RESPIRATION IN PLANTS

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CLASS: XI **BIOLOGY**

1. Define respiration.

The breaking of the C-C bonds of complex compounds through oxidation within the cells, leading to release of considerable amount of energy is called **respiration**.

2. What are respiratory substrates?

Those organic compounds which are oxidized to yield energy are called respiratory substrates. Usually carbohydrates are oxidised to release energy, but proteins, fats and even organic acids can be used as respiratory substances in some plants, under certain conditions.

3. Write the equation for respiration of glucose.

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

4. What is meant by aerobic respiration?

Aerobic respiration is the process of complete oxidation of organic substances in the presence of oxygen, to release carbon dioxide, water and energy.

5. What is anaerobic respiration?

Anaerobic respiration refers to the oxidation of food materials to release energy in the absence of molecular oxygen.

6. Write the equation for anaerobic respiration of glucose.

$C_6H_{12}O_6 \longrightarrow 2C_2H_5OH + 2CO_2$ + energy.

7. Define fermentation.

Fermentation is the process of anaerobic respiration occurring in microbes leading to the formation of alcohol or organic acid.

8. Define respiratory quotient (RQ).

Respiratory quotient is the ratio of the volume of carbon dioxide evolved to the volume of oxygen consumed in respiration.

9. Where does glycolysis occur in a cell?

Glycolysis occurs in the cytoplasm of the cell.

10. Name the scientists who gave the scheme of reactions in glycolysis.

Embden, Meyerhof and Parnas.

11. What does the word glycolysis literally mean?

The term glycolysis stands for glycos meaning sugar and lysis meaning breakdown, glycolysis means breakdown of sugar.

12. How many molecules of ATP are produced when one molecule of NADH is oxidized?

Three ATP molecules are produced when one molecule of NADH is oxidised.

SHORT ANSWER QUESTIONS

1. Why do plants can get along without respiratory organs?

- First, each plant part takes care of its own gas exchange needs. There is very little transport of gases from one plant part to another.
- Second, plants do not present great demands for gas exchange. Roots, stems and leaves respire at rates far lower than animals do.
- Third, the distance that gases must diffuse even in large, bulky plants is not great. Each living cell in a plant is located quite close to the surface of the plant.

2. What are respiratory substrates? Name the most common respiratory substrate.

The compounds oxidised during the process of respiration are called respiratory substrates. Carbohydrates, especially glucose, act as respiratory substrates. Fats, proteins, and organic acids also act as respiratory substrates.

3. Name the components of complex V and mention their functions.

- Complex -V, i.e., enzyme ATP synthetase consists of two components F_1 and F_O.
- F_1, the head piece, is a peripheral membrane protein complex and it contains the site for synthesis of ATP.
- F_0 is an integral membrane protein complex that forms the channel through which protons cross the inner membrane.

4. Why does anaerobic respiration produce less energy than aerobic respiration?

- In anaerobic respiration, the respiratory substrate is partially oxidized to form either alcohol or an organic acid.
- Such a product can further be oxidized, when some more energy will be released.
- In aerobic respiration, the respiratory substrate is fully oxidized to form CO2 and H2O. Hence there is release of more energy than anaerobic respiration

5. How does pyruvic acid enter the Krebs cycle?

- Pyruvic acid is first decarboxylated, i.e., one of the three carbons is oxidized to carbon dioxide.
- It is then oxidized by the enzyme pyruvate dehydrogenase, when NAD is reduced to NADH.
- The 2C- unit is accepted by a sulphur containing coenzyme A (Co-A) to form acetyl Co-A.
- Acetyl-Co-A enters the Krebs cycle and combines with oxaloacetic acid to form citric acid
- Pyruvic acid + Co-A + NAD+ $\xrightarrow[Mg^{2+}]{\text{Pyruvic dehydrogenase}}$ Acetyl –Co-A + CO_2 + NADH + H^+

6. Differentiate between

(a) Respiration and Combustion

(b) Glycolysis and Krebs' cycle

(c) Aerobic respiration and Fermentation.

(a) Respiration and Combustion

	Respiration	Combustion
1	It is a biochemical process.	It is a physicochemical process.
2	It occurs in the living cells.	It does not occur in the living cells.
3	ATP is generated	ATP is not generated
4	Enzymes are required	Enzymes are not required
5	It is a biologically-controlled process.	It is an uncontrolled process.

(b) Glycolysis and Krebs cycle

	Glycolysis	Krebs cycle
1	It is a linear pathway.	It is a cyclic pathway.
2	It occurs in the cell cytoplasm.	It occurs in the mitochondrial matrix.
3	It occurs in both aerobic and anaerobic respiration.	It occurs in aerobic respiration.
4	It generates 2 $NADH_2$ and 2 ATP molecules on the breakdown of one glucose molecule.	It produces 6 $NADH_2$, 2$FADH_2$, and 2 ATP molecules on the breakdown of two acetyl-CoA molecules.

(c) Aerobic respiration and fermentation

	Aerobic respiration	Fermentation
1	Oxygen is used for deriving energy	Occurs in the absence of oxygen
2	Occurs in the cytoplasm and mitochondria	Occurs in the cytoplasm
3	End products are carbon dioxide and water	End products are ethyl alcohol and carbon dioxide
4	Complete oxidation of the respiratory substrate takes place	Incomplete oxidation of the respiratory substrate takes place
5	About 36 ATP molecules are produced	Only 2 ATP molecules are produced

7. Distinguish between the following:

(a) Aerobic respiration and Anaerobic respiration

(b) Glycolysis and Fermentation

(c) Glycolysis and Citric acid Cycle

(a) Aerobic respiration and Anaerobic respiration

	Aerobic respiration	Anaerobic respiration
1	It uses oxygen for deriving energy.	It occurs in the absence of oxygen.
2	It occurs in cytoplasm and mitochondria.	It occurs in cytoplasm.
3	The end products of aerobic respiration are carbon dioxide and water.	The end products of fermentation are ethyl alcohol and carbon-dioxide.
4	Complete oxidation of respiratory substrate takes place.	Incomplete oxidation of respiratory substrate takes place.
5	36-38 ATP molecules are produced.	Only 2 ATP molecules are produced.

(b) Glycolysis and Fermentation

	Glycolysis	Fermentation
1	Glycolysis occurs during aerobic and anaerobic respiration.	Fermentation is a type of anaerobic respiration.
2	Glycolysis results in the breakdown of glucose into two molecules of pyruvic acid.	In this, pyruvic acid is converted into either ethanol (alcohol) or an organic acid.

(c) Glycolysis and citric acid cycle

	Glycolysis	Citric acid cycle (Krebs cycle)
1	It is a linear pathway.	It is a cyclic pathway.
2	It occurs in the cell cytoplasm.	It occurs in the mitochondrial matrix.
3	It occurs in both aerobic and anaerobic respiration.	It occurs in aerobic respiration.
4	One glucose molecule breaks down to generate 2 $NADH_2$ and 2 ATP molecules.	It produces 6 $NADH_2$, 2 $FADH_2$, and 2 ATP molecules on breakdown of two acetyl-coA molecules.

8. What are the assumptions made during the calculation of net gain of ATP?

For theoretical calculation of ATP molecules, various assumptions are made, which are as follows.

(a) It is assumed that various parts of aerobic respiration such as glycolysis, TCA cycle, and ETS occur in a sequential and orderly pathway.

(b) NADH produced during the process of glycolysis enters into mitochondria to undergo oxidative phosphorylation.

(c) Glucose molecule is assumed to be the only substrate while it is assumed that no other molecule enters the pathway at intermediate stages.

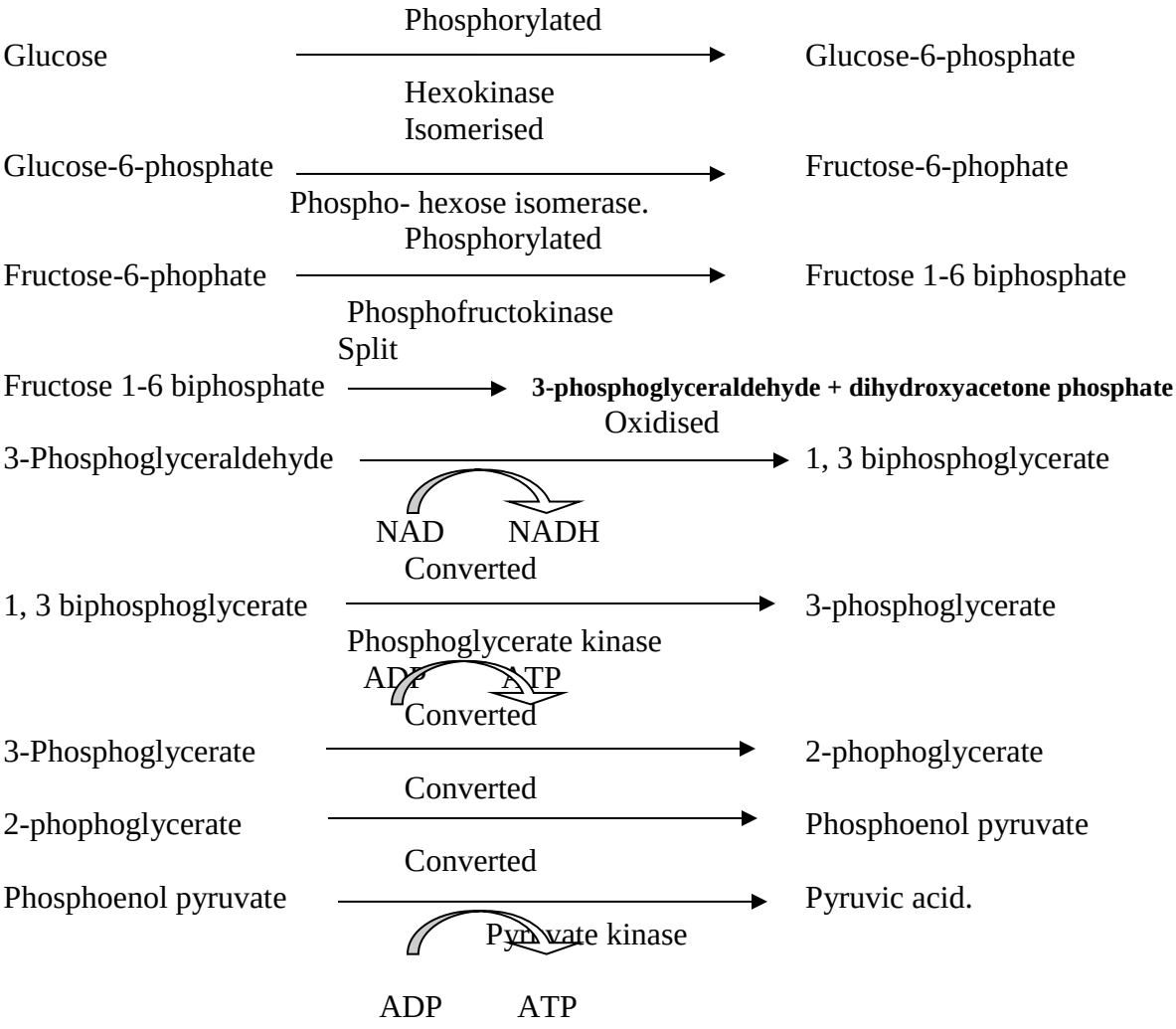
(d) The intermediates produced during respiration are not utilized in any other process.

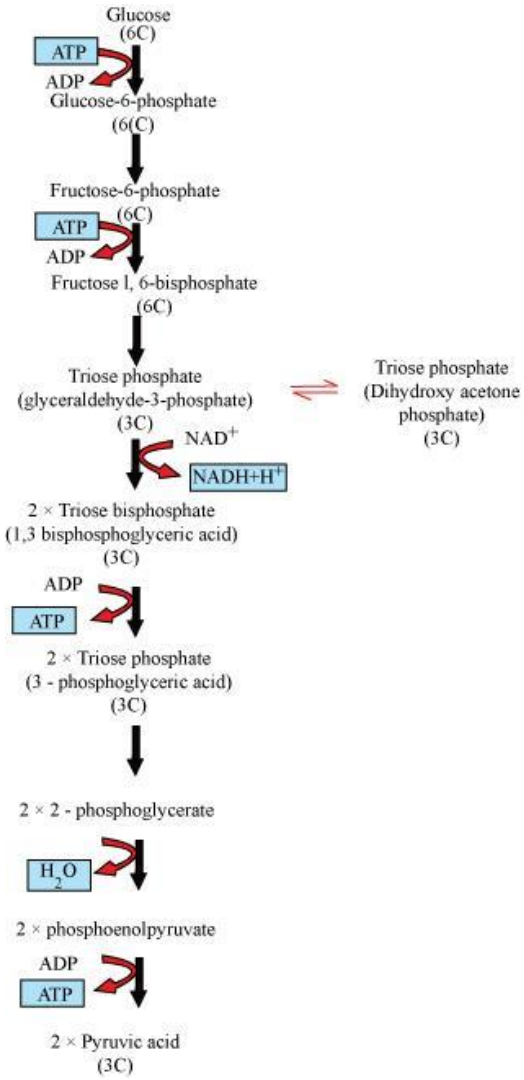
9. Explain the major steps of Glycolysis. Where does this process occur in a cell?

- The reactions of glycolysis occur in the cytoplasm of the cell. The steps are as follows:
- Glucose is phosphorylated to glucose-6-phosphate in the presence of ATP catalysed by the enzyme hexokinase.

- Glucose-6-phosphate is isomerised to fructose-6-phophate, catalysed by the enzyme phospho- hexose isomerase.
- Fructose-6-phophate is phosphorylated to fructose 1-6 biphosphate in the presence of ATP catalysed by the enzyme phosphofructokinase.
- Fructose 1-6 biphosphate is split into two molecules of triose phosphate i.e. one molecule of 3-phosphoglyceraldehyde and one molecule of dihydroxyacetone phosphate, which are interconvertible.
- 3-Phosphoglyceraldehyde is oxidised to 1, 3 biphosphoglycerate with the reduction of NAD to NADH.
- 1, 3 biphosphoglycerate is converted into 3-phosphoglycerate catalysed by the enzyme phophoglycerate kinase. One molecule of ATP is directly produced in this reaction.
- 3-Phosphoglycerate is converted into 2-phophoglycerate.
- 2-phophoglycerate is converted into phosphoenol pyruvate.
- Phosphoenol pyruvate is converted into pyruvic acid.

GLYCOLYSIS





10. Describe the process of citric acid cycle in living organisms.

OR

Explain the major steps in Krebs cycle with diagram. Where does this process occur in a cell?

- Krebs cycle or Citric acid cycle occurs in the mitochondrial matrix.
- Acetyl-Co-A (2C-compound) formed by the oxidative decarboxylation of pyruvic acid combines with oxaloacetic acid (4C-compound) to form a citric acid (6C-compound). This reaction is catalysed by citrate synthetase.
- Citrate is then isomerised to isocitrate. Isocitrate is oxidised in the presence of isocitrate dehydrogenase: NAD is reduced to NADH.
- It is then decarboxylated to form alpha-ketoglutaric acid. Alpha -ketoglutaric acid is decarboxylated and succinyl-CoA is formed in the presence of NAD and Coenzyme-A and enzyme alpha –ketoglutaric dehydrogenase. When Succinyl-Co-A is converted into succinic acid one molecule of GTP is formed and Co-A is released.
- Succinic acid is oxidized to malic acid when FAD is reduced to $FADH_2$.

- Malic acid is then oxidized to oxaloacetic acid, along with the reduction of another NAD molecule into NADH.

CITRIC ACID CYCLE

Acetyl Co A + Oxaloacetic acid	**Converted** →	**Citric acid**
Citrate	**Isomerised** →	**Isocitrate**
Isocitrate	**Decarboxylated** →	**Alpha-ketoglutaric acid**
Alpha-ketoglutaric acid	**Decarboxylated** →	**Succinyl-CoA**
Succinyl-CoA	**Converted** →	**Succinicacid**
Succinicacid	**Oxidized** →	**Malic acid**
Malic acid	**Oxidized** →	**Oxaloacetic acid**

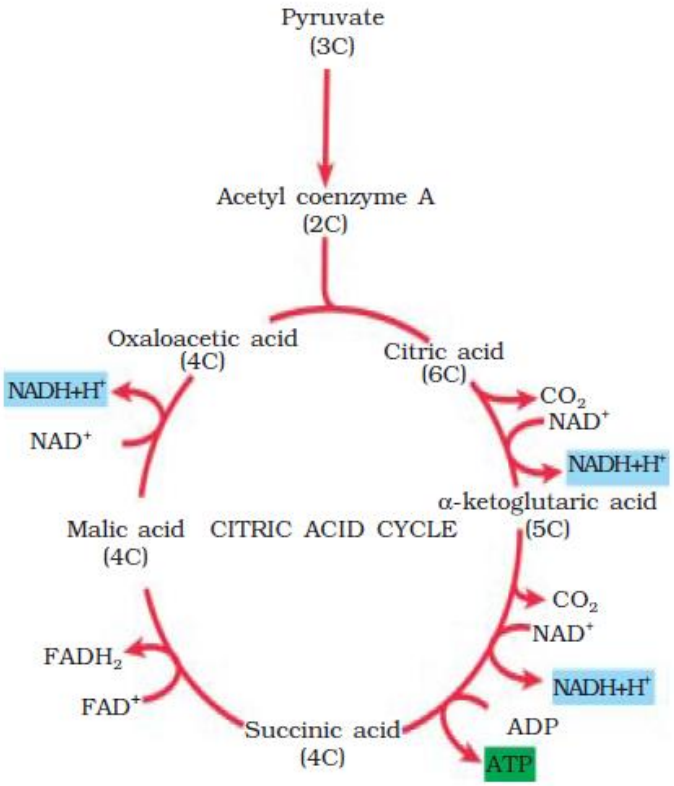


Figure 14.3 The Citric acid cycle

11. What is the significance of step-wise release of energy in respiration?

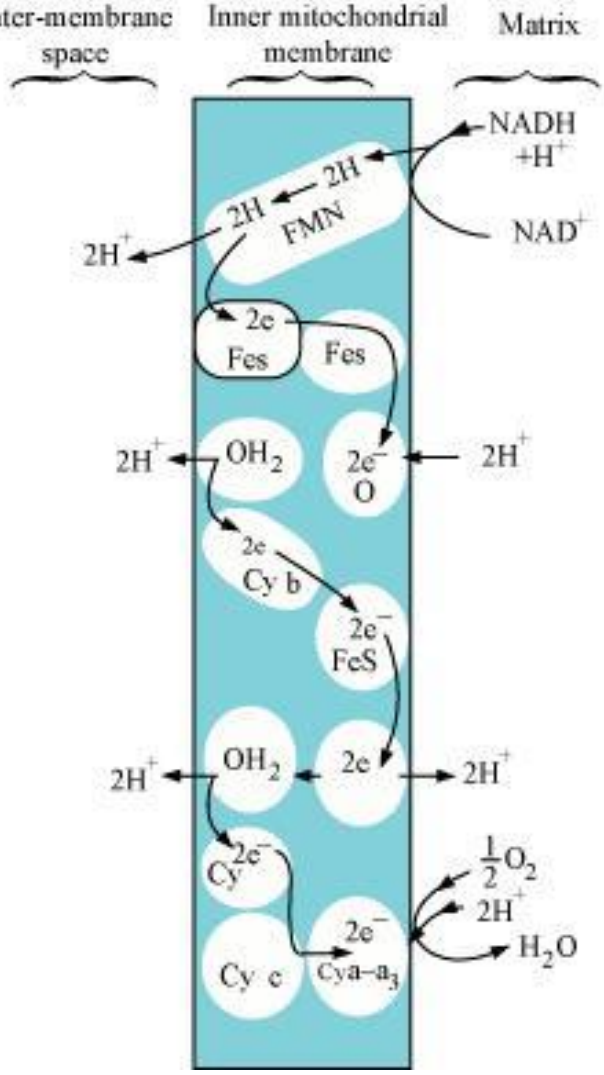
- The process of aerobic respiration is divided into four phases – glycolysis, TCA cycle, ETS, and oxidative phosphorylation.
- It is generally assumed that the process of respiration and production of ATP in each phase takes place in a step-wise manner.
- The product of one pathway forms the substrate of the other pathway.
- Various molecules produced during respiration are involved in other biochemical processes.
- The respiratory substrates enter and withdraw from pathway on necessity. ATP gets utilized wherever required and enzymatic rates are generally controlled.
- Thus, the step-wise release of energy makes the system more efficient in extracting and storing energy.

12. Discuss "The respiratory pathway is an amphibolic pathway."

- Respiration is generally assumed to be a catabolic process because during respiration, various substrates are broken down for deriving energy.
- Carbohydrates are broken down to glucose before entering respiratory pathways.
- Fats get converted into fatty acids and glycerol whereas fatty acids get converted into acetyl CoA before entering the respiration.
- In a similar manner, proteins are converted into amino acids, which enter respiration after deamination.
- During synthesis of fatty acids, acetyl CoA is withdrawn from respiratory pathway.
- Also, in the synthesis of proteins, respiratory substrates get withdrawn.
- Thus, respiration is also involved in anabolism. Therefore, respiration can be termed as amphibolic pathway as it involves both anabolism and catabolism.

13. Explain Electron Transport System.

- ETS or electron transport system is located in the inner mitochondrial membrane.
- It helps in releasing and utilizing the energy stored in $NADH+H^+$ and $FADH_2$. $NADH + H^+$, which is formed during glycolysis and citric acid cycle, gets oxidized by NADH dehydrogenase (complex I).
- The electrons so generated get transferred to ubiquinone through FMN.
- In a similar manner, $FADH_2$ (complex II) generated during citric acid cycle gets transferred to ubiquinone.
- The electrons from ubiquinone are received by cytochrome bc_1 (complex III) and further get transferred to cytochrome c.
- The cytochrome c acts as a mobile carrier between complex III and cytochrome c oxidase complex, containing cytochrome a and a_3, along with copper centres (complex IV).
- During the transfer of electrons from each complex, the process is accompanied by the production of ATP from ADP and inorganic phosphate by the action ATP synthase (complexV).
- The amount of ATP produced depends on the molecule, which has been oxidized.
- 2 ATP molecules are produced by the oxidation of one molecule of NADH. One molecule of $FADH_2$, on oxidation, gives 3 ATP molecules.



14. What are the assumptions made during the calculation of net gain of ATP?

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(b) NADH produced during the process of glycolysis enters into mitochondria to undergo oxidative phosphorylation.

(c) Glucose molecule is assumed to be the only substrate while it is assumed that no other molecule enters the pathway at intermediate stages.

(d) The intermediates produced during respiration are not utilized in any other process.

15. Define respiratory quotient with equations. What is the respiratory quotient for various respiratory substrates?

Respiratory quotient is defined as the ratio of volume of carbon dioxide liberated to the volume of oxygen consumed in respiration.

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

a. **RQ for carbohydrates is one,** because equal amounts of carbon dioxide and oxygen are liberated and consumed respectively.

$C_6H_{12}O_6 + 602 \rightarrow 6CO2 + 6H2O + energy.$ $RQ = \frac{6CO_2}{6O_2} = 1$

b. **RQ for fats is less than one** because they require **more oxygen** for their oxidation.

$2\ (C_{51}H_{98}O_6) + 145\ O_2 \longrightarrow 102\ CO_2 + 98H_2O + energy$ (Tripalmitin) $RQ = \frac{102\ CO_2}{145O_2} = 0.7$

c. When **organic acids are the substrates** for respiration, the **RQ will be more than one**; they require relatively less oxygen for their oxidation.

$2\ (COOH)_2 + O_2 \longrightarrow 4\ CO_2 + 2\ H_2O + energy$ (Oxalic acid) $RQ = \frac{4CO_2}{1O_2} = 4$

d. For anaerobic respiration, the RQ is infinity, because CO2 is liberated, but no oxygen is consumed.

$C_6H_{12}O_6 \xrightarrow{Zymase} 2\ C_2H_5OH + 2\ CO_2 + energy$ $RQ = \frac{2CO_2}{0O_2} = Infinity\ (\infty)$

16. Give a detailed account of the number of ATP molecules produced during various steps of aerobic oxidation of one molecule of glucose.

Balance Sheet of Respiration

	Stage of Respiration	Source	Number of ATP produced	Total ATP
1	Glycolysis	(1) Directly formed ATP	2 mol of ATP	8
		(2) 2 mol of NADH	6 mol of ATP	
2	Oxidative decarboxylation of pyruvic acid	2 mol of NADH	6 mol of ATP	6
3	Krebs cycle	(1) 6 mol of NADH	(6 x 3) 18 mol of ATP	24
		(2) 2 mol of FADH2	(2 x 2) 4 mol of ATP	
		(3) Directly formed ATP	2 mol of ATP	
	Net Gain	38-2=36 ATP	Net Total	38

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