



Government of Tamilnadu
Department of Employment and Training

Course : TNPSC Group I Exam
Subject : Botany
Topic : **Respiration**

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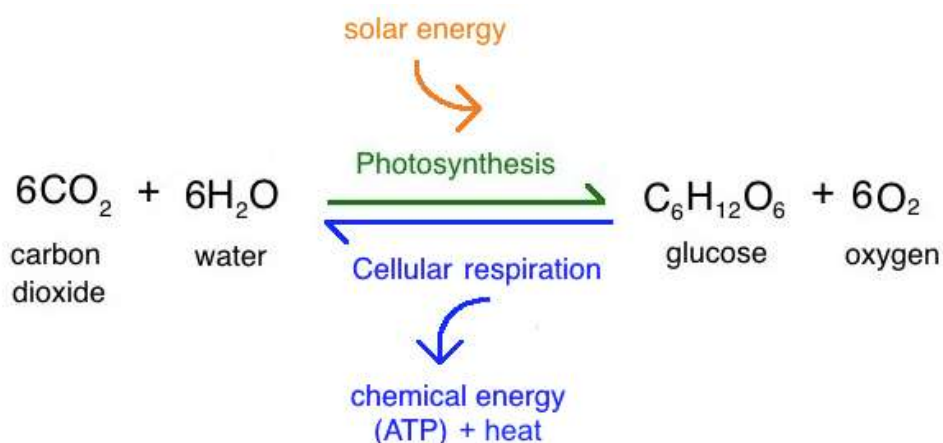
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RESPIRATION

PHOTOSYNTHESIS

- ❖ Photosynthesis is referred as photochemical oxidation and reduction reactions carried out with help of light, converting solar energy into Chemical energy.
- ❖ It is the most important anabolic process.
- ❖ The overall chemical equation for photosynthesis is:



HISTORY OF PHOTOSYNTHESIS

- **1727 Stephen Hales** recognised the importance of light and air in the nourishment of plants.
- **1779 Jan Ingen-Housz** discovered that the green parts of the plant purify the polluted air in the presence of light.
- **1782 Senebier** showed that as the concentration of CO_2 increases, the rate of O_2 evolution also increases.
- **1845 Von Mayer** recognised that green plants convert solar energy into chemical energy of organic matter.
- **1845 Liebig** pointed out that the organic matter was derived from CO_2 and water.
- **1920 Warburg** introduced the unicellular green alga *Chlorella* as a suitable material to study photosynthesis.

- **1932 Emerson** and Arnold showed that the existence of light and dark reactions in photosynthesis.
- **1937 Hill** demonstrated photolysis of water by isolated chloroplasts in the presence of suitable electron acceptor.
- **1941 Ruben and Kamen** Used ^{18}O radioactive Oxygen to prove that oxygen evolves from water
- **1954 Arnon, Allen** and Whatley used $^{14}\text{CO}_2$ to show fixation of CO_2 by isolated chloroplasts.
- **1954 Calvin** traced the path of carbon in photosynthesis and gave C_3 cycle (Calvin cycle) and was awarded Noble prize in 1960.
- **1965 Hatch and Slack** reported the C_4 pathway for CO_2 fixation in certain tropical grasses.

SIGNIFICANCE OF PHOTOSYNTHESIS

1. Photosynthetic organisms provide food for all living organisms on earth either directly or indirectly.
2. It is the only natural process that liberates oxygen in the atmosphere and balances the oxygen level.
3. Photosynthesis balances the oxygen and carbon cycle in nature.
4. Fuels such as coal, petroleum and other fossil fuels are from preserved photosynthetic plants.
5. Photosynthetic organisms are the primary producers on which all consumers depend for energy.
6. Plants provide fodder, fibre, fire wood, timber, useful medicinal products and these sources come by the act of photosynthesis.

SITE OF PHOTOSYNTHESIS

- ❖ Chloroplasts are the actual sites for photosynthesis.
- ❖ All green parts of a plant are involved in photosynthesis.
- ❖ Leaves are the most important organs of photosynthesis.

Difference between C₃ and C₄ photosynthetic pathways

C ₃ pathway	C ₄ pathway
Photosynthesis occurs in mesophyll cells.	Photosynthesis occurs in mesophyll and bundle sheath cells
The CO ₂ molecule acceptor is RuBP	The CO ₂ acceptor molecule is phosphoenol pyruvate.
The first stable product is a 3° C compound called 3 - PGA	The first stable product is a 4C compound called OAA.
Photorespiration rate is high and leads to loss of fixed CO ₂ It decreases CO ₂ fixation rate	Photorespiration is negligible and it is almost absent. Hence, it increases CO ₂ fixation rate.
Optimum temperature is 20°C to 25°C.	Optimum temperature is 30 to 45°C.
Examples of C ₃ plants are rice, wheat and potato.	Examples of C ₄ plants are maize, sugarcane, Tribulus and Amaranthus

Difference between photorespiration and dark respiration

Photorespiration	Dark respiration
It takes place only in photosynthetic cells in the presence of light.	It takes place in all living cells in the mitochondria.
It is light dependent	It takes place in the presence and in the absence of light.
It is the function of chloroplast, peroxisomes and mitochondria	It is the function of mitochondria alone.

RESPIRATION

A process in living organisms involving the production of energy, typically with the intake of oxygen and the release of carbon dioxide from the oxidation of complex organic substances is called Respiration.

The term respiration was coined by Pepys (1966).

- ❖ Respiration is a biological process in which oxidation of various food substances like carbohydrates, proteins and fats take place and as a result of this, energy is produced where O₂ is taken in and CO₂ is liberated.
- ❖ The compounds that are oxidised during this process are known as respiratory substrates.
- ❖ Carbohydrate is the common respiratory substrate.
- ❖ Breaking of C-C bonds of complex organic compounds through oxidation within the cells leads to energy release.
- ❖ During respiration, the whole energy contained in the respiratory substrate is not released all at once.
- ❖ In respiration, oxygen is utilized and carbondioxide, water and energy are released.
- ❖ Respiration is an exothermic reaction and the oxidation of glucose is given in the following equation.

$$\text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \longrightarrow 6\text{CO}_2 + 6\text{H}_2\text{O} + \text{Energy (2900kJ)}$$
- ❖ The energy released during this process is transformed into usable form of energy as adenosine triphosphate (ATP).
- ❖ ATP molecules act as carriers of free energy between energy yielding and energy requiring reactions of the cell.
- ❖ ATP is described as energy currency of the cell.
- ❖ It is a nucleotide consisting of adenine, ribose sugar and three phosphate groups.
- ❖ It is an energy rich compound and contains two high energy terminal bonds.
- ❖ A large amount of free energy is liberated, when these bonds are broken by hydrolysis

Types of Respiration

Respiration is classified into two types as aerobic and anaerobic respiration

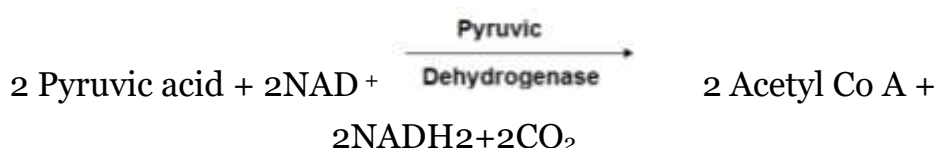
AEROBIC RESPIRATION

- Respiration occurring in the presence of oxygen is called **aerobic respiration**.

- During aerobic respiration, food materials like carbohydrates, fats and proteins are completely oxidised into CO_2 , H_2O and energy is released.
- Aerobic respiration is a very complex process and is completed in four major steps:
 1. Glycolysis
 2. Pyruvate oxidation (Link reaction)
 3. Krebs cycle (TCA cycle)
 4. Electron Transport Chain (Terminal oxidation).

Glycolysis

- ❖ The process by which the glucose (6C compound) is split into two molecules of pyruvic acid (3C compound) is called glycolysis.
- ❖ Three German Microbiologists – Embden, Meyerhof and Parnas, first demonstrated this process in yeast cell.
- ❖ Hence, it is otherwise known as EMP pathway. **It occurs in cytoplasm.** It is common in all organisms.
- ❖ In glycolysis, 4ATP and 2 NADH_2 molecules are formed and 2ATP molecules are consumed in hexose phase. Hence, the net gain is 2ATP and 2 NADH_2 .
- ❖ The two molecules of pyruvic acid formed from a glucose molecule move into mitochondria and are oxidized, decarboxylated to two molecules of acetyl coenzyme A (acetyl Co~A).
- ❖ These 2 carbon compounds are formed by decarboxylation and dehydrogenation.
- ❖ This reaction is catalyzed by pyruvic dehydrogenase and two molecules of NAD^+ are reduced to NADH_2 .
- ❖ During this reaction two molecules of CO_2 are released.
- ❖ Oxidative decarboxylation of pyruvic acid occurs only under aerobic condition. Under anaerobic conditions, the pyruvic acid is reduced either to lactic acid or ethyl alcohol depending on the nature of the organism.



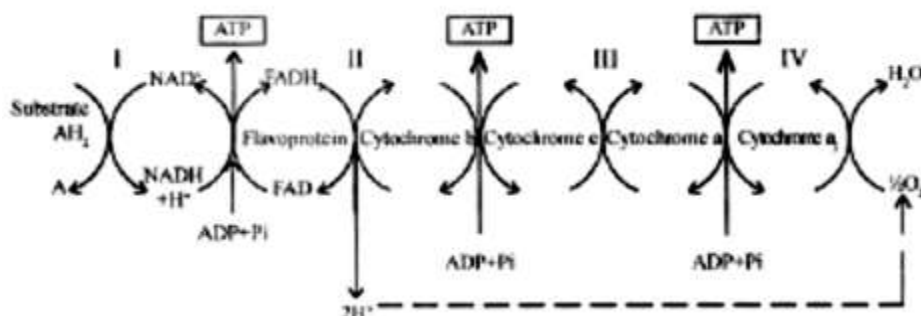
- ❖ In 1937, Sir Hans Adolf Krebs described the catalytic role of pyruvic acid for the production of energy in the cell.
- ❖ The series of cyclic reactions involved in converting pyruvic acid to carbondioxide and water in mitochondria is called Krebs cycle.
- ❖ It is also known as citric acid cycle or tricarboxylic acid cycle – TCA cycle.

Significance of Krebs cycle

- ❖ 2 molecules of acetyl CoA enter into Krebs cycle which on subsequent oxidation generate 6NADH₂, 2FADH₂.
- ❖ When 6NADH₂, 2FADH₂ enter into the electron transport system generate 22ATP molecules. In one step, there is substrate level phosphorylation which directly yield 2ATP molecules.
- ❖ So, during Krebs cycle, every 2 molecules of acetyl CoA enter into Krebs cycle 24 ATP molecules are generated. So, primarily it is a energy producing system.
- ❖ Since, Krebs cycle involves with both anabolic and catabolic processes, it is also described as amphibolic process.

Electron transport chain

- ❖ Electron transport system (ETS) is a chain of electron carriers consisting of NAD⁺, FAD⁺, CoQ and cytochromes (cyt. b, cyt. c, cyt. a and cyt.a₃).
- ❖ The glucose molecule is completely oxidized by the end of the citric acid cycle.
- ❖ But, energy is not released, unless NADH₂ and FADH₂ are oxidized through electron transport system.
- ❖ Transfer of electrons and protons from NADH₂ and FADH₂ to oxygen through a series of components like flavoprotein, cytochrome is called electron transport chain.
- ❖ This process leads to coupling of electrons to form high-energy phosphate bonds in the form of ATP from ADP is called oxidative phosphorylation.
- ❖ The electron transport components are arranged in the inner membrane of mitochondria.



Energy yield

- ❖ Complete oxidation of one glucose molecule yields a net gain of 38ATP.
- ❖ Out of 38ATP molecules, 4ATP are obtained by direct substrate level phosphorylation, 30ATP through oxidation of NADH₂ and 4ATP through oxidation of FADH₂.
- ❖ Since, a large number of ATP molecules are produced in the mitochondria, they are called the 'power houses of the cell'.

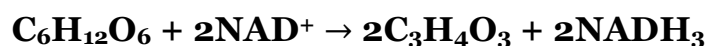
No.	Stages of respiration	Number of molecules of			Total number of ATP NADH obtained
		ATP	NADH ₂	FADH ₂	
1.	Glycolysis	2	2	-	8
2.	Oxidative decarboxylation of pyruvic acid	-	2	-	6
3.	Krebs cycle	2	6	4	24
	total	4	30 ATP	4 ATP	38

Significance of pentose phosphate pathway

- ❖ It provides alternative route for carbohydrate breakdown.
- ❖ It generates NADPH₂ molecules which are used as reductants in biosynthetic processes. Production of NADPH₂ is not linked to ATP generation in pentose phosphate pathway.
- ❖ It provides ribose sugar for the synthesis of nucleic acids.
- ❖ It provides erythrose phosphate required for the synthesis of aromatic compounds.
- ❖ It plays an important role in fixation of CO₂ in photosynthesis through Ru5P.

Anaerobic respiration

- ❖ Anaerobiosis means life in the absence of oxygen. Certain organisms can survive in the absence of oxygen.
- ❖ The respiration which takes place in the absence of free oxygen molecules is called anaerobic respiration.
- ❖ It occurs in yeast and some bacteria. Hence, they are known as anaerobes.
- ❖ Glycolysis alone occurs in these organisms.
- ❖ The splitting of glucose into two molecules of pyruvic acid is given in the following equation.



Respiratory quotient

- ❖ Respiratory quotient may be defined as “the ratio between the volume of carbondioxide given out and oxygen consumed during respiration”.
- ❖ This value depends upon the nature of the respiratory substrate and its rate of oxidation.

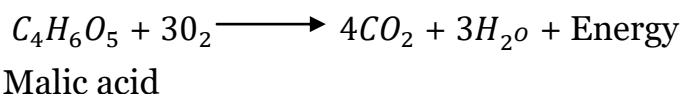
$$\text{Respiratory quotient} = \frac{\text{Volume of } \text{CO}_2 \text{ evolved}}{\text{Volume of } \text{O}_2 \text{ consumed}}$$

Respiratory quotient of a carbohydrate



$$\text{Respiratory quotient of glucose} = \frac{6 \text{ moles of } \text{CO}_2}{6 \text{ moles of } \text{O}_2} = 1$$

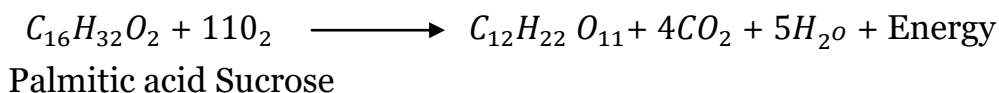
Respiratory quotient of an organic acid



$$\text{Respiratory quotient of malic acid} = \frac{4 \text{ moles of } \text{CO}_2}{3 \text{ moles of } \text{O}_2} = 1.33$$

(more than one)

Respiratory quotient of fatty acid

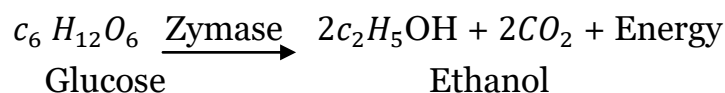


$$\text{Respiratory quotient of palmitic acid} = \frac{16 \text{ moles of } \text{CO}_2}{11 \text{ moles of } \text{O}_2} = 0.36 \text{ (less than one)}$$

Respiratory quotient for anaerobic respiration

- ❖ In anaerobic respiration, carbondioxide is evolved but oxygen is not consumed.

- ❖ Therefore, the respiratory quotient in such case is infinity. For example,

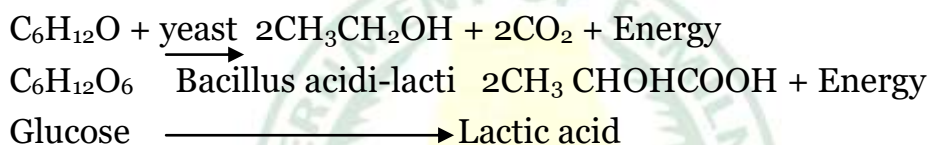


Respiratory quotient of

$$\text{glucose in anaerobic respiration} = \frac{2 \text{ moles of } CO_2}{\text{zero moles of } O_2} = \infty \text{ (infinity)}$$

Fermentation

- ❖ Fermentation literally means a chemical change accompanied by effervescence.
- ❖ The anaerobic breakdown of glucose to carbondioxide and ethanol is a form of respiration referred to fermentation.
- ❖ It is normally carried by yeast cells and accounts for the production of alcohol in alcoholic beverages.



- ❖ When glucose is converted into organic acids such as lactic acid, then this type of fermentation is known as lactic acid fermentation.
- ❖ It is carried out by the bacterium Bacillus acidilacti.