Alcohol Fermentation

Another familiar fermentation process is **alcohol fermentation**. During alcohol fermentation ethanol, a type of alcohol, is produced. In the first reaction, a carboxyl group is removed from pyruvate, releasing carbon dioxide as a gas (Figure 6.24).

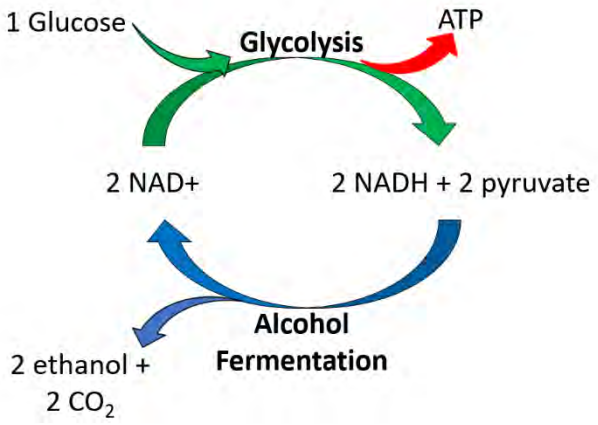

Figure 6.24 shows alcohol fermentation (credit: Jason Cashmore)

The loss of carbon dioxide reduces the molecule by one carbon atom, making acetaldehyde. The second reaction removes an electron from NADH, oxidizing it to NAD^+. When acetaldehyde is reduced, ethanol is formed (Figure 6.25).

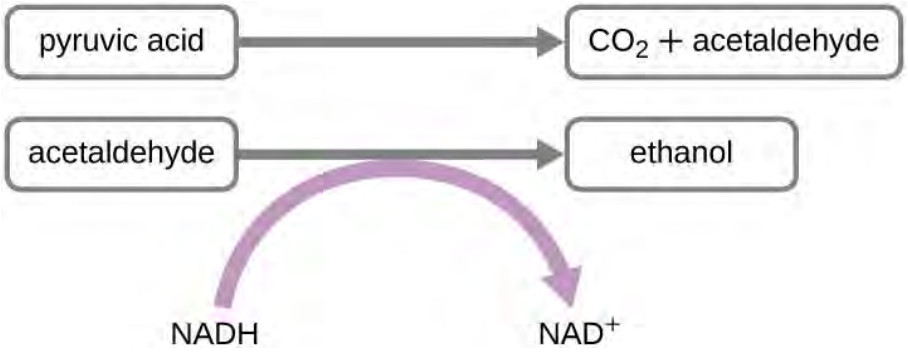

Figure 6.25 The chemical reactions of alcohol fermentation are shown here. (credit: Parker et al. / Microbiology OpenStax)

The fermentation of pyruvate by yeast produces the ethanol found in alcoholic beverages (Figure 6.26). If the carbon dioxide produced by the reaction is not vented from the fermentation chamber, for example, in beer and sparkling wines, it remains dissolved in the medium until the pressure is released. Ethanol above 12 percent is toxic to yeast, so natural levels of alcohol in wine occur at a maximum of 12 percent.

Figure 6.26 The fermentation of grape juice to make wine produces CO2 as a byproduct. Fermentation tanks have valves so that pressure inside the tanks can be released. (credit: Clark et al. / Biology 2E OpenStax)

Anaerobic Cellular Respiration

Certain prokaryotes, including some species of bacteria and Archaea, solely use anaerobic respiration. To oxidize its NADH, a group of Archaea called methanogens reduces carbon dioxide to methane. These microorganisms are found in soil and in the digestive tracts of animals, such as cows and sheep. Similarly, sulfate-reducing bacteria and Archaea, most of which are anaerobic (Figure 6.27), reduce sulfate to hydrogen sulfide to regenerate NAD^+ from NADH.

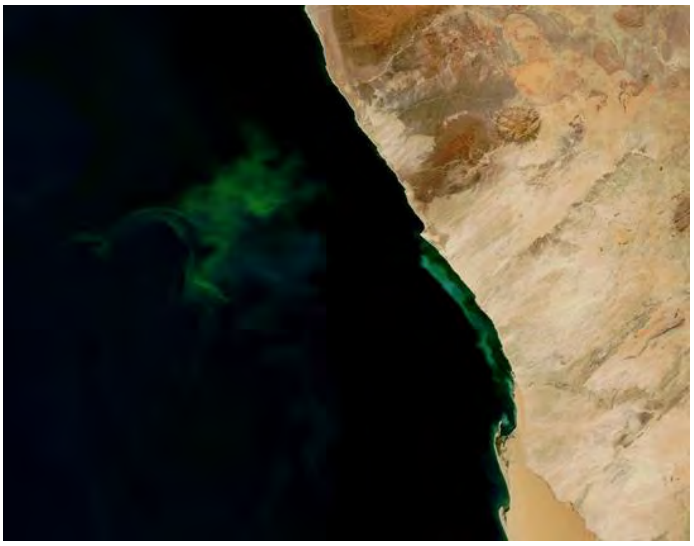

Figure 6.27 The green color seen in these coastal waters is from an eruption of hydrogen sulfide. Anaerobic, sulfate-reducing bacteria release hydrogen sulfide gas as they decompose algae in the water. (credit: NASA image courtesy Jeff Schmaltz, MODIS Land Rapid Response Team at NASA GSFC / Biology 2E OpenStax)

CONCEPTS IN ACTION- Visit this site to see anaerobic cellular respiration in action.

Many prokaryotes are facultatively anaerobic. This means that they can switch between aerobic respiration and fermentation, depending on the availability of oxygen. Certain prokaryotes, like *Clostridia* bacteria, are obligate anaerobes. Obligate anaerobes live and grow in the absence of oxygen. Oxygen is a poison to these microorganisms and kills them upon exposure. It should be noted that all forms of fermentation, except lactic acid fermentation, produce gas. In a laboratory, some bacteria can be identified based on their gas production.

Section Summary

If NADH cannot be oxidized through aerobic cellular respiration, another electron acceptor must be used. Most organisms will use some form of fermentation to accomplish the regeneration of NAD^+, ensuring that glycolysis continues. The regeneration of NAD^+ in fermentation does not directly generate ATP. However, once NAD^+ is regenerated, it can again be used in glycolysis where small amounts of ATP can be made through substrate-level phosphorylation.

Exercises

1. True or False: Lactic acid can be converted back to pyruvate.
2. Which of the following fermentation methods can occur in animal skeletal muscles?
    a. lactic acid fermentation
    b. alcohol fermentation
    c. mixed acid fermentation
    d. propionic fermentation
3. When muscle cells run out of oxygen, what happens to the potential for energy extraction from sugars, and what pathways do the cell use?

Answers

1. True
2. (a)
3. Without oxygen, oxidative phosphorylation and the citric acid cycle stop, so ATP is no longer generated through this mechanism, which extracts the greatest amount of energy from a sugar molecule. In addition, NADH accumulates, preventing glycolysis from going forward because of an absence of NAD^+. Lactic acid fermentation uses the electrons in NADH to generate lactic acid from pyruvate, which allows glycolysis to continue, and thus, a smaller amount of ATP can be generated by the cell.

Glossary

alcohol fermentation: the steps that follow the partial oxidation of glucose via glycolysis to regenerate NAD^+ and produces the products ethanol and carbon dioxide

anaerobic cellular respiration: the use of an electron acceptor other than oxygen to complete metabolism using electron transport-based chemiosmosis

fermentation: the steps that follow the partial oxidation of glucose via glycolysis to regenerate NAD^+; occurs in the absence of oxygen and uses an organic compound as the final electron acceptor

lactic acid fermentation: the steps that follow the partial oxidation of glucose via glycolysis to regenerate NAD^+ and produces the products lactic acid