# Cellular respiration

Cellular respiration refers to oxidation of organic nutrients to obtain energy in form of ATP.

**Respiratory Substrate:**

The organic nutrient which is oxidized during respiration is called respiratory substrate.

It can be
- carbohydrates,
- Proteins and
- Lipids

Their energy yield is as follows

| Substrate | Caloric value (K cal/g) | Physiology value (Kcal/g) |
|---|---|---|
| Carbohydrate | 4.1 | 4 |
| Lipid | 9.45 | 9 |
| Proteins | 5.6 | 4 |

It is obvious from the table that is lipid which yields highest amount of energy on oxidation. It is because carbon is more reduced in them in comparison to degree of reduction of carbon atom in other organic nutrients.

The order of preference of organic nutrients as a respiratory substrate is

Carbohydrate ⟶ Lipid ⟶ Proteins

Carbohydrates are most preferred respiratory substrate despite its energy yield being lower than that of lipid because its oxidation is easier than the oxidation of other respiratory substrates.

Types of Respiration

a. Anaerobic respiration and
b. Aerobic respiration.

Comparative account is as follows

| Anaerobic respiration | Aerobic respiration |
|---|---|
| It takes place in absence of $O_2$. | It takes place in presence of $O_2$. |
| It is primitive. | It is advanced type. |
| Terminal e– acceptor is never $O_2$. In lactic acid fermentation it is pyruvate which is the terminal $e^-$ acceptor.<br>In Ethyl alcohol fermentation it is acetaldehyde which is the terminal electron acceptor. | Terminal $e^-$ acceptor is $O_2$. |
| Respiratory substrate is partially oxidized. | Respiratory substrate is completely oxidized. |
| Energy yield is poor | Energy yield is high. |

| | |
|---|---|
| Respiratory substrate is oxidized by fermentation | Respiratory substrate (glc) is oxidized by<br>Glycolysis<br>Intermediate steps<br>Krebs cycle &<br>Oxidative Phosphorylation |

If carbohydrate is the respiratory substrate, the respiration is called **floating respiration.** If respiratory substrate is protein, the respiration is called as **protoplasmic respiration.**

**Glycolysis**

Glycolysis refers to degradation of glucose into two molecules of pyruvate.During the process of glycolysis, NADH and ATP are also produced.

It was reported by **E**mbden, **M**eyerhof and **P**arnas. So, it is called **EMP- Pathway**.

Glycolysis is also referred as Hexose-bisphosphate pathway.

It is almost universal catabolic pathway of glucose. It is conserved pathway also.

**Location:**

Glycolysis takes place in cytoplasm, because its enzymes are present in cytoplasm, except hexokinase. It is bound to outer mitochondrial membrane.

**Pathway:** Glycolysis is divisible into

a. Preparatory phase and
b. Pay off Phase

Glycolysis does not need $O_2$ to operate.

**Preparatory Phase**

I. Glucose is phosphorylated into glucose-6-(P) with the help of ATP under catalytic activity of Hexokinase. This step is referred as I$^{st}$ priming step because it activates glucose molecule. The step is irreversible. There is an isozyme/isoenzyme of hexokinase which is more specific. It is referred as hexokinase-D or glucokinase. It occurs in liver cells. Its Km value is high, which means its affinity for substrate is low. It is essential to cope up with high concentration of glucose in cell of liver.

II. Glucose-6-(P) undergoes isomeric conversion into fructose-6-(P). This step is catalyzed by (P) glucoisomerase.

III. Fructose-6-(P) is phosphorylated with the help of ATP into fructose-1,6 bis(P). It is catalyzed by Phosphofructokinase [PFK].

IV. Fructose-1,6 bis (P) is very important intermediate. It is called **Harden-Young ester.**
It is subjected to lysis to form dihydroxyacetone (P) and (P) glyceraldehyde in presence of aldolase. In this step lysis of glycolytic intermediate takes place.

V. (P) glyceraldehyde and dihydroxyacetone (P) undergo isomeric conversion in presence of triose isomerase.

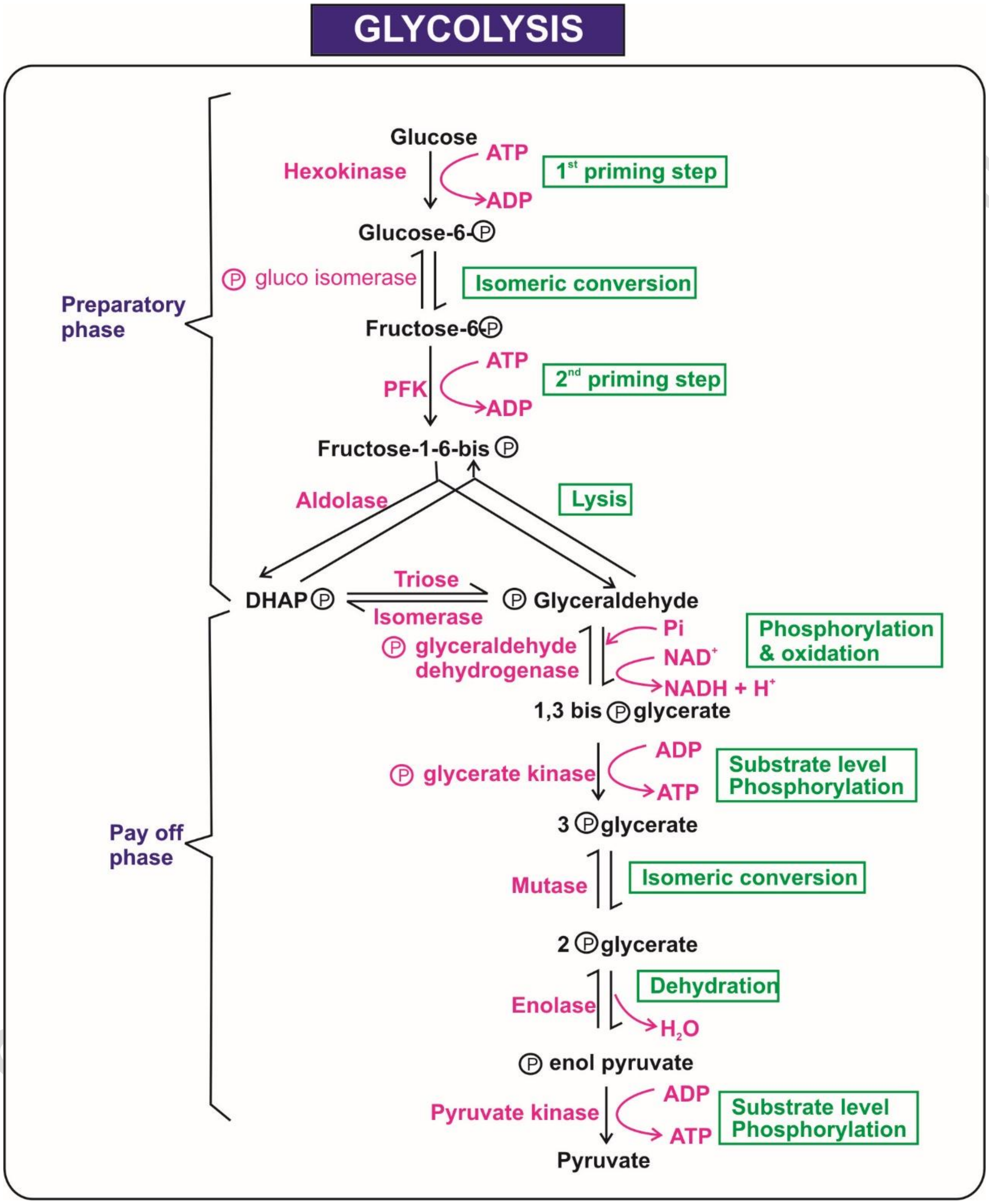
**Pay off phase**

VI. (P) Glyceraldehyde is subjected to phosphorylation and oxidation to yield 1, 3 bis (P) glycerate. It is phosphorylated with the help of inorganic phosphate (Pi). Oxidation of (P) glyceraldehyde is coupled with reduction of $NAD^+$ into NADH & $H^+$.
This is the single step in glycolysis where respiratory substrate is oxidized.

VII. 1,3 bis (P) glycerate is dephosphorylated to form 3(P) glycerate. It is coupled with phosphorylation of ADP to form ATP. Phosphorylation of ADP is due to transfer of Phosphate group from substrate to form ATP, is called **substrate level phosphorylation**.

VIII. 3(P) glycerate undergoes isomeric conversion to form 2(P) glycerate in presence of mutase. (P) phosphoglycerate is converted into phosphoenol pyruvate (PEP) after loss of water. It is catalyzed to enolase.

VIII. PEP is dephosphorylated to form pyruvate. It is coupled with phosphorylation of ADP into ATP. It is another example of substrate level phosphorylation.




i.

Glucose + 2ATP + 2Pi + $2NADH^+$ + 4ADP $\longrightarrow$
2-Pyruvate + 2ADP + 2(NADH + $H^+$) + 4ATP + $4H_2O$

Energy yield:

Standard free energy change for complete oxidation of glucose into $CO_2$ and $H_2O$ is -2840 kJ/mol.

Standard free energy change of partial oxidation of glucose into pyruvate is -146 kJ/mol.

After glycolysis two high energy compounds ATP and NADH are formed.

**Aerobic oxidation of Pyruvate**:
Pyruvate is aerobically oxidized in eukaryotes as well as prokaryotes.
Pyruvate is aerobically oxidized in mitochondria. Its oxidation involves following steps.

A. Intermediate step/Linking step &
B. Krebs Cycle

### A. Intermediate step/Linking step

Pyruvate is transported from cytoplasm to mitochondrial matrix. In matrix, pyruvate is subjected to *oxidative decarboxylation* to form Acetyl CoA.

The step is catalyzed by enzyme **pyruvate dehydrogenase**. It is complex of three enzymes, which requires five coenzymes to act. The coenzymes are **FAD, $NAD^+$, Lipoate, TPP & CoA.**

$$\text{Pyruvate(2)} + 2NAD^+ \longrightarrow \text{Acetyl CoA(2)} + 2(NADH^+ + H^+) + 2CO_2$$

Pyruvate dehydrogenase shows similarity with $\alpha$-Ketoglutarate dehydrogenase. Due to their similarity in their activity and their requirement of same coenzymes, they are thought to have common origin.