QUICK REVISION NOTES
For NEET
BIOLOGY CLASS 11

RESPIRATION

What is Respiration?

Respiration is a metabolic process that occurs in all organisms. It is a biochemical process that occurs within the cells of organisms. In this process, the energy (ATP-Adenosine triphosphate) is produced by the breakdown of glucose which is further used by cells to perform various functions. Every living species, from a single-celled organism to dominant **multicellular organisms**, perform respiration.

Site of Respiration

The mitochondria are the site for the respiration. The respiration reactions are carried out in the matrix and on the oxysomes in the mitochondria. The glucose is broken down with the help of oxygen to release energy in the form of ATP. These energy molecules can be used to drive the other chemical reactions.

There are two types of respiration:

I. aerobic respiration
II. anaerobic respiration

Aerobic respiration

It is a type of cellular respiration that takes place in the presence of oxygen to produce energy. It is a continuous process that takes place within the cells of animals and plants. This process can be explained with the help of the chemical equation:

$$\textbf{Glucose}(C_6H_{12}O_6) + \textbf{Oxygen}(6O_2) \rightarrow \textbf{Carbon dioxide}(6CO_2) + \textbf{Water}(6H_2O) + \textbf{Energy (ATP)}$$

Anaerobic respiration

It is a type of cellular respiration that takes place in the absence of oxygen to produce energy. The chemical equation for anaerobic respiration is

$$\textbf{Glucose}(C_6H_{12}O_6) \rightarrow \textbf{Alcohol } 2(C_2H_5O\,H) + \textbf{Carbon dioxide } 2(CO_2) + \textbf{Energy (ATP)}$$

- **why respiration is called catabolic metabolism?**

The catabolism process refers to the set of metabolic pathways, which includes the breaks down larger molecules into smaller units to release energy.

Respiration is called catabolic process, as energy is produced by the breakdown of glucose molecules.

- **why respiration is called calorigenic process?**

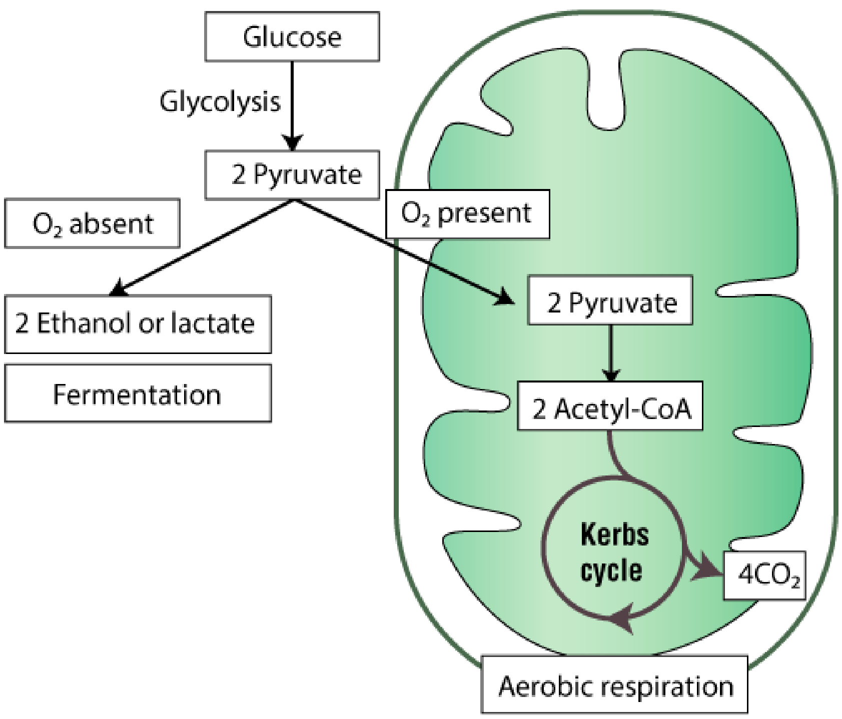
During cellular respiration, glucose is broken down in the presence of oxygen to produce carbon dioxide and water. The energy released during the reaction is captured by the energy-carrying molecule ATP (adenosine triphosphate). Hence, The energy releasing process in living organisms is respiration.

Respiratory substrate.

Respiration occurs in cytoplasm and mitochondria of a living cell. There is no definite time for respiration. This process runs 24 hours throughout the day and night. Though respiration occur in all the cells yet the rate of respiration is more in developing region like flower and leaf buds, germinating seeds, apical region of root and stem. The process of respiration is explained by the following reaction.

What is Fermentation?

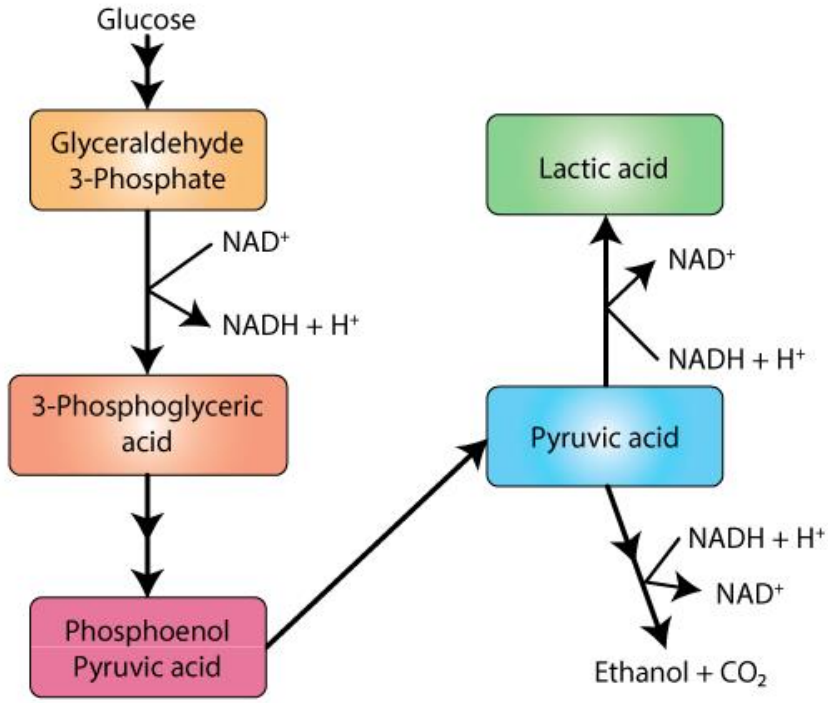
Definition: Fermentation is an enzyme catalysed, metabolic process whereby organisms convert starch or sugar to alcohol or an acid anaerobically releasing energy. The science of fermentation is called “zymology”.



Process of Fermentation

Fermentation is an anaerobic biochemical process. In fermentation, the first process is the same as cellular respiration, which is the formation of pyruvic acid by glycolysis where net 2 ATP molecules are synthesised.

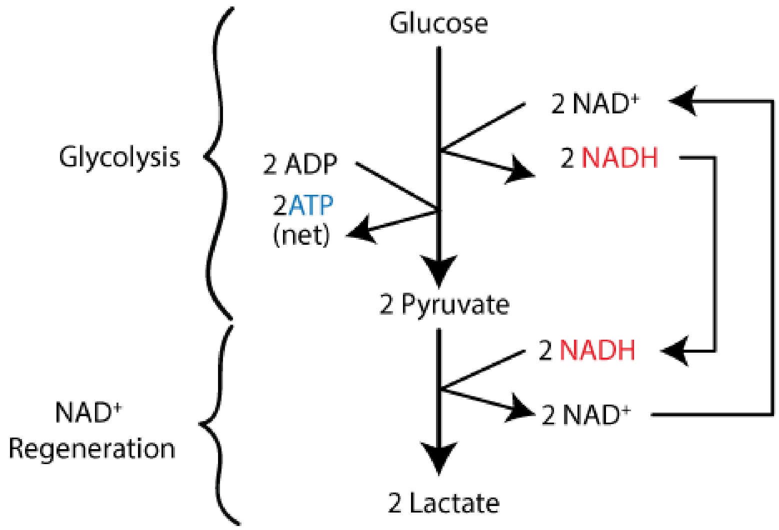
In the next step, pyruvate is reduced to lactic acid, ethanol or other products. Here NAD+ is formed which is re-utilized back in the glycolysis process.



1. Lactic Acid Fermentation

Lactic acid is formed from pyruvate produced in glycolysis. NAD+ is generated from NADH. Enzyme lactate dehydrogenase catalyses this reaction. Lactobacillus bacteria prepare curd from milk via this type of fermentation. During intense exercise when oxygen supply is inadequate, muscles derive energy by producing lactic acid, which gets accumulated in the cells causing fatigue.

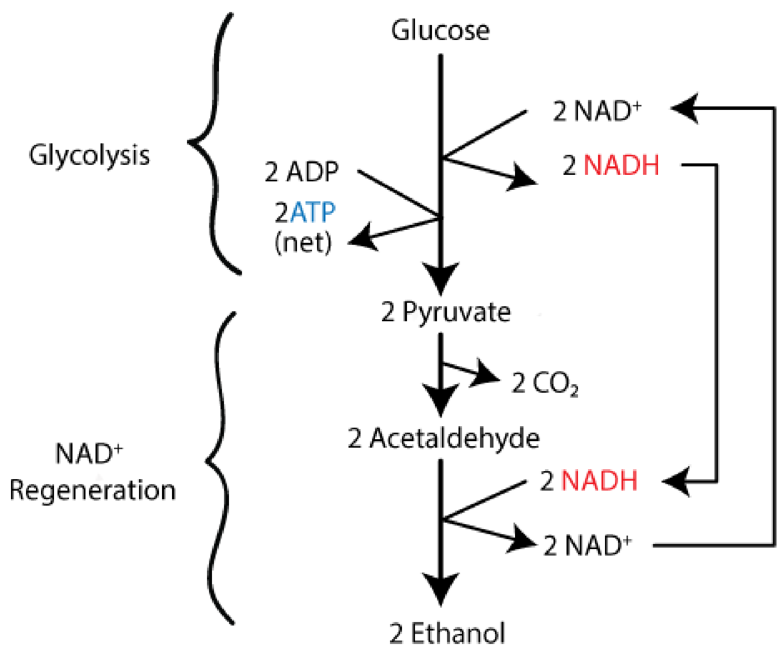
$$C_6H_{12}O_6(Glucose) \xrightarrow[Lactate.dehydrogenase]{Lactobacillus} 2CH_3CHOHCOOH(LacticAcid)$$



2. Alcohol Fermentation

This is used in the industrial production of wine, beer, biofuel, etc. The end product is alcohol and CO_2. Pyruvic acid breaks down into acetaldehyde and CO_2 is released. In the next step, ethanol is formed from acetaldehyde. NAD+ is also formed from NADH, utilized in glycolysis. Yeast and some bacteria carry out this type of fermentation. Enzyme pyruvic acid decarboxylase and alcohol dehydrogenase catalyse these reactions.

$$C_6H_{12}O_6(Glucose) \xrightarrow[Decarboxylase]{Dehydrogenase} 2CH_3CHO(Acetaldehyde)+2CO_2 \rightarrow 2C_2H_5OH(Ethanol)$$



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$$\underset{\text{Glucose}}{C_6H_{12}O_6} + \underset{\text{Oxygen}}{6O_2} \xrightarrow[\text{Co-Enzyme}]{\text{Enzymes}} \underset{\text{Carbon dioxide}}{6CO_2} + \underset{\text{Water}}{6H_2O} + \underset{\text{Energy}}{38ATP}$$

Importance of Fermentation:

1. Alcoholic beverage(brewing)
2. Yogurt production (Dairy)
3. Bread Making (baking)
4. producing Vitamin C
5. Fuel production
6. wastewater treatment
7. preservation of food
8. producing biopolymer
9. Medicine
10. Health benefit

Glycolysis

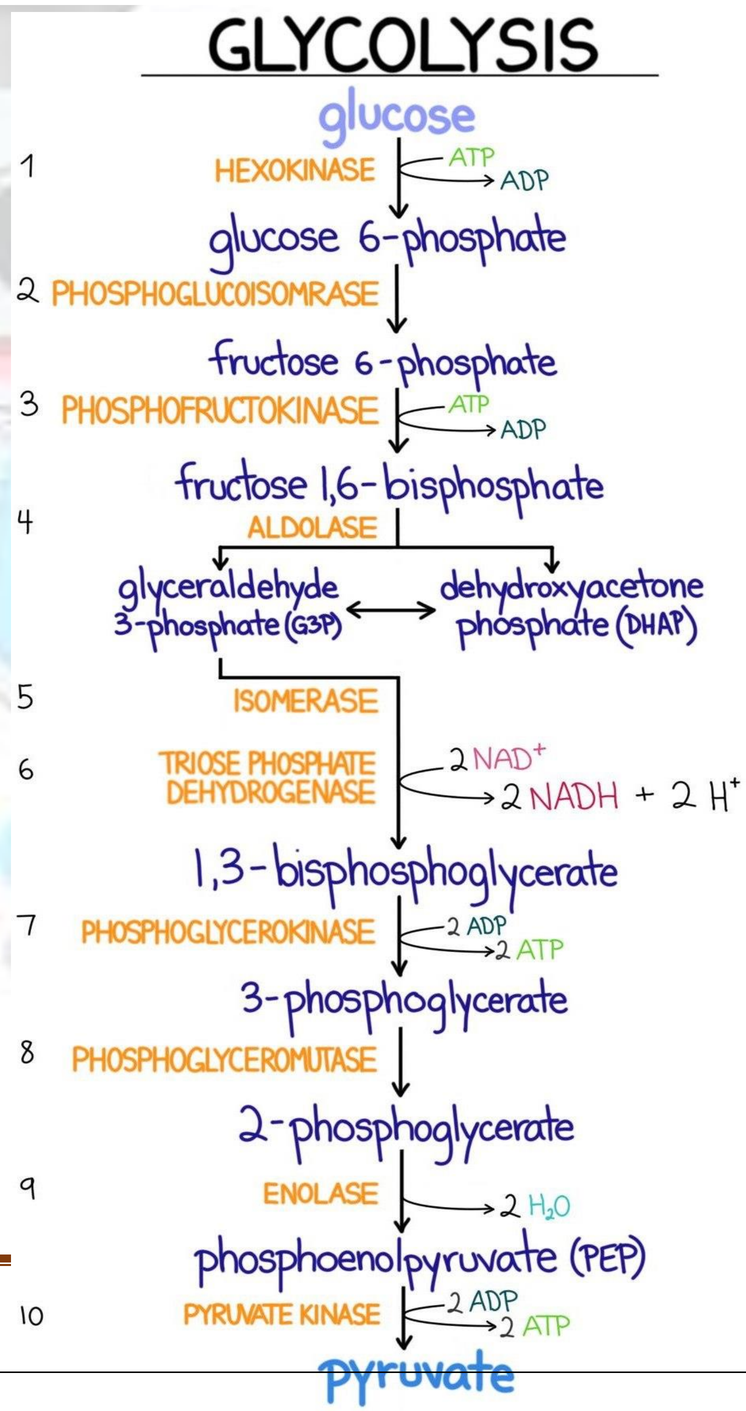
Glycolysis is the process in which glucose is broken down to produce energy. It produces two molecules of pyruvate, ATP, NADH and water. The process takes place in the cytosol of the cell cytoplasm, in the presence or absence of oxygen.

PATHWAY:

1 A phosphate group is added to glucose in the cell cytoplasm, by the action of enzyme hexokinase. In this, a phosphate group is transferred from ATP to glucose forming glucose,6-phosphate.

2

Glucose-6-phosphate is isomerized into fructose,6-phosphate by the enzyme phosphoglucomutase.



3

The other ATP molecule transfers a phosphate group to fructose 6-phosphate and converts it into fructose 1,6-bisphosphate by the action of enzyme phosphofructokinase.

4

The enzyme aldolase converts fructose 1,6-bisphosphate into glyceraldehyde 3-phosphate and dihydroxyacetone phosphate, which are isomers of each other.

5

Triose-phosphate isomerase converts dihydroxyacetone phosphate into glyceraldehyde 3-phosphate which is the substrate in the successive step of glycolysis.

6

This step undergoes two reactions:

- The enzyme glyceraldehyde 3-phosphate dehydrogenase transfers 1 hydrogen molecule from glyceraldehyde phosphate to nicotinamide adenine dinucleotide to form NADH + H^+.
- Glyceraldehyde 3-phosphate dehydrogenase adds a phosphate to the oxidized glyceraldehyde phosphate to form 1,3-bisphosphoglycerate.

7

Phosphate is transferred from 1,3-bisphosphoglycerate to ADP to form ATP with the help of phosphoglycerokinase. Thus two molecules of phosphoglycerate and ATP are obtained at the end of this reaction.

8

The phosphate of both the phosphoglycerate molecules is relocated from the third to the second carbon to yield two molecules of 2-phosphoglycerate by the enzyme phosphoglyceromutase.

9

The enzyme enolase removes a water molecule from 2-phosphoglycerate to form phosphoenolpyruvate.

10

A phosphate from phosphoenolpyruvate is transferred to ADP to form pyruvate and ATP by the action of pyruvate kinase. Two molecules of pyruvate and ATP are obtained as the end products.

Krebs cycle:

The Krebs cycle or Citric acid cycle is a series of enzyme catalysed reactions occurring in the mitochondrial matrix, where acetyl-CoA is oxidised to form carbon dioxide and coenzymes are reduced, which generate ATP in the electron transport chain.

Krebs cycle was named after Hans Krebs, who postulated the detailed cycle. He was awarded the Nobel prize in 1953 for his contribution.

It is a series of eight-step processes, where acetyl group of acetyl-CoA is oxidised to form two molecules of CO_2 and in the process, one ATP is produced. Reduced high energy compounds, NADH and $FADH_2$ are also produced.

Two molecules of acetyl-CoA are produced from each glucose molecule so two turns of the Krebs cycle are required which yields four CO_2, six NADH, two $FADH_2$ and two ATPs.

Krebs Cycle Steps

It is an eight-step process. Krebs cycle takes place in the matrix of mitochondria under aerobic condition.

Step 1: The first step is the condensation of acetyl CoA with 4-carbon compound oxaloacetate to form 6C citrate, coenzyme A is released. The reaction is catalysed by *citrate synthase*.

Step 2: Citrate is converted to its isomer, isocitrate. The enzyme *aconitase* catalyses this reaction.

Step 3: Isocitrate undergoes dehydrogenation and decarboxylation to form 5C **α**-ketoglutarate. A molecular form of CO_2 is released. *Isocitrate dehydrogenase* catalyses the reaction. It is an NAD^+ dependent enzyme. NAD^+ is converted to NADH.

Step 4: **α**-ketoglutarate undergoes oxidative decarboxylation to form succinyl CoA, a 4C compound. The reaction is catalyzed by ***α**-ketoglutarate dehydrogenase* enzyme complex. One molecule of CO_2 is released and NAD^+ is converted to NADH.

Step 5: Succinyl CoA forms succinate. The enzyme *succinyl CoA synthetase* catalyses the reaction. This is coupled with substrate-level phosphorylation of GDP to get GTP. GTP transfers its phosphate to ADP forming ATP.

Step 6: Succinate is oxidised by the enzyme *succinate dehydrogenase* to fumarate. In the process, FAD is converted to $FADH_2$.

Step 7: Fumarate gets converted to malate by addition of one H_2O. The enzyme catalysing this reaction is *fumarase*.

Step 8: Malate is dehydrogenated to form oxaloacetate, which combines with another molecule of acetyl CoA and starts the new cycle. Hydrogens removed, get transferred to NAD^+ forming NADH. *Malate dehydrogenase* catalyses the reaction.

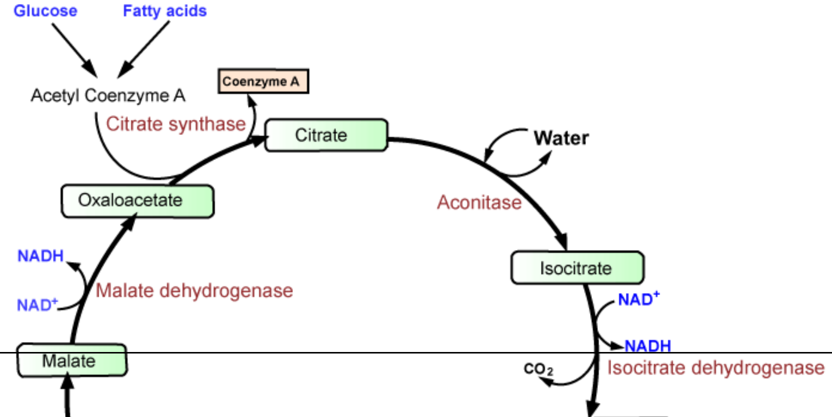


Fig: Krebs Cycle (TCA Cycle)

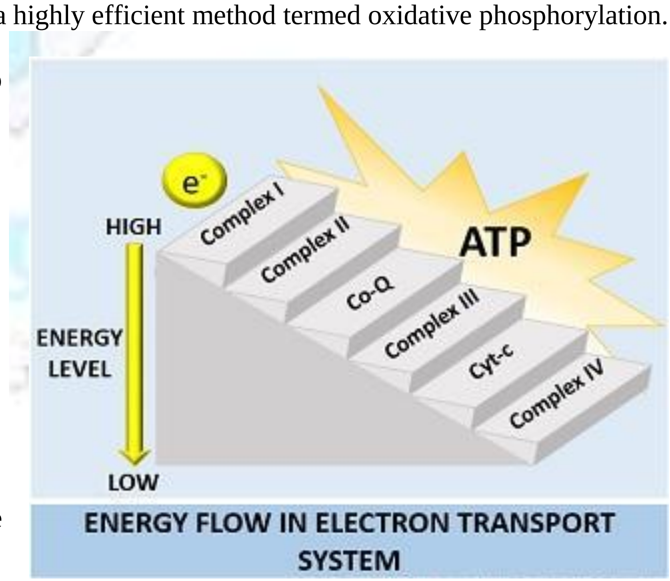
Krebs cycle equation

$$2Acetyl\ CoA + 6NAD^{+} + 2\ FAD + 2\ ADP + 2\ P_i + 2\ H_2O \rightarrow 4\ CO_2 + 6\ NADH + 2\ FADH_2 + 2\ ATP + 2\ CoA$$

Electron Transport Chain:

Electron Transport Chain is a series of compounds where it makes use of electrons from electron carrier to develop a chemical gradient. It could be used to power oxidative phosphorylation. The molecules present in the chain comprises enzymes that are protein complex or proteins, peptides and much more.

Large amounts of ATP could be produced through a highly efficient method termed oxidative phosphorylation. ATP is a fundamental unit of metabolic process. The electrons are transferred from electron donor to the electron acceptor leading to the production of ATP. It is one of the vital phases in the electron transport chain. Compared to any other part of cellular respiration the large amount of ATP is produced in this phase.



Electron transport is defined as a series of redox reaction that is similar to the relay race. It is a part of aerobic respiration. It is the only phase in glucose metabolism that makes use of atmospheric oxygen. When electrons are passed from one component to another until the end of the chain the electrons reduce molecular oxygen thus producing water. The requirement of oxygen in the final phase could be witnessed in the chemical reaction that involves the requirement of both oxygen and glucose.

Electron Transport Chain in Mitochondria

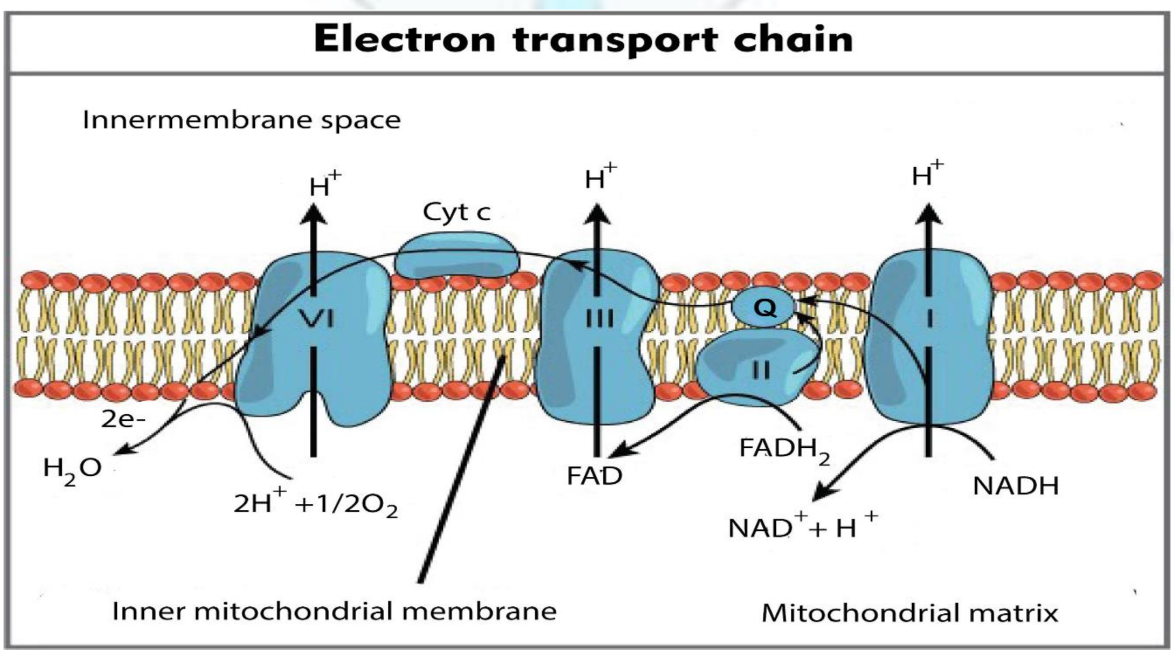
A complex could be defined as a structure that comprises a weak protein, molecule or atom that is weakly connected to a protein. The plasma membrane of prokaryotes comprises multi copies of the electron transport chain.

Complex 1- NADH-Q oxidoreductase: It comprises enzymes consisting of iron-sulfur and FMN. Here two electrons are carried out to the first complex aboard NADH. FMN is derived from vitamin B2.

Q and Complex 2- Succinate-Q reductase: FADH2 that is not passed through complex 1 is received directly from complex 2. The first and the second complexes are connected to a third complex through compound ubiquinone (Q). The Q molecule is soluble in water and moves freely in the hydrophobic core of the membrane. In this phase, an electron is delivered directly to the electron protein chain. The number of ATP obtained at this stage is directly proportional to the number of protons that are pumped across the inner membrane of the mitochondria.

Complex 3- Cytochrome c reductase: The third complex is comprised of Fe-S protein, Cytochrome b, and Cytochrome c proteins. Cytochrome proteins consist of the heme group. Complex 3 is responsible for pumping protons across the membrane. It also passes electrons to the cytochrome c where it is transported to the 4th complex of enzymes and proteins. Here, Q is the electron donor and Cytochrome C is the electron acceptor.

Complex 4- Cytochrome c oxidase: The 4th complex is comprised of cytochrome c, a and a3. There are two heme groups where each of them is present in cytochromes c and a3. The cytochromes are responsible for holding oxygen molecule between copper and iron until the oxygen content is reduced completely. In this phase, the reduced oxygen picks two hydrogen ions from the surrounding environment to make water.



Amphibolic Pathway

Respiration is the breakdown of the complex compounds into simple ones to produce energy molecule, ATP. Hence the process is called catabolic process and the pathway is termed as a catabolic pathway. Actually, respiration is the result of both making and breaking. When energy is required, proteins or fatty acids are broken down to form acetyl-CoA and further processes of respiration occur. This is catabolism. When the body requires fatty acids or proteins, respiratory pathway stops and the same acetyl-CoA is utilized and fatty acids are manufactured. This process of synthesis is termed as anabolism. Thus we can say respiration is the sum process of catabolism and anabolism. Products of the Krebs cycle and glycolysis act as a precursor for the synthesis of fats, proteins, etc. Hence, the respiratory pathway is known as an amphibolic pathway.

What is an amphibolic pathway?

An amphibolic pathway is the one that involves both catabolic and anabolic processes.

Is glycolysis an amphibolic pathway?

Glycolysis provides ATP and chemical intermediates to form biomolecules, hence it is an amphibolic pathway.

Why is respiration an amphibolic pathway?

Respiration involves both catabolism and anabolism. During fatty acid synthesis, acetyl coenzyme A is withdrawn from the respiratory pathway. Respiratory substrates get withdrawn during protein synthesis also.

Why is Kreb's cycle an amphibolic pathway?

Kreb's cycle involves both oxidative and synthetic process. The intermediates like oxaloacetate are used in the synthesis of biomolecules such as amino acids for protein formation.

Respiratory Quotient (RQ):

Aerobic respiration is the process most living things undergo to use food energy efficiently. In this **aerobic respiration**, oxygen is consumed and carbon dioxide is released.

The actual ratio of the volume of carbon dioxide eliminated to the volume of oxygen consumed during the act of cellular respiration is called the respiratory quotient.it is also referred as the respiratory ratio and is denoted by RQ.

RQ = Volume of Carbon dioxide eliminatedVolume of Oxygen consumed

The respiratory quotient depends on the type of respiratory substrate used during the act of respiration. Additionally, the respiratory quotient is a dimensionless number used in the calculations of the basal metabolic rate or BMR when estimated from the carbon dioxide production. These measurements are forms of indirect calorimetry. It happens to be measured using Ganong's respirometer.

Respiratory quotient is the ratio of the volume of carbon dioxide produced to the volume of oxygen consumed in respiration over a period of time. Its value can be one, zero, more than 1 or less than one.

RQ = Volume of $C0_2$ evolved/Volume of 0_2 absorbed:

RQ Equal to Unity:

Respiratory quotient is equal to unity if carbohydrates are the respiratory substrate and the respiration is aerobic.

$C_6H_{12}0_6 + 60_2 \rightarrow 6C0_2 + 6H_20$ RQ = $6C0_2/60_2 = 1$

RQ Less than Unity:

RQ is less than one when respiration is aerobic but the respiratory substrate is either fat or protein. RQ is about 0.7 for most of the common fats. It occurs during germination of fatty seeds.

$C_{57}H_{104}O_6 + 80\ 0_2 \rightarrow 57C0_2 + 52H_20$ RQ = $57C0_2/800_2 = 0.71$ triolein

$2(C_{51}H_{98}0_6) + 1450_2 \rightarrow 102C0_2 + 98H_20$ RQ = $102C0_2/1450_2 = 0.7$ tripalmitin

RQ is about 0.9 in case of proteins, peptones, etc.

RQ Zero:

Succulents do not evolve carbon dioxide during night (when their stomata are open) as the same is used in carbon fixation. They also change carbohydrates to organic acids which utilise oxygen but do not evolve carbon dioxide.

$2C_6H_{12}0_6 + 30_2$ —» $3C_4H_60_5 + 3H_20$ RQ = Zero $C0_2/30_2$ = Zero

RQ More than Unity:

(a) RQ slightly more than unity is found when organic acids are broken down as respiratory substrates under aerobic conditions, e.g.,

$2(COOH)_6 + 0_2$ —» $4C0_2 + 2H_20$ RQ = $4\ C0_2/1\ 0_2 = 4.0$ oxalic acid

$C_4H_60 + 3\ 0_2$ —» $4C0_2 + 3H_20$ RQ = $4\ C0_2/3\ 0_2$ or 1.3 malic acid

$2C_4H_60_4 + 7\ 0_2$ —» $8C0_2 + 6H_20$ RQ = $8\ C0_2/7\ 0_2$ or 1.14 succinic acid

(b) In anaerobic respiration there is no consumption of oxygen. Carbon dioxide is produced in most of the cases. Therefore, respiratory quotient is infinity. Carbohydrate is the usual substrate.

$$C_6H_{12}O_6 \xrightarrow{\text{zymase}} 2CO_2 + 2C_2H_5OH \qquad RQ = 2\ CO_2/\ \text{Zero}\ O_2 \text{ or infinity}$$

An intermediate value is obtained where an organ is undergoing both aerobic and anaerobic modes of respiration.

Importance:

(i) Knowledge of respiratory quotient helps in determining respiratory substrate.

(ii) It helps in knowing the type of respiration being performed

Phosphorylation:

1. Where does phosphorylation occur?
Oxidative phosphorylation occurs in the inner mitochondrial membrane, in contrast to much of the citric acid cycle reactions and fatty acid oxidation occurring in the matrix.

2. What are the 3 types of phosphorylation?
Cells transmit energy and produce ATP by photophosphorylation, phosphorylation at the substratum level and/or oxidative phosphorylation, depending on the type of organism. Phosphorylation refers to a group of phosphates being bound to a molecule.

3. Does phosphorylation require ATP?
ATP. ATP. Within the mitochondrion, ATP, the "high-energy" exchange medium in the cell, is synthesized by the addition of a third group of phosphates to ADP in a process called oxidative phosphorylation. During glycolysis ATP is also synthesized by phosphorylation at the substratum level.

4. What is the purpose of phosphorylation?
Phosphorylation is the mechanism of integrating a group of phosphates into an organic molecule. It plays a critical role in regulating pathways to cellular processes such as cell apoptosis, cycle, development, and signal transduction.

5. What is phosphorylation and why is it important?
Enzymes (e.g., kinases, phosphotransferases) conduct both phosphorylation and dephosphorylation. In the fields of biochemistry and molecular biology phosphorylation is significant because it is a key reaction in protein and enzyme activity, sugar metabolism, and energy storage and release.