Exercise

Short Questions

2. Write three properties that are common to all enzymes.

Ans:

The enzymes are organic catalysts. However, they have many properties of in organic catalysts like

(i) The enzymes increase the speed of chemical reaction by, 10^6-10^{14} times faster than the rate of uncatalyzed reaction.

(ii) Enzymes are highly sensitive to pH and temperature changes of the system.

(iii) Some enzymes require proper co-factor for proper activity.

(iv) Enzymes lower the need of activation energy.

OR

(i) They are made up of proteins.

(ii) They do not used up in reaction.

(iii) They speed up a reaction.

(iv) They are specific in nature.

3. What are ribozymes?

Ans:

Ribozymes:

Ribozymes are the enzymes which consists of RNA and are found in ribosomes

Example:

For example, peptidyl transferase is a ribozyme, which controls polypeptide elongation during translation process.

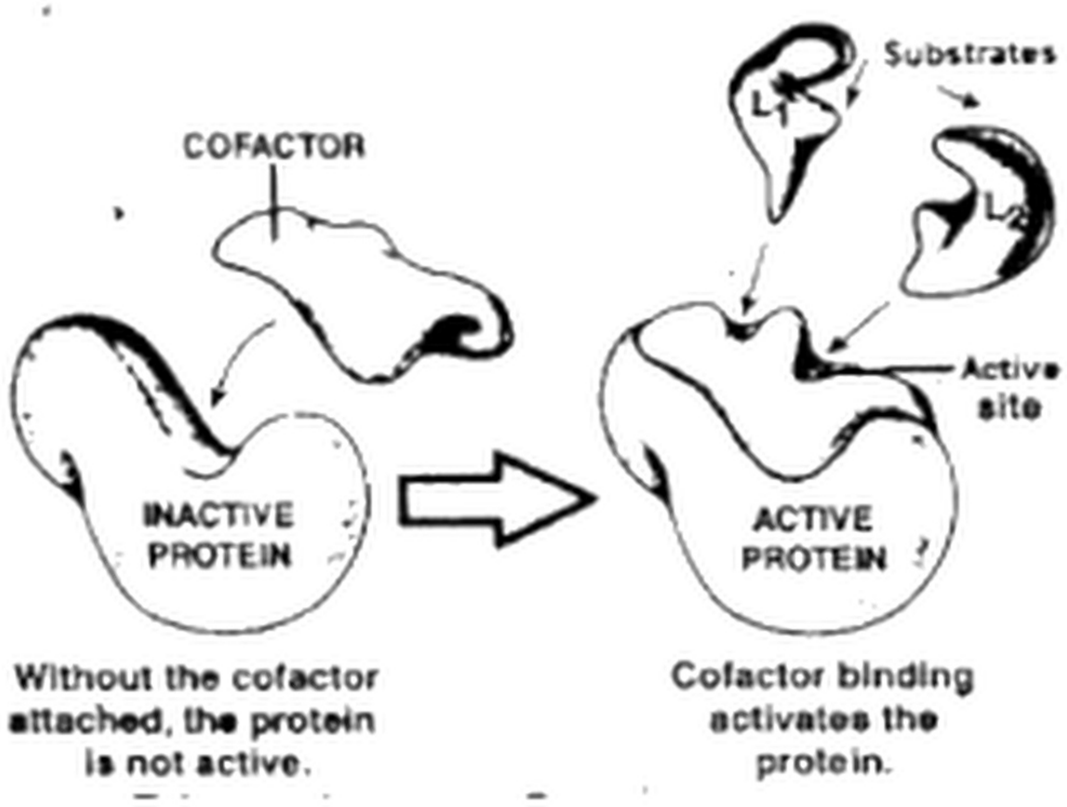
4. What is the structure of enzyme?

Ans:

Structure of Enzymes:

With exception of ribozymes, all enzymes are globular proteins, which are made up of one or more polypeptides

Many enzymes consist of a protein and non-protein (called the cofactor). The proteins in enzymes are usually globular. The intra- and intermolecular bonds that holds proteins in their secondary and tertiary structures are disrupted by changes in temperature and pH.



5. What is active site of the enzyme? Write its shape and function.

Ans:

Active Site:

In biology, the active site is the region of an enzyme where substrate molecules bind and undergo a chemical reaction. The active site consists of residues that form temporary bonds with substrate and residues that catalyse of that substrate (bonding site) and residues that catalyse of that a reaction of that substrate (catalytic site)

Shape of enzymes and components of an active site:

Majority of enzymes, which are protein in nature, can have molecular weights ranging from about 10,000 to over 1 million. Such enzymes have tertiary or quaternary structures.

Function of an active site:

The catalytic activity of an enzyme is located in its active site which is a specific charge bearing three-dimensional cavity. The substrate (the reactant which is to be converted into product) molecules is attached to the active site by non-covalent interactions like hydrogen bonding and hydrophobic reactions

Components of an active site:

Active site consists of 3-12 amino acids which may be scattered in the polypeptide but are brought together in a particular fashion due to secondary and tertiary folding of the protein molecule, e.g. the active site for the aldolase consists of glycin, histidine and alanine amino acids.

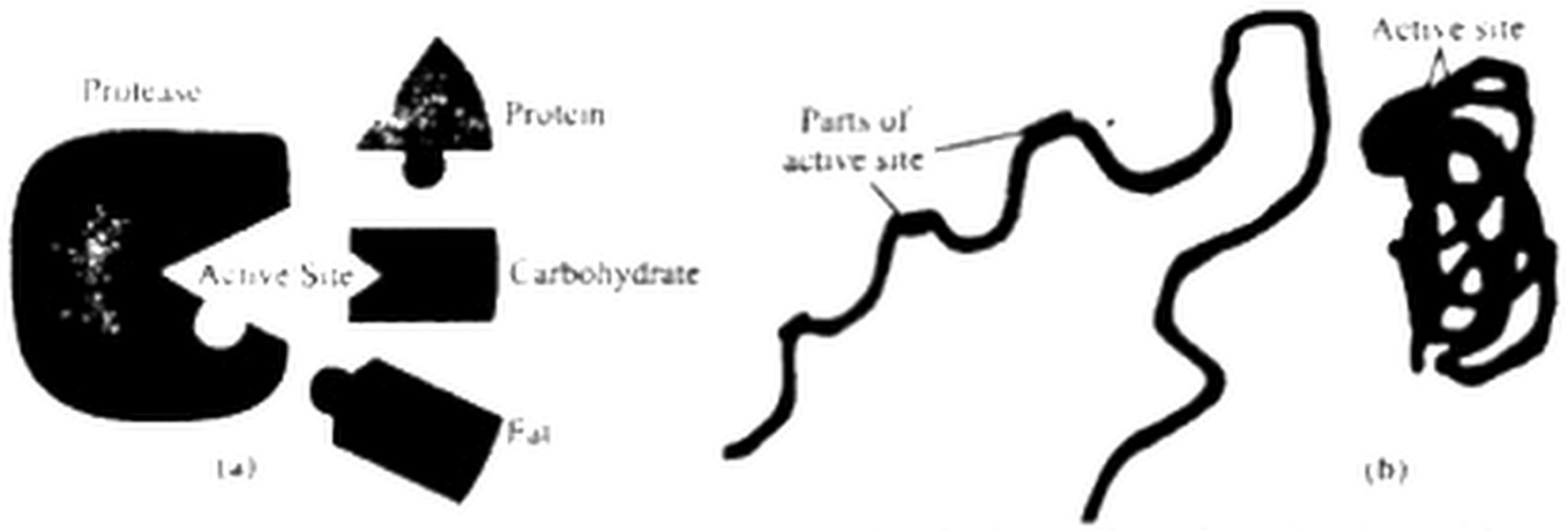
Functional regions of active site:

An active site consists of two functional regions, i.e binding site and catalytic site.

Some amino acids have active site which makes bonds with substrate constitute the binding site while the other amino acids which cause conversion of substrate into product (catalysis) constitute the catalytic site.

Shape of an active site:

The shape of active site is designed according to the substrate therefore only a particular substrate can attach to the active site. However, sometimes related substrate can also bind to the active site.



Active Site: (a) Which substrate fits the active site? (b) Grouping of amino acids of a polypeptide during the formation of tertiary structure to produce an active site.

6. What is cofactor? Explain.

Ans:

Cofactor:

Enzymes consist of a non-protein called cofactor.

OR

A cofactor is a non-protein chemical compound or metallic ion that is required for a protein's biological activity to happen. These proteins are commonly enzymes and co-factors can be considered "helper molecules" that assist in biochemical transformations.

7. Explain the enzyme pepsin that does not require cofactor.

Ans:

The enzyme pepsin that does not require cofactor can also show active and inactive sites.

Pepsin:

Pepsin is an example of such enzyme. It is secreted by gastric gland from stomach wall in an inactive state, the pepsinogen. In this state, it has an additional polypeptide fragment attached to its active site which does not allow the binding of substrate; hence it remains inactive. When pepsinogen is exposed in HCl (as in stomach cavity), the additional polypeptide fragment is removed and as a result, inactive (apoenzyme) pepsinogen is changed into its active (holoenzyme) form, the pepsin.

8. Explain inorganic cofactor.

Ans:

Inorganic cofactor:

The inorganic cofactors are different metallic ions such as Fe, Mg, Cu, Zn etc. These are only attached to the enzyme when substrate gets bind i.e. they are detachable cofactrors are also called activators.

$$\text{Glucose+ATP} \xrightarrow{\text{hexokinase+ } Mg^{+2}} \text{Glusoce-6-phosphate+ADP}$$

9. Explain organic Cofactor.

Ans:

Organic cofactor:

The organic cofactors are either co-enzymes or prosthetic groups. The coenzymes are the derivatives of vitamins.

For example, ATP, NAD^+, FAD^+ are common coenzymes. Like inorganic cofactors. They are also attached to the enzymes when substrate gets bind i.e. they are also detachable cofactors.

Ethyl alcohol $\xrightarrow{\text{alcohol dehydrogenase+NAD}}$ Aceteldehyde+$NADH_2$

10. What is prosthetic group? Give an example.

Ans:

Prosthetic Group:

A prosthetic group is covalently bonded part of an enzyme. Which is permanently attached to enzymes and does not detach after the completion of a reaction.

Example:

An iron containing porphyrin ring attached to some enzymes like cytochromes is the example of prosthetic group.

11. What is the mechanism of enzyme action?

Ans:

Mechanism of enzyme action:

In an enzyme-catalysed reaction, the substrate first binds to the active site of the enzyme to form an enzyme-substrate (ES) complex, them the substrate is converted into product while it is attached to the enzyme (EP complex), and finally the product is released, thus allowing the enzymes to start all over again.

$$E + S \longrightarrow ES \longrightarrow EP \longrightarrow E + P$$

Enzyme Substrate Enzyme-substrate complex Enzyme-product complex enzyme product

Actually, the enzyme can make the local conditions inside the active site quite different from those outside (such as pH, water concentration, charge), so that the reaction is more likely to happen. For example, if a substrate is to be split, a bond might be stretched by the enzyme, making it more likely to break.

12. What is role of free energy of activation in a chemical reaction?

Ans:

Role of free energy of activation in a chemical reaction:

About 1,000 chemical reactions are being carried out in a cell at any time. Energy of activation required for such a large number of reactions cannot be provided by living system.

The living system works in isothermal condition; the excited state of molecules or reactants is achieved by biochemical process. Enzyme € reacts with reactant (A) to form an AE transitional complex. The energy level of AE complex reaches to the energy level of reaction B. AE complex then reacts with reactant B to form AB and enzyme € is released.

$$A+E \longrightarrow AE\ complex+B \longrightarrow AB+E$$

Enzyme does decrease the energy of activation by changing energy dependent process to energy independent process. Thus, the energy of activation is energy required to break the existing bonds and begin the reaction. An enzyme greatly reduces the activation energy necessary to initiate a chemical reaction.

13. List the external conditions that affect rate of enzyme reaction.

Ans:

Factors affecting rate of enzyme reaction:

The rate of enzymatic reaction is measured by the amount of substrate changed or amount of product formed, during a period.

The external conditions that affect rate of enzymes reactions are:

(i) Temperature

(ii) pH

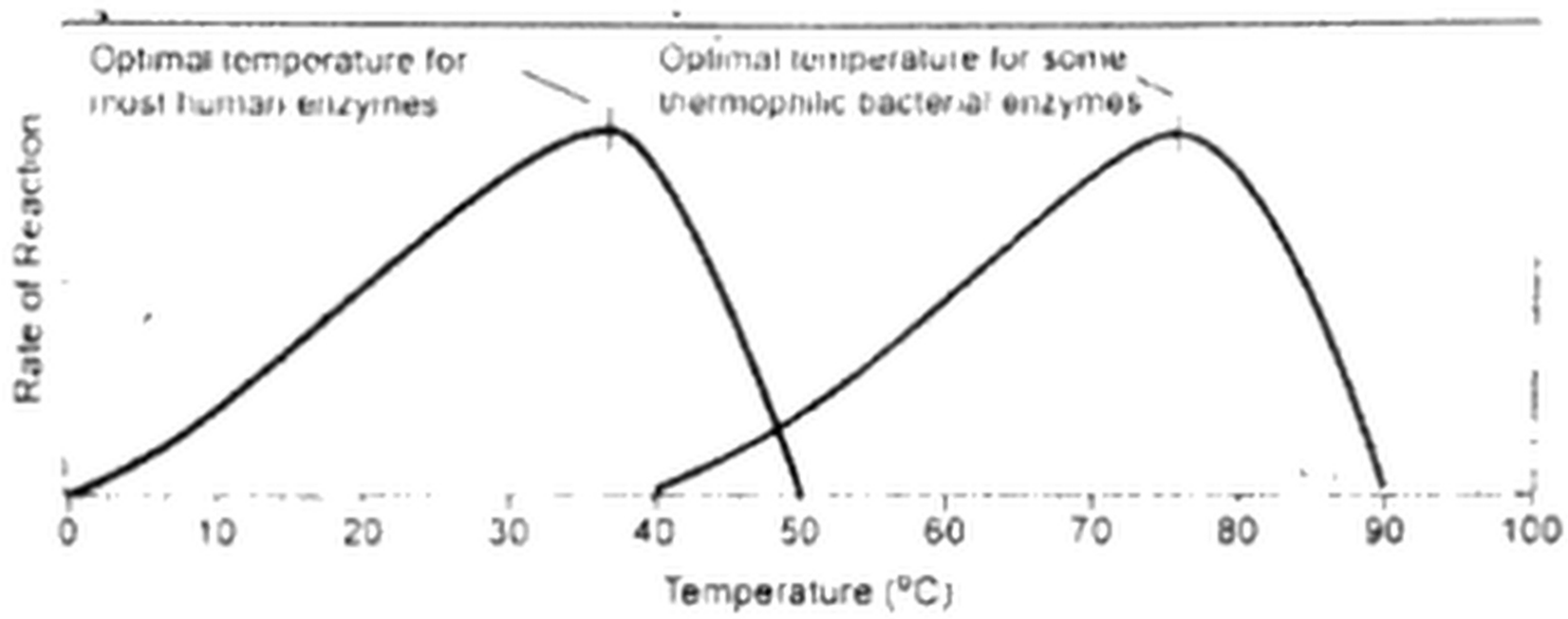
(iii) Concentration of enzymes

(iv) Substrate concentration

14. Compare the optimum temperatures of enzymes of human and thermophilic bacteria.

Ans:

All human enzymes have an optimum temperature of about 37-38°C, but bacteria living in hot springs may have an optimum temperature of 70°C or higher. Such enzymes have been used in biological washing powders for high temperature washes. If temperature is reduced to near or below freezing point. Enzymes are inactivated, not denatured. They will regain their catalytic influence when higher temperatures are restored. This temperature where an inactive enzyme becomes active again is called minimum temperature.



Optimum temperature for human enzymes and thermophilic bacteria.

15. Describe the range of pH at which human enzymes function.

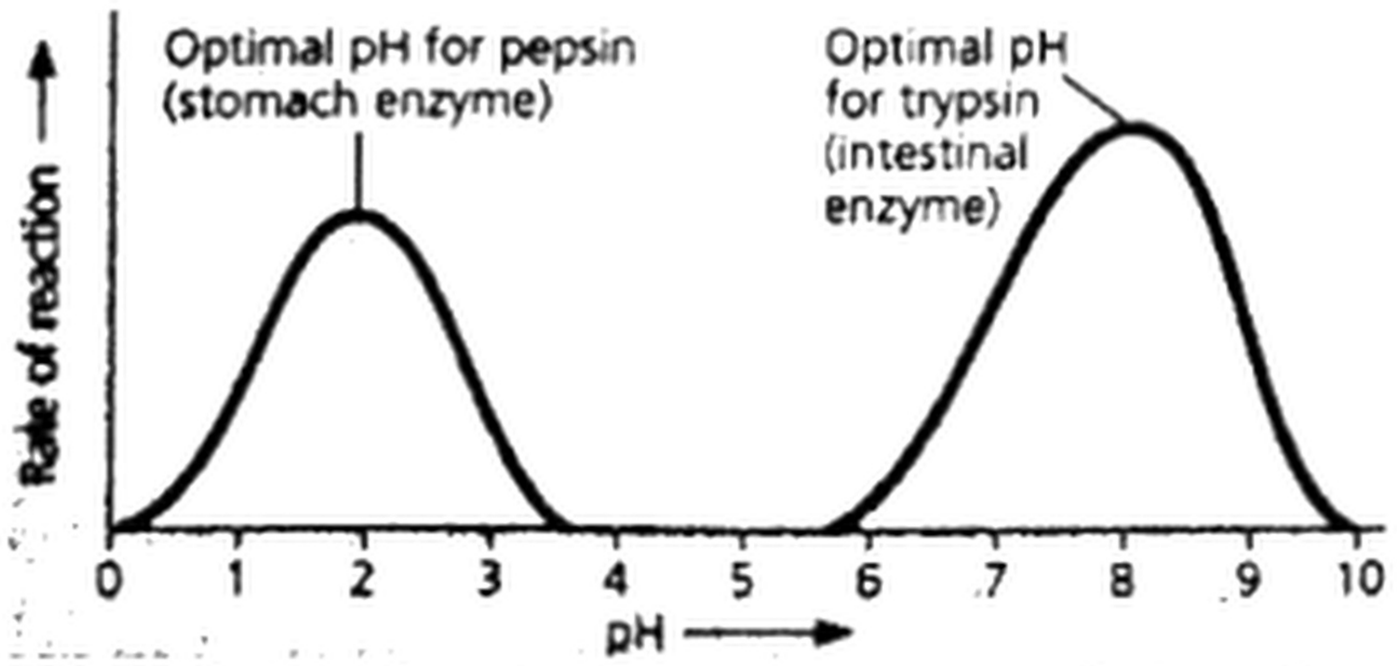
Ans:

pH:

Every enzyme function most effectively over a particular pH range. This narrow range of pH at which the maximum rate of reaction is achieved is called optimum pH.

Effect of pH:

Enzymes confirmation is sensitive to pH changes because pH influences the charges on the amino acid side chains that are involved in maintaining tertiary and quaternary structures of enzymes. Slight change in optimum pH of an enzyme cause ionization of amino acid of the enzyme therefore, they become inactive temporarily. On the other hand, extreme changes in optimum pH alter the ionic charge of the acidic and basic groups of enzymes and therefore disrupt the ionic bonding (denaturation) that helps to maintain the specific shape of the enzyme.



Effect of pH on the rate of an enzyme – controlled reaction

The optimum pH values for most enzymes fall in the range of pH 6-8, but there are exceptions. Some enzymes like papain from green papaya act both in acidic and alkaline media. Protein digesting enzymes pepsin is active in acidic medium at pH 2 and trypsin is inactive at this pH but shows maximum activity n alkaline medium at pH 8.

16. What are enzyme inhibitors? Name the molecules which acts as enzyme inhibitors.

Ans:

Enzyme inhibition:

The phenomenon in which an enzyme fails to catalyze a reaction is called enzyme inhibition and the molecules which react enzyme but are not converted into desired products are called enzyme inhibitors.

In general, the enzyme inhibition is a normal part of the regulation of enzyme activity within cells but sometimes when external factors cause enzyme inhibition. It may become dangerous for life.

Molecules acts as enzyme inhibitors:

The molecules which act as inhibitors include poisons, cyanides, antibodies, antimetabolites, pencillin, sulpha drugs etc. inhibition may be competitive or non-competitive.

17. What is importance of competitive enzyme inhibitors?

Ans:

Importance of competitive enzyme inhibitors:

(a) It supports lock and key hypothesis.

(b) It shows that substances which are similar to substrate are not acted upon by enzymes.

(c) Competitive inhibitors are used as drugs in the control of bacterial pathogens. Antibiotics known as sulphonamides are used to combat bacterial infection.

18. Describe cyanides as irreversible non-competitive inhibitor.

Ans:

Irreversible non-competitive inhibitor:

An irreversible non-competitive enzyme inhibitor destroys enzymes by altering its shape so that the substrate cannot bind to the active site. The examples of irreversible non-competitive inhibitors include cyanides and salts of heavy metals.

Cyanides:

Cyanides are potent poisons of living organism because they can kill an organism by inhibiting cytochrome oxidase essential for cellular respiration. They

block the action of these enzymes by combining with iron which may be present in the prosthetic group.

19. Describe ions of heavy metals as irreversible non-competitive inhibitor.

Ans:

Irreversible non-competitive inhibitor:

An irreversible non-competitive enzyme inhibitor destroys enzymes by altering its shape so that the substrate cannot bind to the active site. The examples of irreversible non-competitive inhibitors include cyanides and salts of heavy metals.

Ions of heavy metals:

Ions of heavy metals such as mercury, silver and copper (Hg^{++},Ag^{+} and Cu^{++}) combine with thiol (-SH) groups in the enzyme breaking the disulphide bridges. These bridges are important in maintaining tertiary structure. When these bridges are broken, the enzyme becomes denatured and inactive.

20. List the diagnostic uses of enzymes.

Ans:

Diagnostic uses of enzymes:

(a) **Aldolase:** Progressive muscular dystrophy, viral hepatitis and advanced cancer of the prostate

(b) **Creatine Phosphokinase:** damage to muscle cells.

(c) **Gamma-gSutarnyl transpeptidase:** in assessing liver function.

(d) **Lactic Dehydrogenase:** in differentiating heart attack anemia, lung injury, or liver disease.

(e) **Lipase:** Damage to the pancreas.

21. Describe venoms as enzymes inhibitors.

Ans:

Venoms as enzymes inhibitors:

Snake venom is highly modified saliva that is produced by special glands of certain species of snakes. Snake venom is a combination of many toxins (proteins) and different enzymes use for the purposes like increasing the prey's uptake of toxins. Snake venom is an inhibits cholinesterase to make the prey lose control of its muscles. Venom is an inhibitor for an essential enzyme's cytochrome oxidase in the cells.

Three are three distinct type of venom that act on the body differently.

(1) Hemotoxic venoms act on the heart and cardiovascular system.

(2) Neurotoxic venom acts on the nervous system and brain

(3) Cytotoxic venom has a localized action at the site of the bite. Venom occupies the active site of the enzyme or combining with the iron which may present in the prosthetic group or which may be required as an enzyme activator.

22. Describe/Explain briefly:

Carbonic anhydrase, active site, holoenzyme, apoenzyme, pepsinogen, cofactors, prosthetic group, non-regulatory enzyme, allosteric enzymes, energy of activation, enzyme inhibitors, reversible inhibition, reversible non-competitive enzyme, irreversible non-competitive enzyme, oxidoreductases, transferases, hydrolases, lyases, isomerases, ligases, proteases, lipases, carbohydrates, nucleases.

Ans:

Carbonic anhydrase:

Carbonic anhydrase is an enzyme that assist rapid inter-conversion of carbon dioxide and water into carbonic acid, protons and bicarbonate ions. This enzyme was first identified in 1993, in red blood cells of cows. Since then, it has been found to be abundant in all mammalian tissues, plants, algae and bacteria. This ancient enzyme has three distinct classes (called alpha, beta, and gamma carbonic anhydrase)

OR

Carbonic anhydrase which can add O_2 in hemoglobin as well as can control the formation of carbonic acid and bicarbonates in blood.

Active site:

In biology, the active site is the region of an enzyme where substrate molecules bind and undergo a chemical reaction. The active site consists of residues that form temporary bonds with substrate and residues that catalyse of that substrate (bonding site) and residues that catalyse of that a reaction of that substrate (catalytic site)

OR

The active site refers to the specific region of an enzyme where a substrate bind and catalysis takes place or where chemical reaction occurs. It is a structural element of protein that determines whether the protein is functional when undergoing a reaction from an enzyme.

Holoenzyme:

An enzyme which requires a cofactor becomes active only if the cofactor is combined with it. Such an active enzyme is called holoenzyme.

Apoenzyme:

If the cofactor is not available, the remaining protein part of the enzyme becomes catalytically inactive and is called apoenzyme.

Pepsinogen:

Pepsin is an example of such enzyme. It is secreted by gastric gland from stomach wall in an inactive state, the pepsinogen. In this state, it has an additional polypeptide fragment attached to its active site which does not allow the binding of substrate; hence it remains inactive. When pepsinogen is exposed in HCl (as in stomach cavity), the additional polypeptide fragment is removed and as a result, inactive (apoenzyme) pepsinogen is changed into its active (holoenzyme) form, the pepsin.

OR

Pepsinogen is released by the chief cells in the stomach wall, and upon mixing with hydrochloric acid of the gastric juice, pepsinogen activates to become pepsin.

Cofactor:

Enzymes consist of a non-protein called cofactor.

OR

A cofactor is a non-protein chemical compound or metallic ion that is required for a protein's biological activity to happen. These proteins are commonly enzymes and co-factors can be considered "helper molecules" that assist in biochemical transformations.

Prosthetic Group:

A prosthetic group is covalently bonded part of an enzyme. Which is permanently attached to enzymes and does not detach after the completion of a reaction.

Example:

An iron containing porphyrin ring attached to some enzymes like cytochromes is the example of prosthetic group.

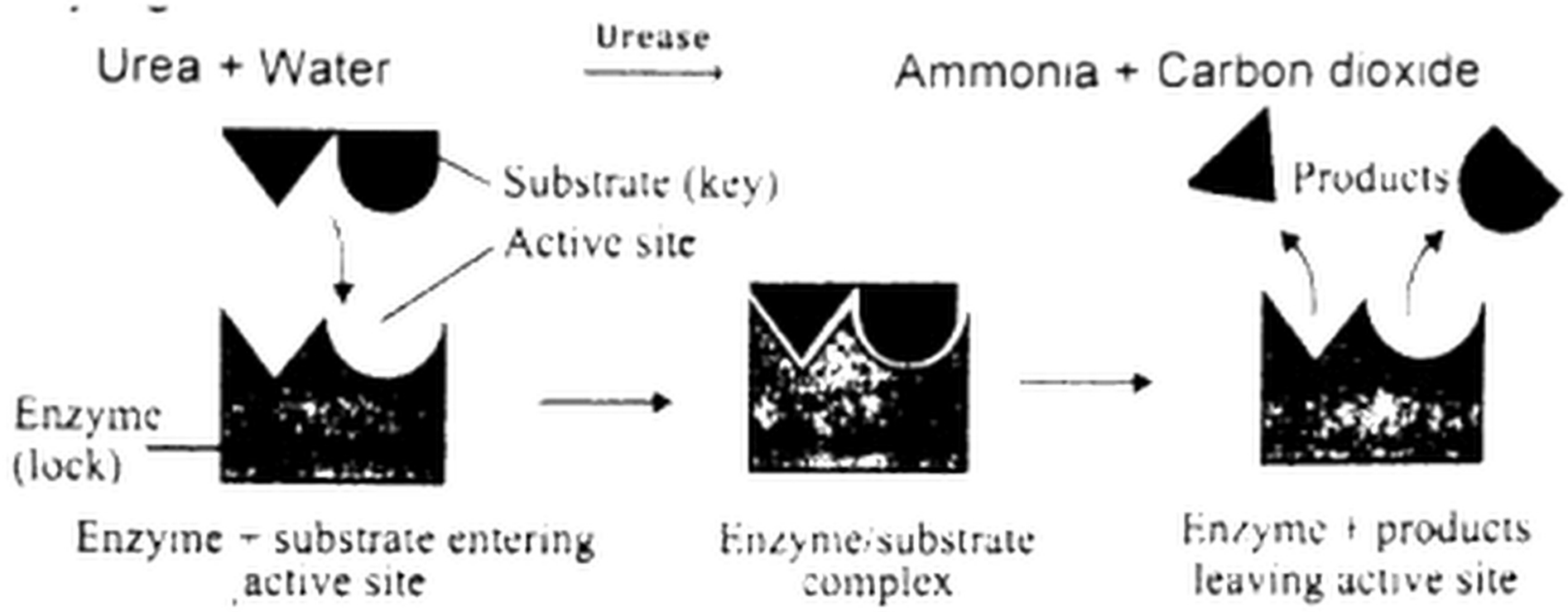
Non-Regulatory Enzymes:

The mechanism of enzyme action can be explained by two different models. Emil Fischer proposed Lock and Key model in 1894.

According to this model active site, have definite structure and rigid shape. Shae of active site is complementary to the shape of substrate. Therefore, the substrate of a specific shape can bind to the active site. The active site remains change or unchanged during the reaction. Lock and key model assume that as a particular key opens a particular lock, a specific enzyme (key) acts upon a particular substrate (lock).

Actually, the notched portion of the key is equivalent to the active site on the enzyme. It reflects that enzymes are highly specific in their action and each enzyme carry out only one particular reaction. The enzymes which work according to this model are called non-regulatory enzymes.

However, this model is exercised by a very small number of enzymes, for example, sucrose, maltase etc. The ability of enzyme to catalyze one specific reaction is perhaps its most significant property. Although, many enzymes show broad range of specificity towards the substrate they catalyzed. When one enzyme can catalyze only one substrate and essentially no other, it is called absolute specificity. E.g. Urease



Fisher's "Lock & Key" Hypothesis of Enzyme Action

Allosteric Enzymes:

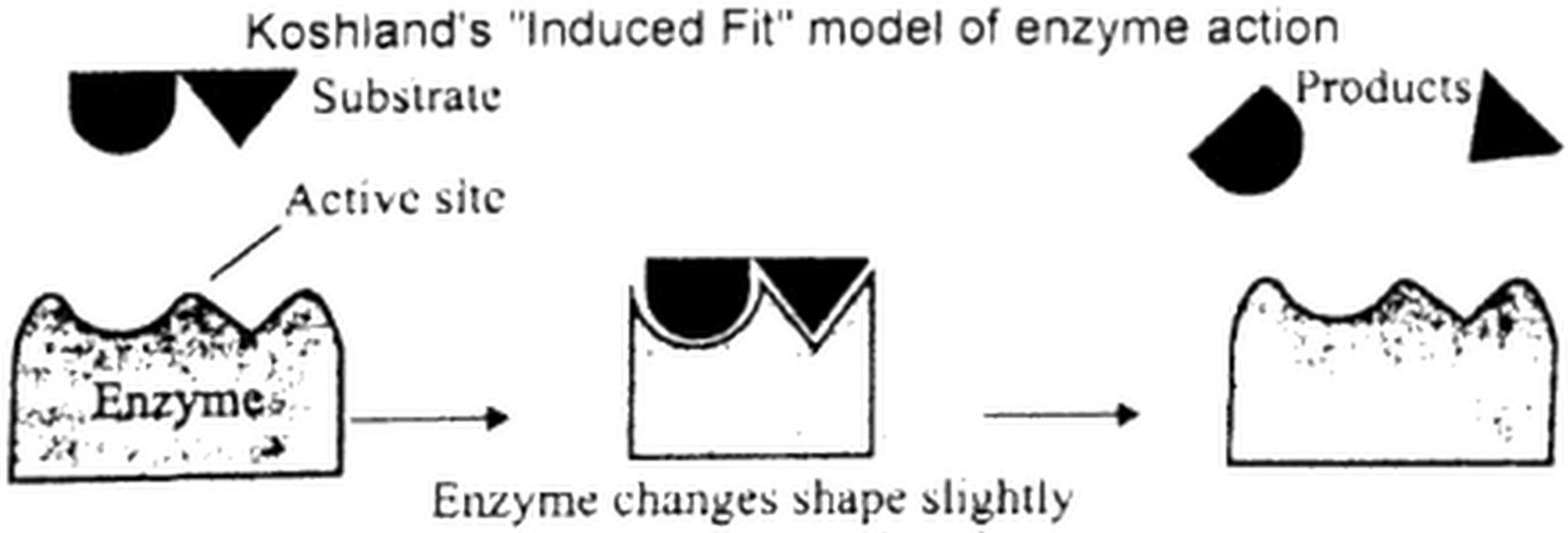
Koshland proposed **Induced fit model** in **1959**.

According to this model, the active site is flexible, therefore it is modified as the substrate interacts with enzyme. The amino acids which makeup the active site are molded into a precise shape which enable an enzyme to perfume its catalytic function more effectively. The change which is induced in the shape of active site is responsible for the change in the shape of substrate into product. As the reaction is completed the active site regains its original shape. This is the flexibility of active site which allow more than one type of related substrates to be attached on the active site and therefore, an enzyme can carry on more than one type of related reactions. The example is carbonic anhydrase which can add O_2 in hemoglobin as well as can control the formation of carbonic acid and bicarbonates in blood.

Enzymes which follow induced fit model, are called regulatory or allosteric enzymes, for example, hexokinase.

$Hb + 4O_2 \xrightarrow{\text{carbonic anhydrase}} Hb4O_2$ (oxyhemoglobin)

$CO_2 + H_2O \xrightarrow{\text{carbonic anhydrase}} H_2CO_3 \xrightarrow{\text{carbonic anhydrase}} H^+ + HCO^-$



Koshland's Induced Fit Hypothesis

Energy of activation:

Molecules do not react with each other unless they are activated in some way. The energy that must be added to cause molecules to react with one another is called activation energy.

Enzyme inhibition:

The phenomenon in which an enzyme fails to catalyze a reaction is called enzyme inhibition and the molecules that react enzyme but are not converted into desired products are called enzyme inhibitors.

Reversible inhibition:

A type of enzyme inhibition in which enzymes activity is blocked by the presence of a chemical that complete with the substrate for binding to the active site is called competitive inhibition. Usually, a competitive inhibitor is structurally similar to the normal substrate and so fits into active site of the enzyme. However, it is not similar enough to substitute fully for the normal substrate in the chemical reaction and the enzyme cannot attack to it to form reaction products. Competitive inhibition is usually temporary, and the inhibitor eventually leaves the enzyme hence it is also called reversible inhibition.

This means that the level of inhibition depends on the relative concentrations of substrate and inhibitor, since they are competing for places in enzyme active sites. Therefore, if the concentration of the substrate is increased relative to the concentrations of the inhibitors, the active site will usually be occupied by the substrate. An example of the inhibitor is malonate. Succinate dehydrogenase that catalyzes the formation of fumarate from succinate is competitively inhibited by malonate.

Reversible non-competitive enzymes:

Reversible non-competitive enzymes inhibitors work not by preventing formation of enzyme-substrate complexes, but by preventing the formation of enzyme-product complexes. So, they prevent the substrate to be converted into product.

Example:

Feedback inhibition is an example of reversible non-competitive enzyme inhibition.

Irreversible Non-competitive Enzymes:

An irreversible non-competitive enzyme inhibitor destroys enzymes by altering its shape so that the substrate cannot bind to the active site.

Examples:

The examples of irreversible non-competitive inhibitors include cyanides and salts of heavy metals.

Oxidoreductases:

The enzymes catalyze oxidation/reduction of their substrate and act by removing or adding electron or H^+ ions from or to the substrate.

Example:

Cytochrome oxidase oxidizes cytochrome.

Transferases:

These enzymes catalyze the transfer of specific functional group other than hydrogen from one substrate to another. The chemical group transferred in the process is not I a free state.

Example:

Hexokinase transfers a phosphate group from ATP to glucose.

Hydrolases:

These enzymes bring about the breakdown of large complex organic molecules into smaller ones by adding water (hydrolysis) and breaking the specific covalent bonds.

Example:

Examples are proteolytic enzymes which breakdown proteins into peptones and peptides such as pepsin, renin, and trypsin. Other digestive enzymes that work in digestive tract are also examples of hydrolases.

Lyases:

These enzymes catalyze the breakdown of specific covalent bonds and removal of groups without hydrolysis.

Examples:

Histidine decarboxylase breaks the covalent bonds between carbon atoms in histidine forming carbon dioxide and histamine.

Isomerases:

These enzymes bring about intra-molecular rearrangement of atoms in the molecules and thus forming one isomer from another.

Examples:

Phosphohexos isomerse changes glucose 6-phosphate to fructose 6-phosphate.

Ligases:

These enzymes bring about joining together of two molecules. The energy is derived by hydrolysis of ATP.

Example:

Polymerases are responsible for linking monomers into a polymer such as DNA or RNA.

Proteases:

These enzymes act upon proteins.

Example:

Pepsin and trypsin (both digest large polypeptides or peptones), aminopeptidases and carboxypeptidases (both digest peptones into dipeptides) and Erypsin (digest dipeptides into amino acids)

Lipases:

These enzymes hydrolyze lipids into fatty acids and glycerol.

Example:

Pancreatic lipases.

Carbohydrases:

These enzymes cause breakdown of carbohydrates.

Examples:

(a) Amylase (digest starch or glycogen into maltose)

(b) Cellulose (digest cellulose into cellubiose, disaccharide)

(c) Maltose (Digest maltose into glucose)

(d) Diastase (acts on starch)

(e) Sucrose (digest sucrose into glucose and fructose)

(f) Lactase (digest lactose into galactose and glucose)

Nucleases:

These are involved in breakdown of DNA and RNA.

Example:

(a) RN Aases (digest RNA into ribonulcleotides)

(b) DNAases (Digest DNA into deoxyribo nucleotides)

(c) AT Pases (cause hydrolysis of ATP in muscles etc)

23: Define:

(a) Metabolism
(b) Enzymes
(c) Active site of enzyme
(d) Cofactor
(e) Coenzymes
(f) Apoenzymes
(g) Holoenzymes
(h) Prosthetic group
(i) Non-regulatory enzymes
(j) Regulatory enzymes
(k) Feedback inhibition
(l) Energy of activation
(m) Reversible inhibitors
(n) Allosteric Site
(o) absolute specifity of enzymes

Ans:

(a) Metabolism:

The sum of all chemical reactions going on in a cell is known as metabolism.

(b) Enzymes:

Enzymes are biological catalysts and therefore they speed up biochemical reactions without being consumes. Without enzymes reactions are possible but they would proceed at very slow speed that will have no significance for life.

(c) Active Site:

In biology, the active site is the region of an enzyme where substrate molecules bind and undergo a chemical reaction. The active site consists of residues that form temporary bonds with substrate and residues that catalyze of that substrate (bonding site) and residues that catalyse of that a reaction of that substrate (catalytic site)

(d) Cofactor:

A cofactor is a non-protein chemical compound or metallic ion that is required for a protein's biological activity to happen. These proteins are commonly enzymes and co-factors can be considered "helper molecules" that assist in biochemical transformations.

(e) Coenzyme:

A coenzyme is an organic non-protein compound that binds with an enzyme to catalyze a reaction. Coenzyme are often broadly called cofactors but they are chemically different. A coenzyme cannot function alone, but can be reused several times when paired with enzyme.

(f) Apoenzyme:

If the cofactor is not available, the remaining protein part of the enzyme becomes catalytically inactive and is called apoenzyme.

(g) Holoenzyme:

An enzyme which requires a cofactor becomes active only if the cofactor is combined with it. Such an active enzyme is called holoenzyme.

(h) Prosthetic Group:

A prosthetic group is covalently bonded part of an enzyme. Which is permanently attached to enzymes and does not detach after the completion of a reaction.

Example:

An iron containing porphyrin ring attached to some enzymes like cytochromes is the example of prosthetic group.

(i) Non-Regulatory enzymes:

According to Lock and key model, active site, have definite structure and rigid shape. Shae of active site is complementary to the shape of substrate. Therefore, the substrate of a specific shape can bind to the active site. The active site remains change or unchanged during the reaction. Lock and key model assume that as a particular key opens a particular lock, a specific enzyme (key) acts upon a particular substrate (lock).

Actually, the notched portion of the key is equivalent to the active site on the enzyme. It reflects that enzymes are highly specific in their action and each enzyme carry out only one particular reaction. The enzymes which work according to this model are called non-regulatory enzymes

(j) Regulatory enzymes:

A regulatory enzyme is an enzyme in a biochemical pathway which, through its responses to the presence of certain other biomolecules, regulates the pathway activity. This is usually done for pathways whose products may be needed in different amounts at different amounts at different times. Such as hormone production.

OR

In a multi-step enzymatic process, there will be one enzyme which will be responsible for the overall rate of that process. This critical rate limiting enzymes is called the regulatory enzyme. Regulatory enzyme shows enhanced or decreased catalytic activities in response to other molecules (signals) in the cell.

(k) Feedback inhibition:

The activity of almost every enzyme in a cell can be regulated by its product. When the activity of an enzyme is inhibited by its own product. It is called Feedback inhibition.

(l) Energy of Activation:

Molecules do not react with each other unless they are activated in some way. The energy that must be added to cause molecules to react with one another is called activation energy.

(m) Reversible inhibitors:

A type of enzyme inhibition in which enzymes activity is blocked by the presence of a chemical that complete with the substrate for binding to

the active site is called competitive inhibition. Usually, a competitive inhibitor is structurally similar to the normal substrate and so fits into active site of the enzyme. However, it is not similar enough to substitute fully for the normal substrate in the chemical reaction and the enzyme cannot attack to it to form reaction products. Competitive inhibition is usually temporary, and the inhibitor eventually leaves the enzyme hence it is also called reversible inhibition.

(n) Allosteric site:

In non-competitive inhibition, the inhibitor molecule binds to an enzyme other than active site. The other binding site of enzyme is called allosteric site.

(o) Absolute specificity of enzymes:

When an enzyme can catalyze only one substrate and essentially no others it is called absolute specificity e.g. urease

24. Write the difference between:

(a) Binding site and catalytic site

(b) apoenzyme and holoenzyme

(c) Prosthetic group and coenzyme

(d) Inorganic cofactor and organic cofactor

(e) Lock and key model and induced fit model

(f) Competitive and non-competitive enzyme inhibitors

(g) Reversible non-competitive enzyme inhibitors and irreversible non-competitive enzyme inhibitors

(a) Binding site and catalytic site:

The active site consists of residues that form temporary bonds with the substrate (binding site) and residues that catalyze a reaction of that substrate (catalytic site). An active site consists of two functional regions, i.e. binding site and catalytic site. Some amino acids have active site which makes bonds with substrate constitute the binding site while the other amino acids which cause conversion of substrate into product (catalysis) constitute the catalytic site.

(b) Apoenzyme and holoenzyme:

If the cofactor is not available, the remaining protein part of the enzyme becomes catalytically inactive and is called apoenzyme.

An enzyme which requires a cofactor becomes active only if the cofactor is combined with it. Such an active enzyme is called holoenzyme.

OR

Difference between Holoenzyme and apoenzyme	
Holoenzyme	**Apoenzyme**
Holoenzyme is an active enzyme consisting of an apoenzyme bound to its cofactor	Apoenzyme is the protein component which lacks its cofactor
Cofactor:	
Holoenzyme is bound to its cofactor	Apoenzyme is the enzyme component without cofactor
Activity:	
Holoenzyme is catalytically active	It is catalytically inactive

Completeness:	
Holoenzyme is complete and can initiate the reaction	It is incomplete and cannot initiate the reaction.
Examples:	
DNA polymerase, RNA polymerase are examples of holoenzyme.	Aspartate transcarbamoylase is an example for apoenzyme.

(c)Prosthetic group and coenzyme:

The organic cofactors are either coenzymes or prosthetic groups. The coenzymes are the derivatives of vitamins.

For example, ATP, NAD^+, FAD^+ are common coenzymes. Like inorganic cofactors they are also attached to the enzymes when substrate gets bind i.e. they are also detachable cofactors.

Ethyl Alcohol Alcohol dehydrogenase+NAD ⟶ acetaldehyde + $NADH_2$

On the other hand, a prosthetic group is covalently bounded part of an enzyme which is permanently attached to enzyme and does not detach after the completion of reaction. An iron containing porphyrin ring attached to some enzyme like cytochromes is the example of prosthetic group.

OR

Difference between Prosthetic group and coenzyme	
Prosthetic Group	**Coenzyme**

Prosthetic group is a type of helper molecule which is a nonproteinaceous compound that helps enzymes to perfome their function.	Coenzyme is a specific kind of cofactor molecule which is an organic molecule that helps enzymes to catalyze chemical reactions.
Bond with Enzymes:	
They bind tightly or covalently with enzymes to aid enzymes.	They bind loosely with active site of the enzyme to help catalytic function.
Composition:	
Prosthetic group are metal ions. Vitamins, lipids or sugars	Coenzyme are vitamins, vitamin derivatives or nucleotides
Main function:	
It mainly provides a structural property to the enzyme.	Coenzyme mainly provides a functional property to the enzyme.
Removal from the enzymes:	
They cannot be easily removed from enzymes	They can be easily removed from enzymes
Examples:	
Flavin nucleotides and heme	AMP, ATP, coenzyme A, FAD, NAD^+, S-adenosyl methionine

(d)Inorganic cofactor and organic cofactor:

The inorganic cofactors are different metallic ions such as Fe, Mg, Cu, Zn etc. These are only attached to the enzyme when substrate gets bind i.e. they are detachable cofactrors are also called activators.

$$\text{Glucose+ATP} \xrightarrow{\text{hexokinase+ } Mg^{+2}} \text{Glusoce-6-phosphate+ADP}$$

On the other hand, the organic cofactors are either co-enzymes or prosthetic groups. The coenzymes are the derivatives of vitamins.

For example, ATP, NAD^+, FAD^+ are common coenzymes. Like inorganic cofactors. They are also attached to the enzymes when substrate gets bind i.e. they are also detachable cofactors.

$$\text{Ethyl alcohol} \xrightarrow{\text{alcohol dehydrogenase+NAD}} \text{Aceteldehyde+}NADH_2$$

OR

	Cofactor (inorganic)	**Coenzyme (organic)**
Definition	It is a non-protein chemical compound that is bound tightly or loosely to an enzyme.	It is defined as small, organic, non-protein molecules, which carry chemical groups between enzymes
Characteristics	These are inorganic substances	These are organic substances
Function	It assists in biological transformations	It aids or helps the function of an enzyme.

Type	They are chemical compounds	They are chemical molecules
Bound	They are tightly bound to enzymes	It is loosely bound to an enzyme.
Action	They act on catalyst to increase e speed of reaction	They act as carriers to the enzymes
Example	Metal ions like Zn^{++}, K^{+}, Mg^{++} etc.	Vitamins, biotin, coenzyme A etc.

(e)Lock and key model and induced fit model:

Lock and key model	Induced Fit model
I. **Active site is a single entity**	Active site is made of two components.
II. **There is no separate catalytic group.**	A separate catalytic group is visualized
III. **Active site is static.**	In contact with substratum, the buttressing group undergoes conformational change.
IV. **Development of transition state is not considered.**	It considers the development of transition state before the reactants undergo change

V. It does not visualize the weakening of substrate bonds	Catalytic group is believed to weaken the substrate bonds by nucleophile and electrophile attack.
VI. It does not explain the mechanism of non-activity in case of competitive inhibitor.	It gives a mechanism for non-action over competitive inhibitor

(f)Competitive and non-competitive enzyme inhibitors:

Competitive inhibitors	**Non-competitive inhibitors**
A competitive inhibitor will block the enzyme's active site (i.e. it will occupy the same space as the natural substrate, blocking it from being catalyzed)	A Non-competitive inhibitor will bind to the enzyme somewhere other than active site of the enzyme, an allosteric site. This will change the shape of the enzyme such that the natural substrate may or may not be able to bind the enzyme's active site, but the enzyme will not be able to complete the chemical reaction necessary.
Antibodies, antimetabolities, pencillin, iodoacetate, melonate, CoA (high concentration)	Acetaldehyde, Di-isopropyl fluorophosphates (DFP-nerve gas), mercury, silver, copper, cyanide

OR

Competitive inhibitors	**Non-competitive inhibitors**

i-	**The structure of inhibition molecules is similar to that of the substance**	The structure of inhibition molecules is entirely different
ii-	**The inhibitors get attached to the active site of the enzyme.**	The inhibitor forms complex at a point other than the active site.
iii-	**It competes with substrate molecule for the enzyme.**	It does not compete with substrate.
iv-	**It does not alter the structure of an enzyme**	It alters the structure of enzyme such that the substrate may get attached to the active site but products are not formed
v-	**The reaction can be reversed by increasing the substrate concentration.**	The reaction goes on decreasing as more and more inhibitors contact the enzyme till saturation is reached
vi-	**Examples are sulpha drugs given to bacteria complete with para-amino benzoic acid (PABA) and folic acid synthesis is inhibited.**	Examples: Cyanide combines with the prosthetic group of cytochrome oxidase inhibits the election transport chain

(g)Reversible non-competitive enzyme inhibitors and irreversible non-competitive enzyme inhibitors:

Reversible non-competitive enzyme inhibitors	irreversible non-competitive enzyme inhibitors:

They work not by preventing the formation of enzyme-substrate complexes but by preventing the formation of enzyme-product complexes so they prevent the substrate to be converted into product.	They destroy enzyme by altering its shape so that the substrate cannot bind to the active site.
Feedback inhibition is an example.	Cyanides and salts of heavy metals are examples