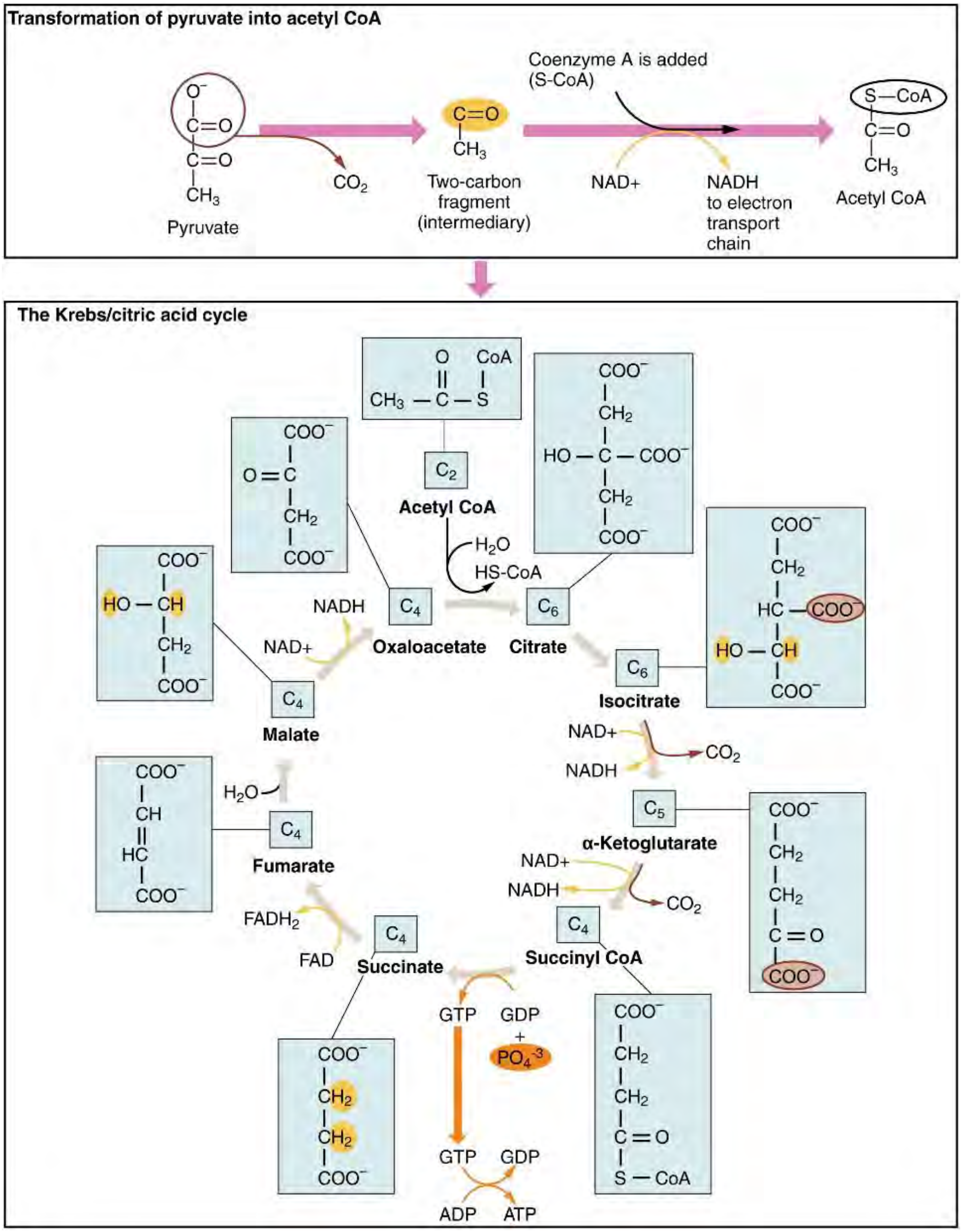

Figure 6.17 Each pyruvate (pyruvic acid) that is generated by glycolysis is converted into a two-carbon acetyl CoA molecule. In the citric acid cycle, the acetyl CoA is systematically processed through the cycle and produces carbon dioxide and high-energy NADH, $FADH_2$, and ATP molecules. (credit: Betts et al. / [Anatomy and Physiology OpenStax])

The citric acid cycle is considered an aerobic pathway because it requires oxygen. The NADH and $FADH_2$ produced during the citric acid cycle must transfer their electrons to the electron transport chain, which is part of the next stage of aerobic respiration--oxidative phosphorylation. If oxygen is not present, NADH and $FADH_2$ cannot be oxidized, and the citric acid cycle cannot occur.

Section Summary

In the presence of oxygen, pyruvate is transformed into an acetyl group attached to a carrier molecule of coenzyme A. The acetyl group is delivered to the citric acid cycle for further catabolism. During the conversion of the two pyruvate molecules into the two acetyl groups, two molecules of carbon dioxide and two molecules of NADH are produced.

The citric acid cycle is a series of redox reactions. This cycle starts with acetyl CoA and oxaloacetate, which combine and form citric acid. For everyone molecule of glucose that enters glycolysis, two molecules of acetyl CoA can be formed. Therefore, the citric acid cycle can make two turns forming: 4 carbon dioxide molecules, 2 ATP molecule (or an equivalent), 6 NADH molecules, and 2 $FADH_2$ molecules.

Exercises

1. What do the electrons added to NAD^+ do?
    a. They become part of glycolysis
    b. They go on to the electron transport chain.
    c. They energize the entry of the acetyl group into the citric acid cycle.
    d. They are converted into NADP.
2. In eukaryotic cells, where does pyruvate oxidation occur?
    a. mitochondria
    b. cytoplasm
    c. nucleus
    d. plasma membrane
3. If a cell has access to three molecules of glucose, how many molecules of NADH could be made during the citric acid cycle?
    a. 3
    b. 6
    c. 12
    d. 18
4. Explain why the citric acid cycle is considered an aerobic pathway.

Answers

1. (b)
2. (a)
3. (d)
4. It is an aerobic pathway because the NADH and $FADH_2$ produced must transfer their electrons to the next pathway in the system, which will use oxygen. If oxygen is not present, this transfer does not occur.

Glossary

acetyl CoA: the combination of an acetyl group derived from pyruvic acid and coenzyme A which is made from pantothenic acid (a B-group vitamin)

citric acid cycle: a series of enzyme-catalyzed chemical reactions of central importance in all living cells that harvest the energy in carbon-carbon bonds of sugar molecules to generate ATP; the citric acid cycle is an aerobic metabolic pathway because it requires oxygen in later reactions to proceed

6.4 Oxidative phosphorylation

Learning objectives

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

- *Describe the location of oxidative phosphorylation in the cell*
- *Describe the overall outcome of oxidative phosphorylation in terms of the products of each*
- *Describe the relationships of glycolysis, the citric acid cycle, and oxidative phosphorylation in terms of their ATP outputs.*
- *Describe the relationships of glycolysis, the citric acid cycle, and oxidative phosphorylation in terms of electron carriers.*
- *Be able to define and explain all bolded terms*

You have just read about two pathways in glucose catabolism, glycolysis and the citric acid cycle. Both pathways generate only small amounts of ATP. Most of the ATP is made during the final stage of aerobic cellular respiration, oxidative phosphorylation. **Oxidative phosphorylation** consists of two parts, the electron transport chain and chemiosmosis. Both processes of oxidative phosphorylation take place on the inner membrane of the mitochondria of eukaryotic organisms and on the inner part of the cell membrane of prokaryotic organisms. Let us take a closer look at the processes that make up oxidative phosphorylation.

Electron Transport Chain

The **electron transport chain** is the only part of glucose catabolism that uses oxygen directly. Electron transport is a series of chemical redox reactions that resemble a bucket brigade or a ball rolling down a staircase (Figure 6.18).

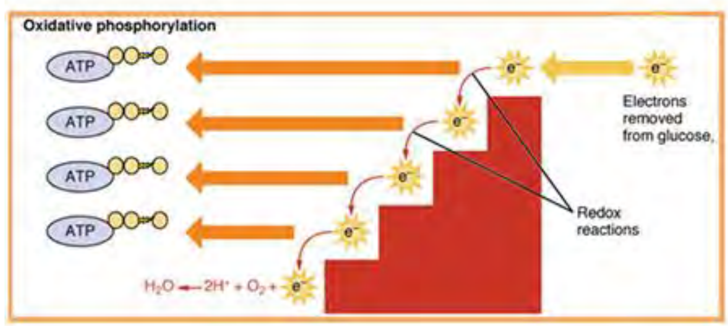

Figure 6.18 The electron transport chain resembles a staircase. As the electron moves down each stair energy are given off, which can be used to generate ATP. (credit: Modified by Elizabeth O'Grady original work of Betts et al. / Anatomy and Physiology OpenStax)

As electrons are passed rapidly from one protein to the next in a series of redox reactions, some energy is released. At the end of the protein chain, oxygen acts as the final electron acceptor. Each oxygen atom accepts two electrons and two hydrogen ions and is reduced to water. See the below equation. Note the equation begins with one oxygen molecule, which is two atoms of oxygen covalently bound together.

$$O_2 + 4H^+ + 4e^- \longrightarrow 4H_2O$$