Chapter 6: Introduction to Cellular Respiration

Figure 6.1 This geothermal energy plant transforms thermal energy from deep in the ground into electrical energy. (credit: modification of work by the U.S. Department of Defense / Biology 2E OpenStax)

The electrical energy plant in Figure 6.1 converts energy from one form to another. This type of electrical plant starts with underground thermal energy (heat) and transforms it into electrical energy that will be used in homes and factories. Like an electrical plant, plants and animals also must take in energy from the environment and convert it into a form that their cells can use. During photosynthesis, plants and other photosynthetic producers take in light energy and convert it into chemical energy in the form of glucose. Glucose is essential because it stores potential energy in its chemical bonds. In cellular respiration, a series of metabolic chemical reactions, energy is extracted from the bonds of glucose and used to make ATP. In this chapter, we will take a closer look at the metabolic pathway of cellular respiration.

6.1 Energy in Living Systems

Learning objectives

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

- *Explain what a redox (reduction/oxidation) reaction is*
- *Know the overall equation for aerobic cellular respiration and be able to explain which molecules are reduced or oxidized into which molecules*
- *Identify ATP and describe how it is involved in energy transfer within cells*
- *Be able to define and explain all bolded terms*

All living organisms perform cellular respiration. Cellular respiration is the process of using potential chemical energy, stored in the bonds of organic nutrients, to generate ATP (adenosine triphosphate). If oxygen is required when performing cellular respiration, the process is called **aerobic cellular respiration**. When oxygen is not required, the process is called **anaerobic cellular respiration**.

Humans, plants, some bacteria, and many other living organisms use aerobic cellular respiration to generate ATP. During aerobic cellular respiration, potential energy from glucose is used to drive the synthesis of ATP with the help of oxygen. During the process, both carbon dioxide and water are released as waste products. In addition, like all energy transformations, some energy is lost in the form of heat. Aerobic cellular respiration can be summarized by the equation below:

Figure 6.2 shows the reaction for aerobic cellular respiration. Note that this process consists of several chemical reactions, as indicated by the multiple arrows. (credit: Jason Cashmore)

Breaking down sugar molecules occurs through a series of chemical reactions. As you can see from Figure 6.2, these reactions begin with one molecule of energy-rich glucose. Glucose is modified through a series of metabolic pathways and eventually leads to the synthesis of large quantities of ATP. Most of these pathways are combinations of oxidation and reduction reactions. Oxidation and reduction reactions occur in tandem. An **oxidation reaction** strips an electron from an atom in a molecule making that atom more positive. That electron is then gained by a different atom in a **reduction reaction**. The atom that receives or gains the electron now has more electrons than protons and therefore becomes more negative (its charge is reduced, hence the name reduction reaction). Because reduction and oxidation usually occur together, these pairs of reactions are called reduction-oxidation reactions or **redox reactions**. Figure 6.3 shows a redox reaction; sodium is oxidized when it loses an electron, and chlorine is reduced when it accepts an electron.

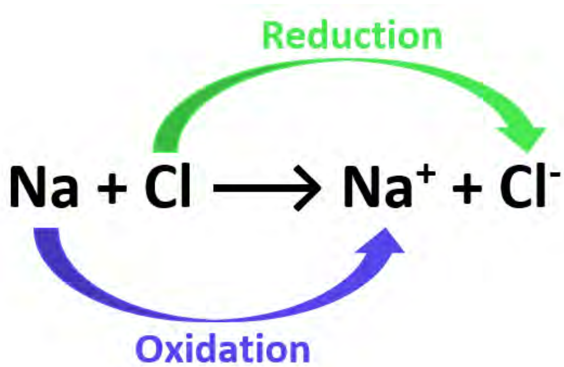

Figure 6.3 shows a redox reaction. Sodium loses an electron, so it is oxidized into a positive sodium ion. Chlorine gains an electron, so it is reduced into a negative chloride ion. (credit: Elizabeth O'Grady)

Electrons and Energy

The removal of an electron from a molecule, oxidizing it, results in a decrease in potential energy in the oxidized molecule. The electron, which is often donated from hydrogen, does not remain unbonded. Rather, the electron is shifted to a second molecule. The molecule that accepts the electron is said to be reduced. During aerobic cellular respiration hydrogen atoms from glucose are oxidized, resulting in carbon dioxide (CO_2). Oxygen molecules are reduced, resulting in water molecules (H_2O). When glucose is oxidized, it removes some potential energy from the molecule which is then used to synthesize ATP (Figure 6.4).

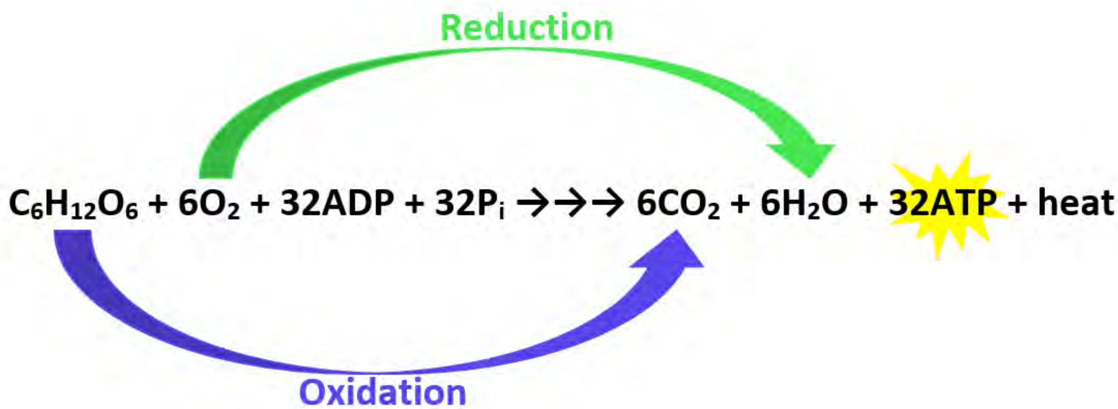

Figure 6.4 shows aerobic cellular respiration as redox reactions. (credit: Jason Cashmore)

Most of an atom's potential energy is found in the form of its high-energy electrons. The transfer of electrons between atoms allows the cell to transfer and use energy in small increments rather than a single, destructive burst. Section 6.2 will focus on how energy is extracted from glucose in small increments to generate ATP. You will see that as you track the path of the energy transfers, you are tracking the path of electrons moving through metabolic pathways. To follow electrons through metabolic pathways it is necessary to learn about electron carriers, special molecules that shuttle electrons throughout the cell.

Check your knowledge

Which of the following is true of redox reactions?

a. Oxidation results in atoms becoming more negative.
b. Reduction results in atoms gaining electrons.
c. Atoms that are oxidized release oxygen.
d. Reduced atoms become more positive.

Answer: b