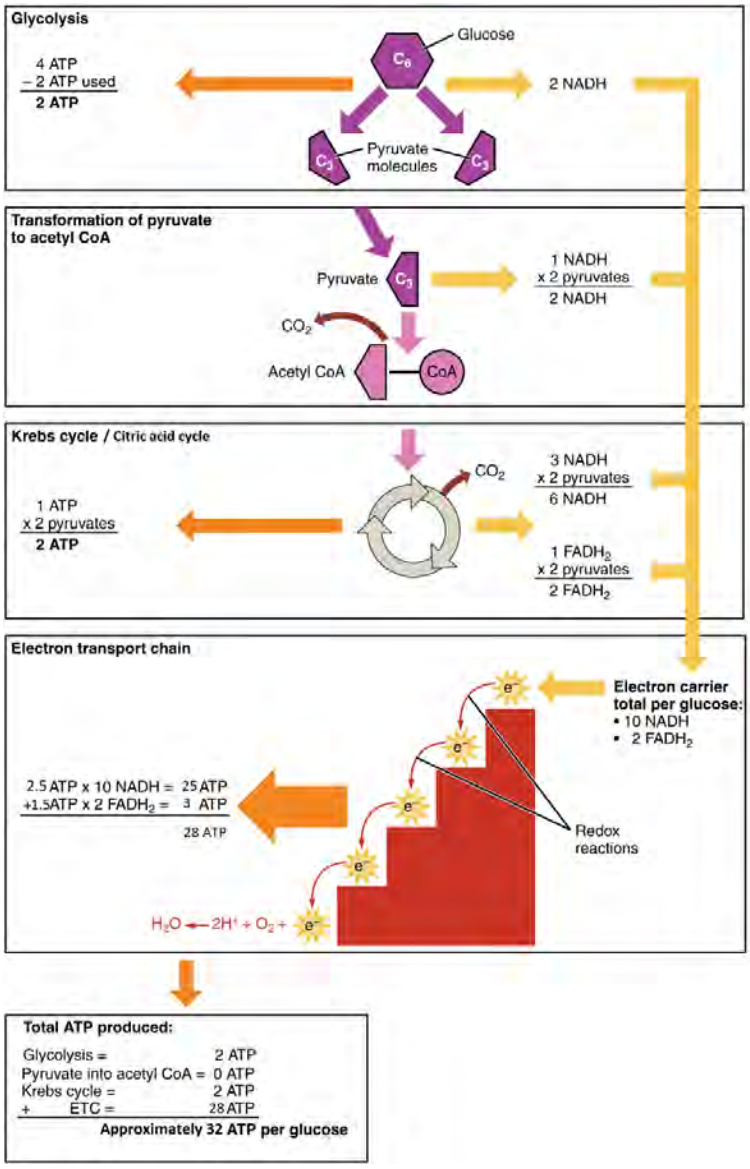

Figure 6.22 Shows the ATP yield for one molecule, one glucose catabolism. (credit: Modified by Elizabeth O'Grady original work of Betts et al. / Anatomy and Physiology OpenStax)

Mitochondrial Disease

What happens when the critical reactions of cellular respiration do not proceed correctly? Mitochondrial diseases are genetic disorders of metabolism. Mitochondrial disorders can arise from mutations in nuclear or mitochondrial DNA, and they result in the production of less energy than is normal in body cells. Symptoms of mitochondrial diseases can include muscle weakness, lack of coordination, stroke-like episodes, and loss of vision and hearing. Most people affected by these types of diseases are diagnosed in childhood, although there are some adult-onset diseases. Identifying and treating mitochondrial disorders is a specialized medical field. The educational preparation for this profession requires a four-year college education degree, followed by medical school with a specialization in medical genetics. Medical geneticists can be board certified by the American Board of Medical Genetics and go on to become associated with professional organizations devoted to the study of mitochondrial diseases.

Section Summary

Oxidative phosphorylation begins with the electron transport chain, where electrons are passed through a series of redox reactions to a final electron acceptor, oxygen. Oxygen accepts two electrons and two hydrogen ions, forming water. The energy released as the electrons are passed through the electron transport chain is used to generate a hydrogen ion gradient across the inner mitochondrial membrane. The potential energy of the gradient is used to generate ATP with the help of the enzyme ATP synthase through the process of chemiosmosis.

Exercises

1. Name the enzyme involved in chemiosmosis that helps the cell make ATP.
2. What happens to NADH when it arrives at the electron transport chain?
    a. It is reduced to NAD^+
    b. It is oxidized to NAD^+
    c. It is reduced to FAD
    d. It is oxidized to FAD
3. Chemiosmosis in eukaryotic cells involves:
    a. the movement of electrons across the cell membrane
    b. the movement of hydrogen atoms across the outer cell membrane
    c. the movement of hydrogen ions across the mitochondrial membrane
    d. the movement of glucose through the cell membrane
4. We inhale oxygen and exhale carbon dioxide. What is the oxygen used for, and where does the carbon dioxide come from?

Answers

1. ATP synthase
2. (b)
3. (c)
4. The oxygen we inhale is the final electron acceptor in the electron transport chain and allows aerobic respiration to proceed. The carbon dioxide we breathe out is formed during pyruvate oxidation and the citric acid cycle when the bonds in carbon compounds are broken.

Glossary

ATP synthase: a membrane-embedded protein complex that regenerates ATP from ADP with energy from protons diffusing through it

chemiosmosis: the movement of hydrogen ions down their electrochemical gradient across a membrane through ATP synthase to generate ATP

electron transport chain: a series of four large, multi-protein complexes embedded in the inner mitochondrial membrane that accepts electrons from donor compounds and harvests energy from a series of chemical reactions to generate a hydrogen ion gradient across the membrane

oxidative phosphorylation: the production of ATP by the transfer of electrons down the electron transport chain to create a proton gradient that is used by ATP synthase to add phosphate groups to ADP molecules

6.5 Fermentation

Learning objectives

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

- *Describe the relationship between anaerobic cellular respiration and fermentation*
- *Describe the types of fermentation that readily occur and the conditions that initiate that fermentation*
- *Be able to define and explain all bolded terms*

For aerobic cellular respiration to occur, oxygen must be present to accept electrons from NADH and $FADH_2$ produced during glycolysis, pyruvate oxidation, and citric acid cycle. What happens when oxygen levels are low or absent? Can cells still produce ATP?

Remember that glycolysis is an anaerobic pathway that allows cells to generate small amounts of ATP through substrate-level phosphorylation in the absence of oxygen. Glycolysis is a type of anerobic cellular respiration. **Anaerobic cellular respiration** enables organisms to generate ATP in the absence of oxygen. However, cells still need a way to oxidize the NADH produced during this pathway. Some living organisms are able to use an organic molecule as the final electron acceptor in times when oxygen levels are low or absent. Processes that use an organic molecule to regenerate NAD^+ from NADH are collectively referred to as **fermentation**. In contrast, some living systems use an inorganic molecule as a final electron acceptor.

Lactic Acid Fermentation

Lactic acid fermentation is a method of fermentation used by animals and some bacteria like those in yogurt (Figure 6.23). This occurs routinely in mammalian red blood cells and in skeletal muscle that has insufficient oxygen supply. When oxygen is in low supply, cells can continue to carry out glycolysis to produce small quantities of ATP. However, because oxygen cannot be used to accept electrons from NADH, an organic molecule must be used in its place. In **lactic acid fermentation**, electrons from NADH are transferred to pyruvate, forming lactic acid (also called lactate). When NADH is oxidized NAD^+ is regenerated, and glycolysis can continue.

In mammals, lactic acid fermentation allows muscle cells to generate small amounts of ATP for short periods of time. Lactic acid build-up causes muscle stiffness and fatigue. Once the lactic acid has been removed from the muscle it is circulated to the liver, where it can be converted back to pyruvate and further catabolized for energy.

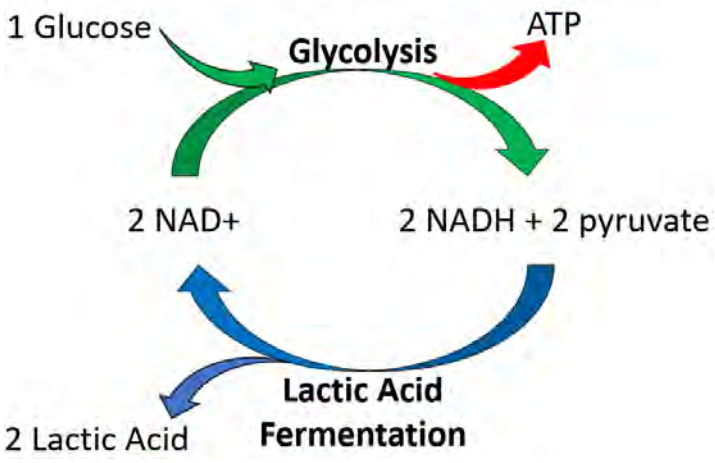

Figure 6.23 Lactic acid fermentation is common in muscles that have become exhausted by use. (credit: Jason Cashmore)