5.4 Energy and Metabolism

Learning objectives

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

- *Understand how energy flows through a living system*
- *Explain what metabolic pathways are*
- *Know the difference between anabolic and catabolic reactions and be able to give an example of both*
- *Be able to define and explain all bolded terms*

All organisms require energy to maintain homeostasis. Most life forms get their energy either directly or indirectly from the sun. Producers, such as plants, can directly capture sunlight and convert it into chemical energy, such as glucose. Because producers make their own food, they are considered autotrophs. Herbivores, carnivores, and omnivores are classified as consumers because they must obtain their chemical energy by "consuming" it. They are considered heterotrophs. Consumers indirectly get their energy from the sun. Herbivores, such as cows, obtain their chemical energy by consuming producers, such as grass. In the case of carnivores, they must obtain their chemical energy by eating other consumers. Omnivores are adapted to consume both producers and other consumers. Decomposers obtain energy through the decomposition of dead and decaying materials. Figure 5.17 is a very simplified food web that shows where energy comes from and how energy flows through living systems.

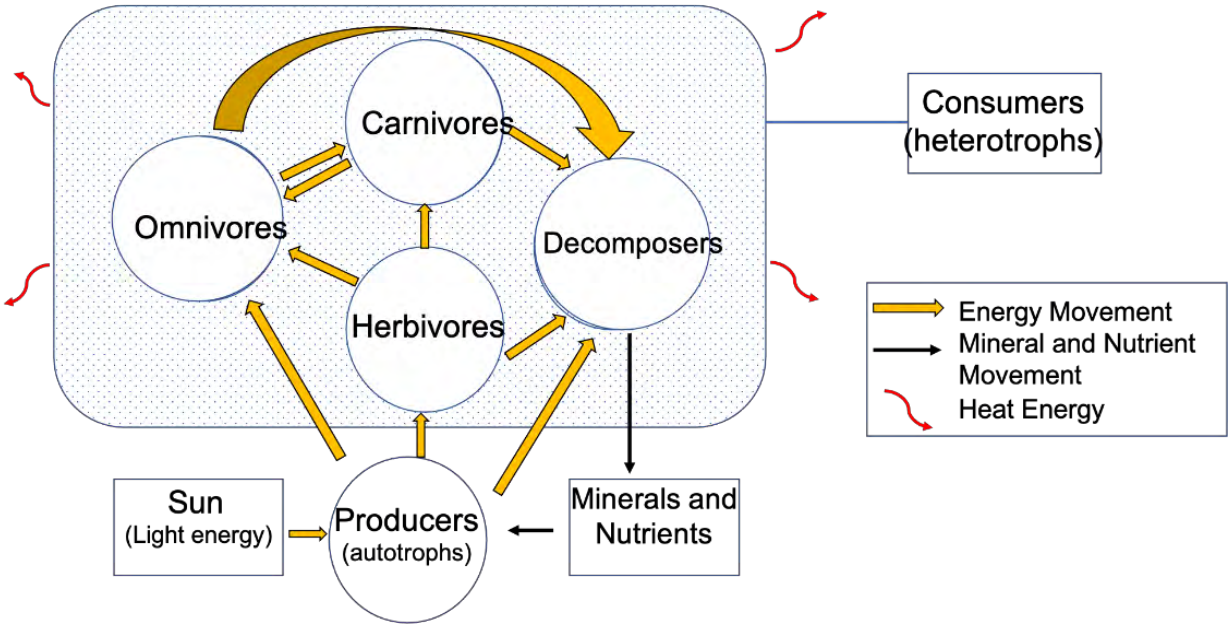

Figure 5.17 A simplified food web model of energy and mineral nutrient movement in an ecosystem. The yellow arrows indicate the flow of energy, the black arrows the movement of minerals and nutrients, and the red arrows the loss of energy in the form of heat. The circles indicate all the species that would be classified under that group. (credit: Elizabeth O'Grady)

Metabolic Pathways

How do producers such as plants capture light energy and convert it into chemical energy such as glucose (Figure 5.18)? How do all cells convert chemical energy found in glucose into ATP? To answer these questions, it is important to understand that energy conversions occur through a series of related chemical reactions called a **metabolic pathway**.

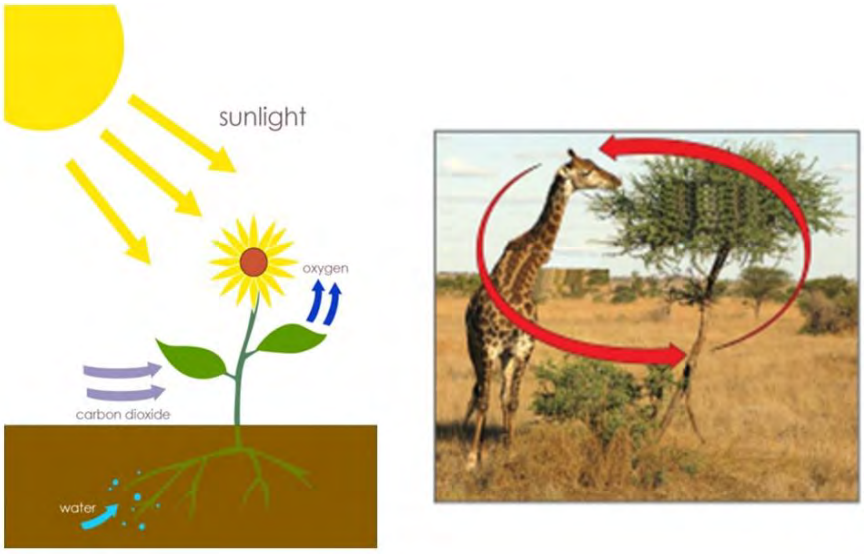

Figure 5.18a Producers capture light energy from the sun and convert it into chemical energy. (credit: At09kg/ Wikimedia) b. Herbivores, like the giraffe, consume the producer and make their own form of chemical energy. (credit: Modified by Elizabeth O'Grady original work of OpenStax; Wikimedia)

Consider the metabolic pathway of photosynthesis. During photosynthesis, plants use energy from sunlight to convert carbon dioxide gas (CO_2) and water (H_2O) into sugar molecules like glucose ($C_6H_{12}O_6$) and oxygen (Figure 5.18). This metabolic pathway is quite extensive and will be covered in chapter 7. For now, we will summarize this metabolic pathway in the following reaction:

$$\mathbf{6CO_2 + 6H_2O + light\ energy \text{-------}> C_6H_{12}O_6 + 6O_2}$$

The glucose produced through photosynthesis can then be used to form adenosine triphosphate (ATP) through a process called cellular respiration. **Adenosine triphosphate (ATP)** is the primary energy currency of all living cells. Cellular respiration is a metabolic pathway that is basically the reverse reaction of photosynthesis. The reaction is summarized as:

$$\mathbf{C_6H_{12}O_6 + 6O_2 \text{------}> 6CO_2 + 6H_2O + energy\ (ATP)}$$

Both photosynthesis and cellular respiration are different metabolic pathways involved in energy transfer for living cells. However, not all cells perform both pathways. For example, animal cells can perform cellular respiration but not photosynthesis. Plant cells, on the other hand, can do both photosynthesis and cellular respiration. Figure 5.19 shows how these two metabolic pathways are connected.

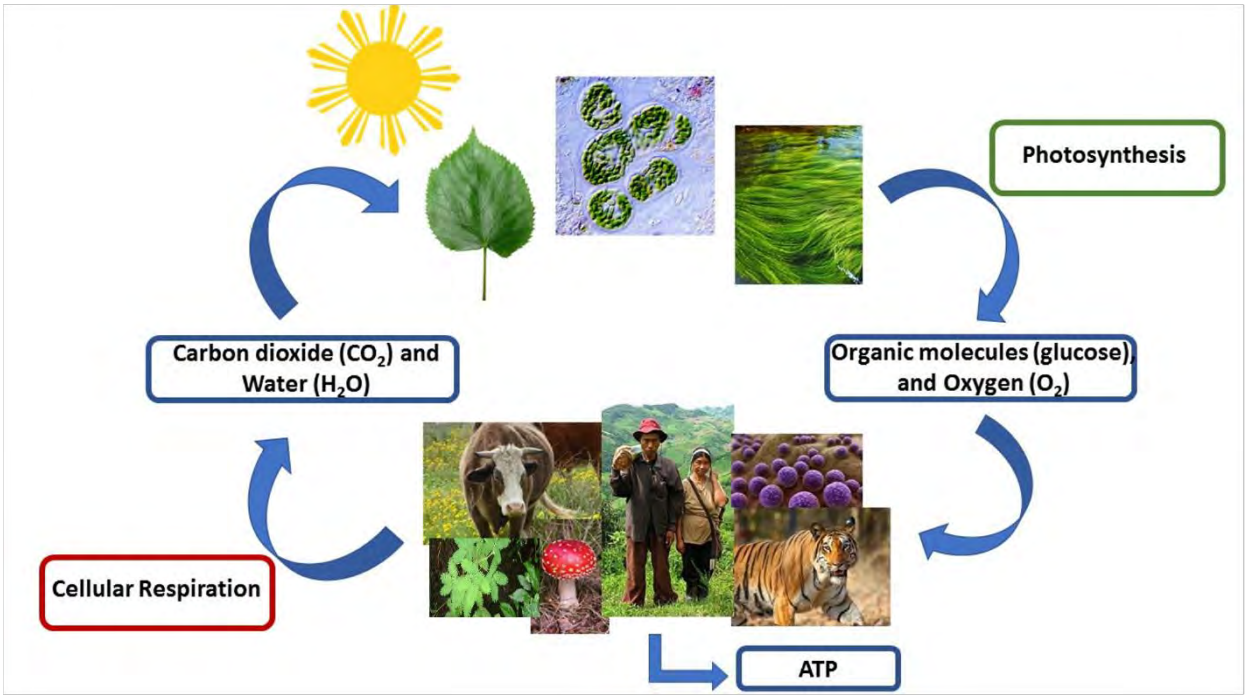

Figure 5.19 Autotrophs use carbon dioxide, water, and light energy to make organic matter and oxygen. Organisms use organic matter and oxygen to generate ATP and produce the waste products of carbon dioxide and water. (credit: Modified by Elizabeth O'Grady original work of / sun- Hariboneagle927 ; leaf-Krzysztof P. Jasiutowicz; cyanobacteria-NASA, algae-Mykola Swarnyk, cow-Chenspec , mushroom-MichaelMaggs plant- Alex Lomas/Concepts of Biology OpenStax humans-Weltenbummler84, Staphylococcus - scientificanimations, tiger-Vijaymp)

Energy converting chemical reactions are classified as either being anabolic or catabolic (Figure 5.20). In **anabolic** reactions, smaller, simpler molecules are combined into larger, more complex substances. Anabolic reactions, such as photosynthesis, require an input of energy. In **catabolic** reactions, such as cellular respiration, larger, more complex substances are broken down into smaller, simpler molecules. Catabolic reactions release energy. Figure 5.5 shows the differences between these two types of chemical reactions.

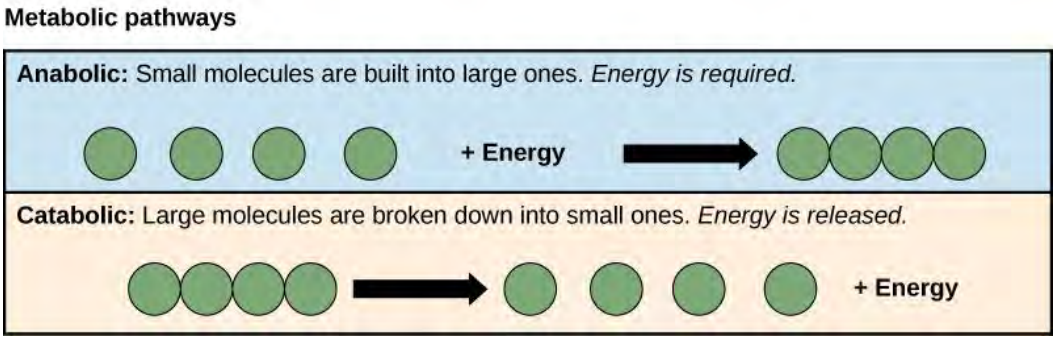

Figure 5.20 Catabolic pathways are those that generate energy by breaking down larger molecules. Anabolic pathways are those that require energy to synthesize larger molecules. (credit: Fowler et al. / Concepts of Biology OpenStax).