Microbial Metabolism

Catabolism and Anabolism Reactions :

The term metabolism is used to refer to the whole set of biochemical reactions within the body or cell of an organism. In these biochemical reactions, either energy is released or is added.

Therefore, metabolism is considered to be a **balanced process of energy conversion**. Accordingly, metabolism is divided into two categories of biochemical reactions in living cells.

1- **The Catabolism Reactions:**
   -Energy-releasing reactions, are the chemical reactions that regulated by enzymes in cells.
   -In these reactions, complex organic compounds are broken down or disassembled into newer compounds.
   -These reactions are generally hydrolysis reactions that release energy (energy).
   -An example of energy-releasing reactions is the cells breaking down carbohydrates and converting them to carbon dioxide and hydrogen.
   -Catabolic reactions provide the building blocks and energy needed for the anabolic reactions to occur.
2- **The Anabolism Reactions:**
   -Energy-consuming reactions represent the other type of chemical reactions that are controlled and regulated by enzymes in cells.
   -During which complex organic compounds are built from simpler compounds, and they consume energy.
   -Examples of these reactions are building proteins from amino acids, nucleic acids from nucleotides, and polysaccharides from simple sugars.
   -Anabolic reactions are those that provide the cell with the materials it needs for its growth.

- **The adenosine triphosphate (ATP) molecule**:
  as the energy released during the anabolic processes is stored in the ATP molecule in order to use this energy later in the anabolic reactions.
- **The role of ATP in energy transfer:**
  The process of breaking down complex food molecules such as glucose releases energy, some of it in the form of heat energy to maintain body temperature as in higher animals,

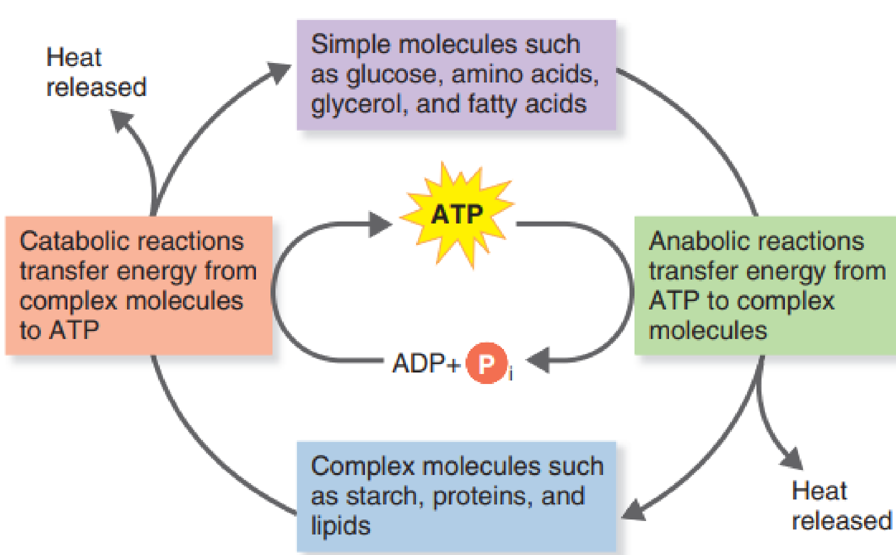
and the greater part in the form of chemical energy by forming ATP from ADP and inorganic phosphate Pi. ATP is generally used as an energy carrier between productive processes and energy-consuming processes.

- **Below are the main different types of work done by ATP:**
  1- In building different life compounds in the cell and according to the cell's need.
  2- It works as a source of energy needed for contraction and movement.
  3- In transporting nutrients across cell membranes.
  4- In transferring genetic information and the biological construction of DNA and RNA
  5- In maintaining body temperature.

When the terminal phosphate group is separated from ATP, adenosine diphosphate (ADP) is formed, the energy required for the anabolic reactions to occur is released.

The figure below shows the role of ATP in coupling catabolic reactions with anabolic reactions. Part of the energy released from catabolic reactions is lost to the environment in the form of heat, while the other part is used by the cell to carry out its various activities. as in the following equation and figure:

$$\textbf{ATP} \longleftrightarrow \textbf{ADP} + (\textbf{PO}_4)^{-3} + \textbf{energy}$$



- **Carbohydrate breakdown:**

  - Most microorganisms consume carbohydrates as a source of cellular energy. Therefore, the breakdown of carbohydrates to produce energy is of great importance in cell metabolism.

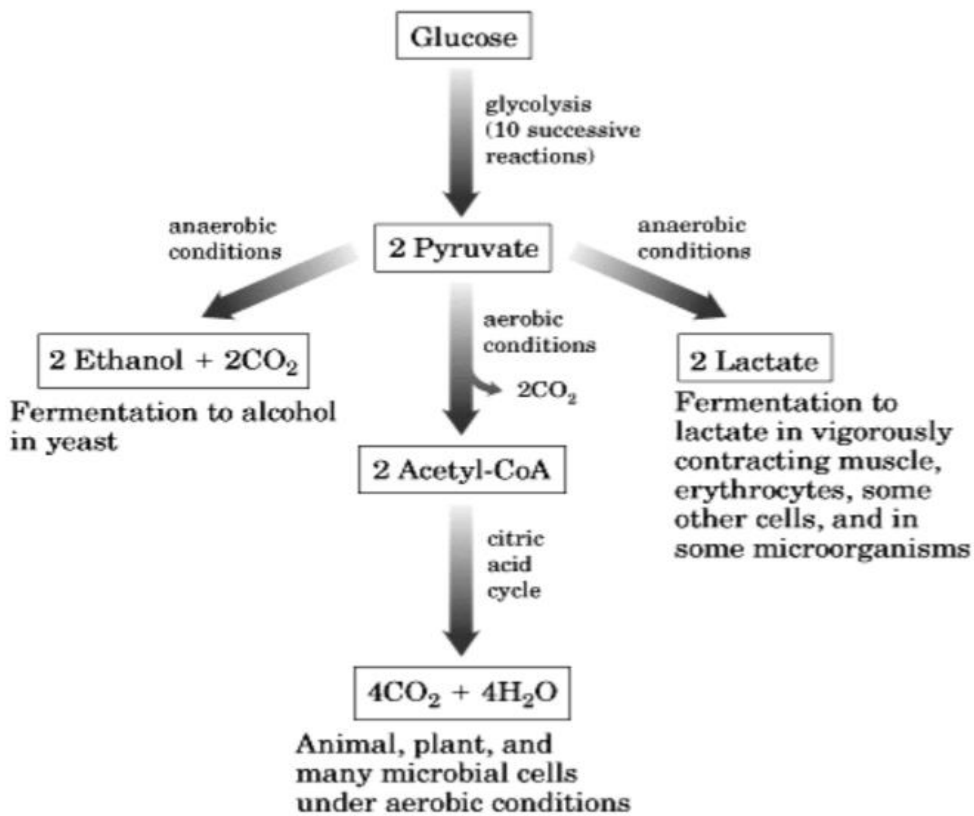
  - The most commonly used form of carbohydrate as a source of energy by the cell is glucose.

  -Microorganisms can also break down various fats and proteins to produce energy.

  -To produce energy from glucose, microorganisms use the processes of cellular respiration and fermentation.

  -It should be noted that the term cellular respiration (internal respiration) here is different from the process of normal respiration (external respiration) inhalation and exhalation.

  -Both cellular respiration and fermentation usually begin with the same first step, **glycolysis**, but they follow two different pathways later on.

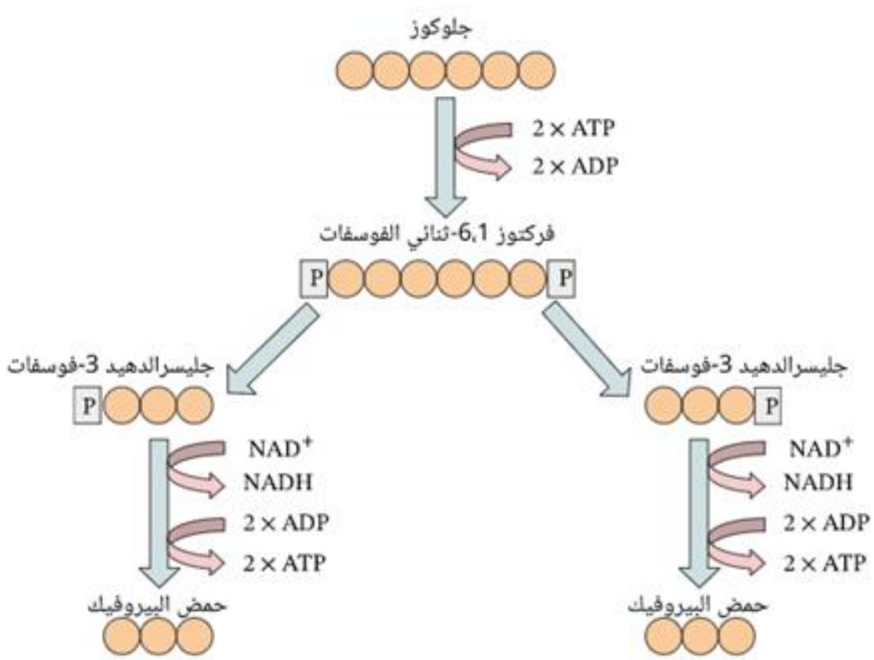


- **Glycolysis :**

The first stage of carbohydrate breakdown is called glycolysis.
-Glycolysis involves the oxidation of glucose to pyruvic acid.
-Glycolysis occurs in most microorganisms and even in most living cells.
-This process does not require the presence of oxygen, meaning it occurs with or without oxygen.
-The steps in this process are called the Embden-Meyerhof pathway, and it includes a series of ten chemical reactions catalyzed by enzymes.

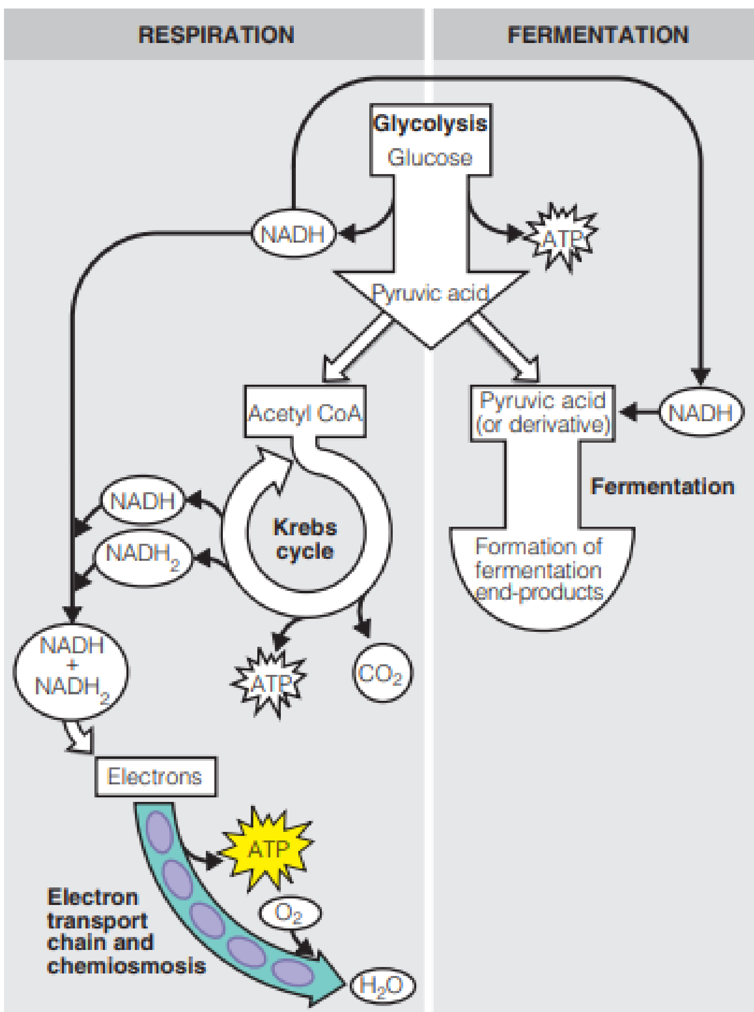
This pathway involves the splitting of a glucose molecule (a six-carbon sugar) into two molecules of pyruvic acid (a three-carbon molecule). In addition to the two pyruvic acid molecules, this process produces ATP and a proton- or electron-carrying compound, (NADH).

There are other pathways for the oxidation of carbohydrates in addition to glycolysis. The most common of these alternative pathways are the phosphorylated pentose (five-carbon sugar) pathway and the Entner-Doudoroff pathway.



Cellular respiration

In order to produce energy from a glucose molecule, bacteria resort to the processes of respiration and fermentation. Both processes usually begin with glycolysis, after which each process takes its own path depending on the presence of oxygen. The fate of the pyruvic acid produced at the end of the glycolysis pathway is either cellular respiration or fermentation. The following figure illustrates the difference between the two cases. Cellular respiration is defined as the process of generating ATP from the oxidation of molecules, while the final electron acceptor is outside the cell and is (almost always) an inorganic compound. The main feature that distinguishes respiration is the presence of an electron transport chain.



There are two types of respiration, aerobic and anaerobic, depending on whether the organism uses oxygen or not. In aerobic respiration, the final electron acceptor is oxygen, while in anaerobic respiration, the final electron acceptor is an inorganic molecule (not oxygen) and, rarely, an organic molecule.

1- Anaerobic respiration:

In anaerobic respiration, the final electron acceptor is an inorganic substance other than oxygen (O_2). In some bacteria, such as *Bacillus* and *Pseudomonas*, the nitrate ion (NO_3^-) acts as the final electron acceptor, reducing nitrate to nitrite ($-NO_2$), nitrous oxide (N_2O), or nitrogen gas (N_2). Other bacteria, such as *Desulfovibrio*, use sulfate (SO_4^{-2}) as the final electron acceptor to form hydrogen sulfide (H_2S). Some **archaea** use carbon dioxide to form methane (CH_4). Anaerobic bacterial respiration, using nitrate and sulfate as final electron acceptors, is essential for the nitrogen and sulfur cycles that occur in nature. The amount of ATP released in anaerobic respiration varies depending on the organism and the reaction pathway. ATP production is not as high in anaerobic respiration as it is in aerobic respiration, because all the electron carriers in the electron transport chain for anaerobic respiration are not present. Therefore, growth under anaerobic conditions is much slower than under aerobic conditions.