DAY SIXTEEN

Respiration in Plants

Learning & Revision for the Day

- Cellular Respiration
- Anaerobic Respiration
- Aerobic Respiration
- Respiratory Quotient
- Factors Affecting Respiration

- The term 'respiration' was coined by **Dutrochet**. It is the process of breakdown of complex molecules to yield energy.
- **Respiration** is a catabolic process of oxidation-reduction reaction, in which the complex organic food materials are broken down to form simpler end products with stepwise release of energy and carbon dioxide.

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + \text{Energy (686 kcal)}$$

- Respiration comprise of two phases. First phase is **gaseous exchange** between environment and organism through body surface such as through stomata and lenticels in plants or special respiratory organs as in higher animals and humans and the second phase is **cellular respiration**.

Cellular Respiration

- It takes place in cytoplasm and mitochondria. It is defined as the most important, cellular, enzymatically controlled, catabolic, exergonic process which involves the stepwise oxidative breakdown of organic molecules to liberate energy, i.e. ATP (energy currency of cell), inside the living cells.
- The organic molecules that undergo oxidation during respiration, to release energy are called **respiratory substrates**, e.g. carbohydrates are the main substrates oxidised to yield energy, followed by fat and lastly, the proteins, used in special circumstances only. Efficiency of cellular respiration is 45%. 114.5 kcal energy is obtained by oxidation of each oxygen molecule.
- On the basis of requirement of oxygen, cellular respiration can be classified into two types–Anaerobic respiration and aerobic respiration.

1. Anaerobic Respiration

- It is an incomplete degradation of organic food without using oxygen, therefore, the end products are never completely inorganic.
- The term '**anaerobic respiration**' is often used in relation to higher organisms as in roots of some plants, muscles of animals or in massive tissues as supplementary mode of respiration.
- But, it is exclusive mode of respiration in many prokaryotes, several unicellular eukaryotes and moulds and is referred to as fermentation.

Fermentation

It is the general term for such processes which extract energy (as ATP), but do not consume oxygen or change the concentration of NAD^+ or NADH. It is similar to anaerobic respiration. Generally, the fermentation is of four types

(i) **Alcoholic fermentation** (common in yeast) The breakdown of the substrate takes place outside the cell to from ethyl alcohol, CO_2 and energy. It is used in brewing industry.

$$C_6H_{12}O_6 \xrightarrow{\text{Enzyme}} 2CO_2 + 2C_2H_5OH \text{ (ethyl alcohol)} + 59 \text{ kcal}/247 \text{ kJ (energy)}$$

(ii) **Lactic acid fermentation** (common in *Lactobacillus*) Here, pyruvate is converted into lactic acid, NAD and energy using Lactic Acid Dehydrogenase (LDH). It is used in production of curd, cheese and yoghurt.

$$C_6H_{12}O_6 \xrightarrow{\text{Enzyme}} 2C_3H_6O_3 \text{ (lactic acid)} + 36 \text{ kcal}/150 \text{ kJ (energy)}$$

(iii) **Butyric acid fermentation** (common in *Clostridium*) It occurs in rotten butter due to which it give fowl smell.

(iv) **Acetic acid fermentation** (common in acetic acid bacteria) This process uses oxygen to release ethyl alcohol and acetic acid as end products.

On the basis of respiration, organisms can be divided as follows:

(i) **Obligate aerobes** Strictly grows in the presence of O_2, e.g. *Bacillus subtilis*.

(ii) **Facultative aerobes** Generally, grows in the presence of O_2, but can grow in anaerobic conditions also, under unfavourable conditions, e.g. cyanobacteria.

(iii) **Obligate anaerobes** Grows only in the absence of O_2, e.g. *Clostridium botulinum*.

(iv) **Facultative anaerobes** Usually, grows in the absence of O_2, but in adverse conditions can grow in the presence of O_2, e.g. *Clostridium tetani*.

2. Aerobic Respiration

- It is stepwise, catabolic process of complete oxidation of organic food into CO_2 and water and energy with oxygen acting as a terminal oxidant, that takes place in cytosol.

$$C_6H_{12}O_6 + 6O_2 \xrightarrow{\text{Enzyme}} 6CO_2 + 6H_2O + 686 \text{ kcal}/2870 \text{ kJ (energy)}$$

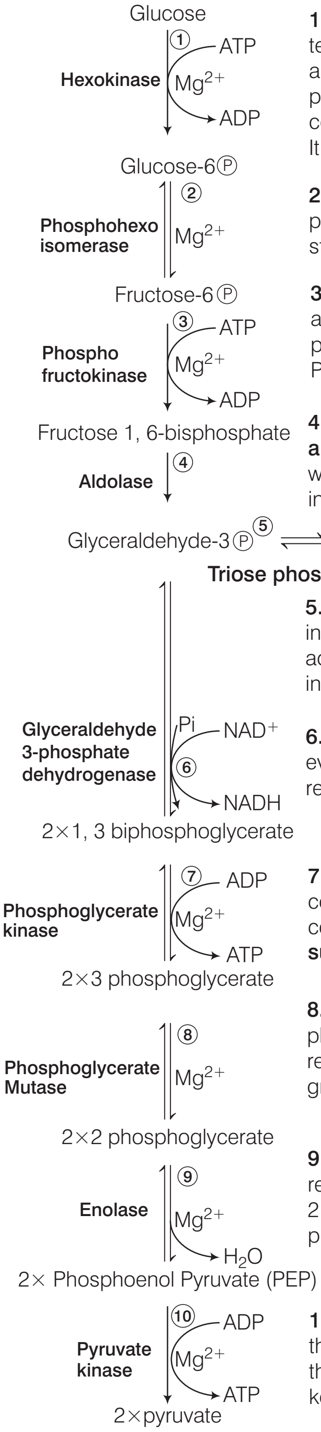
- It is completed in two pathways, i.e. common pathway and Pentose Phosphate Pathway (PPP).
- Common pathway of aerobic respiration consists of three steps
  (i) Glycolysis (ii) Krebs' cycle
  (iii) Electron transport chain and terminal oxidation.

Glycolysis

- Glycolysis (Gk. *glycos*–sugar; *lysis*–dissolution) was discovered by three German scientists **Embden**, **Meyerhof** and **Paranas**, so also called EMP pathway.
- It is defined as stepwise degradation of glucose molecules into two molecules of pyruvic acid. It occurs in **cytoplasm**.
- It can be a major pathway for ATP synthesis in tissues lacking mitochondria, e.g. erythrocytes, cornea, lens, etc. The net reaction of glycolysis is

$$\text{Glucose} + 2NAD^+ + 2ADP + 2H_3PO_4 \longrightarrow 2 \text{ pyruvate} + 2NADH + 2H^+ + 2ATP$$

Schematic Representation of EMP Pathway



1. It is an irreversible reaction in which terminal phosphate of ATP is transferred to an acceptor nucleophile. Hexokinase is present in all cells of all organisms. In liver cells it is called as **glucokinase**.
It is **first priming reaction.**

2. This is a reversible reaction which can proceed in either direction by small change in standard free energy.

3. It is **second priming reaction** of glycolysis and first committed step. Some bacteria and protists have a phosphofructokinase that use Pi not ATP as the **phosphoryl group donor.**

4. This reaction is an example of **reversible aldol condensation,** Zn^{2+} is the cofactor which cleaves the fructose 1, 6-bisphosphate into two 3-carbon units.

5. As only glyceraldehyde-3 (P) can proceed in further reaction of glycolysis, the dihydroxy acetone phosphate is converted reversibly into glyceraldehyde-3 (P).

6. The **first step of payoff phase** that eventually lead to the formation of ATP. This reaction is irreversibly inhibited by Mg^{2+}.

7. It is an exergonic reaction which is in combination with step-6 constitute an energy coupling process. It is an example of **substrate level phosphorylation**.

8. In this reaction, the enzyme, phosphoglycerate mutase catalyse a reversible shift of phosphoryl group between C_2 and C_3.

9. The enzyme enolase promotes reversible removal of H_2O molecular from 2 phosphoglycerate to produce phosphoenol pyruvate.

10. In this, substrate level phosphorylation the product first appear in its enol form and the rapidly converted non-enzymatically to its keto form at pH 7.

Schematic presentation of glycolysis

The net result of glycolysis can be given as follows

Balance sheet of glycolysis

Reactions	Steps	Products	ATP
ATP formation by substrate phosphorylation	• 1, 3-diphosphoglyceric acid (2 moles) → 3 phosphoglyceric acid (2 moles)	2 ATP	2 ATP
	• Phosphoenolpyruvic acid (2 moles) → Pyruvic acid (2 moles)	2 ATP	2 ATP
		Total	4 ATP
ATP formation by oxidative phosphorylation or ETC	• Glyceraldehyde 3 phosphate → 1, 3-biphosphoglycerate (2 moles)	2 $NADH_2$	6 ATP
	Total ATP	4 + 6 ATP =	10 ATP
ATP consumed in glycolysis	• Glucose (1 mol) → Glucose 6-phosphate (1 mol)	– 1 ATP	–1 ATP
	• Fructose 6-phosphate (1 mol) → Fructose 1, 6-diphosphate (1 mol)	– 1 ATP	–1 ATP
		Total	– 2 ATP
	• Net gain ATP = total ATP formed – total ATP consumed	10 ATP – 2 ATP	8 ATP

Oxidative Decarboxylation of Pyruvic Acid

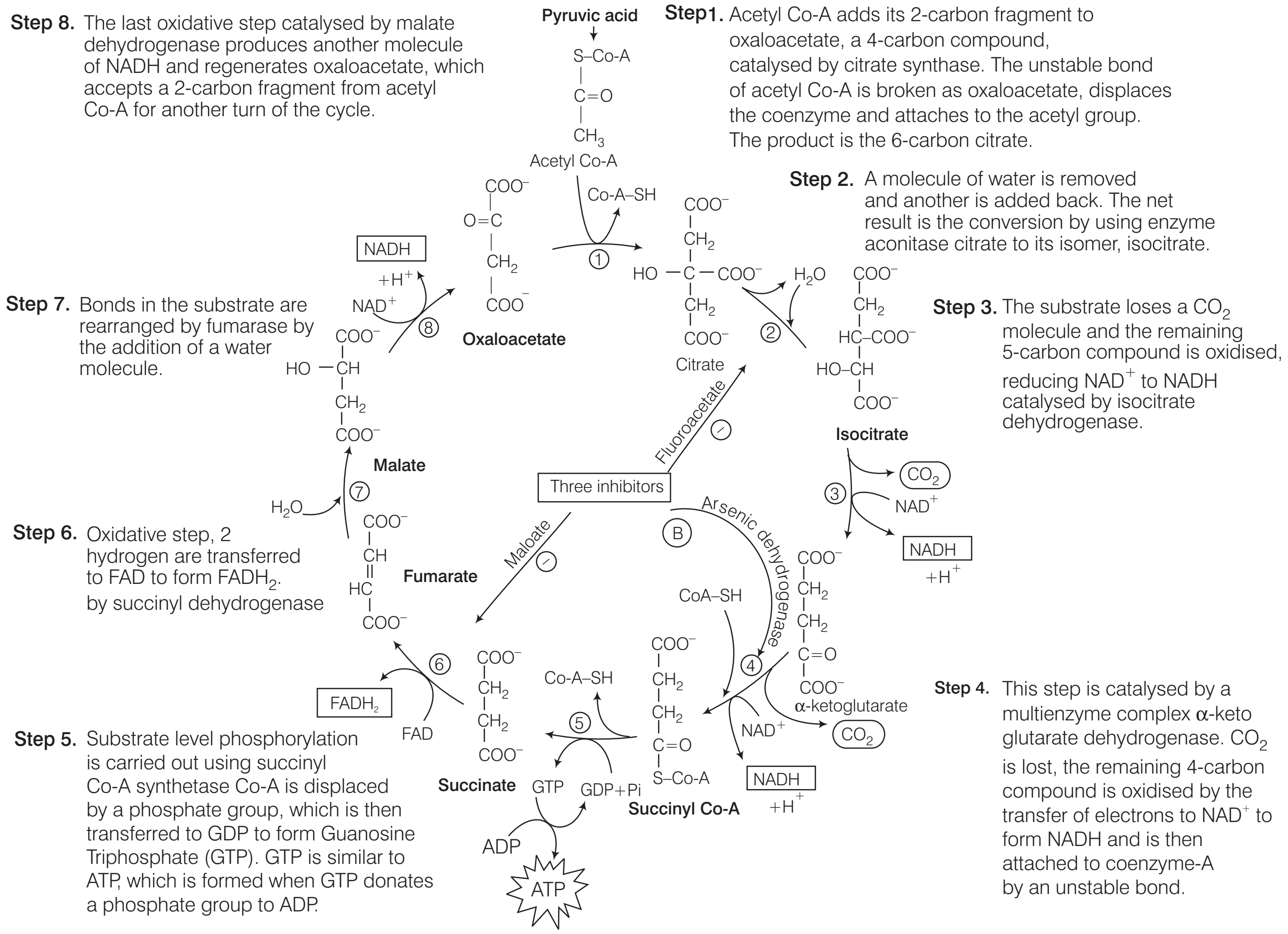
- In the presence of sufficient O_2, each three carbon-pyruvate molecules ($CH_3COCOOH$) enters in the mitochondrial matrix where its oxidation is completed by aerobic means.
- This reaction is also called as the **transition reaction** or **link reaction** between glycolysis and Krebs' cycle. It can be shown as follows

$$\underset{\text{(pyruvic acid)}}{CH_3COCOOH} + \text{Co-A} + NAD^+ \xrightarrow[Mg^{2+}]{\text{Pyruvic dehydrogenase (multienzyme complex) TPP (Thymine Pyrophosphate) and (Lipoic Acid)}} \underset{\text{(Acetyl Co-A)}}{CH_3COS\text{-Co-A}} + CO_2 + NADH^+ + H^+$$

Krebs' Cycle or Tricarboxylic Acid Cycle

- It is also known as **citric acid cycle** because citric acid (tricarboxylic acid) is the first product of this cycle.
- In eukaryotic organisms, all the reactions of Krebs' cycle takes place in the matrix of mitochondria because enzymes of this cycle are present in matrix except succinic dehydrogenase (situated in inner membrane of mitochondria).
- In prokaryotes, the Krebs' cycle occurs in cytoplasm. It is basically a **catabolic reaction**, as it oxidise acetyl Co-A and organic acid into CO_2 and H_2O.
- It acts as a **amphibolic pathway** because it serves in both catabolic and anabolic processes. It is a series of 8 reactions which occurs in aerobic environment.

The balance sheet of Krebs' cycle, i.e. ATP formed and consumed can be summarised as follows



Schematic representation of Krebs' cycle

Net reaction of respiration (glycolysis and Krebs' cycle) can be given as

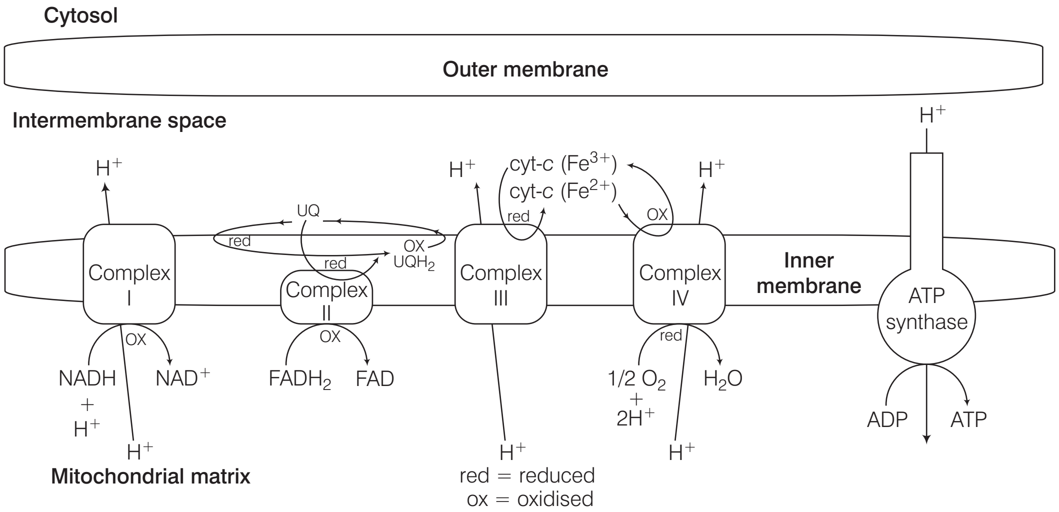
$$\text{Glucouse} + \text{GDP} + 4H_3PO_4 + 10\,\text{NAD} + 2\,\text{FAD} \longrightarrow 6\,CO_2 + 4\text{ATP} + 10\,\text{NADH} + 10H^+ + 2\text{FADH}_2$$

Balance sheet of Krebs' cycle

Reactions	Steps	Products	ATP obtained
ATP formation by substrate level phosphorylation	• Succinyl Co-A (2 mol) → Succinic acid (2 mol)	2 GTP	2 ATP
		Total	2 ATP
ATP formation by oxidative phosphorylation or ETC	• Pyruvic acid (2 mol) → Acetyl Co-A (2 mol)	$2NADH_2$	6 ATP
	• Isocitric acid (2 mol) → Oxalosuccinic acid (2 mol)	$2NADH_2$	6 ATP
	• α-ketoglutaric acid (2 mol) → Succinyl Co-A (2 mol)	$2NADH_2$	6 ATP
	• Succinic acid (2 mol) → Fumaric acid (2 mol)	$2FADH_2$	4 ATP
	• Malic acid (2 mol) → Oxaloacetic acid (2 mol)	$2NADH_2$	6 ATP
		Total	28 ATP
	• Net gain of Krebs' cycle (substrate phosphorylation + Oxidative level phosphorylation)	2ATP + 28ATP	30 ATP

Electron Transport Chain (ETC)

Electron Transport Chain (ETC) or Respiratory Chain (RC) is present in the inner membrane of mitochondria. When the electron pass from one carrier to another in electron transport chain, they are coupled to ATP synthase for the production of ATP from ADP and inorganic phosphate (Pi). A diagrammatic representation of electron flow *via* various electron carrier complexes is shown in figure.



Electron Transport Chain

The enzymes of inner membrane appear to exist as components of these five complexes. The first four members among these complexes constitute the electron transport system, while the 5th complex is connected with oxidative phosphorylation, i.e. conservation and transfer of energy with ATP synthesis.

These complexes are

(i) **Complex I** NADH/NADPH : Co-Q reductase or NADH-dehydrogenase.

(ii) **Complex II** Succinate : Co-Q reductase or succinate dehydrogenase.

(iii) **Complex III** Reduced Co-Q (Co - QH_2) or cytochrome-*c* reductase (consists of cyt-*b*, FeS complex and cyt- c_1)

(iv) **Complex IV** Cytochrome-*c* oxidase (comprises of cyt-*a* and cyt-a_3).

(v) **Complex V** ATP synthase system.

The complex V is ATP synthase complex which has a head piece, stalk and a base piece. The head piece is F_1 (coupling factor 1) and the base piece is F_0 (present within mitochondrial membrane and act as a proton channel). Together $F_0 - F_1$ Complex helps in synthesis of ATP from ADP and Pi.

Oxidation of one molecule of NADH gives rise to 3 molecules of ATP, while $FADH_2$ produces 2 molecules of ATP.

NOTE
- Cyanides, azides, rotenone, antimycin inhibits the electron, transport chain and thus act as respiratory poisons.
- Cyanide inhibit the electron flow between cytochrome-*a* and a_3 whereas Antimycin inhibits the electron flow between cytochrome-*b* and c_1.
- 2-4, dinitrophenol and oligomycin are uncouplers of oxidative phosphorylation. They inhibit ATP synthesis.
- The correct sequence of electron acceptor in ATP synthesis is cyt-$b \rightarrow c \rightarrow a \rightarrow a_3$

Oxidative Phosphorylation

The aerobic respiration is ended with the oxidation of 10 molecules of NADH + H^+ and 2 molecules of $FADH_2$ generated from a molecule of glucose. In this process, the oxygen from atmosphere is used for the oxidation of reduced coenzyme and it is called as terminal oxidation.

The production of ATP with the help of energy liberated during oxidation of reduced coenzyme and terminal oxidation is called oxidative phosphorylation. It was discovered in 1939. There are three hypothesis regarding the mechanism of oxidative phosphorylation. These are

(i) The chemical coupling hypothesis

(ii) The chemiosmotic hypothesis

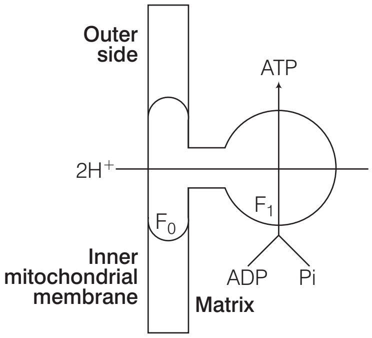
(iii) The conformational hypothesis

Chemiosmotic Hypothesis

It was discovered by **Peter Mitchell** (1976). It suggests that most ATP synthesis in respiring cells comes from the electrochemical gradient (generated due to movement of ions) across the inner membrane of mitochondria by utilising the energy of NADH and $FADH_2$, formed from oxidation of molecules, i.e. glucose.

The hydrogen ions diffuses from higher proton gradient to lower proton gradient.

This electrochemical concentration gradient of proton across a membrane is harassed to form ATP. Therefore, as the process is related to osmosis and is known as **chemiosmosis**.



Diagrammatic presentation of ATP synthesis in mitochondria

Summary of Aerobic Respiration

- Glycolysis = 2ATP + 2NADH + $2H^+$
- Pyruvate oxidation = 2NADH + $2H^+$
- Krebs' cycle = 2GTP + 6NADH + $6H^+$ + $2FADH_2$
- Electron transport system
  - 2NADH + $2H^+$ from glycolysis yield 4 ATP *via* route-2 of ETC (glycerol-phosphate shuttle) or six ATP *via* route-1 (malate aspartate shuttle).
  - 2NADH + $2H^+$ from pyruvate oxidation yield 6ATP molecules in route-1 of ETC.
  - 6NADH + $6H^+$ molecules from TCA (Krebs' cycle) yield 18 ATP molecules in route-1 of ETC.
  - $2FADH_2$ molecules from TCA cycle yield 4 ATP molecules in route-2 of ETC (Electron Transport Chain).
  - Hence, ETS alone produces 32 or 34 ATP.

$$\underset{\text{(Glycolysis)}}{2ATP} + \underset{\text{TCA cycle}}{2GTP} + \underset{\text{(ETS/ETC)}}{32/34\ ATP} \longrightarrow 38/36\ ATP$$

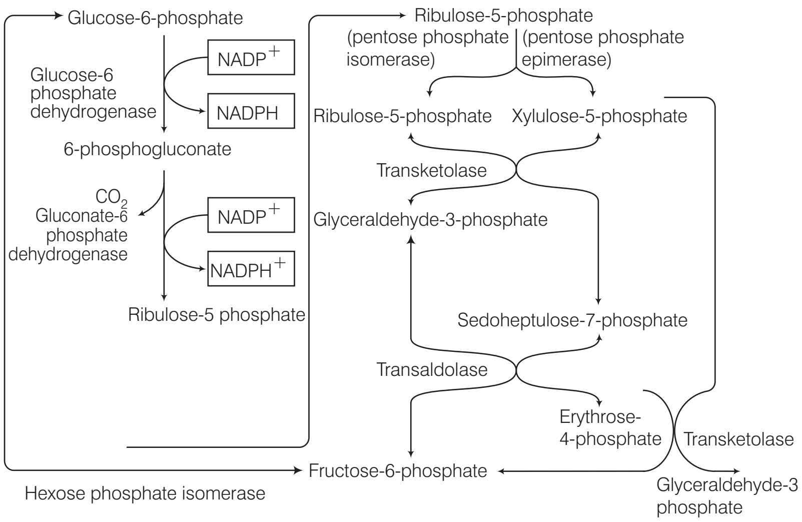
  - 34 or 36 ATP + 2 GTP are produce from one glucose molecule.

- A cytoplasmic enzyme **nucleoside diphosphate kinase** readily converts the GTP formed in TCA cycle to ATP.
- In prokaryotic cells, oxidation of glucose molecule always yields 38 ATP molecules as NADH + H^+ is not present to enter mitochondria.
- Overall **process of aerobic respiration** may be shown by the following equation

$$C_6H_{12}O_6 + 6O_2 + 10H_2O \longrightarrow 6CO_2 + 16H_2O + 686\ \text{kcal (energy)}$$

Pentose Phosphate Pathway (PPP)

- Pentose phosphate pathway (Warburg-Lipman-Dickens cycle) is an alternate method of aerobic respiration, which occurs in the cytoplasm of mature plant cells.
- This pathway accounts for of 60% total respiration in liver cells. As this pathway metabolises glucose-6-phosphate by reaction that bypass the reaction of glycolysis, therefore, it is also known as **Hexose Monophosphate Pathway shunt** (HMP shunt).
- It is an alternate pathway to generate ATP, other than glycolysis and Krebs' cycle. This pathway is a major source for the NADPH required for anabolic processes.
- There are three distinict phases–oxidation, isomerisation and rearrangement. Gluconeogenesis is directly connected to the PPP.
- In this pathway, for every six molecules of glucose, one molecule is completely oxidised in CO_2 and reduced coenzymes, while five are regenerated. The reaction of this pathway can be summarised as follows

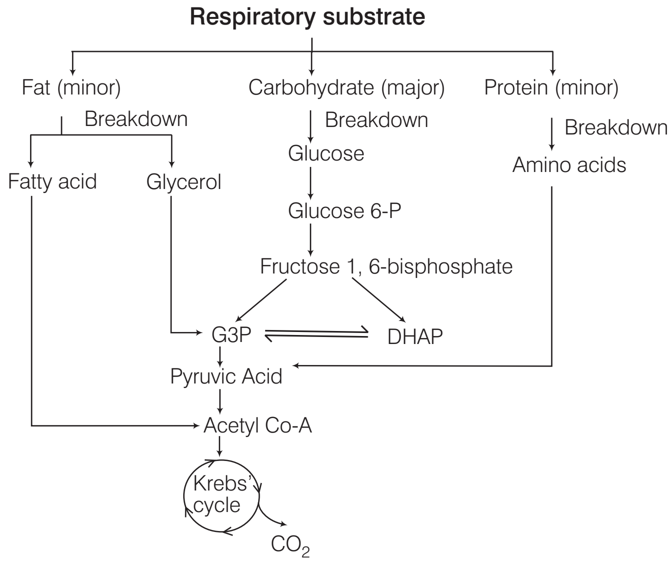


Reactions of the oxidative pentose phosphate pathway in higher plants

Amphibolic Pathway

The pathway in which both, breakdown (catabolism) and build up (anabolism) takes place simultaneously is called amphibolic pathway. Krebs' cycle is amphibolic in nature, as its intermediates are used in other anabolic processes.

A general representation of amphibolic pathway can be shown as follows



Amphibolic pathway of respirations

Respiratory Quotient (RQ)

The ratio of the volume of CO_2 evolved to the volume of O_2 consumed in respiration is called **Respiratory Quotient** (RQ) or **respiratory ratio**.

It can be given by the following equation

$$RQ = \frac{\text{Volume of } CO_2 \text{ evolved}}{\text{Volume of } O_2 \text{ absorbed}}$$

- RQ is measured by **Ganong's Respirometer**.
- RQ for carbohydrates in aerobic respiration is unity

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + \text{Energy}$$

$$RQ = \frac{6CO_2}{6O_2} = 1 \text{ or unity}$$

- RQ for fatty acid is less than 1.

$$\underset{\text{(Tripalmitin)}}{2C_{51}H_{98}O_6} + 145\ O_2 \longrightarrow 102\ CO_2 + 98\ H_2O + \text{Energy}$$

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

- RQ for protein is about 0.9.
- RQ for anaerobic respiration in infinity as oxygen is not used.

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

$$RQ = \frac{2CO_2}{\text{Zero } (O_2)} = \alpha \text{ (infinity)}$$

- RQ for succulents plants at night is zero as no CO_2 is evolved, but fixed internally.
- RQ of malic acid is 1.33

$$C_4H_6O_5 + 3O_2 \longrightarrow 4CO_2 + 3H_2O$$

$$RQ = \frac{4CO_2}{3O_2} = 1.33 \text{ (more than unity)}$$

- RQ of oxalic acid is 4.

$$2(COOH)_2 + O_2 \longrightarrow 4CO_2 + 2H_2O + 60.2 \text{ kcal}$$

$$RQ = \frac{4\ CO_2}{O_2} = 4 \text{ (more than unity)}$$

Factors Affecting Respiration

Various factors affecting respiration can be summarised as

(i) **Amount of oxygen** Rate of respiration is directly proportional to amount of oxygen available.

(ii) **Intensity of light** Rate of respiration is directly proportional to intensity of light.

(iii) **Temperature** The rate of respiration is directly proportional to temperature, i.e. the rise in temperature leads to increased metabolism (cellular respiration) while with lowering in temperature its rate decreases.

(iv) **Dehydration** Rate of respiration is inversely proportional to dehydration, i.e. scarcity of moisture or water in the surroundings/body. It decreases with increase in dehydration in body.

(v) **Minerals** Rate of respiration is directly proportional to (availability of minerals) as some of them play vital role in the process, i.e. acts as catalysts on reaction centres.

(vi) **Tissue injury** The rate of respiration is directly proportional to tissue injuries.

DAY PRACTICE SESSION 1

FOUNDATION QUESTIONS EXERCISE

1 Respiration is accompanied by
(a) decrease in weight (b) increase in weight
(c) weight remains constant (d) decrease in size

2 Respiration is regarded as
(a) catabolic process (b) reduction process
(c) anabolic process (d) synthetic process

3 Alcoholic fermentation takes place in the presence of
(a) maltase (b) zymase
(c) amylase (d) invertase

4 Incomplete breakdown of sugar in anaerobic respiration forms
(a) glucose and carbon dioxide
(b) alcohol and carbon dioxide
(c) water and carbon dioxide
(d) fructose and water

5 What will happen if fermentation is allowed to proceed in a closed vessel?
(a) Vacuum will result
(b) No change will be there
(c) Pressure will develop because of excessive CO_2
(d) Pressure will develop because of excessive O_2

6 Dough kept overnight in warm weather becomes soft and spongy because of
(a) absorption of carbon dioxide from atmosphere
(b) fermentation
(c) cohesion
(d) osmosis

7 In which one of the following processes CO_2 is not released? ➔ CBSE-AIPMT 2014
(a) Aerobic respiration in plants
(b) Aerobic respiration in animals
(c) Alcoholic fermentation
(d) Lactate fermentation

8 The energy releasing metabolic process in which subtrate is oxidised without an external electron acceptor is called ➔ CBSE-AIPMT 2010
(a) glycolysis (b) fermentation
(c) aerobic respiration (d) photorespiration

9 The common phase between anaerboic and aerobic respiration is called
(a) TCA cycle (b) oxidative phosphorylation
(c) Krebs' cycle (d) glycolysis

10 The net gain of ATP molecules in glycolysis is
(a) 0 (b) 2 (c) 4 (d) 8

11 In glycolysis, during oxidation electrons are removed by
(a) ATP
(b) glyceraldehyde-3-phosphate
(c) NAD^+
(d) molecular oxygen

12 Phosphorylation of glucose during glycolysis is catalysed by
(a) phosphoglucomutase (b) phosphoglucoisomerase
(c) hexokinase (d) phosphorylase

13 The number of O_2 molecules required for glycolytic breakdown of one glucose molecule is
(a) zero (b) two (c) three (d) four

14 Pyruvic acid, the key product of glycolysis can have many metabolic fates. Under aerobic condition it forms
(a) lactic acid (b) $CO_2 + H_2O$
(c) acetyl Co-A + CO_2 (d) ethanol + CO_2

15 Phosphorylation of glucose with the help of ATP and hexokinase produces
(a) glucose-1-phosphate
(b) glucose-6-phosphate
(c) glucose-1, 6-diphosphate
(d) fructose-1, 6-diphosphate

16 Which of the following statements is incorrect for glycolysis?
(a) It uses ATP (b) It produces ATP
(c) End product is CO_2 (d) NADH is produced

17 Which one is the correct sequence in glycolysis?
(a) G-6-P $\rightarrow$ PEP $\rightarrow$ 3-PGAL $\rightarrow$ 3-PGA
(b) G-6-P $\rightarrow$ 3-PGAL $\rightarrow$ 3-PGA $\rightarrow$ PEP
(c) G-6-P $\rightarrow$ PEP $\rightarrow$ 3-PGA $\rightarrow$ 3-PGAL
(d) G-6-P $\rightarrow$ 3-PGA $\rightarrow$ 3PGAL $\rightarrow$ P $\rightarrow$ PEP

18 Read the following statements. In which of the following reactions of glycolysis, a molecule of water is removed from the substrate?
I. Fructose-6-phosphate $\rightarrow$ Fructose 1, 6-biphosphate
II. 3-phosphate-glyceraldehyde $\rightarrow$ 1, 3-bisphosphoglyceric acid
III. PEP-Pyruvic acid
IV. 2-phoshoglycerate $\rightarrow$ PEP
V. Glucose $\rightarrow$ Glucose-6-phosphate
(a) IV and V (b) I and III
(c) Only IV (d) Only II

19 Which of the following connects the glycolysis and Krebs' cycle?
(a) Pyruvic acid (b) Glucose
(c) Acetyl Co-A (d) ATP

20 Pyruvic acid before combining with oxaloacetic acid of TCA cycle changes into

(a) acetyl Co-A (b) lactic acid
(c) acetic acid (d) aconitic acid

21 Site of Krebs' cycle in mitochondria is

(a) outer membrane (b) mitochondrial matrix
(c) oxysomes (d) None of these

22 Succinate is oxidised to fumarate in Krebs' cycle by

(a) removal of hydrogen (b) loss of electrons
(c) addition of oxygen (d) removal of oxygen

23 All enzymes of TCA cycle are located in the mitochondrial matrix except one, which is located in inner mitochondrial membranes in eukaryotes and in cytosol in prokaryotes. This enzyme is

(a) lactate dehydrogenase
(b) isocitrate dehydrogenase
(c) malate dehydrogenase
(d) succinate dehydrogenase

24 A single cycle of TCA cycle yields

(a) $2FADH_2 + 2NADH_2 + 2ATP$
(b) $1FADH_2 + 2NADH_2 + 1ATP$
(c) $1FADH_2 + 3NADH_2 + 1ATP$
(d) $1FADH_2 + 1NADH_2 + 1ATP$

25 What is the role of NAD' in cellular respiration?

➜ NEET 2018

(a) It is a nucleotide source of ATP synthesis
(b) It functions as an electron carrier
(c) It functions as an enzyme
(d) It is the final electron acceptor for anaerobic respiration

26 FAD acts as an electron acceptor in between

(a) fumaric acid and malic acid
(b) succinic acid and fumaric acid
(c) malic acid and oxaloacetic acid
(d) citric acid and isocitric acid

27 Electron Transport System (ETS) is located in mitochondrial

(a) outer membrane (b) inner membrane space
(c) inner membrane (d) matrix

28 During which stage in the complete oxidation of glucose is the greatest number of ATP molecules formed from ADP?

(a) Conversion of pyruvic acid to acetyl Co-A
(b) Electron transport chain
(c) Glycolysis
(d) Krebs' cycle

29 The ultimate electron acceptor of respiration in an aerobic organism is

(a) cytochrome (b) oxygen (c) hydrogen (d) glucose

30 Which of the following is synthesised during substrate phosphorylation?

(a) AMP (b) ATP (c) NADH (d) FMN

31 Which among the following is the final electron acceptor?

(a) OAA (b) NADP
(c) Cytochrome oxidase (d) Pyruvate

32 The electron acceptor in ETS is arranged according to

(a) decreasing positive potential
(b) increasing positive potential
(c) increasing negative potential
(d) None of the above

33 What would happen if $NADH_2$ is oxidised to form water in a single step?

(a) Production of 3 ATP (b) Mostly wastage of energy
(c) Production of 12 ATP (d) None of these

34 Chemiosmotic theory of ATP synthesis in the chloroplasts and mitochondria is based on

(a) proton gradient (b) accumulation of K^+ ions
(c) accumulation of Na^+ ions (d) membrane potential

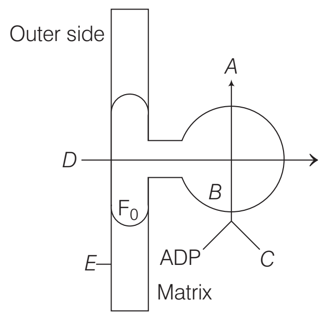
35 Oxidative phosphorylation is ➜ NEET-II 2016

(a) formation of ATP by transfer of phosphate group from a substrate to ADP
(b) oxidation of phosphate group in ATP
(c) addition of phosphate group to ATP
(d) formation of ATP by energy released from electrons removed during substrate oxidation

36 Cyanide resistant pathway is one in which

(a) cyanide breakdown respiratory membrane
(b) electorn transfer directly from complex I to IV
(c) electron transfer directly from complex II to oxygen
(d) None of the above

37 The diagram given below shows the representation of ATP synthesis in mitochondria. Fill in the blanks with appropriate options.



(a) A – ATP, B – F_1, C – Pi, D – $2H^+$, E – Inner mitochondrial membrane
(b) A – ATP, B–Inner mitochondrial membrane, C – F_1, D – Pi, E – 2H
(c) A – F_1, B – ATP, C – Pi, D–inner mitochondrial membrane, E – 2H
(d) A – Pi, B–F_1, C–Inner mitochondrial membrane, D – ATP, E – $2H^+$

38 When one glucose molecule is completely oxidised, it changes

(a) 35 ADP molecules into 35 ATP molecules
(b) 38 ADP molecules into 38 ATP molecules
(c) 30 ADP molecules into 30 ATP molecules
(d) 32 ADP molecules into 32 ATP molecules

39 The complete combustion of glucose in respiration is represented by

(a) $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{Energy}$
(b) $C_6H_{12}O_6 + 6CO_2 \rightarrow 6O_2 + 6H_2O + \text{Energy}$
(c) $C_6H_{12}O_6 + 6O_2 + 6CO_2 \rightarrow 6CO_2 + 6H_2O + \text{Energy}$
(d) $C_6H_{12}O_6 + 6O_2 + 6CO_2 + ATP \rightarrow$
$6CO_2 + 6H_2O + 6O_2 + \text{Energy}$

40 How many ATP molecules could maximally be generated from one molecule of glucose, if the complete oxidation of one mole of glucose to CO_2 and H_2O yields 686 kcal and the useful chemical energy available in the high energy phosphate bond of one mole of ATP is 12 kcal? ➜ CBSE-AIPMT 2016

(a) 30 (b) 57
(c) 1 (d) 2

41 Out of 36 ATP molecules produced per glucose molecule during respiration,

(a) 2 are produced outside glycolysis and 34 during respiratory chain
(b) 2 are produced outside mitochondria and 34 inside mitochondria
(c) 2 during glycolysis and 34 during Krebs' cycle
(d) all are formed inside mitochondria

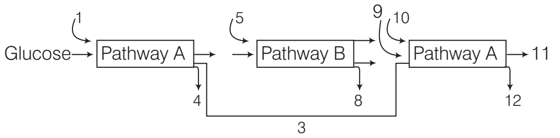
42 Which of the following is an amphibolic pathway?

(a) TCA cycle (b) Calvin cycle
(c) Terminal oxidation (d) ETCs

43 Which of the following biomolecules is common to respiration mediated breakdown of fats, carbohydrates and proteins? ➜ NEET-II 2016, 2013

(a) Glucose-6-phosphate
(b) Fructose 1, 6-bisphosphate
(c) Pyruvic acid
(d) Acetyl Co-A

44 The three boxes in this diagram represent the three major biosynthetic pathways in aerobic respiration and arrows represent net reacts of products ➜ NEET 2013



Arrows numbered 4, 8 and 12 can be

(a) ATP (b) H_2O
(c) FAD^+ or $FADH_2$ (d) NADH

45 When bond between first and second phosphate of ATP is hydrolysed, the amount of energy released (at pH 7) is

(a) 1.2 kcal (b) 3 kcal
(c) 1.5-1.8 kcal (d) 6.5 kcal

46 Respiratory substrates are the organic substance which are ...... during respiration to liberate energy.

(a) oxidised (b) reduced
(c) Both (a) and (b) (d) synthesised

47 In an organism utilising sugars as its source of energy anaerobically, the RQ is likely

(a) 0.7 (b) 0.9
(c) 1.0 (d) infinity

48 Which one of the following has the highest RQ?

(a) Malic acid (b) Protein
(c) Fat (d) Starch

49 In succulents, respiratory quotient is always less than one due to

(a) incomplete oxidation (b) incomplete reduction
(c) complete reduction (d) None of these

50 Respiratory Quotient (RQ) is one in case of

(a) fatty acids (b) nucleic acids
(c) carbohydrate (d) organic acids

51 If volume of CO_2 liberated during respiration is more than the volume of O_2 used, then respiratory substrate will be

(a) carbohydrate (b) fat
(c) protein (d) organic acid

52 If RQ is less than 1.0 in a respiratory metabolism, it would mean that

(a) carbohydrates are used as respiratory substrate
(b) organic acids are used as respiratory substrate
(c) the oxidation of the respiratory substrate consumed more oxygen than the amount of CO_2 released
(d) the oxidation of respiratory substrate consumed less oxygen than the amount of CO_2 released
(e) the reaction is anaerobic

53 Match the following columns.

	Column I		Column II
A.	Oxidation of pyruvate	1.	Inner membrane of mitochondria
B.	$C_6H_{12}O_6$	2.	Acetyl Co-A
C.	Pyruvic acid	3.	Aerobic respiration
D.	Krebs' cycle	4.	Matrix of mitochondria
		5.	Glucose

Codes

	A	B	C	D
(a)	4	5	2	3
(b)	4	5	3	1
(c)	1	5	4	2
(d)	2	3	4	5

54 Match the following columns.

Column I	Column II
A. 4 C-compound	1. Acetyl Co-A
B. 2 C-compound	2. Pyruvate
C. 5 C-compound	3. Citric acid
D. 3 C-compound	4. α-ketoglutaric acid
	5. Malic acid

Codes

	A	B	C	D
(a)	2	5	3	1
(b)	3	1	4	2
(c)	5	1	4	2
(d)	5	3	1	2

55 Match the following columns.

Column I	Column II
A. F_1-particle	1. Forms channel through which protons cross the inner membrane
B. F_0-particle	2. Contains F_1 and F_0-particles and protein stalk
C. ATP synthase	3. Contains site for synthesis of ATP from ADP and Pi
D. Chemiosmotic hypothesis	4. Peter Mitchell

Codes

	A	B	C	D
(a)	2	4	1	3
(b)	1	3	2	4
(c)	3	1	2	4
(d)	4	3	1	2

56 Match the following columns.

Column I	Column II
A. RQ less than 1	1. TCA cycle
B. RQ 0.9	2. Incomplete oxidation of glucose
C. Acetyl Co-A	3. Oxidation of fats
D. Fermentation	4. Fats
	5. Proteins

Codes

	A	B	C	D		A	B	C	D
(a)	1	2	3	4	(b)	5	4	2	1
(c)	4	5	1	2	(d)	1	5	4	2

Directions (Q. Nos. 57-59) *In each of the questions a statement of Assertion is given following by a corresponding statement of Reason just below it. Of the statements, mark the correct answer as*

(a) If both Assertion and Reason are true and Reason is the correct explanation of Assertion
(b) If both Assertion and Reason are true, but Reason is not the correct explanation of Assertion
(c) If Assertion is true, but Reason is false
(d) If both Assertion and Reason are false

57 **Assertion** Under the conditions of high light intensity and limited CO_2 supply, photorespiration has a useful role in protecting the plants from photo-oxidative damage.
Reason If enough CO_2 is not available to utilise light energy for carboxylation to processed, the excess energy may not cause damage to plants.

58 **Assertion** Respiratory pathway is an amphibolic pathway.
Reason The respiratory pathway is involved in both anabolism and catabolism.

59 **Assertion** Respiratory quotient depends upon the respiratory substrate used during respiration.
Reason RQ of carbohydrates is 1.

DAY PRACTICE SESSION 2

PROGRESSIVE QUESTIONS EXERCISE

1 Respiration is different from combustion that is the
(a) energy is released in one step
(b) energy is released in different steps
(c) efficiency is very low
(d) All of the above

2 The rate of respiration in the presence of cyanides, azides and carbon monoxides will
(a) increase
(b) decrease
(c) remain the same
(d) None of the above

3 Out of 38 ATP molecules produced per glucose, 32 ATP molecules are formed from NADH/$FADH_2$ in
(a) respiratory chain
(b) Krebs' cycle
(c) oxidative decarboxylation
(d) EMP

4 The released energy obtained by oxidation is stored as
(a) a concentration gradient across a membrane
(b) ADP
(c) ATP
(d) NAD^+

5 The respiration in germinating seeds produces energy, which can be detected in the form of

(a) water (b) heat
(c) oxygen (d) CO_2

6 Which of the following is produced in oxidative pentose phosphate pathway?

(a) Pyruvic acid (b) Acetyl Co-A
(c) $NADH_2$ (d) NADH

7 Aerobic respiratory pathway is appropriately termed

(a) catabolic (b) parabolic
(c) amphibolic (d) anabolic

8 Metabolic water is the one

(a) used during transamination
(b) used during photosynthesis
(c) produced during aerobic utilisation of glucose
(d) produced during condensation or polymerisation

9 Number of ATP molecules produced by each NADPH is

(a) three (b) two
(c) one (d) five

10 The process by which ATP is produced in the inner membrane of a mitochondia. The electron transport system transfers protons from the inner compartment of the outer; as the protons flow back to the inner compartment, the energy of their movement is used to add phosphate to ADP, forming ATP.

(a) Chemiosmosis (b) Phosphorylation
(c) Glycolysis (d) Fermentation

11 Decarboxylation is involved in

(a) electron transport system
(b) glycolysis
(c) Krebs' cycle
(d) lactic acid fermentation

12 In which of the following reactions of glycolysis, a molecule of water is removed from the substrate?

(a) Fructose-6-phosphate $\rightarrow$ Fructose-1, 6-bisphosphate
(b) 3-phosphate glyceraldehyde $\rightarrow$ 1, 3-bisphosphoglyceric acid
(c) PEP $\rightarrow$ Pyruvic acid
(d) 2-phosphoglycerate $\rightarrow$ PEP

13 Floating respiration is respiration

(a) occurring in cytoplasm
(b) using carbohydrates as respiratory substrate
(c) using fats as respiratory substrate
(d) Both (b) and (c)

14 Mitochondria is called powerhouse of the cell. Which of the following observations supports this statement?

(a) Mitochondria have a double membrane
(b) The enzymes of the Kreb's cycle and the cytochromes are found in mitochondria
(c) Mitochondria synthesise ATP
(d) Mitochondria are found in almost all plants and animal cells

15 In alcoholic fermentation,

(a) triose phosphate is the electron donor, while acetaldehyde is the electron acceptor
(b) triose phosphate is the electron donor, while pyruvic acid is the electron acceptor
(c) there is no electron donor
(d) oxygen is the electron acceptor

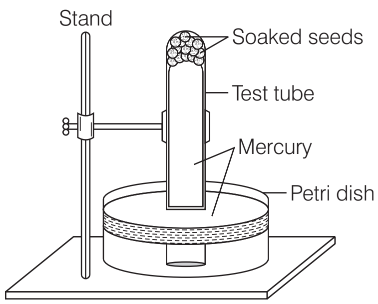
16 The energy content in kcal/g of carbohydrate: protein: triglycerol, respectively is approximately in the ratio of

(a) 1 : 2 : 2
(b) 1 : 2 : 1
(c) 2 : 1 : 1
(d) 2 : 2 : 1

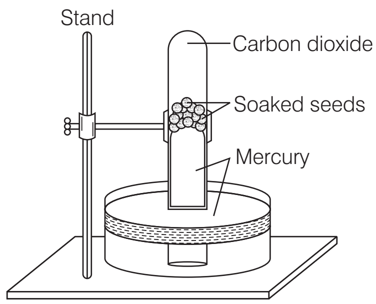
17 How many PGAL are produced by glycolysis of three molecules of glucose? How many ATP are released by respiration of these PGAL till the formation of CO_2 and H_2O?

(a) 4 PGAL – 80 ATP
(b) 6 PGAL – 160 ATP
(c) 4 PGAL – 40 ATP
(d) 6 PGAL – 120 ATP

18 Following diagram shows the demonstration of aerobic respiration.



A

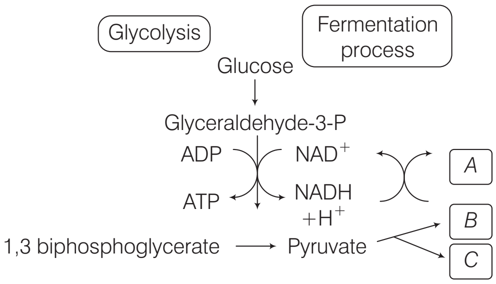


B

What result can be drawn from it?

(a) The experiment shows that CO_2 is evolved in an aerobic respiration of seeds
(b) It shows that O_2 is evolved in an aerobic respiration of seed
(c) Aerobic respiration takes place in the seed in the absence of free oxygen
(d) The potassium hydroxide forms O_2 and water

19 Choose the correct combination of labelling the molecules involved in the pathway of anaerobic respiration in yeast.



(a) A – Ethanol, B – CO_2, C – Acetaldehyde
(b) A – CO_2, B – Ethanol, C – Acetaldehyde
(c) A – Acetaldehyde, B – CO_2, C – Ethanol
(d) A – Ethanol, B – Acetaldehyde, C–CO_2

20 Consider the following statements and choose the incorrect options.

I. The mechanism of breakdown of food material within the cell to release energy is called cellular respiration.
II. Respiration causes the breaking of C—C bond of complex compounds through oxidation within the cells, leading release of energy.
III. The compounds that are oxidised during this process are known as oxidatory substrate.

(a) Only I (b) Only II
(c) Only III (d) None of these

21 Which statement is incorrect for Krebs' cycle?

(a) There are three points in the cycle where NAD^+ is reduced to NADH + H^+
(b) There is one point in the cycle where FAD^+ is reduced to $FADH_2$
(c) During conversion of succinyl Co-A to succinic acid, a molecule of GTP is synthesised
(d) The cycle starts with condensation of acetyl group (acetyl Co-A) with pyruvic acid to yield citric acid

22 Four respiratory enzymes are given below. Arrange them in increasing order of the carbon number of the substrates on which they act.

I. Enolase
II. Aconitase
III. Fumarase
IV. Alcohol dehydrogenase

(a) II, IV, III, I (b) IV, I, II, III
(c) I, IV, III, II (d) IV, I, III, II

23 The Respiratory Quotient (RQ) of some of the compounds are 4, 1 and 0.7. These compounds are identified respectively as

(a) malic acid, palmitic acid and tripalmitin
(b) oxalic acid, carbohydrate and tripalmitin
(c) tripalmitin, malic acid and carbohydrate
(d) palmitic acid, carbohydrate and oxalic acid

24 Read the following statements and select the incorrect statements.

I. When tripalmitin is used as a substrate in respiration the RQ is 0.
II. The intermediate compound which links glycolysis, with Krebs' cycle is malic acid.
III. One glucose molecule yields a net gain of 36 ATP molecules during aerobic respiration.
IV. One glucose molecule yields a net gain of 2 ATP molecules during fermentation.
V. The scheme of glycolysis was given by Kerbs'.

(a) I, II and III (b) II, III and V
(c) I, II and V (d) II and IV

25 Match the following columns.

	Column I		Column II
A.	Krebs' cycle	1.	Stroma of mitochondria
B.	Glycolysis	2.	Matrix of mitochondria
C.	Substrate phosphorylation	3.	Cytoplasm

Codes

	A	B	C		A	B	C
(a)	1	3	2	(b)	2	1	3
(c)	2	3	1	(d)	3	1	2

ANSWERS

SESSION 1

1 (a)	**2** (a)	**3** (b)	**4** (b)	**5** (c)	**6** (b)	**7** (d)	**8** (b)	**9** (d)	**10** (b)
11 (b)	**12** (c)	**13** (a)	**14** (c)	**15** (b)	**16** (c)	**17** (b)	**18** (c)	**19** (c)	**20** (a)
21 (b)	**22** (a)	**23** (d)	**24** (c)	**25** (b)	**26** (b)	**27** (b)	**28** (b)	**29** (b)	**30** (b)
31 (c)	**32** (b)	**33** (a)	**34** (a)	**35** (a)	**36** (c)	**37** (a)	**38** (b)	**39** (a)	**40** (b)
41 (b)	**42** (a)	**43** (d)	**44** (a)	**45** (d)	**46** (a)	**47** (d)	**48** (a)	**49** (a)	**50** (c)
51 (d)	**52** (c)	**53** (a)	**54** (c)	**55** (c)	**56** (c)	**57** (a)	**58** (a)	**59** (b)	

SESSION 2

1 (b)	**2** (b)	**3** (a)	**4** (c)	**5** (b)	**6** (d)	**7** (c)	**8** (c)	**9** (a)	**10** (a)
11 (c)	**12** (d)	**13** (d)	**14** (c)	**15** (a)	**16** (b)	**17** (d)	**18** (a)	**19** (d)	**20** (c)
21 (d)	**22** (d)	**23** (b)	**24** (c)	**25** (c)					