Chapter-5 Respiration in Plants

Very Short Answers Questions:

1. **Different substrates get oxidized during respiration. How does respiratory quotient (RQ) indicate which type of substrate i.e. carbohydrate, fat or protein is getting oxidized?**

   R.Q. =A/B

   What do A and B stand for?

   What type of substrates have R, Q of 1, <1, >1?

A: Respiratory substrates are organic compounds. They differ in their oxygen and carbon content. Depending on this oxygen content, they consume different amounts of O_2 during their complete oxidation releasing different amounts of CO_2.The ratio of CO_2 released to that of O_2 consumed is Respiratory quotient.

A= Volume of CO_2 evolved

B= Volume of O_2 consumed.

R.Q of carbohydrates=1

R.Q of fats <1

R.Q of organic acids>1

2. **What is the specific role of $F_0 – F_1$ particles in respiration?**

A: F_0 – F_1 particles are proteins in the inner mitochondrial membranes. They facilitate the diffusion of protons breaking down the proton gradient. Energy released during this break down is used in phosphorylation of ADP to ATP by $F_0 – F_1$ particles.

3. **When does anaerobic respiration occur in man and yeast?**

A: During exercise inadequate amounts of O_2 is available for cellular respiration. Under these conditions anaerobic respiration takes place in humans.

During yeast fermentation increase in number of yeast cells and alcohol formation results in anaerobic conditions.

4. What is the common pathway for aerobic and anaerobic respirations? Where does it takes place?

A: Glycolysis.

In the cytosol.

5. What cellular organic substances are never used as respiratory substrates?

A: Pure proteins or fats are never used as respiratory substrates.

6. Why is the R.Q of fats less than that of carbohydrates?

A: R.Q is the ratio of CO_2 released to that of O_2 consumed.

Fats have far less amount of oxygen compared to carbon in their molecules. It consumes more oxygen compared to oxygen release.

In carbohydrates CO_2 released and oxygen consumed are equal.

7. What is meant by 'Amphibolic pathway'?

A: A metabolic pathway in which both anabolic and catabolic pathways take place is called as amphibolic pathway.

E.g. Respiratory pathway.

8. Name the mobile electron carriers of the respiratory electron transport chain in the inner mitochondrial membrane?

A: Ubiquinone and Cytochrome C

9. What is the final acceptor of electrons in aerobic respiration? From which complex does it receive electrons?

A: Oxygen is the final acceptor of electrons.

It receives electrons from Complex-IV (cytochrome c oxidase).

10. Do you know of any step in Kreb's cycle where there is a substrate level phosphorylation? Explain?

A: During the cleavage of Succinyl Co A into Succinic acid and Co A in the presence of enzyme Succinic thiokinase a molecule of ATP is formed. This formation of ATP is Substrate level phosphorylation.

Short Answer Type Questions

1.Why is the respiratory pathway referred to as an amphibolic pathway? Explain.

Ans: Because the respiratory pathway is involved in both anabolism and catabolism, it would hence be better to consider the respiratory pathway as an **amphibolic pathway** rather than as a catabolic one. Glucose is the favoured substrate for respiration and enter the respiratory pathway at the first step first.

If fatty acids were to be respired they would first be degraded to acetyl CoA and enter the pathway. Glycerol would enter the pathway after being converted to PGAL.

The proteins would be degraded by proteases and the individual amino acids (after deamination) depending on their structure would enter the pathway at some stage within the Krebs' cycle or even as pyruvate or acetyl CoA.

Since respiration involves breakdown of substrates, the respiratory process has traditionally been considered a catabolic process and the respiratory pathway as a catabolic pathway.

Different substrates would enter if they were to be respired and used to derive energy. These compounds that would be withdrawn from the respiratory pathway for the synthesis of the said substrates.

Hence, fatty acids would be broken down to acetyl CoA before entering the respiratory pathway when it is used as a substrate. But when the organism needs to synthesise fatty acids, acetyl CoA would be withdrawn from the respiratory pathway for it.

Hence, the respiratory pathway comes into the picture both during breakdown and synthesis of fatty acids.

Similarly, during breakdown and synthesis of protein too, respiratory intermediates form the link.

2, Write about two ATP yielding reactions of glycolysis.

Ans: Both the reactions yielding ATP in Glycolysis are **substrate level phophorylation** reactions. Both the reactions are dephosphorylation reactions mediated by ***kinase*** enzymes.

1) 1,3 bisphosphoglyceric acid + ADP → 3-phosphoglyceric acid + ATP

Enzyme being ***Phosphoglycerokinase***

2) Phosphoenolpyruvate + ADP → Pyruvic acid + ATP

Enzyme being ***Pyruvic kinase***

For every molecule of 3carbon compound (Glyceraldehyde -3- phosphate) total 2ATP molecules are released in the Glycolysis. Oxygen is not used in the production of energy in the form of ATP. Phosphorylated substances donate their phosphate to form ATP from ADP.

In anaerobic organisms this is the only energy released. Total ATP for a mole of Glucose are 4 ATP. Net gain is 2ATP as 2 ATP are utilized in the phosphorylation of Glucose and Fructose-6-phosphate.

3. The net gain of ATP for the complete aerobic oxidation of glucose is 36. Explain.

Ans: In respiration ATP are produced directly by substrate level phosphorylation and majority of ATP are produced when electron carriers enters electron transport chain. The balance sheet of ATP production is as follows whem glucose is completely oxidized in aerobic respiration:

I. Glycolysis

1. ATP produced by substrate level phosphorylation

1,3bisphosphoglyceric acid to 2 phosphoglyceric acid	2 x 1 = 2 ATP
Phosphoenol pyruvic acid to Pyruvic acid	2 x 1 = 2 ATP

ATP utilized for phosphorylation of glucose and fructose-6-phosphate	-2 ATP
Net gain of ATP	+2 ATP
2. ATP from $2NADH_2$ generated in glycolysis	
G-3-P to BPGA (each worth 2 ATP)	2 x 2 = 4 ATP
Total ATP from glycolysis	**6 ATP(a)**
II. Oxidative decarboxylation of Pyruvic acid	
Pyruvic acid to Acetyl CoA(each $NADH_2$ worth 3 ATP)	2 x 3 = **6 ATP(b)**
III. Kreb's Cycle	
1. ATP produced in substrate level phosphorylation	
Succinyl CoA to Succinic acid	2 x 1 = 2 ATP
2. ATP from $NADH_2$	
Isocitric acid to Oxalosuccinic acid	2 x 3 = 6 ATP
α ketoglutaric acid to Succinyl CoA	2 x 3 = 6 ATP
Malic acid to Oxaloacitic acid	2 x 3 = 6 ATP
3. ATP from $FADH_2$ (each worth 2 ATP)	
Succinic acid to Fumaric acid	2 x 2 = 4 ATP
Total ATP from Kreb's cycle	**24 ATP(c)**
Net gain of ATP from Glucose = (a+b+c)	**36 ATP**

4. Define RQ. Write a short note on RQ.

Ans: During aerobic respiration, O_2 is consumed and CO_2 is released. The ratio of the volume of CO_2 evolved to the volume of O_2 consumed in respiration is called the **respiratory quotient** (RQ) or respiratory ratio. In living organisms respiratory substrates are often more than one. RQ values are used to know the nature of the respiratory substrate.

RQ = volumeof CO_2 evolved / volumeof O_2 consumed

The respiratory quotient depends upon the type of respiratory substrate used during respiration. When carbohydrates are used as substrate and are completely oxidised, the RQ will be 1, because equal amounts of CO2 and O2 are evolved and consumed, respectively, as shown in the equation below :

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

$$RQ = 6CO_2 / 6O_2 = 1.0$$

When fats are used in respiration, the RQ is less than 1. Calculations for a fatty acid, tripalmitin, if used as a substrate is shown:

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

Tripalmitin

$$RQ = 102CO_2 / 145O_2 = 0.7$$

When proteins are respiratory substrates the ratio would be about 0.9.

Pure proteins or fats are never used as respiratory substrates.

5. Describe briefly the process of fermentation.

Ans: In fermentation, say by yeast, the incomplete oxidation of glucose under **anaerobic conditions** results in pyruvic acid converted to CO_2 and ethanol. The enzymes, *pyruvic acid decarboxylase* and *alcohol dehydrogenase* catalyse these reactions. Other organisms like some bacteria produce lactic acid from pyruvic acid.

The steps involved are:

$$2\text{Pyruvic acid} \rightarrow 2\text{Acetaldehyde} + 2CO_2$$

Enzyme being ***Pyruvate decarboxylase***

$$2\text{Acetaldehyde} + 2\text{NADH} + \text{H} \rightarrow 2\text{Ethyl alcohol} + 2\text{NAD}^{+}$$

Enzyme being ***Alcohol dehydrogenase***

In animal cells also, like muscles during exercise, when oxygen is inadequate for cellular respiration pyruvic acid is reduced to lactic acid by ***lactate dehydrogenase***. The reducing agent is NADH+H+ which is reoxidised to NAD+ in both the processes.

In both lactic acid and alcohol fermentation not much energy is released; less than 7% of the energy in glucose is released and not all of it is trapped as high energy bonds of ATP.

Also, the processes are hazardous – either acid or alcohol is produced. Yeasts poison themselves to death when the concentration of alcohol reaches about 13%.

Fermentation results in Net gain of **2ATP**.

6. Explain various complexes involved in electron transport system of respiration?

Ans: In the Electron Transport **five** different complexes participate. These are present in the inner mitochondrial membrane.

1. Complex I — NADH dehydrogenase.
2. Complex II — Succinic dehydrogenase
3. Complex III —Cytochrome 'b-c_1' complex.(cytochrome 'c' reductase)
4. Complex IV — Cytochrome 'c' oxydase.(cytochrome a_1 and a_2)
5. Complex V — ATP synthase.

1. Complex I — NADH dehydrogenase:Electrons from $NADH_2$ produced in the mitochondrial matrix during citric acid cycle are oxidised $NADH_2$ ehydrogenase (complex I), and electrons are then transferred to ubiquinone located within the inner membrane. Reactive centers contain Fe-S. Translocates protons across the membrane.

2. Complex II — Succinic dehydrogenase: Membrane bound protein. Ubiquinone also receives electrons via FADH2 (complex II) and transfers to cytochrome *bc*1 complex (complex III). Reactive centers contain Fe-S.

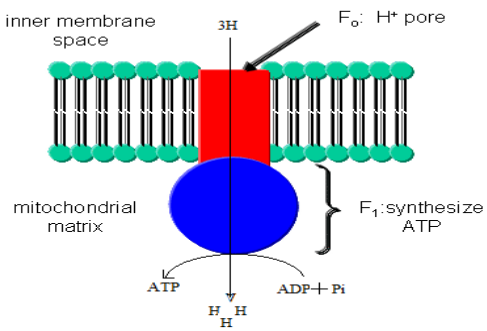
3. Complex III —Cytochrome 'b-c_1' complex: Transfer electrons to cytochrome *c* . Cytochrome *c* is a small protein. Reactive centers contain Fe-S.Translocates protons across the membrane.

4. Complex IV — Cytochrome 'c' oxydase: It got highest affinity for molecular Oxygen and reacts with electrons and protons to form respiratory water in the matrix. It got two copper centers.

5. Complex V — ATP synthase: Acts as proton channel and couples with electron transport and produces ATP.

7. Describe the structure of complex-V and explain the process of oxidative phosphorylation as explained by chemiosmotic hypothesis.

Ans: This complex consists of two major components, F1 and F0.The F1 headpiece is a peripheral membrane protein complex within the mitochondrial matrix and contains the site for synthesis of ATP from ADP and inorganic phosphate. F0 is an integral membrane protein complex that forms the channel through which protons cross the inner membrane into matrix.



The passage of protons through the channel is coupled to the catalytic site of the F1 component for the production of ATP. For each ATP produced, 3H+ passes through F0 from the intermembrane space to the matrix down the electrochemical proton gradient.

Proton motive force develop across the membrane in the inner mitochondrial space as a result electron transport from electron carriers produced in respiration. This results in the proton gradient across the membrane which is essential for ATP synthesis according to **chemiosmatic hypothesis**. ATP synthase acts as proton channel and synthesizes ATP using the energy released in the proton transfer.

Long Answer Typequestions.

1. Give an account of glycolysis. Where does it occur? What are the end products? Trace the fate of these products in both aerobic and anaerobic respiration.

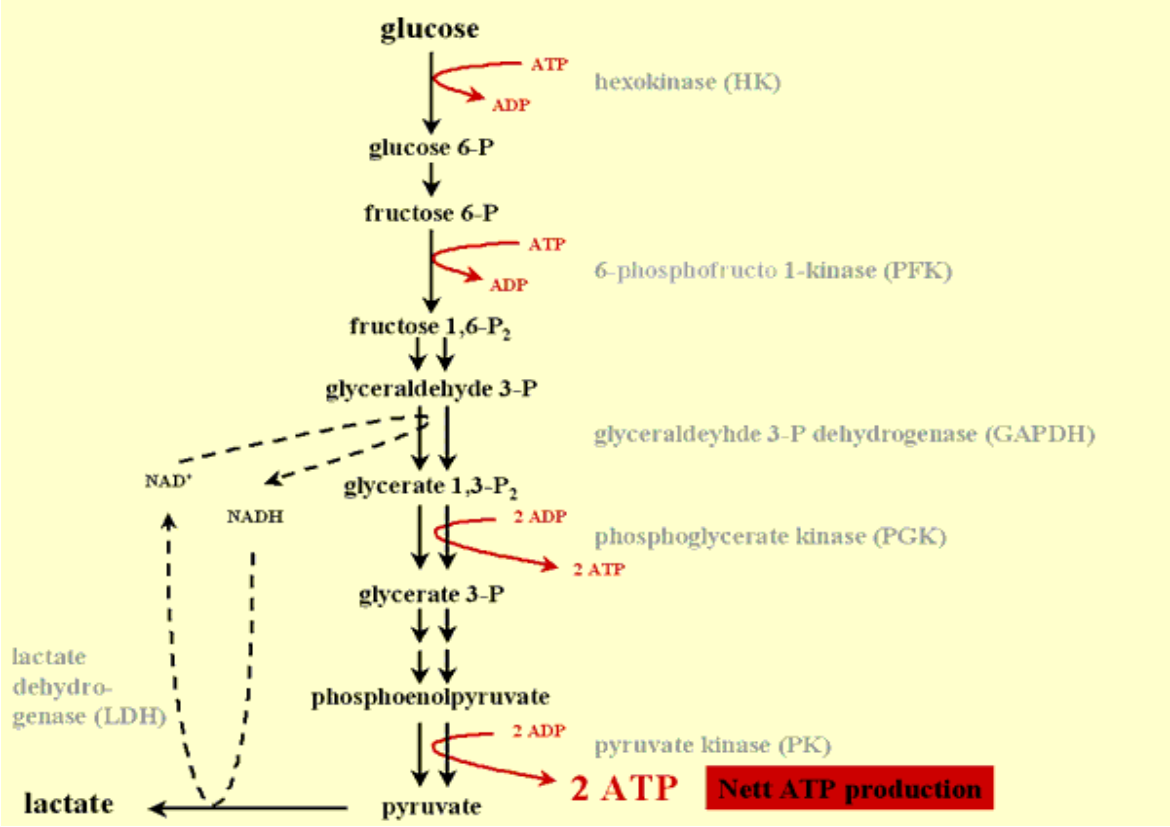
Ans: Glycolysis is incomplete oxidation of glucose to form organic acids like **pyruvic acid**.

The scheme of glycolysis was given by Gustav Embden, Otto Meyerhof, and J. Parnas, and is often referred to as the EMP pathway.

Glycolysis occurs in the cytoplasm of the cell and is present in all living organisms.

In this process, glucose undergoes partial oxidation to **form two molecules of pyruvic acid**.

Glucose and fructose are phosphorylated to give rise to glucose-6- phosphate by the activity of the enzyme hexokinase.



This phosphorylated form of glucose then isomerises to produce fructose-6-phosphate.

In glycolysis, a chain of ten reactions, under the control of different enzymes, takes place to produce pyruvate from glucose.

ATP is utilised at two steps: first in the conversion of glucose into glucose 6-phosphate and second in the conversion of fructose 6-phosphate to fructose 1, 6-bisphosphate.

The fructose 1, 6-bisphosphate is split into dihydroxyacetone phosphate and 3-phosphoglyceraldehyde (PGAL).

There is one step where NADH + H+ is formed from NAD+; this is when 3-phosphoglyceraldehyde (PGAL) is converted to 1, 3-bisphosphoglycerate (BPGA).

Two redox-equivalents are removed (in the form of two hydrogen atoms) from PGAL and transferred to a molecule of NAD+.

PGAL is oxidised and with inorganic phosphate to get converted into BPGA.

The conversion of BPGA to 3-phosphoglyceric acid (PGA), is also an energy yielding process; this energy is trapped by the formation of ATP.

Another ATP is synthesized during the conversion of PEP to pyruvic acid.

Pyruvic acid is then the key product of glycolysis.

Pyruvic acid is the key product of glycolysis.

Fate of the Pyruvic acid:

The metabolic fate of pyruvate depends on the cellular need.

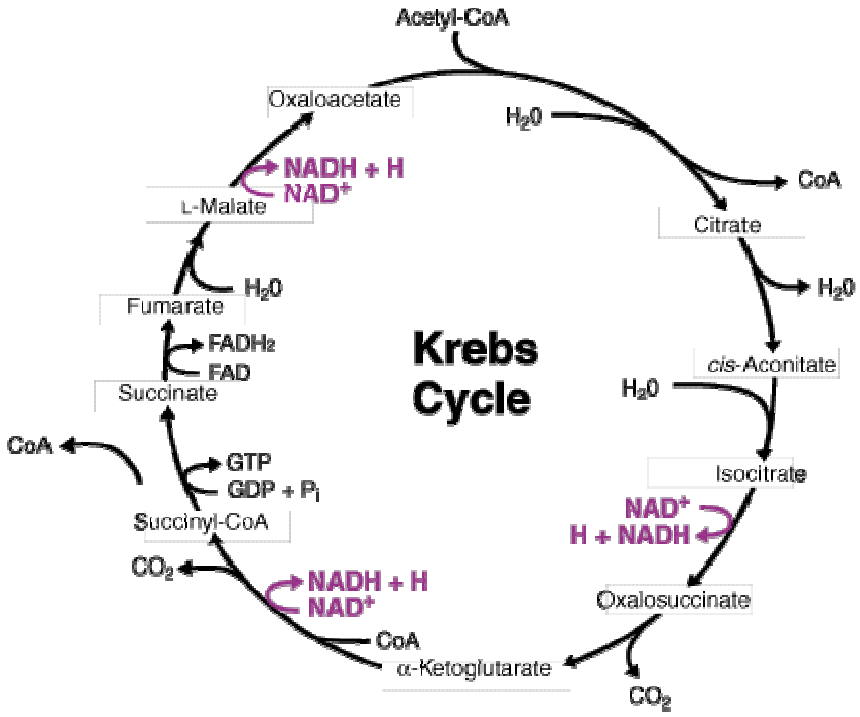
There are three major ways in which different cells handle pyruvic acid produced by glycolysis.

These are lactic acid fermentation, alcoholic fermentation and aerobic respiration. Fermentation takes place under anaerobic conditions in many prokaryotes and unicellular eukaryotes.

For the complete oxidation of glucose to CO_2 and H_2O, however, organisms adopt Krebs' cycle which is also called as aerobic respiration. This requires O_2 supply.

2. Explain the reactions of Kreb's cycle.

Ans: Kreb's cycle takes place in mitochondrial matrix in aerobic organisms.Acetyle-CoA is the connecting link between glycolysis and Kreb's cycle.



Condensation:

The Kreb's cycle starts with the **condensation** of Acetyl-CoA with oxaloacetic acid (OAA) and water to yield citric acid. The reaction is catalysed by the enzyme ***citrate synthase*** and a molecule of CoA is released. As the citric acid is the first

substance, the cycle is called as Citric acid cycle and as it is tricarboxylic acid it is also called as TCA cycle.

Oxakoacetic acid + Acetyl-CoA→Citic acid + Coenzyme A

Dehydration and Hydration:

Citrate is then isomerised to isocitrate by two consecutive reactions of **dehydration** and **hydration** both the reactions being mediated by same enzyme ***Aconitase***.

Citric acid → Cis-aconitase + H_2O

Cis-aconitase + H_2O → Isocitric acid

It is followed by two successive steps of **oxidation** and **decarboxylation**, leading to the formation of α-ketoglutaric acid.

Oxydation:

This is the oxidative reaction of TCA cycle mediated by the enzyme ***isocitric dehydrogenase***. NAD^+ is reduced to yield NADH+H.

Isocitric acid + NAD^+ → Oxalosuccinic acid + NADH+H

Decarboxylation:

The 6C oxalosuccinic acid releases one CO_2 in the presence of ***oxalosuccinic decarboxylase*** enzyme to form 5C compound α-ketoglutaric acid.

Oxalosuccinic acid → α-ketoglutaric acid + CO_2

α-ketoglutaric acid undergoes **oxidative decarboxylation** to form succinyl-CoA. This is the second oxidation reaction of the cycle.

Oxidative decarboxylation(Oxidation –II):

α-ketoglutaric acid + NAD^+ + CoenzymeA → Succinyl coenzymeA + NADH+H + CO_2

In the remaining steps of citric acid cycle, succinyl-CoA is oxidized to OAA allowing the cycle to continue. During the conversion of succinyl-CoA to succinic acid a molecule of GTP is synthesised. This is a **substrate level phosphorylation**. In a coupled reaction GTP is converted to GDP with the simultaneous synthesis of ATP from ADP.

Cleavage:

Succinyl coenzymeA + ADP +Pi → Succinic acid + ATP + CoA

The enzyme being ***Succinic thiokinase***

Oxidation-III:

Succinic acid + FAD^+ → Fumaric acid + $FADH_2$

The enzyme being ***Succinic dehydrogenase*** (membrane bound enzyme)

Hydration:

Fumaric acid + H_2O → Malic acid

The enzyme being ***Fumarase***

Oxidation IV:

Malic acid + NAD^+ → Oxaloacitic acid + NADH+H

The enzyme being ***Malic dehydrogenase***

Energetics of Kreb's cycle:

At three points in the cycle NAD+ is reduced to NADH + H to form 6 NADH + H and one point FAD+ is reduced to FADH2 and 2 FADH2.
In addition two molecules of ATP are formed by substrate level phosphorylation.
Oxaloacitic acid is regenerated.