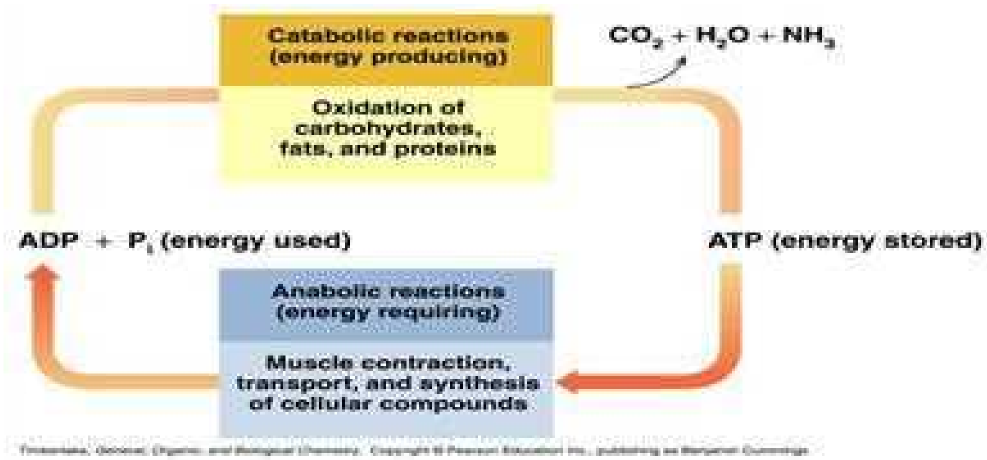
Metabolism of Carbohydrates: -

Metabolism involves

- Catabolic reactions that break down large, complex molecules to provide energy and smaller molecules.
- Anabolic reactions that use ATP energy to build larger molecules

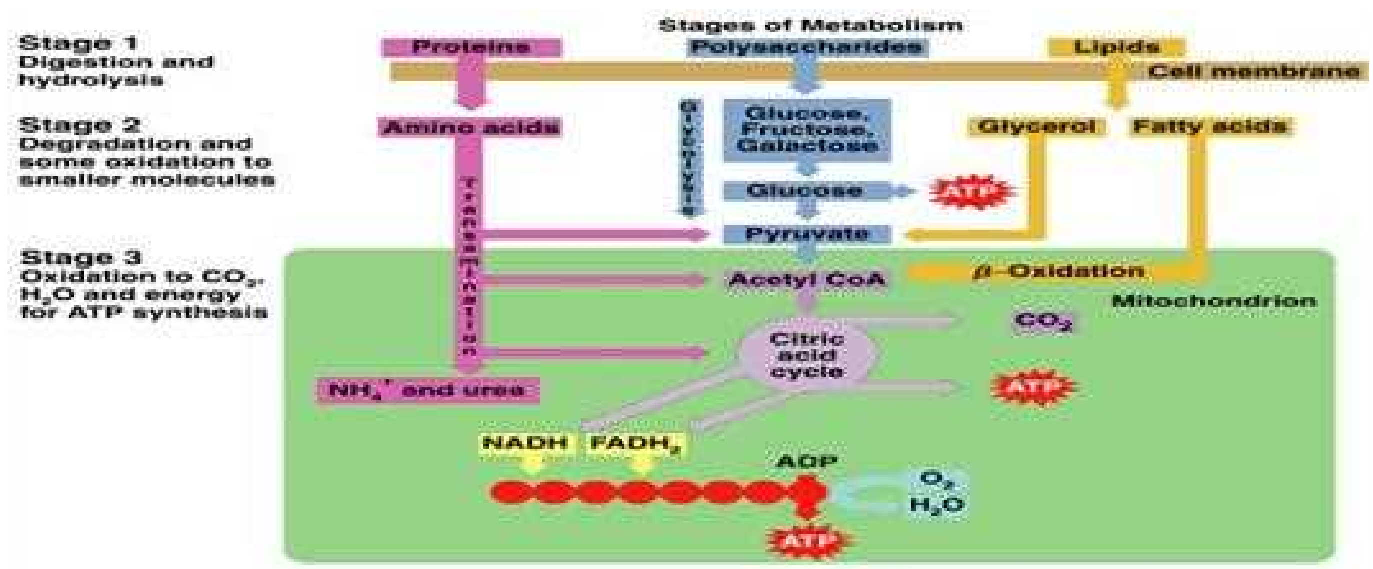


Catabolic reactions are organized as

Stage 1: Digestion and hydrolysis break down large molecules to smaller ones that enter the bloodstream.

Stage 2: Degradation breaks down molecules to two- and three-carbon compounds.

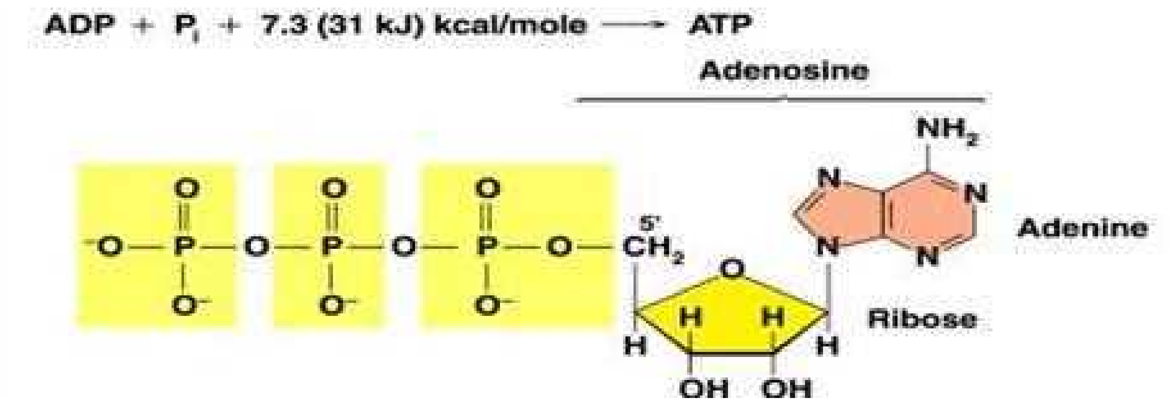
Stage 3: Oxidation of small molecules in the citric acid cycle and electron transport provide ATP energy



ATP and Energy

Adenosine triphosphate (ATP)

- Is the energy form stored in cells.
- Is obtained from the oxidation of food.
- Consists of adenine (nitrogen base), a ribose sugar, and three phosphate groups.
- Requires 7.3Kcal (31 kJ) per mole to convert ADP + P_i to ATP.



Hydrolysis of ATP

- The hydrolysis of ATP to ADP releases 7.3 kcal (31 kJ/mole).

  ATP ⟶ ADP + P_i + 7.3 kcal (31 kJ/mole)

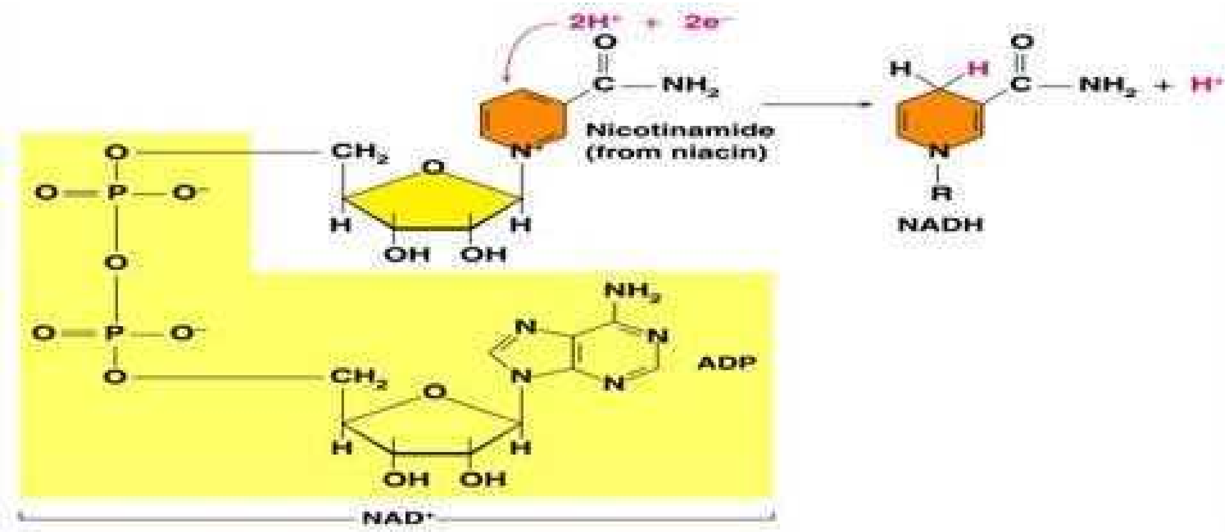
- The hydrolysis of ADP to AMP releases 7.3 kcal (31 kJ/mole).

  ADP ⟶ AMP + P_i + 7.3 kcal (31 kJ/mole)

Important Coenzymes in Metabolic Pathways

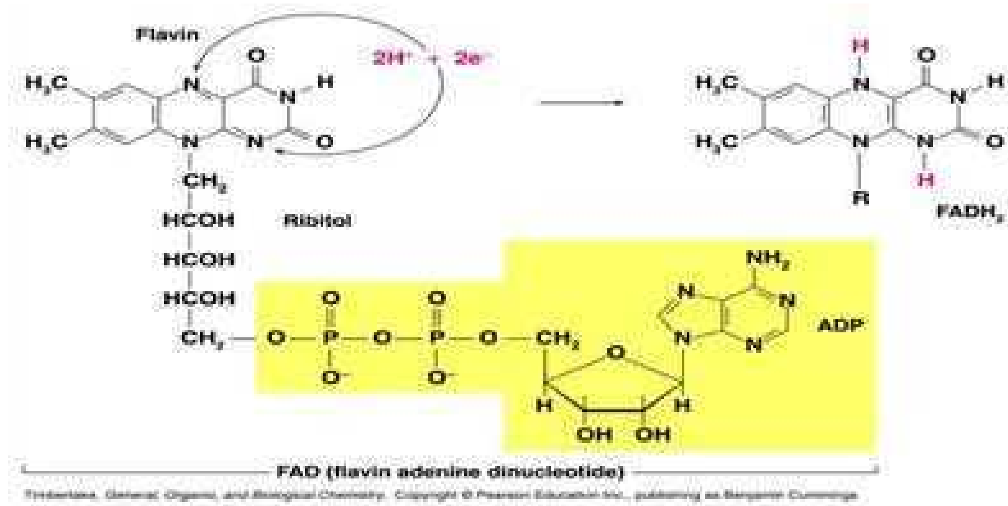
NAD^+

- Is nicotinamide adenine dinucleotide.
- Contains ADP, ribose, and nicotinamide.
- Reduces to NADH when the nicotinamide group accepts H^+ and $2e^-$.



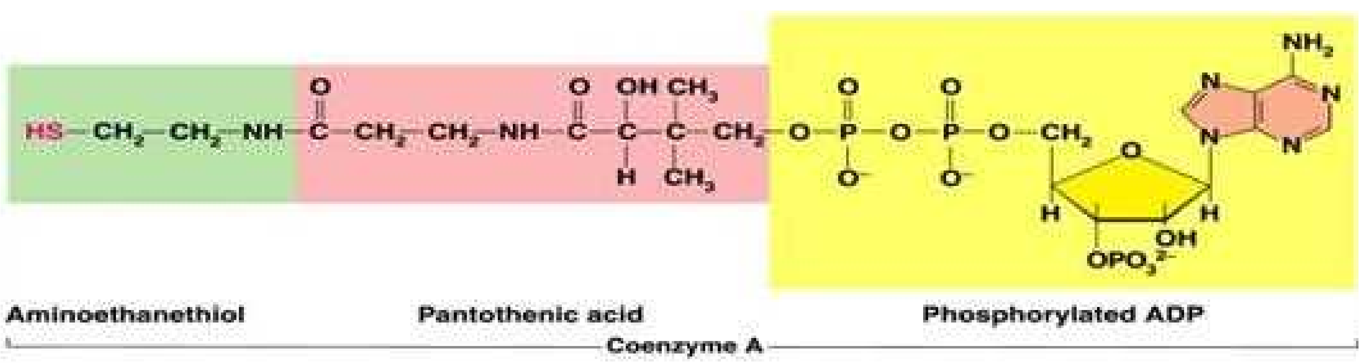
FAD Is Flavin adenine dinucleotide.

- Contains ADP and riboflavin (vitamin B_2).



Coenzyme A

- Consists of vitamins B_3, pantothenic acid, and ADP.
- Activates acyl groups such as the two-carbon acetyl group for transfer.



Carbohydrate Metabolism

Glycolysis: glucose → pyruvic Acid

Glycogenolysis: glycogen → glucose

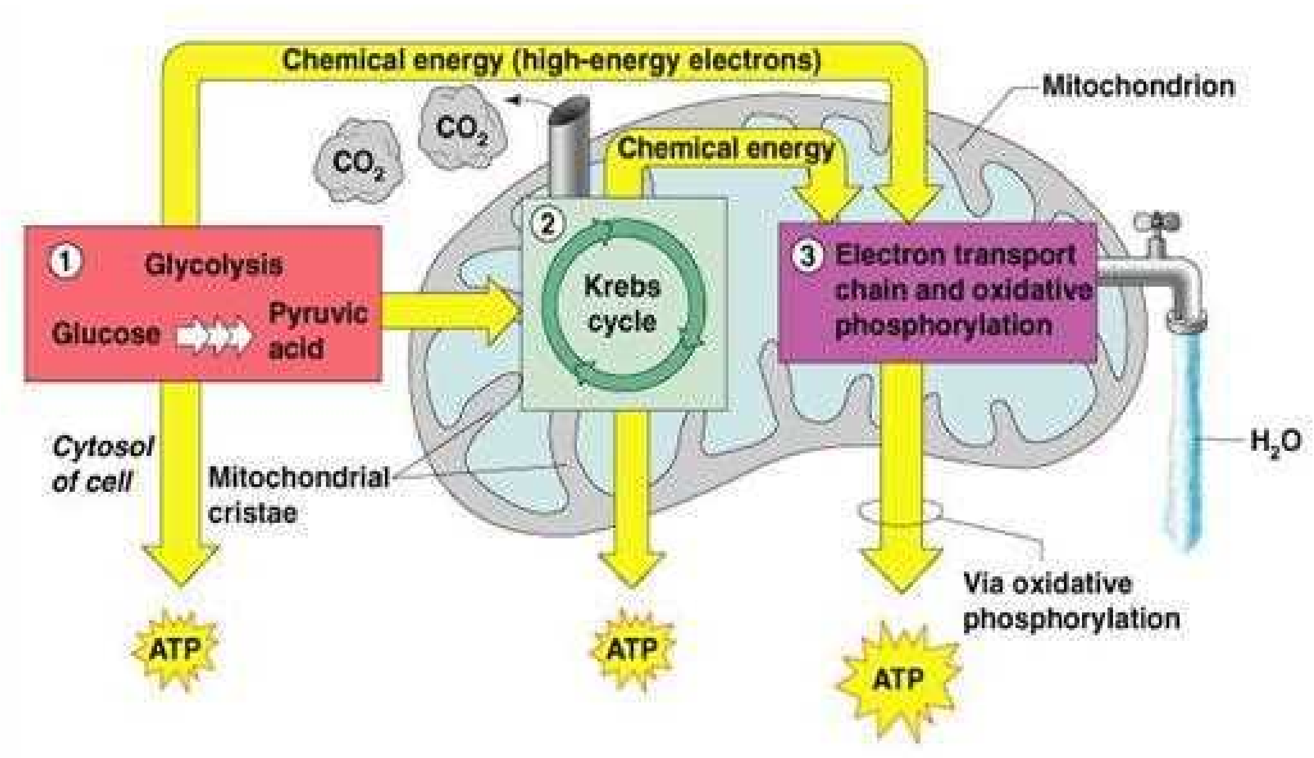
Glycogenesis: glucose → glycogen

Gluconeogenesis: lactic acid, amino acids, or triglycerides (noncarbohydrates) → glucose

Lipogenesis: glucose → Triglyceride

Amino acid synthesis: Convert pyruvic Acid into an Amino Acid requires a transamination

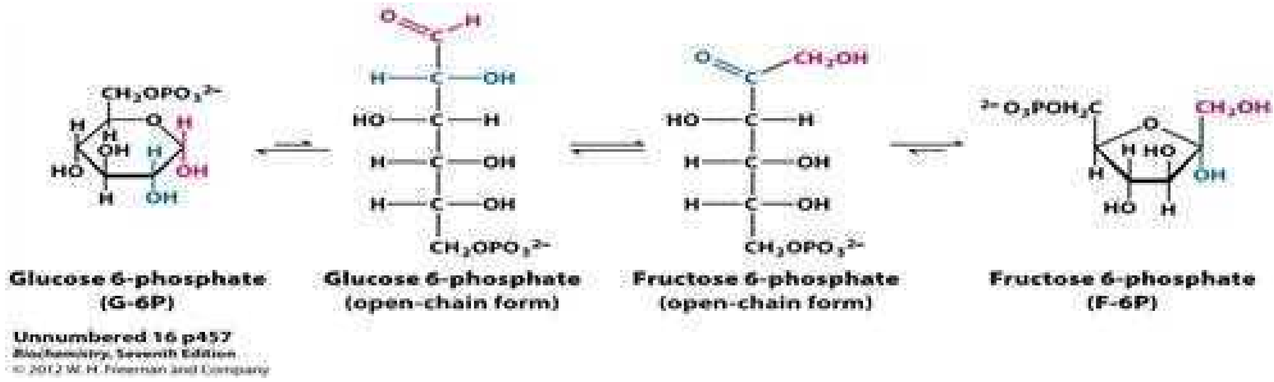
Transamination: Pyruvic Acid + NH3 Amino Acid

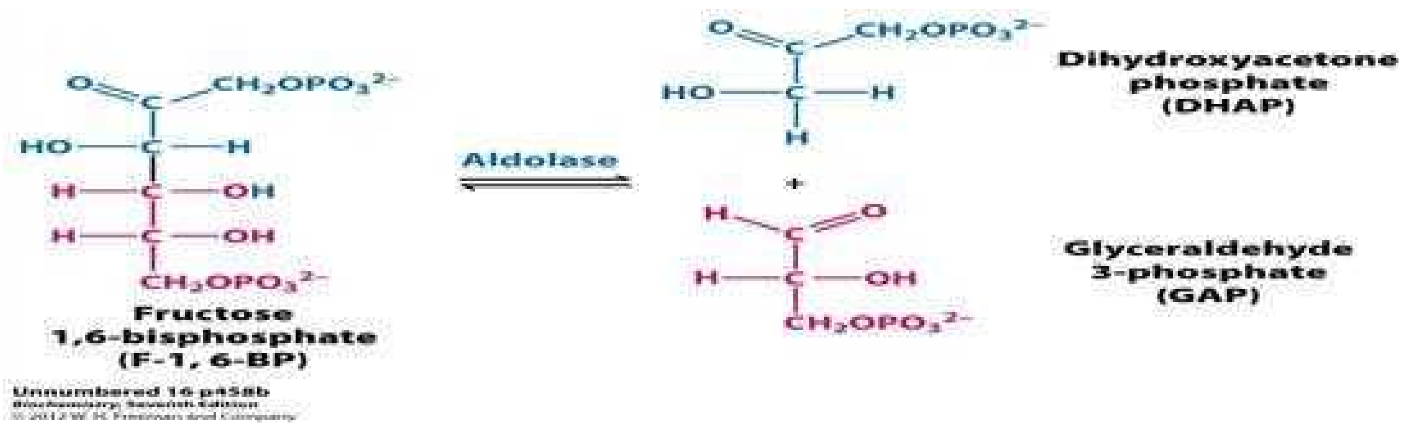


Glycolysis:-(Embden-Meyerhof- pathway)

- Is a metabolic pathway that uses glucose, a digestion product.
- Degrades six carbon glucose molecules to three carbon(2-Pyruvate molecules).
- Occur in cell cytosol(outside the mitochondria).
- Is an anaerobic (no oxygen) process.

Glycolysis: Energy Investment

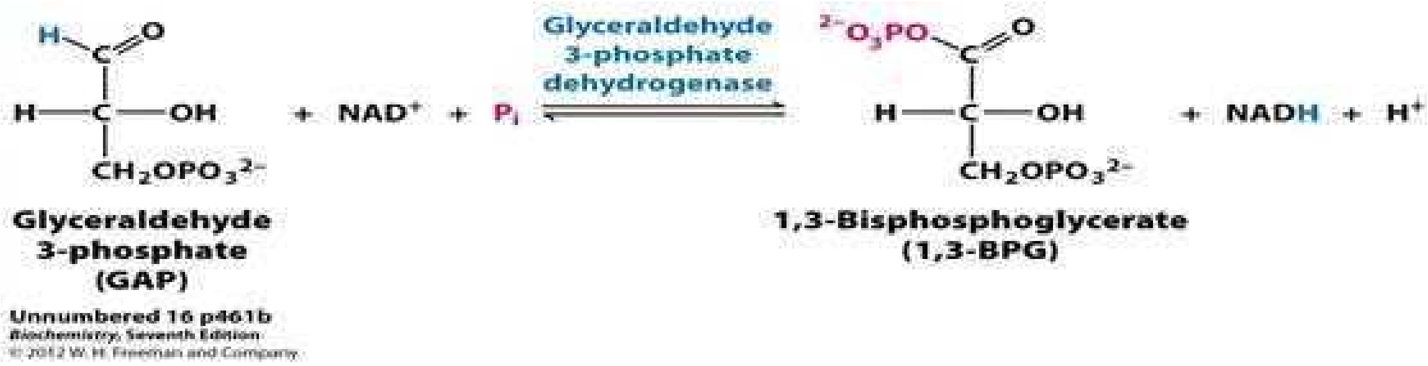


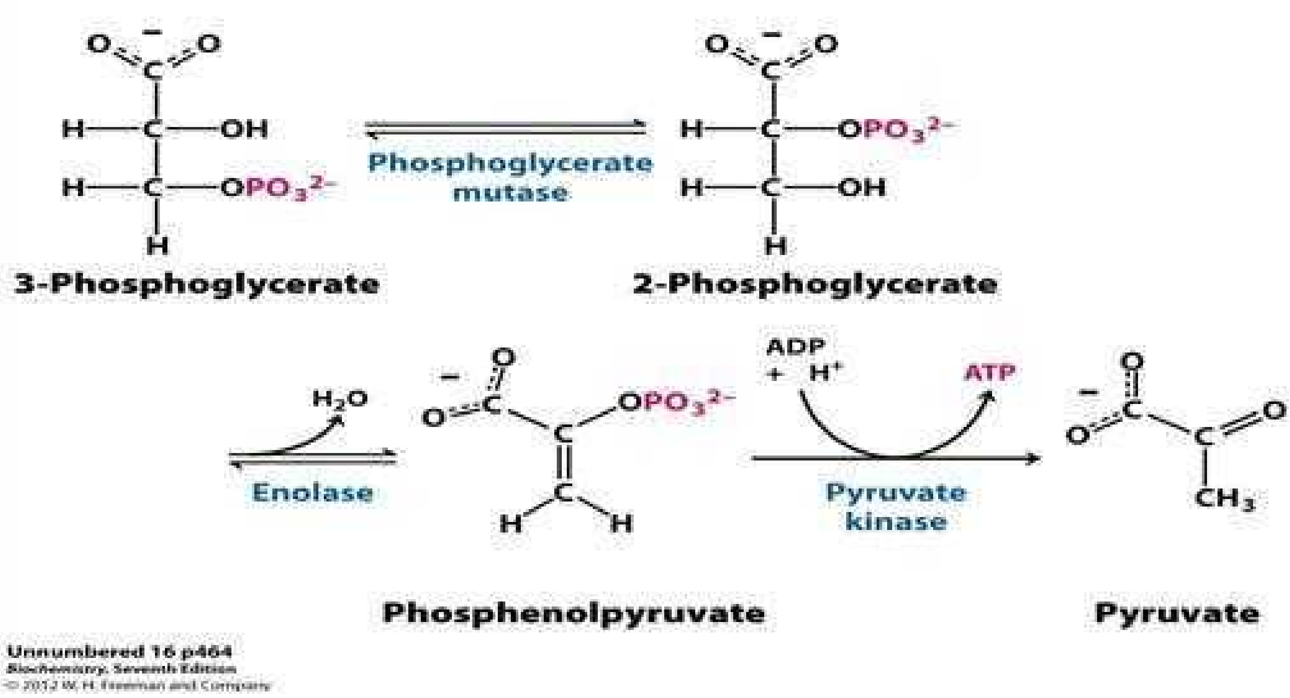


Glycolysis: Energy-Production

In reactions 6-10 of glycolysis, energy is generated as

- Sugar phosphates are cleaved to triose phosphates.
- Four ATP molecules are produced.





In glycolysis

- Two ATP add phosphate to glucose and fructose-6-phosphate.
- Four ATP are formed in energy-generation by direct transfers of phosphate groups to four ADP.
- There is a net advantage of 2 ATP and 2 NADH.

$$C_6H_{12}O_6 + 2ADP + 2Pi + 2NAD^+ \longrightarrow 2C_3H_3O_3^- + 2ATP + 2NADH + 4H^+$$

Glucose **Pyruvate**

Glycolysis is regulated by three enzymes,

- Reaction 1 Hexokinase is inhibited by high levels of glucose-6-phosphate, which prevents the phosphorylation of glucose.
- Reaction 3 Phosphofructokinase, an allosteric enzyme, is inhibited by high levels of ATP and activated by high levels of ADP and AMP.
- Reaction 10 Pyruvate kinase, another allosteric enzyme is inhibited by high levels of ATP or acetyl CoA.
- **Pyruvate:** The subsequent metabolic fate of pyruvate depends on the organism .

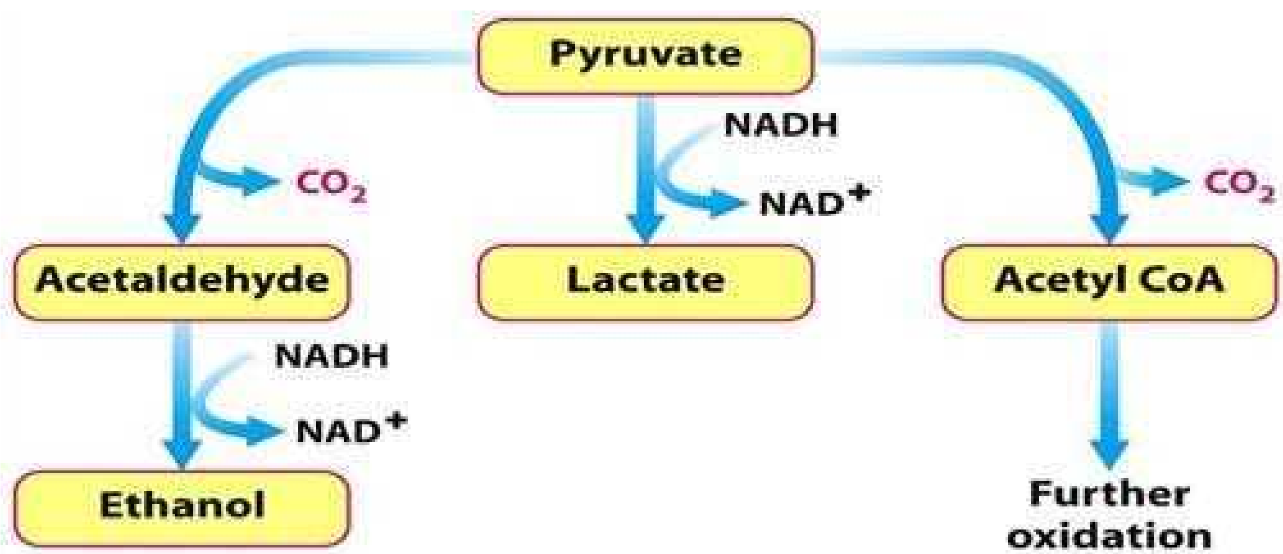


Figure 16.9
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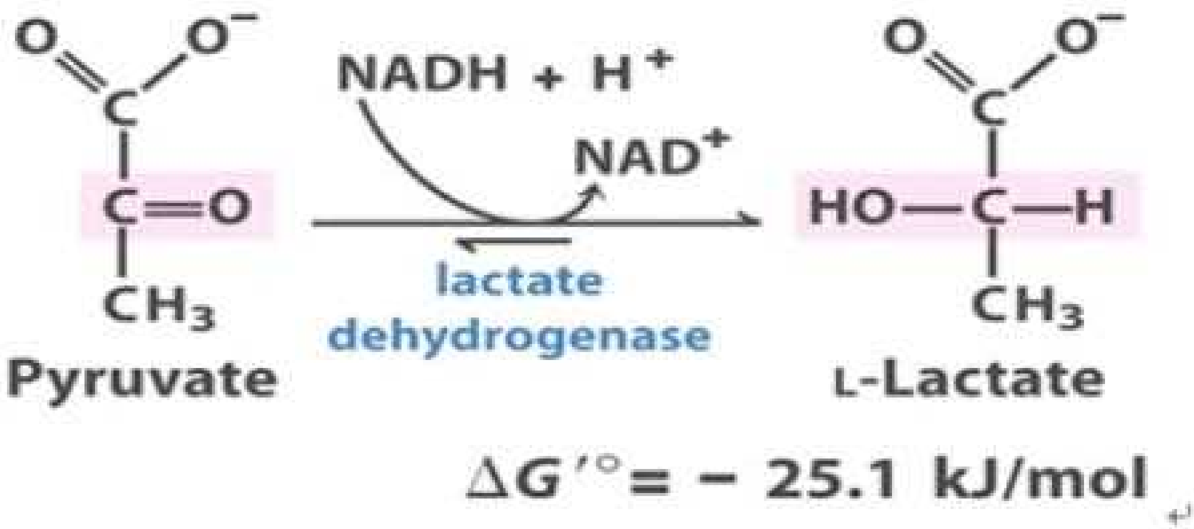
In anaerobic organisms (those that do not use oxygen to generate energy)

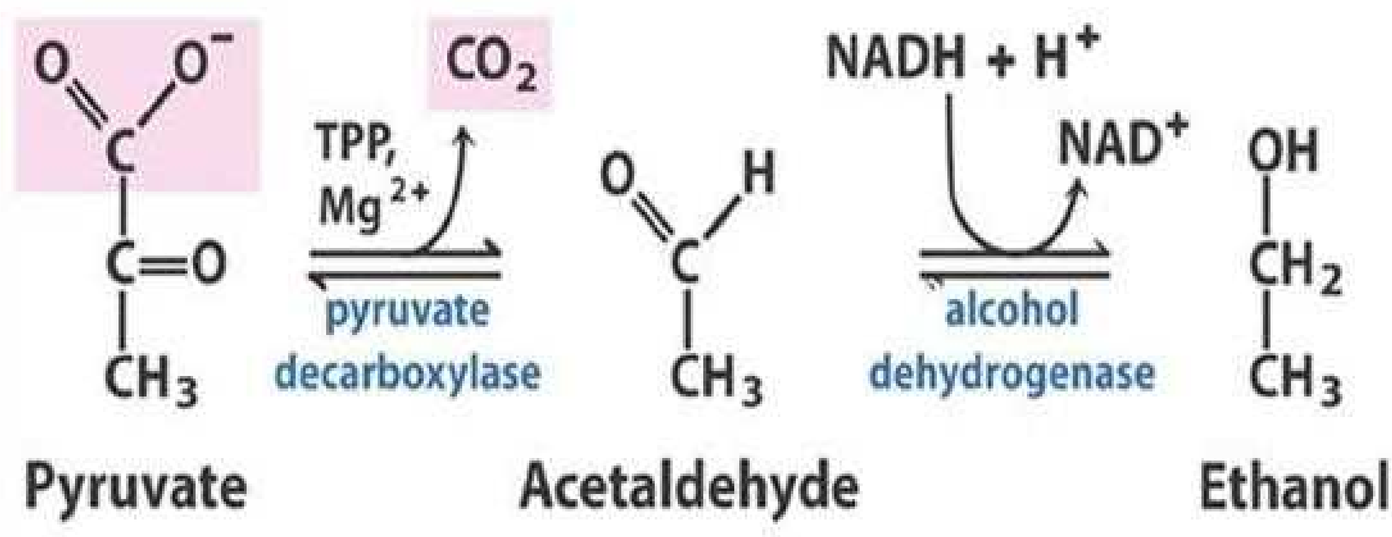
A- Pyruvate is reduced to lactate.



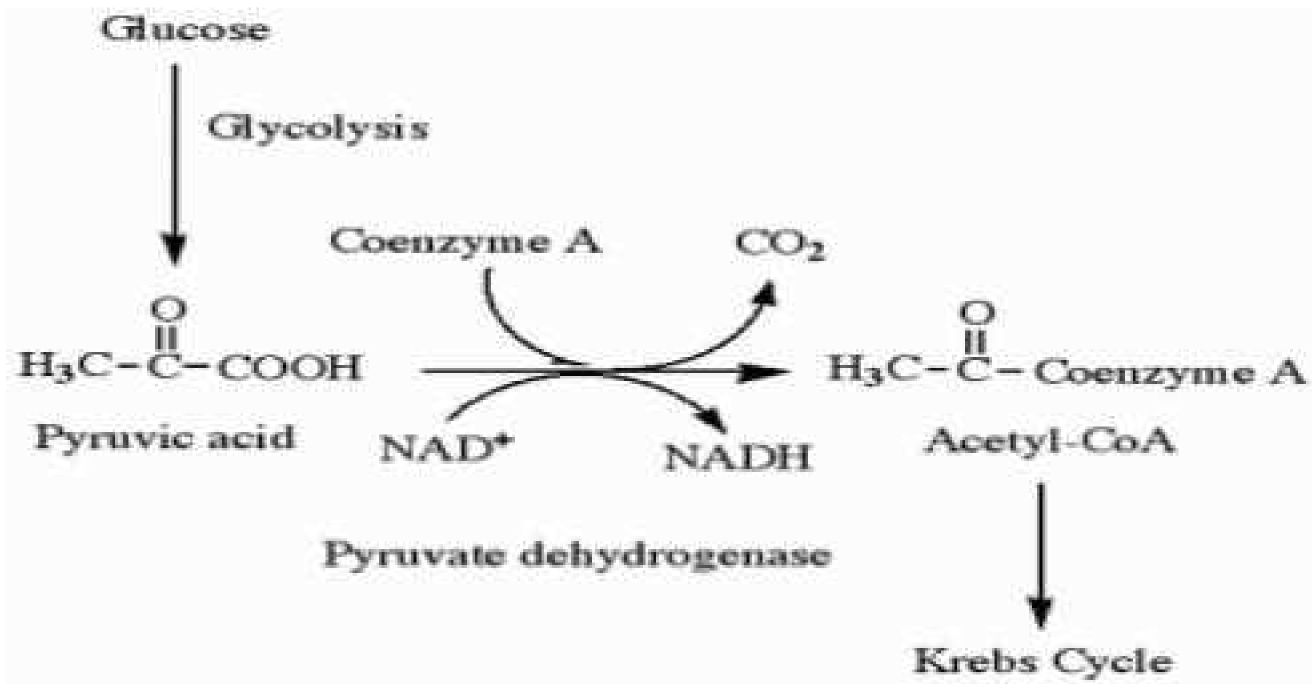
- NADH oxidizes to NAD^+ allowing glycolysis to continue.

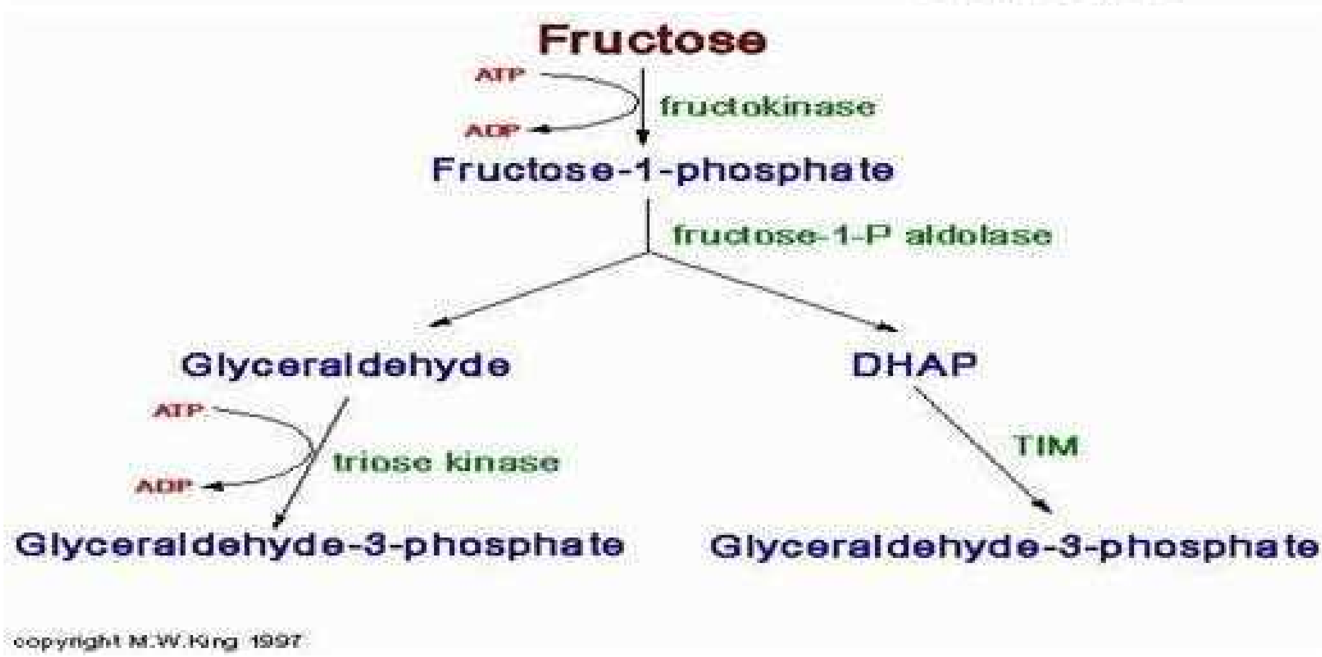
B- Decarboxylates pyruvate to acetaldehyde, which is reduced to ethanol.

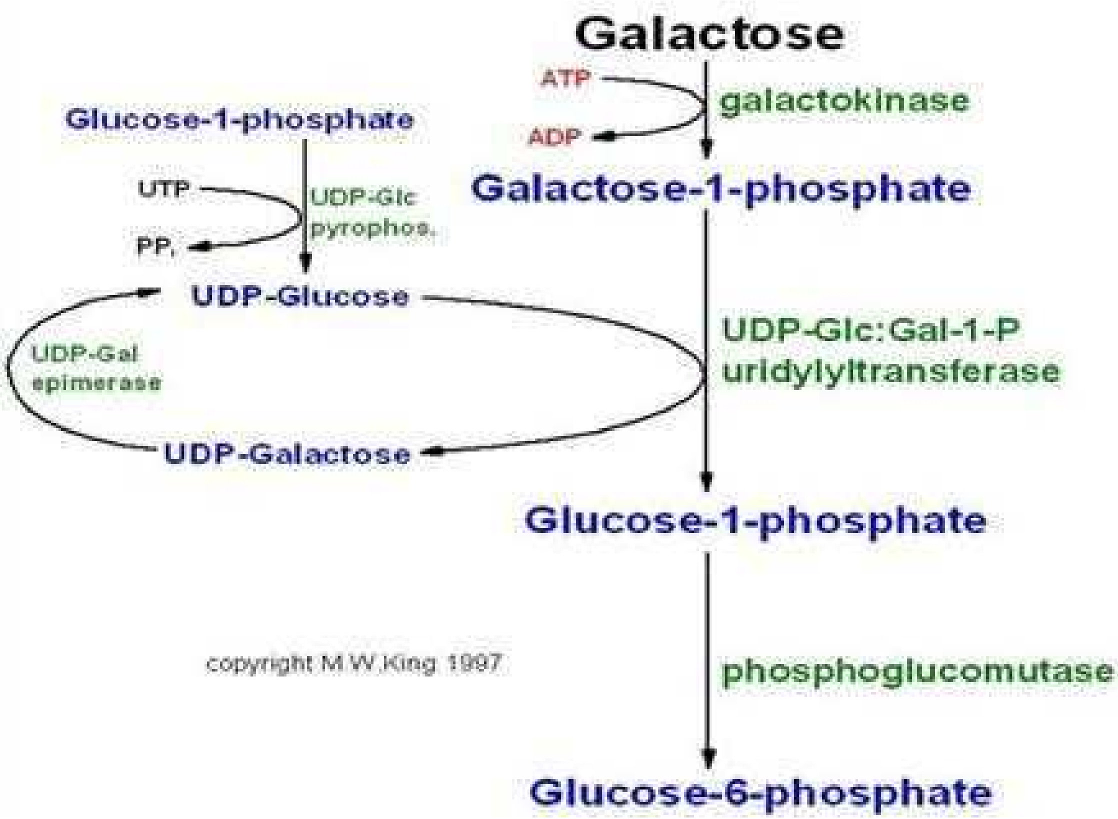
- Regenerates NAD^+ to continue glycolysis.



C- Under aerobic conditions, pyruvate can be completely oxidized to CO2, generating much more ATP, Using oxygen as a terminal electron acceptor, aerobic organisms such as animals and plants completely oxidize pyruvate to form CO2 and H2O in an elaborate stepwise mechanism known as aerobic respiration



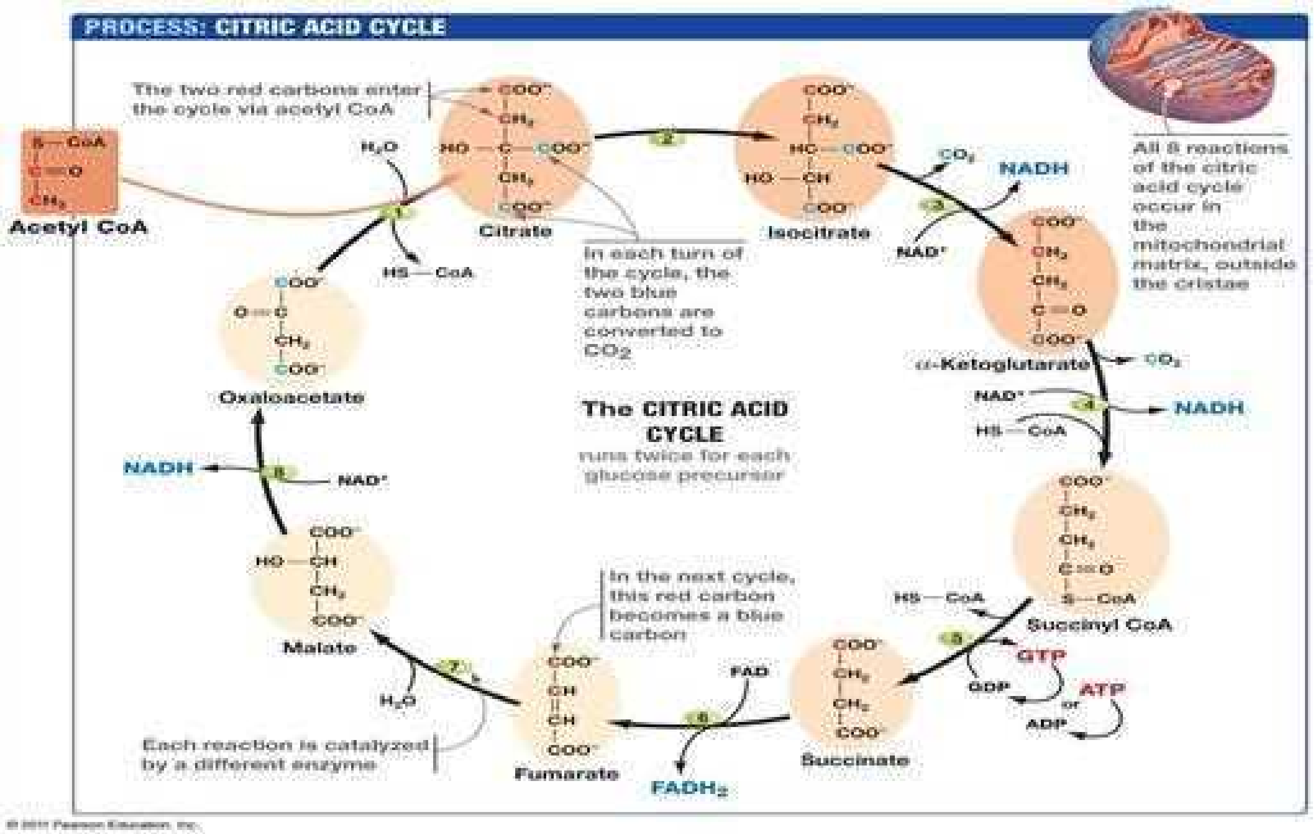


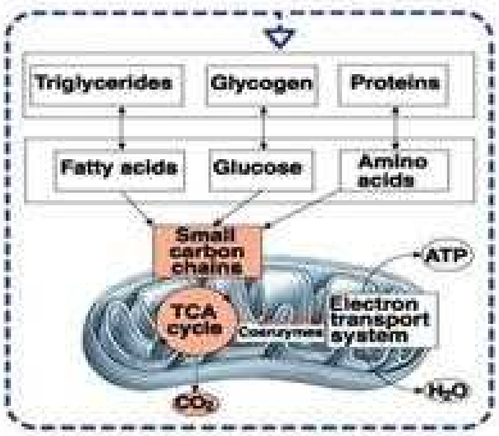


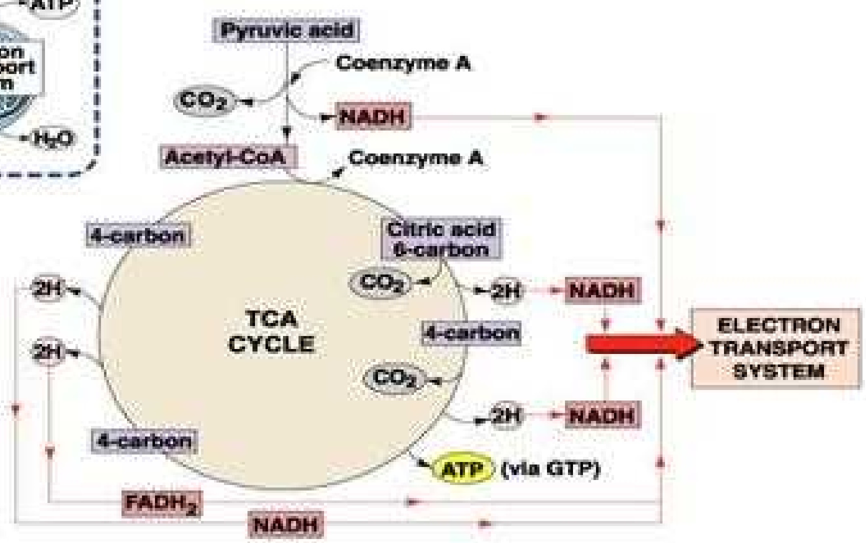
THE KREBS CYCLE

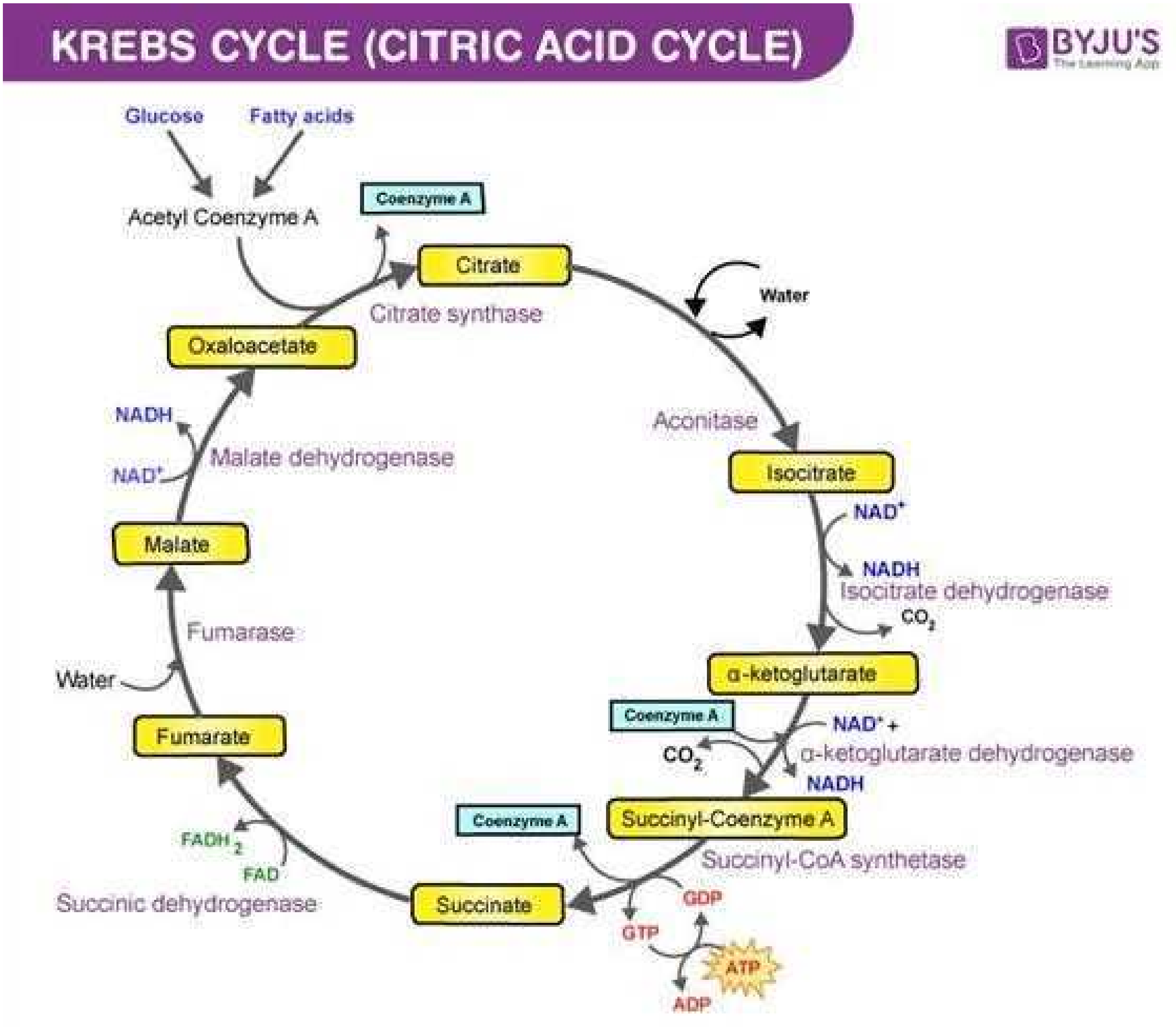
1. The transition reaction, the Krebs cycle and the electron transport system all take place inside the mitochondria.
2. Enzymes for the Krebs cycle are located in the fluid-filled *matrix* of the mitochondria.
3. Pathways: oxygen and glucose diffuse into cells from bloodstream, pyruvate (as an end product of glycolysis) diffuses into mitochondria; CO_2 and ATP diffuse back out of mitochondria into cytoplasm and CO_2 further diffuses back to bloodstream. Water can remain in mitochondria, in cytoplasm, or enter bloodstream for excretion. ATP remains as a source of energy for the cell to do work.
4. Since most of ATP is produced in mitochondria, mitochondria are often called the powerhouses of the cell. The acetyl-CoA now enters the Krebs cycle (also known as the citric acid cycle or tricarboxylic acid cycle). The NADH made by PDH, together with the NADH made by the Krebs cycle itself, is reoxidized by the respiratory chain).

Overview of the Kreb's Cycle









1. Calculating Energy Yield from Glucose Metabolism
   - a. Per glucose, four ATP are formed by substrate-level phosphorylation, two during glycolysis and two during two turns of Krebs cycle.
   - b. Per glucose, ten NADH and two $FADH_2$ take electrons to the electron transport system.
   - c. For each NADH formed inside the mitochondria by Krebs cycle, three ATP result; for each $FADH_2$, only two ATP are produced.
   - d. The glycolytic pathway outside the mitochondria produces only two ATP when the electrons are shuttled to the electron transport system inside the mitochondrion.
2. How Efficient is Aerobic Respiration?
   - a. Difference in energy content between glucose and O_2, and products CO_2 and H_2O is 686 kilocalories.

- b. The ATP third phosphate bond has energy content of 7.3 kilocalories, 36 ATP are produced per glucose breakdown totaling 263 kilocalories.
- c. Efficiency is 263/686 or 39%.

Overview of Cellular respiration:

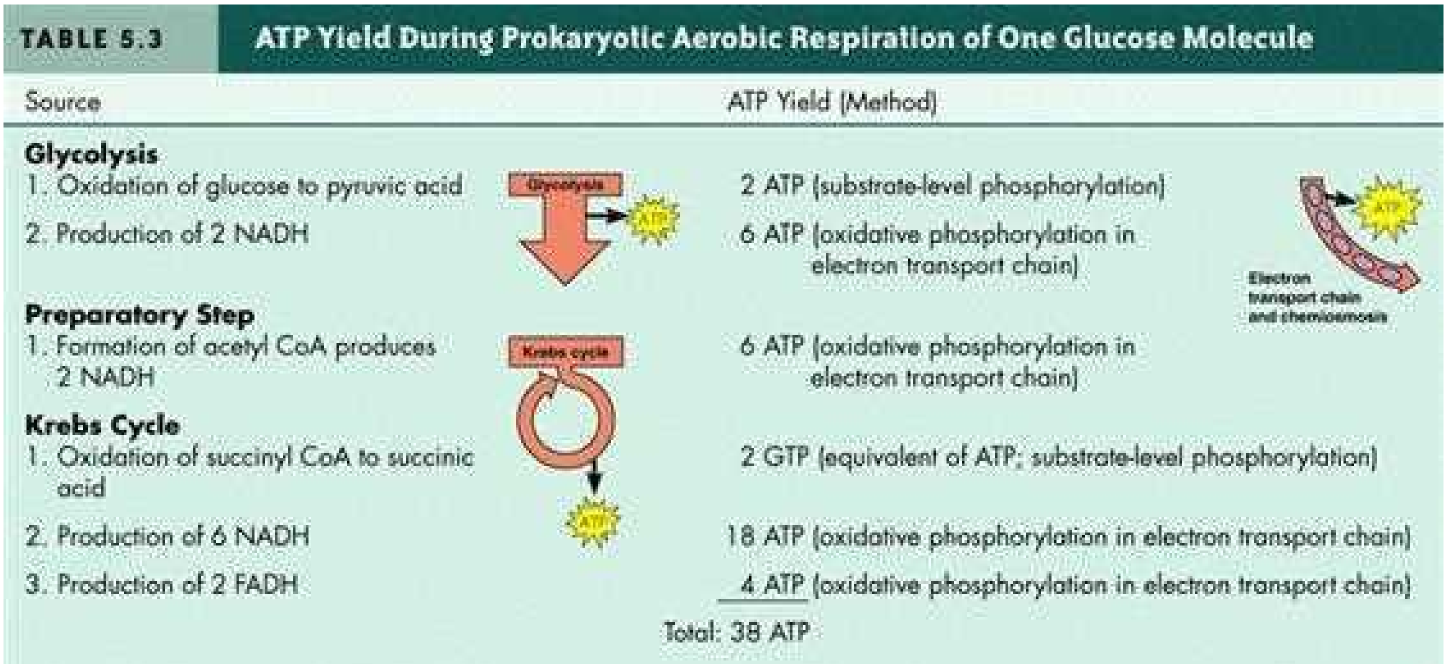


TABLE 5.3 ATP Yield During Prokaryotic Aerobic Respiration of One Glucose Molecule

Source	ATP Yield (Method)
Glycolysis	
1. Oxidation of glucose to pyruvic acid	2 ATP (substrate-level phosphorylation)
2. Production of 2 NADH	6 ATP (oxidative phosphorylation in electron transport chain)
Preparatory Step	
1. Formation of acetyl CoA produces 2 NADH	6 ATP (oxidative phosphorylation in electron transport chain)
Krebs Cycle	
1. Oxidation of succinyl CoA to succinic acid	2 GTP (equivalent of ATP; substrate-level phosphorylation)
2. Production of 6 NADH	18 ATP (oxidative phosphorylation in electron transport chain)
3. Production of 2 FADH	4 ATP (oxidative phosphorylation in electron transport chain)
	Total: 38 ATP