6

ENZYMES

Major Concepts

Different types of cells are performing specific functions. To perform various functions, a cell needs energy. This energy is provided by the chemical reactions. The sum of all the chemical reactions going on within the cells is known as **metabolism**. It consists of **catabolism** and **anabolism.** Reactions which break down complex molecules into simpler molecules, are called **catabolic reactions** or **catabolism**. Reactions which build complex molecules from simpler molecules are called **anabolic reactions** or **anabolism.** Usually, energy is released in catabolism and it is utilized in anabolism. Most of the essential reactions taking place in the body must occur quickly and precisely for a cell to survive. Enzymes work as biological catalyst and control all the chemical reactions making up the metabolism.

Enzymes work on substances called **substrates.** The reaction takes place on a part of the surface of enzyme called the **active site**. The **substrates** are the molecules entering into chemical reactions. The substrates undergo a chemical change resulting in new bonding arrangement between the molecules. The changed substrates are called **products.**

The flow of energy within an organism consists of a long series of coupled reactions. These chains of reactions are called **metabolic pathways.** All the metabolic pathways taking place in our body work to help us to survive.

The enzymes, which remain inside the cells to speed up the reactions, are called **intracellular enzymes** (e.g., enzymes of glycolysis working in the cytoplasm). Often the enzymes made inside the cells are allowed to go out of the cell to do their work outside. These enzymes are called **extracellular enzymes** (e.g., pepsin enzyme working in the stomach cavity). Fungi and bacteria release extracellular enzymes to digest their food.

6.1 ENZYMES AND THEIR CHARACTERISTICS

Enzymes are very important for life and they serve many functions in the body. They are organic catalysts that speed up a reaction in living things. Enzymes have following characteristics.

1. Enzymes are Proteins

All Enzymes are protein in nature except ribozyme. They are made up of amino acids.

2. Enzymes Increase Rate of Reaction

In the absence of enzymes, it may take **months** or years to complete the reactions. The enzymes speed up the reactions millions of times faster as compared to non-catalysed reaction.

3. Enzymes are Required in Small Quantity

Enzymes are not changed in chemical reaction. So they can be used over and over again. Thus, a very small quantity of an enzyme is capable of catalysing a huge amount of substrate.

4. Enzymes are Specific

Enzymes can act only on one substrate and it will not act on a different substrate. For example, amylase will only act on starch and not on proteins or fats.

5. Enzymes Require Co-factor

Many enzymes require a non-protein helper called **cofactor** for their proper working. There are three types of cofactors: activator, prosthetic group and coenzyme.

- **Activator:** Many enzymes require ions such as zinc, iron, copper and chlorides etc. For example, salivary amylase activity is increased in the presence of chloride ions.
- **Prosthetic group:** If the cofactor is tightly bound to the enzyme on permanent basis it is known as prosthetic group. Prosthetic groups are organic molecules. For example haem group.
- **Coenzyme:** When the cofactor is detachable organic molecule it is called **coenzyme.** Examples of co-enzymes are NAD (nicotinamide adenine dinucleotide), coenzyme A and vitamin A.

6. Regulation of enzyme production and activity

Enzyme production can be increased or decreased by a cell according to requirements. Enzyme activity can be regulated by inhibitors or activators.

7. Enzymes make metabolic pathway

Many enzymes can work together in a specific order making metabolic pathways. Metabolic pathway is a series of connected chemical reactions that lead to the conversion of a substance into final product.

6.1.1 ENERGY OF ACTIVATION

The energy needed to start or activate the reaction is called **energy of activation**. At body temperature of living organisms, it is not possible to provide required activation energy for all the metabolic processes. Enzymes lower the activation energy so that these reactions can take place at body temperature. The ways enzymes lower the activation energy are: 1. Enzymes may change the shape of the substrate. 2. Some enzymes alter the charge distribution on substrate. 3. Enzymes may position substrates together in the proper orientation. 4. Some enzymes add or remove functional groups on the substrate.

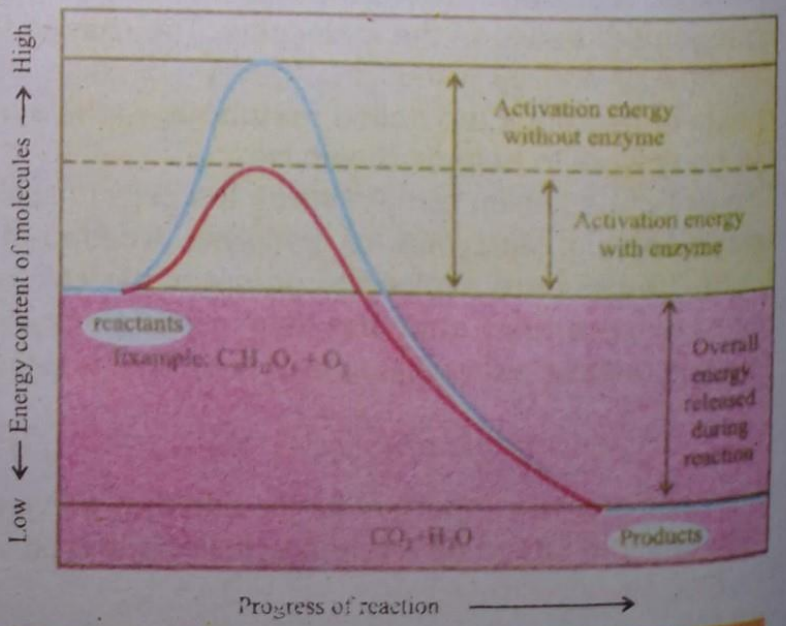


Fig. 6.1: Energy of activation: High activation of energy (blue line) without enzymes. Low activation of energy (red line) with enzymes.

6.1.2 FACTORS AFFECTING ENZYME ACTIVITY

The activity of an enzyme is affected by following conditions:
(1) pH (2) temperature (3) substrate concentration

pH

pH is the **hydrogen ion concentration** in a solution. Enzymes are affected by pH of medium. Each kind of enzyme works best at a particular pH, which is called **optimum pH**. In the stomach enzymes work in acidic medium and in intestine other enzymes work in alkaline medium. For example, enzyme pepsin in the stomach has an optimum pH of about 2. If the pH is much higher or lower than its optimum pH, then an enzyme is **denatured** i.e., it loses its shape.

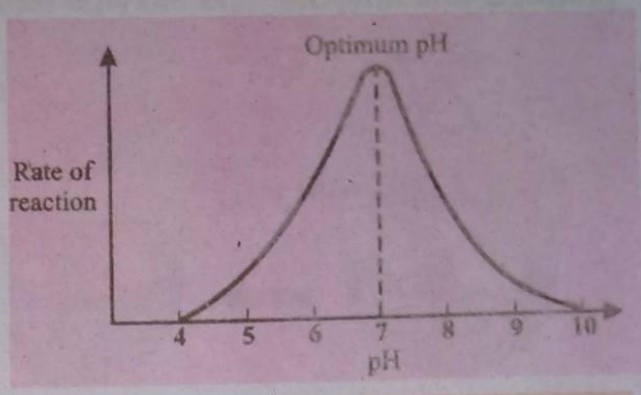


Fig. 6.2: Effect of pH on the rate of enzyme-controlled reaction

Temperature

Heat increases molecular motion. Thus, the molecules of the substrates and enzymes move more quickly, so the rate of reaction increases. The temperature at which an enzyme catalysed reaction happens fastest, is called **optimum temperature.** Different enzymes have different optimum temperature e.g., optimum temperature for human enzymes is 36°C to 38°C.

If the temperature is increased above optimum temperature, then a decrease in the rate of reaction occurs due to denaturation i.e., breakdown at high temperature. If temperature is reduced to below freezing point, enzymes are inactivated but not denatured. They will regain their catalytic activity when higher temperatures are restored.

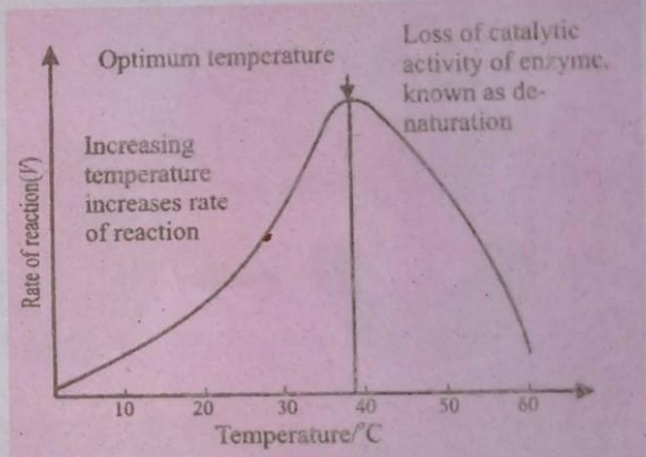


Fig. 6.3: Effect of temperature on the rate of enzyme-controlled reaction

Substrate Concentration

For a given enzyme concentration as the substrate concentration increases the rate of reaction increases up to a limit. A further increase in substrate concentration does not increase the rate any further. This is because at any given moment the active sites of all the enzyme molecules are saturated by substrate molecules.

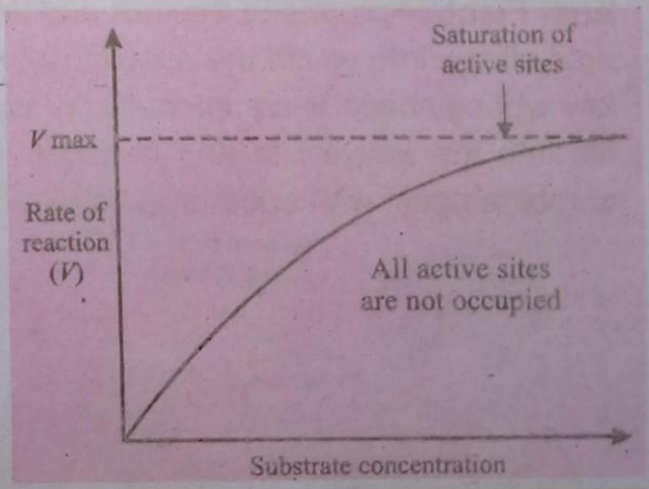


Fig. 6.4: Effect of substrate concentration on the rate of enzyme-controlled reaction

6.2 MECHANISM OF ENZYME ACTION

Most enzymes are far larger molecules than the substrates they act on. The site where the substrate binds with enzyme is known as the **active site**, which has a specific shape. The active

site is usually only a very small portion of the enzyme. The enzyme combines with its substrate to form enzyme substrate complex. Once a reaction has occurred, the complex breaks up into products and enzyme. The enzyme remains unchanged at the end of the reaction.

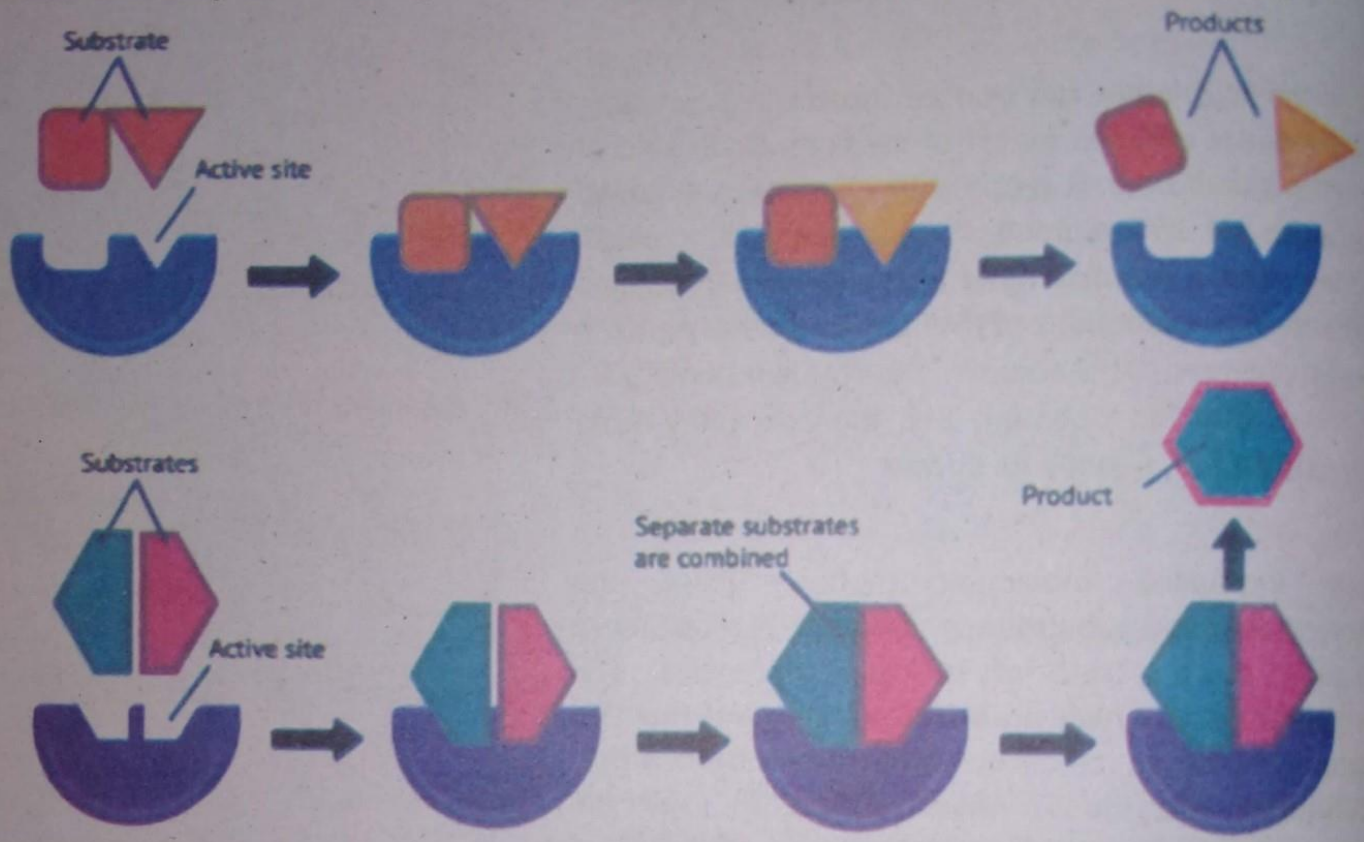


Fig. 6.5: Enzyme actions (a) Breakdown (b) Synthesis

Lock and Key Model

Emil Fischer proposed the lock and key model of enzyme action. The active site has particular rigid shape into which the specific substrate fits exactly. The substrate is imagined being like a key whose shape is complementary to the enzyme or lock. Once formed, the product no longer fits into the active site and escapes into the surrounding medium. The active site is free to combine again with another substrate molecule.

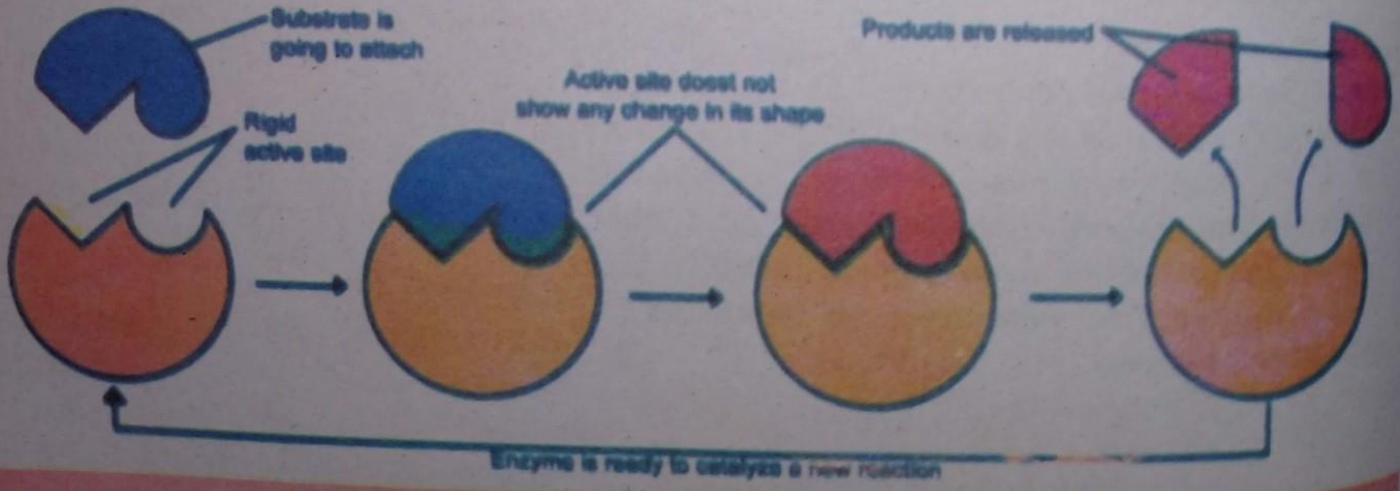


Fig. 6.6: Fischer's "Lock and Key" hypothesis of enzyme action

Induced fit model

Daniel Koshland proposed induced fit model. This model is more acceptable than the lock and key model. It describes that the binding of a substrate to enzyme causes a change in the shape of its active site. Active site is not a rigid structure rather it is flexible.

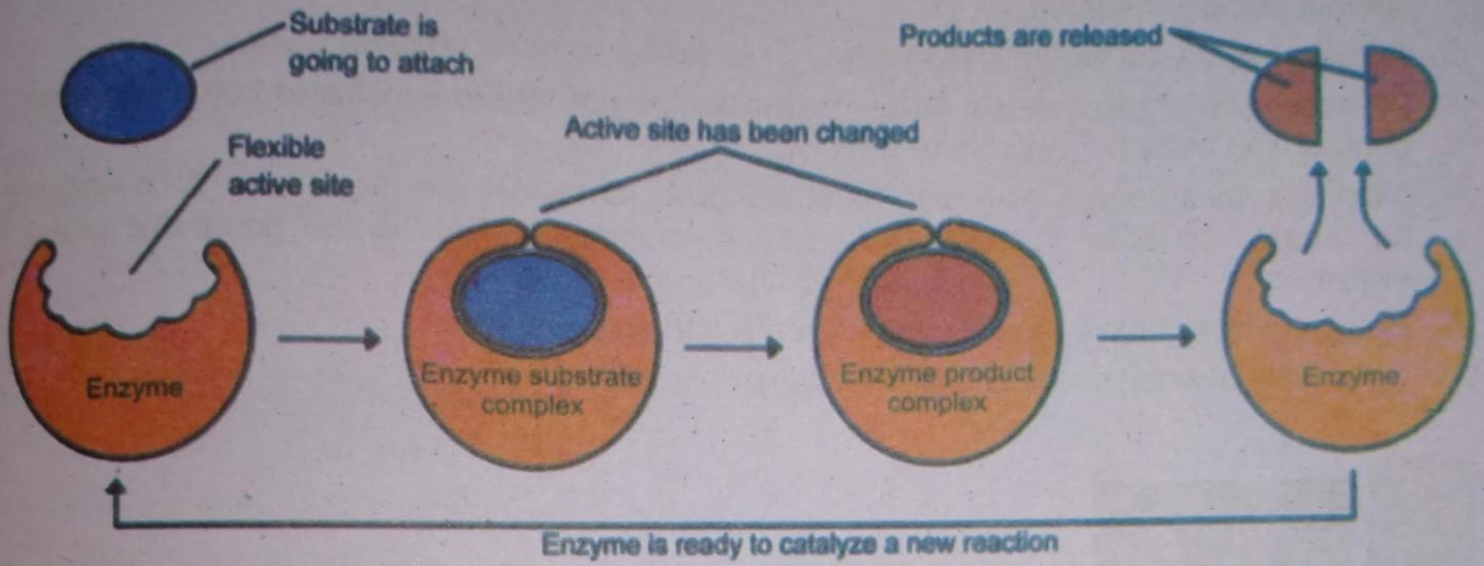


Fig. 6.7: Koshland's "Induced fit model" hypothesis of enzyme action

6.3. SPECIFICITY OF ENZYMES

We have already seen that enzymes are specific. It means one enzyme can act only on particular substrate. It cannot act on any other substance. The examples of specificity of enzymes are:

a. **Proteases** break up proteins into an acid.
b. **Lipase** breaks down only lipids.
c. **Amylase** acts on starch.

Specificity of Enzyme is Due to Its Shape

The figure shows an enzyme protease. There are three-substrates: protein, carbohydrate and fat. You can guess that it is the shape of the active site of an enzyme, which exactly fits the shape of protein, but would not fit the shape of carbohydrate or fat. So, it is the shape of active site that decides what substances it will combine with.

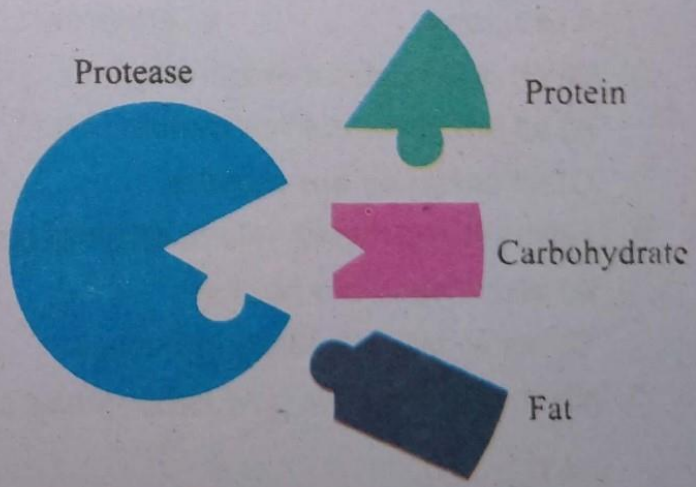


Fig. 6.7: Specificity of enzyme is due to the shape of active site

SUMMARY

1. The sum of all the chemical reactions that occur within a cell or organisms is called metabolism.
2. An enzyme is a biological catalyst which greatly increases the speed of a chemical reaction without being consumed.
3. An enzyme lowers the activation energy necessary to get a reaction going.
4. An active site of enzyme is a three dimensional region where substrates come into close contact and there by react more rapidly.
5. Most enzymes need a co-factor. Most inorganic co-factors are metal ions. A co-enzyme is an organic co-factor such as NAD, and co-enzyme A. FAD is the prosthetic group for enzymes.
6. Enzymes work best at specific temperature and optimum pH.
7. Specificity of enzymes is due to the shape of its active site.

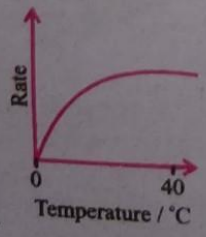
Exercise

MCQs

Select the correct answer:

1. The catalytic activity of an enzyme is restricted to its small portion called:
   A) active site B) passive site C) binding site D) intermediate site
2. Hydrolysis of starch occurs with the help of:
   A) sucrase B) amylase C) cellulase D) lipase
3. Which is true about enzyme?
   A) all enzymes are not protein B) all enzymes are vitamins
   C) all enzymes are proteins D) all proteins are enzyme
4. Lock and key hypothesis of enzyme action supports that:
   A) active sites are flexible B) active sites are rigid
   C) active site efficiency increases D) active site can change its shape
5. Which graph shows how temperature affects the rate of an enzyme-controlled reaction?

A)



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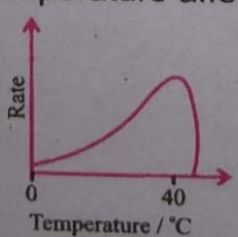

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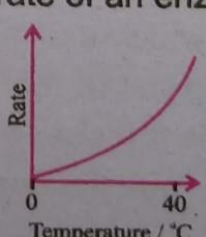

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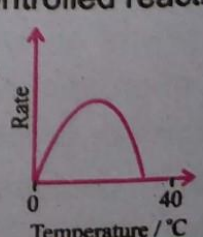

6. The sum of all the chemical reactions in a cell is called:
   A) metabolism B) anabolism C) catabolism D) intracellular space

7. What is true about cofactors?
   A) break hydrogen bond in proteins
   B) help facilitate enzyme activity
   C) increase activation energy
   D) are composed of proteins
8. Enzymes are chemically made up of:
   A) Proteins B) Carbohydrates C) Fats D) Nucleic acids
9. Change in pH can alter the active site by affecting the:
   A) ionization of amino acids
   B) Shape of substrate
   C) ionization of cofactor
   D) Ionization of coenzyme
10. The catalytic region on enzyme recognizes and binds the substrate and carries the reaction. This region is called as:
    A) cofactor B) activator C) inhibitor D) active site

Short Questions

1. Write the difference between:
   (a) catalyst and enzyme (b) anabolism and catabolism
   (c) intracellular and extracellular enzymes.
2. Why enzymes are called biological catalyst?
3. What are the characteristics of enzymes?
4. Name the factors affecting enzyme activity.
5. How enzymes are named?
6. At what temperature human enzymes act the best?
7. Give examples of cofactor.
8. What happens to an enzyme when it is heated up to 100°C?
9. Which protein digesting enzyme functions in acidic medium?
10. Why is less energy needed for reaction to occur when an enzyme is present?
11. Why are enzymes required in small amounts?
12. Why are enzyme specific and why can't each one speed up many different reactions?

Extensive Questions

1. Define enzyme and describe their characteristics and specifications.
2. Explain metabolism with examples.
3. Prove that enzymes are proteins and are specific in function. Explain that specificity of enzyme is due to its shape.
4. Describe that enzymes require co-factor.

5. What is energy of activation? Explain with reference to enzyme.
6. What happens to enzymes when you increase or decrease:
   (a) temperature (b) pH (c) Substrate concentration.
7. Only the related key can open the lock. How this fact is true for enzyme? Explain with examples.

TERMS TO KNOW

• Activation energy	• Coenzyme	• Lipase Lock and Key theory
• Active site	• Cofactor	• Metabolism
• Amylase	• Denaturation	• Product
• Anabolism	• Induced fir model	• Saturation
• Biocatalyst	• Optimum pH	• Substrate
• Catabolism	• Optimum temperature	
• Catalyst	• Enzyme	

ANALYZING, INTERPRETING AND COMMUNICATION

1. Draw graphs showing the effects of temperature pH and concentration of substrate on the rate of enzyme catalysed reactions.
2. Illustrate through a diagram, the lowering of energy of activation by enzyme.

INITIATING, PLANNING AND INTERPRETING

Build or design model of enzyme to demonstrate the working of an enzyme.

USEFUL WEBSITES

1. users.rcn.com/jkimball.ma.ultranet/BiologyPages/E/Enzymes.html
2. ull.chemistry.uakron.edu/genobc/Chapter_20/
3. web.indstate.edu/thcme/mwking/enzyme-kinetics.html
4. www.lewport.wnyric.org/JWANAMAKER/animations/Enzyme-%20activity.html