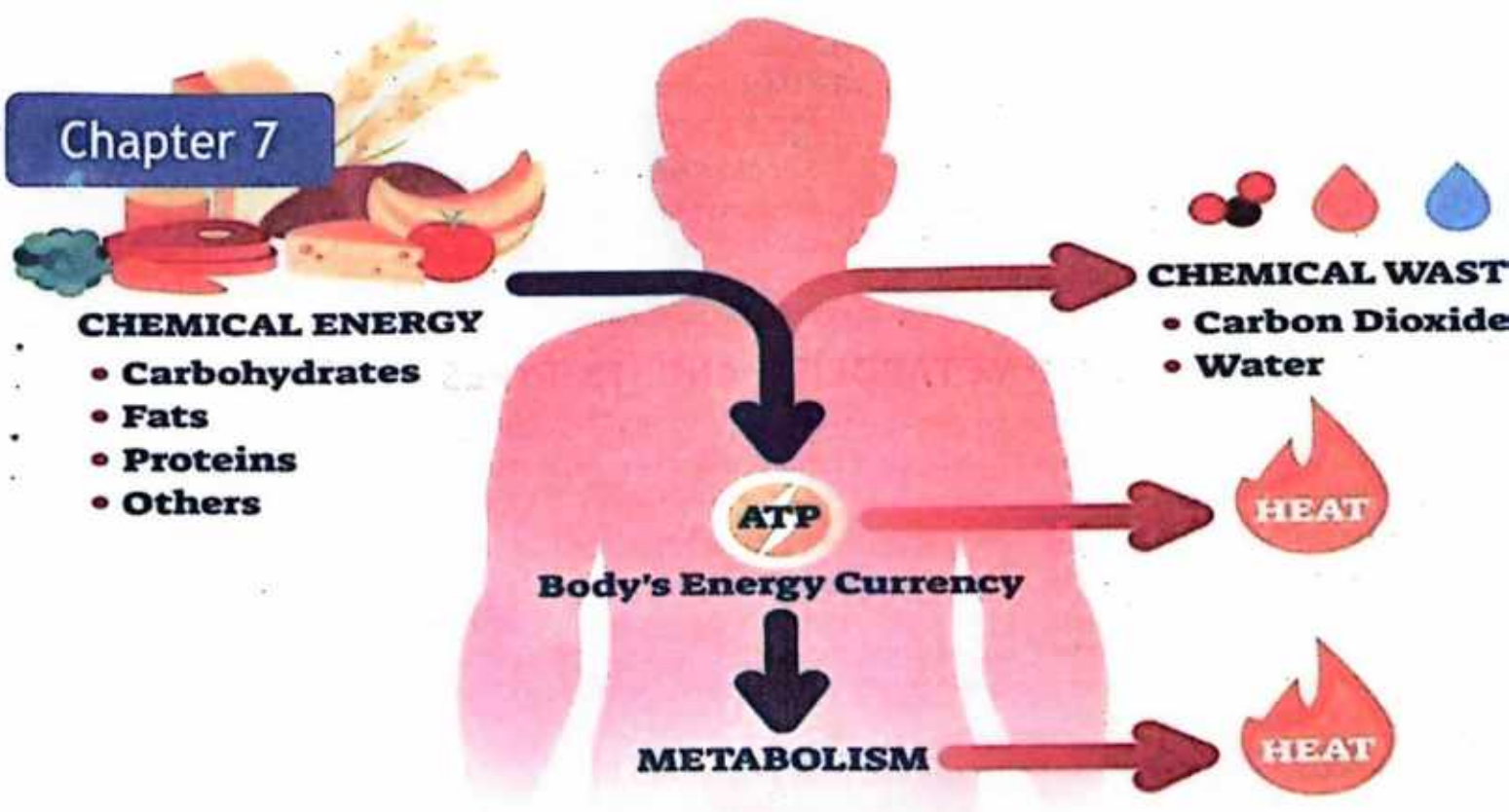


Chapter 7



METABOLISM

SLOs: After completing this lesson, the student will be able to:

1. Define metabolism, catabolism and anabolism with examples.
2. Define enzymes and describe their characteristics.
3. Show the mechanism of enzyme action.
4. Assess the factors which could influence enzyme activity.
5. Describe competitive and non competitive inhibition.
6. Discuss the role of ATP as energy currency.
7. Describe photosynthesis in Plants.
8. Explain aerobic respiration and anaerobic respiration.

Chemical reaction is a process in which one or more substances, the **reactants**, are converted to one or more different substances, the **products**. Chemical reactions are happening every where on earth in non-living environment as well as inside the living organisms. Those chemical reactions which are taking place in living organisms are called **biochemical reactions**. The life of living organisms is sustained due to these biochemical reactions.

7.1 METABOLISM AND ITS TYPES

The word metabolism means to change. The sum of all the chemical reactions going on within each cell of living organisms for the maintenance and sustainability of life is known as **metabolism**.

Metabolism is divided into two types, i.e. catabolism and anabolism. Biochemical reactions which break down complex molecules into simpler molecules, are called **catabolic reactions** or **catabolism**. For example, digestion is the catabolic process in which larger and complex food molecule are broken down into smaller and simpler molecules. Cellular respiration is also a catabolic process where glucose molecules is broken down to CO_2 and H_2O by a series of reactions in all body cells.

Reactions which build complex molecules from simpler molecules are called **anabolic reactions** or **anabolism**. For example, photosynthesis is an anabolic process where simple molecule like CO_2 and H_2O are converted to larger molecule glucose. Condensation of glucose molecules to form glycogen in muscle and liver cells is also anabolic reaction. Usually, energy is released in catabolism and it is utilized in anabolism.

7.2 ENZYMES AND THEIR CHARACTERISTICS

Vital biochemical reactions taking place in the body must occur quickly and precisely for a cell to perform and survive. These metabolic reactions in living organisms are sped up by specific proteins in the body called biological catalysts or enzymes. “Enzymes are biologically active globular proteins made by living cells, which tremendously speed up the biochemical reactions”. Each cell synthesizes its own enzymes and the type of enzymes produced in each cell are specific which is determined by the genes active in that cell.

Enzymes act on specific molecules in the cell called **substrates**. The **substrates** are the molecules entering into chemical reactions. After binding to their specific enzyme, substrates undergo chemical changes resulting in a new bonding arrangement between the molecules. The substrates modified by enzymes are called **products**.

The enzymes, which stay 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. Study of structure, type and role of enzymes is called **enzymology**.

Science Titbits: If you chew your food longer, more starch digesting enzymes amylase is produced and mixed to food that helps in breakdown of food especially starch. Moreover, the process of chewing also triggers the production of HCl in the stomach that regulate the lower pH in stomach to activate the enzyme pepsin, which breakdown the protein.

7.2.1 Characteristics of enzymes

Enzymes have following characteristics.

1. Enzymes are Globular Proteins

All enzymes are made up of chains of amino acids folded to form 3D protein molecules called globular proteins. Few enzymes are RNA in nature called ribozymes.

2. Enzymes increase rate of reaction

Reaction may initiate without involvement of enzymes, but it will be extremely slow and may take months or years to complete the reactions. The enzymes speed up the reactions millions of times faster as compared to non-enzymatic reaction. It is important to know that enzymes only speed up a reaction and do not start a chemical reaction.

3. Enzymes are required in small quantity

Structure of enzymes may slightly change during reaction but they regain their actual shape, so they remain unchanged at the end of the reaction. So they can be used repeatedly. Thus, a very small quantity of an enzyme is capable of catalysing a huge amount of substrate.

4. Enzymes are specific

Enzymes are usually very specific so catalyse only one type of reaction 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 an additional non-protein component for their proper functioning called cofactor. Cofactor usually act as bridge between protein part of enzyme and its substrate or may provide energy to enzyme. There are three types of cofactors:

- Activator:** Some enzymes require detachable inorganic ions as cofactor called activator such as Zn^{++} , Fe^{++} , Cu^{++} and chlorides etc. For example, activity of salivary amylase is increased in the presence of chloride ions.
- Prosthetic group:** If the cofactor is an organic molecule tightly and permanently attached to the enzyme it is known as prosthetic group. For example, Flavin Adenine Dinucleotide (FAD), Haem group etc.
- Coenzyme:** if the cofactor is detachable organic molecule it is called coenzyme. Examples of co-enzymes are NAD (nicotinamide adenine dinucleotide), coenzyme A and vitamin A and C.

6. Regulation of enzyme production and activity

Synthesis of enzymes within the cells and can be increased or decreased by a cell according to requirements. Enzyme activity can be regulated by inhibitors or activators within or from out of cell.

7. Enzymes make metabolic pathway

Many enzymes work together in a specific sequence to make metabolic pathways. Metabolic pathway is a series of connected chemical reactions where multiple intermediate molecules are produced before conversion of an initial substrate into final product.

8. Energy of activation

Minimum amount of extra energy required to activate the molecule to react or start the reaction is called **energy of activation**. Enzymes lower the activation energy so that these reactions can take place at body temperature. Enzymes lower the activation energy by changing the shape and charge of the substrate. Enzyme may provide entirely different mechanism of reaction to lower the activation energy.

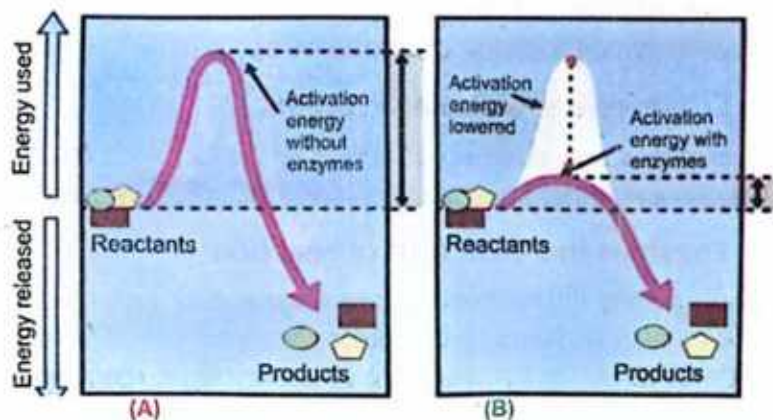


Fig. 7.1: Energy of activation (A) without enzymes
(B) with enzymes

7.3 MECHANISM OF ENZYME ACTION

Most enzymes are far larger protein molecules than the substrates they act on. Specific part on the globular surface of enzyme where substrate binds and actually take part in reaction is called the **active site**. The active site is usually a very small portion of the enzyme which is a charge bearing cavity having a specific shape.

Specific substrate molecule temporarily binds to the active site of enzyme to form **Enzyme Substrate (ES) complex**. Once the ES complex has formed, enzyme catalyzes the reaction to convert the substrate into product, thus converting the ES complex to **Enzyme Product (EP) Complex**. Finally, EP complex breaks up into products and enzyme. The enzyme molecule remains unchanged at the end of the reaction and is available again if needed for same reaction again (fig 7.2).

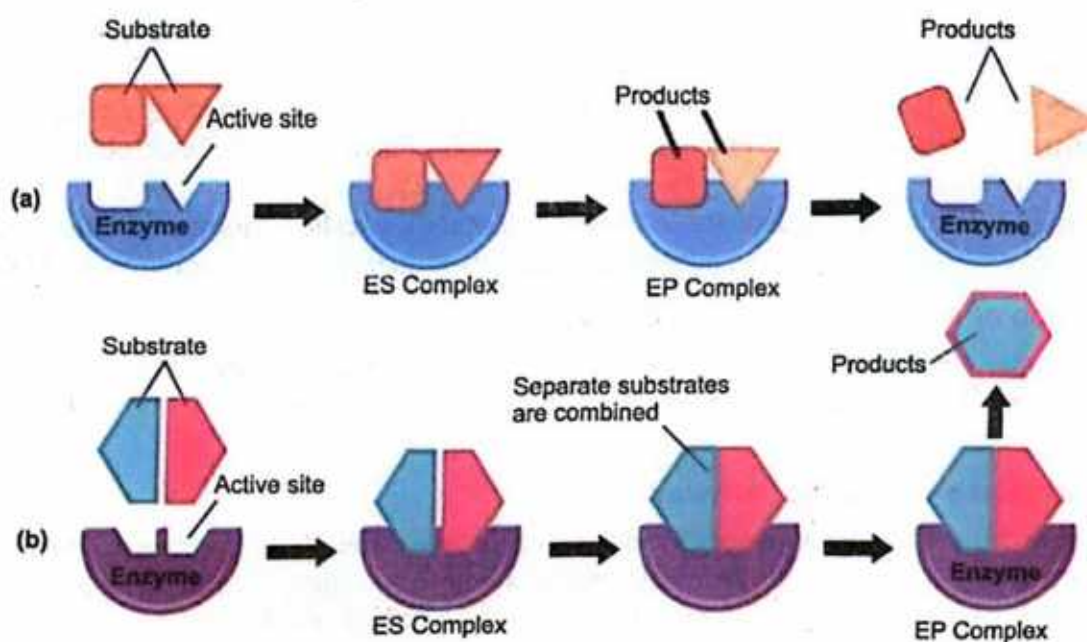


Fig. 7.2 Mechanism of enzyme actions (a) breakdown (b) synthesis

7.4 FACTORS AFFECTING ENZYME ACTIVITY

Several environmental factors affect the rate at which enzymatic reactions proceed.

7.4.1 Temperature: The rate of reaction increases with increase in temperature but up to a specific limit. Each enzyme work best at a specific temperature called **optimum temperature**. Different enzymes have different optimum temperature e.g., optimum temperature for human enzymes is 36°C to 38°C. Any increase or decrease in temperature affect the rate of enzymatic reaction. At very high temperature atoms of the enzyme molecule start vibrating vigorously so, globular structure and active site of enzyme is damaged and it is called denatured. At very low temperature enzyme remain inactive due to fall in available activation energy. They will regain their catalytic activity when normal temperatures are restored.

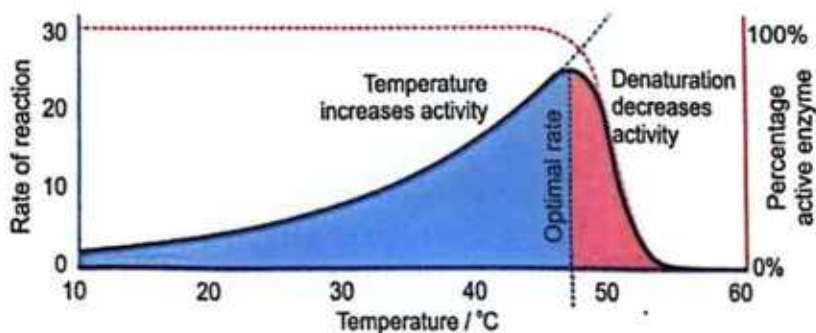


Fig. 7.3 Effect of temperature on the rate of enzyme activity

7.4.2 pH: pH of medium affect the enzyme functioning. Each enzyme perform best at a specific pH, which is called optimum pH. Slight change in pH of the reacting medium below or above the optimum pH reduce the rate of reaction. Extreme changes in pH denature the enzyme. For example, pepsin and trypsin are both protein digesting enzymes. Pepsin perform best in acidic medium in stomach at 2.00 pH whereas Trypsin perform best in alkaline medium in small intestine at 8.00 pH.

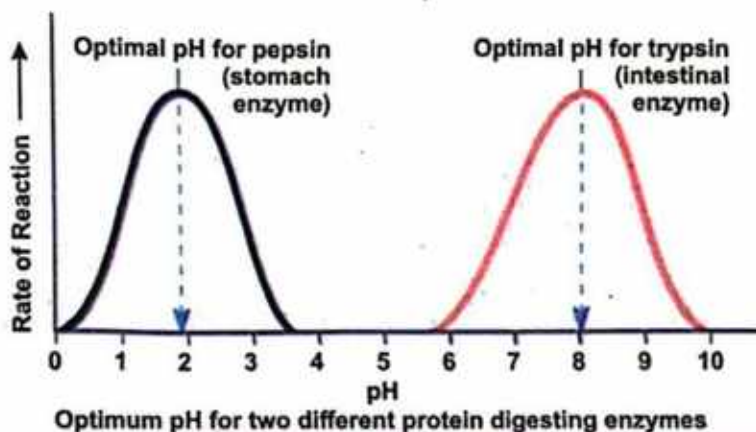


Fig. 7.4: Effect of pH on the rate of enzyme controlled reaction

7.4.3 Substrate concentration: In the presence of enough enzyme molecules at the reaction site, the rate of reaction is directly proportional to the substrate available. So, rate of enzymatic reaction increases with the increase in substrate concentration up to a certain limit. After that, a point is reached when further increase in substrate concentration will have no effect on the rate of enzymatic reaction. It is due to the presence of extra

substrate molecules in the medium which have occupied all the active sites of the available enzyme molecules, this condition is called saturation of active site.

Inhibitors are molecules produced in the cell or enter into the cell from outside and stop the enzymatic reactions while activators are molecules that increase the rate of enzymatic reaction.

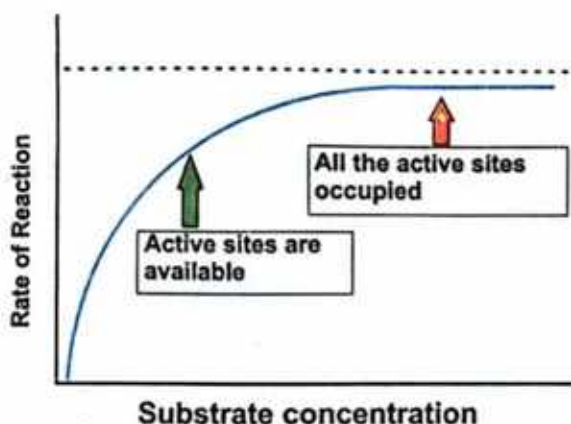


Fig. 7.5: Effect of Enzyme and substrate concentration on the rate of enzyme action

STEAM ACTIVITY 7.1

Temperature affects the rate of enzyme activity.

Procedure:

1. Take five test tubes labelled as A, B, C, D and E. Add 5ml starch solution with pH about 7.0 to all the test tubes.
2. Place test tube A in water bath set at 0°C, test tube B at 20°C, test tube C at 40°C, test tube D at 60°C, test tube E at 80°C for 5 minutes to adjust the temperature of the solutions.
3. Add 1ml starch digesting enzyme (amylase) solution to each test tube A to E, containing the starch solution.
4. After adding enzyme solution into the test tubes, keep the test tubes in specific water baths for 10 minutes to allow the enzyme (amylase) to act on substrate (starch).
5. After 10 minutes, add 1 drop of iodine solution to each test tube to check the presence of starch.

Results:

Test tubes	Observations on adding iodine solution	Results	Logical conclusion of enzyme activity
A (at 0°C)	Blue black color appears	Most of the starch still present	At low temperatures the enzyme (amylase) broke down the starch slowly due to no or lower activation energy available.
B (at 20°C)	Blue black color appears	Some of the starch still present	
C (at 40°C)	No blue black color appear	All the starch broken down	At the optimum temperature the enzyme (amylase) broke down the starch quickly and completely.
D (at 60°C)	Blue black colour appear	Starch still present	At high temperatures the enzyme (amylase) broke down the starch slowly or not at all due to denaturation of the enzyme's active site.
E (at 80°C)	Blue black colour appear	Starch still present	

STEAM ACTIVITY 7.2

pH affects the rate of enzyme activity.

Procedure:

1. Take three test tubes labelled as A, B and C. Add 5ml protein (egg albumin) solution in each tube.
2. Add 2ml water in test tube A, 2ml HCl (*) in test tube B and 2ml NaOH in test tube C and left the tubes for 5 minutes to adjust the neutral pH in test tube A, acidic pH in test tube B and alkaline pH in test tube C.

3. Add 2ml protein digesting enzyme (pepsin) solution to each test tube A, B and C and place all three test tubes in water bath set at 37°C.
4. Left the reaction mixture tubes for 10 minutes to allow the enzyme (pepsin) to act on substrate (egg albumin protein).
5. After 10 minutes, add 2 drops of Biuret solution to each test tube and note any change in colour to check the presence or absence of protein.

Results:

Test tubes	Observations on adding Biuret solution	Results	Logical conclusion of enzyme activity
A (neutral pH)	Pink or purple colour may appear	Most of the protein still present	At neutral pH, the pepsin enzyme could not break down the protein due to inactivation or denaturation.
B (acidic pH)	No pink or purple colour appear	Protein absent, as it is broken down	At acidic pH the pepsin enzyme broke down the protein quickly and completely.
C (alkaline pH)	Pink or purple colour appear	protein still present	At alkaline pH, the pepsin enzyme could not break down the protein due to denaturation.
*optimum pH for pepsin activity is 2-3 pH which is maintained due to presence of an acid like HCl			

7.5 ENZYME INHIBITION

Sometimes enzymes are not able to perform their role due to the presence and interference of some chemicals at the reaction site, this phenomenon is called **enzyme inhibition**. The chemical substance which react with enzyme in place of substrate but does not convert to products thus inhibiting the enzyme action is called **inhibitor**. Inhibitors may block or damage active site temporarily or permanently. Generally, enzyme activity may be temporarily inhibited by accumulated products within the cell to regulate the rate of reaction. External factors responsible for enzyme inhibition are poisons, cyanide, antibiotics, some drugs or accumulated products. Enzyme inhibition may be of two major types:

7.5.1 Competitive inhibition

If enzymes are inhibited due to presence of molecules which occupy the active site due to their similarity in structure and shape to substrate is called competitive inhibition. Such inhibitors are neither converted to products nor they allow the actual substrate to bind hence reaction does not proceed. Competitive inhibition is temporary and can be reversed if the concentration of actual substrate is increased than the concentration of inhibitor molecules.

7.5.2 Non-competitive inhibition

The structure and shape of these inhibitors do not resemble the substrate molecules so they do not occupy the active site. They may attach to enzyme surface at a point other than active site called **allosteric site**. They alter the globular shape of enzyme and damage the active site of enzyme. Thus, actual substrate will not be able to bind to active site and reaction stops.

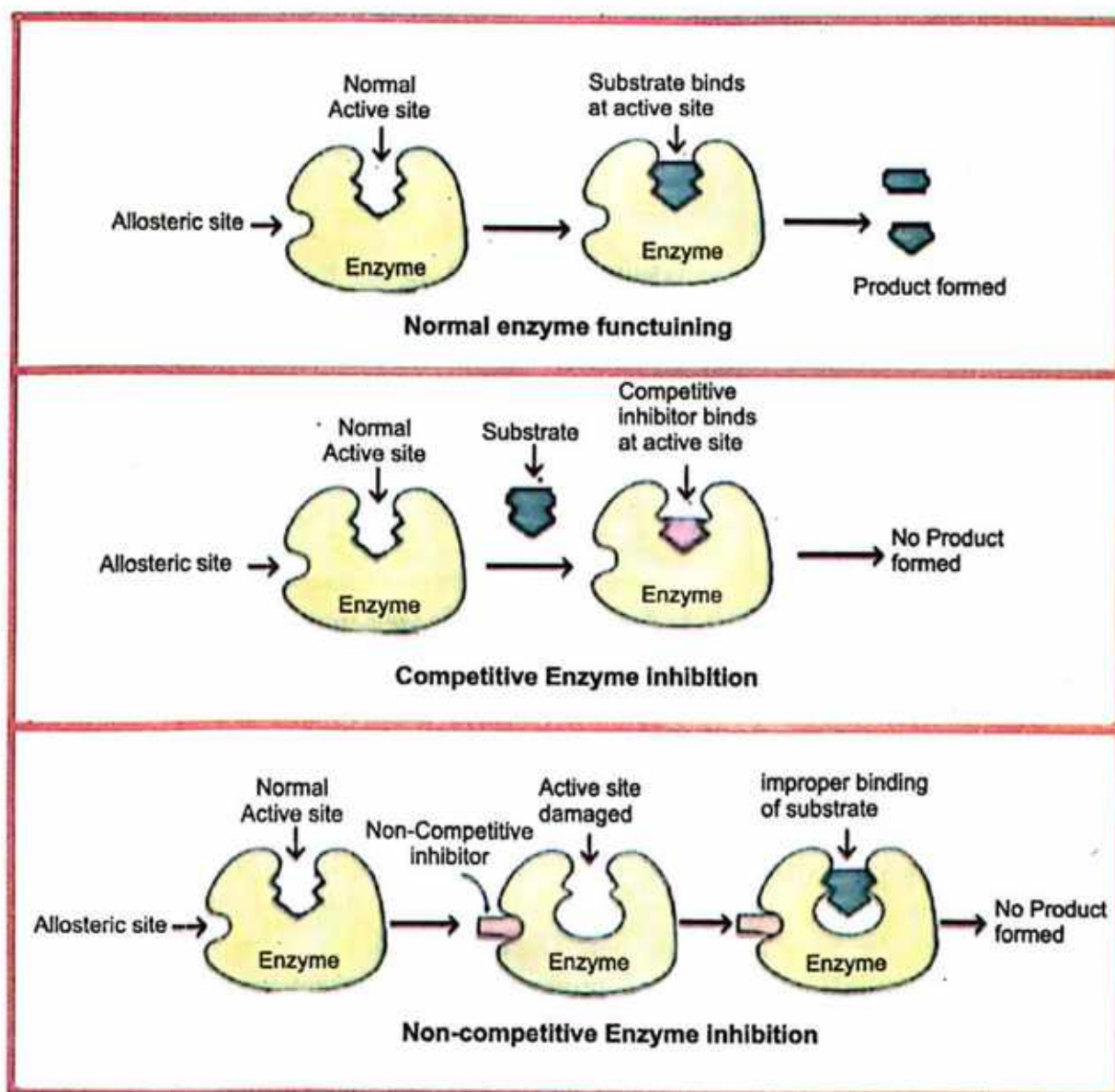


Fig.7.6 Competitive and non-competitive inhibition of enzyme

7.6 ROLE OF ATP-THE ENERGY CURRENCY OF CELL

Life of the living organisms is possible only if constant supply of energy is available in its cells. All the life processes like movement, development, reproduction, thermoregulation, active transport, etc. depend on the availability of energy. The living organisms, use and store energy at the cellular level in the form of Adenosine triphosphate (ATP). ATP is commonly called the "energy currency" of cell because it is an energy rich compound that can store and release energy and can be used much like money. When organic molecules (glucose, amino acids etc.)

Science Titbits

Normally, human cells depend upon the hydrolysis of 100 to 150 moles of ATP per day to ensure proper functioning. ATP is synthesized by catabolic reactions e.g. complete oxidation of one glucose molecule during cellular respiration generate net 36 ATP molecules. Plants can also use light energy to produce chemical energy as ATP.

are broken down in the cells, energy is released that can be captured and stored in ATP molecules. The energy remains stored in the ATP until it is needed. When energy is needed by the cells, ATP molecule is hydrolysed to release energy.

7.6.1 ATP — ADP Cycle

ATP can be converted to ADP and inorganic phosphate by hydrolysis. The third phosphate group separates from ATP and remains in the cell in inorganic form. ADP and phosphate can be converted back to ATP by condensation. The ability of ATP to store and release energy is because of its unique structure.

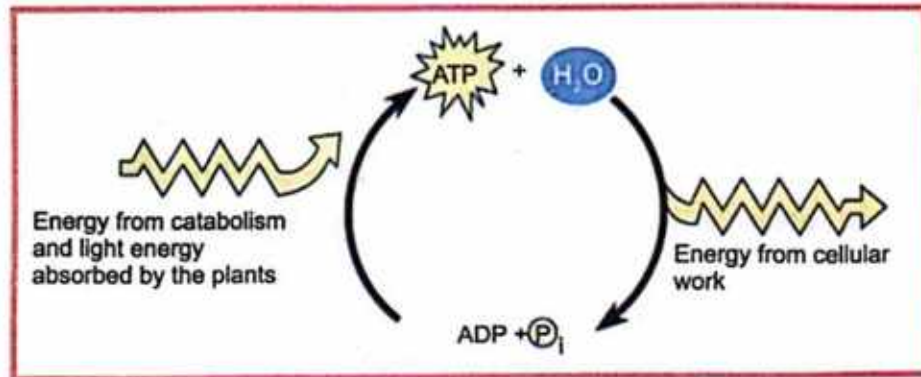


Fig. 7.7 ATP- ADP cycle

7.6.2 Structure of ATP Molecule

ATP molecule consists of three components:

1. Adenine (double ringed Nitrogen Base)
2. Ribose (Five Carbon Sugar)
3. Three Phosphate Groups (PO_4) linked in a chain called a triphosphate group

Adenine nitrogen base binds to Ribose sugar and become adenosine.

Adenine + Ribose Sugar → Adenosine

First phosphate group binds with adenosine to form adenosine monophosphate (AMP). Second phosphate group binds with AMP to form adenosine diphosphate (ADP). Third phosphate group binds with ADP to form adenosine triphosphate (ATP). Thus all three phosphate groups are serially bonded in a linear chain with adenosine to form ATP.

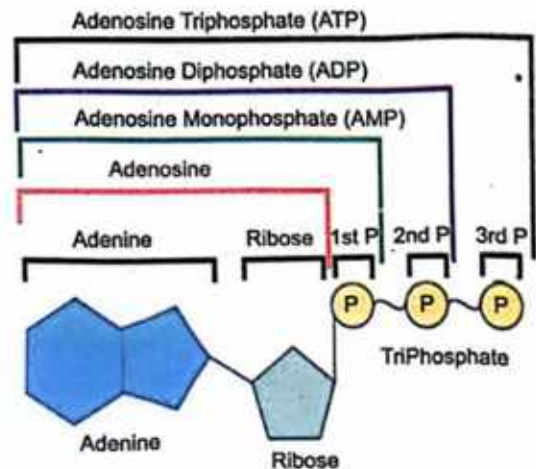


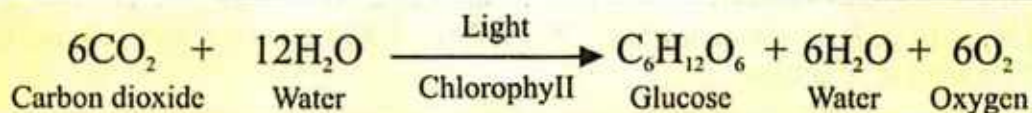
Fig. 7.8: Structure of ATP (high energy bonds indicated by wavy lines)

High Energy Bonds:

The covalent bonds between phosphate groups are called “high energy” or “energy-rich” bonds. The two bonds linking the phosphate group together are represented by a specific sign of wavy lines. The energy stored in these bonds may be used by the cells to carry out their functions.

7.7 PHOTOSYNTHESIS

Photosynthesis is an important biochemical process taking place in plants, algae and cyanobacteria. During this process plants absorb light energy in the presence of chlorophyll and use carbon dioxide and water to make glucose. Oxygen is produced as a by-product during photosynthesis.



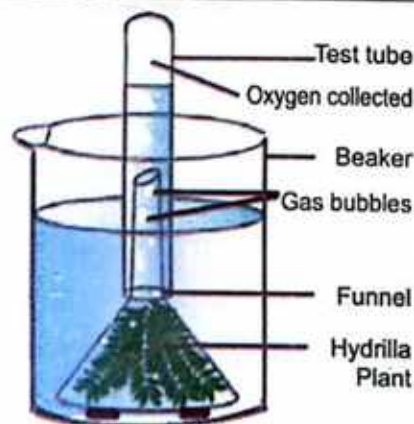
Nearly all life forms depend on photosynthesis for food directly or indirectly. Photosynthesis involves a series of coordinated reactions. The above equation shows summary of photosynthesis process.

STEAM ACTIVITY 7.3

Demonstration of release of oxygen during the process of photosynthesis:

Procedure:

1. Take a 500 ml beaker and half fill it with transparent water.
2. Dissolve about 5 grams of sodium bicarbonate (NaHCO_3) in water that will produce CO_2 in water for the use of aquatic plant.
3. Place few branches of Hydrilla plant in the beaker and cover it with an inverted glass funnel that is fully dipped in water.
4. Slightly raise the funnel above the bottom of the beaker for mixing and free water circulation.
5. Put a water filled inverted test tube on the neck of funnel as shown in figure.
6. Place this apparatus set up in the sun or light for 2-3 hours for photosynthesis to occur.



Observations

1. Bubbles of a gas will start coming out and move upward through water in test tube and collect at the top of the test tube above water level.
2. Bring out the test tube from beaker and put a burning match stick in the test tube, it burns more brightly.

Results:

Burning of match stick confirms that during experiment, the gas collected in the test tube above water is oxygen that is produced during the process of photosynthesis.

7.7.1 Mechanism of Photosynthesis

Photosynthesis occurs in two phases called as light dependent and light independent reactions. In the first phase, light energy is absorbed and then used to produce energy rich molecules ATP and NADPH. These reactions take place in chloroplasts. These reactions occur only in the presence of light so are called **light dependent reactions**. During the second phase carbon dioxide is reduced by NADPH to form glucose molecule. This reduction requires energy which is provided by ATP. These reactions do not use light directly; hence they are known as **light independent reactions**.

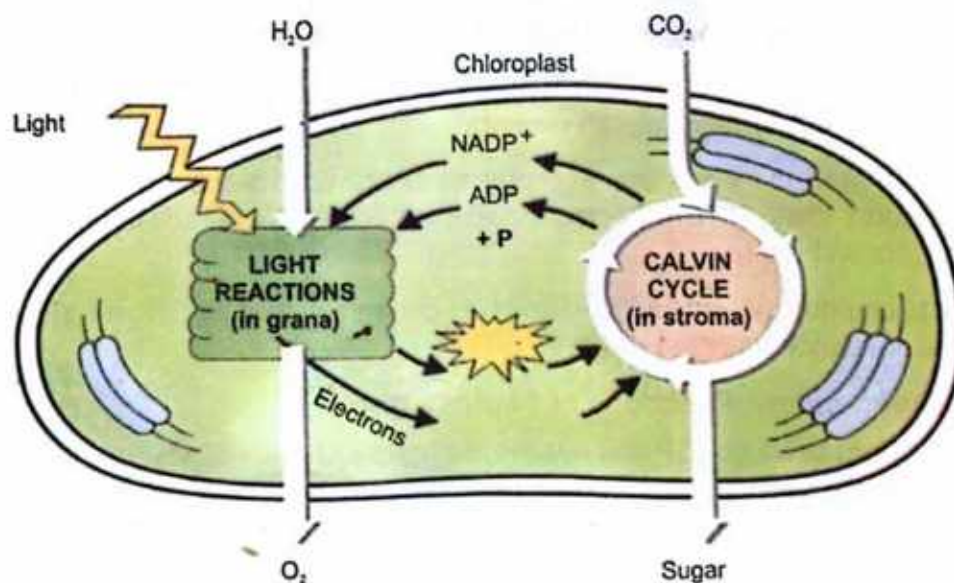


Fig. 7.9: An overview of photosynthesis

7.7.1.1: Light Dependent Reactions of Photosynthesis

The reactions, which depend upon light energy, are called light dependent reactions of photosynthesis. These reactions take place in thylakoid membranes where photosynthetic pigments are arranged into clusters called photosystems. There are two types of photosystems: **Photosystem I** and **Photosystem II**. Process of light dependent reactions starts from photosystem II.

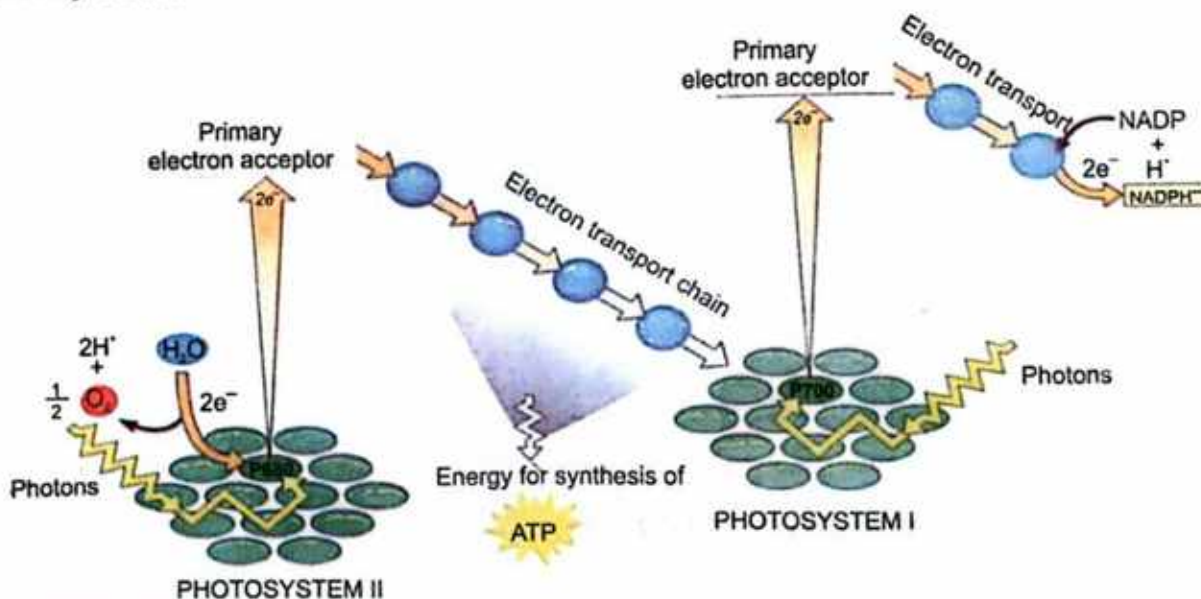


Fig. 7.10: Light dependent reactions of photosynthesis

1. Chlorophyll a of photosystem II absorbs light and a pair of electrons is emitted from it which are accepted by a molecule called primary electron acceptor.

- At the same time, water molecule also splits into oxygen atom, two hydrogen ions (H^+) and two electrons. Splitting of water takes place to compensate the electron loss of light affected chlorophyll of photosystem II and is called **photolysis of water**.
- Oxygen is released out of leaf through stomata.
- Electron pair from primary electron acceptor passes through a chain of molecules called electron transport chain (ETC). Electrons passing through ETC, gradually release energy which is used for ATP synthesis.
- Light also acts on photosystem I which also gives out an electron pair. These electrons and two H^+ of water reduce $NADP^+$ to NADPH.

7.7.1.2: Light Independent Reactions of Photosynthesis

Once the light reactions produce ATP and NADPH, a photosynthetic cell can fix carbon dioxide to synthesize sugar molecules. These reactions do not depend directly on light that is why it is called dark reactions or light independent reactions. It takes place in stroma of chloroplast.

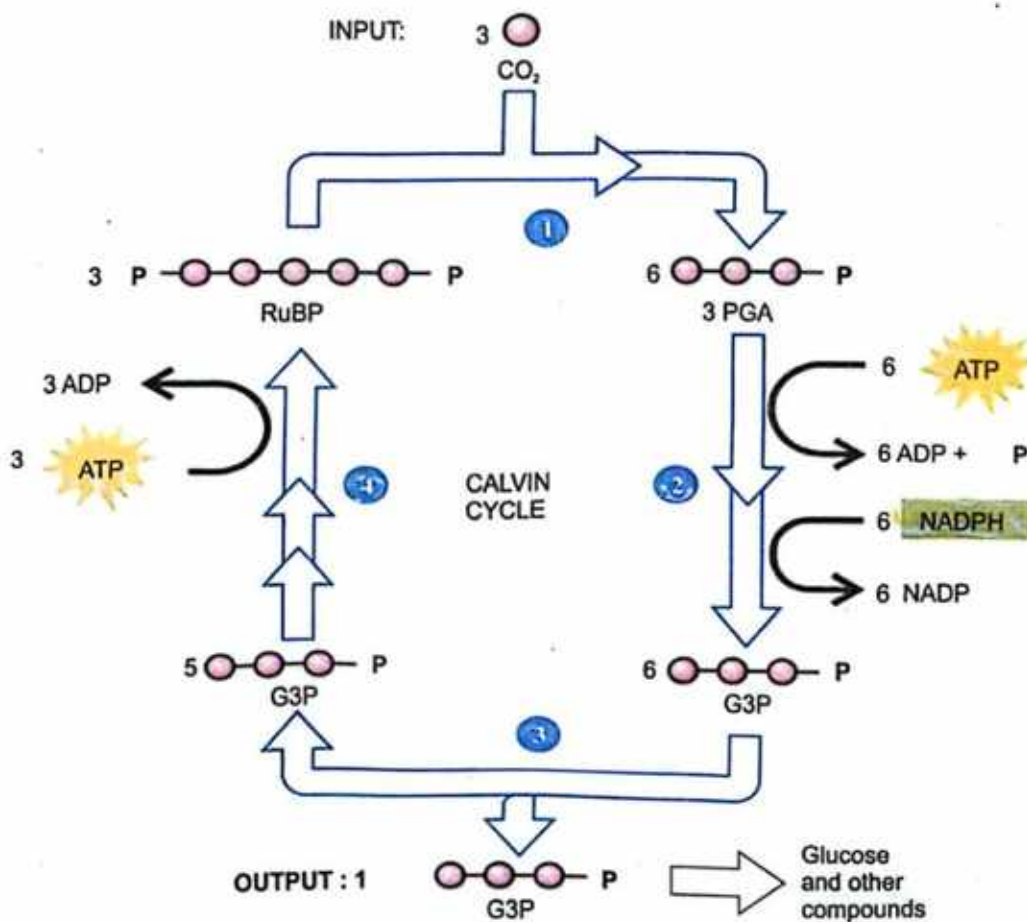


Fig. 7.11: Calvin cycle

The sequence of reactions in this phase was first described by Melvin Calvin and his colleagues so is known as Calvin cycle as well.

1. Carbon dioxide combines with an already existing 5-carbon molecule (RuBP) to form a 6-carbon intermediate molecule.
2. This 6-carbon molecule is unstable and splits into two 3-carbon molecules (3PGA).
3. Now these 3-carbon molecules are reduced to 3-carbon sugar molecule (G3P) by NADPH using energy of ATP.
4. These 3-carbon sugar molecules are used to synthesize glucose and also to regenerate original 5-carbon molecule for next Calvin cycle.

7.7.2 Limiting Factors of Photosynthesis

Rate of photosynthesis can be affected by following environmental factors called a **limiting factor** of photosynthesis.

1. More light intensity and duration of light increase the process of photosynthesis.
2. Carbon dioxide is one of the raw material (substrate) for photosynthetic reaction. More CO_2 concentration increase the rate of photosynthesis but only up to a specific point.
3. Rate of photosynthesis is highest at 25°C called optimum temperature for photosynthesis. Temperature below or above the optimum affect the rate of photosynthesis.

7.8 RESPIRATION

What happens when you burn a fuel like petrol? Energy is released in the form of light and heat. The same sort of things happens in our body. Our fuel is glucose from our food. The process by which energy is produced from food is called **respiration**. Respiration is a chemical process, which takes place in cells.

7.8.1 Anaerobic and Aerobic Respiration

The two main types of respiration are: anaerobic respiration and aerobic respiration. The first phase of respiration called glycolysis, takes place in cytoplasm and is common both in anaerobic and aerobic respiration. During glycolysis, glucose is oxidized into two molecules of pyruvic acid with the yield of two ATP molecules.



a. Anaerobic Respiration

Anaerobic respiration means, respiration in the absence of oxygen. During, anaerobic respiration glucose is not completely oxidized to carbon dioxide and water, but is converted into carbon dioxide and alcohol or lactic acid. This process is also called **fermentation**.

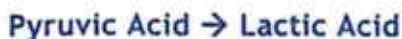
Alcoholic fermentation

In alcoholic fermentation, pyruvic acid produced during glycolysis is converted into ethyl alcohol and carbon dioxide. It occurs in yeast and some bacteria.



Lactic acid fermentation

During tough and continuous exercise our heart and lungs cannot provide enough oxygen to skeletal muscles as per increased requirement. During such vigorous exercise or labour, muscle cells start to carry out anaerobic respiration and each pyruvic acid molecule is converted into lactic acid. Bacteria which convert milk to yogurt also produce lactic acid.



7.8.1.1 Importance of Anaerobic Respiration

Anaerobic respiration is important for living organisms in following ways:

- (1) The earliest living organisms would have to produce energy by anaerobic respiration because the early earth had no free oxygen in its atmosphere.
- (2) Anaerobic respiration by bacteria is used in cheese and yogurt making.
- (3) Fermentation by yeast is used in wine making and baking industry.
- (4) Anaerobic respiration, in the form of lactic acid fermentation provides some energy to muscle cells during running, labour or strenuous exercise.

7.8.2 Aerobic Respiration

Aerobic respiration means respiration in the presence and use of oxygen. During aerobic respiration, glucose molecule is completely broken-down in the presence of oxygen, to produce comparatively large amount of energy along with production of carbon dioxide and water.

Aerobic respiration can be summed up by the following equation.



7.8.3 Mechanism of Aerobic Respiration

The breakdown of glucose does not take place in a single step but in a series of chemical reactions. Energy released from breakdown of glucose is stored in the form of chemical energy in ATP. The complete process of aerobic respiration is divided into four main phases; glycolysis, formation of acetyl CoA, Krebs cycle and electron transport chain.

1. Glycolysis

Glycolysis takes place in cytoplasm of the cell, outside the mitochondria. It occurs both in anaerobic and aerobic respiration. A single molecule of glucose is broken down into two molecules of pyruvic acid having 3 carbons. Two ATP molecules are produced as net energy gain. Two NAD^+ molecules are reduced to NADH.



2. Formation of Acetyl CoA

Each pyruvic acid molecule is now oxidized to a two-carbon acetyl group which also combines with coenzyme A to form acetyl Co A. Carbon dioxide is removed and NADH is produced. The acetyl Co A enters mitochondrion where it will take part in Krebs cycle.



3. Krebs Cycle

Krebs cycle is a cyclic process which takes place in mitochondrial matrix. Coenzyme A is released and acetyl group is passed through a series of reactions. The products of this process

are CO_2 , NADH and FADH_2 . Some energy is released to produce ATP directly, while more energy is produced by oxidation of NADH and FADH_2 in ETC.



4. Electron Transport Chain (ETC)

Electron transport chain is a series of electron carrier molecules located in the inner membrane of mitochondria. The electrons that are removed by oxidation of glucose molecules during glycolysis and Krebs cycle are carried to ETC by NADH and FADH_2 . When electrons coming through NADH pass through ETC, they provide enough energy to synthesize three ATP molecules. However, each FADH_2 produces only two ATP molecules. The final electron acceptor is oxygen atom which ultimately combines with hydrogen ions to produce water.

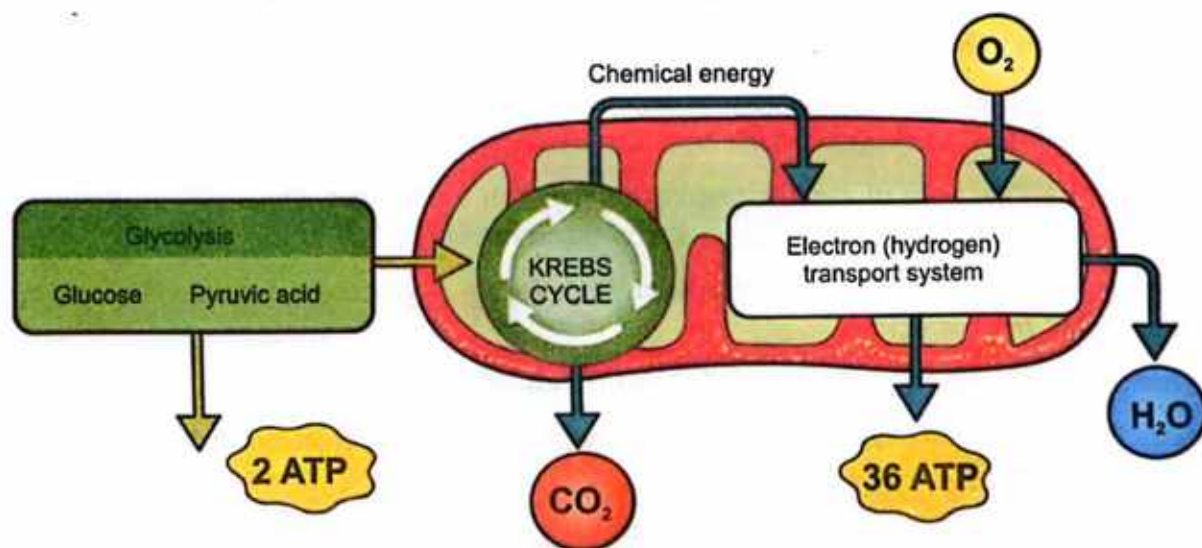


Fig. 7.12: An overview of aerobic respiration

ATP usage in body:

The energy produced as ATP by cellular respiration is used in many ways e.g., working of muscles, nerve impulse transmission, growth and repair of cells, active transport, gland etc. In human body brain uses maximum energy in the form of ATP i.e., 25% of ATP.

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 substrate 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. In plants photosynthesis occurs in chloroplasts.
8. During photosynthesis, light energy is captured by chlorophyll and converted to chemical energy in a way that ultimately results in carbohydrate synthesis.
9. During the light dependent reactions of photosynthesis, chlorophyll electrons become excited. These electrons reduce NADP, forming NADPH and some of their energy is used to phosphorylate ADP, forming ATP.
10. During dark reactions, energy of ATP and NADPH is used to chemically combine carbon dioxide with hydrogen.
11. Cell uses two different types of catabolic pathways to extract free energy from glucose i.e., aerobic respiration and anaerobic respiration.
12. Aerobic respiration is a redox process in which electrons are transferred from glucose (which becomes oxidized) to oxygen (which becomes reduced).
13. The chemical reactions of aerobic respiration occur in four stages: glycolysis, formation of acetyl CoA, the Krebs cycle and the electron transport chain.
14. During glycolysis, which occurs in cytoplasm, a molecule of glucose is degraded to form two molecules of pyruvic acid.
15. Pyruvic acid is converted into acetyl CoA, which enters the Krebs cycle.
16. Water is formed when oxygen combines with Hydrogen and with electrons from the electron transport chain.

EXERCISE

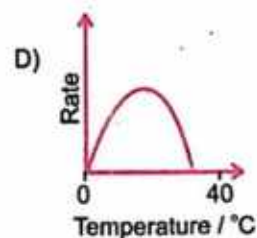
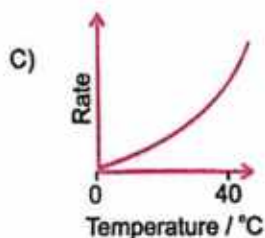
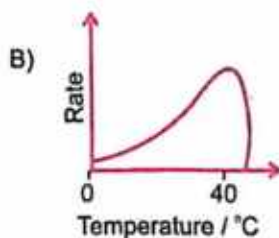
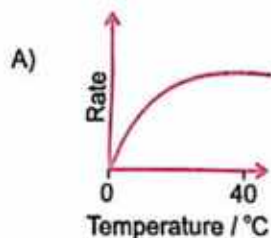
Section I: Multiple Choice Questions

Select the correct answer:

1. 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
2. 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
3. Which graph shows how temperature affects the rate of an enzyme-controlled reaction?



4. 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

5. Change in pH can alter the active site by affecting the:

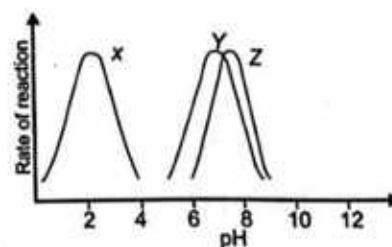
- A) ionization of amino acids B) Shape of substrate
C) ionization of cofactor D) Ionization of coenzyme

6. 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

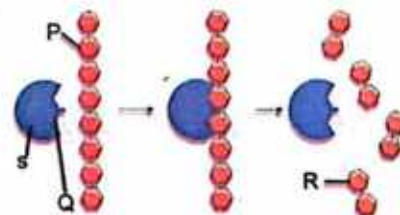
7. The graph shows the activity of three digestive enzymes at different pH levels. Which statement is correct?

- A) Enzyme X and Y are both active at pH 7
B) Enzyme X and Z are both active at pH 4
C) Enzyme Y and Z are both active at pH 4
D) Enzyme Y and Z are both active at pH 7



8. The diagram shows an amylase molecule catalysing the breakdown of a starch molecule. Which are the labelled parts P, Q, R and S?

	Enzyme	Product	Substrate	Active site
A	P	Q	R	S
B	R	S	P	Q
C	S	P	Q	R
D	S	R	P	Q



9. Glycolysis is the breakdown of

- A) fructose B) glucose C) lactose D) maltose

10. The mechanism of ATP synthesis is

- A) phosphorylation B) photosynthesis C) respiration D) glucose

11. In aerobic respiration pyruvic acid changes to

- A) glucose B) fructose C) Acetyl CoA D) citric acid

12. Which of these uses oxygen as the final acceptor?

- A) glycolysis B) electron transport chain
C) Krebs cycle D) photosynthesis

13. Which of these produces carbon dioxide?

- A) Krebs cycle B) electron transport chain
C) glycolysis D) photosynthesis

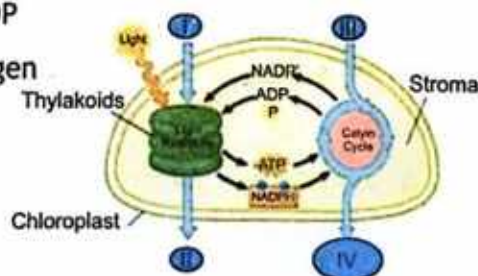
14. What are the products of light reactions in photosynthesis?

- A) ATP, NADPH and oxygen
B) ATP and NADP
C) ATP, PGA and oxygen
D) PGA and oxygen

15. The diagram shows an overview of photosynthesis.

Which numbered molecules is organic biomolecule?

- A. I
B. II
C. III
D. IV

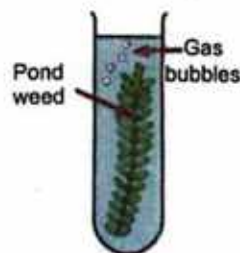


16. Which feature helps plants to make most food by the process of photosynthesis?

- A) broad and flat leaves
B) spiny leaves
C) yellow leaves
D) curled leaves

17. The diagram shows a pond weed in a test tube filled with water. Which conditions would cause the plant to produce more bubbles?

	Dissolved CO ₂	Light	Temperature
A	Present	Bright	Cool
B	Present	Bright	Warm
C	Present	Dim	Cool
D	Absent	Dim	Warm



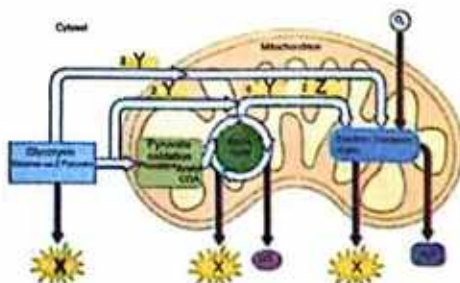
18. Which of the following processes is used by plants to make oxygen during the process of photosynthesis?

- A) intake of water
B) intake of CO₂
C) photolysis of water
D) Calvin cycle

19. The diagram shows overview of cellular respiration.

Which labelled part represents NADH?

- A) X only
B) Y only
C) Z only
D) both Y and Z



20. A child left a carton on the lawn for two days. When the carton was picked up, the grass under it had turned yellow. What caused the grass to change colour?

- A) lack of oxygen
B) lack of carbon dioxide
C) lack of light
D) lack of water

Section II: Short Answer Questions

- Why enzymes are called biological catalyst?
- Name the factors affecting enzyme activity.

3. At what pH pepsin and trypsin enzymes act the best?
4. What happens to an enzyme when it is frozen below 0°C?
5. Which protein digesting enzyme functions in acidic medium?
6. How enzyme lowers the activation energy?
7. Why are enzyme specific and why can't each one speed up many different reactions?
8. Why small quantity of enzyme is enough for catalysing large number of substrate molecules into products?
9. According to induced fit model, the active site is flexible. Does it mean that any substrate can attach with this flexible active site? If not, then explain.
10. Sketch the structure of ATP.
11. Write the equation of: a) photosynthesis b) fermentation c) aerobic respiration.
12. Name the products of anaerobic respiration in muscle cells.
13. Why a part of photosynthesis is called dark reactions.
14. How photosynthesis and aerobic respiration are interlinked with each other

Section III: Extensive Answer Questions

1. Define enzyme and describe their characteristics and specifications.
2. What is energy of activation? Explain with reference to enzyme.
3. What happens to enzymes when you increase or decrease?
(a) Temperature (b) pH (c) Substrate concentration.
4. Only the related key can open the lock. How this fact is true for enzyme? Explain with examples.
5. Describe the structure and uses of ATP.
6. Describe and sketch light reactions of photosynthesis.
7. Describe and sketch dark reactions of photosynthesis.
8. Explain the factors affecting rate of photosynthesis.
9. Compare respiration and photosynthesis with examples.
10. What are the advantages and significance of anaerobic respiration and fermentation in your daily life?