RESPIRATION

SESSION 2022-2023

CCE1

SUBMITTED TO

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B.Sc. III Year

CONTENT

(IV) ATP- The biological energy currency
(V) Respiratory quotient or coefficient(R.Q.)
(VI) Mechanism of Respiration
- (A) Glycolysis or EMP pathway
- (B) Oxidation of pyruvic acid
  - (1) Anaerobic oxidation of pyruvic acid
    - (i) Formation of ethyl alcohol
    - (ii) Formation of lactic acid
  - (2)Aerobic respiration of pyruvic acid
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    - (ii) Oxidative decarboxylation of Pyruvic Acid
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    - (iv) Electron transport system and Oxidative Phosphorylation
      - (a) Component of ETS
      - (b) Mechanism of ETS

(VII) Factors affecting Respiration
(VIII) Production of ATP molecule in Aerobic Respiration

INTRODUCTION

DEFINITION

- Respiration is a process by which organic food materials such as sugars, fats, protein, organic acids are broken down through oxidation , to produce CO_2 , H_2O and energy.

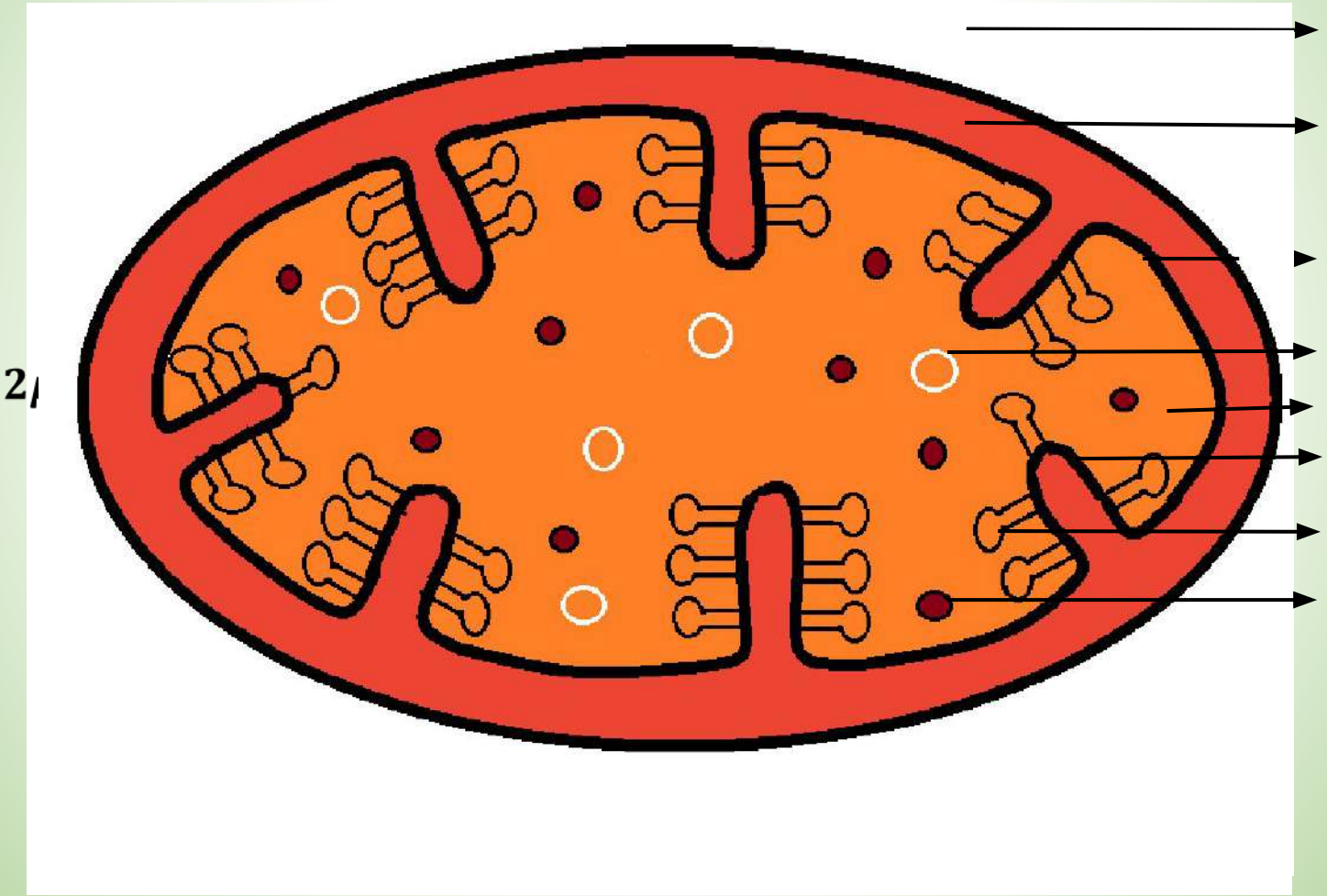
$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + 673\text{Kcal energy}$$

- The energy released during respiration is stored in the bonds of ATP and remaining is lost in heat.
- Energy stored in ATP is usable energy for biological activities.

HISTORY

- The term "respiration" was used in the beginning of 15th century but its importance was worked out by Crooke (1615). He states that life is impossible without respiration. At that time people believed that respiration is found only in animals and not in plants.
- Malpighi (1619), demonstrated that oxygen is needed in high amounts during germination of seeds.
- According to Sachs (1864), the growth is directly proportional to the rate of respiration.

MITOCHONDRIA



L.S of Mitochondria

- Mitochondria(Gk., *mitos* = thread, *chondrion* = particle or granules) are filamentous or granular cytoplasmic organelles found in all aerobically respiring eukaryotic cells.
- Mitochondria was first observed by Kolliker in 1850.

DISTRIBUTION

- Mitochondria are uniformly distributed in the cytoplasm of all eukaryotic cells. They are lacking in prokaryotes.
- But they may be localized to those particular sites which are engaged in metabolic activities.

SIZE

- The length of mitochondria is ranging from 0.3 µ to 4 µ and diameter is 0.2 µ to 2µ.

SHAPE

- Shape of mitochondria is variable. It may be spherical (e.g.. yeast), cylindrical, tubular, filamentous or granular.

NUMBER

- Number of mitochondria in a single cell varies depending upon the species and functional status of cell.
- Metabolically active cells contain more mitochondria.

a) Normal human cells contain about 1,000 to 1,600 mitochondria.

b) In some algae example in *Microsterias* only one mitochondria is present .

c) The number of mitochondria is highest in the flight muscles of insects upto 5,00,000 in one cell.

STRUCTURE

- It contains following structures:

1. Mitochondrial membrane: Every mitochondria is covered by two membranous layers. Each membrane is about 60-70 A^0 thick. It is made up of lipoprotein

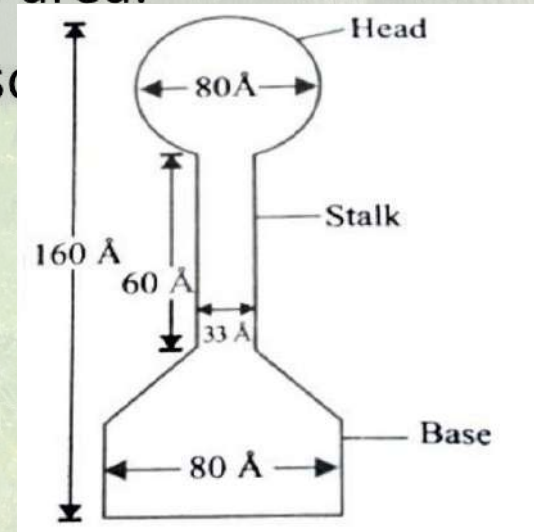
2. Mitochondrial chamber: Two mitochondrial chambers are present in each mitochondria:

i. Outer chamber: It is present in between two membranes. It contains proteins, co-enzymes and electrolytes

ii. Inner chamber: It is present inside the membranes. The inner membrane lines the innermost compartment which is filled with gel-like matrix. It is a homogeneous fluid which contains 2 to 6 circular DNA molecules, 70S ribosomes, tRNA, mRNA, DNA polymerase and enzymes involved in protein synthesis.

3. Mitochondrial Cristae: The inner-mitochondrial membrane is projected into the central space in the form of fingerlike projections or infoldings known as cristae or mitochondrial crests. These cristae increase the inner surface area.

4. Elementary particles or F_1 particle: These particles are also known as oxysomes. These particles are evenly spaced at an interval of 100A. Each F_1, particle is made up of three parts base, stalk or Pedicel and head.



TYPES OF RESPIRATION

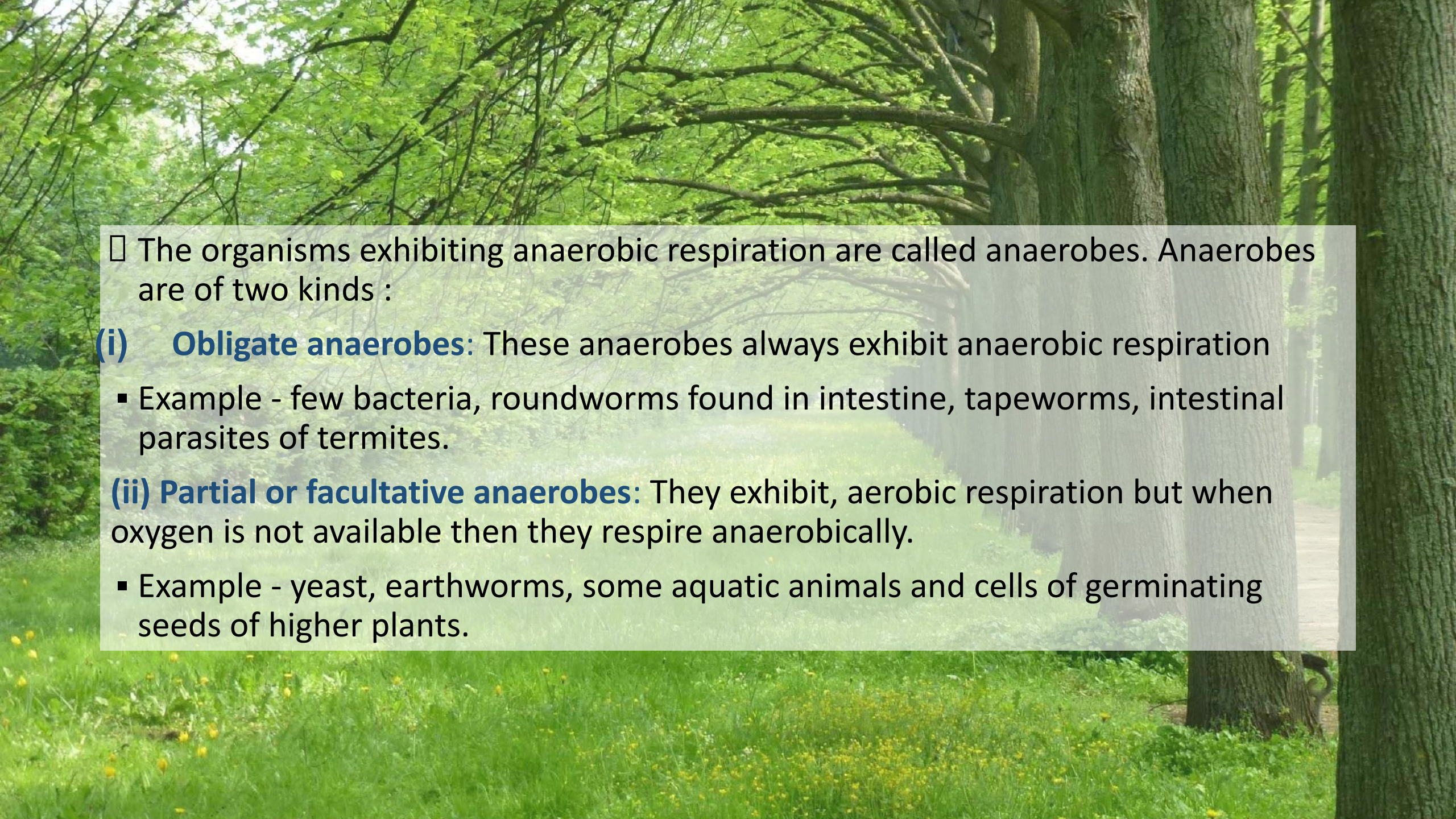
- On the basis of O_2, cellular respiration may be either aerobic or anaerobic.

1. **Aerobic respiration :** Oxidation of food materials in presence of O_2, is known as aerobic respiration, and the organisms respiring through this process are called aerobes. In this process food materials are completely oxidized into CO_2 and H_2O a higher amount of energy (673 kcal) is released.

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + 673\text{Kcal energy}$$

2. **Anaerobic respiration**: Oxidation of food materials in the absence of O_2, is known as anaerobic respiration. In this process food materials are incompletely oxidized into CO_2, and simple organic substances like ethyl alcohol (C_2H_5OH) and a very least amount of energy (21kcal) is released.

$$C_6H_{12}O_6 \longrightarrow 2C_2H_5OH + 2CO_2 + 21\text{Kcal energy}$$



- The organisms exhibiting anaerobic respiration are called anaerobes. Anaerobes are of two kinds :

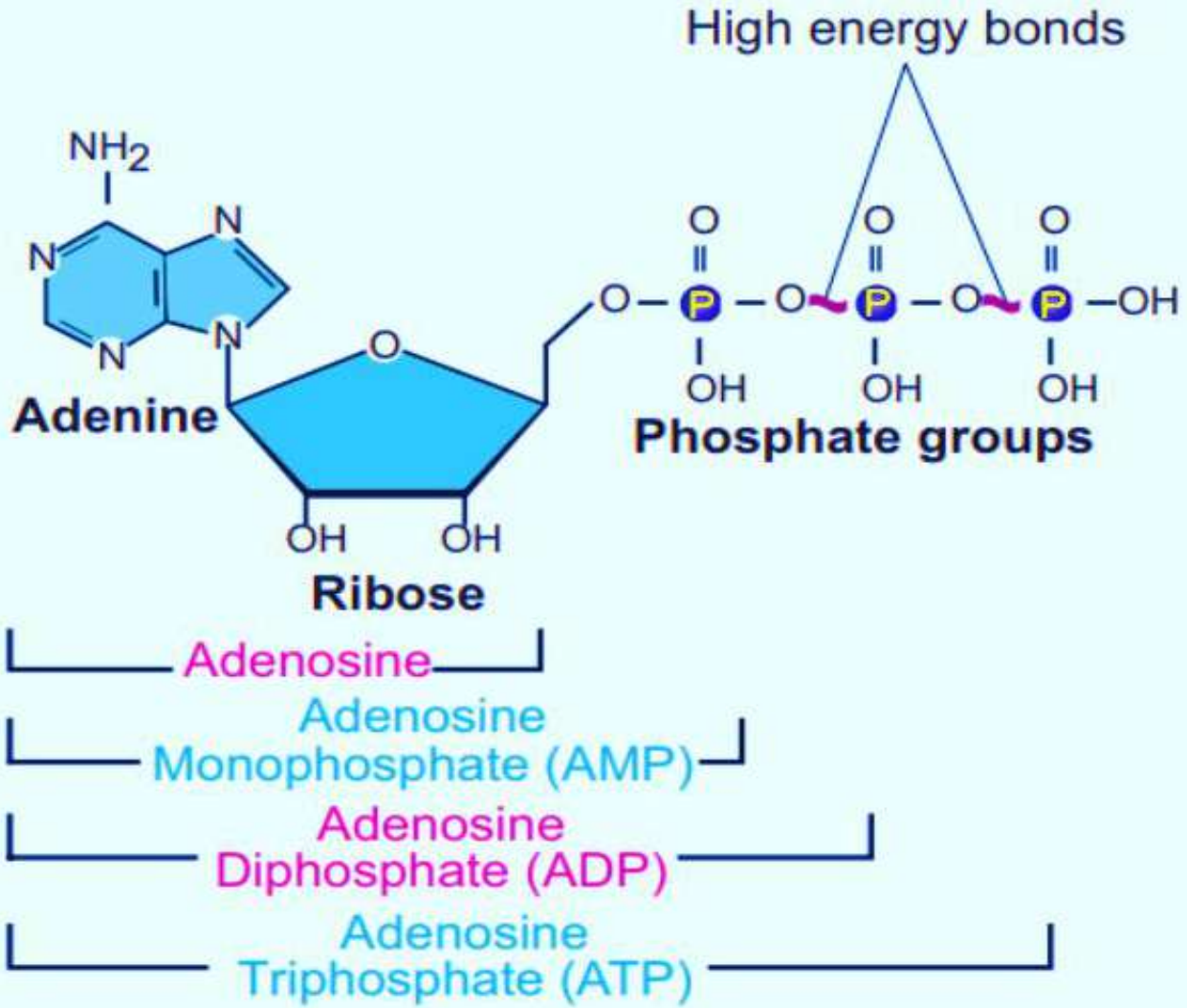
(i) **Obligate anaerobes**: These anaerobes always exhibit anaerobic respiration

- Example - few bacteria, roundworms found in intestine, tapeworms, intestinal parasites of termites.

(ii) Partial or facultative anaerobes: They exhibit, aerobic respiration but when oxygen is not available then they respire anaerobically.

- Example - yeast, earthworms, some aquatic animals and cells of germinating seeds of higher plants.

ADENOSINE TRIPHOSPHATE(ATP)



Molecular Structure Of ATP

- It is modified nucleotide with extra phosphorous.
- It consists of the purine base adenine, a pentose sugar ribose and three phosphate groups.
- The chemical bonds by which the second and third phosphate groups are attached to ATP are called high energy bonds.
- When the phosphate bonds are hydrolysed they are broken and release free energy.

$$ATP + H_2O \longrightarrow ADP + H_3PO_4 + 7.3Kcal$$

$$ADP + H_2O \longrightarrow AMP + H_3PO_4 + 4.5Kcal$$

$$AMP + H_2O \longrightarrow Adenosine + H_3PO_4 + 1.7Kcal$$

- The released energy is utilised in various metabolic activities.

RESPIRATORY QUOTIENT

- The ratio of volume of CO_2 released to the volume of O_2 absorbed during respiration is called respiratory ratio or R.Q..

$$\text{R.Q.} = \frac{\text{Volume of } CO_2 \text{ released}}{\text{Volume of } O_2 \text{ absorbed}}$$

- The value of R. Q. depends upon the chemical nature of respiratory substrate.

1. RQ for Carbohydrates -When the respiratory substrates are the germinating seeds of wheat, barley, oat, paddy or green leaves, tubers, rhizomes (which contain carbohydrate) the value of R.Q. is always one because the amount of CO_2 released during respiration is equal to the amount of oxygen gas utilized.

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + 673\text{Kcal energy}$$

$$\text{R.Q.} = \frac{6CO_2}{6O_2} = \frac{6}{6} = 1(\text{unity})$$

2. RQ for fatty acids - R.Q. of fatty substance is always less than unity (0.7) because fatty substances contain less amount of oxygen in comparison to hydrogen molecules hence it requires more oxygen for their complete oxidation Thus, more oxygen is absorbed and less CO_2, is released during respiration.

- Example- germinating seeds of castor, mustard, linseed, til, etc.

$$2C_{51}H_{98}O_6 + 145O_2 \longrightarrow 102CO_2 + 98H_2O$$

Tripalmitin

$$\text{R.Q.} = \frac{102CO_2}{145O_2} = \frac{102}{145} = 0.7\text{(less than unity)}$$

3. RQ for organic acids- R.Q. of organic acids is always more than one because organic acids are rich in oxygen and they require less amount of O_2, for their oxidation.

- Example - oxalic acid, malic acid.

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$$2(COOH)_2 + O_2 \longrightarrow 4CO_2 + 2H_2O$$

Oxalic acid

$$R.Q. = \frac{4CO_2}{1O_2} = \frac{4}{1} = 4 \text{ (more than one)}$$

4. RQ for green fleshy leaves- Green fleshy leaves of *Bryophyllum*, phylloclade of Opuntia: R.Q. of green fleshy leaves is always zero because of incomplete oxidation of carbohydrate.

$$2C_6H_{12}O_6 + 3O_2 \longrightarrow 3C_4H_6O_3 + 3H_2O + 386 \text{ Kcal}$$

$$R.Q. = \frac{CO_2}{3O_2} = \frac{0}{3} = 0 \text{ (zero)}$$

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5. RQ for anaerobic respiration - The R.Q in the absence of O_2 during anaerobic respiration is always infinite because this process does not require oxygen example yeast

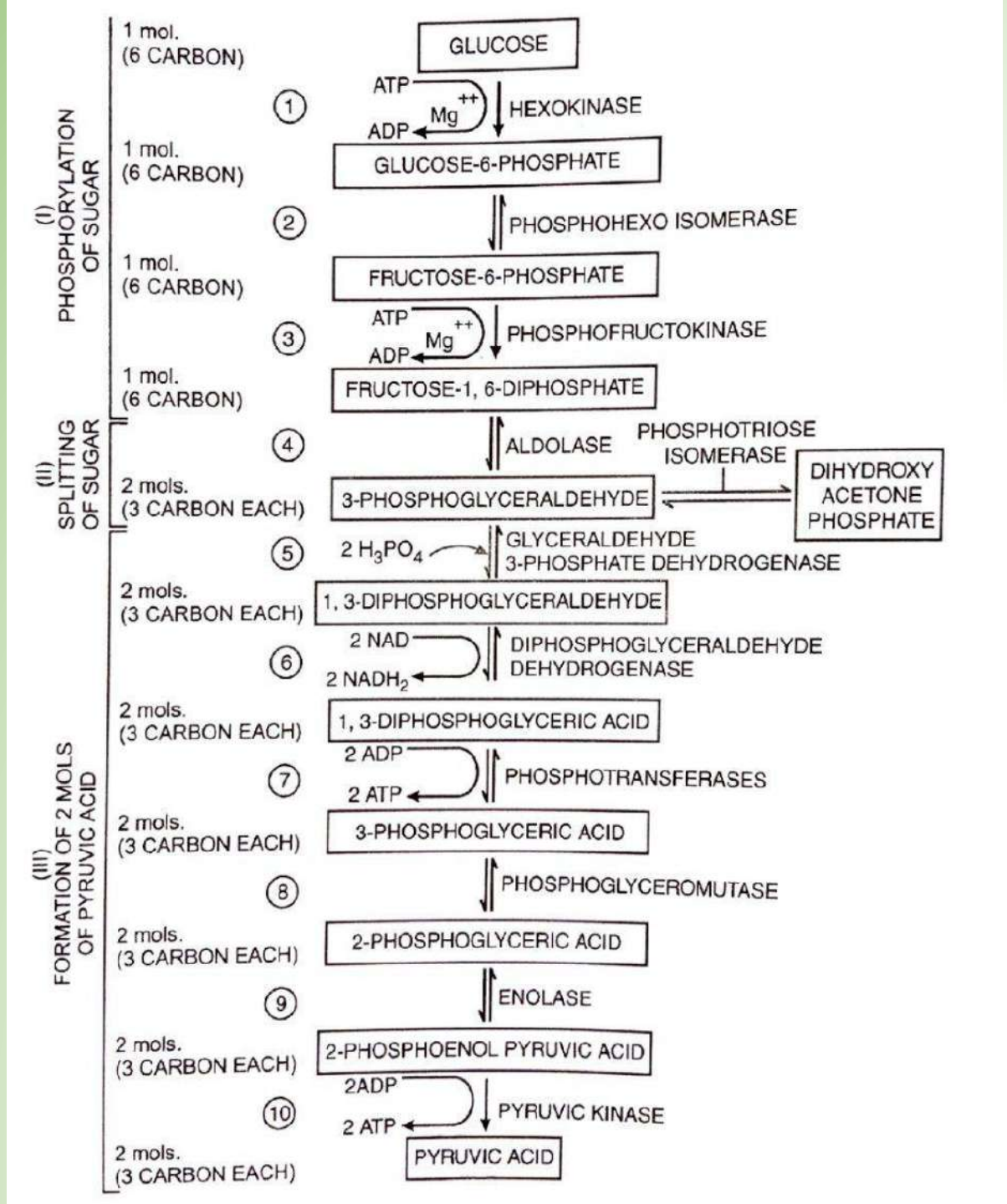
$$C_6H_{12}O_6 \xrightarrow{\text{Zymase}} 2C_2H_5OH + 2CO_2 + 21\ \text{Kcal}$$

$$\text{R.Q.} = \frac{2CO_2}{O_2} = \frac{2}{0} = \infty(\text{infinite})$$

MECHANISM OF RESPIRATION

- The oxidation of respiratory substrates in respiration takes place in stepwise manner by a series of reactions. Each reaction is catalysed by a specific enzyme.
- Prior to enter the process of respiration, the complex carbohydrates are transformed into hexose sugars (glucose and fructose). They function as primary respiratory substrates.
- The initial step in aerobic and anaerobic respiration is same which is called glycolysis.
- Glycolysis means splitting of sugars. This process occurs in cytoplasm.
- During this process, pyruvic acid is formed by the decomposition of glucose. Thereafter, the fate of pyruvic acid depends upon the presence or absence of O_2.

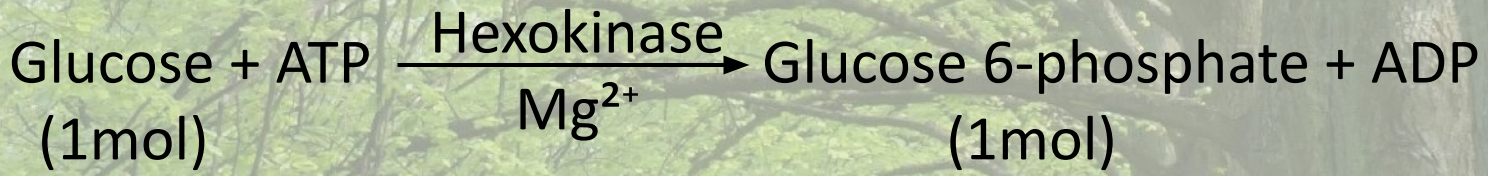
GLYCOLYSIS


(I) PHOSPHORYLATION OF SUGAR
(II) SPLITTING OF SUGAR
(III) FORMATION OF 2 MOLS OF PYRUVIC ACID
1 mol. (6 CARBON)
GLUCOSE
ATP
Mg++
ADP
HEXOKINASE
1 mol. (6 CARBON)
GLUCOSE-6-PHOSPHATE
PHOSPHOHEXO ISOMERASE
1 mol. (6 CARBON)
FRUCTOSE-6-PHOSPHATE
ATP
Mg++
ADP
PHOSPHOFRUCTOKINASE
1 mol. (6 CARBON)
FRUCTOSE-1, 6-DIPHOSPHATE
ALDOLASE
PHOSPHOTRIOSE ISOMERASE
2 mols. (3 CARBON EACH)
3-PHOSPHOGLYCERALDEHYDE
DIHYDROXY ACETONE PHOSPHATE
2 H_3PO_4
GLYCERALDEHYDE 3-PHOSPHATE DEHYDROGENASE
2 mols. (3 CARBON EACH)
1, 3-DIPHOSPHOGLYCERALDEHYDE
2 NAD
2 $NADH_2$
DIPHOSPHOGLYCERALDEHYDE DEHYDROGENASE
2 mols. (3 CARBON EACH)
1, 3-DIPHOSPHOGLYCERIC ACID
2 ADP
2 ATP
PHOSPHOTRANSFERASES
2 mols. (3 CARBON EACH)
3-PHOSPHOGLYCERIC ACID
PHOSPHOGLYCEROMUTASE
2 mols. (3 CARBON EACH)
2-PHOSPHOGLYCERIC ACID
ENOLASE
2 mols. (3 CARBON EACH)
2-PHOSPHOENOL PYRUVIC ACID
2ADP
2 ATP
PYRUVIC KINASE
2 mols. (3 CARBON EACH)
PYRUVIC ACID

- It is also called EMP-pathway because it was discovered by three German scientists, Embden, Mayerhof and Parnas.
- It is also called common respiratory pathway or cytoplasmic respiration.
- All the reactions of this pathway occur in cytoplasm and oxygen is not required in it. Hence, this is the common step for both aerobic and anaerobic respiration.
- In glycolysis, two molecules of 3C-pyruvic acid are formed from one molecule of 6C-glucose. Glycolysis includes the following three steps -

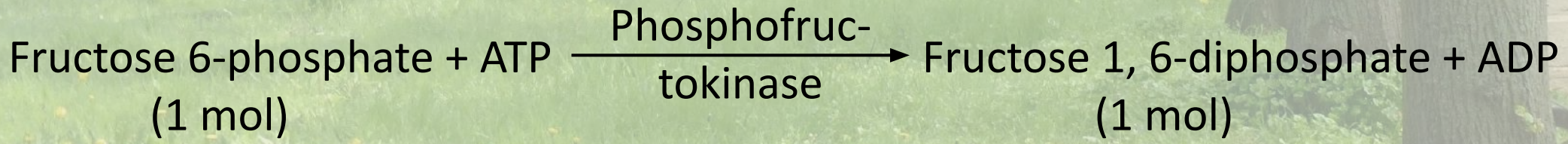
I. Phosphorylation-The synthesis of fructose 1, 6-diphosphate takes place by the phosphorylation of glucose molecule during this process. This process completes in two steps and two molecules of ATP are utilized in it.

(1) First phosphorylation-Glucose molecule is phosphorylated in the presence of ATP to form glucose 6- phosphate. This reaction is catalysed by enzyme hexokinase, and Mg^{2+} serves as cofactor.



(2) Isomerization-Glucose 6-phosphate is isomerized to form fructose 6-phosphate in the presence of enzyme phosphohexoisomerase or phosphoglucoisomerase.

(3) Second phosphorylation-Fructose 6-phosphate so phorylated by ATP molecule formed, is again phos to form fructose 1, 6-diphosphate. This reaction is catalyseu by enzyme phosphofructokinase, and Mg^{2+} functions as cofactor.



 In this way, two molecules of ATP are utilized in the of fructose 1, 6-diphosphate from the formation of one molecu phosphorylation of one molecule of glucose.

II. Splitting of hexose sugar-In this step, two molecules of 3C-suga (3 phosphoglyceraldehyde and dihydroxyacetone molecule phosphate) are formed from ou of 6C-sugar (fructose 1, 6-diphosphate)

(4) Formation of phosphoglyceraldehyde- Fructose 1.6-diphosphate now into two 3C-triose sugars such as one molecule each of 3-phosphoglyceraldehyde and dihydroxyacetone phosphate. This reaction is catalysed by enzyme aldolase.

III. Formation of pyruvic acid-In this step, the formation of pyruvic acid from phosphoglyceraldehyde takes place by the following reactions-

(5) Formation of 1,3-diphosphoglyceraldehyde (DiPGAL)-3-phosphoglyceraldehyde reacts with phosphoric acid (H_3P0_4) to form 1, 3-diphosphoglyceraldehyde (DiPGAL).

3-phosphoglyceraldehyde + H_3PO_4 ⟶ 1, 3-diphosphoglyceraldehyde

(2 mols) (2 mols) (2 mols)

(6) Formation of 1, 3-diphosphoglyceric acid (DiPGA)-1, 3-diphosphoglyceraldehyde undergoes oxidation to yield 1, 3-diphosphophoglyceric acid in the presence of enzyme phosphoglyceraldehyde dehydrogenase. In this reaction, NAD (Nicotinamide Adenine Dinucleotide) functions as hydrogen acceptor.

1,3-diphosphoglyceraldehyde +2NAD $\xrightarrow[\text{dehydrogenase}]{\text{Phosphoglyceraldehyde}}$ 1,3-diphosphoglyceric acid + $2NADH_2$

(2 mols) (2 mols)

(7) Formation of 3-phosphoglyceric acid-In this reaction, one phosphate group from each of the two 1, 3-diphosphoglyceric acid molecules are transferred to two ADP molecules, thus forming two ATP molecules. On transfer of one molecule of phosphate group from 1, 3-diphosphoglyceric acid, it is converted into 3-phosphoglyceric acid. This reaction is catalysed by the enzyme phosphoglyceryl kinase.

1, 3-diphosphoglyceric acid + 2ADP $\xrightarrow[\text{kinase}]{\text{Phosphoglyceryl}}$ 3-phosphoglyceric acid + 2ATP

(2 mols) (2 mols)

(8) Formation of 2-phosphoglyceric acid-3-phosphoglyceric acid is converted nto its isomer 2-phosphoglyceric acid in the presence of enzyme phosphoglyceromutase.

3-phosphoglyceric acid +2ADP $\xrightarrow[\text{mutase}]{\text{Phosphoglycero-}}$ 2-phosphoglyceric acid

(2 mols) (2 mols)

9) Formation of phosphoenol pyruvic acid (PEP)-In this reaction, one molecule of water is removed from each molecule of 2-phosphoglyceric acid resulting in C TOrmation of phospBioenol Pyruvic acid. This reaction is catalysed by enzyme enolase.

$$\underset{(2\ \text{mols})}{\text{2-phosphoglyceric acid}} \xrightarrow{\text{Enolase}} \underset{(2\ \text{mols})}{\text{Phosphoenol pyruvic acid}} + 2H_2O$$

10) Formation of pyruvie acid (PA)-In this last step of glycolysis, the pnate group gets isolated from phosphoenol pyruvic acid resulting in the formation o pyruvic acid (PA). This reaction is catalysed by the enzyme pyruvic kinase.

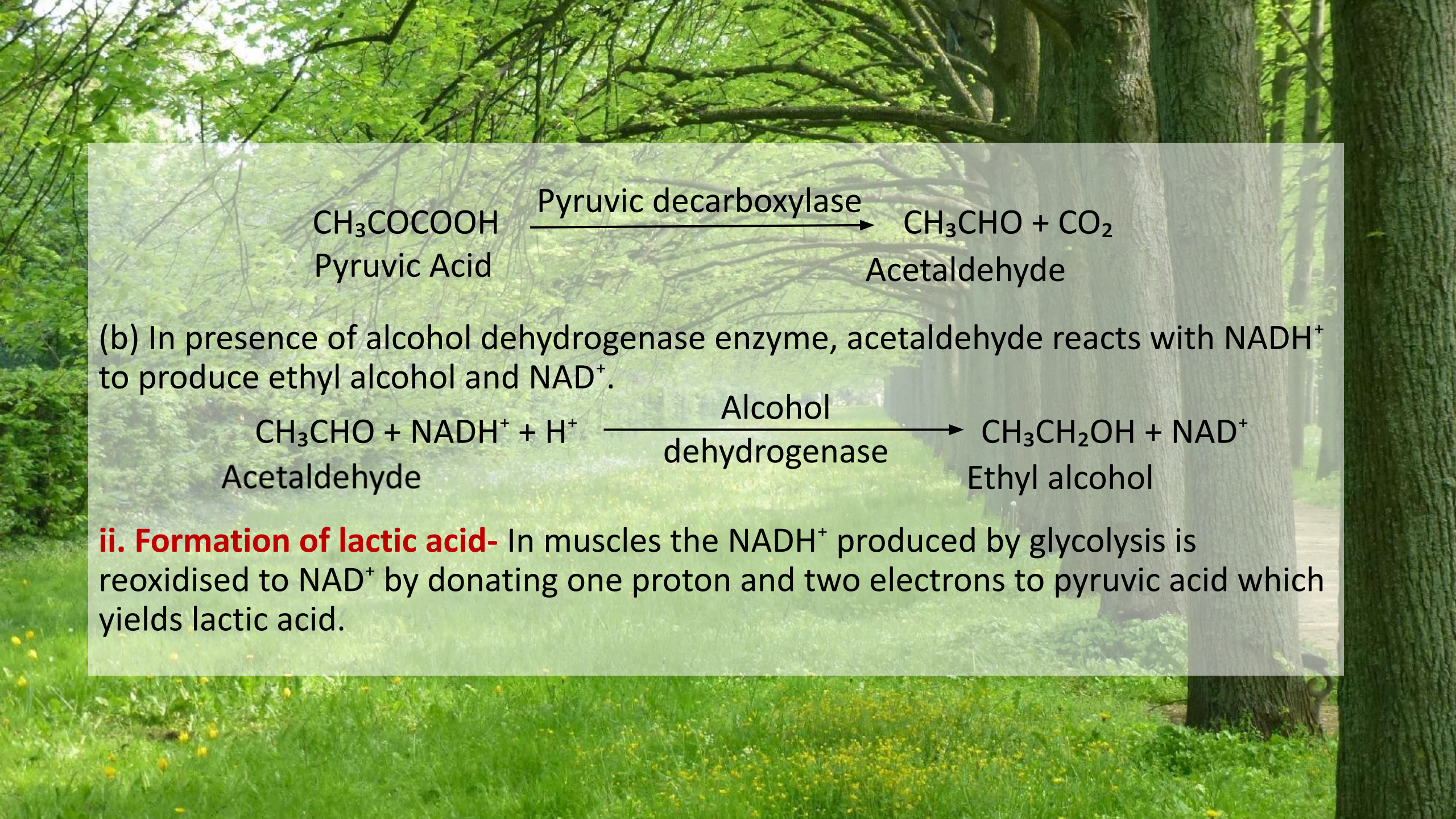
$$\underset{(2\ \text{mols})}{\text{Phosphoenol pyruvic acid}} + 2\text{ADP} \xrightarrow{\text{Pyruvic kinase}} \underset{(2\ \text{mols})}{\text{Pyruvic acid}} + 2\text{ATP}$$

ANAEROBIC RESPIRATION
(ANAEROBIC OXIDATION OF PYRUVIC ACID)

- In the absence of O_2, pyruvate undergoes two types of incomplete reductions. In one case it results in the production of ethyl alcohol (yeast) and in other it produces lactic acid (muscles).
- The mechanism of anaerobic respiration is similar to aerobic respiration upto glycolysis.
- The molecules of pyruvic acid produced in glycolysis are used up in two different reactions as follows:

i. **Formation of Ethyl Alcohol :** In yeast cells anaerobic oxidation of pyruvic acid takes place in following steps:

a) First of all decarboxylation of pyruvic acid takes place in the presence of pyruvic decarboxylase enzyme to produce acetaldehyde



$$CH_3COCOOH \xrightarrow{\text{Pyruvic decarboxylase}} CH_3CHO + CO_2$$

Pyruvic Acid — Acetaldehyde

(b) In presence of alcohol dehydrogenase enzyme, acetaldehyde reacts with $NADH^+$ to produce ethyl alcohol and NAD^+.

$$CH_3CHO + NADH^+ + H^+ \xrightarrow[\text{dehydrogenase}]{\text{Alcohol}} CH_3CH_2OH + NAD^+$$

Acetaldehyde — Ethyl alcohol

ii. Formation of lactic acid- In muscles the $NADH^+$ produced by glycolysis is reoxidised to NAD^+ by donating one proton and two electrons to pyruvic acid which yields lactic acid.

- Skeletal muscles usually derive their energy by anaerobic respiration.
- After vigorous exercise lactic acid accumulates leading to muscle fatigue.
- After rest, however, the lactic acid is reconverted to pyruvic acid and is channelled back into the aerobic pathway.

$$CH_3COCOOH + NADH^+ + H^+ \xrightarrow[\text{dehyrogenase}]{\text{Lactic acid}} \underset{\text{Lactic acid}}{CH_3CHOHCOOH} + NAD^+$$

AEROBIC RESPIRATION (AEROBIC OXIDATION OF PYRUVIC ACID)

- In the presence of oxygen, pyruvic acid is decomposed into carbon dioxide and water and the energy produced during this process is stored in the form of ATP .
- The pyruvic acid formed in the cytoplasm enters the mitochondria because all the enzymes related to aerobic respiration are found in mitochondria only i.e., this process occurs in mitochondria, hence, it is called cellular respiration.
- If respiratory substrate is glucose, there are following four steps in aerobic respiration:

(1) Glycolysis

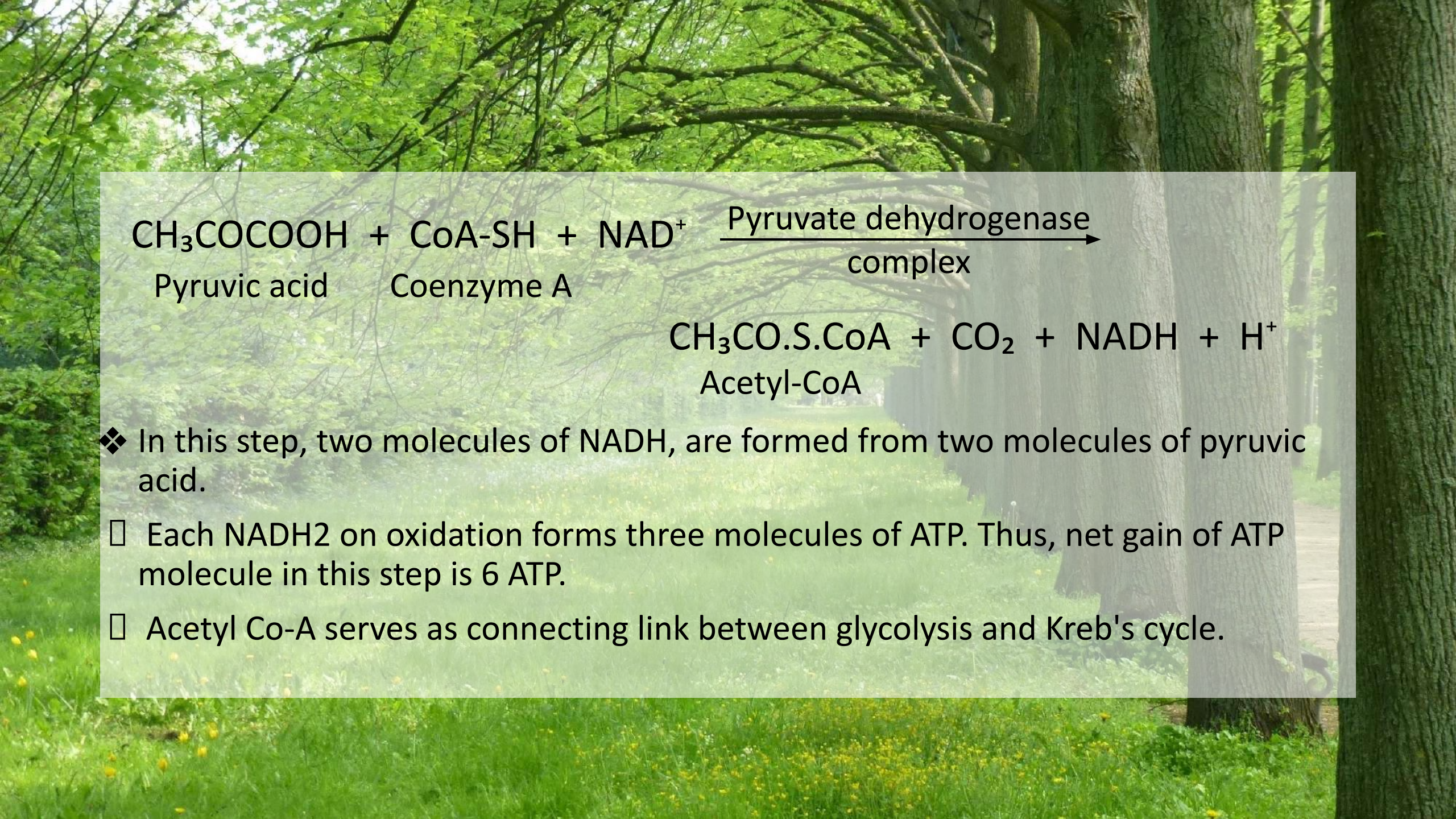
(2) Oxidative decarboxylation of pyruvic acid.

(3) Kreb's cycle or tricarboxylic acid cycle.

(4) Electron transport system and oxidative phosphorylation.

OXIDATIVE DECARBOXYLATION OF PURUVIC ACID

- The pyruvic acid produced in cytoplasm or cytosol enters the matrix of mitochondria .
- Here, it is decarboxylated and the remaining 2-carbon fragment is combined with a molecule of coenzyme A to form acetyl COA.
- The whole reaction takes place in presence of pyruvic acid decarboxylase enzyme and five cofactors viz. Coenzyme A (CoA), Mg^{2+}, T.P.P (Thiamine pyrophosphate), NAD and Lipoic acid.
- The summary for this step of respiration may be written by the equation given below:

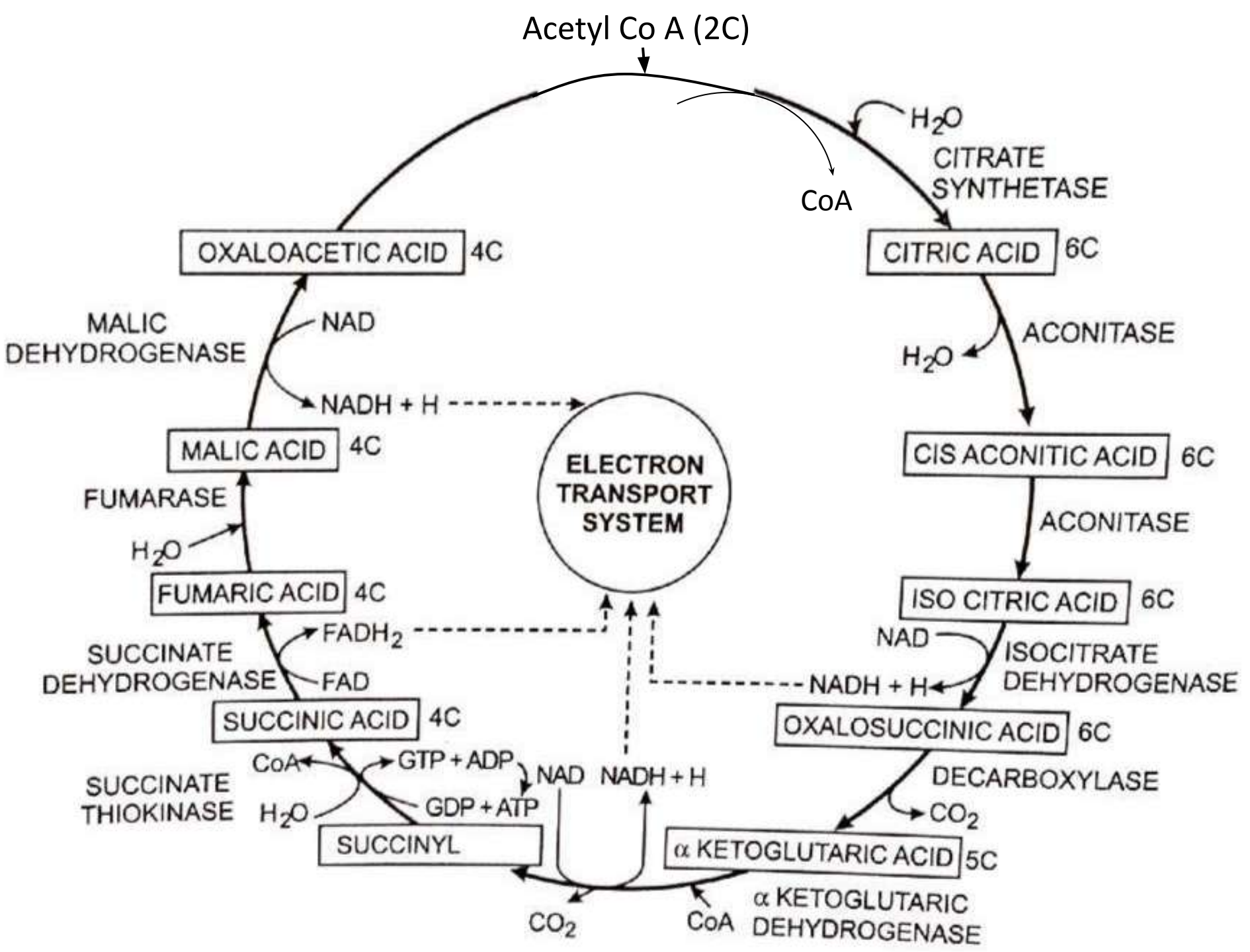


$$CH_3COCOOH + CoA\text{-}SH + NAD^+ \xrightarrow[\text{complex}]{\text{Pyruvate dehydrogenase}} CH_3CO.S.CoA + CO_2 + NADH + H^+$$

Pyruvic acid — Coenzyme A — Acetyl-CoA

- In this step, two molecules of NADH, are formed from two molecules of pyruvic acid.
- Each NADH2 on oxidation forms three molecules of ATP. Thus, net gain of ATP molecule in this step is 6 ATP.
- Acetyl Co-A serves as connecting link between glycolysis and Kreb's cycle.

KREB'S CYCLE


Acetyl Co A (2C)
CoA
H_2O
CITRATE SYNTHETASE
OXALOACETIC ACID 4C
CITRIC ACID 6C
MALIC DEHYDROGENASE
NAD
NADH + H
H_2O
ACONITASE
MALIC ACID 4C
CIS ACONITIC ACID 6C
ELECTRON TRANSPORT SYSTEM
FUMARASE
H_2O
ACONITASE
FUMARIC ACID 4C
ISO CITRIC ACID 6C
$FADH_2$
NAD
SUCCINATE DEHYDROGENASE
FAD
ISOCITRATE DEHYDROGENASE
NADH + H
SUCCINIC ACID 4C
OXALOSUCCINIC ACID 6C
CoA
GTP + ADP
NAD
NADH + H
DECARBOXYLASE
SUCCINATE THIOKINASE
H_2O
GDP + ATP
CO_2
SUCCINYL
α KETOGLUTARIC ACID 5C
CO_2
CoA
α KETOGLUTARIC DEHYDROGENASE

- Pyruvic acid produced by glycolysis undergoes aerobic oxidation in the matrix of mitochondria through the TCA(Tricarboxylic Acid) cycle.
- This cycle serves as a common pathway for carbohydrates, fats and proteins. This cycle is described for the first time by H.A.Krebs in 1943 in pigeon muscles hence it is called as Krebs cycle.
- It is also known to be as T.C.A. cycle or citric acid cycle because it produces tricarboxylic acids.
- All the chemical reactions of Krebs cycle will be completed in following steps:

(i) First of all. pyruvic acid is converted to acetyl co-enzyme A, by the oxidation and decarboxylation as shown in the following reaction:

$$\text{Pyruvic acid} + \text{Co-A} + \text{NAD} \longrightarrow \text{Acetyl Co-A} + NADH_2 + CO_2$$

(ii) The acetyl CoA combines with oxaloacetic acid already present in the mitochondria to form citric acid. It is shown in the following reaction:

$$\text{Acetyl Co-A + Oxaloacetic acid (OAA) + } H_2O \xrightarrow[\text{synthetase}]{\text{Citrate}} \text{Citric acid + Co-A}$$

(iii) In this step water is removed first from the citric acid in the presence of enzyme aconitase which results in the formation of cis-aconitic acid and then water is added to cis-aconitic acid so that isocitric acid is produced. It is shown in the following reactions:

$$\text{Citric acid} \xrightarrow{\text{Aconitase}} \text{Cis-aconitic acid} + H_2O$$

$$\text{Cis-aconitic acid} + H_2O \xrightarrow{\text{Aconitase}} \text{Iso-citric acid}$$

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(iv) In the first step of oxidation of the Kreb's Cycle, isocitric acid is converted to oxalosuccinic acid in the presence of isocitric dehydrogenase enzyme. As a result of decarboxylation of oxalosuccinic acid, α -ketoglutaric acid is produced. In this reaction, the enzyme is same as previous one and Mg^{2+} is required also.

$$\text{Iso-citric acid} + \text{NAD} \xrightarrow[\text{dehydrogenase}]{\text{Isocitric}} \text{Oxalosuccinic acid} + NADH_2$$

$$\text{Oxalosuccinic acid} \xrightarrow{\text{Decarboxylase}} \alpha\text{ -ketoglutaric acid} + CO_2$$

(v) Like pyruvic acid, the oxidation of a-ketoglutaric acid also occurs and as a result of oxidative decarboxylation of α -ketoglutaric acid, succinyl Co-A is formed. In this reaction, a-ketoglutaric acid dehydrogenase enzyme acts as a catalyst.

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$$\alpha\text{-ketoglutaric} + \text{Co-A} + \text{NAD} \xrightarrow[\text{dehydrogenase}]{\alpha\text{ –ketoglutaric}} \text{Succinyl Co-A} + CO_2 + NADH_2$$

(vi) Succinyl Co-A loses Co-A. This reaction is catalysed by succinate thiokinase enzyme, in which guanosine diphosphate (GDP) reacts with inorganic phosphate to form guanosine triphosphate (GTP). GTP like an enzyme reacts with ADP to form GDP and one molecule of ATP is formed.

$$\underset{\text{Guanosine Triphosphate}}{\text{GTP}} + \text{ADP} \longrightarrow \underset{\text{Guanosine Diphosphate}}{\text{GTP}} + \text{ATP}$$

- A molecule of water is also consumed in the conversion of succinyl Co-A to succinic acid.

$$\text{Succinyl Co-A} + \text{GDP} + \text{iP} + H_2O \xrightarrow[\text{thiokinase}]{\text{Succinate}} \text{Succinic acid} + \text{GTP} + \text{Co-A}$$

(vii) In the third step of Kreb's Cycle, succinic acid is oxidised to form fumaric acid. This reaction is catalysed by succinic acid dehydrogenase (Flavo-protein). In this reaction none of Co-enzymes I or II (NAD or NADH) are used. But Flavin Adenine Dinucleotide (FAD), the flavin prosthetic group of the enzyme absorbs two hydrogen (H^+) ions and two electrons from succinic acid and is reduced as given in the following equation:

$$\text{Succinic acid} + \text{FAD} \xrightarrow[\text{dehydrogenase}]{\text{Scuccinic}} \text{Fumaric acid} + FADH_2$$

(viii) Fumaric acid after reacting with a molecule of water forms malic acid. The reaction takes place in the presence of fumarase enzyme.

$$\text{Fumaric acid} + H_2O \xrightarrow{\text{Fumarase}} \text{Malic acid}$$

(ix) In the last and fourth step of Kreb's Cycle, oxidation takes place. In the presence of malic acid dehydrogenase enzyme results in the dehydrogenation of malic acid, and oxaloacetic acid is formed.

$$\text{Malic acid} + \text{NAD} \xrightarrow[\text{dehydragenase}]{\text{Malic}} \text{Oxaloacetic acid} + NADH_2$$

- Oxaloacetic acid thus produced combines with Acetyl CoA to form citric acid which again enter into the cycle, thus the cycle is repeated.

ELECTRON TRANSPORT SYSYEM AND OXIDATIVE PHOSPHORYLATION

- Glucose molecule is completely oxidized by the end of Kreb's cycle. However, energy is not released until NADH and $FADH_2$ are oxidized.
- The synthesis of ATP with the help of energy released by the oxidation of these hydrogen acceptors (NADH and $FADH_2$) is called oxidative phosphorylation.
- But, NADH or $FADH_2$ does not combine directly with oxygen, the electrons reach to oxygen from them through a series of electron carriers. This series of electron carriers is called electron transport system (ETS) or electron transport chain.
- **Components of electron transport system:** The electron transport system is made up of following co-enzymes :

1. Nicotinamide adenine dinucleotide (NAD).
2. Flavoproteins (FAD and FMN).
3. Fe-S protein complex.

4. Co-enzyme Q (Co Q) or ubiquinone (UQ).

5. Cytochrome-b (Cyt-b)

6. Cytochrome-c_1 (Cyt-c_1).

7. Cytochrome-c (Cyt-c).

8. Cytochrome-a (Cyt-a).

9. Cytochrome-a_3(Cyt-a_3).

All the above enzymes are found in F_1 particles of mitochondria.

There are four complexes involved in ETS:

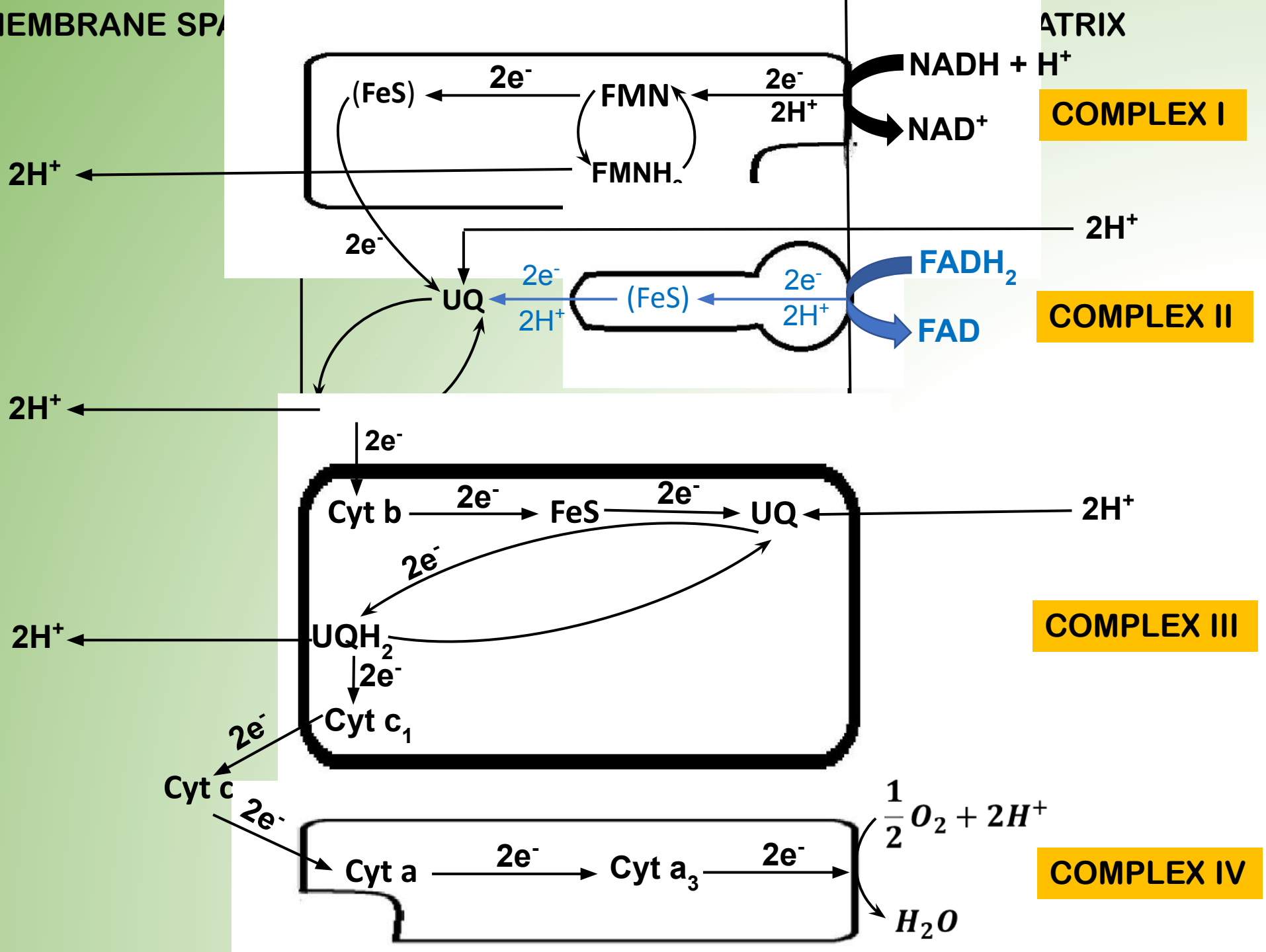
1. Complex I: NADH dehydrogenase complex

2 Complex II: Succinate Dehydrogenase complex

3. Complex III: Cytochrome bc_1 complex

4. Complex IV : Cytochrome aa_3 complex/Cytochrome c oxidase complex

ETS


INTER- MEMBRANE SPA
ATRIX
NADH + H+
NAD+
2e-
2H+
(FeS)
FMN
FMNH2
2H+
2e-
UQ
2e-
2H+
(FeS)
2e-
2H+
FADH2
FAD
2H+
2H+
2e-
Cyt b
2e-
FeS
2e-
UQ
2H+
2e-
UQH2
2H+
2e-
Cyt c1
2e-
Cyt c
2e-
Cyt a
2e-
Cyt a3
2e-
1/2 O2 + 2H+
H2O
COMPLEX I
COMPLEX II
COMPLEX III
COMPLEX IV

Mechanism of ETS:

(1) In the Ist step of ETS, FMN is reduced to $FMNH_2$ by receiving hydrogen from $NADH_2$ and $NADH_2$ itself gets oxidized. One molecule of ATP is synthesized from ADP and inorganic phosphate (ip) in oxidative phosphorylation by using free energy released in this step.

(2) One hydrogen pair from succinic acid is first transferred to FAD to form $FADH_2$

(3) Both $FMNH_2$ and $FADH_2$ get oxidized by transferring their hydrogen to co-enzyme Q (UQ), and UQ gets reduced to UQH_2

(4) The reduced UQ (UQH2) decomposes hydrogen into electrons and protons.

$$2H \longrightarrow 2H^{2+} + 2e^{-}$$

(5) The oxidation of reduced UQ takes place by the transfer of electrons to cytochrome. First of all, reduced UQ transfers electron to cyt-b which later on itself gets reduced. Now, Cyt-c_1 Cyt-c. Cyt-a and Cyt-a_3 go on reducing and oxidizing. respectively by electrons.

(6) In the last step, reduced Cyt-a_3 loses a pair of electrons which are accepted by molecular oxygen alongwith the pair of protons (2H) to form one molecule of water. Thus, oxygen is the terminal acceptor of electrons in this system.

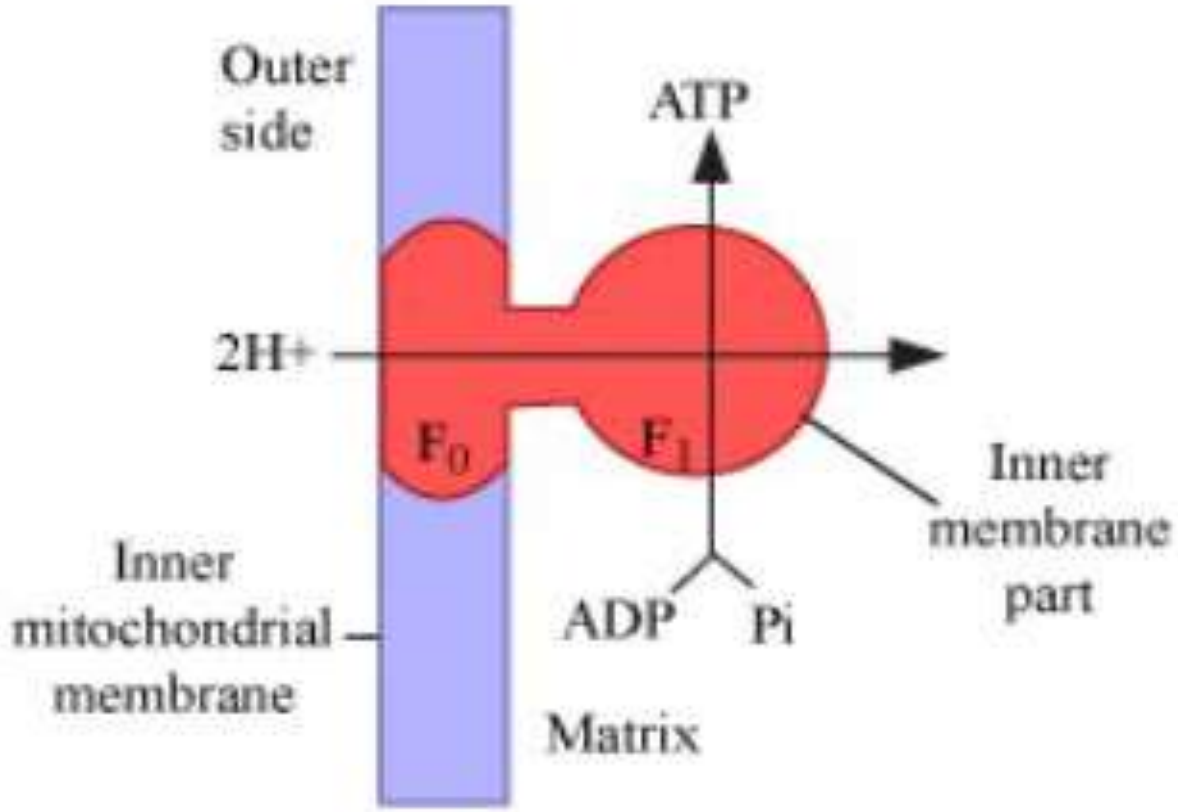
$$\frac{1}{2}O_2 + 2e^- \longrightarrow O_2^-; 2H^+O^{2-} \longrightarrow 2H_2O$$

- The first molecule of ATP is formed between NAD and FMN. The second and third ATP molecules are formed when electrons are transferred from Cyt-b to Cyr-c_1 and Cyt-a to Cyt-a_3.
- Since, succinic acid donates its H_2 to FAD, under this condition the first molecule of ATP does not form. Thus, 3 ATP molecules are produced from each NADH, molecule and 2ATP molecules from each $FADH_2$ molecule.

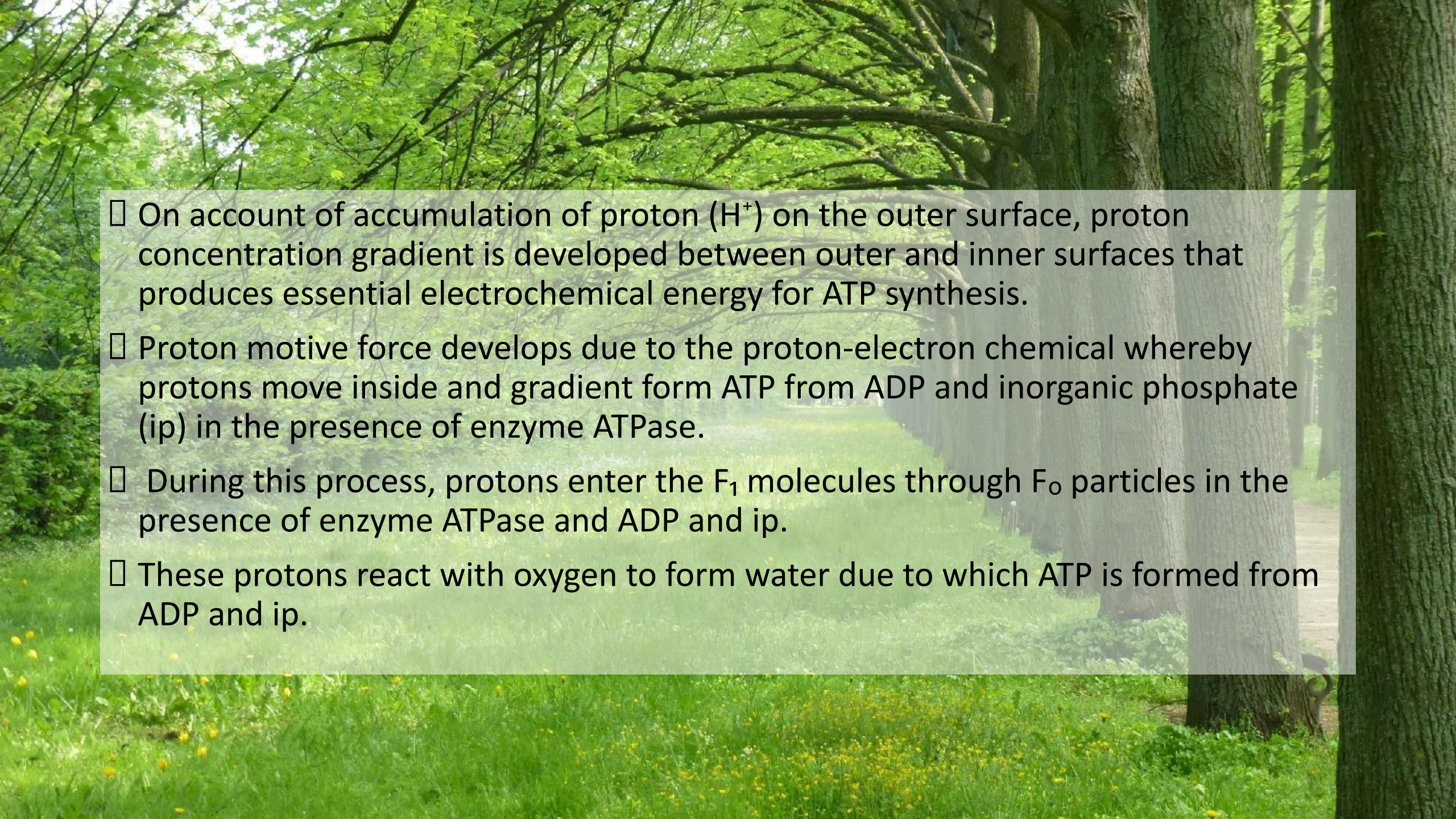
NEW CONCEPT OF OXIDATIVE PHOSPHORYLATION

- The British biochemist Peter Mitchell (1961)) presented the new concept oxidative phosphorylation-Chemo-osmotic hypothesis and for this he was awarded Nobel prize in 1978.
- According chemo-osmotic hypothesis, proton concentration gradient is developed by electron transport chain which is mainly responsible for the synthesis.
- This hypothesis represents The process of ATP synthesis both in mitochondria and chloroplasts (Oxidative phosphorylation Poophosphorylation). In this process, ATP synthetase (Fo and F_1 coupling factor) takes part because it stimulates the ATP synthesis from ADP and inorganic phosphate (ip) in mitochondrial membrane.

- According to this hypothesis, there is a vectorial relationship between oxidation-reduction of electron transport system and ATP synthesis.
- The membranes in which this process completes are called coupling membranes e.g., the inner mitochondria membranes and thylakoid membrane of chloroplast.



- According to this hypothesis, proton gradient develops on the inner membrane of mitochondria during electron transport from NADH to oxygen.
- During each pair of electron transport, 6 protons are formed which are transferred from inner membrane of mitochondria to outer surface.



- On account of accumulation of proton (H^+) on the outer surface, proton concentration gradient is developed between outer and inner surfaces that produces essential electrochemical energy for ATP synthesis.
- Proton motive force develops due to the proton-electron chemical whereby protons move inside and gradient form ATP from ADP and inorganic phosphate (ip) in the presence of enzyme ATPase.
- During this process, protons enter the F_1 molecules through F_o particles in the presence of enzyme ATPase and ADP and ip.
- These protons react with oxygen to form water due to which ATP is formed from ADP and ip.

FACTORS AFFECTING RATE OF TRANSPIRATION

(1) Protoplasm-The rate of respiration in new and rapidly growing cells is higher than in the old and matured cells because the formation and activity of enzymes that are needed in respiration depend upon the normal state of protoplasm.

(2) Food Material-When the quantity of food material such as carbohydrates is more the rate of respiration is also high and low with lower quantity of carbohydrates. This is the reason why green leaves towards light show high rate of respiration in comparison to yellow dried leaves.

(3) Temperature- Generally, the rate of respiration increases between 0^0C -35^0C and above 35^0C the rate of respiration decreases as protoplasm and enzymes get destroyed at 35^0C and above it. At 45^0C, the respiration stops and at 0^0C and below it, the rate of respiration becomes very low.

(4) Water-Water is very essential for all the vital protoplasmic activities. The rate of respiration is very low in dry seeds because in such condition, the protoplasm remains in dormant state.

(5) Carbon dioxide- The rate of respiration decreases with increases of CO_2 If the suitable quantity of air is absent in the soil then quantity of CO_2 increases and therefore the rate of respiration decreases.

(6) Light-Light has no direct effect on respiration. At high light intensity, the formation of carbohydrates by photosynthesis increases which is used in respiration. Hence, the rate of respiration also increases.

PRODUCTION OF ATP MOLECULE IN AEROBIC RESPIRATION

Source	Carbon Flow	Substrate-Level Phosphorylation	Oxidative Phosphorylation	ATP Maximun Yield
Glycolysis	Glucose (6C) ↓ 2 Pyruvates (2C)	2 ATP	6 ATP from 2 NADH	8
Transition reaction	2 pyruvates (3C) ↓ 2 acetyl (2C)+2CO_2		6 ATP from 2 NADH	6
Krebs Cycle	2 acetyl (2C) ↓ 4 CO_2	2 ATP	18 ATP from 6 NADH 4 ATP from 2 $FADH_2$	24
Total	Glucose (6C) ↓ 6 CO_2	4 ATP	34 ATP from 12 NADH 2 $FADH_2$	38 ATP

THANK YOU

Plant - Water Relations

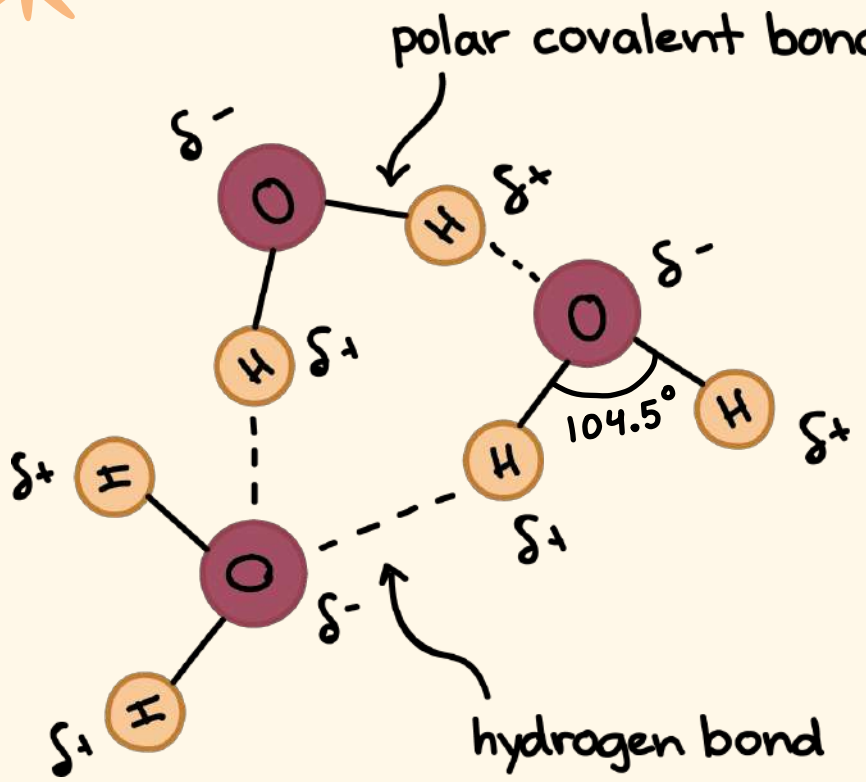
By : Apeksha Gupta (B.Sc. Final year)

Synopsis

- Introduction
- Properties of water
- Importance of water in plant life
- Diffusion and Permeability
- Osmosis & Imbibition
- Plasmolysis
- Water Absorption
- Ascent of Sap

Introduction

Water (chemical formula H2O) is an inorganic, transparent, tasteless, odourless, and nearly colourless chemical substance, which is the main constituent of Earth's hydrosphere and the fluids of all known living organisms. It is an essential source for the existence of life on the planet earth. Water covers about 71% of the Earth's surface, mostly in seas and oceans (about 96.5%). Small portions of water occur as groundwater (1.7%), in the glacier and the ice caps of Antarctic and Greenland (1.7%), and in the air as Vapour, clouds (consisting of ice and liquid water suspended in air), and precipitation (0.001%). Water is essential to both animals and plants, so understanding plant water relations is important. The plants consume enormous amounts of water daily and lose a significant amount of it through transpiration. In living plants, the amount of water may be 80-90%, whereas in seeds, it may be 5-15%.



Structure

Each molecule of water consists of two atoms of hydrogen (H) and one atom of oxygen (O) bonded laterally at 104.5° angle by covalent bonds. They have two hydrogen bonds and two covalent bonds.

Properties of water

Physical properties of water

- It boils at 100°C and freezes into ice at 0°C.
- It freezes into ice and its volume increases. Hence ice floats on water.
- It is an ideal dispersion medium.
- It is an universal solvent.
- Its one molecule ionizes into H+ and OH- ions.
- It is good conductor of heat and electricity.
- Cohesive force is found in water molecules thus ascent of sap takes place.
- It takes part in diffusion, osmosis and imbibition.

Chemical properties of water

- Water acts as catalyst in various activities.
- Water after reacting with sulphur dioxide and carbon dioxide forms sulphuric
- acid and carbonic acid, respectively.
- Metals like sodium, potassium and calcium react with cold water to form alkalis.

Importance of water in plant life

(1) Water is the main constituent of the protoplasm. Normally cells contain 80-85% water and is essential for the working of protoplasm.
(2) Water helps in the absorption and translocation of minerals.
(3) Water acts as a solvent and carrier of many substances. It forms the medium in which several reactions take place.
(4) Water present in the cell vacuole helps in maintaining the turgidity of cells which is must for some activities of life.
(5) Water helps in opening and closing of stomata.
(6) Water is required for the synthesis of carbohydrates by photosynthesis. In this process, it acts as a source of hydrogen atom for the reduction of carbon dioxide.
(7) Water participates directly in many metabolic processes involving hydrolysis and condensation reactions.
(8) In terrestrial plants, it plays a very important role of thermal regulation against high temperatures.
(9) In lower plants, water acts as medium for the mobility of gametes.
(10) In aquatic plants, it helps in pollination and dispersal of seeds and fruits
(11) Water is the main component of photosynthesis.
(12) Deficiency of water affects the growth of plant.
(13) Plants can be classified, on the presence of water into hydrophytes, xerophytes and mesophytes.
(14) Water helps in storage and translocation of food materials.
(15) Chemically, various mineral salts and gases are dissolved in water which are important for biological activities of plants.

Diffusion

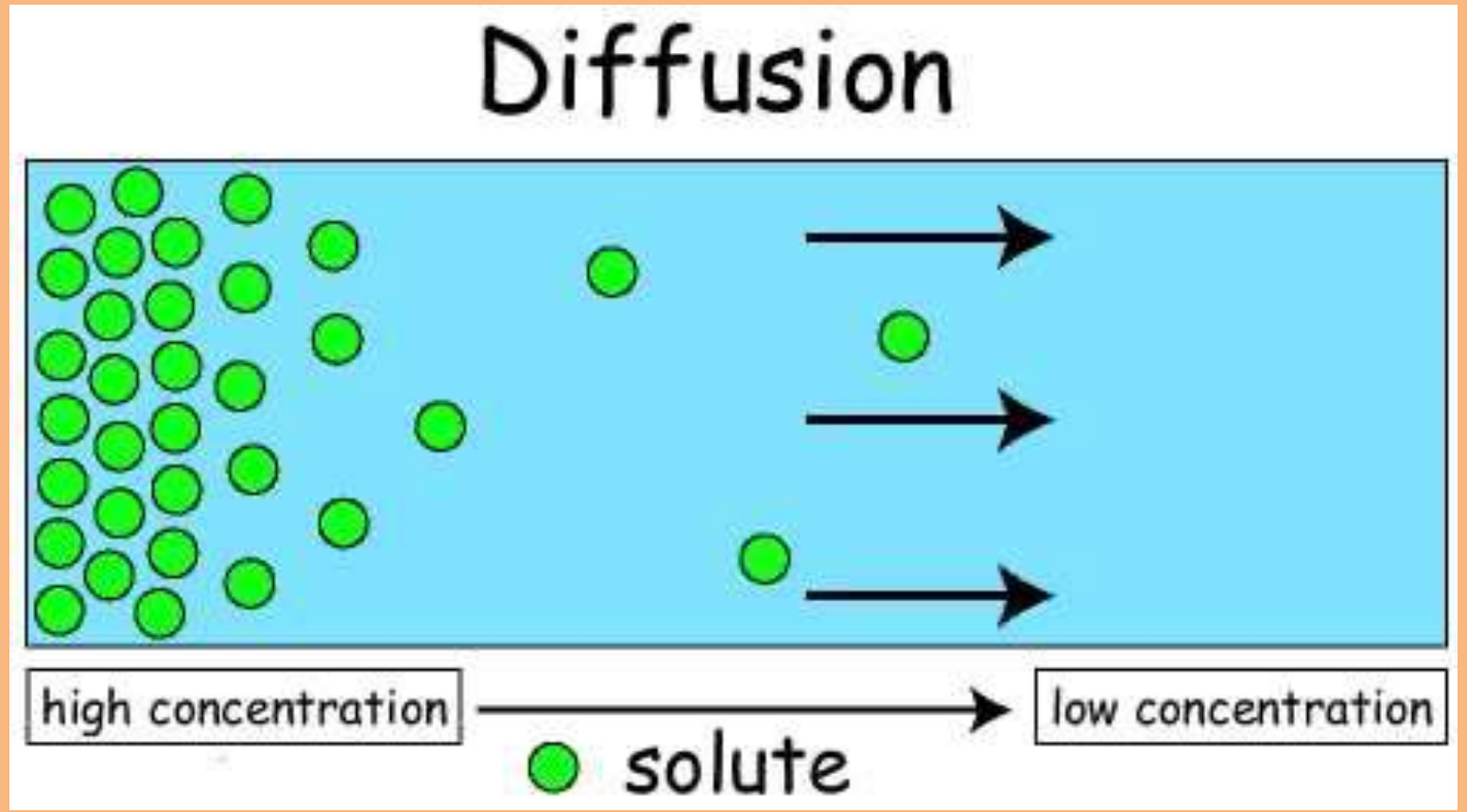
“The movement of molecules or ions of a solid, liquid or gas from the region of their higher concentration to the region of their lower concentration is called diffusion”

E.g. :

- **Intake of CO2 and liberation of 02.**
- **Cell membrane is a porous membrane having numerous minute pores. These pores have diameter of 7-10 A. These pores are formed of some specific protein molecules and of these some pores are negatively charged and some are positively charged. These pores are either always open or they act as valve and they open only when they needed. Various types of ions such as K+, CI-, HCO3- etc. enter through these pores by electro-chemical gradient.**

The diffusing molecules or ions create a pressure which is called diffusion pressure. It can be defined as follows-

Diffusion pressure (DP) is proportional to the number of diffusing particles. If the concentration of diffusing particles is higher in a system then it will have higher DP, on the other hand if the concentration is low then DP will also be low.


Diffusion
high concentration
low concentration
solute

Factors affecting rate of Diffusion

Temperature

The DP increases with the rise in temperature, because at higher temperature the motion energy of the diffusing particles also increases.

Density of diffusing substance

The rate of diffusion is inversely proportional to the square root of density of the diffusing particles. This is called Graham's law of diffusion according to which if the density of the diffusing particles is high, then they have low rate of diffusion.

Medium in which diffusion occurs

The movement of diffusion is very low in concentrated medium.

Diffusion pressure gradient

This is the difference of concentration of specific distance. Hence when it is more the rate of diffusion is high.

Significance of Diffusion in plants

The exchange of CO_2 and O_2 in photosynthesis and O_2 and CO_2 in respiration takes place by independent diffusion in plants.

The loss of water vapour in transpiration takes place by diffusion.

During inactive salt uptake the ions are absorbed by diffusion.

Translocation of food materials takes place by diffusion.

Permeability

The entrance or exit of any substance in the living cell depends on the permeability of cell membrane. If a membrane allows the passage of a substance or water through it, then it is called permeable membrane e.g. fine cloth. However, if a membrane allows penetration of only solvent molecules but not the solute particles, it is said to be semipermeable membrane e.g. egg membrane. On the other hand, if it does not allow both the solvent and the solute particles to pass through it, then it is called impermeable membrane. The biological membranes are known as selectively or differentially permeable membrane, because it allows to pass solute molecules upto a certain extent along with solvent.

According to famous scientists like Michaelis, Scarth and Lloyd, the pores of plasma membrane are lined with charged proteins, hence the -vely and +vely charged particles are passed through them.

Theories of membrane permeability

(1) Retention Pressure Theory- This theory was proposed by Traube (1867), according to which a few substances show great affinity to cell membrane. Therefore, these substances are passed through it while other substances are not allowed to pass through it.

(2) Ultrafiltration Theory-This theory was proposed by Ruhland and Hoffman in 1925. According to these scientists, the cell membrane has numerous minute pores that serve as molecular sieve or ultrafilter. The small sized molecules enter through these pores very easily and rapidly while the large sized molecules cannot do so.

(3)Fat or Lipid Solubility Theory- According to Overton (1900) the fats and lipids are highly surface active. They collect at the cell interfaces and give rise to membrane. The lipid soluble substances like steroids, hormones may pass easily through bilayer and their diffusion depends on lipid solubility.

Theories of membrane permeability

(4) Colloidal Theory- According to this theory, cytoplasmic membranes and protoplasm are found in polyphasic colloidal system and the entrance of various substances takes place on the basis of phase inversion.

(5) Fluid mosaic model- In 1904 Nathanson put forward a mosaic membrane theory. According to this theory, the cell membrane was not a simple membrane, but rather contained mosaic domains with properties similar to Traube's presipitation membrane (artificial membrane). Such a mosaic membrane could provide different pathways for the entry of soluble or insoluble materials

(6) Electrocapillary Theory-This is the modification of ultrafiltration theory. According to this theory the membrane consists of trans membrane channels which have electrostatic charges.

Theories of membrane permeability

(7) Carrier Theory- **According to this theory, certain carriers take part in the permeability of cell membrane. The proteins of cell membrane form channels for the entrance of ions and small atoms which in turn serve as channels for large-sized atoms.**

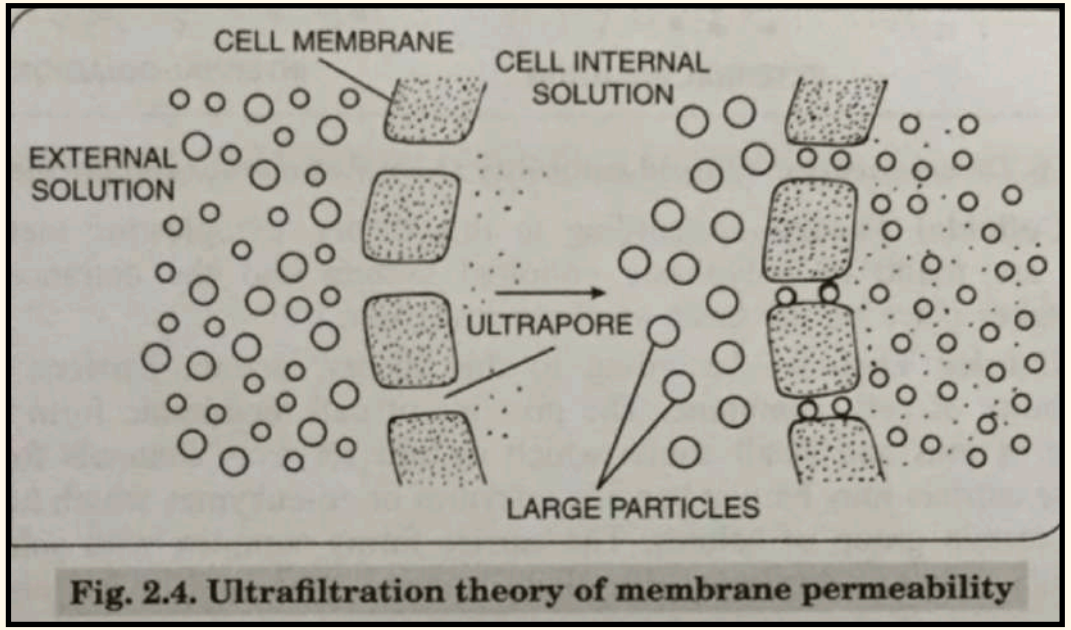
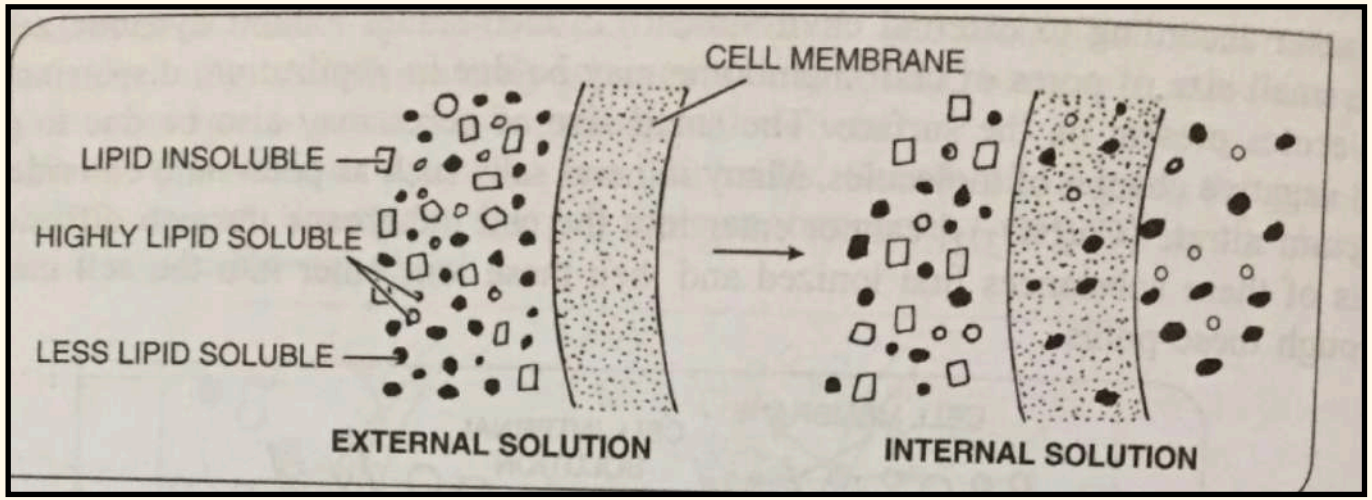


Fig. 2.4. Ultrafiltration theory of membrane permeability



Factors affecting Permeability

The permeability depends on :

- **The size of the pores,**
- **the size of the particles,**
- **the electric charge of the membrane, and**
- **the charges on the diffusing particles.**

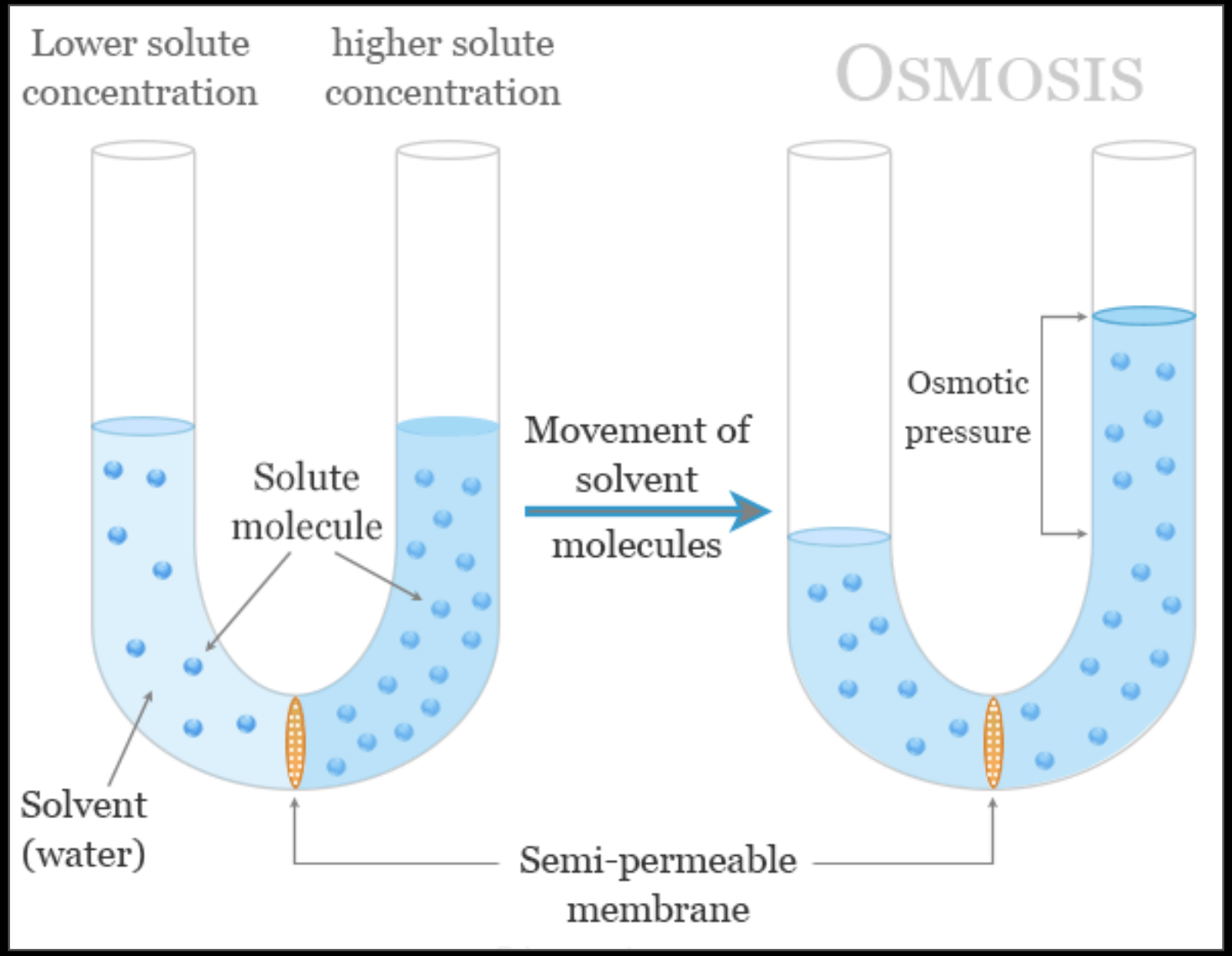
Osmosis

“When the two solutions are separated by means of a semipermeable membrane, the molecules of water (or solvent) move from the region of higher potential (pure solvent or comparatively weak solution) to region of lower potential (more concentrated solution).” This movement of water or solvent is called Osmosis.

Experiment :

To demonstrate this process, a ‘U’ tube is taken and a parchment paper is fitted at the centre of the base of ‘U’ tube which acts like a semipermeable membrane. The right arm of the U-tube is filled with water whereas the left arm is filled with 10% sugar solution. After sometime it is observed that diffusion of water molecules from the right arm of the U-tube starts towards sugar solution filled in the left arm, because diffusion of water molecules takes place from higher concentration to sugar solution having lower concentration.

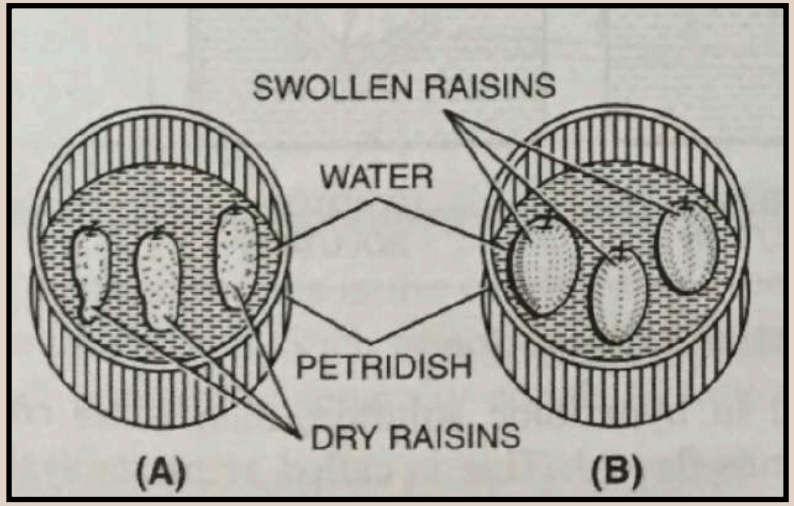
Plants do not contain perfect semipermeable membrane. But in plant cells plasmalemma of cytoplasm and tonoplasts act as differentially permeable membrane and selectivily permeable membrane, respectively. Thus specific solute particles are diffused through these membranes. Moreover all solutes are not diffused.

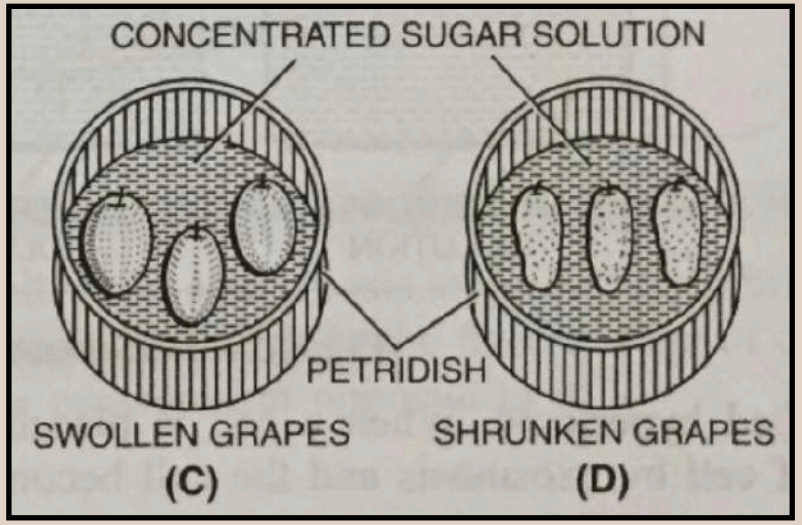

Lower solute concentration
higher solute concentration
OSMOSIS
Solute molecule
Movement of solvent molecules
Osmotic pressure
Solvent (water)
Semi-permeable membrane

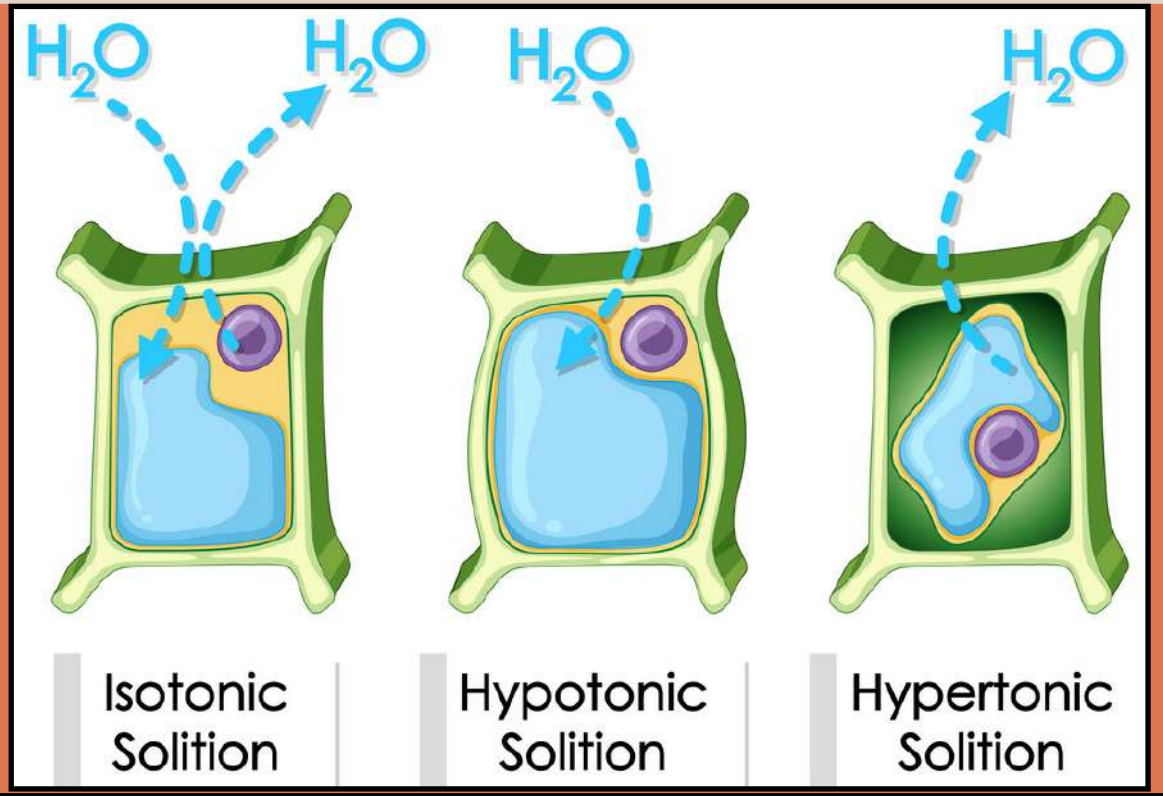
Types of osmosis

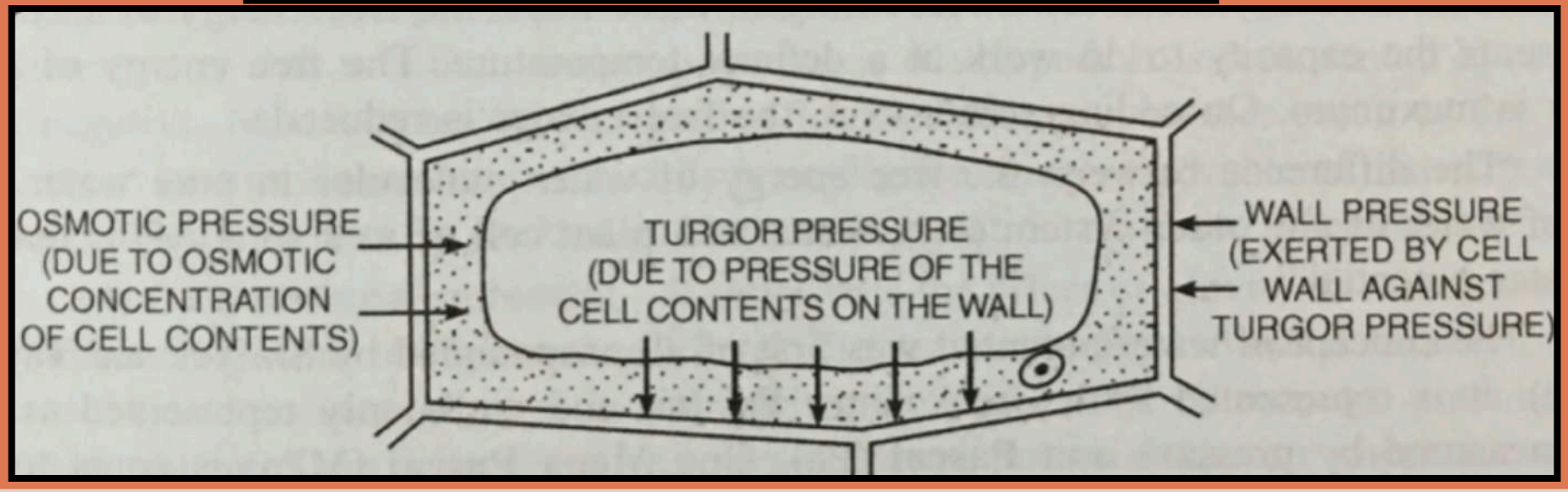
(1) <u>Endosmosis-</u> In the process of endosmosis, the water or solvent molecules enter the cell from outer medium through plasma membrane due to which the cell swells up.

(2) <u>Exosmosis</u>- In the process of exosmosis, the water or solvent molecules move from cell into the outer medium through plasma membrane due to which the cell shrinks.






H_2O
H_2O
H_2O
H_2O
Isotonic Solition
Hypotonic Solition
Hypertonic Solition


OSMOTIC PRESSURE (DUE TO OSMOTIC CONCENTRATION OF CELL CONTENTS)
TURGOR PRESSURE (DUE TO PRESSURE OF THE CELL CONTENTS ON THE WALL)
WALL PRESSURE (EXERTED BY CELL WALL AGAINST TURGOR PRESSURE)

Diffusion pressure deficit

Diffusion pressure deficit is the characteristic of water (solvent) in the solution, but, it is generally called diffusion pressure deficit of solution/ cell. The pressure exerted by diffusing particles is called diffusion pressure (DP). This pressure is directly proportional to the concentration of diffusing particles. The diffusion pressure of pure water or pure solvent is always maximum. If a small quantity of solute is dissolved in it, there is a deficit in diffusion pressure of pure water or solvent ie. there is a difference between diffusion pressures of pure water and its solution.

Osmotic potential

It is the potential developed by solute in a solution and depends upon the number of solute molecules. It's value is always negative (-ve) (or zero in pure water). The value of osmotic pressure (OP) and solute potential or osmotic potential is same.

Osmotic pressure

Osmotic pressure can be defined as the minimum pressure that must be applied to a solution to halt the flow of solvent molecules through a semipermeable membrane (osmosis).

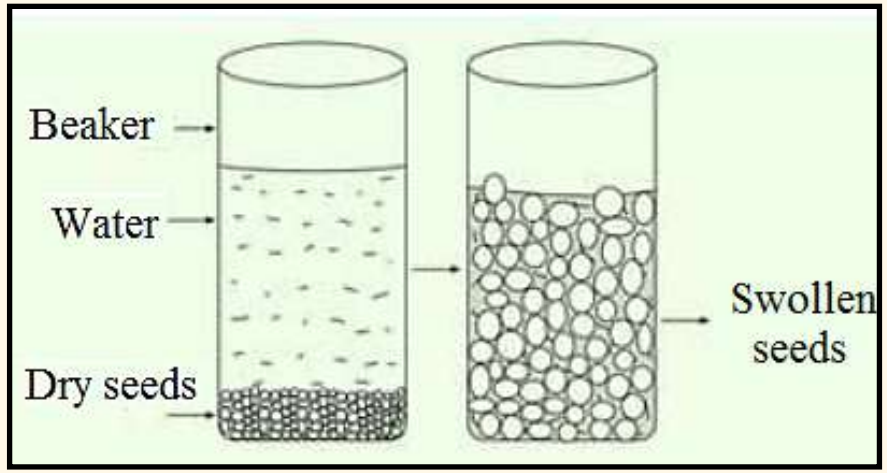
$\pi = iCRT$

Significance of osmosis in plants

(1) The phenomenon of osmosis is important in the absorption of water by root hairs in the plants.
(2) The osmosis makes the cells turgid, which maintains the shape of leaves and other delicate parts of the plant.
(3) Opening and closing of stomata is affected by osmosis.
(4) Dehiscence of many fruits and sporangia occurs due to osmosis.
(5) Cell to cell movement of water occurs throughout the plant body due to osmosis.
(6) Drought and frost resistance of the cells in plants are maintained due to osmotic pressure.
(7) The movements in plants or plant organs are due to osmosis e.g. *Mimosa pudica*
(8) The growing regions of roots remain turgid due to osmosis, therefore roots can easily penetrate the soil.

Imbibition

Imbibition is considered as a special kind of diffusion in which the hydrophillic colloids can absorb water and swell. Actually, imbibition is the phenomenon of adsorption of water or any other liquid by the solid particles or a substance without forming a solution. Though the imbibing substance is solid but electron microscope can reveal minute pores in the substance. These are intermolecular spaces. For example, cell wall is having a network of cellulose microfibrils. The pores of network are partly filled with pectic substances. The water can easily diffuse through these pores. The process of imbibition is related to hydrophillic colloids such as cellulose. pectin and cytoplasmic proteins, which absorb water molecules, other colloidal particles of cytoplasm can also absorb water in this manner and swell. The swelling of the dry seeds and fruits are best examples of imbibition. The volume of these imbibants increase when they are soaked in water.



Significance of Imbibition

(1) Imbibition helps in seed germination, the kernel (endosperm or cotyledon) of seeds is proteinaceous or starchy whereas seed coat is made of cellulose. Therefore, seed coat swells comparatively less than the kernel and bursts, so that radicle comes out.

(2) The swelling of doors and windows of houses during rainy season, is the result of imbibition.

(3) In the absorption of water by roots of plants, the cell wall of root hairs adsorbs water by imbibition.

(4) In ancient times, pieces of dry woods were soaked in water and were inserted into cracks and crevices of rocks, the wood pieces imbibe water and swell up and this created so much pressure that the rocks broke.

Plasmolysis

If a plant cell is placed in a concentrated sugar or salt solution which is having concentration higher than cell sap (i.e., hypertonic solution), then water from the cell sap flows out due to exosmosis. This loss of water from cell sap causes contraction of the protoplasm of cell. Ultimately protoplasm separates from the cell wall and assumes spherical shape. This condition is called plasmolysis.

Deplasmolysis

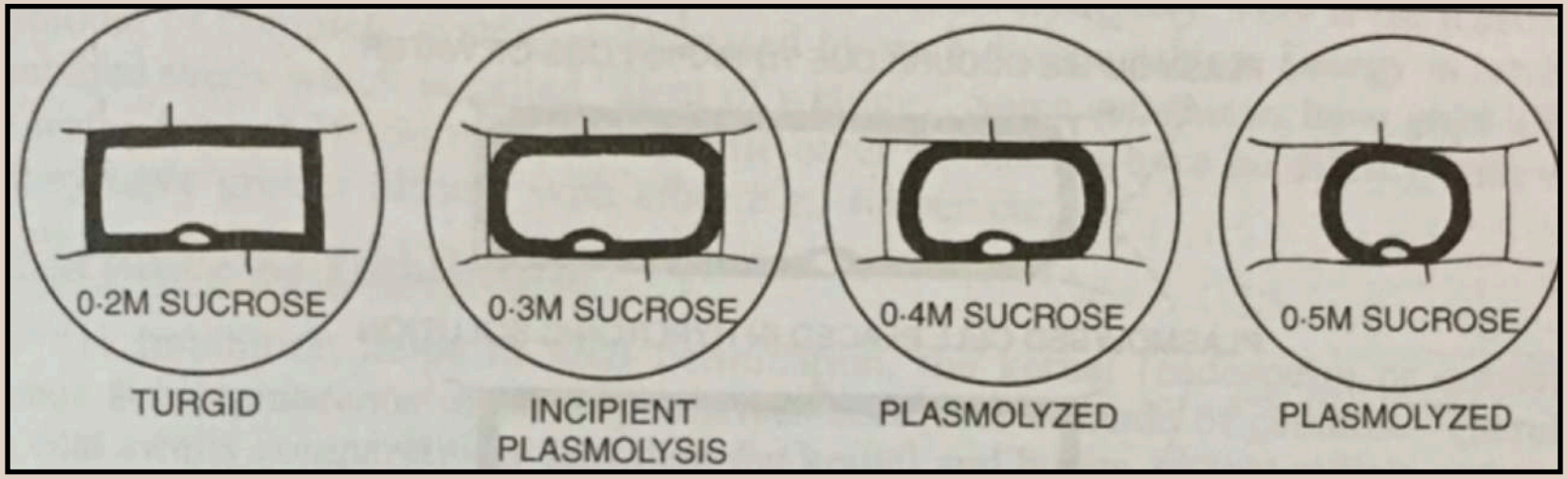
If a plasmolysed cell is placed in water or any hypotonic solution, then water enters into the cell by endosmosis. The protoplasm as well as the cell as a whole attains is original form and shape. This phenomenon is called deplasmolysis.

Significance of Plasmolysis

(1) Plasmolysis indicates whether cell is living or dead, because plasmolysis does not occur in dead cells.

(2) The osmotic pressure of the cell can be determined by this process.

(3) The plasmolysis can also indicate that plasma membrane is living and semipermeable in nature.



Absorption of water

All terrestrial plants absorb water from soil. The soil may have water in different forms, out of which capillary water is generally absorbed by plants.

Types of Soil Water

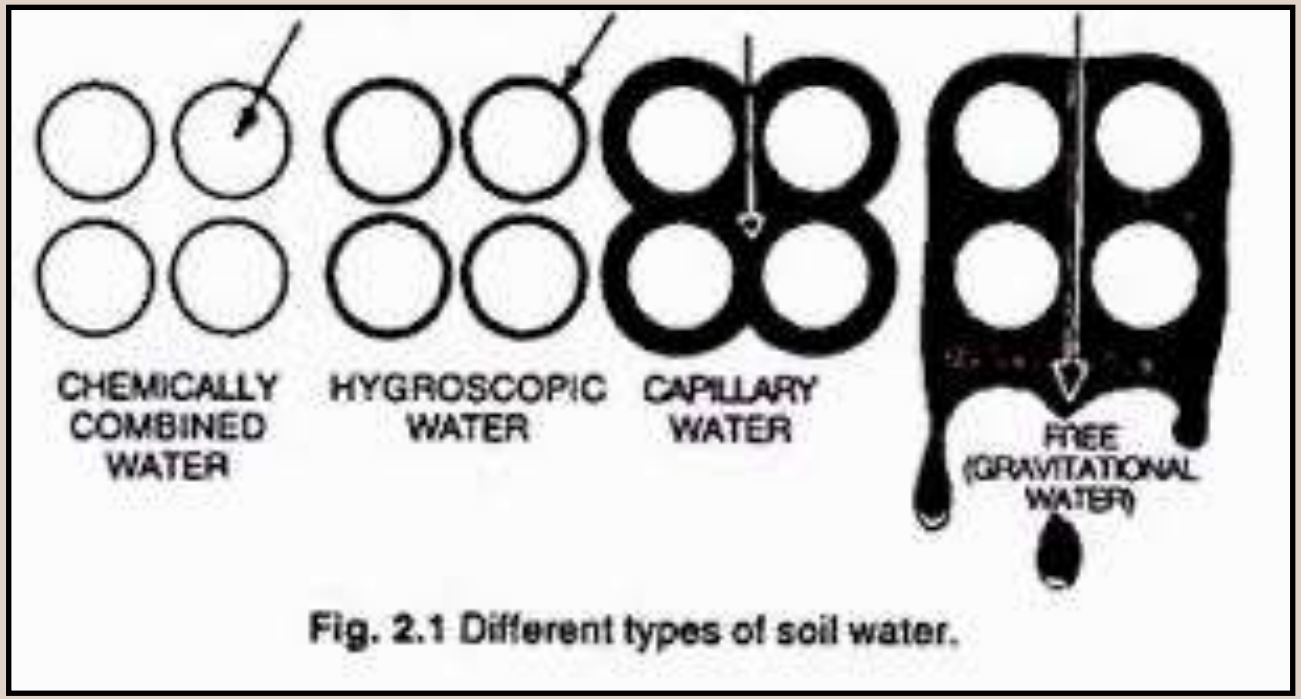
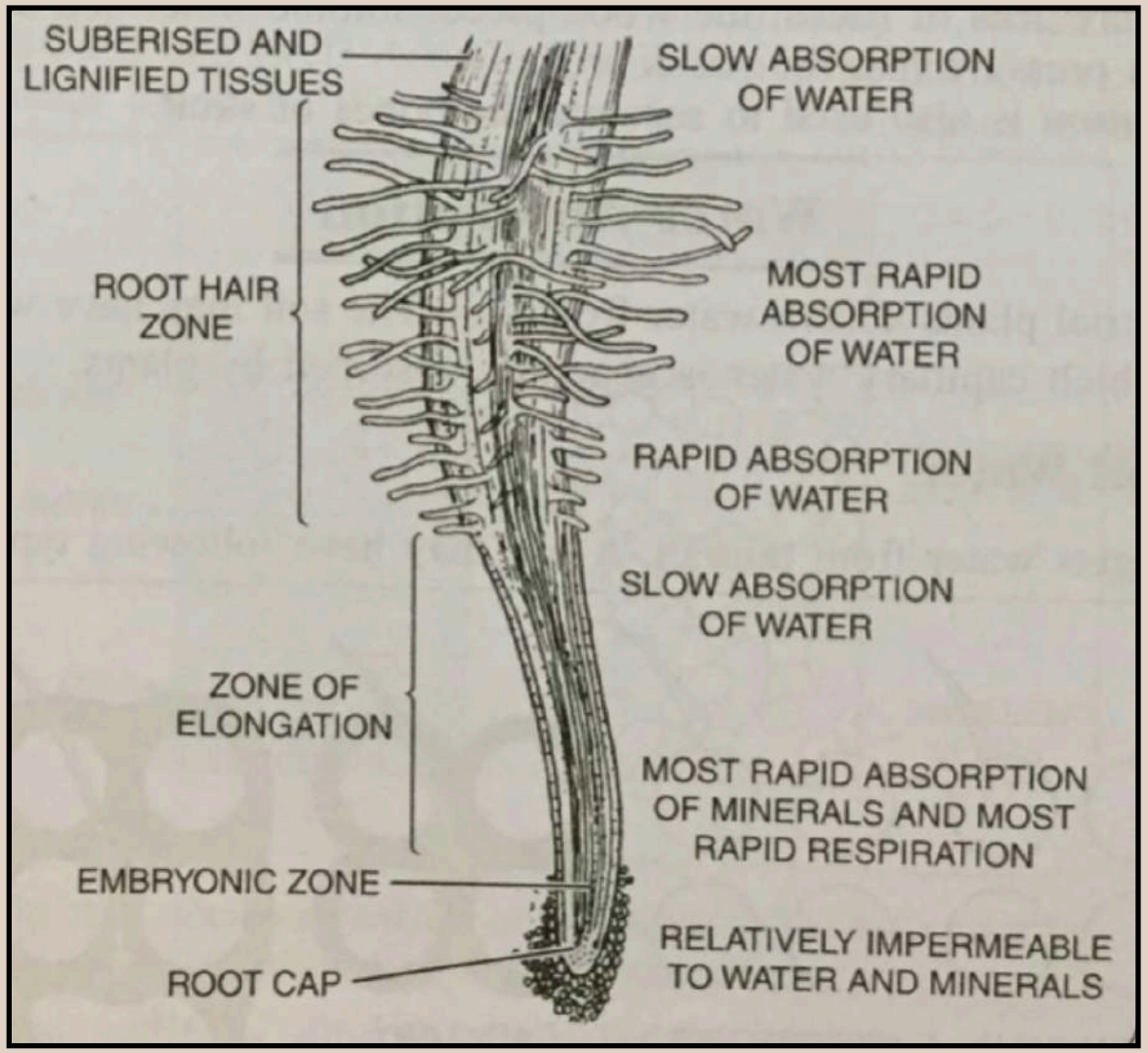
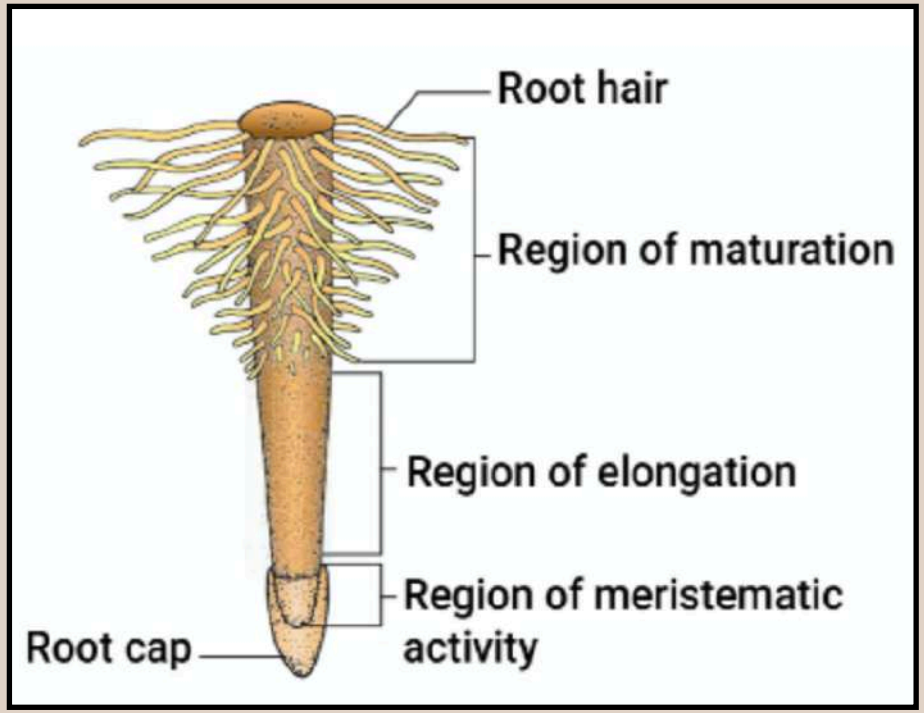


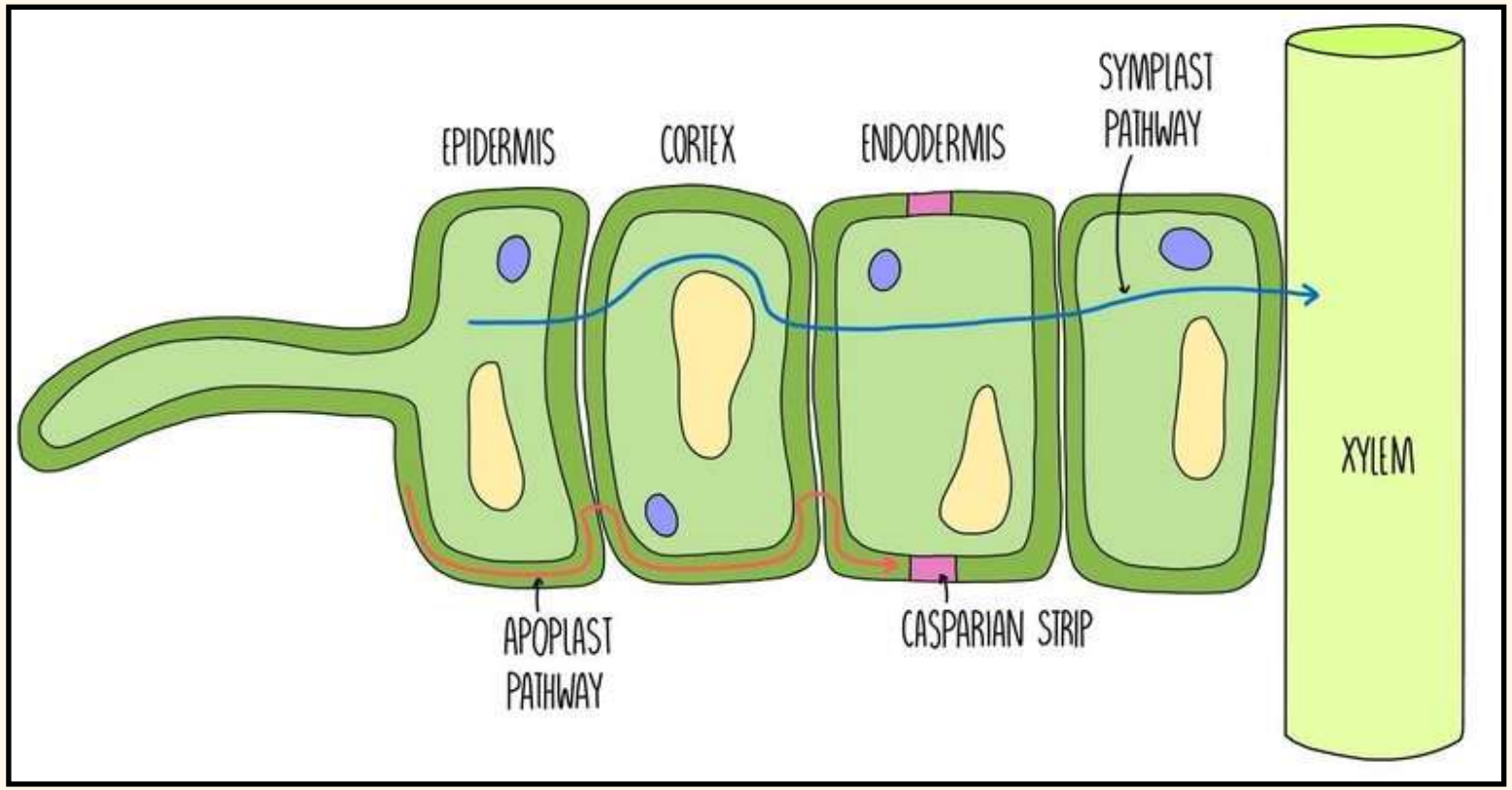
Fig. 2.1 Different types of soil water.

In plants, water is absorbed by roots but the entire surface of root is not involved in water absorption. It is only the root tip, which is concerned with water absorption. The root tip can be differentiated into the following parts :





Pathway of water in root



According to Kramer, absorption of water in plants takes place by two different methods-

(1) Active Absorption

It is absorbed due to the activity of root itself, particularly root hairs. The active water absorption can be of two types :

(A) Osmotic Theory of Active Absorption- According to osmotic theory, water absorption is related to gradient of diffusion pressure. If the xylem sap has higher osmotic
potential than that of soil solution then water is absorbed by the xylem of the root. This theory was proposed by Atkins (1916) and Priestley (1922) for the first time.

In this case, water is absorbed by endosmosis as the osmotic pressure of soil solution is about 1 atm. and the osmotic pressure of cell sap of root hair is 2-3 atm. Due to this difference of osmotic pressure, water enters into the root hair. The first step in this absorption is the imbibition of water by the cell wall of root hair. Then water and some solutes enter through the plasma membrane and peripheral cytoplasm of root hair and finally reach to cell sap of root hair. The water enters into the cell sap and to a lesser extent into the epidermal cells as long as the D.P.D. of root hair cells is higher than soil solution.

This view has not been supported by many scientists. In this type of water absorption energy is not involved but to maintain the balance of salts in root hair, some energy is used. So, it is osmotic active process.

(B) Non-Osmotic Theory of Active Absorption- Famous scientists Bennet Clark et al, (1936), Thimann (1951), Bogen & Prell (1953) believe that in plants active absorption of water takes place through non-osmotic process. They reported that absorption of water is opposite to the value of concentration gradient. Thus for such type of active absorption energy is required. This energy is released from the metabolic activities of root cells like respiration.

(2) Passive Water Absorption

In this case, water is absorbed due to the force orginating in the upper part of the plant by transpiration. The root cells play a passive role. Passive water absorption is regulated by transpiration. As the water is lost from leaf cells, their turgor pressure drops and their DPD is increased. Thus, they withdraw water from adjacent xylem cells, and consequently, a suction force is set up inside the xylem cells. It is well known that xylem of stem is continuous with the xylem of root, but it does not open directly into the soil. Actually, it is surrounded on all sides by living cells of pericycle, endodermis, cortex and epidermis of root. Thus, the suction developed due to transpiration at the tip of stem is transmitted down to root, as a result of which, water is absorbed by root hairs. The role of root is passive in this process, hence it is called passive absorption

Factors affecting Absorption

(1). Soil temperature- It is commonly observed that plants wilt due to increase or decrease in soil temperature. Water absorption is affected by soil temperature. Increase in temperature upto 30°-35°C increases the rate of water absorption. Beyond 39°-40° and below 18°C the rate of water absorption decreases.

(2) Soil air- Water absorption is smooth in porous soil. If the amount of air decreases in soil, the rate of water absorption also decreases. Poor aeration of soil adversely affects the metabolic processes of root.

(3) Soil water- water absorption is normal between field capacity and wilting percentage. If the amount of water is more than field capacity or less than wilting percentage, the rate of water absorption decreases.

(4) Concentration of mineral salts- The water can only be absorbed if the soil solution is hypotonic to cell sap of root hair. If the concentration of minerals is increased, the rate of water absorption decreases.

Ascent of Sap

Terrestrial plants usually absorb water from soil. A large portion of this water is lost by transpiration in plants and a small portion of it is used in metabolic activities like photosynthesis. After absorption by root hair cells, the water moves through cortex into the xylem cells of root.
Then water moves in upward direction and reaches various parts of plant body. This upward movement of water in plants is called conduction or translocation of water. This water is not conducted in pure form but it contains dissolved inorganic and organic substances. So, this is better called as xylem sap, and the movement of this sap in upward direction is called as ascent of sap.

Mechanism and theories of ascent of sap

Different views have been proposed by scientists to explain the mechanism of ascent of sap, which are as follows :
(1) Vital force theories,
(2) Root pressure theories,
(3) Physical force theories.
(1) Vital force theories- to understand the mechanism of ascent of sap, one should be familiar to the fact that maximum height of tree is 400 feet and raising water upto this height against gravitational force, requires a lot of force. Godlewski (1884) first of all proposed a vital theory, which suggests that living cells of xylem parenchyma show rhythmic change in the osmotic pressure, which causes upward movement of water. This is also known as "relay pump theory".

Strasburger (1893) discarded this theory as he pointed out that ascent of sap continues even after killing xylem parenchyma cells. Sir J. C. Bose was a famous scientist. In 1923, he proposed a vital theory to explain the ascent of sap in plants. He invented an electrical probe by which the activity of cell inside the plant body can be detected. With the help of this probe, Dr. Bose concluded that cells of innermost layer of cortex show pulsatory activity i.e., regular expansion and contraction. This activity is responsible for ascent of sap in plants.

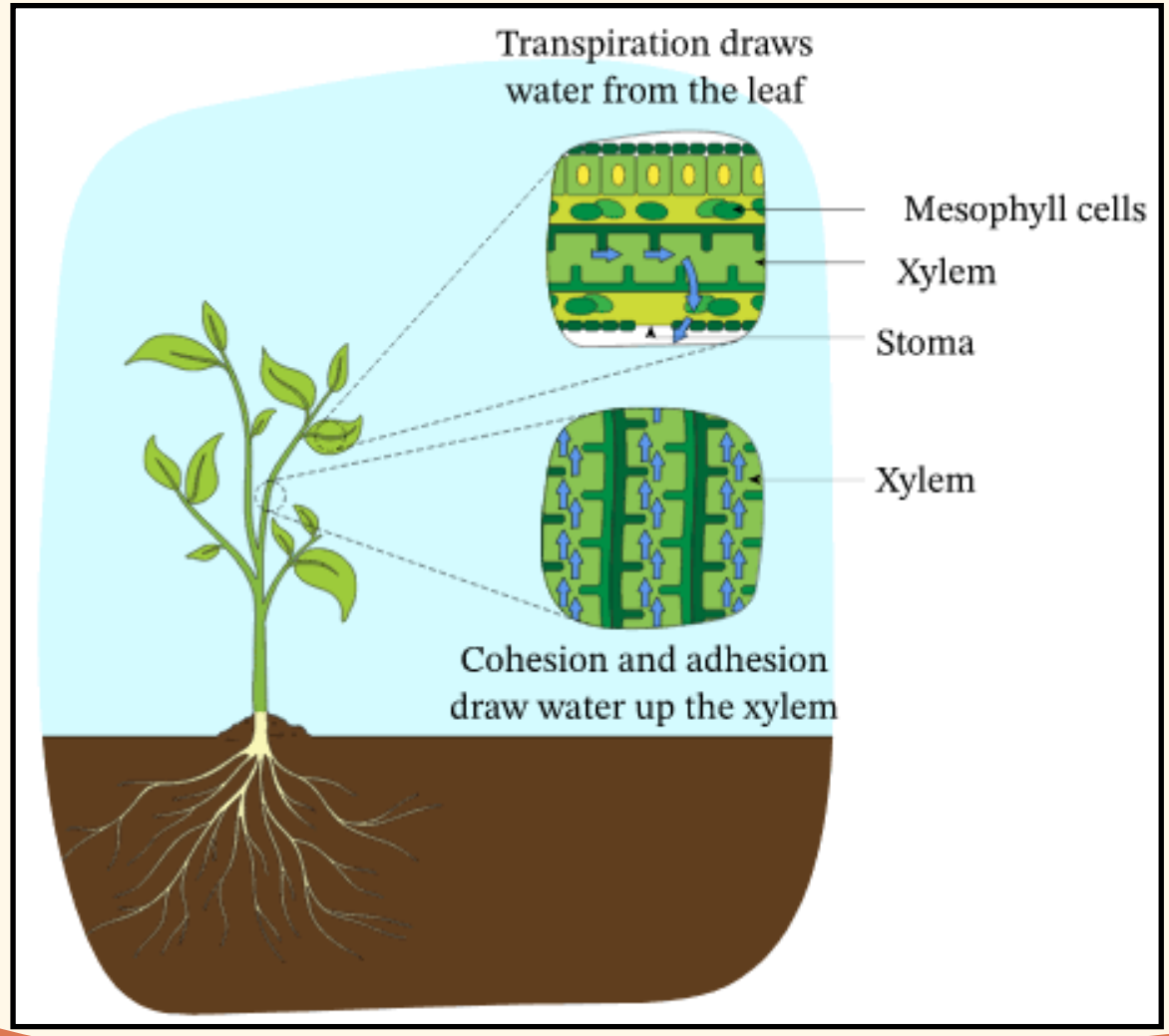
(2) Root pressure theory-The proponents of this theory suggested that ascent of sap occurs due to root pressure. However, the root pressure is absent in coniferous trees, which attain considerable height. Thus, this idea was discarded considering the fact that root pressure is about 2 atm and in some plants, this pressure is absent.

(3) Physical force theories- These theories are based on the fact that some physical force is involved in this process. The following theories are included in this heading:

- Capillary force theory- this theory was proposed by Boehm (1809). According to this theory, xylem vessels act like capillary tubes. As the water rises in capillary tube due to capillary action, the water also rises in xylem vessels. This theory has now been rejected because the magnitude of capillary force is too low. Further, the vessels have more diameter than capillary tube and therefore ascent of sap to desired height cannot occur.
- Imbibition theory- this theory was proposed by Sachs (1878). According to this theory, the rise of water takes place due to imbibition force through the walls of xylem cells. Later, it was shown that water moves through the lumen of cell and not through the walls and therefore, this theory was discarded.
- Transpiration Pull and Cohesion theory or Cohesion theory of Dixon and Jolly- This theory was proposed by Dixon and Jolly in 1894. This theory is the most modern, important and acceptable. This theory is basically based on the following Two Points :

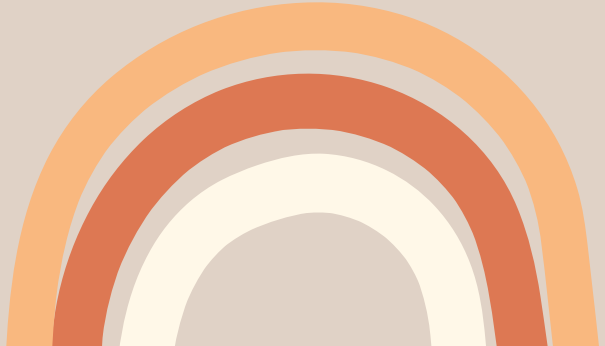
(a) A continuous column of water is formed in xylem due to the cohesive and adhesive properties of water molecules.

(b) The transpiration pull or tension affects this water column.


Transpiration draws water from the leaf
Mesophyll cells
Xylem
Stoma
Xylem
Cohesion and adhesion draw water up the xylem

THANK YOU!

♥



Name : MALLIKA SINGH PARIHAR
Class : Bsc. Final year
Subject : Botany CCE ASSIGNMENT 1
Topic : ENZYMES

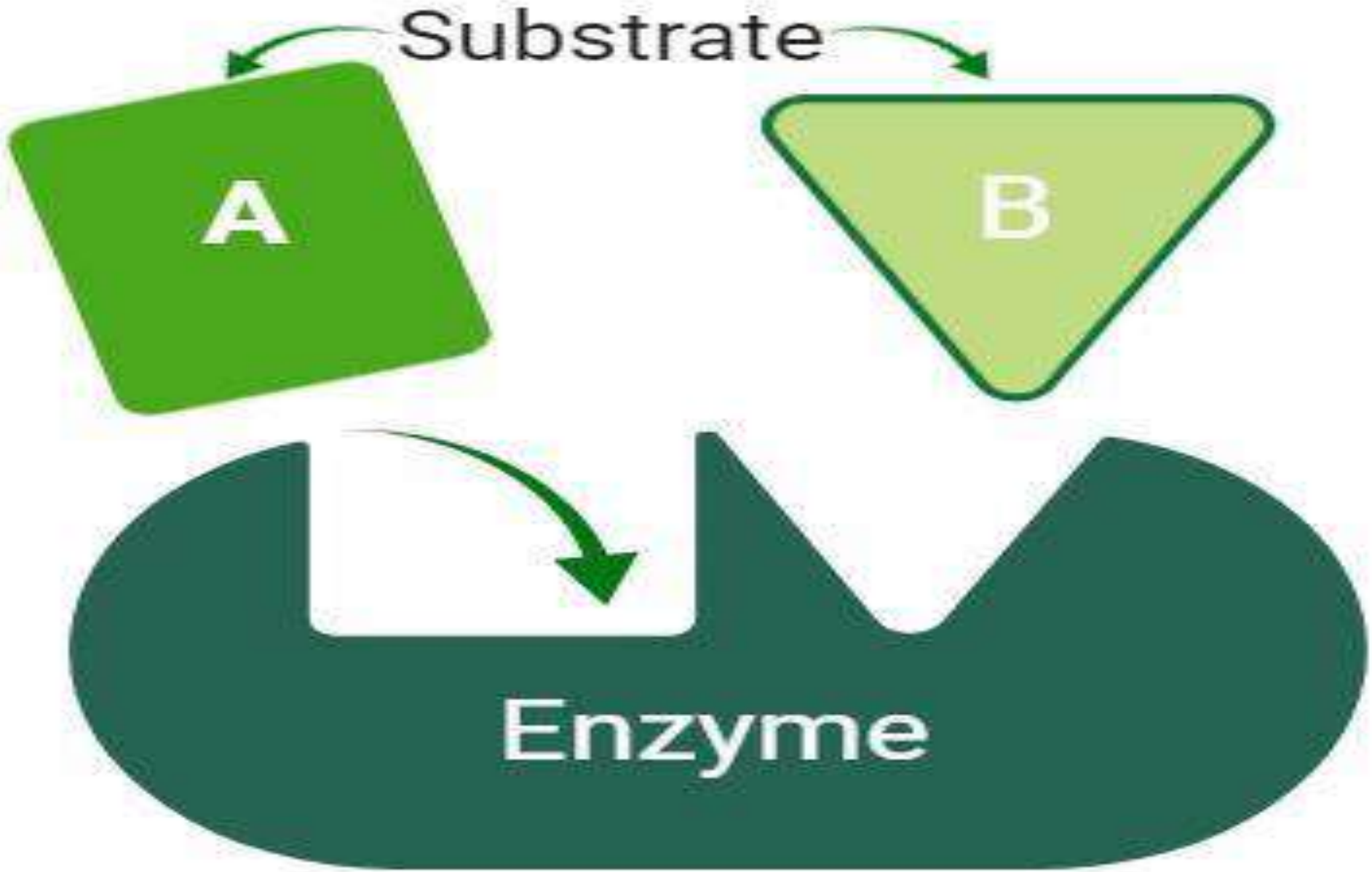
Basics of Enzymology
THE ENZYMES.

ENZYMES

Kuhne coined the term enzyme in 1878. (en = in ; zyma = yeast).

The chemical structure of enzyme was studied by J.B SUMNER in the year 1926.

J.B Sumner , Northop, Stanley recieved NOBLE PRIZE for their work in the year 1947.


Substrate
A
B
Enzyme

TERMINOLOGY

- **SUBSTRATE**

The surface or substance on which the enzyme acts upon is called as SUBSTRATE.

- **PRODUCT**

The substance that is obtained at the end of a chemical reaction is called as a Product.

- **ACTIVATION ENERGY**

The minimum required kinetic energy of a particles substance to initiate the chemical reaction is called as Activation Energy.

- **ACTIVE SITE OF ENZYME**

The part of the enzyme that is responsible for a chemical reaction is termed as Active Sites.

OCCURRENCE OF ENZYMES

- As we know that enzymes are synthesised inside the cell under genetic control.
- Though they are synthesised inside the cell but their acting sites can be different.
- Based on their activity enzymes are classified as --
- (¡) **Endoenzymes** = that act inside the cell , also called intracellular enzymes .for example : in higher organisms
- (¡¡) **Exoenzymes** = that act outside the cell , also called extracellular enzymes . For example : in bacteria , protozoa , insectivorous plants.

CLASSIFICATION OF ENZYMES

- **On the basis of the reaction catalysed enzymes are classified as. :-**

- (1) **Hydrolysing Enzymes**
- These break the substrate in the presence of water.
Example : carbohydrase enzyme for the hydrolysis of carbohydrates etc.

- (2) **Desmolysing Enzymes**
- These take part in reactions other than Hydrolysing reaction are desmolysing enzymes . Example : hydrases that add H20 etc.

MODERN CLASSIFICATION

INTERNATIONAL UNION OF BIOCHEMISTRY

The International Union of Biochemistry and Molecular Biology is an international non-governmental organisation concerned with biochemistry and molecular biology. Formed in 1955 as the International Union of Biochemistry, the union has presently 79 member countries and regions.

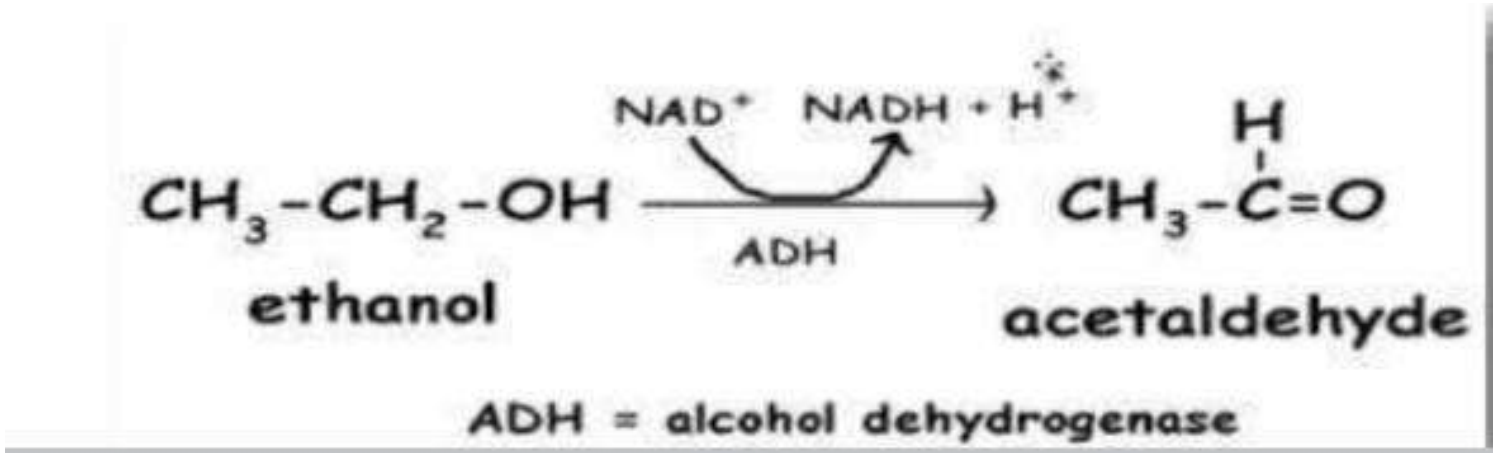
IUBMB CLASSIFICATION

6 TYPES OF ENZYMES HAVE BEEN RECOGNISED BY THE INTERNATIONAL UNION OF BIOCHEMISTRY WHICH ARE AS FOLLOWS :-

- OXIDOREDUCTASES
- TRANSFERASES
- HYDROLASES
- LYASES
- ISOMERASES
- LIGASES

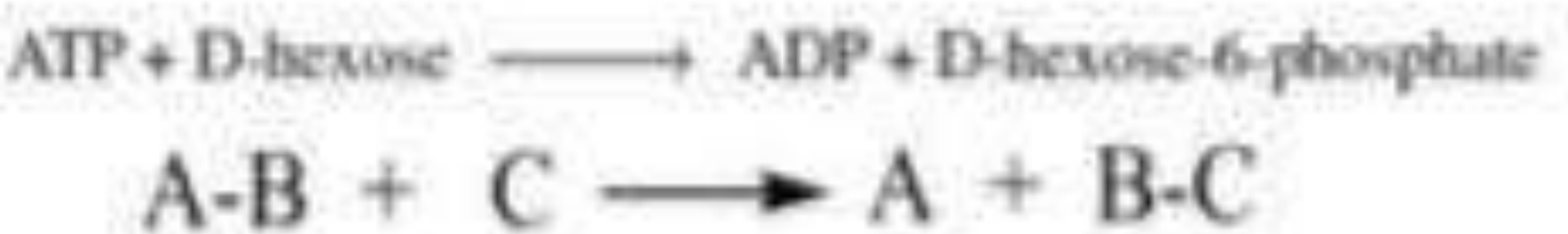
OXIDOREDUCTÀSES

These enzymes take part in biological oxidation processes .
In this process electrons or hydrogen or both are transferred from one substrate to the other.



TRANSFERASES

These enzymes catalyse the transfer of a particular group from one molecule of substrate to molecule of another substrate.



HYDROLASES

, These enzymes catalyse hydrolysis of various substrates with the help of water. As a result of hydrolysis, complex substrate is broken down to simple and small molecules.

LYASES

Enzymes of this group are similar to hydrolases and catalyse the degradation substrate molecules. In case of hydrolases, water is essential for while case of lyases enzymes, water is not required for degradation.

Isomerases

The enzymes of this class catalyse isomerization i.e., internal rearrangement in the molecules of a compound.

LIGASES

The enzymes of this class catalyse the synthesis of a compound by condensation of two or more molecules. In these reactions, ATP are required.

CHARACTERISTICS OF ENZYMES

1. CATALYTIC NATURE

Catalysts are those compounds which speed up the rate of chemical reactions, but they are neither destroyed nor used up in the process.
They are effective in very small quantity.

2.REVERSIBILITY OF REACTION

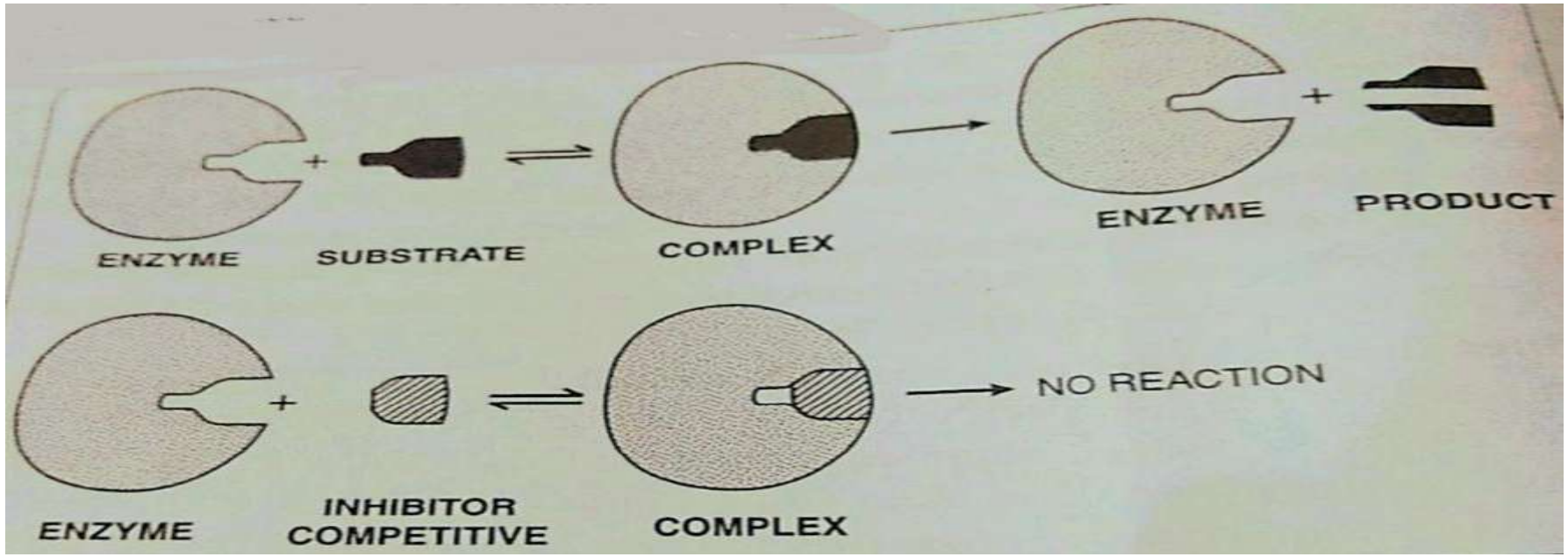
The enzymes have the ability to carry out a reaction either in forward or backward reaction.

3. SPECIFICITY OF ENZYMES

Enzymes are highly specific in nature-Many enzymes become inactive at the moderate temperature 60-70°C.
Initially, when enzymes are in moist they are inactivated by heat.

4. INHIBITION BY POISON

The mode the mode of action of enzymes is inhibited which is called inhibition this process may take place by various means which may be reversible or Irreversible



5.COLLOIDAL NATURE

The diameter of enzyme is equal to the measurement of colloidal particles.
The enzymes have the capacity to increase in the surface area.
The entire surface of the enzyme molecule takes part in this process.

HOLOENZYME , APOENZYME & PROSTHETIC GROUP

HOLOENZYME

Enzymes are composed of two parts. The protein part and a non protein part, such enzymes are called holoenzymes.

APOENZYME

The major part of enzyme is the protein part called Apoenzyme.

PROSTHETIC GROUP

When a non protein part is tightly bound to apoenzyme then it is called prosthetic group.

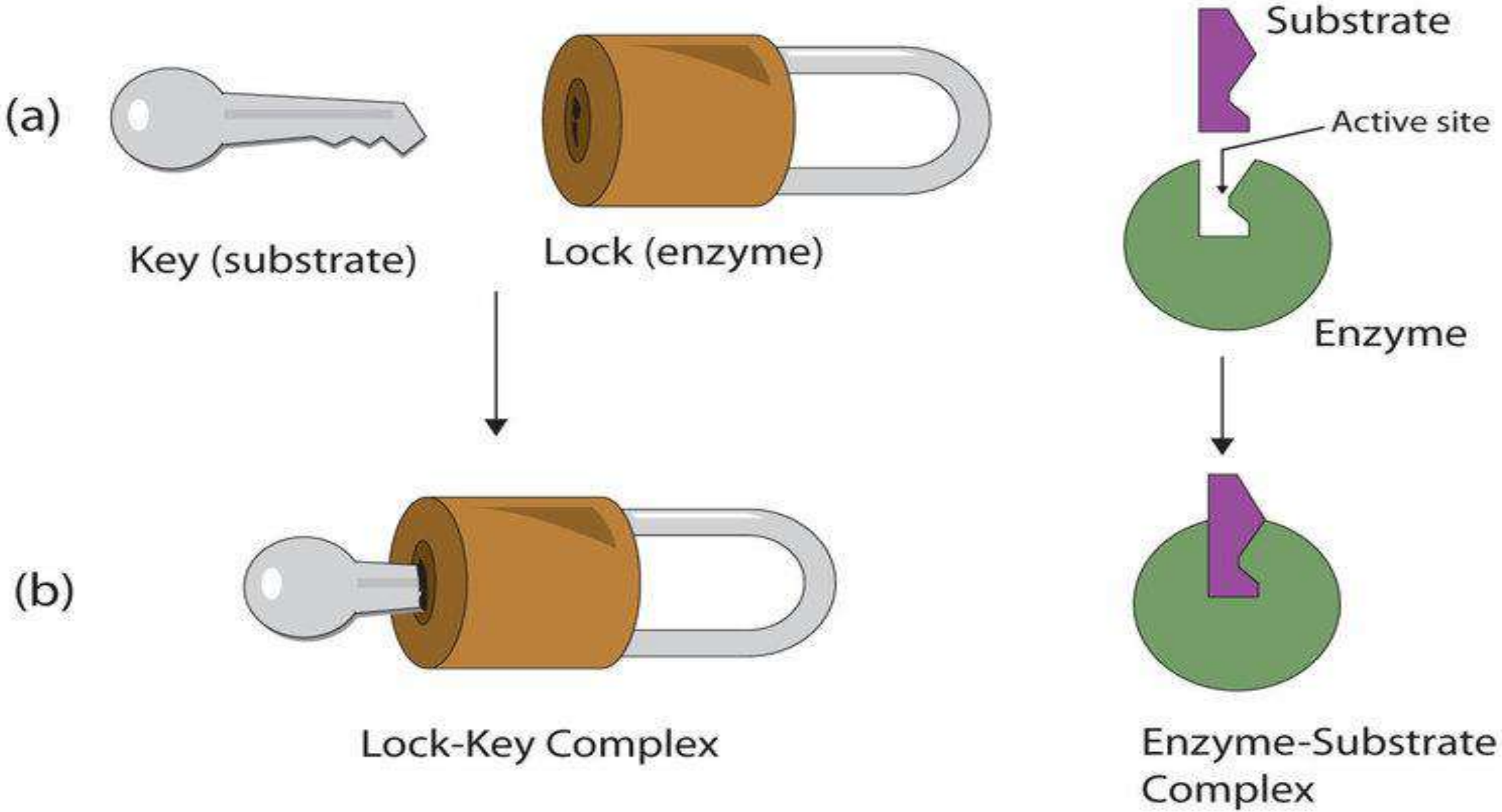
MECHANISM OF ENZYME ACTION

LOCK AND KEY MODELo

Proposed by EMIL FISCHER in 1894

{1} Lock and key hypothesis assumes that the active site of an enzyme are rigid in its shape.

{2} There is no change in the active site before and after a chemical reaction.

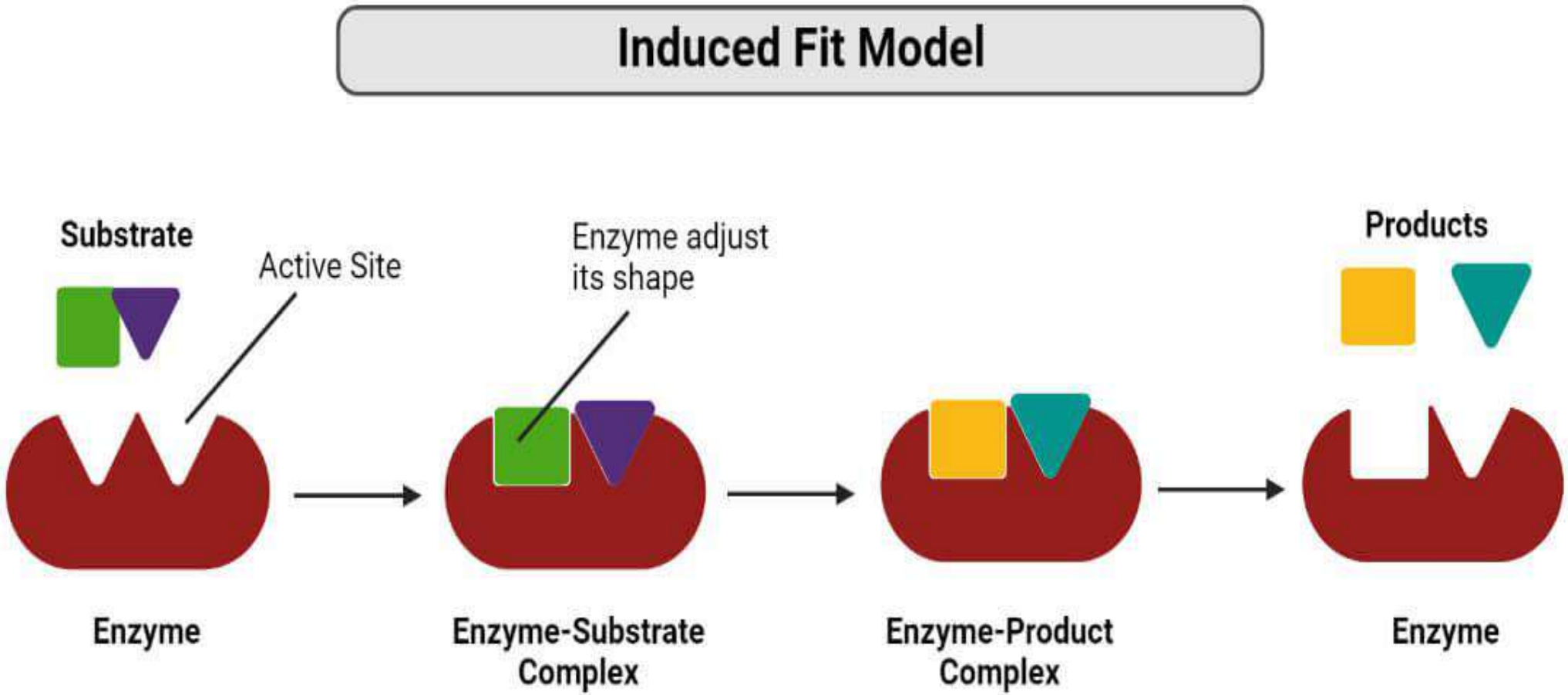

(a)
Key (substrate)
Lock (enzyme)
(b)
Lock-Key Complex
Substrate
Active site
Enzyme
Enzyme-Substrate Complex

MECHANISM 2

INDUCED FIT MODEL

(proposed by DANIAL KOSH LAND in 1958).

According to this exposure of an enzyme to substrate cause a change in enzyme, which causes the active site to change it's shape to allow enzyme and substrate to bind.


Induced Fit Model
Substrate
Active Site
Enzyme adjust its shape
Products
Enzyme
Enzyme-Substrate Complex
Enzyme-Product Complex
Enzyme

FACTORS AFFECTING ENZYME ACTIVITY

The factors that affect the inside activity of enzymes are as follows :-

1. Temperature

2. Substrate Concentration

3. Enzyme Concentration

4. Hydrogen ion Concentration