Enzymes

- Enzymes are biocatalyst ie the catalyst of life
- Catalyst is defined as a substance that increases the rate of chemical reaction without itself undergoing in change in the overall process
- Enzymes may be defined as biocatalyst synthesized by living cells . They are protein in nature(except RNA acting as Ribozyme) colloidal and thermolabile in character and specific in their action.

Properties of enzymes

- All enzymes have some important properties:
- They are all proteins, which is one reason why we need protein in our diet.
- They are all biological catalysts. They speed up a reaction without being used up; this means they can be used over and over again.
- A small amount of enzyme can affect the change of a large amount of chemical.
- The way enzymes work is affected by temperature, pH and pressure. They can be denatured (destroyed) by excessive heat.
- Enzymes are specific that is they control only one reaction. So maltase only acts on maltose, sucrase on sucrose etc

Nomenclature:

Enzymes are considered under two broad categories
Intra cellular enzyme and Extracellular enzymes

1. Intra Cellular enzymes
   They are functional within cell where they are synthesized.
2. Extracellular Enzymes

These enzymes are active outside the cell; all the digestive enzymes belongs to this group

According to IUB system of enzyme classification

International Union of biochemistry (IUB) appointed enzyme commission in 1961.Enzymes are divided into 6 classes (OTHLIL)

- OXIDOREDUTASES
- TRANSFERASES
- HYDROLASES
- LYASES
- ISOMERASES
- LIGASES

1. OXIDOREDUCTASES:
   Enzymes involved in oxidation reduction reaction.

AH_2 + B _____ A+ BH_2 (Oxidation-reduction)

Alcohol + NAD _____ Aldehyde + NADH + H

Examples: Alcohol dehydrogenase, Cytochrome oxidase. L and D aminoacid oxidase

2.TRANSFERASES:

Enzymes that catalyses the transfer of functional group.

A_X + B _____A + B_X (group transfer)

Hexose + ATP _____Hexose 6 phosphate + ADP

Ex: Hexokinase, Transaminases, Transmethylates, Phosphorylases

3.HYDROLASES:
Enzymes that bring about hydrolysis of various compounds.

A_B + H2O_____AH + BOH. Hydrolysis
Acetyl choline + H2O _____choline + acetate

Ex: Lipase, Choline esterase, Acid and Alkaline phosphatase, Pepsin, Urease.

4. LYASES:
Enzymes specialized in addition or removal of water, ammonia, carbon dioxide.

A_B + X_Y_____AX___BY (Addition --_elimination)
Fructose 1,6_bisphosphate_____glyceraldehyde 3 phosphate + dihydroxy acetone phosphate

Ex: Aldolase, Fumarase, Histidase

5. ISOMERASES:
Enzymes involved in all the isomerization reaction.

A_____A'
Glyceraldehyde 3 phosphate_____dihydroxy acetone phosphate.

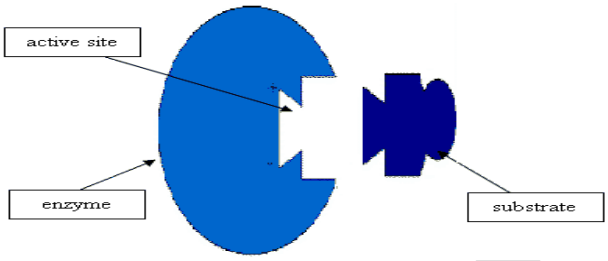
Ex: Triode phosphate isomerase, Retinol isomerase, phosphohexoseisomerase.

6. LIGASES:
Enzymes catalyzing the synthetic reaction where two molecules are joined together and ATP is used.

A+B_____A_B
Acetyl CoA + CO2 + ATP -------malonyl CoA + ADP + Pi

Ex: Glutamine synthase, acetyl Co A carboxylase, succinate thiokinase

ACTIVE SITE



Features of active site

- Existence of active site is due to the tertiary structure of protein resulting in three dimensional native conformation
- The active site is made up of amino acids. amino acids are serine, aspartate, histidine, cysteine, lysine, arginine, glutamate and tyrosine
- Serine is the most frequently found
- Active science or regarded as cleft or pockets occupying a small region in a big enzyme molecule
- Active site is not rigid in structure and shape. It is flexible to promote the specific substrate binding.
- substrate binds at the active site by weak non -covalent bond
- Enzymes are specific in function due to the existence of active sites
- Substate binds the enzyme at the active site to form enzyme substrate complex the product is released after the catalysis and the enzymes available for reuse

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

FACTORS AFFECTING ENZYME ACTIVITY

1.Concentration of enzyme

2. Concentration of substrate

3. Effect of temperature

4. Effect of pH
5.Effect of product concentration
6.Effect of time
7. Effect of light and radiation
8.Effect of activators

1. Concentration of enzyme

As the concentration of the enzyme is increased the velocity of the reaction proportionally increases.

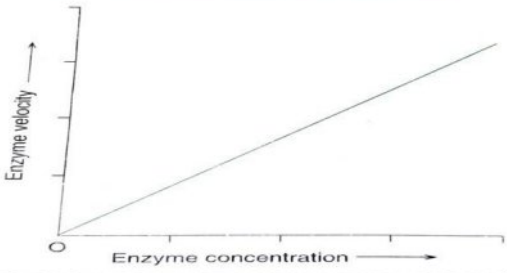
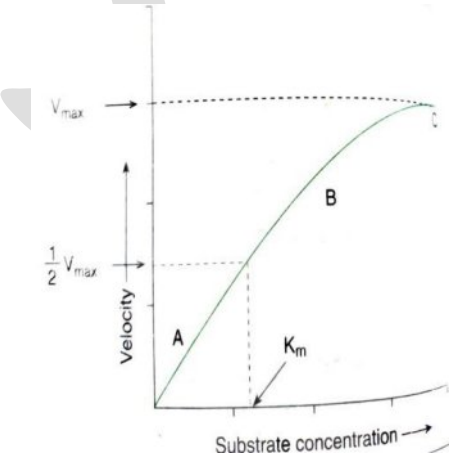


Fig. 6.1 : Effect of enzyme concentration on enzyme velociy.

2. Concentration of substrate

Increase in the substrate concentration gradually increases the velocity of enzyme action within the limited range of substrate level.

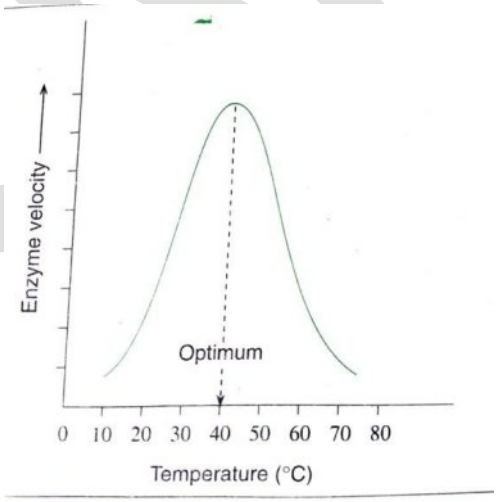


A rectangular hyperbola is obtained when velocity is plotted against the substrate concentration Three distinct phases of the reaction, are observed in the graph

- At low substrate concentration, the velocity of the reaction is directly proportional to the substrate level (part A in graph).
- In the second phase (part B), the substrate concentration is not directly proportional to the enzyme activity.
- In the third and final phase (part C), the reaction is independent of the substrate concentration.

3. Effect of temperature

- velocity of an enzyme reaction increases with increase in temperature after maximum and then declines bell shaped curves usually observe.
- Increase in temperature results in higher activation energy of the molecule and more molecular (enzyme and the substrate)collision and interaction of the reaction to proceed faster.



g. 6.4 : Effect of temperature on enzyme velocity.

- Optimum temperature for most of the enzymes between 40 degree centigrade to 45 degree centigrade.
- when the enzymes are exposed temperature above 50 degree centigrade the denaturation leading to the dearrangement of the structure of protein .

Temperature Coefficient or Q10 is defined as increase in enzyme velocity when the temperature is increased by 10 degree centigrade.for majority of enzymes Q10 is between zero degree and 40 degree.some enzymes are active even and 100 degree centigrade

4. Effect of pH

- Increase in hydrogen ion concentration (pH)considerably influences the enzyme activity and bell shaped curve is normally obtained .
- Each enzyme has an optimum pH at which the velocity is maximum. below and above this pH, the enzyme activity is much lower and at extreme PH the enzyme becomes totally inactive.

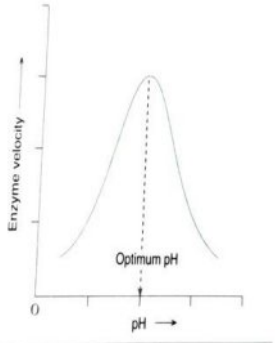


Fig. 6.5 : Effect of pH on enzyme velocity.

- most of the enzymes of higher organisms shows optimum activity around a neutral pH 6 to 8
- Hydrogen ions influences the enzyme activity by altering ionic charges on the amino acid (particularly at active site) substrate ES complex etc.
- some exceptions like a pepsin (1-2) acid phosphatase (4-5)and alkaline phosphate (10 to 11).

5.Effect of product concentration

Accumulation of reaction products generally decreases enzyme velocity .for certain enzymes the products combines with the active site of the enzyme and form a loose complex and thus inhibit the enzyme activity.

6.Effect of time

Under ideal and optimal conditions like (pH & temperature)the time required for an enzyme reaction is less.
variation in the time of the reaction of generally related to the alterations in the pH and temperature.

7. Effect of light and radiation

exposure of enzymes to ultraviolet , beta, Gamma and x-rays inactivates certain enzymes due to the formation of peroxides ex: UV rays inhibit salivary amylase activity.

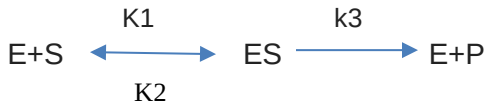
8. Effect of activators
Some of the enzymes certain inorganic metals like magnesium, manganese ,zinc, calcium, Cobalt for their optimum activity
Metals function has activators of enzyme velocity through various mechanism combining with the substrate, formation of ES_metalComplex , direct participation in the reaction and bringing a confirmation change in the enzyme.

Enzyme kinetics:

- Michaelis-Menten constant (or Brig's and Haldane's constant)
- Line weaver- burk double reciprocal plot

Michaelis-Menten constant (or Brig's and Haldane's constant)

The enzyme (E) and substrate (S) combine with each other to form an unstable enzyme-substrate complex (ES) for the formation of product (P).



Here k1, k2 and k3 represent the velocity constants for the respective reactions, as indicated by arrows.
Km, the Michaelis-Menten constant (or Brig's and Haldane's constant), is given by the formula

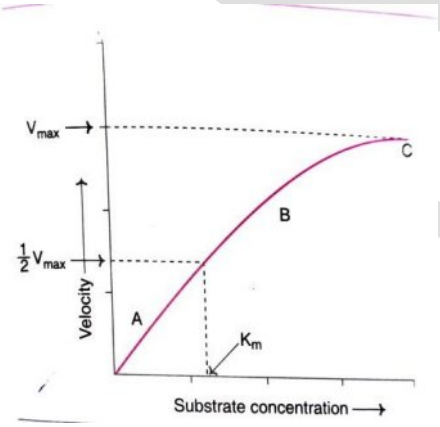
$$Km = \frac{k2 + k3}{K1}$$

The following equation is obtained after suitable algebraic manipulation.

$$V = \frac{Vmax[s]}{Km + [s]} \quad \ldots\ldots(1)$$

Where,
v = Measured velocity,
Vmax = Maximum velocity,
S = Substrate concentration,
Km = Michaelis-Menten constant

Let us assume that the measured velocity (v) is equal to ½Vmax Then the equation (1) may be nd keeping substituted as follows



$$\frac{1}{2}V\ max = \frac{Vmax[s]}{Km + [s]}$$

$$Km + [s] = \frac{2\ Vmax[s]}{Vmax}$$

$$Km + [s] = 2\ [s]$$

$$Km = [s]$$

Michaelis-Menten constant is defined as the substrate concentration (expressed in moles/l) to produce half-maximum substrate velocity in an enzyme catalysed reaction

Km value is a constant

A low K value indicates a strong affinity between enzyme and substrate, whereas a high Km value reflects a weak affinity between them. For majority of enzymes, the Km values are in the range of 10-5 to 10-2 moles.

Line weaver-burk double reciprocal plot

For the determination of Km value, the substrate saturation curve is not very accurate By taking the reciprocals of the equation (1), a straight line graphic representation is obtained.

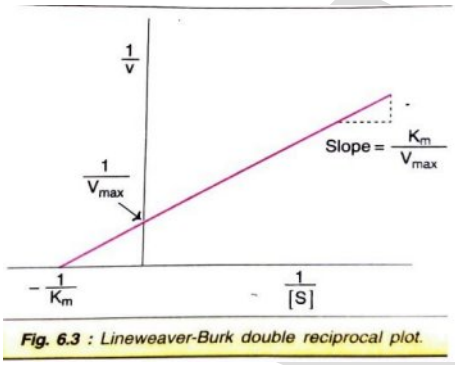


Fig. 6.3 : Lineweaver-Burk double reciprocal plot.

$$\frac{1}{v} = \frac{K_m + [S]}{V_{max}[S]}$$

$$\frac{1}{v} = \frac{K_m}{V_{max}} \times \frac{1}{[S]} + \frac{[S]}{V_{max}[S]}$$

$$\frac{1}{v} = \frac{K_m}{V_{max}} \times \frac{1}{[S]} + \frac{1}{V_{max}}$$

The above equation is similar to y = ax + b.

Therefore, a plot of the reciprocal of the velocity[1/V] vs. the reciprocal of the substrate concentration[1/[S]] gives a straight line. Here the slope is Km/Vmax and whose y intercept is 1/Vmax

The Lineweaver-Burk plot is shown is much easier to calculate the Km from the intercept on x-axis which is -(1/Km). for Further, the double reciprocal plot is useful in understanding the effect of various inhibitions

Enzyme inhibitors

- An enzyme inhibitor is defined as a substance/ molecule that binds to an enzyme and brings about a decrease in catalytic activity of that enzyme.

- The binding of an inhibitor can stop a substrate from entering the enzyme's active site and/or hinder the enzyme from catalyzing its reaction
- Enzyme inhibitors may be organic or inorganic in nature

Enzyme inhibitors are broadly classified into
1. Reversible Inhibitors
2. Irreversible Inhibitors
3.Allosteric Inhibitors

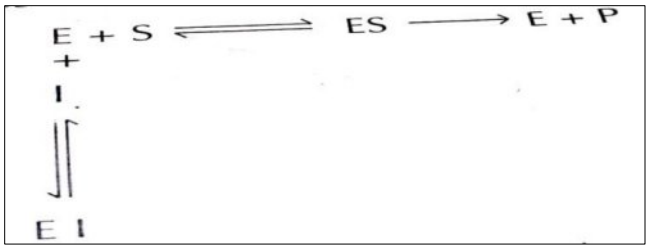
Reversible inhibitors

Reversible inhibitors bind non-covalently with enzyme and the enzyme inhibition can be reversed when the inhibitor is removed. There are 3 different types of reversible inhibitors

1.Competitive inhibitor
2. Non-competitive inhibitor
3. Un competitive inhibitor

Competitive inhibitor:

- In competitive inhibition, the inhibitor(I) is very closely resembles (similar in shape) to the real substrate(S).
- Inhibitor competes with substrate and binds to the active site of enzyme to form an inhibitor-enzyme complex.



- This reduces the number of enzyme molecules available for the substrate molecules to bind to, As a result less catalysis takes place and so the rate of the reaction slows down

- The inhibition could be overcome by a high substrate concentration. In competitive enzyme inhibition, the Km value increases whereas Vmax remains unchanged

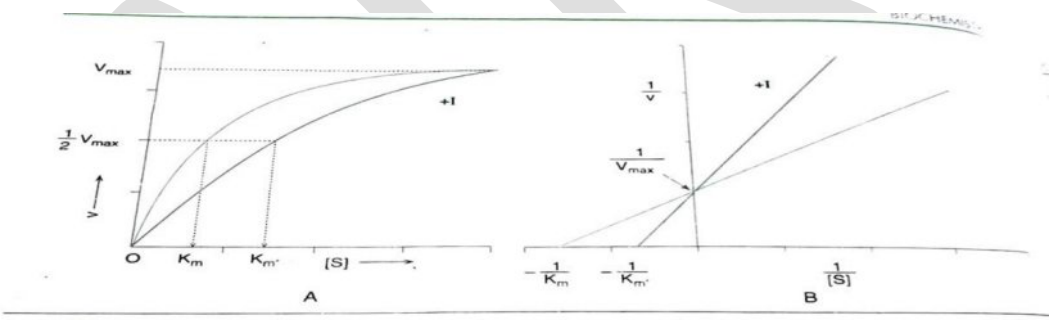


Fig. 6.6 : Effect of competitive inhibitor (I) on enzyme velocity. (A) Velocity (v) versus substrate (S) plot. (B) Lineweaver-Burk plot (Green shaded lines with inhibitor; competitive inhibitor increases K_m, unalters V_{max}

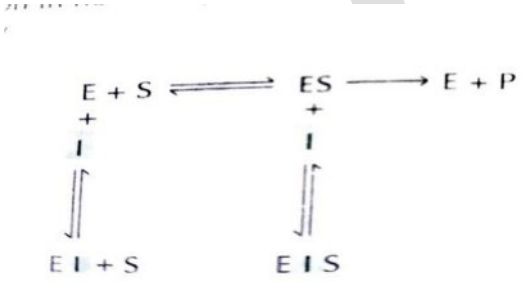
The enzyme succinate dehydrogenase (SDH) is a classical example of competitive inhibition with succinic acid as its substrate. The compounds, namely, malonic acid, glutaric acid and oxalic acid, have structural similarity with succinic acid and compete with the substrate for binding at the active site of SDH.

TABLE 6.2 Selected examples of enzymes with their respective substrates and competitive inhibitors

Enzyme	Substrate	Inhibitor	Significance of inhibitor
Xanthine oxidase	Hypoxanthine Xanthine	Allopurinol	Used in the control of gout to reduce excess production of uric acid from hypoxanthine
Monoamine oxidase	Catecholamines (epinephrine, norepinephrine)	Ephidrene, amphetamine	Useful for elevating catecholamine levels.
Dihydrofolate reductase	Dihydrofolic acid	Aminopterin, amethopterin, methotrexate	Employed in the treatment of leukemia and other cancers.
Acetylcholine esterase	Acetylcholine	Succinyl choline	Used in surgery for muscle relaxation, in anaesthetised patients.
	Para aminobenzoic acid (PABA)	Sulphanilamide	Prevents bacterial synthesis of folic acid.
	Vitamin K	Dicumarol	Acts as an anticoagulant.
	Pyridoxine (vitamin B_6)	Isonicotinic acid hydrazide (INH)	INH is an antituberculosis drug, its prolonged use leads to B_6 deficiency.

Non-competitive inhibitor:

- In non-competitive reversible inhibition, the inhibitor does not compete with the substrate for the active site. It binds to a site other than active site on the enzyme
- The inhibitor has no structural resemblance with the substrate



- The inhibitor does not interfere with the enzyme-substrate binding,but catalysis is prevented,dueto the distortion in the enzyme conformation.

- For Non-competitive inhibition, the Km value is unchanged while Vmax is lowered

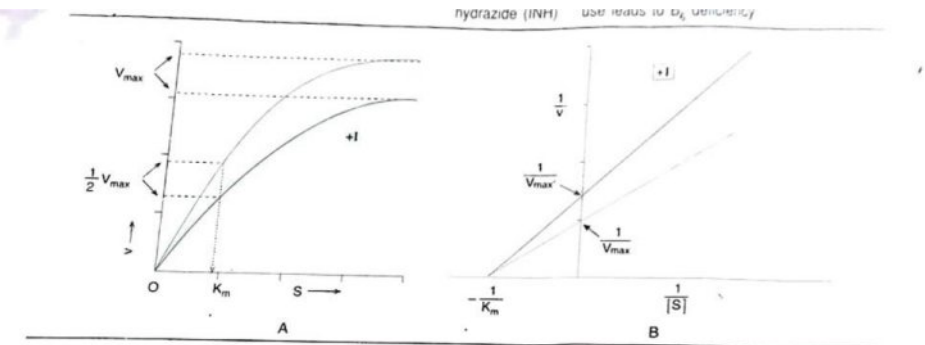


Fig. 6.7 : Effect of non-competitive inhibitor (I) on enzyme velocity (A) Velocity (v) versus substrate (S) (B) Lineweaver-Burk plot (Green shaded lines with inhibitor, non-competitive inhibitor does not change K_m but decreases V_{max}).

Heavy metal ions (Ag+, Pb2+, Hg2+ etc.) can non-competitively inhibit the enzymes by binding with cysteinyl sulfhydryl groups. The general reaction for Hg^{2+}

$$E\text{-}SH + Hg \rightleftharpoons E\text{-}S\text{-}\text{-}Hg^{2+} + H^*$$

Heavy metals also lead to the formation of covalent bonds with carboxyl groups and histidine, often resulting in irreversible inhibition.

Uncompetitive inhibitor**:**

The inhibitor does not bind with enzyme but only binds with enzyme – substrate complex. it should not be confused with non-competitive inhibitors. This is a very rare class of inhibition.

- For Un-competitive inhibition,decreases both the Km unchanged and Vmax values of the enzyme.

Irreversible Inhibitors

Irreversible inhibitors covalently bind to an enzyme, cause chemical changes to the active sites of enzymes, and inactive them, which cannot be reversed (irreversible)

These inhibitors are usually toxic substance

lodoacetate is an irreversible inhibitor of the enzymes like papain and glyceraldehyde 3-phosphate dehydrogenase. Iodoacetate combines with sulfhydryl (-SH) groups at the active site of these enzymes and makes them inactive.

Diisopropylfluorophosphate (DFP) is a nerve gas developed by the Germans during Second World War. DFP irreversibly binds with enzymes containing serine at the active site, e.g. serine proteases, acetylcholine esterase.

Many organophosphorus insecticides like melathion are toxic to animals (including man) as they block the activity of acetylcholine esterase (essential for nerve conduction), resulting in paralysis of vital body functions.

Suicide inhibition: In this type of irreversible inhibition, the original inhibitor is converted to a more potent form by the same enzyme that ought to be inhibited e.g., allopurinol, an inhibitor of xanthine oxidase, gets converted to alloxanthine, a more effective inhibitor of the enzyme

Allosteric inhibition

Some of the enzymes possess additional sites, known as allosteric sites (Greek : allo-other),besides the active site. Such enzymes are known as allosteric enzymes

Allosteric enzymes have one or more allosteric sites.

Allosteric sites are binding site distinct from an enzyme active site or substrate binding site.

Molecules that bind to allosteric site are called effector (or) modular

The enzyme activity is increased when a positive (+) allosteric effector binds at the allosteric site known as activator site

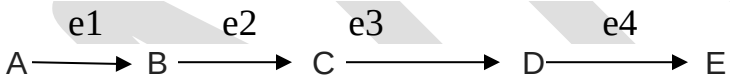
The enzyme activity is decreased, when a negative (-) allosteric effector binds at the allosteric site called inhibitor site and inhibits the enzyme activity.

K –Enzyme/K-class - allosteric inhibitors lowers the substrate affinity to raise Km of enzyme but Vmax unchanged e.g. phospho- fructokinase

M –Enzyme/V-class, allosteric inhibitors reduces Vmax but no change in Km (or)substrate affinity e.g. Acetyl CoA carboxylase.

Feedback regulation/Inhibition

<u>The process of inhibiting the first step by the final product, in a series of enzyme catalysed reactions of a metabolic pathway is referred to as feedback regulation.</u>



A is the initial substrate, B, C, and D are the intermediates and E is the end product, in a pathway catalysed by four different enzymes (e1, e2, e3, e4). The very first step (A → B by the enzyme e_1) is the most effective for regulating the pathway, by the final end product E. This type of control is often called negative feedback.since increased levels of end product will result in its (e_1) decreased synthesis.
Aspartate transcarbamoylase (ATCase) is a good example of an allosteric enzyme inhibited by a feedback mechanism.

REGULATION OF ENZYME ACTIVITY IN THE LIVING SYSTEM

In biological system, regulation of enzyme activities occurs at different stages in one or more of the following ways to achieve cellular economy.

1. Allosteric regulation

2. Feedback Inhibition

3. Proenzymes

4. Protein Modification

5. Induction
6.Repression

Proenzymes(zymogens)

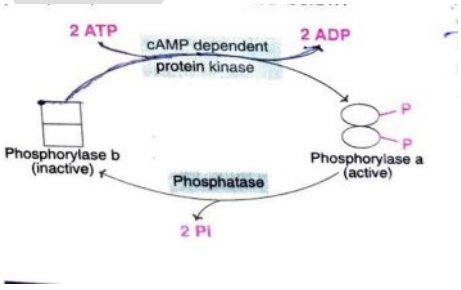
- Inactive form of enzyme which can be achieved by removing a small part on their polypeptide chain.
- Mostly they are blood clotting enzymes and digestive enzymes

(zymogens)	(active form)
Pepsinogen	pepsin
Trypsinogen	trypsin
Prothrombin	thrombin

Protein modification

- A process in which a chemical group is covalently added to or removed from the protein.
- ie either addition of a group to the enzyme protein by covalent bond or removal of a group by cleaving a covalent bond.

- Example - Glycogen phosphorylase is a muscle enzyme that breaks down glycogen to provide energy. This enzyme is a homodimer (two identical subunits) and exists in two interconvertible forms. Phosphorylase b (dephospho enzyme) is inactive which is converted by phosphorylation of serine residues to active form phosphorylase a. The inactive enzyme phosphorylase b is produced on dephosphorylation



Induction

- The term induction is used to represent increased synthesis of enzyme
- Increased gene expressions

- Increased the corresponding number of enzymes
- Examples - The hormone insulin induces the synthesis of glycogen synthetase, glucokinase, phosphofructokinase and pyruvate kinase. All these enzymes are involved in the utilization of glucose.
- The hormone cortisol induces the synthesis of many enzymes e.g. pyruvate carboxylase, tryptophan oxygenase and tyrosine aminotransferase.

Repression

- Repression indicates its decreased synthesis
- Decreased gene expressions
- decreased the corresponding number of enzymes
- substrate can repress the synthesis of enzyme.
- Example - Pyruvate carboxylase is a key enzyme in the synthesis of glucose from non-carbohydrate sources like pyruvate and amino acids. If there is sufficient glucose available, there is no necessity for its synthesis. This is achieved through repression of pyruvate carboxylase by glucose.

Isoenzymes or Isozymes (also known as isoenzymes)

The multiple forms of enzymes are enzymes that differ in amino acid sequence but catalyze the same chemical reaction.

They, however, differ in their physical and chemical ma properties which include the structure, electrophoretic and immunological properties, Km and Vmax values, pH optimum, relative susceptibility to max inhibitors and degree of denaturation.

- Isoenzymes synthesized from different genes e.g. malate dehydrogenase of cytosol is different from that found in mitochondria.

- Oligomeric enzymes consisting of more than one type of subunits e.g. lactate dehydrogenase and creatine phosphokinase.

- An enzyme may be active as monomer or oligomer e.g. glutamate dehydrogenase

- In glycoprotein enzymes, differences in carbohydrate content may be responsible for isoenzymes e.g. alkaline phosphatase

Lactate Dehydrogenase (LDH)

LDH whose systematic name is L-lactate-NAD* oxidoreductase which catalyses the interconversion of lactate and pyruvate

LDH has five distinct isoenzymes LDH_1, LDH_2 LDH_3, LDH_4, and LDH_5. They can be separated by electrophoresis (cellulose or starch gel or agarose gel).

LDH_1 has more positive charge and fastest in electrophoretic mobility while LDH_5 is the slowest.

LDH-1: MMMM (abundant in heart, brain erythrocytes; around 33% of LDH)
LDH-2: MMMH (abundant in heart, brain erythrocytes; around 45% of LDH)
LDH-3: MMHH (abundant in brain, kidneys, lung; around 18 % of LDH)
LDH-4: MHHH (abundant in liver, skeletal muscle, kidney; around 3% of LDH)
LDH-5: HHHH **(**abundant in liver, skeletal muscle, ileum; around 1 % of LDH)

In myocardial infarction, Total LDH increases, and since heart muscle contains more LDH-1 than LDH-2,

An increase of LDH-5 in serum is seen in different hepatic pathologies: cirrhosis, hepatitis and others.

An increase of LDH-5 in heart diseases usually indicates secondary congestive liver involvement.

LDH-1 has high Km value (low affinity) & LDH-5 has low Km value(high affinity).

Creatine Kinase(CK) or Creatine phosphokinase (CPK)

Creatine Kinase (CK) or Creatine phosphokinase (CPK) catalyses the interconversion of phospho creatine to creatine

Three isoenzymes formed by combinations of different subunits:

CK-1: (BB) is abundant in brain and smooth muscle (practically absent from serum)
CK-2: (MB) is abundant in cardiac muscle, some in skeletal muscle (practically absent from serum)
CK-3: (MM) is abundant in skeletal muscle and cardiac muscle (practically 100 % of serum CK)

Alkaline phosphatase

six isoenzymes of alkaline phosphatase (ALP) have been identified.

The most important ALP isoenzymes are α_1-ALP, α2-heat labile ALP, α2-heat stable ALP, pre-βALP, γ-ALP etc.
Increase in a2-heat labile ALP suggests hepatitis whereas pre B-ALP indicates bone diseases.

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COENZYMES

The protein part of the enzyme, on its own, is not always adequate to bring about the catalytic activity. Many enzymes require certain non- protein small additional factors, collectively referred to as cofactors for catalysis. The cofactors may be organic or inorganic in nature.

Co-enzymes are defined as the non -protein, organic, low molecular weight, easily dialyzable substances associated with the functions of enzymes.

The functional enzyme is referred to as holoenzyme which is made up of a protein part (apoenzyme) and a non-protein part (coenzyme).

Haloenzyme = Apoenzyme + Coenzyme

The term prosthetic group is used when a non-protein moiety is tightly bound to the enzyme which is not easily separable by dialysis.

The term activator is referred to the inorganic cofactor (like Ca2+, Mg2+, Mn2+ etc.) necessary to enhance enzyme activity.

Coenzymes participate in various reactions involving transfer of atoms or groups like hydrogen, aldehyde, keto, amino, acyl, methyl, carbon dioxide etc.

Coenzymes play a decisive role in enzyme function.

TYPES OF COENZYMES

- Coenzymes from B-complex vitamins:

Most of the coenzymes are the derivatives of water soluble B-complex vitamins. In fact, the biochemical functions of B-complex vitamins are exerted through their respective coenzymes

TABLE 6.3 Coenzymes of B-complex vitamins*

Coenzyme (abbreviation)	*Derived from vitamin*	*Atom or group transferred*	*Dependent enzyme (example)*
Thiamine pyrophosphate (TPP)	Thiamine	Aldehyde or keto	Transketolase
Flavin mononucleotide (FMN)	Riboflavin	Hydrogen and electron	L - Amino acid oxidase
Flavin adenine dinucleotide (FAD)	Riboflavin	"	D - Amino acid oxidase
Nicotinamide adenine dinucleotide(NAD^+)	Niacin	"	Lactate dehydrogenase
Nicotinamide adenine dinucleotide phosphate ($NADP^+$)	"	"	Glucose 6-phosphate dehydrogenase
Lipoic acid	Lipoic acid	"	Pyruvate dehydrogenase complex
Pyridoxal phosphate (PLP)	Pyridoxine	Amino or keto	Alanine transaminase
Coenzyme A (CoA)	Pantothenic acid	Acyl	Thiokinase
Tetrahydrofolate (FH_4)	Folic acid	One carbon (formyl, methenyl etc.)	Formyl transferase
Biocytin	Biotin	CO_2	Pyruvate carboxylase
Methylcobalamin; Deoxyadenosyl cobalamin	Cobalamin	Methyl/isomerisation	Methylmalonyl CoA mutase

* *Details for each coenzyme are given in Chapter 7 on vitamins*

- Non-vitamin coenzymes: Not all coenzymes are vitamin derivatives. There are some other organic substances, which have no relation with vitamins but function as coenzymes. They may be considered as non-vitamin coenzymes e.g. the ATP, CDP, UDP etc

Table 6.4 Coenzymes not related to B-complex vitamins

Coenzyme	Abbreviation	Biochemical functions
Adenosine triphosphate	ATP	Donates phosphate, adenosine and adenosine monophosphate (AMP) moieties.
Cytidine diphosphate	CDP	Required in phospholipid synthesis as carrier of choline and ethanolamine.
Uridine diphosphate	UDP	Carrier of monosaccharides (glucose, galactose), required for glycogen synthesis.
S - Adenosylmethionine (active methionine)	SAM	Donates methyl group in biosynthetic reactions.
Phosphoadenosine phosphosulfate (active sulfate)	PAPS	Donates sulfate for the synthesis of mucopolysaccharides.

- Nucleotide coenzymes: Some of the coenzymes possess nitrogenous base, sugar and phosphate. Such coenzymes are, therefore, regarded as nucleotides e.g. NAD+, NADP+, FMN, FAD, coenzyme A, UDPG etc.

- Coenzymes do not decide enzyme specificity: A particular coenzyme may participate in catalytic reactions along with different enzymes. For instance, NAD+ acts as a coenzyme for lactate dehydrogenase and alcohol dehydrogenase. In both the enzymatic reactions, NAD+ is involved in hydrogen transfer. The specificity of the enzyme is mostly dependent on the apoenzyme and not on the coenzyme.

APPLICATIONS OF ENZYMES

Therapeutic uses:

Sl No	Enzyme	Mechanism of action	Indicators
1.	L -asparginase	Enzyme hydrolyses L-aspargine required by certain tumour cells	Acute leukemia
2.	α- chymotrypsin	Mucolytic and proteolytic activity	Post surgical infections and dental procedures

3.	Digestive enzymes(amylase,lipase and protease)	Aids digestion in pancreatic insufficiency	Chronic pancreatitis
4.	Streptokinase/urokinase	Increases amount of proteolytic enzyme plasmin	Acute myocardial infarction
5.	Serratiopeptidase	Fibrinolytic activity	Inflammation after traumatic injury &after surgery

Diagnostic uses

Sl. No	Enzyme	uses
1.	Acid phosphatase	• Increase in prostrate cancer • Gauchers diseases • Hyperparathyroidism • Thrombocytosis
2.	Aspartate transaminase	• Increases in myocardial infarction • Muscle diseases • Acute liver diseases • Hemolytic anemia
3.	Isocitrate dehydrogenase	• Increases in viral hepatitis • Liver cirrhosis
4.	trypsin	• Increases in acute pancreatic diseases
5.	Lactate dehydrogenase	• Increases in acute myocardial infarction • Hypothyroidism • Muscle injury
6.	Creatinine phosphokinase	• Decreases in wilsons diseases
7.	Aldolase	• Increases in Muscular dystrophies • Acute liver diseases
