reactions can occur without altering these conditions?

Now body requires some facilitators. These facilitators helps to perform biochemical reactions at low energy. From above discussion it is clear now that each reaction requires some amount of minimum energy to initiate a reaction. This minimum amount of energy is called **activation energy**. If this amount is high the difficult will be the reaction or vice versa e.g. the activation energy needed to break a glucose molecule initially requires energy of 2 ATP molecules.

6.1 DEFINITION

The high amount of activation energy cannot be provided by organism itself therefore they require some facilitators to reduce this activation energy. These facilitators are special molecules made up of mostly protein called **enzymes** (En=inside, zyme = yeast). The name was coined due to observation when yeast was introduced in fruit sap which converted it into alcohol. Now the enzyme are defined as the biocatalyst which facilitate chemical reaction by lowering activation energy.

This action of enzyme allows biological reaction to proceed rapidly at relatively low temperature and pressure tolerable by living organism.

6.2 CHARACTERISTICS OF ENZYMES

- Enzymes are biocatalyst, made up of mostly proteins and therefore three dimensionally folded chains of amino acids with a specific shape. This shape is determined by the sequence of amino acids held together by bonds, for example Hydrogen bonds. Enzymes speed up reactions by bringing reactants together and reducing the activation energy required to start the reaction (enzymatic reaction)
- When an enzyme starts a chemical reaction, catalyzes the reaction hence does not utilized itself which means even a single or little amount of enzyme can start a reaction and catalyze fastly.
- Their presence does not affect the nature or properties of end products.
- Reactants of enzyme are called substrate.
- They are very specific in their action; a single enzyme catalyzes only a single chemical reaction or a group of related reactions.
- A small portion of enzyme where substrate attaches with enzyme is called **active site**. The shape of active site is complementary to shape of the substrate.
- They are sensitive to even a minor change in pH, temperature and substrate concentration.
- Some enzymes require cofactor for their functioning; a cofactor is a non-protien substance which may be organic or inorganic. Zn^{+2}, Mg^{+2}, Mn^{+2}, Fe^{+2}, Cu^{+2}, K^{+1} and Na^{+1} the organic cofactors are NADP, NAD and FAD are used in enzymes as cofactors.

  Cofactor can be categorized into prosthetic group (if organic cofactors are tightly bound to an enzyme) and Coenzymes (if organic cofactors are loosely attached with an enzyme)

- Many enzymes work in a sequential manner to produce a specific product. This pathway is called metabolic pathway.
- Activity of enzymes can be enhanced by activator and can be decreased by inhibitors.
- An **enzyme inhibitor** is a molecule that binds to an **enzyme** and decreases its activity. Since blocking an **enzyme's** activity can kill a pathogen.

6.2.1 Uses of enzymes:

Many enzymes are used commercially in industries. The most common industries are:

- **Paper industry-** To get cellulose for paper making.
- **Food industry-** For making bakery products and pizza.
- **Brewing industry-** For conversion of sugar into alcohol.
- **Bio-detergents-** Use to remove different type of stains.

6.2.2 Factors affecting the activity of an enzymes:

In nature, organisms adjust the conditions of their enzymes to produce an optimum rate of reaction, where necessary, or they may have enzymes which are adopted to function well in extreme conditions where they live.

Substrate Concentration:

It has been shown experimentally that if the amount of the enzyme is kept constant and the substrate concentration is then gradually increased, the reaction velocity will increase until it reaches a maximum after which further increase in the substrate concentration produces no significant change in the reaction rate.

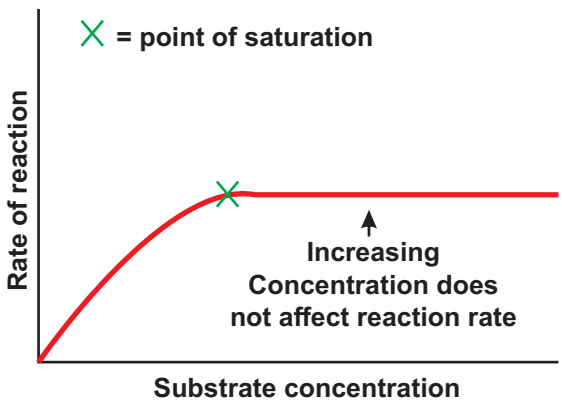


Figure 6.1 Effect of substrate concentration on enzyme activity

In other words, the enzyme molecules are saturated with substrate. The excess substrate molecules cannot react until the substrate already bound to the enzymes has reacted and been released (or been released without reacting).

Temperature:

The protien nature of the enzymes makes them extremely sensitive to thermal changes. Enzyme activity occurs within a narrow range of temperatures compared to ordinary chemical reactions. Enzymes catalyse by randomly colliding with substrate molecules, increasing temperature and increases collision which also increases the rate of reaction,

forming more product. However, increasing temperature also increases the vibrations and structure of enzymes is lost i.e denature enzyme. These changes decreases the rate of enzyme action or it may seized completely.

In summary, as temperature increases, initially the rate of reaction will increase, because of increased kinetic energy. However, the effect of bond breaking will become greater and greater, and the rate of reaction will begin to decrease as shown in given diagram.

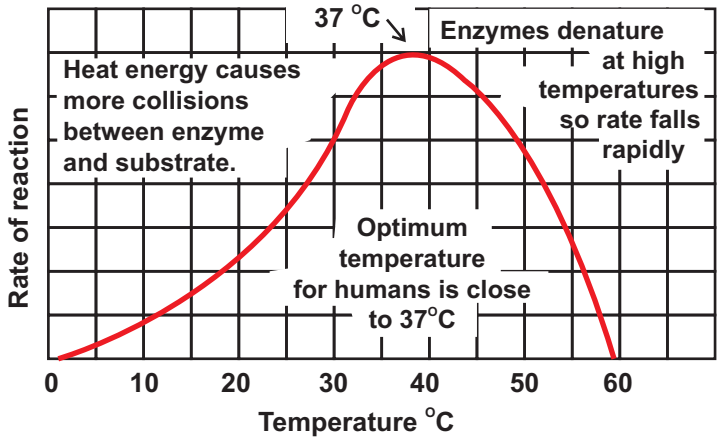


Figure 6.2 Effect of temperature on enzyme activity

pH:

Enzymes are also sensitive to pH due to their protien nature. All enzymes work at their maximum rate at narrow range of pH. The point where the enzyme is most active is known as optimum pH. For example, pepsin works at a low pH i.e. it is highly acidic, while trypsin works at a high pH i.e. it is basic. Most enzymes work at neutral pH 7.4. Small changes in pH above or below the optimum do not cause a permanent change to the enzyme, since the bonds can be reformed. However, extreme changes in pH can cause enzymes to denature and permanently lose their function.

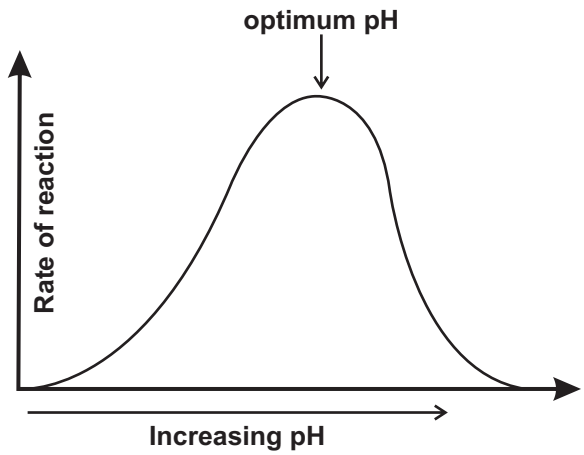


Figure 6.3 Effect of pH on enzyme activity

6.3 MECHANISM OF ENZYME ACTION

Enzyme catalyzes the reaction by attaching to substrate which ends to the product formation. Enzyme exposes its active site to attract specific substrate, makes **enzyme substrate complex** (ESC) after which the product is formed and enzyme is detached from it and used again for the same reaction.

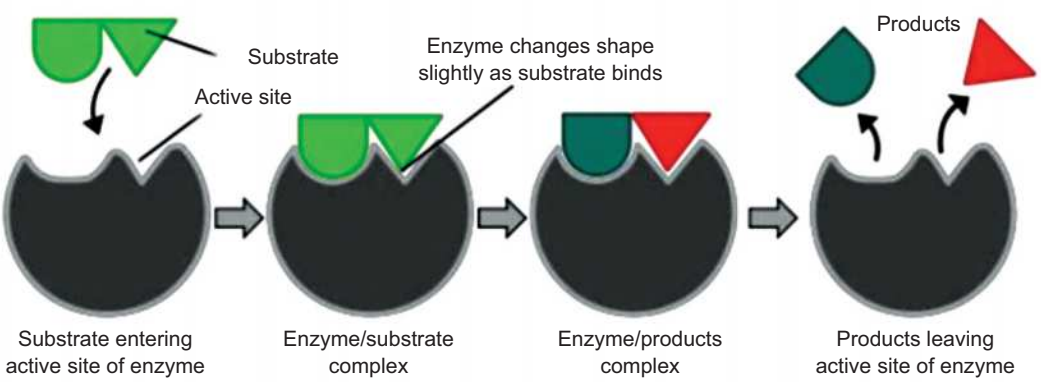


Figure 6.4 Mechanism of enzyme action

6.3.1 Action of Enzyme:

In order to understand the mechanism of enzyme action two theories are proposed; Lock and key model and Induced fit model.

1. The lock and key model:

This theory was first postulated by Emil Fischer in1894 shows the high specificity of enzymes.

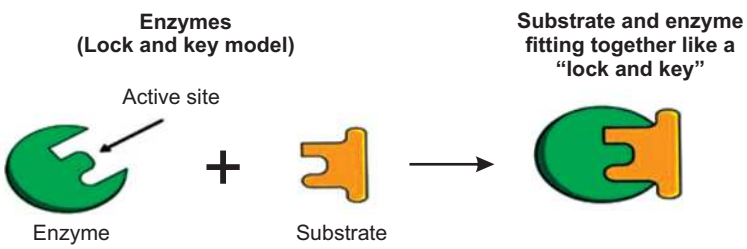


Figure 6.5 Lock and Key model

The "Lock and Key" model to demonstrate how enzymes and substrates fit together. Each enzymes fits specifically to a certain substrate. For example Lipase fits together with lipids to break them down.

This theory explains that the enzyme and the substrate possess specific complementary geometric shapes that fit exactly into one another like a key into a lock, only the correct size and shape of the substrate (the key) would fit into active site (the key hole) of the enzyme (the lock). As shown in the figure 6.5. However, it does not explain the stabilization of the transition state that the enzyme achieve.

2. Induced fit model:

The induced fit model suggested by Daniel Koshland in 1958, it explains that active site continuously changes it shape until the substrate bind to it. It also says that active site of enzyme is flexible (lock and key theory doesnot explain it).

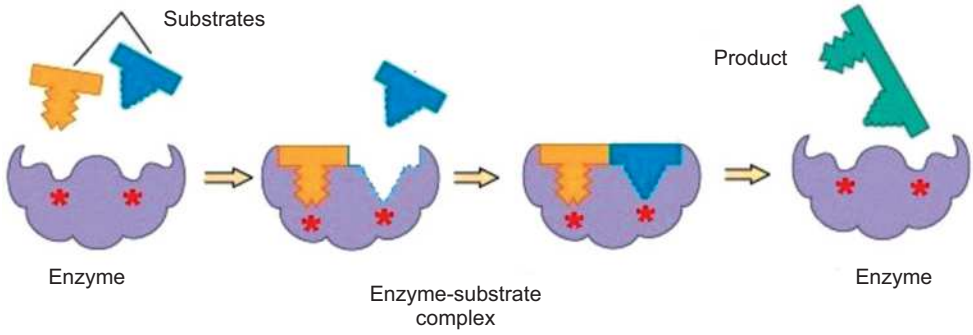


Figure: 6.6 Induced fit model

6.4 SPECIFICITY OF ENZYME

In the human body there are more than 1000 known enzymes and all work with their own substrates. As earlier we have discussed, enzymes are specific in nature therefore a particular enzyme can only bind to its specific substrate and it's all due to its active site. Active site of the enzyme possesses some geometric shape and as the enzymes are made up of protiens and protiens contain different type of amino acids which carry different charges/nature like acidic, basic, hydrophilic etc hence active site is highly specific to its substrate.

Some of the enzymes catalyzes the reaction by recognizing the bond formed between the molecules, the functional group present in the molecules or the geometric shape of the molecules.

There are TWO categories of enzymes: intracellular and extracellular. Intracellular enzymes work inside the cell such as ATPase, cytochrome C reductase etc and extracellular enzymes work outside the cells such as pepsin, lipase etc.

For example: proteases are the enzymes which catalyzes the protiens only and lipase acts on lipids only. It means the enzymes are bond specific, so lipase can act an ester bond in lipids/fats substances.

Summary

- Reactions occur in living organisms called metabolic reaction.
- There are two types of metabolic reaction occur in organisms.
- Anabolism reactions are constructive reactions.
- Catabolic reactions are destructive reactions.
- The minimum amount of energy require to activate a reaction called activation energy.
- The biochemical reaction require high amount activation energy.
- The molecules which facilitate biochemical reaction by reducing activation energy called enzymes.
- Enzymes are biocatalyst made up of mostly proteins and therefore are three dimensionally folded chains of amino acids with a specific shape.
- Reactants of enzymes are called substrate.
- Small portion of enzymes, where substrate attach called active site.
- Enzymes are sensitive to pH, temperature and substrate concentration.
- Activity of Enzymes can be Enhanced by activator and declined by inhibitors.
- Many enzymes are used commercially in industries, like paper, food, brewery, bio-detergents industries.
- The enzymes attach with Substrate form enzymes substrate complex (ESC) after completion enzyme detached while product is formed.
- There are two models to explain enzyme action.
  (i) Lock and Key model (ii) Induce fit model

Review Questions

1. Encircle the correct answer:

(i) All are characters of enzymes except.
(a) Enzyme speed up a biochemical reaction.
(b) Enzymes are sensitive to minor change in pH
(c) Enzyme activity enhanced by inhibitors
(d) Enzyme portion where substrate attach called active site

(ii) Enzymes are
(a) Steroid in nature (b) Protein in nature
(c) Lipid in nature (d) Carbohydrate in nature

(iii) Metabolic reactions are
(I) Constructive reactions
(II) Destructive reactions
(III) Inhibiting reactions
(a) I only (b) I and II only (c) I, II and III (d) II and III only

(iv) The point where the enzyme is most active is known as
(a) Neutral pH (b) Acidic pH
(c) Basic pH (d) Optimum pH

(v) Active site continuously changes it shapes until the substrate do not bind to it, is statement of.
(a) Induce fit model (b) Lock and key model
(c) Fluid mosaic model (d) Both “a” and “b”

(vi) Select the mismatched
(a) Proteases → Carbohydrate (b) Lipases → Lipids
(c) Trypsin → Protein (d) All are correctly matched

(vii) Chemical reaction requires particular conditions to carry down at proper rate, especially.
(a) Temperature and Nature (b) Nature and Pressure
(c) Nature and Structure (d) Temperature and Pressure

(viii) All are factors affecting enzyme activity except.

(a) pH (b) Substrate concentration

(c) Organic solvent (d) Temperature

(ix) Rate of reaction will increase when temperature

(a) Increases (b) Decreases

(c) Below 10°C (d) Both "a" and "c"

(x) Choose the correct statement regarding lock and key model.

(a) Enzyme and substrate posses' specific complementary geometric shapes.

(b) Active site of enzyme is flexible

(c) Active site continuously changes

(d) All above statements are correct.

2. Fill in the blanks:

(i) There are _____types of metabolic reactions.

(ii) Enzymes catalyze chemical reaction by _____ the activation energy.

(iii) Presence of enzyme does not affect the nature or properties of _____.

(iv) In constructive reaction _____ molecules are formed.

(v) Activity of enzymes can be enhanced by _____.

(vi) Small portion of enzyme where substrate attach with enzyme called_____.

(vii) Enzyme activity decreased by _____.

(viii) As temperature increases, initially the rate of reaction will_____.

(ix) Extreme changes in pH can cause enzymes to _____.

(x) In the human body there are more than _____ known enzymes.

3. Define the following terms:

(i) Substrate (ii) Active site (iii) Inhibitor

(iv) Activator (v) Anabolism (vi) Catabolism

(vii) Activation energy (viii) Cofactor (ix) Prosthetic group

(x) Coenzymes

4. Distinguish between the following in tabulated form:

(i) Activator and Inhibitor

(ii) Anabolism and Catabolism

5. Write short answers of following questions:

(i) Why enzymes are specific in nature?

(ii) How enzyme reduces the amount of activation energy?

(iii) Why presence of enzymes does not effect on the nature and properties of end product?

(iv) How substrate concentrations affect enzyme activity?

(v) How enzymes are uses in industries?

6. Write detailed answers of the following questions:

(i) What are enzymes? Describes characteristics of enzymes.

(ii) Describe factors affecting enzyme activity.