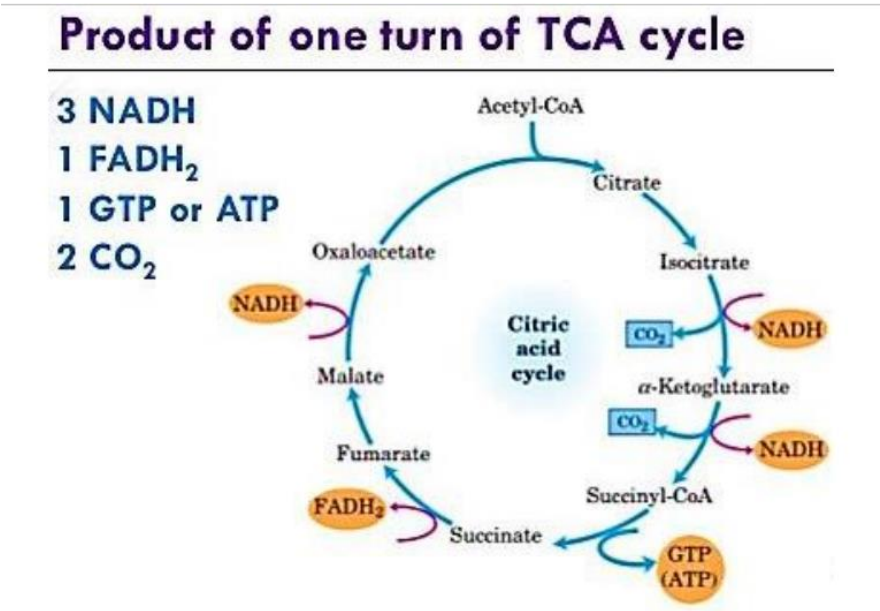
2- Aerobic respiration: It is done in two stages:

First/ Krebs cycle:

The Krebs cycle is named after the scientist who discovered it, Hans Krebs, who assumed the mechanism of the cycle in 1937. It is also called the tricarboxylic acid cycle (TCA) or the citric acid cycle, in reference to the products of the cycle. It is the final pathway for the oxidation of carbohydrates, fatty acids, and amino acids. It is done in the presence of oxygen in the cells of animals, higher plants, and some microorganisms. It is a series of successive biochemical reactions in which most of the potential energy in the molecules resulting from glycolysis is released. A series of oxidation and reduction reactions transfer this energy in the form of electrons to electron-carrying molecules, which are NAD+ and FAD. These electron-carrying molecules are called coenzymes.

Pyruvic acid produced by glycolysis cannot enter the Krebs cycle directly. It must first lose a CO_2 molecule in a process called decarboxylation. The pyruvic acid (a tricarbon) is converted to an acetyl group (a bi carbon) that binds to coenzyme A (CoA) to form a complex known as acetyl CoA, which is the key to the cycle.



When the Krebs cycle is complete, the product of every two molecules of acetyl CoA that enter the cycle is:
• Four molecules of CO_2 by removing a carboxyl group.
• Six molecules of NADH by oxidation-reduction reactions.
• Two molecules of $FADH_2$ by oxidation-reduction reactions.
• Two molecules of ATP produced by phosphorylation at the substrate level.
• Two molecules of GTP, which is similar to ATP in its ability to provide energy.

The carbon dioxide produced in the Krebs cycle is released as a gas into the atmosphere as a by-product of aerobic respiration. The reducing coenzymes NADH and $FADH_2$ are the most important products of the Krebs cycle because they contain most of the energy that was originally stored in glucose.

Second: Electron transport chain or system:

It is a group of electron-carrying molecules arranged in a specific sequence that perform successive oxidation and reduction reactions. The NADH and $FADH_2$ molecules donate their electrons to the first compound (electron carrier) in the chain, then to the second and third, and so on until the electrons reach their final recipient (oxygen or other inorganic molecules). During the transfer of electrons from one carrier to another, energy is gradually released from them. This energy released as a result of the transfer of electrons through the electron carriers in oxidation and reduction reactions is used (i.e. energy) to build ATP. In eukaryotic cells, the enzymes of the electron transport chain are located in the inner membrane of the mitochondria, while in prokaryotic cells, the enzymes are located in the plasma membrane. After the respiratory chain reactions are completed, NAD+ and FAD are reconstituted in order to be reused again in both glycolysis and the Krebs cycle.
As for the overall reactions of this process, they can be summarized as follows:

$$C_6H_{12}O_6 + 6\ O_2 + 38\ ADP + 38\ (PO_4)^{-3} \longrightarrow 6\ CO_2 + 6\ H_2O + 38\ ATP$$

Fermentation:

We mentioned earlier that after the oxidation of glucose to pyruvic acid, either the pyruvic acid is completely destroyed during respiration and the Krebs cycle as

described above or it can be converted into an organic product in the fermentation process, and the fermentation process includes the following:
1- Releasing energy from sugars or other organic compounds.
2- It does not require the presence of oxygen (and can also occur in its presence).
3- It does not require the use of the Krebs cycle or the electron transport chain.
4- It uses an organic molecule that has been built in the cell as the final electron acceptor.

Fermentation produces only small amounts of ATP (one or two ATP molecules per molecule of oxidant) because much of the original energy in glucose remains locked up in the chemical bonds of the organic end products, such as lactic acid and ethanol. However, the unique feature of fermentation for the cell is the high rate of ATP production. During fermentation, electrons and protons are transferred from the reducing coenzymes (NADH, NADPH) to pyruvic acid or its derivatives. The primary function of fermentation is to ensure a constant supply of NAD+ and NADP+ so that glycolysis can proceed. In fermentation, ATP is produced only during glycolysis.

Lactic acid is the same substance associated with muscle exertion in the human body. During exercise, the cardiovascular system cannot provide enough oxygen to the skeletal muscles and the heart (as the blood pump that carries with it the energy source and oxygen needed to oxidize that food and release its energy for the purpose of contracting those muscles) to generate enough energy. In such cases, the muscles switch from aerobic respiration to fermentation in the absence of oxygen, and pyruvic acid is oxidized to lactic acid.

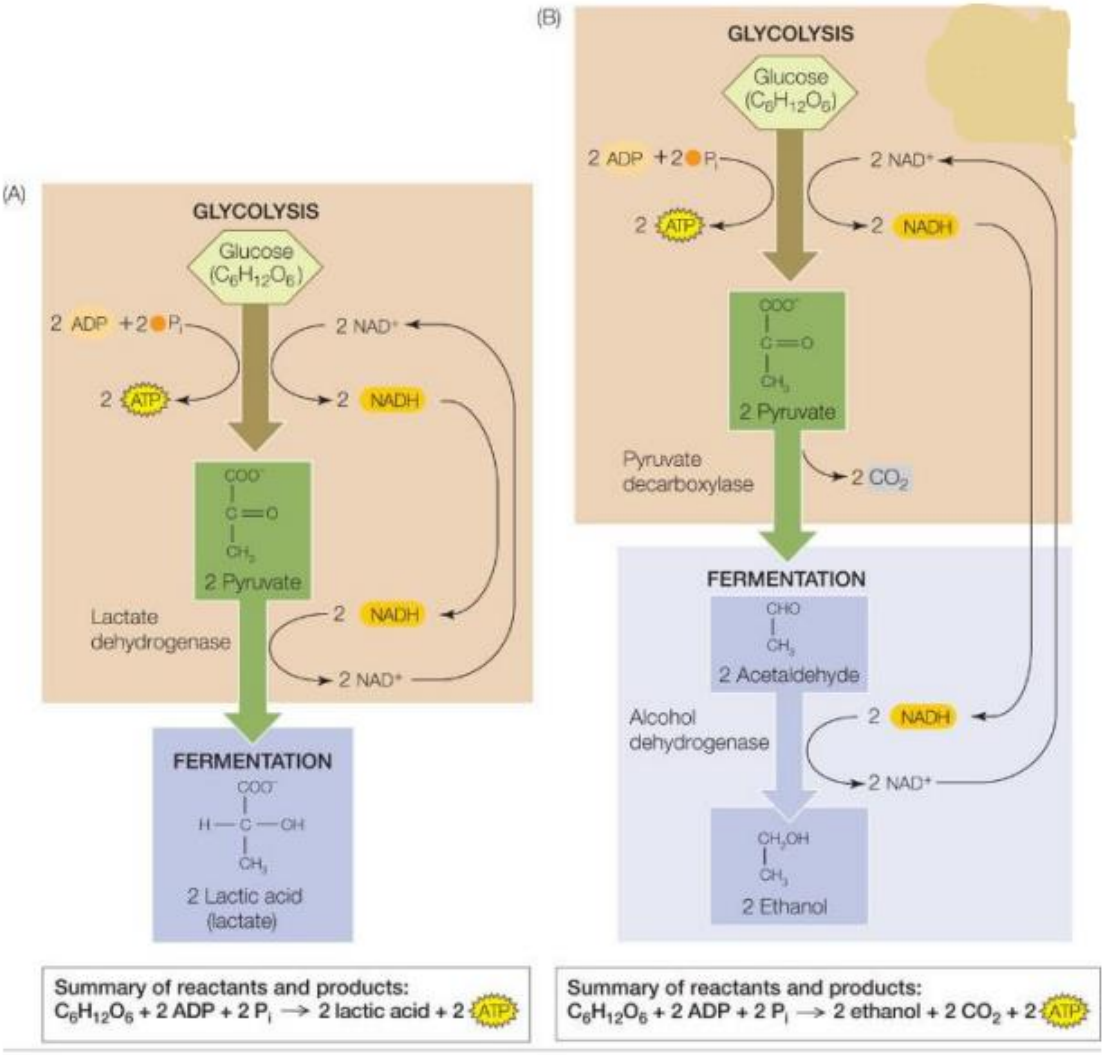
Lactic acid fermentation:

The first stage of lactic acid fermentation, a glucose molecule (during glycolysis) is oxidized to two pyruvic acid molecules. This oxidation releases energy used to build two ATP molecules. In the next step, two pyruvic acid molecules are reduced by two NADH molecules to form two lactic acid molecules. Because lactic acid is the end product of the reaction, no further oxidation occurs, and most of the energy from the reaction remains stored in lactic acid. Therefore, this fermentation produces only a small amount of energy. There are two important

genera of lactic acid bacteria, Streptococcus and Lactobacillus. These microbes produce only lactic acid, which is why they are referred to as homolactic or homo-fermentative fermenters. Lactic acid fermentation can lead to food spoilage. However, this process produces yogurt from milk. There are types of these fermenting bacteria present in the intestines and they are very beneficial. Organisms that produce lactic acid and other organic acids are referred to as hetero-fermentative.

Alcoholic fermentation:

Alcoholic fermentation also begins with the glycolysis of a glucose molecule to produce two molecules of pyruvic acid and two molecules of ATP. Alcoholic fermentation is also a low-energy process because most of the energy remains contained in the final product molecule, which is ethanol. Alcohol is fermented by a number of bacteria and yeasts. Ethanol and carbon dioxide are produced by the yeast of the *Saccharomyces* species as a by-product that the yeast secretes, but it is useful to humans, as the carbon dioxide produced by the yeast is what causes the bread dough to rise.



Metabolism; Anabolism or Biosynthesis:

During biosynthesis microorganisms begins with simple precursors ,such as inorganic molecules or monomers ,and construct more complex until new organelles and cells arise.

Synthesis of Sugars and Polysaccharides:

Many microorganisms can carry out photosynthesis (in which CO_2 is incorporate or fix), these autotrophs can convert this inorganic molecule to organic

carbon, most common pathway is Calvin-Benson cycle: three different stages can be differentiated :

- Carboxylation phase: addition CO_2 to riboues 1,5- biphosphate, forming two molecules of 3-phosphoglycerate.
- Reduction phase: reduction of 3-phosphoglycerate to glyceraldehydes 3-phosphate.
- Regeneration phase: trioses are used to reform ribulose 1,5-biphosphate ,and some hexose sugars like ; glucose and fructose.

Synthesis of Amino Acids:

Amino acid synthesis requires construction of the proper carbon skeletons, amino acid skeletons are derived from acetyl-CoA and intermediates of the TCA cycle, glycolysis and Calvin cycle. Most biosynthetic pathways are more complex and common intermediates often are used in the synthesis of families of related amino acids. The ribosome is the site of protein synthesis,

Lipid Biosynthesis:

A variety of lipids are found in microorganisms, particularly in cell membranes and most contain fatty acids or their derivatives. Fatty acids are monocarboxylic acids with long alkyl chains (the average length is 18 carbons). Some are unsaturated that have one or more double bonds . Most microbial fatty acids are straight chain, but some are branched .Gram-negative bacteria have cyclopropane fatty acids (fatty acids with one or more cyclopropane rings in their chains). Fatty acid synthesis is catalyzed by the fatty acid synthetase complex with acetyl-CoA and malonyl-CoA as the substrates and NADPH as the electron donor, the process need ATP and CO_2. In addition to fatty acid synthesis ,microorganisms also synthesize Triacylglycerol and phospholipids in different pathway.