RESPIRATION

- The breaking of the C-C bonds of complex compounds and release energy is called respiration.
- The compounds that are oxidised during this process are known as respiratory substrates.
- Usually carbohydrates proteins, fats and organic acids can be used as respiratory substances.

✔ plants require O_2 for respiration and they give out CO_2 .
✔ *Plants, unlike animals, have no specialised organs for gaseous exchange but they have stomata and lenticels for this purpose.*

The complete combustion of glucose, which produces CO_2 and H_2O as end products, yields energy .

$$C_6H_{12}O_6 + 6O_2 \text{------------>} 6CO_2 + 6H_2O + \textbf{Energy}$$

During the process of respiration, oxygen is utilised, and carbon dioxide, water and energy are released as products.

The whole process of respiration can be studied under three different steps:.

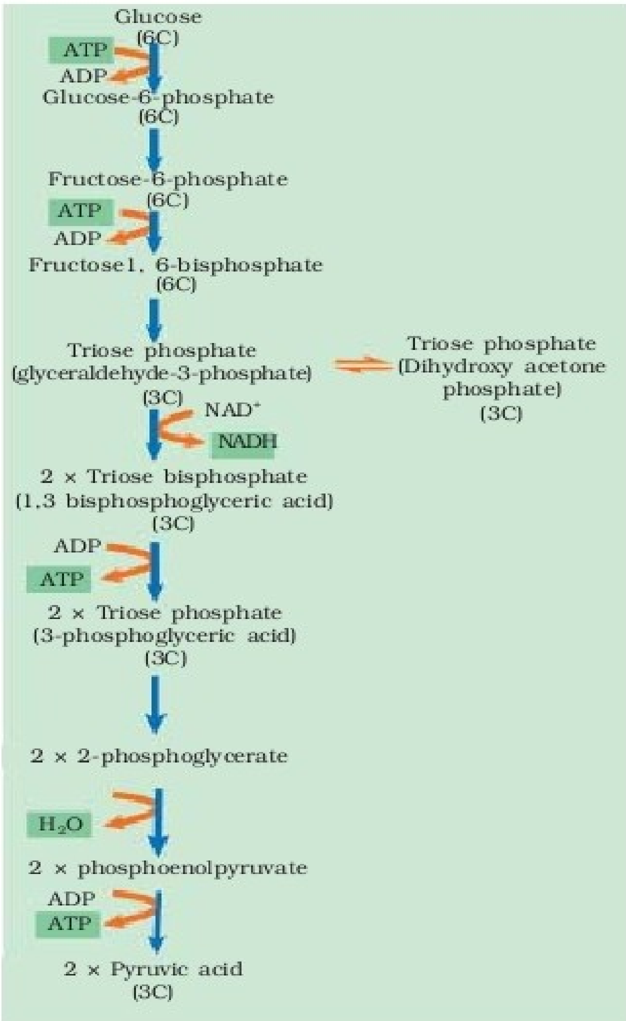
1. GLYCOLYSIS 2.KREBS CYCLE 3. ETS (Electron Transport System)

Glycolysis

- The scheme of glycolysis was given by **Gustav Embden, Otto Meyerhof, and J. Parnas,**
- So often referred to as the EMP pathway.
- In anaerobic organisms, glycolysis is the only process in respiration.
- Glycolysis occurs in the cytoplasm of the cell.
- In this process, glucose undergoes partial oxidation to form two molecules of pyruvic acid.

Steps:-

- Glucose is phosphorylated to give rise to glucose-6- phosphate by the activity of the enzyme **hexokinase**. *An ATP is utilised here.*
- glucose-6- phosphate then isomerises to produce fructose-6-phosphate.
- fructose 6-phosphate is converted into fructose 1, 6-diphosphate. *An ATP is utilised here.*
- The fructose 1, 6-diphosphate is split into dihydroxyacetone phosphate (DHAP) and 3-phosphoglyceraldehyde (3PGAL). *They are interconvertable forms.*
- 3-phosphoglyceraldehyde (3PGAL) is converted to 1, 3-bisphosphoglycerate (DPGA).
  PGAL is oxidised and with inorganic phosphate to get converted into DPGA.
  here NADH + H+ is formed from NAD +
- DPGA is converted into 3-phosphoglyceric acid (3PGA), *here an ATP is produced.*
- Then 3PGA to 2PGA
- 2PGA to PEP (phospho enol pyruvic acid)
- PEP is converted into Pyruvic acid. *here an ATP is produced.*



Fate of Pyruvic acid

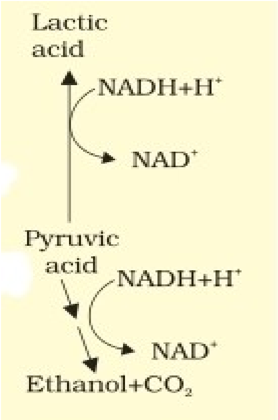
- *in some cells lactic acid fermentation takes place*
- *in some cells alcoholic fermentation takes place*
- *and in others aerobic respiration takes place.*

Fermentation takes place under anaerobic conditions in many prokaryotes and unicellular eukaryotes.

FERMENTATION

- In fermentation, incomplete oxidation of glucose is achieved , under anaerobic conditions.
- In yeast cell pyruvic acid is converted to CO_2 and ethanol.
- In some bacteria lactic acid from is produced from pyruvic acid.
- In animal muscles during exercise, pyruvic acid is reduced to lactic acid . It takes place because of inadequacy of oxygen.
- In both cases the reducing agent is NADH+H+ .

- *In both lactic acid and alcohol fermentation not much energy is released.*



AEROBIC RESPIRATION

The final product of glycolysis, pyruvic acid is transported from the cytoplasm into the mitochondria.

Pyruvate, in mitochondrial matrix undergoes oxidative decarboxylation by a set of reactions catalysed by pyruvic dehydrogenase and in presence of several coenzymes, including NAD+ and Coenzyme A. then acetyl coenzyme A is produced

Mg2+
Pyruvic acid + CoA + NAD+ ------------------------> Acetyl CoA + CO_2 + NADH + H+

The acetyl CoA then enters a cyclic pathway, tricarboxylic acid cycle, also called as Krebs' cycle after the scientist **Hans Krebs** who first elucidated it.

Tricarboxylic Acid Cycle [TCA cycle or Kreb's cycle]

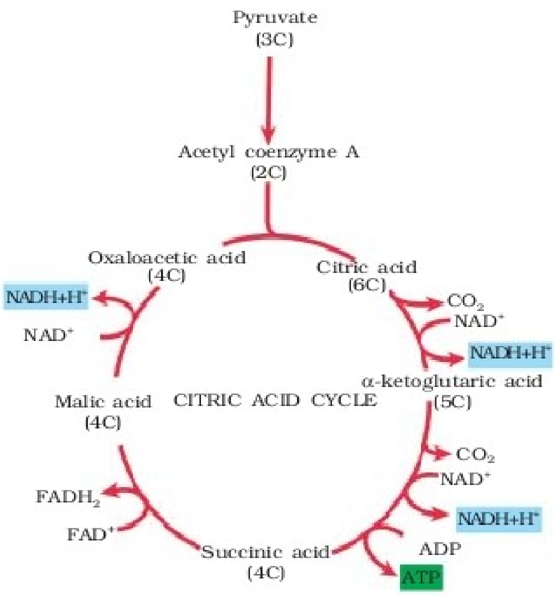
Steps:
1. condensation of acetyl group with oxaloacetic acid (OAA) and citric acid is formed.
(*The reaction is catalysed by the enzyme citrate synthase and a molecule of CoA is released.)*

2. Citrate is then isomerised to isocitrate.

3. Isocitrate is decarboxylated to forma α-ketoglutaric acid

4. Then succinyl-CoA is formed from α-ketoglutaric acid

5. Succinyl-CoA is converted in to succinic acid .here a molecule of GTP is synthesised.



6. Succinic acid is converted into malic acid. Here an FADH2 is produced

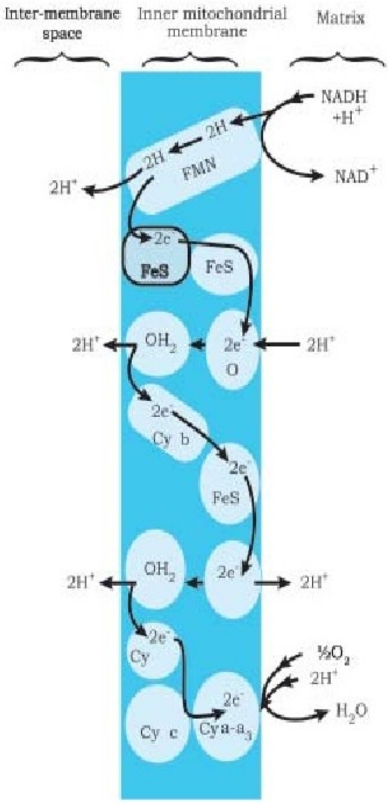
7. Malic acid next to Oxalo Acetic acid.

*** Note the steps at there the $NADH_2$ is produced, in picture

The complete Citric acid cycle is

Pyruvic acid + 4NAD+ + FAD+ + 2H2O + ADP + Pi ---------> 3CO2 + 4NADH + 4H+ + FADH2 + ATP

<u>Electron Transport System (ETS) and Oxidative Phosphorylation</u>



The electron passes from one carrier to another, is called the electron transport system (ETS) .It is present in the inner mitochondrial membrane.

NADH in the mitochondrial matrix are oxidised by NADH dehydrogenase (complex I), and electrons are then transferred to ubiquinone located within the inner membrane.

Ubiquinone also receives reducing equivalents via FADH2 (complex II) that is generated during oxidation of succinate in the citric acid cycle.

The reduced ubiquinone (ubiquinol) is then oxidised with the transfer of electrons to cytochrome c via cytochrome bc1 complex (complex III).

Cytochrome c is a s mobile carrier for transfer of electrons between complex III and IV.

Complex IV (cytochrome c oxidase complex) containing cytochromes a and a3, and 2 copper centres.

When the electrons is passed through this carriers the protons are pumped to the mitochondrial space from matrix.

These protons then try to move back to matrix when their concentration become higher at mitochondrial space. At this time the protons come through ATP synthase (complex V). It is the chemiosmotic hypothesis . This time ATP is produced form ADP.

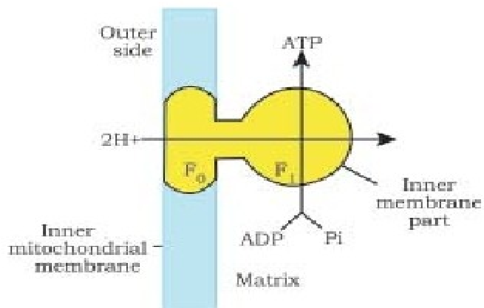
- The number of ATP molecules synthesised depends on the nature of the electron donor.
- Oxidation of one molecule of NADH gives rise to 3 molecules of ATP,
- while that of one molecule of FADH2 produces 2 molecules of ATP.

Oxygen acts as the final hydrogen acceptor. Here the energy of oxidation-reduction is utilised for making proton gradient. It is for this reason that the process is called oxidative phosphorylation.

ATP synthase (complex V) consists of two major components, F1 and F0

The F1 headpiece is a peripheral membrane protein complex and contains the site for synthesis of ATP

F0 is an integral membrane protein complex that forms the channel through which protons cross the inner membrane.



<u>Difference between fermentation and aerobic respiration</u>

Fermentation	Aerobic respiration
Here only a partial breakdown of glucose occur net gain of ATP is 2 for a glucose NADH is oxidised to NAD+ rather slowly	Complete breakdown to CO2 and H2O. 36 ATP NADH is oxidised to NAD+ is very vigorous

AMPHIBOLIC PATHWAY

The respiratory pathway is involved in both anabolism and catabolism, so it can be considered as amphibolic pathway.

The compounds of respiration enter in the synthesis of fatty acids or amino acids.

eg. acetyl CoA enter in fatty acid synthesis
ά-keto glutaric acid enter in glutamic acid synthesis,
succinyl CoA is involved in chlorophyll synthesis.
OAA in aspartic acid synthesis

RESPIRATORY QUOTIENT

During aerobic respiration, O2 is consumed and CO2 is released. The ratio of the volume of CO2 evolved to the volume of O2 consumed in respiration is called the respiratory quotient (RQ) or respiratory ratio.

RQ = volume of CO_2 evolved / volume of O_2 consumed

RQ of carbohydrate is 1
RQ of organic acid is greater than 1
RQ of fat is less than 1

Eg. glucose:-

$C_6 H_{12}O_6 + 6O_2$ ---------------> $6CO_2 + 6H_2O$ + Energy [RQ = $6CO_2 / 6O_2$ = 1.0]

fatty acid, tripalmitin, if used as a substrate is shown:

$2(C_{51}H_{98}O_6) + 145O_2$ ---------------> $102CO_2 + 98H_2O$ + energy [RQ = $102CO_2 / 145O_2$ = 0.7]

RESPIRATORY BALANCE SHEET

	NO.OF CYCLES	NO. OF ATP	TOTAL
GLYCOLYSIS	1	1 X 8	**8**
LINK REACTION	2	2 X 3	**6**
KREBS CYCLE	2	2 X 12	**24**
			38

For a glucose molecule 38 ATP in the case of prokaryotes while in eukaryotes it is 36

…....RAJESH.K..HSST Botany, GHSS Naduvannur, Kozhikode....