Section Summary

Glycolysis is the first pathway used in the breakdown of glucose. Because nearly all organisms on earth use it, glycolysis is thought to have evolved early in the history of life. Glycolysis consists of different phases: The first and second phases prepare the six-carbon glucose for separation into two three-carbon sugars. Energy from ATP is invested in the molecule during this step to energize the separation. The last phase of glycolysis extracts ATP and high-energy electrons and attaches them to NAD^+. Two ATP molecules are invested in the first half, and four ATP molecules are formed during the second half. This produces a net gain of two ATP molecules per molecule of glucose for the cell.

Exercises

1. During glycolysis for one molecule of glucose, a total of _____ ATP are made but of that, the cell nets _____ ATP molecules.
   a. 2; 4
   b. 6; 4
   c. 4; 2
   d. 8; 6
2. The ATP made in glycolysis is made through _____.
   a. chemiosmosis
   b. substrate-level phosphorylation
   c. oxidative phosphorylation
   d. ATP synthase
3. The glucose that enters the glycolysis pathway is split into two molecules of _________.
   a. ATP
   b. phosphate
   c. NADH
   d. pyruvate
4. Both prokaryotic and eukaryotic organisms carry out some form of glycolysis. How does that fact support or not support the assertion that glycolysis is one of the oldest metabolic pathways?

Answers

1. (c)
2. (b)
3. (d)
4. If glycolysis evolved relatively late, it likely would not be as universal in organisms as it is. It probably evolved in very primitive organisms that did not require oxygen and did not need to occur in a membrane-bound organelle.

Glossary

anaerobic: process in which organisms do not require oxygen

glycolysis: the process of breaking glucose into two three-carbon molecules with the production of ATP and NADH

substrate-level phosphorylation: production of ATP from ADP using the excess energy from a chemical reaction and a phosphate group from a reactant

6.3 Citric Acid Cycle

Learning objectives

By the end of this section, you will be able to:

- *Describe the location of pyruvate oxidation in the cell*
- *Explain what happens during pyruvate oxidation including the starting reactants and final products*
- *Describe the location of the citric acid cycle in the cell*
- *Explain what happens during the citric acid cycle including the starting reactants and final products*
- *Be able to define and explain all bolded terms*

In eukaryotic cells, the pyruvate molecules produced at the end of glycolysis are transported into mitochondria. If oxygen is available, aerobic cellular respiration will go forward.

Pyruvate Oxidation

In the mitochondria, pyruvate will be oxidized into a two-carbon acetyl group. This process is done by removing a molecule of carbon dioxide and transferring electrons to NAD^+, reducing it to NADH. The acetyl group will then be picked up by a carrier molecule called coenzyme A (CoA). The resulting molecule is called **acetyl CoA**. (Figure 6.15).

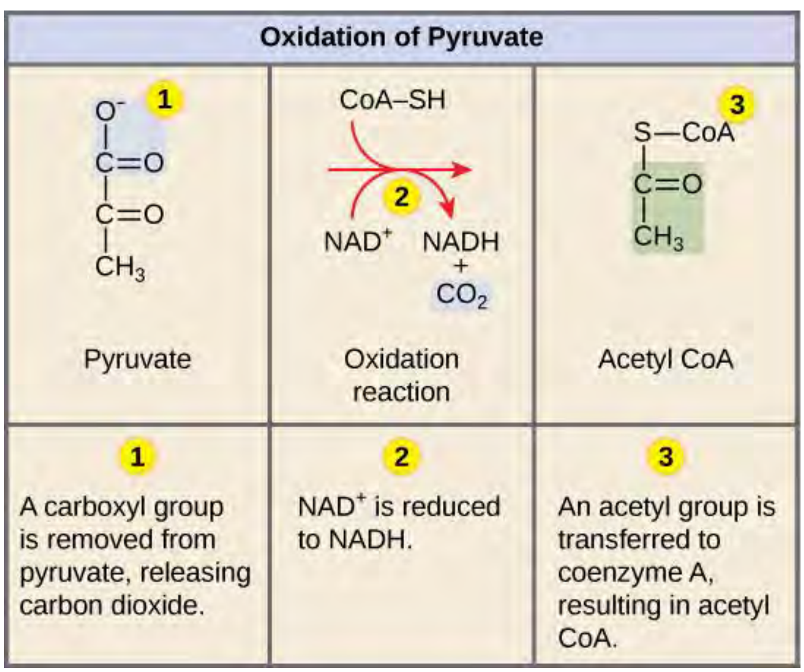

Figure 6.15 Upon entering the mitochondria, pyruvate is converted into acetyl CoA. (credit: Clark et al. / Biology 2E OpenStax)

Acetyl CoA can be used in a variety of ways by the cell. Its primary function is to deliver the acetyl group derived from pyruvate to the next pathway in glucose catabolism, the citric acid cycle (Figure 6.16). Since two pyruvate molecules exit glycolysis, pyruvate oxidation will occur twice producing a total of two Acetyl CoA, two molecules of carbon dioxide, and two molecules of NADH.

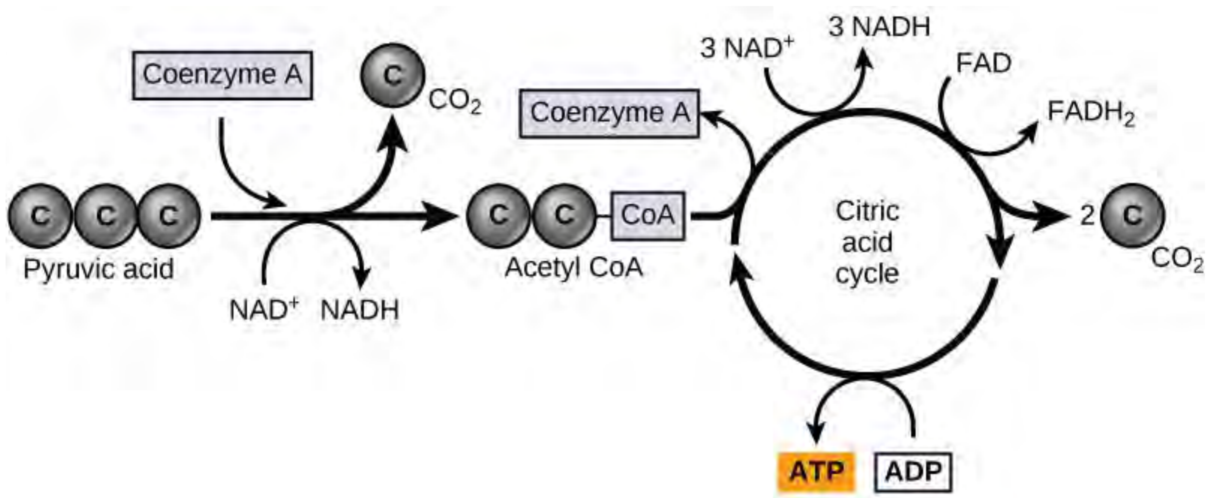

Figure 6.16 Pyruvic acid (pyruvate) is converted into acetyl-CoA before entering the citric acid cycle. (credit: Fowler et al. / Concepts of Biology OpenStax)

The Citric Acid Cycle

Like the conversion of pyruvate to acetyl CoA, the citric acid cycle in eukaryotic cells takes place in the matrix of the mitochondria (Figure 6.9). Unlike glycolysis, the **citric acid cycle** is a closed loop. The last part of the pathway regenerates the molecule used in the very first step, oxaloacetate (Figure 6.16). The citric acid cycle is also commonly referred to as the Krebs cycle after Hans Krebs, a German-born British biochemist who discovered the metabolic pathway.

For each molecule of acetyl CoA that enters the citric acid cycle, two carbon dioxide molecules, one ATP molecule (or an equivalent), 3 NADH molecules, and 1 $FADH_2$ molecule is formed (Figure 6.17). Remember, for every one molecule of glucose that entered into glycolysis, two molecules of acetyl CoA can be formed. As a result, the citric acid cycle can make two turns for every one molecule of glucose, forming a total of four carbon dioxide, two ATP (or an equivalent), six NADH, and two $FADH_2$ molecules.

The six NADH and two $FADH_2$ are electron carriers that will transport electrons to the final stage of aerobic cellular respiration, oxidative phosphorylation. Most ATP molecules will be produced during the final stage.